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BIOSEMIOTICS

VOLUME 3

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Essential Readings in Biosemiotics

Anthology and Commentary

Springer

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Preface

A Stroll Through the Worlds of Science and Signs

Having spent the last ten years in regular correspondence with the world's small but steadily growing population of "biosemioticians," I feel warranted in saying of this diverse group of molecular biologists, neuroscientists, zoologists, anthropologists, psychologists and philosophers: that while each one more or less found their way into this common project alone – proceeding from vastly different starting points and through drastically varying routes – it might yet not be too broad a claim to say that a growing discontent with what was being offered as (or in lieu of) "explanation" regarding the nature of empirically observed, real-world sign processes in their respective fields of origin appears to be the single most common impetus setting the majority of these researchers on their respective paths to what has now converged to become the growing interdisciplinary project of *biosemiotics.* Accordingly, on the website of the International Society for Biosemiotic Studies that I maintain at www.biosemiotics.org, I define the interdisciplinary research agenda of biosemiotics as follows:

"Biosemiotics is the study of the myriad forms of communication and signification observable both within and between living systems. It is thus the study of representation, meaning, sense, and the biological significance of *sign processes* – from intercellular signaling processes to animal display behavior to human semiotic artifacts such as language and abstract symbolic thought. Such sign processes appear ubiquitously in the literature on biological systems. Up until very recently, however, it had been implicitly assumed that the use of terms such as *message, signal, code,* and *sign* with respect to non-linguistic biological processes was ultimately metaphoric, and that such terms could someday effectively be reduced to the mere chemical and physical interactions underlying such processes. As the prospects for such a reduction become increasingly untenable, even in theory, the interdisciplinary research project of biosemiotics is attempting to re-open the dialogue across the life sciences – as well as between the life sciences and the humanities – regarding what, precisely, such ineliminable terms as *representation, sign of,* and *meaning* might refer to in the context of living, interactive, complex adaptive systems" (Favareau 2005: o.l).[1,2]

Indeed, my own entry into this field came as the result of my growing discontent with the inability of cognitive neuroscience to confront issues of experiential "meaning" at the same level that it was so successful in, and manifestly committed to, studying the mechanics of those very same electro-chemical transmission events by which such meanings were being asserted (but not explained) to be produced. Indeed, the 1990s were declared to be "The Decade of the Brain" in the United States – and reservations about the seriousness of such self-aggrandizing hyperbole aside, however, this period did indeed see a great explosion of ideas and energy emanating out of such newly minted hybrid research projects as neurophilosophy, evolutionary psychology, dynamic systems theory, cognitive neuroscience, and Artificial Intelligence/Artificial Life.

What intrigued me about this research then (and now) was the fact that at the heart of these disparate research projects lay the primordial scientific question: *"What is the relation between mental experience, biological organization, and the law-like processes of inanimate matter?"*. However, and for reasons that should become clear as this history progresses, that ancient and comprehensively articulated question progressively became re-formulated – and ultimately replaced – by the much narrower and more presumption-driven question: *"How does the human brain produce the mind?"*. And this is a very different question – making some very different assumptions – from the prior formulation, as we soon shall see.

However, even in response to this perhaps less optimally formulated latter question, many interesting analyses were made, hypotheses proposed and theories advanced – though none proved fully satisfactory, even on the theoretical level, and as the inquiry began taking on its institutionally funded form, fewer and fewer of the major participants in the debate took the opportunity to reflect publicly on whether the question of "How do brains produce minds?" was not itself framed in such a way that there could never be provided a satisfactory answer.

For with the object of study itself being conceptualized either in a modified Cartesian sense (i.e., "mind" as an immaterial system property either emergently produced by, or actually reducible to, the activity of an material brain), or as an "inherently unknowable" phenomenon (McGinn 1999), or as outright category mistake of "folk psychology" (Churchland 1984), it's hard to see how any progress *could* be made on this issue, given the artificially barren parameters within which the search was set.

Towards the end of the century, the application of dynamic systems theory to neuroscience was promising to open up a third alternative to the "dualist-and-immaterialist versus reductionist-and-determinist" impasse, and several visionary brain researchers (e.g. Edelman 1992, Damasio 1994, Freeman 2000, Llinás 2001,

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[1] The abbreviation "o.l." stands for "online" throughout this volume.

[2] The reference list for this section appears in the back of the volume, to maintain consistency with the rest of the editorial material that introduces each reading.

Fuster 2003) were suggesting interesting syntheses that, although not phrased as such by their proponents, attempted to preserve the interdependent reality of both sign relations and material relations in their explications of the phenomenon of "mind."

However, the majority of these searches still proceeded from the yet too partial understanding that somehow "the human mind produces sign relations" – and it was not until neuroscientist and bio-anthropologist Terrence Deacon (1997) suggested a new way of looking at the problem of language origins through the lens of Charles S. Peirce's architectonic of "sign relations" per se that it became clear at least to some people, myself included, that a potentially more viable approach to the conventional mind-brain question might be to *not* begin that study by using the uniquely human manifestation of mental experience as the archetypal example of the system needing explanation, as if it – alone among the products of the natural world – somehow arose *ex nihilo* and persists today *sui generis* – but to inquire first, instead, into the far more fundamental relationship of all purposive organisms to subjective experience (a term which itself, it turns out, denotes a far broader set of natural relations and phenomena than are indicated when one begins a priori with the stipulation that "subjective experience" is something that arises wholly out of, and remains forever locked away within, brains).

Coming upon Deacon's provocative synthesis of Peirce re-set the fundamental terms of inquiry for me, and soon led me to discover the work of Danish biosemiotician Jesper Hoffmeyer – and it is from this point that I date my own decision to become part of the yet nascent interdiscipline of biosemiotics. To this day, I can still recall the precise moment of my casting of this die. I had only gotten as far as page 40 in Hoffmeyer's (1996) *Signs of Meaning in the Universe* when I came upon a passage wherein he compares the concept of self-reference in a system with the perpetual creation of "a map which is so detailed that the cartographer and the map that he is making are swept up into it." This elegant little description so perfectly captured the paradox that most contemporary neuroscientific theory both entailed and yet was simultaneously denying and/or attempting to run away from, that at the end of my reading of that passage – one of many such delightful asides ornamenting the profound and seriously consequential ideas argued for in this book, I e-mailed Jesper Hoffmeyer in Copenhagen, and found myself in Denmark a few weeks later debating the relations between intersubjectivity and mirror neurons at the First Annual International Gatherings in Biosemiotics conference.

Researchers from eighteen different countries were present at that inaugural *Gatherings* conference, with backgrounds ranging from physics and molecular biology to animal ethology, robotics, evolutionary psychology and philosophy of semiotics and of mind. Since entering the interdisciplinary project that this group was in the process of creating, I have learned much about the understandings attained by the various disciplines from which each of my colleagues has been informed – as well as about the longer tradition of "theoretical biology" that remains relatively, and detrimentally, untaught as part of a scientific education in the United States.

The book that you now hold in your hands has been prepared precisely as a resource for this addressing this lacuna. Like any other such anthology, it does not pretend to completeness – absent from representation here, for example, are whole canons of seminally influential work in physical science (e.g., Schrödinger, Heisenberg, Einstein, Eigen), in theoretical biology (e.g., Waddington, Rosen, Kaufmann, Elsasser) and in semiotics (e.g., Deely, Danesi, Merrell, Petrilli) without which the contemporary interdiscipline of biosemiotics would be unthinkable. Instead, selection for inclusion in the volume was limited to those interdisciplinary thinkers who self-identify as "biosemioticians," as well as those "biosemiotic precursors" who have been retrospectively adopted by the community as such (i.e., Peirce, Uexküll and Bateson).

Even within these restricted selection parameters, however, limitations of space have precluded the inclusion of a number of important works by such "second-generation" younger biosemioticians such as Argyris Arnellos, Luis Bruni, Yagmur Denhizen and Yair Neuman, as well as by the more "humanities-based" biosemioticians as Paul Cobley, Marcel Danesi, John Deely, Frederik Stjernfelt and Wendy Wheeler (to name just a very small sample). Thus, mere non-inclusion in this introductory volume does not imply non-centrality to the contemporary project of biosemiotics. Indeed, in many cases, the level of biosemiotic discourse in these works was found to be too advanced for inclusion in this volume, whose aim is to provide an introductory overview only. Having once finished the volume, readers are strongly encouraged to deepen and to continue their study of biosemiotics by consulting the texts cited at the end of the individual articles, as well as those listed in the *Bibliography and Further Reading* lists appearing at the end of the volume.

Finally, two last points about the current volume should be made: one about the organization of the book, and one about the intentions behind it.

Essential Readings in Biosemiotics has been organized as both a teaching tool and as an adventure in thinking. As both a professional teacher and as a lifelong autodidact myself, I have endeavored to design the book such that it can be read from start to finish in the order that the chapters appear for those who will use it for self-teaching and enrichment. Alternatively, its chapters can be assigned piecemeal and selectively for classroom teaching, provided that the instructor already has a sure grasp of the interdiscipline as a whole. For either application, however, it is strongly recommended that both student and non-student readers alike begin their study of this volume by reading the *Introduction* chapter in full, before proceeding to the selection of reprinted texts. Doing so will provide the necessary grounding in both the history of biosemiotics as well as in its theory, allowing for a richer understanding of the subsequent texts.

Of the content of those texts themselves, I will say very little here, having provided in the following volume what I hope to be "comprehensive enough" introductory material to each of them so as to orient the reader to each author's particular life's work and its goals. But I must stress to the reader at the outset – as well as throughout, and also at the conclusion! – that the biosemiotic project is nothing yet resembling a mature, by which is meant a coherent, "science" – and that this volume is not thus a compendium of formulae for "the correct way" of undertaking biosemiotic inquiry. For Biosemiotics is as yet only a proto-science – as will become obvious once one considers the very many different, and sometimes even contradictory, approaches to the study of sign relations in biology that are proposed by the various authors herein.

"I should not like to spare [my reader] the trouble of thinking," wrote Ludwig Wittgenstein, famously, in the preface to his *Philosophical Investigations*, "but to stimulate [the reader] to thinking new thoughts of his own" (1953 [2001]: x^e). Similarly, to borrow an observation about the sign logic of Charles S. Peirce from scholar Thomas Lloyd Short, the biosemiotic proposals that you will find in this book are intended, like all such proposals in natural science, as *hypotheses* – "ideas *not* intended as 'final' but [as working hypotheses] to be applied and developed, perhaps by others. [In other words,] the arguments for these ideas appear not just wholly on the page, but consist instead in *what can be done with them* – just as pragmatism implies" (2007: xii).

"Nothing is yet settled in biosemiotics, everything is on the move," writes biosemiotician Marcello Barbieri, reflecting the consensus of the most recent international biosemiotics conference, "for the scientific exploration of the newly-discovered continent of meaning has just begun" (2007: 112). So, too, is the reader of this volume encouraged to look upon its contents not as a series of dogmatic pronouncements to be accepted or rejected, but as suggestions made in good faith and in full awareness of the enormity of the undertaking, regarding how one *might* profitably go about starting to develop a scientifically accountable framework for the explanation and investigation of the ubiquitous presence of sign relations in the organization and interaction of biological systems.

Read in this way, one can understand biosemiotics for what it really is, and can benefit from this volume in the way that it is intended. For the answers to the questions that biosemiotics asks are not contained within this volume – only some suggestions for building the frameworks that might answer those questions are contained herein. Accordingly, the most important selection lacking inclusion in this book is the one that the reader should afterwards feel compelled to write.

"I can see where this group of disparate thinkers have identified and clarified what the problems are in trying to address the issues of 'meaning' in biology – and they have even convinced me of the ultimate necessity of this task" writes an anonymous reviewer of the current book, "But from what I have read here, it seems like none of them have yet been able to advance a rigorous and detailed enough methodology, framework or platform so as to enable real collaborative scientific effort to begin. Thus, as brilliant as certain ideas or even thinkers may be in isolation – when taken together, 'biosemiotics' as a concrete undertaking seems to have not yet found its footing, and at times gives the impression that it is still flailing around for a foothold."

Having spent the last ten years of my life with this group, and as part of this project, I am actually tempted to agree somewhat with this assessment. But not without this caveat: If one truly recognizes the need for something like a bio-semiotics, then one owes it to science to put one's own best thought and effort to the task. And therefore I ask the reader once again not to approach this volume passively, but to actively develop what one finds worthwhile in a given analysis in one's own scientific work and understanding and to improve upon the inevitable shortcomings that one will by necessity find in here as well.

History has shown that at the beginnings of a trans-disciplinary investigation for which there is as yet no secure, pre-given scientific framework or vocabulary, an initial bout "flailing for footholds" may be unavoidable. But if that same history is a reliable indicator of what is to come, then eventually one of those very flailings will land on solid ground one day – and at that point, the flailing will have become irrelevant: instead, the willingness to have begun the project at all will be shown to have been all along what counted.

Twenty-four attempts at starting this project are included in this volume.

May your reading of it result in a twenty-fifth.

Donald Favareau

Acknowledgments

Conceived at the Sixth Annual International Gatherings in Biosemiotics convened in Salzurg, Austria in 2006, this book was four long years in the making, during which time it doubled in size and scope from a projected twelve essay collection to its present anthology of twenty-four texts plus extensive commentary. To bring this large project to completion thus required the assistance of many individuals, for whose help I am deeply grateful.

In particular, I wish to thank all the living authors whose work appears in the second section of this book for their time and patience in answering my inquiries, as well as for their permission to reprint their works. Assistance in the translation of the original texts was generously provided by Prisca Augstyn, Stefan Frazier, Stasia Getlastname, and Alexander Kravencko, and the introductory material appearing in this volume was improved immeasurably by critical readings and editorial suggestions made by Peter Barlow, Paul Cobley, John Deely, Peter Harries-Jones and Kalevi Kull.

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My own labor on this project I dedicate to all my colleagues in the biosemiotic community – past, present and future.

Don Favareau

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Chapter 1
Introduction: An Evolutionary History of Biosemiotics

Donald Favareau

Abstract[1] The present chapter is intended to provide an introductory overview to the history of biosemiotics, contextualizing that history within and against the larger currents of philosophical and scientific thinking from which it has emerged. Accordingly, to explain the origins of this most 21st century endeavour requires effectively tracing – at least to the level of a thumbnail sketch – how the "sign" concept appeared, was lost, and now must be painstakingly rediscovered and refined in science. In the course of recounting this history, this chapter also introduces much of the conceptual theory underlying the project of biosemiotics, and is therefore intended to serve also as a kind of primer to the readings that appear in the rest of the volume. With this purpose in mind, the chapter consists of the successive examination of: (1) the history of the sign concept in pre-modernist science, (2) the history of the sign concept in modernist science, and (3) the biosemiotic attempt to develop a more useful sign concept for contemporary science. The newcomer to biosemiotics is encouraged to read through this chapter (though lengthy and of necessity still incomplete) before proceeding to the rest of the volume. For only by doing so will the disparate selections appearing herein reveal their common unity of purpose, and only within this larger historical context can the contemporary attempt to develop a naturalistic understanding of sign relations be properly evaluated and understood.

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[1] Pages 1–20 of this chapter originally appeared as *The Biosemiotic Turn, Part I* in the journal *Biosemiotics* (Favareau 2008). The remaining pages appeared as *The Evolutionary History of Biosemiotics* in the volume *Introduction to Biosemiotics: The New Biological Synthesis* (Favareau 2007, in Barbieri, ed.). In keeping with the anthology nature of this volume, I have refrained from substantially changing the original text, though some citations have been updated to reflect the more recent work done by the scholars discussed herein. Accordingly, the bibliographic information for all works published after 2006 appear in the *Bibliography and Further Readings* at the back of this volume, rather than in the References list at the end of the chapter.

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Introduction

When considered together, the following two commonplace observations present an intransigent paradox for contemporary science:

(1) Biological being is a form of physical organization that has evolved in nature.
(2) A sign is something that stands for something other than itself.

In the physical world of nature, science tells us, things are just what they are: atoms do not "stand for" other atoms, and the revolution of the earth around the sun does not mark a new day or night for either of them. With the advent of biological forms of physical organization, however, all of this changes: atoms in their physical configuration as 'odorant' molecules do "stand for" the presence of nearby food or potential danger, and the last thing that the reader of these words is currently considering them as, is precisely what they really are in themselves: utterly inert and intrinsically meaningless black ink forms present upon a field of otherwise undifferentiated white.

The sign relation of "standing for" is ubiquitous in the biological world, but the resistance to studying sign processes in nature *as* genuine *sign* processes – as opposed to just studying the interactions of their material substrates – has a long and principled history in science. It is precisely this history that we need to understand first, if we are ever to understand how something as oddly named as "biosemiotics" has emerged as neither not an anti-science nor a pseudo-science, but as a genuine proto-science aimed at scientifically distinguishing and explaining the use of sign processes and sign relations both between and within organisms.

"Subjective experience" – which is also an undeniably ubiquitous characteristic of all living systems, provided that one does not conceptually reduce the rich multiplicity of organismic experience with the evolutionarily anomalous and biologically minority instance of self-conscious, language-employing *human* 'subjective experience' – is made possible only by the existence of genuine biological (i.e., non-human made) sign relations, yet has been shunned in natural science as a subject of inquiry in its own right.

Indeed, today it is more the norm than the exception for university life science majors to be instructed right at the outset of their studies that "science only studies observable phenomena. It functions in the realm of matter and energy [and therefore] it is a serious mistake to think that the methods of science can be applied in areas of investigation involving other aspects of human experience, e.g., matters of the mind" (Miller and Harley's *Zoology*, 1994: 11). Similarly, Nobel Prize winner Eric Kandel writes at the conclusion of his authoritative *Principals of Neural Science:* "most neuroscientists and philosophers now take for granted that all biological phenomena, including consciousness, are *properties of matter*... and some philosophers and *many neuroscientists* believe that *consciousness is an illusion*" (2000: 1318, italics mine).

And so the question accordingly arises: How did modern science – the communal knowledge-generating system *par excellence* – arrive at this sterile impasse – one where the investigation of individual knowledge-generating systems *as* knowledge-generating systems per se has come to be seen, at best, as a vexingly paradoxical riddle and, at worst, as falling entirely outside the scope of legitimate scientific inquiry?

The first half of this history of biosemiotics attempts to partially illuminate the historical processes by which this particular explanatory Gordion knot was tied.

One might reasonably suppose that an examination into the uniquely influential works of René Descartes (1596–1650) would be a logical place to start this discussion, as Descartes' work is often seen as emblematic of the bifurcation between modernity and pre-modernity in both the sciences and in philosophy, and of demarcating the bifurcation between the "mental" and the "material" realms that we continue to continue his struggle to reconcile, in better and worse ways, today. And, indeed, it will be necessary to discuss Descartes' role in shaping the trajectory of modern science if the history of biosemiotics is to make sense within its larger narrative.

Yet Descartes, too, appears within this role informed by a set of prior understandings and explanatory narratives that are themselves contingent products of history. So if we are to understand the relationship of biosemiotics with regard to the modern science from which it proceeds, and which it to some extent challenges, we must also understand the relation of modern science to the practices and understandings about the natural world from which *it* proceeded and, for the most part, not merely challenged but actively proposed to supplant.

Thus, the first difference between the two projects of "biosemiotics vis-à-vis modern science" and of "modern science vis-à-vis everything that preceded it" can be clearly stated. For as we shall see shortly, the goal of biosemiotics is to *extend* and to *broaden* modern science, while adhering strictly to its foundational epistemological and methodological commitments. It does not seek in any genuine sense of the term to "oppose" much less "supplant" the scientific enterprise, but to *continue* and to *develop* it, re-tooled for the very challenges that the enterprise itself entails, if not demands.

Understanding how and why this is so requires that situate the biosemiotics project within the history of scientific thinking as a whole, and not just within the history and thinking of modern science as delimited and defined by Descartes and his successors.

Thus what better place to begin a history of biosemiotics than with Aristotle, the West's first genuine biologist? For only by tracing the winding evolutionary path that begins in the ancients' observational thinking about life processes, and continues through the heavily mediated symbolic thinking of the medievals about sign processes, may we at last begin to get a clearer view of the Gordian conceptual entanglements between signs and nature that Descartes sought to resolve, not with a yet more entangled synthesis, but with an Alexandrian cleaving that would leave these two halves disconnected and the thread that brings forth their unity forever cut.

And since it is the job of biosemiotics to attempt weaving this thread together again, we must first discover just how and why it got tangled up in the way that it did in the first place. We begin our history proper, then, before it ever occurred to anyone to tie such an explanatory knot out of the naturally occurring continuum bearing humans, culture, animals and nature.

Phase One: Semiotics Without Science

> There is no philosophical high-road in science, with epistemological signposts. No, we are in a jungle and find our way by trial and error, *building our roads behind us* as we proceed. Thus, we do not *find* sign-posts at cross-roads, but our *own scouts erect them*, to help the rest. – Max Born (1882–1970), Nobel Prize in Physics 1954 (Born 1943: 44)

Tracing back such sign-posts as the records that we have access to will allow us, the dawn of what we now call *scientific* knowledge and investigation (as opposed to the practices and dogma of received and "revealed" wisdom as the foundations for human action and belief) in the West is generally said to start with the efforts of the retroactively designated *natural philosophers* of sixth and fifth century BCE Greece. There, if the signs extant are telling us the truth, the investigations undertaken into the observable patterns of natural phenomena and the resulting explanations offered by the pre-Socratics marked a profound cultural and epistemological shift away from mankind's earlier ways of explaining the phenomena of the natural world as manifestations of the wills and whims of a dizzying assortment of intrinsic and extrinsic gods.[2]

And, indeed, this is how the narrative of the birth of science in the West is generally presented: This new form of communal, non-supernatural investigation that does not require god-cause as part of its explanations about the natural world is at the root of what we today call *science.* Historically familiar as that account may be, what is less often appreciated is the fact that this profound cultural and epistemological break between god-causal and non-god-causal explanation simultaneously birthed an even more irresolvable epistemological bifurcation – one that would plague the entire subsequent history of science for the next twenty-three centuries, as we shall see. For in the most general terms, writes historian of philosophy John Deely:

> the individuals credited with the introduction of philosophical thought into human civilizations were men who speculated on what constitutes the objects of human experience in so far as those objects have or involve an existence or being *independent* of what [any given agent, be it gods or human beings] may think, feel or do. The philosophers, in other words, are those individuals who are credited with introducing into human thought the idea of *reality,* or something which 'is what it is' on its *own* grounds, *regardless* of what further relations it may have 'to us' or *how it may appear in experience* (Deely 2001: 3).

"Soon enough this thinking became reflexive," Deely continues, "and raised the question of how [and later, if] such knowledge could be possible in the first place" (ibid). This latter observation, while hugely consequential for the history of science and sign theory that it is our goal to convey here, nonetheless gets us too far ahead of our story for the moment. Rather, we need to linger on Deely's first observation a little longer in order to fully understand all of what is to come, and to sufficiently appreciate the impact of this first major "turn" in our history of scientific understanding. For as biosemioticians will centuries later convincingly argue, this ability to apprehend and understand the extra-mental existence of a world that does

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[2] But see Denhizan 2008 for an illuminating reconsideration of the still lingering effects of the Mesopotamian worldview upon subsequent Western epistemology.

not reduce to our own sensational experience of it, is one of the distinguishing characteristics of our species-specific *human* form of cognition (Hoffmeyer 1996, Deacon 1997, Emmeche 2002, Favareau 2008, and many more).

Ancient Origins: Assuming a Natural Bridge Between World and Mind

Obviously, the slow-building origins of such a deeply human cognitive ability as the one described above must have pre-dated the appearance of the pre-Socratic philosophers by thousands, if not tens of thousands of years. Certainly, one finds highly developed evidence of this ability in the myths of ancient Sumer and Egypt, in the religion of the Caanites, in the burial rituals of Chinese Longshan culture, and the writing systems of the early Indus Valley dwellers. And by the time of the *Upanishads*, the earliest of which is said to date as far back as ninth century BCE, we find that the assumption of a fundamental dichotomy between reality (*Brahman*) and the world of experience (*maya*) is already being posited as the essential human condition – anticipating Plato, to say nothing of the modernists, by centuries and millennia, respectively.

A history of the various responses that have been proposed across cultures to this characteristically human question regarding the proper *relations* between "mind-dependant" and "mind-independent" phenomena would indeed be a fascinating study – although, of course, it is not one that we will have time for here. Restricting our analysis to just the Western scientific tradition, however, we can see right from the start, its recognition of the need to conceptualize a way of bridging the human apprehension of purely mind-dependent phenomena to the veridical apprehension of inescapably mind-independent phenomena.

It is for this reason that we find Plato (427–328 BCE) arguing for the necessity of our gaining *unmediated* access to direct reality in our between-lives apprehension of the Ideal Forms (e.g., *Timaeus 50a–c, Republic 476b–480a; 596a*) and, if we are diligent, through our concerted efforts at retrieving that same knowledge through the practices of *anamnesis* during the course of our own lives (e.g., *Meno 85d–86; Phaedo 72e–73a, Republic 534b–c*). It is also why we find Aristotle (384–322 BCE) arguing, conversely, for the necessity of *inherently mediating* and multiply generative "middle terms" of explanation (roughly akin to Peirce's *interpretants*) that we create, test and then either discard or adopt in our journey from brute perception to the more fine-grained understanding of reality (e.g., *Posterior Analytics* II 2, 90a7–9). Even more biosemiotically, Aristotle posits that the organization of *all* living form is such that nature "prepares the ground" in organisms for those *perceptual* capacities that will be necessary to allow them to achieve their organismic ends, and that "it is for the sake of this that [their] potentialities are acquired" (*Nichomechaen Ethics 1103a32–33*; *Metaphysics IX 1050a 5–10*).

For both Plato and Aristotle, however – and for the majority of their disciples over the course of the next two millennia – the notion that a reliably traversable bridge between mind-dependant experience and mind-independent reality might be 'impossible' for human beings, even in principle, is an unacceptable absurdity (e.g. *Parmenides 135b–c*, *De Anima iii 3–5*).[3] Instead, the serious consideration of this most counter-intuitive idea by a majority of contemporary theorists is a most characteristically *modern* notion – and perhaps the one most responsible for bringing the research agenda of biosemiotics into being in the second half of the 20th century. For it is biosemiotics that will insist that, in the study of biological organization and agency of every kind, it is precisely the naturalistic establishment of *sign relations* that 'bridges' subject-dependent experience (such as we find both in animal sensations as well as in human 'mindedness') with the inescapable subject-independent reality of alterity – an alterity that *all* organisms have to find some way to successfully perceive and act upon in order to maintain themselves in existence.

Interestingly enough, however, the very naturalness of sign relations seems to have appeared unproblematic for the ancient Greeks, whose investigations into the patterns of orderliness discoverable in the natural world were predicated, for the most part, upon the assumption that human beings were built in such a way as to be able to derive veridical knowledge about the phenomena present before them in a world existing independently of their experience. Rather, it would be left to the Hellenistic and medieval Latin scholars who, in their attempts to synthesize the insights of Greek antiquity with Biblical revelation so as to develop the doctrines of the Catholic Church, became increasingly alert to the idea that the mediation between mind-dependant experience and mind-independent reality was not at all a straightforward one.[4] Not at all coincidentally, it is here where we first encounter serious intellectual engagement with the phenomena of signs *qua* signs.

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[3] One can detect some resonance with modernist scepticism in one or two of the minor traditions of the ancient world, most notably those of the "Middle Academy" thinkers Arcesilaus (c. 315–241 BCE) and Carneades (c. 213–129 BCE), and especially the later neo-Pyrrhonean scepticism popularized by Sextus Empiricus (c. 150–225 CE). In the case of the Academicians, however, such doctrine appear to be motivated more by a desire to weaken the stultifying hold that the un-self-critical "dogmatism" of the competing Stoic school then held on the popular imagination, then on the attempt to embark upon anything resembling Descartes' epistemological program of radical doubt (Long and Sedley 1987). Similarly, the Pyrronean revival of 2nd and 3rd centuries Rome appears to have used the inarguable conclusions of sceptical logic purely *instrumentally* in the quest to cultivate the spirit of *ataraxia,* or emotionally detached equanimity, as a "practical philosophy" and recipe for living – a worldview that Diogenes Laertius suggests that Pyrrho may have originally re-fashioned out of the belief systems he encountered in his time in India with Alexander's army (Burnyet and Frede 1997). Most critically: both schools argued *in favor of* the foundational epistemological usefulness of precisely those sense-perceptible "appearances" (Pyrro's *phianomena* and Carneades' *pithanon*) and pragmatic axioms of everyday "folk psychology" (Arcesilaus' *eulogon*) that constitute the "mind-dependant *illusions*" so bewailed by the – let us call them – "*Dogmatic* Sceptics" of modernity.

[4] Indeed, the briefest time spent with either the neo-Platonic theology of Augustine (354–430) or the Aristotelian apologetics of Aquinas (1225–1274) will reveal that 'naïve realism' is *not* a charge that can be levelled against the Latin thinkers (nor their counterparts in the Islamic world, for that matter).

Semiotic Analyses of World-Mind Relations in Hellenic Thought

Eco and Marmo (2000: 65) remind us that prior to the Hellenistic period, the word σημείο (L: *semeion*) was understood by the Greeks almost exclusively as a medical term – one roughly akin to the modern concept of *symptom*, in that referred it only to the outward manifestations of an internal state of affairs. And it is from this word *semeion,* of course, that the word “sign” – “something that suggests the presence or existence of some other fact, condition, or quality”[5] – proceeds.

Yet the broader understanding that “signs” are, in their first and most fundamental sense, relations holding over objects as apprehended by some perceiver (“Signum est res praeter speciem quam ingerit sensibus, aliud aliquid ex se faciens in cogitationem venire”)[6] was first articulated in the West by Augustine of Hippo (354–430), who is thereby generally credited with developing the West’s first true theory of signs *qua* signs. Augustine’s development of such a theory was purely an instrumental one, subservient but necessary to his larger epistemological project of establishing a theory of human *knowing* that, as he felt all such theories should, could lead us to discover how it is that the source of all that is, the Divine God, has constructed we non-divine human beings such that we may partake of justifiably true knowledge of both his Creation and of Him.[7]

As a result, “it was Augustine,” writes Umberto Eco, “who first proposed a *general* ‘science’ or ‘doctrine’ of signs per se – wherein the *sign* becomes the *genus,* of which *words* [are but a particular] *species*” (Eco and Marmo 2000: 65). The point is a critical one for us today, as we attempt to recover from the intractable conceptual errors introduced by the 20th century “linguistic turn” in failing to make the critical distinction between *signs* and *symbols*, as we shall have much opportunity to discuss later. What we need to attend to at this point in our narrative, however, is Eco’s fertile clarification that *signs* (σημεία) for the Greeks were understood as *natural events* acting as symptoms or indices, and [that] they entertain, with that which they point to, a relation based upon the mechanism of inference [taking the form *if* → *then*]. *Words* (λέξη) for the Greeks, by contrast, stand in quite a *different* relation with what they signify [than this *if* → *then* relation]” (ibid).

The questions for Augustine and his commentators would then become: How to understand both: (1) the *if* → *then* relations of the natural world, and how these relations may be reliably inferred by living beings, as well as: (2) the function of this as yet still unspecified “different” (or additional) set of epistemological relations instantiated by human language use?

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[5] An absolutely ordinary – but quite profound, it turns out – definition from the *American Heritage Dictionary* (Houghton Mifflin 2006).

[6] “A *sign* is something which, offering itself to the senses, conveys something other than itself to the intellect.” *De doctrina christiana* II 1, 1963, 33 (trans. Meier-Oeser 2003: o.l.).

[7] De- theologized, this is a large part of the contemporary biosemiotic project as well – which is why Augustine’s extra-linguistic notion of the sign will remain important to us as we move from human knowing to animal sensing to cellular self-organization.

A theologian, Augustine resolves these questions much in the same way that René Descartes will attempt to resolve a similar issue thirteen centuries later: by appeal to an innate power bestowed in us by God. For the purpose of scientific explanation, however, this answer merely pushes the question away. Thus, the search for a more coherent understanding would become the project of a "forgotten" line of medieval inquiry that is yet rediscoverable as it culminates in the works of the scholars of the late medieval Iberian school (the so-called *Conimbricenses*) – and in particular, in the *Tractatus de Signis* of John Poinsot (1589–1644), as philosopher John Deely has been at the forefront of arguing for quite some time.[8] In our own time, the fact that these two tightly interrelated questions remain unresolved, both conceptually and scientifically, would become the initial impetus and driving force for the development of the project of biosemiotics (Sebeok 2002).

The development of that project will be discussed in this history in due time. Yet hints on how to go about approaching such dilemnas are already evident in Augustine, where we find, for the first time in the West, an extended philosophic discussion on both the similarities and the differences between "natural signs" (*signa naturalia*) and what might be called "cultural signs" – or what Augustine himself called "given signs" (*signa data*). *Signa naturalia*, for Augustine, are those signs that, "apart from any intention or desire of using them as signs, do yet lead to the knowledge of something else" (389/1963) – one might think of the relations of physical contiguity, such as the relation of smoke to fire, or the relation of a fossil to the animal's body that left it. "Given signs" (*signa data*), on the other hand, are "those [signs] which living beings mutually exchange in order to show, as well as they can, the feelings of their minds, or their perceptions, or their thoughts" (*ibid*) – such as exemplified, presumably, talk and gestures and the marks on this page and Augustine's *Confessions*.

Subsequent inquirers into the notion of sign relations will come to realize, however, that Augustine's distinctions here raise as many questions as they propose to answer. Among these many questions: *For whom* do such natural signs "lead to knowledge of something else" . . .*other than* those with the "intention or desire for using them" as such? Similarly: Must the given signs that "living beings mutually exchange in order to show . . . the feelings of their minds" be *deliberately* and *expressly* "exchanged" – or may they be subconsciously *performed* and *registered*? Do animals use *signa naturalia* or *signa data*? And in what relation towards each other do these two categories of "natural" and "given" sign relations ontologically stand? Perhaps most importantly of all: Is it the "perception" and "awareness" on the part of some agent that *gives* a sign its representational efficacy – or does the agent merely "apprehend" a relation in the world that is *already there*, regardless of its apprehension or non-apprehension?

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[8] See especially Deely's (1985) translation of Poinsot's *Tractatus de Signis* and its accompanying "critical apparatus" – as well as Deely's detailed explication of the works of the Coimbra school in Deely (2001) (esp. pp. 411–484) and of Poinsot's contribution to a post-modernist theory of perception and understanding in Deely (2007) (passim).

Not because he did not recognize these sorts of questions, but because they were extraneous to his purpose of examining how sacrament and scripture function as the revealed signs of God, did Augustine more or less leave the discussion of signs *qua* signs at this point (Deely 2001: 22). Still, as Meir-Oeser observes, "despite all the internal ruptures and inconsistencies, Augustine's doctrine of signs is based on a definition that, for the first time, intends to embrace both the natural indexical sign and the conventional linguistic sign as [but two sub-]species of an all-embracing generic notion of sign, thus marking a turning point in the history of semiotics" (2003: o.l.).

Certainly, from a history of biosemiotics standpoint, Augustine's early formulation of a sign as primarily being constituted by a relation between one aspect of the natural world and another aspect of that same natural world (a "perceiver") is so manifestly commonsensical and unencumbered with specially-created dichotomies, that had the contingencies of history been otherwise, and had sign study proceeded from Augustine's definitions, rather than from a radically disemboweled version of Aristotle, as we shall soon see it do, we may not have found ourselves here today still trying to establish as a general understanding the idea that the world of sign relations per se did not start with the advent of *homo sapiens* – and that a sign relation is not something that was created *ex nihilo* by the minds of human beings – but rather, that the minds of human beings are themselves the product of a *de novo* use of absolutely natural and biological sign relations.

Signs Without Being: The Loss of De Anima *to Inform* De Interpretatione

The contingencies that have been actualized by history have *not* been otherwise, however – and thus the understandings about sign relations that came to be most generally accepted by the thinkers of post-antiquity were to have dire consequences for subsequent centuries' attempts at incorporating the resulting notion of "sign" relations into the modern project of science. Anticipating briefly: the model of the scientific project that we have inherited today descends in a fairly straight line from the experimentalist instrument of Francis Bacon's *Novum Organon* – an historically situated rejection of what had served as the primary "instrument of logic" and investigation about the natural world for the medieval scholastics: Aristotle's six books on logic known collectively as the *Organon*.

But in calling for a revolution in the approach of scientific investigation from the deductive to the inductive, Bacon and his contemporaries yet inherited an impoverished notion of "sign relations" that would devolve into a literally irreconcilable mind-body dualism at the hands of René Descartes a mere twenty-one years later. This assumption of an essential dualism between material relations and sign relations continues to inform the practices and premises of modern science up unto the present day. And because of this, it is incumbent upon us to spend the necessary amount of time here retracing the historical trajectory that precluded for centuries even the possibility of a science devoted to investigating the myriad ways in which material relations could come to function as sign relations in the lives of living beings.

Significantly, in the seven centuries that followed Augustine, the churchmen studying his doctrine of signs did so only in the sacred context in which it was intended. For examinations into the workings of the world, they turned, of course, to The Philosopher, Aristotle. But the Aristotle of the early Middle Ages was only a partial Aristotle at best, consisting only of the six books translated into Latin by Boethius (480–524) in the sixth century CE. These six books on logic, thought to have been collected by Andronicus around 40 BC so as to present the reader with a structured system of logic, would come to be *the* standard text of non-Biblical learning in the thousand years between the fall of Rome and the beginnings of the modern era – so much so that they became collectively known as just the *Organon* – the "instrument" of knowledge and well-ordered thought.

Critically, however, these six books were only one small part of Aristotle's overall understanding about the logic of human reasoning *and* the logic of the natural world. The rest of Aristotle's works – and the ones through which one can get an understanding of how the logic of human relations both comes out of and fits in with the logic of the natural world (a "biosemiotic" understanding, as it were) – were lost to the West for over a thousand years. And from these impoverished initial conditions, a magnificent edifice that was yet only half-informed was constructed over the course of the next ten centuries.

For the centrality of the Aristotelian *Organon* as the primary "instrument of logic" throughout the whole of the Middle Ages. Yet without the corresponding Aristotelian texts on nature and biology (and on the massively interdependent relations between *biological form* and *function*), the focus of the next dozen centuries, at least as far as the investigation into "sign relations" is concerned, would proceed from Aristotle's meditations of the sign *exclusively* as it is manifested in human experience. Indeed, *De Interpretatione* – that book of the *Organon* that deals most specifically with semantics, hermeneutics and propositional logic – focuses entirely on the relations of "words" and "sentences" and begins thus:

> Spoken words are the symbols of mental experience and written words are the symbols of spoken words. Just as all men have not the same writing, so all men have not the same speech sounds, but the mental experiences, which these directly symbolize, are the same for all, as also are those things of which our experiences are the images (*De Interpretatione:1).*

The implications of this latter notion – i.e., that "those things of which our experiences are the images" are tied in some deep way to "what all men have" in their very constitution *as* men (or, more properly, as human beings and as animals) – Aristotle declines to expand upon in *De Interpretatione*, mentioning suggestively that it "has been discussed in my treatise about the soul, [and] belongs to an investigation *distinct* from that which lies before us here'" (330 BC /1941: 38). Having access to the thought of Aristotle only through Boethius's translation of the six books of the *Organon*, however, the first six centuries of monastic scholars had no access to this referenced "treatise about the soul" and were thus literally prevented from seeing how the arguments of *De Interpretatione* could be understood as but a particular subset of those in *De Anima* (and in *De Sensu et Sensibilibus*).

De Anima, of course, is about life, and the translation of "anima" as "soul" can be a misleading one to modern English speakers who are not philosophers. For anything resembling the body-separable, spirit-like "soul" of the Platonic, Christian and (later) Cartesian traditions is antithetical to what Aristotle is referring to by the term ψΰχή (Latinized as *anima*) in this work. And, in some ways, the understandings of our current science are closer to Aristotle's ideas about *anima* than has been the case at any time since his rediscovery in the West in the 11th century. Thus, a modern gloss on Aristotle's famous dictum that "the soul is the first actuality of a natural body that is potentially alive" might today read: "life is the emergent system property of the interactions of a self-catalyzing system that can adapt to its environment to persevere. Similarly, the basics of his hylomorphism may be restated to reflect the uncontroversial scientific understanding that the biological "form" of such life is the product of its evolutionary and ontogenetic embedding in the world, and itself consists of those particular sets of systemic relations that serve to organize a material substrate into a particular kind of organism.

Thus, to the extent that even this (highly oversimplified) gloss is representative of the interdependent recursivity of Aristotle's biology, we can see that for Aristotle: (1) animal form is shaped in regard to organisms' interaction with the world, and vice-versa (anticipating Darwin, although, of course Aristotle was assuming the fixity of these systemic organism-world arrangements, and not their evolution); (2) the organism's actions upon the world (which subsequently change that world) are both enabled by and constrained by the organisms' systemic biological constitution, including its perceptual capacities (anticipating von Uexküll); and (3) it follows that as the result of (1) and (2) there is both a "realism" to sign relations and a deep necessity for the joining together of the extra-biological relations of external reality to the embedded biological relations within organisms such that "what *occurs* in the case of the perceiving [system] is conceivably analogous to what holds true in that of the things themselves" (*De Sensu vii.)*. Understood biosemiotically, these are the "things of which our experience are the images" and that "all men" share as part of their biology, and that is alluded to in *De Interpretatione*: not self-subsistent external objects, but the knowledge-bearing, suprasubjective reality of sign relations.

In perception, as well as in imagination, in other words, "it is not the stone which is present in the soul but its form" (*De Anima viii*). Understood within Aristotle's overarching conceptual system of hylomorphism, and again translated for modern ears (especially those conversant with dynamic systems theory), this means that there exists a semiotic 'structural coupling' between the *relations constituting organisms* and the *relations constituting the external world* that ensures a veridical alignment between the two that holds across the *scala naturae*. And again, we can see how the development of evolutionary theory two millennia later (as well as the study of animal perceptual worlds *qua* perceptual worlds that we will be discussing shortly) can further inform this conjunction between bio- and semiotic- reality, making the prospects of a either a nominalist or a Cartesian divorce between knowers and the world they know the bewitchment of a symbolic overcoding system that itself no longer recognizes its own grounding in the relations of the material world (see also: Deacon 1997, Hoffmeyer 1996).

Thus, the breaking apart of the subordinate study of human words and propositions in De *Interpretatione* from the superordinate study of animal organization and interaction in the world that Aristotle develops in *De Anima* – a more or less accidental bifurcation owing to the contingencies of history – became the starting point of a developmental pathway whose alternative trajectory would remain *terra incognita* long after the end of the Middle Ages and right up to the last half of the 20th century. Indeed, the ever-widening bifurcation in the scholastic period between the investigations of bio-logic and the investigation of semeio-logic resulted in the assumption that it is what the scholastics called the "mental word" (*verbum interius*) – or what we might designate more precisely today as "linguistically mediated experience" – that was to be the natural starting point and, eventually, the exclusive focus of "sign" study.

Yet this would prove to be a guiding assumption that is at the same too broad and too narrow; for in understanding the essence of a "sign" per se to be an object that is mediated through the mental experience of a human being, this assumption conflates what is merely one *example* from of the superordinate category of "sign relations" into the very *definition* of the entire category itself.

Doing so thus accomplishes a logical conflation and an explanatory reduction at the same time – a misstep that would have profound consequences for the next dozen centuries of philosophic inquiry, and by extension, for the subsequent foundation of modern scientific thought. For it will be precisely the persistent canalization of this evolutionarily inverted 'linguistic-mentalist' conception of what sign relations are *in their essence* that will prove a major obstacle in the forestallment of a successful explication of the biological and semiotic relations making possible animal knowing, human language, and the ways in which these sets of relations do and do not interact and overlap.

Early Medieval Thought: The Conflation of Signs with Mental Tokens

Of the two major "turns" in the history of Western thinking that would lead to the loss of the non-linguistic "sign" concept as a centrally mediating factor between observer-dependant and observer-independent reality, the first one was gradual and the second one more abrupt. The gradual turn was one bequeathed to us by the medieval scholars over the course of the thirteen centuries when they were most responsible for the shaping of Western thought. Unlike the latter "turn" taken at the outset of modernity by such self-conscious modernists as Francis Bacon and René Descartes, the medievals' gradualist and organic turn was *not* a self-conceived rejection of the modes of thinking that came before it; rather, it was intended to be a progressively developing improvement and refinement of all that had been discovered thus far.

For the virtually unparalleled sophistication and subtlety of scholastic thought was the result of a tradition of rigorous analytical commentary upon currently existing analysis, with, ideally, each succeeding iteration adding additional explanatory clarity, refinement, and depth. Such dialogical, community-based inquiry would give rise in time to the medieval invention of the *university* – without which, as Deely (2001: 83–184) reminds us, the later development (as well as the continued existence of) today's *scientific* "community of inquirers" would be unthinkable. Within such focused communal practice, writes Meier-Oeser,

> great effort [was put] into the conceptual analysis of the basic terms and notions. Thus, wherever terms like 'sign' (*signum*) or 'representation' (*repraesentatio*) appeared in the texts commented on, scholastic authors felt obliged either to give an explicit account of these concepts or at least to be able to refer to a place where this has been done. In view of this, the fact that Aristotle in his *On Interpretation* had incidentally called the word a 'sign' (*semeion, symbol*) of the mental concept or that Augustine had termed the sacrament a 'sacred sign' (*signum sacrum*) became most important for the later development of semiotics. For in both cases, the outcome was a large number of detailed explorations of the nature and divisions of *sign* (Meier-Oeser 2003: o.l.).

Indeed, there is simply no space here to do even perfunctory justice to the rich history of the medievals' inquiry into the nature and taxonomy of sign relations. It is a history well worth becoming acquainted with for anyone wishing to do 21st century biology, however, and particularly so in the field of Cognitive Science – given that the late scholastic treatises suggesting the principles required to establish a naturalistic path of mediation between brute sensation, categorical perception, and symbolic abstraction far exceed in analytic depth and detail any such analysis that has yet been offered in our own time.[9]

Nor should this rich fecundity be surprising, for the scholastics were following the principles of what we would today call "dynamic systems processing", and their central practice of analytical commentary was devised to "build into the process" of knowledge-generation the opportunities for systemic self-correction, recursive iteration, and continual, adaptive growth. Thus, far from being the trivial pursuit and pointlessly hypothetical discourse that the modernists would later self-servingly characterize it as, the scholastic project of knowledge yielded scientific riches that, once lost, would have to be "discovered" again in modernity (as we shall see later in this instalment) – as well as riches that have yet to be put to scientific use.

However, the communal scholastic project was a communal human project, after all – and we now know from the study of such dynamic systems in practice, that "initial conditions" can have a disproportionate effect on the eventual outcome states of such a system, and that the continued iteration of certain values at the expense of others can put such systems on a runaway trajectory of fatally self-perpetuating

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[9] Readers interested in pursuing this latter project should find in Tweedale (1990), Magee (1989), Broadie (1989) and especially Deely (2007) inspiration on where to begin. Those wishing more general overviews with which to begin their own investigation into medieval semiotics are strongly urged to consult Eco and Marmo (2000), Kretzmann (1982, 1988), Gill (1999), and Jackson (1969), as well as the relevant chapters in Escbach as Trabant (1983) and Deely (2001).

"locked-in" effects (Kauffman 1995). Something like this can be seen to have happened to the development of the *sign* concept during the Middle Ages, when, having only Boethuis' (480–525) translations of and commentaries upon Aristotle's linguistic and logical treatises, the medieval scholars inherited, from Boethius' Aristotelian commentaries, the notion of the "*ordo orandi"* (or "order of speaking"). Therein, the hierarchy of knowledge is: the things of the external world (*res*) are signified by mental concepts (*intellectus*) which are then signified by spoken words (*voce*) and these are, in turn, signified by written characters (*scripta*) (Magee 1989: 64–92). And supporting this system is the principle that: "at the fundament of written and spoken discourse there is a mental speech (*oratio mentis*) in which thinking is performed" (Meier-Oeser 2003: o.l.).

As oversimplified (and dangerously misleading) as it is, this explanatory schema as Boethius presents it might yet have enabled the development of a naturalistic understanding of human cognition and communication, given that the word "signify" (to generate new sign relations) is used instead of "represents" (to appear as a coded version) throughout. But since the context in which Boethius' words would be read, elaborated on and conceptually developed, was one in which, again, the primary non-Biblical "instrument for understanding" just happened to be, through the sheer accident of history, Aristotle's treatises on the internal logic of *language* and *linguistically-formed propositions* – and *not* his more general treatises on *biological form, function and development* that were lost to the West for the first eight centuries of the medieval period – it is not surprising that the general direction of the medievals' thought on cognition was one that took *linguistic* relations as paradigmatic of *sign* relations in general, rather than vice-versa.

Such a "mirror-image" hierarchy of cognition, we know now, is evolutionarily impossible. But, of course, the medieval scholars were not thinking in terms of an evolutionary universe, but in terms of a fixed one – and one wherein linear chains of being, put and held in place by an unselfconciously anthropomorphized God, were the received *explananda* demanding logically consistent *explanans*. Freed from the demand to provide an evolutionary account of how language-like signs (e.g., the *propositio,* the *lekta,* the *semeionenon,* etc.) must have had their origin in animal communication and cognition, the medievals instead had to account for how these sign relations fit together to *comprise* (as opposed to merely *support*) the uniquely human form of "reason."

Later Medieval Thought: The Conflation of Signs with Linguistic Mental Tokens

In the 11th century, Anselm of Canterbury (1033–1109) would develop the doctrine of "mental images" as the *verba naturalia*, or "words of thought" common to all human beings, anticipating 20th century notions of "mentalese" and "universal grammar" by almost a millenium. Taking such ideas to their logical (if ultimately futile) extension, the publication of Thomas of Efurt's (c. 1280–1350) *Grammatica Speculativia* at the beginning of the 14th century, inspired whole schools of "modist grammarians" to seek to find the ways in which the modal syntactic and morphological characteristics or words (*modi significandi*) must somehow *derive* from the correspondingly modal conceptual representations of an intellect (*modi intelligendi*), that has been passively shaped by its interactions with the modalities proper to the external thing represented (*modi essendi*). In this way, the science of *signs* and the science of *language* were to become increasingly coextensive, and it is this epistemologically inverted hybrid of signs as language-like phenomena – rather than a true science of signs *qua* signs – that would go on to be incorporated into the progressive "linguo-mentalization" the sign concept that is the hallmark of late medieval thought.[10]

For even with the recovery of the lost texts of Aristotle from the Arab world in the 13th century, the much needed re-reading of *De Interpretatione* in light of *De Anima* never occurred (and, indeed, it has not truly occurred yet). Not surprisingly, then, would William of Ockham (c. 1285–1349) exacerbate the incipient dualism between extra-mental relations and sign relations by asserting that the universal properties of things were merely the universalizing mental *signa* (signs) of human minds. In such ground did the seeds of an increasingly linguaform and mentation-centric nominalism flourish, and the self-reinforcing "humanification of the sign" progress.

All of this is not to say, however, that the Middle Ages were entirely bereft of thinkers dedicating their considerable intellects to an examination of the role of sign relations in life. Most notably, Peter Abelard (1079–1142), Thomas Aquinas (1224–1274) and Duns Scotus (1266–1308) all struggled to incorporate the reality of natural, non-linguistic and non-manmade signs (*signa naturalia*) with the reality of the signs unique to human cognition (*signa rationalis*). Similarly, both Roger Bacon (1214–1293) and the anonymous author known to us today only as "Robert Kilwardby" (c. 1215–1290) independently called for, and made explicit attempts at establishing, a "science of signs" (*scientia de signis*) "in terms of a universal notion abstracted from the [phenomena of] particular signs" (Meier-Oeser 2003: o.l.).

Both of these latter projects foundered, however, given the prevailing interests and valences of their time, and were unable to resist the gravitational pull towards misunderstanding *human symbol use* as the archetypal relation that one studies when one studies "sign relations." For then, as now, the attempt to understand more general and fundamental sign processes through the application of criteria that only apply to more specific and derivative sign processes, resulted in an unrecognized "Orwellian rewriting of the evolutionary past in terms of the present"[11] that, not surprisingly, failed to satisfactorily account for the possibility of any sign relations emerging out of the world of nature per se.

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[10] And of modernity, as well, which, although determinedly paying little acknowledgement to its roots in the scholastic tradition has nonetheless inherited unquestioningly the premise that sign relations are human language-like and should be studied accordingly, and has taken this idea to extremes undreamt of by the medievals, as we shall have plenty of opportunity to observe shortly.

[11] This wonderfully insightful phrase is from Terrence Deacon's equally insightful *The Symbolic Species* (1997: 53), a highly recommended entry point into biosemiotics.

Approaching Modernity: The Replacement of Signs with Linguistic Mental Tokens

Much more in the spirit of the times than the projects of Bacon and Kilwardby was the well-received *Summa of Logic* of William Ockham, which urged that it is the 'logical and propositional' character of the sign that is the proper subject of sign study. With Ockham, the medieval concept of *significatio* – "the presentation of some form to the awareness," becomes subsumed under the naïve realist concept of "intuitive cognition" (saving him from the descent into *radical nominalism* that the more strict followers of his logic would later bear) and henceforth begins its long fall into neglect as a way of thinking about the centrality of sign relations as constituting a natural capacity of *all* sentient beings, while *suppositio* – "the capacity of substantive terms to stand for something in a propositional context" becomes increasingly assumed to be the most productive path on which to seek the *foundations* of human cognition (Meier-Oeser 2003: o.l.).

As the man who more than any other medieval thinker popularized the notion of 'nominalism,' Ockham is often referred to as being simultaneously the last of the scholastics and the first of the moderns – and while the first assertion will not bear scrutiny, it is easy to see in retrospect why the second claim is often made. For in Ockham we find the seeds of those preoccupations that would come to characterise so much of the quickly approaching age of modernity: the insistence upon a separation between faith and reason, between nature and nurture, and between all that is empirically determinable, and all that which partakes of only "nominal" (in name only) form.[12]

With Ockham, the Aristotelian categories of "being" are reduced from ten to two: *substances* and (biosemiotically enough!) their *properties* are the only genuine existents: while *quantity, relation, place, time, position, state, action,* and *receivability* are only "concepts in our minds" (*verba mentis*). Such so-called "connotative" concepts, for Ockham, (or may not) be caused by mind-independent substances and their properties, but in either case, they do not partake of a self-subsisting, mind-independent "reality" of their own (Spade 2006: o.l.).[13] And from this eliminativist perspective, it is but a few small steps – soon to be taken, as we shall see – to the modernists' understanding that only "matter" (if that) is "real."

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[12] It is germane to repeat here Deely's observation that it is precisely those aspects of Ockham's writings called the *via nominalia* that were "presciently called the *via moderna*" by his successors at Oxford as the High Middle Ages were coming to a close (2001: 395).

[13] The argument that universal properties and sign relations are mere mental nominalisms seems sound when applied to the attributions of human culture, such as *happiness* or *beauty*. It seems much less sound when applied to the physics of gravity or the ineliminable triadicity of the genetic code – both of which exert real causal influence in the world, while being irreducible to their material particulars. The unique mode of being that is *relation*, as the sciences of the 20th century will show us, is *in eliminable* from any kind of scientific explanation applicable to the kind of cosmos we are in. Being, as Aristotle seems to have always understood it, is not a noun, but a verb. It will be many centuries hence, however, before that common sense notion will be retrieved.

In retrospect, it is easy to see Ockham's "proto-modernism" as not just an isolated act of one man's intellect, but instead as a particularly astute reflection of the underlying *Zeitgeist* that was surely taking form in his particular time and place. For the two centuries just preceding his had had ushered in an age of trans-European commerce and interconnectedness not seen since the time of the Roman Empire. Along with this came a massive influx of foreign texts both ancient and contemporary and the arrival of an advanced mathematical technology, including innovations in observation and measurement, inherited from the Arab world in the full flower of their centuries-long development (Grant 1996). Rigorously wedding Ockham's conceptualist nominalism and his rejection of the Aristotelian categories with the burgeoning empirical and experimental "turn" started less than a century earlier by Robert Grosseteste (1168–1253) and Peter of Maricourt (l. 1269), Ockham's proteges Jean Buridan (1295–1357) and Nicole Oreseme (1323–1382) along with Thomas Bradwardine (1290–1349) and the Merton College school of "Oxford Calculators," would soon be arriving at many of the same mathematical and scientific conclusions later to be "discovered" by Galileo, Newton and Descartes.

Thus, the myth of the "birth of modern science" wherein the West is awakened out of its dogmatic Aristotelian slumber by its reading of Copernicus in the 16th century turns out to be far too neat by half. More accurate to say, as we will see happening shortly, that the self-conscious "birthing of modern science" consisted more in the deliberately public act of "putting to sleep" the old dogs such as Aristotle and the scholastic thinkers. And it will not be until six or seven centuries later that science will retrospectively find out how wise or unwise of an idea that will have turned out to be.

The Road Not Taken: Signs as Organizational Relations

Before ending our brief survey of the pre-modern era, however, it will be illuminative to ask: What then of the medieval road that was *not* taken into modernity?

This road, one that has all but vanished even from modernity's history of medieval thought (Deely 2001: 447–484), and the one most relevant to the 21st century project of biosemiotics, held that a *sign*, above all, partook of the properties of a suprasubjective *relation*. Such relations are understood to be, common-sensibly enough, genuinely existing phenomena in the real world (e.g., gravity, acceleration, organismic lineage) that, because they are *constituted* relationally, can never be explanatorily *reduced* to the properties of any of (or even to the brute sum of) their component material *relata*.

Rather – and as these late medievals saw long before science would develop the corresponding notions of "emergent properties" "downward causation" and "autopoeisis" – what gives "relation" *qua* "relation" its characteristic property and force is that it is a genuinely existing state of affairs in the world that *holds over* the being of two or more material bodies or energy configurations in their interactions with one another – whether *causally by nature* (e.g., gravity and solubility in physics) or *conventionally by culture* (e.g., political hierarchy and social status relationships). Only later will it become clear, as biosemioticians such as Barbieri (2003a, 2007) and Hoffmeyer (1992, 1996) will point out in our own time, that such genuinely causal relations of "holding over" two phenomena may also be, and often are, *conventional by nature* (e.g., the genetic code, the emergent relations of the adaptive immune system, and even the accomplished products of Darwinian evolution that are "organisms" themselves).

So, too, did the many of the now-forgotten scholars of Latinity discover at last that the unique property of the *sign* (a misleading term of reification for what is in every instance a *sign relation*) is that, as a subset of the genuine form of existential being that is "relation" a sign relation simultaneously "holds over" and exerts a uniquely organizing influence upon the *relata* involved in that sign relation (e.g., a word and its meaning, or a symptom and its cause). But exactly in what sense this last formulation is non-trivial, it will be up to centuries-later discoveries in science and biology – and not in rhetoric or logic per se – to reveal, as will become evident as this history of biosemiotics unfolds.

Yet as we have already seen, it was not the path of inquiry made available by proceeding from the understanding that sign relations are a subset of the genuinely causal existential phenomenon of relational organization that became the "taken road" by the majority of medieval inquirers. Rather, it was the obverse and absolutely incompatible attempt to understand sign use itself as a subset of essentially linguistic relations that would continue to be trod into the modern age, where its fundamental error of reverse derivation would prove fatal when the modern sciences of biology and chemistry called upon it to account for how any merely "biochemical set of relations" (i.e., organisms) could conceivably come to "know about" – much less "think about" – the set of physical relations existing independently of, and external to, those sets of biochemical reactions.

And yet, lacking anything resembling a theory of biological evolution – much less the empirical data of neuroscience, immunology, molecular biology, and developmental embryology – that might have compelled these early thinkers to choose the more general and primary, rather than the more species-specific and evolutionarily-derivative understanding of sign relations, the medieval scholars who pursued a human-language based understanding of sign relations may perhaps be forgiven, given the materials that they had inherited to work with.

Yet out of those materials emerged *both* the notion of signs as a subset of relational organization *and* the notion of signs as a subset of linguistically organized practice. And it was only at the very end of the scholastic period, literally during its very eclipse by the advent of the scholastic tradition rejecting modern age, that a successful synthesis between the two understandings would be attained – to lie undiscovered for centuries, as, once more, this particular owl of Minerva "spread its wings only with the falling of the dusk." Let us, then, here *briefly* trace the development of this untaken "turn" in Western thought as we conclude our introductory overview of science and sign theory in the first phases of their ongoing interdevelopment.

The Sign Concept that Still Lies in Wait

A hard-won realization built from centuries of sublime thought, it was only towards the absolute twilight of scholasticism and the dawn of the modern period that a minority of late medieval thinkers, primarily those associated with the Iberian University of Coimbra, would attempt a reconceptualization of the *sign as a relation* that may supercede any given human way of being. Proceeding from a hermeneutic reconsideration of Augustine's original assertion that "a sign, in every case, imports 'something relative to something else' (*aliquid stans pro alio*)", the most prescient of these Iberians, John Poinsot (1589–1644) in his *Tractatus de Signis,* refuted both Platonic realist and Ockhamist nominalist understandings of sign relations with his conclusion that: "the most *formal rationale* of a sign consists in *being* something *substituted for a significate,* whether as an object external, *or* as representable within" (Poinsot 1632/1985: 163; Deely 2001: 426).

In ways which we will expand upon more fully later in this history, Poinsot's understanding of the sign as being a phenomenon that is in its very essence a triadic relation of x *as* y *to* z – and only derivatively characterized by any actually instantiated realization of such a relation (whether a mental sign to a human knower, an odorant molecule to an opossum, or the exchange of Ca+ as a second messenger in the incessant interaction between living cells) – resuscitated the naturalistic Aristotelian understanding of a world of creatures whose internal organization give rise to their external interactions and vice-versa. In such a world, mind-dependant relations and mind-independent relations are tightly woven.

Moreover, Poinsot's that the term *sign* stands for a particular kind of relation in the biological world, instead of a reified thing reveals, as Deely reminds us "those 'things' or 'perceived objects' that we [mistakenly] *call* 'signs' – such as traffic lights, barber poles, words, [thoughts], and so on, are not, technically speaking, *signs* – but only *vehicles* of signification" for the system whose intrinsic-extrinsic relations are arranged accordingly (Deely 2001: 434). Biosemioticians will later argue that, Rather than being a "purely semantic" distinction, Poinsot's understanding, if adopted widely, may help constitute a radical corrective to the futile attempts to discover what it is about neurons (or about nucleotides, or second messenger molecules, or spoken sounds or the ink marks on this page) per se that "signifies" or is a "sign" of anything.

So re-oriented, the discoverable relevant relations "holding over" both system *x* and (entity, state or event) *y* – as those relations become actualized during the course of the interaction whereby *y* is acted upon as a *sign* of *z*, for *x* – can become the focus of empirical and falsifiable scientific investigation. While this may sound like a task only feasible within the massively complex calculations of advanced dynamics systems theory, one should bear in mind that this was exactly the kind of principled scientific and naturalistic "sufficient explanation" that Aristotle was calling for when he wrote that the relations proper to *biologically* organized systems are "enmattered formulable essences" partaking of an interdependent, but absolutely non-mysterian and scientifically examinable "double character" that any full explanation of such systems has to include in its account. "Hence," writes Aristotle

> a physicist would define an affection of soul differently from a dialectician . . .the former assigns the material conditions, the latter the form or formulable essence . . .Thus, [for the dialectician], the essence of a house is assigned in such a formula as ‘a shelter against destruction by wind, rain, and heat’; while the physicist would describe it as ‘stones, bricks, and timbers.’ But there is a third possible description which would say that it was *that form in that material with that purpose or end*. Which, then, among these is entitled to be regarded as the genuine physicist? The one who confines himself to the material, or the one who restricts himself to the formulable essence alone? Is it not rather the one who combines both in a single formula? (*De Anima: i*).

Thus, from Poinsot’s formulation to our current understanding about the generative, recursive dynamics of autopoetic systems, it is only one small step to realizing the full import of Aristotle’s assertion about the “double character” of “enmattered formulable essences” in biology (where systems really do have locally teleological “purposes and ends”): i.e., that sign relations are those genuinely existing, materially manifested relations that *join* system-internal and system-external relations into a web of utilizable experience for *all* organisms – and, indeed, this is one of the founding premises of the contemporary project of Biosemiotics.

And yet, given the success of the medievals in deepening their understanding of the fundamental nature of sign relations to this point, one would hardly think that the time was ripe to abandon the progress made thus far altogether and to assert an even more radical separation of mind-dependant relations from ‘reality’ – if those mind dependant relations were not genuine configurations in the world, but independently existing immaterial ‘entities’ with a mysterious kind of origin and ontology of their own. The modernists will come to refer to these reified phlogiston-like entities as “thoughts” and “ideas” – and this mischaracterization will have serious consequences for the development of science as a whole. In the following section, we will explore this next and most debilitating epistemological turn in the history of sign theory in science. The will be the onset of a new kind of “Dark Age” wherein an acknowledgement of the biological reality of the sign *qua* sign relation, and its primacy in the organization and interaction of living being, becomes temporarily lost to view.

What will replace the understanding of the natural world as a place of interdependent and intersecting relations giving rise to a variety of semi-autonomous entities and forces will be the idea of a world of fundamental entities and forces interacting mechanistically to give rise to only more complexified versions of themselves. Causation, in this framework, can only be material and efficient – entity and force – leaving no room in the world of explanation (and, by extension, in the world) for the unique forms of causality exerted by formality and finality per se. Thus, instead of being understood as kinds of relations that systems can be in such that they exert a unique kind of causal efficacy of their own – one that would call for a more general and interdependent understanding of “entity” and “force” – formality and finality, having no place in the scheme of atomistic billiard-ball causality, were relegated to the newly-created ghostyard of explanation that was the impenetrably private “immaterial mind.”

Such a discontinuous and divisive posit would itself constitute a schism between the classic-scholastic tradition of thinking and any possible system of cohesive thought that could follow. Yet such a schism is, indeed, precisely what René Descartes had in mind when he announced his project to renounce all prior knowledge, and build the edifice of understanding completely anew, in 1641, in his nightgown, by the fire.

Phase Two: Science Without Semiotics

> What is a man? Shall I say a reasonable animal? Certainly not; for then I should have to inquire what an animal is, and what is reasonable; and thus from a single question I should insensibly fall into an infinitude of others more difficult; and I should not wish to waste the little time and leisure remaining to me in trying to unravel subtleties like these.[14]

So wrote the mathematical and philosophical genius René Descartes in 1641, thereby expressing his resistance to the prospect of becoming a biosemiotician, right at the outset of modernity – a modernity that this particular resistance not only heralded, but actually helped to bring into being.

The subsequent history of this resistance would fill many volumes. However, no understanding of the current state of biosemiotics or of the conditions which made its emergence necessary, if not inevitable, would be genuinely intelligible without a brief re-telling of an oft-told tale regarding yet another decisive turn in the road that has led us to our present pass – children of a hostile, and yet impossible, divorce between not only mind and body, nature and culture but, now too, unexpectedly, between scientific explanation and ordinary human understanding – a tale that the philosopher Bruno Latour has christened "The Strange Invention of an 'Outside' World" (1999: 3).

René Descartes: Bifurcating the Natural World into Body and Spirit

It seems natural to us, as the inheritors of Descartes' intellectual legacy, to set the terms of our understanding in the form of an "experiential debate" between that which is "in the world" independent of any minds, and that which is "in our minds" independent of what is in the world. As a consequence of the very terms of this experiential debate, however, latter stands in relation to the former as a kind of impotent Platonic shadow or blind mendicant – and the mind becomes the impenetrable glass through which we see the world darkly, rather than face-to-face.

Yet this commonplace modern understanding, like all human understandings, no matter how infrequently considered, has an interesting and illuminative history of its own. For René Descartes by no means came upon his radical ideas *ex nihilo*, regardless of how he would have us understand him doing so (or, indeed, as he himself may have understood himself as doing so) in the *Meditations* of 1641. For by 1641, both the scholastic tradition and the hegemony of Aristotelian explanation of

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[14] René Descartes, Meditations on First Philosophy, Meditation Two: On the Nature of the Mind, 1641 [1973: 80].

natural phenomena had all but passed into eclipse in Europe. Modern mathematical notation – one of the primary instruments with which both Newton and Descartes would revolutionize our ideas of what it is to "do science" – made its belated arrival on the continent only in the preceding century (where its initial denunciation by Church authorities as a "pagan notion" of the Arabs and the Hindus, and thus to be resisted, stemmed exactly as little of the rising tide of secularity as did their subsequent denunciations of the works of Copernicus, Galileo and Kepler, and for much the same reason: i.e., an exponentially individualistic and mercantile society, the calculus of utilitarian efficiency trumped the zero-sum game of static absolutism).

Yet while the gradual defenestration of Aristotelian physics had already begun in earnest with the works of Buridan (1300–1358) and Oresme (1323–1382) two centuries earlier, equally critical to the spirit of Descartes' project (and to the successful way that it resonated through the ensuing three centuries) was the turn away from received authority and toward the autonomy of the individual that was the *zeitgeist* of the later Middle Ages. Humanism, the Renaissance, a bourgeoning urbanite and merchant population, the Reformation, anticlericalism, the rise of the universities and the antagonism between change and conservatism that marks any such period of rapid development all formed the backdrop against which Descartes would "autonomously" resolve to "abandon the study of the letter, and to seek *no knowledge other than that which could be found in myself* or else in the great book of the world" (*Disc 1:9*).[15]

This was a move that was to prove critical for the subsequent history of Western thought, for what Descartes reports he finds when he looks inside himself is not an *innenwelt* of referential relations reaching out into the world and structured through participation in a ubiquitous human culture of symbolic reference stretching back at least 12,000 years to the establishment of human settlement (to pick an inarguably late but, because of that, uncontestable date in the evolution of symbolic culture). Rather, and bizarrely, he finds instead an immaterial solipsist who suspects he's being lied to.

"I suppose, then," Descartes writes, "that all the things that I see are false; I persuade myself that nothing has ever existed of all that my fallacious memory represents to me. I consider that I possess no senses; I imagine that body, figure, extension, movement and place are but the fictions of my mind . . . and of my former opinions I shall withdraw all that might even in a small degree be invalidated by the reasons which I have just brought forward, in order that there may be nothing at all left beyond what is absolutely certain and indubitable" (1641 [1973: 150]).

Descartes' project, of course, is a quest for "absolute" (read: non-relative) certainty – and the discovery of at least one contextless and necessarily true axiom or assertion that will serve as the foundation for a sturdy system of reliable and correct knowledge to be constructed. Having already devised one such sturdy knowledge-bearing system – that of analytic geometry and its Cartesian co-ordinate system – in 1637, Descartes now embarks on a radical version of the subtractive method in order to successfully discover a single Archimedean point of truth.

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[15] *Discourse on the Method of Rightly Conducting One's Reason and Seeking the Truth in the Sciences*, 1637 [1973: 24].

Thus convinced of the need to reject the *entirety* of received opinion from the past – as well as to renounce the belief in the primacy of embodied sense experience as being the most fundamental route to "knowing" – Descartes decides to consider as "false until proven otherwise" the entirety of both tradition *and* sensation and to seek absolute certainty in the only place then left available to him – i.e., "the thoughts *which of themselves* spring up in my mind, and which were not inspired by anything *beyond my own nature alone"* (ibid).

This decision to assume that methodological solipsism could serve as the foundation for the construction of a veridical, empirical science was, indeed, a "bifurcation" from the understandings of an inherently embodied cognition that had been assumed from antiquity and developed continually, if variously, by the scholastics right up until the time of Descartes himself (e.g., in the works of the Iberian school and, especially, John Poinsot).

Moreover, Descartes' attempt to "build anew from the foundation [and in so doing] establish a firm and permanent structure in the sciences" (1641 [1973: 144]) by first razing to the ground the edifice of inherited error and by then sterilizing himself against the deception of bodily interface with the world by denying the efficacy of embodied relations was ultimately only considered a completely *constructive* success by Descartes – who then goes on to build his edifice for the securing of absolute certainty anew upon his *cogito*, and its corollary proof of the prerequisite existence of a benevolent and non-deceiving God.

Yet, "having abjured history as a means to truth," writes philosopher of science Alisdair MacIntyre, "Descartes recounts to us his own history as the medium through which the search for truth is to be carried on" (1974: 59). And as it is this account that set the course of the next three centuries of thinking about "knowing" in the West, it is worth considering MacIntyre's analysis of Descartes' history-changing enterprise in full:

> "Descartes starts from the assumption that he knows nothing whatsoever until he can discover a presuppositionless first principle on which all else can be founded. [In so doing] he invents an unhistorical self-endorsed self-consciousness and tries to describe his epistemological crisis in terms of it. Small wonder that he misdescribes it. . . .[for first among the many features of the universe and about his own historically embodied being] he does not recognize that what he is *not* putting in doubt is his own capacity to use the French and Latin languages . . . .[as well as] what he has inherited in and with these languages: namely, a way of ordering both thought and the world expressed in a set of meanings. These meanings have a history . . .[but] because the presence of his languages was invisible to Descartes [he does not realize that] how much of what he took to be the spontaneous reflections of his own mind is in fact a repetition of sentences and phrases from his school textbooks – even the *Cogito* is to be found in Saint Augustine" (1974: 60).

Inspired by the reformationist and revolutionary *zeitgeist* of his time, however, Descartes was not the only one of his contemporaries agitating for a clean break with the medieval past. The feeling had been growing, rather, at least since Petrarch retroactively designated the preceding thousand years, between the collapse of the Roman Empire and his own 14th century Italy, to have been "the Dark Ages" of human thought. The multiple European Renaissances, the Protestant Reformation, the rise of the mercantilism and the rapid advancement of printing, lens and machine technologies: all played their parts in laminating this retrospective construction of a "backward" time from which humanity was finally emerging – and contributed to an idealization of the individual "over and above" history and nature – without which the self-conscious seeding of a "scientific revolution" in the first part of the 17th century could hardly have fallen upon more fertile ground.

But if we see the coalescing of this scientific revolution, as most historians rightly do, as one of the major branching-off nodes in the cladistic history of Western thought – and, more importantly, as the branch on which we yet now reside – it will do well for us to examine what Descartes and his radical contemporaries may have unwittingly 'left behind' at this consequential forking of the roads . . .as it just may be something we are going to have to go back and retrieve today if we are to carry on the very vision of scientific progress that Descartes and his contemporaries have bequeathed to us.

For in "asking how an isolated mind could be *absolutely* as opposed to relatively sure of anything in the outside world," notes historian and anthropologist of science Bruno Latour, Descartes "framed his question in a way that made it impossible to give the only reasonable answer . . .[i.e.,] that we are *relatively* sure of the many things with which we are daily engaged . . .[But] by Descartes' time, this sturdy relativism, based on the number of *relations* established *with* the world, was already in the past, a once-passable path now lost in a thicket of brambles" (1999: 4).

Medievalist John Deely echoes Latour's point, expanding upon it even more precisely when he observes that "if we put [late-medievalist John] Poinsot's claim that the doctrine of signs transcends *in its starting point* the division of being into *ens reale* and *ens rationis* into contemporary terms, [then] what is being asserted is that semiotic [whereby the worlds of mind-dependent relations and mind-independent relations are bridged for the cognitive agent through the mediating relation of sign use] transcends the opposition of *realism* to *idealism*" that has come to define the "mind-body" and the "knowledge/fact" debates initiated by René Descartes and persisting to this very day (2001: 483).

With Descartes, rather, "the priority of *signs to objects* becomes lost to view, and [thus the] *objects of experience* become not a partial revelation of surrounding nature and culture, but a screen separating the mind from things" (Deely 2001: 520). Unfortunately, Descartes was not alone in advocating "radical surgery" that would amputate *res cogitans* from the rest of *res extensa* and banish it to its own little private world – an immaterial world, moreover, that would soon be recognized as a scientifically unexaminable world – and yet the only world, supposedly, in which something as ghostly and non-localizable as "sign relations" could appropriately be thought to dwell.

"Nothing Lost": Modernity Proceeds Apace

Certainly, William of Ockham (1285–1349) may have helped forge the blade for Descartes' radical surgery with his own wholesale denial of the existence of mind-independent universal relations and the reduction of our apprehension as such to "only thought-objects in the mind (*objectivum in anima*)" (1323 [1991]) – a considerable ontological demotion of Aquinas' (1225–1274) far more subtle (and biosemiotic) understanding of the apprehension of such relations – like all sign relations – as partaking of "a dual being: one in singular things, another in the soul, and both [contribute their respective] accidents to it" (1252 [1965]). Even more balefully, it can be seen that at the heart of Ockham's cutting away is a dissection that offers no complementary implement for then suturing mind and world back together again.[16]

The more immediate precedent for Descartes' dualism, however, was undoubtedly Francis Bacon's *Novum Organon* – the "new instrument" that, in 1620, announced the inherent futility of reliance on "a mind that is already, *through the daily intercourse and conversation of life,* occupied with unsound doctrines and beset on all sides by vain imaginations" (1620 [1863], italics mine). Instead, and again very much in the spirit of his age, Bacon would proclaim twenty years before Descartes that "Our only remaining hope and salvation is to begin the whole labour of the mind again. . .[and] that the entire work of the understanding be commenced afresh" (*ibid*).

Like Descartes, Bacon saw "error" as a ubiquitous product of the men both of his time and of all time before him – and, like Descartes, rather than understanding fallibility to be an intrinsic aspect of the effective functioning of symbolic reasoning – sought a "mechanism" designed to subtract it out of the human repertoire entirely.[17] "The mental operation which follows the act of sense I for the most part reject," declared Bacon, anticipating Descartes' dream argument (though not his ball of wax). "There thus remains but one course for the recovery of a sound and healthy condition – namely, that the entire work of the understanding be commenced afresh" – again, prefiguring Descartes here, but now advancing the completely contradictory prescription that: "the mind itself be from the very outset not left to take its own course, but guided at every step; and the business be done as if by machinery" (*ibid*).

Bacon's mind-correcting machinery would come from outside: in the communally objective project of empirical experimentalism and induction. Descartes'

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[16] It would yet be several centuries after Descartes' attempt to describe the non-minded world of animals as "mere clockwork mechanisms" (1649/1991: 365–6, 374) – and almost 100 years after Lloyd Morgan would deploy his Occamite Canon – before biologist Francis Crick would note that: "While Occam's razor is a useful tool in the physical sciences, it can be a very dangerous implement in biology" given that the evolution does not organize living beings "parsimoniously" in any straightforward kind of sense. "It is thus very rash to use simplicity and elegance as a guide in biological research" warns Crick (1988).

[17] The tradition of seeing the human being as the perpetually duped and deceived animal – *homo decipi*, as it were – would turn out to be one of the most enduring, if unfortunate, tropes of all modernity, snaking its way out of Plato's cave, through the "revolutionary" pronouncements of Marx and Freud, and to the "revelationary" pronouncements of neuronal and genetic eliminative materialism on the one hand, and the pseudo-postmodernism of "radical deconstructionism" on the other. As I have argued elsewhere (Favareau 2001b), nothing could be more diametrically opposed to the understandings advanced by biosemiotics than this self-regarding yet internally-contradictory stance that I hereby dub "the Fallacy fallacy."

mind-correcting machinery would come from within: in the irrefutable and eternal truths of mathematics and logical deduction. Abduction – the mind-producing process of acting upon what is presently given in an exploratory fashion, equipped only with the underdetermined understandings that have proved most effective thus far – was out of the picture for the interim (at least "officially" and in the symbolically self-reporting human world; the animals, we may assume, were going about their business as they always do: abductively, but not self-reflectively so).

And though neither Bacon's error-reducing inductive method, nor Descartes' error-reducing deductive method succeeded in being adopted by their contemporaries *in toto*, the enacted *synthesis* of their mathematical-experimentalist methodologies – when coupled to the engine of generatively recursive collectivism initiated by the Royal Society in 1660 and still self-developing healthily to this day – would prove to be the single most effective technology for the securing of veridical knowledge ever developed by the mind of man.

Descartes' radical bifurcation, then, was not a failure – rather, in some sense it succeeded far too well. Which is to say that at least half of the severance was successful and went on to germinate beyond any reasonably foreseeable expectation. For after Descartes, the study of "bodies" would proceed entirely independently of the study of "mind" – their realms, after all, were separate in their essences – and thus the truth claims made by science need not be accountable to the truth claims made by the humanities, and vice-versa. And why should have the science of Descartes' time seen this liberation as in any way undesirable? As the more foundational of the two enterprises – in that the object of its study are those organizational principles of the world that exist extra-mentally and can only derivatively be "known" by human beings – why assume the additional burden of having to explain how it is and in what way a human being can come to "know" anything to begin with?

Bacon's experimentalism was soon institutionalized by Robert Boyle's (1627–1692) foundation of "public science", and the establishment of the Royal Society in 1660 made it clear: the laboratory would be the theatre of evidence, and what could not be shown there was outside the realm of science proper. To this domain of the visible and the material, the pure truths of mathematics would soon, too, be admitted, as a result of the works of Isaac Newton (1643–1727), thereby also vindicating Descartes. Thus armed with the error-correcting mechanisms of both induction and deduction – and with the exponential power of a group of interacting agents pursuing individual ends within the *telos* of a formalized system – the study of "bodies" and their material relations would allow human beings to actually leave the planet and return to it in less than another 300 years.

The other half of Descartes' explanatory bifurcation, unfortunately, did not fare as well. Amputated from the natural world of material and logical relations from which it came, "the mind" and all of *its* internal relations – e.g., sensation, perception, subjective experience, knowledge and, in the singular case of human beings, language and symbolic thought – was increasingly ruled unfit as an object of genuine scientific inquiry, and was as such left to hobble down an increasing impoverished back-lane of abstraction, speculation, and pure, virtually ungrounded symbol use. For one of the more unfortunate effects of Descartes and his contemporaries' uniquely influential attempts to cure subjective error was that the "subject" began disappearing from scientific inquiry altogether.

But what needs to be foregrounded here is that it has never been the absolutely natural property of living organization called "the mind" (or, as neuroscientist Rudolfo Llinás (2001) is quick to clarify, "the property of being minded") per se that is to blame for this sad state of affairs. This condition is found everywhere throughout the animal world, once one realizes that the biological system property of "mind" is no more *synonymous* with "human (symbolic, linguaform) mind" than the term "body-" is synonymous with "human (biped, mammalian) body"– and that those creatures lacking language and the ability for abstractive thought are no "less" minded in the functional and biological sense than those lacking opposable thumbs (or, for that matter, gills or wings) are any "less embodied." Here, as everywhere in the natural world, huge differences in capability, capacity, and the structures which have evolved to meet the real-world challenges of life vary extraordinarily across species. But respiration remains respiration; digestion, digestion; locomotion, locomotion; and reproduction, reproduction regardless of whether we are talking about live birth and sexual copulation, egg-laying practices, pollination strategies or spore formation. There, and rightly so, the whole range of relevant and incommensurable differences is openly acknowledged, *in the full acceptance and understanding* that these species-specific adaptations are all serving precisely the one same biologically analogous end.

The single most compelling reason that the biological function of "knowing" is not likewise included in the list of universal attributes of living organisms is *not* because it isn't happening (and happing as variously and as species-specifically as does every other biological universal), but because our very conception of what *constitutes* "knowing" has been warped by Descartes' conflation of "mindedness" per se with "human mindedness" – and "knowing" per se with "symbolic cognition" (again, see Deacon 1997 for a very clear discussion distinguishing between these two *very* different life processes whereby organisms "know" the world).

Persistently, in the back of our minds (which might explain something right there!), we tend to equate "mind" and "knowing" *only* with our particular form of adaptation to this universal biological need.[18] Yet doing so, presents us with a twofold problem: First, if all of the fine-tuned purposive, responsive, evasive, interactive and anticipatory behavior that we observe taking place *ubiquitously* throughout the animal world cannot be calling "knowing," then what shall we call it when, say, a previously motionless copepod reacts to the sudden presence of a quickly approaching predator by discharging a bioluminescent "depth charge" that is time-delayed so as to burst into illumination far from its site of origin in the copepod itself, instantly alerting the predator and sending it off on a false line of pursuit while the copepod

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[18] A joke commonly attributed to comedian Steven Wright captures the dilemma well: "Last night I was all alone in my room and I started thinking, "You know, the human brain is probably the most magnificent structure ever created in nature." . . .but then I thought: "Wait a minute. Who's *telling* me this?"

swims safely away? Are we to say that the self-reflexive ability to symbolize its own experience and to articulate that set of symbols to another are the *criteria* for "knowing" per se? If so, then the bee can never "know" what flower to land on, the deer can never "know" which other animals in its surround to mate with and which to flee from, the penguin can never "know" which chick is her offspring, and – in fact – all other living beings except the human remain essentially the input/output automatons that Descartes claimed they are.

The second problem that this faulty definition raises is this: *If* all animals other than human beings are now and have always been mind-less, how did the human being "evolve" its own mind *ex nihilo*? The problem is a classic *reductio ad absurdum*, once "supernatural" explanations are deemed illegitimate. And remember, it was and is only supernatural explanation that allows Descartes to assume his bifurcation in the first place: God imparts to man a bit of His own Divine essence – "mind" – but He pre-programs the organization of all the other animals' lives "for them" by building into the mechanics of their mindless input/output actions His own Divine plan. It all seems a "bit much" to accept so uncritically at this late date, but not deliberately going back to examine one's inherited and critically unexamined starting assumptions often results in such odd effects . . .as Descartes himself realized all too acutely.

Finally, the unexamined conflation of "mind" with "human mind" leaves the entire question of the species-specific peculiarity of this kind of human "mindedness" untouched. If we are, indeed, dealing with yet another product of biological evolution, what is it that allows the human mind to engage in abstractive, symbolic reasoning, self-reflective intellection, "language games" of all kinds and the ability to imaginatively manipulate reality "off-line" as it were? What is the nature of this kind of cognition and sign use – and in what ways is it similar to and different from its functional counterparts in the lives of the termite and the baboon? Should we look for its source in the physical structure of the brain, as we look for the source of generating the ultrasound of echolocation in the larynx of the bat? Or should we, as Andy Clark (1997) suggests, look also in the distributed cognitive prostheses of the surrounding environment where we "off-load" our symbolic representations for cognitive exploitation in the way that the bluefin tuna exploits the very water vortices it produces in order to propel it along at speeds its own body could never accomplish on its own?

Few of these questions had even been asked prior to the last ten years – and far too few of them are being asked today, precisely because of the persistence of the still far too institutionally enshrined Cartesian conflation of "mind" with its specifically species-particular form of linguistic representation and symbolic reference – and, in some cases, its even less intellectually defensible notion as a disembodied and somehow self-realizing autonomous "entity." This persistent Cartesian misconception has been perhaps the single greatest "block [upon] the road to inquiry" (in the words of Charles S. Peirce), steering natural scientists away from the problem for centuries, and causing the subsequent "investigations" into its nature by philosophers after Descartes, time to become the embarrassingly fruitless project that it has been.

And this is the reason why we have spent so much time discussing this particular fork in the road. For with the explanatory surgery of Descartes' "mind-body bifurcation" now strongly in place by the end of the 17th century, the unparalleled success of the "body" sciences – including the "body" aspects of the biological sciences – were all but officially absolved from worrying about questions of subjective knowing in general, and thus felt no real pressing need to "waste what little time and leisure remaining . . .in trying to unravel subtleties like these" (Descartes 1641:[1973: 80]). Equally unhappily, those thinkers who did, felt an increasing lack of need to consult, or eventually to even be conversant in, science. Descartes' divorce between "material reality" (*res extensa*) and "knowing reality" (*res cogitans*) had worked too well, and the subsequent "history" of natural science – a science that must include beings that *both* know *and* are material – was explanatorily the worse for it.

"History," however, is a notion that comes to us from the Latin word for "narrative" (*historia*) which itself derives from the ancient Greek word for "witness" (ἵστωρ). Thus, unlike the linear record of geological change, history – even scientific history – has actors and, to paraphrase Chekhov, "if there's a gun on stage in act one, chances are that it is going to go off in act three" (1904). And this is precisely what happened next.

From Dyadic to Triadic Relations: "Information" Invades the Scene

Running off the momentum of the newly institutionalized *Novum Organon* of the Royal Society, the 17th through 19th centuries saw an explosion of biological knowledge initiated by Leeuwenhook's deployment of the microscope. Over time, the cellular structures of plants and animals, the exchange of nutrients and gases, the developmental stages of life from inception to death, and the synthesis of organic compounds from inorganic materials were all discoverable through the use of laboratory instruments, while fitting in perfectly with a growing but coherent corpus of physical and chemical understandings. It is only with Wilhelm Johannsen's (1857–1927) introduction of the "gene" concept in 1909 that "information" per se – and not merely its physical something that is going to have to be accounted for by science.

But "information," under the Cartesian schema, could only be one of two things: either a relation proper only to the mind – in which case it was scientifically unexaminable *perforce* – or a pure product of material interactions, operating under mathematico-logical conditions – in which case it was not truly "information *of*" something, but merely whatever it happened itself to materially be (e.g., a catalyst, an agonist, etc.). Von Baer's (1792–1876) discovery of the epigenetic development of the fertilized ovum into structures expressing hereditary traits, however, made both these definitions equally unsatisfactory.

Thus, in coining the word "gene" to denote "the functional unit of heredity" – whatever it might turn out to be – Johannsen, much like today's biosemioticians, merely thematized – and by so doing explicitly problematized – what was implicitly being "discussed but not discussed" with the acceptance of von Baer's non-preformationist germ layer theory of embryonic development in 1827. For if preformationism is wrong, and an organism's cellular structure is not pre-given but developmental – as von Baer's experiments in comparative embryology showed it to be – then some "information exchange" is taking place within the developing embryo in order for undifferentiated cells to become differentiated tissue and thereafter, the resulting structures of arms, brains, livers and limbs.

Johannsen, again, had no more insight into what precisely this "unit of heredity" might turn out to be, nor how it functioned as it did, than did Darwin, Galton, Mendel, Flemming or Weismann – all of whom also posited germ theories of inheritance that, at their core, remained wholly unexplicated with regard to exactly *how* the interaction of this "germ" with the rest of the cellular material could result in the development of absolutely novel structure when at all points there is only. . .the germ and the material.[19] That it does so is clear – but just what the process *is* that explains its ability to do so was a question that the science of Johannsen's time had not even a coherent vocabulary for conceptualizing.

In delineating the distinction between hereditary genotype and metabolic phenotype, however, and in assigning a property to this gene that was in essence *informational* (in that it served to function for the creation of something other than itself for the system that it was embedded in as, materially, itself), Johannsen opened up the "problem of information" in a science that, since Descartes, had nothing but success in dealing with things that acted merely as what they were materially – and not things that acted both as what they were materially and what they were not, but could be used to functionally "stand for."

And accordingly, while great strides have subsequently been made in our understanding of the purely material relations underlying "the genetic code" – conceptually unclear still is the absolutely scientifically legitimate question of just in what sense *information* – defined not just as the inanimate sequence of nucleotides themselves but as the *functional relation* of those nucleotides to a system *for which* they serve as "sequences of code" – can be thought to be an intrinsic property of *things*. For Francis Crick, articulating his "central dogma" of genetic inheritance, "information" was synonymous with "the sequence of amino acid residues" per se (1985: 1); and for Claude Shannon and Warren Weaver, "information" was the diminution of uncertainty in a system absolutely without regard to cognitive

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[19] Again, we are in an analogous position when we try to understand how "signs" of any kind – the ink marks on this page, the waggle dance of bees, a voltage change generated in a cortical neuron – comes to signify something other than itself, when there is only, physically, itself. And the answer of course, here and on the genetic level, is that we must look at "information-bearing" things not in their material isolation – where they are, in fact, nothing but themselves – but also in the function that they serve in the system that makes use of them *as* signs, in order to see how they can be both "nothing but themselves" and "standing for something other than themselves" in the operation of that system. Exploring this logic of relations within the scientific paradigm is, of course, the *raison d'être* of biosemiotics.

or semantic considerations (1949: 8). Both Crick's notion of "information flow" from gene to protein and Shannon and Weaver's mathematical theory of "communication across a channel" thus explicitly deny that the "information" that they are talking about "means" anything in the sense that we associate with the word "meaning."

But here again, we see the intransigent Cartestian conflation still subtly, and perniciously, at work, undermining even the possibility that material relations and symbolic relations might stand in any other relation to one another than that of mindlessness to human-minded. And thus, the rationality driving both Crick's that and Shannon and Weaver's denials is based upon the assumption that all "true meaning" is *symbolic* meaning – i.e., kind of relation that human beings are exploiting when they talk using language or think in terms of abstract representations. And in this sense, of course nucleotides and the exchange of electronic pulses along a length of wire carry no "*symbolic* meaning." Why, then, use this strange word "information" to describe them?

The lexical decision choice made here – as with the use of the terms "signal" in molecular biology, "message" in neuroscience and "communicates" in animal ethology – is, according to biosemiotician Marcello Barbieri, for all parties to understand that "the 'code' for talking about the genetic code is that the term "genetic code" is only a metaphor, and should not be understood as denoting what it would denote in everyday usage" (2003: 229). But if so, and in regard to the other three instances also: the question reasserts itself this 'metaphor' is a metaphor for what? "Processes we do not yet understand," certainly. But what kind of processes? It would seem that the answer is: not just physical processes *qua* their physics, but exclusively biological processes wherein physical phenomena are being acted upon by living systems as if they were veridically informative, representational and meaning-bearing phenomena. And once the existence of such genuinely *semiotic* processes in nature is admitted, a pressing question for science then becomes: How are we to investigate and understand these processes that are both ineliminably physical *and* ineliminably semiotic at the same time?

Yet the refusal to cross the self-imposed Rubicon inherited from the Cartesian legacy – a refusal born out of fear, generally, that if one does engage with issues of "meaning" one has automatically "crossed over" and *out* of the realm of doing real science – prevents theorists like Watson and Crick and Shannon and Weaver from seeing in what way their intuitions to use the words "information" and "communication" can point both them and us to a deeper understanding of those terms, one which is neither eliminative and reductionististic, nor mystical and unfalsifiable, but utterly naturalistic through and through – *if* we remain open to the understanding (that our dedication to science demands of us) that *all* things in the natural world evolved out of that natural world and nowhere else.

If, in other words, there are biological creatures that are alive today that use symbols, and exchange meanings, and have culture, and can deal in counterfactuals and can think abstractly – as undoubtedly there are – *and* there are other living beings evolving under the same physical conditions who are constituted from virtually the exact same genetic material, and who have developed myriad of other capabilities, but just not those particular ones last listed – *and* you deny at the outset that all of this is the result of a Divine miracle – *then* 'thoughts', 'meanings', 'symbols', 'culture' and everything else that we associate today with the human mind must be *grounded* in the structures, events, principles and relations that constitute the natural world. Understanding this, the research questions then become: What particular relations in the naturally occurring world does human symbolic understanding exploit differently, say, than primate indexical understanding does, or that the iconic relations chemotaxis affords for the amoeba? Are the earlier processes still at work in the later ones? How much and what kind of environmental restructuring is necessary for the full functioning of each? And *is* there a primitive organizational sense whereby the digital "differences" in electronic pulses down a length of wire (or, in the biological case, an axon), and the sequential differences in base pairs affixed to the phosphate backbone of a DNA molecule really *do* in-form the immediate next moment of consequential change in a living system? How does all this work? And how does all this work *together?* These are the questions that biosemiotics will wind up asking, seeking *not* a reductionist anthropomorphism of "all things in nature as human" but just the opposite: a principled evolutionary and biological understanding of how all things in human (and in animal life) are natural – including "knowing", including "meaning", including "thought" and because of these last three, including "signs."

Interestingly enough, however, it is not the biosemioticians who stand ready to reject the notion that the biological set of relations constituting "sign processes" are, in fact, massively complex, organically organized material interactions; most biosemioticians would rejoice at such a discovery. Conversely, it is far too often the committed physicalist who so closely (and so incorrectly) equates the entire category of "semiotic processes" with the one limiting case of symbolic, human mental processes, that to talk about the former *is* to talk about the latter – in which case, of course, they are completely right to reject the initial premises. Descartes' bifurcation, in other words, is continuing to keep the sciences of material interaction and the sciences of semiotic interaction apart.

But if biosemiotics has any one single most constructive message to give the mainstream scientific community, surely it is precisely this: a semiotic process is not a ghostly, mental, human thought process. Rather, it is, in the first instance, nothing more nor less mysterious than that natural interface by which an organism actively negotiates the present demands of its internal biological organization with the present demands of the organization of its external surround. And the fact that this is done incessantly – by all organisms, and by us – should not blind us to the significant fact that such moment-to-moment activity is always and perpetually an *enacted accomplishment* – and thus one that is going to have to be explained, if we are ever to understand the bio-logical side of living organisms' material interactions.

Yet so scandalous and counter-intuitive was this notion of genuine sign relations in nature – so drenched with and indistinguishable from, as it were, their singular symbolic manifestation as "mental thoughts and human words," Descartes' 'divine birthright of human intelligence' – that when Darwin's contemporary George

Romanes (1848–1894) presented anecdotal evidence in support of even the possibility of animal intelligence, Edward Thorndike (1874–1949) announced that the goal of his own work would be dedicated to disprove "the despised theory that animals reason" (1898: 39). How human intelligence could ever have "evolved" out of a world of absolutely non-semiotic animal relations then becomes something of a paradox – and, in fact, J. B. Watson (1878–1958) and B. F. Skinner (1904–1990) drew out the logical entailments of this view to eventually argue that human mental states, likewise, were "an illusion" – a position implicitly endorsed by the approach of many manifestly competent neuroscientists, and explicitly argued for in the "eliminative materialism" of Paul and Patricia Churchland (1984, 2002)...still victims of Descartes' destructive dualism, even after all these years.

Not surprisingly, then, do we begin to see at the dawn of the 20th century, cracks and fissures arising in the scientific edifice out of internal tensions generated by the need to keep "subjectivity" out of science not only in its methodology, but also as a focus of investigation – despite the absolutely undeniable facts that: (1) the natural world is full of subjective agents, (2) that the natural world itself must have produced these subjective agents once one rules out the possibility of supernaturalism as a legitimate scientific explanation, and (3) that it is the subjective experiences of these agents that lead them to act upon the natural world in ways that materially *change* that world (and in so doing, change the substrate that world then becomes for the evolution of subsequent subjective agents...). All of this undeniable natural phenomena only becomes denied *as* "natural" phenomena with the adoption of the quite unnatural bifurcation insisted upon by Descartes that puts the entirety of human "mind" – along with every kind of "knowing" operation one might conceivably be tempted to assign to the purposive behavior of non-human animals – into the ghostly realm of the absolutely immaterial ...and, again, despite the overwhelming evidence to the contrary of the existence of a plentitude of knowing, material, purposively acting, biological beings.

Moreover, not only was Descartes' legacy of ontological bifurcation causing cracks and fissures to appear in the explanations being offered for any researcher in the biological sciences who looked too closely at the obviously enacted subjective experience of living organism and the informational capacity of the genetic code, but it was also exerting a complementary tectonic pressure on the long line of philosophers, humanists, and researchers in the social sciences, who found themselves on the other side of the Cartesian divide, trying ever unsuccessfully to meet a challenge that, by its very premises, could never be met. Eventually, a few of the most frustrated – which may really be to say, the most committed – members of these two groups started pushing back against their respective fields' Procrustean demands and Cartesian boundaries, and began scouting around on distant coastlines in an effort to more effectively redraw their disciplinarily inherited, but increasingly unusable maps.

It is to that ever-growing group of interdisciplinarians that we now turn, for their work will provide our entrée into the current state of the field, constituting, as it does, the most recent evolutionary turn in the natural history of *biosemiotics*.

Phase Three: Science with Semiotics

> The key question lying at the root of all this is: How could natural history become cultural history? Or, to put it another way. . .How did something become "someone"? – Jesper Hoffmeyer, *Signs of Meaning in the Universe* (1996: viii).

Because the current cohort of scholars constitutes the "first generation" of self-identified biosemioticians, the history of this cohort as a whole would have to consist in the history of each member, as he or she – faced with the internal contradictions or explanatory evasions of their home discipline – made their own unique pilgrimage to a place where biology and semiotics merged as one. Although doubtlessly fascinating, it would be impossible here to recount all these individual journeys from Istanbul and Los Angeles, Helsinki and Bologna, Toronto and St. Petersburg, Sao Paolo and Prague, and to describe the many and various disciplinary sites of origin spanning across biochemistry and philosophy departments, dynamic systems research labs and anthropological field sites, as well as lifelong private research investigations of individual scholars, many of whose final destinations are, as of this writing, unknown.[20]

What we must do here instead, in order to bring coherence to this account, is to focus on just those few figures most responsible for bringing this diverse group of scholars together. These would be the outspoken interdisciplinary organizers whose explicitly stated program of coalescing semiotics and biology increasingly attracted similarly inclined scholars into their orbit, and whose journals, conferences and book projects would come to constitute the gravitational center around which the interdiscipline of *biosemiotics* would gradually coalesce. And of this handful of "outspoken interdisciplinary organizers" perhaps none was more outspoken, more interdisciplinary, and more organizationally active and astute than the late Thomas A. Sebeok (1920–2001), without whom the current interdiscipline of biosemiotics would not have taken shape in its present form.

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[20] Moreover, and by necessity, not every attempt at a science of biological sign-use undertaken even in the last half century can be included in this short history. Such a survey would, of course, be impossible given the space available and would, by necessity, involve long discussions on the history and major figures of comparative psychology, cognitive science, molecular biology, Artificial Intelligence, pharmacology, cognitive neuroscience and much much more. Yet it is only because of such space limitations that even the individual accomplishments of such generally accepted "proto-biosemioticians" as Elia Sercarz (1988), Sorin Sonea (1988), Günter Bentele (1984), Yuri Stepanov (1971), F.S. Rothschild (1962), and Marcel Florkin (1974) are not discussed at length in this overview. This is not to say, however, that the works of these researchers are insignificant to the larger project whose narrative is recounted here. Florkin, Stepanov and Rothschild – a molecular biologist, a text semiotican, and a psychologist, respectively – each independently coined the term "biosemiotic" to describe where they wanted their investigations to be heading. But because no interdisciplinary movement resulted from these individual efforts, I have made the purely editorial decision to refrain from any in-depth discussion of them overview, and the works of Florkin and Rothschild are examined in much detail later in this volume. No slight on my part is intended by these purely editorial decisions, and those wishing to consult the original works are directed to the bibliography, as well as to the more inclusive "pre-histories" of biosemiotics by Sebeok (1998, 2001a) and Kull (1999a, 1999b, 1999c, 2005).

Joining Sign Science with Life Science: Thomas A. Sebeok

While a growing number of isolated scholars working in widely-separated disciplines were all working away at various *independent* lines of inquiry into the problems of information processing, intercellular communication, behavioral psychology, neurobiology and animal ecology – and long before the birth of such self-consciously "interdisciplinary fields" as "artificial intelligence" "dynamic systems research" or "cognitive neuroscience" – an academic polymath who once described himself as something akin to an "*Apis mellifera,* who darts solitary from flower to flower, sipping nectar, gathering pollen [and] serendipitously fertilizing whatever he touches" (Sebeok, 1995) was to pioneer the practices that the modern-day university refers to as "interdisciplinarity" in the course of founding the project that today bears the title of *biosemiotics.*[21]

This self-described *apis,* Thomas A. Sebeok (1920–2001), left his native Hungary at age sixteen to study at Cambridge University, before immigrating to the United States, where he received his doctorate in linguistics from Princeton in 1945 while simultaneously doing research under both Roman Jakobson at Columbia University and Charles Morris at the University of Chicago (Bernard 2001). A specialist in Finno-Ugric languages, Sebeok's appointment as the head of the Department of Uralic and Altaic Studies at Indiana University led to decades worth of extensive fieldwork not only investigating the internal organization of linguistic systems per se, but also in investigating the higher-order manifestations of such systems, in the form of anthropology, folklore studies and comparative literature (ibid).

Sebeok's growing interest in the organization of semiotic systems in general, combined with his aforementioned polymath intellect, led him to carry out some of the first computer analyses of verbal texts; to investigate the use of nonverbal signs in human communication; and to establish, with Charles Osgood, the pioneering interdisciplinary field of *psycholinguistics* in 1954. Six years later, during a fellowship at Stanford University's Center for Advanced Studies in the Behavioral Sciences, Sebeok indulged his lifelong passion for biology, studying both nonverbal human sign behavior as well as the communication practices of animals, both in the wild and as domesticated by human trainers (Tochon 2000). From this intense period of study came his programmatic call for the founding of the study of *zoösemiotics* – "a discipline within which the science of signs intersects with ethology, devoted to the scientific study of signalling behaviour in and across animal species" (1963).[22]

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[21] As is evident from the footnote above, Thomas A. Sebeok was not the first to coin the compound noun joining "bio" with "semiotics" (again, see Kull (1999a) for a detailed history of the use of the term) – however, it is the specific project that Sebeok initiated and christened as such that is the subject of this history and this book.

[22] Deely notes that it was Margaret Mead who, at the end of a contentious conference about animal communication that Sebeok had organized in 1962, proposed the specific form of the word "semiotics" to denote "patterned communication in all modalities, [whether] linguistic or not" (Deely 2004) – an understanding perfectly congruent with Sebeok's growing conviction that human

Sebeok's commitment to what he considered to be the two fundamental academic virtues of "publishing and teaching as much as possible and, equally importantly, doing one's best to facilitate the success of one's colleagues" (1995: 125, as cited in Kull 2003) led to his refashioning of the Indiana University's Research Center for Anthropology, Folklore, and Linguistics – of which he had been appointed chair – into the Research Center for Language and Semiotic Studies in 1956, and to the co-founding of the International Association for Semiotic Studies in Vienna in 1969. In his activities for both these institutions, Sebeok's reputation as a tireless book editor, indefatigable conference convener, inveterate journal contributor, and all around facilitator of academic interaction across continents and disciplines became (and remains) legendary among his peers.

Thus it was Thomas Sebeok who would be responsible, more than anyone else, for bringing practitioners from the life sciences and the social sciences into dialogue with each other for the course of the next almost forty years, resulting in the collaborative interdisciplinary project that we today know as Biosemiotics. The *Approaches to Semiotics* book series that he founded in 1964 eventually ran to 112 volumes over the course of its almost thirty year run; he was editor-in-chief of the journal *Semiotica* from its inception in 1969 until his death in 2001; and the list of international conferences that Sebeok played a role in initiating with the express goal of bringing scientists and semiotician together would constitute a document – and, indeed, it is one that has yet to be compiled.

Sebeok's Synthesis of East and West

Catalysts, by definition, enable reactions to occur much faster because of changes that they induce in their *reactants*. And so, too, it was with Sebeok who, in the course of building this interdisciplinary network (or symbiotic niche, as he might call it), must in addition be credited as the key figure most responsible for integrating both the current works and the rich theoretical traditions of otherwise forgotten academics toiling in the Soviet East into Western academia's collective consciousness. This he did often through his own smuggling of desperately proffered manuscripts across mutually antagonistic Cold War borders in the 1960s and 1970s (as memorably recounted in Sebeok 1998 and 2001) – actions which themselves serve as a wonderfully apt metaphor for his own "bee-like" approach to the unnecessarily antagonistic disciplinary partitioning between the science and the humanities that he devoted his entire career to cross-pollinating.

These trips darting in and out from behind what was then called the Iron Curtain turned out to have particular significance for the development of Sebeok's *zoosemiotics* program into what he would later call *biosemiotics* (Sebeok 1998). For while

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language "was not much more than that realm of *nature* where the logosphere – Bakhtin's dialogic universe – impinges in infant lives and then comes to predominate in normal adult lives" (Sebeok 2001a).

acknowledging his debt of understanding to both the Swiss "zoo biologist" Heini Hediger (1908–1992) for his pioneering work on the communicative practices of animals (and between animals and humans in the practices of animal training) – as well as to the Italian oncologist Giorgio Prodi (1929–1988) for his equally bold investigations into the semiotics of immunology and call for a comprehensive program of "natural semiotics" investigating the genetic, metabolic, neural and immunological sign exchange processes of the human body (a program that Sebeok would later characterize as "endosemiotics") (Sebeok 1976) – it was Sebeok's 1970 trip to the then "forbidden city" of Tartu in the Estonian Soviet Socialist Republic to meet the Russian semiologist Juri Lotman (1922–1993) – a trip that he would later describe as "a singular Mecca-like field for us pilgrims laboring in the domain of semiotics" (Sebeok 1998) – that would forge the link between Sebeok's lone bee-like investigations and an entire rich tradition of semiotic thought that, at the time, was virtually *terra incognita* in the West.[23]

The Cold War era was a difficult time for such East-West mutual collaboration, however, and Soviet émigré Vyacheslav Vsevolodovitch Ivanov (1929–) recalls that many scholars' works that were forbidden to be published in Moscow at this time had to be surreptitiously channeled to Lotman to be published in Tartu (1991: 36). In turn, it was Sebeok who was entrusted by Juri Lotman with his seminal biosemiotic manuscript *O Semiofere* for translation and publication in the West (Sebeok 1998).[24] Lotman's delineation of the realm of sign relationships permeating human life is, of course, a cognate of the word *biosphere* – the organizational space wherein living beings occur and interact – and was designed to foreground the autopoetic nature of *sets* of sign relations (such as "language" and "culture") as "modeling systems" for embodied action in the world of things by agents. And in this sense – the sense that Jesper Hoffmeyer will later use the same term, though unaware of its prior use by Lotman – it is a deeply biosemiotic notion.

Sebeok, however, found Lotman's own early explication of the concept – which largely restricts its scope of inquiry to the human and symbolic realm of interactions that Vernadsky called the *noosphere*[25] to be an explanatorily *necessary* concept for

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[23] Mihaly Csikszentmihalyi's (1934–) distinction between a "field" and a "domain" remained one central to Sebeok's life and thought. In short: A *domain* refers to an intellectual culture of shared meanings, definitions, assumptions, rules and evidentiary procedures (such as "science," or more finely, "medical science"), while a *field* comprises "all the individuals who act as gatekeepers to the domain...[and who decide] whether a new idea...should be included in the domain" (Csikszentmihalyi 1997: 27–28). And in 1970, Juri Lotman's Tartu-Moscow Semiotic School was by far the closest thing resembling an established *field* of disciplinary gatekeepers for the nascent world of international semiotic study (see Sebeok 1998, Kristeva 1994, Kull 1999c).

[24] The history of this manuscript's subsequent loss at the hand of a translator is recounted in Sebeok (1998). Suffice it to note for our purposes that it would not be until twenty years after the event, in 2005, that the English language translation of Lotman's manuscript would appear in the journal that Lotman himself founded in 1964, *Trudy po znakovym sistemam* – now known in English as *Sign System Studies*, Volume 33.1

[25] Lotman himself resisted this equivalence (1989: 43), insisting that the ability of cognitive agents to shape the material surround of their environment (Vernadsky's *noosphere*) differed from the

understanding our species-specific use of, and immersion in, a world of materially consequential sign relationships – but not to be an explanatorily *sufficient* one for doing so.

For it is one thing merely to assert, as he does himself some time later, that the human being is "a joint product of both natural and cultural forces" (Sebeok 1986a, b: xi). But in and of such an assertion in itself, it remains unclear if what is being talked about are two mutually exclusive and possibly antagonistic forces, or some kind of symbiotic relationship, or merely two largely artificially designated extremes along what is, in fact, a continuum. Still left fully unexplicated then, felt Sebeok, was an explanation of how the set of sign relations constituting the human symbolic semiosphere emerged from – and in some sense remained dependant on – our simultaneous existence as biological beings. For that explication, Sebeok would have to look elsewhere.

Sebeok thus continued his own decades-long study into animal communication both by reading the majority of research literature then extant and through his hands-on work with zoobiologist Heini Hediger (Sebeok 2001b). And as he did so, he became increasingly convinced that the sign relations taking place in animal communication and those in human language – while belonging to a common genus of interaction in the natural world, were yet divergent species that also needed to be understood on their own terms. Starting in 1977 and continuing well into the 1990s, Sebeok published in-depth critiques of the various underestimations, overestimations, anthropomorphism and machino-morphism being then attributed to animal cognition (e.g. Sebeok 1977, 1980, 1988, 1990a).

In these writings, Sebeok is particularly adamant in insisting that what "ape language trainers" such as Duane and Sue Savage-Rumbaugh (1977, 1986), Allen and Beatrix Gardner (1979, 1989) and David and Ann Premack (1977, 1984) were attempting – or at least what they were succeeding at – should not be confused with the idea that these apes had acquired the ability to use "language" in the true sense of the word. Rather, felt Sebeok, such researchers were merely shaping the animals' behavior along purely iconic and indexical (stimulus-response) levels – without themselves having a discriminating enough understanding of sign relations to understand the underlying difference between the two phenomena. Thus, by pronouncing the resulting Skinnerian chain of purely associative reflexes to be the equivalent of "language," Sebeok concluded, these researchers were "looking in the destination

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purely "abstract" cognitive interactions of the *semiosphere*. The distinction that Lotman fails to draw here – as is so often the case in such discussions about "mind and world" that yet accept the assumptions of Cartesian dualism on some fundamentally under-examined level – is the failure to differentiate between the *symbolic* level of embodied, biologically based sign processing, and its equally biological iconic and indexical substrates, with which it is on an experiential continuum. Such delineations are critical to the project of a scientifically sound biosemiotics that can yet account for the realities of abstraction and counterfactual reasoning, and we will have much more to say about these delineations presently. For an edifying discussion of the Lotman/Vernadsky controversy, see Chang (2002) and Kull (1999c).

for what should have been sought in the source" (as he succinctly titled his 1980 paper reviewing this work).

Sebeok was convinced that approaching animal communication as a truncated form of human language, just as Terrence Deacon would argue later in an elegant book-length consideration of language origins, "inverts evolutionary cause-and-effect" (1997: 53). For to Deacon – and to Sebeok – the proper question is not: "Do animals have language the way that we do, and if not, why not?" but rather: "As animals ourselves, how is it that we have language?" For what makes human "language" unique, both Sebeok and Deacon agree, is not the mere ability to map sounds or gestures onto physically co-present things as referents in the first instance – but the far rarer ability to be able to flexibly, systematically and effectively manipulate representations of non-present, impossible and counterfactual conditions in the knowledge that we *are* "manipulating representations" (and not the things themselves) in doing so.

Yet what modern semiotician ever thinks of signs as other than exclusively human cultural products? And what modern scientist ever thinks of biological organization as itself perfused with signs?

The explication that Sebeok was to find was one that he himself had to help to create. And so to understand the synthesis that Sebeok was to propose as the "starting point" for his proposed interdiscipline joining the life sciences with the sign sciences – his *biosemiotics,* as he was soon to call it – one must first understand how Sebeok's long-standing study of the semiotic logic of relations explicated by the American philosopher and scientist Charles S. Peirce (1839–1914) served as the substrate upon which Sebeok's later rediscovery of the research into the perceptual worlds of animals undertaken by the then all-but forgotten Estonian biologist Jakob von Uexküll (1864–1944) would act as a powerfully synthesizing reagent.

Sebeok's Synthesis of Charles S. Peirce

A laboratory trained chemist, astronomer, mathematician and logician, Peirce advanced a logic of sign relations – or "semeiotic" (as Peirce had called it) – that Sebeok was well conversant in, having studied under at least three self-proclaimed epigones of Peirce – i.e., C.K. Ogden (1889–1957), Roman Jakobson (1896–1982) and Charles Morris (1901–1979).[26]

And because Peirce's "architectonic of triadic logic" deeply informs so much of Sebeok's work, it would be impossible to continue this particular "line of emission" in the history of biosemiotics without providing here at least a summary overview

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[26] Later, Sebeok himself would be instrumental in tracking down the author of an obscure unpublished doctoral dissertation on Peirce and commissioning him to revise the all-but-forgotten manuscript thirty years later for publication. This work (Brent 1993) has since become the definitive biography of Peirce.

(or brief flash, as it were) of this, one of the two main sources of incandescence illuminating Sebeok's biosemiotic vision.[27]

A scientist by training and by temperament, it is germane to note that "sign" relations for Peirce are a species of a larger genus of relations whereby potentiality becomes actualized, and the actualized interacts with other likewise realized actualities so as to result in pattern. This, of course, sounds extremely abstract on first glance – but in point of fact, nothing could be more natural (literally) to those brought up in the scientific faith. On the inanimate level, for example, the very "beginning" of our contemporary cosmos was a single point of undifferentiated energy (if, indeed, "energy" is not already too sophisticated a term) whose "development" into our current universe is nothing other than the *history* of its successive recursive change as, at each point, literal physical possibilities are made available only as the result of immediately preceding action, and as one of those possibilities is actualized, a new and slightly changed set of possibilities (and constraints) come into being. Thus, we see (retrospectively): the uncoupling of the unified force, which results in the generation of quarks that then makes possible the generation of hadrons, the results of whose interaction in the rapidly cooling universe gives rise to the existence of neutrons, that can then later join together with the protons to form the universe of atoms that. . .*ad infinitum* (or *finitum*, as the case may eventually be).

The point is that there is nothing mysteriously "metaphysical" about Peirce's notions of what he calls *firstness, secondness,* and *thirdness.* Rather, these relations refer, in a radically fundamental sense, to the scientifically examinable (and scientifically necessary) relations of *possibility, actualized existence* and *law*. That the more recent conceptualizations of chaos and complexity theory have given us a better vocabulary with which to talk about such utterly natural phenomena (e.g., iteration, interaction, emergence, downward causation and – in the case of living organisms – autopoesis) attests to the richness of Peirce's "logic of relations."

A major part of Peirce's logic is his "semeiotic" – or logic of sign relations. Its simplest 'biosemiotic' formulation begins with the observation that the last-most-current or "given" state of affairs in the world to the perceiving agent is present to that agent *in its firstness* as an unlabeled "raw feel" (what others have termed its *qualia*). Of all the things that unlabeled sensation "could be," the agent – given the set of existing possibilities and constraints made possible at that moment by its own biological organization and set of prior associations – "experiences" that set of feels *as x* (hunger, the color red, a flower, etc.), and this *secondness* of experience builds a web of brute sensations into a web of meaningful perceptions.

And, finally, once not just the sensations and the perceptions but the *relations* within that web themselves (i.e., of sensations *to* perceptions, and of perceptions *to* other perceptions) become representable 'as signs' in their own right (e.g., musical

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[27] For more in-depth overviews, see Colapietro (1989, 1996), Deely (1990, 2001), Deledalle (2000), Parmentier (1994), Savan (1976), and the e-resource for all things Peircean, *Arisbe*, at: www.cspeirce.com

notation, mathematical notation, linguistic notation, etc.), the malleable conventionality of *thirdness* becomes available to living organisms, for the re-contexulaization of both *firstness* and *secondness* (sensation and perception) into what we generally refer to as symbolic 'understanding'. And it was precisely the mystery of how and why it is that human beings have become such "savants" in the use of thirdness, while the majority of other species have not, that drove Sebeok to search beyond the elegant theoretical logic of Peirce and into the cacophonous real world of animals and their sign behavior.

Sebeok's Synthesis of Jakob von Uexküll

Sebeok recounts how he had come across what is largely considered to be an execrable translation of an early version of von Uexküll's *Theoretische Biologie* decades earlier, while still a student at Cambridge, but found it both "baffling murky" and "beyond doubt over my head" – as well not at all germane to his then-current project as a sixteen year old Hungarian student attempting to learn English (2001: 64, 1998: 34).

Thirty years later, Sebeok would read von Uexküll's fully finished version in the original German – and this re-reading, in the words of contemporary biosemiotician Marcello Barbieri, "was a kind of fulguration on the road to Damascus" for Sebeok (Barbieri 2002: 285). There is much truth in this characterization, as we shall see. For in his rediscovery of von Uexküll, Sebeok felt had that he had not only found the long missing piece of the puzzle that he had been looking for, but was also convinced that he had found what so many other laborers in so many other fields should have been looking for all this time as well – i.e., an absolutely naturalistic way of understanding the link between the human world of signs and the animal world of signs. So it is to Jakob von Uexküll and his study of the perceptual worlds of animals that we now turn.

Cited by both Konrad Lorenz (1903–1989) and Nico Tinbergen (1901–1972) as the founder of the modern discipline of ethology, Estonian-born German biologist Jakob von Uexküll (1864–1944) devoted his entire life to the study of animals, training first as a zoologist and afterwards going on to the pioneering work in muscular neurophysiology that would result in *Uexküll's law of neuromuscular regulation,* often cited as the "first formulation of the principle of negative feedback [and thus reafferent control] in living organisms" (Lagerspetz 2001: 646). A dedicated physiologist as well as a biologist, Uexküll drew a distinction between the two projects that is worth quoting in the words of his contemporary archivist in full:

"Already in his first monograph Uexküll (1905) assigned different roles to physiology and biology. Physiology should organize the knowledge about organic systems by looking for causalities. Having preserved the advantage of the experimental method, physiology should help to [inform] biology. In distinction to physiology, biology has to use the scientific method to go beyond the investigation of causalities by exploring the laws that [account for] the purposefulness of living matter. Therefore biology should study organisms not as objects, but as active subjects, thus focusing on the organism's purposeful abilities that provide for the active integration into a complex environment. Biology therefore had to deal with holistic units and to maintain a broader scope than physiology in order to grasp the interactive unity of the organism and the world sensed by it. For describing this unity, Uexküll introduced the term *Umwelt* (1909)" (Rüting 2004).

A forerunner and conceptual pioneer of the study of feedback and reafferent control in the workings of what will later come to be called complex adaptive self-organizing systems, Uexküll had no access to the rich vocabulary of "autopoetic" explanation that his own groundbreaking work would engender almost a full century later. Yet Ludwig von Bertalanffy's (1901–1972) "general systems theory" – as well as its increasingly sophisticated descendents (i.e., cybernetics, catastrophe theory, chaos theory and complexity theory) – all issue from von Uexküll's notion of the *Funktionskreis* or "functional cycle" of perception and action that effectively "couples" the ever-changing system that is the organism to the ever-changing system that is the world.

Thus, in the discussion about "causalities" above, Uexküll has no recourse to the vocabulary of "emergent system properties" "recursive downward causation" "dynamic instability" or "autopoesis" that would allow him to delineate for his readers the distinction being drawn between the purely material and efficient relations of brute physiological stimulus-response regularities and the higher-order "systemic" relations between world and organism (as well as organism parts to whole) that are the bottom-up product of – as well as the top-down shaper of – those physiological interactions (both in real-time and in evolutionary time) to begin with.

That said, both Uexküll's pioneering work on marine biology, as well as his prescient conceptualization of feedback systems, leave him only dimly remembered, if at all, in the two fields he most directly spawned (animal ethology and dynamic systems research).[28] And this is undoubtedly due to von Uexküll's Baerian resistance to the Darwinism of his time and to the somewhat "telic" understanding of what he calls "Nature" (1934/1957, 1940/1982). Like von Baer, Uexküll felt that Darwin "treated the concept of causality incorrectly and did not consider the internal [component in the active self-organization and creation] of individual organisms" (cited in Kull 1999d). Given that all these men – Darwin, no less than von Baer and von Uexküll – were working long before the development of modern genetic knowledge, it is perhaps no surprise that each of them sees more clearly the "reverse but complementary" side of the picture that the other neglects.

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[28] We pass over here, due to the limitations of space, von Uexküll's influence on the then-developing field of neuroscience, and especially his influence upon one of its principal founders, Charles Scott Sherrington (1857–1952), who credits von Uexküll frequently and whose work on the neurobiology of reflex, posture and muscle movement was a direct outgrowth of von Uexküll's earlier experiments (Lagerspetz 2001: 646). Suffice it to say that the notion of the "neural net" is already prefigured in Uexküll (1928: 106) – and while many contemporary neuroscientists and roboticists take these notions as their starting points, few have worked their way back to von Uexküll for the purposes of either further enlightenment, nor for the acknowledgement of a debt (but see Fuster (2003) and Ziemke and Sharkey (2001) for exceptions).

It can be seen, however, that von Uexküll was working still very much within a 19th century Romantic intellectual culture that was still vibrant in Estonia, while the science of Darwin's England was increasingly utilitarian, mechanistic and Malthusian. Such historical influence often reveals itself in von Uexküll's word choice. Thus, the original wording of the bracketed text in the paragraph above reads that "Darwin did not consider the internal *strive for perfection* of individual organisms" in lieu of the less teleologically "loaded" description of what is essentially the same concept of proximate, systemic interaction towards homeostatic optima observable in all living organisms that I have substituted for it here.

However, and as Hoffmeyer notes, just as Darwinism needed Mendelian genetics for its full coherence, "it is only through its *integration* with the theory of evolution that [von Uexküll's] *umwelt* theory can truly bear fruit" (1996: 58). For just as the transmutation of species needs a shuffling mechanism to allow for the variations which are then acted upon in natural selection, so too does von Uexküll's Kantian notion – i.e., that, as regards the subjective experience of living creatures, "it is utterly in vain to go seeking in the world for causes that are independent of the subject; we always come up against objects which owe their construction to the subject" (1926: xv) – need to be supplemented with a theory of how such subjects themselves have come to be so uniquely constructed. For von Uexküll, however, this was not seen a problem, but as the very mark of the limits of Kantian reason. "There lies concealed, eternally beyond the reach of knowledge, the subject – Nature" concludes von Uexküll, who would also speak unselfconsciously about "nature's sovereign plan" (1934/1957: 80).

Sebeok, however, as an epigone of Peirce, believed that in science, as in *umwelt*, such ubiquitous law or "plan" is precisely what calls out to be explained. And thus Sebeok began to undertake the long interdisciplinary project of attempting to introduce into the framework of mainstream science and evolutionary theory, an operationalizable synthesis of the Peircean logic of sign relations with the Uexküllian naturalistic research project of *Umweltforschung*. With now a clear vision that the abyss between sign study and biology had found its bridge, Sebeok began the project that we today call *biosemiotics* – a project whose goal was nothing less than a scientific understanding of how the subjective experience of organism, as realized differently by each species' particular biological constitution – comes to play a genuinely causal role in the ongoing co-organization of nature.

A Project of Mass Cross-Pollination: Sebeok's Synthesis of Researchers

As can be inferred from the above, the rediscovery of von Uexküll's work had a profound effect on Sebeok's subsequent work and thought. Two decades later, he would recollect that his re-reading of Uexküll's *Theoetische Biologie* after thirty intervening years studying human and animal communication practices "unfolded a wholly unprecedented, innovative theory of signs, the scope of which was nothing less than 'semiosis in life processes' in their entirety" (1998: 7).

Apt, then – though requiring a little further clarification – is Barbieri's (2002) claim that after experiencing the intellectual "fulguration" that von Uexküll's *umwelt* theory was to him, Sebeok "decided to end his individual search and start an active campaign of proselytization" (285). For unlike the Biblical Saul, Sebeok knew full well that his search was not truly "over" – and that in von Uexküll's *umwelt* theory, he had found but *one* more critically important tool for understanding, with which he could proceed in his ongoing investigations. In this sense, Sebeok was more like Isaac Newton – or perhaps even Francis Bacon, with his own newfound *Novum Organon,* as we have discussed above – than like the spiritually 'completed' Saul.

In other ways, however, Barbieri's charge of "proselytization" is a fair one, given that many of the scholars laboring in the fields of biosemiotics today who find von Uexküll's articulation of *umwelt* to be a manifestly helpful terminological tool were, quite directly, brought to this realization through the efforts of Thomas Sebeok himself.

Indeed, "Sebeok would often point out that the list of those who did semiotics without knowing it would fill the pages of an infinitude of books" writes Sebeok's frequent collaborator Marcel Danesi as part of his mentor's obituary: "If we recall correctly, he referred to this state of affairs as the "Monsieur Jourdain syndrome." Monsieur Jourdain was, of course, the character in Molière's *Bourgeois Gentilhomme* who, when told that he spoke good prose, answered by saying that he didn't know he spoke in prose. Analogously, Sebeok would point out to some scholar in a field such as psychology, anthropology, or medicine, that he or she was, like Monsieur Jourdain, doing something of which he or she was not aware – i.e., *semiotics*. "The number of converts he made for semiotics in this way are innumerable" writes Danesi (2002: o.l.).

A turning point came in 1977, when Sebeok delivered his now-famous speech on "Neglected Figures in the History of Semiotic Inquiry: Jakob von Uexküll" at the *Third Wiener Symposium on Semiotics* in Vienna. Thure von Uexküll (1908–2004), Jakob's son, was in the audience, and not long after, Sebeok, along with Thure (a physician whose pioneering work on the semiotics of psychosomatic disorder and treatment virtually single-handedly raised the field of psychosomatic medicine to prominence in Germany, where it is now part of the mandatory curriculum for all medical students), and Giorgio Prodi (1929–1988), an oncologist studying the "endosemiotics" of immunological self-organization and cell signaling – "conducted a week-long open-ended seminar, so to speak, on the practical and conceivable ins and outs of biosemiotics" (Sebeok 1998: 8).

These "intensive triadic brainstorming" sessions, as Sebeok characterized them, "led directly to the series of pivotal seminars held annually in the late 1980s and early 1990s" at the Glotterbad Clinic for Rehabilitative Medicine near Freiburg (ibid). Drawing an ever widening circle of biologists, physicians, philosophers and semioticians into his orbit, Sebeok in effect fashioned what he would later come to term an interdisciplinary "cybernetic loop" or "self-excited circuit" (Sebeok 1998: 9).

A steady stream of international conferences, monographs, journal articles, special issues, and book collections followed (see Kull 1999a and 2005 for two excellent overviews) – most of them either initiated by, or with significant contributions from, Thomas Sebeok himself. Indeed, in his memorial remembrance of Sebeok, seminal biosemiotician Jesper Hoffmeyer remarks that "without Sebeok's enormous influence and prestige to pave the way, the growth of biosemiotics might well have been seriously hampered through the usual territorial defense mechanisms released more or less automatically in academia whenever somebody attempts crossing [its] Cartesian divides" (Hoffmeyer 2002: 385).

The resulting "yet even more modern synthesis" of Peircean semiotics with Uexküllian *umwelt* theory in the overarching framework of dynamic systems theory that underpins much of modern biosemiotics and that is the direct result of Thomas Sebeok's "proseltylization" in the years following his rediscovery of von Uexküll is not a synthesis that I have either the space for, nor have been commissioned to, explicate in any minimally sufficient detail here (but see Baer 1987, Brier 2003, Danesi 1998, 2000, Deely 1995a, Pertrilli and Ponzio 2001, Sebeok and Umiker-Sebeok 1992 for thoroughgoing discussions thereof).

Suffice it to say, though, that even those colleagues-in-biosemiotics who today reject the Peircean perspective, or the primacy of perceptual *umwelt*, or the likely success of the project of biosemiotics itself (and there are some loyal skeptics who most helpfully hold this view, as we shall see) – even these scholars are no longer scattered researchers working in sterile isolation from one another and in utter ignorance of each other's work, but are instead today "colleagues" in a field called Biosemiotics *because* of the tireless "proselytization" (and cross-pollination) efforts of Thomas A. Sebeok throughout the 1970s, 1980s, 1990s and those years of the 21st century ending only with his death.

In effect, summarizes Barbieri, "the making of biosemiotics [in the form of the field that we see it as today] has been heretofore a 40-year-long affair which can be divided into two phases: the first (1961–1977) was a period of uncoordinated attempts, often of utterly isolated initiatives, while the second (1977–2001) was a period in which individual ideas could fall on a more receptive ground and contribute, under the discreet supervision of Thomas Sebeok, to the collective growth of the field" (2002: 286).

And, indeed, Sebeok's obituary states that of all of his accomplishments, "he was most proud of having brought into being a group of theoretical biologists and semioticians to pursue this field of investigation" (SLIS 2002). It is the ongoing coalescence of this group that we will turn our attention to now – for the history of this ongoing coalescence *is* the extant "history" of Biosemiotics per se (though what will come out of this coalescence, and where that history will lead, remain matters of pure *potentia* at this time).

Sebeok's Legacy and the Continuation of the Biosemiotic Project

One of the many tributes paid to Sebeok in obituary was made by his long-time colleague Marcel Danesi, who – summing up a lifetime's work in fields as diverse as anthropology, linguistics, computer science and zoology, reiterated the claim that what Sebeok himself was most proud of was his having "transformed semiotics back into a "life science" – having taken it back, in effect, to its roots in medical biology [and specifically, the uninterrupted tradition of symptomology found in all cultures]. In other words, he uprooted semiotics from the philosophical, linguistic, and hermeneutic terrain in which it has been cultivated for centuries and replanted it into the larger biological domain from where it sprang originally" (2002: o.l.).

Interestingly enough – and perhaps a tribute to Sebeok's underlying vision all along – it is not "semioticians" per se that one finds attending the conferences and penning the journal articles in the field called biosemiotics today, but molecular biologists, embryologists, philosophers of science, zoologists, roboticists, neurobiologists, psychologists and dynamic systems theorists instead. And most of these have found their way into the field through their own unique and surreptitious pathways, many of whom hold a variety of views regarding the relationship of signs to biology that in no way derive from the works of Peirce or von Uexküll, much less than those of Sebeok himself.

For it turned out that the nerve that was ready to be hit by the promise of a scientifically informed biosemiotics was not at all one that was calling out for excitation in the academic world of semiotics (with a few conspicuous exceptions of course, which will be discussed below). Rather, the priming was taking place variously, but steadily, over the last 50 years of scientific advance and inquiry in the West.

For while Sebeok was busy building networks in Scandanavia and in eastern Europe, back in the West individual researchers in the fields of neurobiology, clinical psychology, molecular biology, artificial intelligence, and philosophy of mind (to name a few) were busily engrossed in their own attempts at either resolving or undoing the disastrous Cartesian dichotomy separating bodies and minds. In neurobiology, for example, one saw the works of Gerald Edelman (1992), Antonio Damasio (1994), Walter Freeman (2000), and Joaquin Fuster (2003)[29] among many others; in AI, the "distributed cognition" theories of Andy Clark (1997), Rodney Brooks (1999), Marvin Minsky (1988), and Douglas Hofstadter (1979); in biology proper, there were the critiques of Walter M. Elsasser (1998), Richard Lewontin (1992), Robert Rosen (1991), and Howard Pattee (1982a, 1988); and in dynamic systems theory, the works of Edward Lorenz (1963), René Thom (1989), Ilya Prigogine (1984), Susan Oyama (1985), and Stuart Kauffman (1995, 2000) – again, just to mention some few of the most obvious.

But these researchers (and many more, some of whom will eventually make their way into the interdiscipline of biosemiotics and whom we will be discussing presently) were, as said, largely pursuing their own independent research agendas, working and exchanging ideas amongst their own disciplinary colleagues, and were not actively involved in constructing a network of researchers from widely divergent academic backgrounds in the sense that Thomas Sebeok was.[30]

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[29] "Bio-semiotic" premises are implicitly discoverable – though never fully articulated as such – in all of these neurobiologists' works to some extent, though none save Fuster show any acquaintance with the work of von Uexküll or Peirce that informs much of contemporary biosemiotics.

[30] Though perhaps it would be fair to say that Stuart Kauffman eventually did also pursue such a deliberately interdisciplinary project, via his long-standing participation in the Santa Fe Institute.

Some small interdisciplinary networking groups *were* independently breaking out here and there at this time, however. Kull recalls three regular series seminars on theoretical biology that arose independently in the Soviet east during the 1970s – one in St. Petersburg led by Sergei Chebanov, one in Moscow led by Aleksei Sharov, and one in Tartu, Estonia led by himself that "all later made a shift towards biosemiotics" (2005: 21). In the West, geneticist Conrad Hal Waddington (1905 – 1975) held a series of conferences entitled *Towards a Theoretical Biology* each year from 1966 to 1969 that attracted such participants as Lewis Wolpert, Brian Goodwin, R.C. Lewontin, David Bohm, W.L. Elsasser, René Thom, Howard Pattee, Ernst Mayr, and John Maynard Smith. Yet while all of these participants undoubtedly both contributed to, as well as came away from, these conferences with an enriched notion of the phenomenon of "self-organization" in complex systems, these conferences did not result in the creation of any one coherently ongoing "group" or specifically focused collective agenda, such as can be found in the current project of biosemiotics.

Instead, the major line of development that would result in the constitution of the field of biosemiotics as it exists today was a series of informal but increasingly productive seminars emerging from the University of Copenhagen beginning in the 1980s and culminating in the ongoing international Gatherings in Biosemiotics conferences which have been held annually since 2001. And by almost every account, the figure at the center of this activity was then, and remains now, the man whose name is now most closely associated with the field of biosemiotics, the Danish molecular biologist and public intellectual Jesper Hoffmeyer (1942–).

Joining Life Science with Sign Science: Jesper Hoffmeyer

Long before beginning his career as a biochemist at the University of Copenhagen in 1968, Jesper Hoffmeyer had already developed, since his days as a student activist in the mid-1960s, a deep theoretical interest in the complicated relationships between science and religion, technology and nature, and authority and belief in the lives of modern individuals. Son of a social reformist physician who had co-edited an antifascist periodical called *Kulturkampen (The Struggle for Culture)* in the 1930s, Hoffmeyer's own deep interest in the intersection of nature and culture led to his founding of a journal entitled *Naturkampen (The Struggle for Nature)* in the 1970s.

A prolific science writer and journalist as well as a working university professor and molecular biologist, Jesper Hoffmeyer "had, by the 1980s, become one of the most visible intellectuals in the debate on technology and society in Denmark" (Emmeche et al. 2002: 38). Deeply inspired by the work of cybernetician and anthropologist Gregory Bateson (1904–1980), Hoffmeyer had been struggling to articulate a non-reductionist understanding of the relationship of organisms to their genomes at a time when the rapid advancement of gene sequencing technology was promising a yet more reductionist understanding of the same, and Richard Dawkins was capturing the popular imagination (as well as that of some scientists) with his notion of "the selfish gene" (1976).

Recalling this period, Hoffmeyer writes that in 1984 it had occurred to him that “the historical consequence of making dead nature [i.e., physics] the model of nature at large was that all the talking – and all mindfulness – went on exclusively in the cultural sphere. As a result we now suffer the divided existence of the two great cultures, the humanities and the scientific-technological culture” (2002: 99).

Finding it intuitively unnatural to attempt an explanation of the hereditary efficacy of DNA in isolation from the DNA-organism system in which it always appears, Hoffmeyer claims that he wanted to invoke in his scientific colleagues of that time “a new kind of curiosity, a curiosity directing its attention towards, what we might call “the wonder of the code” and which does not put that wonder aside by the enclosure of the codes into one or the other state space [of deterministic physics] or life-world [of pure subjective experience]. For it is the nature of the “code” to point outside of its own mode of existence – from the continuous to the discontinuous message, from the physical and therefore law bound message [of the nucleotide sequence] to the more free message [of the organism whose actions in the world will or will not result in that nucleotide sequence’s eventual evolution and survival], and back again in an unending chain” (2002: 99).

“For it is the nature of the ‘code’ to point outside of its own mode of existence.” Almost certainly unaware then of the maxim of St. Augustine, much less of the obscure late-scholasticism of John Poinsot, Hoffmeyer’s common-sense appreciation of the profoundly important distinction between material organization and that same material organization in its use as a sign for something other than itself led him, like Sebeok before him, to an investigation into the semiotic logic of relations between organisms and their environment (1984), between organisms and each other (1988), within organisms (1992), and in the triadic logic of the 19th century scientist-philosopher Charles S. Peirce (1996).

By 1985, write his biographers, was committed to the idea of developing “a semiotics of nature, or *biosemiotics* as he chose to call this effort – [one that could intelligibly explain how] all the phenomena of inherent meaning and signification in living nature – from the lowest level of sign processes in unicellular organisms to the cognitive and social behavior of animals – can emerge from a universe that was not [so] organized and meaningful from the very beginning” (Emmeche et al. 2002: 41).

In this regard, again like Sebeok, whose path he would not yet cross for several more years, Hoffmeyer’s personal passion for, and dedication to, this project – as well as the quality of the work on the subject that he began producing – drew an ever-growing coterie of like-minded individuals into his orbit. In 1984, his initial formulation of a theory of analog-digital “code-duality” in biology was published, and soon thereafter he began his intensive series of collaborations with biologist Claus Emmeche, who would later go on to head the Center for the Philosophy of Nature and Science Studies at the University of Copenhagen, and to become a major figure in biosemiotics in his own right – in addition to authoring a body of related work on dynamic systems theory (1992, 2000a), artificial intelligence (1991, 1994), and the history and philosophy of science (1999, 2002).

By 1986 both Hoffmeyer and Emmeche were attending a Copenhagen study circle with the physicist Peder Voetmann Christiansen wherein the semiotics of Peirce were much discussed. Philosopher and literary analyst Frederik Stjernfelt joined this group (known then as the "Helmuth Hansen Study Circle" after the Danish philosopher) soon thereafter, eventually inviting French mathematician and theoretical biologist René Thom – whose work also drew heavily upon Peircean semiotics and Uexküllian umwelt theory – to deliver a lecture on his development of catastrophe theory (Stjernfelt 2002: 58).

Microbiologist Mogens Kilstrup would later find his way into Hoffmeyer's circle, as would the biologist and cyberbetician Søren Brier (1995, 1998, 2001) , who would several years later establish the interdisciplinary journal *Cybernetics and Human Knowing* in which many of the Helmuth Hansen group would publish seminal articles.[31] During this time, too, Hoffmeyer continued to publish his ideas on code-duality and self-description, now drawing also upon the works of biophysicist and systems theorist Howard Pattee (1969, 1972, 1982a).

In 1989, Hoffmeyer published a seminal article on "the semiosis of life" in Danish, and this was followed by his founding of the proto-biosemiotic journal *OMverden* (roughly: "*Umwelt*") in 1990. "The journal was an intellectual success," writes his biographers, "but a [financial] failure for the publishing company, so its life was brief" (Emmeche et al. 2002: 41). The journal did find its way into the hands of both Thure von Uexküll and Thomas A. Sebeok, however, and when Hoffmeyer went to attend a conference on psycho-neuro-immunology in Tutzing later that same year, he met both of these men for the first time – having spotted Sebeok walking around the conference with a copy of *OMverden* protruding from his jacket pocket (Hoffmeyer 2002: 384).

The joining together of "Sebeok's people" with "Hoffmeyer's people" was a signal event in the development of the contemporary field of biosemiotics. From Sebeok's "semioticians exploring biology" side came such accomplished scholars as John Deely (1986), Myrdene Anderson (1990), Floyd Merrell (1996), and Martin Krampen (1981)[32] – and from Hoffmeyer's "biologists exploring semiotics" side came himself, Claus Emmeche, Søren Brier, Mogens Kilstrup, Frederik Stjernfelt and Peder Voetmann Christensen. It was in the aftermath of this meeting that Sebeok was to declare the investigations of the life sciences and the sign sciences must

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[31] A journal dedicated to the study of "second-order cybernetics, autopoesis and cyber-semiotics" – roughly, the role of feedback and generative recursion in the organization of observing systems, self-maintaining systems, and sign-using systems – Brier's journal is deeply influenced by the work of biologists Humberto Maturana and Francisco J. Varela (1987), cyberneticians Heinz von Foerster (1982) and Ernst von Glasersfeld (1987) as well as the pioneering interdisciplinarity of cybernetician/anthropologist/psychologist Gregory Bateson (1973).

[32] These four, along with Sebeok, Thure von Uexküll and Joseph Ransdell issued a polemical call for a "new paradigm" of semiotically informed science (and vice-versa) at just about the same time that Hoffmeyer was independently coming to the same conclusion in 1984 (see Anderson et al. 1984).

be co-extensive if either was to proceed (1990), and from this point on, the term *biosemiotics* is used to refer to this project by all parties involved.

Less than one year later, Hoffmeyer and Emmeche's seminal two-part paper on code-duality appeared in Anderson and Merrell's anthology *On Semiotic Modeling* (Hoffmeyer and Emmeche 1991) and in Sebeok's international journal *Semiotica* (Emmeche and Hoffmeyer 1991), winning the publisher's top annual award, and bringing the work of the Helmuth Hansen group to an international audience. In 1992, the volume *Biosemiotics: The Semiotic Web* was published, to which no less than twenty-seven authors contributed. This exposure served to establish an ever-growing interface with other biologists and semioticians whose research was converging along these lines, and so the internationally-minded Danish Society for the Semiotics of Nature was also officially established at this time, with the express purpose of bringing together researchers from around the world who were interested in pursuing this new line of inquiry.

It was also in 1992 that theoretical biologist Kalevi Kull, a convener of some of the earliest conferences on semiotic approaches in theoretical biology taking place in the Soviet Union in the 1970s and curator of the Jakob von Uexküll Centre at the University of Tartu in Estonia, would meet Jesper Hoffmeyer at Thure von Uexküll's Glottertal conference near Freiburg – and from then on become the de facto historian both of biosemiotics in the Sebeok-Hoffmeyer tradition and of the tradition of Eastern European theoretical biology in general. Kull would also begin presenting an annual lecture course in biosemiotics at the University of Tartu in 1993 that continues to this day, and has been instrumental in arranging the annual International Gatherings in Biosemiotics, in addition to his own considerable contributions in advancing the field (e.g. Kull 1998a, b, 2000, 2001a, 2001b).

In 1993, Jesper Hoffmeyer published his first full-length monograph on biosemiotics *En Snegl Pa Vejen: Betydningens naturhistorie (A Snail on the Trail: The Natural History of Signification)*, and this book was later translated into English to appear as *Signs of Meaning in the Universe* (1996). It is this exceedingly readable book, perhaps more than any other, that provides most newcomers their entry – and, in many cases, their impetus – into the field, and that most clearly lays out the project of biosemiotics as an attempt to situate culture within nature, while not reducing either to the blind forces of purely mechanical efficient causation.

Written in the attempt to popularize the ideas of biosemiotics to the widest possible audience, the following passage conveys much of the flavor of the work. After discussing the evolution of single-celled life, multicelluars, and the increasing variety of animals' sensory capacities, Hoffmeyer turns to the evolution of human cultural cognition and writes:

> Among all the roles in the ecological theatre there was one pertaining to creatures with lengthy life histories and an especially well-developed talent for capitalizing on their experiences. Often theses creatures, the apes, had developed brains capable of accommodating an extremely complex image of their surroundings, a very sophisticated *umwelt*. [And eventually] there came a day when this creature realized that it was itself an *umwelt* builder; that its role was, in act, a role; that other creatures performed other roles and had different kinds of *umwelt*; that the world was one thing and *umwelt* another; and that, when one died, this

> *umwelt* would actually disappear while the world as such would carry on. ... [Yet over time, this creature was able to] create a bond of a quite unprecedented nature: a double bond founded on the need to share the *umwelt* with one another, i.e., making private experiences public property, turning the subjective into the objective. To cut a long story short, this creature . . .invented the spoken word. (1996: 34–35)

With its provocative ideas cloaked in the simplest of language, the English language publication of Hoffmeyer's *Signs of Meaning* was enthusiastically reviewed (1998) and remains as of the time of this writing probably the single most widely read and frequently cited text on biosemiotics. Its impact on scholars internationally continues as each year new biosemioticians come into the fold as a result of their "stumbling upon" this work (as has been frequently recounted at the annual International Gatherings in Biosemiotics).

And, indeed, directly as a result of the reception to the work's international availability in 1996, Hoffmeyer found himself "communicating with a cross-disciplinary audience of scientists, philosophers and scholars from various specialties [and was] invited to conferences in the fields of systems theory, self-organizing complex systems, cognitive science, general semiotics, media and communication theory and, of course, an increasing number of workshops and symposia devoted specifically to biosemiotics and its relations to other fields of semiotics and biology" (Emmeche et al. 2002: 42).

A slew of journal articles and conference presentations on biosemiotics by the members of the Helmuth Hansen group and their growing coterie of international colleagues followed (see particularly the special issues of *Semiotica* of 1998 (Vol 120 3/4) and 1999 (Vol 127 1/4), as well as the *Annals of the New York Academy of Sciences* 2000 (Vol 901) and, for a more extensive list of publications covering this period, Kull 2005: 20). Eventually these second-generation heirs of Sebeok's Glottertal conferences were able to bring together a growing group of younger researchers for whom the idea of dynamism in autopoetic systems was no longer a "radical proposal" – but was, instead, the starting point from which to proceed to try to build a coherent interdiscipline. And by the middle of the year 2000, the first annual International Gatherings in Biosemiotics was being planned.

A Diverse Ecosystem of Researchers: The Gatherings in Biosemiotics

Thomas Sebeok was most content, it seems, when he was bearing many torches – and after his death at age eighty-one in 2001, each of these had to be picked up and passed on.

Already by this time, however, the center of gravity for the biosemiotics project had been establishing itself at the University of Copenhagen under the auspices of Jesper Hoffmeyer and Claus Emmeche who, along with theoretical biologist Kalevi Kull and cybernetician Søren Brier, established the Biosemiotics Group at the University of Copenhagen in the early 1990s.

And it was this group that, in 2001, finally succeeded in inaugurating an annual international conference devoted exclusively to biosemiotics.

Quite unsure at the time about who, if anyone besides themselves, would show up, the first International Gatherings in Biosemiotics turned out to be an unprecedented success. Held on May 24–27, 2001 at the Institute for Molecular Biology at the University of Copenhagen (in the very room, it was noted, that Wilhelm Johannsen first introduced the word "gene" into science in 1909) the first of these annual conferences was attended by over 30 presenters from 18 countries and produced papers in neurobiology, zoology, artificial intelligence, linguistics, molecular biology, cybernetics, meta-systems transition theory, and the history and philosophy of science.[33]

The international Gatherings have been held five times since then, and while not every researcher working in the field of biosemiotics attends these annual meetings, many – if not most – of the principal contributors to the field do. There, the second-generation heirs of Sebeok's Glottertal conferences bring together a growing group of formerly independent researchers and their younger colleagues for whom the idea of dynamism in autopoetic systems is no longer a "radical proposal" – but is, instead, the starting point from which to proceed to try to build a coherent interdiscipline. In addition, with the inaugural publication this year of the peer-review *Journal of Biosemiotics* and the establishment of the long-planned International Society for Biosemiotic Study in 2005, this "third phase" in the growth and development of biosemiotics promises dramatic changes to the field – most of the more interesting ones, of course, being unforeseeable.

Even from this early standpoint, however, we can discern certain patterns and currents that are sure to play a role. The following selective list of just the most regular of the international conference's participants gives a flavor of the interdisciplinary convergences – and divergences – of approach in the quest to articulate a truly comprehensive science of life and sign processes.[34]

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[33] Many of these papers have since been published in *Sign Systems Studies*, Vol 30.1 (2002).

[34] This history would not be complete without mentioning those related researchers who, although not regular attendees at the Gatherings, continue to produce work that has particular relevance for most biosemioticians. Among these scholars must surely be included Stanley Salthe (1993), Kochiro Matsuno (1999), Luis Rocha (2001), Peter Cariani (2001), Robert Ulanowicz (1986), Mark Bickhard (1999), John Collier (1999), Merlin Donald (1991), David Depew (1996), Bruce Weber (2000) and perhaps most important of all Terrence Deacon (2003), whose 1997 *The Symbolic Species* is perhaps the clearest and most compelling application of Peircean semiotic to evolutionary biology yet produced. And while Deacon does not identify himself as a 'biosemiotician' per se, seminal biosemiotician Claus Emmeche spoke for many when he remarked at the recent Gregory Bateson Centennial Symposium in Copenhagen that "Many biosemioticians consider themselves not only Peirceans, but Deaconians as well." Accordingly, Deacon's work is well represented in the present volume.

Pre-Gatherings Contributions from Outside the Copenhagen-Tartu Nexus

One of the approaches that did not come strictly out of the Copenhagen-Tartu lineage was represented at the inaugural *Gatherings* conference by Prague cell physiologists Anton Markoš and Fatima Cvrčková (2002, 2002a, 2002b) who advance an understanding of living systems that is fundamentally *hermeneutic*. Representatives of a growing interdisciplinary movement towards theoretical biology and interdisciplinary study in the Czech Republic,[35] Markoš and Cvrčková view the current work being done within the contemporary biological paradigm (including their own work) to be an effective – but by necessity only partial – illumination of processes that exceed the potential of formalized representation to exhaustively map them.

Taking an approach towards living organisms that owes as much to the "historically effected hermeneutics" of Hans-Georg Gadamer (1900–2002) as it does to the self-regulatory symbiotic systems theories of Lovelock (1996) and Margulis (1987), Markoš writes that: "[Since the moment of its inception,] life has never ceased to exist and has again and again been confronted by actual conditions, by memory, by forgetting, and by re-interpretations of the remembered" (2002: 163). As Markoš reminds us in his masterful exegesis of scientific study, *Readers of the Book of Life*, the living organization of an organism changes itself and its relations to its surround on a moment-to-moment (as well as on an evolutionary) basis in a way that no machine logic or mathematical formalization could ever (predictively) account for, and it is this very embodiment of a possibility-collapsing "non-logic" that allows a living system to effectively explore and to creatively exploit novel state spaces, giving it "the characteristics of a field, a culture, a statement, and of course, [only] sometimes also of a machine" (2002: 163).

With Gadamer, Markoš asserts that "the nature of knowledge is hermeneutical and is rooted in experience, history and in structures" that are themselves ever-changing as each new moment is changed as a result of the actions taken in the one prior. Attempting to reduce this rich world of living-acting-perceiving-and-signifying onto the "necessarily incomplete, reduced, flattened" descriptions of the objectivist scientific model (Cvrčková 2002: 184) would be akin to attempting to realize Hoffmeyer's self-referential notion of creating "a map which is so detailed that the map maker and the map that he is making are swept up into it" – something that not even the world-modeling organism itself can ever fully objectify, much less make static (1996: 40). Self-described "working biologists just like any others," Cvrčková and Markoš remind us never to lose sight of Korzybski's admonition that "the map is not the territory" – lest we find ourselves taking seriously such

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[35] This movement also includes biologist and philosopher of science Zdeněk Neubauer, systems theorist Ervin Laszlo, cognitive scientist Ivan Havel, animal ethologist Karel Kleisner, and geologist Václav Cílek. An excellent English language introduction to their ideas can be found in Havel and Markoš (2002), which collects the proceedings of a conference that also features contributions from Giuseppe Sermonti, Pier Luigi Luisi, and Mae-Wan Ho. Markoš, Grygar et al.'s *Life as its own Designer* (2009) offers a more in-depth presentation of the group's ideas.

map-sensible but experientially-nonsensical claims as "the genetic code is just a metaphor" and "consciousness is an illusion" ("an illusion...", one should always ask of such a pronouncement, *"...of what?"*).

Likewise making the acquaintance of the biosemiotician at the first *Gatherings* were Yağmur Denizhan and Vefa Karatay (1999, 2002) a dynamic systems engineer and a molecular biologist, respectively, from Boğaziçi University in Istanbul, who build upon the work of theoretical physicist and computer scientist Valentin Turchin's (1931–) meta-systems transition theory in order to model the dynamics of self-increasing complexity in embedded systems, and the subsequent emergence of bottom-up system properties that then come to function recursively as top-down biases and constraints.

Also presenting their work were Physicsts Edwina Taborsky (1998) and Peder Voetmann Christensen (2000), who, almost alone among biosemioticians, have sought to explicate Peirce's own understanding of his semeiotic as being a subset of a logic of relations that can be used to understand how *any* set of relations hold together. Peirce's highly complex architectonic regarding (roughly) *possibility, being, and law* may yet prove to be rich mine for physicists, as well as for biosemioticians, and Taborsky and – along with systems theorists Stanley Salthe (1993) and Koichiro Matsuna (1999) – Christensen are among the first to be blazing this trail.

Relatedly, while physicists Christensen and Taborsky are approaching the organization and interactions of energy and matter from a triadically interactive perspective, biophysicist Howard Pattee has devoted the last 37 years of his life to the study of "precisely those dynamical aspects of physics (time, energy) that are necessary to implement codified instructions" – or, in other words: What are the physics necessary (if not sufficient) for semiosis? (Umerez 2001).

One of the original attendees at Waddington's "Towards a Theoretical Biology" conferences of 1969–1972 Pattee was forecasting, as early as 1965, those few who would listen, that "we may expect that the origin of life problem will shift away from the evolution of the building blocks and the elementary operations of joining them together, to the more difficult problem of the *evolution of control* in complex organizations. This problem is more difficult because the idea of "control" is not defined in the same sense as we can define biochemicals [per se]...A live cell and a dead collection of the identical biochemicals in the same structural organization differ essentially in the amount of *intermolecular control* that exists in each unit (1965: 405–406).

Like so many whose work we've had the occasion to overview here, Pattee's precisely articulated questions would in time help generate the conceptual frameworks and vocabularies needed for addressing them. Thus, the general principles behind such bottom-up and top-down "intermolecular control" would later be codified as "autopoiesis" by Maturana and Varela (1973, 1974) and as "dissipative structure" by Ilya Prigogine (1969), while for Pattee, the notions of the *epistemic cut* and *semantic closure* are necessary to a complete understanding of how and in what scientifically examinable way, matter can come to "stand for" something other than itself in and to a system – and this, of course, is the ultimate research question of biosemiotics.

Developments and Challenges 2001–2010

It would require a book-length monograph of its own to detail the interdisciplinary research interests and data presented annually, at the International Gatherings in Biosemiotics – all of which, in one way or the other, are devoted to the central question of the non-mystical role of "representation" and its "meaning" in the organization and interactions of living organisms. Rather, the most that I can do here is to present a short and by no means complete list of some of the more regular contributors to these conferences and their respective fields of interest, and to strongly encourage the reader to these scholars' work in the original.[36]

In the areas of animal studies, ethology and zoology, Mette Böll (2002), Karel Kleisner (2007, 2008), Dominique Lestel (2002), Timo Maran (2003), Dario Martinelli (2005), Stephen Pain (2007), Morten Tønnessen (2003), and Aleksei Turovski (2000) are all pursuing biosemiotic lines of investigation in their work. Examination into the relations of intercellular signaling processes are being undertaken by molecular biologists Luis Emilio Bruni (2007, 2008), Mia Trolle Borup (2005), Franco Giorgi (2009), Abir Igamberdiev (1999), and Mogens Kilstrup (1997), as well as by immunologist Marcella Faria (2005), embryologists Johannes Huber and Ingolf Schmid-Tannwald (2005), cell biologists Michal Schmoranz (2009) and and Jana Švorcovaá (2009), and pharmocologist Sungchul Ji (2002).

Researchers into dynamic systems theory who are incorporating biosemiotics into their models include Victoria Alexander (2009), Eugenio Andrade (2003), Arnellos Argyris (2007, 2010), Stephan Artmann (2007), Martien Brands (2006), Hernán Burbano (2005), John Collier (2005, 2008), John Darzentis (2006), Yagmur Denizhen (2002, 2008), Assen Dimitrov (2004), László Hajnal (2003), Wolfgang Hofkirchner (2002), Vefa Karatay (2006), Koichiro Matsuno (2007, 2008), Toshiyuki Nakajima (2005), Stanley Salthe (1993, 2008), and Edwina Taborsky (1998, 2001).

Neurosemiotic approaches to brain research and consciousness studies have been proposed by Peter Cariani (2001), Terrence Deacon (1997, 2010), Donald Favareau (2001, 2002, 2008a); Anton Fürlinger (1998), Franco Giorgi (2009), Yair Neuman (2003, 2008, 2009), Sidarta Ribeiro (2003), Andreas Roepstorff (2004), and Allessandro Villa (2005). Relatedly, biosemiotically informed approach to Artificial Intelligence and cognitive robotics has been undertaken by Ryad Benosman (2001), Noel and Amanda Sharkey (1999, 2002), Douglas A. Vakoch (2004, 2008), Stacey Ake (2007), and Tom Ziemke (2003).

Edward J. Baeziger (2009), Franitsek Baluska (2004, 2006), Peter Barlow (2007), Almo Farina (2004), Pierre Madl (2005), Maricela Yip (2005), and Gregory Bateson's biographer Peter Harries-Jones (1995, 2008) all apply a biosemiotic approach to their research into sustainable ecosystems, while anthropologists and cultural theorists Myrdene Anderson (1999), Thierry Bardini (2001), Mark

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[36] Bibliographic information for works cited in this section, but published after 2006 can be found in the *Bibliography and Further Readings* section appearing at the end of this volume.

Reybrouck (2005) and Wendy Wheeler (2007) focus on the cultural semiotics of human-to-human interaction, and researchers associated with the Distributed Language Group such as Stephen J. Cowley (2008, 2009), Charles Goodwin (2006, 2007), Alexander Kravchenko (2009), Joanna Rączaszek-Leonardi (2009), and John Schumann(2005, 2009) are extending the notions of distributed cognition, interaction, and mind.

Enriching and informing all of this discussion is the work of semiotic scholars and philosophers Stacey Ake (2006), Pricsa Augustyn (2005, 2009), Han-Liang Chang (2005, 2008), Sergey Chebanov (1994), Juipi Chien (2004, 2007), Paul Cobley (2006, 2009, 2010), Marcel Danesi (2000, 2007), John Deely (2008, 2009, 2010), Eliseo Fernandez (2008, 2009), Johnathan Hope (2008, 2009), Tuomo Jämsä (2005), Konrad Talmont-Kaminski (2005, 2007), Andres Luure (2002), Aleksei Sharov (2002), Adam Skibinski (2004), Frederik Stjernfelt (2007, 2009), and Tommi Vekhavaara (2002, 2003, 2007), as well archivist for the Jakob von Uexküll Institute for *Umweltforschung*, Torsten Rüting (2004).

And as the result of this intense collaboration and international exchange of ideas, the biosemiotic project of examining the sign processes in life processes is becoming more interdisciplinary and more international every year. In 2005, the International Society for Biosemiotic Study that Thomas Sebeok had proposed over a decade ago was officially founded, and in 2005, the first issue of the international *Journal of Biosemiotics* appeared.

Moreover, and as the surest sign of growth, principled divisions within the biosemiotic project are already beginning to appear. The reach of biosemiotics is growing, and bringing into its orbit those from farther fields. Thus, no longer can it be agrees that a self-identified "biosemiotician" agrees that the semiotic categories of Peirce – or even the *Umweltforschung* of von Uexküll – are the proper starting points on which to build a scientific articulation of sign processes in biology.

Rather, in the nine years since Sebeok's death, the annual International Gatherings in Biosemiotics have been blessed with a steady stream of external challengers and internal self-critique. Tommi Vehkavaara (2002, 2007) and Stefan Artmann (2005, 2007) have been most vocal, and most productive, in challenging the assumptions of the consensus articulation in informed and informative ways. Such informed criticism is of inestimable value to a growing field whose members spend the majority of their year responding to uniformed criticism ("No, it's not sociobiology; no, it isn't spiritualist or vitalist; no, we don't think that an amoeba has thoughts; or that you can attract a spouse using subliminal Neuro-Linguistic-Programming techniques. . .").

And as productive as these meetings have been for the exchange of ideas and the development towards a common goal, equally important is the fact that they have also resulted in a series of penetrating critiques. Such critiques, coming from within the circle of those who have spent considerable time with the published materials (as opposed to those critics from the outside who, upon hearing the term "biosemiotics," simply conflate the project with "sociobiology" "anthropomorphism" or some variant of New Age pseudo-philosophy and then proceed – as they should, were the equation to be correct – to dismiss it out of hand as a pseudo-science), offer penetrating analyses of both the existing shortcomings as well as the future problems that may be inherent in the current articulation of the biosemiotic project as it stands today, and suggest alternative possible ways to develop a semiotically-informed biology without reliance upon the ideas of von Uexküll or Peirce.

Philosopher of science Stefan Artmann, for example, sees biosemiotics as an example of a consilience-seeking "structural science" which he defines (with Küppers 2000) as: any "transdisciplinary formalization programme that tries to discover abstract analogies between research problems of different empirical sciences in order to contribute to their solution" (2005: 234). Along with the majority of biosemioticians, Artmann believes that the more such work is successful, the faster "biosemiotics" will become just an uncontroversial part of everyday biology. "This is the ironic fate of every productive structural science," writes Artmann, "It begins as educated analogizing, constructs step by step an interdisciplinary bridge between disciplines, transforms their way of thinking, supports the progress of scientific knowledge with the help of its transdisciplinary formal reasoning – and eventually becomes superfluous" (2005: 238).

Such an evolution, I feel justified in asserting, is exactly what most proponents of biosemiotics are hoping for – the "best case scenario" resulting from all their efforts to articulate the natural history, and the natural constitution, of the use of sign relations in the biological world. Unlike the practitioners of what he suggestively calls the "Copenhagen interpretation" of biosemiotics (e.g., Hoffmeyer, Emmeche, Kull, et al.), however, Artmann (2005) proposes that a "model-theoretic" approach incorporating mathematical representations of sign relational possibilities (somewhat akin to formalisms of Artificial Intelligence/Artificial Life research) will be critical if the field is to move forward – yet Artmann finds a strong resistance among the Peirceans towards "reducing" sign relations in this way.[37]

Philosopher Tommi Vehkavaara similarly objects that "Charles Peirce's and Jacob von Uexküll's concepts of sign assume an unnecessarily complex semiotic agent" (2003: 547) and that in order for these concepts to be naturalizable for use in an effective biology, they must be shown as arising out of "more primitive forms of representation" (2002: 293). For Vehkavaara, "the minimal concept of representation and the source of normativity that is needed in its interpretation can be based on the "utility-concept" of function" in a self-maintaining system that is able to switch "appropriately between two or more means of maintaining themselves" while in continuous interaction with their environment (2003: 547). Vehkavaara thus urges the adoption of concepts from Mark Bickhard's (1999, 2003) "interactivist" models of autonomous agency as prerequisites to the emergence of the kind of triadic

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[37] It should also be noted here that many of the "non-Peirceans" from outside of the Copenhagen school – such as Prague physiologists Anton Markoš and Fatima Cvrčková – also eschew the idea that formalized equations between "digital signs and bodily (or analog) entities [could] be reduced to an unequivocal correspondence" (Cvrčková and Markoš 2005: 87). Rather, for the majority of more complex organisms (and certainly for mammals), the action of interpretation upon a sign is "its own shortest description" (a la the incompressible algorithms discussed by Kauffman 2000).

sign relations discussed in higher animals by von Uexküll and, *mutatis mutandis,* by Peirce.

Without a doubt, though, the most radical challenge to the Peircean approach to understanding the sign relations of living systems comes from embryologist and *Systema Naturae* (and now also *Journal of Biosemiotics*) editor Marcello Barbieri, who posits an alternative biosemiotic paradigm that is not organicist and qualitative in its origins, but mechanist and quantitative through and through.

Marcello Barbieri: Not Interpretation, but Organic Codes

A molecular biologist and experimental geneticist for over thirty years, Barbieri first proposed his "ribotype theory" of the origin of life in 1981. Working in the tradition of Manfred Eigen (1977), Freeman Dyson (1985) and Graham Cairns-Smith (1982), Barbieri realized from his work in embryology that just as the epigenesis of embryonic development requires an "endogenous increase in complexity" that "reconstructs" the phenotype from the "incomplete projection" of information that is the genotype (2003: 213–215), so, too must have this embodied logic or "natural convention" have had to evolve for doing so at the time when the *esopoesis* of precellular molecular aggregation was evolving into the *endopoesis* of polymerizing ribosoids (and, eventually, into the true *autopoesis* of "cells") (2003: 142).

For Barbieri, this naturally evolved "convention" – though interactive always in a triadic relationship of genotype, phenotype and ribotype – is not to be explained (or non-explained, as he would argue) as being so fundamentally coextensive with life that it – like growth, metabolism, and self-initiated movement – is merely assumed to be a "first principle" of living organization from which the rest of the investigation of biology is to proceed – a position that he feels the Copenhagen school is guilty of perpetuating.[38]

Rather, posits Barbieri, the earliest macromolecular precursors to tRNA not only predated, but actually brought into existence cellular genotypes and phenotypes, through their own physical constitution's ability to establish a reliable correspondence between freestanding nucleic and amino acid aggregates. "Any organic code is a set of rules [or conventions] that establish a correspondence between two independent worlds, and this necessarily requires molecular structures that act like *adaptors*, i.e. that perform two independent recognition processes," writes Barbieri, "This gives us an objective criterion for the search for organic codes, and their existence in nature becomes therefore, first and foremost, an experimental problem" (2005: 119).

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[38] In all fairness, not all members of the so-called Copenhagen tradition subscribe to this line of thinking – Taborsky (2001) and Christiansen (2002), for example, certainly do not – nor, indeed, did Peirce himself. Artmann (in preparation) and Barbieri (2001, this volume) have argued convincingly, however, that the assumption that true *sign* processes start with life (and, for all practical purposes, vice-versa) is retrievable in the works of Hoffmeyer, Emmeche, Kull, et al., and I do believe that this assertion is a reasonable one.

"The cell is the unity of life," writes Barbieri, "and biosemiotics can become a science only if we prove that the cell is a semiotic system."[39] And since at least 1981, this is exactly what Barbieri has been proposing. "Historically we are still very much in a period of DNA supremacy," he wrote back then, "and it will take perhaps a new generation of biologists to realize that genes alone could not have started life on earth any more than proteins alone could. The reason for this is that we are imbued with the concept that a cell is essentially a throwaway survival machine built by the genes, and a genuinely new attitude toward the origin of life will become popular only when this view is replaced by a different one (1981: 571).

Highlighting the introduction of yet another limiting and still far-too-consequential dichotomy into the narrative of Western science, Barbieri argued in his 1981 article that Wilhelm Johannsen did for molecular biology exactly what Descartes did for traditional biology, divorcing genotype from phenotype just as Descartes divorced the mind from body – and in so doing introduced an irresolvable explanatory dualism that is incompatible with the biological reality of interdependent levels of organization.

Rather, argues Barbieri, "the very definition of phenotype leads us therefore to conclude that the genotype-phenotype duality cannot be a complete theoretical description of an organism. It is a didactic concept which was introduced by Johannsen in 1909 to differentiate between hereditary and phenomenological characteristics, and it was only an unfortunate accident that the duality has been elevated to the status of a theoretical category" (1981: 577).

Indeed, he continues "the real distinction between genotype and phenotype is based therefore on the distinction between the one-dimensional world of information and the three-dimensional world of physical structures. The critical point is that there is no *direct* communication between these two dimensions of reality. A gene cannot build a protein any more than a protein can instruct a gene. The central dogma states that information does flow from genes to proteins, but only because it has been "taken for granted" that a third party exists which can actually implement the transition. What is not usually emphasized is that such an intermediary cannot be either another group of genes or another group of proteins" (ibid).

In pointing to the need for a triadic explanation of not just genes and proteins, but genes (one-dimensional information sequences), proteins (three-dimensional physical structures), plus whatever it is joins them explanatorily, and that uses genes to make proteins, Barbieri was not just calling for a new way of thinking about how living cells operate today – but also of how living cells came to be in the first place. Thus was what he then called *semantic theory of evolution* necessary, along with a *semantic theory of the cell* – and from 1981 to 1985, Barbieri worked virtually in isolation to articulate them both.

The gene-carrying cell that we know today, he posited, may have begun as a colony of ribonucleoproteins engaged in producing other colonies of ribonucleoproteins. Proposed before the Cech and Altman's Nobel prize-winning discovery

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[39] Personal correspondence with the author April 21, 2006.

ribozymes in 1989, Barbieri had already forseen the possibility of – and, perhaps more importantly, the need for – something that would play the role of a *polymerizing ribosoids* in 1981. This "ribotype" as he dubbed it, itself had the character of a primitive RNA molecule, yet also had the capacity to catalyze a peptide bond between amino acids. It thus served to *bring together* the previously distinct worlds of RNA molecules and amino acids, introducing into the world the genotype, phenotype and ribotype relation that today *constitutes* the self-replicating cell. Overlooked as a derivative "intermediary" in its modern instantiation as "transfer RNA," such primitive ribotypes were, in fact, the seat of the genetic code and the first "codemakers" to appear in the history of life. Thus, claims Barbieri, "there was no real discontinuity between precellular and cellular evolution. Only the acquisition of sophisticated replication mechanisms brought about by the evolution of quasi-replication mechanisms which had been developed by the ancestral ribosoids to produce other ribosoids" (1981: 573–574).

A revolutionary re-thinking of both the origin of cellular life and of its ongoing internal relations even today, these ideas were expanded upon by Barbieri in his 1985 book entitled *The Semantic Theory of Evolution* – a work that was enthusiastically received both by mathematician René Thom (1923–2002) and by philosopher of science Sir Karl Popper (1902–1994). Almost 25 years worth of theoretical refinement later, Barbieri would present the mature form of his theories in his 2003 masterwork *The Organic Codes: An Introduction to Semantic Biology*. There he would lay out the empirical evidence that has been gathered, in the interim between 1981 and 2003, for existence of a whole array of organic codes that he postulated in the earlier work, including the RNA splicing codes (97–100), the intercellular signal transduction and integration codes (101–108), cellular migration and adhesion codes (112–114), and the cytoskeletal arrangement codes (172–173).

In these codes, as in the genetic code, there is no physical or chemical necessity between, say, the release of a certain neurotransmitter and the cascade of events that follow *save* the presence of the set of conventional internal relationships that have been selected evolutionarily and are embodied in the form of the complex of mediating molecules joining the so-called "first" and "second" messengers. This set of physically realized, biological relationships *is* the extra-genetic code whereby biological specificity is ensured. Thus, argues Barbieri, we have to add the processes of *natural conventions* in addition to the processes of *natural selection* to our study and understanding of the organization and evolution of the natural world (2003: 153).

In its triadicity and interactivity, Barbieri's semantic theory of the cell and its evolution seems to fall well within the biosemiotic perspective we have been discussing above. Yet Barbieri has a challenge for the Peircean-von Uexküllian tradition of Sebeok and Hoffmeyer, in that primordially, for Barbieri, "meaning" is "completely accounted for by objective and reproducible entities" (this volume). In fact, for Barbieri, "*any* time that we discover that the link between two organic worlds [read: between two dissimilar sets of internally convergent or autopoetic relations] requires not only catalysts but also *adaptors*, we are very likely to be in the presence of an organic code, and therefore of organic meaning" (2002: 293).

This focus on the endogenous organization of organisms as the primordial site of meaning-making – and the corollary conclusion that such meaning-making is, in its first instance, mechanical and derivative, rather than experiential and primitive – leads Barbieri to posit a semiotic/hermeneutic threshold in the evolution of living beings:

> "The first semiotic structure that appeared in the history of life was the [ribonucleoprotein] apparatus of protein synthesis, and the genetic code [joining nucleotides to amino acids] was the first code, but not the only one. The evolution of semiosis was essentially due to the appearance of other organic codes, especially in eukaryotic cells, and it was these new codes that increased the complexity of the eukaryotes and eventually allowed them to produce semiotic systems capable of interpretation, i.e. *hermeneutic* systems. The model of Peirce and Sebeok, therefore, is still valid but only for hermeneutic systems. The origin of semiosis (the *semiotic threshold*) and the origin of interpretation (the *hermeneutic threshold*) were separated by an extremely long period of evolution, because interpretation is dependent on context, memory and learning, and probably evolved only in multicellular systems. The history of semiosis, in short, was a process that started with context-free codes and produced codes that were more and more context-dependent. Today, our cultural codes are so heavily dependent on context that we can hardly imagine semiosis without interpretation, and yet *these are distinct processes* and we need to keep them apart if we want to understand their origin and their evolution in the history of life" (2008: 596)

The subjective experience of animals interpreting their surrounds as highlighted by von Uexküll, and even the triadic logic of relations developed by Peirce, claims Barbieri, can only function as "descriptive sciences, not explanatory ones. . .[for in this framework] semiosis requires three basic elements – object, interpreter and sign – which are *preconditional* and therefore *primitive* entities. [As] consubstantial agents of semiosis . . .they are the starting point [whereby a sign relation comes into being] and therefore cannot be reduced any further" (2007: 109).

Thus, although the Peircean/Uexküllian tradition shows us *that* sign relations are critical to the organization and interaction of the biological world, claims Barbieri, they do not show us *how* the underlying physical mechanisms work. For that, he suggests that biosemiotics needs to turn away from qualitative organicism in its approach and instead adopt "good rational, old-fashioned machine-like models" in the investigation of the roles of codes, signs, and meaning in living systems (202: 294).

Such machine models, Barbieri stresses, do not have to be eliminative-reductionist ("for a machine is a machine not when it is reduced to pieces, but precisely when it is put together into a functioning whole"), nor does it have to be physically constructed (e.g., a Turing machine), nor necessarily a set of mathematical equations. "Natural selection," writes Barbieri, "is a mechanistic model which is entirely expressed in words. The important point is that the model has the *logic* of a machine" (2002: 289).[40]

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[40] It is precisely this assertion that, I think, is most strenuously argued against in Anton Markoš' *Readers of the Book of Life*, as discussed above (see also Markoš 2002a: 136, 2002: 221, 2005: 87). Hoffmeyer (1996: 38, 95) and Emmeche (2001: 659) have similarly voiced their opposition to this idea.

> In so arguing against the organicist orientation of the Copenhagen school, Barbieri aligns himself with the mechanistic tradition of "Descartes, Newton, Lamarck, Darwin ...and Jacques Monod" over and against the representative group of biosemiotic precursors cited by Stjernfelt: "Saint-Hilaire, von Baer, D'arcy Thompson, Spemann ...Brian Goodwin, René Thom and Stuart Kauffman" (Barbieri 2002: 284; Stjernfelt 2002: 79).

It remains an open and ongoing question as to whether Barbieri will be successful in his efforts to refashion the primary biosemiotic articulation from one of "signs" to "codes" – or if, indeed, contrary to Barbieri's own current position, a coherent synthesis between his articulation and the presently predominant Peircean-Uexküllian articulation can be achieved.

Untold more possibilities exist, of course, for as Hoffmeyer reminds all newcomers to biosemiotics in the introduction of his seminal work, "To be decent scientists, we must take one another's realities seriously enough to try to eliminate the contradictions" (1996: *ix*). Biosemiotics, he continues, "suggests one way of doing this" – and then he adds with characteristic humanist-scientist understanding, "There may, of course, be other ways" (*ibid*).

Epilogue: On the Future History of Biosemiotics

A heuristic formula for the development of any kind of scientific inquiry might consist in successive initial phases of: observation, intuition, articulation and experimentation – which, if felicitous, then begin to cycle into one other generatively and recursively. If this formulation can serve as even a rough guide to the progression of scientific inquiry, then biosemiotics today is surely well past phases one and two, and is working diligently within phase three with a look to the arrival of phase four, at which time it will no longer be a "revolutionary science" in the Kuhnian sense, but quite simply, part of the background assumptions and paradigm of the everyday "normal science" of biology.[41]

Whether or not this day will come, only the histories that will be written long after this history will reveal. Certainly, the study of sign processes within life processes cannot be forestalled forever, as the more we learn about the former, the more we find ourselves confronted with the latter. Eventually, the "blind faith" that these sign processes can be studied *only* in their material aspects and not *also* in their aspects as signs *qua* signs for the systems that are using them as such, will be forced to give way under the weight of empirical evidence that is even now pouring in daily from the research being done in every area of the life sciences.

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[41] Bruno Latour (1987) distinguishes these two phases in the construction of knowledge as, first, "science in the making" – which is characterized by uncertainty, debate, personality, happenstance and abduction; followed by "ready made science" – which is characterized by relatively uncontentious induction using formulae, models, vocabulary, theories, methodologies and technologies that have been vetted in the earlier phase. The layperson's notion of "science" is generally the latter; the scientist's experience, the former – but as Latour argues against Kuhn, the relation between the two enterprises is not revolutionary struggle, but evolutionary dialectic.

Yet many working scientists do not feel comfortable working at a "science" that is still in its articulation phase. For the claim that "articulation" must come *before* "experimentation" so as to arrive at "understanding" may seem strange to those scientists who are working in long-established fields where the defining and fundamental articulations have already been settled – and, indeed, who may already be on their third and fourth re-articulations, as in physics. But MacIntyre (1974) has argued well that the history of all sciences have followed this chronology of observation, intuition, and articulation before experimentation – for, indeed, how would one know what one was experimenting "on" or "for" if one did not already have in place at least a provisional articulation of what one has intuited based on observation? And success in science has long followed the path, from the pre-Socratics to Copernicus, Newton to Darwin, Einstein and Bohr to Watson and Crick.

"You won't look for something if you don't believe it's even there," notes Marcello Barbieri frequently, and in his (2003) *The Organic Codes*, he relates how

> In the 1950s, it became clear that protein synthesis required a transfer of information from nucleic acids to proteins, and people realized that such a process must necessarily use a code. The existence of the genetic code, in other words, was predicted *before* doing the experiments that actually discovered it, and the results of those experiments were correctly interpreted as proof of the code's existence. [Contrarily,] in the case of signal transduction, the experiments were planned from the very beginning as a means of studying the biochemical steps of the phenomenon, and not as a search for codes, and the biological reactions of that field were regarded *a priori* as normal catalyzed process, not as codified processes. *No code had been predicted, therefore no code was discovered.* . . .[and this is how molecular signal transduction] has been studied ever since" (2003: 233)

Moreover, the fact that researchers were "looking for" a genetic code at all has its roots in the process of observation, intuition and articulation that led Wilhelm Johannsen to propose the existence of a "gene" in the first instance. There again, an *observation* (about familial sameness) led to an *intuition* (about material transmission) that had to be *articulated* [as the "theoretical unit of hereditary" – *whatever* that might turn out to be and some possible candidates were: cell, protein, blood, and vapor, among many others]). In order to articulate his *conceptual posit*, Johannsen designated this *theoretical unit of analysis* as a "gene." Only then could researchers start conducting experiments to find out if this so-called "unit of hereditary" actually existed and, if so, what it physically was and how it worked.

The twisted ladder of the double-helix DNA molecule, could Johannsen or any of his contemporaries had somehow seen it back then, would never have suggested itself as anything other than just a spirally molecule – which, of course, on one level, is all it is. But its *function* is something more, and that is not something that can be ascertained just by looking at its material form alone. Rather, only by looking at its material form in a context of an explanation – an *articulation*, or *provisional theory* – can one begin to do the experiments that will lead to the warranted conclusion that this molecule functions as the "unit of heredity" in this particular set of material interactions that constitutes the "organismic reproduction."

Precisely analogous to the above situation is the current status of the "*sign*" as a legitimate "unit of analysis" in biology, and particularly in neurobiology. There

– as in genetics, as in pharmacology, and as in animal behavior study – of one is *not looking for* the biological construction of a "sign relation" per se within the set of material interactions that constitutes brain activity, then one can see all the chemical-electrical activity there is to be seen – but one will never know how to see it *as* any particular *kind* or *category* of "sign activity" until one has a provisional theory – or *articulation* – positing in just what a "biological sign relation" consists. Even the finest microscope can only *present* – it cannot "make sense of" or explanatorily "reveal." For that one needs a theory – i.e., is an articulation, based on the logical analysis of observed phenomena, which is then subject to informed scientific testing.

Without this, for example, neuronal activation may be mapped down to the nano-volt, for its chemical and electrical properties – which we already understand quite well today – are not going to change. But whether or not we ever even look to see if any particular neuron's activation is currently functioning as part of an indexical circuit, an iconic one, or a symbolic one – to such questions, we will never get an answer, so long as "sign processes" remain misunderstood as equivalent to "human cultural constructs" and not the fundamental biological relations that biosemiotics insists that they are.

In science, one can only get an answer to those questions that it is "legitimate" to ask – and thus the job of biosemiotics right now is to articulate its intuitions about sign processes in biology such that they become accepted as legitimate scientific to ask. Currently, many of these questions are often still avoided as being "not quite legitimate" questions to ask – even despite the repeated insistence of virtually everyone working to advance the biosemiotic project, that what is being asked for is *not* a retreat into mysticism, supernaturalism, immaterialism, or reification of some scientifically unexaminable thing or element called "the sign" per se – but, rather, the same type of rigorous, repeatable, falsifiable examinations into a set of naturally-occurring relations in the world that living beings both need (internally) and use (externally) in order to survive.

One can examine these phenomena in their aspects as sign phenomena (i.e., in their aspects as substitution relations for some non-immediately present other) and still be doing actual science – this is the biosemiotic "message" in a nutshell. But the long legacy of Cartesian reductionism that has allowed modern science to examine the inanimate aspects of the world (Descartes' *res extensa*) so successfully, has kept it closed off from the equally natural product of nature that is "knowing relations" or "cognition" (Descartes' *res cogitans*).

Thus, despite all the problems that Cartesian body-mind dualism keeps increasingly forcing upon life scientists, the majority of experiments being done today – in neuroscience, molecular biology, immunology, pharmacology, etc. – are all informed by a theory that precludes, under the very terms of its bifurcated ontology, even the possibility of coherently – much less scientifically – understanding the phenomena under investigation: phenomena like messaging, signaling, representation, communication, understanding, and sign. Biosemioticians have thought these matters through from both their biological and their semiotic sides, and have come to the conclusion that the problem is not in the phenomena, but in the unnecessary restrictiveness of the informing theories.

Biosemioticians would argue the absolutely legitimate fear of contaminating science with spiritualism, vitalism, anthropomorphism and anti-scientism of every stripe has had the unintended consequence of forcing life-science into the unnatural and reactionary position of materialist reductionism. This, in turn, has diminished it and closed off its explanatory possibilities towards system phenomena that cannot be so reduced – not because such phenomena are spiritual or immaterial, but simply because of their nature as an agent-object-action relations of a biological organism. For any system that is *alive* must maintain itself in a constant state of self-reconstruction – this means that it must simultaneously and incessantly negotiate the organization of both its own internal set of intra-system relations, as well as the organization of its macro-system level interactions with an externality that is constituted by a third set of non-isomorhic causal relations of its own. Merely to *survive* this incessant triadic existential demand (much less to *evolve* within it) necessarily introduces into the phenomena under examination the proximate and system-centric *mediating* relations of *function*, *use*, *purpose*, and *goal* – as well as the superordinate relation needed to achieve all of these relations, the relation of substitution or "standing for" – i.e., the biological relation of *sign.*

Thus, while biosemioticians are *not* challenging in any way the absolute need and manifest success of examining the material aspects of these phenomena *qua* those material (and not "material and also relational") aspects, they do believe that the continued performance of lab experiments uninformed by a strong sign theory will not advance our scientific understanding to the fullest. Rather, biosemioticians will see a neuron firing and say that is a "sign" whose vehicle is this chemical-electrical event – while mainstream neuroscientists will see the same neuron firing and say that parsimony demands we say no more than just: this is a chemical-electrical event. But to the organism that neuron is firing in, which of these two understandings is the more inclusive and veridical? And is it not this organism – this system of interactions – that we are ultimately trying to understand in all its fullness? Left *only* with what can be seen "iconically," we are back to seeing the DNA molecule before there is a coherent theory of genetic inheritance in place. The data and the experimental results will always be the same for both the biosemiotician and the non-biosemiotician in their capacities as "objective" observers. Thus, the burden of proof, quite rightfully, is now on the biosemioticians to articulate why the biosemiotic insistence that the same phenomena must also be explicated from the "subjective" standpoint of the system under examination is not only possible and warranted, and worthy of the development of new scientific conceptual tools – but is also the understanding that may prove to be more predictive, more knowledge-generating, or more explanatorily sufficient than the current biological models that are now in use.

Like Aristotle's ideal naturalist who was able to successfully capture both the material nature of a phenomenon as well as its "meaning" in the lives of the organisms involved with it, without losing the essential aspects of either, biosemiotics strives for an explanatory subjective knowledge/objective knowledge synthesis in order to explain nature's genuine subject/object synthesis that is *biology*. But whether or not anyone currently working in the field of biosemiotics can actually accomplish this explanatory synthesis, of course, remains to be seen. To date, the majority of our efforts have been expended trying to convince our colleagues in the sciences and the humanities that such a synthesis is even necessary. And as premier biosemiotician Claus Emmeche reminds us, while the biosemiotic understanding of sign relations as genuine relations of the natural world may seem to its adherents as a "robust, sophisticated, coherent, well founded, fruitful and comprehensive scheme of thought. . .in the long run, it cannot escape being judged by its fruits, and we do not yet know the historical result of that judgment" (2000b: 224).

And thus we end this brief overview of the ongoing history of biosemiotics as we started it – *in media res*. For while Thomas Sebeok (2001a) referred to the 1970s as the "prehistory" of biosemiotics, and Marcello Barbieri (2002), writing of the 1990s, opined that biosemiotics was as yet still coming into its "adolescence" – it is difficult not to feel as we end this as-yet preliminary "history" that both the reader and I have arrived here at the present moment in 2010 just as the *real* history of biosemiotics is about to get underway.

That said, all that is now left for me to do as a historian of the project is to welcome all our readers to this exciting young interdiscipline, and on behalf of my colleagues in biosemiotics everywhere, to invite you to actively contribute to its ongoing history.

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Part I
Sebeok’s Precursors and Influences

Chapter 2
The Theory of Meaning

Jakob von Uexküll (1864–1944)

Introduction and Commentary: Jakob von Uexküll

> *The average person is only aware of their own subjective view of the world, its space and time, sounds, smells, and colors. Science is trying to manipulate this naïve world view in two different ways. Physics is trying to convince the observer that this view of the world is full of subjective illusions, and that the real world is no more than an incessant dance of atoms controlled by natural laws of causality. Biology, on the other hand, shows the untrained observer that he sees far too little, that the real world consists of a multitude of subjective worlds that may be similar to his own, but whose variations he could spend a lifetime studying and never reach an end. By exploring the Umwelten of other organisms we add to our own a host of different worlds; and the richness of our own world will increase in immeasurable ways. While physics is bound to impoverish the average thinker's view of the world, biology will enrich it beyond measure.*
>
> J. von Uexküll (1928: 22).

As is well evidenced in the history of biosemiotics that opens this volume, the work of Estonian naturalist and experimental biologist Jakob Johann von Uexküll occupies a singularly prominent position in the contemporary attempt to develop a biological science of signs. "When we talk about [Uexküll's bio-analytical concept of] *Umwelt*," writes historian of ideas John Deely, "we are talking about the central category of zoösemiosis and anthroposemiosis alike" (1990: 120). Accordingly, Thomas A. Sebeok, whose revival of Uexküll's all but forgotten work was integral to the launching of the project of biosemiotics proper, never failed to acknowledge his debt to the man whom he considered "single-handedly brought biosemiotics about – *avant*, so to speak, *la lettre* – [with his] wholly unprecedented, innovative theory of signs, the scope of which was nothing less than [the scientific investigation of the manifold of] semiosis in life processes in their entirety" (1998 [2001]:168–169).

Most suggestively of all, perhaps, Tartu Professor of Biosemiotics Kalevi Kull has written that

> Uexküll's work is considered to be a foundation for theoretical biology and for the experimental study of organisms' behavior. Uexküll wanted to make a new biology, one which would not suffer from Bedeutungsblindheit ['meaning blindness']. Thus, in doing one thing, he has been interpreted as doing two: biology and semiotics. Which means that through him, these two fields fuse, or at least cohere, and the study of sign systems is simultaneously both biology and semiotics. However, this is certainly not all that needs to be said about the importance of Jakob von Uexküll (Kull 2001: 3).

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Heeding Kull's admonition – and given the fact that both Sebeok's rediscovery of Uexküll, as well Uexküll's central organizing concepts of *Umwelt* and of *Funktionkreiss* have already been described in this volume and are discussed in much more penetrating detail throughout it subsequently (most notably in the selection that follows, but also in the selections from Sebeok, Hoffmeyer, Krampen, Thure von Uexküll and Brier) – we will examine here at some length more than usual, the biography of this at one time all but forgotten biosemiotic pioneer.

Baron Jakob Johann von Uexküll was born into an aristocratic Baltic-German family on the manor of Keblaste, Estonia on September 8, 1864. His family's linage of nobility could be traced back 700 years at the time of his birth, leading the historian Astaf von Transehe to remark that "to write the history of the Uexkülls is to write the history of the *Livlands* (now Baltics)" (quoted in Harrington 1996: 37). Privately tutored for the first few years of his life, Uexküll attended *Gymnasium* in Coburg, Germany from 1875 to 1877, and *Domschule* in Reval (now Tallinn), Estonia from 1878 to 1883. In 1884, he enrolled in Dorpat (now Tartu) University, where he studied zoology and marine biology, receiving his degree in zoology in 1889. After graduating from university, Uexküll spent the next decade at the Institute of Physiology of the University of Heidelberg in Germany, performing experimental research and studying in the physiology laboratory of Wilhelm Kühne (1837–1900), who was the student of Johannes Müller (1801–1858), the successor in the position to Hermann von Helmoltz (1821–1894) and the originator the concept of "enzyme" in biology (Kull 2001: 10).

Uexküll's research at this time centered around the mechanisms responsible for the neuro-muscular phenomena in sea urchins, octopuses, peanut worms and brittlestars, investigations which took him to both the famous Zoological Station of Anton Dohn (1840–1909) in Naples, as well as to the Paris laboratory of physiologist Etienne Jules Marey (1830–1904), who was the first to use the new technology of *cinéma* to produce time-lapse "moving pictures" of animal movements (Rüting 2004: 39). In Paris, Uexküll employed this new "chrono-photographic" method to research the movements of dragonflies, starfish and butterflies – work that would later have a profound influence on his thinking about the subjective nature of animals' experience of "time."

During this period, too, together with his colleagues in Naples, Albrecht Bethe and Theodor Beer, Uexküll produced an influential paper (Beer, Bethe and Uexküll 1899) that "attacked the use of anthropomorphic terminology in sensory physiology, and proposed a new 'objective' terminology instead – substituting, for example, 'seeing' with *photoreception* and 'smelling' with *stiboreception*. This paper turned out to have a broad impact on the development of behaviorism in the United States and on the 'reflex' concepts of Pavlov and Bejhterev in Russia" (Rüting 2004: 40). Continuing his laboratory research while at the same time becoming deeply convinced of the need for a more fully explanatory and less naively reductionist biology, Uexküll's discovery that the flow of energy in the stimulated nerve net of an invertebrate always moves in the direction of the extended muscle (the now well-known "Uexküll's law" of neuromuscular physiology) was recognized by the awarding of an honorary medical doctorate by the University of Heidelberg in 1907.

Ever more concerned with the explanatory shortcomings of the "biological machine" approach to the investigation of living systems (the obverse error of the anthropomorphic approach that he had condemned in 1899), by 1909, Uexküll had outlined the basics of his subject-oriented approach to the study of animal behavior in his first major monograph, *Umwelt und Innenwelt der Tiere* (roughly: *The Outer World and the Inner World of Animals*). This monograph, full of rich empirical data, is where Uexküll would articuate for the first time his revolutionary *Umwelt* notion – the notion of a biologically instantiated and causally efficacious set of agent-object relations reducible neither to the organization of the subject nor to the organization of the environment but always as the product of the interaction between the two – as well as his conviction that these relations of seemingly "private and subjective experiences" were examinable, within the standard reasonable limits, by science. For Uexküll, *Umweltforschung* – the scientific study of animals' perception and behavior – was to be the leading wedge in the expansion of biology beyond just what is discoverable by chemistry and physics.

It was just at this time, however, that Uexküll's personal fortunes began to deteriorate, as widespread Russian hostility against "the Baltic barons" in the wake of the Russo-Japanese war of 1905 resulted in the burning to the ground of his ancestral manor house at Heimar. In next few years, the combination of World War I and the Russian Revolution resulted in the loss of almost all his property in the Baltic states, and his all but total financial devastation. "If the Balts had led a special existence up to this point as wayfarers between the East and the West," recalls Uexküll's wife, with the outbreak of World War I in 1914, "the narrow path that permitted this travel was abruptly washed away. Now, there were only 'Germans' and 'Russians'" (1964; quoted in Harrington 1996: 55). And, like many of the other of the former Baltic aristocracy now facing ruin in Weimar, notes current director of the *Uexküll Archive* in Heidelberg, Torsten Rüting, Uexküll considered the ascendance of a strong German state as the best, last hope for his ancestral homeland (2004: 42).

Accordingly, when not working on his scientific projects, Uexküll spent much of the next two decades penning nationalistic manifestos – comparing health and decay in the organism with health and decay in the State, and exalting the "holy idealism" of responsible, Kantian-ethic guided "German family life" as against the capitalism-corrupted power fetishism of "English social Darwinism" (Uexküll 1920, 1917). The rhetoric of these interwar writings, it has been charged, may have both been part of, as well as have contributed to, the groundswell of national feelings of persecution and ethnocentrism that Adolf Hitler would later exploit, with such tragic consequences, in the decade from 1935 to 1945.

Yet Uexküll, it has been reliably established, for all his pre-World War II nationalistic fervor, never joined the Nazi party, nor exerted any particular effort towards helping it; was alternately accepted and suspected by the Nazi administrators tasked with reviewing his work; feared the invasion into biology of Nazi "race research"; and was a public critic – to the extent one could be – of what he called the "barbaric" anti-Jewish laws in Russia and in Nazi Germany (Rüting 2004: 40–46; Harrington 1996: 54–71). Still, and for whatever what one believes it says about the man, Uexküll, like perhaps the majority of his countrymen, primarily "watched after his own interests" at this time, neither substantively supporting nor substantively challenging Hitler's regime. Surely, however, Uexküll did his own later intellectual reputation no credit with his impassioned nationalistic advocacy writings of the 1915–1933 period.[1]

Uexküll's academic career likewise experienced a professional stall between the relatively unnoticed publication of his *Umwelt und Innenwelt de Tiere* in 1909 and the much more well-received publication of *Theoretische Biologie* in 1921 – and much of this was due to his outspoken rejection of "mechanist" models then seen as the "future" of in biology. Instead, along with his friend embryologist Hans Driesch, Uexküll argued for the existence of non-mechanical and teleological principles inherent to living systems (e.g., Driesch's *entelechy*; Uexküll's *Bauplan*) – ideas which were seen, justifiably or not, as "mystical" and "unscientific" by the orthodox thinkers of the late nineteenth-century scientific community in Germany. Thus, in 1913, Uexküll's application to head the Kaiser Wilhelm Institute for Biology – which he would presumably re-tool to include *Umweltforschung* – was turned down in favor of the hire of a more orthodox thinker.

Instead, Uexküll was awarded a grant to set up working laboratories in the aquaria of all the zoological gardens in Germany. With the outbreak of World War I, this plan was shelved and the money rescinded. Unable to continue his research, Uexküll used this time to review and prepare for publication the results of his many years of work. *Theoretische Biologie* (1920), the monograph that emerged from this labor, set out Uexküll's *Umweltlehre* in its most perspicuous form yet, and is the book that Thomas A. Sebeok claims posthumously germinated "the flowering of biosemiotics" half a century later.[2]

Theoretische Biologie was well received, though mechanist biologists such as Jacques Loeb (1859–1924) and Richard Goldschmidt (1878–1958) both publicly took umbrage with it. Nevertheless, Uexküll remained without an institutional position until Otto Kestner (1873–1953), a former student of Uexküll's who had recently

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[1] For insightful accounts of Uexküll's scientific and civilian activities during the time of Nazi rule (which consisted almost entirely of continued attempts to keep his research programs from being de-funded by the government) as well of his intellectual friendship and Kantian/Romanticist kinship with the English naturalist turned German nationalist philosopher Houston Stewart Chamberlain (1855–1927), see G. von Uexküll (1964), Schmidt (1975), Harrington (1996) and Rüting (2004).

[2] One of Sebeok's many disquisitions on the role of Jakob von Uexküll in the development of biosemiotics appears within the selection included in this volume (Chapter Six). For the most in-depth discussion of Uexküll's sign theory in this regard, however, the reader is emphatically directed to consult both Sebeok's fullest account of Uexküll's *Umweltlehre,* "Neglected Figures in the History of Semiotic Inquiry" (1977), as well as semiotician John Deely's seminal 2001 article, "Umwelt." Estonian Professor of Biosemiotics Kalevi Kull's entry in this volume (Chapter Thirteen) provides an illuminating account of the intellectual milieu in which Uexküll worked to help found the discipline of Theoretical Biology. Critically, the *Semiotica* (2001) "Special Issue on Jakob von Uexküll" that Kull edited contains over two dozen scholarly articles on Uexküll's work, as considered from almost a dozen different disciplines, as well as the most complete Uexküll bibliography extant.

been appointed Ordinarius of the Physiology Department in the newly-founded University of Hamburg in 1919, secured a position for him in charge of the long-neglected Hamburg aquarium in 1925. Already sixty-one years old at this time, Uexküll used the meagre funds available to him to set up a small laboratory for the investigation of marine animal behaviour in a kiosk adjacent to the aquarium in 1925. One year later, he had fully set up his long-awaited *Institut für Umweltforschung* and was appointed as an *Honorarprofessor* at the University of Hamburg.

Uexküll's *Institut für Umweltforschung* "flourished into a vital research center, and [from 1926] until 1934 produced more than seventy scientific papers under the direct supervision of its head" notes the *Institut*'s current archivist–noting, too, that because researchers coming to the *Institut* "came from different faculties of science and often brought their subjects with them, the works produced were very heterogeneous:

> There was no one single 'model' organism and the subjects covered a broad range of scientific questions. There were works on the physiology of muscles, sense organs, body movements, and works on different aspects of behavior and communication, performed with different animals from marine animals to cockroaches to snakes to dogs. [Of primary importance] was the investigation of the capacity of the sense organs. This basic research could only reveal a first outline of the realizable *Umwelt* of the animal. However, by investigating the animal's ability to perceive and discriminate different physical stimuli, Uexküll tried to obtain initial indications [of these stimuli's] significance for the animal's behavior – and the first ideas about the *signs* that might constitute the animal's *Umwelt*. For Uexküll, this was the basic methodology to analyze the 'subjective space' of the animal. (Rüting 2004: 55)[3]

Uexküll drew upon some of the *Institut*'s research findings from their perceptual-behavioral experiments with dogs, hermit crabs, sea anemones and chickens in his most well-known work in the English-speaking world, his empirically rich and marvelously illustrated 1934 volume *Streifzüge durch die Umwelten von Tieren und Menschen*. At only a little more than 50 pages, the entire small volume was translated and reprinted by Claire Schiller in 1957 as *A Stroll through the Worlds of Animals and Men* for one of the first comprehensive anthologies in animal ethology – the scientific discipline that Jakob von Uexküll and his *Institut für Umweltforschung* is generally credited with inaugurating.

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[3] Exegeses by Thure von Uexküll (1987) and Thomas A. Sebeok (1977) clarify Uexküll's methodology, lest there be any misapprehension about "attempts to read an animal's mind". Writes von Uexküll: "This method of observation means first of all ascertaining which of those signs registered by the scientific observer are also registered [analogously, not necessarily identically] by the living being under observation"(1987: 149). Writes Sebeok: "The *Umweltlehre* of von Uexküll requires no more than that the categories of experience and knowledge [be pragmatically aligned with the extra-mental regularities of] the real universe – not that the two halves of the cycle fully correspond with one another, let alone that the *Innenwelt* completely 'represents' the world. A rather circumscribed repertoire of guiding signs sufficiently serves the purpose of the organism, which is the sustenance of its survival" (1977: 203). Colloquially: The goal is not to try to find out what (or if) an animal "is thinking" – but, rather, what its behavior, when confronted with a certain stimuli, reveals that such stimuli, at that moment and in that situation, "means." The first project has nothing at all to do with biosemiotics – the second is at the heart of it.

In 1940, at seventy-six years of age, Uexküll left the directorship of the *Institut für Umweltforschung* in the hands of his assistant, Friedrich Brock (1898–1958) and published his final major work, *Bedeutungslehre*, which Thomas Sebeok called "a reasoned conspectus for a vast program of research [that holds great] no less than biological, import" and which appears here as the following selection (albeit in a necessarily abbreviated form).

Jakob von Uexküll died on July 25, 1944 on the Allied-occupied island of Capri, where he had been living since his retirement from the *Institut für Umweltforschung* in 1940.

At the time of his death, observes historian of science Anne Harrington, "Uexküll's reputation in Germany was of such a high nature, that the University of Hamburg decided to nominate him for one of Germany's most prestigious national awards, the Goethe Prize for Art and Science" (1996: 71). In life, Uexküll counted among his colleagues and admirers such contemporary luminaries as Ernst Cassier (1874–1945), Rudolf Magnus (1873–1927), Cosima Wagner (1837–1930), Martin Heidegger (1889–1976), Adolf Meyer-Abich (1893–1971), Walter Benjamin (1892–1940) and Rainer Maria Rilke (1875–1926). Indeed, notes Harrington, Uexküll's renown among the scientists of his own time was such that

> Jakob von Uexküll could well have anticipated that his would be an enduring legacy in the annals of holistic life and mind science . . . The physiologist Albrecht Bethe would subsequently hail Uexküll's early comparative physiological work as the most successful science of his peer group. Ethologist Konrad Lorenz saluted him as someone who "knew the strings by which an animal is suspended in its environment to a degree hardly ever surpassed by an ethnologist." Martin Heidegger[4] called Uexküll "one of the shrewdest biologists of our time," while his friend and physiological colleague, Otto Kestner, nominated him twice for the Nobel Prize (1996: 34).

Yet for all this, and as Harrington acutely notes, "today, Uexküll's work remains less widely known, especially in the English-speaking world, than he and his admiring colleagues probably would have anticipated" (1996: 34).

Since the time of Harrington's appraisal a mere thirteen years ago, Uexküll's stature in the scientific and humanities communities has only grown. Within the sciences, animal physiologist Kari Lagerspetz (2001) has cited Uexküll's 1920 work on neuromuscular recursion (see Fig. 2.1) as the first "cybernetic" model of negative feedback and reafferent control in biology; neurobiologist Joaquin Fuster (2003) has employed Uexküll's *Funktionkreiss* concept as the basis for an embodied theory of cognition; and cognitive scientists and roboticists Noel Sharkey and Tom Ziemke (2001) have recognized Uexküll's pioneering notion of parallel neural networking in

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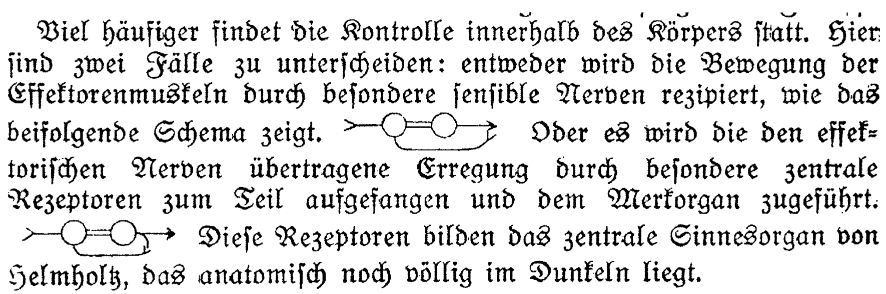
[4] Harrington notes that the recently released Heidegger lecture notes of 1929–1930 reveal that the philosopher had "studied Uexküll's works at remarkable length, particularly *Theoretical Biology* (1920) and *The Inner and Outer Worlds of Animals* (1909) [and that] it may well be that Uexküll's *Umwelt* concept contributed, in a way not yet properly recognized, to Heidegger's intriguingly similar central concept of 'Being-in-the-world' which Heidegger had first comprehensively articulated in *Being and Time*" in 1927 (1996: 53–54).



Viel häufiger findet die Kontrolle innerhalb des Körpers ſtatt. Hier ſind zwei Fälle zu unterſcheiden: entweder wird die Bewegung der Effektorenmuskeln durch beſondere ſenſible Nerven rezipiert, wie das beifolgende Schema zeigt. Oder es wird die den effektoriſchen Nerven übertragene Erregung durch beſondere zentrale Rezeptoren zum Teil aufgefangen und dem Merkorgan zugeführt. Dieſe Rezeptoren bilden das zentrale Sinnesorgan von Helmholtz, das anatomiſch noch völlig im Dunkeln liegt.

Fig. 2.1 Hand-drawn diagrams that Uexküll inserted into the 1920 text of *Theoretische Biologie* to illustrate his original and revolutionary ideas of biological feedback, negative feedback, and reafferent control (reprinted in Rüting 2004)

biology (see Fig. 2.2), sixty years prior to its development by Artificial Intelligence researchers Runelhart and McClelland in 1986.

In the humanities, philosopher Brett Buchanan (2008) has performed the deep archival and exegetical work revealing the profound influence of Uexküll's thought on philosophers Maurice Merleau-Ponty (1908–1961) and Gilles Deleuze (1925–1995); semioticians Thomas A. Sebeok and Marcel Danesi (2000) have developed their wide-ranging Modelling Systems Theory (MST) upon the foundation of a synthesis of Uexküllian, Peircean and Lotmanian ideas; and comparative linguist and historian of ideas Prisca Augustyn (2009) has just recently initiated the long-overdue project of translating the still largely-untranslated Uexküll corpus into modern scientific English, noting, among other relevancies, pioneering linguist Noam Chomsky's consistent and deliberate "use of the term Umwelt throughout his 50 year campaign for the understanding of linguistics as [a form of] theoretical biology" (2009: 2).

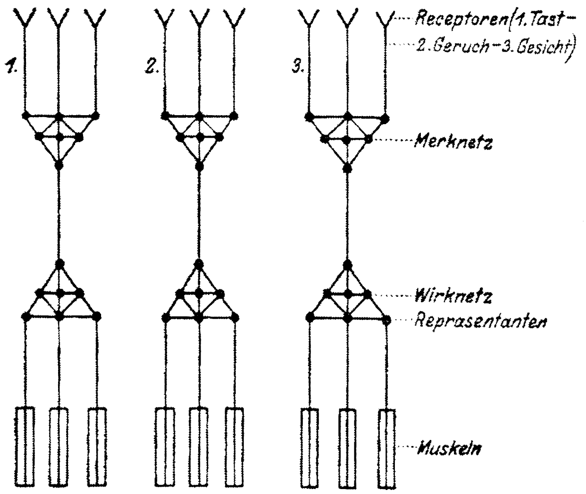


Fig. 2.2 Uexküll's depiction of parallel and interconnected neural networks; appended to the revised edition of *Theoretische Biologie* 1928 (p. 106) – a precursor, writes Lagerspetz, of Rosenblatt's 1958 "perceptron" model for pattern recognition and information storage that led to the still later development of artificially intelligent "neural nets"

Most importantly of all, perhaps, biosemioticians such as Jesper Hoffmeyer, Kalevi Kull, Søren Brier and Claus Emmeche have shown how Uexküll's *Umweltlehre,* when wedded with an equally expanded understanding of post-Darwinian evolution, offers us a scientific way of understanding that the *"subjective experience"* of organisms – far from being either the animal version of human symbolic experience *or* a ghostly epiphenomomenon to be, in a scientifically Victorian fashion, disingenuously shunned and denied – is instead, not only a genuinely existing and biologically instantiated set of agent-object relations, but is, as such, an *organizing principle* in the ongoing co-development, co-evolution and co-maintenance of interdependent living systems: a generative and recursive engine of both evolutionary stability and change.[5]

Jakob von Uexküll could not accept the implications of "nature's meaninglessness" that he saw lying at the heart of his contemporaries' Darwinism. Contemporary biosemiotics, in a small but profound shift of emphasis, remains agnostic about "nature's meaninglessness" (i.e., about the ultimate significance of the totality of nature, and about whether or not the existential predicate "meaningless" can be properly applied to this totality), but finds far too much evidence to the contrary in the scientific literature to believe in nature's internally operative "meaninglessness" – i.e., the radical misunderstanding that "meaninglessness" is a property that permeates the organization of living systens and characterizes the way that the organisms of the biological world interact and have evolved. This shift from a defence of "nature's meaningfulness" to one of nature's "meaning-fullness" does not put the contemporary project of biosemiotics at odds with the critically important insights offered by evolutionary biology in the way that Uexkull understood his own ideas to be. But without the pioneering work done by Jakob von Uexküll in the early 20th century, the 21st century, it is not at all certain that the 21st century interdiscipline of biosemiotics may have ever taken form.

Yet perhaps one more brief word about the following selection is now in order:

Coming out of an earlier tradition in scientific discourse that has now been almost entirely eclipsed, many of Uexküll's ideas and terminology in this selection may at first seem strange to modern ears: his early acceptance of Darwin's then-new theory was eventually replaced by his principled (if perhaps too entire) rejection of it; the milieu in which he lived and worked was still imbued with elements of the previous generation's high esteem for German Romanticism, and there were no ready-made terms or concepts from "cybernetics", "dynamic systems theory", "holistic biology", "gestalt theory" or "complexity theory" that would enable him to express his insights in ways that we today would more clearly associate with

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[5] Uexküll's renown within the biosemiotic community is now such that the *Jakob von Uexküll Centre* for biosemiotic research was opened at the University of Tartu in 1993, and the *Jakob von Uexküll Archiv für Umweltforschung und Biosemiotik* inaugurated at the site of Uexküll's original *Umwelt*-study laboratory at the University of Hamburg in 2004. Still, not all biosemioticians are convinced that proceeding from even an evolutionarily modified Uexküllian framework is the most fruitful possible framework for biosemiotics. See Barbieri (2001 and Chapter Twenty Four of this volume) for an explicit discussion of principled objections to such an approach.

scientific discourse. Instead, Uexküll often relied on musical metaphors as a way of pointing his readers towards the ineliminable aspect of subjectivity that is entailed by the agent-object operations observable in organisms.

Accordingly, the reader may want to make a mental note to keep in mind the very different scientific milieu in which the following selection was written, and to make the appropriate mental emendations – Uexküll's *ego-tone* we would now call *qualia*; his *meaning-carrier properties of objects* are the precursors of Gibson's (1977) *sensori-motor affordances*; and his *contrapuntal duets* or *counter-points* refer to nothing more nor less that the *interdependent nature of species evolution*, wherein the "perceptual and effector cues" of the bat act as "selection pressures" for the morphology of the moth, and vice versa, generatively and recursively. Perhaps most beneficially of all, the reader may also want to re-read this selection anew after having finished reading the rest of this volume – at which point, hopefully, the reader will find some part of their own conceptual *Umwelt* has changed – and that much of what might seem merely "poetic" in the following selection now, may reveal itself as actually being "science in a another language," in retrospect.

The Theory of Meaning (1940)

Preface (*From*: A Stroll Through the Worlds of Animals and Men [1934])

This little monograph does not claim to point the way to a new science. Perhaps it should be called a stroll into unfamiliar worlds; worlds strange to us but known to other creatures, manifold and varied as the animals themselves. The best time to set out on such an adventure is on a sunny day. The place, a flower-strewn meadow, humming with insects, fluttering with butterflies. Here we may glimpse the worlds of the lowly dwellers of the meadow. To do so, we must first blow, in fancy, a soap bubble around each creature to represent its own world, filled with the perceptions which it alone knows. When we ourselves then step into one of these bubbles, the familiar meadow is transformed. Many of its colorful features disappear, others no longer belong together but appear in new relationships. A new world comes into being. Through the bubble we see the world of the burrowing worm, of the butterfly, or of the field mouse; the world as it appears to the animals themselves, not as it appears to us. This we may call the *phenomenal world or the self-world of the animal.*

To some, these worlds are invisible. Many a zoologist and physiologist, clinging to the doctrine that all living beings are mere machines, denies their existence and thus boards up the gates to other worlds so that no single ray of light shines forth from all the radiance that is shed over them. But let us who are not committed to the machine theory consider the nature of machines. All our useful devices, our machines, only implement our acts. There are tools that help our senses, spectacles, telescopes, microphones, which we may call *perceptual tools.* There are also tools used to effect our purposes, the machines of our factories and of transportation, lathes and motor cars. These we may call *effector tools.*

Now we might assume that an animal is nothing but a collection of perceptual and effector tools, connected by an integrating apparatus which, though still a mechanism, is yet fit to carry on the life functions. This is indeed the position of all mechanistic theorists, whether their analogies are in terms of rigid mechanics or more plastic dynamics. They brand animals as mere objects. The proponents of such theories forget that, from the first, they have overlooked the most important thing, the subject which uses the tools, perceives and functions with their aid.

The mechanists have pieced together the sensory and motor organs of animals, like so many parts of a machine, ignoring their real functions of perceiving and acting, and have even gone on to mechanize man himself. According to the behaviorists, man's own sensations and will are mere appearance, to be considered, if at all, only as disturbing static, But we who still hold that our sense organs serve our perceptions, and our motor organs our actions, see in animals as well not only the mechanical structure, but also the operator, who is built into their organs, as we are into our bodies. We no longer regard animals as mere machines, but as subjects whose essential activity consists of perceiving and acting. We thus unlock the gates that lead to other realms, for all that a subject perceives becomes his *perceptual world* and all that he does, his *effector world.* Perceptual and effector worlds together form a closed unit, the *Umwelt.* These different worlds, which are as manifold as the animals themselves, present to all nature lovers new lands of such wealth and beauty that a walk through them is well worth while, even though they unfold not to the physical but only to the spiritual eye. So, reader, join us as we ramble through these worlds of wonder.

The Theory of Meaning [1940]

. . .Only he who is a biologist investigates the planful processes of life and determines their changing meanings. This way of conceptualizing biology has almost vanished; for most investigators the lawfulness of meaning relations is *terra incognita.* I am, therefore, forced to start with the simplest examples, in order initially to convey to the reader some idea about how meaning is to be understood, and then to demonstrate to him that life can only be understood when one has acknowledged the importance of meaning.

I must also state that it is deceptive to: (1) commission a chemist, rather than an art historian, to judge a painting; (2) entrust the critique of a symphony to a physicist instead of to a musicologist; (3) concede to a mechanist, and not a biologist, the right to limit the study of the reality of the behaviors of all living organisms to the law of the Conservation of Energy. Behaviors are not mere movements or tropisms, but they consist of *perception of (Merken)* and *operation upon (Wirken);* they are not mechanically regulated, but meaningfully organized.

This concept naturally defies the "Law of simple explanations" *(Denkokonomie)* that guides the mechanists and has made their investigations easy! But to push problems aside does not solve them. Progress in the life sciences in the last few decades is characterized by behaviorism and the study of conditioned reflexes; one can certainly concede that experiments have become more and more complex, but must declare that [the quality of] scientific thought has become easier and cheaper. Cheap thought has the same effect as an infectious disease – it spreads, and suffocates all attempts at an independent *Weltanschauung* – I ask each naturalist whether he wishes to steer the public to that goal.

The Meaning-Carrier

The sight of winged insects, such as bees, bumblebees, and dragonflies, flying about a flower-filled meadow reawakens in us the impression that the whole world lies open for these enviable creatures. Even earth-bound animals, such as frogs, mice, snails, and worms, appear to move freely in nature. This impression is deceptive. In truth, every free-moving animal is bound to a specific habitat and it remains the task of the ecologist to investigate its limits.

We do not doubt that a comprehensive world is at hand, spread out before our eyes, from which each animal can carve out its specific habitat. Observation teaches us that each animal moves within its habitat and confronts a number of objects, with which it .has a narrower or wider relationship. Because of this state of affairs, each experimental biologist seems to have the task of confronting various animals with the same object, in order to investigate the relationships between the animal and the object. In this procedure, the same object represents a uniform standard measure in every experiment.

American researchers, for example, have attempted indefatigably, in thousands of experiments, starting with white rats, to investigate the relationship of a vast variety of animals to a labyrinth. The unsatisfactory results of this work, despite the most exact techniques of measurement and their most refined mathematical treatment, could have been predicted, because it was based on the false assumption that an animal can at any time enter into a relationship with a neutral object.

The proof of this seemingly surprising assertion is easy to demonstrate by means of a simple example: Let us suppose that an angry dog barks at me on a country road. In order to drive it off, I pick up a stone and frighten it off with an adept throw. Nobody who observes this process and afterwards picks up the stone would doubt that it was the same object, "stone", which first lay on the road and then was thrown at the dog. Neither the shape, nor the weight, nor the other physical and chemical properties of the stone have altered. Its color, its hardness, and its crystal formation have remained the same and yet, a fundamental transformation has taken place: It has changed its meaning. As long as the stone was incorporated in the country road, it served as a support for the walker's feet. Its meaning in that context lay in its playing a part in the performance of the path, we might say that it had acquired a "path-quality." This changed fundamentally when I picked up the stone to throw it at the dog. The stone became a missile – a new meaning became imprinted upon it. It had acquired a "throw-quality."

The stone lies in the objective observer's hand as a neutral object, but it is transformed into a meaning-carrier as soon as it enters into a relationship with a subject. Because no animal ever plays the role of an observer, one may assert that they never enter into relationships with neutral objects. Through every relationship the neutral object is transformed into a meaning-carrier, the meaning of which is imprinted upon it by a subject. The influence that the transformation of meaning exercises on the properties of the object is clarified by two further examples. I take a domed glass dish, which can serve as a neutral object because it has not performed any previous function for human beings. I insert the glass dish into the outside wall of my house and transform It m this way into a window that lets in the sunlight; but, because it also reflects light, it screens out the glances of the passers-by. However, I can also place the glass dish on a table, fill it with water, and use it as a flower-vase.

The properties of this neutral object are not altered at all during these transformations. But as soon as the glass dish has been transformed into a meaning-carrier, "window" or "vase", its various properties acquire a rank-order of importance. The transparency of the glass is a "key" property of the window, while its curvature represents a subsidiary property. In the case of the vase, the obverse is true: The curvature is the key property and the transparency the subsidiary property. Through this example, we can understand why the scholastics divided the properties of objects into “essentia” and “accidentia”. In so doing they had only meaning-carriers in mind; because the properties of neutral objects are not meaning-carriers, they cannot be rank-ordered by importance. Only the tighter or the looser bond between the meaning-carrier and the subject makes possible the separation of the properties into key (essential = *essentia*) and subsidiary (inessential = *accidentia*) ones.

Are we not taught by this example that the forest, for instance, which the poets praise as the most beautiful place of sojourn for human beings, is in no way grasped in its full meaning if we relate it only to ourselves? . . .

The meaning of the forest is multiplied a thousandfold if its relationships are extended to animals, and not only limited to human beings: There is, however, no point in becoming intoxicated with the enormous number of Umwelts (subjective universes) that exist in the forest. It is much more instructive to pick out a typical case in order to take a look into the relationship-network of the Umwelts. Let us consider, for example, the stem of a blooming meadow-flower and ask ourselves which roles are assigned to it in the following four Umwelts:

(1) In the Umwelt of a girl picking flowers, who gathers herself a bunch of colorful flowers that she uses to adorn her bodice;
(2) In the Umwelt of an ant, which uses the regular design of the stem-surface as the ideal path in order to reach its food-area in the flowerpetals;
(3) In the Umwelt of a cicada-larva, which bores into the sap-paths of the stem and uses it to extract the sap in order to construct the liquid walls of its airy house;
(4) In the Umwelt of a cow, which grasps the stems and the flowers in order to push them into its wide mouth and utilizes them as fodder.

According to the Umwelt-stage on which it appears, the identical flower stem at times plays the role of an ornament, sometimes the role of a path, sometimes the role of an extraction-point, and finally the role of a morsel of food. This is very astonishing. The stem itself, as part of a living plant, consists of well-planned interwoven components that represent a better developed mechanism than any human machine. The same components that are subjected to a certain building-plan *(Bauplan)* in the flower stem are torn asunder into four different Umwelts and are integrated, with the same certainty, into various new building plans *(Baupläne).* Each component of an organic or inorganic object, on appearing in the role of a meaning-carrier on the life-stage of an animal subject, has been brought into contact with a “complement” [later: *Kontrapunkt*, or “counterpoint”], so to speak, in the body of the subject that becomes the meaning-utilizer. This conclusion draws our attention to an apparent contradiction in the fundamental features of living nature. The fact that the body structure is ordered according to a plan *(Planmässigkeit)* seems to contradict the idea that the Umwelt structure is also ordered according to a plan *(Planmässigkeit).*

One must not be under the illusion that the plan to which the Umwelt structure accords is less systematically complete than the plan according to which the body structure is ordered. Each Umwelt forms a closed unit in itself, which is governed, in all its parts, by the meaning it has for the subject. According to its meaning for the animal, the stage on which it plays its life-roles *(Lebensbühnei*) embraces a wider or narrower space. This space is built up by the animal's sense organs, upon whose powers of resolution will depend the size and number of its [possibilities for sensorimotor interaction]. The girl's field of vision resembles ours, the cow's field of vision extends away over its grazing-area, while the diameter of the ant's field of vision does not exceed 50 cm and the cicada's only a few centimeters.

The [sensorimotor possibilities] are distributed differently in each space: The fine pavement the ant feels while crawling up the flower stem does not exist for the girl's hands and certainly not for the cow's mouth. The structure of the flower stem and its chemistry do not play any part on the stages upon which the girl or the ant play their life-roles. The digestibility of the stem is, however, essential to the cow. The cicada sucks out the sap it needs from the finely-structured sap-paths of the stem. It is even able, as Fabre[6] has shown, to obtain completely harmless sap for its foam-house from the poisonous spurgeplant. Everything that falls under the spell of an Umwelt (subjective universe) is altered and reshaped until it has become a useful meaning-carrier; otherwise it is totally neglected. In this way the original components are torn apart without any regard to the building-plan that governed them until that moment. The contents of the meaning-carriers are different in the various Umwelts, although they remain identical in their structures. Part of their properties serve the subject at all times as perceptual cue-carriers, another part as effector cue-carriers.

The color of the blossom serves as an optical perceptual cue in the girl's Umwelt, the ridged surface of the stem as a feeling perceptual cue in the Umwelt of the ant. The extraction-point presumably makes itself known to the cicada as a smell perceptual cue. And in the cow's Umwelt, the sap from the stem serves as a taste perceptual cue. The effector cues are mostly imprinted upon other properties of the meaning-carrier by the subject: The thinnest point of the stem is torn apart by the girl as she picks the flower. The unevenness of the stem's surface serves the ant both as a touch perceptual cue for its feelers and as an effector cue-carrier for its feet. The suitable extraction-point that is made known by its smell is pierced by the cicada, and the sap that flows out serves as building material for its house of air. The taste perceptual cue of the stem causes the grazing cow to take more and more stems into its chewing mouth.

Because the effector cue that is assigned to the meaning-carrier extinguishes in every case the perceptual cue that caused the operation, each behavior is ended, no matter how varied it may be. The picking of the flower transforms it into an ornamental object in the girl's world. Walking along the stem changes the stem into a path in the ant's world, and when the cicada-larva pierces the stem, it is transformed into a source for building material. By grazing, the cow transforms the flower stem into wholesome fodder. Every action, therefore, that consists of perception and operation imprints its meaning on the meaningless object and thereby makes it into a subject-related meaning-carrier in the respective Umwelt (subjective

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[6] Henri Fabre (1829–1915), French insect researcher.

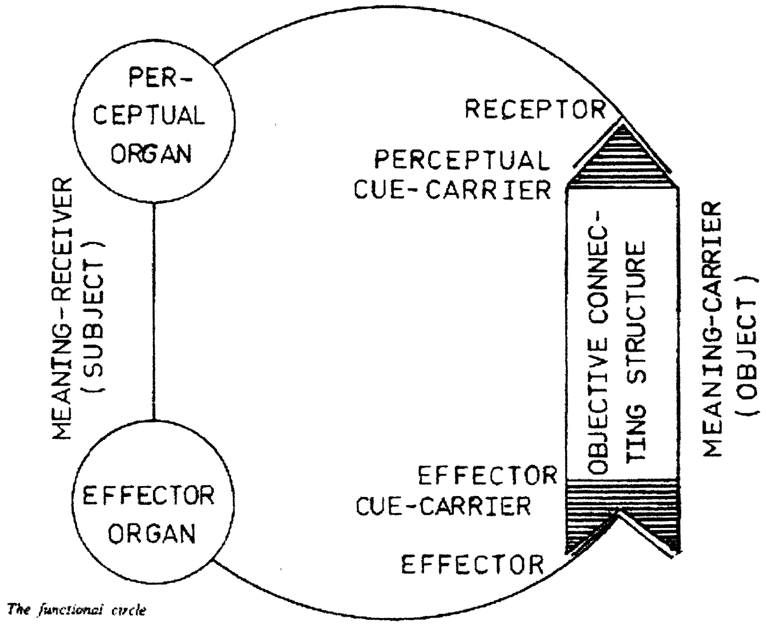

Fig. 2.3 Uexküll's *Funktionkreis* (trans, Schiller 1957)

universe). Because every behavior begins by creating a perceptual cue and ends by printing an effector cue on the same meaning-carrier, one may speak of a functional circle that connects the meaning-carrier with the subject (Fig. 2.3).

Due to its integration into a functional circle (*Funktionkreis*), every meaning-carrier becomes a [contrapuntal] complement of the animal subject. In the process, particular properties of the meaning-carrier play a leading role as perceptual cue-carriers or effector cue-carriers; and other properties, on the other hand, play only a subsidiary role. The biggest part of the body of a meaning-carrier frequently serves as an undifferentiated objective connecting structure *(Gegengefüge)* whose function is only to connect the perpetual cue-carrying parts with the effector cue-carrying parts. – In individual instances, it is enough to trace out the articulation between specific meaning-utilizers and specific meaning-carriers so as to gain an insight into the web of the Umwelts *(Umweltgewebe).*

The Utilization of Meaning

...Meaning is the guiding star that biology must follow. The rule of causality is a poor guide: causal relationships deal only with antecedents and consequences, thereby completely concealing from us broad biological interrelationships and interactions. Whoever invites scientists to follow a new guiding principle must first convince them that it opens up new vistas that advance our knowledge more than the previous ones did. He must also be able to direct attention to hitherto unsolved problems, whose solution can only come about with the help of this new guiding principle.. . .

Loeb's[7] theory of tropism[8] has exercised the largest influence on recent biology. Loeb was a confirmed physicist. He only recognized the interaction between objects, discounting the subject's influence on natural events. In his opinion, only an operational world *(Wirkwelt)* existed, in which all physical and chemical processes took place. One object acts upon the other like a hammer on an anvil, or a spark on a powder keg. The counteraction is due to the kinetic energy conveyed by an agent and the potential energy stored in the affected object. The counter-action of plants resides in the shape and arrangement of the substances in their organs. We need only think about the gutters in the leaves of a tree and about the grains of starch in wheat-seed that may be understood as potential energy. In doing so, one naturally disregards the complete form of the plant, whose structure results from the planned action of impulses of living cell subjects. Certainly, plants do not possess sense organs or nerves – and, therefore, their whole existence seems to take place in an operational world.

Loeb's theory only acknowledged that an operational world exists for animals as well; he refused to recognize a perceptual world by means of a very simple trick. No matter how complicated an animal's performance may be, it will in the end always approach or distance itself from an affecting object. Loeb equated this simple, spatial component of each animal's performance with the performance itself, and thus classified all performances into "turning toward" actions or "turning away" actions. Instead of performances, he named these actions tropisms, with the result that he transformed all living animal subjects into nonliving machines that arrange themselves separately in space. Even the simple magnet, by attracting iron, acts as a positive ferrotrop, and the magnetic needle as a negative polotrop. Loeb's theory became decisive for the way a whole generation of biologists viewed the world.

If we stand before a meadow covered with flowers, full of buzzing bees, fluttering butterflies, darting dragonflies, grasshoppers jumping over blades of grass, mice scurrying, and snails crawling about, we would be inclined to ask ourselves the unintended question: Does the meadow present the same view to the eyes of so many various animals as it does to ours? A naive person will answer this question, without further thought: "Definitely – it is still the same meadow to every eye." A follower of Loeb, however, would give a completely different answer. Because all animals are mere mechanisms, steered here and there by physical and chemical agents, the meadow consists of a confusion of light waves and air vibrations, finely-dispersed clouds of chemical substances, and contacts, which operate the various objects in it. The Umwelt theory contradicts both of these interpretations of the meadow,

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[7] Jacques Loeb (1859–1924), German-American biologist.

[8] Tropism is regular movement in a specific direction in the case of plants and lower forms of animal life, as a reaction to specific stimuli.

because – to cite but one example – the honey-gathering bee does not see the meadow with human eyes, nor is it insensible like a machine.

Colors are light waves that have become sensations: This means that they are not electrical stimuli to the cells of our cerebral cortex, but the *Ich-Ton* [qualia, or self-qualities] of these cells. [. . .This is so because] the colors are the specific energies of cerebral cortical cells that are influenced by the eye. The eye sorts out the light waves and, after transforming them into nerve impulses, transmits them to the cerebral cortex. Similarly, sound-tones are the specific energies of those brain cells that are connected with the ear. The ear records certain vibrations in the air [and yet], the laws of tones are contained in the theory of music. Consonants, dissonants, octaves, fourths, fifths, and so on owe their existence to tone perception and have no separate physical existence. Anyone is invited to explain the tone-sequence of a melody using the law of causality that is valid for all physical processes.

[Moreover,] our sense organs – the eye, ear, nose, palate, and skin – are built according to the principles of a safety-match box. Safety matches only react to selected outside influences. Stimuli also selectively excite sense organs to produce nerve impulses, which are then transmitted to the cerebrum. These mechanical events accord with the law of causality. At this point we arrive at the inner boundary of the sense organs, which takes the form of a living chime whose individual bells are the cells that sound the various *ich-tons*. Is this structural model of the sense organs also found in animals? No doubt the mechanical part of the sense organs in animals is constructed in an analogous manner: They may therefore be regarded as receptor organs. But what about their inner boundary?

Although we cannot know the sense perceptions of our fellow men, their eyes undoubtedly receive visual signs that we call colors. No doubt their ears also receive auditory signs that we call tones. Their noses have the capacity to detect olfactory signs, their palates, taste signs, and their skin, tactile signs. All these signs consist exclusively of ego-qualities. We classify all these qualitatively different sensory signs as “perceptual signs”, which are then projected onto external objects as perceptual cues.

Now we may ask ourselves: When the receptor organs of animals are stimulated, do perceptual signs also occur that correspond to the specific sensory-energies of their brain cells? And are these also projected outward to be used as perceptual cues from which the attributes of all things of the animal’s life-stage *(Lebensbühne)* stem? The pure mechanists deny this scheme. They assert that the receptor organs of animals possess no inner boundary at all but serve only to collect various kinds of external stimuli and put them through to the corresponding parts of the brain. Are the sense organs the expression of various sensory circles, or, functioning as receptor organs, do they merely express various physicochemical kinds of effects of the outside world? Has the eye been shaped by light waves or by colors? Has the ear been shaped by air waves or by tones? Is the nose a product of an air saturated with gases and aroma-particles, or of the olfactory signs of the animal subject? Do taste buds owe their origin to chemical substances dissolved in water or to the subject’s taste signs? Are the receptor organs of animals the product of an outer physical boundary or of an internal nonphysical perceptual boundary?

Because the sense organs of human beings are organs that connect the outer boundary with the inner boundary, it is likely that they perform the same function in animals as well; therefore their construction is due both to the outer and the inner boundary. We cannot consider the receptor organs of animals as merely the product of the outer boundary – proof for this statement is found in the case of fish, which only come in contact with substances dissolved in water; nevertheless, they possess a taste organ as well as a distinct organ of smell. Yet birds, which have the best chance of developing both organs, do not have an organ of smell.

Only when we have clearly understood the problem of the sense organs will the manner in which the whole organism is built become clear. At the outer boundary, they serve as a gutter for the physico-chemical effects of the outside world. Only such effects as hold meaning for the animal subject are transformed into nerve impulses. In turn, the nerve impulses evoke the perceptual signs at the inner boundary of the brain. In this manner the outer boundary also affects the inner boundary and determines the number of visual, auditory, olfactory, tactile, and taste signs that can appear in the perceptual circles of the respective animal subject. In this way the structure of the Umwelts is built up, because each subject is only able to transform the available perceptual signs into the perceptual cues [that inform] its Umwelt.

[...Accordingly,] the process by which the subject is progressively differentiated from [the single notes of] cell-qualia, through to the melody of an organ, [and finally] to the symphony of the organism, stands in direct contrast to all mechanical processes, which consist of the [mere causally efficient] action of one object upon another. The former process is on the same plane as every musical composition. The effect of the meaning-factors of plants and of the meaning-carriers of animals on their meaning-utilizers demonstrates this point very clearly. As the two parts of a duet must be composed in harmony – note for note, point for point – so in nature meaning-factors are related contrapuntally to meaning-utilizers. The shaping of the form of living beings will be more understandable only when we have succeeded in deriving a *theory of the composition of nature* from it.

The Theory of the Composition of Nature

Nature offers us no theories, so the expression “a theory of the composition of nature” may be misleading. By such a theory is only meant a generalization of the rules that we believe we have discovered in the study of the composition of nature.

[Understood metaphorically,] the composition theory of music can serve as a model; it starts from the fact that at least two tones are needed to make harmony. In composing a duet, the two parts that are to blend into harmony must be written note for note and point for point for each other. On this principle the theory of counterpoint in music is based. We must also look for two factors that form a unit in the examples taken from nature. Therefore we always begin with a subject that finds itself in its Umwelt (subjective universe) and we examine its harmonious relationships with individual objects that have appeared as meaning-carriers to that subject.

The organized body *(Organismus)* of the subject represents the meaning-utilizer or, at least, the meaning-receiver. If these two factors are joined by the same meaning, then they have been jointly composed by nature. The content of the theory of the composition of nature consists of the rules that govern such pairings.

When two living organisms enter a harmonious meaning relationship with each other, we must first decide which one of the two is to be designated as the subject and meaning-utilizer, and which is to be assigned the role of the meaning-carrier. Next we will have to look for their mutual properties that are related in the manner that point and counterpoint are. If, in a given case, we know enough about the functional circles (meaning-circles) that join a subject to its meaning-carrier, then we can look for the counterpoint on the perceptual side as well as on the side of the effector. This search will enable us to determine the special meaning rule that the composition has followed.

. . .Let us take, as the first example, the *octopus,* designated *as the subject* in its relationship to *sea-water as the meaning-carrier.* We will immediately perceive a contrapuntal relationship. The fact that water cannot be compressed is the precondition for the construction of the octopus muscular swim-bag. The pumping movements of the swim-bag have a mechanical effect on the noncompressible water that propels the animal backwards. The rule that governs the properties of sea-water acts upon the composition of the cells of protoplasm of the octopus embryo. It shapes the melody of the development of the octopus form to express the properties of sea-water in a counterpoint; first and foremost, an organ is produced whose muscular walls force the water in and out. The rule of meaning that joins point and counterpoint is expressed in the action of swimming.

The same meaning rule in numerous variations governs the development of the living forms of all marine animals: Sometimes they swim forwards, sometimes backwards, sometimes sideways; sometimes they propel themselves with wave-like movements of the tail, sometimes by fins, and sometimes by legs through the water; but the characteristics of the organism bear the same relationship to the properties of the water as point to counterpoint. In each case, the composition that has a common meaning can be proven.

The same applies to all the various circles of the physical medium, whether the animal lives in water, on the land, or in the air. In every case the effector organs for running, jumping, climbing, fluttering, flying, or soaring are formed contrapuntally to the properties of the respective medium. In the case of many insects that live in the water when they are young and in the air when they are older, one can ascertain in the second larval stage how easily the constitution-rule of the new medium causes the initial organs to disappear and new ones to emerge. Inspection of the relationship between the subject's receptors and the medium teaches the same lesson. A sensory organ formed as a counterpoint is always present when a subject meets an obstacle: In the case of light it is the eye, and of darkness, tactile organs or the ear. From the very beginning the bat, like the swallow, is equipped with different means to perceive obstacles in its path of flight.

These, you will reply, are nothing but banalities. Certainly they are everyday experiences that can everywhere be seen. But why has one neglected to draw the only possible conclusion from these experiences? Nothing is left to chance in nature. In every instance a very intimate meaning rule joins the animal and its medium; they are united in a duet, in which the two partners' properties are contrapuntally made for each other... The first requirement necessary for a successful composition of nature is that the meaning-carrier stand out distinctly in the Umwelt of the meaning-receiver. The most diverse perceptual cues can be used to attain this goal. Fabre reports that the female emperor moth makes pumping movements with its hindquarters in order to press its scent glands to the ground. The scent that rises up from the ground is so potent in the male moth's Umwelt that they are attracted to the scented spot from all sides, and are not distracted by any other smells, all of which sink beneath their perceptual threshold. The attraction of this smell is so strong that when a female is placed in a glass case in the path of the males to make her visible but odorless, they are not distracted [by her] from their efforts to reach the scented ground: the meaning-carrier.

[...Likewise], inspection of the functional circles of enemy and food shows us that their range knows no limits, and that the properties of the remotest objects can be contrapuntally connected. I have already discussed the bridging of the constitution rule of the bat and the constitution rule of the night moth by the meaning rule. On one side stands the bat as meaning-carrier, producing only one tone, and on the other side stands the night moth, which can receive only one tone because of its very specialized hearing organ. In both animals this tone is identical. The meaning rule that has created this coordination consists of the relationship between the enemy's attack and its being warded off by the prey. The tone exists as a sign by which bats recognize each other, while it also serves as a signal for the night moth to escape. In the bat's Umwelt it is a "friend-tone" and in the night moth's Umwelt, an "enemy-tone". According to its different meanings, the same tone creates two completely different hearing organs. Because the bat is able to hear many tones, its ear is adapted to resonate broadly. However, it can only emit this one tone.

It would be equally interesting to trace the bridge formed between the tick and the mammal by the use of the meaning rule. The tick sits motionless on the tip of a branch until a mammal passes below it. The smell of the butyric acid awakens it and it lets itself fall. It lands on the coat of its prey, through which it burrows to reach and pierce the warm skin with its sting. It then pumps the liquid blood into itself; it does not possess an organ of taste. The pursuit of this simple meaning rule constitutes almost the whole of the tick's life.

The deaf and blind tick is solely constituted to make every mammal in its Umwelt appear as the same meaning-carrier. This meaning-carrier can be described as an extremely simple mammal without the visible or audible properties that usually differentiate the various species of mammals. For the tick, the meaning-carrier has only one smell, which comes from the sweat common to all mammals. That meaning-carrier is also tangible and warm, and allows itself to be bored into and to have blood extracted from it. In this way it is possible to reduce all mammals – no matter how greatly they differ in shape, color, sound, and smell in our Umwelt – to a common denominator. On approach, the properties of any mammal – be it a human, a dog, a deer, or a mouse – contrapuntally activate the life-rule of the tick.

In our human Umwelt a mammal does not in itself appear as a vivid object, but as a mental abstraction, a concept to be used to classify, not as an object we ever encounter. The case of the tick is quite different. A vivid mammal exists in the tick's Umwelt that has a few properties capable of serving as counter-points and exactly meeting the tick's needs. . . .If one only searches for mechanical explanations, the fit of the hermit crab in the snail shell must rank as a special enigma. This fitting-in cannot be interpreted as a gradual adaption through any modifications in anatomy. However, as soon as one gives up such fruitless endeavors and merely ascertains that the hermit crab has developed a tail as a prehensile "organ to grasp snail shells, not as a swimming organ, as other long-tailed crabs have, the hermit crab's tail is no more enigmatic than is the rudder-tail of the crayfish." The prehensile tail is composed as a counterpoint to the snail shell, just as the rudder-tail of the crayfish is to the water.

Hertz (1937, 1939) made the interesting discovery that honey-collecting bees are only able to differentiate between two shapes: open and closed ones. Beam-shapes and polygons of every kind attract the bees, while closed shapes, like circles and squares, repel them. The gestalt-theorists claim that the reason for this is that the open shapes possess a greater stimulus-value. This point can be conceded to them. But what does this idea mean? The answer becomes immediately apparent the moment we say the following: All inaccessible buds, which the bees shun, have closed shapes. Blossoms that offer them their honey have open shapes. Two spatial-perceptual schemata for blossoms and buds are incorporated into the shape-forming rule of bees because the collection of honey follows the meaning rule. In this manner, the two schemata are firmly joined in counterpoint with the two principal shapes of flowers. But how does nature manage when an animal subject depends on differentiating between shapes but possesses a very primitive central nervous system incapable of forming shape-schemata?

The earthworm pulls linden or cherry tree leaves into its narrow hole. The leaves simultaneously serve as food and protection. It grasps the leaves by their tips in order to roll them up easily. If the earthworm were to try to grasp the leaves at their base, they would resist being pulled and rolled. However, the earthworm's structure does not permit the formation of shape-schemata; to compensate for this deficit it possesses a particularly fine sense organ for taste. We owe to Mangold[9] the discovery that the earthworm can nevertheless distinguish between the pieces that belong to the bases and those that belong to the tips of finely-chopped leaves. The tips of the leaves do not taste the same to the earthworm as do their bases: This distinction allows the worms to treat them separately. Taste perceptual cues, acting as counterpoints, take the place of shape-schemata to make it possible for the earthworms to pull in the leaves, an action that is essential for the survival of the earthworms. In this example one can speak of nature's refined composition.

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[9] Otto August Mangold (born 1891), zoologist, student of Spemann, since 1946 head of the department in Heiligenberg (Max Planck-Institut). He has been occupied, among other things, with embryonal cells.

Experience has taught human anglers that, when angling for fish of prey, they do not need to affix an exact likeness of the prey to the hook. Rather it is enough to offer the pike as bait a simple little silver plate that is a very general facsimile of whitebait. Nature, however, does not need to be taught this lesson. *Lophius piscatorius*, the angler-fish, is a wide-mouthed fish, next to whose upper lip is a long movable bone that causes a silver band to flutter. This band attracts smaller fish of prey that, on snapping at this bait, are sucked into the wide mouth that suddenly produces a whirlpool. The range of the meaning rule is further extended by this example, because it does not connect the form-shaping rule of *Lophius* with its prey's form-shaping rule. The victims are themselves predators who respond to a very simplified image (presented by *Lophius*) of their own prey in their Umwelt and are caught.

A similar example occurs in the case of those butterflies that are decorated with spots resembling eyes. By opening their wings they chase away the small birds that pursue them: These birds automatically flyaway at the sight of the eyes of other small predators that may suddenly appear. In the same way that *Lophius* is unaware how the prey it catches looks in the Umwelt of the fish of prey, the butterfly does not know that the sparrow flees at the sight of a cat's eyes. However, that which brings these Umwelt-compositions into being exhibits an awareness of these facts.

The Tolerance of Meaning

We are already familiar with the example of the flower stem and its transformation in the four Umwelts of the girl, the ant, the cicada larva, and the cow. The flower stem, acting as a meaning-carrier, was in each instance confronted with a new meaning-receiver that could also be described as a meaning-utilizer. The meaning-utilizer used the flower stem as decoration, as path, as supplier of material for the building of a house, and as food, respectively. However, this example has another aspect to it that becomes apparent when we substitute the whole plant for the flower stem. The whole plant then becomes a subject of the flower stem and can be added to the previous four subjects, which become meaning-factors for the flower-stem. The plant cannot then be spoken about as a meaning-utilizer. The reception of meaning can only be equated with a tolerance of meaning. This tolerance has various gradations. The transformation of the stem into an ant-path is easy to tolerate. The extraction of the sap for building the cicada larva's house also causes only slight damage to the plant. However, the picking of the flower by the girl and the grazing of the cow can be fatal for the plant.

In none of these four examples can a meaning rule that is in the plant's interest be discovered. The meaningful role of the spider's web in the life of the fly is in no way in the fly's interest – in fact, it contradicts it. The fly, entangled in the web, cannot use this meaning-carrier in its Umwelt at all: it can only tolerate it. The pea-beetle larva, having bored its tunnel through the pea in order to prepare in good time for its future before the pea hardens, is confronted with the meaning-carrier "ichneumon fly", and can only tolerate its assassin without being able to defend itself. The significance of these apparent contradictions of meaning is immediately clarified when we disregard the particular individual and consider only the species as a whole.

The basis of all life is the submergence of the ephemeral individuals for the sake of the long-lived species. The individuals of every generation mate in pairs to produce a new generation. The number of offspring always exceeds that of the parents. In order to maintain the members of a species at the same number, the supernumerary ones must perish. Consequently, the same number of parents of the next generation provides for the further propagation of the species. The elimination of the excessive members occurs in many different ways. In the case of most species, the duration of life of the individuals is determined by the change in seasons. Each year all one-year-old individuals make way for the individuals of the next generation. Wasp colonies consisting of thousands upon thousands of individuals die out completely every autumn. Only a few females hibernate and establish the same number of new colonies the next year. Our houseflies perish in the autumn; one would think they had all died, and yet in the following spring, they appear in the same numbers. The number of flies that meet a premature end in the web of their enemy – the spider – plays a minute role in the regulation of their population. Migration is a great strain on birds; year after year it eliminates supernumerary individuals not equal to the journey. The number of individuals is not the only important factor for a species; their powers of resistance also play a role. Therefore we can recognize that injury is tolerated because it eliminates weaker individuals so that they do not produce weak offspring.

Hawks and foxes benefit the species upon which they prey; they catch the weak members of the species. When foxes are exterminated, rabbits perish in an epidemic because those infected have not been eradicated in time. Sick animals are impeded in their movements; therefore they have a particular attraction for their enemies. Some birds take advantage of this fact. When the lapwing's eggs are threatened by the approach of an enemy, it does not simply flyaway, but pretends to be lame. Its apparent inability to fly attracts its enemies and diverts them far enough away from the nest, until it flies away to complete safety. The ichneumon fly pursues the pea-beetle larva, thereby protecting the peas, which would otherwise be sacrificed by a supernumerary number of the larvae.

. . .Australia provides us with a remarkable example of the importance of specific enemies for the fauna and flora of a country. A hundred years ago, a South American woman brought a cutting of a Barberry fig cactus to Australia. It thrived in its new homeland. It soon became apparent how useful the prickly plant was for fencing in gardens and farms. The cactus was, therefore, planted everywhere. But it transformed itself into a public menace. It spread over gardens and farms, although it was supposed to be protecting them. It encroached upon forests and strangled all plant life. The authorities intervened when wide areas of land were completely devastated. With hoes and fire they fought the new enemy. When these measures had no effect, they scattered poison from aircraft on the forests overrun by the cactus. The only result of this measure was that all the other plants totally perished but the cactus continued to thrive. In their desperation, the authorities consulted the botanical institutes of universities, who in turn dispatched a number of able researchers to the cactus's original homeland. These experienced observers succeeded in discovering a small caterpillar, belonging to a species of moth, that feeds exclusively on the cactus's flesh. After several years of experiments, millions of eggs of this enemy of the cactus were bred. They were then scattered over the cactus deserts. Lo and behold, within a few years, the cactus jungles were successfully destroyed and the land was reclaimed for cultivation.

It is highly attractive to study the compositions of nature, and to determine the meaning attributable to the tolerance of meaning. Two aspects of this problem must be considered; first, the tolerance of meaning lies behind the elimination of individuals in the interest of the species. In this way all unhealthy and less resistant individuals are gotten rid of. Second, the removal of surplus individuals occurs in the interest of the balance of nature. Von Baer[10] believes that supernumerary gnat-larvae and tadpoles serve fish as food. Spencer[11] made a basic error when he interpreted the destruction of supernumerary offspring as supporting the notion of the "survival of the fittest", in order to support the theory of progress in the evolution of living beings. The question is not the survival of the fittest, but the survival of the normal so as to further the existence of the species.

The Technics of Nature

It was, as far as I can recall, a Mahler symphony that Mengelberg ravishingly conducted in the Amsterdam Konzertgebouw. The great orchestra, reinforced by a male and female choir, rang out in overwhelming splendor and fullness. Next to me sat a young man who was totally immersed in the score and who, with a sigh of satisfaction, closed his copy of the music as the last chord died away. My lack of musical knowledge made me ask him what pleasure he derived from following the written notes with his eyes when his ear could perceive the musical tones directly. He answered me with ardent zeal that only he who follows the score can obtain the full conception of a musical work of art. He went on to explain that each voice, whether human or instrumental, is a separate being that through point and counterpoint melds with the other voices into a higher form. In its turn, this new form continues to increase and grow in richness and beauty to form an entity that conveys the mind of the composer to us. By reading the score; one may follow the growth and distribution of the individual voices, which carry the score like pillars of a cathedral support its all-embracing dome. Only in this way can an insight into the form of a performed work of art be gained; its form is composed of many parts. The young man's answer was very convincing, and raised the question in me whether it is not the task of biology to write a score of nature.

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[10] Karl Ernst von Baer (1792–1876), zoologist, originator of a modern theory of evolution that differs from Darwin's.

[11] Herbert Spencer (1820–1903), philosopher, adherent of the biological theory of evolution.

I was already familiar with the contrapuntal relationships of Umwelt to Umwelt at that time. I began to pursue further the example of the flower stem and its relationships with the four other Umwelts. The girl presented a bunch of flowers to decorate her beloved so the flower stem entered into a love-duet. The ant used the stem as a path and ran along it to the flower pistils, there to milk its “dairy cows”, the aphids, while the cow transformed the fodder that contained the stem into milk. The cicada larva, having developed in its foam-house made from the sap of the stem, soon filled the meadow with its soft love-chirp. Other Umwelts supervened. The bees, joined in a counterpoint with the scent, color, and shape of the blossoms, flew by. Having saturated themselves with honey, they informed their hive-companions of the new sources by way of impressive dances (described in detail by von Frisch[12]). The color of the flower, although not the same to the bees as it is to us, serves them, nevertheless, as a positive perceptual cue because the flower and the bees are composed in counterpoint to each other. Although this is a modest start, it is nonetheless a start in solving the problem that the score of nature confronts us with.

. . .The task of animals and plants in the meadow is not only to display their colors, sounds, and scents. These displays must first appear in the Umwelts of other animals and then be transformed into perceptual signs. The relationships of living things can then be translated into a musical idiom; and we may speak about perceptual and effector tones of the various animal subjects that are joined to each other in counterpoint. Only then can one arrive at nature’s score. In nature the perceptual tones of various animals can be used as counterpoint: The tone that attracts bats in the bat-Umwelt is at the same time a warning-tone in the Umwelt of the night moth. The shell worn by the snail has a dwelling-quality for the snail. After the death of the snail its empty shell remains behind to acquire a corresponding dwelling-quality for the hermit crab. This unison of qualities is fully exploited in the snail-hermit crab composition. . . .

The way a comparison to music can be made in the field of biology is by expanding the meaning of the word “tone” or quality: Mere [seeing-, touching-, smelling- or] hearing-qualities become meaning-qualities of the objects, so that they appear as meaning-carriers in the Umwelt of a subject. In its role as a counterpoint, the shell’s dwelling-quality in the snail’s Umwelt and its dwelling-quality in the hermit crab’s Umwelt are mutually interchangeable, the implication being that each one of the two qualities, although not identical with the other, can nevertheless be adapted by one of nature’s compositions to become the other, because they share the same meaning. Meaning in nature’s score serves as a connecting link, or rather as a bridge, and takes the place of harmony in a musical score; it joins two of nature’s factors. Every bridge has a support on each bank of a river; they are joined as point and counterpoint to each other by the bridge. Point and counterpoint in music are joined by the harmony and in nature by the same meaning. With numerous examples, enough to weary the reader, I have proved that such real factors exist in nature,

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[12] Karl von Frisch (born 1886), German zoologist honored with the Nobel Prize for his research work with fish and bees.

and not merely [a human observer's] logical constructs. We have now reached the point where we may indicate that the meaning-score is a description of nature, just as the score written in notes may be equated with description of music.

If we look at an orchestra, we can see that each individual instrument has a music stand, upon which are found the written notes it will play. The complete score of the work rests on the conductor's desk. We can, however, also see the instruments themselves, and we ask ourselves whether these instruments are possibly attuned to each other by virtue not only of the respective tones they emit, but also of the manner of their entire construction: that is, do they form not merely a musical but also a technical unit? Because most of the instruments to be found in an orchestra are also able by themselves to produce performances of musical compositions, this question cannot immediately be answered in the affirmative. Anyone who has listened to clowns play music with instruments that otherwise are only used for making noise – such as combs, cowbells, and the like – will be convinced that they can indeed produce a cacophony but not a symphony with such an orchestra. If one inspects the instruments of a real orchestra closely, one sees that even their structures are related to each other as counterpoints. This point is even more evident in the orchestra of nature as seen in a meadow: We need merely to think of the flower in the four Umwelts. The relationship between the structures of the flower and of the bee is most striking; in fact, one could say that:

If the flower were not bee-like
And the bee were not flower-like
The unison could never be successful.

Thereby, the fundamental theme of all the technics of nature is expressed. In this statement we can recognize Goethe's wisdom once again:

If the eye were not sun-like,
It could never behold the sun.

But now we can also complete the quotation from Goethe and say:

If the sun were not eye-like,
It could not shine in any sky.

The sun is a celestial light. However, the sky is a product of the eye; it establishes its own furthest plane that embraces the dimensions of the Umwelt. Eyeless living beings know neither sky nor sun.

The Counterpoint as the Motive for the Shaping of Form

We can now apply the technical basic rule (expressed in the bee's "flower-likeness" and in the "bee-likeness" of the flower) to other previously mentioned examples. The spider's web is certainly formed in a "fly-like" manner, because the spider itself is "fly-like". To be "fly-like" means that the body structure of the spider has taken on certain of the fly's characteristics – not from a specific fly, but rather from the fly's archetype. To express it more accurately, the spider's "fly-likeness" comes about when its body structure has adopted certain themes from the fly's melody. The tick's body plan also expresses certain distinctive mammalian themes. The influence of the bat's theme in forming the night moth's ear is the clearest example of the rule. In each case, the counterpoint represents the theme in the structure. We should be familiar with this point after considering the construction of the utensils we use.

The handle of a coffee-cup demonstrates without doubt the contrapuntal relationship of the coffee and the human hand. These counterpoints are the main influences on the themes for making the cup: They are indeed more important than the material of which the cup is made. It sounds banal and self-evident to say that the coffee-cup is "coffee-like". However, this statement implies more than is initially apparent: It implies that the cup performs its function by accommodating coffee, but also that this performance was the theme for producing the cup. The theory of meaning culminates in explicating this connection. The meaning to us of our household utensils lies in their performance. Their performance can always be traced back to the bridge that is built between our and the utensils' counterpoints. At the same time, the performance expresses the theme of this joining together. The chair is a seating accommodation that rises from the floor, whose meaning lies in its being a number of bridges to various counterpoints. Its seating surface, back and armrests find their counterpoint in the human body, to which they form bridges, while the legs of the chair form distinct bridges to the counterpoint, ground. All these counterpoints are simultaneous themes for the cabinet-maker in building the chair.

Time does not permit me to cite even more obvious examples. It should suffice to point out that with all our utensils we have built bridges between ourselves and nature. In so doing, we have come no closer to nature; in fact, we have removed ourselves from her. We have begun with ever-increasing speed to build these bridges to other bridges by constructing simple machines, which cannot be disregarded by man, if he wishes to remain close to nature. In the city we are exclusively surrounded by artifacts. The trees and flowers in our parks and gardens are removed and transplanted at will; we have torn them in toto from nature, and converted them into utensils. The much-lauded human technology has lost all feeling for nature: Indeed, it presumes to solve the most profound questions of life – such as the relationship between man and god-like nature – with totally inadequate mathematics.

All this is incidental. It is much more important to gain an idea about the methods nature uses to evoke her creatures (which she does not make from individual parts in the way we construct objects) from undifferentiated germ-plasma. Arndt's film about the origin of the slime mold showed us that in its first phase of life an ever-increasing number of free-living cells are formed, built in counterpoint to their bacterial food. After the food has been consumed, a new counterpoint steps in immediately as a new theme, to transform the single cells by pushing them on top of each other into tissue cells of a plant that is situated in the wind. If we look at the very limited habitat of the slime mold, we find that it lives in a filamentous form on a ball of old horse dung and as a seed-carrier in the wind that scatters its seeds and is its sole effective factor in nature. The seed-carrier and the seed-disperser play a duet together. The free cells first play a living chime with their identical-sounding ego-qualities. Nature then plays with the single cells together and transforms them by means of a new theme into tissue cells in order to construct a seed-carrying form that presents itself to the wind. We find this process just as mysterious as the change of themes in a Beethoven sonata. However, our task is not to compose a nature sonata but rather it is to write down its score.

We are still in the very early stages of asking such technical questions about the vertebrates. The "bud-like" origin of the organ is bound to an elementary building-plan, and the meaning of each bud is determined by its position in the whole organism, so that its meaning is not lost, and it does not form structures in duplicate. This determination is so certain that, as Spemann has shown, a graft of tadpole epidermis becomes a tadpole mouth after being implanted into the location of the triton's future mouth in the triton embryo: the score for the development for the frog's mouth was simultaneously transferred with the frog's cells. A similar discrepancy would ensue if one tore a sheet out of the music score containing the first violin's part and put it into the corresponding place in the cello's part. The tunnel-boring activity of the pea-beetle larva tells us a great deal about the scores for the shaping of form. In this example, the counterpoint that becomes the theme for the boring of the tunnel is the shape of the fully-developed beetle, which only develops somewhat later. The adult beetle would surely perish if it were not for the tunnel exit built by the larva. The future form can, therefore, play the role of a theme in the development of shape. This fact opens up further possibilities. If the future shape that is the goal of development can itself become a theme, then von Baer is correct when he speaks of goal-directedness in the origin of living creatures. However, he does not grasp all the implications of his statement.

When the spider weaves its web, the various stages of the formation of the web, such as the radial construction of its frame, can be described as the goal of and the theme for forming the frame. The web itself can certainly be designated as the goal of its forming that can in no way be attributed to the fly. However, the fly certainly serves as the counterpoint and as the theme for forming the web. The accomplishment of the boll-weevil is a striking example of the many puzzles with which the technics of nature will continue to face us. Two partners confront each other in counterpoint: the small weevil with a fret-saw as proboscis and the large birch leaf whose fate it is to be sawn up. The saw must take such a direction that the weevil can later easily roll the lower part of the leaf into a bag in which to lay its eggs. The path of the saw has a characteristic curvature and remains the same for all weevils, although its outline is not traced on the birch leaf. Is "the constancy of the path" the theme that lies behind its trace?

The answer to this riddle is one of the secrets of nature's composition, which we encounter everywhere in our research on the technics of nature. The first investigator to busy himself with the problems of the technics of nature appears to have been Lamarck.[13] In any event, his experiment, in which he attempted to reconcile

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[13] Jean Baptiste Antoine Pierre De' Monet de Lamarck (1744–1829), French zoologist who introduced a new system into the animal kingdom. He developed the first theory of evolution and expounded the principles of acquired characteristics.

the origin of the giraffe's long neck with the tall trunks of palm trees, contains the first reference to a contrapuntal relationship. Interest in the technics of nature later disappeared completely and was replaced, mainly because of Haeckel,[14] with speculations about the influence of ancestors on later generations. No one will be able to acknowledge a technical achievement in the assertion that amphibians have resulted from fish. The wishful thinking that so-called "rudimentary" organs exist has been responsible for diverting attention from the truly technical problems that face living creatures. Only the proof furnished by Driesch that two complete half-sized sea urchins, and not two halves of a sea urchin, develop when a whole sea urchin embryo is cut in two cleared the path for a deeper understanding of the technics of nature. Everything that is physical – but not a melody – can be cut in two by a knife. The melody of a song played by the free chime of living bells remains unchanged, even if it directs only half the number of bells.

Progress

This time as I listened to St. Matthew's Passion in beautiful St. Michael's church in Hamburg the biological parallels to music forced themselves upon me once again. This supreme work interwoven with the most beautiful hymns proceeds in the gravest, most fateful manner. However, this was certainly not the progression that investigators in their phantasies attributed to the temporal progression of all that occurs in nature. Why should the mighty drama of nature have unfolded on earth since life first appeared in a manner different from Bach's Passion, which is composed of high and low tones? Was the highly valued advance that is said to have led living creatures from imperfect beginnings to increasingly higher perfection perhaps nothing but a bourgeois speculation on the pragmatics of the market place? In any event, no trace of their imperfection had ever occurred to me even in the case of the simplest animals. As far as I could judge, the material available for building their structure has always been exploited in the best possible way. Each animal has filled its own stage of life with all the objects and fellow actors meaningful to its life. The properties of the animal and the properties of its fellow actors harmonize in every case like point and counterpoint of a polyphonic choir. It was as if the same master's hand had from time immemorial been gliding over the keys of life. One composition followed the next without end – some of them difficult, some easy, some splendid, some dreadful.

Simple, but fully-developed crabs are to be found scurrying about in the ocean tides that once completely covered the earth. After a long period of time had elapsed, the rule of the cephalopodes came to an end when they were wiped out' by the sharks. The Saurians emerged from the warm marshes of the mainland, their gigantic bodies grotesque caricatures of life. The master's hand, however, continued to glide. New forms of untold varieties developed from the tree of life

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[14] Ernst Haeckel (1834–1919), German zoologist, follower of Darwin.

into new melodies without ever showing an improvement from the imperfect to the more perfect. The Umwelts were certainly less complicated at the outset of the world drama than later. However, each meaning-carrier was always confronted with a meaning-receiver, even in those earlier Umwelts. Meaning ruled them all. Meaning tied changing organs to a changing medium. Meaning connected food and the destroyer of food, enemy and prey, and above all, male and female in astonishing variations. In every case an advance occurred, but never progress in the sense of the survival of the fittest; never selection of the superior one, through an unplanned, furious struggle for existence. Instead a melody prevailed, embracing both life and death. . . .

I decided to present the following question to our greatest historian: "Has any progress occurred in the history of human beings?"

Leopold von Ranke writes in his *Epochs of Modern History:*

> If one wanted . . . to presume that progress consisted in the fact that the life mankind develops in each epoch to a higher level- that each generation, therefore, surpasses the previous one in every way – the latest generation would as a result of progress always be the favored one. The previous generations would, however, only be the load-carriers of the succeeding generations – and that would be an injustice done by God. A mediatized (dismissed) generation of this kind would have no meaning in its own right: it would only have meaning insofar as it would be a step upon which the succeeding generation raises itself in a manner that bears no direct relation to the Divine. I assert, however: *each epoch is close to God;* its value does not reside in what emerges from it, but rather lies in its own existence, in its own self.

Ranke rejects the idea of progress in the history of mankind, because all epochs can directly be traced back to God, and none, therefore, can be more perfect than the previous one. What can we understand by an "epoch", in Ranke's sense of the word, other than a homogenous group of human Umwelts within a limited period of time? . . .A particular individual obtains a very small amount of matter from his parents in the form of a germ-cell, itself capable of division, and a keyboard composed of genes. With each cell division these genes are distributed in the same number to the daughter cells. This keyboard is played upon by the form-shaping melodies like the keys of a piano, in order to produce the development of form. Each gene that is set into action acts as a differential stimulus to the protoplasm of its cells to build structures. The form-shaping melodies that produce structure in this manner derive their themes from the form-shaping melodies of other subjects, which they encounter on their stage of life.

> If the flower were not bee-like,
> And the bee were not flower-like,
> The unison would never be successful.

These themes at times derive from the food cycle, at other times from the enemy cycle, and at still other times from the sex cycle. The form-shaping melody draws most of its themes from the medium cycle, e.g., the structure of our eye is sun-like and the construction of the maple leaf's gutters, rain-like. Thanks to the fact that extraneous themes are taken over, each subject's body assumes the form of a meaning-receiver for those meaning-carriers whose melodies are the themes that determine its shape. The flower is a collection of counterpoints that act upon the bee; its form-shaping melody is rich in themes and has contributed to the shaping of the bee, and vice versa. The sun, as the most important of nature's components for us, beams down on me from my sky only because it has been the main theme in building of my eye's structure.

The sun's influence in forming the structure of an animal's eye is just as great as the sun appears to be to it. It may be large and radiant or small and insignificant in the Umwelt-sky of the eye in whose formation it has taken great or little part (little, e.g., in the case of the mole's eye). Let us now consider the moon instead of the sun: if its meaning is relevant to an animal's eye, then it will be a theme in the development of that eye's form. [Similarly], the meaning of mammals reaches into the tick's Umwelt: the melody of the development of mammalian shapes is the theme that also influences the development of the tick's shape. These themes are the smell of butyric acid, the resistance of hair, and the warmth of and ease with which the skin is pierced, That mammals have thousands of other characteristics is of no concern to the tick. Only those characteristics that are common to all mammals appear as themes in the building of the tick; they influence the structure of its perceptual and also its effector organs.

We are always on the wrong track when we try to judge the world of animals by the standards of our own world. I could, of course, claim that the whole of nature has taken part in and has been the theme for the development of my personality, body, and mind: if this were not so, I would lack the organs needed to recognize nature. I can also express this point more modestly and state: I am a part of nature to the extent that she has integrated me into one of her compositions. I am not a product of all of nature, but only a product of human nature, beyond which I have not been granted the powers to perceive. Just as the tick is only a product of tick nature, the human being is tied to his human nature, from which every individual human being begins anew.

The advantage we have over animals lies in the fact that we are able to extend the range of our inborn human nature. Of course we cannot create new organs, but we can assist the functions of our organs. We have developed perceptual aids and effector tools that make us able providing we know how to use them – to broaden and deepen our Umwelt. But we cannot go beyond the perimeter of our Umwelt. Only when we recognize that everything in nature is created by its meaning, and that all the Umwelts are but voices that take part in a universal score, will the way be open to lead us out of the narrow confines of our own Umwelt.

Summary and Conclusion

. . .One should remember that the body of each being is made of living cells, which together form a living chime. The living cell contains a specific energy that enables it to answer every external effect with which it comes into contact with an ego-quality. The qualities can be joined with each other through melodies; they can influence each other despite the fact that they may not be in mechanical contact.

The bodies of most animals are basically similar in that they have organs needed for the metabolism of food; energy obtained from food makes the animal's life-tasks possible. Perception and action are the life tasks of the animal subject acting as a meaning-receiver.

Perception depends on the sense organs, which serve to sort out the stimuli that impinge on them from all sides. They screen out the unnecessary stimuli, and transform those that are of use to the body into nerve impulses. When these impulses have reached the brain, the living chime of the brain cells resounds. The ego-qualities of the chime serve as perceptual signs for outer events. They are imprinted upon the respective sources of the stimuli as corresponding perceptual cues, no matter whether they are sound, visual, smell, or other signs. At the same time, the cell "bells" resound in the organ of perception and in the central effector organ, which in turn translates its own ego-qualities into impulses that activate and direct the movements of the effector muscles. Therefore, a kind of musical process is set in motion by the properties of the meaning-carrier, to which it is led back. And one can conceive of the receptor and the effector organs of the meaning-receiver as counterpoints that correspond to the meaning-carrier's properties. One is persuaded anew that most animal subjects possess an intricate anatomy – the prerequisite for smoothly bridging the gap between them and the meaning-carrier.

The structure of the animal's body is never preformed. The body begins its development as a single cell – a bell – that divides, and whose ontogenetic chime is attuned to a developmental melody. How does it come to pass that two objects such as a bumble-bee and the flower of a snapdragon, whose origins are so different, are constructed in such a way that they harmonize perfectly in every detail? Apparently, their developmental melodies mutually influence each other; the snapdragon's melody appears as a theme in the bumble-bee's developmental melody, and vice versa. What holds true for the bee is also true for the bumble-bee; its development would be unsuccessful if its body were not "flower-like."

Once this cardinal principle of nature's technique is understood, we can state that no progression occurs from the less to the more perfect. Because if a variety of themes of meaning extraneous to the animal influence its development, it is impossible to see how successive generations could alter this situation. Having eschewed speculations about the ancestry (of living things), we are on firmer ground in studying nature's techniques. Yet a major disappointment awaits us. The triumphs of nature's techniques are readily apparent, but the manner in which its melodies are created cannot be [directly] investigated.

Nature's techniques share common features with the creation of a work of art. We can, of course, see the painter's hand apply one color after the other to the canvas until he has completed the painting, but the creative melody that moves his hand is wholly hidden from us. We can certainly understand how a musical clock produces its melodies but we can never understand how a melody constructs such a clock. That is exactly the question that the creation of every living being poses. Every germ cell contains the requisite material, and the keyboard is represented by the genes. Only the melody that brings about the organisms's construction is missing: From whence does it come?

Every musical clock contains a cylinder, from which spikes protrude. As the cylinder turns, these spikes strike strips of metal of different lengths to set the air vibrating; our ears perceive these vibrations as tones. By observing the position of the spikes on the cylinder, a musician will easily be able to recognize the score of the melody the clock plays. Let us for a moment forget that the clock was made by human hands, and let us assume that it is a product of nature. We could then state that we are presented with the physical embodiment in three dimensions of a score that has crystallized out of the melody: The melody represents the clock's "germ of meaning" *(Bedeutungskeim)*, provided that enough adaptive material is at hand. . .Meaning is a decisive factor in nature; it appears always, often in novel and surprising guises.

Let us allow the Umwelts [of other creatures] to pass in review before our mind's eye. We will observe wondrous forms in the gardens that surround the bodies that house the subject; these forms are the meaning-carriers, whose meaning is often very difficult to divine. We will therefore have the impression that the meaning-carriers represent a secret sign or symbol that members of the same species can understand, but that those of another species cannot comprehend. The silhouette of, and the water currents produced by, the fresh-water mussel are the love symbols of the bitterling. The earthworm uses the difference in the taste of the tips and stalks of leaves as a symbol of their shapes. The same tone symbolizes "friend" to a bat but "foe" to a night moth. And so on . . . and on.

Once we are finally convinced by an overwhelming number of examples that each Umwelt is at base filled only with meaningful symbols, then a second even more astonishing fact forces itself upon us: Each subject's symbol is at the same time a meaningful theme for the structure of the subject's body. The body that houses the subject on the one hand produces the symbols that populate the surrounding garden and is, on the other hand, the product of these very same symbols that are the meaningful themes in constructing it. The sun owes its shine and its form high up in the sky that extends over the garden to the eye, as the window of the body that houses ourself. At the same time, the sun is the theme guiding the construction of the window. This principle applies to both animal and man; the same factor of nature manifests itself in both cases.

Let us assume that some natural phenomenon has caused all the night moths to die out. With the help of nature's techniques, we are now faced with the task of correcting this gap in nature's keyboard. How would we proceed? We would probably retrain a day moth to search out flowers that are open during the night; it would also have to develop its sense of smell at the expense of its sense of vision.

The newly-trained moth would, however, be defenseless against flying bats. We would have to devise a sign that would identify the predator, so that the majority of moths could evade it in good time. We would use the squeak of the bat, which is a friendly signal to other bats, as an inimical sign for the moth. The moth would have to be rebuilt and provided with a hearing device to enable it to perceive the bat's squeak. This sign would then enter as a theme in the construction of the bat.

If the night moth were not ‘bat-like’,
Its life would soon end.

One can imagine that the tick came about to close a gap in nature’s keyboard. If so, the meaning-carrier that has general mammalian characteristics would at the same time symbolize “prey” and be a theme in the plan for constructing the tick.

Finally, we will attempt to take a look from outside at our own body, which is like a house with its surrounding garden. We now know that our sun in our sky and our garden, full of flowers, animals, and people, are but symbols of an all-encompassing symphony or composition of nature, which ranks all things according to their significance and meaning.

This overview defines the boundaries of our world. The development of progressively more refined machines and equipment, with which to investigate objects, will not enable us to develop new sense organs. The properties of objects, even when analyzed into their constituent atoms and electrons, will continue to remain sensory and perceptual cues.

When we die, our sun, sky, and earth will vanish; but they will continue to exist in a similar form in the Umwelts of succeeding generations. There are not only the two varieties of space and time, in which objects are distributed. There is also the variety of Umwelts, in which objects assume a multiplicity of ever new and different forms. At this third level, the countless Umwelts represent the keyboard upon which nature plays its symphony of meaning, which is not constrained by space and time. In our lifetime and in our Umwelt we are given the task of constructing a key in nature’s keyboard, over which an invisible hand glides.

Translators

Streifzüge durch die Umwelten von Tieren und Menschen (1934) Translated by Claire H. Schiller (1957)

Bedeutungslehre (1940) Translated and footnoted annotation by Barry Stone and Herbert Weiner (1982)

Chapter 3
The Logic of Signs

Charles Sanders Peirce (1839–1914)

Introduction and Commentary: Charles Sanders Peirce

> *I have formed the opinion that the proper sphere of any science in a given stage of development is the study of such questions as one social group of men can properly devote their lives to answering; and it seems to me that in the present state of our knowledge of signs, the whole doctrine of the classification of signs and of what is essential to a given kind of sign, must be studied by one group of investigators.*
>
> C.S. Peirce (CP 4.9, c. 1906)[1]

For very many biosemioticians – and certainly for Thomas A. Sebeok, who would lay the foundations for what would become the contemporary project of biosemiotics in the 1970s – the lifelong investigation into "the logic of signs" undertaken by scientist and philosopher Charles Sanders Peirce serves as a model for those wishing to begin the investigation into the bio-logic of sign relations in living systems.

Peirce's biographer Joseph Brent tell us that Charles Sanders Peirce "was a singular man: a prodigious, protean, brilliant and productive intellect who lived a humiliating and tragic life" (Brent 2000:1). And while Peirce's contributions to sign logic are what have earned him his singular place in the history of biosemiotics, it will do well to devote just our first two pages here to detailing the circumstances under which Peirce pursued that work, for without this backstory, the relative obscurity of a man who contributed so much to so many different branches of science – and whose scientific innovations are only coming to be appreciated now – will remain enigmatic.

Born in Cambridge, Massachusetts on September 10, 1839, Charles Sanders Peirce was the second son of Benjamin Peirce (1809–1880), a pioneering professor of mathematics and astronomy at Harvard University who helped found both the Smithsonian Institute and the National Academy of Sciences. Growing

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[1] Peirce's words are cited throughout this volume by using the standard notation employed by Peirce scholars and codified by the Peirce Edition Project, which is in charge of preparing the definitive scholarly editions of Peirce's work. The abbreviations used throughout this volume are the standard ones employed in Peirce scholarship: CP refers to the *Collected Papers* (volume and paragraph); while EP refers to the *Essential Peirce* (volume and page).

D. Favareau, *Essential Readings in Biosemiotics*, Biosemiotics 3,
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up in a university-centered neighborhood which included his contemporaries and future colleagues William James (1842–1910), Chauncey Wright (1830–1875), and Oliver Wendell Holmes (1841–1935), Peirce inherited his father's deep love of mathematics, and his conviction that its applicability in science was an expression of the natural world's continuity with, and ultimately knowability by, human beings (1889:2974).

Peirce was an impulsive and impatient student, however, and suffered since his youth from the debilitatingly painful neurological disease of trigeminal neuralgia. This condition, in turn, led to a lifetime of drug dependence that, in combination with the incessant pain from the neuralgia, either caused or exacerbated a lifetime of severe manic depression. Moreover, as a student at Harvard University, Peirce was apparently both arrogant and rebellious, alienating his chemistry professor, Dr. Charles W. Eliot (1834–1926) to such an extent that Eliot – who later became president of Harvard (1869–1909) and a major figure in American academia for the entire period that covered what would have been Peirce's working years – took every opportunity presented to him to see to it that Peirce would never gain employment within American academia (Brent 2000: 108–111, 245, 280).

According to Peirce's biographer, Eliot was joined in this effort by the astronomer Simon Newcomb (1835–1909) who – apparently, out of personal animosity, but ostensibly "outraged" at Peirce's "public immorality of living with a woman to whom he was not yet married" during his brief post-graduate employment as part-time lecturer at Johns Hopkins University – also played an active role in repeatedly sabotaging Peirce's grant application, publication and employment opportunities (Brent 2000: 150–155, 245, 280).

Peirce graduated from Harvard without distinction in 1859, going on to study natural history and paleontology at Cambridge. He later returned to Harvard to do post-graduate work in chemistry, where he eventually earned the school's first *summa cum laude* Bachelor's Degree in that discipline. During this time, Peirce also began working for the United States Coast Survey as a geodesist and gravimetrician this was the work that would provide the main source of his increasingly meager income for the rest of his life (though also toiled briefly at the Harvard Astronomical Observatory from 1869 to 1872, where he produced the world's first photometric star catalogue, establishing each star's relative brightness magnitude).

For the majority of the fifty-five years of his life after graduation from university, however, Peirce was effectively blackballed from academia, and supported himself by writing dictionary and encyclopedia entries, as well articles on logic and general scientific topics for venues such as *Popular Science*. He became almost a complete recluse, and for the last two decades of his life, he and his wife were virtually penniless, and often bereft of both heat and food. They were kept alive by aid from Peirce's older brother, James Mills Peirce (1934–1906), from neighbors who took pity upon them, and from Peirce's only two genuine friends and benefactors, the philosophers Lady Victoria Welby (1837–1912) and William James (1842–1910). Peirce died on April 19, 1914 – leaving behind over 80,000 pages of unpublished manuscript containing the record of his solitary lifetime's worth of investigation into logic, mathematics, philosophy and the nature of signs.

The manuscript pages that Peirce left behind have a fascinating history of their own, well recounted in Houser (1992). Neglected for decades, partially and incoherently re-assembled in the 1930s, and still not fully catalogued, the ongoing re-discovery of those manuscripts' contents in the last three decades constitutes one of the great intellectual re-awakenings in our lifetime. In them, the neglected and often despised Peirce is revealed to be "the first modern experimental psychologist in the Americas, the first metrologist to use a wavelength of light as a unit of measure, the inventor of the quincuncial projection of the sphere, the first known conceiver of the design and theory of an electric switching-circuit computer, and the founder of 'the economy [method] of research'" (Fisch 1981:17).

"In the extensiveness and originality of his contributions to mathematical logic, Peirce is almost without equal," writes Robert Burch in the entry on Peirce in the 2008 *Stanford Encylopedia of Philosophy.* Peirce "introduced the material-conditional operator into logic," notes Burch, "developed the Sheffer stroke and dagger operators 40 years before Sheffer, and developed a full logical system based only on the stroke function. As Garret Birkhoff notes in his *Lattice Theory*, it was in fact Peirce who invented the concept of a lattice around 1883" (*ibid*). Moreover, notes Birkhoff:

> Peirce was one of the first scientific thinkers to argue in favor of the actual existence of infinite sets . . . invented dozens of different systems of logical syntax, including a syntax based on a generalization of de Morgan's relative product operation, an algebraic syntax that mirrored Boolean algebra to some extent, a quantifier-and-variable syntax that (except for its specific symbols) is identical to the much later Russell-Whitehead syntax. He even invented two systems of graphical two-dimensional syntax . . . framed an updated conception of *continua* that seems to embrace Cantor's Paradox but to avoid the outright contradiction . . .published a long paper "Description of a Notation for the Logic of Relatives" in which he introduced for the first time in history, two years before Frege's *Begriffschrift,* a complete syntax for the logic of relations of arbitrary adity . . . [created a] logical system that became the basis for Ernst Schroeder's great three-volume treatise on logic, the *Vorlesungen ueber die Algebra der Logik* . . . and by 1883, along with his student O. H. Mitchell, Peirce had developed a full syntax for quantificational logic that was only a very little different (as was mentioned just above) from the standard Russell-Whitehead syntax, which did not appear until 1910 (yet with no adequate citations of Peirce). . . . Peirce [has since become] widely regarded as the greatest logician of his day. But by all who are familiar with his work, he is considered one of the greatest logicians who ever lived. (Burch 2008:o.l.)

Mathematician, chemist, geodesist, and philosopher, Peirce understood himself primarily as a logician, claiming that from the time he read Bishop Richard Whately's (1787–1863) *Elements of Logic* at age twelve, he "could no longer think of anything except in terms of logic" (EP1:*xxix*). Indeed, it is precisely Peirce's "sign logic" that is of such value to biosemioticans. For as Peirce scholars Nathan Hauser and Christian Kloesel remind us in their introduction to the first volume of the collected writings *The Essential Peirce*: "Although Peirce's many contributions to 'technical' logic – including his 1881 axiomatization of the natural numbers, his 1885 quantification theory and introduction of truth-functional analysis, and his lifelong development of the logic of relations – have considerable importance for the foundations of mathematics, Peirce's main concern was *to build* *an adequate theory of science and an objective theory of rationality*" (EP1: *xxx*, italics mine).

For Peirce, formal logic was merely one derivative and evolutionarily late version of an all-encompassing "sign logic" by which any organism (or system) "capable of learning by experience" comes to know the world.[2] Thus, it is as only as a means towards the accomplishment of his over-arching lifetime's project of developing a *semeiotic* – or "theory of signs" – that his *pragmaticism* (theory of meaning), his *fallibilism* (theory of knowledge), his *tychism* (doctrine of natural chance), his *synechism* (doctrine of natural continuity), his *agapsim* (doctrine of evolutionary agency), and his epistemological and ontological *categories* of generative and inter-dependent *being* arise and have their place. For these are all mere elements of Peirce's singular and lifelong effort to discover and to systematize that *logic of relations* that would "have to be the case" in order for the logic of our inquiry to be able result in veridical knowledge about the logic of the natural world into which it inquires.

Since the intellectual re-discovery of Peirce in 1980s, the amount of scholarship on his life and thought has multiplied – and continues to multiply – at a such a rate that 'Peirce scholar' is a now a recognized professional designation in academia – perhaps ironically enough, given the history of Peirce's struggles in this regard during his lifetime. Yet with the existence of over 80,000 pages of published and manuscript writings extant, and already hundreds of recent volumes dedicated to examining his deeply complex work, it would be both presumptuous and counter-productive to try to offer any but the most cursory overview of what is an often daunting system of thought. Nor does any one of Peirce's published papers, which are ultimately but fragments of his ever-evolving logical system, in itself offer sufficiently full insight into the applicability of Peirce's semiotic for modern-day biologists. Like any other scientific paper, they are not written to "stand alone" but to be read as part of an ongoing investigation into an external system that will continue to reveal new levels of complexity, and new levels of our current state of ignorance, as the very result of our progress in correctly understanding it.[3]

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[2] A recurrent problem in understanding Peirce's formulations before one has grasped the logic of his overall system is exhibited by just this statement, which, if read naively, may give the mistaken impression that Peirce's sign logic is essentially "cognitive". In Peirce's system of signs, however, terms like "knowing", "cognition" and "mind" take on technical meanings so far beyond their more circumscribed conventional usage, that one can only proceed with providing introductory explanations of his work knowing that the more sophisticated understandings cannot be introduced until later. Thus, the preceding formulation could have more accurately been written as: "...a sign logic by which any mode of being capable of taking habits comes to participate effectively in making the supra-sensible at least potentially sensible." But that is not the way to *begin* discussing Peirce if one wants to cultivate a hearing for his views, I have discovered (which is why several of his seminal but denser writings, such as his "On a New List of Categories" (1867), have not been included here).

[3] The "Further Readings" section at the end of this volume is intended to provide sufficient enough guidance to the major introductory materials, so as to lead unto a lifetime of Peirce study, for those so inspired. At the minimum, the two-volume *Essential Peirce* anthology assembled by the scholars at the University of Indianapolis' Peirce Edition Project includes those major texts by Peirce with

Indeed, the “key to unlocking Peirce” – and to understanding the precise value of his role today in contemporary biosemiotics – is well-captured in the words of Peirce scholar T.L. Short, who explains why Peirce’s architectonic of sign logic is fundamentally a scientific, rather than a philosophic, undertaking, and how it was designed to be so by the logician Peirce. Unlike the grand pronouncements of the armchair philosopher, writes Short:

> Peirce’s theses are like hypotheses in natural science: based on observations, they are nonetheless not fully justified by observations already made, but must prove themselves by their fruitfulness to further research, in competition with alternative hypotheses . . . Indeed, no philosopher was ever more besotted with science than Peirce, who made philosophy itself a science, or a set of sciences, to be pursued in relation to the other sciences. [It is for this reason that] Peirce wrote philosophy like a scientist, setting out ideas not intended as ‘final’ – but to be applied and developed, perhaps by others. *The arguments for those ideas appear not just wholly on the page, but consists, instead, in what can be done with them* – just as Peirce’s *pragmatism* implies (2007: 307, 65, xii, penultimate italics added).

In short, Peirce left behind a library’s worth of writing – but not as philosophical dogma that he wished others to uncritically defend. Instead, like the scientist that he was, Peirce struggled in his work to make ever more precise and usable a coherent set of hypotheses for the explication and investigation of the systemic relations constituting sign logic of any kind. But this investigation, like all such genuinely knowledge-bearing investigation, could only be completed, Peirce understood by a community of scholars actively working on (which necessitates refining, changing, and replacing) the hypotheses over time. “The *real*, then,” writes Peirce, “is that which, sooner or later, information and reasoning would finally result in, and which is therefore independent of the vagaries of me and you. Thus, the very origin of the conception of reality shows that this conception essentially involves the notion of a *community*, without definite limits, and capable of a definite increase of knowledge” (CP 5.311, 1868, emphasis in the original).

Accordingly, only by attempting to apply Peirce’s hypotheses to the concrete instances of sign logic observable in language, in animal communication, and even in the intercellular signals that hold organisms together coherently – and that, on a much more complex and reafferent level, allow for the emergence of “thought” in human beings – can biosemiotics determine how much of nature’s bio-logic is accurately captured by, and therefore made amenable to, further knowledge-generating investigation by Peirce’s sign logic. Indeed, in this volume alone, the reader will find biosemioticians using Peircean tools of analysis to provide explanatory frameworks for such variegated biological phenomena as genetic expression (Queiroz et al.), animal behavior (Morris), first-person experience (Brier) and the emergence of symbolic thought and language (Deacon).

For as contemporary biosemioticians undertake the project to understand and explain the manifold of sign relations occurring in the natural world, it becomes

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which all biosemioticians should at least be conversant, whether or not one wants to adopt the Peircean approach to biosemiotics.

all too readily apparent that contemporary biology has as yet no useable vocabulary – much less a firm conceptual framework – for talking about signs *as* signs on any of the manifold biological levels whereupon signs processes appear. Creating such explanatorily viable vocabulary – and developing such scientifically applicable frameworks – for empirical biology constitute the two main (and, of course, inherently interconnected) tasks of biosemiotics today. It is the nature of these tasks that they require new conceptual tools that can work *within* the massively successful intellectual edifice that is contemporary science – a science that, quite rightfully, awaits convincing evidence of the viability of their use.

The language of semiotics – "message", "sign of", "representation", "codes", "communicates", "signals", "displays", "signifies", "informs", etc. – runs ineliminably throughout the many related disciplines comprising biology, and yet a unified scientific framework for understanding the underlying phenomenon that these terms refer to is still at this time lacking, as was discussed in some detail in the introduction to this volume and is alluded to, in one sense or another, by virtually all the subsequent texts, as well. Terrence Deacon's selection in this volume (Chapter Eighteen), however, provides a sterling example of how Peirce's *icon, index* and *symbol* distinction is one just such example wherein whole generations of misunderstanding and confusion about "signs" (e.g., as a general synonym for what are at best *sign vehicles* – a conflation that does therefore not allow us to *distinguish* between the 'brute perceptual', the 'reliably associative', and the maximally flexible virtual levels of sign relations used by living organisms to detect, categorize, and act appropriately upon the world) can be helpfully surmounted, and real advancement in our scientific understandings can be made.

Like all such tools and scientific instruments, whether material or formal, however, genuine advance and creativity comes not with the mere mindless application of the tool, but with discovering new ways in which such tools can be made or modified to yield veridical new useable insights. Charles Sanders Peirce famously wrote that he considered himself "a pioneer, or rather a backwoodsman, in the work of clearing and opening up what I call *semiotic*, that is, the doctrine of the essential nature and fundamental varieties of possible semiosis" (CP 5.488). He also noted, close to the end of his life, and in a part of the same quotation that is often deleted, "I find the field too vast, the labor too great, for a firstcomer" such as himself (*ibid*).

Peirce's plaintive quote recalls that of another pioneering scientist, Nobel Prize winning physicist Max Born (1882–1970), who reminds us that "there is no philosophical high-road in science, with epistemological signposts. No, we are in a jungle, and we find our way by trial and error, building our roads behind us as we proceed. Indeed, we do not find sign-posts at cross-roads, but our own scouts erect them, to help the rest" (1943: 44). As was the case with many of his innovations in mathematics, geodesy, and technical logic, it has taken almost a century for the path that Peirce was blazing to be rediscovered, and for the tools that he had fashioned for doing so, to be taken up once again. Accordingly, the present volume itself may be seen as confirmation of the quote that Peirce scholar David Savan opens his monograph on Peirce's sign logic: "When the materials are all prepared and ready, the architects will appear" (Whitman, *Leaves of Grass*).

The Logic of Signs: Selections from the Writings of Charles Sanders Peirce

From: Logic as Semiotic: The Theory of Signs (1893–1910)[4]

I. What Is a Sign? Three Divisions of Logic

Logic, in its general sense, is, as I believe I have shown, only another name for *semiotic* (σημειωτική), the quasi-necessary, or formal, doctrine of signs. By describing the doctrine as "quasi-necessary," or formal, I mean that we observe the characters of such signs as we know, and from such an observation, by a process which I will not object to naming Abstraction, we are led to statements, eminently fallible and therefore in one sense by no means necessary, as to what *must be* the characters of all signs used by a "scientific" intelligence, that is to say, by an intelligence capable of learning by experience. As to that process of abstraction, it is itself a sort of observation. The faculty which I call abstractive observation is one which ordinary people perfectly recognize, but for which the theories of philosophers sometimes hardly leave room.

It is a familiar experience to every human being to wish for something quite beyond his present means, and to follow that wish by the question, "Should I wish for that thing just the same, if I had ample means to gratify it?" To answer that question, he searches his heart, and in doing so makes what I term an abstractive observation. "He makes in his imagination a sort of skeleton diagram, or outline sketch, of himself, considers what modifications the hypothetical state of things would require to be made in that picture, and then examines it, that is, *observes* what he has imagined, to see whether the same ardent desire is there to be discerned."

By such a process, which is at bottom very much like mathematical reasoning, we can reach conclusions as to what *would be* true of signs in all cases, so long as the intelligence using them was scientific. The modes of thought of a God, who should possess an intuitive omniscience superseding reason, are put out of the question. Now the whole process of development among the community of students of those formulations by abstractive observation and reasoning of the truths which *must* hold good of all signs used by a scientific intelligence is an observational science, like any other positive science, notwithstanding its strong contrast to all the special sciences

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[4] This first section entry is a compilation of Peirce's writing on sign logic that has traditionally been found to be a clear and helpful starting point for those coming fresh to the study of Peirce. It was compiled and titled by Justus Buchler in the volume entitled *The Philosophical Writings of Peirce* (New York: Dover, 1955). Buchler details the sources: "The first of the three selections in I is from MS c. 1897 (CP 2.227–9), the third from MS. c. 1910 (CP 2.231–2). The second selection in I, IIIb, the second selection in IIIc, and IIId are from MSs. c. 1902, c. 1895, and c. 1893 (CP 2.274–302). II is from ms. c. 1903 (CP 2.243–52,254–65). IIIa is from the article "Sign" in Baldwin's *Dictionary of Philosophy and Psychology* 1902 (CP 2.304). The first selection in IIIc is from the article "Index" in Baldwin (CP 2.305, 306)."

which arises from its aiming to find out what *must be* and not merely what is in the actual world.

A sign, or *representamen*, is something which stands to somebody for something in some respect or capacity. It addresses somebody, that is, creates in the mind of that person an equivalent sign, or perhaps a more developed sign. That sign which it creates I call the *interpretant* of the first sign. The sign stands for something, its object. It stands for that *object*, not in all respects, but in reference to a sort of idea, which I have sometimes called the *ground* of the representamen. "Idea" is here to be understood in a sort of Platonic sense, very familiar everyday talk; I mean in that sense in which we say that one man catches another man's idea, in which we say that when a man recalls what he was thinking of at some previous time, he recalls the same idea, and in which when a man continues to think anything, say for a tenth of a second, in so far as the thought continues to agree with itself during that time, that is to have a *like* content, it is the same idea, and is not at each instant of the interval a new idea.

In consequence of every representamen being thus connected with three things, the ground, the object, and the interpretant, the science of serniotic has three branches. The first is called by Duns Scotus *grammatica speculativa*. We may term it *pure grammar*. It has for its task to ascertain what must be true of the representamen used by every scientific intelligence in order that they may embody any *meaning*. The second is logic proper. It is the science of what is quasi-necessarily true of the representamina of any scientific intelligence in order that they may hold good of any *object*, that is, may be true. Or say, logic proper is the formal science of the conditions of the truth of representations. The third, in imitation of Kant's fashion of preserving old associations of words in finding nomenclature for new conceptions, I call *pure rhetoric*. Its task is to ascertain the laws by which in every scientific intelligence one sign gives birth to another, and especially one thought brings forth another.

A *Sign*, or *Representamen*, is a First which stands in such a genuine triadic relation to a Second, called its *Object*, as to be capable of determining a Third, called its *Interpretant*, to assume the same triadic relation to its Object in which it stands itself to the same Object. The triadic relation is *genuine*, that is its three members are bound together by it in a way that does not consist in any complexus of dyadic relations. That is the reason the Interpretant, or Third, cannot stand in a mere dyadic relation to the Object, but must stand in such a relation to it as the Representamen itself does. Nor can the triadic relation in which the Third stands be merely similar to that in which the First stands, for this would make the relation of the Third to the First a degenerate Secondness merely. The Third must indeed stand in such a relation, and thus must be capable of determining a Third of its own; but besides that, it must have a second triadic relation in which the Representamen, or rather the relation thereof to its Object, shall be its own (the Third's) Object, and must be capable of determining a Third to this relation. All this must equally be true of the Third's Thirds and so on endlessly; and this, and more, is involved in the familiar idea of a Sign; and as the term Representamen is here used, nothing more is implied. A *Sign* is a Representamen with a mental Interpretant. Possibly there may be Representamens that are not Signs. Thus, if a sunflower, in turning toward the sun, becomes by that very act fully capable, without further condition, of reproducing a sunflower which turns in precisely corresponding ways toward the sun, and of doing so with the same reproductive power, the sunflower would become a Representamen of the sun. But *thought* is the chief, if not the only, mode of representation.

The Sign can only represent the Object and tell about it. It cannot furnish acquaintance with or recognition of that Object; for that is what is meant in this volume by the Object of a Sign; namely, that with which it presupposes an acquaintance in order to convey some further information concerning it. No doubt there will be readers who will say they cannot comprehend this. They think a Sign need not relate to anything otherwise known, and can make neither head nor tail of the statement that every sign must relate to such an Object. But if there be anything that conveys information and yet has absolutely no relation nor reference to anything with which the person to whom it conveys the information has, when he comprehends that information, the slightest acquaintance, direct or indirect-and a very strange sort of information that would be the vehicle of that sort of information is not, in this volume, called a Sign.

Two men are standing on the seashore looking out to sea. One of them says to the other, “That vessel there carries no freight at all, but only passengers.” Now, if the other, himself, sees no vessel, the first information he derives from the remark has for its Object the part of the sea that he does see, and informs him that a person with sharper eyes than his, or more trained in looking for such things, can see a vessel there; and then, that vessel having been thus introduced to his acquaintance, he is prepared to receive the information about it that it carries passengers exclusively. But the sentence as a whole has, for the person supposed, no other Object than that with which it finds him already acquainted. The Objects-for a Sign may have any number of them-may each be a single known existing thing or thing believed formerly to have existed or expected to exist, or a collection of such things, or a known quality or relation or fact, which single Object may be a collection, or whole of parts, or it may have some other mode of being, such as some act permitted whose being does not prevent its negation from being equally permitted, or something of a general nature desired, required, or invariably found under certain general circumstances.

II. Three Trichotomies of Signs

Signs are divisible by three trichotomies; first, according as the sign in itself is a mere quality, is an actual existent, or is a general law; secondly, according as the relation of the sign to its object consists in the sign’s having some character in itself, or in some existential relation to that object, orin its relation to an interpretant; thirdly, according as its Interpretant represents it as a sign of possibility or as a sign of fact or a sign of reason.

According to the first division, a Sign may be termed a *Qualisign*, a *Sinsign*, or a *Legisign*.

A *Qualisign* is a quality which is a Sign. It cannot actually act as a sign until it is embodied; but the embodiment has nothing to do with its character as a sign.

A *Sinsign* (where the syllable *sin* is taken as meaning “being only once,” as in *single*, *simple*, Latin *semel*, etc.) is an actual existent thing or event which is a sign. It can only be so through its qualities; so that it involves a qualisign, or rather, several qualisigns. But these qualisigns are of a peculiar kind and only form a sign through being actually embodied.

A *Legisign* is a law that is a Sign. This law is usually established by men. Every conventional sign is a legisign [but not conversely]. It is not a single object, but a general type which, it has been agreed, shall be significant. Every legisign signifies through an instance of its application, which may be termed a *Replica* of it. Thus, the word “the” will usually occur from fifteen to twenty-five times on a page. It is in all these occurrences one and the same word, the same legisign. Each single instance of it is a Replica. The Replica is a Sinsign. Thus, every Legisign requires Sinsigns. But these are not ordinary Sinsigns, such as are peculiar occurrences that are regarded as significant. Nor would the Replica be significant if it were not for the law which renders it so.

According to the second trichotomy, a Sign may be termed an *Icon*, an *Index*, or a *Symbol*.

An *Icon* is a sign which refers to the Object that it denotes merely by virtue of characters of its own, and which it possesses, just the same, whether any such Object actually exists or not. It is true that unless there really is such an Object, the Icon does not act as a sign; but this has nothing to do with its character as a sign. Anything whatever, be it quality, existent individual, or law, is an Icon of anything, in so far as it is like that thing and used as a sign of it.

An *Index* is a sign which refers to the Object that it denotes by virtue of being really affected by that Object. It cannot, therefore, be a Qualisign; because qualities are whatever they are independently of anything else. In so far as the Index is affected by the Object, it necessarily has some Quality in common with the Object, and it is in respect to these that it refers to the “Object.” It does, therefore, involve a sort of Icon, although an Icon of a peculiar kind; and it is not the mere resemblance of its Object, even in these respects which makes it a sign, but it is the actual modification of it by the Object.

A *Symbol* is a sign which refers to the Object that it denotes by virtue of a law, usually an association of general ideas, which operates to cause the Symbol to be interpreted as referring to that Object. It is thus itself a general type or law, that is, is a Legisign. As such it acts through a Replica. Not only is it general itself, but the Object to which it refers is of a general nature. Now that which is general has its being in the instances which it will determine. There must, therefore, be existent instances of what the Symbol denotes, although we must here understand by “existent,” existent in the possibly imaginary universe to which the Symbol refers. The Symbol will indirectly, through the association or other law, be affected by those instances; and thus the Symbol will involve a sort of Index, although an Index of a peculiar kind. It will not, however, be by any means true that the slight effect upon the Symbol of those instances accounts for the significant character of the Symbol.

According to the third trichotomy, a Sign may be termed a *Rheme*, a *Dicisign* or *Dicent Sign* (that is, a proposition or quasiproposition), or an *Argument*.

A *Rheme* is a Sign which, for its Interpretant, is a Sign of qualitative Possibility, that is, is understood as representing such and such a kind of possible Object. Any Rheme, perhaps, will afford some information; but it is not interpreted as doing so.

A *Dicent Sign*, is a Sign, which, for its Interpretant, is a Sign of actual existence. It cannot, therefore, be an Icon, which affords no ground for an interpretation of it as referring to actual existence. A Dicisign necessarily involves, as a part of it, a Rheme, to describe the fact which it is interpreted as indicating. But this is a peculiar kind of Rheme; and while it is essential to the Dicisign, it by no means constitutes it.

An *Argument* is a Sign which, for its Interpretant, is a Sign of law. Or we may say that a Rheme is a sign which is understood to represent its object in its characters merely; that a Dicisign is a sign which is understood to represent its object in respect to actual existence; and that an Argument is a Sign which is understood to represent its Object in its character as Sign. Since these definitions touch upon points at this time much in dispute, a word may be added in defence of them. A question often put is: What is the essence of a Judgment? A judgment is the mental act by which the judger seeks to impress upon himself the truth of a proposition. It is much the same as an act of asserting the proposition, or going before a notary and assuming formal responsibility for its truth, except that those acts are intended to affect others, while the judgment is only intended to affect oneself. However, the logician, as such, cares not what the psychological nature of the act of judging may be. The question for him is: What is the nature of the sort of sign of which a principal variety is called a proposition, which is the matter upon which the act of judging is exercised? The proposition need not be asserted or judged. It may be contemplated as a sign capable of being asserted or denied. This sign itself retains its full meaning whether it be actually asserted or not. The peculiarity of it, therefore, lies in its mode of meaning; and to say this is to say that its peculiarity lies in its relation to its interpretant. The proposition professes to be really affected by the actual existent or real law to which it refers. The argument makes the same pretension, but that is not the principal pretension of the argument. The rheme makes no such pretension.

III. Icon, Index, and Symbol

A) Synopsis

A sign is either an *icon*, an *index*, or a *symbol*. An icon is a sign which would possess the character which renders it significant, even though its object had no existence; such as a lead-pencil streak as representing a geometrical line. An *index* is a sign which would, at once, lose the character which makes it a sign if its object were removed, but would not lose that character if there were no interpretant. Such, for instance, is a piece of mould with a bullet-hole in it as sign of a shot; for without the shot there would have been no hole; but there is a hole there, whether anybody has the sense to attribute it to a shot or not. A *symbol* is a sign which would lose the character which renders it a sign if there were no interpretant. Such is any utterance of speech which signifies what it does only by virtue of its being understood to have that signification.

B) Icon

While no Representamen actually functions as such until it actually determines an Interpretant, yet it becomes a Representamen as soon as it is fully capable of doing this; and its Representative Quality is not necessarily dependent upon its ever actually determining an Interpretant, nor even upon its actually having an Object.

An *Icon* is a Representamen whose Representative Quality is a Firstness of it as a First. That is, a quality that it has *qua* thing renders it fit to be a representamen. Thus, anything is fit to be a *Substitute* for anything that it is like. (The conception of "substitute" involves that of a purpose, and thus of genuine thirdness.) Whether there are other kinds of substitutes or not we shall see. A Representamen by Firstness alone can only have a similar Object. Thus, a Sign by Contrast denotes its object only by virtue of a contrast, or Secondness, between two qualities. A sign by Firstness is an image of its object and, more strictly speaking, can only be an *idea*. For it must produce an Interpretant idea; and an external object excites an idea by a reaction upon the brain. But most strictly speaking, even an idea, except in the sense of a possibility, or Firstness, cannot be an Icon. A possibility alone is an Icon purely by virtue of its quality; and its object can only be a Firstness. But a sign may be *iconic*, that is, may represent its object mainly by its similarity, no matter what its mode of being. If a substantive be wanted, an iconic representamen may be termed a *hypoicon*. Any material image, as a painting, is largely conventional in its mode of representation; but in itself, without legend or label it may be called *a hypoicon*.

Hypoicons may be roughly divided according to the mode of Firstness of which they partake. Those which partake of simple qualities, or First Firstnesses, are *images*; those which represent the relations, mainly dyadic, or so regarded, of the parts of one thing by analogous relations in their own parts, are *diagrams*; those which represent the representative character of a representamen by representing a parallelism in something else, are *metaphors*.

The only way of directly communicating an idea is by means of an icon; and every indirect method of communicating an idea must depend, for its establishment upon the use of an icon. Hence, every assertion must contain an icon or set of icons, or else must contain signs whose meaning is only explicable by icons. The idea which the set of icons (or the equivalent of a set of icons) contained in an assertion signifies may be termed the *predicate* of the assertion.

Turning now to the rhetorical evidence, it is a familiar fact that there are such representations as icons. Every picture (however conventional its method) is essentially a representation of that kind. So is every diagram, even although there be no sensuous resemblance between it and its object, but only an analogy between the relations of the parts of each. Particularly deserving of notice are icons in which the likeness is aided by conventional rules. Thus, an algebraic formula is an icon, rendered such by the rules of commutation, association, and distribution of the symbols. It may seem at first glance that it is an arbitrary classification to call an algebraic expression an icon; that it might as well, or better, be regarded as a compound conventional sign. But it is not so. For a great distinguishing property of the icon is that by the direct observation of it other truths concerning its object can be discovered than those which suffice to determine its construction. Thus, by means of two photographs a map can be drawn, etc. Given a conventional or other general sign of an object, to deduce any other truth than that which it explicitly signifies, it is necessary, in all cases, to replace that sign by an icon. This capacity of revealing unexpected truth is precisely that wherein the utility of algebraical formulae consists, so that the iconic character is the prevailing one.

That icons of the algebraic kind, though usually very simple ones, exist in all ordinary grammatical propositions is one of the philosophic truths that the Boolean logic brings to light. In all primitive writing, such as the Egyptian hieroglyphics, there are icons of a non-logical kind, the ideographs. In the earliest form of speech, there probably was a large element of mimicry. But in all languages known, such representations have been replaced by conventional auditory signs. These, however, are such that they can only be explained by icons. But in the syntax of every language there are logical icons of the kind that are aided by conventional rules.

Photographs, especially instantaneous photographs, are very instructive, because we know that they are in certain respects exactly like the objects they represent. But this resemblance is due to the photographs having been produced under such circumstances that they were physically forced to correspond point by point to nature. In that aspect, then, they belong to the second class of signs, those by physical connection. The case is different if I surmise that zebras are likely to be obstinate, or otherwise disagreeable animals, because they seem to have a general resemblance to donkeys, and donkeys are self-willed. Here the donkey serves precisely as a probable likeness of the zebra. It is true we suppose that resemblance has a physical cause in heredity; but then, this hereditary affinity is itself only an inference from the likeness between the two animals, and we have not (as in the case of the photograph) any independent knowledge of the circumstances of the production of the two species. Another example of the use of a likeness is the design an artist draws of a statue, pictorial composition, architectural elevation, or piece of decoration, by the contemplation of which he can ascertain whether what he proposes will be beautiful and satisfactory. The question asked is thus answered almost with certainty because it relates to how the artist will himself be affected. The reasoning of mathematicians will be found to turn chiefly upon the use of likenesses, which are the very hinges of the gates of their science. The utility of likenesses to mathematicians consists in their suggesting in a very precise way, new aspects of supposed states of things.

Many diagrams resemble their objects not at all in looks; it is only in respect to the relations of their parts that their likeness consists. Thus, we may show the relation between the different kinds of signs by a brace, thus:

$$\text{Signs}\,\{\text{Icons, Indices, symbols}\}\,.$$

This is an icon. But the only respect in which it resembles its object is that the brace shows the classes of *icons*, *indices*, and *symbols* to be related to one another and to the general class of signs, as they really are, in a general way. When, in algebra, we write equations under one another in a regular array, especially when we put resembling letters for corresponding coefficients, the array is an icon. Here is an example:

$$a_1x + b_1y = n_1,$$

$$a_2x + b_2y = n_2.$$

This is an icon, in that it makes quantities look alike which are in analogous relations to the problem. In fact, every algebraical equation is an icon, in so far as it *exhibits*, by means of the algebraical signs (which are not themselves icons), the relations of the quantities concerned. It may be questioned whether all icons are likenesses or not. For example, if a drunken man is exhibited in order to show, by contrast, the excellence of temperance, this is certainly an icon, but whether it is a likeness or not may be doubted. The question seems somewhat trivial.

C) Index

[An index is] a sign, or representation, which refers to its object not so much because of any similarity or analogy with it, nor because it is associated with general characters which that object happens to possess, as because it is in dynamical (including spatial) connection both with the individual object, on the one hand, and with the senses of memory of the person for whom it serves as a sign, on the other hand. While demonstrative and personal pronouns are, as ordinarily used, "genuine indices," relative pronouns are "degenerate indices"; for though they may, accidentally and indirectly, refer to existing things, they directly refer, and need only refer, to the images in the mind which previous words have created.

Indices may be distinguished from other signs, or representations, by three characteristic marks: first, that they have no significant resemblance to their objects; second, that they refer to individuals, single units, single collections of units, or single continua; third, that they direct the attention to their objects by blind compulsion. But it would be difficult, if not impossible, to instance an absolutely pure index, or to find any sign absolutely devoid of the indexical quality. Psychologically, the action of indices depends upon association by contiguity, and not upon association by resemblance or upon intellectual operations.

An *Index* or *Seme* (σῆμα) is a Representamen whose Representative character consists in its being an individual second. If the Secondness is an existential relation, the Index is *genuine*. If the Secondness is a reference, the Index is *degenerate*. A genuine Index and its Object must be existent individuals (whether things or facts), and its immediate Interpretant must be of the same character. But since every individual must have characters, it follows that a genuine Index may contain a Firstness, and so an Icon as a constituent part of it. Any individual is a degenerate Index of its own characters.

Subindices or *Hyposemes* are signs which are rendered such principally by an actual connection with their objects. Thus a proper name, personal demonstrative, or relative pronoun or the letter attached to a diagram, denotes what it does owing to a real connection with its object, but none of these is an Index, since it is not an individual.

Let us examine some examples of indices. I see a man with a rolling gait. This is a probable indication that he is a sailor. I see a bowlegged man in corduroys, gaiters, and a jacket. These are probable indications that he is a jockey or something of the sort. A sundial or a clock *indicates* the time of day. Geometricians mark letters against the different parts of their diagrams and then use these letters to indicate those parts. Letters are similarly used by lawyers and others. Thus, we may say: If A and B are married to one another and C is their child while D is brother of A, then D is uncle of C. Here A, B, C, and D fulfill the office of relative pronouns, but are more convenient since they require no special collocation of words. A rap on the door is an index. Anything which focuses the attention is an index. Anything which startles us is an index, in so far as it marks the junction between two portions of experience. Thus a tremendous thunderbolt indicates that *something* considerable happened, though we may not know precisely what the event was. But it may be expected to connect itself with some other experience.

A low barometer with a moist air is an index of rain; that is we suppose that the forces of nature establish a probable connection between the low barometer with moist air and coming rain. A weathercock is an index of the direction of the wind; because in the first place it really takes the self-same direction as the wind; so that there is a real connection between them, and in the second place we are so constituted that when we see a weathercock pointing in a certain direction it draws our attention to that direction, and when we see the weathercock veering with the wind, we are forced by the law of mind to think that direction is connected with the wind. The pole star is an index, or pointing finger, to show us which way is north. A spirit-level, or a plumb bob, is an index of the vertical direction. A yard-stick might seem, at first sight, to be an icon of a yard; and so it would be, if it were merely intended to show a yard as near as it can be seen and estimated to be a yard. But the very purpose of a yard-stick is to show a yard nearer than it can be estimated by its appearance. This it does in consequence of an accurate mechanical comparison made with the bar in London called the yard. Thus it is a real connection which gives the yardstick its value as a representamen; and thus it is an *index*, not a mere *icon*.

When a driver to attract the attention of a foot passenger and cause him to save himself, calls out “Hi!” so far as this is a significant word, it is, as will be seen below, something more than an index; but so far as it is simply intended to act upon the hearer’s nervous system and to rouse him to get out of the way, it is an index, because it is meant to put him in real connection with the object, which is his situation relative to the approaching horse. Suppose two men meet upon a country road and one of them says to the other, “The chimney of that house is on fire.” The other looks about him and descries a house with green blinds and a verandah having a smoking chimney. He walks on a few miles and meets a second traveler. Like a Simple Simon he says, “The chimney of that house is on fire.” “What house?” asks the other. “Oh, a house with green blinds and a verandah,” replies the simpleton. “Where is the house?” asks the stranger. He desires some *index* which shall connect his apprehension with the house meant. Words alone cannot do this.

The demonstrative pronouns, “this” and “that,” are indices. For they call upon the hearer to use his powers of observation, and so establish a real connection between his mind and the object; and if the demonstrative pronoun does that without which its meaning is not understood-it goes to establish such a connection; and so is an index. The relative pronouns, *who* and *which*, demand observational activity in much the same way, only with them the observation has to be directed to the words that have gone before. Lawyers use A, B, C, practically as very effective relative pronouns. To show how effective they are, we may note that Messrs. Allen and Greenough, in their admirable (though in the edition of 1877, too small) *Latin Grammar*, declare that no conceivable syntax could wholly remove the ambiguity of the following sentence, “A replied to B that he thought C (his brother) more unjust to himself than to his own friend.” Now, any lawyer would state that with perfect clearness, by using A, B, C, as relatives, thus:

$$\text{A replied B that he} \left\{\begin{matrix}\text{A}\\ \text{B}\end{matrix}\right\} \text{thought C (his} \left\{\begin{matrix}\text{A's}\\ \text{B's}\end{matrix}\right\} \text{brother) more unjust to himself,}$$

$$\left\{\begin{matrix}\text{A}\\ \text{B}\\ \text{C}\end{matrix}\right\} \text{than to his} \left\{\begin{matrix}\text{A's}\\ \text{B's}\\ \text{C's}\end{matrix}\right\} \text{own friend.}$$

The terminations which in any inflected language are attached to words “governed” by other words, and which serve to show which the governing word is, by repeating what is elsewhere expressed in the same form, are likewise *indices* of the same relative pronoun character. Any bit of Latin poetry illustrates this, such as the twelve-line sentence beginning, “*Jam satis terris*.” Both in these terminations and in the A, B, C, a likeness is relied upon to carry the attention to the right object. But this does not make them icons, in any important way; for it is of no consequence how the letters A, B, C, are shaped or what the terminations are. It is not merely that one occurrence of an A is like a previous occurrence that is the important circumstance, but that *there is an understanding that like letters shall stand for the same thing*, and this acts as a force carrying the attention from one occurrence of A to the previous one. A possessive pronoun is two ways an index: first it indicates the possessor, and, second, it has a modification which syntactically carries the attention to the word denoting the thing possessed.

Some indices are more or less detailed directions for what the hearer is to do in order to place himself in direct experiential or other connection with the thing meant. Thus, the Coast Survey issues “Notices to Mariners,” giving the latitude and longitude, four or five bearings of prominent objects, etc., and saying *there* is a rock, or shoal, or buoy, or lightship. Although there will be other elements in such directions, yet in the main they are indices.

Along with such indexical directions of what to do to find the object meant, ought to be classed those pronouns which should be entitled selective pronouns [or quantifiers] because they inform the hearer how he is to pick out one of the objects intended, but which grammarians call by the very *indefinite* designation of indefinite pronouns. Two varieties of these are particularly important in logic, the *universal selectives*, such as *quivis, quilibet, quisquam, ullus, nullus, nemo, quisque, uterque*, and in English, any, every, all, no, none, whatever, whoever, everybody, anybody, nobody. These mean that the hearer is at liberty to select any instance he likes within limits expressed or understood, and the assertion is intended to apply to that one. The other logically important variety consists of the particular selectives, quis, quispiam, nescio quis, aliquis, quidam, and in English, *some, something, somebody, a, a certain, some or other, a suitable, one*.

Allied to the above pronouns are such expressions as *all but one, one or two, a few, nearly all, every other one*, etc. Along with pronouns are to be classed adverbs of place and time, etc. Not very unlike these are, *the first, the last, the seventh, two-thirds of, thousands of*, etc.

Other indexical words are prepositions, and prepositional phrases, such as, "on the right (or left) of." Right and left cannot be distinguished by any general description. Other prepositions signify relations which may, perhaps, be described; but when they refer, as they do oftener than would be supposed, to a situation relative to the observed, or assumed to be experientially known, place and attitude of the speaker relatively to that of the hearer, then the indexical element is the dominant element. Icons and indices assert nothing. If an icon could be interpreted by a sentence, that sentence must be in a "potential mood," that is, it would merely say, "Suppose a figure has three sides," etc. Were an index so interpreted, the mood must be imperative, or exclamatory, as "See there!" or "Look out!" But the kind of signs which we are now coming to consider are, by nature, in the "indicative," or, as it should be called, the *declarative* mood. Of course, they can go to the expression of any other mood, since we may declare assertions to be doubtful, or mere interrogations, or imperatively requisite.

D) Symbol

A Symbol is a Representamen whose Representative character consists precisely in its being a rule that will determine its Interpretant. All words, sentences, books, and other conventional signs are Symbols. We speak of writing or pronouncing the word "man"; but it is only a *replica*, or embodiment of the word, that is pronounced or written. The word itself has no existence although it has a real being, *consisting in* the fact that existents will conform to it. It is a general mode of succession of three sounds or representamens of sounds, which becomes a sign only in the fact that a habit, or acquired law, *will* cause replicas of it to be interpreted as meaning a man or men. The word and its meaning are both general rules; but the word alone of the two prescribes the qualities of its replicas in themselves. Otherwise the "word" and its "meaning" do not differ, unless some special sense be attached to "meaning."

A Symbol is a law, or regularity of the indefinite future. Its Interpretant must be of the same description; and so must be also the complete immediate Object, or meaning. But a law necessarily governs, or "is embodied in" individuals, and prescribes some of their qualities. Consequently, a constituent of a Symbol may be an Index, and a constituent may be an Icon. A man walking with a child points his arm up into the air and says, "There is a balloon." The pointing arm is an essential part of the symbol without which the latter would convey no information. But if the child asks, “What is a balloon,” and the man replies, “It is something like a great big soap bubble,” he makes the image a part of the symbol. Thus, while the complete object of a symbol, that is to say, its meaning, is of the nature of a law, it must *denote* an individual, and must *signify* a character. A *genuine* symbol is a symbol that has a general meaning. There are two kinds of degenerate symbols, the *Singular Symbol* whose Object is an existent individual, and which signifies only such characters as that individual may realize; and the *Abstract Symbol*, whose only Object is a character.

Although the immediate Interpretant of an Index must be an Index, yet since its Object may be the Object of an Individual [Singular] Symbol, the Index may have such a Symbol for its indirect Interpretant. Even a genuine Symbol may be an imperfect Interpretant of it. So an *icon* may have a degenerate Index, or an Abstract Symbol, for an indirect Interpretant, and a genuine Index or Symbol for an imperfect Interpretant.

A *Symbol* is a sign naturally fit to declare that the set of objects which is denoted by whatever set of indices may be in certain ways attached to it is represented by an icon associated with it. To show what this complicated definition means, let us take as an example of a symbol the word “loveth.” Associated with this word is an idea, which is the mental icon of one person loving another, Now we are to understand that “loveth” occurs in a sentence; for what it may mean by itself, if it means anything, is not the question. Let the sentence, then, be “Ezekiel loveth Huldah.” Ezekiel and Huldah must, then, be or contain indices; for without indices it is impossible to designate what one is talking about. Any mere description would leave it uncertain whether they were not mere characters in a ballad; but whether they be so or not, indices can designate them. Now the effect of the word “loveth” is that the pair of objects denoted by the pair of indices Ezekiel and Huldah is represented by the icon, or the image we have in our minds of a lover and his beloved.

The same thing is equally true of every verb in the declarative mood; and indeed of every verb, for the other moods are merely declarations of a fact somewhat different from that expressed by the declarative mood. As for a noun, considering the meaning which it has in the sentence, and not as standing by itself, it is most conveniently regarded as a portion of a symbol. Thus the sentence, “every man loves a woman” is equivalent to “whatever is a man loves something that is a woman.” Here “whatever” is a universal selective index, “is a man” is a symbol, “loves” is a symbol, “something that” is a particular selective index, and “is a woman” is a symbol.

The word Symbol has so many meanings that it would be an injury to the language to add a new one. I do not think that the signification I attach to it, that of a conventional sign, or one depending upon habit (acquired or inborn), is so much a new meaning as a return to the original meaning. Etymologically, it should mean a thing thrown together, just as έμβολου (embolum) is a thing thrown into something, a bolt, and παράβολου (parabolum) is a thing thrown besides, collateral security, and υπόβολου (hypobolum) is a thing thrown underneath, an antenuptial gift. It is usually said that in the word symbol the throwing together is to be understood in the sense of “to conjecture”; but were that the case, we ought to find that *sometimes* at least it meant a conjecture, a meaning for which literature may be searched in vain. But the Greeks used “throw together” (συμβάλλειυ) very frequently to signify the making of a contract or convention. Now, we do find symbol (σύμβολου) early and often used to mean a convention or contract. Aristotle calls a noun a “symbol,” that is, a conventional sign. In Greek, watch fire is a “symbol,” that is, a signal agreed upon; a standard or ensign is a “symbol,” a watchword is a “symbol,” a badge is a “symbol”; a church creed is called a “symbol,” because it serves as a badge or shibboleth; a theatre ticket is called a “symbol”; any ticket or check entitling one to receive anything is a “symbol.” Moreover, any expression of sentiment was called a “symbol.” Such were the principal meanings of the word in the original language. The reader will judge whether they suffice to establish my claim that I am not seriously wrenching the word in employing it as I propose to do.

Any ordinary word, as “give,” “bird,” “marriage,” is an example of a symbol. It is *applicable to whatever may be found to realize the idea connected with the word*; it does not, in itself, identify those things. It does not show us a bird, nor enact before our eyes a giving or a marriage, but supposes that we are able to imagine those things, and have associated the word with them.

A regular progression of one, two, three may be remarked in the three orders of signs, Icon, Index, Symbol. The Icon has no dynamical connection with the object it represents; it simply happens that its qualities resemble those of that object, and excite analogous sensations in the mind for which it is a likeness. But it really stands unconnected with them. The index is physically connected with its object; they make an organic pair, but the interpreting mind has nothing to do with this connection, except remarking it, after it is established. The symbol is connected with its object by virtue of the idea of the symbol-using mind, without which no such connection would exist.

Every physical force reacts between a pair of particles, either of which may serve as an index of the other. On the other hand, we shall find that every intellectual operation involves a triad of symbols. A symbol, as we have seen, cannot indicate any particular thing; it denotes a kind of thing. Not only that, but it is itself a kind and not a single thing. You can write down the word “star,” but that does not make you the creator of the word, nor if you erase it have you destroyed the word. The word lives in the minds of those who use it. Even if they are all asleep, it exists in their memory. So we may admit, if there be reason to do so, that generals are mere words without at all saying, as Ockham supposed, that they are really individuals.

Symbols grow. They come into being by development out of other signs, particularly from icons, or from mixed signs partaking of the nature of icons and symbols. We think only in signs. These mental signs are of mixed nature; the symbol-parts of them are called concepts. If a man makes a new symbol, it is by thoughts involving concepts. So it is only out of symbols that a new symbol can grow. *Omne symbolum de symbolo*. A symbol, once in being, spreads among the peoples. In use and in experience, its meaning grows. Such words as *force, law, wealth, marriage*, bear for us very different meanings from those they bore to our barbarous ancestors. The symbol may, with Emerson’s sphynx, say to man:

Of thine eye I am eyebeam.

From: New Elements (Καιν¬ά στοιχεία) (1904)

III

1. I now proceed to explain the difference between a *theoretical* and a *practical* proposition, together with the two important parallel distinctions between *definite* and *vague*, and *individual* and *general*, noting, at the same time, some other distinctions connected with these terms. A *sign* is connected with the "Truth," i.e. the entire Universe of being, or, as some say, the Absolute, in three distinct ways. In the first place, a sign is not a real thing. It is of such a nature as to exist in *replicas*. Look down a printed page, and every *the* you see is the same word, every *e* the same letter. A real thing does not so exist in replica. The being of a sign is merely *being represented*. Now *really being* and *being represented* are very different. Giving to the word *sign* the full scope that reasonably belongs to it for logical purposes, a whole book is a sign; and a translation of it is a replica of the same sign. A whole literature is a sign. The sentence "Roxana was the queen of Alexander" is a sign of Roxana and of Alexander, and though there is a grammatical emphasis on the former, logically the name "Alexander" is as much a *subject* as is the name "Roxana"; and the real persons Roxana and Alexander are *real objects* of the sign. Every sign that is sufficiently complete refers to sundry real objects. All these objects, even if we are talking of Hamlet's madness, are parts of one and the same Universe of being, the "Truth." But so far as the "Truth" is merely the *object* of a sign, it is merely the Aristotelian *Matter* of it that is so.

In addition however to *denoting* objects, every sign sufficiently complete *signifies characters*, or qualities. We have a direct knowledge of real objects in every experiential reaction, whether of *Perception* or of *Exertion* (the one theoretical, the other practical). These are directly *hic et nunc*. But we extend the category, and speak of numberless real objects with which we are not in direct reaction. We have also direct knowledge of qualities in feeling, peripheral and visceral. But we extend this category to numberless characters of which we have no immediate consciousness. All these characters are elements of the "Truth." Every sign signifies the "Truth." But it is only the Aristotelian *Form* of the universe that it signifies. The logician is not concerned with any metaphysical theory; still less, if possible, is the mathematician. But it is highly convenient to express ourselves in terms of a metaphysical theory; and we no more bind ourselves to an acceptance of it than we do when we use substantives such as "humanity," "variety," etc. and speak of them as if they were substances, in the metaphysical sense. But, in the third place, every sign is intended to determine a sign of the same object with the same signification or *meaning*. Any sign, *B*, which a sign, *A*, is fitted so to determine, without violation of its, *A*s, purpose, that is, in accordance with the "Truth," even though it, *B*, denotes but a part of the objects of the sign, *A*, and signifies but a part of its, *A*'s, characters, I call an *interpretant* of *A*. What we call a "fact" is something having the structure of a proposition, but supposed to be an element of the very universe itself. The purpose of every sign is to express "fact," and by being joined with other signs, to approach as nearly as possible to determining an interpretant which would be the *perfect Truth*, the absolute Truth, and as such (at least, we may use this language) would be the very Universe. Aristotle gropes for a conception of perfection, or *entelechy*, which he never succeeds in making clear. We may adopt the word to mean the very fact, that is, the ideal sign which should be quite perfect, and so identical – in such identity as a sign may have – with the very matter denoted united with the very form signified by it. The entelechy of the Universe of being, then, the Universe *qua* fact, will be that Universe in its aspect as a sign, the "Truth" of being. The "Truth," the fact that is not abstracted but complete, is the ultimate interpretant of every sign.

2. Of the two great tasks of humanity, *Theory* and *Practice*, the former sets out from a sign of a real object with which it is *acquainted*, passing from this, as its *matter*, to successive interpretants embodying more and more fully its *form*, wishing ultimately to reach a direct *perception* of the entelechy; while the latter, setting out from a sign signifying a character of which it *has an idea*, passes from this, as its *form*, to successive interpretants realizing more and more precisely its *matter*, hoping ultimately to be able to make a direct *effort*, producing the entelechy. But of these two movements, logic very properly prefers to take that of Theory as the primary one. It speaks of an *antecedent* as that which, being known, something else, the *consequent*, may *also* be known. In our vernacular, the latter is inaccurately called a *consequence*, a word that the precise terminology of logic reserves for the proposition expressing the relation of any consequent to its antecedent, or for the fact which this proposition expresses. The conception of the relation of antecedent and consequent amounts, therefore, to a confusion of thought between the reference of a sign to its *meaning*, the character which it attributes to its object, and its appeal to an interpretant. But it is the former of these which is the more essential.

The knowledge that the sun has always risen about once in each 24 h (sidereal time) is a sign whose object is the sun, and (rightly understood) a part of its signification is the rising of the sun tomorrow morning. The relation of an antecedent to its consequent, in its confusion of the signification with the interpretant, is nothing but a special case of what occurs in all action of one thing upon another, modified so as to be merely an affair of being represented instead of really being. It is the representative action of the sign upon its object. For whenever one thing acts upon another it determines in that other a quality that would not otherwise have been there. In the vernacular we often call an effect a "consequence," because that which really is may correctly be represented; but we should refuse to call a mere logical consequent an "effect," because that which is merely represented, however legitimately, cannot be said really to be. If we speak of an argumentation as "producing a great effect," it is not the interpretant itself, by any means, to which we refer, but only the particular replica of it which is made in the minds of those addressed.

If a sign, B, only signifies characters that are elements (or the whole) of the meaning of another sign, A, then B is said to be a *predicate* (or *essential part*) of A. If a sign, A, only denotes real objects that are a part or the whole of the objects denoted by another sign, B, then A is said to be a *subject* (or *substantial part*) of B. The totality of the predicates of a sign, and also the totality of the characters it signifies, are indifferently each called its logical *depth*. This is the oldest and most convenient term. Synonyms are the *comprehension* of the Port-Royalists, the *content*

(*Inhalt*) of the Germans, the *force* of DeMorgan, the *connotation* of J.S. Mill. (The last is objectionable.) The totality of the subjects, and also, indifferently, the totality of the real objects of a sign is called the logical *breadth*. This is the oldest and most convenient term. Synonyms are the *extension* of the Port-Royalists (ill-called *extent* by some modern French logicians), the *sphere* (*Umfang*) of translators from the German, the *scope* of DeMorgan, the *denotation* of J.S. Mill.

Besides the logical depth and breadth, I have proposed (in 1867) the terms *information* and *area* to denote the total of fact (true or false) that in a given state of knowledge a sign embodies.

3. Other distinctions depend upon those that we have drawn. I have spoken of real relations as reactions. It may be asked how far I mean to say that all real relations are reactions. It is seldom that one falls upon so fascinating a subject for a train of thought as the analysis of that problem in all its ramifications, mathematical, physical, biological, sociological, psychological, logical, and so round to the mathematical again. The answer cannot be satisfactorily given in a few words; but it lies hidden beneath the obvious truth that any exact necessity is expressible by a general equation; and nothing can be added to one side of a general equation without an equal addition to the other. Logical necessity is the necessity that a sign should be true to a *real* object; and therefore there is *logical* reaction in every real dyadic relation. If *A* is in a real relation to *B*, *B* stands in a logically contrary relation to *A*, that is, in a relation at once converse to and inconsistent with the direct relation. For here we speak not of a vague sign of the relation but of the relation between two individuals, *A* and *B*. This very relation is one in which *A* alone stands to any individual, and it to *B* only. There are, however, *degenerate* dyadic relations – *degenerate* in the sense in which two coplanar lines form a *degenerate* conic – where this is not true. Namely, they are individual relations of identity, such as the relation of *A* to *A*. All mere resemblances and relations of reason are of this sort.

Of signs there are two different degenerate forms. But though I give them this disparaging name, they are of the greatest utility, and serve purposes that genuine signs could not. The more degenerate of the two forms (as I look upon it) is the *icon*. This is defined as a sign of which the character that fits it to become a sign of the sort that it is, is simply inherent in it as a quality of it. For example, a geometrical figure drawn on paper may be an *icon* of a triangle or other geometrical form. If one meets a man whose language one does not know and resorts to imitative sounds and gestures, these approach the character of an icon. The reason they are not pure icons is that the purpose of them is emphasized. A pure icon is independent of any purpose. It serves as a sign solely and simply by exhibiting the quality it serves to signify. The relation to its object is a degenerate relation. It asserts nothing. If it conveys information, it is only in the sense in which the object that it is used to represent may be said to convey information. An *icon* can only be a fragment of a completer sign.

The other form of degenerate sign is to be termed an *index*. It is defined as a sign which is fit to serve as such by virtue of being in a real reaction with its object. For example, a weather-cock is such a sign. It is fit to be taken as an index of the wind for the reason that it is physically connected with the wind. A weather-cock conveys information; but this it does because in facing the very quarter from which the wind blows, it resembles the wind in this respect, and thus has an icon connected with it. In this respect it is not a pure index. A pure index simply forces attention to the object with which it reacts and puts the interpreter into mediate reaction with that object, but conveys no information. As an example, take an exclamation "Oh!" The letters attached to a geometrical figure are another case. Absolutely unexceptionable examples of degenerate forms must not be expected. All that is possible is to give examples which tend sufficiently towards those forms to suggest what is meant. It is remarkable that while neither a pure icon nor a pure index can assert anything, an index which forces something to be an *icon*, as a weather-cock does, or which forces us to regard it as an *icon*, as the legend under a portrait does, does make an assertion, and forms a *proposition*. This suggests the true definition of a proposition, which is a question in much dispute at this moment. A proposition is a sign which separately, or independently, indicates its object. No *index*, however, can be an *argumentation*. It may be what many writers call an *argument*; that is, a basis of argumentation; but an argument in the sense of a sign which separately shows what interpretant it is intended to determine it cannot be.

It will be observed that the icon is very perfect in respect to signification, bringing its interpreter face to face with the very character signified. For this reason, it is the mathematical sign *par excellence*. But in denotation it is wanting. It gives no assurance that any such object as it represents really exists. The index on the other hand does this most perfectly, actually bringing to the interpreter the experience of the very object denoted. But it is quite wanting in signification unless it involves an iconic part.

We now come to the genuine sign, for which I propose the technical designation *symbol*, following a use of that word not infrequent among logicians including Aristotle. A symbol is defined as a sign which is fit to serve as such simply because it will be so interpreted.

To recapitulate:

An icon	is a sign fit to be used as such because	it possesses the quality signified.
An index		it is in real relation with the object denoted.
A symbol		it determines the interpretant sign.

Language and all abstracted thinking, such as belongs to minds who think in words, is of the symbolic nature. Many words, though strictly symbols, are so far iconic that they are apt to determine iconic interpretants, or as we say, to call up lively images. Such, for example, are those that have a fancied resemblance to sounds associated with their objects; that are *onomatopoetic*, as they say. There are words, which although symbols, act very much like indices. Such are personal, demonstrative, and relative pronouns, for which *A*, *B*, *C*, etc. are often substituted. A *Proper Name*, also, which denotes a single individual well known to exist by the utterer and interpreter, differs from an index only in that it is a conventional sign. Other words refer indirectly to indices. Such is "yard" which refers to a certain bar in Westminster, and has no meaning unless the interpreter is, directly or indirectly, in physical reaction with that bar. Symbols are particularly remote from the Truth itself. They are abstracted. They neither exhibit the very characters signified as icons do, nor assure us of the reality of their objects, as indices do. Many proverbial sayings express a sense of this weakness; as "Words prove nothing" and the like. Nevertheless, they have a great power of which the degenerate signs are quite destitute. They alone express laws. Nor are they limited to this theoretical use. They serve to bring about reasonableness and law. The words *justice* and *truth*, amid a world that habitually neglects these things and utterly derides the words, are nevertheless among the very greatest powers the world contains. They create defenders and animate them with their strength. This is not rhetoric or metaphor: it is a great and solid fact of which it behooves a logician to take account.

From: A Guess at the Riddle (1887–1888)

Chapter I – Trichotomy

Perhaps I might begin by noticing how different numbers have found their champions. Two was extolled by Peter Ramus, Four by Pythagoras, Five by Sir Thomas Browne, and so on. For my part, I am a determined foe of no innocent number; I respect and esteem them all in their several ways; but I am forced to confess to a leaning to the number Three in philosophy. In fact, I make so much use of threefold divisions in my speculations, that it seems best to commence by making a slight preliminary study of the conceptions upon which all such divisions must rest. I mean no more than the ideas of first, second, third – ideas so broad that they may be looked upon rather as moods or tones of thought, than as definite notions, but which have great significance for all that. Viewed as numerals, to be applied to what objects we like, they are indeed thin skeletons of thought, if not mere words. If we only wanted to make enumerations, it would be out of place to ask for the significations of the numbers we should have to use; but then the distinctions of philosophy are supposed to attempt something far more than that; they are intended to go down to the very essence of things, and if we are to make one single threefold philosophical distinction, it behooves us to ask beforehand what are the kinds of objects that are first, second, and third, not as being so counted, but in their own true characters. That there are such ideas of the really First, Second, and Third, we shall presently find reason to admit.

The First is that whose being is simply in itself, not referring to anything nor lying behind anything. The second is that which is what it is by force of something to which it is second. The third is that which is what it is owing to things between which it mediates and which it brings into relation to each other.

The idea of the absolutely First must be entirely separated from all conception of or reference to anything else; for what involves a second is itself a second to that second. The First must therefore be present and immediate, so as not to be second to a representation. It must be fresh and new, for if old it is second to its former state. It must be initiative, original, spontaneous, and free; otherwise it is second to a determining cause. It is also something vivid and conscious; so only it avoids being the object of some sensation. It precedes all synthesis and all differentiation; it has no unity and no parts. It cannot be articulately thought: assert it, and it has already lost its characteristic innocence; for assertion always implies a denial of something else. Stop to think of it, and it has flown! What the world was to Adam on the day he opened his eyes to it, before he had drawn any distinctions, or had become conscious of his own existence – that is first, present, immediate, fresh, new, initiative, original, spontaneous, free, vivid, conscious, and evanescent. Only, remember that every description of it must be false to it.

Just as the first is not absolutely first if thought along with a second, so likewise to think the Second in its perfection we must banish every third. The Second is therefore the absolute last. But we need not, and must not, banish the idea of the first from the second; on the contrary, the Second is precisely that which cannot be without the first. It meets us in such facts as Another, Relation, Compulsion, Effect, Dependence, Independence, Negation, Occurrence, Reality, Result. A thing cannot be other, negative, or independent, without a first to or of which it shall be other, negative, or independent. Still, this is not a very deep kind of secondness; for the first might in these cases be destroyed yet leave the real character of the second absolutely unchanged. When the second suffers some change from the action of the first, and is dependent upon it, the secondness is more genuine. But the dependence must not go so far that the second is a mere accident or incident of the first; otherwise the secondness again degenerates. The genuine second suffers and yet resists, like dead matter, whose existence consists in its inertia. Note, too, that for the Second to have the Finality that we have seen belongs to it, it must be determined by the first immovably, and thenceforth be fixed; so that unalterable fixity becomes one of its attributes. We find secondness in occurrence, because an occurrence is something whose existence consists in our knocking up against it. A hard fact is of the same sort; that is to say, it is something which is there, and which I cannot think away, but am forced to acknowledge as an object or second beside myself, the subject or number one, and which forms material for the exercise of my will.

The idea of second must be reckoned as an easy one to comprehend. That of first is so tender that you cannot touch it without spoiling it; but that of second is eminently hard and tangible. It is very familiar, too; it is forced upon us daily; it is the main lesson of life. In youth, the world is fresh and we seem free; but limitation, conflict, constraint, and secondness generally, make up the teaching of experience.

With what firstness

The scarfed bark puts from her native bay

with what secondness

doth she return,
With overweathered ribs and ragged sails[5]

But familiar as the notion is, and compelled as we are to acknowledge it at every turn, still we never can realize it; we never can be immediately conscious of finiteness, or of anything but a divine freedom that in its own original firstness knows no bounds.

First and Second, Agent and Patient, Yes and No, are categories which enable us roughly to describe the facts of experience, and they satisfy the mind for a very long time. But at last they are found inadequate, and the Third is the conception which is then called for. The Third is that which bridges over the chasm between the absolute first and last, and brings them into relationship. We are told that every science has its Qualitative and its Quantitative stage; now its qualitative stage is when dual distinctions – whether a given subject has a given predicate or not – suffice; the quantitative stage comes when, no longer content with such rough distinctions, we require to insert a possible halfway between every two possible conditions of the subject in regard to its possession of the quality indicated by the predicate. Ancient mechanics recognized forces as causes which produced motions as their immediate effects, looking no further than the essentially dual relation of cause and effect. That was why it could make no progress with dynamics.

The work of Galileo and his successors lay in showing that forces are accelerations by which a state of velocity is gradually brought about. The words cause and effect still linger, but the old conceptions have been dropped from mechanical philosophy; for the fact now known is that in certain relative positions bodies undergo certain accelerations. Now an acceleration, instead of being like a velocity a relation between two successive positions, is a relation between three; so that the new doctrine has consisted in the suitable introduction of the conception of Threeness. On this idea, the whole of modern physics is built. The superiority of modern geometry, too, has certainly been due to nothing so much as to the bridging over of the innumerable distinct cases with which the ancient science was encumbered; and we may go so far as to say that all the great steps in the method of science in every department have consisted in bringing into relation cases previously discrete.

We can easily recognize the man whose thought is mainly in the dual stage by his unmeasured use of language. In former days, when he was natural, everything with him was unmitigated, absolute, ineffable, utter, matchless, supreme, unqualified, root and branch; but now that it is the fashion to be depreciatory, he is just as plainly marked by the ridiculous inadequacy of his expressions. The principle of contradiction is a shibboleth for such minds; to disprove a proposition they will always try to prove there lurks a contradiction in it, notwithstanding that it may

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[5] Shakespeare, *The Merchant of Venice,* 2.6.15–18.

be as clear and comprehensible as the day. Remark for your amusement the grand unconcern with which mathematics, since the invention of the calculus, has pursued its way, caring no more for the peppering of contradiction-mongers than an ironclad for an American fort.

We have seen that it is the immediate consciousness that is preeminently first, the external dead thing that is preeminently second. In like manner, it is evidently the representation mediating between these two that is preeminently third. Other examples, however, should not be neglected. The first is agent, the second patient, the third is the action by which the former influences the latter. Between the beginning as first, and the end as last, comes the process which leads from first to last.

According to the mathematicians, when we measure along a line, were our yardstick replaced by a yard marked off on an infinitely long rigid bar, then in all the shiftings of it which we make for the purpose of applying it to successive portions of the line to be measured, two points on that bar would remain fixed and unmoved. To that pair of points, the mathematicians accord the title of the absolute; they are the points that are at an infinite distance one way and the other as measured by that yard. These points are either really distinct, coincident, or imaginary (in which case there is but a finite distance completely round the line), according to the relation of the mode of measurement to the nature of the line upon which the measurement is made. These two points are the absolute first and the absolute last or second, while every measurable point on the line is of the nature of a third. We have seen that the conception of the absolute first eludes every attempt to grasp it; and so in another sense does that of the absolute second; but there is no absolute third, for the third is of its own nature relative, and this is what we are always thinking, even when we aim at the first or second.

The starting-point of the universe, God the Creator, is the Absolute First; the terminus of the universe, God completely revealed, is the Absolute Second; every state of the universe at a measurable point of time is the third. If you think the measurable is all there is, and deny it any definite tendency whence or whither, then you are considering the pair of points that makes the absolute to be imaginary and are an Epicurean. If you hold that there is a definite drift to the course of nature as a whole, but yet believe its absolute end is nothing but the nirvana from which it set out, you make the two points of the absolute to be coincident, and are a pessimist. But if your creed is that the whole universe is approaching in the infinitely distant future a state having a general character different from that toward which we look back in the infinitely distant past, you make the absolute to consist in two distinct real points and are an evolutionist.[6]

This is one of the matters concerning which a man can only learn from his own reflections, but I believe that if my suggestions are followed out, the reader will

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[6] The last view is essentially that of Christian theology, too. The theologians hold the physical universe to be finite, but considering that universe which they will admit to have existed from all time, it would appear to be in a different condition in the end from what it was in the beginning, the whole spiritual creation having been accomplished, and abiding.

grant that One, Two, Three, are more than mere count-words like "eeny, meeny, mony, mi," but carry vast, though vague ideas.

But it will be asked, why stop at three? Why not go on to find a new conception in a distinct idea for Four, Five, and so on indefinitely? The reason is that while it is impossible to form a genuine three by any modification of the pair, without introducing something of a different nature from the unit and the pair, four, five, and every higher number can be formed by mere complications of threes. To make this clear, I will first show it in an example. The fact that A presents B with a gift C, is a triple relation, and as such cannot possibly be resolved into any combination of dual relations. Indeed, the very idea of a combination involves that of thirdness, for a combination is something which is what it is owing to the parts which it brings into mutual relationship. But we may waive that consideration, and still we cannot build up the fact that A presents C to B by any aggregate of dual relations between A and B, B and C, and C and A. A may enrich B, B may receive C, and A may part with C, and yet A need not necessarily give C to B. For that, it would be necessary that these three dual relations should not only coexist, but be welded into one fact. Thus we see that a triad cannot be analyzed into dyads. But now I will show by an example that a four can be analyzed into threes. Take the quadruple fact that A sells C to B for the price D. This is a compound of two facts: first, that A makes with C a certain transaction, which we may name E; and second, that this transaction E is a sale of B for the price D. Each of these two facts is a triple fact, and their combination makes up as genuine a quadruple fact as can be found. The explanation of this striking difference is not far to seek. A dual relative term, such as "lover" or "servant," is a sort of blank form, where there are two places left blank. I mean that in building a sentence round "lover," as the principal word of the predicate, we are at liberty to make anything we see fit the subject, and then, besides that, anything we please the object of the action of loving. But a triple relative term such as "giver" has two correlates, and is thus a blank form with three places left blank. Consequently, we can take two of these triple relatives and fill up one blank place in each with the same letter, X, which has only the force of a pronoun or identifying index, and then the two taken together will form a whole having four blank places; and from that we can go on in a similar way to any higher number. But when we attempt to imitate this proceeding with dual relatives, and combine two of them by means of an X, we find we only have two blank places in the combination, just as we had in either of the relatives taken by itself. A road with only three-way forkings may have any number of termini, but no number of straight roads put end on end will give more than two termini. Thus any number, however large, can be built out of triads; and consequently no idea can be involved in such a number, radically different from the idea of three. I do not mean to deny that the higher numbers may present interesting special configurations from which notions may be derived of more or less general applicability; but these cannot rise to the height of philosophical categories so fundamental as those that have been considered.

The argument of this book has been developed in the mind of the author, substantially as it is presented, as a following out of these three conceptions, in a sort of game of "follow my leader" from one field of thought into another. Their importance was originally brought home to me in the study of logic, where they play so remarkable a part that I was led to look for them in psychology. Finding them there again, I could not help asking myself whether they did not enter into the physiology of the nervous system. By drawing a little on hypothesis, I succeeded in detecting them there; and then the question naturally came how they would appear in the theory of protoplasm in general. Here I seemed to break into an interesting avenue of reflections giving instructive aperçus both into the nature of protoplasm and into the conceptions themselves; though it was not till later that I mapped out my thoughts on the subject as they are presented in Chapter 5. I had no difficulty in following the lead into the domain of natural selection; and once arrived at that point, I was irresistibly carried on to speculations concerning physics. One bold saltus landed me in a garden of fruitful and beautiful suggestions, the exploration of which long prevented my looking further. As soon, however, as I was induced to look further, and to examine the application of the three ideas to the deepest problems of the soul, nature, and God, I saw at once that they must carry me far into the heart of those primeval mysteries. That is the way the book has grown in my mind: it is also the order in which I have written it; and only this first chapter is more or less an afterthought, since at an earlier stage of my studies I should have looked upon the matter here set down as too vague to have any value. I should have discerned in it too strong a resemblance to many a crack-brained book that I had laughed over. A deeper study has taught me that even out of the mouths of babes and sucklings strength may be brought forth, and that weak metaphysical trash has sometimes contained the germs of conceptions capable of growing up into important and positive doctrines.

Thus, the whole book being nothing but a continual exemplification of the triad of ideas, we need linger no longer upon this preliminary exposition of them. There is, however, one feature of them upon which it is quite indispensable to dwell. It is that there are two distinct grades of Secondness and three grades of Thirdness. There is a close analogy to this in geometry. Conic sections are either the curves usually so called, or they are pairs of straight lines. A pair of straight lines is called a degenerate conic. So plane cubic curves are either the genuine curves of the third order, or they are conics paired with straight lines, or they consist of three straight lines; so that there are the two orders of degenerate cubics. Nearly in this same way, besides genuine Secondness, there is a degenerate sort which does not exist as such, but is only so conceived. The medieval logicians (following a hint of Aristotle) distinguished between real relations and relations of reason. A real relation subsists in virtue of a fact which would be totally impossible were either of the related objects destroyed; while a relation of reason subsists in virtue of two facts, one only of which would disappear on the annihilation of either of the relates. Such are all resemblances: for any two objects in nature resemble each other, and indeed in themselves just as much as any other two; it is only with reference to our senses and needs that one resemblance counts for more than another. Rumford and Franklin resembled each other by virtue of being both Americans; but either would have been just as much an American if the other had never lived. On the other hand, the fact that Cain killed Abel cannot be stated as a mere aggregate of two facts, one concerning Cain and the other concerning Abel. Resemblances are not the only relations of reason, though they have that character in an eminent degree. Contrasts and comparisons are of the same sort. Resemblance is an identity of characters; and this is the same as to say that the mind gathers the resembling ideas together into one conception. Other relations of reason arise from ideas being connected by the mind in other ways; they consist in the relation between two parts of one complex concept, or, as we may say, in the relation of a complex concept to itself, in respect to two of its parts. This brings us to consider a sort of degenerate Secondness that does not fulfill the definition of a relation of reason. Identity is the relation that everything bears to itself: Lucullus dines with Lucullus. Again, we speak of allurements and motives in the language of forces, as though a man suffered compulsion from within. So with the voice of conscience: and we observe our own feelings by a reflective sense. An echo is my own voice coming back to answer itself. So also, we speak of the abstract quality of a thing as if it were some second thing that the first thing possesses. But the relations of reason and these self-relations are alike in this, that they arise from the mind setting one part of a notion into relation to another. All degenerate seconds may be conveniently termed internal, in contrast to external seconds, which are constituted by external fact, and are true actions of one thing upon another.

Among thirds, there are two degrees of degeneracy. The first is where there is in the fact itself no thirdness or mediation, but where there is true duality; the second degree is where there is not even true secondness in the fact itself.

Consider, first, the thirds degenerate in the first degree. A pin fastens two things together by sticking through one and also through the other: either might be annihilated, and the pin would continue to stick through the one which remained. A mixture brings its ingredients together by containing each. We may term these accidental thirds. “How did I slay thy son?” asked the merchant, and the genie replied, “When thou threwest away the date-stone, it smote my son, who was passing at the time, on the breast, and he died forthright.” Here there were two independent facts, first that the merchant threw away the date-stone, and second that the date-stone struck and killed the genie’s son. Had it been aimed at him, the case would have been different; for then there would have been a relation of aiming which would have connected together the aimer, the thing aimed, and the object aimed at, in one fact.

What monstrous injustice and inhumanity on the part of that genie to hold that poor merchant responsible for such an accident! I remember how I wept at it, as I lay in my father’s arms and he first told me the story. It is certainly just that a man, even though he had no evil intention, should be held responsible for the immediate effects of his actions; but not for such as might result from them in a sporadic case here and there, but only for such as might have been guarded against by a reasonable rule of prudence. Nature herself often supplies the place of the intention of a rational agent in making a thirdness genuine and not merely accidental; as when a spark, as third, falling into a barrel of gunpowder, as first, causes an explosion, as second. But how does nature do this? By virtue of an intelligible law according to which she acts. If two forces are combined according to the parallelogram of forces, their resultant is a real third. Yet any force may, by the parallelogram of forces, be mathematically resolved into the sum of two others, in an infinity of different ways. Such components, however, are mere creations of the mind. What is the difference? As far as one isolated event goes, there is none; the real forces are no more present in the resultant than any components that the mathematician may imagine. But what makes the real forces really there is the general law of nature which calls for them, and not for any other components of the resultant. Thus, intelligibility, or reason objectified, is what makes thirdness genuine.

We now come to thirds degenerate in the second degree. The dramatist Marlowe had something of that character of diction in which Shakespeare and Bacon agree. This is a trivial example; but the mode of relation is important. In natural history, intermediate types serve to bring out the resemblance between forms whose similarity might otherwise escape attention, or not be duly appreciated. In portraiture, photographs mediate between the original and the likeness. In science, a diagram or analogue of the observed fact leads on to a further analogy. The relations of reason which go to the formation of such a triple relation need not be all resemblances. Washington was eminently free from the faults in which most great soldiers resemble one another. A centaur is a mixture of a man and a horse. Philadelphia lies between New York and Washington. Such thirds may be called Intermediate thirds or Thirds of comparison.

Nobody will suppose that I wish to claim any originality in reckoning the triad important in philosophy. Since Hegel, almost every fanciful thinker has done the same. Originality is the last of recommendations for fundamental conceptions. On the contrary, the fact that the minds of men have ever been inclined to threefold divisions is one of the considerations in favor of them. Other numbers have been objects of predilection to this philosopher and that, but three has been prominent at all times and with all schools. My whole method will be found to be in profound contrast with that of Hegel; I reject his philosophy in toto. Nevertheless, I have a certain sympathy with it, and fancy that if its author had only noticed a very few circumstances he would himself have been led to revolutionize his system. One of these is the double division or dichotomy of the second idea of the triad. He has usually overlooked external secondness, altogether. In other words, he has committed the trifling oversight of forgetting that there is a real world with real actions and reactions. Rather a serious oversight that. Then Hegel had the misfortune to be unusually deficient in mathematics. He shows this in the very elementary character of his reasoning. Worse still, while the whole burden of his song is that philosophers have neglected to take thirdness into account, which is true enough of the theological kind, with whom alone he was acquainted (for I do not call it acquaintance to look into a book without comprehending it), he unfortunately did not know, what it would have been of the utmost consequence for him to know, that the mathematical analysts had in great measure escaped this great fault, and that the thorough-going pursuit of the ideas and methods of the differential calculus would be sure to cure it altogether. Hegel's dialectical method is only a feeble and rudimentary application of the principles of the calculus to metaphysics. Finally Hegel's plan of evolving everything out of the abstractest conception by a dialectical procedure, though far from being so absurd as the experientialists think, but on the contrary representing one of the indispensable parts of the course of science, overlooks the weakness of individual man, who wants the strength to wield such a weapon as that.

On Pragmatism and Pragmaticism *from*: A Neglected Argument for the Reality of God (1908)

Since I have employed the word *Pragmaticism*, and shall have occasion to use it once more, it may perhaps be well to explain it. About forty years ago, my studies of Berkeley, Kant, and others led me, after convincing myself that all thinking is performed in Signs, and that meditation takes the form of a dialogue, so that it is proper to speak of the "meaning" of a concept, to conclude that to acquire full mastery of that meaning it is requisite, in the first place, to learn to recognise the concept under every disguise, through extensive familiarity with instances of it. But this, after all, does not imply any true understanding of it; so that it is further requisite that we should make an abstract logical analysis of it into its ultimate elements, or as complete an analysis as we can compass. But, even so, we may still be without any living comprehension of it; and the only way to complete our knowledge of its nature is to discover and recognise just what general habits of conduct a belief in the truth of the concept (of any conceivable subject, and under any conceivable circumstances) would reasonably develop; that is to say, what habits would ultimately result from a sufficient consideration of such truth. It is necessary to understand the word "conduct," here, in the broadest sense. If, for example, the predication of a given concept were to lead to our admitting that a given form of reasoning concerning the subject of which it was affirmed was valid, when it would not otherwise be valid, the recognition of that effect in our reasoning would decidedly be a habit of conduct.

In 1871, in a Metaphysical Club in Cambridge, Mass., I used to preach this principle as a sort of logical gospel, representing the unformulated method followed by Berkeley, and in conversation about it I called it "Pragmatism." In December 1877 and January 1878 I set forth the doctrine in the *Popular Science Monthly*, and the two parts of my essay were printed in French in the *Revue Philosophique*, volumes vi. and vii. Of course, the doctrine attracted no particular attention, for, as I had remarked in my opening sentence, very few people care for logic. But in 1897 Professor James remodelled the matter, and transmogrified it into a doctrine of philosophy, some parts of which I highly approved, while other and more prominent parts I regarded, and still regard, as opposed to sound logic. About the time Professor Papirie discovered, to the delight of the Pragmatist school, that this doctrine was incapable of definition, which would certainly seem to distinguish it from every other doctrine in whatever branch of science, I was coming to the conclusion that my poor little maxim should be called by another name; and accordingly, in April 1905, I renamed it *Pragmaticism*. I had never before dignified it by any name in print, except that, at Professor Baldwin's request, I wrote a definition of it for his *Dictionary of Psychology and Philosophy*. I did not insert the word in the *Century*

Dictionary, though I had charge of the philosophical definitions of that work; for I have a perhaps exaggerated dislike of *réclame*.

It is that course of meditation upon the three Universes which gives birth to the hypothesis and ultimately to the belief that they, or at any rate two of the three, have a Creator independent of them, that I have throughout this article called the *Neglected Argument* (N.A.), because I think the theologians ought to have recognised it as a line of thought reasonably productive of belief. This is the "humble" argument, the innermost of the nest. In the mind of a metaphysician it will have a metaphysical tinge; but that seems to me rather to detract from its force than to add anything to it. It is just as good an argument, if not better, in the form it takes in the mind of the clodhopper.

The theologians could not have *presented* the N.A.; because that is a living course of thought of very various forms. But they might and ought to have *described* it, and should have defended it, too, as far as they could, without going into original logical researches, which could not be justly expected of them. They are accustomed to make use of the principle that that which convinces a normal man must be presumed to be sound reasoning; and therefore they ought to say whatever can truly be advanced to show that the N.A., if sufficiently developed, will convince any normal man. Unfortunately, it happens that there is very little established fact to show that this is the case. I have not pretended to have any other ground for my belief that it is so than my assumption, which each one of us makes, that my own intellectual disposition is normal. I am forced to confess that no pessimist will agree with me. I do not admit that pessimists are, at the same time, thoroughly sane, and in addition are endowed in normal measure with intellectual vigour; and my reasons for thinking so are two.

The first is, that the difference between a pessimistic and an optimistic mind is of such controlling importance in regard to every intellectual function, and especially for the conduct of life, that it is out of the question to admit that both are normal, and the great majority of mankind are naturally optimistic. Now, the majority of every race depart but little from the norm of that race. In order to present my other reason, I am obliged to recognise three types of pessimists. The first type is often found in exquisite and noble natures of great force of original intellect whose own lives are dreadful histories of torment due to some physical malady. Leopardi is a famous example. We cannot but believe, against their earnest protests, that if such men had had ordinary health, life would have worn for them the same colour as for the rest of us. Meantime, one meets too few pessimists of this type to affect the present question. The second is the misanthropical type, the type that makes itself heard. It suffices to call to mind the conduct of the famous pessimists of this kind, Diogenes the Cynic, Schopenhauer, Carlyle, and their kin with Shakespeare's Timon of Athens, to recognise them as diseased minds. The third is the philanthropical type, people whose lively sympathies, easily excited, become roused to anger at what they consider the stupid injustices of life. Being easily interested in everything, without being overloaded with exact thought of any kind, they are excellent raw material for *littérateurs*: witness Voltaire. No individual remotely approaching the calibre of a Leibniz is to be found among them.

The third argument, enclosing and defending the other two, consists in the development of those principles of logic according to which the humble argument is the first stage of a scientific inquiry into the origin of the three Universes, but of an inquiry which produces, not merely scientific belief, which is always provisional, but also a living, practical belief, logically justified in crossing the Rubicon with all the freightage of eternity. The presentation of this argument would require the establishment of several principles of logic that the logicians have hardly dreamed of, and particularly a strict proof of the correctness of the maxim of Pragmaticism. My original essay, having been written for a popular monthly, assumes, for no better reason than that real inquiry cannot begin until a state of real doubt arises and ends as soon as Belief is attained, that "a settlement of Belief," or, in other words, a state of *satisfaction*, is all that Truth, or the aim of inquiry, consists in. The reason I gave for this was so flimsy, while the inference was so nearly the gist of Pragmaticism, that I must confess the argument of that essay might with some justice be said to beg the question. The first part of the essay, however, is occupied with showing that, if Truth consists in satisfaction, it cannot be any *actual* satisfaction, but must be the satisfaction which *would* ultimately be found if the inquiry were pushed to its ultimate and indefeasible issue. This, I beg to point out, is a very different position from that of Mr Schiller and the pragmatists of to-day. I trust I shall be believed when I say that it is only a desire to avoid being misunderstood in consequence of my relations with pragmatism, and by no means as arrogating any superior immunity from error which I have too good reason to know that I do not enjoy, that leads me to express my personal sentiments about their tenets. Their avowedly undefinable position, if it be not capable of logical characterisation, seems to me to be characterised by an angry hatred of strict logic, and even some disposition to rate any exact thought which interferes with their doctrines as all humbug.

At the same time, it seems to me clear that their approximate acceptance of the Pragmaticist principle, and even that very casting aside of difficult distinctions (although I cannot approve of it), has helped them to a mightily clear discernment of some fundamental truths that other philosophers have seen but through a mist, and most of them not at all. Among such truths – all of them old, of course, yet acknowledged by few – I reckon their denial of necessitarianism; their rejection of any "consciousness" different from a visceral or other external sensation; their acknowledgment that there are, in a Pragmatistical sense, Real habits (which Really *would* produce effects, under circumstances that may not happen to get actualised, and are thus Real generals); and their insistence upon interpreting all hypostatic abstractions in terms of what they *would* or *might* (not actually *will*) come to in the concrete. It seems to me a pity they should allow a philosophy so instinct with life to become infected with seeds of death in such notions as that of the unreality of all ideas of infinity and that of the mutability of truth, and in such confusions of thought as that of active willing (willing to control thought, to doubt, and to weigh reasons) with willing not to exert the will (willing to believe).

Chapter 4
Excerpts from *Signs, Language and Behavior*

Charles Morris (1901–1979)

Introduction and Commentary: Charles Morris

> *The properties of* '*being*' *a* sign, *a* designatum, *an* interpreter, *or an* interpretant *are relational properties which things take on by participating in the functional process of semiosis. Semiotic, then, is not concerned with the study of a particular kind of object, but with ordinary objects in so far (and only in so far) as they participate in semiosis.*
>
> C. Morris (1938: 4)

In 1929, in an attempt to codify the tenets of 'logical positivism' in a manifesto for the Vienna Circle, mathematician Hans Hahn (1879–1934), political economist Otto Neurath (1882–1945) and philosopher Rudolf Carnap (1891–1970) proclaimed:

> We have characterised the *scientific world-conception* essentially by two features: *First* it is *empiricist and positivist:* there is knowledge only from experience, which rests on what is immediately given. This sets the limits for the content of legitimate science. *Second,* the scientific world-conception is marked by application of a certain method, namely *logical analysis.* The aim of scientific effort is to reach the goal, *unified science*, by applying logical analysis to the empirical material. Since the meaning of every statement of science must be statable by reduction to a statement about the given, likewise the meaning of any concept, whatever branch of science it may belong to, must be statable by step-wise reduction to other concepts, down to the concepts of the lowest level which refer directly to the given. If such an analysis were carried through for all concepts, they would thus be ordered into a reductive system, a *constitutive system*. Investigations towards such a constitutive system, the *constitutive theory,* thus form the framework within which logical analysis is applied by the scientific world-conception (1929; in Sarkar 1996: 331).

Around the same time, on the other side of the Atlantic, philosopher and social theorist George Herbert Mead (1863–1931) was articulating the fundaments of a decidedly non-positivistic 'pragmatic social psychology':

> 'Mentality', on our approach, simply comes in when the organism is able to point out meanings to others and to himself. This is the point at which mind appears, or if you like, emerges... It is absurd to look at 'the mind' simply from the standpoint of the individual human organism; for, although it has its focus there, it is essentially a social phenomenon; ... The self is something which has a development; it is not initially there, at birth, but arises in the process of social experience and activity, that is, develops in the given individual as a result of his relations to that process as a whole and to other individuals within that process (1934: 132–133; 135).

D. Favareau, *Essential Readings in Biosemiotics*, Biosemiotics 3,
DOI 10.1007/978-1-4020-9650-1_4,

A proponent for the unification of the seemingly incommensurable doctrines of both logical positivism and pragmatic social psychology, philosopher Charles William Morris (1901–1979) labored for over forty years to establish what he hoped would be the 'foundations for a science of signs.' Born in Denver, Colorado on May 23, 1901, Morris studied biology, philosophy and engineering at Northwestern University, receiving a Bachelor of Science degree in psychology in 1922. The following year, he became a student of pragmatist philosopher and social psychologist George Herbert Mead (1863–1931) at the University of Chicago, under whose mentorship he completed a dissertation entitled *Symbolism And Reality: A Study in the Nature of the Mind* in 1925. Morris' first job after receiving his doctorate in philosophy was as lecturer at Rice Institute in Texas, where he worked from 1925 to 1931, publishing extensively on pragmatism and the philosophy of mind. In 1932, Morris gained widespread recognition for his comparative philosophical history, *Six Theories of Mind*, and for editing the collection of lectures that comprises George Herbert Mead's *Mind, Self and Society* in 1934. During this time, Morris also travelled to Europe, where he became intimately involved with the scientific projects and philosophy of the Vienna Circle.

In 1935, he participated in the group's first International Congress for the Unity of Science, where the project to create an *International Encyclopedia of Unified Science* was launched by philosopher of science Moritz Schlick (1882–1936). Morris published *Logical Positivism, Pragmatism, and Scientific Empiricism* (including the chapter "Semiotic and Scientific Empiricism") in 1937, and *Foundations to a Theory of Signs* in 1938. The first volume of the *International Encyclopedia of Unified Science*, entitled *Encyclopedia and Unified Science,* with entries by Morris, Otto Neurath, Niels Bohr, John Dewey, Bertrand Russell, and Rudolf Carnap, also appeared that year; and in 1938, Morris' single-authored *Foundations to a Theory of Signs* was issued as the *Encyclopedia's* second volume. Morris' personal and professional relationship with the members of the Vienna Circle long outlasted the unity of the group, however, and he was personally responsible for helping Rudolf Carnap and several other scholors to relocate to America in order to escape persecution by the Nazis during World War II.

Dedicated to the creation of an empirically grounded 'science of signs', Charles Morris "showed from the start that he was a philosopher of mediation and synthesis," writes semiotics scholar Ronald Posner, claiming that Morris "was one of the first to recognize that the leading philosophical movements of his time, pragmatism, empiricism, and logical positivism, were not antithetical, but 'complementary phases of the scientific temper' (Morris 1937: 21; quoted in Posner 1998: 567).

From his doctoral advisor, George Herbert Mead, Morris took the fundamental insight of Peirce's pragmatic maxim: "Consider what effects, that might conceivably have practical bearings, we conceive the object of our conception to have. Then, our conception of these effects is the whole of our conception of the object" (CP 5.402) – and, in an effort to provide a step-by-step, empiricist and positivist account of the sign use and its consequences, wedded it to a keen appreciation of Mead's concept of the relations between our analyzed and unanalyzed concepts regarding "the world that is there" (Mead 1932: 140).

The reasoning of Morris' logic was as follows: The Vienna Circle manifesto to which Morris adhered in his efforts to advance a 'unified science', insisted that every statement made and every concept used in a genuinely *scientific* account or theory must be "statable by reduction to a statement about the given" (1929, in Sarkar 1996: 331). Yet Mead's pragmatic "philosophy of the act" showed that scientists themselves can only intelligently analyze certain puzzling features about the world by "using or appealing to other features of the world that, for the time being, are not puzzling and do not themselves require analysis; they can devise experiments and test their hypotheses only by means of perceptual objects whose meaningful characters are, for the time being, taken for granted" (Cook 1993: 178).

Morris' examination of both the analyzed and unanalyzed concepts used in the language of scientists led him to the conclusion that both the experienced environment – i.e., both Mead's "world that is there" pre-conceptually, as well as the "statable reduction to yet more primitive statements" by which all language users consciously or unconsciously understand the world – work together to produce the "dual control of thought" (1937: 50) that is reflected in Peirce's pragmatic maxim. And thus, because any and every "language involves a formal structure (as analyzed by logical positivism), a relation between signs and objects (as analyzed by empiricism), and social conventions of communication (as analyzed by pragmatism)," reasoned Morris, it would be possible to "include, without remainder" the entirety of scientific study "under the study of the language of science" (Posner 1998: 565).

Morris christened the science that he created through a synthesis of empiricist, logical positivist and pragmatist inquiry, "semiotic" – in acknowledgment of his indebtedness to Peirce, whose "backwoodsman's work in opening up" a theoretical science of signs, Morris felt that he himself was carrying on with his own yet even more empiricist study of signs (Morris 1948: 434, 445). "A sign is exhaustively analyzed when its relations to other signs, to what it denotes or can denote, and to its interpreters, are specified," writes Morris, and "the specification of such relations in concrete cases of semiosis is called *sign analysis*" (1939: 133), a diagrammatic depiction of which Morris provides in Fig. 4.1.

Clearly, Morris' diagram depicts what he considers to be the three dimensions of semiois – "the syntactical dimension, the semantical dimension, and the pragmatic dimension" (1939: 133) – that obtain in any given concrete instance of sign use, along with the three dimensions of semiotic study, whereby the investigator explicates the sign's relations: to the object that it is standing for, to the consequences and conditions of its use, and to its placement within a system of other signs. One would have thought that Morris' repeated use of the word *dimensions* in his analysis would have forestalled any atomizing trifurcation of this concept – yet soon Morris' holistic description of how each and every sign relation was to be studied became the source of ever less integrated *divisions* of sign study (and ever less integrated *definitions*) that persist even to this day. "Otto Neurath warned me years ago that these terms would engender pseudo-problems and distract attention from genuine problems," writes Morris twelve years after the terms are first introduced

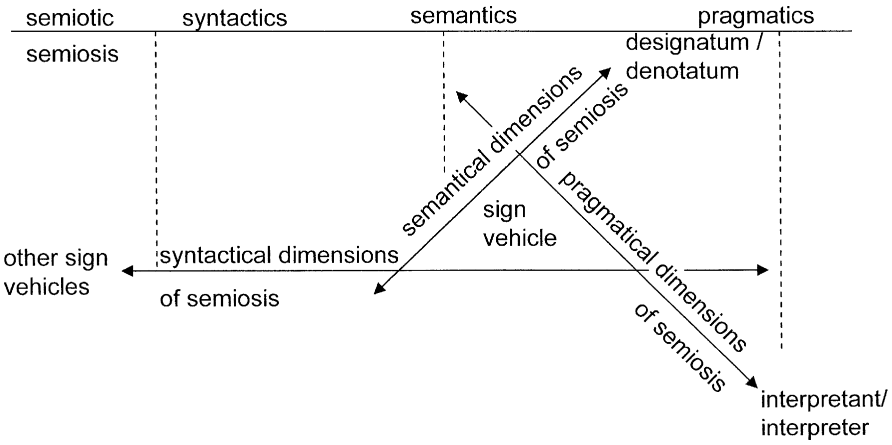

Fig. 4.1 Morris' minimal explanatory requirements for the correct analysis of any sign (from Morris 1939: 133, re-drawn for this volume)[1]

in *Foundations of the Theory of Signs*, "and the course of events has proved, in part, the legitimacy of his fears" (1948: 217).

As we have seen, Morris was attempting to formulate a "unified science" that would reveal the "systematic connection among three historical currents of thought [empiricism, pragmatism, and logical positivism], legitimatizing each of them without rendering the others superflous" (Posner 1998: 566). Morris' point, rather, is that a too exclusive focus on any one of the three dimensions of investigation at the expense of the other two would be ruinous to *any* science, given that "signs are simply the *objects studied by* the biological and physical sciences, related in certain complex functional processes [and that] signs are also the *instruments used by* all sciences, since every science makes use of and expresses its results in terms of signs" (1938: 2).

Flawed, then, because not rising to the level of a *constitutive framework* demanded by a truly unified science, would be an investigation of sign's formal relations to other signs (e.g., the syntactic method of logical positivism) that ignored the pragmatic dimension of the sign use in a social community in its study; or a study of the relationship between a sign and its interpreter (e.g., the pragmatic methods of social science or phenomenology) that ignored the semantic dimension of signs' relationship with their real-world objects; or a semantic ontology of "what there is" (e.g., the reductionist empiricism of laboratory science) that fails to recognize

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[1] Morris draws a box to surround the words *sign vehicle* in the original, but here I follow the precedent of Nöth (1990: 50) and Posner (1998: 567), in depicting the locus where these dimensions meet, and in so doing, comprise a semiotic triad, as a triangle.

the constitutive roles that language and community play in the delineation of such objects of study.[2]

“The main misunderstanding,” writes semiotics scholar Susan Petrilli, “relates to the fact that ‘meaning’ has generally been associated exclusively to the semantical dimension, when, in fact, it is present in all three dimensions” (2005: 193).

We have spent a good deal of time situating Morris’ work in relation to its own time in this introduction, because Morris is, for the most part, misunderstood and perhaps unfairly neglected today, both in academic circles and in biosemiotic circles. In the former, he was, at least for much of the last century, misunderstood as the semiotic successor to Peirce, and one can find many instances of academic authors relying on their readings of Morris for procuring their understandings of Peirce.[3]

Reading Morris as a “substitute” (or synonym) of Peirce – or vice versa – is extremely misguided, as Morris himself would doubtlessly have concurred. For Morris’ sign theory and Peirce’s sign theory differ in fundamental and critically different ways, particularly with regard to the key notion of the *interpretant*, though this discussion goes far beyond what there is space to discuss in this introduction (nor is that the purpose of this introduction to Morris and his work; for illuminating discussions on these differences, however, see Petrilli (1999: 67–102), Deledalle (2000: 114–120); and Petrilli and Ponzio (2005: 167–201)). With the marked rise in the quantity and quality of Peirce scholarship in the last two decades, however, this misunderstanding seems to be abating.

In the biosemiotic community, almost the polar opposite mischaracterization of Morris is often to be found – i.e., that of Morris as a crude epigone of Peirce, an “eliminative behaviorist” in the fashion of John B. Watson (1878–1958) or B.F. Skinner (1904–1990). Much like the Morrisians of yesteryear who did not read Peirce, many of the Peirceans looking to develop a biological sign-science today have not bothered to read Morris – or to read him very deeply, with an eye towards distilling and precipitating the useful elements in his work for use in biosemiotics. Semiotic scholars Susan Petrilli and Augusto Ponzio, however, effectively argue that Charles Morris’s *behavioristic* (not *behaviorist*) *biosemiotics* is one worthy of the name:

“All Morris’ research” – from the writing of his 1925 university dissertation, *Symbolism and Reality*, through his major works *Foundation of a Theory of Signs* (1938), *Signs, Language, and Behavior* (1946), *Signification and Significance* (1964) and his collected *Writings on the General Theory of Signs* (1971) – “can be described as *biosemiotic* in orientation, and in this sense shows a tightly woven

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[2] Anderson et al. (Chapter Twelve, this volume) argue that it was precisely such *pars pro toto* misunderstandings that ascended to dominance in academia in the latter half of the twentieth century – in good measure, and to the detriment of Morris’s project and career.

[3] A sure sign of this is when the author claims a four-part definition of the sign that includes a foundational *interpreter* responsible for bringing together the “sign” relation – for this is where Morris most fundamentally diverges from Peirce, and why John Dewey (1859–1952) deemed Morris’ semiotics “a complete inversion of Peirce” (Morris 1971: 444).

continuity" writes Petrilli and Ponzio, "in that what remains constant is the tenacity that characterizes his *search for a method* and for *rigorously scientific terms* for constructing a science that can account for 'signs' in *all* their [biological] forms and manifestations" (2005: 186, 191).

Charles Morris pursued this project until his death on January 15, 1979, in Gainesville, Florida. In the following selection, we find Morris at the outset of what would ultimately turn out to be his lifelong one-person project, in a position very similar to the one where the newly coalescing community of contemporary biosemiotics finds itself today. "The need of furthering a genuine science of signs is so basic that we must move in this direction as speedily as possible," writes Morris (1938: 22). Yet he is aware from the outset that if one proceeds with either a too-loosely assumed, or a too-rigidly pre-fixed, idea about the object of this analysis – i.e., the "sign" relation – then one may wind up not proceeding scientifically, or not actually investigating the phenomenon that one first set out to investigate at all. Thus, the first and most important job to undertake at this opening phase of the establishment of (bio)semiotics, insists Morris, is to *develop a scientific vocabulary* that clearly states the criteria whereby something does or does not meet the operational definition of the sign phenomena in question.

As a keenly intuitive semiotician himself, Morris distinguished between the 'analyzed terms' that a science needs in order to make progress in its work (e.g., "phenotype", "induction", "catalyst") and the great mass of 'unanalysed' terms, (e.g., "similar", "cause", "change") that support those analyzed terms, and that themselves do not need nor receive analysis by the science, lest one embark upon a potentially infinite regress. Writes Petrilli: "Morris' aim was to ensure that the key words in the 'science of signs' were all *analyzed* terms; [terms so analyzed] by Morris include *interpreter, interpretant, denotatum, signficatum, sign-vehicle, sign-family, signal, symbol, comsign, lansign, ascriptor, designator, appraisor, formator, preparatory stimulus, disposition to respond, stimulus, response, response-sequence and behaviour family*" (2005: 180). To do so, writes Petrilli, Morris

> draws from the biological and physical sciences for unanalyzed terms such as *organism, reaction, sensory organ, need, energy,* and so on. These are combined with other unanalyzed terms adapted from everyday language, such as *behaviour, condition, cause, influence* and *situation* in such a way as to analyze (completely or partially)[4] the terms proposed for [use in the science of behavioristic] semiotics. He claimed that this method was scientifically correct in the sense that he was indicating clearly the discourse field from which he was drawing his undefined terms; his intention was to establish the conditions for their verification or confutation (2005: 177).

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[4] "On the basis of the unanalyzed terms," Petrilli explains, "the analyzed terms of the science in question can be either completely analyzed (or 'defined'), as when we state the *necessary and sufficient* conditions for their application; or they can be only *partially analyzed* (or ['characterized']), as when the *sufficient but not necessary* conditions for their application are asserted" (2005: 180). Morris felt that it is prudent to proceed only from the latter kind of analysis with regards to the key term "sign" at this early stage of the science's development.

Accordingly, Morris is assiduously careful to define all his terms. Thus, for example, when he presents his preliminary formulation of a "sign" as: "Anything, A, that is a preparatory-stimulus which, in the absence of stimulus-objects initiating response-sequences of a certain behavior-family, causes a disposition in some organism to respond, under certain conditions, by response-sequences of this behavior-family" (1946: 57), this formulation is immediately accompanied by clarifications of what constitutes a "preparatory-stimulus", a "response sequence", a "disposition to respond" and a "behavior-family" in his proposed science of signs (1946: 194). Not surprisingly, Morris' definitions change and his terminology gets updated as he works through his self-described "*prolegomenon* to a science of signs" (1948: 434) throughout the course of his forty-year career. Thus, by 1964, the term "significatum" will be replaced with "signification", and the original 1938 formulation for what characterizes, but does not exhaustively define, a sign (i.e., its sufficient but not necessary conditions) is refined from merely:

"S [a sign vehicle] *is a sign of* D [its designatum] *to the degree that* I [its interpretant] *takes mediated account of* D *in virtue of the presence of* S" (Morris 1938: 4) to the more precise formulation:

> Semiosis *is a five-term relation* – v, w, x, y, z – [wherein] v [a sign-vehicle] *sets up in* w [an interpreter system] *the disposition to react in a certain kind of way,* x [an interpretant], *to a certain kind of object (not then acting as a stimulus),* y [a significatum/signifcation], *under certain conditions* [sign contexts], z (Morris 1964: 2).

Thus, almost thirty years later, the underlying foundations of his sign theory remain unchanged: "In semiosis," writes Morris, "something takes account of something else mediately, i.e., by means of a third something. Semiosis is thus *a mediated-taking-account of*" (1938: 4).

Finally, as regards the endlessly disputed term "meaning", it may be interesting for contemporary biosemioticians to note that Morris "does not include that term here at all among the basic terms of semiotic", believing that

> This term, though useful enough at the level of everyday analysis, does not have the precision necessary for scientific analysis. Accounts of *'meaning'* usually throw a handful of putty at the target of sign phenomena, while a technical semiotic must provide us with words which are sharpened arrows. 'Meaning' signifies any and all phases of the sign-process (*the status of being a sign, the interpretant, the fact of denoting, the significatum,* etc), and frequently suggests mental and valuational processes as well; hence it is desirable for semiotic to dispense with the term, and to introduce separate special terms for the various factors which *'meaning'* fails to discriminate. (1946: 19)

Charles Morris' attempts at establishing a science of biosemiotics in the 1940s and 1950s were, as has often been the case, both premature as well as very much against the prevailing disciplinary enthusiasms of his time. "Hostility towards pragmatism from University of Chicago philosopher Mortimer Adler and President Robert Hutchins further ensured the marginalization of Morris and semiotics," writes Morris biographer John Shook (2009: 319). This claim, too, was echoed by Morris' star student at the University of Chicago, Thomas A. Sebeok, who believed that the persevering hostility to Morris' work there "set back the nascent rise of semiotics in the United States by easily a quarter of a century" (Deely 2004: o.l.)

Like Peirce, however, Morris was sanguine about the likelihood that the development of a science of signs that would “render the insights of both the theorists and the practitioners of human action from all over the world compatible with one another within a comprehensive frame of reference” (Posner 1998: 565) would be the work of “many investigators working in many fields and for many generations” (Morris 1948: 434). The current generation has produced its cohort of such investigators, as the rest of this volume will well attest. Yet here at the *prolegomenon* stage of this latest iteration, biosemioticians would do well to remember that one need not adopt Charles Morris’ particular theoretical framework for the analysis of sign relations in living systems, in order to draw inspiration from his tenacious efforts at clarity and precision in laying the foundational stages of a scientific biosemiotics, and to strive to follow in his example.

Excerpts from *Signs, Language and Behavior* (1946)

The Scope of Semiotic

Semiotic has for its goal a general theory of signs in all their forms and manifestations, whether in animals or men, whether normal or pathological, whether linguistic or non-linguistic, whether personal or social.[5] Semiotic is thus an interdisciplinary enterprise.

Part of the widespread interest in this area is motivated by the belief that higher-level sign processes (often called symbols) are of central importance in understanding man and his works. Ernst Cassirer called man "the symbolic animal" ("*animal symbolicum*"), instead of the "rational animal" ("*animal rationale*"), and much contemporary work has shown the aptness of this conception.

The Problem of Approach

The understanding and the effective use of language and other signs has become today an insistent task. Popular and technical literature is filled with discussions of the nature of language, the differences between signs in men and in animals, the differentiation of scientific discourse and such other types of discourse as occur in literature, religion, and philosophy, the consequences of an adequate or inadequate use of signs for personal and social adjustments.

These discussions are carried on from many points of view and for various purposes. There are linguists, psychologists, and social scientists interested in the study of those special kinds of signs which occur in their own specific subject matters; philosophers eager to defend the superiority of one system of philosophy over another; logicians and mathematicians working on the elaboration of a symbolism adequate to their own special disciplines; artists and religionists anxious to justify in an age of science their own special symbols; educators desirous of improving the use of language in the educational process for which they are responsible; psychiatrists aiming to uncover the place which signs play in the personality disturbances of their patients; statesmen seeking to uphold or improve the basic symbols which sustain the social structure; propagandists attempting to discern the ways in which language may be used to direct social change.

All of these approaches and purposes are legitimate. Their multiplicity bears witness to the enormous place which signs play in human life, while the ferment of contemporary discussion about signs is one evidence of the tensions which beset

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[5] *Editor's note:* These first two paragraphs constitute the opening passage of Morris's 1964 volume *Signification and Significance*. I have included them here as an introductory *aperçu* of Morris' biosemiotic project. [DF]

our culture. Language is of such central importance that it becomes an object of central concern in times of extensive social readjustment. It is not surprising that in these days, as in the later Greek and Medieval periods, attempts should be made to develop a comprehensive doctrine of signs. Today this discipline is frequently known as semantics; we shall call it *semiotic*.[6]

And yet it must be admitted that from a scientific, and therefore from a practical, point of view the present status of this discipline is far from satisfactory. We do not often have reliable knowledge to direct fruitfully the applications we would like to make and endeavor to make. The situation is similar to that which the physician frequently encounters: he must do what he can for a particular illness even if adequate scientific knowledge is lacking. It is obvious that we do not possess a developed science of signs, though there are beginnings of such a science in such special fields as linguistics. There are few general principles now available in terms of which existing knowledge can be integrated and from which empirically verifiable predictions can be made. Yet the pressing problems for which such a science would be the proper instrument cannot be disregarded until a developed science of signs is obtained.

In this situation it has seemed wise to adopt a compromise attitude. The need of furthering a genuine science of signs is so basic that we must move in this direction as speedily as possible. The present study is based on the conviction that a science of signs can be most profitably developed on a biological basis and specifically within the framework of the science of behavior (a field which, following a suggestion of Otto Neurath, may be called *behavioristics*). Hence I shall constantly suggest connections between signs and the behavior of animals and men in which they occur. On the other hand, behavioristics is not at present sufficiently developed to account adequately for the more complex human actions, nor for the signs which they utilize. Since our present day problems demand, however, insight into just such complexities, I shall not hesitate to introduce considerations drawn from very gross observations. And everywhere I shall seek for a wide perspective which will help to co-ordinate the great variety of interests, scientific and cultural, in sign phenomena. I share the view that insight into the nature of signs provides us with an instrument which improves our understanding of, and effective participation in, the whole of our contemporary intellectual, cultural, personal, and social problems. In support of this conviction I advise the reader to turn to Chapter 7, which deals with the importance of signs in the life of individuals and societies; a preliminary reading of that material at this time will serve to "fortify" the reader for the analysis which lies ahead.

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[6] "Semantics" is perhaps the most widely accepted name for the discipline which studies signs. "Semiotic," the term here chosen, was used by the Stoics, John Locke, and Charles Peirce. In the medieval period the term "scientia sermocinalis" was frequently employed. Linguists and logicians restrict "semantics" to a part of the whole field, namely the part which deals with the significata of signs. Hence we use "semiotic" as the general term; "semantics" will be employed for that part of semiotic which deals with significata. Later we show how semantics, syntactics, and pragmatics are the main subdivisions of semiotic.

The following study is directed both to scientists and to those concerned with the basic issues of contemporary individual and social life. There is a need today for such a study, inadequate and incomplete though it is bound to be. It may serve as a guide to the genuinely scientific and culturally fertile semiotic which the future will bring.

There is wide disagreement as to when something is a sign. Some persons would unhesitatingly say that blushing is a sign, others would not. There are mechanical dogs which will come out of their kennels if one claps one's hands loudly in their presence. Is such clapping a sign? Are clothes signs of the personality of those who wear them? Is music a sign of anything? Is a word such as "Go!" a sign in the same sense as is a green light on a street intersection? Are punctuation marks signs? Are dreams signs? Is the Parthenon a sign of Greek culture? Disagreements are widespread; they show that the term "sign" is both vague and ambiguous.[7]

This disagreement extends to many other terms which are commonly used in describing sign-processes. The terms "express," "understand," "refer," "meaning" would provide many instances. So would "communication" and "language": Do animals communicate? If so, do they have a language? Or do only men have language? Yes, run some answers; no, run others. We find the same diversity of replies if we ask whether thought or mind or consciousness is involved in a sign-process; whether a poem "refers" to what it "expresses"; whether men can signify what cannot be experienced; whether mathematical terms signify anything; whether language signs are preceded genetically by non-language signs; whether the elements in an undeciphered "dead" language are signs.

In the face of such disagreements, it is not easy to find a starting point. If we are to seek for a formulation of the word "sign" in biological terms, the task is to isolate some distinctive kind of behavior which agrees fairly well with frequent usages of the term "sign": Since usage of the term is, however, not consistent, it cannot be demanded that the chosen behavioral formulation agree with all the various usages which are actually current. At some point the semiotician must say: "Henceforth we will recognize that anything which fulfills certain conditions is a sign. These conditions are selected in the light of current usages of the term "sign," but they may not fit in with all such usages. They do not therefore claim to be a statement of the way the term "sign" is always used, but a statement of the conditions under which we will henceforth admit within semiotic that something is a "sign."

Then from such a starting point a behavioral theory of signs will build up step by step a set of terms to talk about signs (taking account of current distinctions but attempting to reduce for scientific purposes their vagueness and ambiguity), and will endeavor to explain and predict sign phenomena on the basis of the general

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[7] Because of this vagueness and ambiguity a number of scientists have proposed to discontinue the use of the term "sign." Of course behavioristics can be developed without the use of the term; no sign is indispensable. But since the term is in such frequent usage in ordinary language and in writings of semioticians and behavioristicians it has seemed advisable to continue the term but to use it in a more precise manner than is customary. Whether this usage is to be incorporated into behavioristics itself must be left to specialists in the field.

principles of behavior which underlie all behavior, and hence sign-behavior. The aim is to take account of the distinctions and analyses which former investigators have made, but to ground these results whenever possible upon general behavior theory. In the nature of the case such a scientific semiotic will often deviate from current terminology, and can only be developed slowly and laboriously. It will often seem pedantic and less illuminating for many purposes than less scientific approaches – which therefore are to be encouraged in the light of the many problems and purposes which a treatment of signs aims to fulfill. It is not to be expected that all discussions of literary, religious, and logical signs can be translated at once with profit into a behavioral formulation. The present approach does not therefore wish to exclude other approaches to semiotic. But it does proceed upon the belief that basic progress in this complex field rests finally upon the development of a genuine science of signs, and that this development can be most profitably carried on by a biological orientation which places signs within the context of behavior.

Preliminary Isolation of Sign-Behavior

We shall begin by taking two examples of behavior to which the term "sign" is often applied both in common usage and in the writings of semioticians. Then a superficial analysis of these examples will disclose the features which a more technical formulation of the nature of a sign must embody. If both situations reveal certain common elements, then both may be called sign-behavior; the differences in the two situations would then suggest differences between kinds of signs. If analysis shows too great differences, then the alternative would be to choose different terms to describe the two situations, and to adopt a narrower definition of "sign": in either case we would then be in a position to consider whether any additional phenomena are to be called signs, that is, whether the characterization of signs based upon the two examples in question is to be held as a basis for determining when something is a sign or whether it is to be expanded to include situations of a widely different sort.

The first example is drawn from experiments on dogs.[8] If a hungry dog that goes to a certain place to obtain food when the food is seen or smelled, is trained in a certain way, it will learn to go to this place for food when a buzzer is sounded even though the food is not observed. In this case the dog is attentive to the buzzer but does not normally go to the buzzer itself; and if the food is not made available until some time after the buzzer has sounded, the dog may not go to the place in question until the time interval has elapsed. Many persons would say in such a situation that the buzzer sound is to the dog a sign of food at the given place, and in particular, a non-language sign. 1f we abstract from the experimenter and his purposes in this

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[8] See Karl Zener, "The Significance of Behavior Accompanying Conditioned Salivary Secretion for Theories of the Conditioned Response," *American Journal of Psychology*, 50, 1937, 384–403. These experiments make clear the differences in the response of the dog to situations in which the sign is present and those in which it is not present.

example, and consider only the dog, the example approximates what have often been called "natural signs," as when a dark cloud is a sign of rain. It is in this way that we wish the experiment to be considered.

The second example is drawn from human behavior. A person on the way to a certain town is driving along a road; he is stopped by another person who says that the road is blocked some distance away by a landslide. The person who hears the sounds which are uttered does not continue to the point in question, but turns off on a side-road and takes another route to his destination. It would be commonly said that the sounds made by the one person and heard by the other (and indeed by the utterer also) were signs to both of them of the obstacle on the road, and in particular were language signs, even though the actual responses of the two persons are very different.

Common to these two situations is the fact that both the dog and the person addressed behave in a way which satisfies a need – hunger in the one case, arrival at a certain town in the other. In each case the organisms have various ways of attaining their goals: when food is smelled the dog reacts differently than when the buzzer is sounded; when the obstacle is encountered the man reacts differently than when spoken to at a distance from the obstacle. Further, the buzzer is not responded to as food nor the spoken words as an obstacle; the dog may wait awhile before going for food and the man may continue to drive for a time down the blocked road before turning off to another road. And yet in some sense both the buzzer and the words control or direct the course of behavior toward a goal in a way similar to (though not identical with) the control which would be exercised by the food or the obstacle if these were present as stimuli: the buzzer determines the dog's behavior to be that of seeking food in a certain place at a certain time; the words determine the man's behavior to be that of getting to a certain town by avoiding a certain obstacle at a given place on a given road. The buzzer and the words are in some sense "substitutes" in the control of behavior for the control over behavior which would be exercised by what they signify if this was itself observed. The differences between non-language and language signs remain for subsequent discussion.

It is clear at once that the formulation of "sign" frequent in early behavior theory is too simple: namely, it cannot be simply said that a sign is a substitute stimulus which calls out to itself the same response which would have been called out by something else had it been present. For the response to food is to food itself, while the response to the buzzer is not to it as if it were food; and the actual response to the situation in which the sign appears may be greatly different from the response to a situation where what is signified, and not the sign, is present. The dog, for instance, may salivate when the buzzer is sounded but it cannot actually eat unless food is present; the man may feel anxiety when he is addressed, but his turning off the road before reaching the obstacle is a very different response from that which he would make if he had gone directly to the place of blockage itself (and even more different from the behavior of the person who told him of the obstacle.)

Nor can the difficulties in the earlier attempts to identify signs with any and all substitute stimuli be avoided by attempting to say that whatever influences a response with respect to what is not at the moment a stimulus is a sign. For example, a drug will influence the way an organism will respond to stimuli which later affect it, and yet it would be too great a departure from common usage to call such a drug a sign.

The difficulties in these formulations may perhaps be avoided if, as our examples suggest, signs are identified within goal-seeking behavior. So in the light of our analysis of what the two examples chosen as a point of reference have in common (and neglecting for the time being their differences) we arrive at the following preliminary formulation of at least one set of conditions under which something may be called a sign: *If something, A, controls behavior towards a goal in a way similar to (but not necessarily identical with) the way something else, B, would control behavior with respect to that goal in a situation in which it were observed, then A is a sign.*

The buzzer and the spoken sounds are then signs of food and obstacle because they control the course of behavior with respect to the goals of getting food and getting to a certain place in a way similar to the control which food and obstacle would exercise if they were observed. Whatever exercises this type of control in goal-seeking behavior is a sign. And goal-seeking behavior in which signs exercise control may be called *sign-behavior*.

Toward Precision in the Identification of Sign-Behavior

For many purposes the preceding account of a sign is adequate; it at least suggests a behavioral way of formulating what is commonly meant in saying that a sign "stands for" or "represents" something other than itself. But for more strictly scientific purposes a more exact formulation is required in order to clarify the notions of similarity of behavior and goal-seeking behavior. We might at this point simply leave it to the scientists in their field to state further refinements, and indeed anything we add is in the nature of the case tentative. But since our concern is to push semiotic as rapidly as possible in the direction of a natural science, the following suggestions are made.

Implicit in the preceding account are four concepts which need further clarification: preparatory-stimulus, disposition to respond, response sequence, and behavior-family. When these notions are elucidated a more precise statement of a set of conditions sufficient for something to be called a sign can be given.

A *preparatory-stimulus* is any stimulus which influences a response to some other stimulus. Thus it has been found by O. H. Mowrer that the magnitude of the jump of a rat to a shock stimulus is increased if a tone sounds before the shock stimulus is encountered.[9] Such a stimulus differs from other stimuli, say the shock,

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[9] The notion of preparatory-stimulus seems to be in harmony with Mowrer's conception of the "warning" stimuli involved in "implicit conditioning." Speaking of the augmentation of the rat's jumping to a shock when it is preceded by a sound he writes: "This augmentation of the reaction to the *unconditioned* stimulus, by virtue of its being preceded by a warning, or conditioned, stimulus (which does not, however, produce a gross, overt response in its own right), is here termed "implicit

in that as a preparatory stimulus it influences a response to something other than itself rather than causing a response to itself (it may of course also cause a response to itself, that is, not be merely or solely a preparatory-stimulus). By a stimulus is meant, following Clark L. Hull, any physical energy which acts upon a receptor of a living organism; the source of this energy will be called the *stimulus-object*. By a *response* is meant any action of a muscle or gland; hence there are reactions of an organism which are not necessarily responses. A preparatory-stimulus affects or causes a reaction in an organism, but, as Mowrer makes clear, it need not call out a response to itself, but only to some other stimulus. In the account toward which we are moving it is not held that all preparatory-stimuli are signs, but only that preparatory-stimuli which meet certain additional requirements are signs. That a preparatory-stimulus need not when presented call out a response makes intelligible the fact that a command to turn right at a certain place may produce at the time of utterance no overt, or as far as we know, "implicit" response of turning right, and yet may determine that the person, commanded turns right when he reaches the place in question. A preparatory-stimulus does however cause some reaction in an organism, affects it in some way, and: this leads to the introduction of the term "disposition to respond."

A *disposition to respond* to something in a certain way is a state of an organism at a given time which is such that under certain additional conditions the response in question takes place. These additional conditions may be very complex. An animal disposed to go to a certain place to obtain food may not go there even if food is observed – he may not be willing or able to swim across an intervening water barrier or to move if certain other animals are present as stimulus-objects. The complex of conditions also includes other states of the organism. The person commanded to turn at a certain corner may not turn even when the corner is reached: as he walked to the corner he may have come to believe that his informant was deliberately trying to misdirect him, so that confidence in one's informant may be at times a necessary condition for making a response to which one is disposed because of signs.

There may be dispositions to respond which are not caused by preparatory-stimuli, but every preparatory-stimulus causes a disposition to respond in a certain way to something else. Logically, therefore, "disposition to respond" is the more basic notion, and a preparatory-stimulus is a stimulus which causes a disposition to respond in a certain way to something else. And since not all preparatory-stimuli

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conditioning" ("Preparatory Set (Expectancy) – Some Methods of Measurement," *Psychological Monographs*, 52, 1940, 27). It is further related to what K. S. Lashley calls a "conditional reaction" – i.e., a reaction to something which is determined by the stimulus character of something else (see "Conditional Reactions in the Rat," *Journal of Psychology*, 6, 1938, 311–324); to K. A. William's conception of signs as stimuli to preparatory responses ("The Conditioned Reflex and the Sign Function in Learning," *Psychological Review*, 36, 1929, 481–497); and to what B. F. Skinner calls a "pseudo-reflex (*The Behavior of Organisms*, 1938). In the usage of the present account it is not necessarily implied that a preparatory-stimulus is always learned (though it may always be), nor that all preparatory-stimuli are signs. The explanation of the functioning of such stimuli is a problem for behavioristicians. C. L. Hull has suggested that they may be explained in terms of his conception of temporal patterning.

would normally be called signs, and not all dispositions to response which are caused by preparatory-stimuli are relevant to the delimitation of sign processes, additional criteria are involved; and to be in accord with our own preliminary formulation of sign-behavior, these criteria must introduce the notion of behavior toward a goal.

A *response-sequence* is any sequence of consecutive responses whose first member is initiated by a stimulus-object and whose last member is a response to this stimulus-object as a goal-object, that is, to an object which partially or completely removes the state of the organism (the "need") which motivates the sequence of responses. Thus the series "of responses of a hungry dog which sees a rabbit, runs after it, kills it, and so obtains food is a response-sequence." For the sight of the rabbit starts a series of responses to the rabbit in terms of which the rabbit is finally obtained as food. The intervening responses in the sequence can occur only if the environment provides the necessary stimulus for their release and such sources of stimuli may be called *supporting stimulus-objects*. The terrain over which the dog runs in this case provides the support necessary for the responses of following the rabbit and tracking it down, while the rabbit provides the stimuli initiating and terminating the series of responses.

A *behavior-family* is any set of response-sequences which are initiated by similar stimulus-objects and which terminate in these objects as similar goal-objects for similar needs.[10] Hence all the response-sequences which start from rabbits and eventuate in securing rabbits as food would constitute the rabbit-food behavior-family. A behavior-family may in an extreme case have only one member; no limit is set to the number of possible members. Behavior-families have various degrees of inclusiveness. All the objects which a dog eats would, for instance determine an extensive "object-food" behavior-family which would include the rabbit-food behavior-family as a subordinate behavior-family.

In these terms it is possible to formulate more precisely a set of conditions sufficient for something to be a sign: *If anything, A, is a preparatory-stimulus which in*

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[10] This notion of behavior-family is similar to, and indeed a part of, C. L. Hull's conception of the habit-family hierarchy (see *Psychological Review*, 41, 1934, 33 ff.). I have not attempted to probe the problems connected with the terms "need" or "behavior." "Need" is taken as roughly synonymous with "motivating organic state" and not with "what is necessary for survival"; so used an organism may have needs which in fact are fatal to its survival. These two common uses of "need" must be distinguished. On the problem of defining "need" in behavioristics see the monograph by Else Frenkel-Brunswik, "Motivation and Behavior," *Genetic Psychology Monographs*, 26, 1942, 121–265; S. Koch, "The Logical Character of the Motivation Concept," *Psychological Review*, 48, 1941, 15–38, 127–154. As for the term "behavior," it might be possible to identify it with "response-sequence" or "behavior-family." We use "behavior" as a narrower term than "response" and as a wider term than "sign-behavior." Other uses of the term are, however common. For a discussion of the situation see the paper by Egon Brunswik in the forthcoming monograph, *Theory of Behavior* (*International Encyclopedia of Unified Science*, 1(10)). See also the "Symposium on Psychology and Scientific Method," Brunswik, Hull, Lewin, *Psychological Review*, 50, 1943, 255–310.

the absence of stimulus-objects initiating response-sequences of a certain behavior-family causes a disposition in some organism to respond under certain conditions by response-sequences of this behavior-family, then A is a sign.[11]

According to these conditions, the buzzer is a sign to the dog since it disposes the animal to seek food in a certain place in the absence of direct stimulation from food objects at this place, and similarly, the spoken words are signs to the driver since they dispose him to response-sequences of avoiding an obstacle at a certain point on a certain road although the obstacle is not itself at the time of hearing the sounds a stimulus-object.

The merit of this formulation is that it does not require that the dog or the driver respond to the sign itself, the sign serving merely as a preparatory-stimulus for response to something else. Nor does it require that the dog or the driver finally respond overtly as they would if food or an obstacle had been stimulus-objects; it merely requires that if the animal makes the response-sequences which it is disposed to make when certain additional conditions are met (conditions of need and of supporting stimulus-objects) these response-sequences will be of the same behavior-family as those which the food or obstacle would have initiated. In this way the difficulties which earlier behavioral formulations of signs encountered are avoided. And yet objective behavioral criteria are furnished for determining whether something is or is not a sign. It is further believed that these criteria do not deviate from those which underlie certain common usages of the term "sign."

Some Objections Considered

By this time a mixed feeling of dismay, fear, anger, and resentment may well have overcome readers of contemporary literature on "semantics." Semiotic is not merely losing its entertaining character, they may say, but is slipping into the abyss of technicalities and hard work. And so it is! And so it must if the purpose be scientific. For science has always in its advance forced us away from the presented surface of familiar things to the laborious discovery of those properties of things which give insight, predictions, and control of this surface. And there is no reason why the scientific advance of semiotic should shun this road. No reason why sign-processes, for all their immediate sense of familiarity, should not be as complex as any chemical structure or biological functioning. And we have already admitted that for other immediate purposes, other less technical analyses may be more useful.

There is, however, a genuine question as to whether the present approach loses its relevance for the wide range of problems which draw the attention of the contemporary world to signs. And there is a real danger here because of the fact that we are certainly not at present able to analyze in precise behavioral terms the more complex phenomena of esthetic, religious, political, or mathematical signs, or even

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[11] For an analysis of the term "disposition" as applied to signs, see C. L. Stevenson, *Ethics and Language*, pp. 46–59.

the common language of our daily existence. But later chapters will attempt to show that the present approach has, even now, many suggestions to offer in these fields, and that because of a consideration soon to be mentioned, the detailed analysis of signs and their significations in terms of behavior is not always necessary since we can, within limits, accept the results of analyses which have already been obtained in these fields and even verbal reports by a person on his own signs.

An objection frequently raised to the preceding type of behavioral formulation may be expressed as follows: "The observation of response-sequences is at best one test for the existence of signs, and one in fact seldom employed. Take a person reading a book alone in his room, say a book about Alaska; certainly the marks on the pages of this book are signs to the reader at the moment he reads them. And he knows this, and knows what they signify, quite independently of how he would actually respond to Alaska if he were there, and independently in fact of any response which he makes to his environment. This suggests that there is something essentially wrong with a behavioral formulation. Behavior is at times evidence of signs, but there may be other and better and more available evidence – such as that given by self-observation."

Now much of this contention may be admitted: there certainly may be other evidence for sign-processes than the actual observance of response-sequences, and self-observation may supply this evidence. But to admit these points does not show an inadequacy in the behavioral formulation.

The situation may be clarified in this way. The preceding formulation of "sign" is not a definition in the sense that it gives the necessary and sufficient conditions for something to be a sign. It does not say that something is a sign if and only if the conditions laid down are met, but merely that if these conditions are met, then whatever meets them is a sign.[12] There may be various kinds and degrees of evidence that these conditions are in fact met. And it is perfectly possible for there to be other sets of conditions proposed for calling something a sign, and these are acceptable to the present behavioral formulation if they are such that there is a constant connection between the two sets of sufficient conditions.

The central methodological issues may be analyzed as follows. The set of conditions which has been proposed as sufficient for calling something a sign did not stipulate that the organism for which it is a sign actually performs response-sequences of a given behavior-family, but merely that it be disposed to perform them, that is, would perform them under certain conditions. The question then is, what kind of evidence permits us to say that an organism is disposed so to act.

The most complete evidence is of course to make available the conditions in question and then see whether response-sequences of the given behavior-family

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[12] I owe the suggestion of giving only sufficient conditions for saying that something is a sign, instead of giving a definition (that is, sufficient and necessary conditions), to Alfred Tarski. This procedure seems advisable at the present state of the argument, since premature definitions may rule out other phenomena which we may later wish to include. The consequence of the present procedure is that for the moment our statements about signs are limited to signs as identified by the criteria here proposed or by any other criteria which imply these criteria.

actually occur. If one wants to know whether the buzzer is a sign to the dog of food in a certain place, one takes a hungry dog and investigates whether the buzzer is the cause of response-sequences of seeking food in that place when the food itself is not at the time a stimulus-object. If the dog under these conditions goes to the place in question and eats the food there available, then one has shown that the dog was disposed by the buzzer to responses of the same behavior-family that are called out by the presence of food as a stimulus-object at that place.

But there are other possibilities for showing the existence of such a disposition. If we define *a segment of a response-sequence* as any series of consecutive responses within a response-sequence which starts from an initial member but does not contain the final member, then we may often observe that an animal performs such a segment of a response-sequence though it does not perform the whole sequence. If food is not made available to the animal it cannot of course eat food, but it may be observed to go toward the place in question and to salivate or otherwise react in ways characteristic of seeking and eating food. Such data may then be taken as evidence that the dog is disposed to behavior of the kind required by the formulation of a sign, and such evidence is reliable in proportion to the degree to which it is distinctive of the behavior-family in question.

The evidence required may not even be a segment of a response-sequence, may not in fact be a response at all. If, for instance, any state of the organism could be found – say its brain waves – which is such that when this state is present the animal later responds in the way required by the formulation of a sign, then this state of the organism would itself be a sufficient condition for saying that the preparatory-stimulus which occasioned this state was a sign. In other words, there may be other ways of determining the existence of a disposition to respond in a certain fashion than by directly observing the response itself.

Finally, among such ways is the possibility of using in some cases the verbal responses of an organism as evidence of whether something is or is not a sign to this organism. By correlating such verbal responses with the rest of the behavior of the organism it is possible to find out the extent to which they are reliable evidence as to the existence of sign-processes. That they are reliable to some extent is not in doubt, and so semiotic can make use of them as evidence for the existence of signs, and indeed must in its present state make as much use of them as it can. But since signs can occur without verbal responses, and since such responses are not always reliable evidence, they are at best evidence for the existence of signs and not either necessary or sufficient conditions for the occurrence of signs. The science of signs must deal with animals and children and insane persons that cannot report on their behavior, as well as with persons whose reports are often unreliable, so it must start with criteria for the existence of sign-processes which are applicable in these cases. Hence the contention that the behavioral formulation is the primary one with which other sets of conditions are to be correlated as alternative sets of sufficient conditions or merely as evidence that a specific set of conditions is fulfilled.

The book on Alaska read alone may then be said to be to the reader a complex of signs prior to the observation of his overt behavior. But to know this is merely to say that there is some evidence – neural, physiological, verbal – that the man is in a state which has been found empirically to be correlated with observable sign-behavior. That he is now ready to respond in a certain way at a later time can in the last analysis only be determined by correlating his present state with how he actually responds at a later time to a given environment.

It may help to point out that a similar situation is frequent in science and in daily life. A scientist may begin a study of magnetic phenomena by starting with cases in which bodies of a certain kind are found to approach a given body, and in virtue of this fact he calls the latter body a magnet. If now he finds that all magnets have certain other properties, he may accept these properties as sufficient conditions for saying that a given body is a magnet, or at least as evidence that it is a magnet. The situation is akin to saying that a person is angry with someone even before he behaves angrily to that person, or that a person has typhoid fever even before the grosser symptoms which originally identified the disease appear. In all such cases a disposition to a certain later kind of action is attributed to an object or person before the action itself appears because of an empirically found correlation between some earlier state of the object or person and its later action. To say that something is a sign before responses actually take place is a precisely parallel case.

Further Remarks on Sign-Processes

The behavioral formulation of sign-behavior which has been proposed has certain consequences which are worth noting.[13] It avoids, in the first place, the frequent misinterpretation that a sign must itself be a response. Responses may, of course, under certain circumstances be signs but they need not be, and signs need not be responses. For while every sign-process involves a disposition to respond, the sign itself may he any feature of any stimulus-object which acts in the above manner as a preparatory-stimulus; such stimuli are not limited to responses, and only when a response is itself a stimulus of this sort is it a sign.

This approach also avoids the error of those accounts of signs which neglect their relation to the situation in which behavior occurs. Such accounts often imply that the organism responds to the sign alone. But the fact that behavior takes place within a supporting environment implies that the sign alone does not cause the response evoked, since the sign is merely one condition for a response-sequence in the given situation in which it is a sign. The dog upon hearing the buzzer does not seek food wherever it happens to be (though certain components of a food-response – such as salivation – may appear when the buzzer is heard); only if a supporting environment is present will it seek food. If the situation does not support certain responses, then no complete response-sequence of a food behavior-family can take place.

For something to be a sign to an organism requires that the organism be influenced, in the way described, by the presence of that something; it does not require

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[13] Many of the points mentioned in this section are dealt with more fully in the Appendix, “Some Contemporary Analyses of Sign-Processes.”

that the organism signify that the something in question is a sign, for a sign can exist without there being a sign that it is a sign. There can, of course, be signs that something is a sign, and it is possible to signify by some signs what another sign signifies. But this need not take place, and the temptation to attribute such complications to animal, or even to all human, sign phenomena must be constantly avoided.

The proposed formulation also avoids the ambiguity of the frequent attempts to define signs in terms of "appropriate behavior." It is true that the response-sequences prepared by the buzzer are "appropriate" to the goal of securing food in the sense that they are response-sequences of a food behavior-family. It is further true that the buzzer normally will not remain a sign of food if the responses to situations in which buzzers sound do not continue to meet a need, that is, do not obtain food. And yet the question of whether a response-sequence initiated in a situation does in fact reach a certain goal does not enter into the formulation of "sign" itself. The buzzer is a sign if it meets the criteria proposed even if the situation immediately confronting the animal is such that going to the box is inappropriate to the goal of obtaining food, as it would be if such action did not secure food. Since it is obvious that sign-behavior does not in all cases eventuate in appropriate (that is, goal-attaining) responses, it is proper that the general account of signs should not involve the question of the appropriateness of the responses which occur in the situation in which the sign operates.

The proposed formulation also helps to resolve the ambiguities in the various "context" theories of signs. It is true that a sign can be described only by reference to the specific way it functions in specific situations. But since the situation in which the sign appears is generally a very different situation from that in which it does not appear, it is somewhat misleading to suggest that a sign signifies the missing part of a context in which it formerly appeared. The fact that a sign functions as a substitute for an absent something in the control of behavior keeps the "substitutional" emphasis of the context formulations without suggesting that the situations in which the sign does and does not appear are otherwise identical.

Finally, the present account does not depend upon a decision as to how such terms as "habit," "substitute stimulus," and "conditioned response" are to be used. It tries to isolate a certain kind of behavior, sign-behavior (that is, behavior in which signs occur); the relations of sign-behavior to unlearned behavior, habits, substitute stimuli, conditioned responses, implicit responses, antedating responses, pure-stimulus acts, and the like are then further questions to be dealt with by students of the general theory of behavior.

The Basic Terms of Semiotic

It is now possible to isolate the basic terms of semiotic, for such terms will simply refer to various discernible aspects of sign-behavior. The term *sign* has already been introduced, or to speak more exactly, a criterion has been given under which certain things are admitted to be signs – whether in the course of our inquiry other criteria will have to be given to isolate other classes of signs remains for the time being an open question. But we at least are able to say that if something is a preparatory-stimulus of the kind specified in our previous formulation it is a sign. And this is the necessary first step for building a science of signs. For it identifies a subject matter for such a science and permits the introduction of a number of other terms for talking about this subject matter. Such terms can be introduced in a number of ways; we propose the following method of building a language to talk about signs.

Any organism for which something is a sign will be called an *interpreter*. The disposition in an interpreter to respond, because of the sign, by response-sequences of some behavior-family will be called an *interpretant*. Anything which would permit the completion of the response-sequences to which the interpreter is disposed because of a sign will be called a *denotatum* of the sign. A sign will be said to *denote* a denotatum. Those conditions which are such that whatever fulfills them is a denotatum will be called a *significatum* of the sign. A sign will be said to *signify* a significatum; the phrase “to have signification” may be taken as synonymous with “to signify.”

So in the example of the dog, the buzzer is the sign; the dog is the interpreter; the disposition to seek food at a certain place, when caused by the buzzer, is the interpretant; food in the place sought which permits the completion of the response-sequences to which the dog is disposed is a denotatum and is denoted by the buzzer; the condition of being an edible object (perhaps of a certain sort) in a given place is the significatum of the buzzer and is what the buzzer signifies.

In the case of the driver the words spoken to him are signs; the driver is the interpreter; his disposition to respond by avoiding a landslide at a certain place in the road is the interpretant; the landslide at that place is the denotatum; the conditions of being a landslide at that place is the significatum of the spoken words.

According to this usage of terms, while a sign must signify, it may or may not denote. The buzzer can signify to the dog food at a given place without there being food at the place in question, and the landslide signified by the spoken words may not in fact exist. Usually we start with signs which denote and then attempt to formulate the significatum of a sign by observing the properties of denotata. But it is possible at the higher levels of human sign-behavior to determine by decision the significatum of a sign (to “lay down” the conditions under which the sign will denote), and in this case the problem is not what the sign signifies but whether or not it denotes anything. We encounter cases of this nature frequently in the more complex sign-processes.

The relation between interpretant and significatum is worth noting. The interpretant, as a disposition to respond caused by a sign, answers to the behavioral side of the behavior-environment complex; the significatum, as the set of terminal conditions under which the response-sequences to which the organism is disposed can be completed, connects with the environmental side of the complex. Each therefore involves the other. A complete description of the interpretant would include a description of what the organism is disposed to act toward, and a formulation of the significatum is simply a formulation of what would permit the completion of the response to which the organism is disposed because of a sign. The distinction between behavior and environment need not of course coincide with the distinction between the organism and the non-organic world, since an organism can respond to other organisms and to itself. It is because of this that parts of the organism, dreams, feelings, and even interpretants can be signified.

Under the present usage, a sign cannot signify or denote its own interpretant, though it may signify and denote the interpretants of other signs (as in the case of "interpretant" itself). The buzzer does not signify the dog's disposition to respond but signifies food at a given place and time. This usage is not the only possible one, and at no point is the language of semioticians more at variance. A merit of the present usage of "signify" is that it does not make the significatum of every term – such as "spiral nebula" or "atom" – include biological events, though it recognizes that there are no signs which signify without dispositions to respond (that is, without interpretants). And since with this usage a sign does not denote its significatum, the temptation is avoided to make the significatum into a special kind of thing – a temptation which seems to underlie the Platonic doctrine of Ideas and various philosophic doctrines of "subsistence."

The term "meaning" is not here included among the basic terms of semiotic. This term, useful enough at the level of everyday analysis, does not have the precision necessary for scientific analysis. Accounts of meaning usually throw a handful of putty at the target of sign phenomena, while a technical semiotic must provide us with words which are sharpened arrows. "Meaning" signifies any and all phases of sign-processes (the status of being a sign, the interpretant, the fact of denoting, the significatum), and frequently suggests mental and valuational processes as well; hence it is desirable for semiotic to dispense with the term and to introduce special terms for the various factors which "meaning" fails to discriminate.

Since something is a sign, significatum, denotatum, interpreter, or interpretant only with respect to its occurrence in sign-behavior, and since such constituents of sign-processes are studied by other sciences in other connections, the basic terms of semiotic are statable in terms drawn from the biological and physical sciences – a point which will prove to be of central significance for understanding the relation of socio-humanistic studies to the natural sciences. Since the factors operative in sign-processes are all either stimulus-objects or organic dispositions or actual responses, the basic terms of semiotic are all formulable in terms applicable to behavior as it occurs in an environment. Semiotic thus becomes a part of the empirical science of behavior, and can utilize whatever principles and predictions the general theory of behavior has attained or can attain.

The formulation in terms of other signs of what a sign signifies (the description of the conditions which something must fulfill to be a denotatum of the sign) will be called a *formulated significatum.* A formulated significatum is *designative* if it formulates the significatum of an existing sign, and is *prescriptive* if it formulates the significatum which a sign is henceforth to have – a distinction which the commonly employed term "semantic rule" fails to make. A sign may, of course, signify without there being a formulation of what it signifies. A recognition of this simple fact cuts the ground out from under the frequent insinuations that a sign is "without meaning" to a person or animal who cannot "tell what the sign means." For something to signify is a different thing from the often very difficult task of formulating what it signifies.

Semiosis and Semiotic

The Nature of a Sign

The process in which something functions as a sign may be called *semiosis*. This process, in a tradition which goes back to the Greeks, has commonly been regarded as involving three (or four) factors: that which acts as a sign, that which the sign refers to, and that effect on some interpreter in virtue of which the thing in question is a sign to that interpreter. These three components in semiosis may be called, respectively, the *sign vehicle*, the *designatum*, and the *interpretant*; the *interpreter* may be included as a fourth factor. These terms make explicit the factors left undesignated in the common statement that a sign refers to something for someone.

A dog responds by the type of behavior (*I*) involved in the hunting of chipmunks (*D*) to a certain sound (*S*); a traveler prepares himself to deal appropriately (*I*) with the geographical region (*D*) in virtue of the letter (*S*) received from a friend. In such cases *S* is the sign vehicle (and a sign in virtue of its functioning), *D* the designatum, and *I* the interpretant of the interpreter. The most effective characterization of a sign is the following: *S* is a sign of *D* for *I* to the degree that *I* takes account of *D* in virtue of the presence of *S*. Thus in semiosis something takes account of something else mediately, i.e., by means of a third something. Semiosis is accordingly a mediated-taking-account-of. The mediators are *sign vehicles*; the takings-account-of are *interpretants*; the agents of the process are *interpreters*; what is taken account of are *designata*. There are several comments to be made about this formulation.

It should be clear that the terms "sign," "designatum," "interpretant," and "interpreter" involve one another, since they are simply ways of referring to aspects of the process of semiosis. Objects need not be referred to by signs, but there are no designata unless there is such reference; something is a sign only because it is interpreted as a sign of something by some interpreter; a taking-account-of-something is an interpretant only in so far as it is evoked by something functioning as a sign; an object is an interpreter only as it mediately takes account of something. The properties of being a sign, a designatum, an interpreter, or an interpretant are relational properties which things take on by participating in the functional process of semiosis. Semiotic, then, is not concerned with the study of a particular kind of object, but with ordinary objects in so far (and only in so far) as they participate in semiosis. The importance of this point will become progressively clearer.

Signs which refer to the same object need not have the same designata, since that which is taken account of in the object may differ for various interpreters. A sign of an object may, at one theoretical extreme, simply turn the interpreter of the sign upon the object, while at the other extreme it would allow the interpreter to take account of all the characteristics of the object in question in the absence of the object itself. There is thus a potential sign continuum in which with respect to every object or situation all degrees of semiosis may be expressed, and the question as to what the designatum of a sign is in any given situation is the question of what characteristics of the object or situation are actually taken account of in virtue of the presence of the sign vehicle alone.

A sign must have a designatum; yet obviously every sign does not, in fact, refer to an actual existent object. The difficulties which these statements may occasion are only apparent difficulties and need no introduction of a metaphysical realm of "subsistence" for their solution. Since "designatum" is a semiotical term, there cannot be designata without semiosis – but there can be objects without there being semiosis. The designatum of a sign is the kind of object which the sign applies to, i.e., the objects with the properties which the interpreter takes account of through the presence of the sign vehicle. And the taking-account-of may occur without there actually being objects or situations with the characteristics taken account of. This is true even in the case of pointing: one can for certain purposes point without pointing to anything. No contradiction arises in saying that every sign has a designatum but not every sign refers to an actual existent. Where what is referred to actually exists as referred to the object of reference is a *denotatum*. It thus becomes clear that, while every sign has a designatum, not every sign has a denotatum. A designatum is not a thing, but a kind of object or class of objects – and a class may have many members, or one member, or no members. The denotata are the members of the class. This distinction makes explicable the fact that one may reach in the icebox for an apple that is not there and make preparations for living on an island that may never have existed or has long since disappeared beneath the sea.

As a last comment on the definition of sign, it should be noted that the general theory of signs need not commit itself to any specific theory of what is involved in taking account of something through the use of a sign. Indeed, it may be possible to take "mediated-taking-account-of" as the single primitive term for the axiomatic development of semiotic. Nevertheless, the account which has been given lends itself to treatment from the point of view of behavioristics, and this point of view will be adopted in what follows. This interpretation of the definition of sign is not, however, necessary. It is adopted here because such a point of view has in some form or other (though not in the form of Watsonian behaviorism) become widespread among psychologists, and because many of the difficulties which the history of semiotic reveals seem to be due to the fact that through most of its history semiotic linked itself with the faculty and introspective psychologies. From the point of view of behavioristics, to take account of *D* by the presence of *S* involves responding to *D* in virtue of a response to *S*. As will be made clear later; it is not necessary to deny "private experiences" of the process of semiosis or of other processes, but it is necessary from the standpoint of behavioristics to deny that such experiences are of central importance or that the fact of their existence makes the objective study of semiosis (and hence of sign, designatum, and interpretant) impossible or even incomplete.

Dimensions and Levels of Semiosis

In terms of the three correlates (sign vehicle, designatum, interpreter) of the triadic relation of semiosis, a number of other dyadic relations may be abstracted for study. One may study the relations of signs to the objects to which the signs are applicable. This relation will be called the *semantical dimension of semiosis*, symbolized by the sign "D_{sem}"; the study of this dimension will be called *semantics*. Or the subject of study may be the relation of signs to interpreters. This relation will be called the *pragmatical dimension of semiosis*, symbolized by "D_p," and the study of this dimension will be named *pragmatics*.

One important relation of signs has not yet been introduced: the formal relation of signs to one another. This relationship was not, in the preceding account, explicitly incorporated in the definition of "sign," since current usage would not seem to eliminate the possibility of applying the term "sign" to something which was not a member of a system of signs – such possibilities are suggested by the sign aspects of perception and by various apparently isolated mnemonic and signaling devices.

Nevertheless, the interpretation of these cases is not perfectly clear, and it is very difficult to be sure that there is such a thing as an isolated sign. Certainly, potentially, if not actually, every sign has relations to other signs, for what it is that the sign prepares the interpreter to take account of can only be *stated* in terms of other signs. It is true that this statement need not be made, but it is always in principle capable of being made, and when made relates the sign in question to other signs. Since most signs are clearly related to other signs, since many apparent cases of isolated signs prove on analysis not to be such, and since all signs are potentially if not actually related to other signs, it is well to make a third dimension of semiosis co-ordinate with the other two which have been mentioned. This third dimension will be called the *syntactical dimension of semiosis*, symbolized by "D_{sym}" and the study of this dimension will be named *syntactics*.

It will be convenient to have special terms to designate certain of the relations of signs to signs, to objects, and to interpreters. "Implicates" will be restricted to D_{sym}, "designates" and "denotes" to D_{sem}, and "expresses" to D_p. The word "table" implicates (but does *not* designate) "furniture with a horizontal top on which things may be placed," designates a certain kind of object (furniture with a horizontal top on which things may be placed), denotes the objects to which it is applicable, and expresses its interpreter. In any given case certain of the dimensions may actually or practically vanish: a sign may not have syntactical relations to other signs and so its actual implication becomes null; or it may have implication and yet denote no object; or it may have implication and yet no actual interpreter and so no expression – as in the case of a word in a dead language. Even in such possible cases the terms chosen are convenient to refer to the fact that certain of the possible relations remain unrealized.

It is very important to distinguish between the relations which a given sign sustains and the signs used in talking about such relations-the full recognition of this is perhaps the most important general practical application of semiotic. The functioning of signs is, in general, a way in which certain existences take account of other existences through an intermediate class of existences.

A sign is *reliable* to the degree that the members of the sign-family to which it belongs denote; otherwise *unreliable*. The degree of reliability (and so the degree of unreliability) of a sign is capable of quantitative formulation. If the dog obtained food 90 per cent of the times the buzzer sounded, the buzzer sign is 90 per cent reliable; such a statement would not of course insure that the degree of reliability of the sign would continue unchanged in the future. A sign is *iconic* to the extent to which it itself has the properties of its denotata; otherwise it is *non-iconic*. A portrait of a person is to a considerable extent iconic, but is not completely so since the painted canvas does not have the texture of the skin, or the capacities for speech and motion, which the person portrayed has. The motion picture is more iconic, but again not completely so. A completely iconic sign would always denote, since it would itself be a denotatum. A sign which is to some extent iconic may itself have properties which are not iconic and which are not relevant to its signification. One of the dangers of the use of models in science, for instance, arises out of the temptation to ascribe to the subject matter of a theory properties of the model illustrating the theory which are not involved in the theory itself.[14]

The terms which have been introduced in this section constitute only a portion of the terms which students of signs must employ. While a more precise formulation of these terms can no doubt be given, and would be desirable, the present analysis may serve to show that a behavioral formulation of the basic terms of semiotic provides a foundation for the introduction of such other terms as the science of signs finds necessary. This suggests that a behavioral semiotic is comprehensive enough to incorporate the distinctions now current in sign-analysis. The fear that such an approach might be too simple to deal with the complexities of sign phenomena is in this way mitigated.

Signal and Symbol

Various other distinctions between signs will appear throughout our discussion, but there is one basic distinction in the literature of semiotic which warrants consideration now: the difference between signal and symbol. Later we will discuss the way logicians and philosophers have tried to make the distinction in question; for the moment we will begin with the distinction as it has presented itself to students of behavior. A frequent terminology for the difference is "sign" and "symbol," but since we regard both the distinguished items as signs, the terminology chosen will be "signal" and "symbol."[15]

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[14] For a striking illustration see James K. Senior, "On Certain Relations Between Chemistry and Geometry," *Journal of Chemical Education*, 15, 1938, 464–470.

[15] Husserl, Gätschenberger, Dewey, Mead, Langer, Kecskemeti, Ogden and Richards, Pavlov, Hunter, Yerkes, Korzybski, Whetnall and many others operate with some such distinction, some contrasting "sign" and "symbol," while some contrast "signal" and "symbol." The bases for the distinction differ widely.

Robert M. Yerkes remarks as follows:[16] “Not rarely sign and symbol are used as synonymous. I wish to propose differing meanings... Whereas the sign is an experience-act which implies and requires as its justification in terms of utility a succeeding experience-act, the symbol has no such implication and is an experience-act which represents or may function instead of whatever is represented. The sign sooner or later loses its meaning apart from its context; the symbol does not. The sign is not a substitute for the original experience-act, whereas the symbol may be.” The buzzer in our example of the dog would presumably be regarded by Yerkes and certain other students of animal behavior as a sign (that is, signal), whereas if the buzzer stopped sounding before the animal was allowed to seek food (that is, if its response were delayed) such persons would seem to be saying that something else must in the interval act as a substitute for the buzzer if food behavior is later to be called out, and such a substitute would be a symbol. This distinction was made by W. H. Hunter to explain the results of his experiments on delayed reactions.

While it is highly doubtful that all delayed responses need explanation by the introduction of a special class of signs (since a delay in response is compatible with our general description of signs), there is no doubt but that Yerkes is calling attention to differences in sign-processes which are behaviorally recognizable and deserve a name. Suppose that the buzzer produced in the dog some response which then functioned as a sign for food at the given place without the buzzer sounding, then such a “response-sign” would have certain distinctive characteristics – in virtue of the fact that it is relatively independent of the environment and is a substitute for another sign with which it is synonymous. At the language level examples are more easily recognizable. If the driver in the car had been told to turn to the right at the third intersection, he might have held up three fingers of his right hand until he reached the intersection in question, or might have continued repeating the instructions to himself; such action on his part would be a sign to him signifying what the original spoken words signified, and such a sign would guide his behavior in the absence of the spoken signs.

Generalization from such examples suggests the following distinction: Where an organism provides itself with a sign which is a substitute in the control of its behavior for another sign, signifying what the sign for which it is a substitute signifies, then this sign is a *symbol*, and the sign-process is a *symbol-process*; where this is not the case the sign is a *signal*, and the sign-process is a *signal-process*. More succinctly, a symbol is a sign produced by its interpreter which acts as a substitute for some other sign with which it is synonymous; all signs not symbols are signals.

The advantage of such symbols is found in the fact that they may occur in the absence of signals provided by the environment; an action or state of the interpreter itself becomes (or produces) a sign guiding behavior with respect to the environment. So if a symbol operates in the dog’s behavior, the symbol could take the place in the control of behavior which the buzzer formerly exercised: hunger cramps for instance might themselves come to be a sign (that is, a symbol) of food at the

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[16] Chimpanzees, a Laboratory colony, p. 177.

customary place. The relative independence of such signs from signals provided by the environment has, however, as its reverse pole certain disadvantages: symbols are especially unreliable. In the experiment the conditions of the environment were such that food normally was found at a certain place when the buzzer sounded, but not otherwise; it is more unlikely that the environment would be such that food would be in the given place when and only when the animal was hungry. This suggests that the connection between symbols and signals is more intimate than Yerkes' words imply; while it is true that the symbol may perhaps persist as a sign longer than the signal which is not accompanied or followed by a denotatum, the fact that a symbol is ultimately a substitute for a signal means that it too is normally subject in its genesis and its continuance upon its capacity to lead to behavior which on the whole attains goal-objects.

The recognition that a symbol requires an action or state of the organism which provides a substitute sign synonymous with another sign avoids a number of possible confusions. Not all states or actions of an organism which are signs or produce signs are thereby symbols. A person may interpret his pulse as a sign of his heart condition or certain sensations as a sign that he needs food; such signs are simply signals; his resulting words – when substitutes for such signals – would however be symbols. Nor are all sounds uttered by a person or by others symbols even when they are signs: sounds too may be simply signals. Further, the symbol need not itself be an action or state of the organism though it is produced by such an action or state: the written record of a conversation, as a substitute sign for spoken words, is still a symbol though it exists, as written, in the physical environment of the organism. Finally, not all signs produced by an organism by its action on the environment are symbols: the cat which pushes a button which lights a bulb and thus provides itself with the customary sign of food has produced a signal but not necessarily a symbol since the light need not itself be a substitute for another sign.[17]

Doubt may be raised whether the term "symbol" should be used for the kind of sign-behavior which we have isolated. It may be objected that religious symbols, such as a cross, or literary symbols, such as a "golden bowl" symbolizing life, or social symbols, such as representations of a totemic animal, are not symbols in the sense defined. It must be granted that the proposed use of the term is at variance with some common usages, but we have seen that a terminology for semiotic can be expected to show such variance. In the cases in question, however, it is doubtful if the disagreement is in fact great. The cross and the figure of the totemic animal are to be sure iconic, but iconic symbols are admissible on our account as one subclass of symbols. And a particular cross or a particular carved animal may well be substitutes for objects that were themselves signs – the original cross signifying (at the minimum) the crucifixion of Christ and the living animals signifying something about the persons for whom they were signs. The words "golden bowl," as a literary

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[17] The example is from Jules Masserman, *Behavior and Neurosis*, p. 59. It might of course be the case that the light was a substitute for a more primitive sign, such as the sight of the food box used in the experiment. But since in this case the animal only obtained food when the light was on, the sight of the box was not itself a sign of food.

symbol for the fragility of life, are even more clearly substitutes for an actual or imagined bowl, delicate and beautiful but with a fatal flaw, which to Henry James had already taken on the status of an iconic sign; the words themselves are in this case not iconic. So the proposed usage does not in fact seem to violate religious, anthropological, and literary usages. While a symbol may be iconic it is not always required to be such even in nontechnical usages, but it is very commonly regarded as something which is a substitute for other signs and producible by its interpreters.

A more positive argument for allowing "symbol" to mark one pole of the intended distinction can be given in virtue of the claim often made that symbols are more "autonomous" and "conventional" than signals. The proposed usage embodies and explicates this claim. The symbol is "autonomous" in the sense already discussed: since it is produced by its interpreter it may appear under a great variety of environmental circumstances and is to this extent independent of any particular external environment. And the symbol is "conventional" in the sense that no limit is set upon the actions and states and products of the organism that may operate as synonymous signs substituting for other signs. Symbols may, and indeed do, vary widely from one individual to another or from one society to another. The possibility of this variability is explained in our account without the overtones of a "convention" where it is "decided" what is to be used as a symbol. For the distinction we have drawn involves no reference to a voluntary decision in the producer of a symbol; such decisions may of course occur in the case of symbols but they are not necessarily involved in the determination of what is a symbol.

Signs which are substitutes for synonymous signs frequently occur at the more complex levels of sign phenomena. Such signs seem to be appropriately called symbols. But whatever term be used, the distinction in question is of basic importance for the development of semiotic and for the understanding of human sign-behavior.

Alternatives to a Behavioral Semiotic

Some readers must feel strongly that we have "left something out," and perhaps something central to a theory of signs, namely the "ideas" or "thoughts" which the sign causes in its interpreter. At a number of places in our account we will return to this issue; here we must be content to isolate the underlying problem.

It is true that the preceding account has completely and deliberately avoided all use of "mentalistic" terms in building the terminology of semiotic. And it is also true that the mentalistic approach has dominated the history of semiotic and still seems to many thinkers to be a preferable alternative to the approach here developed.

The defense of a behavioral semiotic must not be misunderstood. We have not contended, and do not believe, that such terms as "idea," "thought," "consciousness," and "mind" are "meaningless." Nor have we in any sense denied that an individual can observe his feelings, or his thoughts, or his dreams, or his signs in a way not possible to other individuals. Our purpose is simply to advance semiotic as a science, and it is this purpose alone which determines what basic terms are to be accepted for building the terminology of semiotic. The issue is not between "mentalism" and "behaviorism," but is solely a methodological problem: are such terms as "idea," "thought," "mind" more or less precise, interpersonal, and unambiguous than such terms as "organism," "stimulus," "response-sequence" and "disposition to response"? In choosing the latter terms, we but express the belief that they are the more suitable for scientific advance.

Suppose, for instance, the mentalist should argue – as he often does that for something to be a sign to some interpreter it must give rise to an "idea" in his mind, must cause him to "think" of something else. On this frequent manner of speaking, the buzzer is a sign to the dog only if it causes an idea or thought of food at a certain place. A person who approaches signs behaviorally (biologically) does not have to reply that the dog does not have ideas or thoughts, but merely to ask for the conditions under which we will affirm that the buzzer occasions an idea or thought in the dog. Unless the mentalist furnishes a criterion such that other persons may employ it to test whether the dog has or has not an idea there is no way to determine the precision, interpersonality, or unambiguity of the term. Hence there is no way to control by observation statements made about the signs of the dog; and this means that no science of signs is possible. If the mentalist does propose a criterion meeting these requirements, it will always be found, I believe, that the criterion is couched in terms of biological states or actions of the dog – though it may be claimed that these are only "evidence" that the dog has an idea. But if this is so, the only scientifically relevant part of the claim that the buzzer is a sign to the dog is the part couched in biological terms. Hence semiotic as a science gains nothing by the introduction of mentalistic terms in its primitive terms, for insofar as these terms are not synonymous with behavioral terms they prove to be scientifically irrelevant.

This outcome would not be avoided by proposing to limit semiotic to beings capable of self-observation and capable of reporting on such observations. For the problem of determining whether another person has an idea is not methodologically different from determining whether a dog has an idea. True, the other person may utter the words, "The buzzer makes me think of food at a certain place." But these words are themselves physical sounds uttered by a biological organism, and while they may rightly be used even on our approach as evidence that the buzzer is a sign, the reliability of this evidence can only be checked if we are in possession of some criterion to determine whether the buzzer is or is not a sign of food at a given place. Since the behavioral approach gives this criterion and the mentalistic approach does not, a mentalistic semiotic is not an alternative to a behavioral semiotic even at the level of human beings.

It must be repeated that this does not mean that dogs and persons do not have ideas. A reader can, if he wishes, say to himself that in all sign-behavior which we discuss there occur ideas which we do not and cannot mention. The only point is that if he does this he cannot also say that our account is scientifically inadequate, for terms whose reliability cannot be checked by observation cannot appear in any science, behavioral or otherwise. Whether they occur somewhere else is not a problem relevant to the scientific enterprise. Therefore we conclude that mentalism provides no alternative to a behavioral semiotic if the goal of semiotic is to become a science.

It is however possible that the behavioral approach does not in fact "leave out" anything. It may well be that the main function served by the introduction of "idea" into the criterion for a sign was to permit us to say that something may be a sign to someone even when no overt behavior occurs. This function is served in our account by the term "interpretant," conceived as a disposition to respond in certain ways under certain circumstances. To the extent that this is so, "idea" and "interpretant" may in fact be synonymous signs. And this opens the possibility that all "mentalist" terms may turn out to be incorporable within a behavioral semiotic. Since it is hard to see how the reverse situation is possible, the behavioral approach to signs shows itself once more to be strategically strong.

Does the "phenomenological description" of sign-processes furnish another alternative to a behavioral semiotic? I think not. For in a wide sense of "phenomenological" a behavioral semiotic is phenomenological since it includes a description of observed behavior; and a narrower use of the term (the description by an individual of his own sign-processes) is covered by our admission of self-observation, an admission which is compatible with either a behavioral or a mentalistic psychology, and so does not decide between them. A human being may for instance describe his "experience" in connection with a sign – his feelings, his ideas, his expectations – and may compare in these terms the different signs which we have distinguished and will distinguish.? The resulting reports are reports by an interpreter on his own sign-processes, and give us certain data about these processes which we do not possess in the case of animals unable to report the results of their self-observation. But reports of self-observation in which, say, the term "idea" is used do not themselves determine whether "idea" is synonymous with "observation by an interpreter of his interpretant," that is, observation of his disposition to respond in such and such a way. Some "phenomenologists" might very well report that this is the case. So a phenomenological description of sign-processes, whether in the wider or narrow sense of "phenomenological," does not in itself negate or provide an alternative to a behavioral semiotic. Such a semiotic is able to include reports by interpreters on their sign-behavior and yet can deal with sign-behavior in animals, children, and adults where such reports are not available or not reliable.

While we admit the right of various persons to approach signs in any way they see fit, we see no evidence that mentalism or phenomenology provide alternatives to a behavioral semiotic concerned solely with the development of an empirical science of signs.

The Mentalistic Controversy Resumed

The distinction which has been made between signal and symbol has remained within the context of behavioristics. Signals and symbols are alike signs in that they are preparatory-stimuli controlling behavior with respect to other stimuli; the symbol is a sign producible by the organism itself and a substitute for some other sign, but this difference, while distinguishing signal and symbol, is not regarded as a fundamental difference in their nature as signs. Such a view has, however, frequently been denied, and often mentalistic terms ("concept," "idea," "meaning") have been invoked to account for the difference in question, The discussion is often connected with the view that the distinction between signal and symbol answers to the difference between animals and humans, men having "symbols" in addition to signals because of their "minds." To discuss this issue is a convenient way of raising again the mentalist-behavioral controversy and at the same time of elucidating somewhat more fully the relation of signals and symbols, whether they be pre-language, language, or post-language signs. Susanne Langer's formulation provides a point of departure:

> A sign [that is, a signal] indicates the existence – past, present, or future-of a thing, event, or condition. Wet streets are a sign that it has rained. A patter on the roof is a sign that it is raining. A fall of the barometer or a ring around the moon is a sign that it is going to rain. . . .A whistle means that the train is about to start. . . . A crepe on the door means someone has just died.[18] . . . A term which is used symbolically and not signally does *not* evoke action appropriate to the presence of its object. If I say: "Napoleon," you do not bow to the conqueror of Europe as though I had introduced him, but merely think of him. If I mention a Mr. Smith of our common acquaintance, you may be led to tell me something about him "behind his back," which is just what you would *not* do in his presence... Symbols are not proxy for their objects, but are *vehicles for the conception of objects*. To conceive a thing or a situation is not the same thing as to "react toward it" overtly, or to be aware of its presence. In talking *about* things we have conceptions of them, not the things themselves; *and it is the conceptions, not the things, that symbols directly "mean."* [19]

Signals, on this view, "*announce* their objects," while symbols lead their interpreters to "*conceive* their objects."[20] How is this difference to be explained on the behavioral approach?[21] One relevant point lies in the fact that a symbol is on the whole a less reliable sign than is a signal, since it is producible by the organism and hence may appear, when the organism has a certain need, in situations in which what is signified is not present. The signal being more closely connected with external relations in the environment is more quickly subject to corrections by the environment and hence tends to be more reliable, that is, to lose its sign status when the unreliability becomes rather great. Hence signals do on the whole "indicate existence" more certainly than do symbols. But since signals too have varying degrees of reliability, the difference remains one of degree.

A second difference is connected with the fact – later to be dealt with more fully – that signs become specialized in the extent to which they indicate an environment and to the extent to which they characterize the environment. Certain

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[18] [Philosophy in a New Key, pp. 57–58.]

[19] [Ibid., pp. 60–61]

[20] [Ibid., p. 61]

[21] John Dewey makes a similar distinction, though his explanation of the difference is not put in terms of concepts but in terms of language: signs are "*evidence* of the existence of something else" while a symbol is "a meaning carried by language in a system" (*Logic: The Theory of Inquiry*, pp. 51–52).

signs, and especially certain kinds of language symbols, attain high generality in their characterizing component and lose the specificity of indication which signals frequently have. If a person merely hears someone say "rain," the indication of whether it is raining now or has rained or will rain, or whether the person speaking is referring to all instances of rain, is absent in a way it is not if one hears the patter of rain – and hence the "evidential" value of the term "rain" is relatively slight.

Connected with these two points is a third: when a sign is not reliable and not specific in indication, behavior is naturally hesitant. If the interpreter has other signs at his disposal, as in the case of beings with a language, he may under these conditions pay attention to the sign in question, attempt to formulate its signification, raise questions as to its reliability, assess the bearings of this reliability upon whatever goals he may have, and even make observations upon his own disposition to respond which is produced by the appearance of the sign. And since signs are used for many purposes other than description and prediction, signs low in reliability may still be attended to, produced, and cherished – as in the case of a work of fiction. There results in these ways the great difference between signals at one extreme and symbols at another, but again there is no reason to regard the difference as transcending a behavioral formulation.

And finally, and of greatest importance, is the fact which we have tried consistently to stress: whether a sign does or does not lead to overt behavior depends upon whether or not certain conditions of motivation and environment are fulfilled. The person who hears a patter on the roof need no more act as he would if he were out in the rain than a person who hears the word "Napoleon" need act as he would if he were in the presence of Napoleon. Both signals and symbols involve dispositions to response and both alike may or may not occur in situations in which one acts as he is disposed to act. The difference is not between "announcing" an object in the case of signals and of "conceiving" an object in the case of symbols, but in the degree of absence or presence of the supporting conditions under which dispositions to behavior issue in overt behavior.

Such are at least some of the directions in which a behaviorally oriented semiotic may seek to explain in its terms the phenomena which have led others to claim that symbols (especially language symbols) and signals are so different that they should not both be called signs. It is hard to see what is added by invoking "concepts" as a principle of differentiation. Unless the term "concept" (or "idea" or "meaning") is itself so defined that one can tell when concepts are or are not present, the term offers no help to semiotic. It is more promising to start with an objective approach and then to correlate if possible results so obtained with the reports of self-observation concerning the presence of concepts. It may turn out that concepts are claimed to be present when signs of a certain kind are operative (perhaps general symbols); then the question would arise whether concepts might not be identified with the interpretants of such signs (and so become a special class of "ideas" if ideas were equated with interpretants). The self-observation of concepts (and ideas) would then be the observation by an organism of certain features of its sign-behavior. But these again are matters for the psychologist to decide, and not obstacles for the semiotician, nor arguments against a terminology which embraces signals and symbols as subclasses of signs, nor principles for the explanation of the differences between signals and symbols.

Signs in Animals and Men

Once there is an agreement upon the signification of such terms as “signal,” “symbol,” and “language,” the comparison of non-human and human sign-behavior is an empirical problem falling within descriptive semiotic. As such it is a specific scientific problem, and its answer is to be given by the scientific student of behavior. Without attempting such an answer here, we may notice how the problem looks in terms of the general framework which has been developed. If it is evident that sign-processes at the level of human behavior presuppose and grow out of such sign-processes as occur in animals, it is also evident that human behavior shows an amazingly complex refinement and proliferation of signs beyond that of any other known organism. If there is continuity in some respects, there are also impressive differences in other respects. The difficulty is in doing justice to both sets of facts.

The problem is how to distinguish animal sign-behavior from that of man. Here there are two possibilities: one is to insist that the difference is solely a matter of degree; the other is to insist that there is some unique characteristic of human signs not found elsewhere in the animal world. The first tendency is most prominent in the students of animal behavior since they are aware of the complexity of such behavior; the second is most prominent in the students of the social sciences and the humanities, since they are impressed with the unique place of signs in the subject matters with which they deal. Hence the frequent result that some student of man proposes a unique differentiation of human signs which the student of animal behavior then seeks to show is manifested in at least an embryonic form in the animal world.

There have been many proposals for a unique differentiation of human signs: men have symbols while animals have only signals; men alone have signs of signs; human beings are unique in the transmission of signs by social heredity; human beings use signs voluntarily while animals do not; animal signs occur only in perception while human beings are capable of inferences based on signs; men alone become interested in signs as goal-objects; men alone have language. The critic of such proposals denies that a sharp differentiation has been found and seeks to supply evidence for attributing the claimed characteristic to non-human animals. He need not, and usually does not, deny that these characteristics are found in an extreme degree in the signs in human behavior. That social heredity, for instance, plays a vastly more important role in the transmission of human signs than it does in animals, or that men operate at higher levels of signs than animals do, is in fact not in doubt. The question in each case is merely whether one can say: Here is a unique characteristic of human signs not shared by the signs of any other animal. And certainly most proponents of such characteristics have not convincingly made their case.

All such discussions usually culminate in the question as to whether language is unique to man. Here the issue is in part terminological, since if "language" is made synonymous with "communication" there is no doubt that animals have language; or if only some of the criteria which are incorporated in the preceding definition of language are insisted upon (or different criteria), then too there may be no doubt about the existence of animal language. But if the full proposed definition is accepted, I know of no convincing evidence that any animals other than men have either a signal or a symbol language, though it is to be insisted that the problem is an empirical one and not to be dogmatically resolved. That animal signs at times occur in social acts, that animal signs are often interpersonal and plurisituational, that an animal may itself occasionally produce the sign which it interprets, that some symbols occur in animal behavior does not seem to be in doubt. And yet these facts are not themselves sufficient conditions for attributing language to animals.

The fact that a sign is plurisituational and interpersonal does not make it a language sign, nor does the mere addition of the fact that the sign is produced by an organism. It is further essential that the sign have the same signification to the producers of the sign when produced by them that it has when produced by other organisms, that is, that it be a comsign; and it is by no means clear that this condition is fulfilled in sub-human sign-behavior. Hence even if only the first four of our criteria for a language sign were accepted as a definition, it still remains to be shown that these conditions are all jointly met in living beings other than men. But even if these conditions were met, the fifth requirement is a harder hurdle. For though animal signs may be interconnected, and interconnected in such a way that animals may be said to infer, there is no evidence that these signs are combined by animals which produce them according to limitations of combination necessary for the signs to form a language system. Such considerations strongly favor the hypothesis that language – as here defined – is unique to man.[22]

Even if empirical evidence, possibly gained by novel experimentation, should modify this hypothesis, it is not likely to refute the view that man is characteristically the linguistic animal. And certainly no other animal transmits to such degree its signs by social heredity, attains signs so highly independent of particular situations,

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[22] This is the commonly held view. See A. L. Kroeber, "Sub-Human Culture Beginnings" (*Quarterly Review of Biology*, 3, 1928, 325–342); J. A. Bierens de Haan, "Langue humaine; langage animal" (*Scientia*, 55, 1934, 40–49); Robert M. Yerkes, *Chimpanzees: a Laboratory Colony*. Yerkes differs from Kroeber in believing that there is some evidence of slight cultural heredity in chimpanzees, but agrees that "there is no single system of signs-vocal, gestural, or postural-which may properly be called a chimpanzee language" (op. cit., p. 51). Alfred E. Emerson links language and social heredity as giving the unique features of man: "Instead of the usual mechanism of heredity through genic patterns in the chromosomes which determines relatively stereotyped development by means of enzyme chains, the human species is the only organism which has developed a substitute mechanism for such biological heredity... The development of human social heredity through learned language symbols is of such importance that this human attribute would seem to indicate the valid division line between the social and the biological sciences. It is what the sociologist means when he says that man is unique in the possession of a culture" ("Biological Sociology," *Denison University Bulletin, Journal of the Scientific Laboratories*, 36, 1941, 148–149).

employs symbols to such an overwhelming extent, uses signs (voluntarily and involuntarily) for so many purposes, is so attentive to its signs as signs, passes to such high levels of sign-behavior, performs such complex inferences via signs, or so often makes of signs themselves goal-objects. In all these ways, human language (and the post-language symbols it makes possible) goes vastly beyond the sign-behavior of animals. But language-behavior is still sign-behavior, and language signs rest upon, and never completely take the place of, the simpler signs which they presuppose. The continuity is as real as the discontinuity, and the similarity of human and animal signs-behavior as genuine as the difference.

The present approach thus sharpens, though it does not itself solve, the empirical problem as to the relation of sub-human and human sign-behavior. By refining the terminological apparatus of semiotic and formulating such terms behaviorally, it leads to a more precise statement of the general problem, namely: which kind of signs (signals, symbols, comsignals, comsymbols, language signals, language symbols, and post-language symbols) appear in which organisms' behavior, and what are the evolutionary and genetic relations between the signs which do appear?[23] It is easy (and perhaps correct) to say that signals rather than symbols predominate in animal behavior and that language signs (and post-language symbols) are mainly, and perhaps exclusively, human attainments. But there are a vast number of sign-processes which bridge the gap between these extremes and which presumably serve to connect in evolutionary terms sub-human and human sign-behavior. It is these intermediary sign-processes (symbols, comsigns, etc.) to which attention is here called and about which further knowledge is needed. Some of this knowledge can be gained from existing literature; much of it must be the product of specially designed experimentation. As it is obtained the account of biological evolution will be greatly and significantly enriched.

The Scope and Import of Semiotic: Pragmatics, Semantics, and Syntactics

We have now surveyed the range of material with which a science of signs must deal. There remains only the task of bringing to a sharper focus the scope of this science and of indicating its theoretical and practical importance.

Those readers who are familiar with the literatur e of semiotic may have been surprised that the terms "pragmatics," "semantics," and "syntactics" – so widely

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[23] One central problem here is whether sub-human animals have symbols (as distinguished from signals). References to symbols are common in the literature about sub-human animals, especially in discussions of delayed reactions (see the summary of the work of Nissen, Riesen, Crawford and others in R. M. Yerkes, *Chimpanzee: a Laboratory Colony*, Chapter 10 ("Language and Symbolism")). But J. F. Markey (*The Symbolic Process*, p. 112) is skeptical about there being any symbolic behavior which is not social-vocal in origin; and Hull and the gestaltists give other and divergent interpretations of the delayed reaction experiments from those in terms of symbolic processes. Part of the differences lies in different uses of the term "symbol". All accounts agree that symbolic processes (if they occur at all) are very infrequent in animals as compared with men.

current in this literature – have not figured in our account. Their absence up to this point has, however, been deliberate. These terms have already taken on an ambiguity which threatens to cloud rather than illumine the problems of this field, being used by some writers to designate subdivisions of semiotic itself and by others to designate kinds of signs in the object languages with which semiotic deals. Otto Neurath warned years ago that these terms would engender pseudo-problems and distract attention from genuine problems; the course of events has proved in part the legitimacy of his fears. Yet these terms, if carefully introduced, serve to mark the scope and subdivisions of semiotic, and may now be added to our terminology.

In *Foundations of the Theory of Signs* (p. 6), the three terms in question were defined as follows: *pragmatics* as the study of "the relation of signs to interpreters," *semantics* as the study of "the relations of signs to the objects to which the signs are applicable," *syntactics* as the study of "the formal relations of signs to one another." Later analysis has shown that these definitions need refinement. Even as they stand, however, they give no warrant for their utilization as a classification of kinds of signs ("pragmatical signs," "semantical signs," "syntactical signs"); such extension of their signification is questionable, since it may blur the distinction between signs in various modes of signifying and the signs which make up pragmatics, semantics, and syntactics conceived as the three divisions of semiotic. Hence we shall not employ such an expression as "syntactical sign," since doubt can then arise whether it designates a kind of sign (say, formators) or a sign within the part of semiotic distinguished as syntactics.[24] The terms "pragmatics," "semantics," and "syntactics" need clarification, however, even when restricted to differentiations of the field of semiotic.

Carnap formulates these distinctions in the following way:

> If we are analyzing a language, then we are concerned, of course, with expressions. But we need not necessarily also deal with speakers and designata. Although these factors are present whenever language is used, we may abstract from one or both of them in what we intend to say about the language in question. Accordingly, we distinguish three fields of investigation of languages. If in an investigation explicit reference is made to the speaker, or, to put it in more general terms, to the user of a language, then we assign it to the field of pragmatics. (Whether in this case reference to designata is made or not makes no difference for this classification.) If we abstract from the user of the language and analyze only the expressions and their designata, we are in the, field of semantics. And if, finally, we abstract from the designata also and analyze only the relations between the expressions, we are in (logical) syntax. The whole science of language, consisting of the three parts mentioned, is called semiotic. (*Introduction to Semantics*, p. 9.)

In terms of the approach of the present study, the indicated division of the fields of semiotic needs certain further alterations: the restriction of semiotic to a study of

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[24] A. Kaplan and H. Reichenbach have, among others, used such terms as "pragmatical sign." This extension, which I regard as unwise, is perhaps in part due to my *Foundations of the Theory of Signs*. For in this work a distinction was made between the pragmatical, semantical, and syntactical "dimensions" of sign-processes themselves; this, coupled with the fact that that work did not sufficiently distinguish the modes of signifying nor the difference between the signification and use of signs, might suggest such expressions as "pragmatical sign" and "syntactical sign" – expressions which the present analysis avoids.

language must be removed, the study of the structure of languages other than the scientific must be made possible, other modes of signification than the designative must be dealt with in semantics, and this in turn requires some modification of the formulation of pragmatics.

The following. definitions retain the essential features of the prevailing classification, while freeing it from certain restrictions and ambiguities: *pragmatics* is that portion of semiotic which deals with the origin, uses, and effects of signs within the behavior in which they occur; *semantics* deals with the signification of signs in all modes of signifying; *syntactics* deals with combinations of signs without regard for their specific significations or their relation to the behavior in which they occur.

When so conceived, pragmatics, semantics, and syntactics are all interpretable within a behaviorally oriented semiotic, syntactics studying the ways in which signs are combined, semantics studying the signification of signs, and so the interpretant behavior without which there is no signification, pragmatics studying the origin, uses, and effects of signs within the total behavior of the interpreters of signs. The difference lies not in the presence or absence of behavior but in the sector of behavior under consideration. The full account of signs will involve all three considerations. It is legitimate and often convenient to speak of a particular semiotical investigation as falling within pragmatics, semantics, or syntactics. Nevertheless, in general it is more important to keep in mind the field of semiotic as a whole, and to bring to bear upon specific problems all that is relevant to their solution. The present study has deliberately preferred to emphasize the unity of semiotic rather than break each problem into its pragmatical, semantical, and syntactical components.

There is another current distinction which offers no difficulty in terms of this analysis: the distinction between *pure* and *descriptive* semiotic.

This distinction simply marks the difference between the formative discourse of semiotic and its designative discourse, that is, the difference between semiotic as logic and semiotic as scientific discourse. Semiotic, as a language to talk scientifically about signs, will have its own formative ascriptors (such as "Every sign has an interpretant") and such ascriptors belong to logic; it will also consist of designative ascriptors (such as statements as to what signs signify to certain persons, how signs are combined in a specific language, the origin uses and effects of specific signs), and such ascriptors constitute semiotics a natural science. This distinction applies to each of the subdivisions of semiotic: hence we can distinguish pure and descriptive pragmatics, pure and descriptive semantics, pure and descriptive syntactics.[25] The application of semiotic as an instrument may be called *applied semiotic*.

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[25] R. Carnap makes the distinctions in the case of syntactics and semantics but not with respect to pragmatics; thus on p. 6 of his *Foundations of Logic and Mathematics* he writes that "pragmatics is an empirical discipline." But in pragmatics too we can distinguish between formative and lexicative ascriptors, and so generalize the distinction between pure and descriptive semiotic. The present volume neglects in the main the important work which has been done in syntactics; see Carnap's *Logical Syntax of Language*, and *The Formalization of Logic*. On our position, any kind of discourse can be studied syntactically. Hence syntactics includes Carnap's "logical syntax" as the pure syntactics of the language of science. By the same token any type of discourse (such as mathematical discourse) can be studied semantically.

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Chapter 5

Excerpts from *Universe of the Mind: A Semiotic Theory of Culture*

Juri Mikhajlovič Lotman (1922–1993)

Introduction and Commentary: Juri Mikhajlovič Lotman

> *Modern science from nuclear physics to linguistics sees the scientist as inside the world being described and as a part of that world. But the object and the observer are, as a rule, described in different languages, and consequently, the problem of translation is a universal scientific task.*
>
> J. Lotman (1990: 269)

By the time that Thomas A. Sebeok ventured into the Soviet-held city of Tartu, Estonia to meet with the émigré Russian semiotician Juri Lotman in 1970, a rich half-century's worth of semiotic scholarship had been steadily accruing 'behind the Iron Curtain' under conditions that would have been barely imaginable to Lotman's academic counterparts in the West. Born five years after the Bolshevik revolution in Petrograd (St Petersburg), Russia, on February 28, 1922, Lotman entered Leningrad State University in 1939 to study "philology" under the renowned literary analysts Boris Eichenbaum (1886–1959) and Vladimir Propp (1895–1970). Eichenbaum and Propp had come from a long tradition of Russian "formalist" literary analysts, whose interest in pre-Revolutionary texts and folklore, and whose belief that literary structure was not strictly the product of Marxist historical dialectic, was officially outlawed under Stalin's reign. Indeed, to the extent that the tenets of Literary Formalism were incompatible with those of Soviet Realism, avocation of the former "was a heresy that could lead to deportation to Siberia" (Liukkonen 2008: o.l.).

Less than one year into his studies, however, Lotman was conscripted into the Soviet military. He was not released until 1946, at which time he resumed his studies, graduating from university with excellent grades four years later. As a Jew, however, Lotman was effectively ineligible for consideration for doctoral study, as during this time the Soviet press was engaged in a vigorous campaign against "cosmopolitanism"; and this was widely understood to be a thinly-veiled government endorsement of anti-Semitism. Unable to obtain employment in Russia proper, Lotman finally found a position as a teacher of Russian language and literature at the Teacher Training College in Tartu, Estonia in 1950. In 1954, Lotman joined the Department of Russian Language and Literature at Tartu University, and later became its head. Two years later, the Twentieth Party Congress of the USSR

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inaugurated its official policy of "de-Stalinization" of academia, at which time a gradual and cautious revival of literary and linguistic study began.

"Formalism, was, of course, in complete disgrace," recalls Boris Egorov (1926–), a colleague of Lotman who would often smuggle outlawed work by Russian scholars to Lotman for publication in Tartu. And with Formalism having been "officially banned by Stalin in the 1930s," recounts Egorov, "by the 1960s, the Party-minded orthodox were still very dubious about [the then ascendant Western analytical movement of] Structuralism. So we had very good reasons to be afraid that this new term, Semiotics, would provoke even more fears. We began to reason, thus, by the Aesopian principle: "How might all this be expressed more obscurely?" Then Uspenskji, a mathematician among us, invented the splendid term: *secondary modeling systems*. Clever, and incomprehensible. Just what we needed to get on with our work!" (Toomela 2003: 115).

In 1955, Lotman's colleagues V.V. Ivanov (1929–), I.I. Revzin (1923–1974), and B.A. Uspenskji (1937–) founded the Association for Machine Translation in Moscow. A seminar on mathematical linguistics and structuralism was held at the Moscow State University the following year, bringing together linguists, mathematicians, literary analysts, and cyberneticians. The success of this conference led to the formation of a number of interdisciplinary institutes and projects devoted to the problems of signs, codes, signification, and translation between sign systems. "Invoked initially as an aid in tasks of machine translation, semiotics gradually approached the status of an autonomous discipline," writes historian of Soviet semiotics Daniel Peri Lucid. Lucid cites as a pivotal event in this evolution, Vjačeslav Ivanov's talk at the 1961 Conference on the Elaboration of Information, Machine Translation and Automatic Reading of the Text, wherein Ivanov calls for "a unique semiotic viewpoint to deal with diverse phenomena, including natural and artificial languages, languages of signalization, languages of art, "languages" of animals, and the sign systems of infants and the mentally ill" (1977: 3).

The Symposium on the Structural Study of Sign Systems that was held in Moscow in 1962 is generally considered to be the watershed event by which *semiotics* – or the interdisciplinary study of sign systems per se – became officially established as "an independent field of research and a recognized fact of Soviet intellectual life" (*ibid*: 4). An organizational centre for this interdisciplinary movement was provided by Juri Lotman, who inaugurated the Tartu University Summer School in Semiotics, along with the world's first scholarly journal devoted entirely to semiotics, *Trudy po znakovym sisteman* (*Sign System Studies*), in 1964. The Tartu summer conferences attracted the attention of semioticians from around the world, and would eventually include such attendees as Roman Jakobson (1869–1982), Claude Lévi-Strauss (1908–), Julia Kristeva (1941–) and Thomas A. Sebeok (1920–2001), all of whom would go on to promote the work of Lotman and his colleagues in the West. Similarly, the more than 2000 publications that Lotman was responsible for getting into print – including works by Lev Vygotsky (1896–1934) and Mikhail Baktin (1895–1975) – helped to solidify the theoretical approach to semiotic study known as the Moscow-Tartu school, which is characterized by an emphasis on the examination of multiple sign systems as they dynamically shape each other at an interface (usually cultural, but also evolutionary and biological, as Lotman himself will be the most prominent to argue).

Sign system study under the Moscow-Tartu school shifted the emphasis from an examination of natural language – christened the "primary modeling system" of human communication and cognition – to the examination of such "secondary modeling systems" as literature, cartography, etiquette, gesture, scientific representation, poetry, myth, games, personality, visual art and mathematics.[1] As Egorov noted above, such inquiry into the construction and maintenance of human "world-models" treaded dangerously close to advocating understandings alternative to official Soviet ideology, and Lotman himself would ultimately have to have his most famous manuscript, *O Semiosfere* (*On the Semiosphere*) smuggled out of Estonia by Thomas A. Sebeok for publication in the West (Sebeok 2001: 167).

"The evolution in semiotic theory" under Lotman's leadership in the East during this time, notes a contemporary theorist, "might be compared to the shift from Newtonian to relativistic physics," as the semiotics of the Moscow-Tartu school evolved from a theory rooted in Saussurean linguistics and in mathematical procedures to a biological, organismic approach (Mandelker 1994: 385). "In a series of largely untranslated articles from the time, Juri Lotman, the leading figure of the Moscow-Tartu school, proposed the model of the *semiosphere*, a metaphor based on the principles of cell biology, organic chemistry, and brain science, to map cultural dynamics" writes Mandelker (*Ibid*).

Lotman's 1968 *Lektsii po struktural'noj poetike* (*Analysis of the Poetic Text*) introduced his extended definition of 'structuralism' as the scientific approach most appropriate to the examination of any kind of a *system* or "complete, self-regulating entity that adapts to new conditions by transforming its features while retaining its systematic structure" (Granville 2004: o.l.). Accordingly, any given *modeling system* – whether natural or artificial – must be investigated as "an interrelated, interdependant system composed of units and the rules for their possible combinations" (*Ibid*). In a Summer School talk that set the direction of the Moscow-Tartu school for the next two decades, Lotman, in 1970, defined "culture" as the *totality* of "all human activity [engendering] the elaboration, exchange and retention of information by means of signs" and the goal of a unified semiotics as an examination of the "functional correlation of different sign systems" as they are brought into a unity by culture (and, again, by evolution and biology).

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[1] "*Secondary* refers to the idea that while all [such systems] are founded on the primary system of natural language, they also acquires supplementary structures" of their own, writes Janet Paterson, "*Modeling* suggests that the secondary system represents a structure of elements and the rules for combining them that is analogous to [that present in] the entire sphere of the object of knowledge" so modelled (1993: 209). In 2000, Thomas A. Sebeok and Marcel Danesi will articulate a comprehensive Modeling Systems Theory (MST) for the investigation of all varieties of sign systems discoverable in the natural world; one that replaces human "language" with Uexkullian "*umwelt*" as the Primary Modelling System upon which all subsequent semiotic systems are constructed (Sebeok and Danesi 2000, Deely 2007).

In 1969, the International Association for Semiotic Studies was founded in Paris by Algirdas Julien Greimas, Emile Benveniste, Roman Jakobson, Julia Kristeva and Thomas A. Sebok. Juri Lotman was elected, *in absentia*, as its first Vice-President, and as member of the Editorial Committee for the association's peer-reviewed academic journal, *Semiotica* – a position that Lotman held through ninety-eight volumes, until his death in 1993. Moreover, in addition to his four decades worth of organizational and editorial work for the advancement of interdisciplinary sign study, Lotman's own theoretical contributions to the science of semiotics are profound. As author or co-author of over 800 works of sign study, Lotman is most widely recognized today for his development of the analytical framework of the "semiosphere."

By self-consciously coining a cognate of Edward Suess' (1831–1914) and Vladimir Verdansky's (1863–1945) concept of the *biosphere* – the organizational space wherein living beings occur and interact – Lotman, in designating the space wherein agents interact by using sign relations as the *semiosphere*, was attempting to re-orient the locus of semiotic study from the traditionally "atomistic" examination of "individual acts of semiosis" (whether Peircean or Saussurean) to an examination of the larger system, or matrix, of sign relations within which alone such individual acts have their "meaning."[2]

A "self-contained, single-channel system" such as those presented in Shannonian coding-and-decoding models "is a mechanism for transmitting extremely simple signals and for the realization of a single function, but for the task of *generating* information, it certainly will not do", writes Lotman in the selection regarding the semiosphere that follows (1990: 22). Instead, notes Lotman, among semiosis' most important functions (in addition to the mere transmission and reception of pre-encoded information) are: its ability to combine creatively otherwise discrete messages and bits of information; its ability to generate genuinely new information; its ability to condense, order and in many other ways act upon an ever-growing accretion of information; and its ability to function as a dynamically interactive memory store.

Such multi-modal semiosis characterizes that found among living beings, as both in cultural and in biological evolution, writes Lotman, "when the sum of the *contexts* in which a given text acquires interpretation becomes incorporated in it [in such a way] that we may term it the text's *memory*... this meaning-space created by the text around itself" becomes a relevant factor in each new act of interpretation upon that

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[2] Twelve years later, in 1996, molecular biologist Jesper Hoffmeyer, at that time unacquainted with Lotman's work, would open his seminal work on biosemiotics, *Signs of Meaning in the Universe*, with these words: "This book deals with something for which there is, as yet, no standard word in layperson's language, though there most definitely ought to be. Please forgive me, therefore, introducing at the outset the term we lack: *semiosphere*. The semiosphere is a sphere just like the atmosphere, the hydrosphere, and the biosphere. It penetrates to every corner of these other spheres, incorporating all forms of communication: sounds, smells, movements, colors, shapes, electrical fields, thermal radiation, waves of all kinds, chemical signals, touching, and so on. In short, signs of life" (1996: vii). For a comparison between Hoffmeyer's and Lotman's notions of "semiosphere," see Kull (1998).

text (1990: 57). Each of these embodied acts of interpretation, in turn, brings into being yet new meaning-spaces of its own. Such "meaning-spaces" are both context-dependent, as well as context-creating, opportunities for meaning-making *action* in response to, and upon, a given text – and the meaning-bearing matrix created by a society of participants all interacting within such a possibility space is precisely what Lotman calls the *semiosphere.*[3]

Having its origins in the multiply recursive acts of non-linguistic meaning-making – and in the structures of experience arising therefrom – this semiosphere pre-exists language and gives rise to it, both evolutionarily and in real-time. Accordingly, argues Lotman, it makes no sense to conceive of a single "sign relation" that functions (and could thus be understood) in isolation from all the other sign-relations of the semiosphere – just as, in ecology, it would make no sense to conceive of a single organism or species functioning in isolation from the biology existing in its surroundings.

Rather, "signs" are found in the real world only in the presence of, and as the result of, other signs. Thus, just as the notion of an ecosystem comprising only one species is impossible, so too is the notion of a "meaning system" composed of unconnected and individually subsisting signs. A "sign science" that mistakes the derivative "atomic facts" of a single sign-act as foundational, and that then attempts to construct an agglutinative theory of language or semiosis from that starting point, argues Lotman, is both "inverting evolutionary cause-and-effect" (to use a phrase of Terrence Deacon's) and "searching in the destination for what should have been sought in the source" (to use a phrase popularized by Thomas Sebeok).

The proper unit of investigation for a sign-science is the totality of the semiosphere itself, claims Lotman, and it is within this context that any individual act of semiosis is to be understood and explained:

> The unit of semiosis, the smallest functioning mechanism, is not the separate language but the whole semiotic space of the [sign activity] in question. This is the space we term the semiosphere. The semiosphere is the result and the condition for the development of culture; we justify our term by analogy with the biosphere, as Vernadsky defined it, namely: both the totality and the organic whole of living matter, and also the condition for the continuation of its life (1990: 125).

Lotman's dictum may seem impossibly ambitious at first glance, yet we should remember that Darwin, in a similar fashion, took as the proper unit of his investigations "the biological order" as a whole – and from a careful examination of the patterns exhibited by the whole, deduced a unifying explanatory framework for the analysis of individual organisms and species that are its constituent parts.

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[3] Proceeding from a Peircean, as opposed to a Lotmanian, perspective, neurobiologist and bioanthropologist Terrence Deacon arrives at a strikingly similar conclusion in the excerpt from *The Symbolic Species* that is included in this volume. The reader may wish to take a look at Deacon's diagram of a similarly recursive and meaning-bearing matrix of enacted interpretations (Fig. 18.3, this volume) to obtain a diagrammatic depiction of a Lotmanian "semiosphere" seen from a Peircean perspective.

Juri Lotman died in his adopted home of Tartu, Estonia on October 28, 1993, at age seventy-one, of an embolism. His wife, the literary historian Zara Mints (1927–1990), had died several years earlier, but he was survived by his two sons Mihhail Lotman (1952b), a semiotician, and Aleksei Lotman (1960b), a biologist and environmental activist. Tartu University Professor of Biosemiotics Kalevi Kull reports that "a regular lecture course on biosemiotics was introduced at Tartu University in 1993, in the year of Yuri Lotman's death, and opening with Lotman's introductory words, as he dictated them from his hospital bed. This course is now read every year and is included in the University's standard semiotics curriculum" (Kull 1999: 404–405).

Excerpts from *Universe of the Mind: A Semiotic Theory of Culture (1990)*

Preface

The project of creating a thinking brain adumbrated by Goethe is still relevant today: indeed, with each new advance in science, it has been raised anew, though in different terms. But a very real barrier stands in our way: namely, that we cannot satisfactorily explain what is the thinking brain we are trying to create artificially. Evidently, the reason is that intellectual activity us usually regarded as aquality unique to man. But something that is taken in isolation and not compared with anything else cannot be the object of science.

Our task is thus to find a *series* of "thinking objects", to compare then, and to deduce the invariant features of intelligence. The concept "intelligence" has many aspects and I do not feel competent to make an exhaustive definition of it. However, the task becomes manageable if we restrict ourselves to its semiotic aspect. Thus, if we define intelligence from this point of view, we can reduce it to the following functions:

1. The transmission of available information (that is, of texts)
2. The creation of new information – that is, of texts which are not simply deducible according to set algorithms from already existing information, but which are to some degree inpredictable
3. Memory; that is, the capacity to preserve and reproduce information (texts)

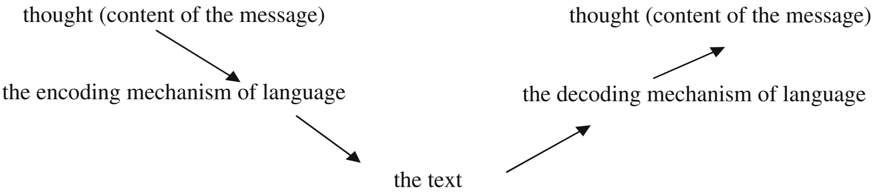
The study of the semiotic systems created by humanity over the course of its cultural history has led to the unexpected finding that these functions are also characteristic of semiotic objects. Thinking along these lines has led us to the concept of the *semiosphere* and convinced us of the importance of studying the semiotics of culture.

The Text as a Meaning-Generating Mechanism

In the Saussurean system of thought, which has long determined the course of semiotic thinking, there is a clear preference for the study of language rather than speech, and of the code rather than the text. Speech and its delimited articulated hypostasis, the text, is of interest to the linguist merely as raw material, as a manifestation of the linguistic structure. Everything that is relevant in speech (or text) is given in language (or code). Elements occurring in a text without any correspondence in the code cannot be bearers of meaning. This is what Saussure means when he says: "The linguist must take the study of linguistic structure as his primary concern, and relate all other manifestations of language to it" (Ferdinand de Saussure 1983). To take linguistic structure as the norm means making it the scientific reference-point for the definition of what is essential and what is inessential in language activity. Naturally, whatever has no correspondence in the language (code) when the message is decoded is "removed". After which just as the metal of the language structure is sifted out from the ore of speech there remains only the dross. This is what Saussure had in mind when he said, "the science of language can do without the analysis of speech".

Behind this scientific position, however, stands a whole complex of assumed, almost non-scientific ideas about the function of language. While the theoretical linguist is interested in the linguistic structure extracted from the text, the everyday receiver of information is concerned with the content of the message. In both cases the text is treated as something that is valuable, not in itself, but merely as a kind of packaging from which the topic of interest is extracted.

For the receiver of a message the following sequence seems logical:



From this point of view it is assumed that in the ideal case the informational content does not change either qualitatively or quantitatively: the receiver decodes the text and receives the initial message. Once again the text is regarded as a "technical packaging" for the message which is what the receiver is interested in.

Should we then think that this artificial model is a model of what language should be, an ideal, from which it is distinguished only by imperfections which are the natural result of the "irrational" workings of Nature? Artificial languages model not language as such but one of its functions – the ability to transmit a message adequately; because semiotic structures when they achieve this function to perfection lose the capacity of serving other functions which are inherent to them in the natural state.

So what are these functions?

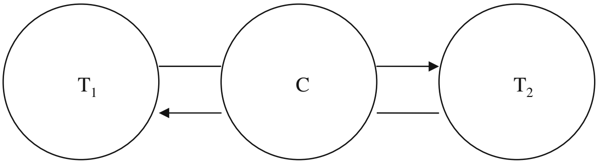
First of all, the creative function. Every system which fulfils the entire range of semiotic possibilities not only transmits ready made messages but also serves as a generator of new ones.

But what is it we are terming "new messages"? Let us agree first of all on what we are so terming. We are not terming "new messages" those messages received from inputs as a result of simple transformations, i.e. messages which are the fruit of symmetrical transformations of the input (an input text obtained by a reverse transformation). If the translation of text T_1 from language L_1 to language L_2 leads to the appearance of text T_2 in such a way that the operation of a reverse translation results in the input text T_1, then we do not consider text T_2 to be new in relation to text T_1. So from this point of view the correct solution of mathematical problems does not create new texts. We might recall Wittgenstein's remark that within logic you cannot say anything new.

The polar opposite of artificial languages are those semiotic systems in which the creative function is strongest: it is obvious that if the most hackneyed of poems is translated into another language (i.e. into the language of another poetic system) then the operation of reverse translation will not produce the input text. The very fact that one and the same poem can be translated by different translators in many ways testifies to the fact that in place of a precise correspondence to text T_1 in this case there is a certain space. Anyone of the texts t_1, t_2, t_3 ... t_n which fill this space may be a possible interpretation of the input text. Instead of a precise correspondence there is one of the possible interpretations, instead of a symmetrical transformation there is an asymmetrical one, instead of identity between the elements which compose T_1 and T_2 there is a conventional equivalence between them. In the translation of French poetry into Russian the rendering of the French twelve-syllable syllabic line by the Russian six-foot syllabo-tonic iambics is a convention, the result of an accepted tradition. Yet in principle it is possible to translate French syllabic verse into Russian syllabic verse. The translator is forced to *make a choice*. There is even greater indeterminacy when, for instance, a novel is transformed into a film.

The text that is produced in these instances we shall term a new one and the act of translation that creates it a creative act.

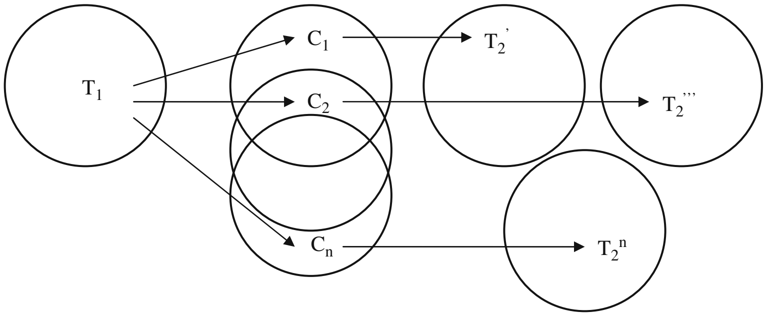
We can represent the adequate transmission of a text using artificial language by the following diagram:



In this case the transmitter and the receiver share the same code, C.

The diagram representing artistic translation shows that transmitter and receiver use different codes C_1 and C_2 which overlap but are not identical. A reverse translation will result not in the input text but in a third text, T_3. Even closer to the actual process of the circulation of messages is the case when the transmitter is faced with not one code but a plural space of codes c_1, c_2, c_3 ... c_n and each of them is a complex hierarchical construction capable of generating a set of texts in equal degree corresponding to it. The asymmetrical relationship, the constant need for choice, makes translation in this case an act of generating new information and exemplifies the creative function both of language and of the text.

Particularly indicative is the situation where it is not simply difference which exists between codes, but mutual untranslatability (for instance, in the translation of a verbal text into an iconic one). The translation is done with the help of the conventional system of equivalences accepted in that particular culture. So, for example, when transmitting a verbal text by a pictorial one (for instance, a picture on a Gospel theme), the space of the theme will overlap in the codes, while the space of the language and style will be merely conventionally correlated within the bounds of the particular tradition. The combination of translatability–untranslatability (each to different degrees) is what determines the creative function.



Since in this case the meaning is not only an invariant remnant which is preserved under all manner of transformational operations, but is also what is altered, we can claim that there is an accretion of meaning in the process of such transformations.

[. . .Another] function of language is the function of memory. The text is not only the generator of new meanings, but also a condenser of cultural memory. A text has the capacity to preserve the memory of its previous contexts. Without this function, there could be no science of history, since the culture of preceding ages (and more broadly speaking, its picture of life) inevitably comes down to us in fragments. If a text stayed in the consciousness of the perceiver only as itself, then the past would be represented to us as a mosaic of disconnected fragments. But for the perceiver a text is always a metonymy of a reconstructed integral meaning, a discrete sign of a non-discrete essence. The sum of the contexts in which a given text acquires interpretation and which are in a way incorporated in it may be termed the text's memory. This meaning-space created by the text around itself enters into relationship with the cultural memory (tradition) already formed in the consciousness of the audience. As a result the text acquires semiotic life.

Any culture is constantly bombarded by chance isolated texts which fall on it like a shower of meteorites. What we have in mind are not the texts which are included in a continuing tradition which has an influence on the culture, but isolated and disruptive invasions. These may be the remnants of other civilizations unearthed by chance from the ground, texts brought in by chance from cultures far off in time or space. Unless texts had their own memory and were capable of creating a particular semantic aura around themselves, these invasions would all remain museum pieces set apart from the main cultural process. But in fact they are important factors in the stimulus of cultural dynamics. For a text, like a grain of wheat which contains within itself the programme of its future development, is not something given once and for all and never changing. The inner and as yet unfinalized determinacy of its structure provides a reservoir of dynamism when influenced by contacts with new contexts.

There is another side to this question. One might expect a text as it lives through the centuries to become faded and to lose the information contained in it. Yet texts that preserve their cultural activity reveal a capacity to accumulate information, i.e. a capacity for memory. Nowadays *Hamlet* is not just a play by Shakespeare, but it is also the memory of all its interpretations, and what is more, it is also the memory of all those historical events which occurred outside the text but with which Shakespeare's text can evoke associations. We may have forgotten what Shakespeare and his spectators knew, but we cannot forget what we have learnt since their time. And this is what gives the text new meanings.

The Semiosphere

Semiotic Space

Up to this point our argument has followed a generally accepted pattern: we have started by taking the single act of communication by itself, and we have examined the relationships which arise between addresser and addressee. This approach presupposes that the study of this one fact will throw light on all the chief features of semiosis and that these features can then be extrapolated on to the larger semiotic processes. This approach accords with Descartes' third rule in *Discourse on Method*. Descartes wrote:

> The third [rule] was to carry on my reflections in due order, commencing with objects that were the most simple and easy to understand, in order to rise little by little, or by degrees, to knowledge of the most complex (Descartes 1969).

This approach also accords with the scientific practice which dates from the time of the Enlightenment, namely to work on the "Robinson Crusoe" principle of isolating an object and then making it into a general model.

However, for this procedure to be a correct one, the isolated fact must be able to model all the qualities of the phenomenon on to which the conclusions are being extrapolated. This is not so in our case. A schema consisting of addresser, addressee and the channel linking them together is not yet a working system. For it to work it has to be "immersed" in semiotic space. All participants in the communicative act must have some experience of communication, be familiar with semiosis. So, paradoxically, semiotic experience precedes the semiotic act. By analogy with the biosphere (Vernadsky's concept) we could talk of a semiosphere, which we shall define as the semiotic space necessary for the existence and functioning of languages, not the sum total of different languages; in a sense the semiosphere has a prior existence and is in constant interaction with languages. In this respect a language is a function, a cluster of semiotic spaces and their boundaries, which, however clearly defined these are in the language's grammatical self-description, in the reality of semiosis are eroded and full of transitional forms. Outside the semiosphere there can be neither communication, nor language. Of course, the single-channel structure is a reality. A self-contained, single-channel system is a mechanism for transmitting extremely simple signals and for the realization of a single function, but for the task of generating information it certainly will not do. This is why we can imagine that a system like this is an artificially-made construction, but in natural circumstances systems of quite another type are at work. Just the fact that it is a universal of human culture, that there exist both conventional and pictorial signs (or rather that all signs are to some degree both conventional and representational), is enough to show that semiotic dualism is the minimal form of organization of a working semiotic system.

Binarism and *asymmetry* are the laws binding on any real semiotic system. Binarism, however, must be understood as a principle which is realized in plurality since every newly-formed language is in its turn subdivided on a binary principle. Every living culture has a "built-in" mechanism for multiplying its languages (as we shall see below, the Paralel and opposite mechanism for unifying languages is also at work). For instance, we are constantly witnessing a quantitative increase in the languages of art. This is especially so in 20th century culture and in other past cultures typologically resembling it. At periods when most creative activity comes from the readership, the slogan that "art is everything we perceive as art" rings true. In the early years of this century cinema ceased being a fairground amusement and became a serious art-form. It made its appearance not alone but along with a whole procession of traditional and newly invented peep-shows. Back in the nineteenth century no one would have seriously regarded the circus, fairground peep-shows, traditional toys, advertisements or the cries of street traders as art-forms. Once it became an art, cinematography at once split into documentary films and entertainment films, camera films and cartoon ones, each with its own poetics. And nowadays there is another opposition to be added, that between cinema and television. True, art becomes more narrow at the same time as the assortment of art-languages increases: some arts in practice drop out of the picture. So we should not be surprised if, when we look closer, the diversity of semiotic systems within a particular culture is relatively constant. But something else is important: the set of languages in an active cultural field is constantly changing, and the axiological value and hierarchical position of the elements in it are subject to even greater changes.

At the same time, throughout the whole space of semiosis, from social jargon and age-group slang to fashion, there is also a constant renewal of codes. So any one language turns out to be immersed in a semiotic space and it can only function by interaction with that space. The unit of semiosis, the smallest functioning mechanism, is not the separate language but the whole semiotic space of the culture in question. This is the space we term the *semiosphere*. The semiosphere is the result and the condition for the development of culture; we justify our term by analogy with the biosphere, as Vernadsky defined it, namely the totality and the organic whole of living matter and also the condition for the continuation of life.

Vernadsky wrote that

> all life-clusters are intimately bound to each other. One cannot exist without the other. This connection between different living films and clusters, and their invariancy, is an age-old feature of the mechanism of the earth's crust, which has existed all through geological time (Vemadsky 1960).

The same idea is expressed more clearly again:

> The biosphere has a quite definite structure which determines everything without exception that happens in it. . . . A human being observed in nature and all living organisms and every living being is a function of the biosphere in its particular space-time (Vemadsky 1977).

In his notes dating from 1892 Vernadsky pointed to human intellectual activity as a continuation of the cosmic conflict between life and inert matter:

> the seeming laws of mental activity in people's lives has led many to deny the influence of the personality on history, although, throughout history, we can in fact see a constant struggle of conscious (i.e. not natural) life, formations with the unconscious order of the dead laws of nature, and in this effort of consciousness lies all the beauty of historical manifestations, the originality of their position among the other natural processes. A historical epoch can be judged by this effort of consciousness (Vemadsky 1988).

The semiosphere is marked by its *heterogeneity*. The languages which fill up the semiotic space are various, and they relate to each other along the spectrum which runs from complete mutual translatability to just as complete mutual untranslatability. Heterogeneity is defined both by the diversity of elements and by their different functions. So if we make the mental experiment of imagining a model of a semiotic space where all the languages came into being at one and the same moment and under the influence of the same impulses, we still would not have a single coding structure but a set of connected but different systems. For instance, we construct a model of the semiotic structure of European Romanticism and mark out its chronological framework. Even within such a completely artificial space there would be no homogeneity since inevitably where there are different degrees of iconism there can be no mutually complete semantic translatability, but only conventional correspondence. Of course the poet and partisan hero of 1812, Denis Davydov, did compare the tactics of partisan warfare with Romantic poetry, declaring that the leader of a partisan band should not be a "theorist" with "a calculating mind and a cold heart": "This poetic profession needs a romantic imagination, a passion for adventure and it is never content with dry prosaic displays of valour. It is a verse of Byron's!" (Davydov 1822). But we have only to look at his study of tactics, *Attempt at a Theory of Partisan Warfare*, with its plans and maps to realize that this fine metaphor was just a pretext for the contrast-loving mind of a Romantic to juxtapose the incompatible. The fact that the unification of two different languages is achieved by a metaphor is proof of the essential differences between them.

But then we have also to take account of the fact that different languages circulate for different periods: fashion in clothes changes at a speed which cannot be compared with the rate of change of the literary language, and Romanticism in dance is not synchronized with Romanticism in architecture. So, while some parts of the semiosphere are still enjoying the poetics of Romanticism, others may have moved far on into post-Romanticism. So even our artificial model will not give us a homologous picture across a strictly synchronic section. This is why when we try to give a synthetic picture of Romanticism to include all forms of art (and perhaps also other areas of culture), chronology has to be sacrificed. What we have said is true also of the Baroque, of Classicism, and of many other "isms".

Yet if we talk not of artificial models but of modeling the actual literary process (or more broadly, the cultural process) then we must admit that – to continue with our example – Romanticism occupies only a part of the semiosphere in which all sorts of other traditional structures continue to exist, some of them going way back into antiquity. Besides, at all stages of development there are contacts with texts coming in from cultures which formerly lay beyond the boundaries of the given semiosphere. These invasions, sometimes by separate texts, and sometimes by whole cultural layers, variously effect the internal structure of the "world picture" of the culture we are talking about. So across any synchronic section of the semiosphere different languages at different stage of development are in conflict, and some texts are immersed in languages not their own, while the codes to decipher them with may be entirely absent. As an example of a single world looked at synchronically, imagine a museum hall where exhibits from different periods are on display, along with inscriptions in known and unknown languages, and instructions for decoding them; besides there are the explanations composed by the museum staff, plans for tours and rules for the behavior of the visitors. Imagine also in this hall tour-leaders and the visitors and imagine all this as a single mechanism (which in a *certain sense* it is). This is an image of the semiosphere. Then we have to remember that all elements of the semiosphere are in dynamic, not static, correlations whose terms are constantly changing. We notice this especially at traditional moments which have come down to us from the past. The evolution of culture is quite different from biological evolution, the word "evolution" can be quite misleading.

Biological evolution involves species dying out and natural selection. The researcher finds only living creatures contemporary with him. Something similar happens in the history of technology: when an instrument is made obsolete by technical progress it finds a resting place in a museum, as a dead exhibit. In the history of art, however, works which come down to us from remote cultural periods continue to play a part in cultural development as living factors. A work of art may "die" and come alive again; once thought to be out of date, it may become modern and even prophetic for what it tells of the future. What "works" is not the most recent temporal section, but the whole packed history of cultural texts. The standard evolutionary point of view in literary history comes from the influence of evolutionary ideas in the natural sciences. With this approach the state of literature at anyone time is judged by the list of works *written* in that year, instead of by the works *being read* in that year – which would produce a very different picture. And it is hard to say which of the lists is more typical for the state of culture at anyone time. Pushkin, for instance, in 1824–1825, took Shakespeare as his most topical writer, Bulgakov read Gogol and Cervantes as contemporaries, Dostoevsky is just as relevant at the end of the twentieth century as he was at the end of the nineteenth. In fact, everything contained in the actual memory of culture is directly or indirectly part of that culture's synchrony.

The structure of the semiosphere is asymmetrical. Asymmetry finds expression in the currents of internal translations with which the whole density of the semiosphere is permeated. Translation is a primary mechanism of consciousness. To express something in another language is a way of understanding it. And since in the majority of cases the different languages of the semiosphere are semiotically asymmetrical, i.e. they do not have mutual semantic correspondences, then the whole semiosphere can be regarded as a generator of information.

Asymmetry is apparent in the relationship between the centre of the semiosphere and its periphery. At the centre of the semiosphere are formed the most developed and structurally organized languages, and in first place the natural language of that culture. If no language (including natural language) can function unless it is immersed in the semiosphere, then no semiosphere, as Emile Benveniste pointed out, can exist without natural language as its organizing core. The fact is that the semiosphere, besides the structurally organized language, is crowded with partial languages, languages which can serve only certain cultural functions, as well as language-like, half-formed systems which can be bearers of semiosis if they are included in the semiotic context. Compare the latter with a stone or a strangely twisted tree-stump which can function as work of art if it is treated as one. An object will take on the function ascribed to it.

In order that all this mass of constructions are perceived as bearers of semiotic meaning we must make a "presumption of semioticity": the semiotic intuition of the collective and its consciousness have to accept the possibility that structures may be significant. These qualities are learnt through natural language. For instance, the structure of the "families of the gods" and of other basic elements of the world-picture are often clearly dependent on the grammatical structure of the language.

The highest form and final act of a semiotic system's structural organization is when it describes itself. This is the stage when grammars are written, customs and laws codified. When this happens, however, the system gains the advantage of greater structural organization, but loses its inner reserves of indeterminacy which provide it with flexibility, heightened capacity for information and the potential for dynamic development.

The stage of self-description is a necessary response to the threat of too much diversity within the semiosphere: the system might lose its unity and definition, and disintegrate. Whether we have in mind language, politics or culture, the mechanism is the same: one part of the semiosphere (as a rule one which is part of its nuclear structure) in the process of self-description creates its own grammar; this self-description may be real or ideal depending on whether its inner orientation is towards the present or towards the future. Then it strives to extend these norms over the whole semiosphere. A partial grammar of one cultural dialect becomes the metalanguage of description for culture as such. The dialect of Florence, for instance, became during the Renaissance the literary language of Italy, the legal norms of Rome became the laws of the whole Roman Empire, and the etiquette of the Parisian court of Louis XIV became the etiquette of all the courts of Europe. A literature of norms and prescriptions comes into being in which the later historian will tend to see an actual picture of real life of that epoch, its semiotic practice. This illusion is supported by the evidence of contemporaries who are in fact convinced that they indeed do live and behave in the prescribed way. A contemporary will reason something like this: "I am a person of culture (i.e. a Hellene, a Roman, a Christian, a knight, an *esprit fort*, a philosopher of the age of the Enlightenment, or a genius of the age of Romanticism). As a person of culture I embody the behavior prescribed by certain norms. Only what in my behavior corresponds to these norms is counted as a *deed*. If, through weakness, sickness, inconsistency, etc., I deviate from these norms, then such behavior has no meaning, is not relevant, simply *does not exist*". A list of what "does not exist", according to that cultural system, although such things in fact occur, is always essential for making a typological description of that system. For instance, Andreas Capellanus, author of *De Amore* (c. 1184–1185), a well-known treatise on the norms of courtly love, carefully codified courtly love and set the standards of faithfulness, silence, devoted service, chastity, courtesy, and so on for the lover; yet he had no compunction in violating a village-girl since according to his world-picture she "as it were did not exist", and actions involving her as it were did not exist either, since they lay outside the domain of semiotics.

The world-picture created in this way will be perceived by its contemporaries as reality. Indeed, it will be *their* reality to the extent that they have accepted the laws of that semiotics. And later generations (including scholars), who reconstruct life in those days from texts, will imbibe the idea that everyday reality was indeed like that. But the relationship of this metalevel of the semiosphere to the real picture of its semiotic "map" on the one hand, and to the everyday reality of life on the other, will be complex. First of all, if in that nuclear structure where the self-description originated, the self-description in fact represents an idealization of a real language, then on the periphery of the semiosphere, this ideal norm will be a contradiction of the semiotic reality lying "underneath", and not a derivation from it. If in the centre of the semiosphere the description of texts generates the norms, then on the periphery the norms, actively invading "incorrect" practice, will generate "correct" texts in accord with them. Secondly, whole layers of cultural phenomena, which from the point of view of the given metalanguage are marginal, will have no relation to the idealized portrait of that culture. They will be declared to be "non-existent". From the time of the cultural history school, the favorite genre of many scholars has been articles of the type, "An Unknown Poet of the Twelfth Century", "Further Remarks about a Forgotten Writer of the Enlightenment Period", and so on. Where does this inexhaustible supply of "unknown" and "forgotten" figures come from? They are the writers who in their time were classed as "nonexistent" and who were ignored by scholarship as long as its point of view coincided with a normative view of the period. But points of view change and "unknowns" suddenly occur. Then people remember that in the year Voltaire died, the "unknown philosopher", Louis-Claude Saint Martin was already thirty-five, that Restif de la Bretonne had already written over 200 novels which historians of literature still cannot properly place, calling him either "little Rousseau" or an "eighteenth-century Balzac"; and that in the Romantic period in Russia there lived a certain Vasily Narezhny who wrote some 25 volumes of novels which were "unnoticed" by his contemporaries until traces of realism were found in them.

So while on the metalevel the picture is one of semiotic unity, on the level of the semiotic reality which is described by the metalevel, all kinds of other tendencies flourish. While the picture of the upper level is painted in a smooth uniform color, the lower level is bright with colors and many intersecting boundaries. When Charlemagne at the end of the eighth century brought sword and cross to the Saxons, and St Vladimir a hundred years later baptized Kievan Russia, the great barbarian empires of East and West became Christian states. But their Christianity was a self-characterization and as such extended to the political and religious metalevel beneath which flourished pagan traditions and all sorts of real-life compromises with them. It could not have been otherwise considering that the conversions to Christianity were forced on the masses. The terrible bloodshed wrought by Charlemagne on the pagan Saxons at Verdun was hardly likely to foster acceptance of the principles of the Sermon on the Mount among the barbarians.

And yet it would be wrong to suggest that this simple change of nomenclature had no effect on the "underlying" levels: for Christianization did turn into evangelization, and, even on the level of "real semiotics", it contributed to the unification of the cultural space of these states. Semantic currents flow not only across the horizontal levels of the semiosphere, but also have their effect in a vertical direction, and promote complex dialogues between the levels.

But the unity of the semiotic space of the semiosphere is brought about not only by metastructural formations: even more crucial is the unifying factor of the boundary, which divides the internal space of the semiosphere from the external, its *inside* from its *outside*.

The Notion of Boundary

The space which in one system of coding is a single person, may in another system be the place where several semiotic subjects are in conflict.

Because the semiotic space is transected by numerous boundaries, each message that moves across it must be many times translated and transformed, and the process of generating new information thereby snowballs.

The function of any boundary or filter (from the membrane of the living cell, to the biosphere which according to Vernadsky is like a membrane covering our planet, and to the boundary of the semiosphere) is to control, filter and adapt the external into the internal. This invariant function is realized in different ways on different levels. On the level of the semiosphere it implies a separation of "one's own" from "someone else's", the filtering of what comes from outside and is treated as a text in another language, and the translation of this text into one's own language. In this way external space becomes structured.

When the semiosphere involves real territorial features as well, the boundary is spatial in the literal sense. The isomorphism between different kinds of human settlement – from archaic ones to Renaissance and Enlightenment plans for ideal cities – and ideas about the structure of the cosmos has often been remarked on. Hence the appeal of the centre for the most important cultic and administrative buildings. Less valued social groups are settled on the periphery. Those who are below any social value are settled on the frontier of the outskirts (the etymology of the Russian word for outskirts [*predmest'e*] means "before the place" [*pered* *mestom*] i.e. before the city, on its boundaries), by the city gate, in the suburbs. If we think of this on a vertical scale then these "outskirts" will be lofts and cellars, and in the modem city the metro. If the centre for "normal" life is the flat, then the boundary space between *home* and *non-home* is the staircase and entrance. And these are the spaces which marginalized social groups make "their own": the homeless, the drug addicts, young people. Other boundary places are public places such as stadia and cemeteries. There is a significant change in the accepted norms of behavior when moving from boundary to centre.

However some elements are always set *outside*. If the inner world reproduces the cosmos, then what is on the other side represents chaos, the anti-world, unstructured chthonic space, inhabited by monsters, infernal powers or people associated with them. In the countryside the sorcerer, the miller and (sometimes) the smith had to live outside the village, as did the executioner in a medieval town. "Normal" space has not only geographical but also temporal boundaries. Nocturnal time lies beyond the boundary. People visit the sorcerer if he demands it by night. The robber lives in this anti-space: his home is the forest (the anti-home), his sun is the moon (the "thieves' sun" in the Russian proverb), he speaks an anti-language, his behavior is anti-behavior (he whistles loudly, swears indecently), he sleeps when other people work, and robs when other people are sleeping, and so on.

The "night-time world" of the city also lies on the boundary of the space of culture or beyond it. This travesty world presupposes anti-behavior.

We have already discussed the process whereby the periphery of culture moves into the centre, and the centre is pushed out to the periphery. The force of these opposing currents is even stronger between the centre and "the periphery of the periphery", the frontier zone of culture. After the 1917 October Revolution in Russia this process took place literally in many shapes and forms: poor folk from the outskirts moved in their masses into the "apartments of the bourgeoisie" who were either turned out or had to squeeze up to accommodate them. There was a symbolic sense too in the moving of the beautiful wrought iron railings which before the Revolution surrounded the royal gardens round the Winter Palace in Petrograd to a working-class area where they were put up round a square, while the tsar's garden was left without a railing, "open". In the utopian plans for a socialist city of the future, of which any number were drawn up in the early 1920, a recurrent idea was that the centre of the town should be a giant factory "in place of the palaces and churches".

In this sense, Peter the Great's transfer of the capital to Petersburg was a typical move to the frontier. The transfer of the politico-administrative centre on to the *geographical* frontier was at the same time the transfer of the frontier to the *ideological* and *political* centre of the state. Later pan-Slavist plans to move the capital to Constantinople involved moving the capital even beyond the actual frontiers.

A similar shift can be observed in the norms of behavior, of language, of style in dress, and so on, from the frontier area into the centre. Take jeans for example: what were once working clothes intended for people doing physical labor became young people's clothes, since young people rejected the central culture of the twentieth century and saw their ideal in the peripheral culture; subsequently jeans spread over the whole domain of culture, became neutral, that is, “common to all”, which is the most important feature of semiotic systems of the centre. The periphery is brightly colored and marked, whereas the nucleus is “normal”, i.e. lacking in color or scent, it “simply exists”. So the victory of a semiotic system involves it shifting to the centre and an inevitable “toning down”. We can compare this with the “usual” cycle of ageing: the rebellious youth with the passage of the years becomes the “normal” respectable gentleman, passing from provocative “colorfulness” to sobriety.

In the frontier areas semiotic processes are intensified because here there are constant invasions from outside. The boundary as we have already pointed out is ambivalent and one of its sides is always turned to the outside. Moreover the boundary is the domain of bilingualism, which as a rule finds literal expression in the language practice of the inhabitants of borderlands between two cultural areas. Since the boundary is a necessary part of the semiosphere and there can be no “us” if there is no “them”, culture creates not only its own type of internal organization but also its own type of external “disorganization”. In this sense we can say that the “barbarian” is created by civilization and needs it as much as it needs him. The extreme edge of the semiosphere is a place of incessant dialogue. No matter whether the given culture sees the “barbarian” as savior or enemy, as a healthy moral influence or a perverted cannibal, it is dealing with a construct made in its own inverted image. It is entirely to be expected, for instance, that the rational positivistic society of 19th century Europe should create images of the “pre-logical savage”, or of the irrational subconscious as anti-spheres lying beyond the rational space of culture.

Since in reality no semiosphere is immersed in an amorphous, “wild” space, but is in contact with other semiospheres which have *their own* organization (though from the point of view of the former they may seem unorganized) there is a constant exchange, a search for a common language, a *koine*, and of creolized semiotic systems come into being. Even in order to wage war there has to be a common language. It is a well-known fact that in the last period of Roman history barbarian soldiers ascended the throne of the Roman emperors, while many military leaders of the “barbarians” served their apprenticeship in the Roman legions (Latimore 1962). On the frontiers of China, of the Roman Empire, of Byzantium, we see the same thing: the technical achievements of the settled civilization pass into the hands of the nomads who turn them against their inventors. But these conflicts inevitably lead to cultural equalization and to the creation of a new semiosphere of more elevated order in which both parties can be included as equals.

Dialogue Mechanisms

What the Renaissance did to Italian culture, the Enlightenment did with French. France had absorbed cultural currents from the whole of Europe: the ideas of the Reformation from Holland – Germany and Switzerland, the empiricism of Bacon and Locke and Newtonian mechanics, the Latinism of the Italian Humanists, and the Mannerism of the Spanish and Italian Baroque; but in the age of the Enlightenment she made all Europe speak her language. At the time of the Renaissance each cultural tendency had had to face a hard choice: either to be a supporter or an opponent of Humanism and the cult of Antiquity, which amounted to supporting or opposing the spirit of Italian culture; similarly in the eighteenth century there was a choice: either to be a follower or an opponent of the ideas of the Enlightenment, namely, religious toleration, the cult of Nature and Reason, and the eradication of age-old superstitions in the name of the freedom of Man. Paris became the capital of European thought, and innumerable texts poured out of France to all the corners of Europe. Compare this period with the pause which followed and which was marked by the publication of Madame de Staël's *De l'Allemagne* (1810): France "became a receiver" again and opened itself to English culture from Shakespeare to Byron, to German culture – Schiller, Goethe – and to the Romantic writers of northern Europe from Kant to Walter Scott.

From the point of view of the "receiving" side the process of reception falls into the following stages:

1. The texts coming in from the outside keep their "strangeness". They are read in the foreign language (both in the sense of natural language and 10 the semiotic sense). They hold a high position in the scale of values, and are considered to be true, beautiful, of divine origin, etc. Knowledge of the foreign language is a sign of belonging to "culture", to the elite, to the best. Already existing texts in "one's own" language, and that language itself, are correspondingly valued lowly, being classed as untrue, "coarse", "uncultured".
2. Both principles – the "imported" texts and the "home" culture – restructure each other. Translations, imitations and adaptations multiply. At the same time the codes imported along with the texts become part of the metalingual structure. During the first stage the dominant psychological impulse is to break with the past, to idealize the "new", i.e. the imported world-view, and to break with tradition, while the "new" is experienced as something salvific. In this second stage, however, there is a predominant tendency to restore the links with the past, to look for "roots"; the "new" is now interpreted as an organic continuation of the old, which is thus rehabilitated. Ideas of organic development come to the fore.
3. During this stage a tendency develops to find within the imported world-view a higher content which can be separated from the actual national culture of the imported texts. The idea takes hold that "over there" these ideas were realized in an "untrue", confused or distorted, form and that "here", in the heart of the receiving culture they will find their true, "natural" heartland. The culture which first relayed these texts falls out of favor and the national characteristics of the texts will be stressed.
4. During this stage the imported texts are entirely dissolved in the receiving culture; the culture itself changes to a state of activity and begins rapidly to produce new texts; these new texts are based on cultural codes which in the distant past were stimulated by invasions from outside, but which now have been wholly transformed through the many asymmetrical transformations into a new and original structural model.

5. The receiving culture, which now becomes the general centre of the semiosphere, changes into a transmitting culture and issues forth a flood of texts directed to other, peripheral areas of the semiosphere.

Of course our picture is highly schematic. In reality the circulation of texts moves ceaselessly in all directions, large and small currents intersect and leave their traces. At the same time texts are relayed not by one but by many centres of the semiosphere, and the actual semiosphere is mobile within its boundaries. Finally, these same processes occur at different levels: periods when poetry invades prose alternate with periods when prose invade poetry; there are times of mutual tension between drama and the novel, between written and oral culture, and between elite culture and oral culture. One and the same centre of the semiosphere can be at one and the same time both active and “receiving”, one and the same space of the semiosphere can be both in one sense a centre and in another sense a periphery; attractions provoke rejections, and borrowings provoke originality. The semiosphere, the space of culture, is not something that acts according to mapped out and pre-calculated plans. It seethes like the sun, centres of activity boil up in different places, in the depths and on the surface, irradiating relatively peaceful areas with its immense energy. But unlike that of the sun, the energy of the semiosphere is the energy of information, the energy of thought.

Semiotic systems are in a state of constant flux. Such is the law too of the semiosphere which is subject to change both in its inner structure and as a whole. In what follows we shall be discussing a particular kind of internal change. Within the framework of each of the substructures which make up the semiosphere there are elements which are fixtures in its space, and elements with relative freedom of movement. The former belong to social, cultural, religious and other structures, while the latter have a higher degree of freedom of choice in their behavior. A hero of the second type can act, that is, can cross the boundaries of prohibitions in a way that others cannot. Like Orpheus or Soslan from the epic of the Narts, he can cross the boundary separating the living from the dead, or like the Benandanti he can wage nocturnal war with witches, or like one berserk he can fling himself into battle, defying all rules – naked or clad in a bearskin, howling like a beast and killing his own people as well as the enemy. He may be a noble robber or a *picaro*, a sorcerer, spy, detective, terrorist or superman – the point is that he is able to do what others cannot, namely to cross the structural boundaries of cultural space. Each such infringement is a deed, and the chain of deeds forms what we call plot.

Symbolic Spaces

Humanity, immersed in its cultural space, always creates around itself an organized spatial sphere. This sphere includes both ideas and semiotic models and people’s recreative activity, since the world which people artificially create (agricultural, architectural and technological) correlates with their semiotic models. There is a two-way connection: on the one hand, architectural buildings copy the spatial image of the universe and, on the other hand, this image of the universe is constructed on an analogy with the world of cultural constructs which mankind creates.

The importance of spatial models created by culture lies in the fact that, unlike other basic forms of semiotic modeling, spatial models are constructed not on a verbal, discrete basis but on an iconic continuum. Their foundation are visually visible iconic texts and verbalization of them is secondary. This image of the universe can better be danced than told, better drawn, sculpted or built than logically explicated. The work of the right hemisphere of the brain here is primary. But the first attempts at self-description of this structure inevitably involve the verbal level with the attendant semantic tension between the continual and the discrete semiotic pictures of the world.

The spatial picture of the world is many-layered: it includes both the mythological universum and scientific modeling and everyday "common sense". Every normal person has these (and many other) layers which form a heterogeneous mixture which functions as a whole. In the mind of modern man there mingles Newtonian, Einsteinian (and even post-Einsteinian) ideas with deeply mythological images as well as persistent habits of seeing the world in its everyday sense. Against this substratum can be seen images created by art or deeper scientific ideas and also the constant transcoding of spatial images into the language of other models. The result is the complex semiotic mechanism which is in constant motion.

The spatial image of the world created by culture is situated as it were between humanity and the outer reality of Nature and is constantly drawn to these two poles. It turns to humanity in the name of the outside world whose image it is, while the historical experience of man subjects this image to constant reworking, striving for accuracy in its representation of the world. But this image is always universal while the world is given to human beings through experience only partially. The contradiction between these two mutually associated aspects is inevitable and ineradicable; together they form the universal plan of content and expression, and the reflection of content in expression is inevitably not wholly accurate.

No less complex are the relationships between human beings and the spatial image of the world. On the one hand, the image is created by man, and on the other, it actively forms the person immersed in it. Here it is possible to draw a Paralel with natural language. We could say that the activity generated by human beings towards the spatial model has its origin in the collective, whereas the reverse tendency affects the individual. But there is also a Paralel in poetic language, which creates a personality which then has a reverse effect on the collective. As in the process of language-formation so in the process of spatial modeling both tendencies are active.

Can There Be a Science of History?

If the function of history is still the same aim of "thinking of the past as it really was" (the formulation is an old one but it is surely true of every historian), then memory is an instrument for thinking in the present although the content of the thought is the past. Or in other words, the content of memory is the past, but without memory we cannot think “here” and “now”: memory is the deep-seated ground of the actual process of consciousness. And if history is culture’s memory then this means that it is not only a relic of the past, but also an active mechanism of the present.

If we have to use a metaphor in order to imagine the capacity for memory, then, the least appropriate one is the image of the library with books on its shelves, or a computer with data of whatever quantity stored in its memory. Memory is more like a generator, reproducing the past again; it is the ability, given certain impulses, to switch on the process of generating a conceptualized reality which the mind transfers into the past. This capacity is part of the general process of thinking and is inseparable from it.

The interrelationship between cultural memory and its self-reflection is like a constant dialogue: texts from chronologically earlier periods are brought into culture, and, interacting with contemporary mechanisms, generate an *image* of the historical past, which culture transfers into the past and which like an equal partner in a dialogue, affects the present. But as it transforms the present, the past too changes its shape. This process does not take place in a vacuum: both partners in the dialogue are partners too in other confrontations, both are open to the intrusion of new texts from outside, and the texts, as we have already had cause to stress, always contain in themselves the potentiality for new interpretations.

Conclusion

The individual human intellect does not have a monopoly in the work of thinking. Semiotic systems, both separately and together as the integrated unity of the semiosphere, both synchronically and in all the depths of historical memory, carry out intellectual operations, preserve, rework and increase the store of information. Thought is within us, but we are within thought, just as language is something engendered by our minds and directly dependent on the mechanisms of the brain, and we are with language. And unless we were immersed in language, our brain could not engender it (and vice versa: if our brain were not capable of generating language, we would not be immersed in it). The same with thought: it is both something engendered by the human brain and something surrounding us without which intellectual generation would be impossible. And finally the spatial image of the world is both within us and without us.

We are both a part and a likeness of a vast intellectual mechanism. Hence the difficulties but also the importance of the kind of research we are doing. The emergent synthesis becomes ever clearer: whether we are studying the structure of the literary text, the functional asymmetry of the hemispheres of the brain, the problems of oral speech or of deaf and dumb language, the advertisements of our modern age or the religious ideas of archaic cultures – we find the different mechanisms of the single intellectual life of humanity. We are within it, but it – all of it – is within us. We are at the same time like *matryoshkas*, and participants in an endless number of dialogues, and the likeness of *everything*, and “the other” both for other people and for ourselves; we are both a planet in the intellectual galaxy, and the image of its *universum.*

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Part II

The Biosemiotic Project of Thomas A. Sebeok

Chapter 6
Biosemiotics: Its Roots, Proliferation and Prospects

Thomas A. Sebeok (1920–2001)

Introduction and Commentary: Thomas A. Sebeok

> *Scarce is the polymath of the magisterial stature of, say, Charles Peirce, capable of reaching athwart more than a couple of disciplines, especially across the humanities and the sciences, which are perhaps uniquely bridged by semiotics.*
>
> T. Sebeok (2002: xxii)

Because the figure of Thomas A. Sebeok looms so large throughout this volume, cited far more here than any other thinker (except, perhaps, Charles Darwin), and because the story of his founding of the contemporary interdiscipline of biosemiotics is recounted in some detail in the introductory overview of biosemiotics that is Chapter One of this volume, we will limit the comments that appear in this reading selection preface to just the barest biographical sketch, so as to allow the reader the pleasure of reading Sebeok's own account of the founding of the "biosemiotics" project in his own words in the following selection.

Thomas Albert Sebeok was born on November 9, 1920 in Budapest, Hungary. At age sixteen, he began his university studies at Magdalene College in Cambridge, where he studied under philosopher and rhetorician Ivor Armstrong Richards (1893–1979), whose monograph *The Meaning of Meaning* (co-authored with Charles Kay Ogden (1889–1957) in 1923), was an early and lasting influence. In 1937, Sebeok enrolled at the University of Chicago, where he attended lectures by, and was briefly under the mentorship of, semiotician and philosopher of science Charles Morris (1901–1979), whose wide-ranging areas of interest were similar to Sebeok's own. At the time of his enrollment, Sebeok was hoping to pursue a career in biology, but the outbreak of World War II in 1939 convinced him that he could be more useful to the world as a linguist, and during the war, Sebeok did much work in developing training materials in Hungarian and Finnish for the United States government.

Sebeok earned his bachelor's degree in linguistics at the University of Chicago in 1941, and from there went on to Princeton, where he earned his Master's Degree in anthropological linguistics and his Ph.D. from the Department of Oriental Languages and Civilizations in 1945. It was during this time, too, that Sebeok made the acquaintance of émigré Russian linguist and literary critic Roman Jakobson (1896–1982), who was teaching both at Columbia University and at the New

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York City New School for Social Research, and who became Sebeok's doctoral dissertation advisor. Sebeok was naturalized as a United States citizen in 1944, and following his graduation from Princeton in 1945, joined the faculty of Indiana University at Bloomington, which became his home university for the next 45 years.

Ever a prolific researcher, author, and academic impresario, the resumé of Sebeok's first decade and a half at Indiana University – long before he got into his stride as world-renowned semiotician, much less biosemiotician – illuminates much about the man:

> A linguist studying Finno-Ugric languages, Sebeok's linguistic fieldwork took him to Central and Eastern Europe, including Lapland and the former Soviet Union. He also carried out studies in the former Mongolian People's Republic, Mexico and in the U.S. (among the Winnebago Indians of Wisconsin and the Laguna Indians of New Mexico). In addition to these studies in grammar and phonology, his interest in anthropology, folklore and literary studies led to early publications dealing with folksongs, charms, games, poems and the supernatural. He carried out some of the first computer analyses of verbal texts and published a path-breaking volume on *Myth* in 1955, and one on *Style in Language*, in 1960. At the same time, he contributed to the creation of the new field of psycholinguistics, publishing, with Charles Osgood, the famous classic text, *Psycholinguistics*, in 1954. By 1960, he had established himself as a scholar known for overcoming academic boundaries between subjects in his own research, in collaborations with scholars in adjacent fields, and in organizational roles as an book and journal editor, founder and officer of several academic organizations, conference organizer, and mentor (Vlahakis 2002: o.l.).

Characteristically enough, however, Thomas A. Sebeok was best known, and is remembered today, for his accomplishments in the forty-one-year period beginning *after* these first fifteen years' worth of preliminary academic accomplishment *prior* to his development of a multidisciplinary research agenda that he would name "Semiotics." Moreover, Sebeok remained intellectually and indefatigably active in intellectual circles right up until the day of his death on December 21, 2001, when he died at his home in Bloomington, Indiana, at the age of eighty-one.

Yet even in the above thumbnail sketch of his "freshman years" as a public intellectual, one can detect Sebeok's trademark "uncontainable interest in everything" and his commitment to what he described as the two fundamental academic virtues of "publishing and teaching as much as possible; and, equally importantly, doing one's best to facilitate the success of one's colleagues" (1995: 125). An inveterate chronicler of not only the traditions that he saw himself as inheriting, but also of the development of those traditions as it was taking place in his own time, Sebeok records that it was at a conference devoted to the study of "the *kinesics* and *paralinguistics* of non-verbal communication" that he had organized in 1962, where anthropologist Margaret Mead (1901–1978) suggested using the term *semiotics* as a "cover noun" to denote the study of "patterned communication in all modalities" (Sebeok 2002: xiii, Sebeok et al. 1964: 5).

This term – which at once captured historical resonance with the work of Peirce and Morris, but was yet sufficiently general to include all the possible manifestations of sign use that Sebeok was interested in actively investigating – became the aegis under which he worked and thought from that point on.[1] The conference proceedings themselves were published by Sebeok in 1964 under the title *Approaches to Semiotics*, spawning a book series of the same name that he personally oversaw, and that eventually ran to 112 volumes over the course of its almost 30 year run.

Philosopher and historian of sign study John Deely proclaims that Sebeok's "publication of *Approaches to Semiotics* volume from the 1962 Indiana conference of surely marks the beginning in North America of semiotics as an intellectual movement" (Deely 2004: o.l.), and within five years of its publication, Sebeok would found the International Association for Semiotic Studies (Association Internationale de Sémiotique) with colleagues Umberto Eco (b. 1932), Roman Jakobson (1896–1982), Roland Barthes (1915–1980), Emile Benveniste (1902–1976), Algirdas Julien Greimas (1917–1992) and Juri Lotman (1922–1993). At this time, Sebeok was also elected as Editor-in-Chief of the association's journal, *Semiotica*, a position that he held from the journal's inception in 1969 until his death in 2001.

Two major bibliographical surveys (Deely 1995, Umiker-Sebeok 2003) of books and journal articles authored by Sebeok at the time of his death lists five-hundred-seventy-nine single-authored or co-authored entries. "Reviews and miscellanea (forewords, encyclopedia articles, etc.)," notes John Deely, "raise the writings to eight-hundred-thirty-three. Editorial work promoting other scholars adds another three-hundred-ninety-five volumes" for a total of 1,228 published scholarly works. Yet, notes Deely

> for all of Thomas A. Sebeok's prodigious range of intellectual involvements, positions, acquaintances, presentations and writings – his visiting appointments in thirty-five universities of twenty different countries; his honorary doctorates in the U.S.A., Hungary, Argentina, Bulgaria, Finland; as president of organizations in anthropology, linguistics, semiotics; his Fulbright grants to Germany, Italy, Argentina, Uruguay, Mexico; as Fellow of the Stanford Center for Advanced Study in the Behavioral Sciences, the East-West Center, the Netherlands Institute for Advanced Study, the National Humanities Center, the Smithsonian, the Woodrow Wilson International Center; etc., etc. – it was into his shaping of the doctrine of *signs* that everything else was gathered and found its place (Deely 2004: o.l.).

Indeed, Sebeok's obituary states that of all his eighty-one years' worth of accomplishments, "he was most proud of having brought into being a group of theoretical biologists and semioticians to pursue this field of investigation" (Vlahakis 2002: o.l.).

Such "bringing together" consisted not just in Sebeok's indefatigable efforts at creating publication venues for these authors, encouraging them in their often neglected efforts, and bringing their ideas to a larger audience by citing them insistently in his own widely-read work – all of which he did unceasingly – but, much

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[1] Recalls Sebeok: "By 1962, I had edged my way into animal communication studies. Two years after that, I first whiffled through what Gavin Ewart evocatively called 'the tulgey wood of semiotics'" (Sebeok 1986a: ix).

more importantly, in his tireless efforts to realize an active and ongoing, cross-disciplinary *community* of scholars who would work together on the puzzles of organismic sign-processing long after he was gone.

It is for such reasons that we think of Thomas A. Sebeok today not so much as the 'founder' of an institutionalized approach to the study of biosemiotics, but as the intellectual and inspirational 'father' of an ever-branching lineage of individual inquirers, all of whom are motivated by the same kinds of questions that motivated Sebeok – but who, were it not for Sebeok's lifelong efforts at illuminating the "family resemblances" uniting all their inquiry, may never have realized the power of that collective unity.

The story of how Thomas A. Sebeok founded the contemporary project of biosemiotics appears in the selection that begins this anthology, and has been recounted in several other highly illuminating texts as well (many of which are listed in the *Further Readings* bibliography appearing later in this volume). But in the following selection, the reader will have the signal pleasure of being taken on a brief but grand tour of the history of biosemiotics by the master of the sign himself. In the selection that follows, Sebeok situates the biosemiotic project at the intersection of its twinned larger contexts of biology and semiotics, and recounts the involvement of himself, Giorgio Prodi (1928–1987), Heini Hediger (1908–1992), and Thure von Uexküll (1908–2004), in attempting to establish the "latest iteration" of the millennia-long project of examining the role of sign relations in life processes.

Biosemiotics: Its Roots, Proliferation and Prospects (2001)

> *Cognition is simply a development of the selective attitude of an organism toward its environment and the readjustment that follows upon such a selection. This selection we ordinarily call 'discrimination', the pointing-out of things and the analysis in this pointing. This is a process of labeling the elements so that you can refer to each under its proper tag, whether that tag is a pointing of the finger, a vocal gesture, or a written word.*
>
> (Mead 1936: 350)

Throughout Western intellectual history, most semiotic theories and their applications have focused on messages – whether verbal or otherwise – in circulation among human beings, generally within their cultural setting. This kind of semiotic inquiry, characterizable as anthropocentric or, even more circumscribed, as logocentric, has been the rule since ancient times.

A partial if conspicuous, yet until recently by and large undeclared, exception to this tradition has been iatric semiotics, concerned with the arts of healing (symptomatology, diagnostics, prognostics, and the like), practiced and written about by physicians such as Hippocrates of Cos (B.C. 460–377) – called by many the Father of Medicine but by some also "der Vater und Meister aller Semiotik" (Kleinpaul 1972: 103; on medical theory and sign theory in Pre-Alexandrian times, see Langholf 1990: 57–68, 82–93, 150–164); or the great Neoplatonist Galen of Pergamon (A.D. 129–c200) (Sebeok 1996). As Baer observed of the Greeks: "Signs [*sēmeia*] are here construed as bodily clues that allow inferences based on observation" (1988: 47).

Iatric semiotics persevered with numberless modern successors of these venerable figures, to name only a few, through Thomas Sydenham (often called the "English Hippocrates") in the 17th century; F. G. Crookshank, also of London, emphatic about "the necessity to Medicine of a Theory of Signs" (1938: 354); Harley C. Shands, a distinguished New York cardiologist turned bountiful semiotician; F. Eugene Yates, a Los Angeles specialist in medical engineering who contends that science in general "has been permeated with semiotic issues all along" (1985: 359); and a host of other contemporaries.

But no pillar of the medical establishment would more crisply and trenchantly discern and signal a crucial paradigm shift in, or a consistently comprehensive semiotic overview of, the intellectual landscape than Thure von Uexküll [hereafter in this text: Thure]. To be sure, his familial as well as medical credentials are unique. So it is apposite and was presumably perhaps foreordained that he would most explicitly pinpoint *biosemiotics* as the underlying exemplar for medicine, especially so in its aspect as a natural science concerned with "illness as a disturbance of a complicated physio-biochemical machine" (1982: 206, 1991).

A few years later, he spelled this out further: "The overwhelming majority of objective evidence of a disease belongs to those types of processes taking place within the body, which, in turn, are divided into subsystems (organ systems, organs, tissue, cells, cellular organelles)" (Thure 1986: 204). Just as, on the macroscopic level, "evolution depends on setting up new systems of communication" (Jacob 1974: 308), so also within the organism, no less than between the organism and its Umwelt. The components listed are among the major participators in the interchange of signs that ceaselessly ebbs and flows on the interior plane; accordingly, the living things are indeed aptly regarded as a web of semioses. In 1976, I tagged such schemes "cybernetic systems within the body" and then termed their operations "endosemiosic" (1985 [1976]: 3).

By 1993, the conceptual framework for internal somatic sign transactions was comprehensively expanded by Thure and two of his medical associates. Since, as these authors point out, all sign processes within "are indirectly linked to phenomena in the organism's environment ... these endosemiotic signs which belong to an 'inner world' have to be translated into the codes of other ... sign systems" (1993: 5–7). Such other codes belong to those exosemiosic transactions which were described by means of what Jakob von Uexküll [hereafter in this text: Jakob] named a functional cycle (cf., e.g., 1973 [1920, 1928]: 151–156; see also T. von Uexküll 1987: 166–169).

"Medicine", as Thure highlighted, was ever "a semiotic discipline" (1992: 455). And, as the historian Carlo Ginzburg pointed out, this "model of medical semiotics or symptomatology", and "the 'semiotic' approach, a paradigm or model based on the interpretation of clues, had become increasingly influential [in the 19th century] in the field of human sciences". But in fact its "roots ... were far more ancient". They can be traced to Mesopotamian forms of knowledge and beyond (1983: 87–91). The medical crafts should thus be seen as the ultimate cradle of – and a lengthy if tacit prologue as well as a vivid backdrop to – not merely endosemiotics but its comprehensively encompassing domain that has become increasingly known in the last quarter of our century as *biosemiotics*. This embraces, according to one recent exposition, "all processes that take place in animate nature at whatever level, from the single cell to the ecosystem", as "concerned with the sign aspects of the processes of life itself, not with the sign character of the theoretical structure of life sciences" (Hoffmeyer 1998: 82). In a different but equally valid formulation, "the socio-semiological limits of intentional communication ... are largely overcome [by means of biosemiotics] as we are introduced to the global logic of the great ecosystem named Gaia where conceptual boundaries finally open up to the encounter between semiosis and life" (Petrilli 1999: 316). Furthermore, as Thure affirms, biosemiotics remains "of central interest for the biosciences and medicine" (1992: 456; for his most extended relation to-date, cf. 1997; for an early map of this then still ill-defined territory, see the collection by Sebeok and Umiker-Sebeok 1992). In short, the province of biosemiotics coincides in its entirety with that of the biosphere, which, in this context, is tantamount to the "semiosphere" (but in a sense far vaster than in Lotman's usage).[2]

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[2] For the contrast between Y. M. Lotman's anthropological usage and V. I. Vernadsky's global usage, see Sebeok (2000).

Terminological issues abound, but this is hardly the place to rehearse the attendant philological niceties beyond acknowledging that the very label of this emerging domain of knowledge seems to have been claimed independently – at least twice in the US and once in the former Soviet Union – over the past few decades. What remains important is to corroborate that the *domain* of biosemiotics and the *field* of biosemiotics[3] surfaced a long time *avant la lettre*; and that, furthermore, its ripeness did not just happen in a simple linear progression but surged by fits and starts as a convoluted affair, winding its long but episodic way through at least three successive 20th century iterations: I register these, respectively, with the names of J. von Uexküll [1864–1944], Heini Hediger [1908–1992], and Giorgio Prodi [1928–1987]. In the telling, I must make it clear that I intend to proceed not as a professional historian but rather as an implicated deponent, a predisposed witness, variously involved in the unfolding chronicle. The following account will therefore have an autobiographical tinge; but I have never before set the better part of it forth in print.

Jakob spent his student days at the University of Dorpat, in Estonia (1884–1888). But all pilgrims' paths eventually lead to Germany – according to the canonical version of his triumphant trajectory – where he became a citizen in 1918, joining (when already in his sixtieth year) the University of Hamburg in 1924. He founded and led the Institute for Umwelt-Research there from 1925 to 1940. Although he produced the first edition of his *Theoretische Biologie* in 1920, he prepared a thoroughly revised second edition in Hamburg, to appear 8 years later then to be posthumously reprinted in 1973. The only English translation, published in 1926, was thus calamitously based on the first edition. This circumstance, aggravated by the poor quality of this rendering, alas retarded the appreciation (especially so, deplorably enough, in the Anglo world) of his Umwelt-science – and, correspondingly, the flowering of biosemiotics – by about half a century. Thomson, in his review of the English version, chose, ambivalently, to "congratulate Dr. D. L. Mackinnon on her remarkably successful translation of what we know to have been very difficult German. No one but an organically philosophical biologist could have achieved such a conspicuous success. Not that the book can ever be easy-reading, in the most lucid translation". Yet, on the other hand, he grouses that "an unnecessary difficulty seems to be raised by the use of difficult terms, which perplex the reader gratuitously" (1927: 419, 415).

I myself first read the book in English in 1936, finding it bafflingly murky; but then I read the second German edition in 1976, and found that, if not pellucid, nonetheless electrifying (Sebeok 1998a: 32–34). Some time later still, this experience led me to instigate and arrange for the publication of two of Uexküll's shorter monographs in English (1982 and 1992).[4]

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[3] For this important distinction – which is particularly pertinent to biosemiotics – between "domain" and "field", see Csikszentmihalyi (1996).

[4] Ironically, Klopfer and Hailman wrote of his earliest classic work, the *Umwelt und Innenwelt der Tiere* (1921 [1909]), that this has "had relatively little effect on animal behavior studies compared with the great originality of its content" (1967: 126). One reason for this seems to have been that it was far ahead of its time; or, in Csikszentmihalyi's parlance, that there was no field competent

But long before then, in the mid-1970s, I resolved to investigate Jakob's writings for my own edification, and to look at what others had written about them.[5] These exploratory readings resulted in a paper titled "Neglected figures in the history of semiotic inquiry: Jakob von Uexküll", which I first presented in an abridged version in August 1977 at the III Wiener Symposium über Semiotik (Borbé 1978); the final, much longer version appeared in a book of mine, *The Sign & Its Masters* (1989 [1979]: 187–207, 290–291). This chapter, my personal appreciation of Jakob and his principal works, was widely noticed, despite the fact that it was in the main researched and, foremost, composed to educate myself. So one needs to ask: just what did this piece accomplish for my readership? The answer is: it redefined and relocated a nonpareil pioneer investigator of a *domain* (*Umweltlehre*) and sanctioned his having done so in a *field* (biosemiotics) appropriate to and by that time at last receptive of his creative achievement.[6]

Thure was among my audience in Vienna. He reacted to my paper about his father with no cavils, indeed, with enthusiasm. We had an extended talk over an ensuing dinner, in consequence of which, as a next step a few months afterwards, Thure came to call on me at my Bloomington home for a further lengthy evening's discussion. These two talks gave early impetus to, then came to decisively shape, the subsequent unfolding of biosemiotics. Among other things, it was during these initial dinner meetings that the two of us hammered out concrete publication plans in English of several works by both Jakob and Thure himself. Most of these eventually appeared in *Semiotica*, or in other series under the auspices of Walter or Mouton de Gruyter, or were issued by other houses in Germany and the US. (Representative items are listed among the references below.)

There were some other far-reaching consequences that flowed from our talks, two among them being especially worth some comments here.

First, the idea of launching a series of annual international conferences devoted to biosemiotics was broached and soon realized by Thure. Repeated about five or six times in the late eighties and early nineties, these were held on the premises of the Glotterbad Clinic for Rehabilitative Medicine in Glottertal, Baden-Württemberg, Germany, under his leadership, with the signal cooperation of Jörg M. Herrmann, M.D., the Clinic's Director. Thure, in his Introduction to one of the sessions, on "Models and methods in biosemiotics", succinctly stated the aims: "to support the experiment of bringing together Humanities, represented by semioticians; Natural

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in the domain to take control over it: "There are several ways that domains and fields can affect each other. Sometimes domains determine to a large extent what the field can or cannot do . . . No matter how much a group of scientists would like their pet theory accepted, it won't be if it runs against the previously accumulated consensus" (1996: 44).

[5] That research was in large part conducted at the Netherlands Institute for Advanced Study, where I was a Fellow during 1973–1974.

[6] See again Csikszentmihalyi (1996). Note my continued emphasis on the availability of a responsive field, which was by no means at hand in 1934, when Bühler first recognized the semiotic character of the *Umweltlehre,* "welcher von vornherein in seiner Grundbegriffen M*erkzeichen* und *Wirkzeichen* sematologisch orientiert ist" (1965 [1934]: 27).

Sciences, represented by experts in molecular biology; and Medicine, a science with an uncertain position between both of them, represented by internists, psychiatrists, and clinical psychologists". He depicted the topic of the conference as "the proposition of an order in nature which has nothing to do with causality, but which canalizes causal processes between living systems and their environment as well as in and between these systems. We maintain", he concluded, "that this order is a semiotic one or at least can be described in semiotic terms" (1990: 1).[7]

Secondly, Thure made arrangements for me to spend a week or so visiting him in Freiburg (in part intended to coincide with Rowohlt's publication of my German paperback, *Theorie und Geschichte der Semiotik*, where I characterized Jakob as "einer der grössten Kryptosemiotiker seiner Zeit" [1979: 10]). Our Freiburg discussions about multifarious biosemiotic topics were carried out, with rare intensity, from morning late into every night, and were happily augmented by the continuous participation of Giorgio Prodi, Director of the Institute for Cancer Research of the University of Bologna. Prodi, an astounding polymath (Eco 1988) who had become my friend several years earlier, encountered Thure for the first time on that occasion; the two of them met only twice more, first in Palermo in the summer of 1984, then the last time in Lucca in the early fall of 1986 (Sercarz et al. 1988). Prodi sparked the third biosemiotic iteration, to which I shall return below after sketching the second.

One of the sundry riddles that mar the gradual coming into view of modern biosemiotics – the second iteration, if you will – is the neglect of Heini Hediger, whose lifelong attempt to understand animals surely marked a milestone in the elucidation of this domain, providing it with a particularly beneficial empirical footing. This seeming indifference – or is it blindness? – to his capital achievements is the more puzzling in the light of Hediger's manifest admiration for Jakob, whose *Umweltlehre* clearly had a decisive influence on his own highly original analyses of the psychology and biology of animal flight response (or negative territoriality). For instance, touching on his 1932 dissertation and work resulting there from, he wrote: "This work was surprisingly successful; it was especially well received by J. von Uexküll at the Institute for Environmental Studies in Hamburg, where I met both him and his successor, F. Brock. For my part, I was extremely impressed by von Uexküll's Umwelt-Lehre .... Consequently, I dedicated another paper following that on my flight work, a study of tameness, to von Uexküll ... these two subjects

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[7] Those attending the Glottertal conferences one or more times included, besides many Germans, Swiss, Danes (e.g., Hoffmeyer), Estonians (e.g., Kull), and myself from overseas. A prominent German semiotician whom I remember being there on each occasion was Martin Krampen, who substantiated *phytosemiotics*, i.e., the semiotics of plants, putting this then novel domain on an equal footing with other recognized branches of biosemiotics (1981: 187; see discussion above). A large wind-up gathering in this series was organized in the nineties by Hoffmeyer; this took place in Denmark, with an expanded attendance on the part of Scandinavian semioticians as well as natural scientists. More recent locations for biosemiotics get-togethers (enumerating here only those which I myself was asked to participate in, several repeatedly) were scheduled in Berkeley, Denver, Dresden, Gaithersburg, Imatra, Guadalajara, Kassel, Las Cruces, São Paulo, Tartu, and Toronto.

formed the basis for my later investigation concerning the relationship between animals and man, especially in the zoo. In addition, they led to the founding of zoo biology ...” (1985: 149). Hediger’s seminal discoveries of the concepts of individual and social space in application to animals of many kinds were later applied to humans and further fruitfully elaborated under such labels as “proxemics” in anthropology (Hall 1968).

Some years afterwards, I myself discussed nine specific circumstances (among no doubt several others) in which man may have “semiotic encounters” with animals (Sebeok 1988: 68–71). These juxtapositions include taming, training in several interdependent variations (*apprentissage*, *dressage*, domestication, and the like). My understanding of such procedures was immensely enriched by Hediger’s wealth of experiences in shaping behavior, especially in zoos and circuses. Hediger totally accepted the principles of zoosemiotics – which of course constitutes a substantial segment of biosemiotics – “[the two of us] have been working together for some time” (Hediger 1985: 151; see further his 1980 book, with numerous examples and references under this heading).[8] As he noted, we “often met in Zurich or Amsterdam”, and, in 1980, he was my guest in New York City. In all these venues, we frequented zoos and watched the training and performances of animals in circuses, some large enterprises (like Barnum & Bailey) and others small (such as the Swiss Circus Knie). His powers of observation and their subtlety far exceeded mine, so he taught me many things about applied biosemiotics which I could never have learned on my own (see, for example, his stunning 1974 article, with striking illustrations, on reciprocal semiosis between man and wild animals, viz., panthers, elephants, etc., in the circus). Hediger’s appreciation of the quintessentially biosemiotic constitution of the Clever Hans phenomenon was also uncommonly insightful (Sebeok and Rosenthal 1981: 1–17). He foretold “that eventually an explanation for the extremely complex and, so far, underresearched problem of the relationships between man and animals will be obtained by means of signal study or semiotics, specifically zoo-semiotics” (1985: 177). Over-all, his legacy is a many-sided, profuse research program for biosemiotics that can easily extend for several

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[8] At the risk of being overcome by terminological surfeit (or vertigo), I can offer the following non-exhaustive rundown – with a basic reference or two – of the currently labeled component branches of biosemiotics that I am aware of: protosemiotics (“the basic feature of the whole biological organization [protein synthesis, metabolism, hormone activity, transmission of nervous impulses, and so on]”, cf. Prodi in Sercarz et al. 1988: 55); microsemiotics (in prokaryotes, cf. Sonea 1988, 1990, 1995); cytosemiotics (in cells, renamed microsemiotics by Yates 1997); endosemiotics (in the *milieu intérieur*, T. von Uexküll et al. 1993); phytosemiotics (plants, cf. Krampen 1981, 1997); zoosemiotics (speechless animals, cf. Sebeok 1972, 1990); mycosemiosis (fungi, Kraepelin 1997); and cybersemiotics (cf. Sebeok 1997: 116; androids, robotics, cyborgs, sensor and muscle augmentation, prostheses [eye-glasses, hearing aids, dentures, artificial limbs, mirrors, etc., cf. Eco 1986: 220–222]). Anthroposemiotics (speechifying animals) is usually excluded. Exosemiotics has been used in two different senses: as the opposite of endosemiotics, or in passing reference to the sign behavior of putative extraterrestrial creatures.

generations ahead; (his 1980 book is a veritable treasure house for a research agenda).[9]

Hediger was a visionary innovator who reached from the inside outwards. He felt entirely comfortable within Jakob's Umwelt paradigm, but, implicitly, with (zoo)semiotics too, which he came increasingly and quite explicitly to embrace and profitably apply in his later years. Giorgio Prodi, to the contrary, was a maverick: a prolific physician and experimental oncologist by profession, a novelist by avocation, but also an intermittent if resolute contributor to biosemiotics. However radically idiosyncratic, Prodi's recreation of a domain for biosemiotics was with little hesitation matched up with an existing field, or academic niche, a luxury not enjoyed by Jakob and only indirectly so, and only after his mid-sixties, by Hediger.[10] His first major book on the subject – which claimed to deal with "la preistoria nelle sue pesanti conseguenze sulla storia e sulla teoria della semiosi" (1977: 5) – was promptly accepted for publication by Umberto Eco; he was asked to deliver a paper on the topic at the Third International Congress of the IASS in 1984 (1988b); and invited to prepare a long English version of the former to appear in *Semiotica* (1988a). He was also chosen to be a key participant in the 1986 workshop on immunosemiotics, organized by Sercarz and others, where he spoke on "Signs and codes in immunology" (1988: 53–64).[11] Here he took a decided position against "semiotics as a pure human domain", in contrast to his own perspective of "a general semiotic domain", and introduced the notion of a "protosign", which belongs to "proto-semiotics ... the basic feature of the whole biological organization" – protein synthesis, metabolism, hormone activity, transmission of nervous impulses, and so on (1988: 63, 55).

More extensively, he labeled the domain, over-all, "natural semiotics" (1988c: 149–170), which seems to be roughly equivalent to mathematician Kergosien's "nature semiotics" (1992: 145), as well as to the phrase "semiotics of nature", occasionally used by Hoffmeyer and Emmeche (1991: 117–118) (but who currently seem to favor "biosemiotics").

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[9] A lengthy, illustrated memorial essay of mine, "The Swiss pioneer in nonverbal communication studies: Heini Hediger [1908–1992]" (Sebeok 2001), was prepared for delivery at a conference on "Semiotics and the Communication Sciences", University of Lugano, Switzerland, May 2–4, 2001. The written version is to appear in a volume of transactions being edited by Peter Schulz.

[10] A reminder: one of the central components of creativity is the *field*, "which includes all the individuals who act as gatekeepers to the domain. It is their job to decide whether a new idea or product should be included in the domain". Publishers and journal editors figure prominently among the "field of experts" who recognize and validate innovation, as are academic administrators, officers of public and private sources of financial support, or, to put it briefly, persons with control over access to critical resources (cf. Csikszentmihalyi 1996: 28, 6).

[11] Tomio Tada's definition of immunosemiotics is: "the study of the general principles underlying the structure of sign systems perceived by different cells of the immune machinery", according to which "restrictions in partner cell interactions must exist as part of an intercellular semiotic system" (Sercarz et al. 1988: vii).

In my judgment, these quasi-synonymous terms are poor substitutes for "biosemiotics", There are several reasons for this, some narrow, others broader. The narrow reason is that the word "nature" is used with quite different technical connotations by Jakob, as explicated in Thure's Glossary: "Systematically ordered and complete structure of all *Umwelts* whose meaning is sought in overlapping composition" (1987: 236). Yet, at other times, Jakob equated "nature" with "true reality": "Da die Tätigkeit unseres Gemüts das einzige uns unmittelbar bekannte Stück Natur ist, sind seine Gesetze die enizigen, die mit Recht den Namen Naturgesetze führen dürfen" (J. von Uexküll 1973 [1920, 1928]: 40).

The over-arching context for biosemiotics is our biosphere in the sense of the organic whole of living matter (cf. footnote 2); and this is the only geosphere which contains living matter. Because there can be no semiosis without interpretability – surely life's cardinal propensity – semiosis presupposes the axiomatic identity of the semiosphere with the biosphere. As Short persuasively argued, "there is no basis for the assertion that semiosis occurs outside of living things" (1998: 49) (except, one may add, man's inert extensions, such as automata, computers, or robots). Local nature (Gaia), however, additionally comprehends the inorganic matrix for the place wherein organisms dwell – the enveloping gaseous mass, waters, and rocks; while cosmic nature further includes the totality of extraterrestrial objects (Sebeok 2000).

Another eccentricity of Prodi's is his avoidance of references to the works of others. For example, in his English article, although dealing with intrinsically biosemiotic issues, viz., of "natural semiology" (1988a: 206), he cites only Frege and the 1923 edition of Ogden and Richards. While this composition style perhaps adumbrates Prodi's striking originality, it fails to align him with any predecessors or successors in semiotics, so his untutored readers may flounder for lack of familiar signposts. But having said this, it was also the case that, during the week we spent together in our open-ended 1979 "intensive seminar" in Thure's company on the practical and conceivable ins and outs of biosemiotics, the three of us got along extremely well; as I commented afterwards, "this uniquely stimulating experience enabled me to enhance my writing and teachings . . . in biosemiotics in its various topical subdivisions" (Sebeok 1998b: 34–35).

In 1988, some months after Prodi's untimely death at the age of 59, I received an invitation from the officers of a medical association in his country to attend a sizable memorial gathering at an isolated resort in Southern Italy, where I was to delineate Prodi's contributions to biosemiotics. As it turned out, my fellow participants were all physicians or biologists. His colleagues seemed genuinely respectful of, indeed, fascinated by, the semiotic side of Prodi's scholarly endeavors, yet none publicly declared a commitment to his line of research.

Such appear to me to have been the three principal biosemiotic iterations of the past century. But these evidently do not exhaust the prehistory of this domain. Other creative figures could be named (although, arguably, in a minor key): for one, Kenneth Craik [1914–1945], the reclusive don of St. John's College, Cambridge, who independently invented "another kind of *Umwelt* theory" (Craik 1943; see Sebeok 1991: 104); and for another (if perhaps tangentially) René Thom [b. 1923], the mathematician whose catastrophe-theoretical excursions into areas of biological morphogenesis were powerfully impacted by Jakob's theorems of the dynamic of life (Thom 1975, passim).

Biosemiotics tends sometimes to be promoted, though I think mistakenly, to contrast with cultural semiotics. But "culture" is not much more than that realm of nature where the logosphere – Bakhtin's dialogic universe – impinges in infant lives then comes to predominate in normal adult lives. Yet in fact even mainstream semioticians range over a wide spectrum of attitudes toward biology. Ernst Cassirer's writings are, for instance, saturated not just by biological intimations – Jakob's impress is palpable throughout (e.g., 1944: 23–26; cf. Thure in J. von Uexküll 1992: 311, footnotes 2 and 3). For A. J. Greimas, zoosemiotics looms somewhere in a hazy if rosy future: "it is destined to become a genuine semiotic realm, both autonomous and promising", he once declared (Greimas and Courtès 1979: 376). Umberto Eco, who once banished zoosemiotics to "il limite inferiore della semiotica" (1975: 21), now concedes that "in the depth of biological processes lie the elementary mechanisms from which semiosis springs" (in Sercarz et al. 1988: 15). Louis Hjelmslev remains silent on the matter. And so on . . .

In an attempt to ascertain dispositions in some depth rather than by a mere impressionistic sampling, I was able to persuade an array of colleagues to scrutinize the *oeuvre* of five pre-eminent semioticians of yore – Peirce, Lady Welby, Charles Morris, Roman Jakobson, and Yuri Lotman – "for harbingers of biosemiotic discernments, judgments, prognostications, or at the very least congeniality" (from my Foreword to Hoffmeyer and Emmeche 1999). Readers interested in pursuing the fascinating results of these searches are referred to *Biosemiotica*, constituting Part I of Vol. 127 (1999) of this journal.[12]

In some crudely simple quantitative terms, biosemiotics can certainly be said to have proliferated over the past decade: for example, as compared to the Sebeok and Umiker–Sebeok volume on *Biosemiotics* (1992), which ran to less than 500 pages, the Hoffmeyer–Emmeche volume *Biosemiotica* (1999), ran to 660 pages; but that was, as well, shortly preceded by another over 250-page double issue of the same journal devoted to a closely kindred topic, "Semiotics in the Biosphere" (Vol. 120 [1998]); plus it was closely followed by the present volume, dedicated to the memory, appreciation, and influence of the domain's chief architect, Jakob. Single-author booklength publications in biosemiotics, like Merrell's (1996) or Hoffmeyer's (1993) or Kull's (in preparation), are multiplying, as are collections such as the one by van der Vijver et al., with yet others in sight. Significantly, new reference books are now routinely graced by separate entries, as in Walter de Gruyter's *Handbook of Semiotics* (Posner et al. 1997–1998: 1: 436–591), the Oxford University Press's *Encyclopedia* (Hoffmeyer 1998: 82–85), *Routledge Companion to Semiotics and Linguistics* (Paul Cobley, ed., 2001), and the expanded second edition of *Handbook of Semiotics* (Winfried Nöth, 1990). Too, I have already listed

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[12] Two among these subjects were my former teachers. To gain a still more rounded historical perspective of this cardinal domain of learning, we hope to arrange for similar probes of writings by other such respected figures, for instance, Susanne Langer.

(in footnote 6) scores of recent conventions on biosemiotics, of diverse sizes and varying composition, assembled at venues over four continents.

It is on the other hand also true that biosemiotics – as general semiotics itself – has not typically become a conventional university-based discipline, nor, in my view, should it have.[13] This is not the place to document, or argue again for, my preference, but it is clear that such formal units of knowledge production are by no means the only possible, let alone the most desirable, type of reputational system of work organization and control. Semiotics, and, *a fortiori*, biosemiotics, is, or should be, a field committed to producing novelty and innovations, not much else. Whitley rightly emphasized (1984: 13) that there exists an "'essential tension' between novelty and tradition, or co-operation and competition", a notable feature of certain kinds of modern scientific works, surely inclusive of biosemiotics. He observed that a "broader and more general social unit of knowledge production and co-ordination is the intellectual field". Such fields, conceived as "relatively well-bounded and distinct social organizations which control and direct the conduct of research on particular topics in different ways", possess identities that are by no means always identical with employment or education unit boundaries. They "vary in the degree of cohesion and autonomy from other [academic] structures, but constitute the major social entities which co-ordinate and orient research across a wide variety of situations.... They reconstruct knowledge around distinct 'subjects' and their organization and change are crucial aspects of intellectual work and knowledge production in the modern, differentiated sciences" (Whitley 1984: 7). By "science", Whitley has of course in mind all forms of modern scholarship, not just the natural sciences; and each intellectual field, or craftwork, he stresses, "has a distinctive language for describing cognitive objects and communicating task outcomes which reduces lay participation in the assessment of contributions and enables results from different production sites to be compared and co-ordinated" (Whitley 1984: 34). In a useful tabular form, he differentiates between scientific fields, in which biosemiotics obviously belongs under his type (e) (Whitley 1984: 158, Table 5.2).

Note that each of our three biosemiotics trailblazers was an intrinsically unconventional academic. Jakob, in support of his consecutive faculty engagements in Germany, was, in addition to his affiliation with the Zoological Center in Naples, particularly active in his own Institute for Umwelt-Research at the University of Hamburg. Hediger was, to be sure, a Professor of Psychology at the University of Zurich, but his concentrated intellectual efforts radiated out of a succession of zoological gardens, first at Dählhölzli (Bern), then Basel, finally, effective 1954, his beloved Zurich Zoo. Prodi, who held the Chair in Experimental Oncology at the University of Bologna's School of Medicine, worked out of his own Instituto di Cancerologia. The functions of these distinctions, which may seem to academic outsiders mere subtle refinements, or frosting atop of a cake, are perfectly understood by professors like me, for I too was the chairman of a Research Center at my

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[13] For glimpses of the relation of semiotics and biosemiotics, see T. von Uexküll (1998: 2189–2190).

institution for 37 years. This is also why the University of Tartu's Jakob von Uexküll Center – a modernized reincarnation (under Kalevi Kull's direction) of the Hamburg prototype – is fraught with such promise of new research departures, supplementing his university's time-honored departmental structures necessarily dedicated to upholding traditional paths of teaching and learning propagation.

An interesting condition specified for the establishment of scientific fields as distinct systems of work organization is that "each field has to control a separate communication system", that is, a benchmark set of shared vocabulary items of its own that differentiates this field from all others as a sort of monopolistic exclusion device (Whitley 1984: 29, 31–32). This is why Jakob's seemingly arcane terminology, often remarked on by biologist commentators and other readers, is so advantageous, even when – or especially because – it provokes an often felt need to have recourse to an accompanying formal Glossary (e.g., in 1982: 83–87). This was pointed out by Thure himself when he insisted that the differences in Jakob's "terminology are not to be regarded simply as a source of difficulty; they may also prove helpful where the various semiotic theories diverge". Here he surely refers to the unavoidable disparities between his father's idiom and Peirce's and Saussure's (1987: 148; see also Krampen 1997: 512).[14]

Although Jakob's research interests in principle encompassed the comportment of *all* organisms, he in fact spun his theory of models and of the attendant functional cycle almost entirely out of his observations of "the worlds of animals and men", particularly marine animals (jellyfish, sea-urchin, octopus, trout) and insects (annelids, ticks, dragonflies). He is therefore justly to be counted among the founders of ethology (Bleibtreu 1968: 13), for this "certainly owes more to his teaching than to any other school of behaviour study" (Lorenz 1971: 277); and many of the phenomena and operational concepts that "gave focus to classical ethology were first described, or at least anticipated" by him (Dyer and Brockman 1996: 529). His design was also commonly used by early investigators of synchronic animal communication processes, as well as for the testing of the hypothesis of "ritualization" – or what I have elsewhere called "the semiosis of *gene-dependency*" – an intriguing special case of diachronic sign science (Sebeok 1989 [1979]: 29–30, Fig. 2.1). Inasmuch as any animal's communication system must be a natural extension of its sensorium, which invokes an understanding of its Umwelt, it is easy to appreciate how indispensable Jakob's insights were to the origins and development of

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[14] There is no evidence that these three masters of the sign were aware of one another. The meandering, diffuse arguments at last June's (1999) twin Uexküll-related meetings (Tartu, Imatra) over matters of basic terminology underline these points. There were sharp debates about the meaning even of such a pivotal term as *Umwelt* and its correct rendering into English, ranging from such approximations as "perceptual universe", "selfworld", or "phenomenal world", to such absurdities as "environment" (but see Immelman and Beer 1989: 88) or "niche". Despite the fact that the closest English equivalent is manifestly "model", the only palpable group consensus reached was the unhelpful surrender, that the German word should be retained in English. Nevertheless, seemingly recondite concerns about technical vocabulary, leading toward a standardized symbol system, tend to reinforce the unity of a field like biosemiotics.

zoosemiotics (Sebeok 1972: 61). Doubtless, the most cited example of the zoosemiotic aspects of Jakob's explorations is his fabled scrutiny of *Ixodes rhitinus*, the cattle tick (whose story Bleibtreu opens his 1968 book with), often revisited, and reinterpreted in a Dresden lecture by Udo Figge as recently as February 1999 in strictly semiotic terms (See now Figge 2001).

Hediger had a sweeping yet intimate knowledge of the behavior of an exceptionally wide range of animals – especially terrestrial vertebrates – based on extensive field work as well as acute observations both in and far beyond the zoo. At the very outset of his remarkable book he specifies: "Insbesondere werden wir uns mit der Zoosemiotik zu befassen haben, also mit den Signalen, die zwischen Tieren und besonders zwischen Tier und Mensch in beiden Richtungen wirksam sind, gewissermassen hin und her schwingen", Later he adds: "Der Zoosemiotik bleibt noch ein weites Feld zu bearbeiten" (1980: 10, 144), but already Hediger himself impressively contributed to this field. Following in Jakob's footsteps, he consistently applied both biological and semiotic criteria to the study of animal communication. Jakob did so implicitly, Hediger eventually in quite categorical terms.

Some have suggested that "Biosemiotics has evolved from the study of animal communication to more general considerations of biological codes" (e.g., Peter Cariani in van de Vijver et al. 1998: 360). This, however, simplifies, even skews, an, in truth, far more labyrinthian sequence of events culminating in biosemiotics to which zoosemiotics is but one contributing factor (Sebeok 1998a: 10). This notwithstanding, zoosemiotics is doubtless "a particularly rich branch of biosemiotics because animals are in some sense semiosic mediators between creation and decay. On a macroscopic scale, they can be viewed as transforming agents fixed midway between the 'composer' plants, organisms that set interpret ants in motion, and 'decomposer' fungi, which break them down", viz., between phytosemiosic and mycosemiosic operations. Too, in their role as gobetweens, animals process signs through media embracing the entire sensory spectrum, each – in conformity with Jakob's teachings – according to, but only commensurate with, its specific array of sense organs (Sebeok 1988: 65; 1997: 116).

Others chose to pursue different pathways to stoke the biosemiotic superstructure, an enticing case in point deriving from some casual remarks of Jakob's to the effect that plants lack a function cycle. Krampen has shown the predominance of indexicality in plant semioses, that plants nonetheless do have feedback cycles connecting sensors and regulators, and how "meaning factors" function in the vegetal (vs. animal) realm – or, in a nutshell, how phytosemiosis differs from zoosemiosis (1981, 1997).

Not surprisingly, the guiding preoccupation of medical practitioners from Hippocrates to our day, notably including both Thure and Prodi, has focused on endosemiosis or "protosemiosis" from the cell to the highest integration level, up to the sphere where the non-conscious inner world may in humans and certain other animals become transmutable, by means of sign connections via neurotransmitters, neurohormones, and other neurobiological processes still far from understood, into consciously experienced reality.[15]

Research at the ephemerally woven frontiers of biosemiotics – evolutionarily the highest and the lowest planetary limits of which are circumscribed by two suggestive metaphors (both, as it happens, of Canadian vintage) – are of quotidian concern. The upper periphery, a virtual community, was dubbed a *global village* by Toronto's Marshall McLuhan (1962: 31). This electronically mediated global forum, located nowhere on the superhighway called the Internet, is a very real, if volatile, network of networks. It is populated by biomimetic creatures with unconventional communication schemes and emotive manifestations actualized by media embodiments, such as animation, robot languages and robot speech, and text. Regular and occasional users are subject to the vagaries of cybersemiotics (cf. footnote 7). (According to a report just issued by the Department of Commerce in 2000, 67% of Americans still do not use the Internet.)

The scalar opposite metaphor was coined by Montreal's Sorin Sonea: the *global organism*. Nor did the similitude with the Internet escape him, as he notes: "Like an electronic communications network the bacterial world possesses an enormous data base, in this case in the form of bacterial genes.... This biological communications network, which possesses more basic information than the brain of any mammal, functions in a manner that sometimes resembles human intelligence" (Sonea and Panisset 1983: 85). Furthermore, the ensemble of bacteria resemble "a vast computerized communications network – a superorganism whose myriad parts shift and share genetic information to accommodate any and all circumstances" (Sonea 1988: 45). The smallest known autopoietic entity is a single self-maintaining bacterial cell: the "biosemiotic atom."

The analogy is powerful, yet not absolute. While being wired is optional – we, who are nonusers, think we have rational grounds for our skepticism – the global prokaryotic community inescapably perfuses the Earth. In a way that is literally mind-boggling, all of us eukaryotes are fashioned of bacteria; we are both their habitats and vehicles for further dispersal. In particular, our central nervous system may be characterized as a colony of interactive bacteria. For this reason alone, any biosemiotic theory failing to take into account the multiform data of bacterial semiosis is as flawed as would be one that ignored the complexities of the verbal code in its social ramifications (Sebeok 1997: 114).

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[15] On nitric oxide, that "pantheon of messenger molecules", and so-called "hedgehog genes", cf. Sebeok (1997: 120, footnote 13).

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Chapter 7
The Clever Hans Phenomenon from an Animal Psychologist's Point of View

Heini K.P. Hediger (1908–1992)

Introduction and Commentary: Heini K.P. Hediger

> *My childhood dream, my lifelong wish, would have been fulfilled if it had really been possible to converse with animals.*
>
> H. Hediger (1985: 177)

Swiss zoologist Heini K.P. Hediger (1908–1992), is the second historical figure named in Thomas A. Sebeok's review of the "three successive twentieth-century iterations of biosemiotics" prior to the one that Sebeok himself initiated. "One of the sundry riddles that mar the gradual coming into view of modern biosemiotics," writes Sebeok, "is the neglect of Heini Hediger, whose lifelong attempt to understand animals surely marked a milestone in the elucidation of this domain, providing it with a particularly beneficial empirical footing" (2001: 66).

Born in Basel, Switzerland on November 30, 1908, Hediger would later recount that his early fascination with animals included, by age six, a self-collected menagerie of "sea anemones, fish, snakes, owls, a fox, an opposum, and a slow loris" (1969: 145). His obsessive attention to the behavior of these animals, and the incessant growth of this menagerie, writes Hediger "was negatively correlated with my success at school" (*ibid*). Still, it was clear to him that the study of zoology was his life's passion, and Hediger went on to excel at his studies of zoology, botany, psychology and ethnology at the University of Basel's Zoological Institute under the tutelage of zoologist and interdisciplinan Adolf Portman (1897–1982) from 1927 to 1932. During this time, Hediger also undertook zoological field work in Morocco, Papau New Guinea, and the Solomon Islands, where he discovered several new species – and even a new genus – of reptiles, this latter being the Melanesian coral snake *Parapistocalamus hedigeri.*

What intrigued him most on these expeditions, however, were the related phenomena of territorial marking and the flight distances involved in the escape behavior in fiddler crabs. Hediger's 1934 paper on these phenomena, "Zur Biologie und Psychologie der Flucht bei Tieren", helped pioneer the then newly emerging field of animal *ethology* (along with his then-unknown colleagues Konrad Lorenz and Nikolass Tinbergen, with whom Hediger maintained an active scientific correspondence for many years, as well as with Jakob von Uexküll, whose

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Umweltforschung was an early influence upon, and inspiration to, him). Indeed, Hediger generally credited as the starting-point of the scientific investigation into animal and human *proxemics*.

Notes Estonian zoologist and biosemiotican Aleksei Turovski: “It is hard to believe in our time, but it seems that Heini Hediger really was the first zoologist who realized that there is no such thing as an animal that is ‘free’ in the anthropomorphic sense: ‘The wild animal does not live in freedom: neither in space, nor as regards its behaviour towards other animals’ wrote Hediger ([1950] 1964: 13). Rather, animals in the wild are ‘bound by space and time, by sex and social status’” (1985: 158). Accordingly, neuropsychologists Graziano and Cooke (2006) note that “Hediger’s work on the flight zone led directly to the concept of personal space in humans” – citing anthopologist Edward T. Hall’s work on interactional propinquity (1963) as well as cognitive scientist J.J. Gibson’s ecological approach to visual perception (1979) and, by extension, to the neurobiological research on the spatial-coding areas of the pre-motor cortex that led to the eventual discovery of “mirror neurons” in primates (Fogassi et al. 1992, 1996).

Yet while Hediger found zoological field work much to his liking – it allowed him to finance and to add to his ever-growing private menagerie, for one thing (1984: 150) – he was equally, if not more, passionate about studying the behavior of wild animals in captivity – most notably, in circuses and zoos. Thus, after receiving his doctorate and working as a lecturer at the University of Basel Zoological Institute under his mentor Adolf Portman from 1932 to 1937, Hediger was finally awarded the directorship of a small zoo in Dählhözli, Bern, where he would work for the next seven years (1937–1944), before going on to serve as the director of the Basel Zoo, and then the Zürich Zoo, for the following 30 years (1944–1954, and 1954–1974, respectively).

At Bern, Hediger’s work overseeing every aspect of zoo management, while simultaneously collecting detailed observations of the day-to-day behavior of its wide variety of animals, resulted in the publication of his most famous book, *Wildtiere in Gefangenscaft: Ein Grundriss der Tiergartenbiologie*, in 1942. Translated into English in 1950 as *Wild Animals in Captivity: An Outline of Zoo Biology*, this book established the field of *zoobiology* as a scientific discipline, and became known as “the zoo Bible” for zookeepers around the world (Hediger 1985: 151). Subsequently, Hediger traveled around the world as a consultant for the design and management of zoos and aquariums, and accepting commissions from the governments of Brazil, India, Switzerland and Australia for overseeing the planning and management of ever more naturalistic, humane and animal-friendly aquariums and zoos.

It was during the course of these travels that Hediger, while touring the zoos of the United States in 1951, visited the Yerkes Laboratories of Primate Biology, where psychologists Keith and Catherine Hayes were attempting to teach a chimpanzee, Viki, how to use human language. Over the course of the next three decades, Hediger would go on to meet and to observe the experiments of virtually all of the major researchers involved in such projects to teach apes to use human language – i.e., Roger Fouts, Robert Allen and Beatrice Gardner, Francine Patterson, Duane and Sue-Savage Rumbaugh – yet, in every instance, it was clear to him that the researcher's animal subjects were not actually "learning language" so much as they were learning how to detect and respond appropriately to the wealth of facial, postural, and other non-verbal signals that their trainers were communicating to them, unaware of their own doing so.

Himself exquisitely attuned to the micro-communicative nature of nonverbal body movements and meaningful display behavior that animals rely on in their interactions with one another – and with the humans who interact with them in circuses and zoos – Hediger, like the chimpanzees, could see that it was the inadvertant signaling behavior of the researchers, and not "human language" that was successfully being learned in these experiments. Hediger's professional expertise regarding the "micro-semiotics" of human-animal interaction placed him in the orbit of Thomas A. Sebeok, whose own inquiry into the more general phenomena of "zoosemiotics" amongst all living organisms was just taking shape in 1964.

Sebeok and Hediger maintained a decades-long friendship, and Sebeok's last single-authored monograph was an homage to Hediger and his work (Sebeok 2001a). Recounting their time together visiting zoos and circuses around the world, Sebeok observes that Hediger's "powers of observation and their subtlety far exceeded mine, and he taught me many things about applied biosemiotics which I could never have learned on my own", and concludes of Hediger that "overall, his legacy is a many-sided, profuse research program for biosemiotics that can easily extend for several generations ahead" (2001a: 36).

Hediger died at his home in Basel, Switzerland in 1992. His name remains famous among zoo managers and zoo designers, and each year the International World Association of Zoos and Aquariums awards its highest award in the field of zoo conservation – the Heini Hediger Award to individuals who have rendered outstanding service to the zoo and aquarium community.

The selection with which Hediger is represented here is from a conference convened at the New York Academy of Sciences in 1981 by Thomas A. Sebeok and the psychologist Robert Rosenthal, arising out of their mutual interest in the processes of non-verbal communication and the effects that such inadvertent signaling by experimenters upon their subjects may play in the skewing of experimental results. Entitled *The Clever Hans Phenomenon: Communication with Horses, Whales, Apes and People*, the conference was inspired by the increasing number of laboratory studies claiming to have successfully taught chimpanzees to communicate using human language, if only in a primitive form.

Present at this conference were some of the major "ape language trainers" of the time, including Herbert S. Terrace and Duane and Sue-Savage Rumbaugh. However, as the title of the conference indicates, most of the scientists attending were sceptical of these "animal language-training" claims, and the majority of the conference was instead dedicated to the investigation of the very genuine *semiotic* (and not *linguistic*) phenomena underlying the "Clever Hans effect" in animal training and experiment.

The "Clever Hans" of the conference title was, of course, *der Kluge Hans*, the celebrated "thinking horse" of retired schoolteacher and horse trainer Wilhelm von Osten, who toured around Germany at the turn of the twentieth century, exhibiting the horse's apparent ability to understand German, tell the time, read the calendar, and do mathematical operations such as multiplication and division. Von Osten did not charge for these performances, and genuinely believed that he had trained the horse to reason like a human being (a claim that an independent commission of scientists in 1904 likewise concluded to be the case). Thus, if Hans was asked to calculate the division of 132 by 12, he would tap out the answer "11" with his foot; if Hans was shown a watch and asked what time it was, he would correctly tap out first the hour, then the minute. In 1907, however, comparative biologist and psychologist Oskar Pfungst demonstrated conclusively that Hans's "reasoning abilities" consisted, in every case, in the horse's attunement to the non-verbal and often unconscious facial, postural and muscular signals that von Osten was exhibiting at the moment that the tap corresponding to the correct answer appeared – at which point the horse would immediately stop tapping, as doing so was followed invariably by his reward (Pfungst, 1911 [1965]).

As Sebeok notes of this affair, the 1904 Hans Commission made the initial mistake of "looking for, in the horse, what they should have looked for in the man" – or, more precisely from the biosemiotic point of view, "looking for in the *destination* what they should have looked for in the *source*" of the sign exchange that was occurring between von Osten and Hans (Sebeok 1980: 417).

As an animal enthusiast since childhood, and a professional zoologist his entire adult life, Heini Hediger was well aware of the fact that "concerning sensory organization, we humans are very often strongly underprivileged as compared with many animals, who also enjoy a much shorter reaction time" (1981: 8). Accordingly, animals are often far better able to detect and correctly act upon the signs that we are unwittingly sending them, than we are able to detect and correctly act upon the signs that they are sending us. Animal training – in circuses, in zoos, and, perhaps, unknowingly, in experiments such as those conducted by the ape "language teachers" – consists almost entirely in setting up such a reliable system of human-to-animal signs, argues Hediger here. Untangling the mystery of animal intelligence, Hediger insisted, demands a rigorous examination into the *animal's* organization of signs (1985: 177).

At the time of the following selection's writing, Hediger, at 74 years of age, had personally visited countless zoos and circuses, and had visited almost all of the major "ape language" trainers and their primate "language learners" (i.e., Washoe, Lana, Sherman and Austin, Koko, and Viki) to date. Yet while admitting that his "childhood dream, [his] lifelong wish, would have been fulfilled if it had really been possible to converse with animals" (1985: 177), Hediger concluded from these visits that, for these researchers, the central lesson of the Clever Hans affair, regarding the relationship between selective seeing and self-delusion, has still not been learned. In this sense, "compared with all his critics," writes Hediger, quoting Pfungst, "Clever Hans was the superior observer" (1981: 19).

The Clever Hans Phenomenon from an Animal Psychologist's Point of View (1981)

It is certainly a unique and highly unusual event for The New York Academy of Sciences to dedicate a conference to a horse named Clever Hans, which lived in Germany, in Berlin, about 75 years ago.

If Clever Hans were still alive, according to his admirers' conviction, he would undoubtedly feel very honored, for they believed firmly "that an animal can think in human way and can express human ideas in human language." This is literally the declaration made in 1914 by one of the authoritative experts, the psychiatrist Gustav Wolff from Basel (Wolff 1914). The amazing fact is that today again there are numerous people who, based on other observations, would sign this same declaration.

Not only did uninformed people have this opinion on Clever Hans, but also prominent scholars, scientists, psychologists, psychiatrists, medical doctors, and many others (Hediger 1967, 1974, Sebeok 1979a).

What had happened? In the year 1904 it was reported that in Berlin the retired schoolteacher Wilhelm von Osten had succeeded in producing evidence that animals – for the time being, horses – could think, talk, and calculate if instructed by the right method. The method invented by Herr von Osten consisted of giving a number to each letter of the alphabet. This association between letter and number the horse had to learn by means of a blackboard.

By tapping the right number with a front hoof on a board mounted in front of him the horse could combine letters into words, words into sentences and so express his thoughts. Through this tapping method the front leg of the horse became a kind of a speaking organ. For each correct answer the horse was awarded with a delicacy. Thomas A. Sebeok, on whose initiative this conference was organized, has described this method and its history very extensively (Sebeok 1979a); so I do not need to enter into this in detail.

Clever Hans, who at the time drew worldwide attention, was the first and most famous of the thinking animals. Soon he was to be followed by others, not only horses, but also dogs and cats. By 1937 there were already over 70 of these so-called thinking animals (Koehler 1937). Since then their number has continued to rise, and allegedly dialogues have been set up with many more representatives of the animal world, in America with dolphins and apes especially.

I would like to confine myself to try to present the Clever Hans phenomenon in a larger sense from the standpoint of an animal psychologist. Above all there are three basic biological phenomena which in this connection I feel are important to consider. They are:

(1) The age-old burning desire of mankind to take up language contact with animals, that is, to understand the language of animals.
(2) The assimilation tendency, that is, the deep-rooted tendency present in all higher living beings – man included – to see in creatures of a different species, with

whom there exists a certain familiarity, creatures of their own kind and to treat them accordingly.

(3) The catalytic effect from human being to animal, which can often be extremely strong.

The history of man–animal relationships has been almost completely neglected by modern behavioral research, but I think it might be useful to consider some experiences of practical men who live in direct contact with a variety of animals not only in scientific laboratories but also in zoos and circuses.

If we want to understand higher animals we remain widely dependent on their specific ways of communication and on the interpretation of their expression. To my knowledge up to this day an actual conversation on the basis of a real language has not yet been established.

To begin with, it is important that we recognize objectively the before-mentioned general, intensive, and ancient desire, for it represents a very essential source of mistakes not only in the matter of animal language, but also in animal experiments generally. In behavior research the well-known proverb, “He who searches will find,” plays an important and often crucial role.

I see a certain relationship between the placebo effect in Medicine and what Robert Rosenthal (1966) in such an impressive way described as the Experimenter’s Expectancy in behavior studies. Just as a patient feels a strong effect from nothing, an experimenter may read a positive result or induce such in the behavior of an animal. Experiments certainly do not always take an objective course in the sense that one stimulus of a known quality and quantity releases a corresponding objectively measurable reaction.

In other words, it depends on what sender and receiver make of a stimulus or a sign; sometimes as much is made of it as the satisfaction of the wishes requires. In this respect, greatest significance should be given to semiotics, especially zoosemiotics, for it endeavors to examine all possible channels of communication as they have been enumerated by Sebeok in 1976 (Sebeok 1976).

Communication, as it preoccupies us here in connection with the Clever Hans phenomenon, is not only a series of flow-processes between a chemical substance and a subject; it is a much more complex connection between the experimenter and the animal.

In many animal experiments, whether psychological or physiological, the effect of the design of the apparatus, of the laboratory, the atmosphere, in short, the whole envelope in which the signs (stimuli) work, is often neglected. One believes in dealing with only one relationship, one channel of communication between the animal and the experimenter, that is to say, the official one. In reality there are complex bundles of relationships, of channels. An animal experiment does not begin only when the animal starts in the training apparatus. In a certain sense it starts by planning, with the invention of the design of the experiment. It will be cut out for the animal in a specifically human way of thinking, based on the posing of the question; and, in addition, the animals are selected in this sense.

As often with the study of man–animal relationships, the conditions of the circus can be helpful since we have to do with big animals, with wide swinging movements, and acoustic effects, which means with conspicuous signs in a typical surrounding. Despite their importance, the micro-signs manifesting themselves there too will be ignored for the time.

When a group of lions on pedestals are to "sit up," the trainer in front of them, in a bent or kneeling position, will give the command and get up with corresponding stimulating calls and, with stretched out arms, will raise stick and whip way up.

If the same animal tamer with the same movements and calls puts himself in front of a group of free-living lions, which, for example, he might encounter in a national park in East Africa, his behavior will induce a general flight reaction. Why? The drastic difference is illuminating: The circus lions are trained and understand the signs given by their master. Free-living lions, however, have no such intimate relationship with man. Like practically all wild animals in nature, they see in him just an enemy, their main enemy from whom they have to run away.

On one and the same stimulus, on identical signs, the two lion groups react in a basically different way according to their individual experience, depending on what man has invested or not invested in them. A free-living untamed and untrained animal reacts completely differently from one well-adapted to the experimental situation, regardless of whether the animal is lion, ape, horse, parrot, rat, or even planaria. This is due not only to the training invested, but also even more to the increased comprehension possibilities and better developed communication channels reached during the close contact with man.

Clever Hans represents an excellent example of these facts: A wild horse or even an ordinary domestic horse does not pay attention to human movements that barely consist of one millimeter, as Oskar Pfungst has shown (Pfungst 1907). It is only on the basis of extraordinary familiarity between Clever Hans and his master, gained during the course of teaching, that the horse became able to interpret as decisive signs movements of the head of his master of even one-fifth of a millimeter deflection.

I would like to emphasize again the importance of familiarity between man and animal. It may fluctuate between 0 and 100%. The free-living animal knows only the flight reaction to an approaching man. The other extreme is absolute tameness, the lack of any flight-tendency that results from a generation-long domestication or what has lately been labeled "laboratorization," or from individual taming and training.

We humans are still much biased by the idea that all animals of a given species are equal, in a way, stereotype figures right out of a textbook of Zoology, fixed genetically to the last detail. In my opinion this is a naive and simplified concept to which we should no longer adhere. Through the catalytic effect of man, surprising changes and an increase in behavior may be caused which surpass by far the genetically given ethogram of a species.

I would like to remind us of the famous wolf "Poldi," which as a young animal was trapped in the wilds and trained by an Austrian police officer, Rudolf Knapp, to become a police dog (Knapp 1936).

The Swiss National Circus shows a white rhino (*Ceratotherium simum*) that was caught in the South African bush as a young animal and which after a few months showed its astonishing acts in front of thousands of people and this in the glare of spotlights and to the sound of blaring music. It also may be freely guided through dense city traffic.

In its original African homeland this rhino, "Ceyla," knew only one reaction towards man and this was the flight reaction. Other relations to man were nonexistent, but these relations changed to the maximum degree, that is, to perfect tameness and trainedness. Today man is its intimate friend, its socially superior companion to whose tiny signs the rhino reacts with great attention and reliability. In a certain sense Ceyla is no longer simply a zoological rhino. Enormous human influence has been invested in it.

The famous chimpanzee, "Washoe," was also born in the African jungle and within a short time reached the highest level of animal–man relationship, a level at which it is believed that even a certain conversation becomes possible. Through the catalytic effects of man extraordinary latencies have been activated in Washoe similar as in "Sarah," "Lana," "Koko," and others. All these surprising activities would never have manifested themselves in the wild.

By visualizing how tremendous the difference of habitat is in which Washoe was born in Africa and of the one in which she later received her language training in America, it will become obvious how very much the animal, its surroundings, the stimuli to which it is exposed have been changed. The whole communication system has been altered. The answers we receive from such an animal must be quite different from those of a free-living chimpanzee.

The biologist and biophilosopher Bernard Rensch in 1973 states:

> While the imporant experiments of the Gardeners and the Premacks show that Chimpanzees to a certain degree may replace words by the use of ASL or plastic figures as symbols these are in fact results which could only be reached through man capable of speaking. In nature nothing similar of human language has ever evolved in Chimpanzees, Gorillas and Orang Utans (Rensch 1973).

In other words, with all animals with which we try to enter into conversation we do not deal with primary animals but with anthropogenous animals, so-to-speak with artifacts, and we do not know how much of their behavior may still be labeled as animal behavior and how much, through the catalytic effect of man, has been manipulated into the animal. This is just what we would like to know. Within this lie the alpha and omega of practically all such animal experiments since Clever Hans.

I have the impression that we biologists find ourselves in a situation corresponding to the atomic physicists from whom we have to learn so much lately. It has been discovered that as soon as single atoms are observed their reactions are influenced. Of course it is a long way from the atom to a living being, a horse or a chimpanzee. However, if the simplest thing, the atom, is influenced in its behavior through the human observer, how much more must we suppose then that two living subjects influence each other through observation.

Maybe it is a general law that through observation the observed will be altered. However, we do not want to indulge in speculations, but it may be certain that every animal experiment – not only the ones concerning language – represents a relation between two living subjects and not simply a relation between a subject and an object whose behavior could be registered objectively. This means that in an animal experiment we have to work not with pure unaltered animal behavior, but always with the behavior of the animal plus the influence of the human observer.

Now, does that mean that we should resign because it is not possible to find out pure animal behavior anyway? Certainly not. We are given the urgent duty to understand the nature of the manifold signs and their mutual alteration flowing between the sender and the receiver. We can do this best by using the methods of zoo semiotics established by Sebeok in 1963 (Sebeok 1976: 57). To this complex belong, for example, the problems of intensive wishing, the mechanism of looking, and so forth.

The closer – in the spatial and psychological sense – the experimenter and the animal find themselves the greater is the danger of mutual influence. Oskar Pfungst (1907: 49) has found a close relationship between the performances of Clever Hans and the distance of his master. Therefore, Otto Koehler, in 1937 already the senior of most prominent of European animal psychologists has demanded with emphasis:

> During the experiment every contact between experimenter and animal has to be strictly avoided. The animal has to decide absolutely free. Experimenters who are not willing or who are not able to fulfill these conditions have to be eliminated harshly. (Koehler 1937: 24)

In his classical investigations on the counting ability of different birds – which reaches the number seven – Koehler himself had set a good example. During the critical experiments the animals were observed from an insulated side-room through the view-finder of a hidden camera. During the experiments with his famous raven, "Jakob", Koehler disappeared from the grounds altogether and read a book or held his lecture in order to exclude even a telepathic influence (Koehler 1943).

Further – repulsed by the nonsense with Clever Hans – Koehler demanded that the experimenter should not wish a definite result. Literally he explained: "Who believes in advance what in reality he could only read out of experimental results, he who does not criticize himself and can not take criticism of others does not do research but he deceives himself" (Koehler 1937: 21). This was exactly the case with Clever Hans.

I do not want to enter into the other precautions demanded by Koehler. But I doubt whether the active scientists who do research on animal language do adhere to the two above-mentioned basic demands of Koehler.

I would like to quote here the Oxford zoologist, Sir Alister Hardy: "Again and again faulty conclusions have been reached because the worker has been unwittingly influenced by an ardent desire for particular results" (Hardy 1965).

It is not easy to explain such an effect. However, with regard to big animals an approach may be found. To this I would like to mention a kind of reverse situation of the zoo where the lack of an intense desire led to failure. By chance I became a witness of an interesting dialogue between an experienced elephant-keeper and a beginner who complained very seriously that the elephants would not obey his orders although he gave them exactly as he was instructed. The old keeper's typical explanation was:

You should not – simply stand there, give orders and move accordingly, but you must participate with your whole inner strength. With all your energy you must want what the elephants should do. You must have the strong will that they do what you order them to do.

For every circus animal tamer this is a clear fact.

From this simple zoo or circus experience I believe we can draw two conclusions: First, through the strong inner effort the human expression and accompanying movements, which have been presented and analyzed so brilliantly by Paul Ekman (Ekman et al. 1972), Erving Goffman (Goffman 1971), and others, are enormously intensified. Second, we have to take into consideration that many animals – elephants also – are excellent observers, often extremely skillful interpreters of the human expression.

To this observation with elephants I would like to add a short remark on a series of preliminary experiments which I made many years ago at the Zoo in Basel. It deals with the chimpanzee, "Max," and his keeper Carl Stemmler who at the time were very popular personalities in Basel. Stemmler had taught his adolescent chimpanzee a few simple tricks, so-called obedience exercises, which mainly served to establish and to secure for the future as long as possible the social superiority of man. One goal of these rather primitive experiments was to test whether any evidence of verbal understanding could be established by giving Max the orders through a loudspeaker while his master was invisible.

The chimp showed that he understood the orders but he would not execute them when his master was not to be seen. When he was present, mute, and made the normal accompanying movements while the orders came from the loudspeaker, Max would obey as if Mr. Stemmler would give the orders personally.

Certainly we do not want to attach an exaggerated significance to these old and crude pilot experiments. However, this much we may conclude from them: They demonstrate the overall significance of the gesture, the expression, that is, of the nonverbal communication during close contact between animal and man. They also show that it is a "multichannel" communication, that each channel has its own specific properties, and that their interaction creates possibilities, the number of which is greater than the sum of the possibilities of each channel taken separately as Sebeok puts it (Sebeok 1976: 78) in connection with the work of Bar-Hillel. In view of the Clever Hans phenomenon, this evidence may not be emphasized enough.

Last year in a Swiss circus I talked with a Polish animal tamer, Mrs. Krystina Terlikowska, who worked with four female tigers and three female lions. Mrs. Terlikowska, an analphabetist who has practiced this profession since she was 8 years old, says that the most important part of her present activity was to talk with the animals. This indeed is a very old and proven recipe for all who have to work with big animals.

By speaking, our expression is activated and enriched. It is of course not the specific language nor the single words that matter but the facial expression, the intonation, the sound intensity, the posture, the movements, and maybe the color of our face, the thermal pattern of our skin, even the smell which changes from moment to moment, and many other factors that we do not know yet, channels not yet investigated.

As is well known, we humans lack, for example, the ability to perceive ultrasonic sound and ultraviolet light. We lack the sense of magnetism, a very fine sense of vibration and temperature, a sense for polarized light, and so on, and so forth. Concerning the sensory organization, we humans are very often strongly underprivileged as compared with many animals, which also enjoy a much shorter reaction time. We have nothing by far to compare with the whiskers and the ear-pouches of cats and so on.

In order to emphasize the significance of our nonverbal communication with animals I would like to mention an observation which in 1979 was made in a well-known private zoo in the Netherlands, in Burger's Animal Park in Arnheim. Dr. Frans de Waal has given a detailed report (de Waal 1980) of which the author has confirmed every word personally.

According to this observation it was possible to teach a chimpanzee mother, "Kuif," who never was able to raise her own young, to give a milk bottle to a foreign young chimpanzee called "Roosie" and to raise it successfully. The whole instruction of the mother was given through the bars of her cage by showing her the necessary actions and by continuous repetition of six words or orders like: raise the bottle, give it to Roosje, hold the bottle tight, hold it a bit higher, stop (take the bottle out of the mouth), and return the bottle. After only three weeks of instruction through the bars of the cage one dared to trust the stepmother with the baby who, up to now, had been raised artifically by human caretakers. The raising by the chimp succeeded perfectly. Later on, the stepmother was able to provide her adopted child partly with her own milk.

This is the first time that such an astonishing experience with bottle feeding through an animal was realized. It shows how effective communication between man and animal can be. This marvelous performance of the stepmother was reached within the short period of 3 weeks and without an artificial language – only through the demonstration and through the spontaneous manifestations of her attendants.

This amazing act of training causes one to ponder the manifold efforts of several researchers to enter into language contact, into a dialogue with apes. The chimpanzee Kuif did not answer with any language signs but by correctly tending the bottle to Roosje. With this doubtlessly she confirms that she understood the human instructions in every detail.

In principle, I recognize here performances similar to those in some language experiments. In each case the chimpanzees were demonstrated the desired actions with the hope that they would react in a certain way. With Kuif it was the correct handling of the bottle; with Washoe, Sarah, Lana, and so forth, it is the production of certain signs in which we would like to see a language. But how can we prove that such answers are to be understood as elements of a language, and that they are not only reactions to certain orders and expression, in other words simply performances of training?

When an outside observer follows and tries to understand the signaling of a chimpanzee trained in American Sign Language (ASL), he has great difficulty in distinguishing preparative from conclusive movements, especially since these movements succeed each other very rapidly. The noninitiated person has a hard time deciding where the preparing movement stops and where the real signal starts and ends, for each signal is embedded seamlessly into another movement (e.g., flower, bug, dirty).

I do not doubt that Washoe and other chimps have learned a number of signs in the sense of ASL. But it seems to me that a better clarification could be reached mainly through the introduction of the orders "repeat" and "hold it." By this the chimpanzee could show that he really understands the single elements and does not execute fast, sweeping movements into which one possibly could read such elements.

With trained animals and animals in the process of being trained – which is quite a different matter – there exists a general tendency not to react in single, self-contained elements but in sequences. In the circus many animal tamers have gotten into embarrassment or even danger of life through this. I am referring to the phenomenon of anticipation. This fact is also known in connection with dog training. Within a tiger group, for example, it may happen that a certain tiger starts the next trick (e.g., jumping through a hoop) before the animal tamer has been able to put into safety the other tigers, that is, to bring them back to their seats. Because of this, dangerous contacts and aggressive conflicts may occur in the manege, which not infrequently lead to catastrophes. With dogs this undesired anticipation of orders is mostly more harmless. It is caused by an extremely fine interpretation of the expression of the clog's master. The dog then executes an order before it has been given officially to him. Are we sure that the possibility of anticipation can be absolutely excluded in language experiments with trained apes? In this situation it may easily make the impression of a spontaneous utterance. There are so many and different pitfalls when you try to interpret animal behavior.

Thomas A. Sebeok (1979b) recently has reminded us of the memorable story of the famous Russian physiologist Ivan Pavlov and his assistant Studentsov. By posing the same problem to five consecutive generations of mice, the two believed they had proved correct the Lamarckian theory of inheritance of learned behavior. As they expected, each generation needed fewer sessions for the mice to master their task. The original number decreased from 300 to 100, 30, 10, and 5.

It was discovered later, however, that the improvement of performance was apparent only and was by no means based on inheritance. What had improved was the treatment of the mice by the experimenter. This is by no means the only experiment by which Lamarck's theory was to be evidenced.

Let me briefly mention the well-known experiment of William McDougall who, similar to Pavlov, also tried to prove the inheritance of effects of training. This time no less than 23 generations of rats were used. Interestingly enough, McDougall was absolutely aware of his possible wishful thinking as Sir Alister Hardy (1965) points out by literally quoting McDougall's apprehension in the following way:

In this connection it is necessary to avow that, during the course of the experiment, there grew up in all of us a keen interest in, I think I must in fairness say, a strong desire for, positive results. From the first it was obvious that a positive result would be more striking, would excite more interest in the biological world, than a negative one. And when indications of a positive result began to appear, it was but human nature to desire that this result should appear as clearly cut and positive as possible. Further, on my own part, there was a feeling that a clear-cut positive result would go far to render tenable a theory of organic evolution, while a negative result would leave us in the Cimmerian darkness in which Neo-Darwinism finds itself.

I was conscious, therefore, of a strong bias in favor of a positive result, and throughout I was consciously struggling against the temptation to condone or pass over any detail of procedure that might unduly favour a positive result. Such details are encountered at every point, more especially in the breeding of the animals. To have disguised from on self this bias, to have pretended that we were superior to such human weakness, would have been dangerous in the extreme. The only safeguards against its influence were the frank avowal of it and unremitting watchfulness against it. I can conceive of no task that could make greater demands upon the scientific honesty of the worker, and it is in part this demand for unremitting watchfulness that renders the work peculiarly exhausting. I can only say that I believe we have succeeded in standing upright, and in fact, for myself, I am disposed to believe that I have leaned over backwards, as we say in America. Whether we have really succeeded in this, the most difficult part of our task, can only be proved when other workers shall have undertaken similar experiments. If our results are not valid the flaw, which has escaped our penetration hitherto, must, I think, be due to some subtle influence of this bias (Hardy 1965).

In fact: is there a more conscientious and a more sincere attitude of an experimenter? It is almost identical with the severe commands of Otto Koehler. And despite all of that McDougall stumbled. Nobody could repeat his important experiment with the same results. Very grave errors had occurred as David Katz demonstrated in a very interesting chapter with the title "The Clever Hans Error and Similar Mistakes of Modern Animal Psychology" (Katz 1937).

The essence of McDougall's experiment consisted-to be brief-in setting the rats at the starting point of the apparatus in a water channel. From there they had the possibility to swim towards the left or the right into a dim or glaringly illuminated channel in order to reach dry grounds. If they chose the glaringly illuminated channel they received a strong electric shock. If they chose the dimly lit channel they could reach dry grounds without punishment (Munn 1933).

The rats' performances improved – with some irregularities – fairly continuously. The total time of the rats spent in the water dropped from 2320 seconds to less than half, that is, 1020 seconds in some of the last generations. Astonishingly, the very last generation was not the best. Its total time in the water had risen again to 1620 seconds. This "anomalous" record for the last generation is according to McDougall, as quoted by Munn (1933) probably due to the death of an assistant who had been handling the rats. So there was a change of experimenter.

Of course in such an experiment it depends greatly upon how the rats have been handled and put into the water. The pretreatment and the starting phase may be decisive. Today we find it normal that the experimenter who puts the animals in the water at least does not know if he is working with trained rats of the generation to be tested or with naive control animals. However, David Katz (1937) to his great astonishment discovered that the experimenter always knew about the origin of the rats. This is just as big a methodological mistake as is direct contact with the experimental animal. But there were even more and quite different sources of mistake involved, as Munn (1933) points out, e.g., in the selection of the animals.

Today by means of numerous experiments it has been proved by Rosenthal (1966), Timaeus (1974), and others that the way and means how an animal is brought into the apparatus may greatly influence the result of the experiment, even the animal's past, the intrauterine as well as the postnatal one. Morton in his fascinating paper (Morton 1968) on handling and gentling laboratory animals has, for example, found that subjects shocked in infancy took longer to respond in an avoidance learning situation.

In other words: What also matters in evaluating the performances of experimental behavior is the animal's past, even in the case of rats. The human influence on the behavior of experimental animals may even start before its birth.

More and more I come to the conviction that the results of animal experiments do not so much depend on the exact sequence and make-up of the experiment itself, but to a great deal also on the past of the individual animal and on the personal attitude of the experimenter. These two important facts are very often what conventionally is neglected most.

Clever Hans is only one example of this but one that should cause us to rethink the whole experimental situation.

With this I come to Factor 2 of my introduction, to the assimilation tendency, that is, the anthropomorphizing of the animal through man and the zoomorphizing of man through the animal. This is not at all a theoretical speculation but a proved practical experience gained through a huge pile of facts (Hediger 1967, 1974, 1940, 1951, 1965).

If, for example, we ask the gorilla Koko: "Are you an animal or a person?" as it happened according to Francine Patterson's report (Patterson 1978), Koko's answer could never be authentic if it is, "Fine animal gorilla." Koko has studied neither zoology nor anthropology. She cannot distinguish between man and animal as two different categories of the zoological system. As with each animal she lacks the notion of species. Therefore she could not know that she belongs to the species *Gorilla gorilla* and the human beings surrounding her to *Homo sapiens*.

According to all we know today about big animals living in close contact with man we have to assume that Koko, based on her assimilation tendency, sees in her mistress (for the time being) a superior specimen of her own species, that is another gorilla. The same stands for the attendants of chimpanzees who at present apply themselves with language studies. There is no reason to believe that, in this regard, they behave differently than apes in a zoo where they are in close contact with their keepers.

As long as we deal with very young animals everybody probably agrees that, to the bottle baby, the caring human being is nothing else but its mother, a mother of the same species. The assimilation tendency to one's own species here is apparent and uncontested.

At the zoo the caretaker of adolescent apes as a rule goes through a significant change of meaning (Bedeutungswandel in the sense of Uexhill) leading to a dangerous situation: he becomes to be a social rival. This may lead to dangerous conflicts and to direct attacks on the keeper. Many – probably most – of the zoo accidents have this motivation not only with apes but also with deer, big cats, antelopes, elephants, and so forth.

In scientific research institutions, the decades-long experiences of zoological gardens should not be ignored completely. Not all zoos are mere show businesses. There have always existed a number of zoos – and the Bronx Zoo is one of the leading – in which scientific research has been done, in spite of the often chronic lack of money and personnel, which in all departments necessitates very strict economical operation.

This gives rise to the following purely practical consideration. If apes really dispose of the great intelligence and the highly developed communication ability that one has attributed to them lately – why in no case in the zoos of the world, where thousands of apes live and reproduce, has it been possible to get one to clean his own cage and to prepare his own food?

As far as I know in all zoological gardens of the world as well as in all Primate stations people still have to be employed to do these simple jobs of daily life. Paradoxically in zoos as well as in laboratories *Homo sapiens* still is the servant of the ape.

One may argue that apes have no interest in such work, that they have no perseverance and that they simply do not want to. By all means I do agree with these arguments for I have always emphasized that one may never conclude incapability when an animal does not obey an order. There is always the possibility that it has understood the order but does not want to carry it out. Apes have no notion of work. We might perhaps teach an ape a sign for work but he will never grasp the human conception of work.

The world-wide evidence of unwillingness of apes to carry out the simplest household activities, that obvious disinterest, almost necessarily leads to the question as to what interests apes at all. With this we are confronted with the problem as to how a research program of future efforts should be designed in order to possibly enter into a dialogue with animals, to lead a conversation with them.

So we try to arrive at a program that makes sense. On what subject may we best converse with an animal? Unfortunately it is not much: Apes, dolphins, or horses have no interest at all in things that are of general interest to humans. By this I mean all that is written in books and the media:

Culture in the broadest sense
Politics, Sports
Business, Finance, Traffic, Technique
Work, Research, and so forth.

What else then remains? Very little it seems to me. Especially when we think that the animal has no access to the future. It lives entirely in the present time (Hediger 1973). Also the past is mostly out of its reach, except for very recent experiences. Therefore there remain the essential daily needs, above all metabolism, food and drink, social and sexual contact, rest and activity, play and comfort, conditions of environment in connection with the sensations of pleasure and dislike, some objects, and possibly a few more things. This is indeed rather modest.

Experimenters who try to enter into a conversation with animals should keep this in mind. Clever Hans has taught us clearly what happens when we force this simple repertoire with an exaggerated program. It again would lead us to believe that "the animal can think in a human way and express human thoughts in human language," as I have quoted in the beginning.

The work of Oskar Pfungst (1907) on Clever Hans, going back to the year 1907, has not really given us a satisfactory solution of involuntary signaling. According to my opinion this problem is far from being solved. Concerning the work of Pfungst I would like to say the following:

(1) It has remained widely unknown.
(2) It has been almost forgotten.
(3) It is not complete.
(4) It gives rise to important criticism.
(5) It has never been repeated and confirmed.

To the Clever Hans critics, Oskar Pfungst's work was so welcome and appeared to be so perfect that they believed it to be 100% right and that they could accept it forever as such. Here again we have to deal with the basic phenomenon, with the idea of wishful thinking, with the experimenter's expectancy, which is central to every animal experiment and which is so difficult to eliminate.

Pfungst also was an experimenter. He too was obsessed by the wish to reach positive results, to prove that a horse or any other animal could not think in a human way and not express human ideas in human language.

He apparently thought he had found evidence that Clever Hans was doing nothing more than watching that famous relaxation jerk of his master when the correct number of knocks was reached, that involuntary almost microscopic head movement, which could measure 1/5 mm or even less (Pfungst 1907: 120). I do not doubt this result but I would be much more convinced had it been confirmed at least once.

The work of Pfungst does in fact contain all kinds of curiosities. The greatest one for me is what he mentions in connection with the so-called laboratory experiments. These are the basis of most of his work and have been carried out in the Psychological Institute of the University of Berlin. By contrast the other experiments and observations took place in the open, in the courtyard where Clever Hans normally would perform, or in a tent which occasionally was set up in that courtyard or in the stable.

In laboratory experiments one generally expects greater precision and more exact experimental conditions than in a stable or courtyard. In reality, during the so-called laboratory experiments a horse was not even present. The role of the horse to be tested was taken over by Oskar Pfungst himself (Pfungst 1907: 77). You will understand now why I permit myself to speak of curiosities of the Pfungst expertise. This, however, is not the only one.

On page 123 of his work Pfungst clearly mentions:

> With the standing of our knowledge of today all attempted explanations have a more or less hypothetical character (*Bedeutung*). Should as a result of further research the herewith attempted explanation prove to be untenable one would have to take under consideration abilities yet unknown in the horse's eye or search for the reason in the brain. Experiments with other specimens of this genus will have to teach us if all other horses have the same ability or if some individuals are privileged.

This shows that Pfungst felt insecure and that he demanded a repetition of his investigations. However, up to now – more than 70 years later – this has never happened. One did not wish to recognize as questionable or even wrong the apparently so clear and convincing explanation given by Pfungst, which he himself considered to be hypothetical. Again and again desire proves to be the most powerful factor in an animal experiment. This fact seems to be unchanged even today.

It is not possible now to consider critically every point of Pfungst's work. To me personally the following statement matters most of all. On page 125, Pfungst confirms that Clever Hans, compared with all his critics, was a superior observer.

Basically this fact puts the human observer into a very difficult position. As I have mentioned before, we have to resign ourselves to the fact that many animals, are far superior to man in terms of their sensory organization. This is true not only for horses but also for primates, rats, and even many invertebrates, maybe even for planaria and protozoa like paramecium.

This is of primary importance for assumedly physiological experiments and also, for example, for the experiments started by James V. McConnell (1968) on the transfer of learned information. From this general situation I can only draw one logical and biological conclusion: training is always part of all the aforementioned experiments. Training is a most intense relation between animal and man, between animal and experimenter, and this within an artificial surrounding which has been imposed upon the animal.

In an experiment we mostly observe results, which we may regard as proof of a hypothesis. However, we still know much too little about how these results have been arrived at, about what has taken place between man and animal during preparations, and during the critical experiments, in other words, all the different communication channels.

Since Clever Hans – more than 70 years ago – I fear we have not made much progress in this regard. Otto Koehler has shown us in an exemplary way how we may practically exclude man as a source of mistake, but he has never demonstrated precisely what we want to eliminate thereby, what human influences.

It is my firm conviction that there is only one way to clear up this complex of problems. We have to grasp the phenomenon at its roots; that is, we have to repeat the Clever Hans experiment from the very beginning under exact laboratory conditions with the tools of zoosemiotics.

Since here we are primarily interested in direct communication with the animal, in animal language, I would like to conclude by quoting the British biologist J.B.S. Haldane (1954). In Paris, 1954, during a lecture at the Sorbonne University he made the following statement[1]:

When a child says to his mother, "I am hungry" or "I want to sleep," he is still animal. When he says, "This I have done this morning," he begins to be man.

To my knowledge, up to now, no animal, not even an ape, has ever been able to talk about a past or a future event.

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[1] *Quand un enfant dit à sa mère: "J'ai faim", ou "Je voeux dormir", i1 est encore animal. Quand il dit: "Voici ce que j'ai fait ce matin", il commence à être homme.*

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Chapter 8
Phytosemiotics

Martin Krampen (1928–)

Introduction and Commentary: Martin Krampen

> *There are three levels of meaningful cycles corresponding to the predominance of indexicality, iconicity, and symbolicity, each higher process including also the lower. Indexicality, on the vegetative level, corresponds to the sensing and regulating, in a feedback cycle, of meaningful stimulation directly contiguous to the form of the plant. Iconicity, on the animal level, is produced by the function cycle, with receptor and effector activity representing, in a nervous system, the 'image' of objects. Symbolicity, on the human level, is produced by perception and action in human society.*
>
> M. Krampen (1981: 194)

Although neither a biologist nor a biologist manqué, visual artist and design analyst Martin Krampen is the author of one of the most seminal "turning-point" texts in biosemiotics. *Phytosemiotics* – the selection that is presented here – is invoked in almost every published overview or introduction to the field (e.g., Barbieri 2001, Deely 1990, Favareau 2007, Kull 2003, Sebeok 2001), and is widely-acknowledged as the text that expanded the purview of Sebeok's zoösemiotic project into the full-blown examination of sign relations pertinent to any living system.

Born on March 9, 1928 in Siegen, Germany, Krampen began his university career studying psychology, philosophy, and theology at the Universities of Tübingen and Heidelberg, as well as studying painting and design at the *Accademia delle Belle Arti* in Florence, Italy. Having received his diploma in Visual Communication at the *Hochschule für Gestaltung* in Ulm, Germany in 1957, Krampen earned his doctorate in Communication Arts at Michigan State University in 1962. By 1965, his professional biography had already read, in part, that:

> Professor Krampen has done extensive research and writing for professional journals on subjects including: world road sign systems, the classification of graphic symbols (as part of a survey commissioned by the Ford Foundation), the perception of apparent movement, industrial design and industrial organization, and the forgetting and retention of pictorial material. As a graphic designer, he has worked in book design, magazines, and advertisements. His design projects have ranged from restyling the format of a newspaper (*La Sera di Roma*) to planning exhibitions and displays for the United States Information Service, Westinghouse, and the 1967 Montreal World's Exhibition. He has won several awards for typography and his graphic design is represented in the permanent collection of the Museum of Modern Art, New York (1965: 31).

D. Favareau, *Essential Readings in Biosemiotics*, Biosemiotics 3,
DOI 10.1007/978-1-4020-9650-1_8,

Following this period, Krampen taught social psychology, semiotics, and psychology of design at a number of universities in Europe and North America, and from 1977 until his retirement as a full professor in 1993, taught Visual Communication at the *Hochschule der Künste* (formerly: the University of Gottingen). Since his retirement from teaching, Krampen remained active as an artist, graphic designer, and researcher (his current research examines the use of color as a *Gestalt* element on the Internet). Yet his place in the history of biosemiotics became secured with the publication of his 1981 article on *phytosemiotics* – the investigation into the use of sign-processes taking place within and between plants.

In the mid-1970s, Krampen's work on the semiotics of road signs came to the attention of Thomas A. Sebeok, whose own decade-long investigations into the semiotics of animal communication by that time had already opened up the field of sign research to include within its purview not only those signs made by humans in their cultural endeavors (collectively: the species-specific project of *anthroposemiosis*), but also, thanks to Sebeok's recent rediscovery of the *Umweltlehre* of Jakob von Uexküll, a principled and non-anthropomorphic framework for the inquiry into animals' manifold ways of receiving and emitting signs in order to successfully negotiate the world.

Sebeok christened this latter project *zoosemiotics*[1] in 1963, as by that time he had come to the conclusion that the practice of "restricting semiotic inquiry to our species" alone – as if humans were the first and only animals to use sign relations to communicate and to know about the world – "was absurd, and that [the discipline of semiotics'] field of reference had to be extended to comprehend the entire animal kingdom in its maximum diversity" (2001: xxi). It was not until 1977, however, reports Sebeok, that he finally discovered in Uexküll's *Umweltlehre* the "sound theoretical basis" needed to ground this inquiry scientifically (*ibid*). Not long after, he recounts,

> There came several dramatic proposals from diverse, unexpected, as well as more or less independent, sources. Beginning in 1981, Martin Krampen followed up on the abduction that plants, too, undergo semiosis, and thus another discipline, *phytosemiotics,* came into being. In 1991, I postulated semiosis in the fungi. And thereby added *mycosemiotics* to the taxonomy. The recognition of far-reaching semiosis in the kingdom Prokaryote, comprising all bacteria (*microsemiosis*), was triggered by a 1983 book by Sorin Sonea and . . . a conceptual framework for identifying the pertinent integration levels [of sign processes in the human body] was presented in a 1993 monograph[2] by the physician son of Jakob von Uexküll, Thure, with two of his medical associates. This domain is now termed *endosemiotics* . . . These newly identified and labelled topics, among others, together now constitute the overall domain of *biosemiotics* (2001: xxi-xxii).

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[1] The word also appears throughout the biosemiotic literature as *zoösemiotics*, an orthographical convention initiated by John Deely in 1990, "to prevent a misunderstanding that I have actually encountered," he explains, "whereby this rich realm of investigation has been unwittingly reduced in hearer's minds to the study of sign systems among captive animals" (1990: 29).

[2] Included in this volume as Chapter Nine.

An empirically-grounded researcher into the measurable effects of visual design, Krampen's 'abduction' about the legitimacy of studying plant semiosis was not the armchair postulate that one might assume from the casual wording of Sebeok's recollection above. Rather, Krampen's interior design based research on the semiotic effects that plants have on the habitats of humans led him to investigate the viability of thinking about the semiotic interactions taking place within plants themselves. Lacking central nervous systems through which afferent sensory input and efferent motor output could be organized into the functional cycles necessary for meaning-making, plants were pronounced to be creatures incapable of manifesting *Umwelt* by Jakob von Uexküll (1940 [1982]: 33). Nor would Krampen – or any other biosemiotician – attribute to plant life the ability to form mental images, to plan, to have personalities and emotions, to cognize, or to empathize with human beings in the sense that such capacities have been attributed to them by certain plant enthusiasts and "New Age" religionists.[3]

Yet the scientific investigation into the biological organisms that are plants reveal that they rely on a complex and interdependent set of highly evolved direction-dependent (i.e., *tropic*) and rate-dependent (i.e., *nastic*) responses to environmental stimuli; are both ontogenetically adaptive as well as interactively territorial; and employ sign-based systems of information transfer both within and across individuals. Such functional real-time responses to environmental stimuli include the exploratory, exploitative and self-preservational reactions to the impingements of moisture, light, gravity, sun direction, barometric pressure, magnetic fields, nutrient gradients, temperature, color (wavelength), physical contact, fluid flow, electrical current, darkness, and the volatile airborne and soluble waterborne chemical signals exchanged within the ecosystems of plants.[4]

Surely, then, argues Krampen in this historically important text, the interactions and organization of these naturally evolved, complex-adaptive living systems must be "structured according to a base semiotics which cuts across all living beings – plants, animals, and humans alike" (1981: 203). Thus, as Anderson et al. will later argue (see Chapter Twelve, this volume): "the fact that sedentary plants have a diffuse and poorly-understood internal communication system – rather than a centralized nervous system – may not disqualify them from possessing an [interior relational web of sign processes called] *Umwelt* any more than it excludes them

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[3] Indeed, perhaps nowhere is *anthropomorphism* more fully understood for the fallacy in reasoning that it is – and is therefore studiously avoided and admonished – than in biosemiotics, which insists upon acknowledging both the commonality and the differences in naturally evolved sign systems. The discipline's foundational insistence on such vigilant non-conflation, then, makes it particularly ironic – and unfortunate – that upon first encountering the word "biosemiotics", the mistaken idea that comes to mind for many people is that the project must be advocating that all non-human organisms "think like humans." Yet this is the one notion that is universally considered to be anathema throughout biosemiotics, which is why I often recommend Terrence Deacon's masterful debunking of this "exactly backwards" idea – his 1997 *The Symbolic Species*, excerpts of which are included in this volume as Chapter Eighteen – to those encountering the often easily misinterpreted texts of biosemiotics for the first time.

[4] For reference to this literature, please see footnote 5.

from existing in [an external] relational web called '*niche*'" (1984: 57) – because *Umwelt,* as Krampen points out in the following selection, refers merely to the totality of "what is *meaningful impingement* for the living being, in terms of its own information processing equipment, sign systems, and codes" (1981: 22).

The publication of Krampen's *Phytosemiotics* article in 1981, writes semiotics scholar John Deely, "swiftly became part of the twentieth-century mainstream development of semiotics, opening the way to a postmodern and global intellectual culture ... [by] showing how the whole of the biosphere is subtended and unified in its interdependencies by the action of signs" (2006: 586). Indeed, and as Sebeok implies above, the realization that the sign-processing abilities in humans did not emerge de novo, but both evolved from and are built upon the more primitive sign-processing abilities of our animal ancestors, leads inexorably to the realization that (functional, non-mentalistic) sign processes enabling the organism to adaptively negotiate its external environment must be a necessary component of *all* living systems – and it is by virtue of this understanding that the contemporary integrative interdiscipline of *biosemiotics* was born.

Krampen's call in this article for the establishment of a dedicated investigation and analysis proper to the level of sign processing observable within and among plants – as opposed to the levels appropriate to the study of sign-processing found in animals, much less the one appropriate to humans – recalls, as Kull (2000: 346) points out, Aristotle's *scala naturae* distinction between the *vegetative, animal*, and *rational* modes of organization and interaction in living systems, with each ascending level augmenting, while still depending upon, the earlier way of being for its support. Accordingly, Kull argues that we can intelligibly speak of a heterarchy of *vegetative, animal,* and *rational* modes of *semiosis* in delineating the various iconic, indexical and symbolic acts of sign-processing that, in the aggregate, constitute human experience (and *mutadis mutandis*, the non-human experience of other organisms).

Deely (1982, 1990, 2001), however, sees Krampen's extension of Sebeok's *zoosemiotics* project to one dedicated to the examination of all biological being, and to the examination of their relations with the *signa naturalia* of every kind (e.g., day/night cycles, barometric pressure gradients, mineral density, etc.) as one that leads us, not so much back to a more scientifically informed reconsideration of the insights of antiquity, but instead to a genuinely "post"-modern transcendence of the mind-matter duality that has characterized modernity since its codification by Descartes. Krampen's proposal, writes Deely, "was key to completing the notion of 'biosemiotics' – the architectonic idea proposed by Thomas A. Sebeok that *semiosis is criterial of life*" (2006: 586).

Deely further notes, however, that since *all* the phenomena that are criterial of biological life – such as metabolism, growth, reproduction and self-repair – must themselves be congruent with, emerge from, and build upon the possibilities, constraints and regularities of the existing physical substratum, the search for the non-biological regularities of the universe that alone make semiosis *veridical* becomes a field of (at least theoretical) investigation in its own right. Deely designates this field – which examines the pre-existing "patterns of knowability" or "virtual thirdness" inherent in the regularities of the non-living surround that can potentially function as signs for some agent – as *physiosemiotics*, to distinguish it from what he considers as the "dangerously misguided" notion of *pan-semiotics*, which would designate the polar opposite belief that the semiosis of living being is inherent in all non-living things (1990: 83–105). Krampen's discipline-changing inauguration of *phytosemiotics*, writes Deely, thus "marks not the final step, but only a penultimate one, in reaching the outlines of the full extent possible of the doctrine of signs" (1990: 103).

Aristotelian or postmodern (or both), Krampen's article occupies a signal place in the history of biosemiotics – and its prescient insistence on the development of a non-anthropomorphic understanding of sign-processing in plants has been amply justified by botanical studies undertaken in the almost three decades since the following selection was written.[5]

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[5] Baluska et al. (2006) provides an excellent overview of the current state of the art in plant behavior and plant signaling studies; the scientific peer-review journals *Plant Physiology, Trends in Plant Science*, and *Plant Signaling and Behavior* report the latest findings in the field; and Simons (1992) and Attenborough (1995) provide readable and informative introductory texts. See also the *Bibliography and Further Readings* section in this volume for a list of similarly relevant texts.

Phytosemiotics (1981)

Introduction: Background of the Problem

The problem of this essay is to establish phytosemiotics, i.e., the semiotics of plants, as an area of inquiry into sign processes, parallel and on an equal footing with anthroposemiotics, the study of human communication, and zoosemiotics (Sebeok 1963, 1972), the study of sign processes occurring within and between species of animals, the three areas forming together the discipline of "biosemiotics".

Subjective Interest

For 3 years, I have been working, in my capacity as a psychologist and semiotician, in an interdisciplinary team together with a designer, a gardener, and a physician in an experiment in living and working among plants. The designer from this team moved, 4 years ago, into a normal commercial greenhouse that was empty at the time. After a preliminary failure with "laissez-faire" gardening and tropical vegetation, he planted, with the help of the gardener, a selection of subtropical plants around small platforms used for office work, sleeping, cooking, and sitting. These plants remain green all year round regardless of the presence of snow and frost outside – if the greenhouse is moderately heated. The designer had his office there and lived there, the doctor monitored his health, and I observed the behavior of the designer, his employees, and his visitors (including myself). In addition, oxygen and carbon dioxide measurements were taken longitudinally under different weather conditions.

A report on this experiment has appeared (Logid 1981). On the basis of the result, the team is suggesting a combination glass-and-stone house with a 50% surface for plants as an alternative architectural solution in the face of fading oil resources (the sunheat caught in the glasshouse can be stored), in the face of air pollution (the oxygen content in the glasshouse is, due to the plants, above the normal level of any room with open windows), and in the face of decreasing environmental quality in our cities. In contrast, the quality of life in this environment is rated very highly by the participants in this experiment (due to the colors of blossoms and leaves, the smells, and the constant change of space resulting from plant growth and seasonal cycles). This advantage must be paid for by way of an average of one hour per day spent on plant care.

I had, however, one problem with the experiment that I could not resolve at the beginning – the problem of its semiotic interpretation. For quite some time I thought that the semiotic content of this enterprise was negative only. This island of green represented, in my estimation, an escape from daily routine with its signs of human communication in bureaucracy and mass media. Plants, unlike letters, punched cards, and tapes, are not malleable. One cannot do with them as one pleases. They require care and grow according to their own plan.

Problem Relevance and the Semiotic Approach

There is little doubt that the problem of new alternative forms of working and living is highly relevant if one considers the crises of energy, environmental pollution, and the general loss of quality in daily life. This is at least true in western industrialized countries, where we witness mass tourism, suburban sprawl, and growing so-called "green" political movements. A project like the one described above seems to give a direct and practical answer to the problems mentioned. There seems to be little room for theoretical questions of semiotics. But the lack of a theory to back up a practice has always made me suspicious. I also find the escapist tendencies in mass tourism, urban sprawl, and "green" politics unsatisfactory. I therefore began to amplify my semiotic interests by searching for a solution to my "cognitive dissonance".

Jakob von Uexküll's Biosemiotics

I had read Jakob von Uexküll's ([1940] 1970) "Bedeutungslehre" (theory of meaning) a long time ago.[6] I had discussed the semiotic importance of the work of this unorthodox German biologist, forerunner of ethology, many times with his son, Thure von Uexküll, who is attempting to develop further the semiotic aspects of his father's work with "biology as a science of meaning in nature". These discussions were often very heated and controversial because I could not cope with what I thought to be a hermeneutic approach to natural science. It took the publication of Jakob von Uexküll's selected writings by his son (Thure von Uexküll 1980), and a careful rereading of the "Bedeutungslehre", to convince me that a basis for a semiotics of plants could be found in Jakob von Uexküll's work. The basic premises of Jakob von Uexküll's theory of meaning in nature may be summarized as follows:

(1) Living beings, from the cell to the most complex organism, are "autonomous". They do not react in a causal and mechanical way to impingements of objects or other living beings as material objects do. Living beings react in a way that is meaningful in terms of their own needs, i.e., they process information according to their specific receptors, nervous systems, and effectors and according to their own code. Therefore, biology can utilize causal and mechanical explanations only to a very limited degree. The main task of the biologist is to reconstruct the meaning of a living being's behavior. This implies finding out exactly which sign processes underlie behavior. In other words, biology is biosemiotics (a term not used by Jakob von Uexküll).

(2) There is a structural correspondence between each living being as an autonomous subject and its own "Umwelt". The term "Umwelt" is difficult

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[6] An English translation of Jakob von Uexküll's "Bedeutungslehre" ("The Theory of Meaning") will appear, with an Introduction by Thure von Uexküll, in *Semiotica* in 1982.

to translate into English. It means the subjective world of what is meaningful impingement for the living being in terms of its own information processing equipment, sign systems, and codes. Since “Umwelt” is not to be confused with “environment”, the original term will be maintained. The structure of connection between a living being and its Umwelt is mediated by sign processes.

(3) There is a meaningful structural correspondence between the Umwelts of different living beings within a species and those of living beings of different species, according to a “general plan of nature”.

(4) The ultimate task of the biologist is to reconstruct piece by piece, in keeping with, and on the basis of, experimental evidence, the hypothesized general plan of nature.

Jakob von Uexküll’s Anthroposemiotics and Zoosemiotics

In order to describe in somewhat more detail the biosemiotic theory of Jakob von Uexküll, one must start with his anthroposemiotics. While this term, again, is not used by him, the meaning of the relationship between each human subject and his Umwelt, as well as the meaningful correlation between the Umwelts of different human beings, is of special importance in Jakob von Uexküll’s biosemiotics. He gives many examples as evidence of different kinds of Umwelts.

One example is a walk through a town. The tailor’s shop contains the concave counterforms of human bodies specialized for different activities in their lives. The clocks in the watchmaker’s shop have replaced (according to abstract human time measures – the natural one of the sun, which used to regulate human lives by the presence or absence of its light). The book shop contains messages between cardboard covers that are of great importance for communication from human Umwelt to human Umwelt. The butcher’s shop contains the carcasses of animals, each of which was, at one time, an organism with an Umwelt of its own, etc. Everything witnessed during a walk through town is geared to human needs. The height of the buildings and of doors and windows is related to the size of the human body. Stairs accommodate ascending legs, bannisters the arms. Each object is given its form and its meaning by some function of human life. In every case, some human affordance is backed up by a counteraffordance of an object. In fact, the meaning of an object to human lives literally consists of its counteraffordance to human affordance.

But the key role of anthroposemiotics in Jakob von Uexküll’s conception arises from the fact that the scientist himself, the biologist, is a human subject surrounded by his Umwelt as if by a transparent bubble, on the surface of which appear his scientific observations in keeping with his own sign systems and codes. Jakob von Uexküll likes to quote, in this respect, the British astronomer and physicist Sir Arthur Stanley Eddington, who said he had two desks, the one he used for writing on, and the other a physical desk consisting of an immeasurably large number of particles (Jakob von Uexküll [1940] 1970). For that matter, a biologist would investigate a different desk than a physicist (Jakob von Uexküll 1935). Therefore, the scientific and especially the biosemiotic investigator must use a special method in order to arrive at a careful reconstruction of the Umwelt of the observed living being in his own Umwelt and on his own terms – a method that would now be called participant observation.

The structural correspondence between each living human organism and its Umwelt is described by Jakob von Uexküll as a "function cycle". The subject literally "grasps" an object, in a double-pronged attack, either directly with his receptors (e.g., eyes) and effectors (e.g., hands), or indirectly with amplifications of his receptors (e.g., microscope) and his effectors (e.g., a tool or a machine). There is a constant feedback of signals from the effectors to the receptors, which is modified by the encounter with the object. The nervous system within the organism mediates between receptors and effectors according to the needs of that organism (e.g., hunger, defense, sexual drive, and the medium in which it lives).

According to Jakob von Uexküll, the receptors receive afferent signals from the object and the effectors are steered by efferent signals to carry out an action upon the object. Both kinds of signals are charged with meaning by the code constituted by the subject's needs. An object may thus be sensed differently and acted upon differently, depending on the actual need. The two faces of the object as a sign are the afferent signals as the signifier, and the induced efferent signals as the signified. The semiosis proceeds on the basis that the afferent signals are constantly cancelled by the efferent signals, either in terms of the consumption of the object, or in terms of a different "perspective", or in terms of a code-switching to another need. The sum of the object signals received and their corresponding action signals constitutes the Umwelt of the organism, which is mirrored by signs as an "inner" counterworld.

The task of the biologist is to study the code according to which a living being, be it human or animal, imparts meaning to its Umwelt, by studying the physical structure of receptors and effectors and by observing, through experimental variation, which signals are processed on each side, i.e., which signs are in the code of the living subject. The study of the Umwelt of human beings is thus, clearly, anthroposemiotic.

The role played by those particular objects in the Umwelt of human beings that are called signs has been studied by Thure von Uexküll (1980). The specific characteristic of the human Umwelt is that it is structured according to the species' framework of space and time; that, by reafferent feedback processes, the phenomenon of "consciousness" (or self-awareness) exists; and that by transmission of sign-objects, particularly of linguistic signs, a common social reality is established.

Following the suggestion of Marx ([1857] 1961: 636) that it is scientifically more correct to explain apes by using knowledge about men than to explain men in terms of apes, the zoosemiotics of Jakob von Uexküll can now be sketched "by subtraction".

Returning to the example of Eddington's desk, this object becomes, in the Umwelt of a fly, a mere horizontal walking surface and is, in that respect, no different from the seat of the chair or the top of a cupboard. In fact, all objects in a human room are reduced, in the Umwelt of a fly, to objects to walk on, objects to feed on, and objects, a lamp for instance, to fly around in a kind of play activity. As Jakob von Uexküll cogently observes, the number of objects pertaining to the Umwelt of an animal corresponds exactly to the number of actions executed by it. But each animal, be it an amoeba, a fly, or a lion, behaves meaningfully on the basis of sign processes with a functional cycle forming signs from afferent signals as signifiers and corresponding efferent signals as signifieds.

The Phytosemiotic Hypothesis

It is the hypothesis of this study that, while plants are autonomous living beings (in the sense of Jakob von Uexküll), their semiosis is different from that of human and animal subjects in such a way that it merits its own semiotic analysis. This semiotic analysis may well form the positive scientific basis lacking so far in the conservationist activities that have until now, largely been based on negation and ideology. The method by which the specificity of plant semiosis can be shown is that of opposition, well known in semiotic inquiry. It would thus be necessary to show by which distinctive features phytosemiotic processes differ from anthropo- and zoosemiotic processes, and at the same time, what their common biosemiotic basis is.

Distinctive Features of Phytosemiotics

Fixation Versus Mobility

Jakob von Uexküll (1922) characterizes the most obvious difference between animals and plants as that of movement and quietness:

> The confusing aspect offered by the thousands of animal worlds is due to the impossibility of finding a moment of rest anywhere. Everything is constantly in the process of breathtaking movement. . .. Again and again the animal must exercise its organs to respond to the requirements of the Umwelt. Sometimes the animal is the persecutor and sometimes the persecuted. But it is always active and thus burns the materials which its digestive cells have extracted in painstaking labor from the nourishment which it has acquired in such a hard way.
>
> The aspect of the reign of plants is quite different. Hectic haste is replaced by comfortable calm. Not that work ceases for a moment, as long as the plant is alive. An uninterrupted stream of liquids enters by the roots, rising along the stem and branches out in all directions to the leaves where it evaporates again in a well-controlled fashion. This stream transports the nourishing salts gained from the earth into all those tissues of the plant which transform them into material of the plant's body. In the laboratory of the leafgreen, the important building block of carbon is produced with the help of the sun. Everything is handled by the fine detail work of living cells which remain autonomous subjects as do those in the bodies of animals. They work in union, according to a plan, by transmitting stimuli and material.

This quotation certainly should not be misunderstood in the sense that plants do not move. There is, for one thing, the phenomenon of phototropism (e.g., Presti et al. 1977), implying relatively slow movement of plants toward light sources. And there is, of course, very visible adaptive movement of plants in response to the pressure of air (wind) or water (stream).

Absence of Effectors and Receptors

The "comfortable calm" of the reign of plants is due to the fact that plants have no specific effector organs – no feet to run with, no arms to gesticulate with, etc. – and, correspondingly, no specific receptor organs – no eyes to look around with, no ears to hear with, etc. Consequently, there is no nervous system mediating between effectors and receptors.

This assertion appears to be in contradiction to an increasing – and quite "fashionable" – body of literature concerned with "plant receptors". For instance, so-called photo receptors have been studied in different strains of Phycomyces, a species of fungus (Delbrück et al. 1977, 1976, Presti et al. 1977). It was found, in one study, that "the Phycomyces sporangiophore is a single cell and responds phototropically, adapting to various light levels.... The authors have analyzed the kinetics of this adaptation, using a tracking machine for greater precision. Dark adaptation is exponential ... i.e. the threshold falls exponentially in the dark, in contrast to scotopic vision where the logarithm of threshold falls exponentially in the dark." In the other studies, the chemical functioning of these photoreceptors was analyzed, with the result that the "bluelight receptor" of Phycomyces is not carotene (as in animals), but riboflavin.

A similar topic in the literature is the search for a functional "plant hormone receptor" (e.g., Dodds and Hall 1980, a review on the problem with a bibliography of 65 titles). Animal hormone receptors are defined as follows:

> Animal hormones are synthesized in clearly defined organs and are then translocated to equally clearly defined 'target' tissues organs ... where they control specific biochemical processes ... the sites with which they interact must have a very high affinity for the hormone. Equally, the sites must show very high specificity for the hormone. These sites, or rather the whole molecule of which they are part, are termed 'hormone receptors'. All such receptors which have been isolated so far have proved to be proteins.

In contrast to a large number of hormones found in animals (more than 40 have by now been identified), only five groups of plant hormones are known so far. These plant hormones have a much simpler structure than animal hormones. According to Dodds and Hall (1980), "The very term hormone is called into question in plants since the site of synthesis is not usually restricted to a specialized organ or tissue ... most if not all plant cells have had the capacity for hormone synthesis at some time in their development and many retain this capacity, even if to a limited extent." In addition, "there is usually no one distinct target for a given hormone since at any one time many different tissues and organs in the plant are capable of responding to it – often in a different way". Obviously, it is this "totipotency of plant cells", a principle formulated already by Haberland (1902), that differentiates so-called photo- and hormone-receptors of plants from those in animals. This does not mean that there is no "differentiation", e.g., "division of labor", between plant cells during the development of plants.

It is typical for the modern conception of "plant receptors" in botany to refer to chemical "binding" processes that are treated, according to information theory, as processes between chemical "messengers" and "target substances", rather than referring to specialized cell compounds or receptor organs as these are present in animals. Moreover, the useful distinction between "exteroceptors" (e.g., photoreceptors) and "interoceptors" (e.g., hormone receptors) is neglected by botanical terminology. I would, therefore, like to maintain Jakob von Uexküll's conception denying plants the capacity of specialized receptor organs, and rather apply to what are called receptors in the above cited literature the term "sensors", according to the parlance of cybernetics with respect to feedback cycles.

Absence of the Functional Cycle

For the same terminological reason, I would agree with Jakob von Uexküll in maintaining that plants do not have a "functional cycle" connecting receptor organs via a nervous system to effector organs. What plants have is a feedback cycle between sensors and regulators. In the absence of a functional cycle in plants, there is no way by which afferent signals can be fitted together with efferent signals to form the signifiers and signifieds of "objects".

Casing Versus Umwelt

Given the absence of a functional cycle, plants cannot have an Umwelt. As Jakob von Uexküll ([1940] 1970) points out: "The plant does not possess Umwelt-organs, it is directly immersed into its habitat. The relationships of the plant to its habitat are quite different from those of the animal to its Umwelt." While humans and animals each have their own Umwelt, plants are confined to their casing.

Meaning Factor Versus Meaning Carrier

Due to the absence of effectors, nervous system, and receptors and the consequent lack of the functional cycle and the resulting Umwelt, plants have no objects that may become the sources or "carriers" of meaning for them. Meaning is mediated for plants by what Jakob von Uexküll calls "meaning factors". Meaning factors are those stimuli among the stream of impingements pressing upon the plants from all sides that are relevant to their life. The plant does not counter external impingements with the double-pronged operation of receptors and effectors, but uses the living sheet of cells of its casing to filter out relevant impingements. These relevant impingements are the meaning factors, i.e., the semiotic factors, for the living plant.

Using the example of the leaves of an oak tree, Jakob von Uexküll shows how phytosemiosis functions. One of the meaning factors, as far as oak leaves are concerned, is the rain. Falling raindrops follow precise physical laws governing the behavior of liquids upon striking a leaf. In this case, according to Jakob von Uexküll, the leaf is the "receiver of meaning", coupled with the meaning factor "rain" by a "meaning rule". The form of the leaves is such that it accommodates the physical laws governing the behavior of liquids. The leaves work together by forming cascades in all directions in order to distribute the rain water on the ground for optimal use by the roots. To put it in more common semiotic terminology, the leaf's form is the signifier and the physical behavior of a raindrop is the signified. The code coupling leaf and raindrop is the oak tree's need of liquid for the transport of nourishing salts into its cells.

Utilization or Meaning by Form Versus Utilization of Meaning by Function Cycle

The difference between plant and animal is that the plant utilizes meaning by means of its form built up according to a "plan of nature", enabling the leaf to fit into the physical behavior of liquids, while humans and animals utilize meaning through their function cycle. The code of a plant's need is a superordinate rule coupling two subordinate rules, the physical laws governing the forming and flowing of drops and the biological formation rules according to which the leaves of a particular species of plants grow in its typical habitat. The code of an animal's need couples relevant objects or animals to the receptors and effectors of the receiving animal. The superordinate rule of the living being's needs may be considered a code to which subordinate rules relate as subcodes.

Predominance of Indexicality Versus Iconicity and Symbolicity

The classical trichotomy of possible relationships between the material aspect of the sign and the object it stands for is, in Peirce, reflected by degrees of iconicity, indexicality, and symbolicity (and in the Saussurean tradition by degrees of motivation, indexicality, and arbitrariness). If one wants to extend this trichotomy to plants on the one hand, versus animals and humans on the other, the absence of the function cycle would suggest that, in plants, indexicality certainly predominates over iconicity. In animals, however, iconicity seems to predominate over symbolicity, since the double-pronged action of receptors and effectors models the object almost as a concave negative image of the two actions. Finally, symbolicity predominates over iconicity in humans because of their widespread social use of language and other arbitrary sign systems.

There are three levels of meaningful cycles corresponding to predominance of indexicality, iconicity, and symbolicity, each higher process including also the lower. Indexicality, on the vegetative level, corresponds to the sensing and regulating, in a feedback cycle, of meaningful stimulation directly contiguous to the form of the plant. Iconicity, on the animal level, is produced by the function cycle, with receptor and effector activity representing, in a nervous system, the "image" of objects. Symbolicity, on the human level, is produced by perception and action in human society.

Communalities Between Phytosemiosis and Zoosemiosi

Selection of Impingements

While there are distinct differences between the sign processes in plants and animals or humans, there are also important communalities among them. One is that they all filter out a specific selection of all those impingements surrounding them. As living beings, they are all capable of drawing a borderline between "self" and "nonself", utilizing only those impingements that are meaningful to their needs.

Suffering the Imposition of Meaning

Plants, animals, and humans not only utilize impingements meaningfully, but also suffer the imposition of meaning. Jakob von Uexküll ([1940] 1970) shows this with the example of the different roles a wild flower in a meadow may play as a meaningful object in different function cycles: It may be picked by a human for a bouquet of flowers, it is utilized as a walkway and plant-louse farm by ants, the larva of the cicada may bore its nest into its stem, and the cow may eat it together with a bunch of grass. Suffering the imposition of meaning is analogously applicable to animals and humans, as is proved by the roles of prey and predator between animals and between animals and humans, and by the suppression of humans by humans. In the "plan of nature", the meaning of suffering the imposition of meaning may range from the reduction of excess individuals in the interest of their own species to reduction in the interest of a whole ecological system, whereas social oppression among humans seems to be dictated by historical and dialectical laws.

Rules of Correspondence Between the Umwelts of Humans, Animals, and Plants – The Method of "Counterpoint"

With the example of oak leaf and raindrop, it was shown that meaning in nature is based on rules of correspondence bracketing subordinate formation rules and physical rules. The favorite example of Jakob von Uexküll for explaining the lawfulness of these meaningful correspondences or – as one would say in semiotics – codes is that of a musical composition of which "nature" is the composer. This whole composition, of which the biologist tries to write the score, i.e., to study the syntagrnatic.rules, is based on the technique of counterpoint. The method is to find the counterpoint to each note of the composition by following the motto: Wherever there is a point, its corresponding counterpoint can be found. The physical behavior of raindrops is the counterpoint corresponding to the point of the leafs form, the soft skin of mammals corresponds to the tick's bite, the path corresponds to man's feet, nourishment to his mouth, an enemy to his weapon, as Jakob von Uexküll has pointed out.

There is one fundamental rule of correspondence between humans and animals on the one hand and plants on the other, this being of critical importance for life: Plants produce the oxygen all humans and animals breathe. In other words, the life of plants corresponds as a counterpoint to the breathing lungs of humans and animals as a point. As Jakob von Uexküll ([1940] 1970) paraphrased Goethe's verse

> Wär' nicht das Auge sonnenhaft
> die Sonne könnt' es nie erblicken.

by postulating

> Wär' nicht die Sonne augenhaft
> an keinem Himmel könnte sie erstrahlen.

we might say:

> Wär' nicht die Lunge pflanzenhaft
> das Atmen könnte nicht gelingen.

and

> Wär' nicht die Pfianze lungenhaft
> gäb's keinen Atemzug auf Erden.

[*Editor's note*: a small study showing a correlated increase in oxygen levels with plant life in the greenhouse has been omitted from this reprint. Its conclusion is as follows:] The consequences of these oxygen and carbon dioxide measurements for healthy working and living conditions are obvious. According to medical experts, there seems to be a clear correlation between the increase of cancer and diminishing oxygen concentration in industrial areas. The data are presented here to demonstrate the meaning of plants to human life and to point out the necessity for further investigation in phytosemiotics.

Three Forms of Life and Their Common Semiotic Aspect

It has been shown above that the semiotics of the vegetative world is different from that of animals and humans, in that the absence of effectors and receptors does not allow for the constitution of a functional cycle, of object signs and sign objects, or of an Umweit. The vegetative world is nevertheless structured according to a base semiotics which cuts across all living beings, plants, animals, and humans alike.

As Thomas A. Sebeok and Thure vori Uexküll have pointed out, many life processes within the animal and human organisms function according to the principle of the vegetative world, i.e., according to the principle of phytosemiotics. This field of semiotic inquiry has been labeled endosemiotics bv them (Sebeok 1976, Thure von Uexküll 1980). As soon as a functional cycle is constituted by the presence of effectors and receptors, through the mediation of a "vegetative" nervous system, the phenomenon of Umwelt arises in animals and humans alike. The semiotic aspects of the Umwelt have been called "exosemiotics" (Thure von Uexküll 1980). Whereas endosemiotics is pertinent to all three forms of life, plants, animals, and humans, and thus pertinent to phytosemiotics, zoosemiotics, and anthroposemiotics, exosemiotics is pertinent to zoo semiotics and anthroposemiotics only. As Thure von Uexküll (1980) suggests, the age-old problem of the dualism of body and soul might thus find a biosemiotic answer. Plants would therefore exhibit predominantly indexical sign systems; in animals, both indexical and iconic signs would appear; whereas human sign processes would display the whole range of the trichotomy, from indexicality via iconicity to symbolicity.

Meaningful Interactions Between Plants and Animals

Thus far, only differences and communalities between the sign processes in plants, animals, and humans have been accounted for. Some examples of semiotic interactions between these living beings will now be presented.

It is well known that plants have chemical defenses against the attacks of herbivore animals such as insects. There are two classes of such defenses. Either chemical deterrents are already present before the attack occurs or such a deterrent is mobilized in response to such an attack. The latter defense is known as "induced resistance". It is practiced frequently in higher plants against infections by microorganisms. Induced resistance sometimes occurs, however, as a counterattack by the plant against the attack of an herbivore insect enemy. As far as this insect-induced resistance in plants is concerned, it is interesting to study the time plants need for mobilization. Most of the observed cases of this type of resistance have long response times, ranging from 12h to as much as several years. But there are examples of relatively rapidly induced resistance.

I am grateful to Thomas A. Sebeok for drawing my attention to such an example published recently (Carroll and Hoffman 1980). It shows a complex sequence of animal attack on the plant, rapid counterattack by the plant, and adaptive countermeasures against this defense of the plant on the part of the animal. The crookneck squash is attacked by a beetle species labeled *Epilachna tredicimnotata* (Coleoptera: Coccinelidae). This bug first uses its specially formed apical teeth to cut a circular trench in the crookneck squash leaf and then feeds only on the cut-out disk. The trenching takes about ten minutes, obviously time enough to isolate a part of the leaf from the chemical deterrent that the plant mobilizes against the attack. The response time of the plant and some further circumstances connected with this interaction between "prey" and "predator" have been investigated experimentally by Carroll and Hoffman.

They used the circumstance that the deterrent mobilized by the crook neck squash against *Epilachna* is a feeding stimulant for another beetle (*Acalymma*). The latter refuses, for instance, to feed on crookneck squash leaves that have been recently removed from the plant and, therefore, cannot yet have been reached by the deterrent (unless it has been locally synthesized). The response time of *Epilachna* attacks on the crookneck squash can now be experimentally "chronometrized" by damaging crookneck squash leaves and varying the time between damaging and cutting a part of the leaf as food for the two kinds of beetles.

The first kind should refuse, the second kind start feeding from the moment at which the deterrent has arrived at the damaged area of the leaf. Carroll and Hoffman found that it takes the crookneck squash about 40 min to mobilize the deterrent and to send it to the attacked area. *Epilachna* is faster, however, and takes only ten minutes to cut out an area from the leaf before the deterrent can reach it! (Or is it content to eat only what it can cut out in 10 min, the plant, in turn, tolerating this minor damage?) After reviewing some similar cases of plant-animal interaction reported in the literature, Carroll and Hoffman suggest that the fact that herbivores often move from one plant to another before having finished feeding might be an adaptive response geared to avoiding the arrival of defensive deterrents at the feeding point.

Meaningful Interactions Between Plants and Men

The "Green Thumb" Theory

As far as the interaction between humans and plants is concerned, there is a widespread popular conviction that some people have "green thumbs": Whatever seed they put into the earth will grow and mature nicely. Others, not gifted with this magic capacity, can do whatever they like – the plants will die for them. I have heard people explain this phenomenon by the alleged radiation of an aura that is particularly "congenial" to plants. But even admitting that living beings possess their own "aura" of radiation (for instance, warm-blooded animals radiate heat), I would suggest that "green thumbs" is a phenomenon analogous to that of "clever Hans" of which Sebeok (1977, 1978) has repeatedly warned us. The "magic", in this case, lies in the fact that some people have a different attitude towards plants, know more about them and, consequently, take better care of them. It is no wonder if plants react positively to this treatment.

Caring for Plants

Another concept of meaningful interaction beetween plants and humans could be based on the differentiation of "meaning" into two classes: There are objects that are “indirectly” meaningful to us, such as words or other communicative signs. But there are also objects that may acquire “direct” meaning. This is, for instance, the case with “cherished” possessions, which may become receptacles of personal memories, e.g., a gift from a friend, or tokens of attitudinal justification, e.g., a “status symbol” or a trophy. Plants, for instance, are generally present in the “object ecology” of a typical middle class home and tend to carry a special meaning for one or more members of the family.

Csikszentmihalyi and Rochberg-Halton (1978) and Rochberg-Halton (1979) have shown in their studies on the meaning of “cherished household possessions” that, for children, parents, and grandparents, quite different objects acquire meaning for quite different purposes. The younger generation names, as its preferred possessions, objects that require active manipulation – e.g., stereo units, musical instruments, pets, etc. The grandparents, on the contrary, prefer objects of passive contemplation, such as family photographs, books, paintings, crockery, etc. The middle generation, the parents, take an intermediate position between their children and their own parents as far as the “motivation” of cherished objects is concerned. Their preference ranges from paintings and books to musical instruments, plants, and stereos (in that order).

The middle rank of objects for the three generations shows a decrease in life characteristics: children prefer pets, parents plants, grandparents crockery. Also, the same objects may obtain different ranks, depending on whether they are ranked according to one or another of three different meaning dimensions: first, reference to self versus reference to other; second, current experience versus memory of the past, and third, personal values. The latter dimension of meaning reflects objects as models of the self or templates of self-development. It is in this dimension that plants, together with books, rank first, i.e., above all other objects. By analyzing the rank order of parents separately, i.e., women versus men, one finds plants only in the rank order of the former, whereas the latter have tools and trophies in their preference list as objects meaningful only to men.

Obviously, in these choices, differences in the conception of self are involved that are due to stereotypes of sexual roles. As Csikszentmihalyi and Rochberg-Halton (1978: 12) put it: “The meaning system built by men is different from that of women partly because they learn to use different things to objectify experience. The feelings and thoughts one has in caring for a plant are bound to be different from the ones a person has when using a camera . . . We are assuming that a plant produces, in its (characteristic) caretaker, feelings of nurturance while a trophy is more likely to invoke a feeling of pride in one’s past accomplishment.”

This phenomenon of plants evoking the nurturance instinct in humans is nicely demonstrated in a report by Newman (1979) on a particular type of interaction with plants, exhibited by a woman who served as a subject in a study on a person’s relation to objects. By eliciting accounts of this woman’s most highly valued activities, Newman found that she focused her main interests on collecting, repairing, and nurturing. Her main collector items were valuable Indian prints, as well as stones she picked up. She repaired her own car and other objects around the house, being directly prompted to do so by her feminist orientation, prescribing that one has to learn to take care of oneself. The nurturing aspect of her activities was clearly visible by the mass of plants in her house. But this aspect was brought out even more by the fact that she used to go to supermarkets and plant stores every so often to buy plants that were dying. "Then she would nurse them back to health, propagate them and give them to friends who would be good to them. Thus, she said, she 'worries a lot' about them" (Newman 1979: 4a). Apparently, her interaction with plants excluded aesthetic contemplation. Caring for plants was a very active form of "rescuing" in the woman's life.

This example shows, in a psychological way, how important plants may become for humans. The study of the psychological relationships between men and plants is still in its very early stages. One of the tasks ahead lies in the development of an attitude-toward-plants-test, which could complement other "environmental inventories", e.g., the Environmental Response Inventory (ERI) of McKechnie (1977), already used in environmental decision making, planning, and aptitude testing.

Learning from Plants

Plants not only evoke nurturance behavior but often become something like "teachers" when we interact with them. The "comfortable calm" they radiate has already been mentioned (Jakob von Uexküll 1922). But they may also become "living examples" of "passive resistance". As Jakob von Uexküll ([1940] 1970) says: "A plant solves its main task by passive surrender to the effects of the Umwelt into which it is slotted. Since the plant is not mobile, it has to face all those external effects which are present in its surroundings. The most efficient means of an animal's self-preservation – escape – is not available to the plant." In addition, the example of the plant's life rhythm can be very instructive to humans. Some plants certainly possess, in their genotype, the capacity to predict, independently from weather conditions, the change of seasons. And Jakob von Uexküll ([1940] 1970) observes, in this respect:

> Since plants are not dead cases, but are constantly forced to defend their lives, we recognize in them a life rhythm paralleling the change of the seasons. Our deciduous trees lose their leaves in autumn and change into plants, independent of water, in order to survive the effects of dehydration imposed on them by frost and frozen ground. The inner rhythm of plants, however, is adapted even more intimately to the changes of the year because it has been shown that our fruits grow best in hot houses, if one exposes the trees to the drop in temperature normal during their blossoming period.

Finally, plants impress us not only with the biotechnical solutions they find to their problems but also with their "wisdom" in architecture: "The houses of men are immobile and immediately betray their locality in their external habitus: Roofs and windows must be built differently, depending on whether snow, rain, storm or heat from the sun menaces the house. Plants, likewise, demonstrate through their form whether they must defend themselves against drought or water, against an excess or a lack of light" (Jakob von Uexküll [1940] 1970).

Generally, human aesthetic experience is heightened in symbiosis with plants, since the plant's foremost "receiver of meaning" is its form, linked with physical "meaning factors" that generally follow physical laws. Thus, plants not only adapt indexically to their environment but also iconically portray the forces of their environment through their meaningful form. A study of literature and poetry, of painting, religion, and other human endeavors should convince us that plants have served as meaningful signs, indexical, iconic, and symbolic, in many cultures because they are living beings possessing features that evoke the attribution of meaning to a very considerable degree.

Discussion and Some Conclusions

Jakob von Uexküll's approach to biology as a science of life is a holistic one: The whole is not explained by the functioning of its parts, but the meaning of the parts is explained according to the plan of the whole, a principle that is not unlike the fundamental proposition of Gestalt theory. Admittedly, with his postulate of a "general plan of nature", one reaches the borderline of the operational. But if the "general plan of nature" is taken as a hypothesis, guiding, step by step, the experimental verification of "rules of correspondence", it loses its pseudoexplanatory character.

It may also become a guideline for ecological research and, indirectly, for the political conclusions based upon it. The ideological veneration of greenery and its attendant blind search for alternatives can be replaced by the detailed study of the symbiosis between humans, animals, and plants, and ecologically sound solutions to contemporary problems can be deduced from it. Despite the impression of progress raised by the constant introduction of new and sophisticated tools between human effectors or receptors and the human Umwelt, the human organism cannot escape the basic vegetative rules of endosemiotics and remains locked together with plants by a mutual rule of correspondence: If men cease to care for plants, i.e., cease to understand their meaning factors and the meaning rules at the basis of their formation rules, they will asphyxiate themselves. As Thure von Uexküll (1980) has put it: "Man is led, from his extravagant position as the observer positioned outside nature and as its unscrupulous exploiter, back into nature, in which he must arrange himself for better or worse." Phytosemiotics can help to improve this arrangement.

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Chapter 9
Endosemiosis

Thure von Uexküll (1908–2004), Werner Geigges (1953–), and Jörg Herrmann (1944–)

Introduction and Commentary: Thure von Uexküll (1908–2004)

> *Observation can show us living systems only 'from the outside,' that is, as they present themselves 'to us.' In order to inquire into their 'inside' . . . we must find out how the living system construes its conditions. It should be emphasized here that "outside" and "inside" are semiotic concepts in that they mark a viewpoint outside or inside the system.*
>
> T. von Uexküll et al. (1993: 194)

"Almost every German university hospital has a chair of psychosomatic medicine," noted the obituary for pioneering clinical biosemiotician Thure von Uexküll upon the occasion of his death at age 96 in 2004. "German medical students are obliged to attend courses in medical psychology, sociology, and psychosomatic medicine, and more than 7,000 beds in German rehabilitation hospitals are devoted to the treatment of patients with psychosomatic disorders," the obituary continued, concluding that "the unique position of psychosomatic medicine in Germany – in comparison with other European countries – is largely due to the continuous engagement of Thure von Uexküll" (British Medical Journal 2004: 1047).

The eldest son of biologist and philosopher Jakob von Uexküll (1864–1944), whose view of the human being as "a system embedded in the environment of other systems" profoundly influenced his own later, highly original contributions to both medicine and to biosemiotics, Thure von Uexküll was born in Heidelberg, Germany, on March 15, 1908, one year prior to the publication of his father's seminal monograph *Umwelt und Innenwelt der Tiere.* During the years 1928 to 1936, Thure studied medicine in Hamburg, Munich, Innsbruck and Rostock, performing his internship as a medical doctor at the Charité Hospital in Berlin from 1936 to 1943. From 1943 to 1945, he was conscripted as a doctor in the German military, despite his refusal to join the Nazi party. In 1945, he became an assistant professor at the University of Munich Medical Hospital, travelling to the United States in 1952 under a fellowship from the Rockefeller Institution to work as a medical doctor and a researcher into what he would later develop as the field of "integrative medicine."

Uexküll returned to Germany in 1955 to serve as Director of the Medical Outpatient Department at the University of Giessen from 1955 to 1965, and as the Director of the Department of Internal Medicine and Psychosomatics at the

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University of Ulm from 1966 until his retirement in 1977, at age 69. Post-retirement, Uexküll continued researching and working as a professor emeritus of internal medicine at the University of Ulm, editing and authoring substantial contributions to the definitive (1564-page) volume on psychosomatic medicine in 1979, now in its sixth edition and required reading for the majority of medical students in Germany. It was also during this time that Uexküll made the acquaintance of polymath Thomas A. Sebeok (1920–2001), with whom, according to many accounts by Sebeok (1979, 1986, 1990, 2001), Thure and Giorgi Prodi (1928–1987) co-founded the contemporary interdiscipline of biosemiotics.

Thure was present at the Third Weiner Symposium über Semiotik in Vienna in August 1977, when Sebeok delivered his seminal paper entitled "Neglected Figures in the History of Semiotic Inquiry: Jakob von Uexküll." The two men later had an extended discussion over dinner that, Sebeok recounts, "gave early impetus to, and decisively shaped, the subsequent unfolding of biosemiotics" (2001: 34).

"First, the idea of launching a series of annual international conferences devoted to biosemiotics was broached and soon realized by Thure," reports Sebeok,

> Repeated about five or six times in the late eighties and early nineties, these were held on the premises of the Glotterbad Clinic for Rehabilitative Medicine in Glottertal, Baden-Württemberg, Germany, under his leadership, with the signal cooperation of Jörg M. Herrmann, M.D., the clinic's director. Thure, in his introduction to one of the sessions, on 'Models and methods in Biosemiotics' succinctly stated the project's aims: "to support the experiment of bringing together the Humanities, represented by semioticians; the Natural Sciences, represented by experts in molecular biology; and Medicine, a science with an uncertain position between both [the Natural Sciences and the Humanities], and represented by internists, psychiatrists, and clinical psychologists." He depicted the topic of the conference as "the proposition of an order in nature which has nothing to do with [brute efficient] causality, but one which canalizes causal processes between living systems and their environment, as well as in, and between, these systems. We maintain", he concluded, "that this order is a semiotic one, or at least can be described in semiotic terms" (2001: 35).

These Glottertal conferences, Sebeok notes, are where Danish biosemioticians such as Jesper Hoffmeyer and his colleagues made the acquaintance of American semioticians such as Sebeok and his colleagues, as well as with biologists and semioticians of the Moscow-Tartu circle such as Kalevi Kull – and were the direct forerunners of today's annual International Gatherings in Biosemiotics conferences, which were originally convened as a follow-up to the Glottertal conferences by Hoffmeyer, Emmeche and Kull.

Thure von Uexküll's role in the development of contemporary biosemiotics, however, extends far beyond the organizational role that he performed in bringing together researchers in medicine, science, and the humanities. For as noted by Kull and Hoffmeyer, Uexküll was an active colleague and collaborator with both the Copenhagen and the Tartu groups of semioticians, authoring a number of seminal biosemiotic papers addressing the fundamental issues of biosemiotics. These included a series of papers examining the bio-semiotic emergence of a sense of "self" (Uexküll 1984, 1986b, 1992a, 1995), in which is posited a theory of "natural semiotic levels ranging from the cell constituting the lowest level (the 'semiotic atom') and progressing through the ascending semiotic levels of vegetative semiosis (e.g., phytosemiotics) to animal semiosis (zoosemiotics) to human sign systems [anthroposemiotics] which allow for the capacity to represent absent objects and possible worlds" (2005: 489).

Moreover, and although his extensive research into human psychosomatic phenomena and its treatment by medical professionals diverged in some important ways from the ideas put forth by his father, Thure von Uexküll throughout his life helped to preserve his father's legacy and to advance and extend the concepts central to Jakob von Uexküll's *Umweltlehre.* Indeed, Thure collaborated with Jakob throughout the last few years of his father's life, co-authoring "a biological variation on a Platonic dialogue" called *Die ewige Frage* in 1943, and contributing a chapter to *Der Sinn des Lebens* (published posthumously in 1947). He also, along with his mother, Gudrun von Uexküll, completed the last nine chapters of Jakob von Uexkull's unfinished final book *Das allmächtige Leben* (1950) by working from the notes left behind by his late father. Thure also edited a collection of his father's works (1980) and authored extensive commentaries upon them after the "re-discovery" of Jakob's *Umweltlehre* by semioticians in the 1980s (1982a, 1987, 1992b, 1993b, 2004).

Throughout his life, however, Thure von Uexkull's primary focus was on "de-mechanising" the approach to medicine that views the patient's body as a broken machine to be put back into working order by the physician; and upon the development of a genuinely "integrative medicine" that would recognize the active role that the body itself plays in the establishment and disestablishment of both health and disease, based upon its interpretation of the signs that impinge upon it not only from the external environment, but from the brain and from the rest of the massively intercommunicating systems constituting the internal environment, as well.

Thus, though he was well aware of (and stressed to his colleagues the importance of considering) the fact that "mental states" *are*, in fact, physical (i.e., chemical and neuronal) states, and therefore are important contributors to both a patient's health and disease, he resisted the over-simple and somewhat "mystical" ideas proposed by some of his colleagues that psychosomatic phenomena such as hypertension and stomach ulcers were *entirely* the product of the patient's cognitive states and could be thus treated solely by psychotherapy, arguing instead that a truly *integrative* medicine must acknowledge the non-mentalistic biosemiosis that characterizes multicellular body processes themselves.

"The overwhelming majority of the objective evidence of a disease," he noted,

> belongs to those types of processes taking place within the body, which, in turn, are subdivided into subsystems (organ systems, organs, tissue, cells, cellular organelles).... The participants in the exchange of signs that takes place on the biological level are thus given ...[and] the sign processes use chemical, thermal, mechanical and electrical processes as sign carriers. They make up an incredible number. If one reflects upon the fact that the human body consists of 25 trillion cells which is more than 2,000 times the number of people living on earth, and that these cells have direct or indirect contact with each other through sign processes, one gets an impression of the amount. Only a fraction are known to us. Yet this fraction alone is hardly comprehensible.... The messages that are transmitted include information about the meaning of processes in one system of the body (cells, tissues,

> organs, or organ systems) for other systems as well as for the integrative regulation systems (especially the brain) and the control systems (such as the immune system) (1986: 204).

Endosemiotics is the term that Thure von Uexküll and his medical colleagues Werner Geigges (1953–) and Jörg Herrmann (1944–) coin in the following selection to describe the vast – and still yet to be fully undertaken – research program into the investigation of the body's multiply interacting systems of non-linguistic, non-mentalistic signs.

In short, just as Jakob von Uexküll's notion of the *Umwelt* of the organism-in-its-surround has been described as "the crucible of the animal's informational relationships, perforce the 'meaningful' ones, with the environment" (Anderson et al. 1984), Thure von Uexküll's even more ambitious project of *endosemiotics* is the attempt to describe and understand the crucible of informational relationships taking place *within* the organism itself. Biology, as Thure mentions, knows this internal interaction space to be vast, with trillions of endlessly interacting cells, exchanging informational "messages" on the ever-changing contours of a moment-to-moment epigenetic landscape. Moreover, the necessarily interacting systems within the body each appear to operate using their own unique sign system, and so one of the most pressing question for a science of the body becomes: How do all these differently operative sign systems *translate* each other's very different kinds of incoming and outgoing chemical, electrical, gradient, frequency-dependent and conformational signals and "messages" so as to be able to causally influence each other into and out of the various transient optimal states needed to result in the coordinated accomplishments of hunting, feeding, fleeing, metabolising, respirating, wound-healing, growth, digestion, excretion and reproduction?

With the initiation of this project – and by his tireless crusade to make integrated, psychosomatic medicine an obligatory part of every medical practioner's education – Thure von Uexküll, as semiotican Marcel Danesi once said of Uexküll's colleague Thomas A. Sebeok, helped "transform semiotics back into a 'life science' – having taken it back, in effect, to its roots in medical biology [and specifically, the uninterrupted tradition of symptomology found in all cultures]. In other words, he uprooted semiotics from the philosophical, linguistic, and hermeneutic terrain in which it has been cultivated for centuries and replanted it into the larger biological domain from where it sprang originally" (2002: o.l.).

Endosemiotics (1993)

Preliminary Remarks

The term *endosemiosis* refers to processes of sign transmission inside the organism. So this article presupposes and starts from a specific systematics which has been derived from systems theory (von Bertalanffy 1968). The relations between systems theory and sign theory have been discussed elsewhere. Here it is sufficient to emphasize the following.

The framework of systems theory describes a graduated order in which, beginning with and "rising" from the phenomena of inorganic nature, the phenomena of all living beings up to human social systems are allocated to different "integration levels". In this article on endosemiosis, we address the second of these integration levels, postulating the cell to be its most elementary integrating unit; in contrast, sign processes occurring within the cell, between its organelles, are regarded as "microsemioses".

Thus, all sign processes occurring in multicellular organisms are "endosemiotic", no matter whether we look at fungi, plants, animals, or humans. Since these organisms differ considerably in their structure and in the differentiation of their parts, it is useful to start out from the highly differentiated higher animals and humans. There we find organs – especially the immune system, the nervous system, and the locomotor apparatus – which do not exist in fungi and plants. All endosemiotic sign processes are indirectly linked to phenomena in the organism's environment. For example, the immune system contains an almost complete list of potential antigens – that is, of substances in the environment which can harm the organism. Moreover, programs for the construction of subjective "phenomenal worlds" are stored in the central nervous systems of higher living beings, containing all details essential to the orientation of motor activity. In this way the nervous system is closely linked to the locomotor apparatus.

Jakob von Uexküll coined the term Umwelt[1] ("subjective universe", "significant surround", "phenomenal world", or "self-world", as opposed to *Umgebung* – "environment"; for a glossary of Jakob von Uexküll's terminology, see Thure von Uexküll 1982). From a semiotic perspective, its implications are the following:

(1) Animals and humans are wrapped in a network of sign processes which connect them with their environment and, at the same time, protect them by transposing this environment, according to its subjective meaning, into Umwelt or "individual reality".

(2) These networks are composed of signs which, because of their "private" character, are accessible only to the encoding subject, whereas they are mere "noise" to all others.

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[1] According to Krampen (1986: 84), J. von Uexküll's term *Umwelt* "means the subjective world of what is meaningful impingement for the living being in terms of its own information processing equipment, sign systems, and codes".

J. von Uexküll termed these *Umwelt*-programs stored in the organism “counterworld” or “inner world” (*Gegenwelt* and *Innenwelt*). We would like to reserve the term “counterworld” for organic systems like the nervous system and the immune system which, independent of other organic systems, store “world programs” of their own. When these “counterworlds”, by means of circular sign relations between nervous system and Immune system, intertwine and form a unity on the higher integration level of the organism, we speak of “inner worlds”.

Such an “inner world” contains templates, as it were, of the sectors of the environment that are significant to the living being. These templates are recorded in signs exchanged between cells and between organs. Therefore, although they are closely related to the organism’s environment we have to call them endosemiotic. Before signs can be exchanged between individuals – animal or human – and their environment, these endosemiotic signs which belong to an “inner world” have to be translated into the codes of other – zoo semiotic or anthroposemiotic – sign systems (in humans, this implies translation into psychological and social sign systems).

The Need for an “Endosemiotic Anatomy”

When we speak of “endosemiotic anatomy”, we are using the term “anatomy” as a metaphor. In contrast with its traditional use, here it is meant to denote a science which describes not static, but dynamic structures being constantly constructed and transformed. We hope that this metaphoric use will help to redefine the term itself. Concepts like “functiona1 anatomy” or “anatomy of functions” represent similar attempts within anatomy to overcome the traditionally static connotation of the term. We assume that the vital relations between the organism’s cells and organs are established and maintained by information transmission through signs and not by rigid tissue structures. Since sign processes do not figure in the traditional medical model of the body, not only the doctrine of signs, but also the organizing principle introduced by systems theory will have far-reaching effects on our conceptions of the structure of the body. The traditional model has been developed by anatomists studying corpses. (“Ana-tomy” is derived from the Greek word for “cutting open”, and originally meant dissection.) In this model’s spatial order, bones, joints, muscles, and internal organs are enclosed by the skin as an outer integument. This image neglects that organisms are “autopoietic” – that is, self-constructing and self-maintaining systems (Maturana 1980) in which bones, joints, muscles, internal organs, and the skin enclosing them also participate in the process of autopoiesis.

Therefore, as Victor von Weizsacker (1930) has put it, health is not a capital resource which one may exhaust, but exists only so long as it is continually generated. If it ceases to be generated, one is already ill.

Antonowsky (1987) has countered “pathogenesis”, a term common in medicine which presupposes health to be the given natural state of the anatomical organism, with his new coinage “salutogenesis”. The difference in perspective is radical: the pathogenetic perspective concentrates on processes which change or destroy given structures of the body, whereas the salutogenetic model emphasizes processes which build up and maintain those structures. And since salutogenetic processes have to be described by looking at sign processes, medicine needs a “semiotic anatomy” for the concept of salutogenesis to come into its own.

Such a model proceeds from the assumption that animals and humans transform, through zoosemiotic and anthroposemiotic sign processes, their “objective” environment (as it presents itself to the neutral observer) into “subjective universes” or “individual realities” enclosing their bodies like “solid shells which, however, are invisible to the outside observer” (Uexküll 1920). These exosemiotic sign processes may be described by means of the functional cycle (*Funktionskreis* – Uexküll 1957) or of the situation cycle (*Situationskreis* – Uexküll 1977).

In establishing a semiotic anatomy, we must take into consideration that the exosemiotic sign processes which transform the objective environment into subjective universes or individual realities require endosemiotic sign processes which build up the immunologic and neural “counterworlds” or “inner worlds” in the animal or human body. There are two conclusions to be drawn from this:

(1) Organism and subjective universe (or individual reality) together form a unified system. Bateson speaks of “units of survival” (1972: 483) and points to the fact that an organism which destroys its *Umwelt* (and perhaps, together with this subjective universe, the sector of its objective environment necessary for the organism’s survival – that is, its “niche”) destroys itself.
(2) This unified system has to be described by a semiotic anatomy as being hierarchically structured in integration levels. On each of these levels, systems (and the sign processes connecting them with each other) appear which then, on a higher integration level, function as subsystems and elements of more complex systems, with more complex signs being exchanged between them. Semiotically speaking, each integration level may be regarded as a suprasystem of sign systems (Nöth 1985), or as context in the sense of a meta-level on which information about information is transmitted (Emmeche and Hoffmeyer 1987, *The Semiotics of Nature: The Linguistic-Genetic Analogy*, unpublished).

For the time being (that is, as long as our knowledge of the details of the incredibly complex informational processes in the body remains sketchy), the project of establishing a semiotic anatomy may be carried out only fragmentarily and provisionally. It will have to be continually elaborated and corrected. Nonetheless, it is possible and imperative to make a start by giving a first outline.

Wieser (1990) indicates the importance of a semiotic clarification of those sign systems which make possible the interaction of cells, organs, organisms, and their environment. He states that

> present evolution research is not so much interested any more in the relationship of genes and environment, mutation and selection or in the problem of how ever-improving individual adaptation comes about, but rather tries to understand how integrated biological systems (organisms, societies, ecosystems) develop from reproducible parts (genes, cells, individuals, populations) – and what the struggle with a kaleidoscopically changing environment contributes to this process. Thus, evolution research should concern itself primarily with the dynamics of the negotiations between the respective parts and their superordinate system as

> well as between this system and the environment (while it should be remembered that the 'system' also belongs to the environment of the 'parts' and therefore helps to shape their fate in the same manner in which its own fate is shaped by the physico-chemical conditions of the environment).

The following may be read as a "list of contents" on which this first sketch of our semiotic project will be based: rising from the first level of the aforementioned *microsemiotic* sign processes occurring inside individual cells, we arrive at the second level, *cytosemiotic* information networks. Cytosemioses shape cells, as subsystems or elements, into tissues and integrate them into the alliance of an organ, thus giving rise to a third integration level on which the cytosemioses of cells are translated or integrated into *organ semioses*.

The plane of organs includes the immune system and the nervous system, whose sign processes build up two different "counterworlds". The counterworld of the nervous system is joined together, through circular sensorimotor sign connections (see Piaget's "sensorimotor circular reactions" [1955]), with the organ of the "locomotor apparatus" to form a unity. Furthermore, the counterworld of the nervous system is linked, through circular neuroendocrine sign processes, with the internal organs. Finally, on the next, fourth integration level, we find "program texts" which are retrievable at any time for semioses: the counterworlds of the immune system and of the nervous system – which is bound up with the locomotor apparatus – are associated by sign connections and merge to form a common "*inner world*"*of the organism* (Fig. 9.1).

Figure 9.1 shows some of the potential links between the endocrinium, the nervous system, and the immune system. The bright lines stand for neural connections, the black lines for hormonal, and the broken lines for postulated connections whose sign-transferring molecules have not yet been detected. This figure gives an idea of the complexity of the network of endosemiotic sign relations.

We have outlined a program for reflecting on the endosemiotic part of a semiotic anatomy. The psychological and social sign systems which likewise belong to a semiotic anatomy are "exosemiotic" and will only be touched upon here. We have to take into consideration that our body-sense (that is, the "body we experience") requires sign processes which already belong – as an example will illustrate – to a *psychological integration* level. Moreover, in animals and humans (with upward and downward effects between the social, psychological, and biotic-endosemiotic levels continually taking place within these bio-psychosocial systems), sign processes of the psychological and the *social integration* level influence the order of endosemiotic sign processes, and vice versa.

This illustrates that it is difficult to keep to the ordering principle of hierarchical organization. This ordering principle takes up the old notion of the "scala rerum". A one-dimensional graduated order, however, cannot account for the complex relationships we are faced with. Therefore, a semiotic anatomy has to lead to multidimensional and ramified models as well as to circular models joining together different integration levels (Uexküll and Wesiack 1988). Moreover, a terminology that is as graphic as possible must be designed.

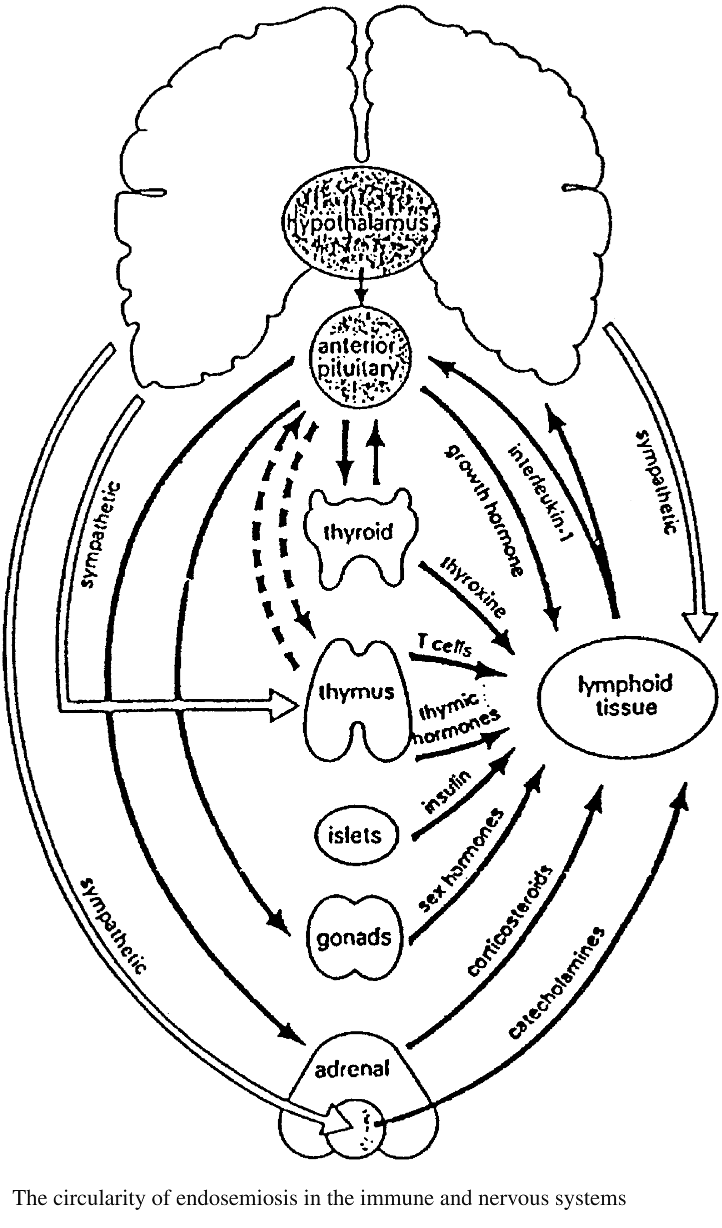

Fig. 9.1 The circularity of endosemiosis in the immune and nervous systems

The Body as a Web of Semioses: Introductory Considerations

Weiner (1989) thinks that a semiotic anatomy is already emerging: "We witness a silent revolution in our thinking on the body in health and disease... This revolution results from the insight that the body is not a mechanical system... but a self-regulating communication system which is integrated into larger systems (consisting of other organisms, institutions and ecologies) of information exchange."

So Weiner places great emphasis upon the investigation of the semiotic structure which results from the interlocking of the various integration levels of cells, organs, organisms, and psychological and social systems.

He emphasizes that inside the body, electrical and chemical signals are the most important vehicles for information exchange; by interacting with specialized cell structures (the receptors), these vehicles enable cells to communicate with each other.

He does not, however, address any of the problems of sign theory which arise in this context. He leaves aside, for example, that the electrical and chemical vehicles are only carriers of messages; that they are not only generated by those cells which emit signs but also are encoded by them; and that for any information to be transferred, the receptors of other cells have to decode them and encode them into new signs.

Yet Weiner depicts the ease with which the "conversions" from one vehicle system into another occur inside the body: the transformation of physical vehicles like pressure, heat, or cold into electrical vehicles, of electrical into chemical, and vice versa, of chemical into electrical vehicles. Here syntactical interrelations and maybe even syntactical hierarchies of signs become apparent. Yet Weiner does not go beyond the signetic perspective, from which signemic[2] problems concerning the coding of vehicles into signs and their "translation" from one sign system into another are not apparent.

Chemically determinable ink lines on a sheet of paper may turn into letters (that is, into semiotically meaningful letters). In analogy, the question of how physical, chemical, or electrical vehicles become signs carrying messages can only be asked (and answered) if it is taken into consideration that, just as an alphabet is not a random collection of meaningless line patterns, endosemiotic codes are not accumulations of meaningless physical, chemical, and electrical processes.

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[2] Ethnologists have coined, by analogy with the linguistic concepts of "phonetics" and "phonemics", the terms "etic" and "ernic" to indicate two different approaches to a foreign culture. An approach from "outside" in which the observer applies the criteria of his or her own culture to foreign phenomena is called "etic". The "emic" method implies the observer′s attempt to use the criteria of the culture under observation. Adopting these ethnological concepts for semiotic purposes, we may characterize the attitude of an observer of signs who is interested only in the physical and chemical properties of the sign vehicles as "sign-etic", In contrast, the observer's attitude is called "sign-emic" if his or her interest is centered on the meanings of sign vehicles (see Uexküll 1990).

The "biosemiotic crunch question" is: how can a human observer decipher signs emitted by living beings of other species? Here we will not discuss this in detail. Suffice it to say that this question concerns the problem of the attribution of meaning (*Bedeutungserteilung*) and that we have to distinguish between the significance of an event as it appears to us as human observers and the significance which the same event assumes for the observed living system. Two points must be taken into account in this context:

(1) The physical and chemical properties by which we identify vehicles inform us of the possibilities for manipulation offered us by the vehicles. So their properties are *meaningful* to us.
(2) We have to infer the meaning which vehicles assume as signs for living systems (or cells and organs) from the way in which these systems behave toward their environment after the vehicles have acted on their receptors. Thus, we have to interpret their behavior as semioses of symptomatization[3] – that is, as symptoms of their biological state; we may then understand this state as the interpretant which attributes to a vehicle the meaning it has for the observed system. In other words, we have to conceive of the behavior as an (indexical) sign pointing to the interpretant. Sebeok (1976) puts this as follows: "Let it be recalled that all objects on the one hand, and the memory, being a reservoir of interpretants, on the other, are also kinds of signs or systems of signs".

Both observations stress the fact that observation can show us living systems only "from the outside" – that is, as they present themselves "to us". In order to inquire into their "inside", into their sign relationships (with themselves, with their environment and other systems), we must find out how the living system construes its conditions. It should be kept in mind here that "outside" and "inside" originally are semiotic concepts in that they mark a viewpoint outside or inside a sign system.

The Conceptual Framework for Identifying Endosemioses

In many respects, endosemioses resemble sign processes in plants (phytosemioses). The greater complexity of endosemiotic sign processes in animal and human organisms, however, calls for a more precise conceptual system which provides a tool for identifying endosemioses.

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[3] We may distinguish three forms of semiosis by considering differences in the contributions of emitter and receiver: (a) *Semioses of information*, in which the inanimate environment acts as a "quasi-emitter", but assumes no semiotic functions - they must be performed by the receiver alone (Bottner 1980); (b) *Semioses of symptomatization*, in which the emitter is a living being which sends signals through its behavior – although these signals are not directed toward any receiver, they inform the expert of the situation and/or the state of the living being; and (c) *Semioses of communication*, the only sign processes in which emitter and receiver share the semiotic tasks (see Uexküll 1990).

In contrast with common causal-mechanistic research, semiotic research does not proceed analytically, but synthetically. Semioses are unified (i.e., systemic) interrelations. To discover such interrelations in nature, semiotic research needs a conceptual repertory which includes synthetical terms and a methodology allowing empirical application and verification of these terms. Moreover, the synthetical terms must be suitable for describing units as emerging phenomena; that is, they have to be dynamic concepts as well.

To arrive at such a conceptual repertory, it is best to start from the principle of correspondences as defined by Plessner (1976):

According to the principle which Uexküll once phrased "Where there is a foot, there is a path, where there is a mouth, there is food, where there is a weapon, there is an enemy", it should be possible to point out correspondences easily and unambiguously.

Plessner discusses the difficulties which arise if the biological principle of correspondences is unreflectingly applied to humans. However, here we are concerned only with the principle itself. It says that in the sphere of living things each affordance presupposes a counteraffordance – that is, it can be realized only through an interaction. In analogy to Hegel's famous example of master and servant, the affordance of the foot presupposes the counteraffordance of the ground, the affordance of the mouth is founded on the counteraffordance of food, etc.

We may express this in the formula "affordance (+) counteraffordance = action". Here action is defined as a synthetical concept. This implies that an action is to be combined from the contributions of two (or more) participants, but also that it is only in the framework provided by an action that phenomena like participants and their affordances can come to the fore. Therefore, "(+)" here is not meant to denote a mathematical concept, but to indicate that "action" refers to the higher integration level (the context) on which two (or more) affordances complement one another to form something new. Accordingly, affordances in their turn may be seen as actions (or subsystems) built from even simpler affordances. Like the concepts of "system" and "subsystem", the concepts of "action" and "affordance" are relative with respect to the level of description.

It is crucial that synthesis here means that a living system and its environment are fitted into an association of affordance and counteraffordance (foot and ground, mouth and food, etc.), and that cooperation and conflict do not give rise to purposeless chaos but to a (biologically) *useful* process, to a "utilization of meaning" (*Bedeutungsverwertung* – Uexküll 1982: 36, 1940: 13).

Mouth and foot belong to the body of a living being, and food and ground are parts of the environment which are chosen (as parts of its subjective universe) by the living being and provided by the environment (in its function as a niche). This relationship between living being and environment constitutes an ecological equilibrium in which the environment must not dictate to the living beings the laws of their survival, and the living beings must not prescribe to the environment its forms of manifestation. This synthetical rule of ecological balance is neglected in the neodarwinist notion of an environment entirely controlling the development of living beings by selection, as well as in the belief that the environment is an inexhaustible supply to be exploited by living beings, and above all humans. Whatever survives and develops is always the unity of organism plus environment (Bateson 1972).

Semiotically speaking, living systems neither find a signified – an "object" – in their environment nor do they arbitrarily create it; rather, they generate it together with the environment (through affordance and counteraffordance) within the framework of their actions. In the course of this process, the "object" is temporarily absorbed into the whole of the system – that is, "assimilated" (Piaget 1952).

Therefore, our synthetical conceptual system has to be modelled on the whole of an action which consists of four parts:

(1) a *living system* (with a receptor for taking in environmental influences as sign vehicles and an effector for answering with a behavior or affordance);
(2) the *sign* (into which the received sign vehicles are encoded);
(3) the *interpretant* (which is responsible for the encoding process or the "attribution of meaning" [*Bedeutungserteilung*]); *and*
(4) *the denoted object* (which is actualized in the course of an attribution of meaning – i.e., through the interaction of the effector's affordance with the environment's counteraffordance).

If the receiver is left out of account, the sign would be characterized by a *triadic relation* (according to Peirce 1988). A tetradic formula, however, would match with the "general sign relation" proposed by Emmeche and Hoffmeyer (1987, *The Semiotics of Nature: The Linguistic-Genetic Analogy*, unpublished):

> Rather than the triadic system of Peirce we would prefer, however, the tetradic system.... From a formal point of view the sign would be defined through a triadic relation. By introducing the fourth link in the "sign relation" (the effector), we want to stress, however, that in actual life not only *reflection* but also *action* is always involved in the use of signs. The interpretation of the sign is part of active life and thus directly or indirectly leads to some kind of behaviour involving the object referred to by the sign.

The simplest model for this conceptual system is the *feedback cycle*. It implies (1) a *system* (with a detector for receptor and a correcting element for effector). The feedback cycle "fixes" (2) a "reference value" – that is, an *interpretant* which assigns a certain meaning ("too high", "too hot", etc.) to the "sign vehicles" of the detector's responses and thus encodes them into (3) *signs* which trigger off the response of the correcting unit (the effector) – i.e., the system's affordance. The system's affordance and the counteraffordance of the "controlled member" together generate (4) the *signified* or object (the reset of the actual value to the reference value – that is, the "utilization of meaning").

As the expression "utilization of meaning" makes evident, the terms "value" and "meaning" in this conceptual framework are "self-referential": affordances are directed toward the reference value of the system; that is, they are meaningful only with respect to this value. The reference value is either fed into the system from outside – this applies to cybernetic machines – or established by the system "itself" (cf. Krampen 1981).

In other words: the "self" of a living being follows the meaning which those parts of its environment it relates to assume for its construction (autopoiesis – Maturana and Varela 1980) and its survival, and thus encodes this meaning into signs governing its behavior. So in biology, too, it is the *code* which is the unifying or *synthetical principle*.

J. von Uexküll phrased this as follows:

> Each component of an organic or inorganic object, on appearing in the role of a meaning-carrier on the life-stage of an animal subject, has been brought into contact with a 'complement', so to speak, in the body of the subject that becomes the meaning-utilizer. (1940: 7; 1982: 30)

We cannot directly observe the interpretant according to which a living system codes effects of the environment on its receptors into signs. We have to infer it from the system's behavior; we have to interpret endosemioses "against the grain", as it were, by reconstructing their "history": we take the last act or behavior of the living system as an indexical sign pointing to the interpretant which, as the coding instance, has assigned to the sign the meaning it has with regard to the system.

Who Is "Some-body"? Inquiring into the Endosemiotic Self

The problem of dynamics. Endosemioses have their own dynamics and are, as we have already emphasized, "self-referential" (that is, circular): they refer to themselves (Maturana and Varela 1988). But who or what is this "self" which in living systems establishes its reference value, and how is it involved in the dynamics of endosemioses? In Peirce's definition of "sign", this "self" is "somebody": "A sign is something which stands to somebody for something in some respect or capacity" (*CP* 2.228–303). Here "somebody" is a receiver of signs and lacks "something" which is shown to him or her by means of "something" (i.e., something else serving as a sign). The receiver's (interpreter's) relationship with the other elements of the sign process is determined by a need. Is it possible to deduce the dynamics inherent to endosemioses from this need?

A need is usually conceived as a force which reaches out for us from somewhere. Piaget (1952) explains that we misunderstand the concept as long as we imagine a force intervening from outside in life processes. It is just the other way round – the need is only an aspect of the dynamics of those life processes.

> The basic needs do not exist, in effect, prior to the motivating cycles which permit them to be gratified. They appear during functioning. One could not say, therefore, that they precede repetition: they result from it as well, in an endless circle. [...] From the psychological point of view, need must not be conceived as being independent of global functioning of which it is only an indication. From the physiological point of view, moreover, need presupposes an organization in 'mobile balance' of which it simply indicates a transitory imbalance. In both kinds of terminology, need is thus the expression of a totality momentarily incomplete and tending toward reconstituting itself... (Piaget 1952: 44 f.; italics added)

The circular process is defined as "endless circle", as a self-contained unity or "totality". If we regard such "totalities tending toward reconstituting themselves" as sign processes, we may say that a “totality” is completed only when the utilization of meaning has been achieved.

When we define the interpretant as the present state of a living system which is a “totality momentarily incomplete and tending toward reconstituting itself ”, this provides us with a synthetical formula by which circular processes can be described as self-generating totalities. Yet the question remains: who or what is the “somebody” or “self ” that establishes the reference values representing the state or interpretant of the living system at a given time?

“Body self ” and the Body as a “Tool” of Life: Code Duality

The endosemiotic processes generating the unity of the organism may be described in analogy to the words or sentences generating the unity of a context. Antonovsky (1987) has termed those processes “salutogenesis”. A text determines the words and sentences it consists of, and at the same time it is realized by them. To transfer this formula onto biological relationships, we need to form an idea of how the whole and its parts generate and determine each other.

We may start from the observation that all cells of our body stem from a single cell, the fertilized egg cell or so-called zygote. It has given the same genetic code as a dowry to all daughter cells. The code provides for them all to carryon their surface an individual “monogram” specific of their biological self – the so-called MH complex (major histocompatibility complex) – which distinguishes them from the cells of all other organisms. The cells of the immune system, which watch over the individuality of the organism, “read” this sign combination and direct their activity against all cells with a foreign monogram (we will discuss this in more detail later). So here “the whole” controls, through the kinship of the body cells, the activity of its parts, and at the same time is generated by this activity.

Moreover, the DNA of an individual’s genetic code, which all its cells have received as a dowry from the fertilized egg cell, is only one variant on the DNA which all individuals of the same generation have inherited from the generations preceding them. The individual owes “the whole” of its manifestation (its phenotype) to the genotype laid down in the gene pool of its generation. This genotype is the totality which, from a semiotic perspective, is represented by each individual of this generation as *pars pro toto*, and at the same time is realized by these individuals as a group.

This relatively abstract notion is put in concrete terms in a model developed by Emmeche and Hoffmeyer (1987, *The Semiotics of Nature: The Linguistic-Genetic Analogy*, unpublished). They assume a “code duality”: In the construction of body cells and organism, the digital genetic code of the DNA is translated into an analogue code (Fig. 9.2).

In Fig. 9.2, the DNA is understood as a part of the evolutionary stream of signs. The receiver system – the fertilized egg, the actual “person” of biology – uses the information transmitted by the DNA for the epigenetic process (that is, for constructing the individual or the phenotype). Metaphorically speaking, the zygote reads the

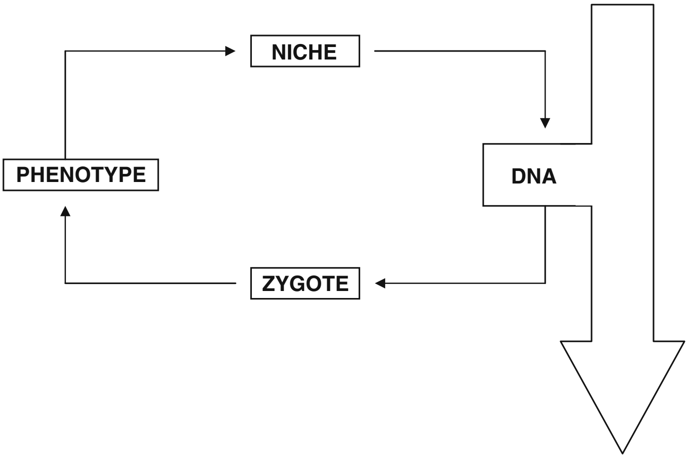

Fig. 9.2 Emmeche and Hoffmeyer's evolutionary stream of signs. From Emmeche and Hoffmeyer (1987: 28, *The Semiotics of Nature: The Linguistic-Genetic Analogy*, unpublished)

book of its DNA and interprets its content as a kind of instruction for building a tool for survival. Only with the help of this tool can the egg cell hope to continue its cell lineage. The tool is required to be sufficiently suitable to survive in its ecological niche and to reproduce itself. The ecological niche is the only real object in the world of living systems (see Emmeche and Hoffmeyer 1987: 28, *The Semiotics of Nature: The Linguistic-Genetic Analogy*, unpublished).

Emmeche and Hoffmeyer think that regarding the individual being as a "tool for testing the suitability of the DNA of the fertilized egg cell" offers an alternative to exaggerated individualistic notions as well as to the topical theory of the individual being a "survival machine for selfish genes" (Dawkins 1976). They stress that their theory does not fall back upon old feudal ideas of the paramount value of the family. (Nor does it resurrect fascist ideas of a single people's pre-eminence, since it emphasizes the common heritage of all living creatures.) They note that their view fits well with a recently renewed deep-felt kinship with all living forms which makes us feel responsible to them. Their image of the fertilized egg cell as a re-staging of the first act of creation on earth is aimed at foregrounding two processes and their interaction: the digital and the analog information processes and their translation into one another.

This view has to be supplemented, however, by systemic aspects so that it becomes evident how far Dawkins, in overemphasizing polar and linear concepts, misses the reality of biological evolution (cf. also Wieser 1990).

At the stage of anthroposemiotic sign systems, the individual gains a new significance: human language has opened up a sphere in which it is clearly up to the individual to develop new ideas and concepts; her or his achievements have become more crucial to the survival of the species than biological adaptation to a given environment. Although in this article we are mainly concerned with endosemiosis, we mention these exosemiotic aspects in passing. For the linguistic definition of "self" is valid in the endosemiotic sphere as well: "*Somebody*" *translates the* *digital message which has been handed down in an immensely long ancestral line into the analog code of present sign processes in order to prompt the construction of an individual which is to serve as a tool for testing and maintaining a "niche".*

"Self" and "Non-self"

In the course of embryonic development, the daughter cells of the zygote differentiate toward separate tasks. This differentiation may be pictured in a model similar to the one Jakobson (1968) uses to describe the differentiation leading from the baby's babbling sounds to adult language: inarticulate vocalizations which are accompanied by a childlike sense of omnipotence develop into consonants and vowels which give rise to the differently articulated phonemes of adult language. Each of these phonemes betrays that it belongs to a certain language. Quite similarly, the differentiated cells of the body show that they belong to the species-specific construction of an adult organism. Furthermore, they point to the individuality of a specific self.

In order to illustrate these considerations, we single out, from the almost indivisible net of innumerable endosemioses, a specific interaction of different body cells: an immune process. (Further below we will depict such processes in a larger context and in more detail.) When we assume that the construction and maintenance of living systems occurs, on all integration levels, in the form of totalities "momentarily incomplete and tending toward reconstituting" themselves by assimilating parts of their environment as "non-self", we notice that those processes are governed by signs. It is signs which attribute to "non-self", according to its relevance to the autopoiesis and the survival of the living system, a positive meaning (= beneficial) or negative meaning (= harmful). Only selective "recognition" of these differing sign qualities allows the living system to maintain and defend its totality.

Endosemiotics addresses itself to conflicts of the body cells with an "inner environment" or "milieu interne"; the task of the immune system is to secure the integrity of the body and to recognize and eliminate "harmful non-self". "Milieu externe" and "milieu interne" are connected by an iconic sign relation.

The cells of the immune system are derived from cells which in the course of embryonic development turned into haemopoietic tissue and travelled into the bone marrow. There they took on the function of precursor cells or stem cells from which, through several intermediate stages, the various sorts of immune cells develop, with the so-called lymphocytes constituting their largest group. When the immune system responds to an encounter with "harmful non-self", the lymphocytes take on specific tasks in cooperation with other cells: they produce antibodies, destroy virus-infected cells, or control the activity of other cells. All these functions are triggered by specific recognition mechanisms and are aimed at warding off harmful "non-self factors". In an immune response, lymphocytes perform some or all of these functions and interact with other cells in a complex web of positive and negative influences.

Recognition of the different sorts of antigens ("harmful non-self") as well as precise regulation of the cooperation of the various cells result from sign processes whose vehicles have been identified in increasing numbers in recent decades. It has turned out that, apart from two global groups of "beneficial non-self" (e.g., nutrients) and "harmful non-self" (e.g., foreign antigens), there is a group of "non-self in the narrow sense". While the first two groups of "non-self" are more or less the same for all living systems or merely differ between species, the last group consists of "non-self" as opposed to the single individual – that is, of "individual non-self".

"Self" and "Individual Non-self"

Each body cell of humans or higher animals bears on its surface, as a kind of monogram, the aforementioned MHC (major histocompatibility complex), marking it as a cell which belongs to that specific individual and is distinguished from the cells of any other individual.

> All cells of the mammal organism, and probably of all vertebrates, possesses in their cell membrane a set of proteins which are the gene products of a specific genetic complex, the so-called 'major histocompatibility complex' (MHC), which controls the fitting of sugar molecules into the protein molecules. These membrane proteins control the activity of T lymphocytes in that the latter will recognize an antigen as 'foreign' only if it is associated with MHC molecules. The MHC, which is known as HLA system in humans, is characterized by a high degree of polymorphism: It is extremely unlikely that two individuals who are not related to each other possess identical sets of MHC products. (Staines et al. 1985)

The MHC controls the activity of T-lymphocytes against cells of their own body which have been infected by a virus and bear on their surface, besides the MHC monogram characterizing their type of cell, a virus antigen (that is, a second sign). Destroying these cells prevents the virus from multiplying inside them. They are sacrificed because viruses need a cell's hereditary substance to multiply.

Moreover, T-lymphocytes also direct their activity against all intact cells carrying a foreign MHC. Our immune system thus will treat all cells of a foreign organism as dangerous non-self. This is a disruptive factor in transplant medicine: to the lymphocytes of the recipient of the transplant tissue, the tissue's MHC molecules appear to be antigens, so that it may be rejected. This is why MHC molecules have also been called "transplantation antigens".

This very function of the immune system, however, which is such an obstacle for transplant medicine, is indispensable in protecting us from cancer. Protection from cancer is based on the capacity to recognize and eliminate body cells whose MHC monograms changed as they were transformed into cancer cells.

"Monograms" consisting of "readable" protein sequences on the cell surface also playa critical part as identification marks in the immune defense against viruses, bacteria, and unicellular or multicellular parasites. Yet viruses are able to change their monograms by mutating; thus in a new infection, they are no longer recognized, and the previously acquired immunity fails. Some parasites can deceive their host by mimicry (Staines et al. 1985), donning a wrap made from proteins of the host's red blood cells (and becoming, as it were, a wolf in sheep's clothing).

“Self” and “General Biological Non-self”

A further MHC protein molecule appears only on the surface of specific immune cells – the B lymphocytes and macrophages – and functions as a signal to other cells participating in the immune response. This signal is recognized by a group of T-lymphocytes, the so-called helper cells; they answer by stimulating the antibody-producing B lymphocytes and thus enable them to “recognize” their specific antigenes. All these cells are joined together in a circular interaction controlled by specific signs, an interaction which we may call the “simplest basic melody” or “basic text” of the immune system. We will now look at this cooperation more closely, since the coherency of the involved elements gives an example of a semiotic “totality tending toward reconstituting itself”.

This coherency becomes apparent in that lymphocytes cannot proceed against non-self on their own. They can decode the signs which control their behavior only with the aid of other cells. Moreover, the lymphocytes’ contribution to the immune response has to be supplemented by the contributions of other cells, above all the macrophages, large cells which can, to a limited extent, operate independent of immune defense processes and eliminate pathogenes (viruses and bacteria) by eating them – that is, by phagocytosis. This capacity is considerably heightened if the pathogenes are marked by specific antibodies provided by B lymphocytes.

The circular process starts with a pathogene (bacterium or virus) encountering a macrophage which “identifies”, by a specific sign, the pathogene as harmful non-self. The vehicle of this sign is a relatively small component of the pathogene-specific antigen; it is called “antigenic determinant” or “epitope”. Signetically speaking, it consists of a certain sequence of amino acid molecules on the surface of a sometimes quite large protein molecule. The signemic attribution of meaning (*Bedeutungserteilung*) – that is, the encoding into a sign denoting an object of phagocytosis – depends on the state of activity of the macrophage (its “appetite”, which is to say its interpretant or reference value); as has been mentioned, the macrophage’s activity substantially increases through combination with an antibody supplied by B lymphocytes.

The macrophage’s response is, as we have said, phagocytosis: the pathogene is eaten; but as long as antibodies are missing, it cannot be digested, or can be only with difficulties. So simultaneously, antigen particles are secreted on the macrophage’s surface and “presented”, as indexical signs, to other cells. The particles serve as signs to B lymphocytes (aided by T helper cells) and lead them to produce the required antibodies. Thus, the macrophage’s reaction is, under a semiotic perspective, a combination of “using behavior” (*Gebrauchsverhalten* – i.e., phagocytosis) and “signaling behavior” (*Signalverhalten* – i.e., presentation of signals) (Tembrock 1975), or of “utilization of meaning” (*Bedeutungsverwertung*) and “attribution of meaning” (*Bedeutungserteilung*) (Uexküll 1982).

Immunoglobulins which are capable of binding and neutralizing antigens serve as vehicles of the antibodies. Above all, however, they attach themselves, like a “wanted” poster, onto the surface of the antigen-bearing bacteria and viruses, thus “denoting” them as prey to the macrophages, whose appetite, as we have said, multiplies if pathogenes are marked in this way.

Antibody-producing B lymphocytes bear on their surface membrane specific receptors exclusively "recognizing" one particular antigen. When a B cell encounters the antigen which fits its receptor it begins to divide, thus giving rise to two cell types. One type develops into mature plasma cells which produce large quantities of antibodies and give them off into the blood. The other type stays back in reserve; these are the so-called memory cells. In a new infection with the same pathogene, they develop very quickly into antibody-producing plasma cells; they are the basis of an acquired immunity against a renewed illness from the pathogene.

However, since a B lymphocyte cannot "recognize" its specific antigen on its own, the circle spanning the macrophage, the pathogene, and the antibody-producing B cell only closes if another cell joins in, the so-called helper cell. Just as an antigen becomes a sign which macrophages can read without difficulty only after it has been combined with its antibody, produced by B lymphocytes, a sign combination which B cells can read is only achieved if substances produced by the helper cells during their contact with the antigen are added to the antigen.

In summary, we may say that the "totality" of the immune system's "semiotic basic melody" which "tends toward reconstituting itself" consists of three stanzas. The first stanza, in which the pathogene interacts with the macrophage and the macrophage exhibits a signal response, is followed by the second stanza, in which the helper cell encodes the signals presented by the macrophage into signs for the antibody-producing B lymphocyte. The last stanza is introduced by B lymphocytes (which in the meantime have multiplied) producing antibodies which the macrophages again encode into signs denoting the pathogene. Thus the process has come full circle.

From a semiotic point of view, this "basic melody" may be understood as a "text" (in the sense of a network of interrelations of meaning; we already spoke of a "basic text" of the immune system). A text can be analyzed as a "semiotic system" which, according to Klaus (1969), "consists of a set of elements and a set of relations among them", and in which there may be distinguished a paradigmatic and a syntagmatic dimension (Nöth 1985: 175). In our example, the paradigmatic dimension is represented by the pathogenes or antigens and the cells participating in the immune process. The syntagmatic dimension concerns the combination (or composition) – that is, the course of the interaction between the respective pathogene and the immune cells. We think that here we are not merely using a metaphor but applying an elementary epistemological structuring operation which allows us to perceive a dynamic course of events as an integrated unity.

When we describe endosemiotic processes as "complex texts" or semiotic systems, a syntagmatic analysis becomes possible "which is concluded when a unit cannot be reduced any more to subordinate units. This unit then is an element of a paradigm" (Krampen et al. 1981). We become aware of "integration levels" if we understand syntagma as the compositional form of a semiotic system which, in its paradigmatic dimension, consists of subsystems as its elements, and if we recall that subsystems may again be reduced to their elements and the relations between these elements. For example, syntagmatic analysis of the cooperation between immune system and hormone system (as of a "complex text" or semiotic system at a higher integration level) would show that immune processes (as one category of subsystems) and hormone processes (as another category of subsystems) represent its paradigmatic dimension, while their cooperation represents its syntagmatic dimension. One integration level lower, syntagmatic analysis of the immune process (as of a "text" or semiotic system) would yield the elements of pathogene and immune cells as its paradigmatic dimension; and so forth.

Outline of a Semiotic Anatomy: The Integration Levels

When a distinction is drawn between phyto-, zoo-, and anthroposemiotics (Krampen 1981; Sebeok 1976), it refers to the pragmatic aspect of signs according to which signs are "for somebody"; that is, the criterion for this taxonomy refers to the respective addressee. The systematics of micro and endosemiotics is based on similar principles.

Such a method of classification does not raise any problems as long as the addressees (such as plants, animals, humans, cells, or cell organelles) can be phenomenologically identified without complications. Difficulties arise, however, if it has to be decided whether a cell aggregation, a tissue, or an organ should be regarded, in an endosemiotic sense, as the addressee "for whom" certain sign processes may possess a pragmatic meaning.

Here we are again confronted with the issue of the *scala rerum*; we have to find criteria for establishing a graduated order of endosemiotic integration levels. Ethology has developed such criteria for the domain of zoosemiotics. By means of these criteria, "temporary" and "permanent communication systems" in animals can be defined as sign receivers; "permanent communication systems" can be divided up into "open associations" (for example, swarms of insects or birds), "colonies", etc. "Specific systems" which consist of individuals of the same species may be distinguished from "non-specific systems" composed of individuals of various species. Also, criteria have been developed to assign "non-specific systems" to different categories (e.g., the categories of symbioses and of parasitism – Tembrock 1975).

It has not yet been investigated whether and to what extent such taxonomic criteria are suitable for identifying different forms of the coexistence of cells in the body – that is, whether they are appropriate in the domain of endosemiotics. We will touch upon "specific" or "relatively specific" systems when we discuss endosemiotic processes in the nervous system and the immune system. For two reasons, however, we get into difficulties if we follow the criterion of specificity and consider organs, which do consist of cells of different origin and function (supporting cells, vascular cells, parenchymal cells, etc.), as "non-specific systems": first, because all these cells are body cells, descended from one cell (the fertilized egg cell); second, because "specificity" is defined differently in physiology and semiotics. Apart from medical findings on symbioses (e.g., symbiosis with certain bacteria on the skin, in the mouth, and in the intestine) and on parasitism (of viruses, bacteria, malaria plasmodia, etc.), we know little about true "non-specific systems" in the body; both phenomena are essential to the immune system's activities, yet strictly speaking, they are beyond the scope of endosemiotics. Therefore, when we speak of "integration levels" in the following, we move on relatively uncertain ground. It can be taken for granted, however, that inside the body we do not find a one-dimensional hierarchical order, but several ramified orders and numerous feedback loops between them.

Four Endosemiotic Integration Levels – A Sketch

With the above reservations in mind, we now give a rough overview of the most important integration levels in an endosemiotic anatomy. The first integration level is found in the aforementioned "microsemiotic" dialogue which takes place between the genes and the activities of the enzymes in the cell body. The genes do not simply dictate the construction of the cell structures; rather, they are interlinked, through their interplay with the enzymes of the cell body, with the processes of cell division during the growth and development of the organism which constructs and organizes itself as autopoietic system.

Moreover, the genes are related to each other in another dialogue: in normal body cells, proliferation and differentiation are subject to a complex genetic control which is brought about, among other influences, by two different kinds of regulatory genes acting in combination: the growth promoting "proto-oncogenes" and their antagonists, the "suppressor genes". The proto-oncogenes are crucial, for example, to the formation of growth factors and of receptors for growth factors; or they influence, as DNA-binding proteins, the "switching on and off" of genes, or are involved in controlling the cell cycle (Welter 1989).

The significance of the interplay of different regulating factors becomes apparent in tumor genesis; it illustrates how microsemiotic and endosemiotic sign processes interlock. If in normal cells proto-oncogenes are changed or unphysiologically activated, they turn into oncogenes which not only transform normal cells into cancer cells, but also may influence a tumor cell's behavior toward other cells.

Tumor genesis, however, always occurs in a "multistage sign process" in which the interpretants of cells are affected so that the cells' responsiveness is activated or deactivated. It has been demonstrated that disturbances of deactivation or the loss of suppressor genes may lead to tumor formation.

That these regulatory genes play a critical part in tumor genesis has been proved first for the retinoblastoma, a malignant degeneration of the retina (Knudson 1973: 325–328).

When we go *from the first to the second integration level*, we enter the endosemiotic sphere where first we come upon cell-to-cell communication by cytosemiotic processes. This transition to the second integration level draws our attention to a semiotic network whose sign processes occur through specific structures, the so-called "gap junctions"; these are fine channels in the cell walls through which neighboring cells communicate directly and which facilitate direct metabolic and electrical contact. Presumably they allow groups of cells to coordinate their steps of development and differentiation and to unify their responses to regulation signals.

> When we summarize the great number of new findings on ‘gap junctions’, an entirely new picture of cell-to-cell communication emerges. The hormone systems with their long-distance effects and the transmitter substances with their shortdistance [synaptic] effects are now joined by the ‘gap junction’ which is the most important component since it makes possible a *combined intracellular* transmission of signals and metabolites. (Maelike 1985)

The importance of these gap-junction connections for cell communication may be illustrated by looking at certain processes triggering an immune response; they constitute a link in the chain of signs which activates the cooperation of certain immune cells. By means of autoradiography it could be demonstrated that macrophages participate in this cooperation not only by using a net of fine cords of cytoplasm to capture “enemy substances” or antigens; through “gap junctions” they also establish direct contact with helper-cell-activated large B cells (plasmablasts), which then multiply to form memory cells and antibody-producing B lymphocytes. Presumably it is sufficient for the macrophages, on whose surface the antigen is represented by a signal, to merely touch the plasmablasts so as to bring about their division (clonal selection – Nossal 1988).

Antibodies, which are carried over great distances by the bloodstream, already belong to a higher integration level of endosemiotic networks, since they can connect immune cells far removed from each other. As they are similar to antigens – which we will examine more closely later – they may be regarded as iconic signs.

On these higher integration levels (beyond the level of gap junctions), where endosemiotic networks link the most diverse cells to form functional units, we may distinguish systems which employ short-distance sign vehicles from those which employ long-distance sign vehicles. Among those of short-distance effect, transmitter substances are a crucial and particularly interesting group; among those with long-distance effects, the various hormone systems are the most important. Their functions interlink and overlap to such an extent that to distinguish different levels of a semiotic anatomy here is of didactic rather than practical significance. For example, catecholamines can be classed with transmitter substances as well as with long-range hormones.

Keeping these reservations in mind, we may describe the connections between cells which do not immediately border on each other as the *second integration level* of a semiotic model of the body. We would like to describe in more detail the connections established by polypeptides and transmitters.

Polypeptides (= growth factors) are substances which in recent years have been identified as vehicles in a network of sign processes which interlock in subtle ways and thus regulate the multiplying of cells in the tissue aggregation of an organ (e.g., of the liver or the skin) with great precision. Here an important semiotic principle becomes apparent: division processes are not set off by a single growth factor, but by a combination of two (or more) such factors. It is as if not single “letters”, but only certain “words” will assume meaning as signs which can be “read” and then answered by cell division.

That tumor cells lack the semiotic competence to “read” combined signs is evidence of the biological significance of this principle. Tumor cells start to divide even when contacting single growth factors – responding, as it were, to isolated letters of their alphabet (Kiefer and Havemann 1988).

In transmitter substances we find a second mode of associating adjoining cells. They are the vehicles for the sign processes which connect adjoining nerve cells. Nerve cells consist of a small cell body and one or many dendrites – long, thin branches which often possess far-reaching ramifications. Each dendrite is linked to dendrites of many adjoining nerve cells. The gap between the contact points of dendrites is called the synapse.

This synaptic cleft serves to establish and interrupt the exchange of information between nerve cells: to initiate communication, transmitter substances are secreted into the cleft, where they produce chemical vehicles for the signs which connect adjoining cells. When the transmission of information is completed, the substances are reabsorbed; they are stored by the nerve endings which generated these vehicles and which in the next transmission of information will again secrete them into the synaptic cleft. The nerve cell responds to the transmitter substance by changing its membrane potential so that, from a signetic perspective, the chemical vehicle (the transmitter substance) is transformed into an electrical vehicle. From a signemic aspect, the nerve cell appears to respond by a signaling behavior (Tembrock 1975): the nerve cell encodes the chemical effect of the transmitter substance on its receptor into a sign and responds to this sign by a signaling behavior – i.e., by changing its membrane potential.

The next coding step in the semiotic sequence of nervous sign processes is carried out by the receptors of certain cell areas to which the electrical signals are addressed. Here we already are on a *third integration level* where cells are combined into organs. In these nerve cell areas, a new code arises which integrates the separate signs to form the complex signs of a uniformly responding organ: now not a single discharge, but the rate of such discharges is coded into a sign. Again the principle is that single signals ("letters") are combined to form sequences of signs ("words"). The cytosemiotic alphabet of the single nerve cell consists of only one letter, the electrical discharge. The alphabets of the neurological areas of the nervous system are comparable to the alphabet of the Morse code in that they consist of different sequences of single cytosemiotic signs. In other words, we are dealing with two alphabets: the first encodes transmitter substances into signs for adjoining nerve cells, which then respond with an electrical signal; the second assembles these responses and codes the electrical discharge frequency into signs for more complex areas of the nervous system. In this way, the network of nerve cells becomes a transport system for high-speed long-distance communication in the body.

As a transport system for sign vehicles, the bloodstream is considerably slower. It carries antibodies and, above all, hormones which allow communication between areas far removed from each other. The chemical vehicles of the various hormone substances are encoded into signs transmitting meaning or information in the following manner: when coming into contact with a hormone, the receptors of the addressee cell activate enzymes on the inner cell wall which, if conditions are suitable, set off one or more "second messenger systems" so as to regulate intracellular activities. Here we see again how closely the different semiotic integration levels are intertwined.

The transport systems of the bloodstream and the nerve network are interlinked by dendrites of nerve cells which are situated in the blood vessels, where they facilitate quick transmission of information. Blood cells (e.g., lymphocytes) attach their receptors to the dendrites in the vascular wall and thus transmit and receive information to and from the brain.

The Principle of Self-organization: Overcoming Reductionist Notions

The principle of self-organization, which makes possible the formation of complex sign systems within the organism, is central to a semiotic anatomy. Here the “silent revolution” of our ideas about the construction of the organism (Weiner 1989) becomes most obvious as we recognize that our long-held reductionist views on neural control are wrong.

Lüscher (1983) states that

> in the last decades the reductionist path in neurobiological research has led to spectacular successes. In spite of these successes one has recently come to the conclusion that the well-ordered functioning of the brain can only be insufficiently understood by mere analysis. . .. If one tries to understand the functioning of the brain or its subsystems and thus traces back the way of analytical dismemberment, one is surprised by the observation that merely joining together the parts does not suffice to explain even the most elementary behavior of the central nervous system. This experience has led to the insight that the brain’s functioning cannot be understood from sole analysis – however diligent and complete – of its components and their interconnections, since the central nervous system as a totality gives rise to a new order.

According to reductionist ideas, neural control processes are supposed to run, just like orders from a telephone exchange, along given anatomical paths which are thus assumed to constitute the neural structures. As we have just seen, however, it is just the other way round: neural structures come into being through the intervention of integrating codes in conjunction with neural processes. So the self-organization of the nervous system can be illuminated by looking at the principle according to which integrating codes emerge.

Lüscher (1983) characterizes this principle by drawing a parallel to the rationale of democracy:

> Democracy is an example of self-organization. The organizing forces are constituted by the rules of the game of democracy. In contrast, organization is understood as the coherent behavior of a system on the basis of superordinate forces or orders. Here dictatorship could serve as an example.

The coherent behavior not only of the nervous system, but of all living systems results from a continual reciprocal tuning-in of the system’s elements. In order to attune themselves to one another (*sich aufeinander abstimmen*), the elements need sign processes by means of which they can inform each other of their biological states and thereby can influence these conditions so that their behavior may express the rule of a majority. Put simply, “pitch signals” (or “mood signals” – *Stimmungs-Signale*) may change pitches (Uexküll 1952), and pitches are contagious. To illustrate how integrating codes come into being on the basis of such an “attuning” or “voting principle” (*Abstimmungs-Prinzip*), we would like to discuss the functioning, first, of a center of the nervous system and, second, of the immune system.

The Respiratory Center as an Example of the Formation of an “Integrating Code”

As Lüscher (1983) stresses, the central nervous system was long understood as a superordinate command center which, like a dictator, imposes on dependent organs and organ systems an order designed to regulate their functioning. This notion of a “heteronomous organization” is based on the model of an assembly of simple machines which will respond to a certain input from the command center by producing ever the same output.

This model, however, did not explain why the organs of those living beings which do not possess a central nervous system also show coordinated responses to environmental stimuli. J. von Uexküll termed these living beings “reflex republics” (*Reflexrepubliken* – 1905: 69; 1957: 34). He describes how in the sea urchin, whose every spine possesses a nerve center of its own, the different nerve centers inform each other of their state and thus, in a process comparable to a vote (*Abstimmung*) in a republic, succeed in coordinating and organizing their functions. He illustrates his model as follows: “When a dog runs, the animal [that is, its brain] moves its legs; when a sea urchin runs, the legs move the animal” (1957: 32).

Konrad Lorenz (1927) demonstrated this principle of coordination by describing how a group of free-living animals attune themselves to each other.

> The members of the jackdaw swarm, which by day flies to the field to look for food and in the evening flies into the woods to sleep, again and again attune themselves to each other through the calls of the single birds so that the swarm as a whole arrives at a unified tendency. When in the morning or evening hours the tendencies of the single birds diverge, one can observe that for a while the swarm flies to and fro: If the ‘djak’ calls outweigh the ‘djok’ calls, the swarm flies towards the woods, and vice versa. These to-ings and fro-ings continue until suddenly all birds give the same one cry and the swarm as a whole flies towards the woods or the field. Then the swarm has been primed by the attuning process [*Abstimmung*] either for the behavior ‘retiring to their places to sleep’ or for the behavior ‘searching for food’. Thus it is dominated by a common pitch [*Stimmung*] or something like a common emotionality. (Uexküll 1963: 174)

In this example, the birds’ calls, as pitch signals, affect the pitches of the single birds and lead to a self-organization of the whole of the swarm. The same kind of coordination has been observed in insects. In his essay “Bienentanz und Menschensprache” (bee dance and human language 1986), U. L. Figge analyzes, from a linguistic perspective, Karl von Frisch’s observations on *Tanzsprache und Orientierung der Bienen* (dance language and orientation of bees – 1965). He describes an episode from the life of a bee colony which impressively illustrates that the self-organization principle of reciprocal attuning also holds for a species entirely different from jackdaws with regard to genetics, anatomy, and functioning.

> In spring . . . part of the colony leaves the hive, together with a queen, and forms a cluster in the hive's immediate vicinity, mostly on a bough. Experienced bees, which hatched out in the year before and as collectors have acquainted themselves with the surroundings of the hive, leave the cluster and fly off as scouts to look for a habitation. On its return from viewing a potential habitation (e.g., the cavity of a tree), a scout bee performs a dance which, depending on its properties, may lead other scouts to inspect the potential habitation. Thus, more and more viewings are carried out which are followed by dances to the swarm and by viewings triggered by these dances, until all scouts perform dances of the same shape. Then a new habitation has been found to which the scouts immediately lead the swarm. (Figge 1986: 46)

In a note Figge adds:

> Up to hundred bees may be involved in the search for a habitation. Accordingly, it takes a long time until they all have fallen into the same dance – sometimes it takes days. Only in rare exceptional cases this agreement is not accomplished. (1986: 67)

Lüscher (1983) demonstrates by the example of the respiratory rhythm that the functional structure of the central nervous system obeys the same principle of self-organization. Defined groups of nerve cells, which do not depend on a superordinate timing unit, attune themselves to each other by semiotic processes.

> Reduced to its essence, this conception implies that [in the respiratory center] two different neuron populations participate in the formation of the respiratory rhythm, one cell population having an inspiratory, the other an expiratory effect [pitch]. Only the population with inspiratory effect is capable of independent activity [it corresponds to the jackdaws wanting to fly to the field]. In contrast to the inspiratory neuron population, the expiratory population tends to inactivate itself [it corresponds to the birds pushing towards their places to sleep]. Left to itself, a given state of activity in the expiratory population will tend, on the basis of a certain time constant, towards zero. To understand rhythmogenesis, it is essential to look at the synaptic linking of the two neuron populations. In summary, one can say that autonomous inspiratory activation increasingly excites the expiratory cell population which in its turn responds by exerting an increasing inhibitory influence on the inspiratory population. Under this inhibitory influence, the excitation in the inspiratory system goes down, followed by a decrease of the excitation in the inhibitory neuron population. Thus, a renewed autonomous development of excitation takes place in the inspiratory neuron population, and the process we have outlined recurs in rhythmic succession.

In this interplay, the carbonic acid content of the blood affects the excitation of the inspiratory cell population, just as hunger has affected the excitation of a jackdaw which wants to fly to the field. Conversely, the blood's oxygen content, which affects the inhibitory neuron population, may be compared to the repletion of the jackdaws setting out for their places to sleep.

From a semiotic viewpoint, the biological state of the single nerve cell (its need for O_2 or surplus of CO_2) equals the deviation from its reference value (i.e., its interpretant); similarly, the degree of repletion or hunger of the single bird corresponds to the deviation from the bird's reference value or interpretant. The respective interpretant encodes the influences of the environment on the receptors of either bird or nerve cell into iconic signs denoting the resources offered by the environment (in jackdaws, the iconic signs are also indexical signs).

We would like to emphasize three points here:

(1) The interaction of the cytosemioses of numerous single nerve cells and the attuning (*Abstimmung*) of their individual interpretants (codes) to each other gives rise to the complex code of an organ (here, the respiratory center), just as the code of the jackdaw swarm originates from the exchange of information on each bird's individual pitch. As emergent phenomena, organ and swarm belong to an integration level of a new complexity where these entireties respond to signs received and encoded by their individuals. That is to say, the individual functions as a receptor within a complex whole.

(2) The next integration level arises from a further "attuning process" (*Abstimmungs-Prozeß*) between the complex code of the respiratory center and the code of nerve cells controlling the heart rate. In this way the respiratory rhythm is included in circulatory regulation.
The preganglionic heart vagus neurons are situated in immediate vicinity to the inspiratory brainstem neurons. Their discharge pattern is joined to the respiratory rhythm and characterized by expiratory activation. At the same time, in many branches of the sympathetic nerve, including the sympathetic heart nerve, the inspiratory part of the respiratory center is one of the central driving forces. So here we are dealing not with a simple superimposition of excitation or with "irradiation", but with a complex attuning process between sympathic and vagal heart innervation on the one hand and respiratory rhythm on the other. This connection is most prominent in a resting person and can be recognized most clearly by "respiratory sinus arrhythmia". But even after denervating the pressoreceptor reflexes and eliminating the mechanical factors of breathing, inspiratory inhibition and expiratory activation of the heart vagus can be observed; the opposite is true for the sympathetic nerve. This connection of heart rate and breathing can be used to condition the heart rate since breathing offers a voluntary access to autonomic innervation. In the complex system of neural heart rate control, the effect of each inspiration may be interpreted as a shift of heart rate control toward a "defense reaction" (Köpchen et al. 1981); this reaction is accompanied by activation of the sympathetic heart nerve and immediate inactivation of vagal innervation, and may be understood along the lines of Cannon's (1953) emotional "emergency pattern".

(3) From the aspect of endosemiosis, the "pitch" of the respiratory center is the "integral" of countless cellular semioses; on the even more complex level of the integration of the organism with its environment, this resultant is translated into the psychological sign of a vital body sense. For example, this sense determines our behavior toward the environment when we have "difficulty in breathing". This again illustrates that endosemiosis and exosemiosis are closely intertwined and that, as we emphasized in the beginning, a "body being experienced" requires sign processes which belong a psychological integration level.

The "Inner World of the Nervous System" and the Unity of Perception and Movement

In order to understand the nervous system as an organ in a semiotic anatomy of the body we have to realize its function for an "inner world". Its sign processes as a whole are an endosemiotic mirror, so to speak, of the exosemiotic *Umwelt* or subjective universe (but not of the environment – i.e., the outside world). The nervous system is connected to the outside world only through the sense organs, which may be seen as specialized receptors. Like all receptors of the nervous system, they are designed to filter arriving stimuli and to transform them into electrical excitation. J. von Uexküll (1909) described this as follows:

> So in the nervous system the stimulus itself does not really appear but its place is taken by an entirely different process which has nothing at all to do with events in the outside world. This process can only serve as a *sign* which indicates that in the environment there is a stimulus which has hit the receptor, but it does not give any evidence of the quality of the stimulus. The stimuli of the outside world are altogether translated into a nervous sign language. (1909: 192)

To keep stimuli distinguishable, different nerve tracts (acoustic, visual, tactile, etc.) connect the various kinds of stimuli with the respective brain areas. These areas of the nervous system thus constitute an "inner mirror of the world" which in the course of evolution has been inserted between the sense organs taking in the outside world and the motor parts of the nervous system (i.e., the locomotory apparatus). As a result of this development,

> no more outside stimuli transformed into excitation signs directly reach the motor networks. These networks receive all excitations second hand from a new excitation universe which has emerged in the central nervous system and rises between environment and motor nervous system. All actions of the muscle apparatuses must only be looked at in relation to and understood from this excitation universe. The animal does not flee any more [as primitive organisms do] from the stimuli sent by the enemy but from a reflection of the enemy springing from a mirror world. (Uexküll 1909: 194 f.)

Instead of "mirror world" (*Spiegelwelt*), J. von Uexküll sometimes uses the term "counterworld" (*Gegenwelt*), because in this phenomenal universe, the objects of the environment are represented by schemata which are not, as in a mirror, products of the environment, but rather "tools of the brain" ready to come into operation if the appropriate stimuli are present in the outside world. In these schemata, sensory and motor processes are combined – as in Piaget's (1955) sensorimotor circular reactions – to form complex programs controlling the meaning-utilizing (*bedeutungsverwertend*) behavioral responses. They are retrieved when the sense organs have to attribute semiotic meanings to stimuli.

Mountcastle (1975), a contemporary brain researcher, gives an impressive description of how the nervous system, far from passively reflecting the environment like a mirror, generates a "counterworld" with sign processes of its own:

> Each of us believes himself to live directly within the world that surrounds him, to sense its objects and events precisely, to live in real and current time. I assert that these are perceptual illusions, for each of us confronts the world from a brain linked to what is 'out there'

> by a few million fragile sensory nerve fibres. These are our only information channels, our lifelines to reality .... The central neuron is a story-teller with regard to the afferent nerve fibres; and he is never completely trustworthy .... Sensation is an abstraction, not a replication, of the real world.

The Immune System: Recognition, Memory, "Self" and "Non-self"

The "few million fragile sensory nerve fibres" are not the only connection between the organism and the outside world surrounding it. In the beginning we already indicated that the body constructs the immune system as a "second counterworld" which can change our conscious perception only indirectly, but, if circumstances permit, profoundly. Moreover, there is a resemblance between nervous system and immune system which is not only of semiotic but also of epistemological significance.

Reconstruction of foreign semioses which we observe may inform us of the meaning which the signs have for the interpreter who or which is different from us, but it cannot convey the content of the "experience" which the interpreter "has" when receiving the signs. We may empathize with foreign interpreters, but we cannot turn into them.

This points to a fundamental mystery: each sign contains the "self" of its receiver as a distinctive code. To put it more precisely, each sign leads to a change of the individual, subjective "self" of the receiver who or which in this manner is informed about the signified "non-self" and its properties. "Green", "hard", "blue", or "warm" are modes of experience in which the self finds itself changed in comparison with a previous or different state, and which, by the same token, signify properties of something which is "not the self" – for example, a meadow, a stone, the sky, or the bath water. These modes of experience are preverbal. Translating them into everyday language conceals their mystery.

Rainer Maria Rilke has given artistic form to this mystery, particularly in his Sonnets to Orpheus. One of them begins:

> Banana, full round apple, orange, pear,
> gooseberry. There's something here that speaks
> death and life into the mouth ... I swear ...
> Read it on a child's face, when its cheeks
> pop with relish. What infinity!
> Can't you feel inside your mouth a growing
> anonymousness, and, where words were, a flowing
> of suddenly released discovery? [4] (First part, Sonnet XIII; 1936: 61)

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[4] *In the original German version:*

> Voller Apfel, Birne und Banane,
> Stachelbeere ... Alles dieses spricht
> Tod und Leben in den Mund ... Ich ahne ...
> Lest es einem Kind vom Angesicht,

Such self-experiences seem to depend on the nervous system. From the discoveries of immunology, however, it appears that they have a biological counterpart which in all probability provides the earliest biological basis for our conscious self-experience. It has been a known fact for quite a long time that organisms are able to distinguish self from non-self, and that this capacity is vital to their "integration".

For example, the nervous system reliably informs our conscious body experience, by means of sensations of pain, about the dividing lines between self and non-self. When, as a result of a nerve injury, the sensation of pain fails, the organism is exposed to injury which it will not fend off, or will even inflict on itself. Yet even single cells are capable of distinguishing self and non-self. The cells of the immune system have developed this capacity into a specific function: as we have said, they are able to "recognize" foreign proteins (e.g., in the surface membrane of viruses, bacteria, and parasites). This is required for the intruders to be eliminated in time. The foundations of this capacity have to be investigated by semiotic means.

Another semiotic problem area is the organism's memory for diseases from which it has recovered. We say that the organism has aquired "immunity" against these diseases. But it has been known only for a few decades that immunity means that the organism is able to distinguish, on the endosemiotic level of its cells, self from non-self.

When N. K. Jerne was awarded the Nobel Prize for his discoveries in immunology, he gave a short outline of the history of his discipline (1985). Among other things, he described how in 1890 von Bering and Kitasato discovered the first antibodies in the blood of animals which had been treated with diphtheria and tetanus toxins, and how they proved that the antibodies were capable of neutralizing the toxins. For a long time it was thought that all cells of the animal and human organism could produce such antibodies. Only in 1960 was it established that only certain blood cells, the so-called lymphocytes, possess this capacity. In humans their number is approximately 10^{12}, exceeding the number of nerve cells by one order of magnitude. After all, the lymphocytes altogether come to one percent of our weight. They circulate through our body in blood and lymph, coming into contact with almost all body cells and closely cooperating with some of them in immune defense.

In describing processes in the immune system, scientists had to borrow, as had happened in molecular genetics, linguistic concepts. Emmeche and Hoffmeyer (1987, *The Semiotics of Nature: The Linguistic-Genetic Analogy*, unpublished) stress how unusual this procedure is in biology and medicine, disciplines which for a hundred years have persistently struggled to bring their terminologies into line with the terminology of physics.

Indeed, concepts like "program", "genetic code", "information", "memory", or "recognition", which suddenly became well-acknowledged and even indispensable concepts in biology and medicine, do not make any sense in physics. Here again, the

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wenn es sie erschmeckt. Dies kommt von weit.
Wird euch langsam namenlos im Munde?
Wo sonst Worte waren, fließen Funde,
aus dem Fruchtfleisch überrascht befreit. [1936: 60]

“silent revolution” has won through. It has forced researchers to use a vocabulary which runs counter to their conception of the world, and to describe the behavior of cells not in causal-mechanical but in semiotic terms.

Jerne began his speech as follows:

> Grammar is a science that is more than 2000 years old, whereas immunology has become a respectable part of biology only during the past hundred years. Though both sciences still face exasperating problems, this lecture attempts to establish an analogy between linguistics and immunology, between the descriptions of language and of the immune system. (1985: 1057)

The Semiotics of the Immune System

The analogy between language and immune system reaches even further than the one between language and the genetic code. To understand this we have to recall some facts about the structure of amino acids.

The nucleotide sequences of the genetic code may be compared to the signs of Morse code. Just as the sign sequences of Morse code are decoded and translated into the letter sequences of a language composed of words, the nucleotide sequences of the genetic code are decoded and translated into the 20 sign sequences constituting the “alphabet” of the amino acid code.

The innumerable and remarkably different protein bodies of which the body substances of all living beings, from viruses to mammals, consist are assembled from these 20 amino acids. Lymphocytes can “read” these protein bodies. Therefore, they must have a code at their command by means of which they can compare immensely complicated alphabets.

Protein bodies are long chain molecules whose links are formed by varying sequences of amino acids. If each amino acid is understood as a letter in an alphabet, protein bodies can be compared to texts composed of very long strings of letters. The number of amino acids in a large protein molecule roughly corresponds to the number of letters in one column of a newspaper article. In such a column, the letter sequences of words and sentences are arranged in one row underneath another. In contrast, the sequences of the amino acid alphabet are folded into each other, since in organisms the protein molecules are rolled up into complex tangles, even where they form the surface of cells. Therefore, only the few amino acid sequences on the surface – which are comparable to single words or short sentences – can be “read”. To the immune system they are a dictionary consisting, as it were, of the “proper names” of the countless protein molecules from which the organisms of all living beings are constructed.

These “proper names”, which sometimes contain only ten amino acids, have been termed “epitopes” (from the Greek epi “upon”, and topos “place”). Since the human immune system can recognize the epitopes or “proper names” of all the many millions of protein bodies which occur in the body substance of millions of different organisms, from viruses to mammals, its range comes up to the total of the telephone books for all major cities on all continents of the world. As the immune system can "read" all the "proper names", it is capable of producing antibodies specific to these markings. Antibodies are attached as a kind of label to the invading viruses or bacteria so that other cells participating in the immune defense can decipher these "wanted posters" and recognize the intruders as candidates for destruction.

Jacquemart and Coutinho (1988) oppose mechanistic notions by pointing out the explicitly semiotic character of these molecular reactions:

> antigen and antibody, in so far. as immunological qualities based on molecules [*sic*], are mutually constituted . . .. [A] molecule does not have epitopes. This quality is brought to the molecule by a paratope (the 'proper name' of the antibody), which determines the place, the size, the molecular components Implicated in the linkage etc. A paratope, to some extent . . . concretises a possibility that can be expressed by a given molecule (the 'epitope'). (1988: 178)

From a semiotic point of view, the immune system "recognizes" foreign signs which it has never before encountered. Yet the way in which .this problem is solved supports the view that non-self can only be recognize as a variety of self, and that, as Plato stated, only the known IS recognizable.

The lymphocytes (producers of the antibodies which attach themselves to invaders as a label or "mark of Cain") wear on their surface receptors which are built exactly like the antibodies they have sent out. So they wear the very same amino acid sequences by which the "proper name" of a specific protein molecule can be identified. When the lymphocyte comes into contact with such a protein body, it starts to divide into many daughter cells. Some of these cells mature into large lymphocytes which give off great numbers of antibodies into the blood. The remaining daughter cells do not develop up to this stage, but stay back in reserve so that when an invasion of the same kind recurs, protein molecules can immediately respond by massive antibody production. These cells preserve the secret, as it were, of the invaders' proper name. As the "memory" of the immune system, they are the basis of immune recognition.

By comparing the code of the immune system to the telephone books of all cities on earth, we have already indicated that to recognize "unknown" substances which have never before come into contact with the organism and for which "memory cells" have not yet been formed requires enormous resources. Each of the many mil1ions of lymphocytes wears on the receptors of its surface membrane an ammo acid sequence which can "read" the "proper name" of another protein molecule. Thus, the immune system keeps ready millions of lymphocytes with their different receptors for millions of protein bodies which the organism might possibly have to confront in its lifetime.

In order to illustrate this immense abundance, we have to contrive a simile: imagine that the Federal Bureau of Investigation has possession of a collection which contains the fingerprints of all people on earth; for each set of fingerprints it employs a separate officer who sets out and searches for a person in the population whose fingers match the document. Well over 90 percent of the officers will search in vain for their candidate their whole lives long, and very few will ever make a strike. But then, these few will not have identified something unknown; they will have ascertained the fingerprints they already knew. In other words, to identify the unknown means to recognize something familiar; non-self is a potential variety of self.

To the semiotician, this conclusion is rather banal. It implies that the unknown is recognized by iconic signs. The group of lymphocytes wear on their receptors millions of iconic representations of antigen epitopes. However, only the contact with – or the contiguity to – the counterpart of the epitope, which is constituted by the amino acid sequence upon the foreign protein molecule, supplements the iconic quality with the indexical quality required for the sign "non-self". Figuratively speaking, our body carries with it a gigantic collection of photographic plates waiting to be developed into pictures of all possible enemies it may ever encounter; only when the immune system is faced with an enemy will a plate from this "counterworld" constructed by the immune system be developed.

On the other hand, there are pathogenes which are no longer detected once they have forced their way into a body cell. Among these, viruses also can use their DNA to impose their building plan on the cell so that it starts to replicate the virus in large numbers and neglects its original functions. Only the so-called killer cells (T-Iymphocytes) are capable of identifying the infected cells and destroying them along with the viruses inside them. If this process gets under way, the killer cells begin to multiply very quickly and to master the infection. The AIDS virus can "hide" not only in body cells but also in macrophages and lymphocytes (helper cells); in this way it remains "unrecognized" and is not attacked by the immune defense, which regards it as "self". It is as if a conflagration starts at the fire station, or as if terrorists disguised as police officers occupy the FBI and alter its functioning to serve their purpose.

The Immune System as a "Voting Republic" (*Abstimmungsrepublik*): Self as "Primordial Sign" (*Urzeichen*)

In identifying the *unknown* as non-self, the immune system makes use of the mysterious kinship between self and non-self. Yet paradoxically, this procedure makes it difficult, if not impossible, to recognize what is *known*.

Antibodies mean "self" only to the lymphocyte – which produces them and wears antibodies of the same kind on its surface that serve as receptors. To other lymphocytes, they are "non-self" – wearing the fingerprints, as it were, of a potential enemy – and appear as antigens against which they produce further antibodies.

It has indeed been demonstrated that when the immune system of an animal produces specific antibodies in response to an antigen, it also develops antibodies directed against those first antibodies. The "self" of one lymphocyte is "non-self" to another. This astonishing chain reaction goes on and on: the "anti-antibodies" formed by the second lymphocyte induce a third lymphocyte to produce antibodies against them, and so forth. Thus the immune system is a gigantic network of antigen-antibody interactions (Jerne 1985, Kohler et al. 1984).

This stream of signs, which at the contact of a lymphocyte with an antigen sweeps like a gust of wind through the entire immune system, leads the different cells to attune (*abstimmen*) their interpretants to one another. So the immune system is a "semiotic republic" similar to the respiratory center or the jackdaw swarm. On a higher integration level, the various antigen-antibody interactions form the unity of an organ which can, in spite of its immense complexity, respond as a whole to signs received by a single cell.

Actually, the complexity of the whole process becomes even more amazing, because other cells such as T-lymphocytes and monocytes join the interactions of the antibody-producing B lymphocytes. The image of a multinational state comes to mind, whose nations speak the most diverse languages. Yet instead of a Babel of languages we have an "exemplary democratic order" structured through a "voting (*Abstimmung*) by signs".

This order also includes a semiotic peculiarity: in their great majority, the antibodies which are emitted by B lymphocytes into the blood where they can be detected in the form of specifically constructed protein bodies (gammaglobulins) – are "signs to absent addressees". They can only convey their message when a suitable antigen (e.g., a bacterium or virus with the correct epitope) enters the bloodstream.

So in the incredibly complex Babel of voices within the immune system we detect the recurrence of a particularly fascinating message: life is always and everywhere a dialogue between self and self – in endless variations self finds its own image in the shape of non-self.

The "Inner World" as a Unity Composed of the "Counterworlds" of the Nervous System and the Immune System

We have shown that the semioses of the nervous system and the immune system set up two different "counterworlds". Before we discuss evidence that these two "counterworlds" are integrated to form a common "inner world", we would like to distinguish some of their typical features.

The most striking difference can be seen in how directly each of the two systems participates in the formation of consciousness. In the counterworld of the nervous system, programs are stored for constructing a world which we consciously perceive and experience. This world includes our body, which is, as "experienced body", its center; as we have already indicated, this point is crucial to a semiotic anatomy. In contrast, the counterworld of the immune system contains programs for confronting the environment in ways which elude our conscious experience.

Nevertheless, there exist connections between the two systems by which they are integrated to form a common "inner world". A new discipline called psycho-neuro-immunology (see Ader 1981) addresses itself to the interactions between psyche and immune system.

Psyche as Translator of "Counterworld" into World

How are we to imagine the psyche? The answer is: our psyche is a translator. The "neural counterworld", which our brain composes of the signs streaming into it on different nerve tracts from all parts of the organism and, via the sense organs, from the outside world, is translated by the psyche into what we experience as our body and our world.

When talking of a psyche, we also have to take a closer look at the concept of consciousness. What does it mean that, in contrast to immune processes, brain processes participate directly in the formation of consciousness? For, paradoxically, we are "outsiders" to all "inner" (i.e., endosemiotic) sign processes, whether they occur in the nervous system or in the immune system (we can illuminate them only by complicated methods, and "understand" their messages only through biosemiotic interpretation), whereas we are "insiders" of all sign processes by which the outside world and our body are presented to us as conscious realities. The "inner" sign processes of the brain are, like all "inner" or endosemiotic events, inaccessible to our conscious experience; but, unlike all other endosemioses, they participate directly in its formation. That is, all consciously experienced "outside" realities are translations of "inner" sign processes which occur in our brain and are inaccessible to our experience and understanding.

Here it should be recalled that originally, "inside" and "outside" are semiotic concepts which take on spatial connotations only when we look at our motoricity. Moreover, "participation in the formation of consciousness" and "consciousness" are "emergent phenomena" which cannot be anticipated and derived from the observation of elementary states, and manifest themselves "out of the void", as it were, in a leap from the endosemiotic to the psychosemiotic integration level. The following remarks are aimed at illustrating the dynamics of this transition.

The "Experienced Body" as a Translation of the "Counterworld" of the Nervous System: Phantom and Scotoma Limbs

We have shown that in the "counterworld" of the nervous system, the "unity of perceiving and moving" (see the subtitle of Weizsacker 1940) is prepared by the construction of programs for "sensorimotor circular reactions" (Piaget 1955). The "counterworld" has to be "translated" into the world which we perceive and consciously experience as our "reality". This conscious world has an important biological function: it enables us to deal with our environment by active movements. As has been emphasized above, simpler systems (e.g., plants) are not capable of such motor activity. Our conscious "I" or ego is an instance of the psyche which principally translates sensory informations arriving at the brain into orientation signs (or advance organizers) for our motor behavior (Freud 1911).

Among these sensory data, those belonging to the "muscle sense" or kinaesthetic sense are of particular interest. At each moment they convey to the "I" not only the exact position of all limbs, but also that it actually does possess a body. In a fascinating account, the neurologist Oliver Sacks (1986), who once became a neurological patient himself, relates his personal experience of what happens when those data are missing or are no longer being translated into a body experience. He writes:

> And indeed it is this 'muscle sense', as it was once called, before Sherrington investigated it and renamed it 'proprioception' – it is this sense . . . by which the body knows itself, judges with perfect, automatic, instantaneous precision and motion .of all its moveable parts, their relation to one another, their alignment in space. . .. One may be said to 'own' or 'possess' one's body – at least its limbs and moveable parts – by virtue of a constant flow of incoming information, arising ceaselessly, throughout life, from the muscles, joints and tendons. One has oneself, one *is* oneself, because the body knows itself, confirms itself, at all times, by this sixth sense. (1986: 46 f.)

The continually changing pattern which results from a sea of proprioceptive sign processes in the brain corresponds to the autopoiesis of a "neural counterbody" forming the center of a "neural counterworld" which also is in a state of constant flux. The cerebral process in which this "neural counterbody" is translated into the "experience of our body" constitutes the basis for a "subjectively experienced anatomy" as it is exercised in the body-centered psychotherapeutic methods (autogenic training, functional muscle relaxation, etc.) so as to help patients to become better acquainted with their own body and to treat it more carefully.

Sacks calls for a new neuropsychology which investigates these connections and their disturbances.

> Classical neurology was essentially static: its model was a model of fixed centres and functions. Neuropsychology on the other hand, is essentially dynamic: it sees countless systems in continual interaction and interplay. (1986: 162)

To explore the streams of signs and their interactions, neuropsychology requires a neurosemiotic framework by which the salutogenetic programs and the codes of "gnostic systems" can be deciphered according to which the body reads itself as a text permanently writing and reformulating itself.

These codes correspond to what neurologists call "body schema" without yet knowing how to actually put this concept to use. There are illnesses which begin to betray their secret if they are seen as disturbances of the body schema or as translation error. The best known of these disturbances is the syndrome of phantom limb pain – pain in an amputated (i.e., *absent*) limb – which has been frequently and thoroughly described, but scarcely understood. The phantom limb has its counterpart in the phenomenon of the "scotoma limb" which Sacks describes from his own experience: the limb is anatomically intact, yet to the patient it is a foreign object which does not belong to his or her body. After an accident, Sacks had to undergo an operation. When he looked at the operated leg from which the plaster cast had been removed, he was amazed as well as utterly disconcerted:

> Yes, it was there! Indisputably there! . . . A leg – and yet, not a leg: there was something all wrong. . .. It was indeed 'there' in a sort of formal, factual sense: visually there, but not livingly, substantially, or 'really' there. It wasn't a real leg, not a real thing at all, but a mere

> semblance which lay there before me. . .. It was clear that I had a leg which looked anatomically perfect, and which had been expertly repaired, and healed without complication, but it looked and felt uncannily alien – a lifeless replica attached to my body. (1986: 91)

At that moment he remembered how as a young doctor he was called to a patient whose complaints he did not comprehend then: "I thought . . . of . . . his pale, scared face, and the consternation as he whispered: 'It's just a counterfeit. It's not real. It's not mine.'" (1986: 91).

What had happened? In both cases proprioceptive data were missing or did not reach the respective areas of the brain. This impressively illustrates that our living body, which we experience as the center of our reality, is the product of a "neural counterbody" which is continually shaped and reshaped by the ceaseless flow of proprioceptive signs from the muscles, joints, and tendons of our limbs to the brain. This "neural counterbody" is the center of a "neural counterworld" which our brain constructs and reconstructs from the likewise permanent flow of signs from the sense organs. Counterbody and counterworld are amalgamated to form an indissoluble unity because all the events we perceive in the environment are counteraffordances – that is, they are related to actual or potential affordances of our motor system and combine with these to form the spatial grid by which we orient ourselves.

When a nurse attended to Sacks's unreal leg, her actions became equally unreal:

> Her activity had seemed meaningless and unreal, presumably, because the leg felt meaningless and unreal. And because the leg felt senseless, in all senses of senseless, absolutely senseless and unrelated to me, so had her motions which had been related to it. As the leg was merely a semblance, so her motions . . . seemed merely a semblance. Both had been reduced to meaningless semblance. (1986: 92 f.)

As soon as the salutogenetic formation of the "neural counterbody" in the brain is disturbed – either because the stream of proprioceptive signs from the limbs is cut off or because for some reason the interaction of the respective cerebral systems is blocked – the translation into the experience of a "real body" in a "real world" collapses. This shows again that endosemioses and exosemioses are closely interlinked.

Psycho-Neuro-Immunology: The Interweaving of "Counterworlds" into an "Inner World"

When we described the translation of a non-conscious neural counterworld into a consciously experienced physical reality, we did not mention that this translation process may be influenced by the immune system – that is, by the counterworld it constructs to fight harmful substances which our sense organs are unable to detect.

Usually we do not notice such influences. However, if we are, for example, running a fever in the course of an infection, our sense of reality may be considerably changed by pyrogenous substances produced by the immune system. Conversely, there is evidence that processes occurring inside our psychological reality may affect – via the nervous system the immune system.

That the neural and immunological counterworlds are interwoven by sign connections to form a unified inner world has been most impressively demonstrated in the experimental conditioning of immune processes. Semiotically speaking, conditioning means a "semantic link-up of meanings" between psychological experiences and endosemiotically controlled processes in the organism. The classic example is Pavlov's work with dogs whose gastric secretion could be set off by the sound of a bell if the sound had previously been often enough coupled with innate stimuli for secretion (e.g., the smell of food).

Ader (1981) demonstrated in animal experiments that sweetener can suppress immune processes if it has previously been administered together with a substance which inhibits the immune system. Yet conversely, the subjective reality of the animals was changed as well: they avoided the sweetener which they had liked before.

This shows that the neural and immunologic counterworlds are integrated to form a conjoint inner world which corresponds to a *fourth endosemiotic integration level*; this inner world then is translated into an experienced reality.

A number of substances have been identified which serve as vehicles in the sign processes between nervous system and immune system. The first group consists of the neurotransmitters; among them, noradrenalin and adrenalin play an essential part in the regulation of the immune system. The details of immunoregulation, however, are still unknown (for a bibliography on this subject, see Klosterhalfen and Klosterhalfen 1990).

A second kind of sign connection is established by the neurohormones, which are associated with psychological processes. They are known to influence the course of illnesses in which the immune defense is activated usually they are discussed in the context of "stress hormones and immunity". Glucocorticosteroids are the best-known hormones of this group. In small quantities they can stimulate the immune defense, whereas in large quantities they have an immunosuppressive, anti-inflammatory effect and reduce resistance to infections (for references see Klosterhalfen and Klosterhalfen 1990). These and other substances of similar effect seem to modify the responsiveness of immune cells to signs by changing their interpretant.

Furthermore, the nervous system responds to processes in the immune system: during an immune response the activity of neurons in the ventromedial hypothalamus increases. Lymphocytes can produce a "glucocorticoid releasing factor" which raises, via the hypophysis, the corticoid level in the blood, and in this way prevents immune responses from escalating. Besides, interleukin 1, which is generated by lymphocytes, can also stimulate the secretion of ACTH (adrenocorticotropic hormone) and corticoids (Besedovsky et al. 1986).

Immune responses have been investigated in persons exposed to different kinds of strain: in astronauts, in widows and widowers, and in students taking exams. In all of these studies, stress situations were found to have significant effects on the immune system.

In astronauts, "mitogenic stimulation" was inhibited – that is, their lymphocytes no longer responded to substances which usually serve as sign-vehicles for triggering cell division. Interestingly enough, this was not due to stress hormones but to weightlessness, which seemed to have a direct effect on the interpretants of the cells.

Significant connections between psychological processes and the behavior of immune cells were found in widows and widowers as well as in men whose wives were suffering from breast cancer. Apart from the fact that the division rate of lymphocytes was reduced, the activity of socalled killer cells – lymphocytes specializing in direct elimination of invading viruses and bacteria – was also inhibited. This again indicates that interpretants of cells can be altered as a result of psychological events.

In the context of AIDS, such considerations have gained particular relevance: to what extent do psychological factors influence the outbreak and the course of AIDS in persons infected with the HIV virus?

The syndrome of AIDS, especially the underlying immunodeficiency, impressively confirms the significance of the semiotic function of sign recognition: an important peculiarity of the AIDS virus, its preference for a certain cell type (the T4 cells), can be explained by the fact that the virus uses an area on their surface as a receptor. This area is associated with the T4 marker, a protein by which T4 cells are distinguished from other lymphocytes. When the virus attacks the cell, its first step is to attach itself to this spot.

There has also been discussion as to whether psychological factors affect the onset and the course of cancer. To date no conclusive evidence is available (Hiirny 1990). In the long term, however, this research may well lead to the development of new preventive and therapeutic options (Klosterhalfen and Klosterhalfen 1990).

The Observer as Meta-Interpreter

How can we answer now the principal question of biosemiotics: whether a human observer is actually capable of deciphering the signs of foreign living beings?

We have seen that in biosemiotics we are dealing with problems of interpretation – that is, of translation. Translations may be understood as "linkages of meaning"; translations of endosemiotic sign processes will have to link, for example, cytosemiotic signs to word signs. This leads to "meta-interpretations" in which an observer has to interpret a cell's behavior toward its environment as a clue indicating its responses to its own interpretations. Thus, the observer has to assume that the cell encodes the effects of the environment on its receptors into signs, and that these signs control its behavior toward its environment.

To transform such assumptions into empirically testable statements, the observer first has to interpret – in a semiosis of information – the physico-chemical properties of the environment (in our example of immune processes, the physico-chemical properties of the antigen) and their effects on the receptor of the observed cell (the physico-chemical interaction with the respective sections of the receptor, the so-called "idiotopes") as quasi-mechanical events – that is, "signetically". From the cell's state or behavior the observer then has to infer its interpretant, which attributes to the changes in the receptor a meaning as a sign that will dictate the response of the cell.

However, having thus interpreted our behavior as observers, we are faced with an epistemological problem: how are we to justify our interpretations, derived from our human experience, of living systems which are so remote from us biologically? How can we use anthropomorphic terms like “sign” and “semiosis”, and postulate endosemiotic signs whose meanings are linked to the meanings of human linguistic signs and may thus be translated into them?

We have found that all processes of life happen between varieties of “self” which encounters itself as “non-self”. One form of variation is the combination of simple signs to form more complex signs. It will have to be investigated in detail to what extent the signs of more complex integration levels may actually be understood as “integration products” in which signs of more elementary levels are joined together to form more complex units.

We have mentioned evidence supporting the view that more elementary signs as they are exchanged between cells on an endosemiotic level are gradually “computed” and integrated so as to construct more complex signs.

“Semiotic voting republics”, in which cells of the immune system or of the nervous system and even birds are integrated to form more complex units, provide additional examples of such organizing principles of life.

Thus, objections that we are applying anthropomorphic concepts may be countered by a genetic argument referring to the hierarchic order of life: a systemic and semiotic order of nature is becoming apparent in which simple signs are integrated to form more and more complex signs, and this systemically structured universe of signs comprises humans, too, as senders and receivers of signs.

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Chapter 10
Signs and Codes in Immunology

Giorgio Prodi (1928–1987)

Introduction and Commentary: Giorgio Prodi (1928–1987)

> *Reality is interpreted by* a priori *systems provided with their own* codes *that are themselves the* a posteriori *products of their system's natural history (and therefore: of the reality that the system can read).*
>
> G. Prodi (1998: 63)

Giorgio Prodi was a accomplished oncologist, poet, novelist and philosopher whose lifelong interest in examining the connection between biology and epistemology Thomas A. Sebeok would repeatedly invoke as constituting one of the three main precursor attempts at founding biosemiotics as a research agenda in the twentieth century. Indeed, Sebeok reports that long before he first met Prodi in the mid-1970s, "Prodi had forged, without explicit reference to any other previous or contemporary thinker, still another variant of this sprouting, or re-emerging domain" of sign study, to which he had given the title "natural semiotics" (1998: 34).[1] Yet Prodi's role in the history of biosemiotics is not merely that of a precursor to Sebeok. Rather, Sebeok also credits Prodi as being one of the three main founders of contemporary biosemiotics, recalling the seminal planning sessions of 1977 when he met with Prodi and Thure von Uexküll in Freiburg to conduct "an intensive week-long open-ended seminar, so to speak, on the practical and conceivable ins and outs" of what they would jointly develop later as the contemporary research agenda of biosemiotics (1998: 194).

Born in Scandiano (Reggio Emilia), Italy, on August 2, 1928, Gigio Prodi graduated from the University of Bologna with a doctorate in medicine in 1952. Prodi would spend the entirety of his academic career at this very university, holding the chairs of General Pathology (1966–1968), Experimental Oncology (1969–1978), and Oncology (1979–1987). In 1973, he founded and directed the University of Bologna's Cancer Research Institute, and a few years later founded

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[1] One of Prodi's early manuscripts on this topic, entitled *La preistoria nelle sue pesanti conseguenze sulla storia e sulla teoria della semiosis,* came to the attention of fellow semiotician and novelist Umberto Eco (1932–), who saw to its publication in 1977, introducing Prodi's work on "natural semiotics" to the community of general semioticians, most of whose work was still rooted in anthroposemiotic analysis (Sebeok 2001: 67).

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the interdisciplinary Interdepartmental Cancer Research Center that now bears his name. “As a member of numerous scientific societies and associations,” writes Guido Paolucci, Prodi’s successor to the directorship of the Cancer Research Center, Giorgio Prodi “came to represent an undisputed cultural point of reference for the University, both nationally and internationally. Continues Paolucci:”

> [Prodi’s] zest for learning and life led him into the field of epistemology, in which he became an international authority. In the field of literature, he was to publish prize winning novels, short stories and poems [in addition to a vast scientific bibliography of over 300 publications on oncology] . . .He pursued his three main fields of research: medical oncology, philosophy, and literature, separately, secure as he was in his knowledge of being a specialist in all three...His life and work formed a mosaic of interconnections between philosophy and science [and] a reading of his encyclopaedic scientific, philosophical and epistemological publications provides a map by which to retrace his steps in pursuit of a better understanding of biological phenomena and that which pertains to the significance and structure of thought (Paolucci 1996: ii).

One year after Prodi’s death in 1987, Sebeok published in *Semiotica* an English language précis that Prodi had made of his own 1977 masterwork in ‘natural semiotics,’ *Le bai materiali della significazione.* Condensing into fifty pages the arguments and findings of his 259-page 1977 monograph, Prodi’s précis, entitled, ‘*Material Bases of Signification*’ (1988) remains an extraordinarily dense read that is nonetheless extraordinarily rewarding. This précis being a highly concentrated distillation of an already exceedingly dense work itself, to condense it even further in order to accommodate the space limitations of this volume would have rendered it dense to the point of incomprehensibility. Instead, I will attempt to convey to the reader a sense of some of the large-scale concerns and theses appearing in Prodi’s 1977 manifesto of “natural semiotics” in this introduction, in the hopes that this overview will be conceptually sufficient to allow a contextualized reading of the following selection. This selection, entitled ‘Signs and Codes in Immunology’, reflects many of Prodi’s larger concerns and ideas, and is a transcript of the conference paper that Prodi presented at the NATO Advanced Science Institute Conference on ‘The Semiotics of Cellular Communication in the Immune System,’ just one year before his death.

Even in this short conference paper, one can witness the broad scope of Prodi’s semiotic systematic – a systematic that is firmly grounded in the purely efficient material and energy exchanges of the material world *as those changes come to shape* the biological systems that adapt to them. As a thoroughgoing but non-naïve materialist, Prodi insisted that “biological systems” themselves are no more than densely interacting sets of purely efficient material and energy exchanges whose being never transcends that of the material and energy exchanges that bears them, and in which they live their lives. In the following few pages, I will try to lay out the essence of Prodi’s ‘natural semiotics’.

“A frame of existing facts is the territory upon which one moves and in which, contemporarily, one searches for the explanation of moving”, writes Prodi, “yet if there is an existing network of facts, and if we are part of it, our nature (structure, functions) stems from it – and as a specification of this, it can be neither contradictory nor external. We need not raise the issue of justifying the network, but rather, of being justified by it . . .through the [material] network facts that are our make-up, and the [material] facts that connect us with the outer existence, we are submerged without any possible interruption in the most general web of facts" (Prodi 1982: 15).

Because of the material ubiquity of reality, notes Prodi, "dualism is not overcome by synthesis, but rather by the ascertainment that at the very base of it all, there is no duality" (1987b: 119). In this sense, Prodi may be seen as something of a reverse-pansemiotician, for his conviction is not that mind is in matter, but that mind – just like everything else in our universe – is nothing *but* matter and energy exchange, a complex chain of ramifying (though at each point always still purely physical) interactions, regardless of how far from the holistic material bedrock of reality that we may subjectively experience our "minds" to be. Thus, he argues:

> If we were able to undo a sign in its various steps, we would discover that every step is formed by a reader-thing that interprets another thing which, in turn, is seen as a sign, that is, subsequently read by yet another thing. All the molecular processes that we are beginning to be aware of rather well, in the present day, (from the proteinic synthesis to the employment of energy, from the duplication of the DNA to the transmission of nervous drives) belong to this typology. Man's cerebral functioning is surely terribly complicated [. . .] but it is hard to believe that it may operate differently from a continuous molecular recognition of significance. (Prodi 1987b: 147).

Yet Prodi's semiotic materialism, as evidenced in the following selection, is generative, and not eliminative: here, the purely material systems that are "organisms" are literally shaped and reshaped, both in phylogeny and ontogeny, by their interactions with the world. "Meaning in nature is thus the *relations of correspondence* between material states which appear as *triggers for change*," writes Prodi (1988: 195). Prodi characterizes such pre-biotic, but naturally occurring and regularized, relations of correspondence in the material world as the *proto-semiotic* relations grounding the ability of organisms with biosemiotic capacities to reliably "know" the world. "Life begins when onto such a uniform world, *conditions of selectivity* are superimposed," writes Prodi, "or, better, when conditions of selectivity are *generated from* the conditions of uniformity" (1988: 55). Grounded in these two simple principles, Prodi's materialist biosemiotics yields molecular (and later cellular and multi-cellular) "reading machines" that are in all cases "constructed on the referent" of that part of external reality which is their complementary substrate. Prodi discusses the examples of enzymes and their substrates to illustrate the underlying physical complementarity driving not just primitive semiosis, but, ultimately, all semiosis:

> The transformation of indifferent things into signs is linked to the stabilizing of the [molecular] reader and confers advantages on the latter (taking the word advantage in a nonanthropomorphic sense as signifying stability, and subsequently competitive advantage as well). In this kind of dynamic, a sign establishes itself as such because it is useful; in other words, it creates new thermodynamic and energy conditions for its user. Thus the signaling phenomenon has a concrete natural basis and retains this even when the [composite that is the] signaling machine attains the level of cultural complication . . .

> Bacteria offer us a concrete example of the function. Let us suppose there exists a large population of bacteria in contact with *n* sign-things, such that each member is capable of reading-metabolizing the *n* referents. If, thanks to the mutation produced by the accidental disorder, one of the individuals is enabled to exploit an *n + 1* metabolite, then an evolutionary step has taken place in the bacterium in question and in all the clones that descend from it. This is manifested in an expansion of the reading area. What has happened to the n+ *1* thing is that it has acquired a natural possibility of being read, and can be deciphered as a sign. The microorganism's environmental range has thus increased. What chance has the new clone of being stabilized? Neither more nor less than the advantages deriving from reading . . .
>
> A condition of this kind might seem to be very mechanistic, but this is by no means the case; [for] the new circumstances and reading possibilities are not only external aspects (in relation with the referent) but also internal ones (consisting of a rearrangement of the sign relationship that makes up the individual). There is no doubt that *n + 1's* capacity to be read arises only if the new reading system appears, but the new reading system is inconceivable without *n + 1*. The possibility of reading is thus constructed on the referent. All a structure can do during evolution is expand into the forest of things surrounding it and learn to decipher more and more of them, modifying both itself and the things in the process. Little by little, the forest is converted into a place of family, connatural presences utilized by the structure; it becomes an interpretable sign complex. In the last analysis, it is things that have themselves read, building suitable structures to this end (1988a: 209, 211–212).

Increase in biological complexity thus results *from* – and not merely *in* – an increase in the number of real-world referents being read, "fostering the development of [ever-more] adapted, progressive reading machines" (1988a: 226), argues Prodi. For since "the general principle is that reading systems construct themselves upon signs, and these signs are solicited by referents" (1988a: 208), at a certain level of complexity, the "signs of referents" themselves begin to function as "referents" (in the manner, Prodi acknowledges, of Peircean *interpretants*), resulting in the evolution of the appropriate reading mechanisms, accordingly.

Moreover: "Since stored signs are 'meaningful for [*x*]' . . . there are connections between the internal signs. No matter how segmented they are, they do not form a sequence of 'accidental' units; if this were so, we would be quite incapable of explaining that connective function which we call knowledge . . .Thus, [given that these connections, too, are physical realities, and thus can also function as referents], they carry meaning for a specific connecting apparatus that can review them, see which are meaningful in relation to a given situation or adjustment to the environment, and link them together" (1988a: 230).

Thus, by invoking the exact same processes described taking place in the immune system in 'Signs and Codes in Immunology,' and by proceeding from the simplest and most direct "physically complementary relation" of the *epitope* to the most mediated and non-linear (but still ultimately physically complementary) chain reactions running through the central nervous system, Prodi goes onto to detail how his materialist biosemiosis is operative in the organization of: animal collectivity (1988a: 223), human social life (1988: 225), communal intersubjectivity (1988a: 224), hypothesis generation (1988a: 232), memory (1988a: 226), the objectification of extra-mental reality *as such* (1988a: 237), and the ultimate human accomplishment that is the full recognition of signs as signs (1988a: 235). "In this model, there are no halts," writes Prodi scholar Felice Cimatti, but only

> ongoing transformations, living forms turning yet into other more or less complex forms of life. Moreover, we are not the ones, as presumptuous subjects, to 'know' the object; rather, things alone [transform us in our interactions with them, such that they become "known"] to us. We are thus nothing but the ultimate transformation of other things, linked, in turn, to many others, and so on, all the way up to those very things we are presently knowing ...Thus, the world does not account for an *a priori* distinction between subjects and objects which are separated and differ from each other, but only on more or less complex systems, all tied to an articulated web of relations that coincides with life...subject and object cannot therefore constitute the starting point of knowledge's developing process. Still they represent the final point, though never wholly attainable, for if such a full separation would ever occur, the biological continuity that links them, would break down. That would mean not just the end of semiosis or knowledge, but of life itself (2000: 352–353).

In this sense, Prodi's material bases of signification, monadic at its core (1988a: 191), dyadic in its action (1988a: 201), and triadically informative as to the real nature of being as the complexity of a "reading machine's" own reading operations come to recognize their own recursive effect upon the reading (1988a: 241), presents us with perhaps the most fully worked out biological account of the oft-misunderstood doctrine underlying Peircean biosemiotics' naturalistic realism – i.e., the idea that it is the nature of objects that ultimately give rise to (or *bestimmit*) the nature of their sign vehicles (which, in turn, ultimately give rise to the nature of their interpretants – and which, in turn, ultimately give rise to the nature of their interpreters).

Accordingly, "life, semiosis and material logic are biologically coextensive terms in Prodi's model," writes Prodi scholar Felice Cimatti, and thus

> the separation between sign and referent as seen in the classical semiotic triangle will never occur. [Rather, such 'separation' can be experienced] only to the extent that we have lost all recollection of their original spatial contiguity when the translating chains that link the first to the second are extremely prolonged. Their separation is, as said before, only apparent: the sign is always contiguous to its object, what varies, instead, is the extension of the translating chains (2000: 376, 365).

It is perhaps as an extension of this very logic of contiguity, and of 'translating chains', that the dedication page of Thomas A. Sebeok's first book bearing the title *Biosemiotics* bears the inscription: "*In memoriam:* Giorgio Prodi (1928–1987): Bold trailblazer of contemporary biosemiotics" (Sebeok and Sebeok 1992).

Signs and Codes in Immunology (1988)

Introduction: Semiotics and Immunology

Immunological reaction consists in deciphering molecular structures (e.g., antigens, antigenic epitopes), and this deciphering is demonstrated by the [life-sustaining appropriateness] of the response itself (i.e., the production of antibodies or antibody-equivalents). These responses are specific, and each one is directed only towards the single antigenic structure by which it has been provoked. Therefore, the immune system performs an "interpretation" of the material objects that it can explore; it is triggered by some of them, and toward these only it builds its specific response. In a very general perspective, antigens are [information-bearing, or] "meaningful things" for an immune system, because of their capacity to trigger the system in a specific way. They are therefore "signs" which the immune system is able to interpret.

Immunocompetence is a thus a "system of interpretation", which works on the basis of a particular physiology and with particular rules, as its "code" of interpretation. Importantly, the property "to be a sign" only exists in relation to a system of interpretation: a molecule is an antigen only in relation to an immune system. An "absolute sign" does not exist, precisely to the extent that an "absolute antigen" does not exist. It is accordingly justified to attempt to verify if the concepts of semiotics (as they emerge from the study of linguistics and other human sciences) can be applied to immunology. Caution and care must be used, however, because very distant cultural domains are involved, and empty metaphors can easily be produced: but in both cases, it is a matter of [the scientific examination of] "things" that are identifiable as "signs" by a deciphering system – in relation to which, they *are* properly "signs".

Systems of Deciphering

Molecular structures are identified by the immune system as provided with a definite special shape resulting from the sequence of their constituents. This brings about a sharp discrimination between the "self" – against which the reaction does not occur – and the "not self". The laws that regulate such reaction must therefore also explain its absence.

Among not-self molecules, definite structural traits allow the distinction between one antigen and the others. The single epitope is confronted with (introduced in) a system of interpretation by which it is manipulated and explored. The single immune system is confronted with (being internal to) the epitopic universe which it is capable of interpreting. This interpretation can be in some extent ambiguous (cross-reactions among different antigens, as they were synonyms; autoimmune reactions; tolerance against not-self molecules), and this fact causes pathological conditions, or can be used in prevention or therapy, Namely, it is possible to manipulate the system, if its rules are known.

The attitude of the immune system to read the world is comparable to that of the nervous system, though in a very different way and on very different objects.

The nervous system is devoted to the discrimination of inputs from the environment (inside and outside) in term of localization and characterization of the emitters, and is based on cooperating elements working in a fixed and invariant position (neurons, synapses). The immune system works by discriminating molecules present inside the body, through elements which cooperate, move, and collide in a free medium. As far as the nervous system is concerned, during the evolution of man such a complexity was attained, that allowed the formation of language and the interpretation of reality through a symbolic medium (semiotics as usually considered). It is matter of higher order: in a linguistic system a sign (e.g. a word) is “triadic” and its connection with reality is mediated by the body of the language itself. What is the relationship between these two signs (a word and an antigen), so distant in the domain of reality?

The problem is that of the semiotic threshold. When, during evolution, can we attribute the character of sign to a matter of fact (thing or event)? When does it raise in nature the occurrence of a thing which is “meaningful” for another thing? The semiotician usually fixes the threshold at the level of man, saying that sign is something which stands for something else in the frame of a language.

We are searching for the natural ancestors of this very recent (human) situation. In our opinion the threshold has to be placed much behind.

Biology as Natural Semiotics

We think that the threshold for “sign” is situated at the very beginning of the biological domain, characterizing its origin and its basic structure. The pre-biological universe is constituted by standard and uniform situations, both of chaotic-statistic type (plasma, gases and liquids) and of repetitive type (crystals). Any condition of selectivity or specificity is absent. Life begins when to such a uniform world, conditions of selectivity are superimposed or, better, when conditions of selectivity are generated from the conditions of uniformity. This status is possible because of the production of molecular structures endowed with sufficient complexity, proper to the chemistry of carbon. An enzyme, which can be considered the simplest example of this status, selects its substrate among a number of meaningless molecules with which it can collide: it reacts and forms a complex with only its molecules partner. This substrate is a *sign* for the enzyme (for *its* enzyme). The enzyme explores reality and finds what corresponds to its own shape: it is a lock which searches and finds its proper key. In philosophical terms, an enzyme is a reader that “categorizes” reality determining the ensemble of all the molecules which can factually react with it. The term *category* is used here both in a Kantian sense (a “point of view” of a reader who gives order to the world) and an Aristotelian sense (the objective ensemble of things presenting a given character). This semiotics (or proto-semiotics) is the basic feature of the whole biological organization (protein synthesis, metabolism, hormone activity, transmission of nervous impulse, and so on). In all these cases a specific relationship between a reader and its sign is clearly established.

Often a molecule is at the same time sign and reader. An organism is constituted by (results from) a high number of these correspondences. Biology is, in itself and in all its aspects, a natural semiotics. (This topic is treated in much more detail in the works quoted in bibliography). This "protosemiotics" constitutes also the ground of the immune reactions.

If a matter of fact is a sign, the reader for whom such a matter of fact is a sign has a proper code of interpretation, and only on the base of this code the matter of fact is a sign. If a molecular structure is interpreted by the immune system as an epitope (and is therefore a sign for the system) the question is: how is the code constituted, how does it work to interpret its reality. The mechanism must be based on the general well established reactions of deciphering (DNA coding, protein syntheses and so on). Then the question can become the following: how these reactions are combined to produce an "immunological interpretation". A novelty, in term of natural history, always is obtained as a more complex relation among ancient and well working mechanisms. Also the great novelty represented by the immune system follows this rule (the language too, in our opinion).

Semiotic Repertoire

The proof that a matter of fact is a sign for a code is the response of the system itself. The proof that a molecule is an antigen for the immune system is the production of a complementary specific molecule (an antimolecule, as a free antibody or as a membrane-associated protein), or can be also a specific interference on this production. The main point is the mechanisms which link the two terms: how the antigen is connected with the synthesis of its anti-structure.

The instructive theory maintains that the antigenic epitope has primary function in the process, because, in some way, that anti-structure built on it: the antigen constitutes the mold for the production of its antibody. This does not exist before the antigen, both as molecule and information, and is constructed *after* and *on* the antigen.

The system has an endless capability to face all the possible epitopic structures.

Such a theory is impossible. Antibodies are proteins, and as all other proteins, are produced from an existing codification represented by DNA sequences. An instructive theory should be based on a totally unknown mechanism of protein synthesis.

The second possibility is that the genetic code contains a certain finite numbers of sequences, capable to rule the synthesis of the anti-structures for all the epitopes. In this case the function of the antigen is less important (through ever necessary), because it simply triggers the work of a preexisting machinery: it selects the single response from the repertoire of all the possible responses. This is the ground of the selective theories. The system of interpretation (repertoire and rules) is an *a priori* of the interpretation of the single epitope: it is properly a code (in the general sense of a systematic modality of interpretation, in the same way that a language is a code).

This mechanism, only supposed till few years ago, is nowadays well known. In each cell of the body all the DNA sequences are present for the anti-epitopic structures, obviously in a finite number, but covering all the possible shapes of antigens.

They are placed in some definite positions in chromosomes (for instance in chromosomes 14, 2, and 22 as far as heavy and light chains of man are concerned). In a definite set of lymphocytes these DNA sequences can be arranged by translation and joining with a random mechanism, so that diversity is generated starting from the same repertoire: in each cell a given combination of DNA pieces is reached, different in principle from any other. So from a repertoire of different sequences a repertoire of different cells is obtained: the semantic dictionary of the immunological code is distributed among a high number of cells, which are in this way different from each other and genetically specific. The core of the system is therefore an heterogeneous population of cells which *as a whole* can read all the epitopes, but only one of them (in principle) can read a single epitope (of course it is not completely true, because the same combination has a certain probability to be reached in different cells). The mechanism of VDJ and C joining is one of the most interesting results in molecular biology.

Therefore the system contains an internal repertoire (as codification of complementary structures) of the epitopic universe: it is an a priori mechanism in relation to the events it can decipher, into which it can fall. In this sense it is not an exception, because all the biological entities are *a priori* in relation to their environment, through a posteriori products of natural history.

In this sense we can say (using with caution these expression) that antigens are the "totally alien" which is introduced into the domain of the language (of the known), being analyzed by a categorical system (made part of a process of interpretation, and, in this sense, "razionalized" by the system).

From the Repertoire to the Syntax

The repertoire of the anti-epitopic DNA sequences constitutes the semantic component of the system. As in all the languages, also a syntactic component is necessary, which establishes the rules for the use of the repertoire: how a definite proposition can be obtained using the words of the dictionary.

The immunological repertoire is, per se, a pure potentiality, that must be transformed in an actual process to obtain the product of the reaction. *Syntax* means rules, and rules means essentially a restriction of possibilities. In fact a syntactic scheme in a language forbids most of the combinations among the words of a dictionary, and allows only few of them: it restricts drastically the high number of random combinations of the words resulting from a kind of thermodynamic collision, and establishes the permitted structures.

The "meaning" resides precisely in this process: from an indefinite causality to an ordered situation, interpretable also in terms of the theory of information and of the theory of communication. It is matter of a "channeling" of the semantic entities into the definite pathway of the syntactic rules.

To use the repertoire, the first step for an antigen is to be handled in a proper manner by macrophages, to be exposed on the surface of a proper cell, and then some fixed processes among specialized cells can take place.

This is the channeling we are speaking about: each step of this represents a structure-antistructure selection trough specific receptors, both between two cells and between a lymphokine and a cell. Only at the end of the chain is the antibody forming cell triggered to clonal amplification and anti-epitope production. Also after this process, some other chains of molecular events must take place, to modulate the amount of the products formed. Many aspects of this picture (many rules of this grammar) are nowadays known, appearing as particular cases of the general "protosemiotics" we are speaking about. Cooperation between T and macrophages, between T and B, between T and T, the action of the different interleukins and so on are all chapters of this glottology. We underline that all the steps are performed, and exist before the "historical" (here and now) event of antigenicity (e.g. the entry of a toxin): the matter of fact simply selects one of the possible channels, individuating the way: a kind of a generative process to form a phrase through a grammar. So the production of an anti-epitopic structure taken from the repertoire can be seen as the formation of a phrase using simpler units of sense.

Also the complex individuation of an input from the external world performed by the nervous system is a definite channeling, each step of which consists in a relationship between molecular partners (the action of ionic pumps that allows the formation of the electric potential, the synaptic relation between neurotransmitters and their receptors, and so on): the only relevant difference is that in the case of the nervous system the channeling is prefixed also in spatial terms as an anatomically defined network, while in the immune response the channeling must be determined each time through statistical encounters of cells.

Semiotics and Syntax: The Syngenetic Restriction

The repertoire contains also the anti-self sequences, and the organism is potentially capable to destroy itself through its immune system.

This event does not take place, because syntax includes rules that forbid that channeling in the direction of what is self, and excludes the self as target. Interpreted either as deletion of clones or as a product of cooperative reactions, tolerance is obtained and maintained through a chain of molecular specificities: also the absence of reaction is a reaction.

Usually the specific trait of the immune system is considered the response against not-self. But two quite different aspects must be considered together: the response is both against not-self (therefore is a general exclusion of self: it is not a choice but a giving up of a large set of choices) and *specific* (against a given epitope).

In the case of antibody production, at the end of the channel we obtain a free anti-epitopic molecule, which can react with the correspondent epitope.

In the case of a cell-cell reaction (cytotoxicity) and in all the cell-cell reaction, an identification of "selfness" is necessary.

Each cell of the system, to cooperate with another cell, must be sure that it is matter of a cell of the *same* system (of the same organism or of an organism of the same individual characteristics) and deciphers on it some signs of “selfness” that mean “compatibility”. This deciphering opens the gate, and the chain can begin. The same happens for the destruction of the cell-target: “foreing” is always interpreted in the frame of the “familiar”, as if it were necessary to preliminary ascertain the use of the same grammar. In fact a language presupposes that the speakers agree to use that language, adopting its syntax and its semantic repertoire: the *unknown* which a language must always face (forming continually *new* phrases) is liable to interpretation because it is introduced in the frame of the *known* (which is *old* and well established, and is precisely the system, the mechanism of interpretation). The signals of selfness are genetically determined: in fact they must be invariant, not dependant on the “personal history” of the individual, or on environmental influences. They are constituted by MHC-coded antigens. The problem of presentation of an antigen together with MHC products (as two separate points, or as one point) is well known.

On the contrary, tolerance is an “historical” event, and depends on what the system finds during its development: it is not genetic but ontogenetic. Important to remark, also tolerance is restricted. This “view of differences in the frame of equality” is compatible with a concept of the immune system as phylogenetically developed mainly to maintain the integrity of the self against the tendency to disorder represented by mutations: the function of the system is to preserve the neatness of the genetic message from the ground noise, and the reaction against exogenous materials (bacteria, toxins, virus) would be only a side effect. Cells presenting “deviation” from the permitted scheme (self cells which become non-self), are eliminated, and for this is necessary that the exploring immune cell can before recognize selfness: it explores continually normal cells and individuates the altered ones confronting these with its (normal) scheme. So an immune cell is the touchstone of the self.

Idiotypic Networks

The amino acid sequence of the antibody combining site is necessarily “new”, therefore antigenic, and produces an immune response. The variable region of the correspondent antibody is the equivalent (in immunological terms) of the antigenic epitope: both (epitope and anti-antibody) can bind to the same amino acid sequence, which constitutes the variable region of the antibody. In its turn, the variable region of an anti-antibody is an epitope, and so on. In the whole immune system an “internal image” of the epitopic universe is present not only in the sense that the anti-epitopic sequences of DNA are present in the repertoire, but also that the system is provided with a universe of internal epitope-equivalents: the outside world has, so speaking, its representatives in the inside domain of the body. The production of anti-images is a continuous function of the system, which is always in a state of internal activity, a kind of at rest work. Therefore the input of an antigen can be seen also as a perturbation induced in a condition of equilibrium, forcing the system to reach another condition of equilibrium.

The character of an a priori mechanism is even more clear. But this does not mean that the immune system (or, generally speaking, an organism) is a kind of "autopoietic" monad, and that the external world is only a shadow: the system is derived from the outside and reacts towards the outside interpreting it. On the other hand, always we see that, in the course of phylogeny, a more precise and efficient interpretation of reality parallels a higher (and not a lower) degree of autonomy of the reader versus the reality to be read.

What is Semiotics for Immunology (and Vice Versa)?

Immunologists can probably be stimulated by the concepts of semiotics (as by those of theories of information and of communication).

They are particularly sensitive to all the phenomena of signaling. Nevertheless the danger is high that they are tempted by a metaphoric use of the terms, that can confuse the argument. In fact semiotics is normally intended as a theory of *human* and *cultural* signs and codes. It involves symbolic activity, hypothetical structures, a formal logical frame and a certain degree of consciousness. Then questions of the following kind (perfectly meaningless) can be posed, and in fact are: if the immune system can make choices, or can build hypotheses, or has an intentionality in synthesizing its antistructures, and so on.

The different modalities in deciphering objective referents develop during natural history in absolute continuity, one from another, but they are distinct, and must be considered distinct. The continuity does not exclude sharp qualitative differences, and the existence of real "crises" in this pathway. A point of crisis is certainly represented by human knowledge, which is in continuity with, but cannot be reduced to, previous systems of meaning. A domain of modalities is also a domain of terms that we use about them, so it is necessary to define the meaning of the words and the context in which they are placed. In this perspective we have specified the term "sign" as a diadic entity which becomes triadic when a sufficient complexity is reached.

A symbolic conventional sign cannot represent the situation of the immune sign, or, even more so, of the "categorical" biological sign (which we have exemplified in the function of an enzyme molecule).

In any case, whether the concepts of semiotics can help the immunologist in his experimental work is, in my opinion, doubtful.

On the contrary, I think that immunology can give fruitfully its concepts to semiotics, to build a general theory of signs and codes, whose scheme we have traced starting from the origin up to the stage of human knowledge.

In our view, it is not symbolic language which "explains" the machinery of the cell, but it is this machinery that must explain (through a situable complexity) the nature of a symbolic language.

There is disagreement between those that consider semiotics as a pure human domain, and the present view of a general semiotic domain: the only question is where to place the threshold for sign. To avoid confusion, the term "protosign" could be used instead, up until the human sign, but this seems to me rather artefactual.

In any case, the common points are that reality is interpreted by *a priori* systems provided by their own codes, and that all are the *a posteriori* products of their natural history (and therefore of the reality that they can read).

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Chapter 11
From Animal to Man: Thought and Language

René Thom (1923–2002)

Introduction and Commentary: René Thom

> *In a few years' time we shall look back in amusement at those writings in which biologists are astonished that the human gene contains hardly more than a thousand times more information than that of the humble coliform bacillus and that it contains much less than those of a triton or a grain of corn. As if the distribution of nucleotides in a DNA chain were equally probable! As if the maintenance and duplication of nucleic material did not require the presence of a cytoplasmic milieu to which it is strictly and specifically adapted! In this connection, only one hypothesis seems plausible: On account of the constraints that the global viability of the system imposes, the DNA chain must organise itself in relatively autonomous and stable segments, the 'significant' segments. Furthermore, these can present a hierarchy of functional subordinates, just as a language splits up into sentences, words and letters. The 'genetic code' barely corresponds to the most elementary level, that of the letters in a word: the 'level of first articulation' of the linguists…Is not such a discipline which tries to specify the connection between a global dynamic situation, (the 'signified'), and the local morphology in which it appears (the 'signifier'), precisely a 'semiology'?*
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> R. Thom (1983: 168–169)

Musing upon the intellectual foundations of his biosemiotic worldview, Thomas A. Sebeok once remarked, more seriously than not, "I consider myself a Thomist – a René Thomist, that is" (1991: 157). Given that Sebeok – a self-described biologist manqué, a professional linguist, and a committed interdisciplinarian in many ways, but in no sense a mathematician – would claim such intellectual affinity with a man whose life's work revolved around differential equations and topological geometry, may seem to call out for explanation for some readers, as may the inclusion of mathematician René Thom in this book. Those more intimately acquainted with Thom's writings, or with the history of biosemiotics, however, will understand at once Thom's place in this anthology of biosemiotic writings, and why Sebeok regarded "the semiotic intimations of the French polymath René Thom as nuggets of pure gold [and as] pointers towards the elevation of the doctrine of signs to the status of a theory or a science" (1979: viii).

René Frédéric Thom was born on September 2, 1923 in Montbéliard, France. The son of shopkeeper parents, Thom early displayed a genius for mathematics, graduating with honors from Collège Cuvier in Montbéliard in 1938. He received his baccalauréat degree in elementary mathematics from Besançon in 1940, and a baccalauréat degree in philosophy the following year in Lyon. He attended the Lycée

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Saint-Louis in Paris in 1942, and was accepted into the prestigious École Normale Supérieure in Paris in 1943, where he studied under the algebraic topologist Henri Cartan (1904–2008), co-founder of the mathematical collective that published under the pseudonym of "Nicolas Bourbaki."

After graduation, Thom followed Cartan to the University of Strasbourg in 1946, taking a research post with the Centre National de la Recherche Scientifique which allowed him to complete his doctorate in 1951. His doctoral thesis, entitled *Fibre Spaces in Spheres and Steenrod Squares*, contained the foundations of his later theory of *co-bordism* – a hybrid of topological and algebraic approaches to the study of jointly bound manifolds that would play a decisive role in his thinking about both animal morphology and semiotic intelligibility several decades later, and for which he was awarded mathematics' highest honor, the Fields Medal, seven years later.

While on a fellowship to do mathematical research in the United States after the completion of his doctorate, Thom attended seminars by the mathematicians Eugenio Calabi (1923–) and Kunihiko Kodaira (1915–1997) and held personal discussions with Albert Einstein (1879–1955), Norman Steenrod (1910–1971) and Hermann Weyl (1885–1955). Two years later, he returned to France, where he taught topology and mathematics at the University of Grenoble from 1953 to 1954, at the University of Strasbourg from 1954 to 1963, and, from 1964, at the Institut des Hautes Études Scientifique at Bures-sur-Yvette, France, where he would spend the rest of his academic career. Thom was awarded the *Grand Prix Scientifique de la Ville de Paris* in 1974, and died in his home at Bures-sur-Yvette on October 25, 2002, at the age of 79.

According to his obituary, Thom recounted late in his life that the awarding of the Fields Medal in 1958 had "brought him the freedom to choose what research he wanted to do, and for him that was essential. He began to take the whole of science as his canvas. He was not a theoretical or experimental scientist, in the sense of designing experiments and predicting results, but rather a philosopher of science, writing about the long-term future developments in the sciences that needed to occur" (London Times 2002). Accordingly, after 1963, Thom's work moved away from its previous emphasis on working out the mathematical equations of differential topology (the field which he had already contributed such lasting innovations as the notions of characteristic classes, co-bordism, the Thom transversality theorem, the Thom conjecture of genus minimization in class homology, and what are now called by differential topologists, 'Thom spaces') and towards the exploration of what would later be called *singularity theory* – i.e., the study of how geometric "stability" emerges from, and is maintained within, the ever-shifting manifold of a multi-dimensional dynamic.

An interdisciplinary thinker by temperament,[1] Thom realized that the principles of structural organization and form-creation revealed by the study of singularity

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[1] "Thom was forced to invent catastrophe theory in order to provide himself with a canvas large enough to accommodate the diversity of his interests," writes colleague Christopher Zeeman (1977: 373).

mapping may prove fruitful to the application of any field of inquiry where the anomalous "emergence of order out of chaos"(cf. Prigogine 1984, Holland 1992, Kauffman 1995) – or to use Norbert Wiener's famous phrase, wherein the puzzle of "islands of negentropy ... resist[ing] the general stream of corruption and decay" (1973: 27) – is an issue. Today we are used to thinking about naturally occurring processes in such terms, but it should be remembered that when René Thom was pioneering such thinking in 1964, the sciences of "chaos theory", "self-organization", "dissipative structures" and "dynamical, far-from-equilibrium, complex-adaptive systems theory" were, in effect, awaiting their seeding in the work of Thom's own soon to be developed *catastrophe theory*.

Conceived in 1964 and presented to the world for the first time in a series of two articles in 1968, Thom's "outline for a general theory of models" sought to use the equations of singularity theory to characterize the dynamic topology of multidimensional possibility space wherein structural "stability" of any kind (e.g. organismic, social, ecosystemic, or linguistic) not only emerges and maintains itself, but also wherein such stability-inducing form *changes* in response to perturbation in ways that either preserve, modify or destroy its original formal integrity. Thom calls the points whereat a continuous process "jumps" into discontinuity, and in so doing is reconfigured into a newly continuous state, *catastrophe points*, after the Greek word *καταστροφή* – a term used to designate that point in the ongoing development of events (e.g., a drama), whereat a "sudden turn" initiates a consequential new trajectory.

Such continuity-breaking and trajectory-changing events are critical to the development of any kind of *form* – biological and socio-historical, as well as mathematic and topological, according to Thom. Not surprisingly, then, Thom considers the proper object of his investigation to be *morphogenesis* – i.e., "form" creation per se. Thus, he cites as formative influences upon his thinking the works of structuralist biologist D'Arcy Thompson (1860–1948), organicist neurologist and Gestalt psychologist Kurt Goldstein (1878–1965) and developmental embryologist Conrad Hal Waddington (1905–1975).[2]

In trying to understand the differentiating yet non-random processes of embryonic development, Waddington, like Thom, understood himself to be grappling with foundational questions that go back to the beginning of systemic biological inquiry in the West; and with the attempt to provide modern-day scientific answers to Aristotle's still largely unanswered questions about *forms* and *ends*. "How does development produce entities which have Form, in the sense of integration or wholeness," asked Waddington, "and how does evolution bring into being organisms which have Ends, in the sense of goal-seeking or directiveness?" (1957: 9).

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[2] Thom cites only one more thinker as a conceptual precursor in this passage introducing his magnum opus, *Structural Stability and Morphogenesis*; it is animal ethologist and *Umwelt* theorist Jakob von Uexküll (1864–1944). The relationship between Uexküll's *Bedeutungslehre* and Thom's *semiophysics* still awaits an extended scholarly analysis (but see Baer 1987: 196–201 and Sebeok 1979: Chapter 3). For more recent biosemiotic analyses of the relationships between Uexküll's *Bedeutungslehre* and Thom's *semiophysics*, see Augustyn (2005) and Bundgaard and Stjernfelt (2010).

Accordingly, in the preface to the English translation of Thom's 1972 work in catastrophe theory, *Structural Stability and Morphogenesis*, Waddington notes that in this work, René Thom is turning his attention to "one of the major problems in epistemology" – the problem of discontinuity in a world that appears to be constructed upon four dimensions of continuity; in short, the problem of the emergence of new *form*. "It is easy to accept," writes Waddington, "that the chemical composition of differentiating cells needs for its description a multidimensional function space, and that the sudden boundaries created between one tissue and another are examples of Thomian catastrophes" (1975: xvi). Thom, in turn, drew considerable inspiration in his work from Waddington's (1940, 1957) concept of the *epigenetic landscape* as the dynamic substrate of conditions making possible the multiple realizations of probabilistic form.

For Waddington, the puzzle to be solved in developmental biology is to understand exactly what happens at each point along the ever-complexifying developmental pathways of embryogenesis, such that a single undifferentiated cell can divide and interact with its progeny so as to eventually result in the massively differentiated and biologically specific cells, tissues, limbs, bones, organs, and interconnected functional systems of the organism (see Fig. 11.1). Part of this puzzle, felt Waddington, entails discovering the underlying principles and mechanisms whereby slight (but statistically inevitable) deviations and perturbations along such pathways either do, or do not, result in massive change or developmental failure.

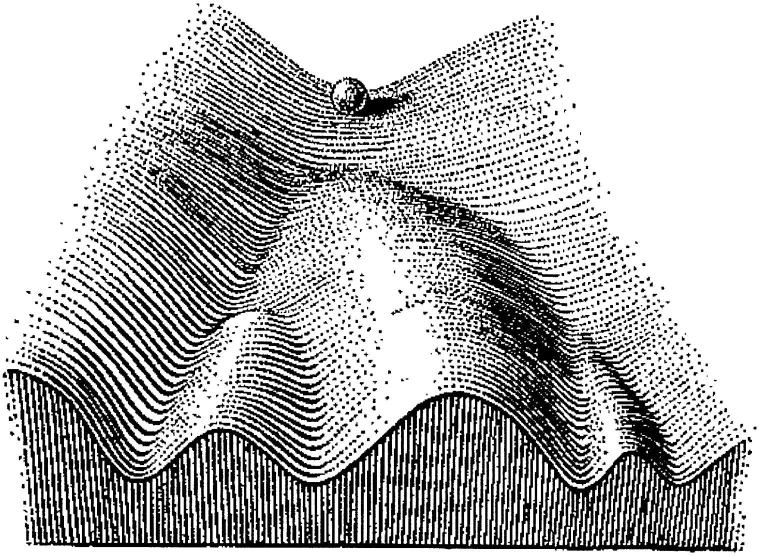

Fig. 11.1 *Waddington's Epigenetic Landscape*: Waddington's heuristic depiction of the developmental history of the fertilized egg during embryogenesis. Multiple alternative pathways of possibility appear at every point, but certain pathways (*chreods*) have become more evolutionarily "en-trenched" and can only be avoided by the crossing of "thresholds" that then make available alternative pathways, and so on, serially, throughout (Illustration from Waddington 1957: 29)

In Waddington's work, Thom saw deep parallels with his own. "A process (P), is *structurally stable* if a small variation in initial conditions leads to a process (P^1) isomorphic to (P) in the sense that a small transformation in space-time (an ε-homomorphism in geometry) will bring the process (P^1) back to the process (P). This leads us quite naturally to Waddington's notion of 'chreod' and of the 'morphogenetic field' in general," wrote Thom, noting, too, that "this idea of interpreting cellular differentiation in terms of a 'stable metabolic regime' – i.e. an *attractor* of biochemical kinetics – is often attributed to [physicists Max] Delbrück (1906–1981) and [Leó] Szilárd (1898–1964). When in fact, it was stated in its local form, which is the only correct one, in C. H. Waddington's *Introduction to Modern Genetics* in 1940" (Thom 1983: 16, 17fn). Catastrophe Theory, explained Thom, consists in "the mathematical study of the 'bifurcations' presented by these multi-dimensional attractors, and the topological nature of the catastrophes that result" (Thom 1983: 20).

For Thom, however, the transient and ever-consequential coming-into-being and destruction of chreodic pathways of possibility and actuality in the organism constitute not only the dynamic of embryological development, but are the key to explaining the persistence of the organism itself. Thom thus felt that the phenomenon of "life" itself is best thought of as a processural and "lifelong epigenesis" whereby the organism's structural stability is maintained only by the incessant interaction "between [morphogenetic sub-]'fields' of a more elementary character, from which emerges the structurally stable configurations that assure control, homeostasis of the metabolism, and the stability of reproduction" (1983: 26).

Addressing areas of concern similar those of Howard Pattee (1926–) and Giorgio Prodi (1928–1987) – whose independently undertaken investigations are also represented in this volume as Chapters Ten and Seventeen, respectively – Thom is interested in the emergence (and the often counter-intuitive consequences) of both systemically-generated *constraints* and *affordances* within the dynamics of a generatively active-space.

With Prodi (1988: 22), Thom believes that the ongoing dynamics of the living organism constitute an interacting "field of vectors" wherein local dynamics that have become structurally stable *a posteriori* (through the attainment of their "limit state") "rule over an open set of neighboring points" *a priori*, in the manner of Waddingtonian "attractors," thereby effectively, partitioning the system whole into various domains of semi-autonomous attractor states.[3] In turn, such various domains of locally consequential attractor states are separated from one another by points of discontinuity "which form what we call the set of *catastrophe points* of the process" (Thom 1983: 194).

"There is therefore no mystery in the notion of the *morphogenetic field*", writes Thom. Rather

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[3] In 2000, neurobiologists Gerald Edelman and Guilio Tononi would propose a similarly rich concept of the transient but consequential "dynamical functional clusters" that arise and dissipate in brain activity – a concept is very Thomian in spirit, if not in origin.

> this notion simply expresses the fact that a process happens in conformity with a [topology] given *a priori*, and in a structurally stable manner. In every natural process, one first tries to isolate those areas where the process is structurally stable: [These are] the 'chreods' of the process – islets of determinism separated by zones where the process is indeterminate or structurally unstable. By introducing dynamic models, one then tries to break down each chreod into elementary catastrophes, and then to bring the organisation of these elementary chreods back to a stable global form by the action of an implicit singularity of the dynamics [which constitutes its] 'organising centre' (1983: 16).

At the heart of Catastrophe Theory, notes Thom, is the realization that "the properties of this set constitute the *morphology* [i.e., the topology of continuity and discontinuity] of the process" under observation (1975: 38). As such, Thom understood Waddingtonian *chreods* as "coherent *systems of catastrophe*" that could be taxonimized into characteristic classes, or archetypes, of "form"creating processes.

Thom's taxonomy of "elementary catastrophes" – i.e., the morphologies of formal possibility – include *folds* (the destruction of an attractor, and its capture by an attractor of lesser potential), *cusps* (the bifurcation of an attractor into two disconnected attractors), *hyperbolic umbilics* (the singularity – or "organising centre" – presented by the crest of a wave as it breaks), and many more (1975: 110; 1983: 19). Such elementary catastrophes, Thom notes, are found both in inanimate as well as animate structures – crystals and hurricanes, as well as in tree branching, bronchial tubing and neuronal dendrition.

"But it is clear," writes Thom, "that [elementary catastrophes] would not be sufficient to account for all the development of a living being" (1983: 20). For this, claims Thom, requires that "the appearance of a new 'phase' in an initially homogenous milieu leads to an appearance of the kind which we call a 'generalized catastrophe.'" Thom uses the term "global control form" to capture this ontogenetically emergent self-stabilizing dynamic characteristic of a living being. "An animal, for example, is distinguished by its global stability: submitted to a shock, to a stimulus (s), it will reply by a reflex (r) which will have the effect, in principle, of annulling the perturbations caused by the stimulus (s)" (1983: 23).[4] With Pattee (1961, 1966), then, Thom is interested in examining the ways in which the increase in complexification of a systems' internal interactions can result in system-preserving "simplification" by the eventual canalization of "conformation-dependant propagation rules" that then to function as "nonholonomic constraints" upon the system's self-maintaining yet adaptive dynamics.

With Pattee, too, Thom, understands that the capture and control of possibility trajectories by a system's constituent-level "constraints" may, especially in interaction with one another and with a responsive environment, allow such systems

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[4] In this regard, it is interesting to compare Thom's 1966 criterion of "life" as a finality-manifesting and self-stabilizing "global control form" with the similarly motivated notions of life as a processural and self-maintaining 'autopoesis' as articulated by Maturana and Varela in 1973, and with Robert Rosen's 1971 notion of life as characterized by replicative systems of metabolism and repair ("M,R systems") that are "open to material causation, but closed to efficient causation" (1971: 57). Of the three approaches, only Thom's attempts to account for all four forms of Aristotelian causation in the biology of living systems.

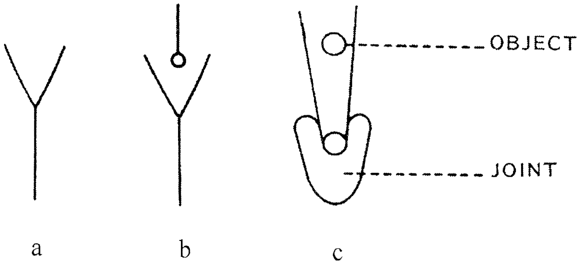

Fig. 11.2 *Evolution of the Grip Morphology:* (**a**) depicts a standard "bifurcation" catastrophe in the development of a system: Each of the two "branches" is being directed towards a different attractor state. (**b**) depicts the capture of a third attractor state between the original two – the *grip* archetype. (**c**) depicts the grip archetype as it manifests in the biological morphology of ball-and-socket, bone-and-joint, ligand-and-receptor (and perhaps even Uexküll's sensorimotor "forceps")

to enter into higher-dimensional possibility spaces.[5] Thom see this phenomenon, too, as a generator of both biological and phenomenological form. The emergence of Thom's "grip archetype" (Fig. 11.2) neatly illustrates how this shaping of immediate-next possibility by topological constraints canalized previously in time can result in the emergence of biological function, embryogenetic development, and the embodied *Gestalt* of organismic "knowing."[6]

Having introduced Catastrophe Theory in 1968 simultaneously in two forms: one, with a paper on semiotics, and the other, with a paper on biological morphology that he understood as being complementary to the first, René Thom qualified for the title of "bio-semiotician" a good five years before Thomas A. Sebeok first introduced the term. "Clearly," wrote Thom in this foundational paper, "it is in Biology, the science nearest to man, that one would expect to see the reappearance of the notion of *meaning*" ([1968] 1983: 168).

Accordingly, analyses of the emergence of form-born and form-bearing structures and "meaning topologies" appear side-by-side with the investigation into biological development and its possibility morphologies in Thom's writings.[7] Thom's theories of meaning, like those of all biosemioticians, cannot be properly understood if disengaged from his understandings about biology – which is why we have taken the time to present at least an orienting grounding to the basics

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[5] Jesper Hoffmeyer articulates a similar argument about the generative dialectic between biological "fatedness" and "freedom" in 1996: Chapter Three of *Signs of Meaning in the Universe* (1996).

[6] In this last conceptualization, Thom clearly reveals his indebtedness to Jakob von Uexküll's *theory of meaning,* wherin the organism "grasps the world [experientially] with the two forceps of its receptor organs and its effector organs" (1940: 22.). Similarly: "How, then," asks Thom, "shall we characterize *perception* if not as: The modification of a competent dynamic under the sensory aspect of external reality?" (1983: 263).

[7] In English, see, especially: Chapters 10 through 15 of *Mathematical Models of Morphogenesis* (1983), Chapters 2 and 8 of *Semiophysics* (1990); and Chapter 13 of *Structural Stability and Morphogenesis* (1975), which appears in a slightly abbreviated version as the selection which follows.

of Thom's Catastrophe Theory to the reader in this introduction. Hopefully, that grounding will prove sufficient to allow the reader to follow Thom's thinking in the following selection, where – after having considered the topological morphologies characteristic of genetic mutation (1975: 281), death (1975: 285), and the origins of metabolism (1975: 286) and evolution (1975: 291) in the chapter prior, Thom now turns his considerable mathematical and philosophical skills to an examination of the problems of reproduction tool use, language society and memory in living systems.

The selection that follows was written by Thom between 1964 and 1968, for publication in his first book-length treatment of catastrophe theory, which was published in 1972. It was released in an English version in 1975, and by 1976 had come under the careful attention of Thomas A. Sebeok, who publically praised Thom's work and who consistently stressed its potential for the development of a biology-based science of signs (1976: 156). Sebeok later cultivated a professional relationship with Thom, who found in Sebeok a kindred interdisciplinary spirit (Thom 1977: 44), and in 1990 – due in no small part to his then decade long acquaintance with Tom Sebeok – René Thom published a book-length manuscript detailing his *semiophysics*, or embodied topological theory of meaning.

"Concerned in the first place with the seeking out of [the morphology of] *significant forms* in order to build up a general theory of *intelligibility*," writes Thom (1990:vii), *Semio-Physics: A Sketch,* is as difficult and *sui generis* a conceptual framework as is catastrophe theory, from which it derives. By turns Peircean, Uexküllian, and Lotmanian, it is nonetheless ultimately a *structuralist* theory of meaning, proceeding from the foundational assumption that "the problem of a *structurally stable mapping* lies at the heart of every theory of representation and of semantics" (Wildgen 2005: 3).[8]

Developed almost twenty years after the following selection was written, an in-depth discussion of Thom's *semiophysics* here will not help the reader coming to this volume for an introduction to biosemiotics and its seminal texts (nor would have the reprinting a selection from *Semio-Physics* in place of the chosen selection, given the prerequisite acquaintance with catastrophe theory that it assumes). But a small discussion here of its twinned pair of foundational concepts will give the reader a general sense of the theory's fundamental approach.

At the basis of Thom's *semiophysics* are the complementary morphogenetic topologies that Thom calls *salient forms* and *pregnances*. *Salient forms* are defined as "any experienced form clearly separate from the continuous background against which it stands out" (1990: 162).[9] Physically discontinuous by definition, such

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[8] As the aggregate effect of reading this anthology as a whole should make clear, however, the currently perceived "conceptual antagonism" that might seem to make impossible a coherent reconciliation between the *structuralist* and *Peircean* approaches to meaning – as between the *organicist* and *mechanist*, *Baerian* and *Darwinian*, and *Hoffmeyerian* and *Barbierian* ones, to take just some contemporary examples – appears more and more untenable the more one reads, and will almost certainly not withstand the continued growth and development of the field.

[9] Cf C. S. Peirce's notion of firstness and iconicity, as well as Gregory Bateson's notion of a "difference which makes a difference" as the fundamental unit of information.

salient forms are "translated into [analogous] discontinuities in the subjective sensorial state, sometimes with enormous amplification" and cascading propagating effects, writes Thom (*ibid*). They differ from morphogenetic *pregnances* in that

> Although salient forms can have a certain impact on a subject's sensory apparatus (a flash of lightning can dazzle), this effect remains transient and short-lived. Salient forms are likewise registered in the short-term memory, but have no long-term effect on the behavior of the subject (human or animal) or on its physiological state. The situation is different where forms that carry a biological significance for the animal are concerned. Among these are the forms of prey for the (hungry) predator, of the predator for its prey, of a sexual partner at the appropriate time. The recognition of these forms gives rise to a very ample reaction in the subject: the freeing of hormones, emotive excitement, and behavior designed to attract or repulse the inductive form. I will call such forms *pregnant,* and this specific character of theirs, *pregnance* (1990: 167).

"Pregnances," writes Thom, "are non-localized entities emitted and received by salient forms" (1990: 16). "Of course," he notes, "all pregnant forms are *ipso facto* salient" (just as the Peircean "index" is *ipso facto* "iconic" on a more primitive level). To illustrate this, Thom uses the well-known example of Pavlov's dog, wherein "the *salient form* that is the sound of the bell is *invested* by the alimentary *pregnance* of the meat" (in a manner recalling Uexküll's "meaning-stamping"). For Thom, a morphogenetic analysis of the Pavlovian example aptly illustrates the general phenomenon of *semiosis,* whereby such *pregnance* can be seen as akin to "an invasive fluid spreading through the field of perceived *salient forms*, the salient form acting as a 'fissure' in reality through which seeps the infiltrating fluid of *pregnance*" (1990: 194).

Accordingly, Thom uses the phrase *par réversion de la causalité génératrice* to denote that property of *pregnance* that Sebeok, when discussing the Peircean index, calls "the inverse of physical [efficient] causality [whereby] the index [or *pregnance*] always performs as a sign the vector of which is towards the past" (Sebeok 1986: 50). When such morphologies of *pregnance* emanating out of *salient forms* – in other words, when the *meanings* invested in entities by the triadic agent-object-action sign relation – become incorporated into biological systems (either evolutionarily or in the lifetime of the organism) for use in dealing with future similar relations, the resulting process of in-form-ation reveals that "semiotic" activity "in its origin, is linked in an essential manner to *biological* control systems," writes Thom, "or more exactly, as said by older thinkers who were not afraid of words, to biological finality (*finalité*: ultimate purpose)" (1983: 286).

Language, Thom will next go on to argue, is not only what frees the human being from their "enthrallment by objects" [i.e., those physically present *salient forms* and their *pregances*, both those immediately present and those that have become biologically canalized] – the "tyranny of the here and now"– but is also a *collectively-realized social control structure* for Thom (1983: 274–275). "In man, as in animals, symbolic activity originates in the need for regulation: *homeostasis* in the living organism and, similarly, *stability* in the social body" writes Thom (1983: 269). Consequently, the signals used in a collectivity are *vectors of pregnance*: "the transfer a pregnance from one member of the community to another, or to several others, so promoting collective behavior" (1990: 22). These vectors, the "substrate space" of Thom's "intelligible ontology" (1990: 57) correspond to Lotman's *semiosphere* – a point made in some depth by Lotman scholar Edna Andrews (2003: 54), though Thom himself seems never to have read Lotman's work.

In short: Thom's *salient forms* are topically disjoint objects (including biological agents) that function as *sign vehicles*, and his *pregnances* are the *meanings* that these sign vehicles become invested with as a result of their interaction in the world (including their interaction with other *pregnances* and other *sign vehicles*).

And as Thom notes, "the ideal of contemporary science – and of positivism – is to reduce everything to *salient forms*, with no interaction allowed other than collision between salient forms, and to do away entirely with *pregnance*" (1990: 162). With this last observation, Thom proves himself a biosemiotician in spirit, if not in name.

His legacy in the history mathematics solidly established and recognized by the time of his receipt of the Fields Medal at age thirty-five, Thom was free to spend the next four decades developing his thought in whatever ways he found most worthwhile. He was to come into contact with the nascent biosemiotics community in Denmark in 1986, when was invited by semiotician Frederik Stjernfelt to give a talk on catastrophe theory to Jesper Hoffmeyer and Claus Emmeche's "Helmuth Hansen Study Circle" (later to become the Danish Semiotics of Nature Association) at the University of Copenhagen.

Even more consequentially, in 1985, Thom arranged for the publication and personally wrote the preface for a book by a young biologist who, completely independently of Sebeok's or Hoffmeyer's biosemiotics, had been painstakingly developing a "semantic biology" of his own. That book was entitled *The Semantic Theory of Evolution* (1985) and its author, Marcello Barbieri, would go on to become one of the world's leading biosemioticians, and the founder of the theory of "the organic codes" (2003).

Thus, while the explanatory shortcomings of catastrophe theory in the 1970s would give way to the more expansive dynamics of chaos theory in the 1980s (which would, in turn, give way to complexity theory in the 1990s and – some might argue – to biosemiotics in first decade of the 21st century), it should be now clear why Thomas A. Sebeok so enthusiastically embraced René Thom as a kindred spirit and a fellow pioneer in the attempt to create a scientifically defensible, and wholly naturalistic, theory of signs.

From Animal to Man: Thought and Language (1975)

The Animal Mind

Genetic Forms

It is striking to observe how efficiently the capture of prey is realized, even at the lowest levels of the phylogenetic tree. This forces us to postulate that each animal has an organic chart of its mobility that enables it to control its own actual movements with remarkable precision so as to capture its prey or flee from its predators.[10] However, there is no reason to believe that this chart is permanent; it is more often associated with an object of fundamental biological importance (e.g., a prey or predator) and is focused on that object. We shall designate the innate forms, handed down in the endowment of the species and determining a well-defined motor action; by the name of *genetic forms*. Then, as soon as an external form is recognized as a genetic form, a perception catastrophe takes place, and the "ego" is recreated in an action, in the motor chreod (of capture or flight) that the genetic form projects onto the external form.

This poses an important theoretical problem: how can these genetic forms be represented, and on what space are they defined? Although it is not easy to reply to these questions, one thing is certain: it would be wrong to represent these forms as permanently fixed engrams, like prints on a photographic plate. In reality, they are defined dynamically, by a kind of never-ending embryology which extends into the motor chreod focused on the form. From this comes the fact that the metrical control of genetic forms is in general not very rigorous and often supranormal releasers trigger off the reflex more effectively than the normal biological form. Besides, the space on which these forms are defined can only exceptionally be identified with the outside space, and when the identification happens without external cause we say that there is a *hallucination*. Very probably this biologically disastrous phenomenon of hallucination is as rare in animals as in man, and it can be realized only in pathological states like those of sensory deprivation. In states of normal vigilance the permanent input of the senses into the mind represses the intrusion of genetic forms in the cycle of sense and motor activities.

Thus the ego of the animal is not, in principle, a permanent entity, any more than his vision of space is global. The *territory* of an animal is, in reality, an aggregate of local charts, each associated with a well-defined motor or psychological activity (areas for hunting, congregating, sleeping, etc.), and. passage from one chart to another takes place through well-defined visual or olfactory markers. For certain animals some of these charts can extend over enormous distances, as with migrating

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[10] The idea that mental activity must realize some model of the environmental space of the animal – so ineluctable to my profane mind – seems very uncommon among physiologists. It does occur, however, in J. Z. Young (1964).

birds, but here again the charts are centered on a territory and have a well-defined physiological vocation.

These, then, are the characteristic signs of the animal mind: impermanence of the ego, alienation by genetic forms, and decomposition of space into local charts, each associated with a partial ego. However, in the higher animals at least, there are mechanisms acting to remedy this fragmentation.

Animal in Quest of Its Ego

One of the most evident manifestations of this impermanence of ego, still clearly apparent in man, is the circadian alternation of sleep and wakefulness. It is not unreasonable to see this cycle as a realization of the predation loop, synchronized to the alternation of day and night. In animals the wakeful period is appropriate for hunting-night time for nocturnal predators, and day time for diurnal; and sleep is then the ill-defined period covering the transition between the satisfied predator and the hungry predator identified with the prey, as we have seen. Then, beginning with reptiles, we see the appearance of a mechanism smoothing to some extent the transition from sleep to wakefulness: dreaming.

Dreaming

It is well known that the relative length of dream or paradoxical sleep increases as one climbs the phylogenic tree. It is natural to see this paradoxical sleep as a kind of virtual spatialization of the genetic forms; dreaming gives rise to a partial ego, without come-back to the dreamer, without substance or liberty – a veritable prey of its preys or its predators. Thus we could define dreaming as a constrained activity, dealing fictitiously with fictitious objects. As such, sleep permits a considerable temporal extension of the ego during this period of unconsciousness.

Play

Another factor having an important role in stabilization of the animal ego is play. Observe, for example, a young cat in the process of playing; it will behave as if attacking genuine prey in front of an object like a ball of wool or string, having only a distant morphological analogy with its prey. The animal is certainly not deceived; it has created a playful ego that is not at all disturbed by the lack of final reward when the pseudoprey is found to be inedible. Thus play is a dual activity to dreaming; whereas the latter is a constrained activity dealing fictitiously with fictitious objects, the former is a spontaneous activity practiced in reality on real objects. Of course play may follow rules: in fact, it is often a highly structured combination of rules. But the absence of effective reward makes it into a free activity that the animal may abandon or take up at any moment.

Also this predatory playful activity gives valuable experience in distinguishing between edible and inedible objects; this exploration goes on almost continuously in human babies between 8 and 11 months of age. In this sense wakefulness in animal and man is a state of continuous virtual predation. Every perceived object is treated as a virtual prey, but only objects of sufficiently promising form can initiate the capture process, while the others are weighed by perception, which in man behaves in this respect like a virtual hand. The etymology of *percipere* is "to seize the object continually in its entirety."

A Fundamental Contradiction in Biological Regulation: The Persistence of the Subject and Periodicity of Actions

The Predation Loop

The essential regulation constraint on an animal is feeding, which alone allows it to replace its loss of chemical energy and to restock its reserves. Now feeding implies predation, the presence of another living being (animal or plant), the prey, which is to be captured and ingested. The corresponding morphology is thus the capture morphology (Fig. 11.3), whose simplest algebraic realization is given by the Riemann-Hugoniot catastrophe. As we want specifically to express the asymmetry between subject and object, between predator and prey, we associate to each living being (or, in linguistic terminology, each *actant*) a minimum of a potential on the space of internal variables. Then the spatial capture of one actant by another is to be interpreted as the capture of the basin representing the prey by the basin of the predator. This leads to representing the capture morphology as a typical section of the cusp by an oriented line L of the universal unfolding of the catastrophe (Fig. 11.4). For example, on a line parallel to the Ou-axis, the point K

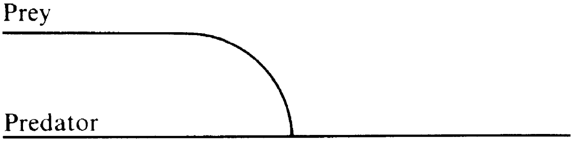


Fig. 11.3 The capture morphology

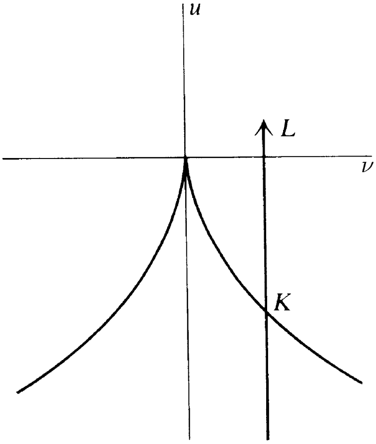
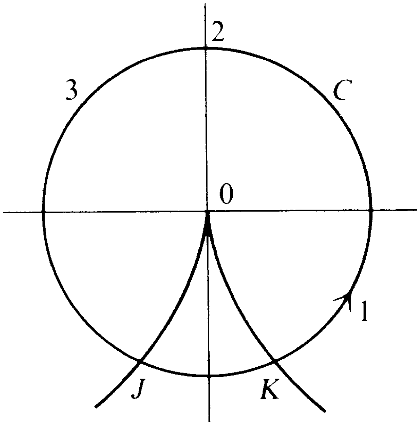


Fig. 11.4 Capture morphology as section of a cusp catastrophe unfolding

Fig. 11.5 The predation loop



where this parallel meets the discriminant curve $4u^3 + 27v^2 = 0$ denotes the catastrophe point where the prey is ingested by the predator. Now such an interaction is fundamentally irreversible. If we want to arrange things so that the animal can again be in a state of capture of a new prey, we must replace the oriented line L by a closed cycle C which restores the organism to its original state, a requirement of the periodicity of actions. Such a closed cycle must necessarily be centered on the origin, the organizing center of the catastrophe (Fig. 11.5). However, if we lift this closed cycle to the space of internal variables, we find that, often having traversed arc *123* of C, the predator *becomes its prey*. Thus the periodicity of the action implies an identification between predator and prey, a *confusion of actants*.

Faced with so paradoxical a conclusion, one might be tempted to reject the model; however I think to the contrary, that this difficulty of principle must occur in all models. Even more, I think that the progressive elimination of this difficulty sheds unexpected light on many aspects of biological morphogenesis and on the origins of magical ritual in man (on *participation*[11] in the sense of Lévy-Bruhl). We can suppose that the spatiotemporal continuity of the organism, of the domain of space-time occupied by it, is the very basis of the unity of the organism. However, if we extend this requirement to the "semantic spaces" describing the internal properties of an organism, we might easily encounter situations that contradict this

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[11] The belief that man can transform himself into an animal is very widespread even today, and the animals into which he believes that he can change himself are universally those that are in the relationship of predator on man (wolf, tiger, shark, etc.) or his prey. In particular, in many primitive tribes the hunt begins with a ceremony of a virtual dance in which the hunter, dressed in a skin of the prey, imitates its movements and behavior. In biological morphology, on the other hand, the presence in many predators of bait organs, like the end of the tongue of a lamprey with its wormlike form, can scarcely be explained other than by the existence in the genetic endowment of a simulating structure of the mind of the prey (or sometimes of the predator; for example, the ocellate designs on the wings of some butterflies, which have the effect of keeping birds off).

requirement of spatiotemporal connectivity. It could be that the essential function of the mind and cerebral organization is to overcome this contradiction. What does this mean?

The hungry predator having traversed arc *123*, is its prey until it reaches point *J*, where the cycle *C* meets the upper branch of the bifurcation cusp. There is a catastrophe at *J*, the *perception* catastrophe. If the predator is its prey before *J*, this means that the mind of the predator is dominated, alienated by the image of its prey. In some sense, the nervous system is an organ that allows an animal to be something other than itself, an *organ of alienation.* As soon as the external prey *p* is perceived and recognized by the predator, it becomes itself again, and it jumps from the surface corresponding to the prey to its own surface in an instantaneous *cogito.* At this moment, the chreod of capturing the prey is triggered, this chreod having several modalities according to the behavior of the prey (fight, flight, etc.); thus this is a motor chart focalized, at least at the beginning, not on the organism but on the prey. The ingestion catastrophe occurs at *K*; and a spatial smoothing of this catastrophe gives rise to the digestive tube, a tubular neighborhood of the trajectory of the prey in the interior of the organism of the predator (Fig. 11.6).

How should we interpret this catastrophe which, at *J*, ensures the organic continuity of the predator despite the mental discontinuity? Consider the hysteresis loop associated with the folding defined by the predator-prey conflict (Fig. 11.7); it has a simple interpretation in terms of energies. The *Ov*-axis denotes the amount of reserve chemical energy, and in the capture chreod the predator must reach into his energy reserves (on the lower sheet, decreasing *v*) in order to convey the prey p to the point *K* of ingestion. We might regard the vertical arc *Jb* as the central nervous system in vertebrates; or, considering the stable sheets as rivers, the arc *Jb*

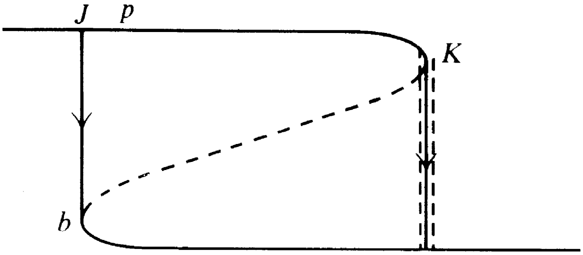


Fig. 11.6 The digestive tube

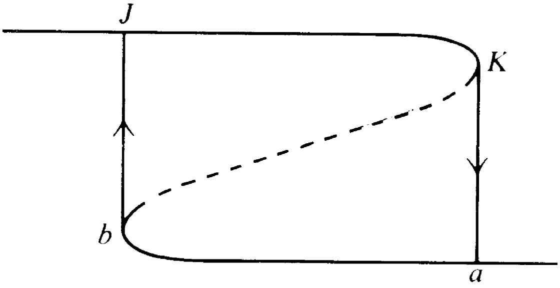


Fig. 11.7 The hysteresis loop

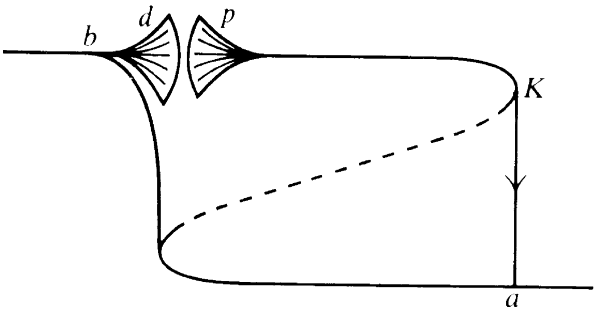


Fig. 11.8 The dissociation of neural crests

might be interpreted as a capture process of the upper river by a particularly active affluent of the lower river. This capture catastrophe is none other than the neurulation producing the invagination of the nervous tube in the epidermis. After capture, the arc *bd* (Fig. 11.8) will be a dead valley where the hydraulic circulation will become ramified, leading eventually to a generalized catastrophe; this corresponds to the dissociation of neural crests which will mainly contribute to the organogenesis of sensory organs. On the other side of this threshold *d*, there will be another generalized catastrophe*p* describing the spatial indeterminism of the position of the prey. Recognition of the analogy between the perceived form *p* and the typical form, the "genetic" form, initiates the perception catastrophe by a phenomenon of resonance, for how can we ever recognize any other thing than ourselves?

The Reproduction Loop

Biological reproduction is a process in which a parent organism *A* creates a descendant *A*', which breaks off spatially from the parent (Fig. 11.9). Therefore the morphology realizing this is the emission morphology obtained by reversing the orientation of line *L* of Fig. 11.4 in the universal unfolding of the Riemann-Hugoniot catastrophe.

If again we form a cycle *C*, as in the previous case, we find this time that we arrive at a less paradoxical conclusion; the parent organism *A* perishes at point *K* (Fig. 11.10), captured by its descendant *A*', and after traversing arc *123*, the descendant becomes a parent, as is normal after a lapse of a generation. Here the confusion

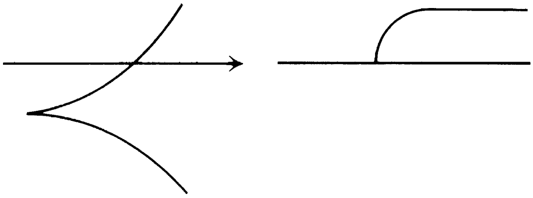


Fig. 11.9 The emission morphology

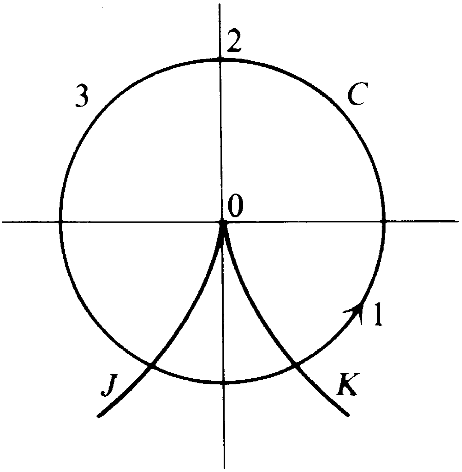


Fig. 11.10 The reproduction loop

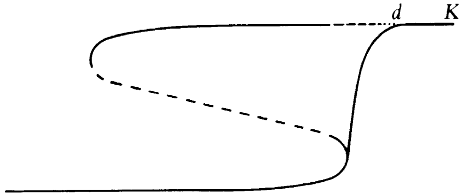


Fig. 11.11 Continuity via capture

of actants is natural, with daughter becoming mother after puberty. But if we want the parent to have several descendants in order to ensure the permanence of the subject, it is necessary to proceed as with the predation loop: we must guarantee continuity with the upper sheet by a process of capture (Fig. 11.11).

Hence the descendant sheet *A*' must perish at the threshold *d* in a generalized catastrophe, expressing the reduction of the corresponding tissue into a set of dissociated cells in the process of multiplication, and then the elimination of these cells from the organism by rejection toward the outside.

Sexuality

It is possible to give an interpretation of sexuality in this plan, if we suppose that one step in reproduction must necessarily comprise a capture process. The profound motivation of sexuality is probably not the exchange of genetic material, as is usually supposed, but rather the smoothing of the reproduction catastrophe. The spatial separation of a descendant from a parent organism is never easy when these organisms have a complex constitution. In males, the emission of gametes is relatively easy, since they are very small cells with respect to the organism, and also this emission is often helped by the presence of a female acting as attractor, conforming to the gift morphology: In females, the fertilitization of an ovum by sperm coming from: the exterior creates an organism that is genetically and therefore metabolically

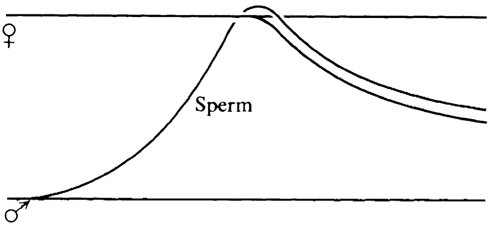


Fig. 11.12 The excision morphology

different from the mother, thus allowing her to reject this organism by the formation of a shock wave (or an antigene reaction, biologically speaking). In this way the capture morphology manifests itself in the female gamete in relation to the sperm; it is also often apparent in oogeneses in many species where the future ovum engulfs adjacent cells for nourishment by a process of phagocytosis. Another probable symptom is the blockage of meiosis in the ovum (the formation of polar globules).

At any rate, it is important to keep in mind all the morphologies present in sexual interactions: those of emission, capture, gift, and excision (the male gamete excises the descendant of the female organism; see Fig. 11.12). All these morphologies occur in the universal unfolding of the double cusp.

Homo Faber

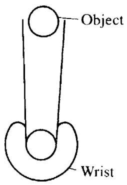
Organs and Tools

The capture chreod typically includes two phases: a somatofugal phase of throwing out an organ to seize the prey, and a somatotrophic phase of carrying the prey, once seized, toward the mouth.

Roughly speaking, the use of tools corresponds to a smoothing, a *threshold stabilization*, between these phases. For example, when we want to gather fruit from a tree, it is often useful to grasp first the branch carrying the fruit, so that the characteristic of being prey extends from the fruit to the branch on which it is growing. Playful activity adds further to this extension. This stabilization at the extreme point of the somatofugal extension has brought about an organogenesis based on *opposition*: the opposition of thumb and index finger, the opposition between the two hands, and so forth. The *grip* archetype is probably only an organic realization of the hysteresis cycle that we met in the study of a bone joint (Section 9.6B); the vertical segments correspond to the fingers, the upper sheet IS an arbitrary object, and the lower sheet is the wrist (Fig. 11.13). The hand appears as a universal rotula with an exogenous tibia of arbitrary form.

Man, the omnivore, must kill and tear up his animal prey; therefore outside objects are to be considered, in play, not only as prey but also as tools. This has implied a global transfer of organogetic fields into fields of tool manufacture. In addition to the fields associated with the elementary catastrophes (such as splitting, pricking, and piercing, etc.; see the table in Fig. 11.14), there are fields, such as

Fig. 11.13 The grip



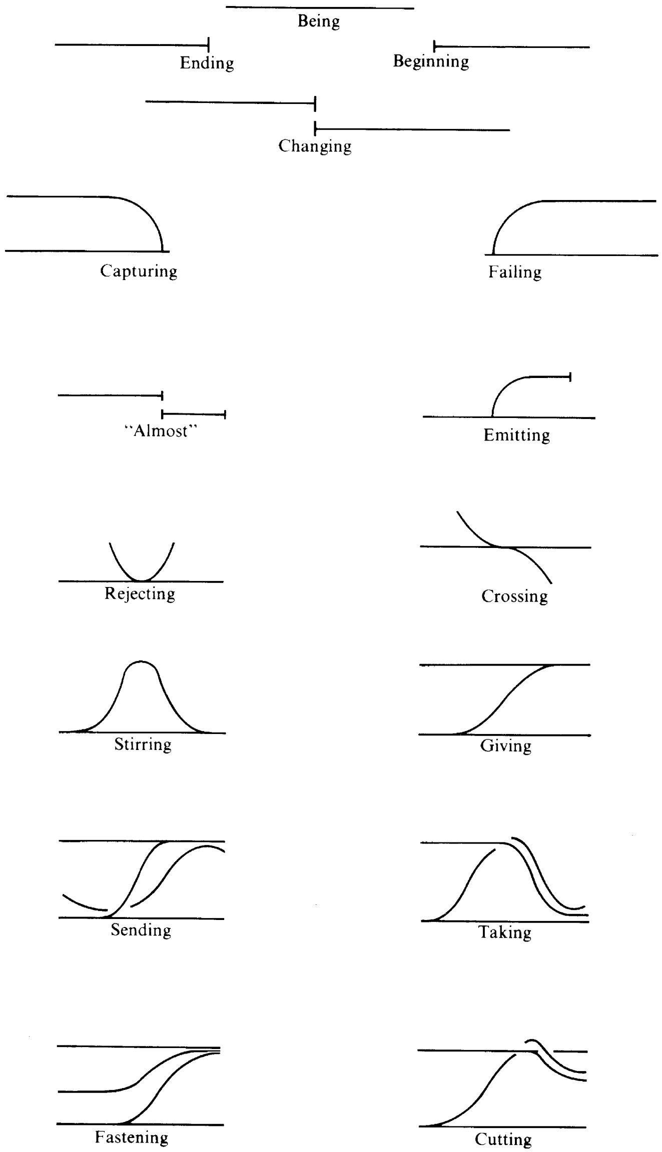


Fig. 11.14 The table of archetypal morphologies

polishing and planning, associated with the conflict between two solid objects that we met in the epigenesis of a bone. Each tool has it own space *T*, in which it is created by a kind of embryology; this space. has its own epigenetic gradients unfolding the functional catastrophe that the tool provokes. Thus almost all everyday objects (tools, furniture, etc.) have a bilateral symmetry, just like animals, and a proximal-distal gradient. In use, the characteristic space *T* of the tool is canonically identified with the local motor chart of the organism and often realizes an important extension of it.

An Example: The Construction of a Club as a Chreod

The *projectile chreod* is known throughout the animal kingdom; it consists of throwing an object in order to hurt an enemy. To begin with, the projectile is often produced by an appropriate organ of the animal that throws it (in a hydra, its nematocyst; in a cuttlefish, its ink; some monkeys bombard their attackers with their conveniently produced excrement). This chreod has been highly specialized in man by the use of a club; he tries to split open his enemy's head and provoke a swallow-tail catastrophe, and this requires the projectile to have a typical beveled form. The mental picture of this catastrophe to be wrought on the adversary creates a secondary field, that of the manufacture of the club. This process can be described as follows. Unlike those of many fields found in animals, the initial data, namely, the form of the block to be fashioned, are very varied; from the variety of different forms of the basic material, the worker must produce a unique form. Thus the construction of the club is a highly attracting chreod and demands the continual presence in the worker's mind of the required form. In this sense it is the earliest example of a rigorously finalist process in which instantaneous direction at each moment is the result of a conflict between the end required and the present condition of the material being worked. Such a process can be described as follows.

When the worker takes up the block of rock *B* that he has chosen to work, he compares it in his mind with the required result *O*. This comparison produces a mental shock wave which stimulates a work process, for example, to file from B along a face *f*. When this face is sufficiently flat, a new comparison with *O* induces the filing of another face *f'*; later the worker may rework face *f*. Let me give a geometrical interpretation of this process (Fig. 11.15). The *Oxy*-plane parameterizes the forms of the block being worked, where *O* is the ideal form; two half-lines of functional catastrophes, *D* and *D*', radiate from *O* for example $x = \pm y$; the process fields *X* and *X*' are represented by parallel vector fields with slopes – 2 and + 2 directed toward negative *x*; at *D* the field changes from *X*' to *X*, and at *D*' from *X* to *X*'. Under these conditions, starting from any point in *DOD*' with the regime *X* or *X*' will lead to the required form *O*. When *O* is achieved (or considered to be achieved), the process reflex will disappear, and the chreod of making the tool will give way to that of using it, which will normally come next in the global function field.

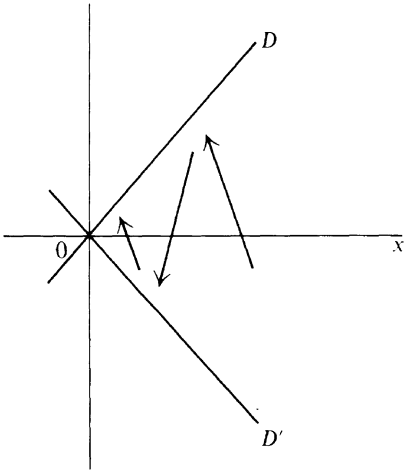


Fig. 11.15 Construction as a finalist attraction chreod

In this way, the secondary morphology with support *DOD*’ is a funneled breaking field of the type encountered in mean coupling fields (see Section 6.2B); in fact, in the formalism of organogenesis described in Section 10.4, this secondary field is in some sense the analytic extension by smoothing of the shock waves of the primary chreod, and generally the internal variables of the secondary field are the external variables of the primary field. But here there is a new feature: the secondary static field enters into competition with an opposing field, the initial form of the block *B* chosen by the worker. Consequently, he must also take an auxiliary block *A* (tertiary morphology) to smooth *B*, and the conflict between these two fields produces the funneled configuration of the secondary static field (and observe that the bounding shock waves *D* and *D*’ give, by analytic continuation, the edges of the wound to be inflicted on the adversary). This gives a secondary catastrophe whose external variables characterize the relative position of *B* with respect to *A* and whose non punctual organizing center has for support the shock waves *D* and *D*’. The tertiary field formed by the smoothing of these shock waves is a static field, indicating the attraction by *B* of an auxiliary block *A*. To sum up, the set of the motor fields of the hands forms a semantic model of at least twelve dimensions, the dimension of a product of two copies of the group of Euclidean displacements.

It is the same hand that fashions and brands the club, and this functional subordination between chreods is evidence of a syntax already almost as refined as that of language. In particular, the formal process of organogenesis (Section 10.4), transforming a mean coupling field on all external space *U* into a static field with internal space *U*, is already realized in mental activity.

These considerations raise the question of how it is that the human mind can achieve this complicated architecture, this hierarchy of fields, of which animals appear incapable, even though the brains of the higher vertebrates are so little different, anatomically and physiologically. Personally, I believe that this capability depends on a topological discontinuity in the kinetics of nervous activity, that in the human brain there is a device simulating self-reproducing singularities of epigenesis allowing, in the presence a catastrophe with internal space Y and unfolding U, the unfolding space to be mapped back into the internal space, causing the confusion of internal and external variables. Such a device would not require any great modification of the anatomical or physiological structures.

Homo Loquax

The Double Origin of Language

The appearance of language in man is a response to a double need:

1. For a personal evolutive constraint, aiming to realize the permanence of the ego in a state of wakefulness.
2. For a social constraint, expressing the main regulating mechanisms of the social group.

The first constraint fulfills the need to virtualize predation. Man in a state of wakefulness cannot pass his time like an infant of 9 months seizing every object and putting it in his mouth. He has greater things to do; he must "think," that is, seize the things lying between exterior objects and genetic forms, namely, *concepts*.

The second constraint expresses the need for the social body to disseminate the information necessary for its survival, like the presence of nearby enemies or prey. Language then works as a *sense relay*, allowing one individual X to describe to another Y what he, X, is in a position to see but Y, less well placed, cannot see.

The social constraint will create structures in the most unstable zone of the individual by an effect of interaction between hierarchical levels of organization; these structures will be on the shock waves separating sleep and wakefulness, or genetic and spatial forms, and these shock waves will exfoliate. A baby is equipped at birth with a stock of sensory-motor schemas, genetic forms that manifest themselves in the so-called *archaic* reflexes. Later, toward 6 months, these schemas undergo a kind of melting, a generalized catastrophe, coinciding with the onset of infantile babbling. This babbling seems like the need to expel by the process of articulation some of these alienating genetic forms, clearly a playful emission of forms, not a capture of forms. Recall that a genetic form is not fixed, but rather is equipped with mechanisms of self-regulation analogous to those of a living being; a concept occurs by superposition, by projecting the regulation schemes of the subject onto a spatial form, an exterior image. By a geometrical analogy, we might say that the concept forms by exfoliation from the spatial image, where the normal coordinate along which the exfoliation takes place is associated with the direction of an articulated emission whose phonetic structure has little to do with the genetic form that gave its regulation to the concept. (This is the Saussurian idea of the arbitrariness of sign.) This association forms by habituation, with the emission of the sound occurring with the (playful or biological) use of the corresponding object. On the other hand, the laws of combination, the syntax, of these words are not arbitrary since they are imposed by the semantic interactions between the concepts, themselves defined by the regulation schemes of the subject and thus of the concepts.

If a child spends the time between 1 and 3 years of age without other human verbal contact, the articulatory emission catastrophe (the babble) rapidly degenerates into the production of a few crude sounds (the verbalization of "wolf children"). The exfoliation of the semantic support space of the concept is inhibited by the incoherence or absence of the sounds associated with the object; this results in the mental retardation or idiocy to which these children are condemned. Those who have studied these wolf children have observed their extreme reactions to some noises like the cracking of a nut. There is little doubt that their minds are still dominated by a small number of alienating forms of genetic origin. Man gets rid of these alienating forms by giving them a name and so neutralizing their hallucinatory powers by fixing them on a semantic space distinct from space-time.

If man has escaped from the fascination of things through the use of language, he remains under the fascination of action incorporated as the grammar of the language (a verb conjugates, etc.). Only the Oriental philosophers have tried to withdraw the subject of this fascination by reducing virtual action to pure contemplation.

Syntax and Archetypal Morphologies

It is well known that all speech can be decomposed into elementary phrases, each phrase being characterized by the fact that it contains precisely one verb, ignoring here the difficulties (about which specialists are still debating) of the definition of the traditional grammatical categones: noun (substantive), adjective, verb, preposition, and so forth. The fact that any text can be translated from one language to another confirms the belief that these categories are almost universal. Now, given a spatio-temporal process which we are to describe linguistically, are there any formal criteria relating to the intrinsic morphology of the process that enable us to predict the decomposition into phrases?

To this end, we must start by "objectively" describing a spatiotemporal morphology. In fact every linguistically described process contains privileged domains of space-time bounded by catastrophe hypersurfaces; these domains are the *actants* of the process, the beings or objects whose interactions are described by the text. As a general rule, each actant is a topological, ball and hence contractible; this is the case, for example, for animate beings. At each moment t we contract each actant to a point and when two actants interact this implies that their domains come into contact in a region of catastrophe points which we also contract to a point of intersection of the lines of the two contiguous actants. In this way we associate a graph with every spatiotemporal process.

In then propose that the total graph of interactions describing the process can be covered by Sets U_i such that the following conditions are met:

1. The partial process with support U_i is described by one phrase of the text.
2. The interaction subgraph contained in U_i belongs to one of the sixteen archetypal morphologies of the table of Fig. 11.14.

In principle each of the morphologies is generated by a construction of the following type. In the universal unfolding of each elementary singularity, take a ray emanating from the organizing center and having contact of maximum order with the discriminant variety, and then displace this ray parallel to itself to avoid the confusion of actants at O. Then lift this ray to the space of internal variables, with each actant being represented by the basin of a minimum, to give the corresponding interaction. It may be necessary to cheat a bit by bending the rays in order to ensure the permanence of the actants to times $t = \pm\infty$. Furthermore, certain verbs called iteratives require repetitions of an action, and in this case the basic cell is described by the archetypal morphology. The occurrence of excision morphologies, characteristic of sexual reproduction, is noteworthy.

This theory of the spatial origin of syntactical structures accounts for many facts, for example, the restriction to four actants in an elementary phrase and the origin of most of the cases in a language with declension: the nominative, for the subject; the accusative, for the object; the dative, with verbs having the morphology I the instrumental, with verbs having the excision morphology of cutting, or ablative. The only classical case that cannot be interpreted by this tableau is the genitive, which is an operation of semantic destruction, dislocating a concept into its regulating subconcepts in a kind of inverse embryology (see Thom 1973).

The Automatisms of Language

It remains to account for the palpably automatic character of the formation of syntactical structures. To this end we suppose that each main verb type (each archetypal morphology) is represented mentally by an oscillator, which vanishes at the organizing center at a certain critical energy level E_c. When $E < E_c$, it typically describes a cycle in the universal unfolding with almost a stationary point on a sheet or a branch of the discriminant variety; the corresponding arc describes one of the typical sections generating the associated archetypal morphology. For example, in a verb of the capture morphology there will be a cycle C in the universal unfolding of the Riemann-Hugoniot catastrophe with the stationary point k on the capture branch. When $E = E_c$, the radius of C tends to zero and the cycle vanishes at the organizing center O. This gives the unstable potential $V = x^4$ in the internal space, and then the situation evolves toward a generic situation with the representative point in the uv-plane following a curve close to the capture branch K inside the cusp. This results in the formation of two dummy actants corresponding to the minima of potential, and then these dummy actants will play an instrumental role in the capture of the concepts of the meaning. Each dummy actant excites the concept and reduces it to its splitting into image + word; finally the dummy actant unites with the word and is emitted as a word.

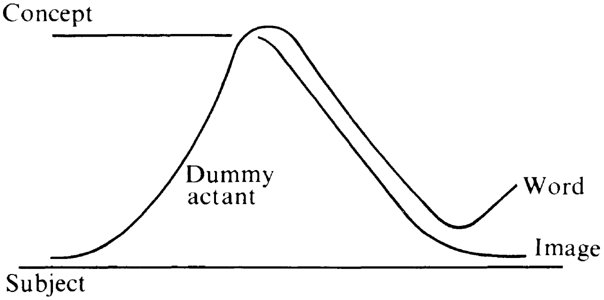


Fig. 11.16 The take morphology

Such a process then describes the emission of a phrase of type SVO, subject-verb-object. First the vanishing of the cycle *C* leads to the emission of the verb *V*, and then the packet of two dummy actants liberates the subject-object; each of these actants interacts with the corresponding concept, which it maps on the subject image axis while the dummy actant is re-emitted as a word (substantive). The total morphology is that of the verb "to take" (see Figs. 11.14 and 11.16). Thought is then a veritable conception, putting form on the dummy actant arising from the death of the verb, just as the egg puts flesh on the spermatizoid; thus thought is a kind of permanent orgasm. There is a duality between thought and language reminiscent of that which I have described between dreaming and play: thought is a virtual capture of concepts with a virtual inhibited emission of words, a process analogous to dreaming, while in language this emission actually takes place, as in play.

More details of the problem of grammatical categories and the question of the order of words in a sentence are given in Appendix 2.

The Origin of Geometry

In the state of wakefulness, of continuous virtual predation, man can reach out to any point sufficiently close to his body; and these voluntary movements give rise to proprioceptive sensations which permit a rigorous metrical control of the displacement of limbs far more precise than the control of induced movements. Thus we can assert that, very early in human development, there are local charts associated with the organism that describe all the metrical structure of Euclidean space.

The use of tools allows us to extend this chart by adjoining to it the chart associated with the tool. Even better, the disappearance of alienating forms, which center the chart on an external prey, enables these charts to be adjoined indefinitely to each other. For example, the operation of measuring, by adjoining a yardstick to the end point of a previously measured length, is typically an extension of a chart by the chart associated with the yardstick. This is how geometric space is made up: a space of pure unmotivated movement, the space of all the play-movements of which we feel we are capable.

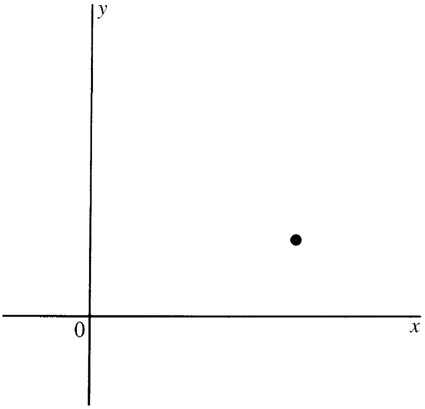


Fig. 11.17 Cartesian axes

It is striking to observe how most spaces, even in pure mathematics, are not homogeneous but are well and truly endowed with a base-point, an origin, the mathematical equivalent to a subject in a state of continual predation in the space. Even the typical picture of Cartesian axes *Oxy* (Fig. 11.17) conjures up irresistibly a mouth about to close on the typical point p, the prey. It is surely not by chance that the most of the catastrophes of organic physiology are idempotents ($T^2 = T$) like projection onto an axis, measurement in quantum mechanics, or the capture by the mind of a meaning (just as we say "I've got it" to mean that we have understood).

Although the acquisition of a global appreciation of metrical space appears early in man, the same is not true of its representation by pictures. Although the psychologist J. Piaget has been led to believe, through an examination of drawings, that children acquire topological structures before metrical ones (Piaget and Inhelder 1956), I think that this conclusion is based on a misunderstanding of the process of the formation of semantic spaces by exfoliation of the spatial image. Thus a 3-year-old child knows how to recognize whether his piece of cake is smaller than his neighbour's; but when he tries to draw, he clearly wants above all to draw objects and not the ambient space in which they lie, which is very difficult from him. Now each object is generally seen from a privileged direction,. giving it a simple apparent contour and revealing best the three-dimensional form of the object. Generally this direction is perpendicular to the plane of bilateral symmetry for an object, like an animal or a tool, having such a symmetry; only man is represented first face-on, rather than in profile. For a complicated object, like a car, there are subobjects that may be necessary for recognition, like wheels. In a global chart of the object, the subobjects may be correctly located but drawn with their own privileged perspective, thus explaining the phenomenon of flattening that Luquet (1927) has described in many designs by children (e.g., see Fig. 11.18). In such cases there is a conflict between the global perspective and the requirement of semantic dominance of an object over its sub-objects. The relationships of surrounding, touching, and so on, which are considered by Piaget as "topological," are in fact semantic relationships of dominance between concepts, relationships expressed precisely by the genitive case (the wheels of the car, the eyes of the head, etc.).

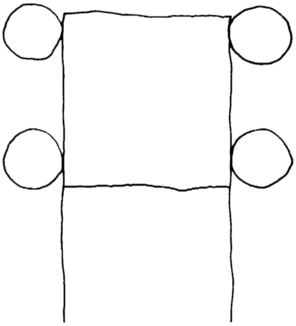


Fig. 11.18 "Flattening" as example of semantic dominance

Three Important Kinds of Human Activity

Art

Can artistic activity appear in our semantic models? Of course this is so with poetry, which uses ordinary language, and music, which requires the use of a discrete notation. For visual arts, however, the case is less clear even though the recurrence of typical motifs and forms suggests that the idea of the chreod and, with it, semantic models may be valid; but what characterizes these activities with respect to ordinary language is the use of concepts, that is, systematically excited chreods. This has the effect of harming the global intelligibility of the model and obscuring or removing the sense. From where, then, does our feeling of beauty come? From the idea that the work of art is not arbitrary, and from the fact that, although unpredictable, it appears to us to have been directed by some organizing center of large co dimension, far from the normal structures of ordinary thought, but still in resonance with the main emotional or genetic structures underlying our conscious thought. In this way the work of art acts like the germ of a virtual catastrophe in the mind of the beholder. By means of the disorder, the excitation, produced in the sensory field by looking at the work, some very complicated chreods (of too great a complexity to resist the perturbations of the normal thought metabolism) can be realized and persist for a moment. But we are generally unable to formalize, or even formulate, what these chreods are whose structure cannot be bent into words without being destroyed.

Delirium

One of the basic postulates of my model is that there are coherent systems of catastrophes (chreods) organized in archetypes and that these structures exist as abstract algebraic entities independent of any substrate, but it must not be forgotten that the substrate does have a part fundamental in the dynamic of these forms. In particular, if the substrates A and B are independent or only weakly coupled, the morphology of support A is practically independent of that of support B. During normal mental activity, there are a large number of relatively independent substrates, each undergoing its own determinism or evolution. In this respect mental activity is only simulating the dynamic of the external world, which admits many independent or weakly coupled domains, made possible in particular by spatial separation. But such a separation of substrates inside a unique functional system as highly interconnected as the nervous system is very difficult to maintain; it is unstable and can break down under crude physiological influences (fever, drugs, etc.). Then the coupling interactions between two substrates A and B can increase to the extent that an archetype defined on A can evolve on B and upset the normal evolution of B's own dynamics; furthermore, this mixture of substrates destroys the more refined chreods, whose organizing centers have high codimension, in favor of more primitive fields that are more stable and more contagious. This will give rise to a syncretistic mental dynamic with oversimple structures – what is usually called *delirious thinking*.

In this connection, a good doctrine in the use of analogies in science remains to be established. Local isomorphisms of dynamical situations over independent substrata are, I think, very frequent, and many of them have yet to be recognized; because they are so frequent, however, these analogies have neither the weight nor the significance that the incautious might be tempted to attribute to them. It is an enormous step from noticing the presence of isomorphic morphological accidents on different substrates, to establishing some fundamental coupling between these substrates to explain these analogies, and it is precisely this step that delirious thinking takes. If some of my arguments, particularly in biology, have seemed to the reader to lie on the boundaries of delirium he might, by rereading, convince himself that I have, I hope, at no point made this step.

Human Play

In play the mind is given over to an eminently combinatorial activity; it constructs and uses a semantic model according to rules that it knows and respects. In the simplest case the rules are such that the strategy is determined; there are only a finite number of possible evolutions, which can be considered in turn. Frequently, however, the rules are not powerful enough to determine the system completely, and play appears as a kind of artistic activity in which the player, motivated by some esthetic sense, tries to form the most attractive and effective moves. But playing games is fundamentally different from artistic activity in that the set of rules must be consciously kept in mind. It is completely incompatible with delirium because it requires a mental domain kept completely free and independent of any external coupling, in which the mind may realize high-codimensional chreods; thus formalized, or axiomatic, thought can be considered as a game whose rules, forming the organizing center, are codified as a system of axioms. In this way, formal thought can be regarded as magic that has been psychoanalyzed and made conscious of its organizing structures.

Playful activity, left to itself, is not slow in creating gratuitous, worthless examples of semantic models with no other semantic realization than their own combination, nor is it slow to decline into trivia. Although some of modern mathematics is perhaps guilty of this charge, it is no less true that mathematical activity among mankind has essentially been inspired by reality and finds there its constantly renewed fecundity. The axioms of arithmetic form an incomplete system, as is well known. This is a happy fact, for it allows hope that many structurally indeterminate, unformalizable, phenomena may nevertheless admit a mathematical model. By allowing the construction of mental structures simulating more and more closely the structures and forces of the outside world, as well as the structure of the mind itself, mathematical activity has its place in the warp of evolution. This is significant play *par excellence* by which man can deliver himself from the biological bondage that weighs down his thought and language, and can assure the best chance for the survival of mankind.

The Structure of Societies

We are now going to outline roughly the structures of animal and human societies as metabolic forms. A society is a metabolic form first and foremost because it survives the individuals that constitute it; there is a permanent flux of constantly renewed individuals assuring the continuation of the social form. Moreover, there is an interaction between the individuals maintaining the stability of this form. This interaction often materializes as a circulation of complexity, of information, through the social body.

Basic Types of Society

There are two basic types of society.

1. *The military society***.** Here each individual occupies a specified position and regulates his own movement so that the global form of the society is preserved, as well as his position within the society. It is clear that global invariance of the spatial body requires a permanent interaction of each individual with the individuals surrounding him. As the circulation of information, considered as a fluid, must be structurally stable, the simplest process to give this effect is a gradient circulation: here a positive function u is defined on the social body, called authority, zero at the boundary, and each individual is constrained to control his movement toward the closest individual on the trajectory of grad u in the direction of increasing u. This function u must have at least one maximum, and the individual at this point is the chief, because he takes orders from no one. Because delays in the transmission of orders may have a disastrous effect on global stability, particularly in troubled times when very rapid changes of behavior are necessary, u can have no other critical point apart from the single maximum personified by the chief. Thus the social body is a ball under monarchical rule.

As an application of this proposition, we see that most animal groups with invariant structures are topologically balls, generally governed by a chief, for example, flocks of birds, shoals of fish, or herds. However, the existence of a chief is not always obvious: the queen is not the director[12] in a hive of bees, but more complicated morphogenetical fields are in operation. Another example is slime molds.

Although this is the simplest structurally stable structure, it is not the only one. Military societies with many, or even with no chiefs are possible, but then the social body must be at least a three-dimensional manifold in order to admit a structurally stable ergodic field without singularity.

2. *The fluid society.* Here the typical example is a cloud of mosquitoes: each individual moves randomly unless he sees the rest of the swarm in the same half-space; then he hurries to re-enter the group. Thus stability is assured in catastrophe by a barrier causing a discontinuity in behavior. In our societies this barrier is fixed and doubly realized by the conscience of the individual and by the laws and repressive organisms of the society, and so our societies are of an intermediary type: they are not rigorously fluid, for they are stratified into social classes separated by shock waves that are difficult for an individual to cross. The classical analogy between the society and the individual organism is well known: the distinction between primary (production), secondary (distribution), and tertiary (direction) is echoed by the three fundamental layers of an embryo, but societies, unlike individuals, rarely reproduce themselves by budding (swarming). Marxism, which would explain the structure and evolution of societies solely in economic terms, is equivalent to Child's metabolic theory of embryology and suffers from the same simplifications. A typical character of social morphogenetical fields is that they modify the behavior of individuals, often in a lasting and irreversible way, as in the case of those who are persuaded to give all, including their own lives, for the preservation of the global social form, considered as supreme. This is an effect, without parallel in inanimate nature, that has disastrous consequences as far as the continuance of social injustice is concerned.

Other Aspects of Societies

1. *Money.* As a token for bargaining, money circulates in the opposite direction to goods and services and therefore tends to move away from consumers and accumulate at the producers. But as it must follow a closed path in the social body, it is necessary for an artificial mechanism to carry it in the opposite direction. Such a mechanism can depend only on the structure of society, on authority; in this way money is imbued with the gradient of authority (grad u) by the process of taxes. When it arrives at the summit, it is divided up by the chief, who can, in a permanent (or at least annual) catastrophe, share out the portions where necessary; in

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[12] Note that in a beehive the place (i.e., the function) of an individual in the society varies with his age. As the worker bee grows older, her activities move away from the germinal center (care of recently enclosed larvae) toward somatic roles (wax-worker, then honey-gatherer).

fact, this power is one of the essential means of government. Thus, in all societies, the gradient of production and the gradient of authority have a tendency to organize themselves in an antagonistic manner and so bring about a sufficiently stable circulation of money.[13]

2. *The mind of a society.* In this respect we might ask whether a social group acquires a "mind" that could have an autonomous existence. It seems that the social mind has a fragmentary character very similar to that of the animal mind: society finds its identity only in the face of an urgent threat, like war, where its existence and stability are threatened; similarly, the spatial conscience of the society has a local character, focalized on certain threatened zones. On the other hand, one may see in large collective displays such as fetes and celebrations an activity homologous to dreaming in the individual, a virtual manifestation of genetic "social" forms. Individual semantics is perhaps another example.

The view outlined above is basically pessimistic, for it shows that social injustice is inextricably bound up with the stability of the social body. Personally I believe that the only way of reducing oppression is to stop giving an ethical value to social forms, in particular, to nations. The celebrated dictum of Goethe, "Better injustice than disorder," can be justified only inasmuch as disorder may generate even worse injustices; but this danger is not likely if the members of a society have achieved sufficient moral values for them not to exploit a temporary lapse of authority to their own profit. In this case, a very labile situation, with a fluctuating authority, has the best chance of providing a regime optimal for each member.

It is tempting to see the history of nations as a sequence of catastrophes between metabolic forms; what better example is there of a generalized catastrophe than the disintegration of a great empire, like Alexander's! But in a subject like mankind itself, one can see only the surface of things. Heraclitus said, "You could not discover the limits of soul, even if you traveled every road to do so; such is the depth of its form."[14]

Conclusion

Here, before the final discussion, is a summary of the main points that have been made.

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[13] In this model of society, the intellectuals (artists and thinkers) figure as the axis of the money circulation; in their central position, freed from the need to produce, deprived of the advantages and responsibilities of power, they are the eye of this continual hurricane. In terms of the model of Section 1 1.1C we might regard them as the chromosome of the social body.

[14] I have twice allowed myself to translate the Heraclitean λoγos as "form." Allowing that to Heraclitus the *logos* is the formal structure that assures for any object its unity and its stability, I am convinced that this particular use of the word "form"(meaning the equivalence class of structurally stable forms) in this book is a reasonably good approximation.

Summary

1. Every object, or physical form, can be represented as an *attractor C* of a dynamical system on a space *M* of *internal variables*.
2. Such an object is stable, and so can be recognized, only when the corresponding attractor is *structurally stable*.
3. All creation or destruction of forms, or *morphogenesis*, can be described by the disappearance of the attractors representing the initial forms, and their replacement by capture by the attractors representing the final forms. This process, called *catastrophe*, can be described on a space *P* of *external variables*.
4. Every structurally stable morphological process is described by a structurally stable catastrophe, or a system of structurally stable catastrophes, on *P*.
5. Every natural process decomposes into structurally stable islands, the *chreods*. The set of chreods and the multidimensional syntax controlling their positions constitute the *semantic model*.
6. When the chreod C is considered as a word of this multidimensional language, the meaning (*signification*) of this word is precisely that of the global topology of the associated attractor (or attractors) and of the catastrophes that it (or they) undergo. In particular, the signification of a given attractor is defined by the geometry of its domain of existence on *P* and the topology of the regulation catastrophes bounding that domain.

One result of this is that the signification of a form *C* manifests itself only by the catastrophes that create or destroy it. This gives the axiom dear to the formal linguists: that the meaning of a word is nothing more than the use of the word; this is also the axiom of the "bootstrap" physicists, according to whom a particle is completely defined by the set of interactions in which It participates.

Let us now consider the prejudicial question of experimental control.

Experimental Control

Are these models subject to experimental control? Can they give experimentally verifiable predictions? At the risk of disappointing the reader, I must answer in the negative. This is an inherent defect of all qualitative models, as compared with classical quantitative models. When the processing studied is entirely within a chreod *C*, all that the experiment can do is to confirm the stability of the chreod; when the process has several chreods C_1, C_2, ... separated by indeterminate zones, the process is by definition structurally unstable, and no individual prediction is possible. The only benefit to be drawn from the model is a statistical study of the morphologies presented by a *set* of processes of the type under consideration; this is the method used in quantum mechanics and often in quantitative biology. In the case of a single chreod, it might be possible to construct, by internal analysis of the chreod, a quantitative model; but for this the dynamical properties of the substrate must be well understood – something that is rarely possible, except in the study of shock waves in hydrodynamics, where some partial progress has been made. In general, the way is blocked by the nonexistence of a quantitative theory of catastrophes of a dynamical system; to deal with this it would be necessary to have a good theory of integration on function spaces and we saw in Section 7.3 the difficulties of such a theory.

The strict empiricist, faced with this deficiency, will tend to reject these models as speculative constructions, devoid of interest; and, as far as present scientific progress is concerned, he is probably right. On a larger scale, however, there are two reasons that might commend them to the scientist.

The first reason is that *every quantitative model first requires a qualitative isolation from reality* in setting up an experimentally reproducible stable situation. We take the main divisions of science, the taxonomy of experience, into physics, biology, chemistry, and so forth as given a priori, a decomposition bequeathed on us almost unconsciously by our perception and used by every scientist, no matter who he is, rather like Monsieur Jourdain speaking prose. Should it not be of interest in this situation to reconsider this decomposition and integrate it into the framework of an abstract general theory, rather than to accept it blindly as an irreducible fact of reality?

The second reason is our ignorance of the limits of quantitative models. The enormous successes of 19th century physics, based on the use and exploitation of physical laws, created the belief that all phenomena could be justified in a similar way, that life and thought themselves might be expressed in equations. But, on reflection, very few phenomena depend on mathematically simply expressed ("fundamental") laws: scarcely three, namely, gravitation (Newton's law), light, and electricity (Maxwell's law). Their simplicity is only apparent, and only expresses how gravitation and electromagnetism are intimately connected with the geometry of space, the result of a statistical effect of a large number of isolated, independent, small phenomena. The situation is different at the level of quanta; the fundamental reasons for the stability of matter are still unknown, and the stability of the proton remains unexplained. Quantum mechanics, with its leap into statistics, has been a mere palliative for our ignorance.

Furthermore, even when a system is controlled by explicit laws of evolution, it often happens that its qualitative behavior is still not computable and predictable; as soon as the number of parameters of the system increases, the possibility of a close calculation decreases-what Bellman (1961) has called the curse of dimensionality. Those who sell electronic gadgetry would have us believe that the computer age will be a new era for scientific thought and humanity; they might also point out the basic problem, which lies in the construction of models.

Since Newton's proud cry, "Hypotheses non fingo," it has been hoped that a happy intuition, a lucky guess, would be sufficient to reveal the fundamental laws underlying everything; but this method of blind groping without any intuitive support seems now to have produced as much as it is able. After all, it is not impossible that science is now approaching the ultimate possibility of finite description; then the indescribable and unformalizable will be on hand, and we shall have to face this challenge. We shall have to find the best means to approach the action of chance, to describe the symmetry breaking generalized catastrophes, to formalize the unformalizable. For this task, the human brain, with its ancient biological heritage, its clever approximations, its subtle esthetic sensibility, remains and will remain irreplaceable for ages to come.

So what I am offering here is not a scientific theory, but rather a method; the first step in the construction of a model is to describe the dynamical models compatible with an empirically given morphology, and this is also the first step in understanding the phenomena under consideration. It is from this point of view that these methods, too indeterminate in themselves, lead not to a once-and-for-all explicit standard technique, but rather to an art of models. We may hope that theoreticians will develop a quantitative model in the framework of a given substrate, just as quantum mechanics has been developed for elementary interactions. But this is only a hope.

Philosophical Considerations

There is no doubt it is on the philosophical plane that these models have the most immediate interest. They give the first rigorously monistic model of the living being, and they reduce the paradox of the soul and the body to a single geometrical object. Likewise on the plane of the biological dynamic, they combine causality and finality into one pure topological continuum, viewed from different angles. Of course this requires the abandonment of a universal mechanism and Laplacian absolute determinism, but have these ever been anything but wishful thinking?

Our models attribute all morphogenesis to conflict, a struggle between two or more attractors. This is the 2,500 year old idea of the first pre-Socratic philosophers, Anaximander and Heraclitus. They have been accused of primitive confusionism, because they used a vocabulary with human and social origins (conflict, injustice, etc.) to explain the appearance of the physical world, but I think that they were far from wrong because they had the following fundamentally valid intuition: *the dynamical situations governing the evolution of natural phenomena are basically the same as those governing the evolution of man and societies*, profoundly justifying the use of anthropomorphic words in physics.[15] Inasmuch as we use the word "conflict" to express a well-defined geometrical situation in a dynamical system, there is no objection to using the word to describe quickly and qualitatively a given dynamical situation. When we geometrize also the words "information," "message," and "plan," as our models are trying to do, any objection to the use of these terms is removed. And this will represent not a little progress for present-day molecular biology.

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[15] It is striking how all past and present techniques of foretelling the future depend on the following principle: a generalized catastrophe (tea leaves in a cup, lines on the palm of a hand, drawing of cards, the shape of a chicken's liver, etc.) is studied and its morphology is then associated, by a suitable isomorphism, with the preoccupations and difficulties of the client. This method is not absurd insofar as the dynamic of morphogenesis may contain local accidental isomorphisms with the dynamic of human situations, and often a gifted soothsayer may well elicit some valuable conclusions from this examination. To classify these isomorphisms in some definitive manner would be to embark on the characteristic form of delirious thought.

Epilogue

I should like to have convinced my readers that geometrical models are of some value in almost every domain of human thought. Mathematicians will probably deplore abandoning familiar precise quantitative models in favor of the necessarily more vage qualitative models of functional topology; but they should be reassured that quantitative models still have a good future, even though they are satisfactory only for systems depending on a few parameters. The qualitative methods considered here, which appeal to the ideas of the morphogenetic field and chreod associated with singularities of the bifurcation set of an infinite-dimensional function space, avoid this difficulty. In theory, they still provide only a local classification, and so only a local investigation of the singularities of morphogenesis; the problem of integrating these local models into a stable global structure (dynamical topology), although sketched out in the case of living beings, remains wide open.

An essential tool is still missing: a more precise description of the catastrophic process of the disappearance of an attractor of a differential system and its replacement by new attractors. This problem is not only of theoretical importance. Physicists, if they want one day to obtain information about very small processes at subquantic level, will need the intermediary of the interaction of a *highly controlled process with an enormous degree of amplification*. Such processes, in which an infinitesimal perturbation may cause very large variations in the outcome, are typically catastrophes.

Biologists will perhaps reproach me for not having spoken of biochemistry in precise terms. This is true, and I do not deny the importance of chemical constraints on the dynamic of life. But I believe that any such constraint, and any chemical bond, can be considered as a geometrical factor in an appropriate space. Writing the equation, in atoms, that connects two constituents of a chemical reaction is one, the coarsest, of these constraints; the topology of biochemical kinetics and its relation with the spatial configuration of macromolecules are others that are certainly more decisive. On the other hand, *what is it that assures us that the formal structures governing life as a stable process of self-reproduction are necessarily connected with the biochemical substrate that we know today?*

As far as life and social sciences are concerned, it is difficult for me to judge whether my present ideas may be of interest, but in writing these pages I have reached the conviction that there are simulating structures of all natural external forces at the very heart of the genetic endowment of our species, at the unassailable depth of the Heraclitean *logos* of our soul, and that these structures are ready to go into action whenever necessary. The old idea of Man, the microcosm, mirroring World, the macrocosm, retains all its force: who knows Man, knows the Universe. In this *Outline of a General Theory of Models* I have done nothing but separate out and present the premises of a method that life seems to have practiced since its origin.

A mathematician cannot enter on subjects that seem so far removed from his usual preoccupations without some bad conscience. Many of my assertions depend on pure speculation and may be treated as day-dreams, and I accept this qualification-is not day-dream the virtual catastrophe in which knowledge is initiated? At a time when so many scholars in the world are calculating, is it not desirable that some, who can, dream?

Appendix 1

A Model for Memory

Structure of memory.

We propose the following structure for memory:

1. A relatively slow dynamic (P,ψ) representing consciousness and mental activity.
2. A rapid auxiliary dynamic (M, X).
3. A weak coupling between these two dynamics by a third system (Q, X), of type a product of N linear oscillators, each with the same period.

The configuration space of Q is then an N-dimensional torus T^N. The parallel constant field in Q is structurally unstable and evolves through resonance toward a structurally stable situation characterized by the presence of attracting cycles. There may be competition between several possible resonances corresponding to slightly different biochemical states of neurons. To fix the idea, suppose that the possible resonances are parameterized by the points of a set J of phase differences in the torus T^N, varying, in principle, according to the past history of the individual. Suppose, for example, that J is a tree with successive bifurcations; then the terminal points of the tree will correspond to specifically catalogued memories. When Q is in a stable regime corresponding to such an external point s, the system Q will impose a certain weak coupling between (P, ψ) and (M, X) with the effect of producing a mean coupling field in P; the unique attractor of this mean field will then capture the dynamic ψ, recalling the memory belonging to s. The internal evolution of Q is itself governed by a secondary coupling with (P, ψ); when mental activity requires the recollection of a memory, Q will become unstable and the representative point in J will return to the origin of the tree$J$ and then move toward an external point.

Two factors come into play at each bifurcation of J.

1. The coupling with (P, ψ), which can direct the choice in one direction or another.
2. The local chemical memory affecting the probabilities of each of the branches of the tree at the corresponding vertex.

Very probably the structure of J is not absolutely determined but depends on the genetic information and the experience of the lifetime of the individual. On the other hand, the external points probably cover only a very small part of all the possible couplings leading to mean fields with stable attractors. In this sense it can be said that our brains contain not only our actual memories, but also all virtual memories that we could have but never shall have.

The Mechanism of Acquiring a Memory

Each branch point of the tree J can be represented by a partial oscillator D with three .states: two stable regimes a and b corresponding to the branches of J issuing from the point, and an indifferently excited state. Each stable state synthesizes substances (RNA?) m_a and m_b, respectively, in the affected neurons, and these substances catalyze the return to the corresponding state. However, active synthesis of these substances, and their deposit in the neurons, cannot start until the excitation of D has died down. The recollection of the memory s will usually lead to the excitation of a reflex $r(s)$ by the organism. This reflex $r(s)$ may have agreeable or painful effects on the organism. When the effect is painful, there will be a generalized excitation of the local oscillators D in Q and the substances giving rise to this choice will be suppressed; this will leave almost no trace of the chemical of the choice just made. On the other hand, if the effect is agreeable, the excitation of the local oscillators D will be reduced and material m_a or m_b, according to the choice just made, will be synthesized. It could also be that the pain wave in Q generates the synthesis of substances unfavorable to the return to the corresponding regime.

Temporary loss of memory is a well-known and curious phenomenon. There are two possible explanations: either the dynamic Q cannot reach the required terminal point s because the local chemical memory at one of the bifurcations of J prevents it (this is the Freudian interpretation, which we forget memories connected with disagreeable sensations): or Q does reach s, but this was actually not a point, so that Q ends up a little to one side and gives a coupling that recalls the general structure of the bifurcations of the mean field, but, because of an auxiliary perturbation, the horizontal component Y does not give rise to any attracting cycle. The memory is there, virtual, in the consciousness, and needs only the field that excited it. In this case the best way of recalling the memory is to start again from the beginning, if possible some time later.

Whatever else are the virtues of this model, it shows that there is little hope of localizing memories either spatially, in specific neurons, or chemically, in well-determined substances.

Appendix 2

Grammar, Languages, and Writing

Grammatical categories and the typology of languages.

We have seen that concepts have a regulation figure, a *logos*, analogous to that of living beings, We might regard a grammatical category (in the traditional sense) as a kind of abstract *logos*, purified to the point that only the rules of combination and interaction between such categories can be formalized. From this point of view, we say that a grammatical category C is semantically closer than a category C’ if the regulation of a concept of C involves mechanism intervening in the regulation of C’. For example, take a name of animate being, say a cat: this cat must make use of a spectrum of physiological activities for survival – eating, sleeping, breathing, and so forth; once these are satisfied, he can then indulge in less necessary but quite normal activities – playing, purring, and the like. Similarly each substantive has a spectrum of verbs describing the activities necessary for the stability and the manifestation of the meaning of the concept. Since the verb is indispensable for the stability of the substantive, it is less dense than the noun. The adjective shares in the stable character of the noun, but it is defined on a space of qualities, deeper than space-time, the support of the verb.

When a category *C* is denser than *C*', there is, in general, a canonical transformation from *C* to *C*'. The inverse transformation, however, is generally not possible.

These rules lead to the following order, in decreasing semantic density, for the traditional grammatical categories: noun-adjective-verb-adverb affixes and various grammatical auxiliaries. In the emission of a sentence the meaning is analyzed and the elements are emitted in the order of increasing density. In the model of Section 13.4C the density of the concept is, in practice, the time required by the dummy actant to reduce the concept to the representative sign. It is much longer for a complex being like man than for an inanimate object, whose regulation is much simpler. As an example, the normal order of emission of a transitive phrase, subject-verb-object, would be verb-object-subject; the object is less stable than the subject, since in such a transitive process the subject survives the whole interaction whereas the object may perish. (The cat eats the mouse, the morphology.) The reception order, the one most favorable to the best reconstitution of the global meaning, is generally the opposite order: subject-object-verb. Now researches on the universals of language have shown that the pure emissive typology V-O-S is practically nonexistent (see Greenberg 1966), whereas the receptive typology S-O-V is well represented (e.g., Japanese, Turkish, and Basque). This reflects a fundamental fact in the dynamic of communication: the act of speaking is initiated by the speaker, and in general he has a greater interest in being understood than the listener has in understanding. Consequently the transposition of the emissive order into the receptive order is generally carried out by the speaker, and this gives predominance to the reception typology. However, the mixed emissive typology S-V-O is the most common.

An elementary sentence generally contains other ancillary elements that go to make up a nuclear phrase; these are the *adjuncts*. The principal kinds of adjuncts are the epithet adjectives (A-N or N-A) and genitives (G-N or N-G). The adjective is semantically less dense than the noun; therefore the receptive typology of the epithet is N-A, the emissive A-N; and similarly for the genitive: receptive N-G, emissive G-N. Since a preposition is less dense, an adjunct of type Pre-N is an emissive type, in harmony with the order V-O, while a postposition N-Post is in harmony with O-V.

The second principle governing the typology of languages is this: the free adjuncts (those not tied to the central verb, e.g., A and G) have an inverse typology to the verb-object nucleus. This leads to the two main types of languages:

Emissive	Receptive
V-O	O-V
Pre	Post
N-A	A-N
N-G	G-N

English is not typical, since it has preserved from an older receptive stage the typology A-N for the epithet adjective and the partial type G-N in the Saxon genitive (John's house). For further details see my 1973 article on the subject.

The Origin of Writing

The mental reconstruction of the organizing centers of elementary fields spreads, by a very natural contagion, to the functional fields of the hand. The external variables of the elementary catastrophes will be realized as spatial variables. The stylization of an action is nothing more than a return to the organizing center of this action. To the extent that the Riemann-Hugoniot cusp is conceptually stabilized by the concept of division or separation, the catastrophe can be realized by writing in clay with a stick the symbol <. Similarly the sign $\wedge$ is, like the previous one, an old Chinese ideogram meaning to enter or penetrate, and this could well be a stylization of the elliptic umbilic. In this way we cannot but admire the suitability of the Chinese system of writing; the dominant influence of the spoken word in the West has resulted in an alphabeticalor syllabic system of writing, and the expression (*signifiant*) has violently subjugated the meaning (*signifié*).

In conclusion, we have seen that an analysis of the grammatical structures of language requires a subtle mixture of algebra, dynamics, and biology. Without pretending to have a definitive answer to a problem whose difficulty can scarcely be measured, I venture to suggest that these ideas may contain something of interest for many specialists. [16,17]

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[16] Suppose now that the number of these categories organizing the meaning was reduced and that a typology of the events so instituted was possible; then such a typology, based on an exhaustive description of the structures of the message, would form the objective framework within which the representation of the contents, identified with the semantic micro-universe, would be the only variable. The linguistic conditions of the understanding of world would then be formulated (Greimas 1966).

[17] It thus appears that the future of syntactical research lies in intranuclear investigation, which alone will allow an investigation of the interior of the nucleus and the phenomena based there, and which will produce, in the intellectual order, structures at least as complicated as those of the cell, the molecule, and the atom of the material order (Tesnière 1966).

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Chapter 12
A Semiotic Perspective on the Sciences: Steps Toward a New Paradigm

Myrdene Anderson (1934–), John Deely (1942–), Martin Krampen (1928–), Joseph Ransdell (1931–), Thomas A. Sebeok (1920–2001), and Thure von Uexküll (1908–2004)

Introduction and Commentary: *A Semiotic Perspective on the Sciences*

> *Semiotics has itself thrived in a generative atmosphere of specialization and synthesis. Now, in an expanding intellectual universe, we converge with several other strains of scholarship. In this brief paper, we not only acknowledge this convergence and complementarity, but actively welcome the emerging rapprochement, which we interpret as representing a radical shift in scientific paradigm. This conceptual revolution transcends a dichotomous Cartesian, analytic view of the world, in the direction of a view embracing the whole, respecting complexity, and fostering synthesis.*
>
> (Anderson et al. 1984: 7)

"In the spring of 1983, Thomas A. Sebeok proposed the writing of a kind of 'position paper' or 'manifesto,' jointly with John Deely, Martin Krampen, [Myrdene Anderson, Joseph Ransdell] and Thure von Uexküll, to explore the possibility of semiotics providing a new paradigm or framework in terms of which it will be possible to overcome the divide between the so-called two cultures, and pointing out a direction for the overdue reintegration of the human and natural sciences at a level of synthesis beyond the false dichotomy which has bred the multifarious, stale oppositions of realism and idealism" (Anderson et al. 1984: 35).

Almost a quarter of a century after Thomas A. Sebeok and colleagues issued the above call for what would eventually become the contemporary interdiscipline of 'biosemiotics,' the synthesis of sign science and life science envisioned at that time seems to be finally coming into its own. Today, the spirit of Sebeok's Glottertal conferences of the early 1990s, which brought together researchers from the life sciences with researchers from the sign sciences to help each other explore the role of signs in nature, has now taken institutional form as the *Annual International Gatherings in Biosemiotics* – while his 1991 proposal for the founding of an *International Society for Biosemiotic Studies* finally became a reality in 2005. Already over 300 members strong, that Society maintains an active web presence at www.biosemiotics.org. There, scholars from around the world collaboratively engage in the project that declares its goals to be:

> the study of the myriad forms of communication and signification observable both within and between living systems, Biosemiotics is thus the study of *representation, meaning,*

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> *sense*, and the biological significance of sign processes in nature – from intercellular signaling processes to animal display behavior to such human semiotic artifacts as language and abstract symbolic thought. As such, the interdisciplinary research project of biosemiotics is attempting to re-open the dialogue across the life sciences – as well as between the life sciences and the humanities – regarding what, precisely, such ineliminable terms as *sign* and *meaning* ultimately refer to in the context of living, interactive, complex-adaptive systems (www.biosemiotics.org).

Today, as a result of the intense cross-disciplinary exchange of ideas made possible by the annual international conferences, the dedicated peer review journal *Biosemiotics*, and the outreach efforts of the International Society for Biosemiotic Studies, Sebeok and colleagues' long-envisioned research agenda investigating the relationships between sign processes and life processes is becoming exponentially more interdisciplinary and internationally recognized every year. Indeed, the number of university courses now exclusively devoted to Biosemiotics is steadily increasing, with the first PhDs in Biosemiotics having recently been awarded at the University of Tartu, Estonia – this university having been selected as the permanent new home of the late Thomas A. Sebeok's vast personal library of biology and semiotics literature. One can only imagine how gratified Sebeok would have been, had he lived to see the recent explosion of interest in the field.

For as recently as 1995, reflecting upon the impact-to-date of the 1984 manifesto, Sebeok had written that

> unfortunately, although the 'two cultures' [of science and the humanities] as ideal assemblages, still by and large "can't talk to each other", that is only the lesser part of our – that is, the semiotics community's – predicament. Much more enfeebling is the prevailing estrangement *within* the riven world-wide semiotics commonwealth itself, between the many who would style themselves humanists and a scientifically cultivated minority. In a paper, *A semiotic perspective on the sciences: Steps toward a new paradigm* (Anderson et al. 1984), six of us tried to address this dilemma, but in the short run, to little avail. The number of scholars who nimbly scud back and forth between the 'two cultures' remains heartbreakingly minuscule (1995: 3).

Yet today, less than fifteen years later, scholars from both the natural sciences and the social sciences are taking up the challenge to learn enough about semiotics to be able to produce semiotically-informed analyses of the phenomena they study – just as semioticians have begun to educate themselves on the basic biology of life's manifold communicative and representative sign-processes, so as to be able to contribute to one of the most exciting intellectual dialogues of our time: the investigation of the role of signs for life itself.

Certainly this dialogue would never have come into being in its present form, were it not for Thomas Sebeok and a host of interdisciplinary thinkers, to whose work the current field of biosemiotics owes considerable debt, but who, for reasons of space, are not represented by reprinted selections in this volume. Such widely read and deeply influential pioneers include Floyd Merrell, Stanley Salthe, Paul Bains, Eugene Yates, Edwina Taborsky, Frederik Stjernfelt, Nathan Houser, Vincent Colapietro, Mads Bergmann, Menno Hulswit, Eugene Baer, Roland Posner, Paul Boussiac, Marcel Danesi, David Savan, Augusto Ponzio, Susan Petrilli, Brook Williams, Paul Cobley, Winifred Nöth, Ferrucio Ross-Landi, and Lucia Santaella Braga, just to name a few.

Of particular importance are the three of the six authors of the following selection whose other work is not represented by reprinted articles in this volume, but who nonetheless have left and continue to leave an indelible mark upon the contemporary research agenda of biosemiotics.

Myrdene Anderson (1934–) is an American-born anthropologist, linguist, and semiotician who received her PhD in Anthropology from Yale University in 1978 and is now Associate Professor of Anthropology, Linguistics, and Semiotics in the Department of Sociology and Anthropology at Purdue University. A past president of both the Central States Anthropological Society and of the Semiotic Society of America, her principal research interests are systems, scientific, and semiotic approaches to the understanding of human socio-culture; the ethnography of marginality; and the longitudinal ethnographic study of pastoral and nomadic peoples, especially the Saami people of Lapland. Anderson's research on Saami ethno-semantics commenced in 1971 and continues today, augmented by other projects involving both fieldwork and archival investigations. These other projects include the study of real and metaphoric trash; an ongoing ethnography of the Artificial Life movement; research on alternative gardening practices; reflections on play and folklore; and the unpacking of anthropological praxis. This is in addition to her continued deep involvement with the biosemiotic community, at whose annual international conferences she is a regular speaker, as well as being a founding member of the International Society for Biosemiotics Studies.

John Deely (1942–) has been writing on the interface of science and semiotics since his first publication on the philosophical implications of the theory of evolution in 1965. A Professor of Philosophy and Semiotics at the University of St. Thomas, Houston, and past President (2003) and past Executive Director (2006) of the Semiotic Society of America (SSA), Deely was chosen by the SSA to be its first living Thomas A. Sebeok Fellow in 1993. In 1985, Deely translated and edited the critical bilingual edition of John Poinsot's (St. John of the Cross') 1632 *Tractatus de Signis* – "the earliest known treatise to demonstrate the unity of semiotics as a systematic inquiry into the action of signs as consequent upon their unique being as triadic relations" (Deely 2005: 212).

Deely was awarded the first Mouton d'Or Award for the best essay published in the field of semiotics by the journal *Semiotica* for the calendar year 1981, and he was awarded that prize a second time in 2004. His 1990 *Basics of Semiotics* has been translated into ten languages, and his other major works include his massively influential *Four Ages of Understanding: The First Postmodern Survey of Philosophy from Ancient Times to the Turn of the Twenty-First Century* (2001), *What Distinguishes Human Understanding?* (2002), *The Semiotic Animal* (with Susan Petrilli and Augusto Ponzio (2005), *Intentionality and Semiotics* (2007), *Purely Objective Reality* (forthcoming) and the trilogy *Augustine & Poinsot: The Protosemiotic Development* (2007), *Descartes & Poinsot: The Crossroad of Signs and Ideas* (2008), and *Peirce & Poinsot: The Action of Signs from Nature to Ethics*

(2009). In 2010, a collection of thirty of Deely's most seminal articles, all of which have profound relevance to the project of biosemiotics, were collated by semiotician Paul Cobley and released, with illuminating commentary by Cobley, as *Realism for the 21st Century: A John Deely Reader*. Married to Maritain scholar Brooke Williams Deely (née Smith), Deely is also chief editor of the University of Scranton's *Approaches to Postmodernity* book series, of which Jesper Hoffmeyer's (2008) *Biosemiotics*, excerpted in this anthology, is the second volume.

Joseph Ransdell (1931–) is a Fellow and past President of the Charles S. Peirce Society, whose principal research interests are the history of philosophy, and the theory of meaning. Ransdell was an Associate Professor of Philosophy at Texas Tech University at the time that the article reprinted here was Written. He retired from teaching in 2000 and has remained active as a scholar and webmaster of academic materials ever since. In 1993, Ransdell established the PEIRCE-L Internet Forum and shortly thereafter created the website *Arisbe: The Peirce Gateway* at http://www.cspeirce.com/arisbe.htm which Ransdell has successfully designed to function as the gateway to all the resources on the World Wide Web related to the life and work of Charles S. Peirce. The *Arisbe* website – in conjunction with the invaluable archival and exegetical work that continues to be produced by Ransdell and his colleagues at the Peirce Edition Project, and which for the last two decades has been painstakingly reviewing the over 80,000 pages of manuscript left behind by Peirce in order to prepare the definitive scholarly edition of his works – deeply informs the biosemiotic analyses of those scholars working in the Sebeokian tradition of biosemiotics.

In sum, Sebeok's 1995 worries about the success of the research project outlined in the 1984 'manifesto' that is reprinted as the following selection appear, in retrospect, to have been premature. Rather, we can now see how the conceptual and programmatic seeds that Sebeok and his colleagues had been planting diligently throughout the 1970s and 1980s were quietly taking root throughout the 1990s, only to begin sending out their first, still very tentative, shoots aboveground now. It seems appropriate, then, to conclude the first half of this anthology with this groundbreaking article that not only sets out the mission statement, as it were, of the biosemiotics that lies in wait – "a semiotics which provides the human sciences with a context for reconceptualizing foundations and for moving along a path which, demonstrably, avoids crashing into the philosophical roadblock thrown up by forced choices between realism and idealism, as though this exclusive dichotomy were also exhaustive of the possibilities for interpreting experience" (1984: 8) – but also, by its very collaborative and interdisciplinary nature, remains a paragon of biosemiotics scholarship itself.

A Semiotic Perspective on the Sciences: Steps Toward a New Paradigm (1984)

Changing Paradigms

In the expanding intellectual universe of contemporary science, semiotics provides an environment in which specialists from many fields converge toward an interdisciplinary union. This poses the question of the exact role semiotics plays in bringing about such a union. Is it a discipline, a method, or an approach and perspective contributing to the integration of the sciences and of knowledge in general?

An Expanding Intellectual Universe

A paradox worthy of attention: both specialization and synthesis percolate on the edges of human knowledge. Boundaries of systems generate patterns of catastrophe, fields of inclusion and exclusion, figures and grounds of *Gestalten*, and relations of energy information and spacetime, all of which flipflop and fascinate us the more.

Semiotics has itself thrived in such a generative atmosphere of specialization and synthesis. Now, in an expanding intellectual universe, we converge with several other strains of scholarship. In this brief paper, we not only acknowledge this convergence and complementarity, but actively welcome the emerging rapprochement, which we interpret as representing a radical shift in scientific paradigm (see Kuhn 1970). This conceptual revolution transcends a dichotomous Cartesian, analytic view of the world, in the direction of a view embracing the whole, respecting complexity, and fostering synthesis (cf. Percy 1983, Singer 1980).

In his “Pretext” to *Space structures,* mathematician Arthur Loeb (1976: xv) addresses a dilemma which must face the majority of academic semioticians – whether one’s targeted audience will be a *union* or an *intersection* of specialists. There may be different solutions for various contexts of communication, but in this paper we opt for the fuzzy generality of a union as preferable to the potentially trivial token intersection. Much phatic communion by interdisciplinary semioticians, unfortunately, tends to the latter pole, with prominence given to the recitation of genealogies (cf. Bouissac 1976, 1979, 1981). The former pole, on the other hand, might fall under the rubric of “ecumenical” semiotics (Sebeok 1977b), a semiotics which provides the human sciences with a context for reconceptualizing foundations and for moving along a path which, demonstrably (e.g., Williams 1984), avoids crashing into the philosophical roadblock thrown up by forced choices between realism and idealism, as though this exclusive dichotomy were also exhaustive of the possibilities for interpreting experience.

Avoiding this particular roadblock is no mere empty claim, still less a maneuver or tactic. It is rather the rationale enabling semiotics to reintegrate the natural and human sciences in the higher synthesis proper to a doctrine of signs. Before striding into ecumenical territory, however, the next sections touch ever so fleetingly several of the more recently polished figures and less polished concepts in semiotics.

Semiotics as Perspective

A quote from Peirce (1934: 302) – "this universe is perfused with signs" – anticipated the leaky boundary between semiotic scholarship and the traditionally specialized research parallel to it in the humanities, social sciences, life sciences, and conceptual sciences. In all of these fields, significant work tends to be accomplished by individual scholar-scientists in touch with themselves and with their sibling disciplines, and hence aware of the value in exchange. Any boundaries which become the justification for their contents demand incessant maintenance, at the cost of internal investments in metabolism and fantasy.

Much venom has been expended, in accusation as well as in defensive jest, declaiming semiotics as a colonizer of well-established academic disciplines. At the same time, confusion reigns both among and beyond the *cognoscenti* as to whether semiotics is an approach, a field, a discipline, a method, a theory, a science, or a disease (Deely 1976, 1982a, Eco 1976, 1980, Ransdell 1979, Rey 1973, Scruton 1981, Sebeok 1977b). Above all, semiotics must be a perspective. But the currency of both these topics suggests a fundamental uncertainty in the sanctum of signs. This uncertainty in itself might be either provocative or sapping in its effects. The state-of-the-art conference, "Semiotics: Field or Discipline?", sponsored by the Research Center for Language and Semiotic Studies at the Bloomington campus ofIndiana University in October of 1984 may prove to be a watershed between ambivalent specialization and confident synthesis in semiotics.

Hyphenated Semiotics

As happens in the ontogeny of any enterprise, semiotics has generated a terminology, some of enduring utility, some of it outgrown, and some of the tokens never intended to be other than expressive. Some speciality fields have been labeled by juxtaposing the subject matter with the approach, as in the case of "medical semiotics" "legal semiotics" and "semiotics of architecture". There have been adjectives further delineating aspects of the semiotic approach, such as "experimental semiotics", "empirical semiotics" (Shank 1984, Deely and Lenhart 1981: 317–343), and experiential semiotics' (discussed in Ransdell 1979, 1982).

Finally there are several sets of prefixes and compounds suggesting distinct genera of sign phenomena as the focus of inquiry, and here one recalls "endosemiotics", "exosemiotics", "anthroposemiotics", "zoosemiotics", and "phytosemiotics". Humans, the students of semiotic science, may perforce cast the enterprise anthropocentrically. Inexcusable, however is the glottocentric, or any unqualified logocentric, bias.

Until the recent decade, it was biologically acceptable to refer to two kingdoms of living things and to underline the unique properties of humans within the socalled animal kingdom. In this spirit, Sebeok in 1963 and later (1965: 1006, 1979: 3560, Sebeok et al. 1972: 61) contributed "zoosemiotics", distinguished "anthroposemiotics", and anticipated "phytosemiotics". The last subject has been explicitly broached by Krampen (1981), and defended as a domain of study by Deely (1982b). Although zoosemiotics and anthroposemiotics suggest some discontinuity between ethologically-grounded communication and species-specific genres of humans, this oversimplifies the more interesting realities, as has often been noted (Sebeok 1965, 1975a, 1977a, Umiker-Sebeok and Sebeok 1980, Deely 1978b, 1980).

As will be discussed, plants communicate complex messages, including tree-to-tree pheromonal warnings about caterpillar predators (reported by Orians and Rhoades 1983, Baldwin and Schultz 1983), and cell-to-cell memory within cotton seedlings providing increased resistance to mite predation (Karban and Carey 1984). This is but to indicate that study and documentation of plant-plant and plant-animal-plant communication has grown vastly over the past decade (Montalverne 1984).

At still other levels, it is now recognized within biology that, rather than two, there are at least three (Woese 1981), if not five (Whittaker 1969, Margulis 1970, 1981), kingdoms of living things. Beyond the confines of traditional biology, moreover, our planet, Gaia, has evolved as a system profoundly shaped in many stages by its living constitutents (Lovelock 1972, 1979, Bargatzky 1978).

In this position paper, we reinspect some prevailing continuities and discontinuities in semiotic phenomena and within the leagues of thinkers coming to grips with these. Whether old labels befit new concepts, or new labels old concepts, is only part of our problem. There exists no convenient catastrophe between emerged and emerging. Consequently we emphasize the evolution both of the universe and of our knowledge systems in a semiotic perspective. We suggest that the insulation between the conceptual sciences and the natural sciences is as counterproductive as that within the various branches of the humanities, social sciences, and natural sciences. Moreover, these diverse fields can be broached and integrated with semiotics and other systems sciences. The paramount and, we posit, essential contribution of semiotics to this emerging synthesis lies in Peircean semiotic (Ransdell 1977, 1985a, b, Krampen 1979) and its acknowledgement of the panoply of sign relations and the participation of the interpretant – a *doctrine* rather than a science of signifying.

The Concept of "Umwelt"

Semiotics will always be discovering and rediscovering thoughtful wrestlers of the sign. A valuable review of some of these semiotic thinkers, along with other issues, including ecumenicalism, already exists in Sebeok's seminal sketches of Jakob von Uexküll (Sebeok 1979: 187–207) and Karl Bühler (Sebeok 1981: 91–108), which gave rise to similar sketches of Francis Lieber (Kevelson 1981), R. G. Collingwood

(Russell 1981), John Poinsot (Deely 1982c), and eventually to the ongoing series of Special Sessions in "Neglected Figures in the History of Semiotic Inquiry" at the Annual Meetings of the Semiotic Society of America. Here we draw particular attention to recent translations of two works. The earlier of these works was unknown to Peirce, and the later one was written without reference to Peirce. Yet there is striking anticipation of Peirce's semiotic in the earlier work and a resonance of it in the later one.

The first is the *Tractatus de signis: The Semiotic of John Poinsot* (1632), presented in integral bilingual format (forthcoming 1985). This work adumbrated in a foundational way the contemporary Peircean enterprise of assimilating the study of natural and cultural phenomena alike to the perspective of semiotic (Winance 1983). Developed entirely around the idea of relative being and tracing that idea across the ages to its origins in ancient Greek philosophy, this work effectively demonstrates at once the unifying power of semiotic vis-à-vis the fractured intellectual traditions of modem philosophy and the foundational thrust of the doctrine of signs toward an establishment for the first time of an experimental anthropology equally able to account for what is and what is not present in human experience in physically isolable ways.

The other is Jakob von Uexküll's *Bedeutungslehre* (1940), edited by Thure von Uexküll as "Jakob von Uexküll's 'Theory of Meaning'" and presented as a special issue of *Semiotica* 42.1 (1982). Jakob von Uexküll was significant in the founding of behavioral physiology, or ethology, though he seems to have been unacquainted with either Saussure or Peirce, and never heard of Poinsot, but, like his younger acquaintance Cassirer, did draw on Kant.

Von Uexküll's understanding of the sign in biological systems allocated quite different roles to animal and to plant "behavior". While this continues to be a conventional division of labor, with ethologists restraining themselves to the study of macroscopic animal behavior and plant physiologists concentrating on microscopic plant behavior, Jakob von Uexküll's particular rationale for this dichotomy was unique. He suggested that animals, being mobile, possess receptor and effector organs integrated by a nervous system. With these, the animal is able to model its *Umwelt,* or significant surroundings. Plants, according to Jakob von Uexküll, lack these organs and consequently have no *Umwelt,* no cognitive map, a view consonant with biological assumptions held up to the current decade. He visualized plants as being passively immersed in a habitat, which directly communicates with the plant by "meaningful" stimuli. These ideas are discussed, of course, by Jakob von Uexküll (1940, 1957), and by Thure von Uexküll (1982a, b), Earl W. Count (1973: 4–8, 221–223), Donald R. Griffin (1981), Martin Krampen (1981: 187–209), John Deely (1981, 1982a: 93–106) and Thomas A. Sebeok (1979: 187–207).

Exposure to these ideas enriches us, provided only that we appreciate them in the context of their own times as well as in relation to our own both of which in turn are colored by the past in different and seldom unimportant, if elusive, ways. It is the concept of *Umwelt* which intrigues us most with respect to Jakob von Uexküll. The species-specific *Umwelt* complements an individual but necessarily species-constrained *Innenwelt.* These correlatives mediate all constellations of sign traffic having relevance to the animal.

The *Umwelt* is then the crucible of the animal's informational relationships, perforce the "meaningful" ones, with the environment. In fact, for the animal, the environment *consists of* these sign relationships, with conspecifics, with predators and prey, with shelter, weather and terrain, and with odors, sounds and silence. In many respects, this anticipates and complements the notion of the *niche* as high-dimensional hyperspace (Elton 1927, Hutchinson 1957). G. Evelyn Hutchinson's *An Introduction to Population Ecology* (1978) includes a generous chapter on the history of the concept of niche, which developed from a rudimentary and ancillary notion in 1857 (Hansmann 1857) to a sophisticated concept with Grinnell in 1924 (Hutchinson 1978: 152–212, 1979: 243–247).

Unfortunately, many contemporary researchers assess niche only through measures of energy relations, and, hence, reduce a whole and dynamic system to a skimpily-looped teleology, albeit one elegantly-clad quantitatively. Efforts to address this reductionism are sprinkled throughout the literature (e.g., Allen and Starr 1982, Patten and Auble 1980, Pimm 1982, Smith and Morowitz 1982, and both special issues of *Synthese* 43.1 and 43.2), but have had little effect on technicians exercising methodologies, that is, on persons working in the field who are not scholar-scientists.

That sedentary plants have a diffuse and poorly-understood internal communication system rather than a centralized nervous system may not disqualify them from possessing an *Umwelt* any more than it excludes them from existing in a relational web called "niche". Niche is the scientist's best approximation of an inferred *Umwelt;* as such, it may be operationalized to incorporate relatively few of the countless and themselves interacting orbits of sign relations. Simulations in such working models serve a purpose if they humble us as to the actual complexity of organism in its surroundings, or of species in niche, but delude those who are satisfied by empirical constructs. The use of the less familiar *Umwelt* as a semiotic term is partly to remind us that the web of sign relations is at all times informational and energetic, spatial and temporal, objective and subjective.

Here we confront the former, linear paradigm head-on, because none of these pairs is a dichotomy. Each is a unitary relationship, with aspects implicating other aspects. The Cartesian analytic and reductionistic "either-or" must succumb to a synthetic, holistic, and provoking "both-and". Much of the confusion surrounding studies of miscalled "animal language" can be traced directly to this theoretical point (Deely 1975, 1978b, 1982a, Sebeok 1977a, Sebeok and Umiker-Sebeok 1980, Sebeok and Rosenthal 1981; and so on).

Challenges for Semiotics

Imputed discontinuities in knowledge systems have led too often to unnecessary and deleterious divisions of labor. Of particular consequence is the cleavage between ethology and ecology and between scholar and scientist. A semiotic perspective bridges these enterprises, particularly when semiotics can encompass the study of dynamical systems as a whole.

Focus in the Division of Labor

It is clear that Jakob von Uexküll's *Umwelt,* a qualitative and meaningful model of a species' significant surround, and his *Innenwelt,* the individual's actualized version of that surround orchestrated by its nervous system, both integrate consummate environments, exterior and interior. This is one more dichotomy which is collapsing in the emerging paradigm. Practitioners utilizing the niche concept increasingly acknowledge the complexity inherent in a species' *Umwelt.* In so doing, they may not always have benefit of von Uexküll's label (e.g., Patten and Auble 1980), but accomplish this by default when confronted with anomalies such as the ubiquity of "maladaptive" or "dysfunctional" behavior which refuses to reduce to "adaptive" or "functional" rationales.

More fundamentally it is clear that ethology and ecology have wandered along unnecessarily divergent paths. This division of labor, like those between the study of "animals" and "plants" (fortunately still united in ecology), of the macroscopic and the microscopic, and of "individual" and "system", is a costly one. Recent attempts to reintegrate the "three E"s' of ethology, ecology, and evolution (e.g., in Stonehouse and Perrins 1977, Krebs and Davies 1978, 1984), while exciting, show no inclination to transcend the old paradigm. Table 12.1 illustrates some of the tensions and gaps in our knowledge exacerbated by prevailing patterns of specialization in academia, which reflect in turn dualistic tendencies in our world view. Of course, dichotomies may come naturally to organisms which happen to be bilaterally symmetric, but any cross-cultural inspection of cosmologies will demonstrate that this biological

Table 12.1 Fractures in knowledge arising from the division of scientific labor

Imputed discontinuities	*Some disciplines affected*
Living – nonliving	Natural sciences – physical sciences
Animal – plant	Zoology – botany
Human – alloanimal	Social sciences – natural sciences
Verbal – nonverbal	Linguistics – ethology
Disregarded continuities	*Some disciplines affected*
Space – time	Ecology – evolution
Matter/energy – information	Ecology – ethology
	Social sciences – humanities
	Economics – psychology
Macroscopic – quantum	Ethology – biochemistry/astronomy
Regularly-negotiated boundaries	*Some disciplines affected*
Inside – outside	all
Self – other	
Digital – analogue	
Episodic level/storage – continuous flow	
Quantification – qualification	
Analysis – synthesis	
Abduction – deduction – induction	all

arrangement hardly determines a dualistic species-mindset for us, any more than our experience with time predicts a linear, causal universe shared by all *Homo sapiens* (see Lee 1959, Snyder 1978, Curtis 1978, Hall 1984).

The macrosemiotic and the quantumsemiotic (the megasemiotic and the microsemiotic) present twin challenges to the human investigator: first, how to understand phenomena of such grain and at such exotic levels in terms of semiosis respecting that system; and second, how best to communicate this understanding to others. These parallel the problems inherent in human-scale phenomena which must be translated between cultural codes in space-time or between species. A number of scholars (including Bateson 1972, Curtis 1978, Dawkins 1976, Delbrück 1978, Florkin 1974, Haraway 1976, Jones 1982, Laudan 1981, Merchant 1980, Wechsler 1978) emphasize the role of metaphor/metonymy in the processes of elucidation and explication.

In all cases the need is to avoid specious and redundant divisions of academic labor grounded in methodology without further explicit theoretical rationale. Those aspects of scientific endeavor which appear overdetermined are likely to be those which will prove maladaptive in the longer term (see Dobert 1981: 116–119, Ransdell 1979: 286–288).

Fuzz in the Unity of Science

All attractive paradigms, such as evolution, ecology, and Gaia, which will be discussed below, deal with relationships of complex phenomena which in themselves are laden with complexity. Systems thinking, whether self – consciously scientific or folk wisdom, is responsible for any number of general-purpose aphorisms, such as: "All things change so that all things can remain the same"; "The present contains the past"; "A whole is greater than the sum of its parts"; "Life is change"; "The whole is simpler than its parts"; and the like.

Semiotics concerns itself with systems as well – systems of signs, of communication, of clues, and of meaning. Thus far, however, semiotics has seldom dealt with dynamical systems as a whole: those nonlinear, irreversible realities where energy explicitly fuses with information, such as experience, ontogeny, and phylogeny. Because of the specialization of semiotics in systems seemingly unconstrained by energy relations, the shape of change, whether directional or nondirectional, has too often been neglected. Thompson, in introducing catastrophe theory in his book, *Rubbish Theory,* protested that "semiology cannot distinguish change from noise" (1979: 61). This need not be the case, and Thompson's choice of terms here already signals a great deal to the sophisticated readership (Sebeok 1971: 53). Hence one reason for the present paper.

Catastrophe theoretical concepts have been introduced into mainstream semiotics by Sebeok (1976, 1977a, b, 1979) and by Thom himself, in print (1968, 1970, 1973, 1974, 1975a, b, 1978, 1980), and in person at the 1979 international meetings in Vienna and at ISISSS "80" in Toronto. In brief, catastrophe theory models topologically discontinuous phenomena, those having boundaries in space-time, including those which change with time. However, "time" in these models is usually two-point physical time or products of the same, and the number of independent parameters is likewise pragmatically limited to four. A semiotic perspective can potentially deal with space-time sensitive to the grid and rhythm of the phenomenon-observer relationship and in the degree of resolution desired. Behavior of matter/energy-information in space-time may be both described and explained, either quantitatively or qualitatively, but should not be reduced to any of these parameters. Table 12.2 lists the provocative elements of systems and some of their dynamical properties. In sampling scholarly work across the centuries, we discover that most of the acknowledged minds, and many others, resonated to these basic properties of systems. This in itself is properly exciting, but need evidence no more than a human propensity for integrating complexity.

There is currently a pervasive distrust of comprehensive paradigms. Much work passing as science meanwhile amounts to mere data accumulation, with or without some perfunctory and transiently stylish methodology. Whenever the ties binding methodology, theory, and epistemology are severed, the exercise of the first becomes, at best, highly ritualized play, and, at worst, imitation of the antecedent, grounded science or scientist. For our purposes here, we reject the two-cultures view of scientist and scholar (Snow 1959, 1964). Only when "scientist" is constrained to be "inductive", "empirical", or "experimental" (see Ransdell 1982), can this antinomy even be imagined. The basic relationships in the necessary triadic abduction/deduction/induction preclude the pedestaling of anyone process.

Table 12.2 Generic systems elements and processes

Systems elements:
- *Space-time*, disjoint given cognition
- Matter/energy conflated to *energy*
- *Information* implicated by energy

Process variables:
- Continuous *flow*
- Episodic *level/storage*

Trends in the maturation of systems:
- *Complexification:*
  - Intensification of *flow of information* and energy
  - Intensification of *storage* of information and *energy*
  - Compartmentalization and miniaturization:
  - Vertical *stratification – hierarchies*
  - Horizontal *differentiation – specialization*
- *Negentropy, self-organization, and directionality:*
  - *Integration* and extensive feedback circuitry
  - Interchangeable units and *equifinality*
  - *Irreversibility*
- *Dissipative structures*

Rather more insightful than any tension between scientist and scholar are the overlapping modalities of art, craft, and science. The semiotician functions as an artist during that portion of the enterprise which is largely means-oriented expression and shaped by enabling constraints, as a craftsperson while instrumentally ends-oriented and shaped by limiting constraints, and as a scientist when additional rules are superimposed to instruct the synthesis and discard of information and to evaluate “significance”. This systems substructure of art, craft, and science is sensitive to cultural and individual styles, neither precluding other modalities nor imposing an unequivocal trichotomy (see Spencer-Brown 1972, Stokes 1973). “Science” appears to be the more dynamic and emergent dialectic of all constraints, temporal and spatial, informational and energetic, and *may* be more apt to transcend culture, although it rarely if ever does; Outside semiotics, as well, scholarship and science are necessarily, even inevitably, fused in matured minds. “Maturation” as a systems concept relates to such features as degree of integration, rather than to temporal ones (see Table 12.2).

Evolution and Biogenesis

The concept of evolution taken generically designates the processes of continuity and change in any dynamical system, including but not limited to biological systems. Reappraisal of this concept incorporates such elements as coevolution, symbiosis, and biogenesis, and transcends the linear traditions with their post-Renaissance emphasis on efficient cause-effect and “progress”.

On the Evolution of the Concept of Evolution

In the beginning was the word – at least one for each language-culture group – which dealt with the origins of the cosmos and which imputed relations between the significant characters of the drama. Each people has thus acknowledged its involvement in the systems of evolution and ecology in its spatiotemporal surround. The science of predominantly temporal relations of living things reached another plateau of maturity with Darwin’s theory of evolution. The science of predominantly spatial relations of living things in their environment was similarly stimulated, on the one hand, focusing on energy relations, by Haeckel’s concept of ecology and Elton’s notion of niche, and, on the other hand, focusing on information relations, by Saint-Hilaire’s concept of ethology with von Uexküll’s formulation of *Umwelt.* These individuals’ names serve as both touchstones and watersheds in biology, much as the name of Peirce serves within semiotics proper. Within the panoply of biological sciences up to this point, semiotics has had the most extensive overlap with ethology, which has even been called “natural semiotics” by Sebeok (1977a).

Originally, of course, evolutionary science developed out of the postRenaissance Western linear traditions, with their emphasis on time, “efficient” or “productive” causality and its effects (“progress” and “perfection”), all rooted in assumptions of the “great chain of being” chronicled by Lovejoy (1936). To this day one reads of “higher” and “lower” organisms, of “complex” and “simple” languages, of “advanced” and “primitive” societies, with the latter perhaps “preliterate” or “underdeveloped”. Ludel’s critique (1982) of studies on interspecies communication makes this point very well. Given coevolution (discussed in the following section), there has always been interspecies communication; the laboratory variety is artifice. We are inevitably steeped in anthropocentrism and ethnocentrism. Neither species, group, nor individual can truly transcend its phylogeny, history, and ontogeny. This is how “the present contains the past”. But the present is not determined by the past. While anthropocentrism and ethnocentrism cannot be, strictly speaking, controlled, they can be controlled *for,* in part, through our very awareness of them.

In the narrow sense, evolution designates the process and the study of continuity and change in living systems organized in holons of species. Species are unique semiotic systems in that they are for the most part reproductively closed, but open within the framework of *Umwelt* to information and energy relations of far greater magnitude and complexity than can be explained by reference to narrow notions of differential reproduction, fitness, adaptation, or competitive exclusion (Conrad 1972, Crook 1970, Peters 1983, Johnston 1976, Waal and Van Hooff 1981). Hence, they can best be understood with reference to teleonomy and open systems rather than by the teleology of final cause (Pittendrigh 1958, Mayr 1974, brief discussion in Deely 1966: 91–92 n. 96). Whether evolutionary change is gradual or through pulses of semiosis and equilibria (Gould 1977), or both, patterns in the persistence, diversification and extinction of forms exhibit the trends characterizing maturation in systems generally (see Table 12.2). These trends of intensification in the circulation and storage of information and energy, tendencies to stratification and specialization, and consolidation of functional guilds and dissipative structures will be discussed as semiotic phenomena in the sections to follow.

Meanwhile, of habit and necessity, we use the terms “evolution”, “ecology”, and “ethology” in many less technical contexts, in both more focused and more general ones. For example, systems of ideas, such as those of semiotics or of evolution itself, evolve and have ecologies transacting appreciable resources, specifically, energy-information.

The overwhelming pattern in the development of such conceptual systems is their increasing encompassment of knowledge (Haken 1977, Marney and Schmidt 1976, Sahal 1982, Scharfe 1982, Simon 1969, Thom 1974), or holism (see Smuts 1926 for an early use of this term), at the same time as they generate and systematize more and more particularistic data. We witness, at every scale, “human” and quantum, similar behavior in dynamical systems, whether we limit our purview to material systems (focusing on energy relations – e.g., Gerard 1957, 1960, Miller 1978, Miller and Miller 1982), or to nonmaterial systems (focusing on information relations – e.g., Ackoff and Emery 1972, Bateson 1972, 1979, Thom 1975a, Tomkins 1975), or to both concrete and abstract (presumably whole) systems (e.g., Adams 1975, 1981, Bertalanffy 1973, 1981, Boulding 1978, 1981, Buckley 1968, Hirsch 1984, Jantsch 1980, 1981, Koestler 1967, 1978, Laszlo 1972, 1983, Maruyama 1963,

Table 12.3 Levels of evolutionary transformation

Factors in biological transformation	Fundamental unit affected	Elemental medium of message	Nature of message
Teleonomic epigenesis	Taxon (at any level of inclusion) and organism	All media, with *push* of ENERGY-INFORMATION	Trajectory of actualized enabling and limiting in phylogeny and ontogeny
Natural selection	Organism (as situated in all encompassing and overlapping systems)	All media, with *pull* of ENERGY-INFORMATION	Drag of differential replication of certain alleles at expense of others, as consequence of “differential reproduction” evidencing “fitness” in an encompassing system and resulting in “adaptation”, *or* precipitating from scholastic factors extrinsic to system
Mutation	DNA, chromosome	INFORMATION	Change of information (substitution, loss, or addition, at level of “gene” allele or nucleotide) generating variation of both genotype and phenotype
Recombination	Sex cell	INFORMATION	Unique recombinations of information contributing to variation of both genotype and phenotype
Gene flow	Population	SPACE-TIME	Information transfer (between populations linked to mobility of individual allele-carriers)
Gene drift	Population	SPACE-TIME	Information skewing (within a population isolate of individual allele-carriers

1976, Wilden 1972, Zeleny 1980). Table 12.3 further maps out these basic systems domains and their associated processes.

Abstract-concrete and conceptual-material are commonly treated as synonymous pairs, which clouds their utility as semiotic parameters in any systems analysis. Not every systems approach through the ages has been consciously holistic or semiotic, let alone has each made explicit the dialectic of information, energy, and dissipative structures (Prigogine and Stengers 1979, 1984). Nor has each acknowledged the dynamic and open properties of the object/subject of study and of the very semiosis of study. It follows that, for reasons of period or preference, there have been various ways to engage systems. One enduring approach is through semiotic events, even though this has thus far been unduly focused upon information relations. The overemphasis on the study of energetics, and the reduction of phenomena to quantitative measures in terms of energy, as in the vulgar forms of ecology and cultural ecology, while dominant in the literature, show signs of an exiting paradigm. We believe the emerging paradigm respects the dynamic relation of energy-information and nonequilibrium trajectories, as can be seen in our final section.

It has often been noted that evolution in physical systems is associated with entropy – the decrease of order with movement toward equilibrium; this is in accordance with the second law of thermodynamics. Yet, in living systems, evolution is associated with an increase in order; this complementary process has been called the second law of systems (Makridakis 1977), and is often referred to as negentropy (Allen 1981). At the same time, nonequilibrium dynamics have become understood in physical systems largely through the contributions of Prigogine (1962, 1980) and coworkers, who also recognize ubiquity of nonequilibrium in living and cultural systems (Prigogine and Stengers 1979, 1984).

Because of its recent evolutionary spurt – from cybernetics to dissipative structures – there is no monolithic "systems theory". This makes for an eclectic approach. It is less savory as a technique, for some persons equate knowledge with control (e.g., Batty and Hutchinson 1983, Laszlo 1983, Pattee et al. 1966), not realizing that, where semiotic components playa major role, the *more* we understand the complexities of a system, the *less* we should be confident of our power to manage it. (Cf. Berlinski 1976).

On Coevolution

Given this dynamic in the evolution of all systems – energetic, informational, and whole – we follow without surprise the substance of refinements in the theory of evolution itself. First, still dealing with the living world, came the awareness of coevolutionary processes which network biota in webs of relationships (Bateson 1972, 1979, Ehrlich and Raven 1964, Holling 1976, Hutchinson 1957, 1978, Margalef 1968, Odum 1969, 1981, Smith 1975, Varela et al. 1974). Applying to this insight the specific realization of the role of signs as mediating the whole of experience and providing its structure, this situation has aptly been characterized the *semiotic* web (Deely 1978a, 1982a, applying the metaphor from the title of Sebeok 1975b). Survival is significant therefore not primarily at the individual nor even at the species level, but at that of a larger community circulating energy-information. That expanding open system is not amenable to definitive study under the microscope or beyond telescopic glass. It can be modeled, however, and this artifact compared with other orders of reality.

The entire biotic world must consist of coevolutionary products, yet their relationships are so complex that biologists seldom chart more than a pair of species at a time, to show their interdependence, their complementarity, and/or their synchrony

(Futuyma and Slatkin 1983, Nitecki 1983, Thompson 1982). What Teilhard de Chardin (1959) called the "biosphere" would, following the Gaia hypothesis, include the lithosphere, hydrosphere and atmosphere as well. Coevolutionary models stress the importance of cooperative forces over competitive ones, but must also account for speciation of biological forms within some scale of ecosystem, as well as transformations at the level of the latter.

Somewhat at odds with these assumptions of coevolution, Dawkins (1976, 1982) argues for the gene as the competitive unit participating in natural selection – hence the "selfish gene". Klopf (1982) has carried this metaphor to another level in his "hedonistic neuron". Our knowledge of the behavior of systems suggests that perseverance is apt to be a feature of the more inclusive holon, even at the expense of or in spite of certain of the included ones. A corollary of this observation is the fact that subsystems need not "serve" overarching systems, and may even be organized in tight guilds of interaction which bear only slightly on other aspects of the system. This reasoning leads one to agree with Dawkins' particular conclusion that genes need not be "adaptive", without it at all compelling agreement with the overall tenor and theses of his arguments.

In an essay critical of but inspired by Dawkins, Hull (1981: 33) points out that one must not conflate the two-step evolutionary processes of replication and interaction. Replication concerns coded information: interaction (with numerous internal and external environments) concerns the transaction of meaningful energy-information. The latter process entails interactions, with conspecifics and with others, which appear to be more complex than cooperation (including others in *energy-information)* or competitive (excluding others from *energy-information),* and which must be reassessed at each order of semiosis (see Count 1973: 4–8, Gatlin 1972, Swanson 1983).

We may note here in passing that sociobiology (Wilson 1975, 1978), predicated on a competitive model of behavior, appears to be a direct descendant of Darwin's linear evolution, and in some "ways the converse of coevolution". It is certainly conceived in a presemiotic perspective, and its extensions seeking to explain the evolution of culture (Lumsden and Wilson 1981, 1982) suffer, as Huntingford (1982) and others (cf. commentaries following Lumsden and Wilson 1982) well show, from emphasis on competition within a framework of energetic payoffs, and from inattention to interesting complexities. In these discussions which often fail to integrate competition and cooperation, energy and information, and still other dynamics within or beyond the nucleotide or species, we recognize tinges of "survival of the fittest" notions of "selection-*in*". A semiotically-informed view of natural selection's role in evolutionary processes would first prefer the paraphrase "survival of the *not unfit*" to approximate the "*selection-out*" actually occurring, where those elements, individuals, or populations left out of the game (cf. Slobodkin 1968) may simply be victims of stochastic events. Second, natural selection itself is but one of a number of semiotic processes involved in biological transformation; these processes will come up for further discussion later in this paper, and in Tables 12.3 and 12.4.

Table 12.4 Extended parameters in grid of natural selection

Systems element	Pattern of operation[a]	Mode of manipulation
SPACE	Through extension	In *occupying* space
	(studied in ecology with emphasis on energy)	
TIME	Through extension	In *accessing* past In *monitoring* present In *projecting* future
	(studied in ethology and linguistics with emphasis on information)	
		In *replicating* into future
	(studied in ecology with measures of “differential reproduction” or “fitness”)	
INFORMATION	Through circulation	By *creating* information
	(studied in evolutionary biology and the social sciences, periodically biased synchronically or diachronically)	
ENERGY	Through circulation	By *harnessing* By *using* By “*wasting*” energy
	(studied in ecology and economics, variously biased by species, ecosystem, and geography)	

[a] Traditional division of scientific labor indicated in parentheses

On the Metacoevolution of Gaia

Even more recently, and long anticipated, follows a proposition of *metacoevolution.* We refer to the Gaia hypothesis, advanced first by Lovelock (1972), and since elaborated by himself and others (Lovelock and Margulis 1974a, b, Watson et al. 1978, Lovelock 1979, 1983, Margulis 1981). A quite parallel speculation has also been advanced in Germany by Bargatzky (1978), but we shall limit our discussion to the more fully documented Lovelock version of the hypothesis. At last, we are presented with evidence that Gaia – planet earth and its atmosphere – has coevolved with its living constituents. Living things have not unilaterally adapted to conditions of the planet. Rather, the relationship has been reciprocal, with living forms contributing to the very qualities of the nonliving environment which make Gaia habitable – particularly atmospheric qualities, but also those of its lithosphere, oceans and seas. Gaia is a subsystem in a larger cosmos, but a subsystem having tighter relations of matter/energy-information within its guild of networks than to the balance of the universe. Moreover, with equally enormous consequences for semiotics, Whittaker (1969) and Margulis (1970, 1971, 1981, Margulis and Schwartz 1982) have advanced evidence for five, not two, kingdoms of biota, and have implicated amutational symbiosis as a criterial force in evolution, as will be taken up in the next section.

According to Lovelock and coworkers, the earth's unlikely, unstable, and disequilibrious atmosphere advertises the presence of control systems into which more conventionally living systems feed. Without its living components, Gaia's carbon dioxide concentrations in the soil and in the atmosphere would each adjust to new levels, water vapor distribution would be altered, temperatures would increase by some 20 °C, and cycling in solids, as weathering, for example, would be profoundly affected. All these factors would reflect the decreased throughput of energy-information which is the forte of living systems (Lovelock 1983).

Microevolution: Endosymbiosis in Cell Evolution

While one cannot go so far as to equate the sense in which the genetic code and human language are each "languages" (Shanon 1978), the genetic code has been acknowledged as a digital language of life forms, with mutations or permutations of nucleotides along the DNA or RNA strands being the equivalent of changes of meaning when revisions in replication have consequences (Conrad 1972, Eigen et al. 1981, Hartman 1975, 1982, Tomkins 1975). This code can also incorporate promiscuous DNA (e.g., Lewin 1984), nomadic genes (e.g., Ferris et al. 1983), freeloading viruses (e.g., Bremermann 1983), and subviral viroids and prions (Diener 1983), which then replicate as an integral part of the host genome. Particularly in plants, repetitive sequences of DNA contribute to variability with Lamarckian-like consequences (e.g., Marx 1984).

Natural selection operates at this level, and on any number of levels over and above the genetic. According to Lovelock and Margulis (1974b), natural selection is also operative on the level of the inclusive holon of Gaia. Margulis, alone (1970, 1971, 1981) and with others (Whittaker and Margulis 1978, Margulis and Schwartz 1982), has also pursued the possibility of amutational evolution, and the contemporary hypothesis of five kingdoms is strongly associated with her name, although it should be noted that her work builds upon the pioneering thought of Whittaker (1969). As she points out (Margulis 1981: 15–36), there has been an undercurrent of suspicion about the dual-kingdom classification for over a century, but other solutions to the problem have not anticipated Margulis' comprehensive rationale for the five kingdoms. (Still other modifying schemes have been proposed, notably that of Woese (1981), which envisions rather three main kingdoms of phylogenetic descent, archaebacteria, true bacteria, and eukaryotes, this final kingdom inclusive of slime molds, protozoa, fungi, animals, and plants, all having mitochondria deriving from photosynthetic bacteria introduced into some remote common ancestral linkage.)

Margulis' formulation, popular in part because of the several textbooks she has contributed (Margulis 1970, 1981, Margulis and Schwartz 1982), also involves kingdoms which have not diverged in an orderly manner involving only descent through replication, showing rather evidence of ancestral encapsulation of elements from one kingdom by an emergent one in a process involving cell endosymbiosis. The five kingdoms so developing are the monera (bacteria), protoctista (microbes and descendents, mostly water-dwellers, such as seaweed), fungi, plants, and animals. According to the earlier two-kingdom thesis, transformations occurred in descent due to such factors as mutation, gene flow, genetic drift, and natural selection. These factors have been difficult to map, let alone measure. Table 12.3 shows a systems translation of these still important evolutionary mechanisms, together with that of epigenesis. This last notion, in fact quite ancient in biology (Nogar 1963: 292–294), has been underappreciated in the recent past for ideological reasons (specifically, anti-"vitalist" phobias), but it continues to be an indispensable notion, as has been shown both scientifically (Waddington 1960) and philosophically (Deely 1969, see also Nogar 1973: 374 n.l), so it is hardly surprising to find revisionist evolutionists working to reintegrate this factor (e.g., Gould 1977).

Margulis in particular (Margulis 1970, Whittaker and Margulis 1978) has demonstrated that specialized organelles such as chloroplasts, cilia, and mitochondria in eukaryote plants and animals (those having cells with nuclei), are encapsulated, endosymbiotic prokaryotes (simpler organisms traceable back to the monera). This contrasts with the long held assumption that organelles were the result of internal differentiation arising mainly through mutation and selection. The process as demarcated by Margulis is called the endosymbiotic theory of cell evolution (Margulis 1981: 1–14). Specifically, monera forms are implicated directly in certain organelles found in plants and in protoctista, while the latter have contributed organelle material to all three of the plant, animal, and fungal kingdoms. This indicates that even phylogenetic lines are open systems in a web of actual and possible semiosis, with the incorporated organelles negotiating a niche in descendent cells and these cells in encompassing organelles.

Biogenesis on Gaia

Even though we have not paused to distinguish "life" from "nonlife", the former, it would appear, possesses some facility for replication and for adeptly processing free energy-information as so-called "throughput" (see Gerard 1960: 263, for an early use of this concept under the spelling "thruput"). Energy-information circulated as an end, within or without the hoi on, can be called throughput. This compulsive consumption is favored by modeling systems in organisms, modeling systems such as memory or language, which render space-time a manipulatable element in an *Umwelt.* In throughput, a system intensifies its momentum and directionality, and may thereby increase its relative autonomy as well, becoming less affected by coordinate and superordinate holons. "Introspective" holons, or guilds, characteristically circulate energy-information within their bounds, much of it self-serving throughput.

As we have seen, ecosystems composed of living and non-living elements, at whatever holon of inclusion, behave in a manner analogous to organisms themselves. The Gaia system, composed of active and inert elements, behaves similarly. Perhaps any system interacting with a living one takes on the properties of "life", and/or becomes as well a mirror for projections of living observers.

There continue to be speculations as to origins: origins of the universe, of the earth, of the genetic code, of life on earth and possibly elsewhere, even – despite strictures in the Constitution of the oldest society for the study of language *(Statuts de la Société de Linguistique de Paris,* "deuxième article", adopted in 1866: comment in Deely 1982a: 108–109) of specifically human language. The cosmological components of such speculation have helm fanned especially by advances in the quantum sciences, focusing on the ultra-micro and ultra-mega in space-time. Nascent journals such as *Origins of Life* and *BioSystems* devote most of their space to the conundrum of beginnings as well as of becomings. Beyond anthropocentric notions of space and time which are relevant to us in our scale of participation in the universe, "beginning" necessarily has other meanings (see Davies 1981).

The received wisdom about the origin of life revolves around some "primordial soup". These biogenesis models concentrate on the inorganic-organic boundary – that is to say, on chemical constituents, a body of theorizing summarized by Dickerson (1978: 70–73).

Another approach to biogenesis, first broached in 1966 by Cairns-Smith and subsequently developed (Cairns-Smith 1966, 1982, Cairns-Smith and Walker 1974), sets the stage with minerals rather than chemicals. Minerals have more explicit structure to start with, from crystals to fibers, and habits of growth, of becoming. They have "insides" and "outsides", and consequently boundaries to actualize and sustain through "negotiation".

In the Cairns-Smith scenario, minerals such as colloidal clays resulting from the weathering of common rocks, evolved systems not only of growth but of self-replication, shaped in the familiar crucible of natural selection. It was in the dynamic of natural selection that carbon took over from, say, the silicon in these clays, to produce the carbon-based systems we now dub "living". It is ironic that we experience a reverse revolution now, at another level, but a silicon takeover nonetheless, as computer chips direct us to serve their ends. (See Jastrow 1981: 162, Wesley 1974: 233–241).

Nonequilibrium Dynamics

The evolution of a paradigm, such as that of evolution itself, exhibits the momentum of nonequilibrium trajectories now recognized in the study of biology, culture, and dynamical systems generally throughout the cosmos. Dynamical systems far from equilibrium evolve with punctuational spurts constantly precipitating evident discontinuities. As semiotics evolves to attend to both energetic and informational phenomena in space and time, the field can provide the very mortar to the new synthesis in human knowledge systems.

Dissipative Structures

Thus far we have sketched the pattern of generalization and specialization, expansion and contraction, in the history of semiotic and systems sciences. However, the conservative paradigms of. evolution generally, even refinements such as coevolution, metacoevolution of Gaia, endosymbiosis in cell evolution, and speculations as to biogenesis, all tempt us to think, misleadingly, in terms of equilibrium models. In point of fact, dynamical systems, those irreversible processes in time exemplified in Fig. 12.1, do *not* always behave homoeostatically. Equilibrium sustained by homeostatic feedbacks is a cybernetic null hypothesis, Real phenomena are more interesting and less domesticated, predictable, or static.

All these systems are actually directional, self-generating, and indeterminately open. The importance of such temporal processes involving fluctuation, equifinality (convergence) and multiple solutions (divergence) has been most elegantly demonstrated in physics by Prigogine (1962) and coworkers (Prigogine et al. 1972, Nicolis and Prigogine 1977) and extended to the larger scientific landscape by Prigogine and Stengers (1979, updated and translated 1984). Our views of the complexity of human beings, human language and culture, and living systems generally, prompt us to look more closely at this latest approach in systems theory. (See excellent

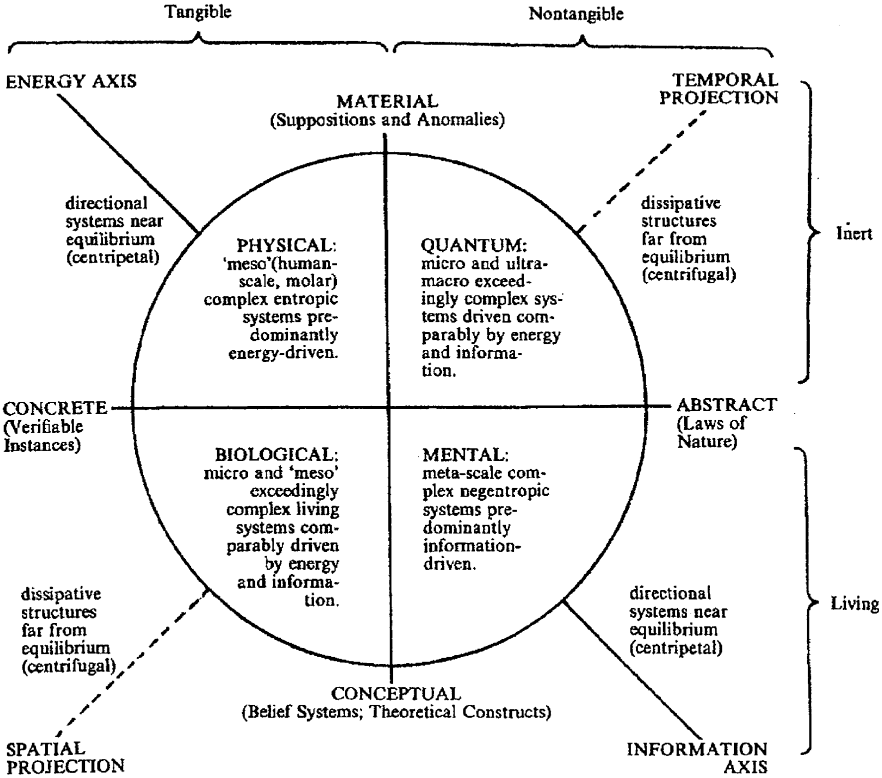

Fig. 12.1 Dynamics associated with prototype systems

treatments in Adams, 1975, 1981, Corning 1983, Eigen and Winkler 1981, Jantsch, 1980, 1981, Jantsch and Waddington 1976, Zeleny 1980).

Anything sufficiently interesting to study, whether concrete or abstract, will fall into the category of dynamical systems. Those systems farther from equilibrium Prigogine refers to as dissipative structures, for they feed on free matter/energy to create new orders of information, new relations of coordination and hierarchy (Allen and Starr 1982: 8–66, Bookchin 1982: 348–366, Pattee 1973: 131–156, Prigogine 1980: 104–128, Simon 1973: 4–11).

Current discourse in the biological sciences about the existence or prevalence of saltational evolution, or punctuated equilibrium (associated with Stephen Jay Gould 1977, Eldredge and Cracraft 1980, Wiley and Brooks 1982, 1983), fits rather well with the features of dissipative structures. The more conventional view of evolutionary change is one of gradualism, not of spurts of catastrophic reorganization. These spurts, or catastrophes in Thom's formulation, occur when dissipative structures near bifurcation points respond to what would earlier have been below-threshold information.

Returning to Fig. 12.1, the quadrants of living systems and quantum systems share the property of being quintessential nonequilibrium phenomena, characterized as dissipative structures. In living systems, the free matter/energy-information is throughput in this original "consumer-oriented" system, and in the process it is the quantum phenomena which are "put through", The frenetic activity of "life" – growth, replication, metabolism, play, language, culture, even waste and war, to name the more familiar of semiotic events – arrests the centripetal and centrifugal forces within Gaia, and permits more rounds on the treadmill.

Very little headway has been made by any body of scholar-scientists in comprehending life and biogenesis, partly because (as with messages, which exist in decodings) we are looking at the wrong side of the equation for the answer. (Other kinds of prismatic myopia have been nicely uncovered under the rubric of "Looking in the Destination for What Should Have Been Sought in the Source" – Sebeok 1979: 84–106.) Communication begins with a decoder, not with the encoder, whether "intentional" or not: This insight is particularly crucial to the understanding of evolution as a part of semiosis. Similarly, life is a result of one of the most interesting innovations with Gaia, namely, death. It is death which permits the throughput to condense into regions of order in an unstable, dissipative structure. These regions are the domain life.

Charges of an "organismal heresy" (e.g., Moore 1983) still sting in the life sciences and in the physical sciences, whenever a system larger, smaller, or more abstract than an "organism" "behaves". First, biology must cope with an elastic notion of "organism", or else explain away the slime mold and other eclectic congregations of cells. Curiously, exercising this same growing knowledge of system behavior in the social sciences brings accusations of "neo-mechanicism" (e.g., Thullier 1983)!

That systems behave, or transact energy-information, is the case even in the absence of any living constituents. These nonliving systems endure rather than replicate, unless they evolve as in Cairns-Smith's model within some selective grid similar to natural selection. But the archetype it is less characterized by throughput, than the living system. In short, systems under this archetype are without the benefit of death. But, with living processes in the picture, even the inert "dies", as it were, and, given culture can also be "born again" (see Thompson 1979). This cycling of matter/energy-information speeds up the stuff of messages and magnifies the assortment of synapses. It is one explanation for the organismic behavior of some systems inclusive of inert matter.

Out of this process of maturation in systems (see Table 12.2), information can decouple from energy, crystallize as meaning in space-time, and condense as knowledge even less tied to space-time. In this semiotic scenario, natural selection becomes a more dynamic concept. As routinely interpreted in Table 12.3, selection is the only evolutionary transformational factor which implicates energy. Any overemphasis on energy-management in ecological explanation is due to a focus on natural selection among these factors, and on some measure of natural selection which reduces to gross "reproductive success" or "fitness", post hoc judged as "adaptation". Vast amounts of literature juggle the inferences deriving from various operational definitions of these two terms alone (e.g., Conrad 1972, 1983, Peters 1983), and the circularity involved in notions of adaptation, wherein survival indicates adaptation and adaptation favors survival, have received more and more critical attention (e.g., Eldredge and Tattersall 1982).

Here it may be useful to look more closely at an expanded systems view of natural selection, dealing, in Table 12.4, with just this one evolutionary factor.

A replicating organism may be in a situation to minimize, optimize, or maximize, proximately or ultimately, some means or ends, either through hard-wiring, soft-wiring, or some combination thereof, by virtue of intention, evolutionary trajectory, or stochastic factors, all of which reflect and were shaped by its past phylogenetic and ontogenetic history. Organisms seldom just metabolize and replicate. Some even opt to behave "altruistically". Understanding living organisms calls for an appreciation of the non-energetic activities transpiring – not just the information-management implicated by energy-shaped habits of food and space, but information-circulating systems monitoring time, minimizing tedium, or generating chaos as well as order. It is due to the powerful negentropic properties of life that disorder can be not just tolerated, but even accentuated and intensified in such diverse cultural forms as art and war, for example (see Sebeok 1981: 210–259, Maruyama 1976, Rappaport 1979, Peckham 1965). Intensification of circulation of energy-information, or throughput, has as a by-product the increased hierarchic organization and flexibility we associate with systems, particularly those containing living members.

Information, Communication, Meaning

The foregoing viewpoints distance themselves from narrowly functional and causal explanations of complex phenomena. It is tempting in the same vein to venture out onto one more rink. This concerns the origins of signs. Indeed, however the universe originated, energy-information, a sign of the first degree, was either a product or a by-product. If the sign is a viable key for the understanding of complex systems, then it must have these twin properties of energy-information. To transcend conventional semiotics, explorers in general semiotics have had to deal with *dynamic* processes involving both information and energy. There are numerous complementary and overlapping semiotic disciplines, such as ecology and economics, where the neglected element in the system as conventionally investigated is instead information, communication, or meaning.

Through *exaptation* (to extend the term for incidental preadaptation in evolution from Gould and Vrba 1982), semiotics can find familiar handholds in much of the spectacular work in the inert quantum fields and biochemistry. Sometimes semiotics is itself mined for insights, rendering some of the most technical work accessible when the metaphors are recalqued. In this genre would be Tomkins' suggestion of a metabolic code (1975), Florkin's ambitious serial publications in biochemistry, only represented here by his 1974 chapter on biosemiotics, and Bochner and Ames' (1982) elucidation of biochemical message units called "alarmones", and "Yates" (1982) detailed work on physiological systems and homeokinesis.

We suggest, nodding to Peirce, that the universe originated with the sign. This thirdness would have to presuppose secondness, and it in turn firstness. The evolution from free energy-information, interaction, communication, meaning, and condensed meaning stored in knowledge systems can all be understood as further by-products in the ontogeny of the universe-system. In the maturation of systems, sketched in Tables 12.2 and 12.4, energy-information systems intensify and complexify, precipitating horizontal and vertical holons of organization. Consequently, there were subsystem boundaries transacting resources from an early stage. Life introduces even more discontinuities into play.

As suggested at the outset, boundaries are defined by sign activity: transaction, manipulation, maintenance, and catastrophe (Anderson 1985) – all implicate semiosis. In the evolution of edges, we can trace the ricochet of digital systems building on analogue ones, and subsequent bootstrapping. Edges first fence *out,* making for an inside vis-à-vis an outside, and then transact with and through that boundary. If not tied solely to biological systems, "exosemiotics" may still have utility as a label for the study of exoholon behavior, which presently is dominated by an energetics perspective in ecology and by an informational one in ethology. Subsequently, edges fence *in,* permitting internal functions of metabolism, circulation, replication, and waste, or "endosemiotic" behavior, The two faces of this boundary integrate, of course, in natural selection, when still other hierarchies and coordinate holons come into play.

The first "living" forms would have circulated "natural" energy-information in increasingly redundant, overdetermined analogue systems. The first instance of superposed digitality would be some kind of differentiation, a guild, streamlining that redundancy. This applies in either the primordial soup model or the cell endosymbiosis model. However, the first "living" forms need not be visualized as grains of replicating matter, later to differentiate internally and diversify, when those grains could themselves have been differentiations within an encompassing cosmos. A recurrent pattern in emergent systems is the interplay between "upward evolution" and "downward evolution". The outgoing paradigm emphasized the former, a narrow view of the new paradigm emphasizes the latter, while a synthetic semiotic respects and integrates both.

The genetic code may have been the earliest innovation of a double articulation "language" (Martinet 1965, Hockett's "dual patterning" 1960, Hartman 1975, 1982, Eigen et al. 1981, Jakobson 1970, Weigin 1981). As in human verbal language, a finite number of primitive signs (with earlier significance on another level), lose that significance or are revalued when operating as raw materials for a new sign system. This amounts to reshaping an analogue system from a digital one (Sebeok 1962).

Taking into account all that is now understood about throughput dynamics in dissipative structures, we can appreciate human language as one more energy-information processor, along with trophic level, thermoregulation, play, dreaming, and art; all are self-serving and *not explicable through function.* The "functions" of human language fall into two, now interpenetrating classes – internal representation or modeling (as underlies *Umwelt),* which we label "language", and inter-individual communication or "speech", both species-specific faculties (Sebeok 1979: 45–55, see also Dawkins and Krebs 1978). The narrower and proper sense of "language" predominately relates to space and storage in the framework of Table 12.2, and its correlate of "speech" specializes in the parameters of time and flow. Allo-organisms – our old-fashioned "plants" and "animals" – have faculties to process analogous resources of information and energy. Yet it is increasingly agreed that human verbal language did not emerge from a nonverbal, vocal antecedent, at least not from an antecedent communication system narrowly defined (cf. Maritain 1957, Jerison 1975, Kenny et al. 1972, Merrell 1982, Spuhler 1977).

As with human verbal language, other forms of internal modeling and external communication are similarly reduced mistakenly to a functional grid. Certainly human language is a flexible tool in ultimately interacting with the significant surround; but it also serves as a *toy* in the manipulation of that world, as well as of past worlds, future worlds, and an infinite number of fantasy worlds. Modeling fidelity, then, is *not* a measure of the "adaptiveness" of human language, nor of any other of these modeling and communication systems. As long as such a system is not too "maladaptive", it can stay in the "existential poker" (Slobodkin 1968: 190) of evolution.

In other words, the "function" read into these modeling systems is the tip of an iceberg. The rest of the iceberg is a stabilizing guild of tight relations, a web of dissipative structures. Information-driven, these modeling systems essentially prey upon order, shredding it, circulating the energy-information it entails. Negentropy ensues for the processor, and order for the organization of the processor. At the same time, noise, disorder and even chaos are compulsively converted into meaningful order.

However, order costs. Whether we examine crystals or organisms, we find that perfect symmetry is virtually impossible. Yet deviations from symmetry, from order of any kind, constitute information of a finer grain, and are apt to be captured by the larger system for some use, hence converting what is noise at one level into meaningful pattern at another. In vertebrate bilateral symmetry, for example, this results in handedness, footedness, brainedness, eyedness, and any number of other partially charted divergences resulting from the near-symmetrical partners becoming differentially specialized; the flaw is transformed into a necessary complement in a system undergoing complexification. (The deplorable choice of the term "dominance" of one side, to describe the relation of bilateralized functions, rather than speaking in terms of differential specialization and the total integration of behavior, has had the unfortunate effect of misleading some readers of, if not writers in, the field.) Brain lateralization, human language, and human speech demonstrate once more the semiotic power of a boundary.

Symbiosis as Semiosis

Explicit in all the emerging models involving the life sciences has been attention to complexity of co-occurrence and context. Organisms coexist, coevolve, by means of semiosis and the relations it entails. Margulis lists some of the classical types of relationships in the biological world (1981: 162–163), warning that the lines dividing such relationships are either fine or fuzzy. Symbiosis, mutualism, commensalism, parasitism, and predator-prey, even autotrophic and heterotrophic habits, all are modulated by the immediate environment and by the phylogenetic and ontogenetic past of the organism. As mentioned earlier, she discards entirely the two-kingdom classification for living organisms, submitting a scheme (and a nomenclature – 1981: 353–363) justifying five kingdoms evolving endosymbiotically. All these relationships involve communication and lend themselves to, or require, semiotic understanding, even though the terms "phytosemiotics", "zoosemiotics", and "anthroposemiotics" are inadequate on several counts.

First, these terms imply qualitative discontinuity between all the semiotic phenomena under study; this appears less and less to be the case. Then, with the five-kingdom classification, "plants" and "animals" return through the looking glass to become strictly folk taxa once more. Nor can one with confidence simply reparcel semiosis according to the putative five kingdoms, not only because these are provisional, as we noted above, and will doubtless remain so for some time, but because, more fundamentally, they may not even be interesting or significant in sorting different *types* of semiosis.

There is a paucity of empirical data to suggest the nature of any unique properties of semiosis, whether interpreters be classified by pseudo – kingdom, kingdom, phylum, or even species. Some dramatic biochemical signs recur with similar and dissimilar interpretants across kingdoms, and sometimes this can be a clue to coevolution, such as the sex pheromone of the sow exuded by the underground truffle (presumably the excavating boar is also an agent in dispersion of the truffle). Among sometimes visually-perceptible signs, neoteny (retention of juvenile characteristics into a later stage), whether embryological, anatomical, physiological, or behavioral, such as roundness with eye spots among mammals (Montagu 1981) is overwhelmingly attractive – which is doubtless favorable for the neotenous creature. (Indeed, in our culture, it has spilled over into our preference for cars and comic strips, and mascara accentuating the eye spots of women). But it turns out that, in systems terms, neoteny is a recurring expedient, a way to playa different tune, as it were, using the same notes. Analogues to the originally-noted embryological neoteny can be found later in ontogeny, in society, in culture, and even in the evolution of speech insofar as it shares unique properties with the neonate's cry.

Once the spiraling dynamics of semiosis are examined, as is being done in the alloprimate-human communication research (Sebeok and Umiker-Sebeok 1980, Sebeok and Rosenthal 1981), our assumptions overdetermine everything from choice of subject (neotenous and intelligent primate relative) to result (semiosis leaks). This is not an auspicious time to distinguish categorically subtypes of semiosis, whether by originator, object, interpretant, or interpreter, as our knowledge of these pales before our understanding of the sign.

Yet, as it matures, semiotics will surely continue to generate, label, classify, investigate and discard new and passing concepts. One hears indictments in all fields about creeping, hollow jargon having more to do with social relations than with the subject matter. Semiotics as a perspective has minimized this through its incessant reference to the masters of the sign (e.g., Sebeok 1979).

In retrospect, the term "semiotics" has worn well. But we regularly relive the frustration of participants in the Indiana University Conference of Paralinguistics and Kinesics in 1962 (Sebeok et al. 1964, 1972; see especially the close of the discussion on pages 275–276). Persons were attuned to the disadvantages of a marked term, such as "nonverbal", to characterize the field of study, particularly when it exposes some logocentric tendencies.

Such problems will not be solved here. In fact, with this paper, we propose problems for our nimble and nebulous science rather than solutions. In an academic climate suffering from terminal paradigm burnout, optimism for any general or unified approach is bound to invite scorn. Nevertheless, a convergence is underway, a maturing in numerous guilds of thought – such as evolved formulations of systems theory, the inviting synthesis between macroevolutionary and microevolutionary theory, Lovelock's Gaia Hypothesis, Loeb's Design Science Group at Harvard, artificial intelligence projects, and all the other strains of synthetic work providing grounds for optimism about the possibility of a general unified perspective within the framework of what we have called "ecumenical semiotics". The synergy of symbiosis is in fact underway.

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Part III
Independent Approaches to Biosemiotics

Chapter 13
Theoretical Biology on Its Way to Biosemiotics

Kalevi Kull (1952–)

Introduction and Commentary: Kalevi Kull

> *Semiosic practice—the behavior of organisms, including the everyday behavior of humans—is the acquisition and application of knowledge. In humans, due to the usage of propositional and narrative sign systems, semiosic practice develops into a 'knowing* of *knowing', or semiotics* sensu lato. *A methodical acquisition and organization of knowledge leads to science.*
>
> K. Kull (2009: 84)

Appropriate as it was to conclude the last section with a forward-looking article by Sebeok and his collaborators so it is fitting to begin this one with a backwards-glancing article by biosemiotician Kalevi Kull. Founder of the world's first Ph.D. granting program in Biosemiotics, Kull bridges both biosemiotics' Sebeokian past and its post-Sebeokian future. And like his late good friend and Colleague, Thomas Sebeok, Kull is as committed to the facilitation of the publication of others' work – and to the archival chronicling of biosemiotic's long and perhaps still largely undiscovered history – as he is towards the contribution of his own original scholarship to the field. Yet as biosemiotic's *de facto* archivist and historian, Kull rarely includes his own biography among those past and present biosemioticians whose lives and works he chronicles. This introduction aims to fill in that one blind spot in Kull's biosemiotic scholarship.

Botanist, ethologist, theoretical biologist, and historian of science, Kalevi Kull continues a long tradition of biosemiotically-oriented research in his native Estonia. "Due to the deep analogies observable between living and linguistic systems," reports Kull in describing the founding of the Biosemiotics curriculum at Estonia's Tartu University, "the feeling here has been that it may also be possible to discover the general theoretical explanations which span these fields. Especially because both the *biological tradition* of [Tartu University alumni] Karl Ernst von Baer (1792–1876), Jakob von Uexküll (1864–1944) and Thure von Uexküll (1908–2004), as well as the *semiotic tradition* of [Tartu University faculty] Juri Lotman (1922–1993) and Mikhail Lotman (1952–) run strongly through Estonian intellectual life, we feel that there is a solid basis here in Tartu for work on this subject" (2009:p.c.).

Born in Tartu, Estonia, on August 12, 1952, Kull's first acquaintance with the works of Jakob von Uexküll came in 1968, when he was working as a young

D. Favareau, *Essential Readings in Biosemiotics*, Biosemiotics 3,
DOI 10.1007/978-1-4020-9650-1_13,

assistant at the Puhtu Ornithological Station with a small group of scientists who were studying the ontogeny of bird thermoregulation. “These were romantic days with many hours spent in a tent on an islet, “ recalls Kull, ‘chronometrizing’ the behavior of nestlings and their parents; other hours spent at night in the lab, experimenting with small birds’ reactions to different temperatures, and still more time with a heap of books about theory of biology” (*ibid*). The building in which the Ornithological Station itself was housed, it turns out, was in the former summer home of Jakob von Uexküll, and over time, Kull’s own work in biology, and in biosemiotics, would become deeply influenced by Uexküll’s *Umweltlehre.*

Fittingly, Kull received his education in biology at Tartu University, home of the world’s oldest semiotics program, as well as the world’s oldest semiotics journal *(Sign Systems Studies)*, both founded by Juri Lotman (1922–1993) in 1964. Lotman would eventually become a colleague of Kull’s, as would pioneering biosemiotician Thure von Uexküll, creating a ripe atmosphere for the continuing development of biosemiotics, and earning Tartu University Thomas A. Sebeok’s praise as “a singular Mecca-like field for us pilgrims laboring in the domain of semiotics” (2001: 164).[1]

Within this already proto-biosemiotic intellectual milieu, Kull received his degree as a field ecologist in 1975 and began work immediately as an ecophysiologist, studying the various mechanisms of balance in lives of organisms in their natural conditions, and in particular, the mechanisms of species coexistence within species-rich communities. Accordingly, after his ethological work studying the mechanisms of temperature homeostasis (including the ontogenesis of thermoregulation and the behavioural aspects of temperature regulation in birds at the Puhtu Ornithological Station), Kull spent several years conducting experimental work at the Vooremaa Forest Ecology Station in eastern Estonia, studying the ecophysiological mechanisms of growth limitation in plants, and developing mathematical models of these mechanisms, based on his research findings.

This early work in theoretical biology – and the realization that many of his students were unaware of all but the latest and most thoroughly orthodox developments in experimental science – inspired Kull to organize the Estonian Spring School in Theoretical Biology in May 1975. These conferences for students and faculty have since become annual events, taking place each year in a different part of the Estonian countryside and each year devoted to a different single topic in theoretical biology. Thus, past Spring Schools have been devoted to theoretical biological theories of growth, death, sleep, sex, communication – and even to the concept of theoretical biology itself.

In 1978, with Tartu University already a nexus of the burgeoning Tartu-Moscow school of semiotic study, Kull and his colleagues organized a joint Russian-Estonian conference entitled “Biology and Linguistics” which explored the possible relations between these two synchronically stable but diachronically novelty-generating

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[1] Just as fittingly, and thanks to the efforts of Kalevi Kull, Tartu University today is the home of the *Thomas A. Sebeok Memorial Library*, housing Sebeok’s personal, and extensive, collection of literature devoted to biology, semiotics and biosemiotics.

systems. The success of this conference led to a series of increasingly biology-oriented semiotic conferences aimed at augmenting the more "general semiotic" conferences that Juri Lotman had initiated at Tartu University with the founding of Estonian Summer School in Semiotics in 1964, and continued throughout the 1980s, and brought into this slowly coalescing field of "bio-semiotics" such future seminal biosemioticians as Sergey Chebanov and Alexei Sharov.

In 1992, Kull was named a Professor of Ecophysiology at the University of Tartu, and became head of the Ecophysiology Division in the university's Institute of Zoology and Botany. In this position, Kull and his team of researchers discovered a plant community with the highest small-scale species diversity in Europe, and established the Laelatu Biological Station for the permanent study of that site. In 1989, Kull had drawn upon his earlier work at the Vooremaa Forest Ecology Station to write, with his brother Olevi Kull (1955–2007) *Dinamicheskoe modelirovanie rosta derev'ev (Dynamical Modelling of Tree Growth)*. Eight years later, Kull would write *Puisniidud* (*Wooded Meadows*) about the most species-rich botanical communities of northern Europe, with his colleague Toomas Kukk.

1992 was also the year that Kull made the acquaintance of both Thomas Sebeok and Jesper Hoffmeyer at the conference for biology and semiotics that Sebeok and Thure von Uexküll had organized with Jörg Hermann at the Glotterbad Clinic for Rehabilitative Medicine in Glottertal, Germany. By many accounts, this meeting "marks the dividing line between the initial period in the establishment of biosemiotics, and biosemiotics as it is presently practiced" (Hoffmeyer 2008: 365). No longer confined to just those general semioticians and small handful of scientists that Thomas Sebeok had personally recruited to the project, the reach of biosemiotics now began to expand exponentially with the growth of "satellite" biosemiotics communities in Copenhagen and Tartu, led by the biologists Hoffmeyer and Kull, respectively (and between whose groups there has remained much productive collaboration and contact).

In 1993, Kull was instrumental in the establishment of the *Jakob von Uexküll Center* for biosemiotic study at the Estonian Naturalists' Society. A regular lecture course on biosemiotics was also introduced at Tartu University by Kull that year, "in the year of the death of Juri Lotman," Kull notes, "but [commencing] with his introductory words, as dictated in the hospital" (1999: 404). This course is now offered every year and is included in the University's standard Semiotics curriculum. Given the receptivity towards biosemiotics evidenced at his University, Kull traded his position in the Ecophysiology Division to join the Department of Semiotics in 1997, where he continues to teach biosemiotics, ecosemiotics, general semiotics, theoretical biology, and the history and philosophy of life science.

Kull assumed editorship of the world's original semiotics journal, *Sign Systems Studies,* in 1998, and in 2001, he edited the special quadruple issue of *Semiotica* dedicated to Jakob von Uexküll. "Forty-one distinguished academics from fifteen different countries have produced a 828-page volume with papers on history, philosophy, theoretical biology, ecology, linguistics, arts, biology, literature and computer science" in this volume, notes biosemiotician Marcello Barbieri, in reviewing this Special Issue – and, despite his own theoretical disagreements about the "anti-mechanism" found in many of these papers, he concludes that together they form "a powerful, pulsating new vision about the fundamentals of life: a new theory of signification and biological meaning" (2002: 283).

Not long after, and due in no small part to Kull's Sebeok-like organizational efforts, biosemiotics as an international interdisciplinary research agenda began taking on a life outside of the still largely humanities-based home that Sebeok had been able to provide it with. In collaboration with Claus Emmeche and Jesper Hoffmeyer, Kull co-organized the first annual international Gatherings in Biosemiotics conference at the University of Copenhagen in 2001. Thirty scientists and scholars from eighteen countries attended that event, which in many ways marked another watershed moment and turning-point in the development of biosemiotics. "There," I have written elsewhere, having been myself privileged to attend that groundbreaking event, "these second-generation heirs of Sebeok's Glottertal conferences were able to bring together a growing group of younger researchers for whom the idea of fully causal, semiotic dynamism in autopoetic systems was no longer a 'radical proposal' from the humanities – but was, instead, the self-evidently naturalistic starting point from which to proceed to build a coherent and scientifically grounded interdiscipline" (2008: 41).

The first annual international Gatherings in Biosemiotics was convened in the very room at the University of Copenhagen where Wilhelm Johanssen (1857–1927) first introduced the word "gene" in 1909. Appropriately enough, the second annual international Gatherings in Biosemiotics, hosted by Kull, was convened at Tartu University and featured sessions in the former houses of both Karl von Baer and Jakob von Uexküll. Since 2006, Kull has been the Head of the Tartu University's Department of Semiotics and, in 2007, became the world's first full Professor in Biosemiotics, establishing there the world's first doctoral degree-granting programme in Biosemiotics in 2008.

Having himself been deeply involved in biological fieldwork, experimental biology, ecology, ethology, theoretical biology and biosemiotics, Kull is uniquely positioned to situate the contemporary research agenda of biosemiotics within the larger history of theoretical biology. Having done so already in two previous publications (1993 and 2000), Kull expands upon his previous research in the following selection, providing the reader with a rich historical background within which to contextualize both the non-Sebeokian readings (i.e., Florkin, Rothschild, Bateson, Pattee) and the post-Sebeokian (Hoffmeyer, Emmeche, Markoš, Brier, Witzany, Deacon, and Barbieri) readings that comprise the second half of this anthology.

Theoretical Biology on Its Way to Biosemiotics (2009)

> *Den Lebens-Prozess . . . halten wir nicht für ein Resultat des organischen Baues, sondern für den Rhythmus, gleichsam die Melodie, nach welcher der organische Körper sich aufbaut und umbaut.*[2]
>
> Karl Ernst von Baer (1864: 280)

> *Symphony or embryo, the principle is the same:*
> *the more complex the pattern, the more important the silences.*
>
> Robert Pollack (1994: 76)

"What would a fully adequate theory of biology look like?" is a question that has been central to the field of Theoretical Biology during all of its existence, and that is still pertinent to us today, as we begin developing what is perhaps the third "great wave" in theoretical biology, which is biosemiotics. As such, it would do well for us to review some of the historical trajectory that has brought us to this point.

Biological theories and theoretical concepts in biology are obviously as old as biology itself, since there cannot be any science without its theoretical aspect. However, "theoretical biology" as a *discipline* – with its dedicated monographs, periodicals, professionals, and nomenclature – arose primarily at the beginning of the 20th century. The works which launched the field were Johannes Reinke's "Einleitung in die theoretische Biologie"[3] (1901) and Jakob von Uexküll's "Theoretische Biologie" (1920a).

The meaning of the term "biology" had already been reserved since the year 1800 when it was defined by Karl Friedrich Burdach (and a year later by Jean-Baptiste Lamarck and Gottfried Reinhold Treviranus), to denote the integrity of various aspects and forms of life (including plants, animals and humans, morphology, physiology and behaviour, etc.). This is how the term has been interpreted since the end of the 19th century (e.g., by the leading European journal "Zeitschrift für Biologie", edited by Wilhelm Kühne) and is still understood today. In the same way, Theoretical Biology has set as its aim the development of a theory which can be applied for understanding the phenomenon of life however and wherever it occurs.

During the 100 years since its birth at the beginning of the 20th century, theoretical biology has experienced two remarkable peaks of interest. The first was in the 1930s, and the second was in the 1960s and 1970s. These first two peaks will be briefly characterised below, given that a third peak of interest is just showing the first signs of its possible emergence now (this peak will be briefly discussed at the conclusion of this article).

In short, this essay will attempt to suggest some contexts and associations of the semiotic view in biology, by making a short review of the development of theoretical

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[2] We hold life process not for the result of the organic construction, but for the rhythm, as a melody, according to which the organic bodies build and rebuild themselves.

[3] "Introduction to theoretical biology".

biology over a one century period, as viewed from the side of biology. The latter is an important restriction, since the picture may look considerably different from the viewpoint of and in the context of semiotics. It is important to emphasize this since biosemiotics, although now accepted as a distinct branch in semiotics, has still not established itself widely in biology. For instance, one can find chapters devoted to biosemiotics in contemporary semiotic textbooks, and corresponding sections in large semiotic conferences, whereas the same is quite rare in biological (or even ethological) reviews or congresses. However, the situation today is already different from that of two decades ago, when Dietmar Todt (1987) and Joachim Schult (1989: 261) claimed: "Es ist ohne jeden Zweifel so, daß [..] die Semiotik bisher in die Biologie kaum Eingang gefunden hat."[4]

Delimiting the period to one century also means that according to the approach used in this review and the meaning given here to the term "biosemiotics", this branch of science (or a corresponding approach) may have existed under some other name before this period and will exist after it. Such a situation is certainly common for many, if not for almost all sciences. The fact that there are not many comprehensive analyses of the history of theoretical biology, despite its rapid development in this century, is an additional hurdle to the making of this analysis.

Biology at the Beginning of the 20th Century

To understand the atmosphere in biology during Reinke's and Uexküll's time, it is important to note that the decades around the turn of the century were very productive in starting simultaneously a series of new branches in biological research. Among these, the following can be listed:

(1) the beginning of genetics through the rediscovery of Mendel's laws;
(2) the beginning of mathematical biology and research into population variability, under the name of biometry (Karl Pearson); and the establishment of the first journal ("*Biometrika*") in this field (1901–1902);
(3) the beginning of biophysics (Jacques D'Arsonval et al. 1901);
(4) the first book with the title "theoretical biology" (Johannes Reinke 1901);
(5) the boom of neovitalism (Hans Driesch);
(6) intensive work in the field of morphogenesis (Wilhelm Roux's "Entwickelungsmechanik");
(7) also, ecology as an independent science took its first steps at this time (Warming 1895).

All of these events had long-lasting effect on biology, and considerably influenced its theoretical discussions. We may say, I suppose, that at that time theoretical biology as a branch of biology was born. Before that time, there existed works which

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[4] "There is no doubt that semiotics has yet hardly found any input to biology".

can be classified as theoretical biology, but as a branch with its own specialised journals, books, terminologies and devoted specialists, it did not previously exist. This period of intensive diversification in biology at the turn of the century is somewhat comparable to the great peak in theoretical biology which took place in the 1960s and 1970s.

Jakob von Uexküll (1864–1944), who developed one of the first comprehensive systems of notions for semiotic biology, was probably the most important figure in biosemiotics in the first half of the 20th century. His books "Umwelt und Innenwelt der Tiere" (1909), "Bausteine zu einer biologischen Weltanschauung" (1913), "Theoretische Biologie" (1920a, 1928), "Bedeutungslehre" (1940), popular scientific books "Biologische Briefe an eine Dame" (1920b), "Streifzüge durch die Umwelten von Tieren und Menschen" (Uexküll and Kriszat 1934),[5] and many articles, introduced an approach and terminology which was for a long time used and accepted only by a small group of scientists, but that now (and particularly in the last decade) has found rapidly spreading use in the works of semioticians, as well as in the works of many psychologists, anthropologists, ecologists, philosophers, and computer scientists. It should be noted that Uexküll was, primarily, a biologist who was not content with the commonly used level of scientific argumentation, and who thus decided to place biology on a solid philosophical basis.

Uexküll stressed that his approach was a development of the views of German physiologist Johannes Müller (1801–1858), whose law of specific sensory energies states that "the modality of the sensation depends in an immediate manner only upon what region of the central organ is put into a corresponding excited state, independent of the external causes bringing about the excitation" (Schlick 1977: 165). Or, as formulated by Uexküll (1931a: 209): "Eine lebende Zelle besitzt ihren eigenen Ichton".[6] As for his philosophical grounding, Uexküll applied the epistemology of Immanuel Kant to his research of animals' behavior and their subjective experience. The term *Umwelt* in its meaning of the subjective world of an organism had been used by Uexküll since 1909 (in his article of 1907 he still uses the term "Milieu", in distinction from "Außenwelt").

Uexküll also emphasized that he was a follower of Karl Ernst von Baer's (1792–1876) line of thinking in biology. He cited many times Baer's interpretation of biological time, and felt drawn also to his other views in general biology. Indeed, the Baltic German embryologist Baer developed an approach in biology which has later been considered as an alternative and comparable in its importance to that of Darwinism (cf. "I insist on the rigid separation of von Baer and Haeckel" [Gould 1977: 4] and "Baer, and not Darwin, should become the central historical figure in theoretical biology" [Salthe 1993b: 247]).

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[5] "Animal's umwelt and internal world", "Building blocks of a biological worldview", "Theoretical biology", "Theory of meaning", "Biological letters to a lady", "Strolls through the worlds of animals and men".

[6] A living cell possesses its own self-tone.

It is well-known that Uexküll was not acquainted with the works of semioticians. Almost his only conversations with people close to semiotics were those in Hamburg with Ernst Cassirer (1874–1945) and Heinz Werner (1890–1964, the co-author of "Symbol Formation"; Werner 1919), however, they were both much younger, and Uexküll's views were already established at that time. Later, he also corresponded with philologist Heinrich F. J. Junker (1889–1970). Far more important were probably the influences he took from the late romanticist atmosphere in Estonia, from the special biological environment in the Biological Station of Naples, and from the Heidelberg laboratory of Wilhelm Kühne (1837–1900, a pupil of Johannes Müller and the author of the "enzyme" concept).

Uexküll developed his approach in an extensive way in his book "Theoretische Biologie", the second edition (1928) of which became well-known and was later reprinted. Hermann Keyserling was among the early philosophers who proposed a whole epistemology to be based on Uexküll's approach.

In the context of semiotics, it is of interest here to draw attention to one aspect of Uexküll's methodology, namely, his very frequent use of musical metaphors. This practice was actually quite common among romanticist biologists. We also find it in the works of Baer (1864). However, in the writings of Uexküll, metaphors like *Ton, Tastatur, Melodie, Motiv, Kontrapunkt, Komposition* and others seem to play a particularly important role. Uexküll, when building his "subjective biology" – and at the same time criticizing Darwinians for not being scientific enough – needed a new vocabulary, as well as a new methodology. Since he did not know semiotics or any other applicable terminology from the humanities, he used terms from music for this purpose. "So sind die organischen Faktoren, die wir bei der Entwicklung bisher kennen gelernt haben: Gene, Plan und Protoplasma – Noten, Melodie und Klavier. Gene und Plan scheinen stets ganz tadellos zu sein, nur bei ihrer Einwirkung auf das Protoplasma können Störungen vorkommen, die wir experimentell ausnutzen; – wie eine Sonate Beethovens, die auf dem Papier tadellos ist, in ihrer Ausführung auf dem Klavier aber oft recht viel zu wünschen übrig lässt"[7] (Uexküll 1913: 175). This aspect in Uexküll's works deserves special analysis.

In areas which later have interested biosemioticians, several other trends can also be listed from this early period.

Charles Darwin (1872) wrote a book on the evolution of emotions, which was an early work on ethology; ethology was established as a branch and mainly developed in the 20th century. In this context, a great impact on research in behavioural science in the 20th century was made by George John Romanes (1883) (1848–1894). "Following Spencer, Romanes traced the objective manifestations of mind back to the most primitive forms of life, to plants and protozoa; indeed he conceived mind as an organic development out of the phenomenon of life" (Richards 1989: 349).

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[7] "The organic factors that we have studied in development so far – genes, plan, and protoplasm – are thus notes, melody, and piano. Genes and plan always seem to be quite perfect, only at their influence on the protoplasm disturbances can occur, which we experimentally exploit – like a Beethoven's sonata, which is perfect on paper, but in their execution on piano often leaves much to be desired."

As a reaction to important achievements in biochemistry and the spread of reductionism in biology, holistic views started to reappear in the last decades of the previous century. In an introduction to the textbook of physiological and pathological chemistry by Gustav Bunge (1887) (1844–1920, a scientist of Tartu University), neovitalism was introduced on to the scene (Eduard von Hartmann 1906). It is noticeable that the first monographs on theoretical biology, as well as the wider usage of the term "theoretical biology" derived from biologists of clearly neovitalistic inclination (Reinke 1901). Sergey Meyen (1977) has shown in his article "The principle of sympathy", "how Driesch had expressed all the basic dilemmas of biology" (Karpinskaya 1994: 114). Hans Driesch's analysis of biological form is not very far from the interpretation of biological form in contemporary works on biosemiotics. When speaking about the positive sides of neovitalism, it is important to emphasize the basic assumption, that holistic concepts can be introduced in a fashion that does not violate any physical laws (Elsasser 1982: 21). An analogous assumption should hold when speaking about the positive features of several representatives of neo-Lamarkism (an approach which also has some features important for the history of biosemiotics): it should be assumed that Crick's central dogma holds. And indeed, at least several neo-Lamarckians (e.g., German botanist Carl Nägeli, and British paleontologist David M. S. Watson) have clearly stated that acquired characters are not inheritable (cf. Bowler 1983, Cannon 1957, Mayr 1972), which means that the third mechanism of evolutionary perfection (an autogenetic one, or based on genetic predisposition) was considered possible besides those of natural selection or acquired adaptation.

The biologists adhering to the soft version of vitalism (or taking a compromise position between vitalism and mechanicism), according to Ernst Mayr, "might be best referred to as organicists", since "vitalism has become so disreputable a belief in the last 50 years that no biologist alive today would want to be classified as a vitalist" (Mayr 1988: 13). This should be considered in relation to the fact that Uexküll's name has been listed as the second one after Driesch in the articles about neovitalism in several encyclopedia. To the organicists in this sense, Mayr classifies among others also the above mentioned Johannes Müller. Here, Max Delbrück's (1976) view can be recalled, showing a deep analogy between the Aristotle's hylomorphic principle (usually held to be the beginning of vitalism) and the principle implied in DNA (cf. Mayr 1988: 13).

Among the early anti-Darwinian theories, developed in the end of the 19th century, one of the possibly more interesting ones for later biosemiotic views was the *autogenetic* theory of evolution (as established, e.g., by Carl Nägeli and Theodor Eimer). Its main statement is the existence of an immanent (intrinsic) source of evolutionary change, the intrinsic trend towards the diversification of structure and behaviour (cf. Csanyi and Kampis 1985). Theodor Eimer stressed the predictability of that trend, using the term orthogenesis (cf. Mayr 1988: 499). Several psycholamarckists, such as Edward Cope, were also quite close to these views. "It was their unshakable belief in teleology that induced Karl Ernst von Baer and other of Darwin's contemporaries to attack the theory of selection so temperamentally. Indeed, the belief in a teleological force in nature was so firmly anchored in the thinking of many that even among the evolutionists this belief had more followers in the first 80 years after 1859 than did Darwin's theory of selection" (Mayr 1988: 59).

After the works of August Weismann, it became generally accepted that acquired characters cannot be inherited. In modern terms, genetic memory works as read-only, as a ROM. As a result of this discovery, the autogenetic theories were thrown into the dustbin of history, together with all they included. The nomogenetic theory of evolution (Lev Berg, Alexandr Lyubischev, Sergey Meyen) has been one of the rare (and a quite unknown for the majority of biologists) approaches which still held and developed in a way the autogenetic view.

Memory is certainly an important component in semiotic processes. In this aspect, there exists a forgotten investigation from the theoretical biology of the beginning of the century – Richard Semon's (1911) (1859–1918) analysis of biological systems, based on the notions of *mneme* and *engram* (which is related in its approach to the works of Ewald Hering (1912), Eugen Bleuler, Edward Cope, Eugenio Rignano and Samuel Butler; cf. Blandino 1969). Bertrand Russell's book "The Analysis of Mind" was largely based on Semon's approach, through which the latter has also indirectly influenced contemporary philosophy. However, it is interesting to mention that in his later works Russell did not cite Semon's name almost at all. The probable reason for this is hidden in Semon's belief to the inheritance of acquired characters, i.e. the view due to which its supporters lost their position on the map of science. But exactly in the way that this part of Darwin's views (pangenesis) were considered indifferent in relation to his main views, so also in the case of Semon this assumption does not greatly influence his general ideas on biological memory.

The First Wave of Theoretical of Biologists: 1920–1940

Between the peaks of theoretical biology of 1900 and the 1960s–1970s, there was also a remarkable wave in the 1930s. It was characterized by the publication of the first influential monographs calling themselves "theoretical biology" (Ludwig von Bertalanffy, Erwin Bauer), Nicolas Rashevsky's mathematical biophysics, Alfred Lotka's and Vladimir A. Kostitzin's mathematical biology, and the start of several journals in this field. This has been called the golden age of theoretical ecology (Scudo and Ziegler 1978). As a result of works by Ronald A. Fisher, Sewall Wright and John B. S. Haldane, the Darwinian theory of natural selection obtained its mathematical basis, and the so-called modern synthesis took place, giving rise to the synthetic theory of evolution. According to Ernst Mayr (1988: 550), "An unexpected achievement of the synthesis was its effect on the prestige of evolutionary biology. The 1920s and 1930s experienced an absolute low in the esteem of evolutionary biology within biology." Since that time, neo-Darwinism became the dominating view in biology for a considerably long time, and holism became unpopular. These developments did not give much to semiotic biology, at least during their first decades.

At the same time, holistic views in biology were still quite strong, but this can be seen as late inertia from the neo-vitalist or organicist period of the beginning of the century. Of the more mathematically-biased holistic biologists, the works of D'Arcy Wentworth Thompson (1917), Joseph Woodger (1930/1931, 1952), Ludwig von Bertalanffy (1932) should be mentioned.

Besides Uexküll with his "Bedeutungslehre" (1940), there were also several other biologists influenced by neovitalistic approaches, in whose works some insights into semiotic biology can be found, among them Edgar Dacqué (1878–1945), Karl Friederichs (1878–1969), Friedrich Brock (1898–1958), Adolf Meyer-Abich (1893–1971), Richard Woltereck (1877–1944), and others.

Edgar Dacqué's (1929) title "Leben als Symbol" for his book indicates that he, may be, had some semiotic ideas in mind. "Das Individuum ist also, wie schon gezeigt, Symbol, in dem die Entelechie der Art begrenzten Ausdruck findet"[8] (Dacqué 1929: 102). However, the book itself is not directly a semiotic one.

Karl Friederichs (1937) analysed the terms *Bedeutung, Sinn,* and *Wert* in his book on ecology. He also proposed the replacement of Uexküll's term *Umwelt* by *Eigenwelt* (self-world), which he saw as more appropriate.

Adolf Meyer-Abich (1963, Meyer 1934) has interpreted the work of Uexküll as the first formulation of functional archetypes, in addition to the morphological archetypes already known in biology for a long time. According to a sectarian view of Meyer-Abich, physics should be a part of biology, not vice versa. However, this view can be seen in another light, if interpreted it in the light of the ideas of Walter Elsasser (1982) or Robert Rosen (1991a) on the need for broadening the basis of physics in order to include the nature of living processes.

Friedrich Brock, who was a pupil of Uexküll and his follower in the *Institut für Umweltforschung* in Hamburg, carried out some experimental research into animal *Umwelts*. He has also underlined the closeness of *Umweltlehre* to Leibniz's philosophy (Brock 1939; also Lassen 1939/1941).

Richard Woltereck (1932, 1940), in his "Ontology of living", has emphasized the existence of many intermediate forms between the somatic unconscious and the mental conscious intentional. He has also analyzed the concept of adaptation from the point of view of subjective biology, and has stressed the role of representation for intentional phenomena. His approach might be considered as a development of Uexküll's views. "Für den lebenden Körper existiert nur, was ihn erregt, wofür er resonant ist, was für ihn Bedeutung besitzt"[9] (Woltereck 1940: 431).

Thus, the influence of the organicist approach to the growth of semiotic trends in biology has probably been conspicuous, however, this has obtained a wider acceptance only due to the works of Uexküll, the role and results of other scientists of this trend being left almost unnoticed in the period dominated by genetic preformism. I do not claim with this that the works mentioned above are all valuable

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[8] "The individual is, as already shown, a symbol, in which the entelechy of the species finds its limited expression".

[9] "For the living body exists only what excites it, what he is resonant with, what has a meaning for it".

for contemporary semiotic biology, but I do claim that Uexküll was not alone in his views.

In parallel, it should also be mentioned that in the works of several semioticians of that time (Charles Morris, Ernst Cassirer, Roman Jakobson), biology was already seen as occupying a space close to the science of signs.

The Second Great Wave and Zoosemiotics, 1960–1980

As noted, the 1960s precipitated the rise of a new powerful wave of theoretical biology, with the "Journal of Theoretical Biology", biocybernetics, information theory, systems theory, Waddington, Rosen, many new journals and book series, etc. This was a period of applied mathematics in every field of biology, together with a diversification of theoretical approaches. Due to the great influence of biocybernetics in this period, communication processes received much attention by biologists.

This was also the start of extensive molecular biological research, with the deciphering and understanding of the genetic code and the principal ways of information transfer in a cell. There were also a rise in the application of information theory in biology, and the quick development of mathematical biology, biophysics, and biocybernetics. At the same time, ethology became very popular.

Ecology, for which this period was also a time of large extension, is a branch of biology in which holistic views have had a strong influence, together with reductionist approaches, of course. Eugene P. Odum (1964) "clearly delineated these two camps and placed himself in the forefront of the holists" (McIntosh 1988: 201). However, as Anna Bramwell (1990) has illustrated, these relationships are very complex and any superficial division is not correct. According to Bramwell, the organicist biology of Uexküll's time was that which gave the initial power to ecological views, extending far outside a professional biology.

The powerful introduction of cybernetic ideas and the concept of information into biology was thought to solve the eternal problems of the teleology of living together with the relationships of mind and matter. However, these problems, instead, resolved into many branches. Among them, an interesting book by Miller et al. (1960) should be mentioned; this applied the notion of plan to the explanation of animal behaviour. Along the lines of this period, Uexküll's approach could be intepreted as an early development of some biocybernetic notions. Also, several notions of Hans Driesch were taken into use in the theory of self-regulating systems (for instance, equifinality, by Ludwig von Bertalanffy, Paul Weiss, and others). There were, however, scientific branchings emerging from biocybernetics, represented by Gregory Bateson, and from the collaborations between Humberto Maturana and Francisco J. Varela – three names often quoted in contemporary biosemiotic works.

Susan Oyama, referring to Gerd Sommerhoff (1974), has stated that "understanding of goal-directedness requires neither mentalistic language nor invocation of machine models, but conceptual clarity and investigation of actual relationships among variables and their consequences" (Oyama 1985: 133). Thus, despite the explanations given to goal-directedness in cybernetics (bearing in mind here the analogies between Uexküll's functional circle and Norbert Wiener's feedback loop and its applications in neurobiology, e.g. by Pyotr K. Anokhin), and Kari Lagerspetz's (1959) and Ernst Mayr's analysis of biological teleology (proposing the term "teleonomy" to make these biological phenomena acceptable to scientists of other philosophical backgrounds), it seems to be, nevertheless, appropriate to propose these terms for the next round of analysis – semiotic analysis (cf. Powell 1986).

This situation may have helped create an environment in which the semiotic approach could be applied in biology. It began as zoosemiotics, primarily through the works by Thomas Sebeok.

Sebeok's work has been immense, and it is largely due to him that biosemiotics, first, appeared in the 1960s, and second, is stepping towards its heyday today. Instead of listing his works I refer here to his bibliography (Deely 1995).

The belief in the at least potential possibility to conjoin semiotics with biology was also not alien to several other leading semioticians. In 1967, Roman Jakobson said (1971: 675): "The complete failure of mechanistic efforts to transplant biological (e.g., Darwinian or Mendelian) theories into the science of language or to fuse linguistic and racial criteria led linguists temporarily to distrust joint designs with biology, but at present, when both the study of language and the study of life have experienced continuous progress and stand before new, crucial problems and solutions, this scepticism must be overcome."

Along with Sebeok, there were several others who started to use semiotic terminology in ethology and biological communication studies. For instance, Günter Tembrock (1971), influenced by zoosemiotics, applied the concepts of syntax, pragmatics, and semantics, as basic aspects in his classification and analysis of communication phenomena in biology.

Another branch in biology, besides ethology, which started to search for ways of integration with general linguistics, was molecular genetics. Marcel Florkin (1900–1979), a Belgian biochemist, published a large paper on the biosemiotics of biochemistry, in which he applied the Saussurean approach to molecular processes of the cell (Florkin 1974; cf. Emmeche and Hoffmeyer 1991). In addition, George Beadle and Muriel Beadle wrote: "Science can now translate at least a few messages written in DNAese into the chemical language of blood and bone and nerves and muscle. One might also say that the deciphering of the DNA code has revealed our possession of a language much older than hieroglyphics, a language as old as life itself, a language that is the most living language of all" (Beadle and Beadle 1966: 207).

However, the majority of these attempts to apply semiotic terminology in biology (e.g., Tembrock, Florkin, Beadle) did not go very deep. This means, one still probably cannot see in them the establishment of semiotic biology as an approach which considers the living process itself as having a basically semiotic nature. In this sense, particularly as concerns molecular biology, one may distinguish between the application of linguistic and semiotic approaches, the former being much more widely used in that period.

According to Robert Rosen (1991b, 217), who has for a long time searched for non-reductionistic ways of building the theory of biology (as has another exact scientist in the field, Walter Elsasser), “biology is the way that we will find answers to most, if not all, of the deep questions which have engaged the human mind throughout our history. I have always believed that biology is the central science, in which all others converge, and which in turn illuminates them all with new light.” Not very far from these thoughts, in a series of conferences “Towards a theoretical biology” in 1968–1972 with a small circle of foremost scientists, the paradigm for the theory of general biology was sought. According to the conclusion made by the organizer of these conferences Conrad Waddington, this paradigm should come from general linguistics (Waddington 1972). This idea was developed in the papers of several participants: Howard Pattee, Brian Goodwin, René Thom, Christopher Zeeman. My idea that this was not so distant from the route to biosemiotics (Kull 1993a), can be illustrated by a quote from Sebeok (1989: 281): “Uexküll’s scheme could, I think, productively be accommodated within Zeeman’s developing model of the brain, thus making it amenable to mathematical exploration and generalization to cover any information with tolerance properties; in particular, this would allow for the combination of language structure with tolerance structure along lines worked out in some detail by Thom.”

However, in the mutual integration of biology and linguistics, some new mathematical problems received more attention than did their semiotic counterparts, for instance, Noam Chomsky’s generative grammars (Lindenmayer and Rozenberg 1976). Also, much research on the biological foundations of language (Lenneberg 1967, Lieberman 1984, Walker 1978) was quite far from semiotics.

The name “biosemiotics” probably first appeared also in the 1960s. One can find it used already in 1961 by Friedrich S. Rothschild (1899–1995) in the conference “The Psychology of the Self” in New York. According to Rothschild (1962: 777): “This approach presupposes acceptance of our position that the history of subjectivity does not start with man, but that the human spirit was preceded by many preliminary stages in the evolution of animals. The symbol theory of psychophysical relation bridges the gulf between these disparate avenues of research and unites their methods under the name of “biosemiotic”(see also Rothschild 1989, 1994, Bülow and Schindler 1993, Anderson 2003). It should be acknowledged that a book by Stepanov (1971) includes a chapter entitled “Biosemiotics”, in which he described the views of Jakob von Uexküll, and which has sometimes been considered as one of the earliest known usages of the term.

Despite the first introductions to the field of biosemiotics being published in this period, a wide increase in knowledge about zoosemiotics, a corresponding interest in animal languages, and some seemingly important preliminary work towards the integration of linguistics and biology, it appears in retrospect that there were still very few people who really believed that biosemiotics was a deep, true fundament for future biology at this time. Sebeok (1968, cited in Deely 1990: 85–86), however, was an exception to this rule, noting that: “A mutual appreciation of genetics, animal communication studies, and linguistics may lead to a full understanding of the dynamics of semiosis, and this may, in the last analysis, turn out to be no less than the definition of life." Soon, many other scholars from a variety of disciplines began to share this view (see Anderson 1990 and Eder and Rembold 1992 for overviews).

1980s and 1990s: Establishing the Field of Biosemiotics

The decades after the great peak in the 1960s and 1970s marked a clear decline in general interest in theoretical biology. Biosemiotics, simultaneously, is remarkably growing. But let me first note some trends appearing in neo-Darwinian biology, emphasizing the communicative aspects.

"In the past two decades the importance of sexual selection has again been acknowledged [. . .] this topic has become one of the major concerns of sociobiology" (Mayr 1988: 505). This means a growing interest in the role of certain aspects of communication by evolutionary biology. Along with the works by Edward O. Wilson, William D. Hamilton, Amotz Zahavi and others, the concept of "memes" (Richard Dawkins) has achieved a wide distribution in biologists' writings. John Maynard Smith developed a game theoretic model to describe the evolution of communication. John Maynard Smith and Eörs Szathmary (1997) have written about the biological background of language origins. Gerald Edelman (1992: 74) proposes to develop "sciences of recognition, sciences that study recognition systems", including into them evolutionary biology, immunology, and neurobiology. From philosophy (but following the same biological tradition), Daniel Dennett has made strong attempts to explain the intentional aspects of living systems.

On the microscopic level, the linguistics, and step-by-step semiotics, of molecular texts have been more and more analyzed in molecular biology (e.g., Brendel et al. 1986). "I shall guess, the history of linguistics will be repeated in the development of molecular biology" (Berlinski 1978: 180). According to Robert Pollack (1994: 151), "molecular biology now confronts a new and unpredicted uncertainty, a boundary on our ability to know the final meaning of the genes we study". "The trend is clear: we can expect to find more and more examples of the richness of a real language in our cells. DNA and protein have grammar and syntax, and we have already come upon typographical errors, double meanings, synonyms, and other subtleties" (Pollack 1994: 153).

The rediscovery of Uexküll's work by Sebeok was quite sudden. In his "selected and annotated guide to the literature of zoosemiotics and its background" (Sebeok 1969), Uexküll's name is still lacking. Despite some occasional references earlier (cf. Sebeok 1989 [1979]: 193), the breakthrough was made in Sebeok's talk at the "III Wiener Symposium über Semiotik" in 1977 (Sebeok 1989: 187). Through Sebeok, this had a positive feedback effect on ethology and many other areas, which started to refer to Uexküll again. Shortly after the reclamation of Uexküll by Sebeok, Thure von Uexküll published a compendium of his father's works, supplied with extensive commentaries (Uexküll 1980). This was followed by publication of translations of "Bedeutungslehre" and "Streifzüge. . ." in "Semiotica" (J. v. Uexküll 1982, 1992), and the inclusion of Uexküll into "Classics of Semiotics" (Krampen et al. 1987). Uexküll did not write much about plants (other than his well-known example of oak and rain, which may not have been a particularly good example of what he was trying to show from the point of view of a professional plant ecophysiologist). To fill this gap, Martin Krampen (1981) wrote an article, from which the field called *phytosemiotics* is considered to have begun. John Deely (1986, 1990) responded with a critique that introduced the notion of *physiosemiosis* to denote the realm of pre-biotic conditions necessary for biosemiosis to take place.

The evolutionary perspectives of biosemiotics have been developed, e.g., by Günter Bentele (1984), and by Marcello Barbieri (1981; 1985), who has introduced the term "natural convention" in addition to "natural selection", and who wrote about *The Semantic Theory of Evolution* in 1985. A programmatic paper for biosemiotics, in which a series of statements on the semiotic aspects of biological evolution is formulated, is the collective article by Myrdene Anderson et al. (1984), in which they stress the importance of coevolution and symbiosis, noting that communication begins with a decoder, not with the encoder, whether "intentional" or not. This insight is particularly crucial to the understanding of evolution as a part of semiosis.

A major new aspect appeared through the discoveries made in immunology, which showed that there exists another system capable of learning and informing the whole animal body, besides the nervous system. After the works of Niels Jerne, which pointed out some linguistic features of the system, a remarkable book on immunosemiotics was published (Sercarz et al. 1988). Shortly after that, the semiotic interpretations of the processes taking place inside an organism were integrated in a large paper on endosemiotics (Uexküll et al. 1993). To Thure von Uexküll's (1979, 1982, 1986) credit is also the building of a bridge between biosemiotics and psychosomatic medicine, a project to which he devoted his life. The book "Biosemiotics" edited by Thomas Sebeok and Jean Umiker-Sebeok (1992) with its twenty-seven authors was probably the first book with "biosemiotics" in the main title. Innovative and diverse, it remained for a long time the largest volume in this field.

The paper by Jesper Hoffmeyer and Claus Emmeche (1991) on code duality seems to herald a new quality in the works on biosemiotic ontology, since it introduces a formulation of biological information which is applicable to all levels of living systems, and which is the guiding thread of all the following writings by Hoffmeyer in his characterization of "semiosic body-mind".

Semiotics has been seen as a tool for approaching the epistemologic problems of biology. This has several dimensions. Firstly, biosemiotics seems to propose for biology a sort of philosophical basis or background, in a hope to replace the one which has been applied at least since Ernst Haeckel, namely "Evolutionstheorie als Weltanschauung" (cf. Uexküll 1907, Weingarten 1993). Secondly, it enables the introduction of subjectness, i.e. organism as a subject, into the biological realm (cf. Uexküll 1931b, Woltereck 1932). And thirdly, it helps to understand the development of mental features through the semiotically interpreted evolutionary epistemology (Schult 1989, Hoffmeyer 1996b). (Since there is a difference between genetic and evolutionary epistemology, the proper aspect here may be genetic epistemology, cf. Kesselring 1994.) Hoffmeyer has emphasized the importance of biosemiotics as an approach which can resolve the dualism: “To modern science, dualism still holds good as a way of dividing the world into two kingdoms, those of mind and matter, the cultural and the natural spheres [. . .]. And it is this boundary that biosemiotics seeks to cross in hopes of establishing a link between the two alienated sides of our existence – to give humanity its place in nature” (Hoffmeyer 1996a: 94). According to the biosemiotic view, “system could be *more or less rational*; rationality is something that can occur at levels other than that of the human psyche” (Hoffmeyer 1996a: 93).

Within the last decades, there has also been much particular work done on developing the semiotic understanding of different biological phenomena.

Eugen Baer (1984: 6) said, “we must look at adaptation as a semiotic phenomenon, that is, as a process of signification.” This is an important point, since the notion of adaptation certainly requires reinterpretation. The existing notion of adaptation in biology, which is either connected to fitness and thus disconnected from form, or, when described as a form then loses its testability, needs a new theoretical foundation. The drawbacks of the contemporary approach were described by Stephen Jay Gould and Richard Lewontin (1979).

An interesting case in which semiotic aspects appear, is mate recognition, and together with this, the mechanism which is responsible for the origin and holding of biological species as discrete units (Schult 1989, 1992, Kull 1992, 1993b). This is closely related to the recognition concept of species as developed by Hugh Paterson (1993). The role of genetic communication between bacteria was investigated by Sorin Sonea (1992) in a similar context. Another semiotically interesting phenomenon, in which discreteness also arises, is categorical perception (Stjernfelt 1992). These are examples of more general reciprocal mechanisms, which are responsible for a large set of spatial, temporal and morphological discreteness in various biological systems, at the same time being a prerequisite of any linguistic phenomena.

Barend van Heusden, when speaking about biosemiotics, has tried to formulate the specificity of human perception. “Humans are aware of the fact that they do not actually perceive forms . . . but that they perceive *with* forms, that . . . the world presents itself to us as different from a remembered past” (Heusden 1994: 68). Thure von Uexküll has stressed that the difference lies in the temporal aspect, namely that there appears a time lag between the perception and reaction in the case of humans. Indeed, the more biology is integrated into semiotics, the more important it will be to reformulate the sources of the clear difference between bio- and anthroposemiosis.

Yoshimi Kawade (1996) has renewed the semiotic interpretation of biomolecular processes. Ray Paton (1997) has analyzed in what sense a biological form can be a text, or an enzyme can be a verb (on the organism as a text, cf. Sebeok 1977, Löfgren 1981, Kull 1997).

There are also attempts to make the information concept more appropriate for biology with the help of semiotics (Sharov 1992). “With semiotics the observer could be brought right into the models. Furthermore, this now allows the *meaning* of information to be modeled as well as the information itself, as is done in information theory. Indeed, as I conceive it now, information theory must become embedded in semiotics" (Salthe 1993a, xi; cf. Hoffmeyer and Emmeche 1991). Brier (1995) has analyzed the problems of the integration of biosemiotics and cybernetics.

The term "ecosemiotics" was introduced by Winfried Nöth (1996), followed by a series of responses in a special issue of "Zeitschrift für Semiotik". However, the semiotic approach to ecology was introduced earlier, e.g., by Alexandr Levich (1983), whose particular interest concerned the applicability of Zipf's law in the ecological communities.

Hoffmeyer's book (1996) deserves particular attention. He is more clear and more radical than previous authors, claiming that biosemiotics is an approach which can give the solution to the main problems of mind-body dualism and relationships of humans and nature. A collective review of this book is going to be published in "Semiotica". However, there are many issues in the philosophy of biology about which Hoffmeyer does not say a word. In the extremely complex and inter-twined sphere of biological theories, silence can sometimes be the best answer, particularly in the formation phase of its views. When the development proceeds, however, more will become expressed and interpreted. And semiotics, among others, is hopefully teaching us to behave in an otherwise too complex mixture of meanings in the theoretical spheres of biology.

Thus, to conclude the description of this last chapter, which began with Sebeok's reopening of Uexküll, one can characterize it as a rapid growth of biosemiotics in this period. In addition to the publication of Uexküll's translations into English, many new authors came into the field, special issues of journals appeared (Semiotica 120(3/4), 1998; 127(1/4), 1999; 134(1/4), 2001; "Zeitschrift für Semiotik" 8(3), 1986, 15(1–2), 1993, 18(1), 1996; European Journal for Semiotic Studies 9(2), 1997; Cybernetics and Human Knowing 5(1), 1998; 7(1), 2000; Sign Systems Studies 30(1), 2001, etc.), a series of books were published within a short time (Sebeok and Umiker-Sebeok 1992, Salthe 1993a, Witzany 1993, Pollack 1994, Yčas 1994, Hoffmeyer 1996a, Deacon 1997), and many books on semiotics paid much attention to biosemiotics (Deely et al. 1986, Deely 1990, Nöth 1990, 1994, Sebeok 1990, 1994, Posner et al. 1997, Merrell 1996).

Historically Important Meetings

In addition to published works, epistolary and oral discourse, no doubt, also play a role in scientific development. In this context, at least Thomas Sebeok's contribution has to be mentioned.

In a short time, a number of symposia, workshops and conferences in biosemiotics have been organized, almost all taking place within the last decade. It is worth mentioning the workshop "The Semiotics of Cellular Communication in the Immune System" in 1986 in Italy (Sercarz et al. 1988) with a contribution by Umberto Eco (1988). Probably of particular importance were the small workshops in Glottertal (Germany) which took place in 1990 and 1992, in which an attempt was made to establish an International Biosemiotics Society (cf. Sebeok 1991: 7) and in which some Copenhagen and Tartu biosemioticians first met. Also, a meeting "Biosemiotics and Biotechnology" in 1991 in Denmark should be mentioned. After that, symposia on biosemiotics were held in International Congresses of Semiotics, in Berkeley (USA) 1994, and in Guadelajara (Mexico) 1997. The meetings of the International Society for the History, Philosophy and Social Studies of Biology held in Leuven (Belgium) 1995, and in Seattle (USA) 1997, also included biosemiotic sections. An important event was the conference in Toronto, called "Semiosis. Evolution. Energy", in 1997. The congress "Symbiogenesis and Carcinogenesis" in Freiburg, Germany (1998) was probably the first meeting in experimental biology which included a session on biosemiotics (Endocytobiology and Cell Research 13, Supplement).

In Denmark, a series of smaller biosemiotic meetings were held, mainly due to the activies of Jesper Hoffmeyer, Claus Emmeche, Svend Erik Larsen, and others. Since the end of 1980s, the biosemiotic group was formed at the Institute of Molecular Biology of the University of Copenhagen. There exists the Danish Society for the Semiotics of Nature.

Concerning the relationships with theoretical biology, it is interesting to mention that three regular seminars on theoretical biology, which arose independently in St. Petersburg (leaded by Sergey Chebanov), in Moscow (Alexei Sharov, Alexandr Levich), and in Tartu (Kalevi Kull, Toomas Tiivel) in 1970s, having a nomogenetic bias, all later made a shift towards biosemiotics. Together they organized the conference "Biology and Linguistics" in Tartu in February 1978, which was probably one of the first larger biosemiotic meetings on a world scale. In October 1988, a small workshop "Semiotic approach in theoretical biology" was held at Laelatu Biological Station (Estonia). From 1988 to 1990, Alexei Sharov organized a series of seminars and "Winter Schools on Biosemiotics" at Moscow University. Sergej Chebanov established similar activities at the University of St. Petersburg. In 1998, Nikolai A. Zarenkov gave a lecture course "Semiotic-linguistic theory of biology" at Moscow University.

In Estonia, about which I know more, a great deal is also going on. An issue of the periodical "Vita aeterna" (no. 5, 1990) of the students' Theoretical Biology Group of Tartu University was devoted to biosemiotics. Since 1993, several guest scientists (Thure von Uexküll, Jesper Hoffmeyer, Sergey Chebanov, Barend van Heusden, Thomas A. Sebeok) have lectured on biosemiotics in Tartu University. In 1993, the Jakob von Uexküll Center was established in Tartu. Recent Estonian Spring Schools in Theoretical Biology were entitled "Theory of Recognition" (1995), and "Languages of Life" (1996). A regular lecture course on biosemiotics was introduced by Kalevi Kull in Tartu University in 1993, in the year of the death of Juri Lotman, but still with his introductory words, dictated in hospital. Now, this course is read every year and is included in the standard semiotics curriculum. Also, a biosemiotic course was offered by zoologist Aleksei Turovski at Tallinn University of Educational Sciences in 1997.[10]

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[10] Several major developments in the institutionalization of biosemiotics have taken place in the 21st century, after the writing of this article. I will only mention a few of them here. In 2001, as initiated by Copenhagen and Tartu biosemioticians, a new series of annual conferences known as the international Gatherings in Biosemiotics have taken place, and has become the major biosemiotics conference series in the world. A dedicated journal, *Biosemiotics*, and a book series (of which this

The 21st Century and Post-Darwinism

The majority of biosemioticians have been quite critical towards neo-Darwinism (e.g., Salthe 1993a and 1997, Witzany 1993). Indeed, post-Darwinism as it has developed in recent decades seems to correspond and fit much better with the needs of semiotic biology. Hoffmeyer (1996a: 58) wrote: "We need a theory of organisms as subjects to set alongside the principle of natural selection, and Jakob von Uexküll's umwelt theory is just such a theory. Ironically, however, it is only through integration with the theory of evolution that the umwelt theory can truly bear fruit."

Except for some cases when this was used to denote the whole period after Darwin's death, the term *post-Darwinism* as signifying the overcoming of the neo-Darwinian period was first used not later than 1986, at a meeting in Osaka on structuralism in biology (Ho 1989). That meeting, which declared itself in clear opposition to the "mainstream" theoretical biology, also noted its historical continuity to a "marginal" tradition in theoretical biology, coming from Joseph Needham, Joseph Woodger and other members of the Cambridge Club of theoretical biology (Goodwin et al. 1989: vii, Abir-Am 1987). On the other hand, it is very noticeable that the nomogenetic approach in Russian biology, represented by Lev Berg, Alexandr Lyubischev, Sergey Meyen and others, which has brought its tradition back to Karl Ernst von Baer with his criticisms of Darwinism, resembles in many aspects the above-mentioned structuralistic biology (Schreider 1977, Brauckmann and Kull 1997). Meyen, in his later works, considered it possible to reach a theory (a new synthesis) into which these particular views on evolution can be included.

The main emphasis of the post-Darwinian explanation of evolution is concerned with the role of the form and activity of organism. The neo-Darwinian mechanism of natural selection appears to represent a special case in the post-Darwinian picture of evolution. In this context, it is interesting to note some recent trends in evolutionary biology, which emphasize the role of an organism's activity. One of these is the resurgence of interest in the Baldwin effect – the importance of individual adaptation and learning for evolution (Baldwin 1896; e.g., Belew and Mitchell 1996). The other is represented by works which consider epigenetic changes (through the mechanisms of epigenetic inheritance) to be primary factors in evolutionary change (Jablonka 1994). There are also other works emphasizing organisms as subjects of evolution (Weingarten 1993, Kull 1993b).

Due to the results of molecular biological research and the modeling of complex systems, it is evident that the material structure of living systems is now understood in remarkable detail. In other words, the molecular mechanism of life is more or

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volume is a part) have also been established, under the editorship of Marcello Barbieri and Jesper Hoffmeyer. The International Society for Biosemiotic Studies has been established (Favareau 2006, www.biosemiotics.org). Too, both graduate and undergraduate courses in biosemiotics have been taught in the United States, Singapore, and Estonia – this latter university (Tartu University, whose alumni include Karl Ernst von Baer and Jakob von Uexküll) being the first in the world to offer a doctoral degree in biosemiotics, and which now houses the biosemiotic library of the late Thomas A. Sebeok).

less solved. However, as a matter of fact, biologists still cannot precisely define or delimit what to call the living process. This seems to be a point at which, intuitively, semiotics may be of assistance. However, if some set of molecular processes of a cell will be identified as semiosis, i.e. truly semiotic, describable fully, including all its components, in exact molecular terms, then, why should not this situation mean that semiosis can be modeled mathematically. This would create a new situation for semiotics itself, since no semiosis has been fully described before (in the sense of an external "objective" point of view, the view from "nowhere" of natural science), due to the participation of conscious mind in all cases. However, even in the case of cellular semiosis, the system is not simple at all. A possible scenario of this says, that the mathematical models, except may be the ones for the most primitive semiotic systems, are of such level of complication, and in principle not reducible to more simple ones enabling comprehension without losing their identity with semiosis, that the only way to describe these systems is to apply the natural language, as has traditionally been done in semiotics. This aspect has hardly been discussed in biosemiotics (except of, for instance, avoidance of mathematics by Uexküll, Hoffmeyer, etc.). However, this may be important in order to achieve the acceptance of the semiotic view by biologists who are used to the natural scientific approach.

There exists an additional reason to believe in the fecundity of this scenario. Namely, natural language presumes and includes the process of categorization. Categorization discerns natural languages from formal ones – the latter use logic to define and delimit their terms, whereas in natural languages the categorization which delimits the signs is a pre-linguistic process, analogous to speciation, or category-formation in perception. The categories as wholes with diffuse boundaries, although separated from the neighboring categories by hiatuses, are objects upon which natural languages are based, and for the description of which they are well suited. This is similar to the way in which we can quite easily describe biological species using natural languages, the mathematical and formal definition of which causes many problems. "Privileged sameness relations cannot be found for the demarcation of the species" (Dupré 1981: 83). This is the same as if we tried to turn the scientific analysis of tokens or words, particularly that which concerns their meanings, into a mathematical theory. No doubt, the linguists who do it via their mother tongue, can do it no worse.

Conclusion

In conclusion, has been a considerable difference between the holistic and reductionistic, or Baerian and Darwinian, schools of thought in biology in the successfulness of their attempts to conjoin signs and life, or semiotics and biology. Many of the semiotic biologists can be identified as belonging to the holistic, or Baerian biology. An explanation of the scarcity of semiotic biology in this century thus stems from the fact that Baerian biology has been in a suppressed minority position almost throughout of this century, except may be only for the first and last decades (i.e., in the periods of neovitalism or organicism, and post-Darwinism), when its supporters were slightly better known or noticed. However, the dialogue between these two lines of thinking in biology has never stopped, and has continuously enriched both views. The rapid growth of biosemiotics in the last decade can be seen as a parallel to the rise of post-Darwinism in evolutionary biology, which is also a result of that dialogue. What is needed, and what it may hopefully bring, is both the broadening and deepening of the views. This would include the better understanding and skillful interpretation of deep but forgotten investigations, grasping more from scientists of other views. However, this requires less ideology and more logic in science.

Many examples of semiotic interpretation of biological phenomena have already been collected, and there is a set of ideas about the generalizations and paths to pursue. Their review would grow into a volume or more. However, what is still seemingly absent is a methodical explanation for ordinary biologists on how to apply semiotic analysis to the systems which they know.

The next stage in the development of biosemiotics (in analogy to the developmental logic of other branches of sciences), which may probably be reached soon, is the stage of larger reviews which try to list and integrate the whole field. And of course, there should appear open criticism of the whole approach from various sides – which has until now been quite exceptional and tentative.

We may therefore already notice, I believe, some signs of the beginning of the *third* wave in theoretical biology (after its start in the turn of the century, its first wave in the 1920s and 1930s, and the second wave in the 1960s and 1970s), with a possible keyword *meaning*. It may mean the synthesis of theoretical biology and biosemiotics, biology and semiotics. Or it may turn out to have an even much deeper meaning of its own.

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Chapter 14
Laws of Symbolic Mediation in the Dynamics of Self and Personality

Friedrich S. Rothschild (1899–1995)

Introduction and Commentary: Friedrich S. Rothschild

> *Biosemiotics can not replace neuroanatomy and neurophysiology, because it must rely on these disciplines in order to obtain the data for its analysis of communication processes. However, in questions involving the connection of the psychic with the somatic, and the coherence of the somatic and the psychic, a new comprehension, obviously inaccessible to the pure physiology of the central nervous system, becomes feasible through it.*
>
> F. S. Rothschild (1963: 507)

Semiotican Myrdene Anderson reports that biosemiotics founder Thomas A. Sebeok would often identify as *cryptosemioticians*, those prescient thinkers whose work was deeply predictive of the future project of biosemiotic analysis without them being aware of it as such (e.g., the ancient physician Galen). Conversely, *protosemioticians* was the term that Sebeok would assign to those self-consciously groundbreaking pioneers of biosemiotics who lived before the field *per se* had been established, such as Charles Sanders Peirce (Anderson 2003: 301). Biosemiotician Kalevi Kull, in considering the belated discovery of Friedrich S. Rothschild's six decades' worth of work by contemporary biosemioticans only at the turn of the 21st century, wonders whether either of these two terms would rightly apply to Rothschild, given that "he both knew semiotics and applied it [to biology]" and had even been the first to use the term *biosemiotics* in a scientific paper, in 1963 (199: 129).

Yet, notes Kull, "there was simply no information exchange between Rothschild and other biosemioticians" during the long course of Rothschild's career as a neurologist, psychiatrist and semiotician from 1935 to 1995. Accordingly, writes Kull, "we need to add a fourth class [in addition to the *proto-, crypto* – and 'contemporary working' semioticians of Sebeok's] to classification scheme – i.e., the category of *endemic semioticians*" (1999: 129). "This is a branch of normal good scientists," writes Kull, "about whom nobody in our field knows – or a small scientific group who are developing the field on their own, publishing in journals which are not read by their colleagues in other countries" (*ibid*). Indeed, although Rothschild kept working and publishing at least up until 1986, no mention of Sebeok or any other biosemiotician appear in any of his work yet discovered. Peirce and Uexküll – as

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well as Waddington and Prigogine – *are* specifically cited in Rothschild's work, however, and Rothschild was well-informed enough about the development of a number of related areas of inquiry to take pains to specify exactly in what ways his version of "biosemiotics" differs from the tenets of structural semiology, phenomenology, information theory and cybernetics (Rothschild 1993: 507, 1994: 108–114).

Born on December 17, 1899, in Giessen, Germany, Friedrich Solomon Rothschild studied medicine, medical psychology and psychiatry in the Universities of Giessen and München, from 1918 to 1923. From 1925 to 1928, he worked in Heidelberg with psychotherapist Frieda Fromm-Reichmann (1889–1957) and psychoanalyst Erich Fromm (1900–1980), and in Frankfurt from 1928 to 1933 with neuroanatomist and clinician Kurt Goldstein (1878–1965). With the rise of the Nazi party and the appointment of Adolf Hitler as Germany's chancellor in 1933, Rothschild, a Jew, fled Germany for Palestine, eventually settling in Jerusalem, where he worked as a Professor of Clinical Psychiatry in Hebrew University's Faculty of Medicine from 1936 until his retirement in 1965.

"As a leader of the Israel branch of the Association for Dynamic Psychiatry," reports Kull, "Rothschild published most of his later papers in the journal *Dynamische Psychiatrie.* On June 24, 1989, a symposium entitled *From Causality to Communication – The Biosemiotics of Friedrich S. Rothschild,* and dedicated to Rothschild on the occasion of his 90th birthday was held in Berlin, at the German Academy of Psychoanalysis, which resulted in a special issue of *Dynamische Psychiatrie* 22 (3/4), 1989, and later a book by Bülow and Schindler (1993)" (Kull 1999: 131). Rothschild died on March 6, 1995, at the age of ninety-six, in Israel.

Rothschild's decision to attempt to develop a biosemiotic theory for biology came to him early in his career. In 1935, he published an extended monograph summarizing his previous work on brain asymmetry entitled (when translated into English) *The Symbolism of Brain Structures: Studies on the Structure and Function of the Central Nervous System in Vertebrates and Man.* His subsequent books and papers, none yet translated into English, reveal similar preoccupations: *On the similarities in the construction of the central nervous system and the endocrine system* (1934), *The self and the regulation of experience* (1950), *The symbolic dances of bees as a psychological and neurobiological problem* (1953), *The central nervous system and the symbols of experience* (1958), *Transcendental phenomenology as the semantics and structure of pyschophysical function* (1961), and *God and World in Teilhard de Chardin's biosemiotic evolutionary theory* (1974).

Accordingly, within the few published works by Rothschild that are now available in English (Rothschild 1962, 1963, 1968, 1994), the wealth of convergence with contemporary biosemiotic theory is striking. "Within the structure of the central nervous system (CNS) and among the excitations that arise in it is revealed the syntactic order of a communicating sign system," writes Rothschild, explaining the ideas that motivated his work in neuro-biosemiotics since the 1930s to an audience of fellow neurologist in 1963. "This order is as necessary in the CNS as in any other system in the service of communication, if it is to convey significant messages," observed Rothschild, before cautioning his audience that:

> The difficulties created by the categorical rift between manifestations of consciousness as against physiological brain processes cannot be solved by merely proclaiming a unity of body and mind. Nor will it suffice to view these two avenues of analysis as two aspects of a higher unity beyond the grasp of human understanding: the first, the anatomical and physiological analysis of processes occurring in the central nervous system, and the other, the introspective analysis of the consciousness. For once this formula is accepted, nothing prevents us from continuing in the style of the old dichotomy. Rather, it is necessary to introduce novel methods of thought based on the intimate connection of psyche and soma, rather than on their separation. For this purpose, the semiotic method is the only choice remaining (1963: 475–476).

Only a neuroscience that includes a biosemiotic component, insists Rothschild, can satisfactorily explain the workings of the CNS in its fullness (1963: 507). Rothschild's 1935 argument that "the meaning of the CNS manifested in consciousness is lost by examining the CNS purely [in its physics] as an object – just as the denotative meaning of a written word would be lost by such an examination," wrote philosopher and scientist Michael Polanyi (1891–1976) in 1965, "anticipates my own theory of body and mind by thirty years" (Polanyi 1965: 809).[1]

Similarly, many of the hypotheses about the nature of brain function that Rothschild advanced in 1960s predated by decades a number of similar hypotheses later to be proposed by Antonio Damasio (1994, 1999) and Gerald Edelman (1991, 2001) made on the basis of the subsequent forty years worth of neurobiological research. In particular, Damasio's psycho-neurobiological theories regarding the hierarchy of reafferent neural processes that finally result in self-reflective consciousness is well anticipated by Rothschild's description of the cascading "representation, re-representation, and re-re-representation of relations on the respective levels" of the central nervous system that gives rise to the appearance of a auto-reflective "self" (Rothschild 1963: 484). Equally impressively, Rothschild's neuroanatomical understanding appears to be considerably ahead of its time in insisting that "these different levels [of neuronal organization] should not be thought of as being localized in anatomically specific parts of the CNS, as in Jackson's and Penfield's conceptions . . . rather, the same elementary mass of ganglion cells [will assume] different functional connections" under differing input and circumstances (1963: 485), in the manner of Edelman and Tononi's much later hypothesized "transient yet dynamic functional clusters" (Edelman and Tononi 2001).

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[1] Rothschild's analogy with the futility of attempting to analyze word meaning purely as a problem in physics is echoed by Albert Einstein's observation (recalled by Howard Pattee in Chapter Seventeen of this volume) that one could, if one wished, construct a graph of air pressures as a way of "analyzing" the beauty and emotional power of a Beethoven symphony, but that one would thereby be ignoring the very thing that, in doing so, one first set out to explain. This same logic underlies philosopher Daniel Dennet's (1992) "flight simulator video game" arguments against the explanatory viability of a purely physicalist explanation of brain activity for understanding and explaining our experience of "mind". Observing the activity of the electronic impulses taking place on the computer's circuit board, no matter how minutely, Dennet argues, will not reveal the relevant entities, categories, and relations that constitute the consequential semiotic products of those activities for the user of the software.

Notable, too, is Rothschild's prescient delineation of the relation between language and the brain. Presaging the biosemiotic arguments of Terrence Deacon (1997), and as opposed to the positivist conception of human language as "a hard-wired and innate capacity" (as advocated by such linguistic theorists Noam Chomsky (1975) and Steven Pinker (1994)), Rothschild agues that:

> Man differs from other vertebrates in that a further communication system has become superimposed *over* the central nervous system. This system, however, is not provided by nature in form of a physical structure. Rather, every human being must learn it in infancy in the form of language from his fellow men and must develop it personally. . .. In it, thought and will emerge together with developing speech and *transform* perception, emotion, and behavior in specific ways. Thus the function of the central nervous system becomes newly organized. The original animal style of channeling the excitations becomes inhibited with the emergence of thought and will and is cast in new molds of excitation configurations. What fundamentally distinguishes man from the animal, then, is not his brain as an organ given by nature. In spite of its particular development, it belongs to the same level of communication systems as that of the anthropoid apes. It is, rather, the specific way in which man uses his brain [within the systemic structure of language] (1962: 781).

Semiotician Myrdene Anderson notes how much of Rothschild's thinking forecasts that of decades later biosemiotic work by Jesper Hoffmeyer – "Rothschild emphasizes the semiotic significance of membranes, borders, and edges as mediators" (2003: 309), writes Anderson – who also notes parallels with the work of Gregory Bateson. Like Bateson, Rothschild Posits that "in the [semiotic] intentionality of the noetic system – acting not vis-à-vis the world, but acting to experience the world through the neural system – the ego emerges as an endless stage of learning-for-the-sake-of-learning – what Bateson recognized as learning to learn, or *deutero-learning*" observes Anderson (2003: 311). Accordingly, there are many biosemioticians today who would welcome the realization of Rothschild's suggestion that "it would be an interesting biosemiotic exercise to describe the life cycle of an anthropoid, say a chimpanzee, and to compare it with a human, in order to emphasize the *difference* between an animal with a dominant neural system and an animal with a dominant noetic system" (1994: 78).

Thus far, then, it would appear that Rothschild's self-proclaimed "biosemiotics" overlaps to a considerable extent with the contemporary project, and may be of some use to it. As with almost all of the entries in this volume, however, one must keep in mind that Rothschild's biosemiotics came out of, and still carries with it, the baggage of a certain intellectual background – in this case, one that cannot at all points be effectively mapped onto the contemporary biosemiotic. Most critically, Rothschild acknowledges throughout his writings that his thinking has been profoundly influenced by, and his work ultimately grounded in: (1) the *Lebenphilosophie* of his contemporary Ludwig Klages (1872–1956), and (2) his own personal conversion experience from atheism to Christianity, which took place in the middle 1950s.

Well regarded in his own time, but relatively forgotten today, Ludwig Klages (1872–1956) was a "biocentric psychologist" who understood the psychology of human beings to be predicated upon the struggle between the vital, but unlabeled and chaotic, Heraclitian flux of immediate animal experience, and the delimiting and "thanatonic" structures of symbolic thought. The product of a confluence of then-contemporary trends in German neo-Romanticism, *Lebensphilosophie,* and existentialism, Klages held that "the original sin of mankind transpired at the moment when the ecstatic, image-laden, and rhythmically pulsating life that man enjoyed during the primordial phase of existence was invaded by 'spirit' (*Geist*), an entity whose essence is expressed in such phenomena as the will-to-power, purposeful activity, and the dictatorship of reason" (Cartney, 2001: o.l.).[2]

Klage's basic opposition here can ultimately be seen as a posited duality between the primacy of iconic biological experience and what is considered to be the degeneracy of linguistically and conceptually mediated experience (or the culture of symbolic reference, to use Terrence Deacon's term). Rothschild accepts Klages' conceptual scheme, for the most part, and the corpus of Rothschild's work reveals an increasingly religious endeavor to reconcile these two "asymetrical" tendencies within human nature, as well as to account for their evolutionary development (as well as the justification for that development) from simpler animal form. The key to understanding Rothschild's conclusions from a 21st century biosemiotican's perspective, I believe, is given here: "When developing biosemiotic theory, I did not think of Christianity at all," writes Rothschild, "Its point of departure is brain anatomy, the asymmetry of the human organism, and the science and philosophy of Klages" (1994: 256). "It was only after reading Teilhard de Chardin's works and studying the history of Christianity," reports Rothschild, did he "realize the full power and purpose of biosemiotic theory" (*ibid*).

The philosophy of Klages that was such a deep influence on Rothschild, as we have seen, is an exaltation of what Peirce would call the immediacy of Firstness, brute experience before words, and being at it appears to the organism before the work of thought reduces (or to use Heisenberg's term "collapses") "the manifold of

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[2] A virulent and outspoken anti-Semite, Klages' work today is celebrated on such websites as the one dedicated to the founder of the American Racial Nationalism movement, Revilo Oliver, at: http://www.revilo-oliver.com/Writers/Klages/Ludwig_Klages.html. Despite the good deal of fairly scurrilous material on the pages surrounding it, the scholarship on Klages that has been collected at that site is impressive (if a bit fawning) and will certainly prove of interest to those wishing to better understand Rothschild's thought. We learn there, for instance, that "Klages refuted the doctrine of *fixed signs* which had so misled his predecessors, who erroneously ascribed atomistic character traits to discrete signs, without perceiving the contextual matrix from which these signs are born. Yet the biocentric investigator does not concern himself with such expressive fragments: *for life can only be found in organic wholes*" (Cartney: o.l.).

Even more provocatively: "In the unique phenomenology of Ludwig Klages, *images* constitute the souls of such phenomena as plants, animals, human beings, and even the cosmos itself. These images do not deceive: they *express*; these living images are not to be 'grasped,' not to be rigidified into concepts: they are to be *experienced*. The world of *things*, on the other hand, forms the proper subject of scientific explanatory schemes that seek to 'fix' things in the 'grasp' of *concepts*. 'Things' are appropriated by men who owe their allegiance to the will and its projects. The agents of the will appropriate the substance of the living world in order to convert it into the dead world of things, which are reduced to the status of the material components required for purposeful activities, such as the industrial production of high-tech weapons systems. This purposeful activity manifests the outward operations of an occult and dæmonic principle of destruction. In his three volume *Reason as the Antagonist of the Soul,* Klages calls this destructive principle 'spirit' (*Geist*) ...[arguing that] it is precisely *the images and their ceaseless transformations* that constitute the only realities" (Cartney o.l.).

sensuous impressions to a unity" (CP: 1.545). At the opposite end of Klages' moral universe is the idea of runaway Thirdness – lawfulness towards self-selected ends regardless of the means. Rothschild's project was to understand the *evolution* from Firstness to Thirdness in living systems. Accordingly, his Haeckel-like evolutionary taxonomy holds that organisms have been joined to the world through the indexicality of Secondness (what Rothschild calls their "*outer adaptation*" of morphological and physiological adaptation to the environment), and that each new system of lawfulness in evolution (cellular, gastrula, neural, noetic) becomes superimposed upon its still operative, but now increasingly less dominant, more primitive one. And because each of these biological systems has evolved its *own* dedicated sign-system, the second-level semiotic evolutionary process of "*inner adaptation*" – adaptation of one biological sign system to another – becomes necessary (Rothschild 1994: 19–34, 43–65, 114–141).

The analysis of the interdependent communicative (i.e. semiotic) relations between one naturally evolved sign system and another, and the embedded lawfulness by which each subsumes the other, are at the heart of Rothschild's biosemiotics. Yet this would seem to be examination into the ontogeny of end-directedness in organisms and the phenomena of ever new lawfulness (and thus "end" *generation*) in evolution, of the kind that might accounted for in a Peircean perspective (and perhaps, less satisfactorily, in a neo-Darwinian one) without any recourse at all to deistic teleology. Yet, it turns out that the theories of Peirce and Darwin apparently lacked the moral compulsion of those of Klages, which had so profoundly shaped Rothschild's thinking, however. So perhaps it is not surprising that Rothschild instead found the Jesuit philosopher Pierre Teilhard de Chardin's (1881–1955) "orthogenetic theories of organisms' ever complexifying progress towards God" more applicable to his own study of the ever complexifying semiosis and awareness in organisms.

"The things of the world express themselves in signs", wrote Klages, and just as the word on a page expresses the intention of its author, the things of the world, argues Rothschild, express the intention of God. "Communication, not causality, is the original ontological relation", writes Rothschild (1994: 293), thus the ubiquity of communication processes in Man do not terminate in "dead nature" at their external pole. Rather, claims Rothschild, "the original ontological reality is a unity . . .God, as the absolute unconditioned, in relation to the nature of which, all the processes in the world are conditioned" (1994: 316). Likewise, God's communication to us is the creation of a world in which the conditioned and the unconditioned are themselves in perpetual communication – with man being the transient creation of the former pole and God being the eternal creator of the latter pole (1994: 315–317). With Teilhard, Rothschild understood this apical form of being as a "forward spring" in evolution, pulling all less developed forms towards its own (Teilhard 1950: 209).

In 1994, at age ninety-five, Rothschild oversaw an English translation of a 1986 summation of his life's work, which itself draws heavily upon the ideas first presented in his 1935 *Symbolik des Hirnbaus,* and yet incorporates the strong commitment to monotheism to which he converted around 1955 (1994: 324). Entitled *Evolution as Inner Adaptation to God* (now remarketed in the United States as

Creation and Evolution: A Biosemiotic Approach), Rothschild's *magnum opus* situates his biosemiotic theory within a Manichaean cosmology of entropy and negentropy that are identified throughout with Eros and Thanatos, respectively. In their undifferentiated unity, these two constitute the Transcendental Subjectivity (TS) – the *principle*, or *form,* of being that Rothschild identifies with God. "TS is the creative, psycho-physical power of God," writes Rothschild, and "*communication*" is the materialized [form, or lawful principle of] TS whereby God communicates to the world, determines "meaning, transcends space and time, and directs the evolution process" (1994: 296–298, 333). Thus, the downwardly causal effects of the mind (or higher-level systems) upon the body in directing its activity reveal the same "transcendental" organizing principles of that of God:

> Although the [semiotic activity] in any higher system opposes that of the preceding one and consequently inhibits it, nevertheless, it also has to adapt to this preceding one, because it is dependant upon its information and [semiotic activity] if it is to realize its own. . . The model and image of one's own body as well as the model and the image of the world have to be supported by the [semiosis] of the preceding systems in order to be experienced as images pertaining to a real palpable world. Similarly, only in the same way do the behaviour patterns become real behaviour, i.e. actions by movement. Thus we arrive again at the basic task incumbent on the central nervous system as a communication system. This is the integration of reciprocally opposed modes of [semiosis] into an individuated experience and behaviour (1963: 481, 488).

Critically, Rothschild uses the word "intention" here in all of the places where I have inserted the word "semiosis" and its cognates, so as to illustrate the potential usefulness of Rothschild's ideas for contemporary biosemiotics, once the necessary "frame of reference" has been shifted. But, of course, for Rothschild, semiosis is the *product* of intention (defined in his 1994 book's glossary as "the psychological activity directed to a goal" (1994: 332) – and not vice-versa, as it would be for many biosemioticans. This must be the case, however, if Rothschild's deistic teleology as first principle is to hold: "The relation between body and mind has the same logical structure as the relation between clues and the image to which the clues are pointing," writes Rothschild (1994: 324).

Accordingly, while one side of the human organism points towards the *objectified subjectivity* (or "man-ness") that is manifested in it, the other side of the human organism points towards the principle of *transcendental subjectivity* or ("God-ness") that is also manifested in it. The entire system is deeply *bio-semiotic*, believes Rothschild, because his God is a form-creating and ultimately organizing "principle" – i.e., the over-arching principle of self-organizing, self-preserving and self-realizing process out of which the communicative and self-sustaining principles of biological organization (or "life") emerge and are themselves the *signs*. Signs, in short, are ultimately noetic stepping stones and mediators for organisms – first to the world, then to each other, then to themselves, and finally to God.

By this point in his theory, Rothschild has undoubtedly ventured into areas that most contemporary biosemioticians would hesitate to include within the framework of biosemiotics. Still, there remain many interesting and potentially suggestive insights to be found in Rothschild's biosemiotic theorizing, and – as we must do with the texts of all of the other authors in this volume – we must take what may be useful and worth developing from these necessarily primitive efforts, and leave the rest to mere historical interest. With regard to the complex set of sign-exchanging biological relations that Rothschild is drawing our attention to, however, his explorations into the organization and interaction of sign processes in living systems may yet yield useable insights, once one realizes that Rothschild's Teilhardian orthogenesis is not the only explanatory framework wherein his detailed observations about the nature of biological sign processes and the need for translational "sign systems for joining sign systems" may be fecund and coherent for biology.

Laws of Symbolic Mediation in the Dynamics of Self and Personality (1962)

The concept of the symbol shows the way to overcome René Descartes' partition of man into the self as *res cogitans* and the body as *res extensa*. In the symbol, psychological meaning and physical sign appear as a unit. We find the personality of a human being in the meaning of his words and actions, habits and gestures, and we experience this meaning as being identical with its bodily bearer, resembling the unity of symbol and meaning.

Klages (1950), in his studies of expression, and Spranger (1924, in his *Verstehende Psychologie* of personality, apply this concept of the symbol. It is unnecessary to probe the justification of these authors for their application of it because, for our point of view, a different use is central. Symbols are not only a *model* for the unity of body and mind of people as they present themselves to us outwardly in their behavior and appearance. Symbols also provide a *method* of understanding this unity from within as it is reflected in the constitution of personality. This paper is based on the hypothesis that all emergence of *psyche* (or *experience*) in man and animal is associated with *sign systems* in the function of a symbolic medium, [analogous to the way that] human thought is linked with language.

Let us start from language. Apart from its task in the communication with other people, language, in inner virtual speech, acts as the medium for comprehending and reflecting experience in thought. Only with the help of a symbolic sign system in the form of language is man able to rise above the immediacy of his emotions and perceptions toward the supremacy of reason and the experience of an objective world of facts.

The central nervous system is a communication system that transforms the excitations of the sense organs and the signals received through hormones and other chemical substances into the code of its own excitations. Through these coded excitations it steers the actions and reactions of the organism. The central nervous system also enables the organism to decode the excitations generated in these vital communication processes. Through the latter process the organism discloses to itself in living experience, that is, in emotions and perceptions, the significance of its own situation and the character of its environment. Just as the decoding of words yields meaning, the decoding of excitations within the central nervous system yields perceptions, emotions, and imagery: that is, the phenomena of mental life.

Language ranks highest in the hierarchy of the internal sign systems, which are superimposed in layers upon each other in the course of evolution. The lowest level of communication processes corresponds to those of the somatic periphery, of the sense organs, peripheral nerves, and muscles, and is directly related to palpable reality. On the level of the vertebrates the neural canal is taken out of the somatic periphery and forms, as the central nervous system, a superimposed system within which the information of the lower communication system is reflected and brought to a new synopsis and interpretation. In language man created the last and highest in this evolution of communication systems. This system reflects the information furnished by the central nervous system in a new synthesis and thus makes possible an interpretation of life and the world through the logic of intellect and reason. The meaning that man finds today within himself and in the universe is the result of an interpretative process that evolved in the course of hundreds of millions of years and produced appropriately organized internal sign systems. In this organization the individual possesses a priori precepts on how to understand his situation in relation to his environment (Rothschild 1958, 1959).

The evolution of subjectivity to the level of contemporary man is usually regarded as an epiphenomenon of the evolution of life through gene mutations and the pressures of selection according to neo-Darwinistic theory. However, can we be satisfied with a genetic explanation of the human spirit that knows of no factors other than the chance of mutation and the cruelty of selection? With all respect for its sound scientific foundations one still feels that something is missing in this theory. Supplementation is needed in order to make ourselves understandable to ourselves as we are, with all the dimensions of our human inwardness. This supplement is provided by the analysis of the evolution of internal sign systems along the lines of the symbol theory of psychophysical relation. Protozoa, invertebrates, vertebrates, and finally man appear as four developmental stages of subjectivity. In each stage, a new sign system overlays the already established ones and makes the unfolding of a new and higher level of experience possible. Using the information stored and forever reactualized within the phylogenetically older systems, man finally achieved his own depth and range of interpretation, and his freedom of response in the dialogue between self and the world. This, his own subjectivity, appears as the most astonishing and the most revealing among the marvels of the universe.

It is impossible to examine fully and to prove scientifically in one paper the soundness of our hypothesis that the human personality is constituted by a hierarchy of inner communication systems, among which language ranks highest. Yet the lawfulness prevailing in this hierarchy is simple and clear. Understanding of the problematics of man including his psychopathology flows with inner necessity from this structure. This should make the value of our hypothesis evident even in a sketchy exposition.

The scientific exploration of sign systems such as language we designate, with Morris (1938), as *semiotic*. In this discipline usually three aspects are distinguished. If we restrict ourselves to examine the physical form of the signs and the rules of their arrangement, we comprehend the *syntax*. If, furthermore, we consider the relation of the signs to their meaning, we engage in *semantics*, and as we include the exploration of the concrete communication processes, we arrive at *pragmatics*. Semiotic demands the consideration of all aspects in order to do justice to the subject. Only in language, however, the demand to examine the three aspects of a communication process can be fulfilled directly because language, not only assists in constituting the ego, but it also expresses this constitution. In phylogenetically more archaic communication systems such as the central nervous system, part of the functions are unconscious and non-perceptual. Thus they are accessible only through indirect methods. For the latter the semiotic of language in all its aspects, writing included, serves as a model from which these indirect methods and hypotheses can be derived.

Thus the meaning of the central nervous system's code may be explored, of course, by a phenomenological analysis of our own experience. For the study of the utilization of this information, which is the pragmatics of communication with the world, behavior may serve as material. The syntax, however, of this communication system, in its relation to its semantics and to its pragmatics can be disclosed only indirectly. Our knowledge of the anatomy and physiology of the central nervous system, the many specific observations concerning the role of the various centers of the central nervous system in their influence on experience and behavior, all this knowledge is arranged according to the categories and interests of the neurophysiologist. Thus it does not conform to the task of the semiotician who has to find within the code of the central nervous system the specific order that enables the organism to decode it as the order of experience. The situation of the semiotician resembles that of the zoologist von Frisch. He searched in the observed behavior of bees for the signals used by these animals to convey to their comrades where food could be found. Through his research, the symbolism of the bee's dancing was discovered (von Frisch 1954).

It is not by chance that for Husserl (1928), the phenomenologist, language appeared particularly suited to demonstrate various forms of *intentionality.* From the point of view of the symbol theory of psychophysical relation, all phenomenological research can be used in semantics. In all stages of its evolution, subjectivity intends only by means of symbolic structures, just as, by means of the words of a sentence, it intends the thought expressed in that sentence. Through phenomenological reduction, that is, by primarily refraining from any judgment as to the reality of phenomena, Husserl isolated the semantic aspects. In other words, he separated the imparting or interpretation of meaning from the pragmatic and the syntactic aspect. Thus he evaded the encounter with the body-mind problem, specifically the fact that subjectivity depends on actual communication processes that determine its mode of linkage to reality. On this basis his phenomenology became a well substantiated science of pure subjectivity.

A very different attempt of getting rid of the body-mind problem was made by cybernetics. This discipline proceeded by excluding the semantic aspect of communication and took upon itself the task of exploring the inner communication systems of organisms. The particular attraction of cybernetics resides in the factually unfounded belief that this science of the communication of signals in machines and in living systems will be able to replace a theory of the meaning connected with those signals. This does not seem permissible. The category of meaning may be introduced only if at the same time a subjectivity is accounted for that either expresses itself through the spatial and temporal order of physical events or comprehends them, as signs, the meaning of these signs, the semantics find no explanation in the mathematical physical framework of communication and information theory. The latter deals with the technique of transmission, utilization, and storing of signals. The meaning of the signals must be taken for granted (Wiener 1948).

Phenomenology can provide the material for *semantics*, if it compensates for the phenomenological reduction by including the life processes by which transcendental subjectivity implements its sense-giving achievements. Biology and neurology orientated towards communication theory can supply the material for a *syntax* if they compensate for mechanistic reduction and acknowledge that the communication processes within organisms convey meaning.

The understanding, moreover, of human production and behavior which Dilthey (1957) originated as the method of humanities and, particularly, of history becomes the method of the *pragmatics* of communication between all animated beings and their environment. This approach presupposes acceptance of our position that the history of subjectivity does not start with man, but that the human spirit was preceded by many preliminary stages in the evolution of animals.

The symbol theory of psychophysical relation bridges the gulf between these disparate avenues of research and unites their methods under the name of *biosemiotic*. This approach that regards as its subject for exploration animals as unity of body and psyche, and human beings as unity of body, mind, and spirit. We speak of biophysics and biochemistry whenever methods used in the chemistry and physics of lifeless matter are applied to material structures and processes created by life. In analogy we use the term biosemiotic. It means a theory and its methods which follows the model of the semiotic of language. It investigates the communication processes of life that convey meaning in analogy to language.

My theorizing thus far would be only wishful thinking, had it not been possible to formulate *biosemiotic* laws that led, amongst other results, to a novel understanding of the connection between structure and function in the central nervous system. Many of the biosemiotic interpretations concerning details of the central nervous system as an internal communication system published by me in 1935 were confirmed since then by the subsequent developments of neurophysiology. The same principles have been applied successfully to analyses of the structures and function of intraorganismic information systems such as the vegetative nervous system and to the hormonal system. The latter two systems adapt the sign systems, stratified in hierarchic order through evolution, to each other, and make their integrated function possible (Rothschild 1950). On the basis of these results, I feel justified in laying before you the basic laws of biosemiotic even though it would exceed the frame of this paper to provide the evidence and proof for their detailed formulations.

By laws I understand here the rules of syntax of each single communication system and the rules valid for the simultaneous utilization of different communication systems as they coexist in all animals and in man. If these rules are not followed, the consequences resemble those of offenses against the grammar of the language we use. The communications may become meaningless. Thus the organism may become endangered by consciously or unconsciously failing to understand correctly the situation in which it finds itself. If, as a consequence, it does not respond to it correctly in the function of vital communication systems, it may mean death.

Organisms, moreover, do not merely live, they also experience life. For Instance they can transcend the here and now of their body, perceive objects far removed in space, actualize events long past. Thus the life giving transcendency becomes transcendental subjectivity, the origin of an intentionality. It enables the organism to interpret the meaning of-signs within inner communication systems as experiences, and eventually to express their meaning in forms created by the organism itself, culture and language, for instance.

There is a structural similarity between the syntax and the meaning of a symbolic communication system. It is due to the intentionality that connects them. As the meaning of a communication is comprehended, its syntax is understood better and, as the syntax is understood, the meaning is clarified. These circumstances are known best from language. The ordering of reality achieved by thought corresponds to the syntax of the language used in thinking. In analogy to this, in every communication system that has emerged in the course of evolution, the syntax of the communication system, and the intentionality of communications are connected in a lawful fashion. Based on this connection it was possible to carry out the earlier mentioned semiotic analysis of the central nervous system and to formulate the biosemiotic laws that I propose to expound now.

Subjectivity occurs in three modes of genesis. It arises in the evolution of species up to man in phylogenesis; it reveals itself in the development from the ovum to the completed organism in ontogenesis; and in every moment of waking life it takes shape as a form of autogenesis, of existential acts. It bears witness for the inner unity of the life phenomenon that the same biosemiotic laws are valid in all three forms of genesis. In each genesis the same single phases correspond to each other. If I demonstrate the biosemiotic laws through the phases of life's evolution, the results can be transferred without difficulty into the other geneses.

Life may be compared to a stream in which the never-resting processes of matter take their course and in which, on the other hand, the intentions of the transcending principle sustain an uninterrupted process of becoming, either in the growth of organism's forms or in its mode of behavior or experience. Despite this unceasing movement of events streaming through them, the organisms remain stable as units and also propagate as stable units. Today the distinction between living and lifeless matter is seen in this constancy of actually unstable structures, structures able to maintain themselves against the entropy prevailing in matter, that is, against the tendency toward diminishing order due to thermal motion.

In its most simple and original form this capacity of life appears in the genes, the macromolecules within the chromosomes. Biologists hold that such units existed and multiplied as autonomous structures in the primal atmosphere of the earth by means of free hydrogen without oxygen. In this primal process, from the point of view of biosemiotic, an intention of *self-realization* that achieves fulfillment by self-reduplication finds expression. Such communication of their own essence to other matter presupposes the capacity for these elemental organisms to preserve their unity against all agents of change. Only if this requirement of inner *self-assertion* is satisfied, that is, the established structure are secured as bearer of the own essence or the self, is self realization possible. A disturbance of the established arrangement in the macromolecules of the genes may lead to mutations that are changes of essential character. These mutations may also destroy the structure of the organism as a coherence of signs in a way that the synthesis of its meaning as a unity, an essence, is no longer possible. Here meaninglessness equals lifelessness, death.

This threat to given life elicits from the original passive state of the organism a component of activity, of inner self-assertion, transforming it *from an object into a subject of intentionality.* The first biosemiotic law expresses the intention to safeguard the structure that conveys the own essence, the self as a coherent *unity.* It is the basic rule of biosemiotic syntax. The way it is realized can be thoroughly studied only if living and experiencing take place in differentiated organisms in which different communication systems overlay each other and in which special organs like cerebellum and the adrenal cortex serve exclusively this function of asserting somatopsychic unity. The physiological concept of homeostasis refers to such efforts of the organism. The ego's mechanisms of defense, so searchingly studied in psychoanalytic theory and practice, are psychological attempts to fulfill this requirement of preserving the organism as a somatopsychic unity in situations of conflict. Their role in the dynamics of personality, particularly their relation to functions of neurologic and hormonal control, becomes entirely understandable only if they are recognized as inadequate solutions of the general problem of the inner unity of man.

Having outlined the manifestations of the first biosemiotic law we must reconsider the primal structures of life in order to understand the necessity of the second law. Self-realization, like that of a gene or a virus living independently, became impossible during the known history of the earth. When immediately utilizable sources of energy and building material were no longer available, photosynthesis and respiration took over in order to provide energy for complicated anabolic processes. This increased the danger of destruction for the structure carrying the essential sense of the organism. Self-realization now necessitated fusion with the alien element and the intention to understand it in order to deal with it, to handle and use it, or to defend oneself against it. Self-realization now called for communication with the alien element in order to recognize its character. The monologue of the steadily repeated own word in self-reduplication had to be joined by a dialogue in which alien voices too could be heard.

Self-realization, however, and recognition of the alien essence are conflicting intentions. This being the case they could produce at best only a static situation: Life therefore could develop the abundance of its forms only after having succeeded in overcoming the contrast. This new evolutionary step is represented by the diploidy of chromosomes and by the formation of the cell. In twos, or groups of twos, couples of equal or very similar primal units with their centers of nucleic acid, combined in symbiosis. One of the conjugates could attend to self-preservation and self-realization, the other one to the fusion with the alien essence. At the same time each of the partners allowed the other one to profit from the diploid association and the division of labor.

From this development, two structural characteristics of the cell resulted:

(1) The cytoplasm, as the instrument of reaction to and absorption of alien substances, was organized around the nucleus as the carrier of the individual character. Thus a structure was joined to the organism that was dominated by the

genes while, also, substances and energies from the environment could become effective in it.

(2) With the diploidy of chromosomes, an *inner duality* within the unity of the organism, an *inner polarization* was initiated. This development beginning with the protozoal cytoplasm led then to the formation of sense organs of the cerebral hemispheres, and finally to the "thou," "he," "she," and "it" of language. As those symbolic representations of the other and the alien came about, they made it possible, through the absorbed information, to interpret and to experience the qualities and images of environment, of the non-ego. All this may be traced back to the capacity for inner polarization that was acquired with diploidy.

The preceding observations may be formulated as the second biosemiotic law: Inner polarization is necessary in order to permit the subjectivity of organisms to communicate with the objects of the world simultaneously with realization of the own self. This law dominates the arrangement of all communication systems from the cell upward. The manifestation of this inner polarity include the differentiation of motor and sensory systems in the sensorimotor foundations of experience and behavior, the bisexual disposition of organisms, the asymmetry between right and left, the differentiation of the vegetative nervous system into a parasympathetic and sympathetic component, and the arrangement of the central nervous system in homolateral and heterolateral centers (Rothschild 1950).

To the further evolution of subjectivity from the unicellular to the multicellular animal and finally to man, a third law applies. By stages, new communication systems appear, laid out as if the information of each respectively earlier system was processed by a reflecting consciousness. As a symbolic expression of this reflecting intentionality each new system shows in its syntactic structure a mirrorlike inversion in relation to the preceding system (Rothschild 1961). Based on this arrangement, essential traits from the information of the reflected system can be abstracted, gathered in new syntheses and organized in new symbolic structures. The particulars of the relation between such a system of a higher order and the preceding system can be studied in vertebrates in the relationship between the central nervous system on one side, and the peripheral systems of the body on the other side. The latter, as we saw earlier, corresponds to the communication system of the invertebrates.

Man differs from other vertebrates in that a further communication system became superimposed over the central nervous system. This system, however, is not provided by nature in form of physical structure. Every human being must learn it in infancy in form of language from his fellow men and must develop it personally. It is characteristic and essential, that here there is no information organized in a new code, to be decoded by the new mode of intentionality, as was the case with the central nervous system in relation to the peripheral system. While the information is, within the old system, in the process of coding and decoding, it is comprehended by the new mode of intentionality, the logical act of consciousness. The latter interprets and organizes the information in a novel manner. In it thought and will emerge together with developing speech and transform perception, emotion, and behavior in specific ways. Thus the function of the central nervous system becomes newly organized. The original animal style of channeling the excitations becomes inhibited with the emergence of thought and will and is cast in new molds of excitation configurations. What fundamentally distinguishes man from the animal is not his brain as an organ given by nature. In spite of its particular development, it belongs to the same level of communication systems as that of the anthropoid apes. It is rather the specific way in which man uses his brain. It originates from one, usually the left, hemisphere a new dominating communication system.

The primary independence from a code given within the individual body makes the intersubjectivity possible that characterizes the new communication system. Its form of functioning is identical for all persons and thereby endows the world of human spirit with its objective character. It also necessitates the experience of the essence of the other person, the Thou, in order to constitute itself. The analysis of intersubjectivity is essential for the self-understanding of man; I can here only mention the subject in passing. It may be found treated more exhaustively in Husserl (1950), in Buber (1937, 1948) and most recently, in Teilhard de Chardin's book: *The Phenomenon of Man* (1959).

As each new inner communication system emerges in evolution, it transcends its predecessor's horizon of meaning and requires for its actualization a new mode of intentionality. In this new form of intentionality, subjectivity is active and dominates over that of the preceding system because it is in opposition to it and thereby prevents an independent activity of the more archaic systems. The necessity of this *dominance* constitutes the third biosemiotic law: without such dominance, the new system cannot develop its function. This law can be validated not only semantically, by way of phenomenological investigation, but also pragmatically in behavior and, above all syntactically through anatomical and physiological data. In the following I shall mention only some of its consequences for the dynamics of the self.

[Human symbolic] acts in their independence from a biologically given code transcend the whole world of phenomena in space and time and create a horizon of things, ideas, and values that exist in their conceptual firmness beyond the heraclitic stream of material and animal events. However, these concepts in their abstractness are empty unless filled with meaning by the communication systems which are subordinated to them. The controlling systems depend on the information and the concretizing form of realization obtained from the dominated ones. The recent research on sensory deprivation provides illustrations of the consequences of such impoverishment in meaning caused by deficient replenishment of information from the dominated systems. Due to this dependency the clearest plan and the strongest wish will remain mere thought and fantasy, if the movement impulses of the body and muscular activity are not at their disposal for the purpose of putting them into practice.

All dynamic problems of personality are rooted in this antinomy of dominance and dependence in the human self. It is the most essential character of the acts of the self that in their primary independence from any nature-given code, these acts are free. The subjectivity of man can carry them out only if it is not actively engaged in the intentionality of a more archaic system. Man's potential freedom from the latter raises him above all other creatures of nature; it holds, as in a metaphysical focus, the mystery of the relation between man and the transcending principle. It offers him greatness as well as tragedy.

One of the problems of man in this respect is the fact that this freedom must adapt itself with each step of its realization to the communications of the preceding, now only passively functioning systems. This means essentially that it must conform with the first and second biosemiotic law prevailing in these systems:

(1) No act of true self-realization is possible unless the free spirit and will of man first fulfills the requirement of inner unity with the materiality and emotionality of his organism.
(2) Man must recognize the bondage of ego to nonego and of nonego to ego, the inner polarity, as the precondition of all communication.

This necessity to conform to the first and second biosemiotic laws is experienced as the demand of truth in our thinking and the demand for existential authenticity in the decisions of our will. To maintain his inner freedom always within the frame of truth and of existential authenticity is for the self of man such a tremendous and difficult task that he can fulfill it only imperfectly.

Man feels anxiety and guilt if he fails in this task, anxiety if not fulfilling the intentionality of the dominated systems, guilt if not fulfilling that of the dominant one. Nevertheless the ego has its defenses through which it evades feelings of anxiety and guilt: Freud's psychoanalysis made us thoroughly familiar with them. Both forms of evasion serve the purpose of lessening the actualization of conflict between the dominating and dominated systems; they do not demand from man the exertion of true self-realization. Nature itself devised such methods. In rhythmic phases it relinquishes unity, polarity, and dominance in order to find the peace of sleep through a state of inner passivity. The faculty for this change is used also in hindering communications from completing their course toward experience and behavior whenever fulfillment of the biosemiotic laws is too difficult. The best example of such inhibition of communication is repression.

In a positive way, the shaping of experience and behavior is facilitated by play and fantasy. For the child, the intentionality of play is fundamentally different from that of the earnestness of adult situations. The freedom and sovereignty of the self in play and fantasy does not call for obedience to the rules of the dominated systems. Pathological dynamics begin if man evades the burden of the demands imposed by the biosemiotic laws. Then he avails himself of the relief afforded by the intentionality of play and by the change from waking to sleep at the very moment when his life situation would demand wakefulness and seriousness to the highest degree. Thus the natural failing of man in the face of his possibly superhuman task is aggravated not only by self-deception regarding the true nature of his problem, but also by the strain on his inner adaptability. All this disposes him increasingly toward decompensation and reduces his capacity for individuation and self-realization. Each personality reveals in its characteristics the measure of success and failure that the self achieved in confrontation with his long history of evolution.

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Chapter 15
Concepts of Molecular Biosemiotics

Marcel Florkin (1900–1979)

Introduction and Commentary: Marcel Florkin

> *The recognition of* systems of relata *at the integrative molecular level indicates that* biomolecular order *is governed by* systems of signification *which we may consider in a structuralist (intensive) perspective, besides the thermodynamic viewpoint and the quantifying (extensive) viewpoint of information theory.*
>
> M. Florkin (1979: 13)

Biochemist Marcel Florkin was born in Liège, Belgium on August 15, 1900. He published his first scientific paper while still a medical student at the University of Liège in 1926. Having graduated with his doctorate in medicine in 1928, Florkin became the first chair of the newly formed Department of Biochemistry on the Faculty of Medicine at the University of Liège in 1934, where he worked for over forty years, holding the position of *professor emeritus* from the time of his retirement until his death on May 3, 1979. Over the course of an illustrious fifty year career, Florkin published over sixty scientific volumes and came to be recognized as one of the founders of modern biochemistry. He was awarded both the French *Légion d'honneur* and the prestigious Belgian Francqui Prize in Biological and Medical Science for his pioneering work on comparative biochemisty, and in 1951 founded the Belgian Society of Biochemists, a society that counts over two thousand members today.

His reputation already securely established within the history of biochemistry, Marcel Florkin also occupies a signal place in the history of biosemiotics as well, coining the very independantly of Sebeok, Rothschild and Stepanov, in order to describe the sign-bearing syntax of biomolecular configuration. Indeed, as early as 1934, decades before Hershey and Chase's experiments establishing DNA as the molecular vehicle of inheritance, Florkin had become convinced that "biochemical correlations of morphological features do exist and that the study of biochemical characteristics, had they not relied on sophisticated techniques, would have been used by naturalists, instead of morphological observations, thus leading them with equal success to the idea of evolution in biological systems" (Schoffeniels 1979: 354).

Perhaps not surprisingly, Florkin's biographer and fellow biochemist, Ernest Schoffeniels, recalls that even as a medical student, Florkin was closely associated

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with the world of arts and letters, and was keenly interested in the history and evolution of ideas – interests that he maintained and cultivated his entire life (1979: 357). "The epistemological concern appears early in the career of Marcel Florkin and is best illustrated in [his 1944 treatise] *L'Evolution Biochimique*," writes Schoffeniels, calling the monograph "a cornerstone both in Florkin's scientific career, and in the development of a then rather young field of investigation. It is certainly not presumptuous to state that the book was geminative in establishing the importance of the biochemical approach in evolutionary thinking, and established Marcel Florkin as a leading figure in the organization of scientific knowledge. There he showed that biological concepts such as those of [speciation] and adaptation find their counterpart at the molecular level" (1979: 356).

The then-radical thesis of *L'Evolution Biochimique* was that the biochemical makeup of organisms could *drive* evolutionary change, and was not just the passive and derivative product of population-level selection pressure. This thesis met a good deal of resitance at the time, as Florkin indicates in the following selection, but became increasingly vindicated with the development of the field of *comparative biochemistry* that he helped pioneer. Thus, although the ideas of *L'Evolution Biochimique* were several decades ahead of their time, from this point on in his career, Marcel Florkin "would never disengage from his interest in solving, at the molecular scale of dimension, the most irritating problems that biology presents to the ingenuity of man," writes Schoffeniels (1979: 354).

Among the large-scale problems that Florkin set himsef to solve in the developing field of what we today call Molecular Biology were: (1) the organization of a sound conceptual framework for the then newly born field of *evolutionary biochemsitry*; (2) the development of a pioneering and thoroughgoing *biochemical systematics* – which evolved into a 30 year long that resulted in the publication of the 52 volumes comprising the three Florkin-edited and oftimes single-authored book series: *Comparative Biochemistry, Chemical Zoology,* and *Comprehensive Biochemistry*; (3) the continued effort to argue for the evolutionary biochemical theses presented in *L'Evolution Biochimique*; and (4) of particular interest to the history of biosemiotics: the attempt to understand biochemical interaction in what Florkin christened its "biosemiotic" aspects.

Accordingly, the following selection presents Florkin's wholly orginal "biosemiotic theory" of biochemical interaction. Appearing as the first half of Volume 29 in his *Comprehensive Biochemistry* series in 1974, Florkin's 'Concepts of molecular biosemiotics and molecular evolution' can be seen in many ways as the capstone of his then 50 year long career in biochemistry. The result of a lifetime's immersion in a field wherein "our present generally accepted knowledge on the biosynthetic steps and chains that lead to the building blocks of cells have come about as an aggregation of isolated facts, rather than a synoptic whole" (Jaenicke 1981: 615), and completed just a few months before an auto accident left him crippled and in ill health for the remaining five years of his life, Florkin's *Concepts of molecular biosemiotics and molecular evolution,* we may assume, was his attempt at synthesizing all that a lifetime studying the chemistry of living beings had revealed to him.

It is, however, by no means an easy read. Fellow biochemist Lothar Jaenicke, having elsewhere acknowledged Florkin as one of the "founders of comparative biochemistry" (1981: 615), reviewed the following selection at the time of its publication, and found the text to be almost impenetrable. "The author's phenomenal knowledge of the facts and historical perspectives and his intellectual insight into his material can only be marvelled at," writes Jaenicke, but, he then notes, the denseness of the terminology and the complexity of the systemic understanding proposed "conveys little even to a fairly sophisticated reader" (1975: 190–191). The synopsis that Jaenicke ultimately prepared for his review, however, reveals a good deal of understanding of Florkin's project, and the ideas that Florkin was attempting to argue for:

> The intention [of the volume] is to bring systematic order into the presentation of phylogenetic development, in which the evolution of life is assumed to be from simple biomolecules by asymmetric, autocatalytic, and aggregating forces. The molecular processes occurring during the phylogenesis of organisms (Florkin's "diachronic molecular epigenesis") are mostly considered on the basis of cellular chain molecules (Florkin's "metabolic catenary biosyntagms") which become better suited to their structure, function, or regulation, and more versatile, by lengthening or shortening, branching and ramification. The causes are point mutations, feedback, selection, gene duplication, etc. Useable biomolecules thus function, after self-aggregation, into structures of higher order on the physiological and ecological plane. (1975: 191)

Addressing himself, without his knowing it, to many of the same problems then being analysed by physicist and future biosemiotician Howard Pattee, Florkin begins his treatise with a discussion of the benefits and limitations of applying Information Theory to the explantions of biology. During the course of the biochemical evolution of life on Earth, writes Florkin, "the reciprocal relations between the various biosystems [first jointly developed, and then further developed *within*, an evolutionary ecosystem that] became more and more elaborate, leading to the exchange of molecules that were not only of nutritional importance, but acquired regulatory and control properties, acting as transferrers of signs and signals" (1974: 12). Accordingly, continues Florkin (by quoting Johnson), "In biology, the 'extensive' property (information, or negative entropy) can have *significance* for the feasibility of living process only if it is modulated by an 'intensive' property which *indicates* the 'biological relevance' or 'purposefulness' of that information" (1974: 10). The goal of a "biosemiotic" molecular biochemistry is thus to discover the nature of these "intensive" (i.e., system internal) causal properties.

Florkin situates his understanding about the evolution of such "intensive causal properties" within the "cybernetic molecular network" that constitutes the entirety of the Earth's biomass (1974: 11). The molecules that are precursors to biological chemical messengers, and that have causal efficacy upon other molecules in such an ecosystem, Florkin refers to as *ecomones* (the *–mones* suffix presumably denoting their semio-chemical ontology, after the fashion of the pheromones, allomones and kairomones that are studied by entomologists). In relationship with one another, a pair of such molecules may be deemed *co-actones* acting, essentially, as the polar molecular complements of stimulus-response dyads (Florkin's somewhat grammatically confusing term for such dyadic pairing throughout this text is: "couples of *relata*") (1974: 53–64).

Anticipating some of contemporary biosemiotics' later terminology, Florkin distinguishes between *exocoactones* – molecules "which are liberated in the [environment] by a co-actor and [then exert causal influence on] the co-actee" – and *endocoacatones*: "molecules which are not liberated by a coactor in the environment" but are instead liberated within the organism as biomolecules, which issue from an active site to modify a passive site (1974: 12, 123). The co-evolution of exo-coactonic and endo-coactonic action within an environment results in an exponentially complexifying organizational and semiotic dynamic – biological "evolution" as we commonly understand the term – and Florkin goes to great pains in all his writings on "molecular evolution" to demonstrate that one result of such phylogenetic evolution is a correspondingly complexified organizational and semiotic dynamic at the level of organisms' biochemistry.

Deriving his terminology and conceptual framework for semiotic organization from what he sees as the "existential, not psychological" system of *structural semiology* developed by pioneering linguist Ferdinand de Saussure (1857–1913), Florkin's description of the hierarchically generative semiotics of cellular biochemistry begins with the fundamental sign-bearing relationship of the *bioseme*:

> The signification system [in molecular biosemiotics] implies a *sign* (defined as *significant* + *signified*) and a *receptor*, eventually reached through a sequence of intermediary steps... at the level of a *bioseme*, the *significant*, an aspect of molecular configuration, and the *signified*, an aspect of biological activity, compose the *sign*... [thus] the sign, of which a bioseme is the minimal significant, is a double-faced (significant + signified) material entity (molecular configuration + biological activity). (1974: 15)

Interacting upon one another in the massively complex biochemical system that is the organism, such *biosemes* become structurally united into *biosyntagms* – "a unit of signification higher than a bioseme and composed of significant units in a relation of reciprocal solidarity – i.e., an associative configuration of biosemes" (1974: 16, 123). Nucleotide bases are thus the *biosemes* of genetic transcription that, when oriented to as codons, become the *biosyntagms* of genetic translation, in that they bear a "higher-order" meaning or relevance for the activity of the yet even higher-order biosyntagm of tRNA (1974: 27–34).

In both genetic expression and in intercellular organization and interaction, therefore, as biomolecular order complexifies, new and ever higher-order levels of *signification* becomes possible: "Some of these dense associations are architectured in the form of the higher level of integration of cell organelles and of cells themselves by recourse to a number of couples of *relata* such as enzyme-substrate, hormone-receptor, multichain regulatory protein, etc.", writes Florkin (1974: 11). On higher levels still, maintains Florkin, "the molecular biosemiotics of the activities of the brain" (1974: 14) enable both human and animal cognition – and at the ecological level, "a number of end-products of the biosynthetic catenary biosyntagms are neither significant at the molecular integrative level, nor at the structural or physiological levels of the organism, but are significant as *ecomones*" in the shared surround of environment (1974: 106) – bringing the evolutionary feedback loop of biosemiotic signified and significance full circle. “In such a perspective,” writes Florkin, “the evolution of organisms and the evolution of the biomolecular order (biochemical evolution) are recognized as interrelated facets of the same natural reality” (1974: 116).

Developing these ideas from within the field of laboratory biochemistry in the early 1960s and 1970s, Marcel Florkin almost certainly was not aware of Thomas A. Sebeok’s contemporaneous project of *zoosemiotics* – which was still almost a decade away from its own exploration into *endosemiotics*, and its subsequent rechristening as *biosemiotics*. Nor would he have been aware of psychologist Friedrich Solomon Rothschild’s homonymous coining of the term “biosemiotics” to describe the psychical-physical nexus of organisms, almost a dozen years earlier. Indeed, it would have been a very interesting meeting had these three very differently oriented thinkers ever met to exchange ideas.

Much unlike Sebeok and Rothschild, however, Florkin insisted that the biosemiotic “signs” that he was examining were “material and functional” – not denotative nor connative – phenomena through and through. “The *bioseme*,” Florikin states in no uncertain terms, “carries no *Bedeutung* or *Sinn.* Its *significant* consists of an aspect of molecular configuration and its *signified* of an aspect of biological activity” (1974: 10). For this reason, argues biosemiotician Marcello Barbieri, Florkin’s “dualistic model, based on Saussure” has not been taken up by contemporary biosemiotics, as it presumes a genotype-phenotype duality that “is entirely determined by chemical necessity” and that therefore does not account for the critically mediating role between genes and proteins that constitutes the “natural convention” of the genetic code (Barbieri 2001: 201).

Still, Florkin’s models – besides being of great historical interest for the prescience by which they foreshadow such later thinking as Valentin Tuchin’s *metasystems transition theory* and Mario Gimona’s *protein linguistics* research project – remain of interest to biosemioticians, as well, for their insistence upon the critical role of emergent, higher-order semiotic properties in enabling the generativity of organismic development and evolution. Thus, collection of essential readings in biosemiotics would be complete without the inclusion of the following historical, and still very productively suggestive and illuminating, text.

Concepts of Molecular Biosemiotics (1974)

The Concept of Molecular Evolution

The expression “molecular evolution” covers a number of different topics. One of them is prebiological evolution or “chemical evolution”. This domain is based on the study of models and on the experimental development of different hypotheses, a subject which will be dealt with in Chapter 5 (Vol. 29B).

Another aspect of molecular evolution, to which the present chapter is devoted, is the study of the changes which can be identified at the molecular integrative level at different points of the phylogenetic sequence of organisms (biochemical evolution). The concept of descent with change at the molecular level was formulated in 1944 by the present author:

> The study of biochemical characteristics depends upon techniques which are frequently complicated, and such a study is more difficult to accomplish than direct observation of external morphological characters. Nevertheless, had naturalists started from these, rather than from morphological observations they would have been bound to conceive the idea of evolution of animals (Florkin 1949).

This “confident statement” as it is called by Dessauer’, has been ratified by molecular evidence. As pointed out by Simpson’, the concept of evolution at the molecular level was therefore conceived before the advent of molecular biology: “Before the importance of DNA was known Florkin had already discussed the systematics and evolution of various families of molecules.” (Simpson 1964). To quote H. F. Blum:

> It was brought into particulary clear focus by Florkin in his little book: LYvolution biochimique (1944) that we may trace an evolutionary pattern of biochemical compounds which corresponds in its implication to our tracing of the evolution of morphological aspects of the species of living organisms.

Once for all we wish to state that the expression “biochemical evolution” is an elliptic one meaning the pattern of changes of biomolecular epigenesis (diachronic molecular epigenesis) along the phylogeny of organisms, as derived by naturalists.

Oppositions to the Concept of Biochemical Evolution

The concept of “biochemical evolution” i.e. of the existence of a pattern of evolution at the molecular level has been the object of much adverse criticism. “Mayr”, for instance, has stated that

> Much of the difference among organisms is a matter of difference of systems rather than in unit components.

The same view, current at the time of the publication of Florkin’s book, has been formulated again by another veteran biologist, P. Weiss, who brings up against molecular evolution the concept of the biochemical unity of organisms as claimed by Baldwin and by Florkin.

This is a matter of semantics, as what these authors showed is the biochemical unity of organisms, as expressed in the common “central metabolic pathway” common to all cells, from Protista to insects and vertebrates.

It is abundantly clear that the changes undergone by the metabolic pathways grafted on to the central system, along the evolution of organisms consist, not only of changes of systems by the recombination of existing units, but also of an increasing number of unit components, the biocatalysts of the terminal and lateral extensions in the metabolic pathways as well as of end-products. Another objection is expressed by Mayr:

> “No case is known to me,” he writes, “in which a change of body chemistry initiated a new evolutionary trend. Invariably it was a change of habits or habitat which created a selection pressure in favor of chemical adjustments” (1964: 68).

It will be enough to consider the importance of such biochemical innovations as the system of calcification of the cuticle of a turbellarian ancestor of the molluscs, the sclerotization of the cuticle of the annelid ancestors of Arthropods, the patterns of ossification in fish, the biochemical patterns of the amniote egg as it appeared in reptiles, or the isosmotic intracellular regulation which allowed marine invertebrates to invade fresh water and land, to escape, while recognizing the role of natural selection in its proper perspective, falling in a naive panselectionism.

It might be claimed that the epistemology of evolution is, as we have repeatedly said, situated at the level of organisms, while the changes described by comparative biochemists are situated at the molecular level. This would not be a fair deal, as comparative biochemistry studies molecular changes with recourse to concepts concerned with molecular configurations, reactions and activities, phylogeny being called upon to provide the scheme of descendance, a frame and a situation of the problem.

Synchronic Molecular Biosemiotics

The Fitness of the Environment

The surface of the earth receives energy almost entirely as solar radiations and this intake of energy is compensated by terrestrial radiation. The biosphere is in a steady state remote from the equilibrium state. The entropy of the biosphere defined as the whole biomass and its environment increases with time.

In an influential book published in 1948, Schrödinger (1948), impressed by the new knowledge of the ordered hereditary transmission of relations between nucleic acids and proteins, appearing as a contradiction with the statistical laws of physics and with the tendency of things to go over into disorder, wrote:

> Life seems to be ordered and lawful behaviour of matter, not based exclusively on its tendency to go over from order to disorder, but based partly on existing order that is kept up.

Schrödinger defines the process by which an organism maintains itself at a fairly high level of orderliness (fairly low level of entropy) as "sucking orderliness from its environment" by which he means that while in the whole biosphere entropy increases with time, entropy is kept at a fairly low level at certain points in the system by displacement from randomness to order. Schrödinger states that the organism not only transforms free energy into work and increases the entropy of the whole system, but also feeds on "negative entropy" (abbreviated by Brillouin 1949 to negentropy). Entropy is zero at 0 K and positive above it, while it is impossible to go below. "Negative entropy" in Schrödinger's expression means a displacement from disorder to order. In the consideration of the flow of energy through the biomass, it is "free energy" which is generally referred to in calculations. The molecular free energy is defined as follows

$$G = H - TS$$

in which H is the molar energy content, T the absolute temperature and S the molecular entropy content. As said above, the main free-energy source in organisms is presently considered as being the high-energy bond of ATP. While it is commonplace to describe a chemical reaction in living organisms by defining the reactants, the products and the free-energy changes occurring in the reaction, in a number of reactions in which ATP is hydrolyzed or synthesized, the process to which the chemical reaction is coupled remains obscure; such is the case in muscular contraction, active transport, oxidative phosphorylation or photosynthetic phosphorylation. These appear as aspects of "molecular energy machines" (McClare 1971) the theory of which is not dealt with in classical thermodynamics and remains to be developed as does the energetics of protein folding.

In 1913 appeared the widely read book of L. J. Henderson (1927), *The Fitness of the Environment*, which was considered by some as a platitude and by others as deserving endless commentaries which still are a subject of writing nowadays (Brinton 1958, Parascandola 1971). Henderson rejects all sorts of teleological views and quotes Bacon concerning final causes, which are like vestal virgins.

> They are dedicated to God, and are barren.

The core of Henderson's thought is expressed by the sentence in which he considers:

> that peculiar and unsuspected relationships exist between the properties of matter and the phenomena of life; that the process of cosmic evolution is indissolubly linked with the fundamental characteristics of the organism; that logically in some obscure manner cosmic and biological evolution are one,

and also, more concisely when he writes:

> the whole evolutionary process, both cosmic and organic, is one.

In a lucid comment, Speakman (1966) expresses Henderson's thought as follows:

> The environment seems to be well fitted for the sustenance of life in ways over which the organism has no control and which, indeed predate the existence of the organism.

The ways in which "cosmic and biological evolution are one" have been sought in the laws of classical thermodynamics and more particularly in the Carnot-Clausius principle. In the overall balance, cosmic and biological evolution result in an increase of entropy as predicted by the second law. The concept of evolution as an aspect of this law has been formulated by a number of authors and especially by Lotka (1925) and by Blum (1968). It has been considered unacceptable by a number of authors on the basis of the idea that evolution, as well as the maintenance of the organisms imply, as stressed by Schrödinger, an increase in order.

That "cosmic and biological evolution are one", as stated by Henderson, could only be understood after the formulation by Prigogine (for a general formulation, and literature, see Prigogine 1971) of the concept of chemical instabilities leading to a spontaneous self-organization of the system both from the point of view of its space order and its function: "there indeed exists a *new state of matter* induced by a flow of free energy far from equilibrium" (Prigogine 1971).

Short-time oscillations have been detected in a number of biochemical reactions (Prigogine 1971) and arguments have been formulated in favour of instabilities breaking dissipation symmetry, and leading to spatial organization. Chemical instabilities may be associated with biological structures and with their change in descent. These views confer a new interest upon "traffic" pathways in the cybernetic network of the biochemical continuum and upon the system of signification expressed in their branching, control and regulation.

Furthermore it leads to a better definition of the vaguely defined "internal factors" of evolution, possibly by a consideration of the limitations imposed on primordial proteins, with respect to their primary structure, by their mode of synthesis and their persistence in the medium in which they developed, by taking into account the laws of the thermodynamics of irreversible phenomena and particularly the entropic criterion of evolution of energetically open systems (Glandsdorff and Prigogine 1964, Prigogine 1971) according to which, as stated by Buvet (1971) "in open systems, compounds of internal structures different from equilibrium ones spontaneously arise, which may be considered to have no 'raison d'etre' other than bending this entropy production in the way of minimalization". In such a system the existence of which involves a source of energy and a sink for the energy flowing through the system, energy is used up and dissipated for the maintenance of the steady state remote from the equilibrium, a steady state depending on cyclic chemical processes and on the chemical and energetic coupling of anabolic and catabolic cycles.

Molecular Information

The entropy (in the sense it has in thermodynamics) of a DNA molecule is a function of the configuration in which the atoms are ordered. It is expressed in the relation:

$$k \cdot \log D$$

(k, Boltzmann constant; D, measure of atomic disorder). In statistical terms, entropy is defined as

$$S = -k \sum_{i=1}^{1-n} \log p_i$$

$\left(\sum_1^n = 1;\right.$ where $p_i =$ the probability of an idealized physical system in the state i of n possible states). Szilard (1929) has pointed out the formal similarity of this equation defining entropy and the equation defining information

$$H = -\sum_{i=1}^{1-n} p_i \log p_i$$

$\left(0 \leq p_i \leq 1; {}_1^n p_i = 1;\right.$ where $p_i =$ relative probability of the ith symbol generated by a source).

The fundamental relations between information and entropy have been developed by Shannon and Weaver (1949) and by Brillouin (1956), to whose writings the reader is referred.

In our present theory, displacement from randomness, or negentropy is quantified in information, or rather in the quantity of information, expressed in "bits".

This unit of information corresponds to the simplest possible form of message transmission. In the case of a binary symbol, i.e. which can take two or only two alternative forms (for instance "yes" or "no", or a dot or dash in the Morse system). The "elementary quantity of information" that can be transmitted by a simple "binary" symbol (choice between two alternatives) corresponds to a *bit* (binary digit)

2 bits correspond to a choice between 4 alternatives
3 bits correspond to a choice between 8 alternatives
4 bits correspond to a choice between 16 alternatives
or in general
n bits to a choice between 2^n alternatives

The information content I corresponds to the number

$$I(\text{bit}) = ld2^n \qquad (ld = \log_2 = \log \text{ to the base } 2)$$

When we deal with several (n) symbols and with several (m) symbol types, the general equation reads

$$I\,(\text{bit}) = ld\,m^n = nld\,m = 3.32\,n \log_{10} m\,(\text{bit})$$

As pointed out by Quastler (1953) who was the first to understand the biological pertinence of the information theory formulated by Shannon (1948) in 1948, an amino acid has about the information content of a word and a protein that of a prose paragraph. He calculated the capacity of a mammalian DNA molecule as $2 \cdot 10^{10}$ bits of information. Morowitz has calculated the information content of a cell of *Escherichia coli* and found it equal to $2 \cdot 10^{11}$ bits. These data illustrate the high content of a mammalian cell in information defined as negentropy i.e. in physical terms.

Biomolecular Relata

As said above, negentropy is an extensive property and the information theory quantifies it. As noted by Johnson (1970):

> . . . in biology, the extensive property; information or negative entropy can have significance for the feasibility of living process only if it is modulated by an intensive property which indicates the biological relevance or purposefulness of that information.

Brillouin himself has written (Brillouin 1956):

> the present theory of information completely ignores the value (or meaning) of the information handled, transmitted or processed.

The whole mass of living organisms may in the perspective of the present discussion, be considered as a large collection of molecules assembled in a certain order and forming a *biochemical continuum* (Florkin 1965, 1966) composed of all the molecular aspects of the organisms and of their metabolic extensions. This concept situates the consideration of the whole biomass at the molecular level, i.e. a cybernetic molecular network. The sediments at the deepest bottom of the oceans, and the organic matters coating sand and mud particles there, are linked to the surface of the seas by a cloud of molecules, this cloud being of variable density. The same notion applies to soils and to fresh water.

The whole of the biochemical continuum forms a large population of molecules densely associated in parts and more separate in other regions. Some of the dense associations are architectured in the form of the higher level of integration of cell organelles and of cells themselves by recourse to a number of couples of *relata* such as enzyme-substrate, hormone-receptor, multichain regulatory protein, etc., and a mechanism has been developed for the replication of a material including in the frame of the flux of matter and energy, a flux of information. In a cell there is a flow of information from nucleolus to cytoplasm and this is coupled with a flow of material particles, the ribosomes, dependent upon the activity of the nucleolus. Not only are the ribosomal RNAs transferred in that way, but also the RNAs which carry the specificity for protein synthesis. This information depends upon the existence, in the nucleus, of a collection of DNA molecules inherited from the parents, carriers of the molecular order expressed in the structure and nature of the organism.

Monocellular and pluricellular organisms associate in communities whose populations maintain themselves and form, in association with different components of the environment, ecosystems inside which and between which currents, not only of matter and energy, but also of information are flowing (Florkin 1966, Sondheimer and Simeone 1970). The biochemical continuum is the result of a slow evolution starting from the organic abiogenic continuum resulting from the prebiotic (chemical) evolution. The transition from the abiogenic organic continuum (Florkin 1969) to the biochemical continuum is characterized by a decisive step: the emergence of the steady state remote from the equilibrium state and of the prime aspects of nutrition in the form of a flow of matter and energy through the open system of organized aggregates (precells, protocells).

As stated by Eigen (1971)

> . . . General principles of selection and evolution at the molecular level are based on a stability criterion of the (non-linear) thermodynamic theory of steady states. Evolution appears to be an inevitable event, given by the presence of certain matter with specified autocatalytic properties and under the maintenance of the finite (free) energy flow necessary to compensate for the steady state production of entropy.

The reciprocal relations between the various biosystems and with the medium became more and more elaborate, and it led to the exchange of molecules that were not only of nutritional importance, but acquired regulatory and control properties, acting as transferrers of signs and signals. Many ecological aspects should be classified as *molecular reactions* (liberation of molecular factors by organisms in the habitat) and *molecular actions* (infringements of molecular factors upon organisms). In an ecosystem, besides the contribution of the trophic chains in supplying molecules endowed with nutritive functions and ensuring the flux of matter and of energy one may describe non trophic molecules active in insuring a flux of information as well as the constitution and maintenance of the community (*ecomones* Florkin, 1965, 1966). An ecomone may have multiple actions. For instance, the concentration of dissolved carbohydrates in sea water varies from place to place and is a factor of the nature and growth of the phytoplancton. On the other hand the ecological importance and the action as ecomones, of the carbohydrates is expressed in the regulation of the pumping rate of Lamellibranchia.

Some ecomones are recognized as being specifically active in the process of the coaction of organisms upon each other. Such specific substances or *coactones* are determinant in the relationship between the coactor (active and directing organism) and the coactee (passive and receiving organism). A number of coactones are liberated by the coactor in the medium and reach the coactee. These we may call *exocoactones*. Among these are, for instance the molecular factors of the orientation of animals through the perception of the odour of the animal taken as food. The feeding behaviour of an animal when reaching a plant to which it has been attracted by an exocoactone may be specifically unlocked by plant products which we may call *endocoactones*.

A special category of exocoactones is represented by those substances produced in a coactor and acting on a coactee, both coactor and coactee belonging to the same species. These exocoactones are called *pheromones*. According to Karlson and Lüscher (1959)

> pheromones are defined as substances which are secreted to the outside of an individual and received by a second individual *of the same species*, in which they release a specific reaction, for example a definite behaviour or developmental process.

The other exocoactones and endocoactones, transmitting chemical signals to individuals of other species we may call *allomones*, as suggested by Brown and Eisner (1968).

The circulation of molecules and macromolecules through the biochemical continuum and the factors controlling their distribution is a field of active biochemical evolution and adaptation in which it is possible to detect the aspects of natural selection shaping both sign and receptor and the evolution of reciprocal interactions between organisms and between groups of organisms.

Molecular Biosemiotics

The recognition of systems of *relata* at the integrative molecular level indicates that biomolecular order is governed by systems of signification which we may consider in a structuralist (intensive) perspective besides the thermodynamic viewpoint and the quantifying (extensive) viewpoint of the information theory.

When Wiener once wrote that one could consider an organism as a language, he meant that the concepts of information and cybernetics are applicable to organisms. It would be better to resist the temptation of considering biomolecular *relata* along the lines of language studies. Linguistics is dealing with linguistic signs, i.e. with psychological entities, relating in the receptor's mind a psychic acoustic image and a concept. Language is a vector of ideas, as are other aspects of semiology, such as the alphabet of the deaf-mutes, symbolic rites, marine signalization, etc. All these languages, framed in the social mass, represent substitutes of human experience which can be transmitted in space and time.

We shall therefore pray for the banishment of the abusive use of the term "language" from the field of molecular biosemiotics, while granting that there is, on the other hand, a language and a graphology of the chemist and of the biochemist, aspects which are not dealt with in this review.

Consequently, we find it advisable to avoid the application of the *specific* concepts of linguistics (word, phrase, etc.) to biosemiotics and, however tempting it may be, to decide not to introduce such expressions into it.

While linguistic semiology deals with human psychological phenomena and the communication of concepts, molecular biosemiotics deals with existential aspects of cells and the *relata* it studies are not always of the nature of signals. It is on the other hand imperative to keep the concepts of general semiology as understood in the social mass of men, when they go beyond this domain to connote the field of molecular biosemiotics, as we believe that in a future development, linguistic semiology will become based on molecular biosemiotics of the activities of the brain. We shall therefore use in the perspective of this subject several general concepts elaborated by De Saussure (1971) such as significant and signified, synchrony and diachrony, syntagm and system with the special meaning they have in molecular biosemiotics. It must be noted that in the mind of F. de Saussure these concepts arose from the consideration of existential (not psychological) aspects of natural science.

To define the concept of significant, Saussure recalls that water, H_2O, is significant in a way which belongs neither to oxygen nor to hydrogen:

> it is a combination of hydrogen and oxygen; taken apart, each of these elements has none of the properties of water (De Saussure 1971) (translation by author)

Synchrony and diachrony are borrowed by De Saussure from the theory of evolution, and diachronic is synonymous with evolutionary.

It is therefore fitting to situate these concepts in the most general context of semiotics, the general science of signification, of which linguistics and biosemiotics are special aspects. However, the concept of the *word* is specifically linguistic as it means the smallest free unit of *denotation*. It is a cultural unit and should consequently not be confused with the material and functional (not denotating) units of molecular biosemiotics. The same holds for the phrase and for discourse, which are the support of connotative developments of values defined by their situation in a semantic field. They belong to dialectic logic and not, as in the case of biosemiotics, to structural logic.

Molecular biosemiotics is an aspect, not of human sciences, but of molecular biology. As stated by De Saussure (1971), in linguistics, the sign which he considers as the association of a significant and a signified, is arbitrary with reference to the relation between its two faces. In molecular biosemiotics, on the other hand, significant and signified are in a necessary relation imposed by the natural relations of material realities.

Biosemes

Minimal configuration aspects, carriers (significant) of molecular signification (signified), either sequential, structural, functional, protective, connective, motive, signaling, catalytic, processing, regulating, priming, repressing, releasing, etc., we shall call biosemes (units of significant). The sign (theme of signification) is formed by the doublet of significant and signified of the bioseme. The signification system implies a sign (significant + signified) and a receptor, eventually reached through a sequence of intermediary steps.

It must be noted that, while in the terminology of linguistic semiology, the sign is "a double faced psychological entity", the sign of which a bioseme is the minimal significant is a double-faced (significant + signified) material entity (molecular configuration + biological activity). This avoids the controversial nature of the relation significant (symbol) – reference (concept) – referent (the thing signified), as introduced by Richards and Ogden (1924) in linguistics. The referent is the object denoted by the significant (in the case of the word *tree*, f.i., the object tree), while the reference is the signification (a concept) carried by the word to the receptor. This, Pullman (1962) has defined as the information carried to the receptor, what Frege (1892) had defined as *Sinn* in contrast to the referent which is *Bedeutung*. To illustrate the distinction, we may write /*Charles Darwin*/and/the author of the *Origin* *of Species*/. The *Bedeutung* remains the same but the reference (*Sinn*) is different. The same difficulty concerning the linguistic signified appears in the opposition of denotatum and designatum, denotation and connotation, denotation and meaning (literature in Eco 1972).

At the level of a bioseme, the significant, an aspect of molecular configuration, and the signified, an aspect of biological activity, compose the sign, and the theme of signification. This is one more reason if necessary, to avoid referring to "words" and "sentences" when dealing with biomolecular aspects, while it is also a reason for adopting the notion of the sign in a special section (biosemiotics) of general semiotics. This denomination we shall apply to the general science of signs, while applying the name of general semiology (Barthes 1964) to the discipline concerned with systems of signs in relation with the laws of the languages framed in the social mass.

A bioseme carries no *Bedeutung* or *Sinn*. Its significant consists of an aspect of molecular configuration and its signified of an aspect of biological activity.

Biosemes, the units of signification involved in molecular *relata*, correspond as said above, to intensive aspects of negentropy. The system of signification obtaining in each case of relation with a receptor can be considered, not only from the intensive point of view but also as categories of information. Such is "structural information"; defined by Büchel (1967) as the information required to construct a system from its parts.

Büchel (1967) considers a watchmaker putting together the parts of a watch.

> Whenever a mechanism containing an information of n bits is built, the thermodynamic entropy of that mechanism or its environment must increase by the amount of at least kn log 2 where k is the, Boltzmann constant. The quantity kn log 2 is, in fact, the information measured not in bits but in caloric units (cal/grad) [cal/deg. C]. So we may consider the information to be "structural negentropy" contained in the mechanism.

Büchel's structural negentropy or structural information is denoted by Ryan (1972) by the symbol I_S.

Another category of information, "bound information", an expression introduced by Wilson (1968) is defined by Ryan (1972) as the information which is "required to specify the precise microstate of any resonant system". What Ryan (1972) calls "functional information" corresponds, according to his definition, to the entropy change corresponding to the order put in (or maintained in) the environment-of-action. We may tentatively recognize this functional information as corresponding to an extensive aspect (information theory) of the intensive concept of the signified as defined above in the context of molecular biosemiotics.

While placing the general (extensive) aspect of organic evolution and its inevitability in a thermodynamic context, we should carefully avoid deriving mechanisms of molecular evolution as a process (intensive aspects of biomolecular changes in the phylogeny of organisms) from thermodynamic concepts, as it has unfortunately sometimes been done, leading to utter confusion.

Biosyntagms

In the Macedonian "phalanx", the term "syntagm" designated the compact unit composed of specialized categories of warriors in several rows, pointing their weapons at the periphery. A biosyntagm we shall recognize as being a unit of signification higher than a bioseme, and composed of significant units in a relation of reciprocal solidarity, i.e. an associative configuration of biosemes.

A biomolecule may carry several biosyntagms and, on the other hand, a biosyntagm may extend to several biomolecules. The biosyntagm corresponds to the metonymic aspect of molecular biosemiotics. Cistrons, operons, the double helix of DNA, enzymes, biosynthetic assembly chains, are examples of biosyntagms at the integrative molecular level, and are composed of aspects of signification solidary in the course of the information process and presenting a relation of the whole (biosyntagm) to the parts (biosemes)[1].

Sequencing Biosyntagms

The signified of such biosyntagms, the composing biosemes of which are nucleotides or codons, is of a sequencing nature, governing the sequence of nucleotides or of amino acids, in their polymers. To this section belongs the secondary sequencing biosyntagm of DNA, the tertiary biosyntagm of tRNA and the primary biosyntagm of mRNA. The reader is referred to Vol. 24 of this Treatise for a detailed treatment of the biochemistry of these polynucleotides and of the genetic code governing the couples of *relata* between mRNA, tRNA and ribosomes. Limiting our attention to molecular biosemiotics, we may recall that the structural information of DNA is introduced in the course of its synthesis, which can be reproduced in vitro in the presence of a DNA polymerase – a model in which the information is introduced by hydrogen-bonding base pairing but in which base pairs are recognized by the enzyme involved, which also excludes other base pairs. In one of a number of models proposed to account for this property it is considered that, as the polymerase contains a bioseme acting as a site for triphosphate, the template binds a base which is accepted or rejected by the polymerase. When the base satisfies – the geometry and is acceptable, the enzyme may undergo a (ligand-induced) configuration change and the synthesis proceeds (Fig. 15.1).

DNA polymerase, consisting of a single polypeptidic chain carries a biosyntagm of several biosemes, coupling for a number of couples of *relata*. Kornberg (1969) records at least five of them. The *template site* binds the chain where a base pair is

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[1] The term syntagm has been used by De Saussure (1971) in the field of linguistics to designate a succession of semes in time as it is impossible to articulate two different sounds at the same time, an aspect which does not always obtain in molecular biosemiotics, while the time factor is considered in catenary biosyntagms.

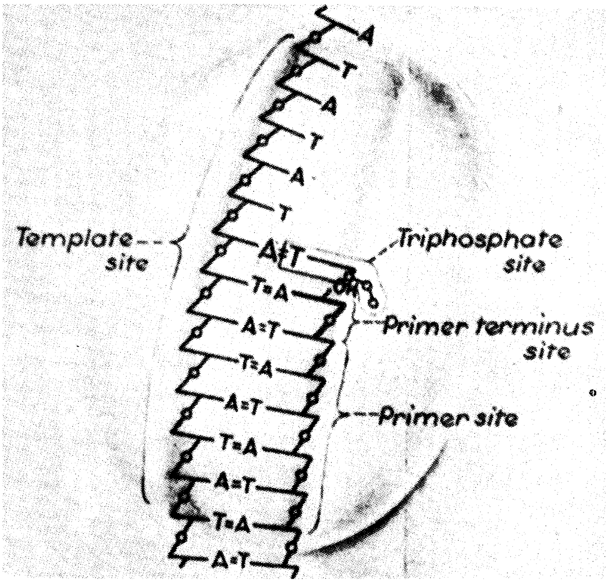

Fig. 15.1 Catalytic sites in the active center of DNA polymerase (after Kornberg 1969)

formed. At the *primer site*, the growing chain is located. The *primer terminus* is a site for recognition of 3′-hydroxyl group of the primer's terminal nucleotide. The incoming nucleotide substrates bind at the *triphosphate site*. There is also a site for the hydrolytic cleavage of 5′-monophosphates from this end of the chain.

Heteropolymer tetramers frequently present multiple forms of associations of their constituting units in the same organism or even in the same cell (polymorphism). A familiar example is afforded by lactate dehydrogenase, which is formed by four polypeptide chains, each of mol. wt. 33,500 and which exists in five different forms in rat tissues (isoenzymes). The overall reaction catalyzed is the same in all cases, but they differ in an aspect of the signified, the K_m value for the substrate. The five isoenzymes are five different combinations of the two polypeptides M and H, which are homologous but show differences in amino acid content and sequence. M_4 predominates in muscle and H_4 predominates in heart. The other forms are M_3H, M_2H_2 and MH_3, the relative amounts of which are under genetic control and differ from tissue to tissue (Kaplan 1968).

Many cases of isoenzymes are known and they also are heteropolymer biosyntagms, the different forms of which show differences with respect to kinetic characteristics. Vertebrate hemoglobins are in most cases heteropolymer tetramers composed of chains α and β in equal proportions $(\alpha_2\beta_2)$ Polymorphism has been recognized in the hemoglobins of many vertebrate species. The horse has two hemoglobins, with two different α chains and a common β chain (Trujillo et al. 1967). The two different α chains differ by the substitution of a glutamine for a lysine (Kilmartin and Clegg 1967).

The well-known polymorphism of human hemoglobin results from the presence of β and δ chains, a result of gene duplication. Fish have up to twenty hemoglobins. In all these cases, common in animal forms, polymorphism results from the existence of multiple polypeptide chain types and the possibility results in the formation of multiple heteropolymer tetramer types, showing diversification at the level of aspects of the signified.

Biosemiotics of the Flux of Information from DNA to Proteins

The origin of this flux resides in the sequencing syntagm of DNA and results in the sequenced syntagms of proteins.

(a) Genomic transcription (biosemes = bases)
(b) Translation (biosemes = codons)

In translation, the couple of *relata* established by mRNA is established between a codon on itself and the anticodon nucleotide sequence of tRNA, the only molecule to be recognized by mRNA. *It is in the process of charging tRNA that the signified of an amino acid expresses itself with respect to the accomplishment of polypeptide sequencing*. This very important biosemiotic aspect has been established in a most elegant way by Chapeville et al. (1962).

The ribosome-mRNA syntagm is known as a polysome, in which the number of ribosomes associated with mRNA varies.

An initiation codon as bioseme in the reading of a message phrases its translation from triplets into amino acids.

The sequencing syntagm of DNA *transcription* is composed of biosemes consisting of nucleotides, while in the couples of *relata* involving mRNA (i.e., *translation*) the biosemes are the codons (base triplets, at least in general).

To recapitulate the biosemiotic aspects of the flux of information in protein synthesis, we may state that a first couple of *relata* is established between an amino acid and a specific activating enzyme. A second couple of *relata* is established between the enzyme (with amino acid attached) and a specific tRNA. But the point of attachment is non specific, as all tRNAs have the same three terminal nucleotides (see Lewin 1970). In a third couple of *relata*, a *specific triplet codon* on mRNA is coupled *with its anticodon on tRNA*. This is the domain of the code-translating mechanism.

From the point of view of biosemiotics it is important to recognize the universality of the generality of codon assignments. An important biosemiotic aspect is the fact that, though the code is degenerate (i.e. that some amino acids have assigned to them more than one codon) at the stage of translation (and of the formation of a couple of *relata* between tRNA and the codons of mRNA), the couple of *relata* involved is highly specific of the codon and of the specific anticodon bearing tRNA, i.e. that for every codon there is a specific tRNA. The degeneracy of the code is not biosemiotically situated at the translation stage, but in the fact that more than one type of tRNA, in a given organism, is associated with some of the amino acids (literature in Lewin 1970).

Biosemiotic Characters of Amino Acids

We have met these properties when considering the nature of structural information in the process of the folding of tertiary biosyntagms, and also in the stage of formation of aminoacyl-tRNA. Information belonging to the amino acid units of configuration in polypeptide chains should be classified thermodynamically as structural information. From the point of view of molecular biosemiotics, we may consider the amino acid side groups as endobiosemes. In Fig. 15.2, the amino acid side groups have been arranged to emphasize their relationship and their biosemiotic content. The side groups b–g are hydrocarbons of progressive bulk and of parallel progressive hydrophobicity. Phenylalanine, besides its great hydrophobicity, contains an aromatic ring and like tyrosine and tryptophan, is able to contract couples of *relata* with other aromatic rings through overlapping of π electron clouds (*e.g.* in the interaction between protein and heme in myoglobin and hemoglobin). Histidine has one pair of electrons on one of its nitrogen atoms, which is used in metal binding. Cysteine is able to form disulphide bridges. In proline the side chain may force a bend on the polypeptide chain and may disrupt an α helix. Some of the side groups contain flat rings (f, g, m, n, u); two carry negative charges (q, r), three carry positive charges (s, t, u). Three are hydroxyl-containing (k, 1, m).

> According to the sequence of these groupings on the main chain, the protein molecule may fold into a complex three-dimensional "globular" structure in which a large proportion of the groups fit into a precise but irregular arrangement. (Cairns-Smith 1971).

Dickerson and Geis (1969), discussing the nature of the structural information governing the signification of animal structural fibrous proteins record three basic configurations in these protein chains: the α-helix, the collagen triple helix and the β sheet. If a strong and rigid material is used (tendon, fish scales) the collagen helix is adopted, while the α helix is used if a more flexible material is required, and the β sheet (silk) if the material has to be flexible, but strong. The resulting structure is determined (structural information) by the amino acid content and sequences.

> Pro and Hypro are incompatible with an α helix and such a helix occurs in the absence of large quantities of these residues. Polyglycine itself, lacking side groups, has been crystallised in both the β sheet and the polyproline helix, and the two classes with high glycine content are just the silks and collagen. Just as the sequence $(\text{-Gly-Ser-Gly-Ala-Gly-Ala-})_n$ induces a β sheet structure, so the sequences similar to $(\text{-Gly-X-Pro-})_n$ induce a collagen triple helix. (Dickerson and Geis 1969).

We may now return to the couples of *relata* established between tRNA, synthetase and amino acid; a relation in which the properties of the amino acid are involved as specific biosemes. It has been shown that there is a change of signified of the activating enzyme during complex formation, as a result of a configuration change (significant), as a consequence of its association with tRNA. It has been recognized, for instance, that in the cases of proline and valine, the enzyme-tRNA complex is more resistant to heat that the enzyme (Chuang et al. 1967) and that the binding of tRNA to the synthetase-amino acid-AMP complex induces in the protein structure, a configuration change resulting in a loss of helical structure (Ohta et al. 1967).

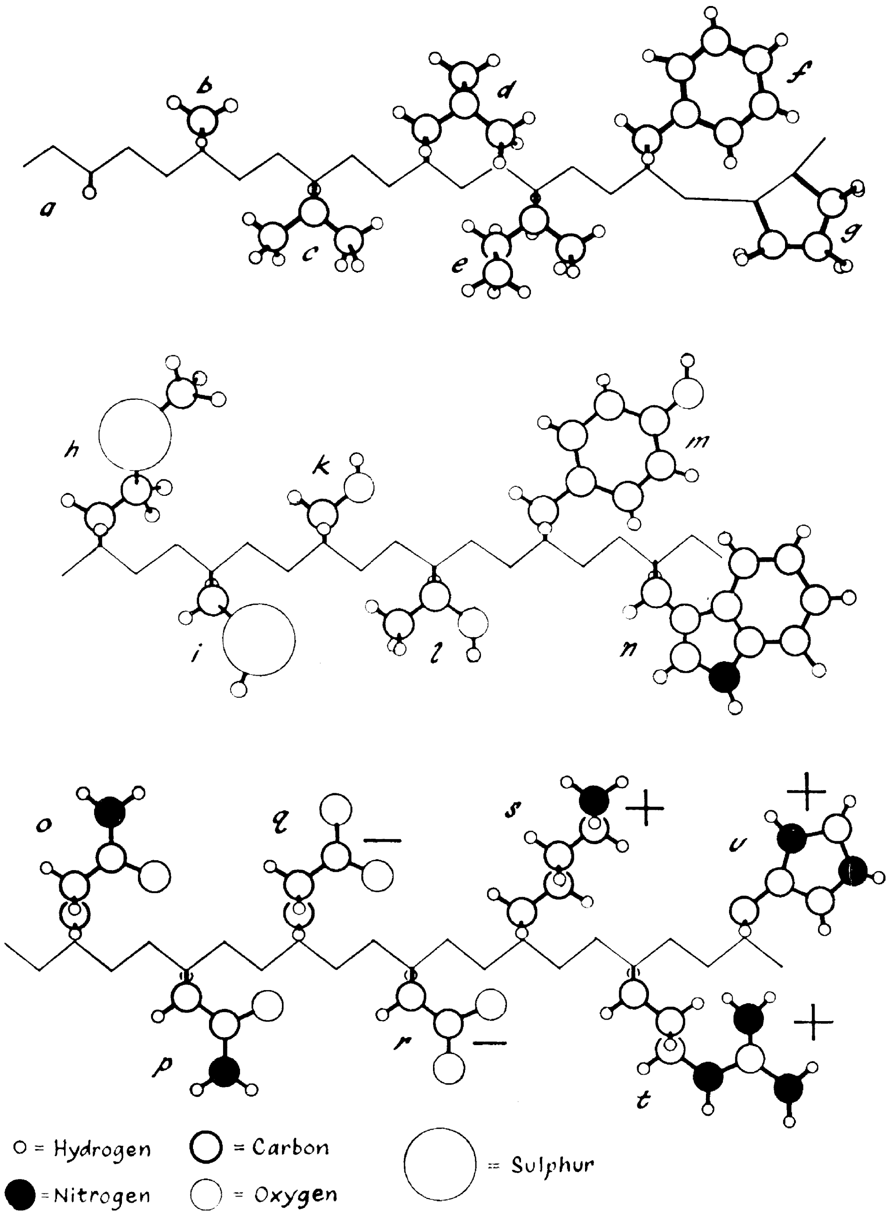

Fig. 15.2 Amino acid side chains (Cairns-Smith 1971)

It appears that the binding of the amino acid to its synthetase increases the availability of the site to tRNA on this synthetase. A model has been proposed by Yarus and Berg (1969), indicating a number of successive ligand – induced configuration changes modifying the significant and the signified of successive biosemes.

As suggested in Fig. 15.3, the synthetase passes through four stages:

(1) isoleucine and ATP bind to the synthetase and there is a configuration change of the bioseme which acts as binding site for tRNA (from closed to open, a state in which rapid entry and exit of tRNA is possible).
(2) As a result, isoleucyl-AMP is formed on the enzyme.
(3) The tRNA binds and the configuration of the binding site specific for the amino acid is thereby modified (change of significant).
(4) Isoleucine is transferred on the tRNA.

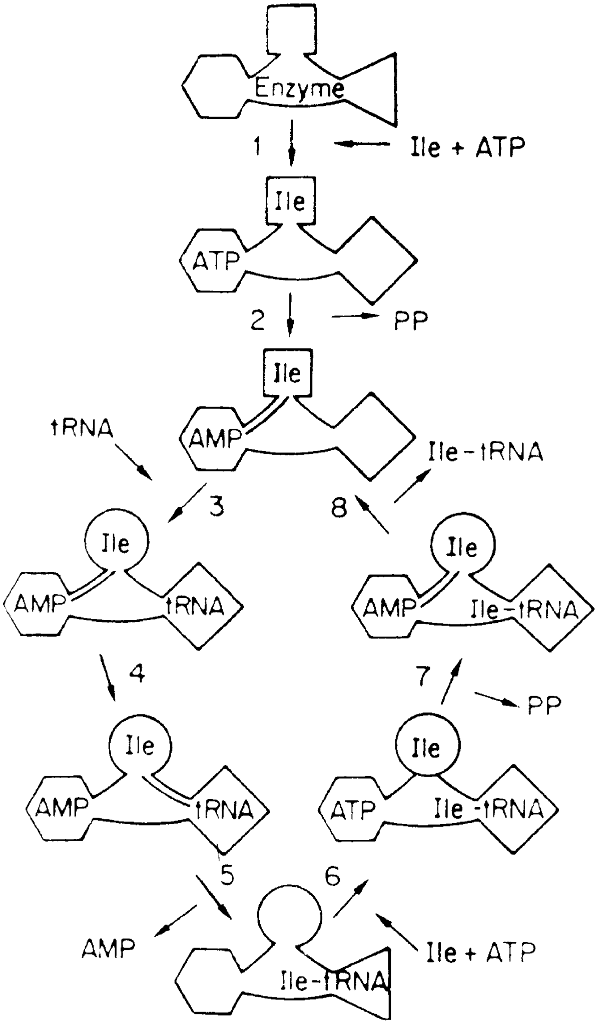

Fig. 15.3 The catalytic cycle of isoleucyl-tRNA synthetase. (Yarus and Berg 1969)

(5) The amino acid leaves its site, with a change of the tRNA-binding site into the "closed" form.
(6) Isoleucine and AMP bind, reconverting the tRNA-binding site into the "open" form.
(7) With a loss of inorganic phosphate, isoleucyl-AMP is formed.
(8) Isoleucyl-tRNA is released and the conformation of the amino acid binding site is changed.

As demonstrated by Baldwin and Berg (1966) the transfer or a wrong amino acid to tRNA is avoided by the destruction of any "wrong" complex.

Multigene Biosyntagms

Chromosomes are mixed biosyntagms composed of molecules of DNA, of RNA and of proteins.

The Configuration of Biosemes

We know enough of the biosemes involved at the integrative molecular level to define their configurations.

It must be pointed out that in the context of transient information, the transfer is insured by labile couplings. These couplings may be ionic interactions, hydrogen bonding or hydrophobic interactions. On the other hand the forces involved "must be sufficiently localized so that they can build up a defined geometric pattern" (Eigen and De Maeyer 1966). Very specific binding may be due, for instance, to specific types of H bonding as is the case in complementary base recognition (Stent 1971, Watson 1970, Watson and Crick 1953), the pairs AU and GC being the strongest and most stable, probably due to one strongly polarized hydrogen bond (Eigen 1971).

Tertiary biosyntagms often present a configuration situating the nonpolar groups (hydrophobic) inside and the polar ones outside. Non polar groups such as Val, Leu, Ile, Pro and Phe show the distribution and as stated above are active in the folding up of tertiary protein biosyntagms and structure stabilization. Non-polar biosemes are sometimes found at the surface of the biosyntagm where they play a role for instance in the formation of quaternary biosyntagms or in the formation of couples of *relata*. Charged side chains of amino acids are generally situated at the outside.

As stated above, the bonds involved in information processing are labile non-covalent bonds. However, the permanent storage of information for hereditary transfer does require the formation of covalent bonds.

For the purpose of processing in synchronic epigenesis, the permanent form of DNA is transferred into a transient form, mRNA, transient with respect to a time lapse greater than the duration of a generation. While it is relatively permanent compared with the time of incorporation of an amino acid into a peptide chain (Eigen and De Maeyer 1966). An example for readout of information is the code transfer from mRNA to an amino acid sequence, in which the transient form is represented

> by the specific interaction between complementary codons somehow checked by the ribosomal enzyme, the processing of the read information is the storage into the new permanent form of amino acid sequence in the polypeptide chain. (Eigen and De Maeyer 1966)

While the information is in the labile form, errors may be introduced during storage or readout for instance at the DNA level, producing point mutations.

Biosemes should not be considered as rigid configurations. Indeed a number of aspects of ligand-induced configuration changes may be identified, accompanied by changes of the signified which are determinant in integration and regulation at the molecular level.

Diachronic Molecular Biosemiotics

Diachronic Molecular Epigenesis

It is important to insist once more on the elliptic character of the expression "biochemical evolution", meaning changes *at the biomolecular level* along the phylogeny of organisms. The existence of this kind of change has first been documented by the present author (Florkin 1944, 1949) who has also used the expression "heteromorphic evolution" to designate, in the phylogenetic sequence of homologous biomolecules, "the acquisition of a modified component, with a lesser degree of isology" (Florkin 1960, 1957). But, as noted by Dobhzansky (1955):

> We must remember that heredity, development and evolution are essentially epigenetic and not preformistic. We do not inherit from our ancestors, close or remote, separate characters, functional or vestigial. What we do inherit is instead, genes which determine the patterns of developmental processes.

Given a set of DNA (sequencing) biosyntagms and a given set of environmental conditions, the development is determined. This is a synchronous process, a derivation of order from the order provided by the parental genes, while the "heteromorphic" changes of biomolecules along the evolution of organisms is a diachronic process, resulting from changes at the level of the genome or of the regulation of the genome.

While the derivation of the phenotype from the genome is determined (in definite environmental conditions) "biochemical evolution" is epigenetic as a process as well, as Dobhzansky (1955) remarks, as heredity and development.

In evolution at the biomolecular level (molecular changes in the phylogeny of organisms), what we consider is the diachronic (evolutionary) epigenesis of a synchronic epigenesis.

Therefore the present author (Florkin 1971) has suggested using the phrase "molecular epigenesis" (in evolution) or "diachronic (molecular) epigenesis" rather than "molecular evolution" or "heteromorphic evolution". As was stated above, while the information is shunting the metabolic traffic of synchronic molecular epigenesis and flows in the labile form, errors may be introduced during storage and readout, for instance at the DNA level with the production of mutations (Dixon

1966, Granick 1965, Jukes 1966b, Manwell and Baker 1970). This mutagenic aspect is lacking in the case of amino acid sequences, unable to reproduce the error copy and subject as stressed in a previous section, to conformation changes involved in metabolic regulation.

When we analyze the simplest type of cell known to us, of a *Mycoplasma*, we find that it is composed of a set of 30 different kinds of biomolecules: twenty amino acids, five nitrogenous aromatic bases (adenine, guanine, uracil, thymine, cytosine), a fatty acid (palmitic acid), two sugars (α-D-glucose and α-D-ribose), glycerol and choline (after Lehninger 1970). If we now consider the molecular composition of a cell of *Escherichia coli*, we find that it is composed of 70% of water and 30% of dry matter. The latter is made of approximately the following numbers of molecules: 3000 proteins, 1 DNA, 1,000 RNA, 50 carbohydrates, 40 lipids, 500 intermediates and building block molecules, 12 inorganic ions (percentage in weight: proteins, 15; nucleic acids, 7; carbohydrates, 3; lipids, 2; metabolites 2; inorganic ions, 1) (Lehninger 1970).

In a way, the many forms of biomolecules found in mammals or in insects are the descendants by an epigenetic process which is repeated in all individuals in the course of their ontogeny, of those of their ancestors. To say that they are descendants cannot however be taken without a grain of salt. When we refer to DNA the diachronic molecular epigenesis is situated at the level of hereditary transfer and we are dealing with real descendants. When we refer to other biomolecules the epigenetic process consists of a molecular change at the level of the transient molecules (RNA, enzymes, regulators, etc.) involved in the biosynthetic process which is repeated in each of the descendants. Such changes concerned in modifications of biosynthetic pathways involve not only a configuration change of the biomolecules, but a radical change of biological activity. This change of configuration and of activity, which has been designated as “biochemical innovation” (Cohen 1963) as “functional epigenesis”, as “functional radiation” (Florkin 1971) we may, in order to connote a biosemiotic aspect, designate as “*commutation*”.

Innovation of molecular activities is, as we shall see, one of the ways through which the patterns of biosynthetic pathways are modified in the evolution of organisms.

No invention of configuration will reach the status of a bioseme except by entering into a couple of *relata* and it is only in this case that it will reach the threshold of the impact of natural selection at the level of individual organisms.

Physiological Level

By function, the physiologists mean a collection of molecular activities, recognizable, at a higher integrative level, in the phenomenology of their integrated aspect.

If we consider, for instance, the electroplax membrane of the electric eel *Electrophorus electricus*, we recognize at the membrane level the existence of a receptor for acetylcholine, ligand-inducing configuration changes (changes of signified) at the level of the membrane fabric, the result of which is a change of membrane potential (literature, see Podelski and Changeux 1970).

If we consider, again at the level of cell membranes, the effectors of the adenylate cyclase system we recognize the adenylcyclase as the primary enzyme system through which hormonal peptides alter the metabolism, the structure and the function at the level of target cells. In the target cell, information is carried by the hormone to a receptor and it is received, decoded and transduced into the expression of the endocrine action at the molecular integrative level. In such a system the receptor is coupled with a response mechanism, while in the case of the hormones active at the genomic level, the receptor is selected among multiple receptors.

To quote Rodbell et al (1970):

> In informational terms, this system selectively receives, translates and amplifies the "message" contained with the structure of the hormone to give a new messenger.

This kind of regulatory catenary biosyntagm is divided by Rodbell into several biosemes: hormone-binding sites (discriminators), coupling processes (transducers) and catalytic component (amplifiers).

As underlined above, the orthologous proteins show little or no variation of signified in the course of the evolution of organisms. This is the case with cytochromes *c*, all yielding to whatever organism they belong, the same first-order rate constant for: their reactions with bovine cytochrome *c* oxidase over a wide range of cytochrome *c* concentrations (Smith 1984). But there are large variations, among the cytochromes *c* of different species, of the binding of various inorganic anions by the ferric form of the protein (Barlow and Margoliash 1961),

Margoliash et al. (1970) have suggested the existence of a correlation between the ion-binding properties of cytochrome *c* and the transport properties of mitochondria and proposed a model for the ion-carrier function of cytochrome c at the level of the mitochondrial inner membrane (see the *Harvey Lecture* by Margoliash 1972).

Considering the integrative level of the "functions" at the higher level of physiological integration we may recognize what the present author has called "physiological radiations" (Florkin, 1960, 1966a, b, 1957, 1971, 1962, 1959, 1963, 1967), or "physiological epigenesis" (Florkin 1971). In such "radiations" (a term used in a meaning akin to the familiar biological concept of adaptive radiations) while the configuration of a biomolecule is not modified, advantage is often taken in the evolution of organisms at the physiological level, of different properties and activities of the biomolecule, i.e. of other aspects of an already present signified.

Carotenoids, for instance, absorb light. In the case of the phototropism of plants, they transfer the electromagnetic energy to an enzyme, while in photosynthesis, they transfer it to chlorophyll. In animals, the absorption of light by the carotenoids, obtained from plants and more or less modified, are used in many ethological services: attraction of insects and birds towards flowers and fruits, sexual dichronism in insects, feather colours in birds resulting from different states of oxidation of carotenoids of alimentary origin. On the other hand carotenoids may undergo *cis-trans* isomerization which is utilized in vision as well as in the perception of odours (Briggs and Duncan 1961). In fish, carotenoids are involved in photoresponse (Goodwin 1951). In the trout, for instance, xanthophores are coloured by lutein and erythrophores by astaxanthin, two carotenoids involved in the nature of skin colour (Steven 1948). But in certain species of fish, as for example in *Salmo iridaeus*, another property of the same molecular unit is taken advantage of, the molecule of astaxanthin being also used as a fertilization hormone (Hartmann et al. 1947). Many such physiological radiations, active at the physiological level, can be identified.

Thyroid hormones exert their main signification as growth stimulators but they are involved in metamorphosis, in the regulation of basal metabolism, in protein metabolism, in osmoregulation, etc.

Dopamine appears in the biosynthetic syntagm as a precursor of norepinephrine (Kirshner 1959). On the other hand it seems to have assumed a neurohumoral role at the level of the brain of mammals (Bertler and Rosengren (1959) and of *Helix* (Kerkut and Walker 1961). It also plays a regulatory function at the level of the heart of *Venus mercenaria* (Greenberg 1960). Finally the fact that dopamine is the only catecholamine which can be identified in the ganglia of different mollusks (lamellibranchiates or gastropods) (Sweeney 1963) is in accordance with the notion that it plays in some organisms the same role as epinephrine or norepinephrine in others.

Enzyme systems and their associated components (substrates, coenzymes, cellular regulators, hormonal regulators) frequently contribute to changes at the higher physiological level by the introduction of one or several of their components into a more specialized system. The visual function of the vitamins A is the only one it has been possible to demonstrate in animals other than mammals and birds. In the latter two, without showing commutation, the carotenoid configuration obtained a new signified in controlling the formation of the mRNA commanding the keratin synthesis in epithelial cells. In the visual cycle in which vitamins A are involved, retinene is produced by the reduction of vitamin A_1. The enzyme involved is the common alcohol dehydrogenase. This universally distributed enzyme is inserted here in a new system which is extremely specialized.

Peroxidase, in *Balanoglossus* is used as a luciferase (Dure and Cormier 1963).

We propose to define physiological radiations as the insertions of the same molecular significant (with possible uses of different aspects of the signified) in several biosemiotic aspects at levels of integration higher than the molecular level. This concept differs from the concept of commutation in which the molecular signified is radically changed in phylogeny, and from the concept of heterotypic expression (Mason) in which a biomolecule is involved by its unmodified biosemes in different catenary biosyntagms at the molecular integrative level.

Physiological radiation (a concept which obtains at the physiological integrative level) must also be distinguished from the concept of different utilizations of a same biomolecule as receptor in the formation of couples of *relata* at the molecular level of integration. We may designate such biomolecules as polygamic. Besides their role as endobiosemes in protein macromolecules, amino acids show a high degree of polygamy. As underlined by Krebs (1966).

> . . . Glycine takes part in the synthesis of purine bases, porphyrins, creatine, glutathione, bile acids, and hippuric acid. Serine is a precursor of ethanolamine and choline, both of which are constituents of phospholipids. Methionine plays a role in the synthesis of creatine and choline, aspartic acid is a precursor of pyrimidines, and tyrosine is a precursor of adrenaline, noradrenaline and thyroxine.

Ecological Level

A number of end-products of the biosynthetic catenary biosyntagms are neither significant at the molecular integrative level nor at the structural or physiological levels of the organism, but are significant as ecomones.

At the level of integration of ecosystems, the biosemiotic structure of ecomones and of the structures with which they contract their coupling are problems for the future. As in the case of messenger hormones, the contact of a coactone with a receptor is at the starting point of a catenary informative syntagm.

Wilson and Bossert (1963) and Wilson (1965, 1968) have described ways in which coactone actions may have been modified in the evolution of organisms. One of these ways is the adjustment of fading time. For instance, by a reduction of the emission rate or a raising of the threshold concentration, the lapse of time separating the emission of a pheromone and the disappearance of the active space can be shortened. As Wilson (1970) remarks this has been "a chief design feature in the evolution of alarm and trail systems" affording an increase in information per signal and an "opportunity for the transmission of more discrete signals".

As the duration of action of acetylcholine is shortened by its inactivation by cholinesterase, a pheromone can also be deactivated. This is the case, for instance, among bees; the pheromone 9-ketodecenoid acid, the queen substance ingested by worker bees is enzymatically deactivated (Johnston et al. 1965). Instead of being restricted, the active space of a coactone may be expanded. This is the case for the insect sex pheromones, pinpointing very small targets within very large spaces.

Another evolutionary acquisition is the multiplication of coactone-producing exocrine glands in the same species. In another aspect which we may call ecological radiation of coactones, their signified is used in different ways in different ecological contexts. *trans*-α-Keto-2-decenoic acid in the beehive, acts as a caste-inhibitory pheromone while in the nuptial flight it acts as the primary female sex-attractant. Combinations may also introduce new signifieds. When confined with queens for hours, beeworkers, combining scents acquired from the queen with their own, are attacked by nest mates (Morse and Gary 1961).

Pluribiomolecular Nature of Biochemical Adaptations

Specific adaptive aspect of a molecule is not common and this is one of the reasons for the occasional use of expressions, such as "non Darwinian evolution" or "neutral changes". We should keep in mind that adaptation at the molecular level is not necessarily obvious at the level of a single molecular species. Rather, such adaptations more commonly result from changes at the level of molecular species involved in a complex polygenic adaptive mechanism. This concept has been formulated by the present author (Florkin 1966). An example of the polygenic nature of biochemical adaptations is provided by the cocoon of the silkworm (literature in Florkin 1966), The physical properties of fibroin insuring the protective function of the cocoon, depend on the peculiarities of protein synthesis in the distal part of the silkgland. The structure of fibroin, the main cocoon protein, may be explained by the specific nature of a category of mRNA liberated therein. But a detailed analysis shows that if the explanation of the *composition* and *structure* of fibroin is situated at the level of a given gene, the very *existence* of the cocoon depends on other factors as well: the nature of the specific food of *Bombyx mori*, the mulberry leaves; its attraction by these leaves (endocoactones); the behaviour leading to masticate and swallow the leaves (endocoactones); the enormous appetite of the silkworm during the second part of the fifth instar; the characteristics of the removal of the amino acids from the hemolymph, the regulation of the nymphal weight, etc. All these factors contribute to the very existence of a cocoon.

The cocoon formation in the silkworm appears originally as a secretion of a protective sheet for the prenymphal molt and the nymphal life in the conditions met in nature by the wild ancestor of the domestic form. The protein fibroin, the function of which is related to its physical properties, largely derives from a great excess of specific food rich in glutamic acid, glutamine, aspartic acid and asparagine. This very specific food is ingested in great bulk during the period of activity of the silk gland and thus provides it with a series of amino acids selectively absorbed. The peculiar structure of fibroin, with its recurring sections made up of small amino acids, depends on the nature of the messenger RNA specific of the distal part of the gland.

The period of activity of the silk gland is accompanied by a derivation of the pyruvate-producing constituents of the food towards the posterior part of the gland in which pyruvate is used to synthesize alanine, glycine and serine, according to pathways corresponding to those found in other forms of animal life. Some glycine and serine can also be included directly in the fabric of fibroin, and this is also the case for tyrosine, taken from the hemolymph. The aspartic and glutamic acids and their amides, forming an important proportion of the proteins of mulberry leaves, are among the main pyruvate producers in the silk glands. The final section of the silk thread is of endogenous origin. Its production is not only part of the accomplishment of an adaptation subserving ecological functions, but it also subserves the physiological function of regulating the normal size of the nymph by a derivation of a part of the substance of the larva towards the production of silk.

At the time of hatching, another adaptation at the cocoon level sets in. It depends on the chemical structure of sericin, a protein synthesized in the distal segment of the silk gland and coating the fibroin fibers. Sericin is the specific substrate of an enzyme secreted by the moth and by which sericin is specifically dissolved, permitting the separation of fibroin threads and the passage of the imago (Kafatos and Williams 1964).

Coevolutionary Diachronic Epigenesis

Species evolve in relation to aspects of the environment but they do not evolve in isolation.

The term “coevolution” was coined by Ehrlich and Raven (1964) to designate *evolutionary reciprocal interactions* between different kinds of organisms among which there is *no exchange of genetic information*. Molecular aspects of biochemical coevolution depend on the formation of couples of *relata* and can be identified among groups of organisms living in a close ecological relationship.

The clearest demonstration of a coevolutionary diachronic molecular epigenesis has been accomplished by Ehrlich and Raven in their paper mentioned above (Ehrlich and Raven 1964). An extensive survey of patterns of plant utilization and information on factors affecting food plant choices shows that the emergence of the biosynthesis of secondary plant substances has been critical in the evolution of angiosperm subgroups and perhaps of the angiosperms themselves.

Reciprocal selective responses appear “as a factor in the origination of organic diversity”.

Angiosperms have, in diachronic molecular epigenesis, developed catenary biosyntagms leading to the biosynthesis of a variety of “secondary substances” (see Chapter 2 of this Volume). These compounds are not inimical to the plant’s maintenance and growth. But some reduce the palatability of the plant for animals. This protection would, so to speak, introduce the plant into a new adaptive zone, with a possible evolutionary radiation and a characterization of new families. Another new adaptive zone would be entered when a population of insects, for instance, would become enabled to feed on some previously protected plant group. Here, in the absence of competition from other phytophages the population of insects considered would be free to diversify freely.

Ehrlich and Raven (1964) underline that in situations in which the supply of the “preferred” plant is limited enough to become a factor of survival of a larva, the change of food plant would be favoured. After the restriction of certain groups of insects to a narrow range of food plants the formerly repellent substances of these plants would become attractants.

In this field the diachronic aspect must be kept in view, as a molecular innovation may have had a selective advantage in the context of a remote period and that the nature of the adaptive zone may have been modified by the organisms that entered it.

We refer the reader to the paper of Ehrlich and Raven for a wealth of arguments in favour of the thesis that

> the fantastic diversification of modern insects has developed in large measure as the result of a stepwise pattern of coevolutionary stages superimposed on the changing pattern of angiosperm variation.(Ehrlich and Raven 1964)

Before the molecular coevolutionary aspects of food plant selection in butterflies as documented by Ehrlich and Raven were described, the present author (Duchâteau et al. 1953, Florkin 1966a, b) had described what we now call biochemical coevolution in the case of the “specialized” type of pattern of inorganic constituents of the hemolymph in Lepidoptera, as well as in the larval stages of Hymenoptera which they considered as an evolutionary aspect parallel to the evolution of angiosperms (see Chapter 4, Vol. 29B).

Interesting cases of biochemical coevolution consist in the predator-prey relationship and the parasite-host relationship, the plants and pollinators relationship or the relationship of partners in symbiosis. Allelopathy (a term coined by Molish (1937) to designate the effects on the growth of a plant of products of other plants) is active in the distribution patterns of plants (Muller 1966). All these aspects inserted in the biochemical continuum provide examples of biochemical coevolution, characterized by reciprocal evolutionary interactions and confirming that, even at the molecular integrative level, species do not evolve in isolation.

That the signified of biomolecules may be recognized as being involved at levels of integration higher than the molecular one, for instance at the level of the self-assembly in supramolecular structures, at the physiological or ecological levels is reviewed in part IV.

While the concept of the evolution of organisms as an expression of biochemical evolution remains a subject of study, it has received a great deal of support from the recognition of the concordance of the phylogenetic trees of sequencing or sequenced biomolecules and of the organisms concerned. This supports the concept according to which the structure and nature of organisms are expressions of the biomolecular order implemented by the heterocatalytic command of the specification of amino acid sequences. The pressure of natural selection should not be considered as being exerted on specific biomolecules, but on organisms, i.e. on the biomolecular order expressed in the structure and nature of the whole collection of biomolecules of which the organism is made. This molecular order is subject to changes in descent and to selection pressure. In such a perspective the evolution of organisms and the evolution of the biornolecular order (biochemical evolution) are recognized as interrelated facets of the same natural reality.

Glossary

Alleles Alternative forms of a gene occurring at a definite place on a chromosome.

Allelopathy Effects of products of a plant on the growth of another plant.

Allomones Coactones(see below) transmitting chemical signals to individuals of other species

Analogy (biochemical) Biomolecules having similar functions in different groups of organisms are designated as analogous.

Anticodon A sequence (on RNA) complementary of a codon (see below).

Battery of producer genes (Eucaryotes) Unlinked structural (producer) genes coordinated by integrator genes.

Bioseme Minimal configuration aspect, carrier (significant) of molecular signification (signified), either sequential, structural, functional, protective, connective, motive, signaling, catalytic, processing, regulating, priming, repressing, releasing, etc.

Biosyntagm An associative configuration of biosemes composed of significant units in a relation of reciprocal solidarity.

Biosynthetic primary pathways Biosynthetic catenary pathways of general occurrence.

Biosystem The expression of the diachronic (evolutionary, hereditary) relations of biomolecules.

Catenary metabolic biosyntagms Biosyntagms composed of chains of enzymes involved in a catabolic or an anabolic metabolic pathway.

Central metabolic biosyntagm A catenary biosyntagm found in the majority of cells and allowing for the acquisition of free energy in the form of ATP high-energy bonds, and for the provision of the starting points of biosynthetic pathways.

Cistron Portion (biosyntagm) of the nucleotide sequence of DNA which provides the sequencing information for a single polypeptide chain.

Coactones Ecomones (see below) active in the process of relationship of an active and directing organism and a passive and receiving organism

Codon A bioseme consisting of three adjacent nucieotides and coding for an amino acid.

Coevolution Evolutionary reciprocal interactions between different kinds of organisms among which there is no exchange of genetic information.

Commutation Radical change of the significant and of the signified of a biomolecule in diachronic epigenesis.

Continuum (biochemical). All molecular aspects of organisms and their molecular extensions.

Diachronic (molecular) epigenesis Diachronic (in the phylogeny of organisms) epigenesis of the synchronic (limited to life span) epigenesis. Results in biomolecular changes along the branches of phylogeny.

Ecomones Non-trophic molecules contributing to insure, in an ecosystem, a flux of information between organisms.

Endocoactones Coactones which are not liberated by the coactor in the environment

Evolution Divergence in the gene pool of populations of organisms, resulting in differential selection, by differential reproduction, of genetic variations in the populations concerned and governed by interaction of population size, migration rate and selection intensity.

Evolution (biochemical) Trivial expression designating the pattern of changes accomplished through diachronic molecular epigenesis along the phylogeny of organisms.

Evolution (molecular) Trivial expression including chemical (prebiological) evolution and biochemical evolution (see above).

Exocoactones Coactones liberated in the medium by a coactor and reaching the coactee.

Heteropolymer Quaternary biosyntagm resulting from the association of different tertiary biosyntagms.

Heterotypic expression Insertion of a bioseme in a new catenary biosyntagm.

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Chapter 16
Form, Substance and Difference

Gregory Bateson (1904–1980)

Introduction and Commentary: Gregory Bateson

> *The elementary cybernetic system with its messages in circuit is, in fact, the simplest unit of mind; and the transform of a difference travelling in a circuit is the elementary idea. . . .The way to delineate the system is to draw the limiting line in such a way that you do not cut any of these pathways in ways which leave things inexplicable.*
>
> G. Bateson (1972: 465)

"[My father's] intellectual path did not fit neatly within any familiar discipline," writes cultural anthropologist Mary Catherine Bateson (1938–), daughter of polymath Gregory Bateson and anthropologist Margaret Mead – and the person upon whom the precocious child interlocutor featured in Bateson's Socratic-style "meta-logue" analyses is modeled. Anthropologist, zoologist, social psychologist, biologist, epistemologist, systems theorist, communications theorist and ecologist, Gregory Bateson "grew up in a household focused on natural history, most especially on the debates surrounding evolution and genetics," writes Mary Catherine, "and was oriented from birth towards science" (2000: vii).

Born on May 9, 1904, Gregory Bateson was the third son of the legendary geneticist William Bateson (1861–1926), the man who introduced modern science to the work of Gregory Mendel, and whose own research into the phenomena of variation and discontinuity within the natural processes of evolution – which entailed an iconoclastic challenging of the biometric reductionsism of his day – exerted a lifelong influence on Gregory's turn of mind (Forsdyke 2009, Lipset 1982: 142–159). "We commonly think of animals and plants as *matter*," wrote the elder Bateson, foreshadowing some of his son's later preoccupations, "but they are really *systems*, through which matter is continually passing" (1928: 209).[1]

The making of such distinctions as that between the material substrata of living systems and the constitutive relations which alone make such systems *living* systems would become a hallmark of Gregory's lifelong attempt to delineate the relations in which organismic "knowing" can have arisen from, and does yet find its

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[1] Writing in 1971, at age sixty-five, Gregory Bateson would dedicate what would become his most famous work, the collection of essays entitled *Steps to an Ecology of Mind*, in part to: "William Bateson, my father, who was certainly ready in 1894 to receive the cybernetic idea" (1972: xxii).

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rightful place in, the natural world. Convinced that a naturalistic account of "mind" can only be intelligently undertaken from the bringing together of a multiplicity of perspectives, and anticipating by decades both the feasibility and the necessity of "interdisciplinary" research, "it was yet not clear for many years, even to Gregory," recounts his daughter, "that his disparate, elegantly crafted and argued essays [on such topics as bilateral symmetry, alcoholism, animal communication and cultural epistemology] were about a single subject" (2000: viii).

Obtaining, characteristically, a Bachelor of Science Degree in Natural Science (with a concentration in zoology) from Cambridge University in 1925 – as well as a Master's Degree in Anthropology from that same institution five years later, Bateson also conducted anthropological fieldwork studying the Baining and Sulka tribes of New Britain from 1927 to 1928. His first fieldwork in New Guinea was an investigation of the social lives of the Iatmul people, which he undertook from 1929 to 1930. Subsequent to his graduation from Cambridge in 1930, Bateson returned to New Guinea to conduct further fieldwork in 1932, there meeting the American anthropologist Margaret Mead (1901–1978), to whom he would later be married from 1936 to 1950.

Naven, the book in which Bateson recounts his fieldwork with the Iatmul, was published in 1936. A groundbreaking work that contains the seeds of many of Bateson's later fully-developed ideas about double description, logical typing, and the presence of systemic interactions within a circular social system that constrain potential feedback runaway states (i.e., schismogenesis),[2] *Naven*, Bateson writes in its Epilogue, is a book as much about the nature of deriving "explanations" from "data" *per se* (whether done by anthropologists, scientists or everyday people) than it is a conventional "anthropological study" (1936 [1958]: 280–303). Notes Bateson biographer and biosemiotic scholar Peter Harries-Jones:

> At the time, theories of functionalism provided a formula enabling anthropologists to write systematic accounts of local culture without worrying too much about the relations beween subject and object, self and other, observer and the observed. By contrast, *Naven*, as its subtitle – *A Survey of the Problems Suggested by a Composite Picture of the Culture of a New Guinea Tribe Drawn from Three Points of View* – indicates, took the relationship of observer to observed as its central focus. Naven discusses how ethnographic method gave rise to "fallacies of misplaced concreteness" – a term Bateson borrowed from the English philosopher Alfred North Whitehead – that derive from hiding points of view [*as* 'points of view' – both others' and one's own – from oneself in one's explanations] and treating them instead as scientific data (1998: 64).

This concern with the careful delineation of interdependent and multiply-embedded semiotic phenomena so as to avoid epistemological error

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[2] The cybernetic concept of "feedback" had not yet been formally developed at the time that Bateson was writing *Naven* in 1936 (cf., though, Uexküll 1928), and Bateson credits his later reception of the idea through the work of Warren McCulloch in 1942 as a turning-point in the development of his understanding.

would prove to be a driving force in Bateson's later work in psychology, philosophy, evolutionary theory and ecology – work which can be increasingly characterized as "biosemiotic", or at least "proto-biosemiotic", as we shall see.

From 1936 to 1938, Bateson and Mead conducted fieldwork together in Bali, pioneering the use of motion-picture photography as an ethnographic medium. The product of this work was their co-authored 1942 volume entitled *Balinese Character.*[3] In 1939, Bateson and Mead returned to United States, where Bateson worked as Anthropological Film Analyst analyzing German propaganda films at the Museum of Modern Art in New York from 1942 to 1943, and for the United States Office of Strategic Services in Southeast Asia – where he occupied posts in Ceylon, India, and Burma from 1943 to 1945. As Bateson scholar Peter Harries-Jones notes, Bateson rarely supported himself with university teaching positions or full-time academic affiliation, but instead financed almost his entire career with research grants allowing him to pursue his interests – and by so doing achieved a degree of multidisciplinary sophistication that is still all too rare in academia (2008: p.c.).

"In 1942," recalls Bateson, "at a Macy Foundation conference, I met Warren McCulloch and Julian Bigelow, who were then talking excitedly about *feedback*" (1972: xix). Bigelow (1913–2003), then an electrical engineer, had been working with Norbert Wiener (1894–1964) at MIT on the development of automatic anti-aircraft defence systems that could track moving targets and adjust their own aim and firing positions accordingly. Given that this project, by its very nature, investigated the recursive relations of information and communication, signals and response, Wiener would later coin the term *cybernetics* (from the Greek word for "governor") to denote "the entire field of control and communication theory, whether in the machine or in the animal" for which such "signal science" would have applicability (1948: 11). Over time, biologists such as Warren McCulloch (1898–1969) and mathematicians such as Walter Pitts (1923–1969) would advance such cybernetic research into the newly-developing fields of cognitive science, computer engineering and artificial intelligence.

"The writing of *Naven* had brought me to the very edge of what later became *cybernetics*, but I lacked the concept of negative feedback," recalls Bateson, "[and so] when I returned from overseas after the war, I went to Frank Freemont-Smith of the Macy Foundation to ask for a conference on this then-mysterious matter. Frank said that he had just arranged such a conference with McCulloch as chairman. It thus happened that I was privileged to be a member of the famous Macy Conferences on Cybernetics" (1972: xix–xx). Convened as an interdisciplinary working group of accomplished mathematicians, biologists, engineers, and anthropologists, the Macy

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[3] The onset of World War II had made it difficult for scholars such as Mead to publish their research findings in a timely fashion in academic journals, and *Balinese Character* is in many ways more Mead's own summative analysis of her findings than it is a true intellectual collaboration with Bateson, whose central role in the project was to devise effective, unintrusive, and scientifically responsible methods of filming naturally occurring social interaction, notes Peter Harries-Jones (2009: p.c.).

Conferences on Cybernetics consisted of a series of ten conferences, held in various locations in the United States during the period 1946–1953, and was dedicated to such topics as self-organization in neural networks, homeostasis and learning, information theory and *Gestalt* psychology, and social and linguistic constructions of the "self" (Pias 2003).

Bateson would later recount his participation in these conferences as "one of the greatest events of my life" (Brockman 1977: 10), and averring that "my debt to Warren McCulloch, Norbert Wiener, John von Neumann, Evelyn Hutchinson and other members of these conferences is evident in everything that I have written since World War II" (1972: xx).

It would be to fundamentally misunderstand Bateson and his work to infer from this statement, however, that "Bateson is a mechanist who supports a technical, computer-oriented approach to ecological order" cautions Peter Harries-Jones, when, in fact, "the opposite is the case: far from being a mechanist, Bateson became the single most committed reformer of cybernetics . . .[as well as] its most trenchant critic [who] thoroughly and continually opposed its dominant face of determinism and control" (1995: 104–105).

Whereas for mechanically oriented cyberneticians such as Shannon and Wiener, the concept of "information" entailed the reduction of uncertainty and the elimination of noise within a channel (Shannon and Weaver 1949; Wiener 1973), for Bateson, "information" consists precisely in the detection of, and adaptation to, the manifold of patterns (and, equally importantly: to the patterns of patterns) present in the "noise" that is the source of the "transforms of experience" (1972: 465). Bateson's view was the foundation for what would retrospectively come to be labeled "second-order cybernetics", and the differences between this view and the mechanical "first-order cybernetics" born out the study of electro-mechanical servo-mechanisms are numerous and profound.

In a passage exemplifying the difference in the two approaches, Bateson observes that:

> In a computer, which works by cause and effect, with one transistor triggering another, the sequences of cause and effect are used to simulate logic. Thirty years ago, we used to ask: Can a computer simulate all the processes of logic? The answer was yes, but the question was surely wrong. We should have asked: Can *logic* simulate *all sequences of cause and effect*? The answer would have been no. (1979: 58)

The world in which organisms find themselves – and the world in which such things as "organisms" themselves have come to be – is not the world of the mechanical engineering theorists, wherein "signals" can deterministically cause, or even unambiguously "point to" independently existing states of being in the world. Such a conception assumes a Cartesian subject-object duality that would make biological evolution impossible to explain naturalistically. Instead, it smuggles a God-like (or mechanical engineer-like) "controller" into the explanation of even the most apparently "self-organizing" and "self-regulating" systems, and endows the concept of "information" with an almost phlogiston-like quality that can inhere in "things" like neuronal and electrical impulses.

Bateson, by contrast, saw that cybernetic theory implied that "information" itself was a fundamentally *relational* concept – i.e., a "difference" between states of being that existed not "in itself", but only such as was registered *as* relevant to the workings of a given system *by* that very system at a given moment (1979: 79). This move from a "third-person" cybernetic view to one wherein the configuration of a system that has been made "ready to receive" *a* as indicating *b* in context *c* under conditions *d* at a temporally co-ordinated time *e* makes relevant as areas of scientific investigation whole swathes of biological reality ignored by "command-and-control" cybernetics, such as higher-order learning, context, ambiguity, purpose, adaptive discontinuity, creative communication, and the critical importance of "relationship" *per se* in the systemic holism of biological interaction and recursion.

"Learning" – in the very broadest sense of the term: the active bringing into being of such relations – thus underlies the processes common to both evolutionary adaptation and cultural adaptation, concluded Bateson. And so, to investigate the processes of both adaptive and maladaptive learning across the widest possible spectrum of manifestation, Bateson undertook a series of outwardly-appearing "disparate" research projects involving monkeys, dogs, otters, dolphins, octopi, as well as human schizophrenics, alcoholics and families.

This research took place at a variety of institutes and under a variety of sponsorships, including the Langley-Porter Psychiatric Clinic in San Fransciso (1949–1951), the Veterans Administration Hospital in Palo Alto, California under the aegis of the University of California Medical School (1949–1950), Stanford University (1951–1962), the Virgin Islands Communications Research Institute (1963–1964), and the Oceanic Institute in Waimanalo, Hawaii (1964–1972), and resulted in a number of Bateson's most famous papers on communication, psychological disorder, epistemology, family dynamics, evolutionary and cultural adaptation, and animal communication – papers which introduced such key Batesonian concepts as *logical typing, heterarchy of recursion, double description, metacommunication, deutero-learning, double-bind epistemology,* and the insistance upon clear explanatory distinctions between the concepts of *map* and *territory*, *creatura* and *pleroma*, and *analogue* and *digital* coding.

By 1972, it was clear to Bateson – if not to many others – that the disparate findings of his seemingly "scattered" research agenda did, in fact, add up to a coherent whole. As his research assistants at the time recall, the reason that the research projects, when seen together as a list on paper, appeared "all over the place" was because that which was being examined was, in fact "all over the place" – or ubiquitous – in the natural world (Wilder and Weakland 1981: 46). This ubiquity consists in the irreducibly interactional processes whereby any system capable of learning by trial and error can adapt itself to an ever-changing world that its own actions help to constitute, as well as to further change. In the broadest way possible of understanding such processes, Bateson finally characterized them, in 1972, as together constituting an "ecology of mind."

Accordingly, Bateson entitled the collection of his twenty years worth of essays considering these processes, *Steps to an Ecology of Mind* – choosing the word "steps" to indicate the he, like so many of the authors whose work appears in this volume, considered his own life's work at best a prolegomena to a more fully developed science of the future. However, even though it is a collection of essays selected, ordered and commented on by Bateson himself in the effort to make evident the connections between the ideas contained therein, *Steps to an Ecology of Mind* does not offer up its conclusions in a straightforward manner, nor does one exhaust its labyrinthine depths of insight and suggestive possibilities in a single – or even in a dozen – readings.

The publication of *Steps to an Ecology of Mind* did, however, establish Gregory Bateson as an original and important thinker, one whose *sui generis* analyses of the systemic relations underlying both nature and culture would prove to be a formative influence on a generation of interdisciplinary thinkers – not least among these being the biosemioticians Jesper Hoffmeyer, Terrence Deacon, Luis Bruni and Søren Brier. Indeed, at a 2004 conference convened by Hoffmeyer to commemorate the centenary of Gregory Bateson's birth, interdisciplinary scholars from around the world presented the results of their own Bateson-inspired work in biology, anthropology, psychology, systems theory, linguistics and ecology. The title of the conference (and the sub-title of the proceedings which have since been published) was *Gregory Bateson as a Precursor to Biosemiotics* – and according to Mary Catherine Bateson, who delivered its plenary lecture, both the conference as well as the project of biosemiotics itself constitute exactly the kind of mutually engaged dialogue between scientists and humanists that her father devoted his entire life both advocating and exemplifying.

Gregory Bateson died on July 4th, 1980 at the Esalen Institute in Northern California, two years after his retirement as a Professor of Anthropology and Ethnology at the University of California in Santa Cruz. Having further developed the ideas of *Steps to an Ecology of Mind* in his 1979 monograph *Mind and Nature: A Necessary* Unity, and working constantly on what would later be issued as the posthumous volumes *Angels Fear* (co-authored by Mary Catherine Bateson) and *A Sacred Unity* (co-authored by Rodney Donaldson), Bateson struggled throughout his life to develop and articulate his unique ecological vision – one which refused to rest content within the pre-given paradigms and received disciplinary frameworks of his time. It may not be too presumptuous to suppose, then, that Gregory Bateson would have looked favourably upon the project of biosemiotics that is just now coming into being, whether or not he would have agreed with all of its particular posits.

In the selection that follows, Bateson presents to a heterogeneous audience of scholars an introductory overview of some of his most foundational ideas: the distinction between systems capable of drawing distinctions, and therefore, of knowing (*creatura*) as compared to systems of purely mechanical interaction which have not attained such capabilities (*pleroma*); the difference between representation (e.g., a *map*) and that which exists independent of such representation (e.g., the *territory* that such maps are attempting to depict); and the nature of "difference" *per se* and its relation to the concept of "mind." As such, this selection provides an excellent *entrée* into the thought of Gregory Bateson for those encountering his work for the first time – just as it continues to serve as a rich vein of insight for those now seeking to build upon these ideas in the ongoing development of biosemiotics.

Form, Substance and Difference (1972)

Let me say that it is an extraordinary honor to be here tonight, and a pleasure. I am a little frightened of you all, because I am sure there are people here who know every field of knowledge that I have touched much better than I know it. It is true that I have touched a number of fields, and I probably can face any one of you and say I have touched a field that you have not touched. But I am sure that for every field I have touched, there are people here who are much more expert than I. I am not a well-read philosopher, and philosophy is not my business. I am not a very well read anthropologist, and anthropology is not exactly my business.

But I have tried to do something which Korzybski was very much concerned with doing, and with which the whole semantic movement has been concerned, namely, I have studied the area of impact between very abstract and formal philosophic thought on the one hand and the natural history of man and other creatures on the other. This overlap between formal premises and actual behavior is, I assert, of quite dreadful importance today. We face a world which is threatened not only with disorganization of many kinds, but also with the destruction of its environment, and we, today, are still unable to think clearly about the relations between an organism and its environment. What sort of a thing is this, which we call "organism *plus* environment?"

Let us go back to the original statement for which Korzybski is most famous-the statement that *the map is not the territory*. This statement came out of a very wide range of philosophic thinking, going back to Greece, and wriggling through the history of European thought over the last 2,000 years. In this history, there has been a sort of rough dichotomy and often deep controversy. There has been a violent enmity and bloodshed. It all starts, I suppose, with the Pythagoreans versus their predecessors, and the argument took the shape of, "Do you ask what it's *made of*– earth, fire, water, etc.?" Or do you ask, "What is its *pattern*?"

Pythagoras stood for inquiry into *pattern* rather than inquiry into *substance*.[2] That controversy has gone through the ages, and the Pythagorean half of it has, until recently, been, on the whole, the submerged half. The Gnostics followed the Pythagoreans, and the alchemists follow the Gnostics, and so on. The argument reached a sort of climax at the end of the 18th century when a Pythagorean evolutionary theory was built and then discarded – a theory which involved *mind.*

The evolutionary theory of the late 18th century, the Lamarckian theory, which was the first organized transformist theory of evolution, was built out of a curious historical background which has been described by Lovejoy in *The Great Chain of Being*. Before Lamarck, the organic world, the living world, was believed to be hierarchic in structure, with Mind at the top. The chain, or ladder, went down through

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[As noted in the original,[1] this chapter is a transcript of the 19th Annual Alfred Korzybski Memorial Lecture that Gregory Bateson delivered at the Oceanic Institute in Hawaii on January 9, 1970.]

the angels, through men, through the apes, down to the infusoria or protozoa, and below that to the plants and stones.

What Lamarck did was to turn that chain upside down. He observed that animals changed under environmental pressure. He was incorrect, of course, in believing that those changes were inherited, but, in any case, these changes were for him the evidence of evolution. When he turned the ladder upside down, what had been the explanation, namely, the Mind at the top, now became that which had to be explained. His problem was to explain "mind." He was convinced about evolution, and there his interest in it stopped. So that if you read the *Philosophie Zoologique* (1809), you will find that the first third of it is devoted to solving the problem of evolution and the turning upside down of the taxonomy, and the rest of the book is really devoted to comparative psychology, a science which he founded. Mind was what he was really interested in. He had used habit as one of the axiomatic phenomena in his theory of evolution, and this of course also took him into the problem of comparative psychology.

Now the status of mind and pattern as the explanatory principles which, above all, required investigation was pushed out of biological thinking in the later evolutionary theories which were developed in the mid-19th century by Darwin, Huxley, etc. There were still some naughty boys, like Samuel Butler, who said that mind could not be ignored in this way – but they were weak voices, and incidentally, they never looked at organisms. I don't think Butler ever looked at anything except his own cat, but he still knew more about evolution than some of the more conventional thinkers.

Now, at last, with the discovery of cybernetics, systems theory, information theory, and so on, we begin to have a formal base enabling us to think about mind and enabling us to think about all these problems in a way which was totally heterodox from about 1850 through World War II. What I have to talk about is how the great dichotomy of epistemology has shifted under the impact of cybernetics and information theory.

We can now say – or at any rate, can begin to say – what we think a "mind" *is*. In the next 20 years there will be other ways of saying it and, because the discoveries are new, I can only give you my personal version. The old versions are surely wrong, but which of the revised pictures will survive, we do not know.

Let us start from the evolutionary side. It is now empirically clear that Darwinian evolutionary theory contained a very great error in its identification of the unit of survival under natural selection. The unit which was believed to be crucial and around which the theory was set up was either the breeding individual or the family line or the subspecies or some similar homogeneous set of conspecifics. Now I suggest that the last 100 years have demonstrated empirically that if an organism or aggregate of organisms sets to work with a focus on its own survival and thinks that that is the way to select its adaptive moves, its "progress" ends up with a destroyed environment. If the organism ends up destroying its environment, it has in fact destroyed itself. And we may very easily see this process carried to its ultimate *reductio ad absurdum* in the next 20 years. The unit of survival is not the breeding organism, or the family line, or the society.

The old unit has already been partly corrected by the population geneticists. They have insisted that the evolutionary unit is, in fact, not homogeneous. A wild population of any species consists always of individuals whose genetic constitution varies widely. In other words, potentiality and readiness for change is already built into the survival unit. The heterogeneity of the wild population is already one half of that trial-and-error system which is necessary for dealing with the environment. The artificially homogenized populations of man's domestic animals and plants are scarcely fit for survival. And today a further correction of the unit is necessary. The flexible environment must also be included along with the flexible organism because, as I have already said, the organism which destroys its environment destroys itself.

The unit of survival is a flexible organism-in-its-environment.

Now, let me leave evolution for a moment to consider what is the unit of mind. Let us go back to the map and the territory and ask: what is it in the territory that gets onto the map? We know the territory does not get onto the map. That is the central point about which we here are all agreed. Now, if the territory were uniform, nothing would get onto the map except its boundaries, which are the points at which it ceases to be uniform against some larger matrix. What gets onto the map, in fact, is *difference*, be it a difference in altitude, a difference in vegetation, a difference in population structure, difference in surface, or whatever. Differences are the things that get onto a map.

But what is a difference? A difference is a very peculiar and obscure concept. It is certainly not a thing or an event. This piece of paper is different from the wood of this lectern. There are many differences between them-of color, texture, shape, etc. But if we start to ask about the localization of those differences, we get into trouble. Obviously the difference between the paper and the wood is not in the paper; it is obviously not in the wood; it is obviously not in the space between them, and it is obviously not in the time between them. (Difference which occurs across time is what we call "change.")

A difference, then, is an abstract matter.

In the hard sciences, effects are, in general, caused by rather concrete conditions or events-impacts, forces, and so forth. But when you enter the world of communication, organization, etc., you leave behind that whole world in which effects are brought about by forces and impacts and energy exchange. You enter a world in which "effects" – and I am not sure one should still use the same word – are brought about by *differences*. That is: they are brought about by the sort of "thing" that gets onto the map from the territory. This is difference.

Difference travels from the wood and paper into my retina. It then gets picked up and worked on by this fancy piece of computing machinery in my head.

The whole energy relation is different. In the world of mind, nothing-that which is *not*-can be a cause. In the hard sciences, we ask for causes and we expect them to exist and be "real." But remember that zero is different from one, and because is different from one, zero can be a cause in the psychological world, the world of communication. The letter which you do not write can get an angry reply; and the income tax form which you do not fill in can trigger the Internal Revenue boys into energetic action, because they, too, have their breakfast, lunch, tea and dinner and can react with energy which they derive from their metabolism. The letter which never existed is no source of energy.

It follows, of course, that we must change our whole way of thinking about mental and communicational process. The ordinary analogies of energy theory which people borrow from the hard sciences to provide a conceptual frame upon which they try to build theories about psychology and behavior-that entire Procrustean structure-is non-sense. It is in error.

I suggest to you, now, that the word "idea," in its most elementary sense, is synonymous with "difference." Kant, in the *Critique of Judgment*-if I understand him correctly – asserts that the most elementary aesthetic act is the selection of a fact. He argues that in a piece of chalk there are an infinite number of potential facts. The *Ding an sich*, the piece of chalk, can never enter into communication or mental process because of this infinitude. The sensory receptors cannot accept it; they filter it out. What they do is to select certain *facts* out of the piece of chalk, which then become, in modern terminology, information.

I suggest that Kant's statement can be modified to say that there is an infinite number of *differences* around and within the piece of chalk. There are differences between the chalk and the rest of the universe, between the chalk and the sun or the moon. And within the piece of chalk, there is for every molecule an infinite number of differences between its location and the locations in which it *might* have been. Of this infinitude, we select a very limited number-which become information. In fact, what we mean by information-the elementary unit of information-is a *difference which makes a difference*, and is able to make a difference because the neural pathways, along which it travels and is continually transformed, are themselves provided with energy. The pathways are ready to be triggered. We may even say that the question is already implicit in them.

There is, however, an important contrast between most of the pathways of information inside the body and most of the pathways outside it. The differences between the paper and the wood are first transformed into differences in the propagation of light or sound and travel in this form to my sensory end organs. The first part of their journey is energized in the ordinary hard-science way, from "behind." But when the differences enter my body by triggering an end organ, this type of travel is replaced by travel which is energized at every step by the metabolic energy latent in the protoplasm which *receives* the difference, recreates or transforms it, and passes it on.

When I strike the head of a nail with a hammer, an impulse is transmitted to its point. But it is a semantic error, a misleading metaphor, to say that what travels in an axon is an "impulse." It could correctly be called "news of a difference."

Be that as it may, this contrast between internal and external pathways is not absolute. Exceptions occur on both sides of the line. Some external chains of events are energized by relays, and some chains of events internal to the body are energized from "behind." Notably, the mechanical interaction of muscles can be used as a computational model.[3]

In spite of these exceptions, it is still broadly true that the coding and transmission of differences outside the body is very different from the coding and transmission inside, and this difference must be mentioned because it can lead us into error. We commonly think of the external "physical world" as somehow separate from an internal "mental world." I believe that this division is based on the contrast in coding and transmission inside and outside the body.

The mental world-the mind-the world of information processing-is not limited by the skin.

Let us now go back to the notion that the transform of a difference traveling in a circuit is an elementary idea. If this be correct, let us ask what a mind is. We say the map is different from the territory. But what is the territory? Operationally, somebody went out with a retina or a measuring stick and made representations which were then put upon paper. What is on the paper map is a representation of what was in the retinal representation of the man who made the map: and as you push the question back, what you find is an infinite regress, an infinite series of maps. The territory never sets in at all. The territory is *Ding an sich* and you can't do anything with it. Always the process of representation will filter it out so that the mental world is only maps of maps of maps, ad infinitum.[4] All "phenomena" are literally "appearances."

Or we can follow the chain forward. I receive various sorts of mappings which I call data or information. Upon receipt of these I act. But my actions, my muscular contractions, are transforms of differences in the input material. And I receive again data which are transforms of my actions. We get thus a picture of the mental world which has somehow jumped loose from our conventional picture of the physical world.

This is not new, and for historic background we go again to the alchemists and Gnostics. Carl Jung once wrote a very curious little book, which I recommend to all of you. It is called *Septem Sermones ad Mortuos*, Seven Sermons to the Dead.[5] In his *Memories, Dreams, Reflections*, Jung tells us that his house was full of ghosts, and they were noisy. They bothered him, they bothered his wife, and they bothered the children. In the vulgar jargon of psychiatry we might say that everybody in the house was as psychotic as hooty owls, and for quite good reason. If you get your epistemology confused, you go psychotic, and Jung was going through an epistemological crisis. So he sat down at his desk and picked up a pen and started to write. When he started to write the ghosts all disappeared, and he wrote this little book. From this he dates all his later insight. He signed it "Basilides," who was a famous Gnostic in Alexandria in the 2nd century.

He points out that there are two worlds. We might call them two worlds of explanation. He names them the *pleroma* and the *creatura*, these being Gnostic terms. The pleroma is the world in which events are caused by forces and impacts and in which there are no "distinctions." Or, as I would say, no "differences." In the creature, effects are brought about precisely by difference. In fact, this is the same old dichotomy between mind and substance.

We can study and describe the pleroma, but, always, the distinctions which we draw are attributed *by us* to the pleroma. The pleroma knows nothing of difference and distinction; it contains no "ideas" in the sense in which I am using the word. When we study and describe the creatura, we must correctly identify those differences which are effective within it.

I suggest that “pleroma” and “creatura” are words which we could usefully adopt and it is therefore worthwhile to look at the bridges which exist between these two “worlds.” It is an oversimplification to say that the “hard sciences” deal only with the pleroma and that the sciences of the mind deal only with creatura.

There is more to it than that.

First, consider the relation between energy and negative entropy. The classical Carnot heat engine consists of a cylinder of gas with a piston. This cylinder is alternately placed in contact with a container of hot gas and with a container of cold gas. The gas in the cylinder alternately expands and contracts as it is heated or cooled by the hot and cold sources. The piston is thus driven up and down.

But with each cycle of the engine, the *difference* between the temperature of the hot source and that of the cold source is reduced. When this difference becomes zero, the engine will stop.

The physicist, describing the pleroma, will write equations to translate the temperature difference into “available energy,” which he will call “negative entropy,” and will go on from there.

The analyst of the creatura will note that the whole system is a sense organ which is triggered by temperature difference. He will call this difference which makes a difference “information” or “negative entropy.” For him, this is only a special case in which the effective difference happens to be a matter of energetics. He is equally interested in all differences which can activate some sense organ. For him, any such difference is “negative entropy.”

Or consider the phenomenon which the neurophysiologists call “synaptic summation.” What is observed is that in certain cases, when two neurons, A and B have synaptic connection to a third neuron, C the firing of neither neuron by itself is sufficient to fire C; but that when both A and B fire simultaneously (or nearly so), their combined “impulses” will cause C to fire.

In pleromatic language, this combining of events to surmount a threshold is called “summation.”

But from the point of view of the student of creatura (and the neurophysiologist must surely have one foot in the pleroma and the other in creatura), this is not summation at all. What happens is that the system operates to create differences. There are two differentiated classes of firings by A: those firings which are accompanied by B and those which are unaccompanied. Similarly there are two classes of firings by B.

The so-called “summation,” when both fire, is not an additive process from this point of view. It is the formation of a logical products-a process of fractionation rather than summation.

The creatura is thus the world seen as mind, wherever such a view is appropriate. And wherever this view is appropriate, there arises a species of complexity which is absent from pleromatic description: creatural description is always hierarchic.

I have said that what gets from territory to map is transforms of difference and that these (somehow selected) differences are elementary ideas.

But there are differences between differences.

Every effective difference denotes a demarcation, a line of classification, and all classification is hierarchic. In other words, differences are themselves to be differentiated and classified.

In this context I will only touch lightly on the matter of classes of difference, because to carry the matter further would land us in problems of Principlia Mathematica.

Let me invite you to a psychological experience, if only to demonstrate the frailty of the human computer. First note differences in texture are *different (a)* from differences in color. Now note that differences in size are *different (b)* from differences in shape. Similarly ratios are *different (c)* from subtractive differences.

Now let me invite you, as disciples of Korzybski, to define the differences between "*different (a),*" "*different (b)*," and "*different (c)*" in the above paragraph.

The computer in the human head boggles at the task.

But not all classes of difference are as awkward to handle.

One such class you are all familiar with. Namely, the class of differences which are created by the process of transformation whereby the differences immanent in the territory become differences immanent in the map. In the corner of every serious map you will find these rules of transformation spelled out-usually in words. Within the human mind, it is absolutely essential to recognize the differences of this class, and, indeed, it is these that form the central subject matter of *Science and Sanity*.

An hallucination or a dream image is surely a transformation of something. But of what? And by what rules of transformation?

Lastly there is that hierarchy of differences which biologists call "levels." I mean such differences as that between a cell and a tissue, between tissue and organ, organ and organism, and organism and society.

These are the hierarchies of units or Gestalten, in which each sub-unit is a part of the unit of next larger scope. And, always in biology, this difference or relationship which I call "part of " is such that certain differences in the part have informational effect upon the larger unit, and vice versa.

Having stated this relationship between biological part and whole, I can now go on from the notion of creatura as Mind in general to the question of what is a mind.

What do I mean by "my" mind?

I suggest that the delimitation of an individual mind must always depend upon what phenomena we wish to understand or explain. Obviously there are lots of message pathways outside the skin, and these and the messages which they carry must be included as part of the mental system whenever they are relevant.

Consider a tree and a man and an axe. We observe that the axe flies through the air and makes certain sorts of gashes in a pre-existing cut in the side of the tree. If now we want to explain this set of phenomena, we shall be concerned with differences in the cut face of the tree, differences in the retina of the man, differences in his central nervous system, differences in his efferent neural messages, differences in the behavior of his muscles, differences in how the axe flies, to the differences which the axe then makes on the face of the tree. Our explanation (for certain purposes) will go round and round that circuit. In principle, if you want to explain or understand anything in human behavior, you are always dealing with total circuits, completed circuits. This is the elementary cybernetic thought.

The elementary cybernetic system with its messages in circuit is, in fact, the simplest unit of mind; and the transform of a difference travelling in a circuit is the elementary idea. More complicated systems are perhaps more worthy to be called mental systems, but essentially this is what we are talking about. The unit which shows the characteristic of trial and error will be legitimately called a mental system.

But what about "me"? Suppose I am a blind man, and I use a stick. I go tap, tap, tap. Where do *I* start? Is my mental system bounded at the handle of the stick? Is it bounded by my skin? Does it start halfway up the stick? Does it start at the tip of the stick? But these are nonsense questions. The stick is a pathway along which transforms of difference are being transmitted. The way to delineate the system is to draw the limiting line in such a way that you do not cut any of these pathways in ways which leave things inexplicable. If what you are trying to explain is a given piece of behavior, such as the locomotion of the blind man, then, for this purpose, you will need the street, the stick, the man; the street, the stick, and so on, round and round.

But when the blind man sits down to eat his lunch, his stick and its messages will no longer be relevant-if it is his eating that you want to understand.

And in addition to what I have said to define the individual mind, I think it necessary to include the relevant parts of memory and data "banks." After all, the simplest cybernetic circuit can be said to have a memory of a dynamic kind-not based upon static storage but upon the travel of information around the circuit. The behavior of the governor of a steam engine at Time 2 is partly determined by what it did at Time 1 – where the interval between Time I and Time 2 is that time necessary for the information to complete the circuit.

We get a picture, then, of mind as synonymous with cybernetic systemthe relevant total information-processing, trial-and-error completing unit. And we know that within Mind in the widest sense there will be hierarchy of sub-systems, any one of which we can call an individual mind.

But this picture is precisely the same as the picture which I arrived at in discussing the *unit of evolution*. I believe that this identity is the most important generalization which I have to offer you tonight.

In considering units of evolution, I argued that you have at each step to include the completed pathways outside the protoplasmic aggregate, be it DNA-in-the-cell, or cell-in-the-body, or body-in-the-environment. The hierarchic structure is not new. Formerly we talked about the breeding individual or the family line or the taxon, and so on. Now each step of the hierarchy is to be thought of as a *system*, instead of a chunk cut off and visualized as *against* the surrounding matrix.

This identity between the unit of mind and the unit of evolutionary survival is of very great importance, not only theoretical, but also ethical.

It means, you see, that I now localize something which I am calling "Mind" immanent in the large biological system-the ecosystem. Or, if I draw the system boundaries at a different level, then mind is immanent in the total evolutionary structure. If this identity between mental and evolutionary units is broadly right, then we face a number of shifts in our thinking.

First, let us consider ecology. Ecology has currently two faces to it: the face which is called bio-energetics-the economics of energy and materials within a coral reef, a redwood forest, or a city-and, second, an economics of information, of entropy, neg-entropy, etc. These two do not fit together very well precisely because the units are differently bounded in the two sorts of ecology. In bio-energetics it is natural and appropriate to think of units bounded at the cell membrane, or at the skin; or of units composed of sets of conspecific individuals. These boundaries are then the frontiers at which measurements can be made to determine the additive-subtractive budget of energy for the given unit. In contrast, informational or entropic ecology deals with the budgeting of pathways and of probability. The resulting budgets are fractionating (not subtractive.) The boundaries must enclose, not cut, the relevant pathways.

Moreover, the very meaning of "survival" becomes different when we stop talking about the survival of something bounded by the skin and start to think of the survival of the system of ideas in circuit. The contents of the skin are randomized at death and the pathways within the skin are randomized. But the ideas, under further transformation, may go on out in the world in books or works of art. Socrates as a bio-energetic individual is dead. But much of him still lives as a component in the contemporary ecology of ideas.[6]

It is also clear that theology becomes changed and perhaps renewed. The Mediterranean religions for 5,000 years have swung to and fro between immanence and transcendence. In Babylon the gods were transcendent on the tops of hills; in Egypt, there was god immanent in Pharaoh; and Christianity is a complex combination of these two beliefs.

The cybernetic epistemology which I have offered you would suggest a new approach. The individual mind is immanent but not only in the body, It is immanent also in pathways and messages outside the body; and there is a larger Mind of which the individual mind is only a sub-system. This larger Mind is comparable to God and is perhaps what some people mean by "God," but it is still immanent in the total interconnected social system and planetary ecology.

Freudian psychology expanded the concept of mind inwards to include the whole communication system within the body-the autonomic, the habitual and the vast range of unconscious process. What I am saying expands mind outwards. And both of these changes reduce the scope of the conscious self. A certain humility becomes appropriate, tempered by the dignity or joy of being part of something much bigger. A part-if you will-of God.

If you put God aside and set him vis-à-vis his creation and if you have the idea that you are created in his image, you will logically and naturally see yourself as outside and against the things around you. And as you arrogate all mind to yourself, you will see the world around you as mindless and therefore not entitled to moral or ethical consideration. The environment will seem to be yours to exploit. Your survival unit will be you and your folks or conspecifics against the environment of other social units, other races and the brutes and vegetables.

If this is your estimate of your relation to nature *and you have an advanced technology*, your likelihood of survival will be that of a snowball in hell. You will die either of the toxic by-products of your own hate, or, simply, of over-population and over-grazing.

The raw materials of the world are finite.

If I am right, the whole of our thinking about what we are and what other people are has got to be restructured. This is not funny, and I do not know how long we have to do it in. If we continue to operate on the premises that were fashionable in the pre-cybernetic era, and which were especially underlined and strengthened during the Industrial Revolution, which seemed to validate the Darwinian unit of survival, we may have 20 or 30 years before the logical *reductio ad absurdum* of our old positions destroys us. Nobody knows how long we have, under the present system, before some disaster strikes us, more serious than the destruction of any group of nations. The most important task today is, perhaps, to learn to think in the new way. Let me say that *I* don't know how to think that way. Intellectually, I can stand here and I can give you a reasoned exposition of this matter; but if I am cutting down a tree, I still think "Gregory Bateson" is cutting down the tree. *I* am cutting down the tree. "Myself" is to me still an excessively concrete object, different from the rest of what I have been calling "mind."

The step to realizing-to making habitual-the other way of thinking-that one naturally thinks that way when one reaches out for a glass of water or cuts down a tree-that step is not an easy one.

And, quite seriously, I suggest to you that we should trust no policy decisions which emanate from persons who do not yet have that habit.

There are experiences and disciplines which may help me to imagine what it would be like to have this habit of correct thought. Under LSD, I have experienced, as have many others, the disappearance of the division between self and the music to which I was listening. The perceiver and the thing perceived become strangely united into a single entity. And this state is surely more correct than the state in which it seems that "I hear the music." The sound, after all, is *Ding an sich*, but my perception of it is a part of mind.

It is told of Johann Sebastian Bach that when somebody asked him how he played so divinely, he answered, "I play the notes, in order, as they are written. It is God who makes the music." But not many of us can claim Bach's correctness of epistemology-or that of William Blake who knew that the Poetic Imagination was the only reality.

The poets have known these things all through the ages, but the rest of us have gone astray into all sorts of false reifications of the "self" and separations between the "self" and "experience."

For me another clue-another moment when the nature of mind was for a moment clear-was provided by the famous experiments of Adalbert Ames, Jr. These are optical illusions in depth perception. As Ames' guinea pig, you discover that those mental processes by which you create the world in three-dimensional perspective are within your mind but totally unconscious and utterly beyond voluntary control. Of course, we all know that this is so-that mind creates the images which "we" then see. But still it is a profound epistemological shock to have direct experience of this which we always knew.

Please do not misunderstand me. When I say that the poets have always known these things or that most of mental process is unconscious, I am not advocating a greater use of emotion or a lesser use of intellect. Of course, if what I am saying tonight is approximately true, then our ideas about the relation between thought and emotion need to be revised. If the boundaries of the "ego" are wrongly drawn or even totally fictitious, then it may be nonsense to regard emotions or dreams or our unconscious computations of perspective as "ego-alien."

We live in a strange epoch when many psychologists try to "humanize" their science by preaching an anti-intellectual gospel. They might, as sensibly, try to physicalize physics by discarding the tools of mathematics.

It is the attempt to *separate* intellect from emotion that is monstrous, and I suggest that it is equally monstrous-and dangerous-to attempt to separate the external mind from the internal. Or to separate mind from body.

Blake noted that "A tear is an intellectual thing," and Pascal asserted that "The heart has its reasons of which the reason knows nothing"; and we need not be put off by the fact that the reasonings of the heart (or of the hypothalamus) are accompanied by sensations of joy or grief. These computations are concerned with matters which are vital to mammals – namely, matters of *relationship*, by which I mean love, hate, respect, dependency, spectatorship, performance, dominance, and so on. These are central to the life of any mammal and I see no objection to calling these computations "thought" – though certainly the units of relational computation are different from the units which we use to compute about isolable things.

But there are bridges between the one sort of thought and the other, and it seems to me that the artists and poets are specifically concerned with these bridges. It is not that art is the expression of the unconscious, but rather that it is concerned with the relation between the levels of mental process. From a work of art it may be possible to analyze out some unconscious thought of the artist, but I believe that, for example, Freud's analysis of Leonardo's "Virgin on the Knees of St. Anne" precisely misses the point of the whole exercise. Artistic skill is the combining of many levels of mind-unconscious, conscious and external-to make a statement of their combination. It is not a matter of expressing a single level.

Similarly, Isadora Duncan, when she said "If I could say it, I would not have to dance it," was talking nonsense, because her dance was about *combinations* of saying and moving.

Indeed, if what I have been saying is at all correct, the whole base of aesthetics will need to be re-examined. It seems that we link feelings not only to the computations of the heart but also to the computations in the external pathways of the mind. It is when we recognize the operations of creatura in the external world that we are aware of "beauty" or "ugliness." The "primrose by the river's brim" is beautiful because we are aware that the combination of differences which constitutes its appearance could only be achieved by information processing, i.e., by thought. We recognize another mind within our own external mind.

And last, there is death. It is understandable that, in a civilization which separates mind from body, we should either try to forget death or to make mythologies about the survival of transcendent mind. But if mind is immanent not only in those pathways of information which are located inside the body but also in external pathways, then death takes on a different aspect. The individual nexus of pathways which I call "me" is no longer so precious because that nexus is only part of a larger mind.

The ideas which seemed to be me can also become immanent in you. May they survive – if true.

Notes

1 A lecture delivered at the 19th Annual Alfred Korzybski Memorial Lecture Series at the Oceanic Institute in Hawaii, on January 9, 1970.

2 R. G. Collingwood has given a clear account of the Pythagorean position in The Idea of Nature (Oxford 1945).

3 It is interesting to note that digital computers depend upon transmission of energy "from behind" to send "news" along wire from one relay to the next. But each relay has its own energy source. Analogic computers, e.g., tide machines and the like, are commonly entirely driven by energy "from behind." Either type of energization can be used for computational purposes.

4 Or we may spell the matter out and say that at every step, as a difference is transformed and propagated along its pathway, the embodiment of the difference before the step is a "territory" of which the embodiment after the step is a "map." The map-territory relation obtains at every step.

5 Written in 1916, translated by H. G. Baynes and privately circulated in 1925. Republished by Stuart & Watkins, London, and by Random House, 1961. In later work, Jung seems to have lost the clarity of the Seven Sermons. In his "Answer to Job," the archetypes are said to be "pleromatic." It is surely true, however, the constellations of ideas may seem subjectively to resemble "forces" when their ideational character is unrecognized.

6 For the phrase "ecology of ideas," I am indebted to Sir Geoffrey Vickers' essay "The Ecology of Ideas" in Value Systems and Social Process (Basic Books 1968). For a more formal discussion of the survival of ideas, see Gordon Pask's remarks in Wenner-Gren Conference on "The Effects of Conscious Purpose on Human Adaptation," 1968.

Chapter 17
The Physics and Metaphysics of Biosemiotics

Howard H. Pattee (1926–)

Introduction and Commentary: Howard H. Pattee

> *I define a symbol in terms of its structure and function. First, a symbol can only exist in the context of a living organism or its artifacts. Life originated with symbolic memory, and symbols originated with life. I find it gratuitous to use the concept of symbol, even metaphorically, in physical systems where no function exists. Symbols do not exist in isolation, but are part of a semiotic or linguistic system.*
>
> H. H. Pattee (2001: 18)

While Thomas A. Sebeok was busy building cross-disciplinary networks in Scandinavia and in eastern Europe during the last half of the twentieth century, back in the West, individual researchers in the fields of neurobiology, clinical psychology, molecular biology, artificial intelligence, and philosophy of mind – as well as a few rare polymaths, such as Gregory Bateson – were independently inaugurating their own attempts at either resolving or undoing the ingrained Cartesian dichotomy separating bodies and minds. One of the few islands of Sebeok-style multidisciplinary collaboration in the West, apart from the Macy Foundation conferences of cybernetics discussed elsewhere in this volume, was the Rockefeller Foundation series of conferences entitled *Towards a Theoretical Biology* that geneticist Conrad Hal Waddington (1905–1975) held in Bellagio, Italy each year from 1966 to 1970, and that attracted such disparate participants as René Thom, Lewis Wolpert, John Maynard Smith, Brian Goodwin, Richard Lewontin, Michael Arbib, Walter Elsasser, David Bohm, Ernst Mayr, Alexander Graham Cairns-Smith and Howard Pattee.

The invitation of Howard Pattee – a physicist whose doctoral research was in X-ray optics – to a conference dedicated to the establishment of a more fully explanatory biology, soon proved eminently justified. For as early as 1963, in a lecture given at *The Second International Conference on The Origins of Prebiological Systems* (featuring, among others Alexander Oparin, J.B.S. Haldane, J.D. Bernal, Norman Pirie, and Sidney Fox), Pattee was forecasting to anyone in the scientific community who was prescient enough to listen, that with the discovery of the genetic code, science has not so much uncovered a self-evident set of answers to the questions of the origins and organization of life, but instead, whole new set of even

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deeper scientific problems that may not necessarily be amenable to existing perspectives and methodologies. Anticipating his own later "semantic closure" principle at a time when the wave of enthusiasm for genetic reductionism was reaching its peak, Pattee predicted:

> we may expect that the origin of life problem will shift away from the evolution of the building blocks and the elementary operations of joining them together, to the more difficult problem of the *evolution of control* in complex organizations. This problem is more difficult because the idea of 'control' is not defined in the same sense as we can define [the relevant] biochemicals [*per se*]. . .A live cell and a dead collection of the identical biochemicals in the same structural organization differ essentially in the amount of *intermolecular control* that exists in each unit (1965: 405–406).

And in the forty-five years subsequent to the making of that observation, Howard Pattee, perhaps more than any other physicist, has been at the forefront of examining "precisely those dynamical aspects of physics that are necessary to implement codified instructions" (in Umerez 2001) – or, in other words, in seeking an answer to the question: "What are the physics necessary (if not sufficient) for *semiosis*?"

Born in Pasadena, California on October 5, 1926, Howard Hunt Pattee traces the origins of his development as a scientist and as a theoretical biologist to his reading of biometrician Karl Pearson's (1857–1936) 1892 classic *The Grammar of Science*. Therein, Pearson asks rhetorically: *"How, therefore, we must ask, is it possible for us to distinguish the living from the lifeless, if we can describe both conceptually by the motion of inorganic corpuscles?"* (1892 [1937]: 287). Pattee reports that he was no more than 13 years old when he came upon this passage, which he recognized even then as offering not an unanswerable conundrum, but the impetus for a research programme in biophysics – one which Pattee has since pursued, often single-handedly, for his entire life.

Pearson's question and its variants reappear in the questions that Pattee sets for himself: "How does the motion of matter lead to records of this motion?" (1971: 310), "How are universal, inexorable, natural laws related to local, arbitrary symbols?" (2001: 9) "How does a reversible dynamics gradually become an irreversible thermodynamics?" (2005: 283), "What is the simplest possible ecosystem?" (1968: 219), "What does it mean to correlate some aspect of a dynamical law with a timeless structure?" (2005: 285) and "How does a molecule become a message?" (1969: 1) – these are, of course, *biosemiotic* questions all.

Yet long before he would lead a conceptual revolution in biophysics by attempting to work out possible solutions to these questions, Pattee was still working on his PhD in physics in 1949 when he took note of the fact that similar concerns were forcing themselves into the writings of physicists Niels Bohr (1885–1962), Max Delbrück (1906–1981) and Erwin Schrödinger (1887–1961). "None of these distinguished scientists [future Nobel Prize winners all] appeared to have any clear answers to the problem of the relation of physics to life, so I knew that there must be a fundamental problem here" recalls Pattee (2009: p.c.)

"At the time," Pattee recounts elsewhere, "physics and mathematics were inseparable in my mind [. . . which means that] I did not clearly distinguish formal symbolic models from reality" (2001: 8). All that changed, however, with Pattee's reading of mathematician Hermann Weyl's (1885–1955) then just-published *Philosophy of Mathematics and Natural Science* in 1949. "Perhaps the philosophically most relevant feature of modern science is the emergence of *abstract symbolic structures* as the 'hard core of objectivity' behind – as [astrophysicist Arthur Stanley] Eddington puts it – 'the colorful tale' of the subjective 'storyteller' mind" wrote Weyl, in a quote that seems to have awoken Pattee from his youthful and dogmatic mathematical slumber (*ibid*).

By 1953, Pattee had completed his doctoral research at Stanford University, where he was involved in the development of X-ray optics to be used for the study of biological structure. Franklin and Gosling's success in using X-ray diffraction to reveal the physical structure of nucleic acids during this period, and the subsequent revelations regarding the existence of a "genetic code," only confirmed Pattee in his belief that the critical explanatory notion of "information" (as well as its related concepts of prior "measurement" and posterior "records") in molecular biology was at best an empty-at-the-center placeholder, and that a scientific understanding of adaptive evolution would remain incoherent, or essentially 'magical,' Until such terms could be scientifically defined.

From 1961 to 1968, Pattee authored a set of "six dense papers on heredity [wherein] he argues for the presence of some degree of pre-biotic molecular order facilitating the appearance of macromolecular sequences (well before 'self-organization' and 'order for free' ideas began to enjoy any notoriety)" notes Pattee's biographer Jon Umerez (2001: 164). During this period, Pattee also experimented with several self-organizing schemes using "molecular automata" models for generating and replicating situated copolymer sequences through a neural-network-like "training" or "learning" process, in the hopes of discovering the mechanics behind the eventual canalization of "conformation-dependant propagation rules" that come to function as *nonholonomic constraints* upon the system's self-maintaining yet adaptive dynamics (Pattee 1961, 1966).

As a result of this early work in "origin of life" modeling, writes Pattee, "I eventually recognized a fundamental problem in all such rule-based self-organizing schemes, namely, that in so far as the organizing depends on internal fixed rules, the generated structures will have limited potential complexity, and in so far as any novel organizing arises from the outside environment, the novel structures have no possibility of reliable replication without a symbolic memory that could reconstruct the novel organization" (2001: 10). In short, claims Pattee, he came to appreciate the fact that both Karl Pearson's central question of 1892 about the distinction between living and non-living systems, and John von Neumann's observation in 1966 that any possibly evolving self-reproducing automaton would require a non-dynamic description to control its dynamic construction were both instances of "the same general matter-symbol problem: how to bridge the necessary separation between a rule and what it controls, a description and what it describes . . .the observer and the observed, and even the mind and the brain" (2009: p.c., 2001: 10).

From a consideration of these related sets of problems, Pattee arrives, by 1968, at the first of his life's work organizing principles: the articulation that "an *epistemic cut* is required for [the organic functioning of] all dynamical laws" operative in the construction and maintenance of any living system (1969a). Pattee's "cut" is not just the operational concession made by the early 20th-century quantum physicists, however (though that cut may be seen as yet another "special case" of the more general phenomenon). Rather, writes Pattee:

> this 'cut' has a primitive origin and is found in all living organisms. It is simply an extreme case of the distinction made, even by the first cells, between stimuli that cannot be correlated and stimuli that can be correlated, or that follow a recognizable pattern. In terms of information storage, we say that some records of events can have a compressed description (like laws) because of intrinsic correlations, while other records (like initial conditions) have no shorter description than the records themselves (2001: 13).

Having come to this conclusion by 1969, Pattee's centrally organizing research question then became: "whether bridging the epistemic cut could even be addressed in terms of physical laws" (*ibid*). Forty years into this project, Pattee writes: "I will state at the outset that I have not solved this problem. In fact, even after decades of effort, I have not made much progress other than clarifying the problem" (2005: 283). Yet Pattee is being too modest here by several orders. For while it is true that neither he nor anyone else has yet to fully bridge what he calls *the epistemic cut* between configurations of physical matter and the ability of that same matter to "stand for" something other than itself (and, in so doing, exert a causal influence not exhaustively reducible to its constituent physics), his tireless efforts in this direction have spawned a generation (or perhaps, now, two) of physicists, systems theorists, and biosemioticians who have been both inspired and enlightened by his work.

As one of the founders of the Biophysics programme at Stanford University in 1958, Pattee's transdisciplinary approach, and the nature of the questions that he posed, planted the seeds for the later flowering of such "epistemologically" concerned research agendas as Artificial Intelligence, Complex Adaptive Dynamical Systems Theory, Second-Order Cybernetics, Cognitive Robotics and, of course, Biosemiotics. In the following decade, his contributions to the *Towards a Theoretical Biology* conferences would become widely cited and influential. Of the distinguished group of thinkers taking part in the Bellagio conferences, Howard Pattee was one of the few participants besides Waddington himself to give a paper at each of the four annual meetings, and the titles of these papers reflect Pattee's abiding theoretical concerns: *The physical basis of coding and reliability in biological evolution* (1968a), *Physical problems of heredity and evolution* (1969a), *The problem of biological hierarchy* (1970) and *Laws and constraints, symbols and languages* (1972).

In 1971, Pattee joined the Center for Theoretical Biology at the State University of New York at Buffalo, working with fellow biophysicist Robert Rosen (1934–1998) and General Systems theorist Ludwig von Bertalanffy (1901–1972). His pioneering papers published between 1969 and 1973 developed an evolutionarily coherent Hierarchy Theory – one that can account for the increasing "simplicity" (or "regularity") exhibited by evolving systems as their own internal organization becomes increasingly complex – and these papers, along with the groundbreaking anthology in *Hierarchy Theory* that he published in 1973, together remain classic texts in that still-developing field. And as a result of his work as a professor (now Professor Emeritus) in Systems Science at the State University of New York at Binghamton since 1975, Pattee's ideas and inspiration have been realized in a variety of fruitful ways by his students such as philosopher and neurophysiologist Peter Cariani, cybernetician and cognitive scientist Cliff Joslyn, biophysicist and computer scientist Michael Conrad and computational biologist and complex systems modeller Luis Rocha. Indeed, the multidisciplinary seriousness of his students says much about Pattee as a teacher.

"This does not mean that anything like a scientific or philosophical school" has formed around Pattee *per se*, writes Jon Umerez in a Special Issue of *Biosystems* that is devoted to Pattee's work, "but that the underlying motivation and the kind of problems characteristic of Peirce's thinking are being worked out, within their own disciplines, by people scattered around both geographically and academically" (2001: 172).

So, too, has Howard Pattee exerted a formative influence on post-Sebeokian biosemiotics, especially as reflected in the work of Claus Emmeche and Jesper Hoffmeyer, who seek, like Pattee, to understand the nature and the origin of the "epistemic cut" between living systems and their surrounds (see especially Hoffmeyer and Emmeche's seminal 1991 paper on "code-duality", and the discussion of same by Hoffmeyer in Chapter Nineteen of this volume.) Indeed, in the selection that follows, Pattee draws very little distinction between the ideas of "biosemiotics" and his own lifelong project having long averred that the projects are, in many ways, "studying the same thing, using somewhat different approaches and language" (2007: p.c.). Most consequentially of all, perhaps, Howard H. Pattee stands as a premier role model for biosemioticians and for scientists everywhere, in his lifelong dedication to the principle that the accomplishment of conceptual precision in articulating one's questions will, in time, help generate the explanatory frameworks and vocabularies needed for addressing them.

The Physics and Metaphysics of Biosemiotics (2005)

Abstract Biosemiotics recognizes that life is distinguished from inanimate matter by its dependence on material construction under the control of coded symbolic description. This distinction between matter and symbol extends from the origin of life throughout all of evolution to the distinction in philosophy between brain and mind and the distinction in physics between laws and measurements. These distinctions are an epistemic necessity that separates the knower from the known. The origin of life requires understanding the origin of symbolic control and how inanimate molecules becomes a message. I cannot solve this problem, but I discuss the necessary physical conditions that would allow evolvable symbolic control of matter to exist.

The Problem of Biosemiotics

The concept of Biosemiotics requires making a distinction between two categories, the material or physical world and the symbolic or semantic world. The problem is that there is no obvious way to connect the two categories. This is a classical philosophical problem on which there is no consensus even today. Biosemiotics recognizes that the philosophical matter-mind problem extends downward to the pattern recognition and control processes of the simplest living organisms where it can more easily be addressed as a scientific problem. In fact, how material structures serve as signals, instructions, and controls is inseparable from the problem of the origin and evolution of life. Biosemiotics was established as a necessary complement to the physical-chemical reductionist approach to life that cannot make this crucial categorical distinction necessary for describing semantic information. Matter as described by physics and chemistry has no intrinsic function or semantics. By contrast, biosemiotics recognizes that life begins with function and semantics.

Biosemiotics recognizes this matter-symbol problem at all levels of life from natural languages down to the DNA. Cartesian dualism was one classical attempt to address this problem, but while this ontological dualism makes a clear distinction between mind and matter, it consigns the relation between them to metaphysical obscurity. Largely because of our knowledge of the physical details of genetic control, symbol manipulation, and brain function these two categories today appear only as an epistemological necessity, but a necessity that still needs a coherent explanation. Even in the most detailed physical description of matter there is no hint of any function or meaning.

The problem also poses an apparent paradox: All signs, symbols, and codes, all languages including formal mathematics are embodied as material physical structures and therefore must obey all the inexorable laws of physics. At the same time, the symbol vehicles like the bases in DNA, voltages representing bits in a computer, the text on this page, and the neuron firings in the brain do not appear to be limited by, or clearly related to, the very laws they must obey. Even the mathematical symbols that express these inexorable physical laws seem to be entirely free of these same laws.

The Epistemic Cut

What does calling the matter-symbol problem "epistemological" do for us? Epistemology by its very meaning presupposes a separation of the world into the knower and the known. That is, if we can speak of knowledge *about* something, then the knowledge representation, the knowledge vehicle, cannot be in the same category as what it is about. This separation is often called the epistemic cut (e.g., Pauli 1994). In physics this cut is exemplified by the fact that laws and measurements (or states) must be separate categories. Why is this fundamental?

The laws are universal and do not depend on the state of the observer (symmetry principles) while the initial conditions apply to the state of a particular system and the state of the observer that measures them. The laws of physics are assumed to be inexorable. That is, the laws do not allow alternatives and therefore the concept of information that is defined by the number of alternatives does not apply to the laws themselves. A measurement, in contrast, is an act of acquiring information about the state of a specific system that has many alternative states. Two other explicit distinctions are that the microscopic laws are universal and reversible (time-symmetric) while measurement is local and irreversible. There is still no question that the measuring device must obey the laws. Nevertheless, *the results* of measurement, the timeless semantic information, cannot be usefully described by these time-dependent reversible laws (e.g., von Neumann 1955).

Physics usually assumes human observers. The origin of life question is: How did this separation, this epistemic cut, originate? As Hoffmeyer (2000) has pointed out, the apparently sharp epistemic cut between these categories makes it difficult to imagine how life began and how these two categories evolved at higher levels. The epistemic cut appears to be a conceptual as well as a topological discontinuity. It is difficult to imagine a gradual cut. The problem arises acutely with the genetic code. A partial code does not work, and a simple code that works as it evolves is hard to imagine. In fact, this is a universal problem in evolution and even in creative thought. How does a complex functioning set of constraints originate when no subset of the constraints appears to maintain the function? How does a reversible dynamics gradually become an irreversible thermodynamics? How does a paradigm shift from classical determinism to quantum indeterminism occur gradually? At least in the case of thought we can trace some of the history, but in the origin of life we have no adequate history. Even in the case of creative thought, so much goes on in the subconscious mind that the historical trace has large gaps.

I will state at the outset that I have not solved this problem. In fact, even after decades of effort I have not made much progress other than clarifying the problem. My approach has been to start at the most elementary level and with the simplest cases where the two categories of matter and symbol might meet in some objective sense (Pattee 1969).

The problem is that even the simplest symbol system requires a code and an interpreter to introduce objective function or meaning to a physical system, and such a system has no obvious precursors. What I do claim, and what I will discuss, is that even though symbol systems do not appear to be restricted by physical laws, nevertheless there exist general lawful conditions that must be met for any symbol system to exist. There are also good reasons to expect some symbol systems and codes to be better than others in terms of their evolvability (Pattee 200la).

Simplifying the Problem

Biosemiotics has biological, linguistic, and philosophic components in addition to the physics of symbols. These can certainly be studied profitably without solving the matter-symbol problem or the origin of life problem. At the same time we must not assume that a good biological model with semiotic controls in some sense advances the basic matter-symbol problem. Biosemiotics also recognizes that to objectify the concept of the epistemic cut between matter and symbol we must make explicit what we mean by the acts of observation and interpretation at the most primitive level. This requirement for an irreducible triad of sign, interpreter, and referent was a central point of C. S. Peirce's semiotics. The key issue is: What is an individual observation? What is an interpretation? Only with an act like detection, pattern recognition, or observation does the need arise for symbols as a category distinct from matter. Only with the concept of interpretation of symbols do the concepts of semantic information and communication arise.

So, the question of the origin of the epistemic cut can be approached by asking: What are the conditions under which the simplest act of observation and interpretation take place? This question is ambiguous and a source of controversy even in the highly evolved domain of physics where it is called the "measurement problem." Measurement is a physical process, but the *function* of measurement, recording specific initial conditions, is beyond physical laws to describe. One way to see this is to ask for the cause of a measurement. What determines when and where a measurement is made? Clearly this decision is not made by the laws, but by the observer. In the context of the origin of life the question becomes even more ambiguous because the most primitive observer is not defined. To define the simplest observer we might ask: What is the function of an observer? This leads to even more ambiguous questions: What is the simplest function? What is the simplest system where a physical interaction requires an interpretation because it has acquired significance or meaning beyond simply obeying the universal laws? What is the simplest system that requires symbolic communication as a category distinct from physical interactions?

The Generalized and Simplified Observer

In classical physics the concept of observer was taken for granted and interpreted quite literally. Modem physics changed this view. Maxwell's demon, relativity, and quantum theory forced physics to be more explicit about the role of the observer. The classical literal observer was replaced by a metaphysical, metaphorical, and even mythical abstraction that was used often in thought experiments. These observers could not exist except in the imagination. Maxwell imagined an observer as a molecular gatekeeper. Einstein imagined an observer riding a photon. Quantum theory has imagined all kinds of observers at all levels from decohering wave functions to Schrodinger's cat to human consciousness.

What have all these observers in common? In all these cases of real or imagined observers, the process of observation is itself considered as initiated by a system separate from the system being observed. It is a terminated event resulting from an interaction of a local, bounded individual system with a time-dependent dynamical system. The individual is objectively separable from the surrounding, and the act of observing is terminated by the appearance of some form of record, memory, or consequence of the observed event. In other words, while the event being observed is constantly changing according to the dynamical laws, the observation freezes some aspect of the system by correlating it with a timeless structure or record. The mathematician Emil Post (1965) saw the essence of writing symbols the same way. He said, "Activity in time" is the source of symbols but this, " … activity itself is frozen into spatial properties."

There are a lot of ambiguous terms here. What do we mean by an individual? What is a record or a consequence of an observation? What does it mean to correlate some aspect of a dynamical law with a timeless structure? What is a timeless structure according to physics? To answer these questions requires some discussion of hierarchies of physical descriptions, since physical description can be extended from the fundamental microscopic time-dependent dynamical laws to ever-larger aggregates that have relatively fixed macroscopic shapes. These are called solid bodies, boundary conditions or constraints. They require a different description than the microscopic laws.

Hierarchies of Description

The legacy of classical reductionism is the support of a common illusion. It is the illusion that because everything must obey detailed microscopic physical laws, it follows that such a description of this detail forms the most fundamental or most "real" explanation for all higher-level behaviors. For at least a century physicists have recognized, sometimes only tacitly, that this is not the case. The first failure of reductionism was thermodynamics with its irreversible laws that can never be formally derived from or reduced to the reversible microscopic laws. The conceptual problem is that in the microscopic laws the observables are about individual particles, while the observables in statistical laws are about populations. These descriptions illustrate the concept of complementarity used in the special sense that neither of two descriptions can be derived from, nor reduced to the other. Max Planck (1960) made the point: "For it is clear to everybody that there must be an unfathomable gulf between a probability, however small, and an absolute impossibility… Thus dynamics and statistics cannot be regarded as interrelated."

The same complementarity exists between most hierarchical levels of description. The gulf between levels is not always as unfathomable as between determinism and chance, but the necessity of multiple models remains clear. The lower-level description details must remain tacit if the higher-level description is to be efficacious. Consequently, the relation between hierarchical levels appears as both restrictive with respect to the lower-level details, but generative with respect to higher-level behavior. There is no clearer example than natural language where the lexical details restrict the potentially infinite alphabetical sequences thereby generating small enough dictionaries to be practical, and grammars restrict the infinity of word sequences thereby generating meaning. The choice of word forms is largely arbitrary as the thousands of languages show, but the constraints of grammar appear to have strong semantic components and are nearly universal.

Unfortunately, the origin of natural language is itself too obscure to help us with our more primitive problem. Igor Stravinsky (1970) expressed the apparent paradox of constraints in the context of composing: "The more constraints one imposes, the more one frees oneself from the chains that shackle the spirit… and the arbitrariness of the constraint serves only to obtain precision of execution."

As I mentioned, the next levels in physics above the microscopic and statistical dynamic levels are the molecular and solid-state levels that can be interpreted as boundary conditions or constraints that are not usefully described by a temporal dynamics. They are modeled as time-independent or stationary states, even though we know that they change over longer time scales and are still dynamical systems at the lower level shorter time scales. Differing time and energy scales are a common distinction between hierarchical levels in physics (Simon 1962, Pattee 1973).

Levels of Constraint

Constraints form an open-ended category. Just because these structures do not change relative to the lower level dynamics they enter the lower level dynamics as boundary conditions on the possible motions. It is only because of this enormous simplification achieved by describing structures as constraints rather than by a stationary dynamics that descriptions of many large molecular structures and all types of artifacts and machines are possible.

There are an endless number of structures that can act as semiotic constraints on a dynamics (Pattee 2001b). They can be loosely classified as fixed structures, like crystals, tabletops, and train tracks, and flexible structures, like enzymes, escapements, and switches. Fixed constraints can limit or direct the path of a dynamical system depending on the shape of the constraint, but to speak of controlling the path of a dynamical system implies possible alternative paths and therefore control constraints must have more than one shape. Life is all about controlling rates of dynamical systems and depends crucially on such allosteric constraints at the macromolecular level, enzymes being the prime example.

Following Hertz, physicists call such path-dependent, flexible, or allosteric constraints *nonholonomic*, and in most cases they are nonintegrable and modeling them requires computer simulation. As I will discuss later, the physical existence of such flexible control constraints requires structures held together by both strong and weak bonds. The point to remember is that while these flexible molecular constraints greatly restrict the detailed dynamics at the lower level they generate entirely new dynamical behavior at the higher levels (Pattee 1973, Hoffineyer 1998, Juarrero 1998).

We assume that even the most complex symbol system, like the brain, has a correct and detailed physical description, at least in principle, but we recognize that a correct model need not be a useful model. Recall Einstein's reply when asked if everything has a correct physical description. He said, "Yes, that is conceivable, but it would be of no use. It would be a picture with inadequate means, just as if a Beethoven symphony were presented as a graph of air pressure." At this cognitive level is seems clear that physical description is inadequate, but this is too complex a level for my discussion. Remember, my aim is to find the simplest level of complexity where the description of a system in terms of physical laws alone becomes inadequate or non-explanatory. Or ultimately, at what level of the hierarchy do codes and symbols and intrinsic meaning enter the material world of physics?

Setting Up the Conditions for Evolution

Flexible constraints can function as codes and symbols but only under very special conditions. I need to justify why these conditions are necessary. These conditions are essentially the conditions for open-ended evolvability. This is not helping directly with the origin problem. No matter how correctly we describe the macromolecules of organisms in terms of physical models there is as yet no adequate model explaining why collections of these molecules should organize into functional units like metabolic cycles, memory and codes for self-replication that can support open-ended evolution. All I can do is set up the problem clearly by specifying the minimum logical and physical conditions necessary for evolution as we know it. What preceded that level of complexity is precisely the origin of life problem.

Von Neumann was the first to express the logic of self-replication that is capable of open-ended evolution. His argument was entirely abstract and by no means logically complete. It explicitly abstracted away matter, energy and all physical laws. I will first elaborate on von Neumann's logic and then I will take up the necessary *physical* conditions to realize this logic, or what he thought "may be the more important half" of the problem. Finally I will suggest some properties of memory, codes, symbolic control, and material construction that would promote efficient evolutionary search and natural selection.

The Logic of Self-replication

Von Neumann's logical argument for the necessity of symbols as distinct from dynamics in self-replication were intuitive and require elaboration to clarify his points. The motivation for his argument was to understand complex systems and to design computers, but his basic conclusions apply to existing cellular replication. His logic is all the more remarkable because this work was done from 1948 to 1951 so he did not know in any detail how real cells replicate. Von Neumann began by observing that the medium of communication that feeds the automaton is completely different than the automaton itself or its output. This was his recognition that symbols are a different category than matter, what is now called the software-hardware distinction in computers.

Consequently, in order to implement his *simulation* of self-replication he needed to create symbolic parts corresponding to the material parts of the automaton. He then proposed "axiomatizing" the automaton in some way so that its output is more like the hardware of the automaton. He saw that this is a problem because it appears to erase the symbol-matter distinction that he had already recognized as important. Nevertheless, his later logic confirmed the necessity of a sharp distinction between the symbols representing instructions or programs and the symbols representing hardware or dynamical rules used to manipulate the symbols. He also warned: "By axiomatizing automata in this manner one has thrown half the problem out the window and it may be the more important half. One does not ask the most intriguing, exciting and important questions of why the molecules or aggregates that in nature really occur... are the sorts of thing they are, why they are essentially very large molecules in some cases, but large aggregations in other cases." I will return to this more important half later.

Von Neumann then introduced the concept of complexity and the "completely decisive property of complexity, that there exists a critical size below which the process of synthesis is degenerative, but above which the phenomenon of synthesis, if properly arranged, can become explosive." He was thinking of biological evolution and its open-ended variety. The essential condition here is that the individual self that is being replicated must be only one of an indefinite number of different potential selves all of which can be replicated by the same process. This raises two questions: (1) How do you describe or represent the individual *self* that is being replicated? And (2) What defines the set of all possible individual selves that potentially can be replicated?

Logic will get you only so far with these questions. For example, the concept of replication implies assembling or constructing a new individual that is like another. Von Neumann realized that how this construction can be done will depend on the nature of the available parts and on how the parts are to be assembled. He saw that if the parts were too elementary, like atoms, then the assembly would be a long and complicated process, while if the parts were too complex, like robots, then there would be no real problem. He called this the "parts problem" and abstracted away the matter and energy of real construction by defining some functional operations on parts, like recognizing, moving, cutting, joining, etc., that are to be symbolically represented. There is a great amount of arbitrariness in these choices of parts and operations, but as we shall see, the basic logical separation of symbolic description and material construction will not depend on these choices.

The more fundamental question is how you make sure the replicated individual is like the original. How do you make a copy? There are two approaches. One is to copy the original parts themselves by *inspection* and then assembling the corresponding part in the copy. The other is to use a *description* of the original that when interpreted amounts to instructions enabling the assembly of the parts in the copy. Both of these methods have advantages and disadvantages that go beyond logic and depend on the physical nature of space, time, and the nature of the parts. Von Neumann using heuristic reasoning found that taking advantage of both approaches gives the most promising results, and in fact we now know that both approaches are used in all living systems in the way that von Neumann proposed.

Inspection vs. Description

Von Neumann's use of *inspection* and *description* are metaphors of highly evolved cognitive activities that need to be more precisely defined in the context of the simplest replicating unit. Copying by inspection means using physical interaction with the object directly without the use of a code, a translation, or an interpretation. Casting from a mold or template is such a direct process. Examples of direct shape-matching processes are the copying of the base sequence in nucleic acids and the binding of a substrate by an enzyme. I should emphasize here that the physical interaction of base pairing and substrate binding are not in themselves functional or semiotic processes. It is only by virtue of their roles in the process of self-replication that they are interpreted as functional. Such a template might be interpreted in Peirce's terms as an iconic sign.

A description, on the other hand, requires more complicated physical interactions that couple the description to what it stands for, its referent. This interaction in the context of self-replication can be called a code or an interpretation, and because the code constraints are themselves constructed from a description they are not determined by physical necessity. It is implicit in the concept of a code that it must apply to more than one description. In fact, to allow evolution the code must apply to an open set of potential descriptions. Again I emphasize that only by virtue of its potential function for an individual's survival can this be distinguished as a semiotic process. This chemical arbitrariness in the coding enzymes Jacques Monod (1971) calls the "principle of gratuity." It is also this construction from a description that

Barbieri (2004) calls “artifact-making,” a distingishing characteristic of life. It is the reason that the semantics of genetic symbol systems and the novelties of evolution have no adequate physical description even though they obey physical laws in every detail.

It is not clear that von Neumann saw this point since he was concerned with the logic, not the physics. However, he did argue that a description had the advantage of being quiescent, relatively time-independent, and free of the dynamics of the system it describes. He saw that copying by direct inspection in real time would run into a problem with any dynamic part that was continually changing in time. What state would be copied in that case? He also suggested that a complete and detailed inspection, including inspecting the inspection components themselves, would probably lead to logical antinomies of self-reference. He did not elaborated on this, but he may have been thinking of the measurement process in which detailed description leads to an infinite regress unless terminated by an epistemic cut between the system and the measuring device (von Neumann 1955).

Von Neumann’s Basic Argument

Because of these intuitions, Von Neumann began simply by postulating the existence of both symbolic and material components in the forms of a description and a constructor. The constructor would both interpret and construct what was described using parts from a reservoir. The constructor was universal with respect to an open-ended set of descriptions one of which was the description of the constructor itself. In his notation, A was the constructor and <p(A) was the description of the constructor. If $\phi(A)$ was fed to A as instructions, A would construct a copy of itself, A'. We can symbolize this as $\phi\ (A) \rightarrow A = A'$. This is not self-replication because the description has not been replicated. One might at first think that to copy the description we also need to feed the constructor a description of the description, $\phi\ [\phi(A)]$, but this leads to an infinite regress since that description must also be copied, and so on.

This leads to the crucial recognition that *a symbolic description, whatever form it may take, has a physical structure that is independent of its interpretation*. To *read* the description means to *interpret* the description. To *copy* the description means *not to interpret* the description but to copy only its physical structure. Since the description is quiescent, this can be done by inspection or by some template process. The constructor can only interpret the description, so it is necessary to add another component, B, called the copier and its description $\phi\ (B)$. We then can write $\phi\,(A+B) \rightarrow (A+B) = \phi\left(A'+B'\right) \rightarrow \left(A'+B'\right)$. This is almost self-replication except for the ambiguity of how the material hardware output of the constructor A connects up with the symbolic descriptive output of the copier B. In other words, what is missing is just the answer to the classical problem of how the symbolic description is related to the material construction. Von Neumann “solved” this by creating a new control component, C, that inserts the new description into the new hardware constructor and separates the offspring from the parent. This amounted to what is called the operating system of a computer that takes care of the software-hardware housekeeping. This is not a clear solution. In the cell we know that the control of cell division is a very complex process that is not yet fully understood.

The essential evolutionary consequence of this logic is that now any additional description, D, of some new structure or function when added to this basic description will be constructed and incorporated into all future generations:

$$\phi\,(\mathrm{A}+\mathrm{B}+\mathrm{C}+\mathrm{D}) \rightarrow (\mathrm{A}+\mathrm{B}+\mathrm{C}) = \phi\left(\mathrm{A}'+\mathrm{B}'+\mathrm{C}'+\mathrm{D}'\right) \rightarrow \left(\mathrm{A}'+\mathrm{B}'+\mathrm{C}'+\mathrm{D}'\right)$$

This is as far as von Neumann's logic takes us. The main point of his logic is that open-ended evolution requires more than a complex time-dependent dynamics and complex chemical reactions. There must be a time-independent passive memory that by means of a coded description controls the dynamical rates of specific constructions or chemical syntheses. What I will now take up are the physical requirements that would allow such a complicated symbol-matter logical scheme to actually work in a reasonably effective way. I repeat that this is not solving the origin problem. Von Neumann himself had no clue. He thought, "That such complex aggregations should occur in the world at all is a mystery of the first magnitude." In my view, the place to look for clues is in the actual physical requirements of symbol systems where we may imagine simpler systems than we find in today's highly evolved organisms that satisfy these requirements.

Physical Requirements for Efficient Memory

The physical conditions necessary for memory storage are relatively simple to state as contrasted to the conditions for writing and reading of memory. The first condition is that there exist many inherently equiprobable constraint structures with adequate stability. Equiprobable means that the structures are energy degenerate or the energy of each state is the same. These states need not be exactly the same energy as long as the energy differences do not significantly affect the setting of the state by writing or the communication of the state by reading. Linear copolymers are the simplest common physical structures satisfying these conditions.

Such relatively time-independent memory structures function as long-term, high capacity storage. They can exist physically in one, two, three dimensions, or n-dimensional networks if defined by connectivity. The advantages of the linear sequence memory, like nucleic acids and Turing machine tapes, and language text are (1) open-endedness or extendable capacity, (2) uniformity and simplicity of writing and reading, including ease of random access, (3) universal coding for all sequences, (4) storage is passive and relatively isolated from the dynamics under its control. In the context of the origin of life, copolymer chains are the simplest abiogenic structures that have the necessary stability and potential memory capacity.

The disadvantages of linearity are (1) lack of parallel processing or associative access, (2) low density of information storage, and (3) the necessity for an explicit code to couple one-dimensional energy degenerate sequences to the energy-dependent three-dimensional dynamics.

One can also speak of analog memory and codes as in analog computation that does not involve a language. This has been suggested by Hoffmeyer and Emmeche (1991), Juarrero (1998), Hoffmeyer (1998) and Barbieri (2003) in contrast to discrete or digital memories and codes. The problem with analogs is that they are all special purpose structures like individual molecular messengers that have limited informational capacity and must be interpreted individually. An autocatalytic or metabolic network may be interpreted as containing an implicit informational dynamics, but lacking an explicit passive memory structure and code it is difficult demonstrate that they are more than an analogy or metaphor. In other words, how do we show that a complete description of the dynamics is inadequate to explain the behavior if there is no explicit non-dynamic memory structure? On the other hand, as Hoffmeyer (2000) suggests, some form of implicit analog codes may have existed as precursors of the explicit discrete codes of present life.

Physical Requirements for Coding and Construction

In even the simplest existing cells the steps from the symbolic base sequence in DNA to a functioning enzyme are too complex to have originated without simpler intermediate stages. However, to control construction or synthesis, even the simplest one-dimensional discrete-state memory storage that exists by virtue degenerate energy states, must somehow control the rates of specific dynamical interactions. This means that the linear degeneracy must be broken. This must be done by new interactions between the linear storage elements. In present cells this is a complex process that requires several steps. First, the DNA sequence is transcribed to messenger RNA by template copying. Next the coding enzymes and transfer RNAs translate the base triplet code to the corresponding amino acids that are then joined in sequence by the messenger RNA and ribosome machinery. Finally, the one-dimensional sequence folds into a functioning enzyme. In this process there are cases of descriptions and constructions by both template inspection and coded descriptive translations.

The discovery of enzymatic RNA made it possible to imagine a much simpler translation process in which RNA can function both as a constructing enzyme and as a symbolic description of an enzyme. By description I mean a passive structure that can be copied by template inspection, and by construction I mean a dynamic catalytic process that joins molecules by strong, covalent bonds. The main point is that this double function is only possible by virtue of the two configurations of RNA, the passive one-dimensional sequence memory and the folded three-dimensional active ribozyme.

The Physics and Semiotics of Folding

Folding transformations are the most significant semiotic process in all living systems. Folding is fundamental because it is the process that transforms the passive symbolic informational sequences into dynamic rate-controlling constraints. Physically to describe folding in any structure requires two types of bonds, strong bonds that preserve the passive topological structure of what is folded, and weaker bonds that acting together hold the active folded structure in place. This is just the definition of folding. For example, to fold a sheet of paper means forming a three-dimensional shape without changing the two-dimensional topology of the sheet by tearing or gluing. As long as the strong-bond topological sequence structure is energy degenerate it can serves as an informational constraint or a passive memory. Folding removes this degeneracy by allowing new weak bond interactions between the elements resulting in an active enzyme. A *physical description* of protein folding is an energy minimization process or a relaxation of many weak bond interactions under the constraints of the strong bonds holding the linear sequence together (Frauenfelder and Wolynes 1994).

How should we describe the semiotics of this process? What I want to avoid is confusing the physics and the semiotics. First, I am defining a condition for symbolic information storage as a physically indeterminate (energy degenerate) structure. I assume that all symbol vehicles obey physical laws and have, in principle, a physical description, but that does not imply that they are physically determined. Quite the contrary is true. Such a degenerate sequence structure can have an immense number of physically indeterminate sequences. Therefore the interpretation or function of any such informational sequence is literally metaphysical (beyond physics).

It is important to understand that from a physical point of view the actual folding process is an entirely physical process of minimizing the energy under the constraints of the sequence. The strong-bonded sequence can be called informational because it is one of many physically equivalent alternative sequences. The folding itself is not informational because no new information is added in the process of minimizing the energy. (There are special cases where folding information may be added from scaffolding molecules.)

Semiotic Closure

The question is: How do we define the system that is interpreting the information? I need an objective criterion for what "self" is doing the interpreting, because there are innumerable energy degenerate structures that are not descriptions and many catalytic events that are not functional. Such a criterion must answer the question: What is the nature of the individual organization that must refine physical description with an interpretation? Such a criterion is satisfied by a *physical* implementation of the *logical* "self" that reads and interprets descriptions in von Neumann's formal self-replication.

The essential logical requirement for self-replication that von Neumann described is that all the components that implement description, translation, and construction are themselves described, translated and constructed within the "self" that is being replicated. This amounts to a *logical closure* that defines a "self." Physically this requires elaboration. There is more to the strong and weak bond requirement than the ability of the weak bonds to cause the strong bonds to fold into a functioning enzyme.

The strong bonds also stabilize the passive memory and the integrity of the primary structure of enzymes. The weak bonds bind the enzyme to its substrate and control the rate of catalyzed strong bond formation. In effect, the strong bonds form the skeleton for both descriptive and constructive molecules while the coordinated organization of weak bonds define the shapes necessary to control the strong bonds, both the strong bond folding and individual strong bond formation or breaking.

These are the *physical* conditions required to implement von Neumann's logical closure. I have called this *semantic closure*, but Luis Rocha (2001) has more accurately called it semiotic closure because its realization also includes the syntax and pragmatic physical controls.

This complex interrelationship of strong and weak bonds is the minimum physical requirement that allows the realization of von Neumann's quiescent symbolic description and dynamic material construction. Of course the actual physical forces come in more than two strengths and evolution has refined structures at many hierarchical levels using different types of forces. Many types of strong and weak bonds enter into the complex process of folding (e.g., Wolynes et al. 1995).

The Minimal Interpreter

Based on the concept of semiotic closure, I would define an interpreter as a semiotically closed localized (bounded) system that survives or selfreproduces in an open environment by virtue of its memory-stored controls and constructions. That distinguishes interpreters from inanimate physical systems that evolve dynamically simply because they follow the memoryless state-determined laws of nature. I believe that this minimal concept of interpreter is consistent with Ghiselin's (1997) more elaborate definition of an "individual" that also applies to higher levels, like species, that are not adequately described by physical laws. However, there is still a problem with defining *one* individual interpreter.

Symbols exist in memory, but they are not symbols in isolation. Symbols are recognized in an individual interpreting system just because they function in propagating the system. But we cannot stop there. We immediately see that "propagating a system" is ambiguous. The individual is not enough. The whole idea of evolution depends on a *population* of individuals that can differ in their memories. This leads directly to the central issue of evolution: What kinds of symbolic descriptions, control constraints and material constructions promote survival of *populations*? Of course there is no complete answer to this question except the course of evolution itself. All we can do is look carefully at what is actually going on in existing organisms, and see if we can discover some answers to von Neumann's question of why the molecules are the sorts of thing they are.

Requirements for Efficient Search and Selection

After asking this question von Neumann remarked that it was "a very peculiar range" for the parts since they were many orders of magnitude larger than the physically elementary particles. He did not discuss this except to suggest that the size had to do with the reliability of control since in automata there is a direct correlation between number and size of parts and reliability. A certain level of reliability is certainly one requirement in order to prevent error catastrophe, but another way to look at the question is in terms of function. How small could an enzyme be and accurately bind a substrate and catalyze a specific single bond. It would have to be a large enough structure to establish a shape with the necessary specificity to recognize a substrate by folding up a linear chain. Simple models suggest that of the order of 100 amino acids is necessary.

This size creates two fundamental problems. The first problem is that the number of copolymer sequences of such lengths is immense, well beyond actual enumeration. One of the oldest, non-religious arguments against Darwinian evolution is the apparent improbability of chance mutations producing any successful protein, let alone a species. This is still an argument of "intelligent design" advocates. This argument is based on the assumption of the sparseness of functional sequences and the immensity of the search space. The weakness of this argument is that the actual probabilities of the events in question are largely unknown.

Formulated in biosemiotic terms, to address this problem we need to know what fraction of the innumerable potential symbol strings in a genetic memory has some meaning or function when expressed by a population of individual interpreters. We need to know how the enormous space of sequences maps into the space of biological functions. The second classical problem is that functions appear to be discretely separated. That is, one function does not smoothly transform into another function. This results in the so-called trapping problem on a function or fitness landscape.

Both these problems have been studied extensively, greatly assisted by the use of computational models. Of course, there are no pure theoretical answers. Some basic empirical knowledge is required of the actual polymers that form the memory sequence space, the nature of codes that map to protein sequences, the nature of folding, and the nature of the constructive or controlling enzymes. The auspicious discovery of molecular genetics was that many mutations are neutral with respect to function and fitness (Kimura 1983). Along with the redundancy in the genetic code, this neutrality permits searches over a wide region near a function optimum or a local fitness peak thereby alleviating the trapping problem. Trapping is also greatly reduced by the large number of saddle regions that increases with the dimensionality of the memory sequence space (e.g., Kanerva 1988). This lends weight to the concept of quasispecies and the advantages of mutation rates near the error threshold (Eigen 1971, Eigen and Schuster 1979).

This search problem has been studied extensively for the simple RNA worlds of sequences and their folding (e.g., Schuster et al. 1994, Schuster 1998, Crutchfield and Schuster 2003). Again the mapping of passive memory sequences to shapes that could function as enzymes appears to be highly redundant with many sequences resulting the same three-dimensional shape. Furthermore, these sequences are distributed more or less uniformly over the entire sequence space. This means that a random search need not find just one needle in a haystack, but only one of many needles uniformly distributed over the whole haystack. That is, wherever a random search begins in sequence space, it is likely that a description of a useful molecule will be found nearby.

Analogies and Disanalogies of Genetics with Natural Language

Biosemiotics is the study of all forms of signification and communication. It recognizes that life is distinguished from the nonliving world by its dependence on signs. However, of the innumerable examples of pattern recognition, recording, signaling, and communication throughout all levels of living organizations only two clear examples of open-ended, creative language systems exist, the genetic language and natural languages. These languages can be characterized by (1) a small, fixed alphabet, (2) one-dimensional expressions in discrete sequences, (3) an immense sequences space with no significant restriction or bias from physical laws, (4) expressions not limited in what they can potentially describe by what currently exists, (5) the interpretation of sequences or their function is complex requiring highly parallel dynamic interactions. In the case of genetic sequences, the essential step is folding in which many strong constraints and weaker forces act in parallel. In the case of the brain, millions of neurons are involved in interpreting even the simplest expressions.

Natural language structure illustrates the strong and weak bond principle, not with a hierarchy of physical forces but with a hierarchy of rules. The lexical rules are the most rigid beginning with the alphabet and the words in the lexicon. The grammar rules are weaker than the lexical rules in the sense that syntax cannot control or modify the alphabet or the dictionary. The semantics of the text does not generally alter syntax. We usually assume our writing will not change the basic meanings of words or the grammar rules depending on what we write. Similarly the sequence or meaning of the code's base triplets is not changed by the functions of enzymes they describe. However, both languages have evolved exceptions to these rules, the genetic system with special editing enzymes, reverse transcription and cutting and splicing, and natural language with freedom to add new words and to violate grammar rules with figures of speech.

Of course there are enormous differences between these languages both in their embodiments, their stability, and in their range of meanings which one would certainly expect considering they originated only at the very beginning and the end of the evolutionary time scale. The genetic language began with the origin of life, and it took 4 billion years of evolution to create brains with the capability to create natural languages. The genetic language can be called highly successful in creating adaptive functions that keep life going over this enormous time span. We often refer to natural language as the defining characteristic of human intelligence. The power of language has dominated history and shaped all our cultures, but whether it will tum out to be a longterm evolutionary success is not at all obvious. Human language has not existed for more than 100,000 years and it is quite possible that it has become both too powerful and too far removed from natural selection to benefit the species. It is already attempting to adapt genetic messages to human desires rather than to the biological necessities for survival. Assuming humans survive the dangers of natural language, one wonders what higher level of language might evolve. If humans do not survive natural language, one wonders what alternative biosemiotic structures might take its place.

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Chapter 18
Excerpts from *The Symbolic Species*

Terrence Deacon (1950–)

Introduction and Commentary: Terrence Deacon

> *The self that is the source of one's experience of intentionality; the self that is judged by itself as well as by others for its moral choices, the self that worries about its impending departure from the world, this self is a symbolic self. It is a final irony that it is the virtual, not actual, reference that symbols provide, which gives rise to this experience of self. This most undeniably real experience is a* virtual *reality.*
>
> T. Deacon (1997: 452)

In 1866, the recently formed *Societe Linguistique de Paris* passed an official resolution banning the presentation of any further papers regarding the origins of human language. The nature of the inquiry itself, it was decided, lacked even the possibility of scientific certainty – and all work pertaining to it was likewise dismissed on the grounds of being empirically irresolvable, incorrigibly speculative and unproductively divisive. Almost 150 years later, neurobiologist and biological anthropologist Terrence W. Deacon would author an empirically vigorous and conceptually groundbreaking study of language origins challenging many of the core assumptions underlying both the biological innatist and the evolutionary psychological theories of language evolution that had found their way into scientific discourse since the *Societe's* inquiry-blocking resolution.

Born in Seattle, Washington in 1950, Deacon received his bachelor's degree from Fairhaven College of Western Washington University. During this time, Deacon also studied communications with systems theorist and Gregory Bateson protégé, Anthony Wilden (1935–) who was then teaching at Simon Fraser University in British Columbia. While still an undergraduate, Deacon had already authored a groundbreaking work of synthesis and scholarship entitled "Semiotics and Cybernetics: The Relevance of C. S. Peirce" as his senior thesis in 1976. Anticipating his own later arguments about the hierarchal nature of reference, Deacon, in this early document, rechristens the Peircean categories of *Firstness, Secondness* and *Thirdness* as *potential*, *instantive* and *systemic* relations, respectively, in order to show the systematic "order by which signs can be progressively constructed from simpler forms, and *to which* they can be analyzed or interpreted" (1976: 30).

D. Favareau, *Essential Readings in Biosemiotics*, Biosemiotics 3,
DOI 10.1007/978-1-4020-9650-1_18,

Reviewing this early thesis afresh in 2004, Deacon now considers it "very much a youthful student's document" and notes that he had written this text "before I had realized that the icon-index-symbol relation should be conceived in a Batesonian logical type framework, which became the background for the *Symbolic Species* argument."[1] Moreover, adds Deacon, "when I wrote *The Symbolic Species* (1996) two decades later, although I was a longtime serious Peircean convert, I did my very best to absolutely minimize Peircean terminology and philosophy without sacrificing the underlying theory, in order to make it accessible" (2008: p.c.).

For all its author's disclaimers, however, this early document remains an incisive and still prescient text, one that is all the more impressive given both the age at which – and the age in which – it was written. For in 1976, the synthesis of Peircean and Batesonian ideas that Jesper Hoffmeyer would introduce to the scientific community as constituting *biosemiotics* still lay another 20 years away – and Deacon, at the time of developing this framework of analysis, was no more aware of the parallel project for the scientific understanding of sign-use that Hoffmeyer was developing (but not yet publishing) in Denmark, than Hoffmeyer would have been of the writings of the American college student Terrence Deacon at that time. Nor had Deacon come to his appreciation of the applicability of Peircean relations to biological inquiry through an acquaintance with the work of Thomas A. Sebeok and his colleagues at that time. Rather, and again like Hoffmeyer, Deacon seems to have needed to creatively employ the conceptual tools provided by Peircean sign-logic in order to better understand and explain the workings of the biological world. And it is this project that he has pursued with a singular intensity and interdisciplinarity ever since, educating himself in virtually every area of the life sciences from animal ethology to molecular biology, and wedding this knowledge with insights from philosophy, linguistics, anthropology, cybernetics, information theory and the modeling of self-organizing systems.

After completing his undergraduate studies, Deacon enrolled in a graduate program at Harvard University with the intention of studying the unpublished works of Charles Sanders Peirce that are archived in Harvard's Houghton Library. Because he ultimately found it difficult to interest an advisor in this effort, however, Deacon eventually shifted his focus and enrolled in Harvard's doctoral program in Biological Anthropology, where he completed his Ph.D. thesis detailing the circuitry of the neural homologues of language areas in monkey brains – while independently continuing his studies of Peirce on the side. In 1984, Deacon was offered an assistant professorship at Harvard, where he continued to work in both neurobiologically-based Biological Anthropology and Peirce studies until 1992,

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[1] Professor Deacon was generous enough to provide me with a copy of this long-ago written text, after the fact its existence came up in casual conversation at the *Gregory Bateson Centennial Conference* that Jesper Hoffmeyer was hosting at the University of Copenhagen in 2005. A published version from 1976 does exist (see the reference list for this section), although copies are extremely rare. However, Deacon is willing to provide an electronic copy to anyone sending him a request for it, and this and many of his other seminal papers can be downloaded from his website at http://teleodynamics.com.

when he accepted positions at both Harvard Medical School and Boston University. After publishing *The Symbolic Species*, his groundbreaking synthesis of Peirce and Biological Anthropology, in 1997, Deacon moved to the University of California at Berkeley in 2002, where he currently holds senior positions in both Anthropology and Neuroscience.

The explanatory power of multidisciplinarity is integral to Deacon's work, as reflected in his recent self-description of his research interests, wherein he lists: "investigations into the neural basis and evolution of language; vertebrate brain evolution and development; neuronal transplantation; evolutionary theory and social-psychological-biological interactions; semiotic theory; emergence, complex systems, self-organizing processes. My neurobiological research," he writes, "is focused on determining the nature of the human divergence from typical primate brain anatomy, the cellular-molecular mechanisms producing this difference, and the correlations between these anatomical differences and special human cognitive abilities, particularly language. In pursuit of these questions I have used a variety of laboratory approaches including the tracing of axonal connections, quantitative analysis of regions of different species brains, and cross-species fetal neural transplantation" (2007:o.l.).

Deacon's empirical investigations into the brain's neuronal organization and its evolution across species – together with his concomitant theoretical investigations into the organization of organismic sign-processes and *their* evolution across species – has, most recently, been augmented by his computer-modelling investigations into the thermodynamic emergence of persistent and reproducible form per se. Together, these constitute the three bases upon which he hopes to articulate "a scientifically precise theory of emergent dynamics". Such a theory, hopes Deacon, would at last "complete Charles Darwin's [self-described] 'unfinished one long argument' [by revealing] the relationships between natural selection and self-organization processes, the origins of life and proto-life, the emergent dynamics of neural processing underlying conscious experience, and the emergence of teleological and semiotic processes" both in nature and in that particular species of nature we call culture (*ibid*).

Situated thusly, Deacon's widely-influential *The Symbolic Species: The Co-Evolution of Language and the Brain* (1997) is but one part of a projected trilogy of monographs aimed at articulating with scientific precision the naturalistic history that led "from matter to mattering." Deacon's soon-to-be released *Homunculus: The Emergence of Mind from Matter* will constitute the second volume in this series, and the tentatively titled *Golem: Making Things Think* will be the third. Reading the titles in reverse order of their appearance reveals the explanatory scope and width of Deacon's project. Reading the one volume that has now appeared reveals its explanatory breadth and depth.

In *The Symbolic Species*, Deacon synthesizes findings from anthropology, linguistics and comparative neuroanatomy, as well as from his own laboratory research in cellular and molecular biology, to inform his Peircean semiotic approach to the question of language evolution. In it, he carefully delineates how the iconic and indexical sign-processing abilities discoverable in other species are a necessary, but not sufficient, stepping-stone to the eventual evolution of self-consciously symbolic human language use – and how human brains and minds evolved their unique characteristics in response to the special demands imposed by increasingly symbolic communication and interpretation practices. "To explain this difference" between human and all other animal forms of sign-processing and cognition, writes Deacon, "and to describe the evolutionary circumstances that brought it about, are the ultimate challenges in the study of human origins" (1997: 22).

In the selection that follows, Deacon begins with a consideration of the oft-asked question: "What is it that separates human cognitive ability from the cognitive abilities of all other animals?" Along with many another thinker, Deacon's short answer is: "language." Language alone, Deacon argues, provides the cognitive tools for experientially transcending the animal prison of the physically pre-given, the immediately consequential, and the eternal here-and-now. It does this by allowing us to knowingly re-combine representational tokens of that reality – and all of its counterfactual possibilities – "off-line". Mastery in the manipulation of such virtual possibility space interposes an unprecedented degree of deliberation into the stimulus-response-consequence cycles of animal being, allowing for the eventual development of logic, mathematics, technology, art – and for the species-specific experience of personally narrative "selves" (1997: 254–278; 340–349).

Deacon parts ways with the majority of contemporary language theorists, however, in averring that the fundamental phenomenon underlying and enabling "language" is not its syntax, but the human capacity for symbolically referential understanding. Accordingly, Deacon argues that neither language-specific genetic mutations, nor human-unique brain structures are at the heart of the human lanuage capacity, and that although common computation-like rules appear to govern syntax (and these, in turn, interact with the socially invented codes of arbitrary difference and différance), these phenomena are themselves but the later biological and social evolutionary consequences of symbolic ability. An evolutionary shift in early hominid social relations necessitated the development of a shared culture of *symbolic reference,* argues Deacon, and this began a coevolutionary dynamic that led both to changes in the brain and to the complexification of language, recursively (1997: 193–252; 349–410).

Thus, while acknowledging that human brains have undergone a number of important evolutionary changes since the time of our pre-linguistic ancestors, Deacon draws upon a wealth of neurobiological and anthropological evidence to argue against theories that "invert evolutionary cause and effect" (1997: 53). He critiques theories that treat language as a "lucky after-effect of general intelligence" or else the accident of some miraculous "mutation" that literally endowed humans with the formal computation processes required for language (cf. Chomsky's posited "language acquisition device" and "universal grammar") – and resists even moreso the posit of an internal, *a-priori* "mental language" (cf. Fodor's "mentalese") that is hard-wired into, and remains Locked away inside of, individual human brains. Rather, argues Deacon, the species-specific capacity for symbolic "language" use arose as, and remains still, the agent-internalized "orientation" to an *externally* existing system of meaning-making to which human brains have had to (and still have to) adapt. "Symbolic thought does not come innately built in" to us, writes Deacon, "but develops by internalizing the symbolic processes that underlies language" (1997: 21–46; 411–464; 22).

It is precisely at this point, however, that the reader who has become accustomed to thinking of "language" as the product of a computer-like brain's built-in coding-and-decoding mechanism, *or* as a purely cultural construct, unmoored in any way to the material facts of biology and animal evolution, comes up against a seeming paradox: If human thought is the internalization of external language use, then what is human language use an externalization of – if not human thought?

Deacon's answer to this paradox is a scientifically rigorous updating of the infinitely generative, yet fundamentally reality-grounded sign logic of Charles Sanders Peirce. Carefully explicating Peirce's notion of a *symbolic* relation as a nested hierarchy of *iconic* (perceptual), *indexical* (associative) and higher-order, rule-bound (conventional) referential relations, Deacon – very much in the spirit of Peirce – shows how the employment of such a system as one's primary way of knowing about the world comes to manifest itself as an experiential heterarchy, or *emergent system,* of significant relations (as depicted schematically in Fig. 18.3 of the selection that follows).

Fundamental, to Deacon's argument is a reworking of evolutionary psychologist James Mark Baldwin's (1861–1934) theory of organic selection, which argues that the very context wherein natural selection takes place can itself be modified by the behavior of its inhabitants – and that this modification may, in turn, generate subsequent new sets of selection pressures. Yet in invoking a Baldwinian theory of language evolution, Deacon specifically resists what he refers to as "the Lamarkian caricature" that Baldwin's idea is often confused with – i.e., that assumes a simple transfer of adaptative response (cf. Pinker's "language instinct") from outside to inside the genome (1997: 326). "No innate rules, no innate general principles, no innate categories [for language] can be built in by evolution," writes Deacon, because for such emergent *symbolic* relations are not decomposable into invariant cross-generational mappings between language structures and brain structures (1997: 339). Biologically grammar could no more evolve than could biologically innate words, argues Deacon. Instead, what human beings have evolved is "a constellation of many indirectly related contributory influences and biases – and *not* an innate replica of a prior facultative behavioral response" (1997: 326).

This constellation of bias and influences constitutes *an orientation* – or learning emphasis – for a mode of being-in-the-world which has in a sense become a predominantly *virtual* world of our own evolutionary creation. An expanded pre-frontal cortex arose as a response to the unique processing demands of community-grounded symbol use, Deacon argues, and has resulted in a "front-heavy" cognitive bias which induces us to "recode our experiences, to see everything as a representation", to "always expect there to be a deeper hidden logic" to "ruminate, question, wonder and infer" (1997:436)....and then to construct relationships, systems, societies and selves as answers to those questions and those inferences. In so doing, we change our niche – and in return, our increasingly symbolic niche changes us.

Surely, Deacon argues, language and the brain have co-evolved. Yet for all its conceptual depth, groundbreaking synthesis and explanatory rigor, Deacon does not lose sight of the fact that the arguments presented *The Symbolic Species* can only explain one part of a still larger puzzle regarding the puzzling ontological relationships between "things" and "thought." For the biological systems whose use of signs is examined in *The Symbolic Species* – i.e., animals and humans – are systems that are already purposeful, that come "pre-equipped" with sensory and motor capabilities, and that have been immersed in long histories of sign-processing by the time that the scientist comes to consider them. Having presented a compelling and scientifically rigorous argument about how such biological systems' sign systems are organized and operate, and how the sign systems of *Homo sapiens* differs from, yet is biologically continuous with, the sign systems of other organisms, Deacon argues that the question that then next demands an answer is: How have such "systems" that are *both* "semiotic" and "biological" – come to be in the first place?

The Symbolic Species is Terrence Deacon's attempt to provide scientific clarity to the question: "How could human language have originated?" Within the next few years, Terrence Deacon plans to publish the next two volumes in his career-long effort to "complete Darwin's one long argument" by addressing the even more fundamental questions: "How could sign systems have originated?" and "How could biological systems have originated?"

"A scientifically adequate theory of semiotic processes must ultimately be founded on a theory of information that can unify the physical, biological, cognitive, and computational uses of the concept," writes Deacon, "unfortunately, no such unification currently exists, and more importantly, the causal status of informational content remains ambiguous as a result. Lacking this grounding, semiotic theories have tended to be predominantly phenomenological taxonomies rather than dynamical explanations of the representational processes of natural systems" (2007: 123).

"Biosemiotics must be derived from scientifically precise and falsifiable first principles," argues Deacon, and should not merely content itself with "analogical generalizations from phenomenological semiotic taxonomies" (2006:o.1.). Ultimately, he argues, we "must show how a phenomenological semiosis evolves from biosemiosis," and how the relations underlying biosemiosis emerge from their constitutive thermodynamic, morphodynamic (e.g. self-organizing) and teleodynamic (e.g. functional) levels of organization (*ibid*).

Deacon's soon to be released next volume, tentatively titled *Homunculus: The Emergence of Mind from Matter*, will expand on the arguments about evolutionary semiosis presented in *The Symbolic Species* by explicating the kinds of self-organizing dynamics that would be necessary for the prior evolution of physical chemistry into "semio-chemistry" – and with it, the biological basis of reference. Such an explication, if successful, would establish a much-needed explanatory bridge from the scientific findings of classic information theory and physics to the meaning-making processes of semiosis.

Until that time, the reader who has not yet read *The Symbolic Species* will find ample reasons for doing so after reaping the characteristically rich and profoundly perspective-changing rewards awaiting in the following excerpt.

Excerpts from *The Symbolic Species* (1997)

An Evolutionary Anomaly

As our species designation – *sapiens* – suggests, the defining attribute of human beings is an unparalleled cognitive ability. We think differently from all other creatures on earth, and we can share those thoughts with one another in ways that no other species even approaches. In comparison, the rest of our biology is almost incidental. Hundreds of millions of years of evolution have produced hundreds of thousands of species with brains and tens of thousands with complex behavioral, perceptual, and learning abilities. Only one of these has ever wondered about its place in the world, because only one evolved the ability to do so.

Though we share the same earth with millions of kinds of living creatures, we also live in a world that no other species has access to. We inhabit a world full of abstractions, impossibilities, and paradoxes. We alone brood about what didn't happen, and spend a large part of each day musing about the way things could have been if events had transpired differently. And we alone ponder what it will be like not to be. In what other species could individuals ever be troubled by the fact that they do not recall the way things were before they were born and will not know what will occur after they die? We tell stories about our real experiences and invent stories about imagined ones, and we even make use of these stories to organize our lives. In a real sense, we live our lives in this shared virtual world. And slowly, over the millennia, we have come to realize that no other species on earth seems able to follow us into this miraculous place.

We are all familiar with this facet of our lives, but how, you might ask, could I feel so confident that it is not part of the mental experience of other species – so sure that they do not share these kinds of thoughts and concerns – when they cannot be queried about them? That's just it! My answer, which will be argued in detail in the following chapters, has everything to do with language and the absence of it in other species. The doorway into this virtual world was opened to us alone by the evolution of language, because language is not merely a mode of communication; it is also the outward expression of an unusual mode of thought-symbolic representation. Without symbolization the entire virtual world that I have described is out of reach: inconceivable. My extravagant claim to know what other species cannot know rests on evidence that symbolic thought does not come innately built in, but develops by internalizing the symbolic process that underlies language. So species that have not acquired the ability to communicate symbolically cannot have acquired the ability to think this way either.

The way that language represents objects, events, and relationships provides a uniquely powerful economy of reference. It offers a means for generating an essentially infinite variety of novel representations, and an unprecedented inferential engine for predicting events, organizing memories, and planning behaviors. It entirely shapes our thinking and the ways we know the physical world. It is so pervasive and inseparable from human intelligence in general that it is difficult to distinguish what aspects of the human intellect have not been molded and streamlined by it. To explain this difference and describe the evolutionary circumstances that brought it about are the ultimate challenges in the study of human origins.

The question that ultimately motivates a perennial fascination with human origins is not who were our ancestors, or how they came to walk upright, or even how they discovered the use of stone tools. It is not really a question that has a paleontological answer. It is a question that might otherwise be asked of psychologists or neurologists or even philosophers. *Where do human minds come from?* The missing link that we hope to fill in by investigating human origins is not so much a gap in our family tree, but a gap that separates us from other species in general. Knowing how something originated often is the best clue to how it works. And we know that human consciousness had a beginning. Those features of our mental abilities that distinguish us from all other species arose within the handful of million years since we shared a common ancestor with the remaining African apes, and probably can mostly be traced to events that took place only within the last 2 million. It was a Rubicon that was crossed at a definite time and in a specific evolutionary context. If we could identify what was different on either side of this divide – differences in ecology, behavior, anatomy, especially neuroanatomy – perhaps we would find the critical change that catapulted us into this unprecedented world full of abstractions, stories, and impossibilities, that we call human.

It is not just the origins of our biological species that we seek to explain, but the origins of our novel form of mind. Biologically, we are just another ape. Mentally, we are a new phylum of organisms. In these two seemingly incommensurate facts lies a conundrum that must be resolved before we have an adequate explanation of what it means to be human.

The Hierarchical Nature of Reference

The assumption that a one-to-one mapping of *words* onto *objects* and vice versa is the basis for *meaning* and *reference* was made explicit in the work of the turn-of-the-century French linguist Ferdinand de Saussure. In his widely influential work on *semiology* (his term for the study of language), he argued that word meaning can be modeled by an element-by-element mapping between two "planes" of objects: from elements constituting the plane of the signifiers (e.g., words) to elements on the plane of the signified (the ideas, objects, events, etc., that words refer to).[2] On this view, the mapping of vervet monkey alarm calls onto predators could be considered a signifier-signified relationship.[3] But how accurately does this model

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[2] See de Saussure (1916). I have simplified this account considerably from what de Saussure described. He recognized an orthogonal "plane" to that of reference, associated with the combinatorial and diachronic (time-dependent) processes of language.

[3] E.g., Cheney and Seyfarth (1992).

word reference? Although it is natural to imagine words as labels for objects, or mental images, or concepts, we can now see that such correspondences only capture superficial aspects of word meaning. Focusing on correspondence alone collapses a multileveled relationship into a simple mapping relationship. It fails to distinguish between the rote understanding of words that my dog possesses and the semantic understanding of them that a normal human speaker exhibits. We also saw that the correspondence of words to referents is not enough to explain word meaning because the actual frequency of correlations between items on the two planes is extremely low. Instead, what I hope to show is that the relationship is the reverse of what we commonly imagine. The correspondence between words and objects is a secondary relationship, subordinate to a web of associative relationships of a quite different sort, which even allows us reference to impossible things.

In order to be more specific about differences in referential form, philosophers and semioticians have often distinguished between different forms of referential relationships. Probably the most successful classification of representational relationships was, again, provided by the American philosopher Charles Sanders Peirce. As part of a larger scheme of semiotic relationships, he distinguished three categories of referential associations: *icon*, *index*, and *symbol*.[4] These terms were, of course, around before Peirce, and have been used in different ways by others since. Peirce confined the use of these terms to describing the nature of the formal relationship between the characteristics of the sign token and those of the physical object represented. As a first approximation these are as follows: icons are mediated by a similarity between sign and object, indices are mediated by some physical or temporal connection between sign and object, and symbols are mediated by some formal or merely agreed-upon link irrespective of any physical characteristics of either sign or object. These three forms of reference reflect a classic philosophical trichotomy of possible modes of associative relationship: (a) similarity, (b) contiguity or correlation, and (c) law, causality, or convention. The great philosophers of mind, such as John Locke, David Hume, Immanuel Kant, Georg Wilhelm Friedrich Hegel, and many others, had each in one way or another argued that these three modes of relationship describe the fundamental forms by which ideas can come to be associated. Peirce took these insights and rephrased the problem of mind in terms of communication, essentially arguing that all forms of thought (ideas) are essentially communication (transmission of signs), organized by an underlying logic (or *semiotic*, as he called it) that is not fundamentally different for communication processes inside or outside of brains. If so, it might be possible to investigate the logic of

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[4] Though I will avoid most of Peirce's complex terminology and only obliquely suggest the unique philosophical context in which he embedded his semiotic theory, I believe the following analysis will stay close to his original insights, which focused on representation as process, not as a static relationship, and recognized these sign types as hierarchical levels of representation, not as opposed categorical alternatives. For a brief set of excepts of some of Peirce's core writngs on the topic, I recommend Buchler, ed. (1955). Many of Peirce's major writings on the semiotic basis of logic were compiled in the Hartshorne and Weiss, eds., collection of Peirce's papers (1978), especially Vol. II.

thought processes by studying the sign production and interpretation processes in more overt communication.

To get a sense of this logic of signs, let's begin by considering a few examples. When we say something is "iconic" of something else we usually mean that there is a resemblance that we notice. Landscapes, portraits, and pictures of all kinds are iconic of what they depict. When we say something is an "index" we mean that it is somehow causally linked to something else, or associated with it in space or time. A thermometer *indicates* the temperature of water, a weathervane indicates the direction of the wind, and a disagreeable odor might indicate the presence of a skunk. Most forms of animal communication have this quality, from pheromonal odors (that indicate an animal's physiological state or proximity) to alarm calls (that indicate the presence of a dangerous predator). Finally, when we say something is a "symbol," we mean there is some social convention, tacit agreement, or explicit code which establishes the relationship that links one thing to another. A wedding ring symbolizes a marital agreement; the typographical letter "e" symbolizes a particular sound used in words (or sometimes as in English, what should be done to other sounds); and taken together, the words of this sentence symbolize a particular idea or set of ideas.

No particular objects are intrinsically icons, indices, or symbols. They are interpreted to be so, depending on what is produced in response. In simple terms, the differences between iconic, indexical, and symbolic relationships derive from regarding things either with respect to their form, their correlations with other things, or their involvement in systems of conventional relationships.

When we apply these terms to particular things, for instance, calling a particular sculpture an *icon*, a speedometer an *indicator,* or a coat of arms a *symbol*, we are engaging in a sort of tacit shorthand. What we usually mean is that they were *designed* to be interpreted that way, or are highly likely to be interpreted that way. So, for example, a striking resemblance does not make one thing an icon of another. Only when considering the features of one brings the other to mind because of this resemblance is the relationship iconic. Similarity does not cause iconicity, nor is iconicity the physical relationship of similarity. It is a kind of inferential process that is based on recognizing a similarity. As critics of the concept of iconicity have often pointed out, almost anything could be considered an icon of anything else, depending on the vagueness of the similarity considered.

The same point can be made for each of the other two modes of referential relationship: neither physical connection nor involvement in some conventional activity dictates that something is indexical or symbolic, respectively. Only when these are the basis by which one thing invokes – another are we justified in calling their relationship indexical or symbolic. Though this might seem an obvious point, confusion about it has been a source of significant misunderstandings. For example, there was at one time considerable debate over whether hand signs in American Sign Language (ASL) are iconic or symbolic. Many signs seemed to resemble pantomime or appeared graphically to "depict" or point to what was represented, and so some researchers suggested that their meaning was "merely iconic" and by implication, not wordlike. It is now abundantly clear, however, that despite such resemblances, ASL is a language and its elements are both symbolic and wordlike in every regard. Being capable of iconic or indexical interpretation in no way diminishes these signs' capacity of being interpreted symbolically as well. These modes of reference aren't mutually exclusive alternatives; though at anyone time only one of these modes may be prominent, the same signs can be icons, indices, and symbols depending on the interpretive process. But the relationships between icons, indices, and symbols are not merely a matter of alternative interpretations. They are to some extent internally related to one another.

This is evident when we consider examples where different interpreters are able to interpret the same signs to a greater or lesser extent. Consider, for example, an archeologist who discovers some elaborate markings on clay tablets. It is natural to assume that these inscriptions were used symbolically by the people who made them, perhaps as a kind of primitive writing. But the archeologist, who as yet has no Rosetta Stone with which to decode them, cannot interpret them symbolically. The archeologist simply infers that to someone in the past these may have been symbolically interpretable, because they resemble symbols seen in other contexts. Being unable to interpret them symbolically, he interprets them iconically. Some of the earliest inscription systems from the ancient Middle Eastern civilizations of the Fertile Cresent were in fact recovered in contexts that provided additional clues to their representations. Small clay objects were marked with repeated imprints, then sealed in vessels that accompanied trade goods sent from one place to another. Their physical association with these other artifacts has provided archeologists with indexical evidence to augment their interpretations. Different marks apparently indicated a corresponding number of items shipped, probably used by the recipient of the shipment to be sure that all items were delivered. No longer merely iconic of other generic writinglike marks, they now can be given indexical and tentative symbolic interpretations, because something more than resemblance is provided.

This can also be seen by an inverse example: a descent down a hierarchy of diminishing interpretive competence, but this time with respect to interpretive competences provided by evolution. Let's consider laughter again. Laughter indicates something about what sort of event just preceded it. As a symptom of a person's response to certain stimuli, it provides considerable information about both the laugher and the object of the laughter, i.e, (original) that it involved something humorous. But laughter alone does not provide sufficient information to reconstruct exactly what was so funny. Chimpanzees also produce a call that is vaguely similar to laughter in certain play situations (e.g., tickling). Consequently, they might also recognize human laughter as indicating certain aspects of the social context (i.e., playful, nonthreatening, not distressing, etc.), but they would likely miss the reference to humor. I suspect that implicit in the notion of humor there is a symbolic element, a requirement for recognizing contradiction or paradox, that the average chimpanzee has not developed. The family cat and dog, however, probably do not even get *this* much information from a human laugh. Not sharing our evolved predisposition to laugh in certain social relationships, they do not possess the mental prerequisites to interpret even the social signaling function of laughter. Experience may only have provided them with the ability to use it as evidence that a human is present and is probably not threatening. Nevertheless, this too is dependent on some level of interpretative competence, perhaps provided by recalling prior occasions when some human made this odd noise. Finally, there are innumerable species of animals from flies to snails to fish that wouldn't even produce this much of a response, and would interpret the laughter as just another vibration of the air or water. The diminishing competences of these species corresponds with interpretations that are progressively less and less specific and progressively more and more concrete. But even at the bottom of this descent there is a possibility of a kind of minimalistic reference.

This demonstrates one of Peirce's most fundamental and original insights about the process of interpretation: the difference between different modes of reference can be understood in terms of *levels* of interpretation. Attending to this hierarchical aspect of reference is essential for understanding the difference between the way words and animal calls are related. It's not just the case that we are able to interpret the same sign in different ways, but more important, these different interpretations can be arranged in a sort of ascending order that reflect a prior competence to identify higher-level associative relationships. In other words, reference itself is hierarchic in structure; more complex forms of reference are built up from simpler forms. But there is more to this than just increasing complexity. This hierarchical structure is a clue to the relationships between these different modes of reference. Though I may fail to grasp the symbolic reference of a sign, I might still be able to interpret it as an index (i.e., as correlated with something else), and if I also fail to recognize any indexical correspondences, I may still be able to interpret it as an icon (i.e., recognize its resemblance to something else). Breakdown of referential competence leads to an ordered descent from symbolic to indexical to iconic, not just from complex icons, indices, or symbols to simpler counterparts. Conversely, increasing the sophistication of interpretive competence reverses the order of this breakdown of reference. For example, as human children become more competent and more experienced with written words, they gradually replace their iconic interpretations of these marks as just more writing with indexical interpretations supported by a recognition of certain regular correspondences to pictures and spoken sounds, and eventually use these as support for learning to interpret their symbolic meanings. In this way they trace a path somewhat like the archeologist learning to decipher an ancient script.

This suggests that indexical reference depends upon iconic reference, and symbolic reference depends upon indexical reference – a hierarchy diagrammatically depicted in Fig. 18.1. It sounds pretty straightforward on the surface. But this simplicity is deceiving, because what we really mean is that the competence to interpret something symbolically depends upon already having the competence to interpret many other subordinate relationships indexically, and so forth. It is one kind of competence that grows out of and depends upon a very different kind of competence. What constitutes competence in this sense is the ability to produce an interpretive response that provides the necessary infrastructure of more basic iconic and/or indexical interpretations. To explain the basis of symbolic communication, then, we must describe what constitutes a symbolic interpretant, but to do this we need first

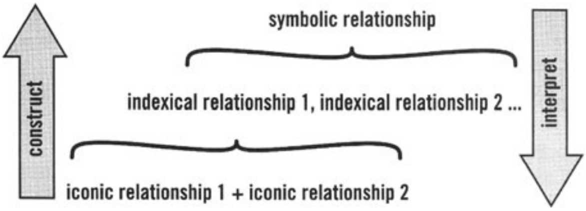


Fig. 18.1 The hierarchic relationships between the three fundamental forms of reference-iconic, indexical, and symbolic. Symbolic relationships are composed of indexical relationships between sets of indices and indexical relationships are composed of iconic relationships between sets of icons (diagrammed more pictorially in Figs. 3.2 and 3.3). This suggests a kind of semiotic reductionism in which more complex forms of representation are analyzable to simpler forms. In fact, this is essentially what occurs as forms are interpreted. Higher-order forms are decomposed into (replaced or represented by) lower-order forms. Inversely, to construct higher representation, one must operate on lower-order forms to replace them (represent them) In C. S. Peirce's terminology, each is an interpretive process, and the new signs substituted for the previous signs at a different level are "interpretants" of those prior signs (see text for details)

to explain the production of iconic and indexical interpretants and then to explain how these are each recoded in turn to produce the higher-order forms.

So, we need to start the explanation of symbolic competence with an explanation of what is required in order to interpret icons and build upward. Usually, people explain icons in terms of some respect or other in which two things are alike. But the resemblance doesn't produce the iconicity. Only *after* we recognize an iconic relationship can we say exactly what we saw in common, and sometimes not even then. The interpretive step that establishes an iconic relationship is essentially prior to this, and it is something negative, something that we don't do. It is, so to speak, the act of*not* making a distinction. Let me illustrate this with a very stripped-down example.

Consider camouflage, as in the case of natural protective coloration. A moth on a tree whose wings resemble the graininess and color of the bark, though not perfectly, can still escape being eaten by a bird if the bird is inattentive and interprets the moth's wings as just more tree. Admittedly, this is not the way we typically use the term *iconic*, but I think it illuminates the most basic sense of the concept. If the moth had been a little less matching, or had moved, or the bird had been a little more attentive, then any of the differences between the moth and the tree made evident by those additional differences would have *indicated* to the bird that there was something else present which wasn't just more tree. If the bird had been in a contemplative mood, it might even have reflected on the slight resemblance of the wing pattern to bark, at least for the fraction of a second before it gobbled the hapless moth. Some features of the moth's wings were iconic of the bark, irrespective of their degree of similarity, merely because under some interpretation (an inattentive bird) they were not distinguished from it.

Now, it might seem awkward to explain iconicity with an example that, could be considered to be no representation at all, but I think it helps to clarify the shift in emphasis I want to make from the relationship to the process behind it. What makes the moth wings iconic is an interpretive process produced by the bird, not something about the moth's wings. Their coloration was *taken* to be an icon because of something that the bird *didn't* do. What the bird was doing was actively scanning bark, its brain seeing just more of the same (bark, bark, bark . . .). What it didn't do was alter this process (e.g., bark, bark, not-bark, bark . . .). It applied the same interpretive perceptual process to the moth as it did to the bark. It didn't distinguish between them, and so confused them with one another. This established the iconic relationship between moth and bark. Iconic reference is the default.

Even in an imagined moment of reflective reverie in which the bird ponders on their slight resemblance, it is the part of its responding that does not distinguish wing from bark that determines their relationship to be iconic. Iconic resemblance is not based on some prior ground of physical similarity, but in that aspect of the interpretation process that does not differ from some other interpretive process. Thus, although a respect in which two things are similar may influence the ways they tend to be iconically related, it does not determine their iconicity. Iconism is where the referential buck stops when nothing more is added. And at some level, due either to limitations in abilities to produce distinguishing responses or simply a lack of effort to produce them, the production of new interpretants stops. Whether because of boredom or limitations of a minimal nervous system, there are times when almost anything can be iconic of anything else (stuff, stuff, stuff . . .).

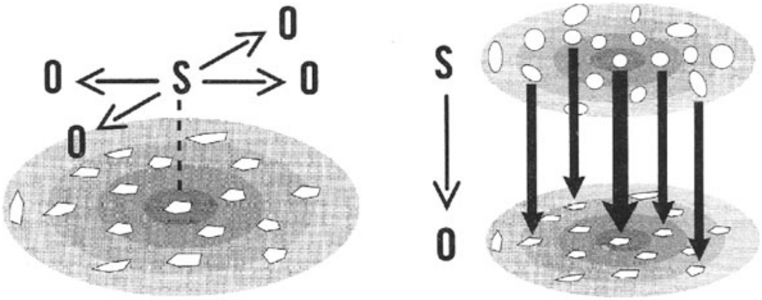
What does this have to do with pictures, or other likenesses such as busts or caricatures that we more commonly think of as icons? The explanation is essentially no different. That facet or stage of my interpretive recognition process that is the same for a sketch and the face it portrays is what makes it an icon. I might abstractly reflect on what aspects of the sketch caused this response, and might realize that this was the intention of the artist, but a sketch that is never seen is just paper and charcoal. It could also be interpreted as something that soaked up spilled coffee (and the spilled coffee could be seen as a likeness of Abe Lincoln!). Peirce once characterized an icon as something which upon closer inspection can provide further information about the attributes of its object. Looking at the one is like looking at the other in some respects. Looking at a caricature can, for example, get one to notice for the first time that a well-known politician has a protruding jaw or floppy jowls. The simplification in a diagram or the exaggeration in a cartoon takes advantage of our spontaneous laxness in making distinctions to trick us into making new associations. In this way a caricature resembles a joke, a visual pun, and a diagram can be a source of discovery.

In summary, the interpretive process that generates iconic reference is none other than what in other terms we call *recognition* (mostly perceptual recognition, but not necessarily). Breaking down the term *re-cognition* says it all: to "think [about something] again," Similarly, representation is to present something again. Iconic relationships are the most basic means by which things can be re-presented. It is the base on which all other forms of representation are built. It is the bottom of the interpretive hierarchy. A sign is interpreted, and thus seen to be a representation, by being reduced (i.e., analyzed to its component representations) to the point of no further reduceability (due to competence or time limitations, or due to pragmatic constraints), and thus is ultimately translated into iconic relationships. This does not necessarily require any effort. It is in many cases where interpretive effort ceases. It can merely be the end of new interpretation, that boundary of consciousness where experience fades into redundancy.

Interpreting something as an indexical relationship is this and more. Physical contiguity (nearness or connectedness) or just predictable co-occurrence are the basis for interpreting one thing as an index for another, but as with the case of icons, these physical characteristics are not the cause of the indexical relationship. Almost anything could be physically or temporally associated with anything else by virtue of some extension of the experience of nearness in space or time. What makes one an index of another is the interpretive response whereby one seems to "point to" the other. To understand the relationship that indexical interpretations have to iconic interpretations, it is necessary to see how the competence to make indexical interpretations arises. In contrast to iconic interpretations, which can often be attributed to interpretive incompetence or the cessation of production of new interpretants, indexical interpretations require something added. In fact, icons arise from a failure to produce critical indices to distinguish things.

Consider the example of a symptom, like the smell of smoke. When I smell smoke, I begin to suspect that something is burning. How did my ability to treat this smell as an indication of fire arise? It likely arose by learning, because I had past experiences in which similar odors were traced to things that were burning. After a few recurrences it became a familiar association, and the smell of smoke began to indicate to me that a fire might be near. If we consider more closely the learning process that produced the indexical competence, the critical role of icons becomes obvious. The indexical competence is constructed from a set of relationships between icons, and the indexical interpretation is accomplished by bringing this assembly of iconic relationships to bear in the assessment of new stimuli. The smell of smoke brings to mind past similar experiences (by iconically representing them). Each of these experiences comes to mind because of their similarities to one another and to the present event. But what is more, many of these past experiences also share other similarities. On many of these occasions I also noticed something burning that was the source of the smoke, and in this way those experiences were icons of each other.

There is one important feature added besides all these iconic recognitions. The *repeated correlation* between the smelling of smoke and the presence of flames in each case adds a third higher-order level of iconicity. This is the key ingredient. Because of this I recognize the more general similarity of the entire present situation to these past ones, not just the smoke and not just the fire but also their co-occurrence, and this is what brings to mind the missing element in the present case: the probability that something is burning. What I am suggesting, then, is that the responses we develop as a result of day-to-day associative learning are the basis for all indexical interpretations, and that this is the result of a special relationship that develops among iconic interpretive processes. It's hierarchic. Prior iconic relationships are necessary for indexical reference, but prior indexical relationships are



ICON: Associated by stimulus generalization or conventional similarity

INDEX: Associated by spatial-temporal correlation or part-whole contiguity

Fig. 18.2 A schematic diagram depicting the internal hierarchic relationships between iconic and indexical reference processes. The probability of interpreting something as iconic of something else is depicted by a series of concentric domains of decreasing similarity and decreasing iconic potential among objects. Surrounding objects have a decreasing capacity to serve as icons for the target object as similarities become unobvious. The form of a sign stimulus (S) elicits awareness of a set of past stimulus memories (e.g., mental "images") by virtue of stimulus generalization processes. Thus, any remembered object (0) can be said to be re-presented by the iconic stimulus. Similarly, each mental image is iconic in the same way; no other referential relationship need necessarily be involved for an iconic referential relationship to be produced. Indexical reference, however, requires iconic reference. In order to interpret something as indexical, at least three iconic relationships must b also recognized. First, the indicating stimulus must be seen as an icon of other similar instances (the *top* iconic relationships); second, instances of its occurrence mm also correlate (*arrows*) with additional stimuli either in space or time, and these need, to be iconic of one another (the *bottom* iconic relationships); and third, past correlations need to be interpreted as iconic of one another (indicated by the concentric arrangement of *arrows*). The indexical interpretation is thus the conjunction of three iconic interpretations, with one being a higher-order icon than the other two (i.e., treating them as parts of a whole). As pointed out in the text, this is essentially the kind of reference provided by a conditioned response. ICON, Associated by stimulus generalization or conventional similarity; INDEX, Associated by spatial-temporal correlation or part-whole contiguity

not in the same way necessary for iconic reference. This hierarchic dependency of indices on icons is graphically depicted in Fig. 18.2.

Okay, why have I gone to all this trouble to rename these otherwise common, well-established uses of perception and learning? Could we just substitute the word "perception" for "icon" and "learned" association for index? No. Icons and indices are not merely perception and learning, they refer to the *inferential* or *predictive* powers that are implicit in these neural processes. Representational relationships are not just these mechanisms, but a feature of their potential relationship to past, future, distant, or imaginary things. These other things are not physically re-presented but only virtually re-presented by producing perceptual and learned responses like those that would be produced if they were present. In this sense, mental processes are no less representational than external communicative processes, and communicative processes are no less mental in this regard. Mental representation reduces to internal communication.

What, then, is the difference between these uncontroversial cognitive processes underlying icons and indices and the kind of cognitive processes underlying symbols? The same hierarchical logic applies. As indices are constituted by relationships among icons, symbols are constituted by relationships among indices (and therefore also icons). However, what makes this a difficult step is that the added relationship is not mere correlation.

The Symbolic Threshold

The common sense idea is that a symbolic association is formed when we learn to pair a sound or typed string with something else in the world. But in the terms we have been developing, this is what we mean by an *indexical* association. The word (iconically associated with past occurrences of similar utterances) and the object (iconically associated with similar objects from past experiences) and their past correlations enable the word to bring the object to mind. In this view, the association between a word and what it represents is not essentially distinguished from the kind of association that is made by an animal in a Skinner box. We might, for example, train a rat to recognize a correlation between hearing the sound of the word "food" and food being dropped into a tray. The conditioned stimulus takes on referential power in this process: it represents something about the state of the apparatus for the animal. It is an *index* of the availability of food in the Skinner box; a symptom of the state of the box. Words can serve indexical functions as well, and are sometimes used for this purpose almost exclusively, with minimal symbolic content. Consider, for example, the use of function words like "there," exclamations like "Aha!", or even proper names like "George Washington." These derive reference by being uniquely linked to individual contexts, objects, occasions, people, places, and so on, and they defy our efforts to define them as we would typical nouns or verbs.

One indication that someone understands the meaning of a new word is whether they can use it in a new sentence or novel context. If the new word was just learned as a part of an unanalyzed phrase, or mapped to some restricted acquisition context, then we might not expect it to be correctly used out of this context. But the ability to use a word correctly in a variety of contexts, while fair evidence of symbolic understanding, is not necessarily convincing as a proof of understanding. The ability to shift usage to a novel context resembles transference of one learning set; and indeed, searching for the common learning set features among the many contexts in which the same word might be used is a good way to zero in on its meaning. If someone were to learn only this – i.e., that a particular phrase works well in a range of contexts that exhibit similar features or social relationships they might well be able to fool us into believing that they understood what they said. However, on discovering that they accomplished this by simply mapping similar elements from one context to another, we would conclude that they actually did not understand the word or its role in context in the way we originally imagined. Theirs would be an iconic and indexical understanding only. Being able easily to transfer referential functions from one "set" to another is a characteristic of symbols, but is this the basis for their reference?

Psychologists call transfer of associations from one stimulus to another similar one "stimulus generalization," and transfer of a pattern of learning from one context to another similar context the transfer of a "learning set." These more complex forms of indexical association are also often confused with symbolic associations. Transference of learning from stimulus to stimulus or from context to context occurs as an incidental consequence of learning. These are not really separate forms of learning. Both are based on iconic projection of one stimulus condition onto another. Each arises spontaneously because there is always some ambiguity as to what are the essential parameters of the stimulus that a subject learns to associate with a subsequent desired or undesired result: learning is always an extrapolation from a finite number of examples to future examples, and these seldom provide a basis for choosing between all possible variations of a stimulus. To the extent that new stimuli exhibit features shared by the familiar set of stimuli used for training, and none that are inconsistent with them, these other potential stimuli are also incidentally learned. Often, psychological models of this process are presented as though the subject has learned *rules* for identifying associative relationships. However, since this is based on an iconic relationship, there is no implicit list of criteria that is learned; only a failure to distinguish that which hasn't been explicitly excluded by the training.

Words for kinds of things appear to refer to whole groups of loosely similar objects, such as could be linked by stimulus generalization, and words for qualities and properties of objects refer to the sorts of features that are often the basis for stimulus generalization. Animals can be trained to produce the same sign when presented with different kinds of foods, or trees, or familiar animals, or any other class of objects that share physical attributes in common, even subtle ones (e.g., all hoofed mammals). Similarly, the vervet monkeys' eagle alarm calls might become generalized to other aerial predators if they were introduced into their environment. The grouping of these referents is not by symbolic criteria (though from outside *we* might apply our own symbolic criteria), but by iconic overlap that serves as the basis for their common indexical reference. Stimulus generalization may contribute essential structure to the realms to which words refer, but it is only one subordinate component of the relationship and not what determines their reference.

This same logic applies to the transference of learning sets. For example, learning to choose the odd-shaped object out of three, where two are more similar to each other than the third, might aid in learning a subsequent oddity-discrimination task involving sounds. Rather than just transferring an associated response on the basis of stimulus similarities, the subject recognizes an iconicity between the two learning tasks as wholes. Though this is hierarchically more sophisticated association than stimulus generalization – learning a *learning pattern* – it is still an indexical association transferred to a novel stimulus via an iconic interpretation. Here the structure (of the new training context is seen as iconic of a previous one, allowing the subject to map corresponding elements from the one to the other. This is not often an easy association to make, and most species (including humans) will fail to discover the underlying iconicity when the environment, the training stimuli, the specific responses required, and the reinforcers are all quite different from one context to the next.

There are two things that are critically different about the relationships between a word and its reference when compared to transference of word use to new contexts. First, for an indexical relationship to hold, there must be a correlation in time and place of the word and its object. If the correlation breaks down (for example, the rat no longer gets food by pushing a lever when the sound "food" is played), then the association is eventually forgotten ("extinguished"), and the indexical power of that word to refer is lost. This is true for indices in general. If a smokelike smell becomes common in the absence of anything burning, it will begin to lose its indicative power in that context. For the Boy Who Cried Wolf, in the fable of the same name, the indexical function of his use of the word "wolf" fails because of its lack of association with real wolves, *even though the symbolic reference remains.* Thus, symbolic reference remains stable nearly independent of any such correlations. In fact, the physical association between a word and an appropriate object of reference can be quite rare, or even an impossibility, as with angels, unicorns, and quarks. With so little correlation, an indexical association would not survive.

Second, even if an animal subject is trained to associate a number of words with different foods or states of the box, each of these associations will have little effect upon the others. They are essentially independent. If one of these associations is extinguished or is paired with something new, it will likely make little difference to the other associations, unless there is some slight transference via stimulus generalization. But this is not the case with words. Words also represent other words. In fact, they are incorporated into quite specific individual relationships to *all* other words of a language. Think of the way a dictionary or thesaurus works. They each map one word onto other words. If this shared mapping breaks down between users (as sometimes happens when words are radically reused in slang, such as "bad" for "very good" or "plastered" for "intoxicated"), the reference also will fail.

This second difference is what ultimately explains the first. We do not lose the indexical associations of words, despite a lack of correlation with physical referents, because the possibility of this link is maintained implicitly in the stable associations between words. It is by virtue of this sort of dual reference, to objects and to other words (or at least to other semantic alternatives), that a word conveys the information necessary to pick out objects of reference. This duality of reference is captured in the classic distinction between sense and reference. Words point to objects (reference) and words point to other words (sense), but we use the sense to pick out the reference, not vice versa.

This referential relationship between the words – words systematically indicating other words -forms a system of higher-order relationships that allows words to be *about* indexical relationships, and not just indices in themselves. But this is also why words need to be in context with other words, in phrases and sentences, in order to have any determinate reference. Their indexical power is *distributed*, so to speak, in the relationships between words. Symbolic reference derives from *combinatorial* possibilities and impossibilities, and we therefore depend on combinations both to discover it (during learning) and to make use of it (during communication). Thus the imagined version of a nonhuman animal language that is made up of isolated words, but lacking regularities that govern possible combinations, ultimately a contradiction in terms.

Even without struggling with the philosophical subtleties of this relationship, we can immediately see the significance for learning. The learning problem associated with symbolic reference is a consequence of the fact that what determines the pairing between a symbol (like a word) and some object or event is not their probability of co-occurrence, but rather some complex function of the relationship that the symbol has to other symbols. This is a separate but linked learning problem, and worse yet, it creates a third, higher-order *unlearning* problem. Learning is, at its base, a function of the probability of correlations between things, from the synaptic level to the behavioral level. Past correlations tend to be predictive of future correlations. This, as we've seen, is the basis for indexical reference. In order to comprehend a symbolic relationship, however, such indexical associations must be subordinated to relationships between different symbols. This is a troublesome shift of emphasis. To learn symbols we begin by learning symbol-object correlations, but once learned, these associations must be treated as no more than clues for determining the more crucial relationships. And these relationships are not highly correlated; in fact, often just the reverse. Words that carry similar referential function are more often used alternatively and not together, and words with very different (complementary) referential functions tend to to (in the original text) be adjacent to one another in sentences. Worst of all, few sentences or phrases are ever repeated exactly, and the frequency with which specific word combinations are repeated is also extremely low. Hardly a recipe for easy indexical learning.

One of the most insightful demonstrations of the learning difficulties associated with the shift from conditioned associations to symbolic associations comes not from a human example, but from a set of experiments that attempted to train chimpanzees to use simple symbols. This study was directed by Sue Savage-Rumbaugh and Duane Rumbaugh,[5] now at the Language Research Center of Georgia State University, and included four chimps, two of which, Sherman and Austin, showed particular facility with the symbols. It is far from the "last word" on how far other species can go in their understanding of language-like communication, and further studies of another chimpanzee (from a different subspecies) that show more developed abilities[6] will be described subsequently (see Chapter 4), but this work has the virtue of exposing much of what is often hidden in children's comparatively easy entry into symbolic communication, and so provides an accessible step-by-step account of what we usually take for granted in the process. In what follows I will outline these experiments briefly. Only the most relevant highlights will be

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[5] See Savage-Rumbaugh et al. (1978, 1980); and Savage-Rumbaugh (1986). In the stripped-down account presented here, I focus only on the two of the four chimps who were most successful (Sherman and Austin) and who continued to participate in subsequent language experiments.

[6] Described in Savage-Rumbaugh and Lewin (1994).

described and other aspects will be simplified for the sake of my purpose here. Of course, my attempts to "get inside the chimps' heads" during this process are fantasy. Though I will use somewhat different terminology from the experimenters to describe this transition from indexical to symbolic communication, I am reasonably confident that my interpretation is not at odds with theirs. However, the interested reader should refer to the excellent account of these experiments and their significance in Savage-Rumbaugh's book describing them.

The chimps in this study were taught to use a special computer keyboard made up of lexigrams-simple abstract shapes (lacking any apparent iconism to their intended referents) on large illuminated keys on a keyboard mounted in their cage. Duane Rumbaugh's previous experiments (with a chimp named Lana)[7] had shown that chimps have the ability to learn a large number of paired associations between lexigrams (and in fact other kinds of symbol tokens) and objects or activities. But in order to respond to critics and more fully test other features of this ability, Duane and Sue began a new series of experiments with a group of chimps to test both chimp-chimp communication and chimps' ability to use lexigrams in combinations (e.g., syntactic relationships). Not surprisingly, the chimps exhibited some interesting difficulties when they were required to use lexigrams in combinations, but they eventually solved their learning problems and exhibited a use of the lexigrams that was clearly symbolic. In so doing they have provided us with a remarkably explicit record of the process that leads from index to symbol.

In order to test Sherman and Austin's symbolic understanding of the lexigrams, the chimps were trained to chain lexigram pairs in a Simple verb-noun relationship (a sequence glossed as meaning "give," which caused a dispenser to deliver a solid food, and "banana" to get a banana).[8] Initially there were only 2 "verb" lexigrams and 4 food or drink lexigrams to choose from, and each pair had to be separately taught. But after successful training of each pairing, the chimps were presented with all the options they had learned independently, and were required to choose which combination was most appropriate on the basis of food availability or preference. Curiously, the solution to this task was not implicit in their previous training. This was evident in the fact that some chimps tended stereotypically to repeat only the most recent single learned combination, whereas others chained together all options, irrespective of the intended meanings and what they knew about the situation. Thus they had learned the individual associations but failed to learn the system of relationships of which these correlations were a part. Although the logic of the combinatorial relationships between lexigrams was implicit in the particular combinations that the chimps learned, the converse exclusive relationships had not been learned. For example, they were not explicitly trained to avoid any number

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[7] Rumbaugh (1977).

[8] I have simplified the paradigm a bit by omitting mention of an additional key that signaled the start of a trial (sometimes glossed in a sort of tongue-in-cheek fashion as "Please") and one to signify its end (sometimes glossed as a period). These were essentially irrelevant to the problem except as added distractors, since they did not vary from trial to trial, and such glosses could be quite misleading.

of inappropriate combinations such as “banana juice give.” Though these errors are implicit for us, who treat them symbolically from the start, the combinatorial rules that allow pairing in some but not other cases was vastly underdetermined by the training experience (as it is also in a child’s experience of others’ word use).

It is not immediately obvious exactly how much exclusionary information is implicit, hut it turns out to be quite a lot. Think about it from the naive chimpanzee perspective for a moment. Even with this ultra-simple symbol system of six lexigrams and a two-lexigram combinatorial grammar, the chimpanzee is faced with the possibility of sorting among 720 possible ordered sequences (6°5°4°3°2°1) or 64 possible ordered pairs. The training has offered only four prototype examples, in isolation. Though each chimp may begin with many guesses about what works, these are unlikely to be in the form of rules about classes of allowed and disallowed combinations, but rather about possible numbers of lexigrams that must be pressed, their positions on the board, their colors or shape cues that might be associated with a reward object, and so on. Recognizing this limitation, the experimenters embarked on a rather interesting course of training. They set out explicitly to train the chimps on which cues were not relevant and which combinations were not meaningful. This poses an interesting problem that every pet trainer has faced. You can’t train what *not* to do unless the animal first produces the disallowed behavior. Only then can it be immediately punished or at least explicitly not rewarded (the correlation problem again). So the chimps were first trained to produce incorrect associations (e.g., mistaking keyboard position as the relevant variable) and then these errors were explicitly not rewarded, whereas the remaining appropriate responses were. By a complex hierarchic training design, involving thousands of trials, it was possible to teach them to exclude systematically all inappropriate associative and combinatorial possibilities among the small handful of lexigrams. At the end of this process, the animals were able to produce the correct lexigram strings every time.

Had training out the errors worked? To test this, the researchers introduced a few new food items and corresponding new lexigrams. If the chimps had learned the liquid/solid rule, and got the idea that a new lexigram was for a new item, they might learn more quickly. Indeed they did. Sherman and Austin were able to respond correctly the first time, or with only a few errors, instead of taking hundreds of trials as before. What had happened to produce this difference? What the animals had learned was not only a set of specific associations between lexigrams and objects or events. They had also learned a set of logical relationships *between the lexigrams*, relationships of exclusion and inclusion. More importantly, these lexigram-lexigram relationships formed a complete system in which each allowable or forbidden co-occurrence of lexigrams in the same string (and therefore each allowable or forbidden substitution of one lexigram for another) was defined. They had discovered that the relationship that a lexigram has to an object is a *function* of the relationship it has to other lexigrams, not just a function of the correlated appearance of both lexigram and object. This is the essence of a symbolic relationship.

The subordination of the indexical relationships between lexigrams (symbol tokens) and foods (referents or objects) to the system of indexical relationships between lexigrams is schematically depicted in three stages of development in

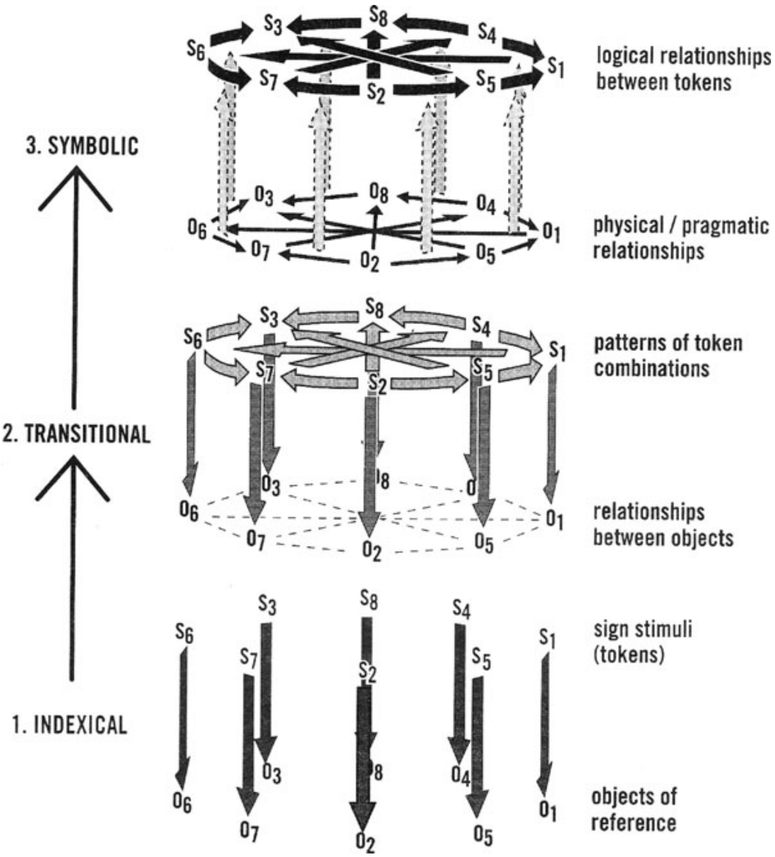

Fig. 18.3 A schematic depiction of the construction of symbolic referential relationships from indexical relationships. This figure builds on the logic depicted in Fig. 18.2, but in this case the iconic relationships are only implied and the indexical relationships are condensed into *single arrows*. Three stages in the construction of symbolic relationships are shown from *bottom* to *top*. First a collection of difference indices are individually learned (varying strength indicated by *darkness of arrows*). Second, systematic relationships between index tokens (indexical stimuli) are recognized and learned as additional indices (*gray arrows* linking indices). Third, a shift in (reversal of indexical *arrows*) mnemonic strategy to rely on relationships between tokens (*darker arrows* above) to pick out objects indirectly via relationships between objects (corresponding *lower arrow* system). Individual indices can stand on their own in isolation, but symbols must be part of a closed group of transformations that links them in order to refer, otherwise they revert to indices

Fig. 18.3. Individual indexical associations are shown as Single vertical arrows, mapping each token to a kind of object, because each of these relationships is independent of the others. In contrast, the token-token interrelationships (e.g., between lexigrams or words), shown as horizontal arrows interconnecting symbols, form a closed logical group of combinatorial possibilities. Every combination and exclusion relationship is unambiguously and categorically determined. The indexical reference of each symbol token to an object after symbolic reference is

achieved is depicted with arrows reversed to indicate that these are now subordinate to the token-token associations.

In the minimalistic symbol system first learned by Sherman and Austin, reference to objects is a collective function of relative position within this token-token reference system. No individual lexigram determines its own reference. Reference emerges from the hierarchic relationship *between* these two levels of indexicality, and by virtue of recognizing an abstract correspondence between the system of relationships between objects and the system of relationships between the lexigrams. In a sense, it is the recognition of an iconic relationship between the two systems of indices. Although indexical reference of tokens to objects is maintained in the transition to symbolic reference, it is no longer determined by or dependent on any physical correlation between token and object.

This makes a new kind of generalization possible: logical or categorical generalization, as opposed to stimulus generalization or learning set generalization. It is responsible for Sherman and Austin's ability to acquire new lexigrams and know their reference implicitly, without any trial-and-error learning. The system of lexigram-lexigram interrelationships is a source of implicit knowledge about how novel lexigrams must be incorporated into the system. Adding a new food lexigram, then, does not require the chimp to learn the correlative association of lexigram to object from scratch each time. The referential relationship is no longer solely (or mainly) a function of lexigram-food co-occurrence, but has become a function of the relationship that this new lexigram shares with the existing system of other lexigrams, and these offer a quite limited set of ways to integrate new items. The chimps succeed easily because they have shifted their search for associations from relationships among stimuli to relationships among lexigrams. A new food or drink lexigram must fit into a predetermined slot in this system of relationships. There are not more than a few possible alternatives to sample, and none requires assessing the probability of paired lexigram food occurrence because lexigrams need no longer be treated as indices of food availability. Like words, the probability of co-occurrences may be quite low. The food lexigrams are in a real sense "nouns," and are defined by their potential combinatorial roles. Testing the chimps' ability to extrapolate to new lexigram-food relationships is a way of demonstrating whether or not they have learned this logical-categorical generalization, which is a crucial defining feature of symbolic reference.

At some point toward the end of the training, the whole set of explicitly presented indexical associations that the chimps had acquired was "recoded" in their minds with respect to an implicit pattern of associations whose evidence was distributed across the whole set of trials. Did this recoding happen as soon as they had learned the full set of combination/exclusion relationships among their lexigram set? I suspect not. Try to imagine yourself in their situation for a moment. You have just come to the point "where you are not making errors. What is your strategy? Probably, you are struggling to remember what specific things worked and did not work, still at the level of one-by-one associations." The problem is, it is hard to remember all the details. What you need are aids to help organize what you know, because there are a lot of possibilities. But in the internal search for supports you discover that there is another source of redundancy and regularity that begins to appear, besides just the individual stimulus-response-reward regularities: the relationships between lexigrams! And these redundant patterns are far fewer than the messy set of dozens of individual associations that you are trying to keep track of. These regularities weren't apparent previously, because errors had obscured any underlying systematic relationship. But now that they are apparent, why not use them as added mnemonics to help simplify the memory load? Forced to repeat errorless trials over and over, Sherman and Austin didn't just learn the details well, they also became aware of something they couldn't have noticed otherwise, that there was a system behind it all. And they could use this new information, *information about what they had already learned*, to simplify greatly the mnemonic load created by the many individual rote associations. They could now afford to forget about individual correlations so long as they could keep track of them via the lexigram-lexigram rules.

What I am suggesting here is that the shift from associative predictions to symbolic predictions is initially a change in mnemonic strategy, a recoding. It is a way of offloading redundant details from working memory, by recognizing a higher-order regularity in the mess of associations, a trick that can accomplish the same task without having to hold all the details in mind. Unfortunately, nature seldom offers such nice neat logical systems that can help organize our associations. There are not many chances to use such strategies, so not much selection for this sort of process. We are forced to create artificial systems that have the appropriate properties. The crucial point is that when such a systematic set of tokens becomes available, it allows a shift in mnemonic strategy that results in a radical transformation in the mode of representation. What one knows in one way gets recoded in another way. It gets *re-represented.* We know the same associations, but we know them also in a different way. You might say we know them both from the bottom up, indexically, and from the top down, symbolically. And because this recoding is based on higher-order relationships, not the individual details, it often vastly simplifies the mnemonic problem and vastly augments the representational possibilities. Equally important is the vast amount of implicit knowledge it provides. Because the combinatorial rules encode not objects but ways in which objects can be related, new symbols can immediately be incorporated and combined with others based on independent knowledge about what they symbolize.

[In a later series of experiments,] Sherman and Austin, as a result of their experience with a previous symbol system, receded new lexigram-object associations into two new symbolic categories that superseded their individual associations. It took them hundreds or thousands of trials to learn the first simple one-to-many associations. This was because they began with no systemic relationship in their still small lexigram repertoire for a general reference to "food" or "tool." They had to learn them the hard way, so to speak, indexically. But as soon as they did learn these associations, they were primed to look for another higher-order logic, and once it was discovered, they were able to use this logic to generalize to new associations. Instead of hundreds or even thousands of trials, the availability of a symbolic coding allowed them to bypass further trials altogether, an incredible increase in learning efficiency. The chimps essentially knew something that they had never explicitly learned. They had gained a kind of implicit knowledge as a spontaneous byproduct of symbolic recoding.

I have chosen to recount this ape language study not because it portrays any particularly advanced abilities in chimpanzees, or because I think it is somehow representative. In fact (as noted earlier), more recent studies by these same experimenters, with a pygmy chimpanzee (or bonobo) named Kanzi, have demonstrated far more effortless and sophisticated symbolic abilities.[9] Rather, I have focused on this earlier study because of the clarity with which it portrays the special nature of symbol learning, and because it clearly exemplifies the hierarchic relationship between symbolic and indexical reference. The *reductio ad absurdum* training ploy is particularly instructive, not because it is an essential element but because it provides an explicit constructive demonstration of the index-by-index basis of the eventual symbolic relationship. It also demonstrates how normal associative learning strategies can interfere with symbol learning. Indexical associations are necessary stepping stones to symbolic reference, but they must ultimately be superseded for symbolic reference to work.

Unlearning an Insight

The problem with symbol systems, then, is that there is both a lot of learning *and unlearning* that must take place before even a single symbolic-relationship is available. Symbols cannot be acquired one at a time the way other learned associations can, except *after* a reference symbol system is established. A logically complete system of relationships among the set of symbol tokens must be learned before the symbolic association between any one symbol token and an object can even be determined. The learning step occurs prior to recognizing the symbolic function, and this function only emerges from a system; it is not vested in any individual sign-object pairing. For this reason, it's hard to get started. To learn a first symbolic relationship requires holding a lot of associations in mind at once while at the same time mentally sampling the potential combinatorial patterns hidden in their higher-order relationships. Even with a very small set of symbols the number of possible combinations is immense, and so sorting out which combinations work and which don't requires sampling and remembering a large number of possibilities.

One of the most interesting features of the shift in learning strategy that symbolic reference depends upon is that it essentially takes no time; or rather, no more time than the process of perceptual recognition. Although the prior associations that will eventually be recoded into a symbolic system may take considerable time and effort to learn, the symbolic recoding of these relationships is not *learned* in the same way; it must instead be *discovered* or perceived, in some sense, by reflecting on what is already known. In other words, it is an implicit pattern that must be recognized in the relationships between the indexical associations. Recognition

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[9] Savage-Rumbaugh and Lewin (1994).

means linking the relationship of something new to something already known. The many interdependent associations that will ultimately provide the nodes in a matrix of symbol-symbol relationships must be in place in order for anyone of them to refer symbolically, so they must each be learned *prior* to recognizing their symbolic associative functions. They must be learned as individual indexical referential relationships. The process of discovering the new symbolic association is a restructuring event, in which the previously learned associations are suddenly seen in a new light and must be reorganized with respect to one another. This reorganization requires mental effort to suppress one set of associative responses in favor of another derived from them. Discovering the superordinate symbolic relationship is not some added learning step, it is just noticing the system-level correspondences that are implicitly present between the token-token relationships and the object-object relationships that have been juxtaposed by indexical learning. What we might call a symbolic *insight* takes place the moment we let go of one associative strategy and grab hold of another higher-order one to guide our memory searches.

For this reason, a child's initial discovery of the symbolic relationships underlying language is only the beginning of the demand on this type of learning/unlearning process. Each new level of symbols coding for other symbolic relationships (i.e., more abstract concepts) requires that we engage this process anew. This produces a pattern of learning that tends to exhibit more or less discrete stages. Since the number of combinatorial possibilities that must be sampled in order to discover the underlying symbolic logic increases geometrically with each additional level of recoding, it is almost always necessary to confine rote learning to one level at a time until the symbolic recoding becomes apparent before moving on to the next. This limitation is frustratingly familiar to every student who is forced to engage in seemingly endless rote learning before "getting" the underlying logic of some mathematical operation or scientific concept. It may also contribute to the crudely stagelike pattern of children's cognitive development, which the psychologist Jean Piaget initially noticed.[10] However, this punctuated pattern of symbolic conceptual development is a reflection of symbolic information processing and not an intrinsic feature of developing brains and minds.

The ability of Sherman and Austin to discover the abstract symbolic references for "food" and "tool" provides an additional perspective on the difference between indexical associations and symbolic associations. Consider the potential conflict between the lexigram-object relationships they had previously acquired and this new set of associations. If their prior associations were supported only by the correlations in lexigram-object-reward occurrence, then re-pairing the same objects with a new lexigram would be expected to partially if not totally extinguish the prior association. Although it would be possible to provide additional contextual cues to enable the chimps to decide which of two competing associative strategies to use (e.g., simply run trials without the alternatives available) and thus learn and retain both, there would still be interference effects (i.e., their prior associations might

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[10] Piaget (1952).

interfere both with relearning the new associations and with shifting between them in different contexts). Unfortunately, data to assess this are not available, but we can infer from Sherman and Austin's learning shifts, and their subsequent maintenance of the prior symbolic associations, that neither extinction nor interference was a significant problem.

This ability to remember large numbers of potentially competing associations is an additional power of symbolic reference that derives from the shift in mnemonic strategy to token-token relationships. Competition effects grow with increasing numbers of overlapping associative categories in typical indexical reference relationships. Not only would the choice among alternatives in any use become a source of confusion, but because they were competing for reinforcement, each would weaken the association of the others. Though some of the interference effects also attend symbol use, and often are a cause of word retrieval errors and analysis delays, in terms of associative strength there is an opposite effect. Competing sets of overlapping associative relationships on the indexical level translate into mutually supportive higher-order semantic categories on the symbolic level. These become sources of associative redundancy, each reinforcing the mnemonic trace of the other. So, rather than weaken the strength of the association, they actually reinforce it.

This helps to explain where the additional associative glue between words and their referents comes from. Though token-object correlations are not consistently available to the symbol user, indeed are rare, this loss of associative support is more than compensated by the large number of other associations that are available through symbolically mediated token-token relationships. Individually, these are comparatively weak associations, with a low correlated occurrence of any two tokens in the same context; but they are not just one-to-one associations. They are one-to-many and many-to-one associations that weave symbol tokens together into a systematic network of association relationships, and the pattern has a certain coded isomorphism with relationships between objects and events in the world. As a result of sharing many weak interpenetrating indexical links, each indexical association gains mnemonic support from a large number of others because they are multiply coded in memory. Together, their combined associative strengths make them far more resistant to extinction due to diminished external correlations with objects than are individual indexical associations. Thus, not only is symbolic reference a distributed relationship, so is its mnemonic support.

In summary, then, symbols cannot be understood as an unstructured collection of tokens that map to a collection of referents because symbols don't just represent things in the world, they also represent each other. Because symbols do not directly refer to things in the world, but indirectly refer to them by virtue of referring to other symbols, they are implicitly combinatorial entities whose referential powers are derived by virtue of occupying determinate positions in an organized system of other symbols. Both their initial acquisition and their later use requires a combinatorial analysis. The structure of the whole system has a definite semantic topology that determines the ways symbols modify each other's referential functions in different combinations. Because of this systematic relational basis of symbolic reference, no collection of signs can function symbolically unless the entire collection conforms to certain overall principles of organization.

Symbolic reference emerges from a ground of nonsymbolic referential processes only because the indexical relationships between symbols are organized so as to form a logically closed group of mappings from symbol to symbol. This determinate character allows the higher-order system of associations to supplant the individual (indexical) referential support previously invested in each component symbol. This system of relationships between symbols determines a definite and distinctive topology that all operations involving those symbols must respect in order to retain referential power. The structure implicit in the symbol-symbol mapping is not present before symbolic reference, but comes into being and affects symbol combinations from the moment it is first constructed. The rules of combination that are implicit in this structure are discovered as novel combinations are progressively sampled. As a result, new rules may be discovered to be emergent requirements of encountering novel combinatorial problems, in much the same way as new mathematical laws are discovered to be implicit in novel manipulations of known operations.

Symbols do not, then, get accumulated into unstructured collections that can be arbitrarily shuffled into different combinations. The system of representational relationships, which develops between symbols as symbol systems grow, comprises an ever more complex matrix. In abstract terms, this is a kind of tangled hierarchic network of nodes and connections that defines a vast and constantly changing semantic space. Though semanticists and semiotic theorists have proposed various analogies to explain these underlying topological principles of semantic organization (such as ± feature lists, dictionary analogies, encyclopedia analogies), we are far from a satisfactory account. Whatever the logic of this network of symbol-symbol relationships, it is inevitable that it will be reflected in the patterns of symbol-symbol combinations in communication.

No Mind Is an Island

Because of our symbolic abilities, we humans have access to a novel higher-order representation system that not only recodes experiences and guides the formation of skills and habits, but also provides a means of representing features of a world that no other creature experiences, the world of the abstract. We do not just live our lives in the physical world and our immediate social group, but also in a world of rules of conduct, beliefs about our histories, and hopes and fears about imagined futures. This world is governed by principles different from any that have selected for neural circuit design in the past eons of evolution. We possess no brain regions specially adapted for handling the immense flood of experiences from this world, only those adapted for life in a concrete world of percepts and actions. These unsuited neural systems have been forced into service, and do the best they can to accommodate to an alien world and recode its input in more familiar forms. The consequences are both marvelous and horrendous.

One of these alien realms is the realm of other minds. The problem of other minds has recently found its way into studies of animal social behaviors-often phrased in terms of a "theory of mind," Basically, the question is whether animals know that there is *someone* behind their perceptual experience of others. Do animals act socially on the basis of what they think others are thinking? To have a "theory of mind," in this nonphilosophical sense, is to have a mental representation of the subjective experience of others. A number of ingenious experiments have attempted to test whether animals tend to behave in response to what they infer others know, feel, or desire. Not surprisingly, the results are often hard to interpret.

It is a difficult question to answer experimentally, because it is possible for an intelligent and perceptive animal to learn to anticipate another's behavior in response to different conditions, irrespective of any model of why they are responding the way they do, and so give a false impression of representing a mental cause as opposed to merely developing an unanalyzed, conditioned response. This experimental difficulty is analogous to the problem we encountered earlier of determining whether a given referential behavior is symbolic or merely indexical. The parallel is not just a superficial one. Both are questions about the mode of representation. Is the representation of the expected behavior of the other mediated simply by a pairing of past instances of others' responses to similar circumstances, or by some additional representations about how these responses are caused by (recoded as) the hidden experiences of others?

Apart from postulating an innate "theory of mind module," how could such a mental representation be produced? In other words, what is necessary in order for information from another's behavior to be interpreted as representing another mind? The nature of this representation will depend on whether the individual is only able to interpret the behavior patterns as indices of future tendencies to behave, or is able also to interpret them as indices of mental states. The lack of symbolic referential abilities in nonhuman species limits them to representation of associations between stimuli, including the behaviors of others. These relationships can be quite numerous and complex, providing the animal with extensive familiarity with the predispositions of others. Probably most of the intimate behavioral knowledge we gain about friends and family members is of this type.

But the additional step to building an independent mental representation of the subjective experience of another, represented as if one were able to trade places, requires a symbolic jump. Since indexical reference grows out of repeated experiences of explicit pairing of stimuli or events, there is no possibility that pairing with another's mental state could be learned by association. It is an abstract attribute, inferred from the systematic patterns of the indexical relationships between observed conditions and behaviors, and identified with and opposed to one's own experiences. Constructing another point of view requires the ability to maintain awareness of the indexical information, and to use this to produce a representation of what it would be like to experience it from a different perspective, a complicated double-negative referential relationship, This is a cognitive task that almost certainly requires prefrontal cortex involvement, and evidence of failure to be able to take the other's perspective is a common disability of patients with significant prefrontal damage. Some striking examples of related difficulties of taking another "perspective" are described by Antonio Damasio in *Descartes' Error*. In this regard the hypersociality of Williams syndrome patients, and their intense monitoring and solicitation of others' responses in social interactions, may also be understood not just as a function of modified affect but as a shift in cognitive style, in which an exaggerated prefrontal bias may lead to an exaggerated reliance on symbolic prediction of others' behaviors. This may be particularly important if indexical representation of the predispositions of others is impaired. The inverse argument may also apply to autistic individuals. Because of a difficulty with perspective shifting, they may only develop knowledge of another's predispositions to behave by virtue of attention on physical behaviors as indices. Thus, the ability to form a representation of another's mental experience, as opposed to just their predispositions, is both mediated by symbols and dependent on many of the same mental operations and neural substrates as are critical to symbolic abilities.

As novelists and poets amply demonstrate, the range of personas and experiences that can be conveyed through symbolic media is unbounded. In a very real sense, this gives us the ability to share a virtual common mind. Because symbolic representation maintains reference irrespective of indexical attachment to any particular experiences, when an idea or a narrative of someone's experience is reconstructed by another, it can be regrounded, so to speak, by interpreting it in terms of the iconic and indexical representations that constitute the listener's memory. Symbolic reference is interpreter-independent, because each interpreter independently supplies the nonsymbolic ground for it.

Such Stuff as Dreams Are Made On

If consciousness is inevitably representational, then it follows that a change in the nature of the way information gets represented inevitably constitutes a change in consciousness. Consciousness of iconic representations should differ from consciousness of indexical representations, and this in turn should differ from consciousness of symbolic representations. Moreover, since these modes of representation are not alternatives at the same level but hierarchically and componentially related to one another, this must also be true of these modes of consciousness as well. They form a nested hierarchy, where certain conditions in the lower levels of consciousness are prerequisite to the emergence of consciousness at each higher level.

All nervous systems support iconic and indexical representational processes, irrespective of their size and complexity. They are the basic ingredients for adaptation. To some extent, I suspect that every living nervous system exhibits consciousness with respect to the iconic and indexical representations it can support. It's just that for some, this is a very limited realm. Their interpretive capacity will determine their capacity for consciousness. The differences between species in this regard are not qualitative, but quantitative. In species with more complex brains, representational states will be more numerous, more diverse, have a greater range of arousal amplitude, and will integrate across signals that cover a greater scope in both space and time. Statistics of large numbers and immense differences in magnitude have a way of making quantitative differences appear to be qualitative differences. It is therefore easy to imagine that the human difference is a difference of this kind, a significant quantum increase in the capacity. And to some extent it is. It's just not the only or even the major difference.

To appreciate why human beings are able to experience conscious states unprecedented in evolution, we do not need to have solved the mystery of consciousness itself. We do not need to understand the mechanism underlying conscious states in order to recognize that since they are based on representations, any difference in representational ability between species will translate into a difference in the ability to be conscious of different sorts of things. The formal characteristics of the interpretation process, whether iconic, indexical, or symbolic, will define the elements of a creature's conscious universe. So the development of an unprecedented form of representation – symbolic representation – while not the origin of consciousness, has produced an unprecedented *medium* for consciousness. This doesn't deny generic consciousness to other species; it only denies a particular aspect of consciousness that is based on symbolic abilities. Our brains share a common design logic with other vertebrate brains, and so we also share all those aspects of consciousness that are mediated by the iconic and indexical representation that these other species experience. Since iconic and indexical referential relationships are implicit and essential components of symbolic reference, the modes of consciousness that other species experience are an essential ground for consciousness of the symbolic world. We live most of our concrete lives in the subjective realm that is also shared with other species, but our experience of this world is embedded in the vastly more extensive symbolic world.

The evolution of symbolic communication has not just changed the range of possible objects of consciousness, it has also changed the nature of consciousness itself. Common sense psychology suggests that a lot of thinking gets done in the form of talking to oneself, editing and re-editing imaginary future or reconsidered past conversations, even when this also involves writing or typing out these thoughts to see how well the shorthand of imagined monologues translates into a coherent argument. Of course, these sorts of internal conversations must be unique to human brains while the majority of the other modes of thought are not. And given that our brains have only recently been "made over" to aid language processing, it is likely that the proportion of neural space and time dedicated to these various mental activities strongly favors the nonlinguistic. This does not necessarily imply that other species do not "replay troubling past experiences over and over again, or that they are incapable of actively imagining possible experiences in some immanent future." They simply do not do so with the aid of symbolic reference or linguistic mnemonics. It also does not imply that imagistic thinking in humans lacks symbolic character and symbolic logic, though these forms of cognition are capable of following chains of association that are also uninfluenced by language.

The Russian cognitive psychologist L. S. Vygotsky suggested in the 1930s that a significant number of normal human psychological processes could be understood as internalized versions of processes that are inherently social in nature.[11] He gave language a central role to play in this because its fundamentally social nature provides a mental tool for gaining a kind of subjective distance from the contents of thought, that is, from our own subjective experiences. By importing, as it were, an implicit speaker-listener relationship into cognition, we create a tool for self-reflection by a sort of virtual social distancing from our own thought process. Thus we can talk to ourselves as though talking to others. Vygotsky conceived of mental development as a process of condensing and streamlining this internalized social process.

Language functions as a sort of shared code for translating certain essential attributes of memories and images between individuals who otherwise have entirely idiosyncratic experiences. This is possible because symbolic reference strips away any necessary link to the personal experiences and musings that ultimately support it. The dissociation allows individuals to supply their own indexical and iconic mnemonics in order to reground these tokens in new iconic and indexical representations during the process of interpretation. My imagistic and emotional experience in response to the episodes described in a novel is distinct from that of anyone else, though all readers will share a common symbolic understanding of them. The "subjective distance" from what is represented confers a representational freedom to thought processes that is not afforded by the direct recall or imagining of experiences.

This is crucial for the development of self-consciousness, and for the sort of detachment from immediate arousal and compulsion that allows for self-control. Self-representation, in the context of representations of alternative pasts and futures, could not be attained without a means for symbolic representation. It is this representation of self that is held accountable in social agreements, that becomes engaged in the experience of empathy, and that is the source for rational, reflective intentions. According to Vygotsky, this sense of self emerges slowly as children mature. It becomes progressively more facile in perspective shifting and at the same time consolidates greater control over the other aspects of self that derive from nonsocial sources, such as the experience of pain and effort, the arousal of basic drives, or the physical boundaries of control over events. And, as studies of this process in various mentally and socially handicapped children suggest, the extent to which it is developed depends both on the extent of exposure to relevant social-symbolic experiences and on the symbol-processing capacity of the individual.

Unlike the interpretation of icons and indices (a process which is uniquely personal and insular within each brain), symbolic representations are in part externally interpreted – they are shared. For example, though each of us supplies the interpretation of the words and phrases we hear and use, on a moment-by-moment basis, the

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[11] Vygotsky (1978).

implicit injunctions and constraints that determine each individual interpretation are borrowed from the society of users, and the symbolic reference that results is only reliable insofar. As each interpretation corresponds with those performed by others. Imagine that Washington Irving's character, Rip Van Winkle, had remained in his magical slumber for many centuries. Upon awakening, not only would he be out of touch culturally, but he would find himself constantly misinterpreting the meaning of many still familiar-sounding words and phrases being spoken by those around him. As languages evolve and meanings and patterns of use drift away from older patterns, reference is maintained by continuity but not fidelity to the past. Symbolic reference is at once a function of the whole web of referential relationships and of the whole network of users extended in space and time. It is as though the symbolic power of words is only on loan to its users. If symbols ultimately derive their representational power, not from the individual, but from a particular society at a particular time, then a person's symbolic experience of consciousness is to some extent society – dependent – it is borrowed. Its origin is not within the head. It is not implicit in the sum of our concrete experiences.

Consciousness of self in this way implicitly includes consciousness of other selves, and other consciousnesses can only be represented through the virtual reference created by symbols. The self that is the source of one's experience of intentionality; the self that is judged by itself as well as by others for its moral choices, the self that worries about its impending departure from the world, this self is a symbolic self. It is a final irony that it is the virtual, not actual, reference that symbols provide, which gives rise to this experience of self. This most undeniably real experience is a *virtual* reality.

In a curious way, this recapitulates an unshakable intuition that has been ubiquitously expressed throughout the ages. This is the belief in a disembodied spirit or immortal "pilgrim soul" that defines that part of a person that is not "of the body" and is not reducible to the stuff of the material world. My ability to appreciate symbolic reference is not "reducible" to the indexical or iconic reference I use to ground my interpretation, though it is dependent on these lower-level modes of reference. Symbolic reference is also independent of any particular interpretive process, and retains its referential invariance despite interpretation by very different iconic and indexical processes in different minds. Its virtual nature notwithstanding, it is the symbolic realm of consciousness that we most identify with and from which our sense of agency and self-control originate. This self is indeed not bounded within a mind or body, and derives its existence from outside – from other minds and other times. It is implicitly part of a larger whole, and to the extent that it too contributes to the formation of other virtual selves and worlds, it is virtually present independent of the existence of the particular brain and body that support it. This may seem a shallow sort of disembodiment that pales in compared to mystical images of "out of the body experience" – it is more similar to the legacy of self composers leave in their music or great teachers bequeath to their students – but this symbolic aspect of self is nonetheless the source of our internal experience of free will and agency.

Abstract symbolic objects, like the Pythagorean theorem, guide the design and construction of innumerable human artifacts every day. Imagining counterfactual conditions, like what I might have done if I were the one who had stumbled on a reported accident scene, can cause me to enroll in medical first-aid training and perhaps some day aid an accident victim. Even imagined worlds – Olympus, Valhalla, Heaven, Hell, the "Other Side" – influence people's behavior in*this* world. Indeed, assumptions about the "will" of an ineffable God have been among the most powerful tools for shaping historical changes. These abstract representations have physical efficacy. They can and do change the world. They are as real and concrete as the force of gravity or the impact of a projectile.

On the other hand, the self that persists to influence others and continue shaping the world independent of the brain and body that originally animated it is detached from the specific iconic and indexical experiences that once grounded it in a personal subjective experience. This is precisely what makes it available for regrounding in the subjective experience of others, of becoming part of the self that controls, and feels, and connects with yet other selves from the locus of a different body and brain. In this regard, this part of personal identity is intersubjective in the most thoroughgoing sense of the term, and is capable of true transmigration, though not necessarily as a unified whole.

By this twist of logic, or rather its untangling, we also again return to Descartes' elaboration of the religious insight that only humans have a soul, and that this core of the self derives from a realm that is of the nature of language, pure mathematics, or geometry. Descartes' insight, currently maligned as archaic and antiscientific, seems to have more than a passing similarity to the notion I have developed here. But his rationalist assumptions-like those represented in theories of innate knowledge of language, computational theories of mind, or claims that human brains have a special essence/that imbues them with intentional ability-reflected an implicit analytic or top-down perspective on the nature of symbolic reference. By failing to appreciate the constitutive role of lower forms of reference, iconic and indexical reference, this perspective kicks the ladder away after climbing up to the symbolic realm and then imagines that there never was a ladder in the first place. This leaves symbolic reference ungrounded and forces us to introduce additional top-down causal hypotheses, such as the existence of an ephemeral soul or the assumption that there can be forms of computation or mental language (mentalese) that are intrinsically meaningful, in order to fill in for this missing causal role in the explanation.

But unlike the eliminative materialist alternative, the perspective I have outlined does not suggest that this top-down experience of self is all epiphenomenal nor that some of the claims about the nature of the mind which derive from it are based on mystical notions. The symbolic representation of self is solidly grounded in simpler representations of self, derived from simpler forms of representation, and yet the arrow of cognitive processes points neither from lower to higher nor from higher to lower forms of reference. As symbolic reference and symbol minds co-evolved from the nonsymbolic, each level of process drawing adaptive novelty from the other, so do the levels of self-representation that constitute our experience bring themselves into being in a moment-by-moment coevolutionary process. As the symbolic process can be the co-author of our unanticipated brains, so can the symbolic self be the co-author of the component neural processes that support it. We live in a world that is both entirely physical and virtual at the same time. Remarkably, this virtual facet of the world came into existence relatively recently, as evolutionary time is measured, and it has provided human selves with an unprecedented sort of autonomy or freedom to wander from the constraints of concrete reference, and a unique power for self-determination that derives from this increasingly indirect linkage between symbolic mental representation and its grounds of reference. With it has come a more indirect linkage between mind and body, as well. So this provides a somewhat different perspective on that curious human intuition that our minds are somehow independent of our bodies; an intuition which is often translated into beliefs about disembodied spirit and souls that persist beyond death. The experience we have of ourselves as symbols is in at least a minimal sense an experience of just this sort of virtual independence – it's just not an independence from corporeal embodiment altogether. Though this might seem like a weak consolation in comparison to the freely transmigrating homunculus of mythical tradition, we should not underestimate the miraculous power of symbols to break down even vast barriers of space, time, and idiosyncratic experience that would otherwise separate us impenetrably.

As we have seen, the symbolic threshold is not intrinsic to the human-nonhuman difference. It is probably crossable to some extent in many different ways by many species. This means that we are not the only species that could possess such a "pilgrim soul," to use William Butler Yeats's elegantly descriptive phrase. It was a Darwinian accident, or miracle, of nature that this ability arose once and persisted for so long; but it has provided each of us with the opportunity to participate in bringing new "souls" into the world, not by procreation, but by allowing our own symbolic selves to be shared by other human beings, and perhaps by other animals, or perhaps eventually even by artifacts of our own creation.

Ends

> Thirty spokes share the wheel's hub.
> but it is the hole in the center that provides its usefulness
>
> Lao Tsu, from the Tao Te Ching

As a species, we seem to be preoccupied with ends, in all senses of the word. We organize our actions around imagined extrapolations of the consequences they will produce, We struggle in vain to comprehend the implications of our own impending cessation of life. And we weave marvelously and elaborate and beautifully obscure stories to fill our need to find purpose in the fabric of the universe. This fills no obvious adaptive need. Our evolution never included selection favoring anything like this intense and desperate drive. And yet it is so powerful as to be able to overcome some of the most irresistible predispositions that evolution has provided. If we are language savants compared to other species, then a preoccupation with ends is the special exaggerated compulsion that complements our unique gift.

Symbolic analysis is the basis for a remarkable new level of self-determination that human beings alone have stumbled upon. The ability to use virtual reference to build up elaborate Internal models of possible futures, and to hold these complex visions in mind with the force of the mnemonic glue of symbolic inference and descriptive shorthands, gives us unprecedented capacity to generate independent adaptive behaviors. Remarkable abstraction from indexically bound experiences is further enhanced by the ability of symbol to reference to pick out tiny fragments of real world processes and arrange them as bouys to chart an inferential course that predicts physical and social events. The price we pay for this is that our symbolically mediated actions can often be in conflict with motivations to act that arise from more concrete and immediate biological sources. Arguments in support of the classic notion of free will frequently cite this capacity to use reason (that is, symbolic inference and model building) to overcome desire and compulsion. One might respond that calling some actions "free" and others not oversimplifies what is really only a matter of the degree of the strengths of competing compulsions to act, some compulsions arising from autonomic and hormonal sources and others from our imagined satisfaction at reaching a symbolized goal. But there is an important sense in which these competing compulsions are not equal.

Those that arise from purely physiological sources, or physiological sources mediated by conditioned associations, could be called bottom-up processes for producing action. They are much more tied to mechanism and thus exhibit few degrees of freedom and limited spontaneous variation, They are comparatively predictable, though any organismic process inevitably exhibits tangled paths of causality. But symbolically mediated compulsions to act are far more chaotic, in the technical sense of that word, far more susceptible to the influence of tiny initial differences in starting assumptions or ways of dividing up experiences and qualities symbolically. This is because symbolically mediated models of things – whether theories, stories, or just rationally argued predictions-exhibit complicated nonlinearity and recursive structure as well as nearly infinite flexibility and capacity for novelty due to their combinatorial nature. It is not so much that our actions arise from a totally unconstrained and compulsion-free center of intentions, but that the potential starting point, the intended purpose we have modeled, can be drawn from such a vast variety of alternatives with little initial difference in motive power.

Final causality, according to Aristotle, is exhibited when processes are driven not by antecedent physical conditions but by ends. In some ways this is like time reversed. In hindsight it is easy to infer that certain past conditions were necessitated by the way things turned out. Deductive inference is a lot like this sort of reflective inversion of temporal and physical order. The consequence is already implicitly included in the premises. In symbolic thinking, this results in what might be called a sort of symbolic compulsion. Certain statements compel certain others. Aristotle reserved another term for such compulsion – *formal causality* – but I think there is an important way that this links to the other, classic conception of cause in terms of the ways that symbols work. Little of our reasoning is so precise as to be called deductive, and yet the way that certain beliefs compel others can have neatly this force. Ideologies, religions, and just good explanations or stories thus exert a sort of inferential compulsion on us that is hard to resist because of their mutually reinforcing deductive and inductive links. Our end-directed behaviors are in this way often derived from such "compulsions" as are implicit in the form that underlies the flow of inferences. So one might say that thinking in symbols is a means whereby formal causes can determine final causes. The abstract nature of this source makes for a top-down causality, even if implemented on a bottom-up biological machine.

Though the evolution of brains has been about systems for modeling and predicting events in the world, the evolution of symbolic abilities has not just amplified this ability far beyond that in any other species, it has also introduced an insidiously inverted modeling tendency. The symbolic capacity seems to have brought with it a predisposition to project itself into what it models. The savant, instead of seeing a field of wildflowers, sees 247 flowers. Similarly, we don't just see a world of physical processes, accidents, reproducing organisms, and biological information processors churning out complex plans, desires, and needs. Instead, we see the handiwork of an infinite wisdom, the working out of a divine plan, the children of a creator, and a conflict between those on the side of good and those on the side of evil. We carry a nagging doubt about anything really being accidental. Coincidence isn't just coincidence, it's a sign, and bad luck and disease don't just happen, perhaps a sorcerer has wished harm on the village. Wherever we look, we expect to find purpose. All things can be seen as signs and symbols of an all-knowing consciousness at work, or the marks of mythical events that occur in a dream time, behind the scenes of the universe. We are not just applying symbolic interpretations to human words and events; all the universe has become a symbol.

This is the evidence that we have become symbolic savants in the deeper sense of that metaphor. We are not just a species that uses symbols. The symbolic universe has ensnared us in an inescapable web. Like a "mind virus," the symbolic adaptation has infected us, and now by virtue of the irresistible urge it has instilled in us to turn everything we encounter and everyone we meet into symbols, we have become the means by which it unceremoniously propagates itself throughout the world.

It is clear that we feel more comfortable in a world that is meaningful, living a life that has meaning. The alternative is somehow too frightening. But why? Why should the ability to acquire symbolic abilities and conceive of things symbolically also bring with it a powerful urge to see it in every conceivable context? It could be seen as part of the predisposition to acquire symbols in the first place, part of the overdesign of the mind to ensure that symbols get discovered. But I think it may be a more mundane feature of cognitive and sensorimotor biases in general. The autistic savant is in this way no different from the kitten that sees every small mobile object as a representative prey toy, or the baby who interacts with every holdable object as a thing to be put into the mouth – for reasons that probably flow ineluctably from the Darwinian-competitive structure of neural information processing. Brains are spontaneously active biological computers in which activity patterns incessantly compete for wider expression throughout each network. Under these conditions, the dominant operation simply runs on its own and assimilates whatever is available. In us, this appears to be the expression of what I have called front-heavy cognition, driven by an overactive, busybody prefrontal cortex. It gets expressed as a need to recode our experiences, to see everything as a representation, to expect there to be a deeper hidden logic. Even when we don't believe in it, we find ourselves captivated by the lure of numerology, astrology, or the global intrigue of conspiracy theories. This is the characteristic expression of a uniquely human cognitive style; the mark of a thoroughly symbolic species.

One of the essentially universal attributes of human culture is what might be called the mystical or religious inclination. There is no culture I know of that lacks a rich mythical, mystical, and religious tradition. And there is no culture that doesn't devote much of this intense interpretive enterprise to struggling with the very personal mystery of mortality. Knowledge of death, of the inconceivable possibility that the experiences of life will end, is a datum that only symbolic representation can impart. Other species may experience loss, and the pain of separation, and the difficulty of abandoning a dead companion; yet without the ability to represent this abstract counterfactual (at least for the moment) relationship, there can be no emotional connection to one's own future death. But this news, which all children eventually discover as they develop their symbolic abilities, provides an unbidden opportunity to turn the naturally evolved social instinct of loss and separation in on itself to create a foreboding sense of fear, sorrow, and impending loss with respect to our own lives, as if locking back from an impossible future. No feature of the limbic system has evolved to handle this ubiquitous virtual sense of loss, Indeed, I wonder if this isn't one of the most maladaptive of the serendipitous consequences of the evolution of symbolic abilities. What great efforts we exert trying to forget our future fate by submerging the constant angst with innumerable distractions, or trying to convince ourselves that the end isn't really what it seems by weaving marvelous alternative interpretations of what will happen in "the undiscovered country" on the other side of death.

In many ways this is the source both of what is most noble and most pathological in human behaviors. Supported by these interpretations, reason can recruit the strength to face the threat of emptiness in the service of shared values and aspirations. But the dark side of religious belief and powerful ideology is that they so often provide twisted justifications for arbitrarily sparing or destroying lives. Their symbolic power can trap us in a web of oppression, as we try through ritual action and obsessive devotion to a cause to maintain a psychic safety net that protects us from our fears of purposelessness. The interaction of symbolic cultural evolution and unprepared biology has created some of the most influential and virulent systems of symbols the world has ever known. Few if any societies have ever escaped the grip of powerful beliefs that cloak the impenetrable mystery of human life and death in a cocoon of symbolism and meaning. The history of the 20th century, like all those recorded before it, is sadly written in the blood that irreconcilable symbol systems have spilt between them. Perhaps this is because the savantlike compulsion to see symbols in everything reaches its most irresistible expression when it comes to the symbolization of our own lives' end. We inevitably imagine ourselves as symbols, as the tokens of a deeper discourse of the world. But symbols are subject to being rendered meaningless by contradiction, and this makes alternative models of the world direct threats to existence.

Almost certainly this is one of the other defining features of the human mentality: an ever present virtual experience of our own loss. And yet we know so little about what it is that we fear to lose. Perhaps if we understood this symbolic compulsion, and the consciousness it brings with it, we might find this emptiness at the center a bit less disturbing.

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Part IV

The Contemporary Interdiscipline of Biosemiotics

Chapter 19
The Semiotics of Nature: Code-Duality

Jesper Hoffmeyer (1942–)

Introduction and Commentary: Jesper Hoffmeyer

> *Transdisciplinarity will be of no help so long as everybody stays safely inside her own disciplinary borders, politely transgressing no internal disciplinary taboos. Rather, 'inter-disciplinary scholarship' only becomes fruitful when we collectively take the risk to confront problems in the ways those problems may be seen within disciplines other than our own.*
>
> J. Hoffmeyer (2008: xvi)

A prolific science writer and journalist, as well as a working university professor and molecular biologist, Jesper Hoffmeyer was born in Copenhagen, Denmark on Februrary 21, 1942. "Born during the second world war in occupied Denmark and to a family with strong anticlerical and moderate leftist persuasions," recounts Hoffmeyer, "I was destined to develop a materialistic, and indeed a positivistic, understanding of our world. To fight irrationalism in all its disguises was an inherent value in my upbringing and in choosing to become a biochemist, I faithfully continued along this path . . . But over time, it gradually occurred to me that some of the central tenets of such materialistic self-confidence were perhaps less secure than had been previously assumed" (2010: *forthcoming*).

In particular, as a biochemist working at the University of Copenhagen's Molecular Biology Department during the rise of genetic determinism and the promiscuous, if conceptually ungrounded, use of the term "information" in molecular biology in the 1960s and 1970s, Hoffmeyer became increasingly concerned over the fact that, despite its self-evidently anti-scientific implications,

> Cartesian dualism, to modern science, still holds good as a way of dividing the world into two kingdoms: those of mind and matter, or the cultural and the natural spheres. . . .[As a result,] we have no idea what to think about the various consequences for humanity of biomedical technology. We have no real conception of how a minded humanity could have evolved out of a mindless natural world, and not even the beginnings of a decent theory as to what consciousness actually is. In short, we have not even touched on the question of humanity's place in nature. Indeed, how could we, when we have consistently placed people – as *minded* beings – outside the brackets in the study of nature? . . .[Yet, rather than facing up to these dilemmas, the institutional adoption of] Cartesian non-intervention is still the easiest compromise and one which ensures that both the humanities and the natural

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> sciences can get on with their work undisturbed. And it is this boundary that biosemiotics seeks to cross, in the hopes of establishing a link between the two alienated sides of our existence – to give humanity its place in nature. (1996: 92–94).

Hoffmeyer's work since that time has been devoted to bridging this deep divide in human knowledge and self-understanding. It is therefore hardly surprising that he would eventually make the acquaintance of Thomas A. Sebeok. Sebeok, in turn, would become a great promoter of Hoffmeyer's work, devoting an entire issue of his journal, *Semiotica*, to a critical appreciation of Hoffmeyer's seminal biosemiotics monograph, *Signs of Meaning in the Universe* (1996).

The meeting between Sebeok and Hoffmeyer would not take place until 1990, however but by 1985, report Hoffmeyer's biographers, and independent of any knowledge about Sebeok's project whatsoever, Hoffmeyer had already begun working on his own project "to develop a semiotics of nature, or *biosemiotics* as he chose to call this effort, [that could intelligibly explain how] all the phenomena of inherent meaning and signification in living nature – from the lowest level of sign processes in unicellular organisms to the cognitive and social behavior of animals – could emerge from a universe that was not [so] organized and meaningful from the very beginning" (Emmeche et al. 2002: 41). And, parallel to Sebeok's discoveries on the other side of the Atlantic, Hoffmeyer's investigations into the semiotic logic of relations between organisms and their environment (1984), between organisms and each other (1988), and within organisms (1992) eventually led him to the triadic logic of the 19th century scientist-philosopher Charles S. Peirce (1996, 2008).

"I was never interested in learning Philosophy or Semiotics simply for the sake of learning them," recalls Hoffmeyer during a roundtable discussion session featuring some of the founders of contemporary biosemiotics in 2007, "Rather, I found that I had to learn these things in order to be able to do Biology correctly" he recalls (Favareau et al. 2008a: 3).

For "only a sufficiently rich concept of *semiosis*," writes Hoffmeyer, "can provide the conceptual tools necessary to explanatorily re-integrate living creatures (including, of course, human beings) into the natural world from which they came – but from which they have since been effectively excluded by a scientific ontology that has, at least since the time of Descartes, consistently encouraged scientists to *de-semiotize* [or, conversely, to un-self-reflectively anthropomorphise] all the naturally occurring communicative and fundamentally interactive processes of living systems" (Hoffmeyer 2008: xvi, xiv).

Developing this rich notion of semiosis from *within* the scientific community was an additional challenge for Hoffmeyer, just as it was for Sebeok, who was simultaneously trying to such an understanding from within the largely science-averse intellectual community of the humanities. Yet, as was likewise the case with Sebeok, Hoffmeyer's personal passion and dedication to this project – as well as the groundbreaking nature of the publications that he began producing – soon drew an ever-growing coterie of like-minded individuals into his orbit. In 1984, his initial formulation of a theory of analog-digital "code-duality" in biology was published, and soon thereafter he began his intensive series of collaborations with biologist Claus Emmeche, who would later go on to head the *Center for the Philosophy of Nature* *and Science Studies* at the Neils Bohr Institute in the University of Copenhagen, and to become a major figure in biosemiotics in his own right, in addition to authoring a body of related work on dynamic systems theory (1992, 2000a), artificial intelligence (1991, 1994), and the history and philosophy of science (1999, 2002).

The story of Hoffmeyer's subsequent 25 years work in disseminating biosemiotics into the larger scientific community and to the generally educated public – and of his picking up of Thomas A. Sebeok's torch by organizing interdisciplinary biosemiotics conferences after the death of Sebeok in 2001–has been recounted in considerable detail in the "history of biosemiotics" chapter that opens this anthology as its Chapter One. However, some additional recollections of that era from Hoffmeyer himself, prepared as part of a memorial volume to Thomas A. Sebeok, provide a memorable picture of the project in its early days. As this text is unlikely to be widely available elsewhere, and since the theoretical aspects of Hoffmeyer's biosemiotic project have already been substantially detailed in Chapter One, these most recent autobiographical recollections are worth reprinting here in full, and help serve as an excellent historical orientation to the reprinted selection that follows.

Writes Hoffmeyer:

"In the late 1980s I decided to brave the common sense conceptions of the natural science society in Denmark by actively engaging my research in pursuit of a study of natural semiosis. This decision did bring me outside the good company of science, but fortunately, it also brought me into the very good company of Thomas A. Sebeok [whose] idea of animals as semiotic creatures was probably as much at odds with hegemonial conceptions in the humanities as was the idea of 'natural semiosis' in the scientific establishment. [The way in which this historic meeting came about is as follows:] In 1988 Claus Emmeche and I wrote two papers analyzing different aspects of the concept of a semiotics of nature – mostly, at first, to clarify our own thoughts on the matter. Eventually we considered the possibility of publishing these papers that obviously did not fit into the normal schemes of scientific journals. Through tortuous paths, one of the papers reached the hands of Myrdene Anderson, who offered to publish it in the book she was editing with Floyd Merrell called *On Semiotic Modelling* (this was Hoffmeyer and Emmeche 1991). The other paper was submitted to the *Journal of Social and Biological Structures*, but never reached the editorial process since the journal had, unknown to us, just recently stopped publishing. Tom Sebeok later told me that Harvey Wheeler, the editor of this journal, had turned a couple of its unpublished papers over to him, and among them was our joint paper, which then finally appeared in *Semiotica* in 1991 (as Emmeche and Hoffmeyer 1991). I recollect this event as the first time that we directly communicated with Tom.

"In retrospect, I think that two things are worthwhile noticing about the course of events that finally led to the publication of these two early papers. First, the separation between natural science and the humanities was so ingrained in our minds that it had not occurred to us, as biologists, to search the semiotic literature for precedents of reflections on the semiotics of nature – and it was thus only after having submitted the papers we learned about Tom Sebeok's work. Second, very likely we might have searched in vain for a scientific journal willing to publish those papers, and the surprising open-mindedness towards our ideas that we did ultimately encounter in the semiotic society does, to a high extent, reflect the efforts that Tom had, for two decades, invested to implant biosemiotics into the recognized landscape of the discipline. In the absence of the reception that our paper received from the semiotic society, we might, I am afraid, have given up all together pursuing the subject of the semiotics of nature any further than those two, then, unpublished manuscripts.

"There was one other string leading us to Sebeok's world, however, and that was a string leading the German semiotic society, especially Martin Krampen's work on phytosemiotics (Krampen 1981), and further to the late Thure von Uexküll, who was then a professor emeritus of internal medicine at Ulm University. Tom and Thure had become friends through their collaboration of reintroducing Jakob von Uexküll's work to the English speaking world (Uexküll 1982 (1940), Uexküll 1992), and now, in 1990, they cooperated on establishing the first international English-language meeting devoted exclusively to biosemiotics. The meeting was organized by Jörg Hermann and took place on June 7–9, 1990, in the most beautiful Schwartswald landscape at the Glotterbad Rehabilitation Clinic where professor Hermann was, and still is, head of the medical section. And although these early Glotterbad meetings did not, in the end, produce an international biosemiotic society – that would have to wait until 2005 – they did surely signal the birth of biosemiotics as a viable field of study, if not a discipline.

"Thus, while for the next decade biosemiotics would mainly unfold its life in modesty, and under a diversity of umbrellas – ranging from literature and semiotics proper to evolutionary biology – it definitely did grow in maturity and authority during the 1990s, helped to no slight degree by the efforts of Tom Sebeok, who not only did everything he could to initiate, promote, and publish works on biosemiotics but also was always personally available with advice and encouragement through his legendary e-mail network. . . .[Accordingly,] in my speech of thanks at the occasion of the 25th Annual Meeting of the Semiotic Society of America in 2000, where I was awarded the Thomas A. Sebeok Fellowship, I dared prophesize that "I find it reasonable to expect that biosemiotics will slowly find its way into the very diverse garden of biological sciences. As such it will grow, we may hope, to become one strong resource for biological theorizing, among others" (Hoffmeyer 2010: *forthcoming*).

By the time that Hoffmeyer received the Sebeok Fellowship award, biosemiotics as an interdisciplinary research agenda was indeed growing – and by 2004, Hoffmeyer had completed his second major treatise on biosemiotics, from which the following selection is reprinted. Translated by Hoffmeyer himself from Danish into English, and appearing in 2008 as *Biosemiotics: An Examination Into the Signs of Life and the Life of Signs,* this successor volume to his popular and easily accessible *Signs of Meaning in the Universe* (1996) was written for a more scientifically sophisticated audience, or at least one conceptually equipped by having read and understood the prior text. Still, although the latter volume's target audience is somewhat different than the former's, Hoffmeyer's journalism-honed prose remains as unpretentious and accessible here as ever, requiring little in the way of preliminary explanation, as Hoffmeyer discusses one of the fundamental notions of his biosemiotic theory – that of "code-duality" – in the following reprinted selection from his most recent monograph on biosemiotics.

The Semiotics of Nature: Code-Duality (2008)

Preface

When a brown hare spots a fox approaching in the open landscape, the hare stands bolt upright and signals its presence instead of fleeing. The explanation for this behavior, according to ethologist Anthony Holley (1993), is that a hare can easily escape a fox simply by running – a fact that the fox seems to "know" (whether by learning or instinct). Apparently, then, what is happening in this situation is that the hare's behavior sends a message to the fox: "I have seen you" – and as a result, they can both be spared the effort of running.

A modern Darwinist may claim that this communicative exchange is easily explained by the increased fitness conferred upon individuals by the lowering of their energy expenditures. That is an important insight with which I shall not quarrel. And yet, I cannot help feeling that something is missing in this kind of explanation. For how can we be so sure that these animals themselves – as environmentally situated organisms of blood, flesh and brain – take no creative part in their own behavior? The Neo-Darwinist explanation would require us to delegate to their genetic apparatus the whole burden of anticipating the outcome of all and every future communicative situation these animals may encounter. But why would evolution equip mammals with brains containing billions of extremely energy-costly nerve cells if such brains were then not allowed to make any decisions not already anticipated by the genes?

Charles Darwin (1871 [1981]) the more traditional Darwinists got it right in the sense that no behavior is likely to evolve in the organic world that significantly lowers the fitness of phenotypes exhibiting such behavior. This is an extremely important insight – but it should not blind us to the deeper questions surrounding the undeniable *intentionality* of communicative behavior. Living creatures are not just senseless units in the gene survival game, they also *experience* life (and perhaps even "enjoy" it as we say when human animals are concerned).

In other words, there is, as we shall see in this book, an element of natural play, and not just of natural selection, discoverable in the natural world. There, organisms never "try to survive" – for the simple reason that they cannot know that they are going to die. Rather, they try to escape or to counteract life-threatening events as those events present themselves; more precisely: they just do what they must to do to live. In brief: Organisms strive, and this *striving* – a word Darwin did not himself shy away from using – cannot be set aside in any genuine attempt to understand the workings of animate natural systems.

Making scientifically responsible sense of this "striving" is one of the challenges that the emerging scientific field called *biosemiotics* sets out to accept – and it does so by presenting an understanding that communication is more than just machine-like exchange of information-packets. True communication, biosemiotics argues, is based on *semiosis*, or sign processes. Sign processes are what this book is all about, and I shall be delving deeply into the question of "What is a sign?" – As well as many questions regarding how can signs be understood scientifically – throughout this text.

For the purposes of this preface, however, it will suffice for now just to say that a sign is something that refers to something else – with the essential addition that it takes somebody (i.e., a receptive living system) to make the reference. The meaning conferred by a sign is thus acutely dependent on the nature and the context of its receptive system, the sensing body – and its relations with externality are mediated at all points by the active establishment and disestablishment of such signs. A sign process, then, is more than just a mechanical transfer of information packets because the sign embraces *a process of interpretation*. And yet, it is precisely the phenomena that comprise this interpretative activity that is neglected (and not recognized as engendering its own measure of causal efficacy in the world) in both traditionally conceived Information Theory and in most contemporary mainstream Evolutionary Theory.

Yet by making just this slight (and empirically well-justified) expansion in our basic view of nature – i.e., to accept that semiosis and interpretative processes are essential components in the dynamics of natural systems – biosemiotics, as I hope to show – provides the conceptual tools necessary to explanatorily reintegrate living creatures (including, of course, human beings), into the natural world from which they came ... and from which they have been effectively excluded by a scientific ontology that has, at least since the time of Descartes, consistently encouraged scientists to *de-semiotize* all the naturally communicative and fundamentally interactive processes of living systems.

Caveats

When I set out to write this book in 1999, biosemiotics was still in its initial phase *en route* to becoming an autonomous field of its own (I will provide some further background on the history of the field in the Post Scriptum to this book). Back then, however, apart from a small group of semioticians who were following the lead of the pioneering linguist and semiotician Thomas A. Sebeok, only a handful of medical doctors and biologists were actively engaged in investigating the potential of this newly developing perspective on the study of life. The whole field was at the time relatively open, but also largely anchored in a shared understanding of semiotic processes derived from the pioneering sign logic of the American logician, scientist and philosopher Charles Sanders Peirce (1839–1914).

Today, only one decade later, the situation has radically changed and biosemiotics has been taken up as a field of study by chemists and physicists, as wells as philosophers and cognitive scientists, anthropologists, psychologists and scholars from many other disciplines in both the humanities and the natural sciences. This growth spurt in the development of biosemiotics as an international research project is welcome, since it will force every one of us who is working in this field to become more exacting in our arguments, and because it widens up the agenda of the biosemiotic perspective to encompass the entire study of life.

But this recent rapid growth also entails that the views that I present in this book may not cover all the competing conceptions of biosemiotics now being debated within the field. I have chosen, nevertheless, to keep the title *Biosemiotics* from the original Danish edition of this book, for although there are certainly now other views of the field, this book surely comes close to expressing the original understanding of biosemiotics as envisioned by Thomas A. Sebeok and Thure von Uexküll – as well as, I feel confident, the majority (although certainly not all) of those scholars that are currently engaged themselves in the development of biosemiotics.

It is unavoidable too, I suppose, that this text reflects my own original background as a biochemist and scientist. Many readers might have wished for a broader treatment of areas such as *zoosemiotics* or *medical biosemiotics*, and also perhaps for a more comprehensive analysis of Peircean philosophyas a resource base from which to explicate the biosemiotic approach. I can only hope that such readers will show tolerance towards these perceived deficits in the text. No single person can claim competence in all the varied scientific disciplines that must be brought into play in order to reveal biosemiotics in all of its potential and, at the same time, to consistently grapple with all the philosophical implications that it holds.

Similarly, another group of readers may argue that the investigation into sign processes at the "micro level" – i.e., *cytosemiotics* and, in general, *endosemiotics* – have been given undue emphasis in the book. I have done this for a reason, however. For biosemiotics is often dismissed by scholars – not least, those from the humanities – who fundamentally misconceive it as an attempt to project anthropomorphic features upon an existing world of nature that, as we all learned in school, can easily be explained without reference to human mental states and constructs. Yet I believe that no other caricature could more mischaracterize the true aims and principles of biosemiotics – and indeed, I, too, discuss the fallacy of anthropomorphism in some depth later in this book.

Rejecting anthropomorphic explanations of nature, while not falling into the opposite trap of eliminative reductionism, biosemiotic analysis is yet, too, a rejection of the idea of scientific knowledge as a kind of knowledge obtained by taking, to use Thomas Nagel's felicitous expression, the "view from nowhere" – the assumption that the knowledge of reality that we do have, in other words, does not include ourselves as knowing creatures produced by, and inside of, the very same nature that we are attempting to explain. This conception of scientific knowledge is not only absurd, but it systematically corrupts our understanding of the world because it hides the very tools that might help us to see how we both emerge from, and still now essentially belong in, nature – and to thereby be able to scientifically answer another question that Nagel puts to us: "How can it be the case that one of the (the objective set of) 'people in the world' is . . . *me*?" (Nagel 1986: 13).

We may not feel that we can ever answer this question adequately, but a first premise for approaching such an answer must be that we can somehow explain the existence of *me-ness* in the world. How could evolution create such a strange thing as a self-reflective "me" or an "I"? An evolutionary theory that does not give us any tools to see how such a question can be meaningfully answered leaves us as objectified biological robots, or zombies. I must assert upfront that I firmly believe that neither the reader nor I are zombies – and consequently, that a decent biology must search for the evolutionary root forms of what it is to be an "I", or a first person *singularis*.

A key to answering this question, I am going to argue in this work, lies in a sufficiently rich concept of *semiosis.* Biosemiotic analysis takes us back to the questions of how life and semiosis first appeared on Earth, and we shall see that these are, in fact, not two distinct questions, but a single united one: semiosis is an essential aspect of life already at the primitive unicellular level. It is my guess that readers not only from the sciences, but also from the humanities, will be greatly surprised to learn how nearly impossible it is to gain an understanding of the interactions and organization constituting the world of living nature without a semiotic terminology and – perhaps even more fundamentally, a semiotic way of thinking. I do hope, moreover, that this book will show that the attempt to cross the traditional borders between major areas in university life does bring us necessary new insights. Transdisciplinarity will be of no help so long as everybody stays safely inside his or her own disciplinary borders, politely transgressing no internal disciplinary taboos. Rather, "interdisciplinary scholarship" only becomes fruitful when we collectively take the risk to confront problems in the ways those very same problems may be seen within disciplines *other* than our own.

Accordingly, the major challenge in writing this book has not so much been to assemble and to present the many and varied kinds of knowledge that must be assimilated in order for the biosemiotic project to take on its real significance. It does indeed appear at first glance to be a far jump from the analysis of "languaging" in the human animal to the analysis of "courtship trembling" in the water mite, or from "the logic of self-organization and emergence" to "the biosemiotics of modern petrochemical agriculture." So I have tried to make clear all the conceptual links and unique level properties that come into play as we move from one of these phenomena to the other.

A harder problem by far, however, lies in the attempt to surmount the theoretical and philosophical difficulties of putting insights from areas that traditionally have been seen as "scientific" into play with insights that have traditionally seen as "belonging to the humanities" (Hoffmeyer 1975). For on the one hand, biosemiotics is engaged in developing conceptual tools for *theoretical biology* (and thereby also, indirectly, for experimental biology), while on the other hand, biosemiotics contributes to the development of a *general semiotics* that will be inclusive enough to conceptualize the human being as being not only *in,* but also deeply *of,* nature – and in so doing, biosemiotics contributes to renewed reflections in natural philosophy.

Moreover, because of the ambitious nature of the attempt, I have little doubt but that readers coming from backgrounds on each side of the Cartesian disciplinary divide will at times feel their scholarly sensitivities violated by this book. To them, I may only suggest that they attempt to localize their misgivings not to the entire project undertaken here, but only to such particular mistakes and misstatements as they may find herein – and to share my own hope that time will teach us all to do a better job of transdisicplinary communication. For there is no way that we can make progress, if we allow ourselves to remain stuck, each on our respective sides of the Cartesian dividing line, in our attempts to understand a reality that refuses to so divide itself.

And in that regard, I believe that I need to add one further note of explanation here at the outset of this book. This concerns my belief that if communication across large ranges of scientific disciplines shall succeed in producing new fruitful ideas, it is absolutely necessary to transcend the narrow terminology of each particular discipline in our speaking to one another. Terms are used in very different senses inside different disciplines and it has been my experience that everyday language should be used as much as it is practically possible to do so when undertaking transdisciplinary work, in order to make one's ideas as *explicit* as possible to all participants in the conversation. Thus, for example, throughout this book I have deliberately employed illustrative materials that may seem like simple text book figures to the expert eye. Such a commitment to baseline clarity and explicitness is often misunderstood as disciplinary trivialization – but I believe that one should rather see it as a necessary step in the research process itself. We do not get anywhere if we do not understand each other, which means that the mediating process becomes itself a vital part of all transdisciplinary research.

Code Duality

Weismannism

In the 1890s, the German naturalist August Weismann famously showed that somatic cells and germ cells lead totally separate lives in the organism. A cell line consists of a clone of cells that can be traced directly back to a single ancestor cell, and Weismann argued that the separation between the cell lines that will become sex cells and those that will differentiate into all of the other cells of the body takes place early in embryogenesis. This finding was significant, for it seemed to imply that properties acquired by the organism during the course of its own life cannot in any way affect the sex cells, and thus, the offspring. In other words: *acquired properties are not heritable* – and in showing this, Weismann hoped he had safely refuted the mechanism for evolution proposed nearly a century earlier by the French biologist Jean Baptiste Lamarck (Lamarck 1809).

Yet as we shall see, Weismann's new doctrine has turned out to be far from as certain as it was for a long time thought to be. For by and large, it is difficult to understand the great and enduring significance ascribed to Weismannism if one does not also reflect upon the ideological and religious aspects of the scientific controversy between Lamarckism and Darwinism that this doctrine more than anything else would put an end to. That the cruel and purposeless process that natural selection essentially is should be the real cause behind the wonderful arrangement of life forms in animate nature – and thus also the explanation for our own human nature – was not a message that most people liked to believe. Many, therefore, took refuge in various versions of neo-Lamarckism, doctrines that not only implied the possibility that traits that one had cultivated in one's own life could be inherited by one's children, but also – and more importantly – implied the belief that there was in nature an inherent strive for perfection – *la marche de la nature* in Lamarck's terms.

It should be noted here that at the end of the 19th century, Darwinism was nothing like the uncontested theory in biology that it is today – and there was indeed no really compelling biological evidence for its truth (Ruse 1979). Religious forces in the United States, in particular, were capable of successfully fighting Darwinism for a considerable portion of the early 20th century – and especially in paleontology the eventual conversion to Darwinism became a long, drawn-out affair. Similarly, the animosity against religion was a frequent component in Darwinian rhetoric and Weismann himself was a dedicated materialist with an aversion to the spiritualist and vitalist overtones present in much neo-Lamarckian theorizing of the time (Depew and Weber 1995, Depew 2003).

Dusty as these conflicts may seem today, there is no doubt that fires are still smoldering within their ashes. For to the modern mind, Darwinism stands for rationality, materialism, and clear separation of science from ideology or religion – whereas Lamarckism brings associations of irrationalism and religious interference in scientific matters. Thus, still today, critical re-considerations of Darwinism automatically call forth a suspicion that it is, in fact, not just the specific postulates of Darwinism – but scientific rationality as such – that is being rejected. The old conflicts between science and the Church are not so easily forgotten.

Here, however, we must nevertheless venture to have a closer look at this whole complex of ideas. For we are going to argue that Weismann's doctrine is based on a specific semiotic trick that is characteristic of living systems in general – a trick which Weismann himself could not have uncovered, because it presupposes a knowledge about the molecular-semiotic dynamics of life processes that had not yet been discovered in his time. And yet while the inner core of Weismannism will be in a certain sense confirmed by this reformulated understanding, it is one which in no way supports the aggressive transmission-genetic[1] reduction of evolutionary biology that Weismannism otherwise seems to justify. On the contrary, it appears that the Weismann doctrine depends on a duality between analogue and digital representations that opens the door to a sophisticated interaction between the domains of the genetic and the somatic.

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[1] Genetics, properly speaking, comprises both a transmission aspect and an expression aspect. The transmission aspect is concerned with the transmission of genes from generation to generation, whereas the expression aspect deals with the question of how genes actually do produce the traits ascribed to them. For most of its history, however, the science of genetics has restricted itself to the first of these two aspects, the transmission phenomena, while more or less leaving the expression problem for the future. It is one thing, for instance, to claim that the taboo against incest is genetically anchored, quite another to explain how a gene might manage to cause such an effect. See more on this in Chapter "Universe of Mind: The Semiophere", especially Lenny Moss's distinction between gene-P and gene-D (Moss 2001). This emphasis on the transmission aspects, of course, has made the reductionist strategy so much easier to perpetuate.

Life as a Dead End

In textbook versions of Weismann's doctrine, the reader usually is shown a figure with a sequence of sex cells connected by arrows from left to right, and where from each sex cell, a diagonal arrow branches off point to a picture of an adult organism. This last icon is normally depicted as a dead end with no further connections to its future sex cells or the progeny derived from these sex cells, as shown in Fig. 19.1. The adult lions in Fig. 19.1 do of course contribute their sex cells to the offspring, but since, according to Weismann's doctrine, the sex cells are unaffected by the actual life of the lions themselves, this contribution plays no autonomous role in the scheme and should be left out. This figure is well suited to illustrate why Weismann's doctrine blocks the way for the Lamarckian belief in the inheritance of acquired properties.

But if the arrows are meant to symbolize straightforward causal connections, then the figure is less satisfactory. For parents certainly influence the life and survival chances of their offspring in many other ways than through delivering their sex cells. Many species exhibit prolonged periods of parental care – and even in species with no distinct parental care, offspring is typically left to hatch in suitable places where the survival chances of the offspring are higher than they would be elsewhere. Organisms, to a large extent, choose their own habitats and their own mating partners. They select and consume resources, generate detritus, and construct important components of their own environments such as nests, holes, burrows, paths, webs, dams and chemical environments (Lewontin 1983, 1992).

The British biologist John Odling-Smee has suggested the term "niche construction" for the organism's own contribution (positive or negative) to the establishment of suitable ecological conditions for its offspring: "Organisms, through their metabolism, their activities, and their choices, define, create and partly destroy their own niches. We refer to these phenomena as 'niche construction'" (Odling-Smee 1988; Odling-Smee et al. 1996). That organisms often downright destroy their own living conditions at a locality is well known, as for example, can be seen by the many documented instances of "ecological succession" wherein one species typically changes the ecology of its local environment such that a rival species can then flourish there, and in so doing wipes out the original species.

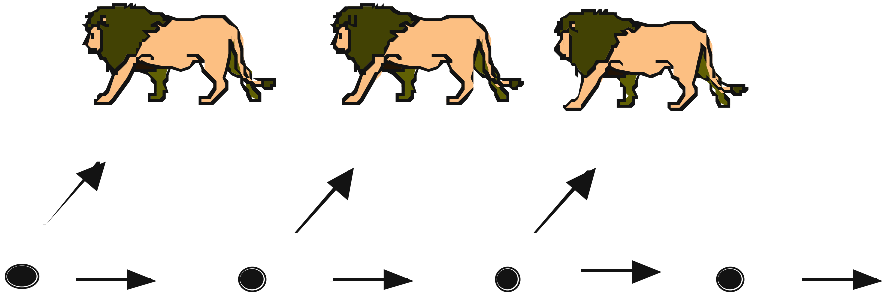

Fig. 19.1 Weismann's doctrine. The *filled circles* represent sex cells (see text)

The Darwinian consensus has long been that we can by and large neglect these kinds of influences, because such activities are seen as genetically determined. According to this understanding, the genotype determines not only a morphological phenotype, but also a behavioral phenotype. And thus in a statistical analysis, the sex cell and its genome can therefore represent the individual and, for all intents and purposes, its characteristic activity. It is, of course, admitted that the determinism is not complete and thus the phenotypic variety that may be observed in one and the same genotype (or gene pool, if the analysis concerns variations inside a population) under different environmental conditions is then referred to with (and supposedly explained by) concepts such as "reaction norm" or "phenotypic plasticity." However, since natural selection plays out over a huge number of generations and among many individual organisms, it is routinely assumed that the effect of this type of variation will ultimately be averaged out, so that one may safely bypass niche construction effects when accounting for the mechanisms driving evolution.

Odling-Smee, not surprisingly, considers this an explaining away of the problem:

> To us the idea that niche construction can be dismissed because it is the product of natural selection makes no more sense than the counterproposal that natural selection can be disregarded because it is a product of niche construction. From the beginning of life, all organisms have, in part, modified their selective environments, and their ability to do so is, in part, a consequence of their naturally selected genes. Niche construction and natural selection are two processes, operating in parallel, but also interacting (Odling-Smee 2001: 118).

The intricate interplay between natural selection and niche construction may be nicely illustrated by the survival strategy that has evolved in one of "Darwin's finches," *Cactospiza pallida,* from the Galapagos Islands. This finch has constructed a niche identical to the niche that elsewhere in the world is occupied by woodpeckers. But instead of using its beak directly to drill a hole in the wood, *C. pallida* has developed a technique of using a cactus spine held in its beak to dig the insect out. In this case, Odling-Smee explains, it was not first the anatomy of the bird that was formed by natural selection to solve a given task – but rather, this finch, like so many other species, utilized a much more general and flexible adaptation: the capacity for learning. The ability of the finch to use a cactus spine is not guaranteed by the presence of some relevant gene ("the gene for thorn digging?") – and yet it develops quite reliably as a consequence of the general ability of the bird to profit from its experiences in interacting with its milieu (Odling-Smee 2001).

In the context of this book, it would be tempting to say that the bird makes use of its own semiotic competence to *create an interpretant* (a habit) upon seeing a cactus spine in the relevant situation. And, as Odling-Smee remarks, this creation of a new way of living (or *niche*) in itself implies that natural selection is now driven to reinforce the selection pressure on the bird's ability to learn.

In the traditional scheme, then, evolutionary processes may in principle be described by just two equations. The first describes the change of organisms (O) as a function of organism and environment (E): $d(\mathrm{O})/dT = f(\mathrm{O},\mathrm{E})$, and the second describes the change in the environment as an autonomous process: $d\mathrm{E}/dT = g(\mathrm{E})$.

Already in his influential 1983 paper, Richard Lewontin showed that if one was to pay regard to the fact that organisms themselves may often influence their niche, this scheme would have to be changed to a set of coupled differential equations reflecting the reality of the interaction between organisms and environment – and that, in fact, each of them is a function of the other: $d\mathrm{O}/dT = f(\mathrm{O},\mathrm{E})$ and $d\mathrm{E}/dT = g(\mathrm{O},\mathrm{E})$. While the process in the first of these scenarios figuratively might be depicted as species that climb mountains, then, in the niche-construction scenario species would jump trampolines in the sense that in this situation there are no fixed equilibrium points (Lewontin 1983).

We shall return to the difficulties of upholding an efficient Weismann-barrier, in the sense of a non-interventionist view of individuals in the evolutionary game of natural selection. But before we pursue this problem any further, it is necessary to take a closer look at a trend that I will call "the genocentric turn" in biology. This is the tendency of biologists to shift the emphasis of their analyses and investigations from the level of the organism to the level of the gene – seeing genes, rather than organisms, as the operational level for selection.

Gene Selectionism

With Crick's articulation of the central dogma, Weismannism obtained a sort of molecular confirmation. For since proteins may, roughly speaking, be identified with the machinery of the body – and are as such directly responsible for its activity and behavior – the implication of the central dogma was that the body machinery cannot feed back into the genome. The body thereby ended as a strange blind alley in evolutionary theory landscape. It is little surprise that a theory that sees organisms as causal dead ends in the evolutionary game would sooner or later give birth to the idea that organisms, rightly considered, are just instruments for the strategic interests of genes. It was the well-writing Oxford biologist Richard Dawkins that, back in 1976, disseminated this idea in his book "The Selfish Gene." And this was an idea that met with considerable sympathy both inside and (particularly) outside of biology. According to this idea, often called *gene-selectionism,* the organisms that classical Darwinism focused on as the substrate for natural selection should be seen rather as kinds of "survival machines" or "vehicles" that are merely *used by the genes* in *their* competition for a ticket to the next generation.

According to this scenario, genes that have instructed their organisms well increase their chances of becoming multiplied via their offspring. Thus, while the organisms themselves are short-lived, their genes will continue to survive as copies or replicas in (statistically speaking) half of the offspring. Genes in Dawkins' terminology thus become *replicators:*

> What was to be the fate of the ancient replicators? . . . Now they swarm in huge colonies, safe inside gigantic lumbering robots, sealed off from the outside world, communicating with it by remote control. They are in you and me; they created us, body and mind; and their preservation is the ultimate rationale for our existence. Now they go by the name of genes, and we are their survival machines (Dawkins 1976: 21).

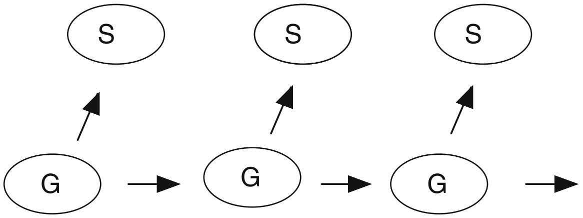

Fig. 19.2 Molecular Weismannism. G = germ cells, S = somatic cells

But something is jarring here, isn't it? An over-smart semiotic loop perhaps: "they created us . . . "? After all, on the face of it, it was "us" that created the "gene." This is not a joke, for it highlights the essential trouble with Dawkins' concept of the "gene" – i.e., its misleading ambiguity as to what kind of a thing "the gene" really is. For in fact, it was the Danish botanist Wilhelm Johannsen who in 1909 created the terms *gene, genotype* and *phenotype*. But Johannsen's "gene" was very different from the modern idea of genes, since Johannsen certainly did not imagine that the gene existed as a material thing.[2] For him, the gene was simply a tool for calculations (similar to the measure of "IQ" that had been introduced at about the same time by the French psychologist Alfred Binet). However, as is well known, the concept of the gene was soon taken over by fruit-fly geneticists who did not have Johannsen's reservations about a straightforward material interpretation. The famous *Drosophila* Group led by Thomas Hunt Morgan came to see the genes as "pearls on a string" (Morgan et al. 1915) – and after Watson and Crick's discovery of the DNA's double-helix structure in 1953, we finally got the modern biochemical concept of "the gene." It is this biochemical concept of the gene that is implied when we are told that the human genome contains some 25,000 genes.[3]

But when Dawkins (1976, 1989) writing about genes, claims that "they created us," a closer inspection reveals that "they" do not at all refer to the biochemical genes but to a much less well-defined entity called an "evolutionary gene." The evolutionary gene is refers to any short piece of DNA on a chromosome that segregates and recombines with appreciable frequency. Such "pieces" must be reasonably short, since it is essential for Dawkins' hypothesis that the gene *itself* is a replicator, meaning that it can multiply through replication. And this again presupposes that this "gene" is not often broken up; and the longer the "gene" is, the higher is the risk that it may be broken up by the processes of genetic recombination (e.g., by the so-called "crossing-over" effect of meiotic division, the process whereby new germ cells are formed.)

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[2] Johannsen actually compared the concept of *the gene* as a material structure that resides within the cells with the naive belief – of the peasants of his own time – that a team of horses was hidden inside the locomotive.

[3] I had better be careful here. A few years ago, the estimated number of genes in the human species was something like 80,000. After the publication of the map of the human genome in 2001, there were reported to be only 30,000–40,000 genes. And the latest estimate I saw had only 20,000–25,000 genes (*Nature* October 21, 2004).

Thus, one strange thing about Dawkin's gene concept is that nothing guarantees that the "gene" itself need be a functional unit. As Sterelny and Griffiths have put it:

> If genes are just arbitrary DNA sequences, then most of them will have no more systematic relation to the phenotype than an arbitrary string of letters has to the meaning of a book (Sterelny and Griffiths 1999: 79).

We shall not pursue the implications of this observation any further here, but content ourselves by noting that a clear understanding of what "a gene" in the above sense really *is* recedes even further when the question is studied in more detail (Neumann-Held 1998). So much more odd, then, is the claim that these ambiguous and mysteriously "intentional" entities should have "created us body and mind."

What we will note here, however, and what is especially problematic to a Dawkinsian understanding, is the well-known chemical fact that DNA molecules are essentially passive under normal physiological conditions. For as I have argued elsewhere (Hoffmeyer 1997), it is the very inertness of the molecule under normal conditions that makes DNA so adequate as a "memory"-carrier. One cannot well "store memory" in a substrate that also takes an active part in the everyday business of the cell.

But DNA molecules, as Evelyn Fox Keller (1995) reminds us, do nothing and remain inert until the arrival of a varied and highly specific set of proteins that (as we shall see in Chapter 5) have the manifold tasks of: opening up the double helix; copying the signifying strand onto mRNA at a chosen site; modifying this mRNA in a diversity of ways; transporting the mRNA out of the nucleus to the "protein factories" (endoplasmatic reticulum) in the cytoplasm; and much, much more.

In eukaryotes, the passive DNA is protected by specific proteins inside the cell nucleus, where it is continuously controlled and repaired when it has become damaged. In short, the *active* components of the cell are the proteins that work together in subcellular complexes or membranes – and, as we will see in Chapter 5, these complexes are the *real* "doers" in cellular life that constitute the "agency" of the cell. To ascribe such agency to DNA is highly contra-indicated from the chemical point of view.

Digitalism

The widespread tendency to see DNA as the main actor in the unfolding life process is probably due to the fact that the genetic code, as carried in the DNA molecules, is a digital code. And, in fact, Western culture is profuse with "digitalism" – by which I mean an exaggerated trust in the performative power of digital codes (Hoffmeyer 2002). Let me take a moment here to explain what I mean.

The word *digital* comes from the Latin word for finger, *digit* – and a digital code is quite generally a code based on symbols that, like the fingers, are discontinuous: for instance, the numbers 1, 2, 3, 4, 5... or the letters of any writing system or alphabet. The lengthy strings of 0's and 1's that make up the algorithms in binary computation "language" have recently come to stand as the quintessence of digitality – but the prior invention of the book was already based on a digital code (of letters), so the modern distinction between so-called digital electronic media and old-fashioned books is dangerously misleading when it comes to a clear understanding of codes.

The alternative to a digital code is an analog code, and this kind of code is based on the principle of analogy. In an old watch, for instance, the pointers circle the watch dial in a kind of analogy of the (perceived) rotation of the sun around the Earth. In the same way, the height of the mercury column in a thermometer can be said to analogously reflect the magnitude of the actual temperature. One might also call a glove an analog coding of a hand, and in a certain sense one might even see the wings of the bird as an analogue codification of the aerodynamic properties of air currents.

Note, however, that the coding principle in digital codes is necessarily *arbitrary*, relative to the content. That the word "horse" in English refers to a big grazing mammal with a certain kind of mane cannot be recovered from the form of the letters but must be known through another process, as when speaking to a Frenchman, that same animal in French has the equally arbitary designation "cheval." Digital codes are necessarily based on symbolic signs (in the Peircean sign trichotomy), whereas analog codes are based on icons and/or indices (as discussed in Chapter 8).

Since the genetic code is based on a sequence of discrete signs that are grouped together in sequences of triplets (e.g. the trinucleotide sequence UUU that is translated to the amino acid *phenylalanine*) – and whose relation to the amino acids they are coding for is mediated through a complex historically established interplay between protein- and RNA molecules (see further in Chapter 5) – the genetic code is a clear case of digital coding.

To return to my earlier point: In Western culture we are accustomed to think of digital codes as superior to analog codes. He who masters numbers and letters (or computers!) clearly has a higher status than he who relies on the less formalized, analog ways of understanding reality. That science accords high authority to digital coding schemes may of course be traced back to the Galilean idea (now so widely adopted) that the language of God, or now reality, is mathematics. But it is hard to escape the feeling that this privileging of the digital representation also somehow reflects the separation between plan and execution that has been such an important principle behind the success of the industrial society.

Since the execution of work in industrial production is supposed to follow deterministically from the pre-given plan, there is left little or no space for *interpretation* at the level of execution.[4] In traditional industrial production, all creativity was delegated to the planners, and workers were not supposed to add anything innovative to the process. The element of creativity was not part of work on the floor.

If we take this model and project it upon the theory of evolution, a "digitalist" reading of genetic expression follows naturally. For just as the overwhelming

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[4] Planning itself, of course, may contain elements of analog coding such as diagrams or drawings, but these are generally superstructures based on numerical or otherwise abstract codifications.

productivity of industrial society was obtained through a separation of planning from execution in a "master-servant" relation, evolutionary theorists have argued that evolutionary creativity should be explained by a separation of the genetic master plan (the DNA) from the mundane operations of the cytoplasm – with the cytoplasmic processes themselves, of course, obeying the dictums of the genome.

Seen in this way, "digitalism" may be thought of as yet another example of the well-known tendency of science to transform the dominating structures of social reality into natural reality. But this account makes digitalism as a historical bias that belongs to a particular historical period, i.e., the epoch of industrial society – and one might perhaps expect that it would gradually loose its hold over the imagination of researchers as this form of production looses its dominant status in society.

For in fact, the strict separation between planning and execution is scarcely typical anymore for production processes in the advanced sectors of almost any modern economy. On the contrary, it is semiotic competence that is now increasingly in demand. Thus it ought to amuse sociologists of science that "digitalism" now seems increasingly challenged in science by models of embodiment – i.e., models where the bodily anchoring of cognitive or biological functionality are seen as essential to that functionality (Damasio 1994; Van Gelder and Port 1995; Deacon 1997; Etxeberria 1998; Rocha 1998; Lakoff and Johnson 1999, Clark 2002).

The development of clever computers and robots has undoubtedly been facilitating this change of perspective (Hendriks-Jansen 1996; Clark 1997; Ziemke and Sharkey 2001; Sharkey and Ziemke 2001a, b). The understanding that cognitive and biological processes cannot really be comprehended in isolation from their character as somatic processes reflects a growing awareness in the computer age of the fact that digital pre-specifications are essentially *dependent* on the agency of autonomous structures and mechanisms acting in space and time. That such relations are best grasped from within a semiotic frame of reference seems obvious to this author (Hoffmeyer 2002) – and the rejection of theoretical positions that ignore the decisive significance of our bodily existence for cognitive function has been, of course, a central theme in the biosemiotic tradition (Hoffmeyer 1996; Brier 2000; Kull 2000; Danesi 2001; Emmeche 2001; Favareau 2001).

Code-Duality

In 1991, Claus Emmeche and I suggested that life at the most fundamental level may be characterized by a dynamic trait that we called *code-duality* – i.e. a recursive and unending exchange of messages between analog and digital coding surfaces (Hoffmeyer and Emmeche 1991, 2005, Emmeche and Hoffmeyer 1987).

As analog codifications, organisms recognize and interact with each other in ecological space, whereas as digital codifications (genomes) they are passively carried forward in time from generation to generation (in sexually reproducing species, after recombination via meiosis and fertilization). Seen in this perspective, life must be understood as "semiotic survival" – survival via a fundamental code-duality.

Our idea of code-duality was much inspired by Gregory Bateson's grandiose attempt in the book *Mind and Nature* to draw a connection between thought and evolution as deeply related processes (Bateson 1979). We were also inspired by the American biophysicist Howard Pattee's suggestion that living systems must necessarily operate through the interactions between two complementary "modes" – a time-independent or symbolic (linguistic) mode and a time-dependent dynamic mode (Pattee 1972, 1997). I shall return to a discussion of Pattee's idea of an "epistemic cut" shortly, but preliminary to that, let us here consider the original presentation of the idea of code-duality. The idea was introduced in the context of a discussion regarding what kind of "status" one should ascribe to life. In answering this question, we took as our point of departure the Batesonian understanding of life as systems possessing the ability to process information in the sense of "differences that make a difference." The following pages is a slightly modified version of the original presentation in (Hoffmeyer and Emmeche 1991).

> *Who* [*is*] *the subject to whom the differences worked on by such a system should make a difference?* If one admits at all that living systems are information processing entities, then the only possible answer to this question is: The system itself is the subject. Therefore a living system must exist "for" itself – and in this sense it is more than an imaginary invention of ours: For a system to be living, it must create itself, i.e. it must contain the distinctions necessary for its own identification as *a system*. Self-reference is the fundament on which life evolves, it is its most basal requirement. (Tellingly, this fact does not pertain to non-living systems: There is no reason for the hydrological cycle to know itself. Thus, rivers run downstream due to gravity, water evaporates due to the solar heat, nowhere does the system depend on self-recognition). Another way to express this whole matter is to say that differences are not intelligible in the absence of a purpose. If nothing matters, matter is everything.
>
> But what is the basis of this self-reference that is at the basis of life? We shall suggest here that the central feature of living systems allowing for self-reference – and thus the ability to select and respond to differences in their surroundings – is *code-duality,* i.e. the ability of a system to represent itself in two different codes, one digital and one analog.[5] (Symbolically, this code-duality may be represented through the relation between "the chicken and the egg")
>
> Thus, self-reference clearly depends on some kind of re-description. The system must somehow be able to construct a description of itself in order to perpetuate itself (Pattee 1972, 1977). This description furthermore must stay inactive in – or at least protected from – the life-processes of the system, lest the description should change – and thereby ultimately die with the system. In other words, the function of this description is to assure the identity of the system through time: it is the memory of the system. In all known living systems, this description appears in the digital code of DNA (or RNA) that is eventually distributed to the germ cells.
>
> We suggest that it is by no means accidental that the code for memory in living systems is of a digital type. For what must be specified through the memorized description is not the specific material details of the presently living system, but only their structural relations

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[5] Two decades ago, I suggested a less fully developed version of the idea of code-duality (Hoffmeyer 1987).

in space and time.[6] If such abstract specifications could be expressed through an analog code, only very simple systems would be possible and those would probably not survive. For a parallel: if human communication and memory depended solely on analog codes – e.g. exclusively the ability to mime – if, in other words we did not posses the digital code of language, our cultural memory would be as short as that of chimpanzees – and our social structure would be accordingly as simple.

And in a complementary fashion, in order for the system to work the memorized description in the digital code must be translated to the physical reality of an actual living system. For this translation (the developmental process) to take place, the fertilized egg cell (in sexually reproducing species) must be able to decipher the coded instructions of the DNA[7] as well as to follow its instructions in a given way. This need for the active participation of cellular structures in realizing the digital codification of the DNA into its analogue protein and organism form shows us that a sort of ‘tacit knowledge’ is present in the egg cell (Polanyi 1958; Pattee 1977). And the existence of this tacit knowledge inherent within the cellular organization must be presupposed by, rather than materially built into, in the DNA-description. Thus, the digital re-description alone is far from a total description of the organism.

The realization in space and time of the structural relations specified in the digital code determines what kind of differences in the surround the system will actually select and respond to – or, in Uexküllian terms, these sepcifications determine not just the anatomical and physiological build up of the organims but also the kind of Umwelt the organism will get Through this realization, a new phase in the perpetuation of the system is initiated: the phase of active life. One might say that in this phase – the ‘analog phase’ – the “message” of the memory is *expressed*.

Eventually, the system will survive long enough to pass on its own copy of the digitalized memory (or part of it) to a new generation: this corresponds to a back-translation of the message to the digital form. But this latter process takes on its true significance only when seen at the level of the population. For it is the population (rather than the single organism) that passes on “messages” about conditions of life to the memory of the collective (the gene-pool). The population could in this sense be considered a codification that itself expresses a message. This codification, however, necessarily is analog – since it has to interact with the physical surroundings, and thus must share with these surroundings the properties of physical extension and contiguity.

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[6] For example, if the gene codes for a distinct enzyme, the rate of degradation of this enzyme will determine how long the enzyme will remain active in the cell, and thus also determine the concentration of metabolites that are available for catalytic reaction. Since the concentration of metabolites will oft en have a regulatory influence on other cellular processes, the gene indirectly also determines the temporal relations between these different processes (see Fig. 5.5). However, the gene cannot, for good reason, determine precisely where in the cell a given molecule will be located at a given time. This problem may perhaps be illustrated by imagining a protein that is the size of a family car. The cell would, in relation, be the size of Copenhagen (although spherical rather than flat). And, due to the intricate internal structure of the cell, the freedom of movement of the proteins inside the cell would hardly be any bigger than the freedom of movement of a car in the street web of Copenhagen.

[7] Please notice that there is no sequence of nucleotide triplets per se – just an endless string of bases whose “reading” *determines* what will be acted upon as actual triplets. The base sequence, CAGTCAAAGAAC, might for instance be read as composed by the triplets: CAG-TCA-AAGAAC. But in another reading frame it might be read as C-AGT-CAA-AGA-AC. (See Chapter “Universe of Mind: The Semiophere” for further details on the semiotics of the genome.)

> The chain of events that sets life apart from non-life – i.e. the unending chain of responses to selected differences – thus needs at least two codes: one *code for action* (behavior) and one *code for memory* – the first of these codes necessarily must be analog, and the second very probably must be digital (Hoffmeyer and Emmeche 1991).

Looking back at this first presentation it must be noted that many readers, unfortunately, felt this concept of code-duality to be confusing, and presumably this confusion has two main sources. One has to do with the way that the term "code" is used, since the term has quite different connotations in different disciplines (e.g., jurisprudence, genetics, computing). The other source for confusion is more principled and concerns the conception of living creatures *as* "codes." This idea may easily switch on a warning signal that what I am arguing for is a kind of universal "pansemiosis" – Is *everything* in this world just signs, then? Am I claiming that there is no reality beyond that of signs?

Let me immediately answer these two questions in the negative. The claim that the world contains nothing but signs is as reductionistic and unfruitful as the claim (in the epistemological sense) that all the phenomena of the world can be reduced to their quanta of matter and energy.

Admittedly, what Peirce called "brute force" or the category of Secondness (cf. Chapter 3) is an irreducible aspect of our world that cannot in a meaningful way be thought away, as little as chance and Firstness can be neglected. And because of this, John Deely has introduced the concept of *physiosemiosis* as a designation for semiotic processes taking place in inanimate nature (Deely 1990, 1994, 2001; see also Christiansen 2002; Taborsky 2002).

For example, the meteoric storms of the past are still visible today through the traces they left as craters on our moon where craters may be seen as an enmattered "memory" about those distant times. Now, it takes an intelligent being, of course, to decode this connection between real-world states and events and to interpret the cavities on the surface of the moon as meteor craters. But the possibility of such an interpretative act was nevertheless latently present in the very "mark" of the indentation itself – a mark, to be sure, that nobody took an interest in before human beings started wondering about the puzzles of the universe.

Nature's "taking of habits" – in other words, its tendency to develop new regularities as the result of its own ongoing interactions – has been at work at all times. Semiosis, or "the action proper to signs" (Deely 1991), should not be seen as an either/or phenomenon that suddenly appeared on Earth when life began. A more sensible view is that the origin of life initiated new avenues for semiosis to follow, avenues that implied new and unheard kinds of freedom. Living systems are anticipatory, in the sense that they systematically recognize and exploit (interpret) important regularities (causal relations) in their surroundings, and in so doing living systems gained access to the world of genuine triadic sign processes.

One should therefore distinguish between the kinds of semiotic processes that occur in physical, biological, and psychological systems. Semiotic freedom is much more pronounced in the latter two than in the former: In dealing with purely physical systems, one can in almost all cases get away with disregarding the semiotic dimension, with no lack of explanatory sufficiency. But this quickly becomes absurd if human nature is one's concern. Biology falls somewhere between the two.

However, the word *pansemiosis* carries connotations to German *Naturphilosophie* and especially to Friedrich Schelling's conception of the world as *panpsychic*. And regardless of what Schelling exactly did mean by this – and, as this is uncertain, I shall not pursue the matter here – it does seem to me inappropriate to confuse natural processes with human psychology. But it may not follow that this quite legitimate rejection of the overwhelmingly anthropocentric notion of *panpsychism* should be conflated with, and thereby also infect the reception of the concept of *pansemiosis*.

For this latter concept, explicitly, does *not* extend "humanness" to penetrate the universe at large – but rather sees the human being as one among infinitely many instantiations of a universal semiosis. And since this confusion seems inescapable, the term *pansemiosis* tends to block understanding more than it advances it. The relevant answer to the "accusation" of pansemiosis, therefore, is to make clear that the project of biosemiotics neither subscribes to nor advances the claim that there is nothing in the world but signs.

Likewise, the concept of *code-duality* thus implies neither a reductive pansemiosis nor a naïve anthropomorphism. Having made this clear, let us now confront the question of what, then, *is* meant by "code" in the expression "code duality."

In its everyday meaning, the word "code" refers to the customary use of distinct entities or actions for communicative ends, such as when we speak of a dress-code or about different social milieus having different behavioral codes. In semiotics, the term has had two rather different designations. Under the influence of Information Theory, it was used in the 1960s and 1970s in the sense of: "a context-free set of rules for the encoding, transmission and decoding of information" (Thibault 1998: 125). And as discussed in the section on the Central Dogma, the DNA code has been conceived as a code in this sense.

But in attempting to apply this concept, complications abounded even in these years. For even in the simple cases, where we limit ourselves to considering just the essential "information transfer" from a gene segment of DNA to a functional protein, it has proven to be impossible to speak of a genuinely "context-free" and unbreakable set of rules that in all cases will assure the correct transfer of information. For, and as we shall see in Chapter 5, the cellular – or organismic – context exerts a number of causal consequences at several key steps in this process, often in unpredictable ways (via so-called RNA-editing, for example, or via ambiguities in the "correct" reading of those stop-codon triplets that determines the end point for the addition of amino acids to the growing protein chain). Therefore, when the shorthand term "genetic code" is now used – as it is more often than not – to express the idea that genes are coding "for" certain specific phenotypic traits such as missing eyes in salamanders or schizophrenia in human beings, we are of course much farther from a position where one could talk about a "context-free" code in the precise sense of Information Theory.

Yet the information-theoretical concept of "code" has been, and still is, of great use in engineering the transfer of data (as distinct from "information") in telecommunication systems and underlies much of the efforts to build "intelligent machines." Modern semiotics, however, has abolished the conception of a code as a "simple mechanism for pairing of concept and reference."[8] The focus in recent years has been on understanding the concept of code *as a vehicle for creation of meaningful activity*. Winfried Nöth puts it thus:

> Als Kodes erforschen Semioitiker kulturelle Zeichensysteme der verschiedensten Art, von der Verkehrszeichen bis zur Mode, vom Morsekode über der Kode der Heraldik bis zu den Kodes des Theaters. Häufig ist mit Kode nichts anderes als ein Zeichensystem gemeint (Nöth 2000: 216).

From this point of view, *a code is a semiotic resource* that enables us to create and express certain types of meaning but not others. Seen as a sign system, body language, for example, is very well-suited to express emotional content such as disgust, joy or ennui; it may also, when more artfully used, be narrative – as we know it from mime. But it can only with much effort – if at all – express abstract and logical connections, such as a non-existence or denial, as I shall discuss below.

Digital Codes

The term *digital codes* thus covers a whole set of codes, that are alike in that they are all based on discrete sign tokens as well as an arbitrary (conventional, historical or customary) relation between the sign token and the signified. This property endows digital codes with certain special advantages that are unique to the phenomena we call life and culture. Of these advantages, three in particular must be emphasized (Hoffmeyer 2001):

The first is that *messages expressed in digital codes do not have to obey the limitations of freedom imposed by natural laws*. Possible as well as impossible messages may be expressed in digital codes. Thus, in a novel, Meryl Streep might well have lunch with Socrates; a mega size cod might ravage the streets of Oslo; or the wives of pilots might start giving birth to children having wings. Conversely, it is hard to see how any of these impossible events should be communicated via analog codings such as mime – or at least not without additional use of conventional signs of many kinds, including symbolic cultural gestures and sign language, both of which are fundamentally digital codes.

Too, digital codes are, of course, always based in material processes and can for that reason be destroyed: books may be burned, computers may be smashed, or the freedom of speech might be restricted. But this kind of destructive action does not change the reality of that content which has (at least once) been coded, only the material carrier of the code.

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[8] One exception is the die-hard tradition based on Noam Chomsky's ideas of a *generative grammar* (Chomsky 1965), and in particular Jerry Fodor's *language of thought* (Fodor 1975) or Steven Pinker's *mentalese* (Pinker 1994)– but see Deacon, (1997, 2003) for the biosemiotic rebuttal to these ideas.

And exactly the same is the case for the digitally coded "message content" of genes. This, too, has the freedom to be impossible in the sense that the fertilized egg, by executing such coded instructions, could produce a non-viable individual. And in fact, this happens all the time (among other reasons, because of the processes of genetic crossing-over, whereby the hereditary material is recombined in new – and not always viable – patterns). It is this property of digital codes that explains the surprising evolutionary *creativity* of living systems, the incredible combinatorial capacity and the consequent incessant testing of the eventual limits for possible combinations.

The second advantage of digital codes is their *time independence* and consensual *objectivity*. Digital codes are ideal codes for memory. Only because Plato wrote down the dialogues of Socrates do we know them today. Had the dialogues not been coded in written language, but instead in mimed episodes, they would probably not have survived intact for more than a few generations at most.

The key to digital codes' "objectivity" is that they depend on a shared convention. The Canadian communication theorist Anthony Wilden has pointed to one critical difference between analog and digital codes (among many others) as being that "a digital code is 'outside' the sender and receiver and mediates their relationship; an analog code *is* the relationship which mediates them" (Wilden 1980: 173).

At first look, this definition might seem to fit poorly with the understanding of the genome as a digital code, because the genome is "transferred" through cellular divisions (mitosis or meiosis) and therefore spatio-temporal continuity is maintained between sender (the parent organisms) and receiver (the zygote, or fertilized egg). But the topological detail that chromosomes "travel," so to speak, from generation to generation *inside* a cell shouldn't detract us from seeing that it is exactly the principle of separation between germ cell and body processes (see the discussion on Weismannism, above) that is the deeper reason why Lamarckian inheritance does not work as an evolutionary principle.[9] Thanks to its secluded existence in protected isolation from the metabolic jungle of the cell – and thus due to its very passivity – the DNA code is capable of conserving experiences (in the sense of nucleotide sequences) shaped by past survival outcomes under the then prevailing ecological conditions. Such structures are inherently signs of these past relations, and this is exactly why genes are not functional in themselves, but must be unfolded through the operation of an interpreting agency.

The third advantage of digital codes is that they can be used as *tools for abstraction* – and this is why they are necessary for making meta-messages, messages that deals with the way that other messages should be understood. Gregory Bateson pointed out that such meta-messages may well be communicated in the analog, and he used the example of young monkeys engaged in so-called "play." In these circumstances, when the monkeys snapped at one another while creating an simulation of a combat situation, this snap would actually signify the following "meta-message" about itself: "this is not a bite" (Bateson 1972: 177–193).

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[9] Lamarckian inheritance – by conflating the analog and the digital – loses the fertility of their interplay, which, seen semiotically, is the key to evolution.

The negative message – the "absence" of a bite – cannot be directly communicated in the analog, so instead it is announced as a positive message: the presence of a bite-*signifying* snap. The snap is an indication of something that is *not* there. Bateson also commented that this is probably as far as an analogically coded communication event can go in the direction of the abstract category of "not." For real abstractions to take place, digital codes and their more arbitrary and "detached" conventions are needed.

Thus, while we still do not know the full syntactic structure of the genetic code, we know that the so-called "regulatory genes," for example, function as such meta messages – and the regular occurrence of atavistic reappearances such as the three toed horse indicates that actual deletion is not the only way to get rid of outmoded ontogenetic instructions. Active negation of what still remains may suffice. "Abstraction" in this sense thus furnishes the kind of creative plasticity that, in the absence of which, the evolutionary process might perhaps not have become as rich as it actually is.

Analog Codes

"If you say to a girl 'I love you', she is likely to pay more attention to the accompanying kinesics and paralinguistics than to the words themselves" writes Gregory Bateson and continues: "We humans become very uncomfortable when somebody starts to interpret our postures and gestures by translating them into *words* about *relationship*. We much prefer that our messages on this subject remain analogic, unconscious, and involuntary" (Bateson 1972: 374). Analog codings such as body language go much further back in evolution than spoken language does and are also much more strongly anchored in human emotional constitution. As Wilden says:

> The analog is pregnant with *meaning* whereas the digital domain of *signification* is, relatively speaking, somewhat barren. It is almost impossible to translate the rich semantics of the analog into any digital form for communication to another organism. [[On the other hand:] what the analog gains in semantics it loses in syntactics, and what the digital gains in syntactics, it loses in semantics. Thus, it is because the analog does not posses the syntax necessary to say "No" or to say something involving "not" that one can *refuse* or *reject* in the analog, but one cannot *deny* or *negate* (Wilden 1980: 163).

It must be admitted that the classification of coding strategies into digital and analog derives at least part of its attraction from the exaggerated weight that formerly was ascribed to such purely formal aspects of human communication, as its grammar, its logical structure, its rationality, and so on. And more than perhaps anybody else of his time, Gregory Bateson managed to uncover the paralinguistic and paralogical dimensions of communication in humans as well as in animals.[10]

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[10] More recently, the related fields of Interactional and Conversation Analysis have disclosed that an amazingly high proportion of everyday, moment-to-moment linguistic communication is grounded in such paralinguistic interaction. For a biosemiotic perspective on this work, see Favareau (2002, 2007).

He thereby acquired and advanced an acute understanding of the much overlooked importance of analog codings in natural systems.

As a semiotic category, however, “analog coding” is perhaps not quite satisfactory and I shall use it here primarily as a counter-concept to “digital coding.” Specifically: I will use “analog coding” as a common designation for codings based on some kind of similarity *in the spatio-temporal continuity*, or on internal relations such as part-to-whole, or cause-and-effect. “Digital coding,” in contrast, will be used to designate sign systems where the relations of sign to signified are due to a demarcation principle of purely *conventional* or *habitual* origin.

In Chapter 7, we will have a closer look at endosemiotic analog codings as indexical and iconic sign processes inside the organism. While on the ecosemiotic level, we have already seen how Jacob von Uexküll occupied himself with what I am hear calling analog codes. Uexküll sometimes referred to these as “contrapuntal duets” and noted numerous examples in nature, such as the relation between flies and spiders or between birds and butterflies decorated with spots as icons for eyes. He wrote: “By opening their wings they chase away the small birds that pursue them: These birds automatically fly away at the sight of the eyes of other small predators that may suddenly appear” (Uexküll 1982 [1940], 59). Such spots are an example of analog coding in nature.

Code-duality therefore implies that the *singularis* of the digital code is placed on equal footing with the *pluralis* of analog codings that make up the biosemiosis of life. This positioning of the single digital code as in a sense equal to the totality of analog codings is justified by the unique properties of digital codes that I have discussed above. Moreover, it is precisely the play between these two types of coding that makes evolution possible, as analog and digital coding are two equally necessary forms of referential activity. They appeared, I would argue, as twins in the individuation process that gave rise to life’s internal logic. For as I have written earlier:

> . . . had it not been for digital coding there would have been no stable access to the temporal world – i.e., the unidirectional continuum of pasts and futures – and therefore there could have been no true agency or communication. On the other hand, had it not been for the analog codes there could have been no true inter-action *with* the world, no other-reference, and no preferences. To claim that only the digital twin is semiotic, whereas the analog twin remains in the sphere of classical dynamics, is to block the only possibility for transcending the ‘epistemic cut’ of Howard Pattee. Code-duality and semiosis open up a dimension of our world and its evolution that is left underdetermined by thermodynamics. Organismic “context space” expands at an accelerating rate in proportion to the increase in the semiotic sophistication of species[11]; for, simply put, there are so many more different ways to be smart than there are different ways to be simple (and may this be the reason why the speciation rate among mammals is five times higher than the speciation rate among lower vertebrates) (Hoffmeyer 2001).

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[11] That “context space expands” in our biosphere is in accordance with the analyses given by Stuart Kauffman (2000, 151), in the book *Investigations*, where he shows that the *adjacent possible* – i.e., the set of states that could possibly be realized in the next step of the ongoing material reconfiguration of the biosphere – exhibits exponential growth: “Our biosphere and any biosphere expands the dimensionality of its adjacent possible, on average, as rapidly as it can.”

The concept of code-duality thus illuminates the semiotic core at the heart of the evolutionary process[12] and thereby also the evolving semiotic dynamic that leads life on Earth toward the development of life forms possessing still more sophisticated kinds of semiotic freedom (Hoffmeyer 1992).

Analog and digital codes are tricky concepts, however, because a code that in one context is analog may in another context be digital and *vice versa*. Computer games, for example, are of course operating on digital codings and yet the image presented on the screen is an analog representation. And the converse is often true for hieroglyphs, where the isolated signs may (at least in some cases) be taken as analog codings – whereas the same signs, when interpreted as part of a text, become symbols making up a digital code.[13] The latter case is comparable with that of a painting that, when seen in isolation, might perhaps represent an aspect of the inner state of the painter's mind, but which, when seen on the wall together with other paintings at an exhibition, becomes instead one of a series of discrete signs that as an ensemble make up a higher order message. In the terminology of Bateson, this represents a shift in logical type[14] in the sense that the painting as physical object per se, and the painting as an exhibited artifact, do not belong to the same logical type. One might perhaps even say that it is only in the context of the higher logical type that the picture is indeed a painting.

Paintings, at any rate, would be a very different kind of thing if exhibitions did not exist. The exhibition digitizes the work of the artist and at the same time conserves it as a painting. Through this operation, the painting becomes simultaneously more free and less engaging: It may now be recombined with other objects in collections, in art historical-works, or even in interior design. But this increase in freedom is paid for by a loss of individual meaningfulness – which may be the reason why artists often do not like to sell their paintings.

Examples of such analog-digital shifts are numerous in the biological world[15] and they are presumably always involved in the kind of phenomena we call emergent. Analog codings, for example, may be digitized when brought to bear in the processes of so-called *quorum sensing*. The word "quorum" is taken from legal language, and is used in connection with meetings (typically general assemblies) where there have to be a certain number of attendants for the meeting to

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[12] Code-duality may also be seen as the semiotic core of cultural evolution (Hoffmeyer and Emmeche 1991, 2005 [1991]).

[13] The analog-digital *gestalt shift* may in some cases be observed in individual hieroglyphs that may function both as ideograms and as phonograms. A hieroglyph resembling an eye may, depending on the context, signify either the notions *blind*, *awake*, or *weep* – but it may also signify simply the sound *ir,* because the name for an eye is *irt* (*Den store danske Encyclopædi* vol. 8, p. 438).

[14] Bateson is here referring to Bertrand Russell's type theory (Russell and Whitehead 1910–1913).

[15] Stjernfelt (1992) has observed that the linguistic concept of *categorial perception* perhaps might be extended so as to cover transformations from iconic to symbolic representations quite generally, and this idea concords with the significance I have ascribed here to the analog-digital shift. An alarmone, as will be discussed in connection with endosemiotics in Chapter "The Clever Hans Phenomenon", is yet another example of such a shift.

be legally competent to transact business. When this is the case, a *quorum* is said to apply.

In biology, *quorum sensing* has become the designation for a kind of communicative activity in bacteria where the density of bacteria present is a causal factor. In short, quorum sensing is due to a process where each single bacterium excretes a certain chemical compound such that the concentration of this compound in the medium will reflect the number of bacteria per unit of volume. Quorum sensing occurs if the compound, after having reached a threshold concentration, binds to a regulatory protein in the cell and thereby initiates the transcription of specific genes. An interesting example of quorum sensing occurs in a species of squid, *Euprymna scolopes*, that hunt small fish by night on the coral reefs off the coast of Hawaii. Moonlight causes the squids to cast a shadow that makes them easy catch for predators. As a defense strategy *E. scolopes* has evolved a sophisticated way of emitting light that effectively "hides" its own shadow. "Counter-illumination" is the name given to this kind of camouflage, and it is only made possible by the squid's symbiotic relationship with a luminous bacteria called *Vibrio fishery* that live in the mantel cavity of the squid. Living off of food provided by the digestive system of the squid, the bacteria emit light of the exact same intensity and color as the light reaching the squid from the moon, and this prevents predators from seeing the squid from below (McFall-Ngai and Ruby 1998).

In the morning, the squids bury themselves in the sand and excrete 90–95% of the bacteria, which brings their density well below the threshold level. Apparently the squid is in full control of bacterial growth rate by adjusting the supply of oxygen, and at sunset the population of bacteria reaches the threshold level once again.[16]

Interestingly enough, the same compound – N-acyl-homoserine lacton (with a variable acyl group) – seems to be used as a "signal" in many different manifestations of quorum sensing. In *V. fischeri,* high concentrations of this compound[17] cause an induction of the so-called lux-gene, and thereby a 100–1,000-fold increase in bioluminescence. The concentration of N-acyl-homoserin lacton, quite generally then, operates as an analog coded message about bacterial density – a message that can then be digitized to become a sort of a either/or switch by which, in this case, the squid switches on and off its "false" light.

The opposite situation, where natural digital codes are transformed to analog codes, is known for instance from the nervous system. Here every single neuron makes up an either/or mechanism in the sense that, either the cell delivers a series of action potentials, or it doesn't. In a typical nerve, however, there are large numbers of axons running in parallel, and the accumulated signal will come as a continuously varying signal reflecting the fraction of neurons that at each time emits an action potential. And, as noted by Favareau (2002) the threshold at which a neuron does or does not "fire" its digital (all or nothing) action potential, is mediated throughout

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[16] A thorough treatment of the biosemiotics behind this phenomenon has been given by Luis Bruni (2002, 2003).

[17] The acyl-group in this case is a 3-oxohexanoyl group.

by the analog presence of the ever-changing number and kinds of neurotransmitter molecules that are currently occupying the synaptic gap. Code-duality, then, seems to be as much a property of neuronal transmission as it is of genetic transmission.

The Epistemic Cut

As already mentioned, one of the sources that inspired Emmeche and my work on code-duality was the American biophysicist Howard Pattee's theory that life is characterized by its operating simultaneously in two complementary modes, a "dynamic" mode and a "linguistic" mode. Pattee referred in this connection explicitly to Niels Bohr's application of the principle of complementarity on the phenomenon of life (Pattee 1977). In later papers, Pattee talks about a semiotic mode rather than a linguistic mode, but in principle the idea is the same. In 1997, Pattee discussed his ideas by quoting John von Neumann:

> We must always divide the world into two parts, the one being the observed system, the other the observer .... That this boundary can be pushed arbitrarily deeply into the interior of the body of the actual observer is the content of the principle of the psycho-physical parallelism – but this does not change the fact that in each method of description the boundary must be put somewhere, if the method is not to proceed vacuously (von Neumann 1955).

Pattee then explicate his idea as follows:

> Von Neumann defines a physical system, *S*, whose detailed behavior must follow from the fundamental laws of physics, since these laws describe all possible behaviors. But if the particular behavior of *S* is to be calculated, we must measure the initial conditions of *S* by a measuring device, *M*. Therefore, the essential function of measurement is to generate a computable symbol, usually a number, corresponding to some aspect of the physical system. Now, the measuring device also must certainly obey the laws of physics, even in the process of measurement, so it is possible to correctly describe the measuring device by the laws of physics. One must then think of the system and measuring device together as just a larger physical system $S = (S + M)$. But then to predict anything about *S* we must have a new measuring device to make new measurements of even more initial conditions. Obviously, this way of thinking gets us nowhere except an infinite regress. The point is that the function of measurement cannot be achieved by a fundamental dynamical description of the measuring device, even though such a law-based description may be completely detailed and entirely correct. In other words, we can say correctly that a measuring device exists as nothing but a physical system, but to function *as* a measuring device, it requires an observer's simplified description that is not derivable from the physical description. The observer must in effect choose what aspects of the physical system to ignore and invent those aspects that must be heeded. This selection process is a decision of the observer or organism, and cannot be derived from the laws (Pattee 1997).

A few moments reflection as biologists shows us that not only humans but all living creatures are fundamentally engaged in processes of measuring, and therefore Pattee's epistemic cut follows automatically from the above consideration:

> we must define an *epistemic cut* separating the world from the organism or observer. In other words, wherever it is applied, the concept of semantic information requires the separation of the knower and the known. Semantic information, by definition, is about something (*ibid*).

Pattee is anxious to underline that his epistemic cut is not yet another version of Cartesian dualism, but only a "descriptive dualism." In the perspective of this book it remains, however, a big question, as to whether or not Pattee is right in this – for central to the current investigation is the question: Through what processes exactly could a dynamic functional mode possibly *become* a semiotic functional mode? Pattee is not very specific when it comes to this question.

As did Bohr, and later, von Neumann, Pattee has taken a far and courageous step forward in facing the "limit-paradox" that necessarily arises when one subscribes to an ontology of natural law – i.e. that conception of the world that Pattee formulates quite unambiguously in the first few lines of the quote given above, when he claims that the laws of physics yet *"describe all possible behaviors"* (my italics).

To transfer Bohr's complementarity principle of physics[18] to the biological sphere of life seems not, however, to be particularly helpful in solving the limit paradox. For if complementarity is thought of as being ontological, then we are right back in dualism, which Pattee explicitly condemns. But if complementarity is thought of as being epistemic, then we must consider it as an assertion to the effect that we cannot describe the semiotic dimension of the world in the same language that we use to describe its dynamic aspects. And this, supposedly, is due to the shortcomings of language or of thought as such: The semiotic aspect of life is, so to say, just a glimmer that we cannot think ourselves apart from because we are, in an existential sense, wrapped up in it.

This manner of thinking is, in fact, quite widespread and is related to the position, recommended by the philosopher Daniel Dennett (1987), called "our taking of the intentional stance." Briefly stated, this view holds that we cannot understand the life of other humans (or of animals) without describing those lives as guided by, or woven into, intentionality. This does not mean that these creatures *possess* intentionality as a real property – rather, the thesis states only that we cannot understand these creatures, unless we pretend that they do.

That scientists and philosophers willingly accept such an absurd conception of what human life is about in its deepest or most fundamental content – that, in other words, one accepts that the feelings, experiences, aspirations, sorrows and desires of human beings (to say nothing of the experiential world of other forms of animal life) is all just chimerical hot air, bears witness, in my mind, to how deeply anchored the ontology of natural law is in the self-understanding of the scientific mind. I hope the reader will excuse me for the comparison, but it really does remind me of the ever-more complex (and increasingly less likely) sets of epicycles that Ptolemaic astronomers had to introduce into their explanations of the planetary orbits in order to uphold the belief in the geocentric system. Rather than seeking shelter in such powerless conceptions about what, for all of us without exception, is the deepest

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[18] The complementarity principle of quantum theory refers to effects such as the wave-particle duality, in which different measurements made on a system reveal it to have either particle-like or wave-like properties. In Bohr's understanding, complementarity reflected the weaknesses of human language and not any deeper property of reality (Einstein and Infeld 1938).

and most real content of our lives – i.e., the fact that those such life is being *experienced* – the author shall suggest that it is instead the ingrained belief in the *exclusive* ontology of natural law that is given up.

This does not mean that we disregard the reality of those laws, but that we refrain from reifying them as ultimate explanations and first principles. And it means that we, as Peirce recommended, should understand the natural laws that we see existing as phenomena that are themselves in need of explanation.

Much in the same way that Einstein re-contextualized the "universal" laws of Newton by showing them to be the local products of more general principles, Peirce saw natural laws as the secondary products of a more general tendency in the universe to generate regularities (or "habits" as he often called them). Rather than seeing the universe as characterized by lawfulness, its primary state, according to Peirce, is indeterminacy and chance. And thus the formation of regularities, such as for instance natural laws, must be explained by other means – for natural law thus is a product of evolution, and not its source.

The tendency of nature to generate regularities – or, as it is more commonly described today, to self-organize – may be understood as the very first exposition of the principle that will develop through cosmic evolution to become semiosis, the ability of living systems on planet Earth (and possibly many other places in the universe) to form *interpretants* – or self-maintaining and self-perpetuating habits, if you like.

This change of basic viewpoint will allow us to reach a solution to Pattee's paradox of the epistemic cut, because now we can assume that not only the "symbolic functional modes" (related to DNA function), but *also* the "dynamic functional modes" (related to the functional cytoplasm) are both, in the end, semiotic functional modes. For the difference between the two modes is, at bottom, a difference in the kind of semiotic dynamics involved. Thus, the sign processes characteristic to the dynamic functional mode, i.e. the protein world so to say, are indexical and iconic (i.e., analogly coded) rather than symbolic or digital as are the sign processes connected to DNA function. The analog coded signs correspond to the jumble of topologically organized indexical and iconic sign processes in the cells that are responsible for the interpretation of the digital genetic instructions as well as the execution of them. Or, as we wrote above: "To claim that only the digital twin is semiotic whereas the analog twin remains in the sphere of classical dynamics is to block the only possibility for transcending the semantic cut."

Replicators and Interactors

Pattee's distinction between the dynamic and the symbolic (or semiotic) domains forms a strange and certainly non-intended parallel to Richard Dawkins' distinction between vehicles and replicators, discussed above. As we saw, "gene vehicles" are, in Dawkins' terminology, a designation for organisms and thus for metabolically driven activities including movements and growth, or in short, the dynamic domain. Replicators, on the contrary, are the genes themselves (in whatever way such "genes" may be defined in Dawkins' context) and these, of course, correspond to the symbolic domain in Pattee's view. But there is an enormous difference between the two theories, for the whole point of Dawkins' construction is that replicators are the real *agents* at the scene, whereas the contribution from organisms (vehicles) are just that of passively assisting in the processes of copying and spreading as many replicators as possible. Yet for Pattee, the measuring processes (i.e. the processes whereby organisms are sensing and interpreting their environments) are presupposed for the symbolic domain to make any sense at all, and to imagine the relation between the symbolic and dynamic domains as a master-slave relations makes no sense. But in Dawkins' way of thinking replicators become masters while the organisms/vehicles are obedient slaves whose untiring efforts only serve deliver the much sought-after prize of multiplication to the replicators.

Metaphorically speaking, one might say that where Pattee thinks that the organisms of this world use words in order to get along and to produce more organisms, Dawkins thinks that the words use organisms to produce more words, and that the organisms are just tools for this self-promoting process. Seen from the perspective of both Pattee and biosemiotics, Dawkins commits a logical error in that he treats symbols as if they were things ("replicators") – and, worse yet, not merely "things" but things with purpose, for the very term "replicator" implies a sort of agency – but an agency that one can hardly imagine to be a property of a DNA molecule (Deacon 2002: 122). The gene may be legitimately termed to be "a replicative unit," but it can not, in normal the use of language, be a replicat*or*.[19]

The American philosopher David Hull attempted to clarify this discussion by substituting the term "interactor" for the term "vehicle" (Hull 1980). In Hull's terms, *replicators* are units that make more units like themselves (more or less reliably) and thus conserve and transfer information across generations via the processes of natural selection. *Interactors*, on the contrary, are units that spontaneously interact with their surroundings in ways that may either promote or restrict the spread of replicators. Replicators thus form lines of descendants and have kinship relations with one another. Interactors have causal effects on their environments in the here and now, during only the course of their own lifetimes. In most versions of genetic Darwinism, organisms are *interactors,* whereas genes are *replicators* (Depew and Weber 1995).

For years now, this dualistic terminology has managed to penetrate and, in fact, to dominate debates on evolutionary theory. One may then choose to put special emphasis on the fact that replicators effect interactors by supplying them with information that may provide them with a competitive edge relative to other interactors (as in theories of *gene-selectionism*). Or, one may instead put emphasis on the fact that interactors influence replicators by their decisive role in determining which information winds up being, in fact, transmitted to the next generation (as in *classical selection* theory). The question resolves to whether replicators or interactors

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[19] Dawkins would perhaps reject outright the notion of a symbolic domain as something really existing. But then, how would he propose to solve the von Neumann-Pattee paradox?

should be ascribed causal priority in life's evolution. Seen from the perspective of the present book (cf. Chapter 3), the answer is that we are dealing here with two different kinds of causality, where replicators exert formal causality, while interactors exert efficient causality. Final causality, *sensu Peirce,*[20] makes use of both tools and is, in this context, connected to life's code-dual structure.

In short, the replicator/interactor terminology relies on an inherent reification that serve to restrict discussions to a nearly rachitic[21] understanding of causality. And thus, by re-framing the evolutionary processes as the interdependent interactions between digital and analog codings (wherein the contents coded belong to the historical subject of the lineage, which is both the product of, and the subject for, selection), biosemiotics de-privileges the theme of "the competition motive" that has, almost to the point of obsession, dominated the understanding of evolution by contemporary Darwinians.[22]

As an alternative to the fetishization of "Darwinian competition," the semiotic perspective makes us turn our investigation toward the processes whereby new significative patterns are generated and exchanged. Such processes seem to hold the key to the general evolutionary trend towards the appearance of creatures that increasingly depend for survival on their semiotic sophistication.

Organisms

Amusingly enough, it was Dawkins and his kindred souls who have helped paved the way for a more biosemiotic understanding of life processes. For in the attempt to procure the necessary *lebensraum* for gene-selectionism, they provided a number of sharp arguments to show that positing "the organism" as the basic unit of biology is an irreparably anthropomorphic construction.

For example: In most biological models, as well as in everyday "folk psychology," the prototype "organism" remains essentially a vertebrate, like ourselves. Vertebrates are always well-integrated, coherent organisms with well-defined forms.

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[20] ". . . that mode of bringing facts about according to which a general description of result is made to come about, quite irrespective of any compulsion for it to come about in this or that particular way, although the means may be adapted to the end. The general result may be brought about at one time in one way, and at another time in another way. Final causation does not determine in what particular way it is to be brought about, but only that the result shall have a certain general character" (*CP* 1: 211).

[21] Young readers may not know the disease *rachitis* – or rickets (which, by the way, in Denmark we call "English disease") – that is caused by a deficiency of vitamin D, and which, in the childhood of this author, was still sufficiently common for everybody to know the characteristically hollow-chested look of children having suffered from this disease.

[22] Ironically, this is an obsession that plays right into the hands of precisely those radical social-constructivist theories (e.g., those claims that reality, or at least the scientific model of it, is *nothing but* a social construction set up to perpetuate unequal power relations) that many scientists so despise.

They consist of genetically uniform cells and have well-defined life-cycles, starting with a single cell and ending in reproduction via the transmission of germ cells.

However, by far most organisms of this world are *not* vertebrates – and most of them do not obey the aforementioned criteria very well. Neither plants nor fungi have the kind of individual identity and autonomy that vertebrates have. Their life-cycles do not necessarily start either from, nor as, single cells, and they are not as genetically homogenous as are the vertebrates. Many invertebrate animals also deviate from our conception of how a typical organism lives. Thus, for instance, many insects undergo metamorphic changes that give them totally different body shapes from that of their earlier life-stages – and many corals swim freely around as individual larvae, but end up as colonies where individuality is completely extinct.

The idea that most seriously undermined the classical concept of the organism was probably Dawkins' notion of the "extended phenotype" – for this idea implied a dissolution of the supposed unity between the organism and the genotype. By the term "extended phenotype," Dawkins referred to situations where genes are selected for because of their effect on a *different* organism than the one that is carrying the gene. The phenotypic *effect* of the gene, in such cases, is played out in a foreign organism.[23] The most dramatic examples of this mechanism are probably found in parasites. An example is a species of fungus, *Enthomophtora muscae*, that infects and kills ordinary house flies. In addition to killing the flies, however, the parasite also causes dead females to develop a set of special traits, such as distended abdomens, that acts as sexually attractants to the male flies . . . who are then subsequently infected and killed by the fungal parasite (Moeller 1993, cit. in Sterelny and Griffiths 1999: 72).

Similarly, Stephen Jay Gould has discussed the case of the parasitic barnacles of the crustacean *Rhizocephala*, which completely take over behavioral control in the crabs that they parasitize. These parasites suspend the crab's internal molt cycle (which might otherwise allow the crab to shed the parasite) and successively transform the brood care behaviors of the crabs in such a way that they will start nursing the parasitic eggs instead of their own (Gould 1996: 15–16).

Morever, not only parasitism – but symbiosis, too – may be of a mutualistic kind, as we saw in the case of the bladderwort in Chapter 3. Such interactive mutualism is often so tightly interwoven that it feels more natural to talk about one "joint organism" or a "superorganism" – as in the case of *lichens* (a general term for a mutualistic ensemble of a fungi and algae). Another example is the fungus-growing and -harvesting ants. In this case, the fungi produce sterile fruit that the ants use to feed their larvae. The subterranean fungus gardens of such ants may be 20 m long, and the fungi are nursed with a meticulousness that would awake indignation in the unions of agricultural workers. This particular example of inter-species collaboration must be called an evolutionary success story, for it occurs in more than 200 versions, involving different species of ants and fungi respectively. And in some

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[23] Vehkavaara (2003) has suggested the term *externalized purposes* for this survival strategy.

cases the integration is so complete, that neither the ant nor the fungus could survive without it.

Similarly, the partnership between higher plants and fungi that is found in root modules, *mycorrhiza*, is also of vital importance for both partners. In this case, the fungi extend out, as mycelium, into the soil and thereby provide their plant host with improved access to nutrients and water. In turn, the fungi profit from access to the organic compounds that are produced by the plant. The mycelium can also interconnect different plants – even of different species, writes Alan Rayner:

> By providing communication channels between plants, mycorrhizal mycelia are thought to enable adult plants to "nurse" seedlings through fungal 'umbilical cords', to reduce competition and to enhance efficient usage and distribution of soil nutrients (Rayner 1997: 63).

However, there is also a risk connected to this arrangement:

> On the other hand, they can be piratized, as demonstrated by the yellow bird's nest plant, *Monotropa hypopitys,* which by tapping into mycorrhizal networks is able to divert resources from the trees that participate in these networks (*ibid*).

Another of Rayner's examples is the rot that is found in hollow trees. "Rot" is intuitively conceived as a disease, but in trees it is often just one link in a normal recycling process – i.e., a process whereby resources are redistributed from parts of the tree that no longer take active part in the life processes to those other parts of the tree where active life processes still occur. The growth of trees typically proceeds in a thin layer just inside the bark, and as the tree ages, more and more dead wood is left behind in the middle of the tree. Fungi then degrade the dead wood in the middle, and thereby initiate a hollowing out of the tree (so-called "heart rot") – which then offers habitats for a wide range of different animals. By sending roots into the resulting compost, the tree actively recycles the material derived from its own dead wood.

Hardly anybody has a full overview of all the species that coexist in an old tree but, counting microorganisms, the number may well approach one thousand. Yet this should not surprises us, as the human organism, as is well-known, is itself the domicile for numerous species of microorganisms that do useful or even vital work for us – in the saliva, in the skin, in the intestinal tract, and elsewhere.

Accordingly, the biochemical and physiological interactions necessary to the maintenance of these many symbiotic relations is equally quite comprehensive. In the aforementioned case of quorum sensing, the newly hatched squid early on develops a "ciliated microvillus field that will tend to potentiate the bacterial inoculation" – and that is capable of preventing all bacteria other than *V. fischeri* from colonizing the light organ. Yet as soon as the light organ has been inoculated with *V. fischeri* a 'programmed' massive cell death is released, whereby the ciliated surface coating is again eliminated.

This "program" is released thanks to a short-lived and irreversible signal emitted by the bacteria, writes McFall-Ngai and Ruby (McFall-Ngai and Ruby 1998). In brief: cells in the cavities in the light organ where the bacteria attach themselves respond by undergoing comprehensive cytological alterations, during which some of them swell to four times of their former volume, at the same time as a marked increase in the number of *microvilli* sets in. At this point, the cells start excreting a substrate that is rich enough to assure a very short bacterial generation time (time lapse between divisions) of approximately 30 min. In the course of 10–15 h, the density of bacteria is stabilized at a level that is determined by the host organism's regulation of the oxygen concentration. When the bacteria have reached their maximal density, they stop producing the proteins intended for formation of flagella – which may indicate that they use their flagella for the sole purpose of getting access to the light organ, for after having been so admitted, the flagellas then become an unnecessary burden (though it is not known at this time where the signal that blocks the formation of flagella comes from).

This slightly pedantic description of the mechanisms behind mutuality in the squid *V. fischeri* symbiosis is meant to illustrate how very subtle the integration between symbiotic organisms often is, and has to be. When organisms that are so fundamentally different that they belong to different species (or even to different kingdoms) are going to cooperate, they are forced to overcome a host of obstacles concerning the establishment of unambiguous reciprocal interactions at all levels, from chemistry to social behavior.

The Darwinian calculus of gross reproductive advantages and disadvantage seems strangely poor in this context, because it reduces almost to mystery the minutiae of practical solutions to all the challenges of incompatibility. The naked end result, the "increased fitness" that is supposed to explain the eventual fixation in the gene pool of mutualistic interaction patterns, tends to hide the complex reality of the moment-to-moment lived reality. Or to say it another way: By lumping together the numerous subtle interaction processes into the one single conceptual viewpoint of selection, one has already, in advance, ascribed priority to a retrospective view of things. But since such an end point must always be "unknown" to the agents while the process is actually going on, this perspective implies a systematic distortion of our understanding of what really happens *when* new behavioral patterns appear.

From the biosemiotic perspective, it is rather obvious that the "control" mechanisms overseeing all the numerous reciprocal processes that necessarily have to be in place in order to scaffold an initial mutualism between organisms from different species, need not be digitally and unambiguously coded at localized loci (i.e., on the chromosome – where, not inconsequentially, mutational events might spoil the cooperative interaction without being selected against). Yet outside of biosemiotics, the idea that a non-digitized but relatively stable semiotic scaffolding of these integration mechanisms might establish itself is a strongly underestimated possibility, – if it is considered at all.

The Analog Coding of Epigenisis

Before expounding the biosemiotic view, however, we must first consider a critique of the classical Darwinian focus on the individual that does not, as the just previously described criticisms do, deal with symbiotic relations (either parasitic or mutualistic) – but instead claim that ordinary classical "individuals" should be understood as *conglomerates of competing cell lines* – and that these cell lines, rather than individuals, constitute the units of natural selection.

Yale biologist Leo Buss proposed just this theory in his book entitled *The Evolution of Individuality*, wherein he delivers a frontal attack on the doctrine of Weismannism. In it, Buss writes: "While Weismann's inheritance theories were ultimately proved fictional, their corollary – that the individual is the sole unit of biological organization – was nevertheless incorporated as a tacit assumption in the modern synthetic theory of evolution" (Buss 1987: 3). But, Buss continues, as far back as when the fundaments of the neo-Darwinian synthesis were put down, data that contradicted Weismann's doctrine were already known by embryologists. The problem was that embryologists were strangely absent from the discussions leading up to the modern synthesis – and so it happened that Weismann's theory was canonized as a synthesis, in spite of its being in disagreement with known developmental patterns. For development exhibits significant variation from one taxonomic group to another, and in some cases the Weismannian hypothesis does indeed hold – but in most cases it does not.

Buss, after reviewing the data on all the main taxonomic groups, shows that the most common form for development is so-called *somatic embryogenesis* – where there is no autonomous germ cell line. In somatic embryogenesis, one and the same cell line may participate in somatic functions (as stem cells) and yet throughout ontogenesis, conserve the competence to form germ cells. This mode of development is possessed by all plant- and fungus groups and, with a single exception, also by all protoctists (unicellular eukaryotic species). And even in the animal kingdom, we find somatic embryogenesis dispalyed in no fewer than nine taxonomic groupings (among them cnidarians, bryozoa and even some annelida species (ibid: 21–22)) Thus, the particulars of so-called *preformationistic embryogenesis*, where Weismann's doctrine does obtain, are in no way typical for life forms on our planet.

And once Weismann's theory is removed from center stage, "the vertebrate individual" loses its favored position in biology, as well. With the loss of the individual as the natural centre for the evolutionary process, a new space is then opened for Buss' own alternative perspective:

> The thesis developed here is that the *complex interdependent processes* which we refer to as *development* are reflections of ancient interactions between cell lineages in their quest for increased replication. Those variants which had a synergistic effect and those variants which acted to limit subsequent conflicts are seen today as patterns in metazoan cleavage, gastrulation mosaicism, and epigenesis (Buss 1987: 29).

Buss' book takes us on a fascinating (and essentially semiotic) journey into the webs of cheating, humbug, bluff, and out-maneuvering that – according to his theory – were the means that individual cell lines used in their reciprocal competition to become multiplied as much as possible (Chapter 7 examines some of these processes in more detail). On the embryological process he writes:

> Following a variable period of maternal control on embryonic cell fate, the metazoan embryo becomes organized into one of several discrete bauplans via interactions between

> embryonic cell lineages. The principal epigenetic interactions defining cell fate – those of induction, competence, and cell death – are all interactions in which one cell lineage acts to limit the replication of another, while enhancing its own. The fact that embryos develop by epigenesis is *prima facia* evidence that these very "programs' represent interactions between variant cell lineages arising in the course of the ontogeny of ancestral forms" (Buss 1987: 30).

Buss' heavy emphasis on "the competition motif" as the preferred explanatory tool, is, as the reader should surely know by now, not shared by the author of this book. But in placing *the developmental process* in the centre of his evolutionary thinking, Buss calls attention to an epigenetic perspective that underlines the autonomous significance of a long neglected domain – i.e., the domain that I have in this book called "the analog code." And this domain (or "coding") is, in fact, nothing more nor less than the semiotic loops coupling embryonic cell lines together into a unit that – in spite of all internal competition – presses a shared destiny upon them all.

We can conclude then, that Dawkins, Buss, and many of the others that have challenged the classical conception of the individual organism as the uncontested unit of selection, do indeed have convincing arguments. This, however, does not persuade us to accept that genes or cell lines should then be automatically installed in the role that the individual has surrendered.

On the contrary, it confirms us in seeing evolution in the light of code-duality, for if organisms are not natural units of selection, they are at least natural units of communication. Via the digitally coded messages in their genome, they are literally in a line of "communication" with both their ancestors and with their eventual offspring. And via the multiple analog coded messages of their current bodies, they take part in the local semiosphere and interact with other creatures, whether conspecific or not. "The organism" must then be seen as a nodal point in a semiotic landscape – one that gradually changes through time (evolution) and thereby leaves marks (genetic changes) in the conservative DNA code.

It is to some extent a matter of taste if you would like to think of these remaining marks by calling them "selected." Since in any case, the proper *efficient causality* at issue here lies in the web of analogly coded communication, Dawkins' position would actually presuppose that "formal causality should be seen as *primary to* efficient causality." . . .But this is a discussion that reminds one more than a little of the medieval discussions arguing the sex of angels.

Life Cycles as Units of Evolution

In 1985, the American psychologist Susan Oyama of John Jay College in New York, published an important book in which she recommended that we give up altogether the idea that the developmental process is directed by some special "information" that is "transmitted" by genes (Oyama 1985). The "information" that manifests throughout the life cycle of an individual, Oyama claimed, is rather information that is constructed by and with the developmental process itself. With a pertinent choice of words, she named her book *The Ontogeny of Information*.

Oyama's point – which is closely connected to the one taken in the present book – is that developmental processes depend on "information" from a range of different sources, and that genes are only one of these sources. The conception of a special genetic "program" that unfolds its predetermined logic through embryogenesis is mistaken, because this program – if the program metaphor should be valid at all – is not self-reliant, but only works at all because it is played out in a context that is derived from elsewhere.

And, indeed, there is no reason to believe that an organism could be preprogrammed to solve the multiple challenges it will meet in its lifetime. In this respect, the organism confronts the same horizon of troubles that has finally convinced the would-be creators of "autonomous agents" to change their paradigm from one of rational preprogramming (the old artificial intelligence approach) to one of training and learning (Clark 1997).

For from the very beginning, embryogenesis presupposes that tissues in the growing embryo have the capacity for selecting and responding appropriately to relevant stimuli (which is exactly what an "autonomous" robot to some extent may *learn* to do but cannot be *instructed* to do). The developmental process, in other words, is not an *instructional* process, but a process of self-*calibration*. As such it is, of course, supported by the ever-present availability of necesssary protein resources that the cell at each moment may derive, by activating relevant sections of the genetic library, but basically it remains a process where individuals create themselves in a self-organizing interaction with their environment (the metaphoric here is my own, not Oyama's).

The ordinary expression that "a gene codes *for* this or that trait" therefore tacitly takes for granted that the conditions under which such a trait can be "expressed" are the conditions that are "normal." In cases where such conditions are not normal, however, the trait in question may perhaps not be developed, even though the gene is there. And as Paul Griffiths and Russel Gray have pointed out "normal conditions" is not an unambiguous concept. Genes in an acorn, for instance, are supposed to code "for" the development of an oak tree – but by far, *most* of all acorns do not sprout but are eaten or just rot away on the forest floor. So in this case, what are the "normal conditions" that this gene finds itself in? (Griffiths and Gray 1994, also cf. Ruth Milikan's discussion of functionality in Chapter 3).

This phrase "under normal conditions," then, actually hides a whole lot of interesting things, so that on the one hand we have the genes and on the other hand we have "all the rest." But here is an interesting symmetry. For just as one might say that "a gene codes for a trait *when conditions are normal*," one might equally justifiably say that "each and all other developmental resources code for a trait *when genes are normal*."

Many bird young, for example, must learn the song of their own species by first listening to the song of their parents. To say that "their song program probably is coded for in the genes if things are normal" implies, with the invocation of "normality," the fact that the bird parents do, in fact, sing. But one might as well say, that the song of the young "is coded for in the song of the parents" – presupposing, of course, that the necessary proteins – and thus genes – needed for constructing the relevant anatomical structures in the throat are intact.[24]

This gene-environment symmetry argument is the central component in a complex of ideas that Oyama, Griffiths, Gray and others have developed under the name of *Developmental Systems Theory* (DST) (Oyama et al. 2001). According to DST, species-specific traits are formed with the help of structured sets of developmental resources within self-organizing processes, and there is no need to appoint any "centralized information source." Some of these developmental resources are genetic, while most others – from the cytoplasmic machinery of the fertilized egg to the social structurings that influence human psychological development – are non-genetic.

It may perhaps come as a surprise to some readers that such parity between information sources is suggested at all – for such is the extent to which the rhetoric of modern genetics has managed to make us identify "heredity" and "genes" as two sides of the same coin, such that our eyes have become closed to the obvious. For organisms do, of course, inherit a lot of other things than just their genetic material. Above all, they inherit a suitable milieu or habitat (without which, such genetic material would remain inert).

Mice are not borne at the bottom of the sea, and fish not born on land, to spell it out. Or, to give a more appropriate example: Cuckoo young are, as is well-known, hatched in nests belonging to birds of other species, and it has therefore been believed – following a suggestion by Konrad Lorenz – that the cuckoo, contrary to what is the case in other bird species, did not need to be imprinted on by conspecific adult birds in order to mate with cuckoo partners. It was supposed, in other words, that correct cuckoo behavior was genetically buffered. A recent study, however, has shown that, at least in the cuckoo species *Clamator glandarius*, the converse is true. Adult cuckoos in this species do actually look for nests with newly hatched young – not necessarily their own – and then sit in a nearby tree singing their songs. And this, apparently, is enough for the cuckoo young to take on the cuckoo song – or to be reimprinted with it, in those cases where they had already become imprinted on by the songs of the foster birds (Soler and Soler 1999).

The above serves as a good example of the point that I want to argue, because with regards to it, nobody quarrels with the idea that genetic imprinting is involved. What is noteworthy (and far too often overlooked), however, is that the interdependence between genetic expression and learned behavior is so subtle. The latter

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[24] Molecular genetics has increasingly undermined the simple genotype-phenotype relationship that was so passionately believed in just a few years ago. For it has become increasingly apparent that genomic systems exhibit unexpectedly *integrative* aspects. The lactose-positive phenotype in *E. coli*, for example, presupposes not only that the *lac*-operon proteins are expressed, but also that the genes that code for adenylate cyclase and for the cAMP receptor protein are expressed. "In many cases," writes James A. Shapiro (1999, 25), "it is really impossible to assign a specific organismal phenotype to a particular locus, because its gene product(s) can participate in the execution of multiple cellular or developmental programs."

is not merely an addition to the former, as is often implied. Rather, the individual organism only emerges out of a process of their dynamic interaction, and the full significance of such alternative types of "inheritance" only shows up when one learns to see the intimate interplay between genetic heredity and environmental heredity.

Similarly, Konrad Lorenz' concept of "innate behavior" was heavily criticized as far back as the 1950s by the American psychologist Daniel S. Lehrman, who pointed to many cases that contradicted Lorenz' concept of "instinct." In this regard, we shall consider here the very illustrative case of prenatal "learning by doing" in ducklings, as studied by developmental biologist Gilbert Gottlieb and as discussed in Griffiths and Gray (1994: 279).

Ducklings normally acquire a preference for their mother's species-specific call signal from the very beginning of their lives. Gottlieb discovered, however, that ducklings would not develop this "preference" if they were prevented from themselves vocalizing while still in the egg. Apparently, duckling embryos have to be exposed to their own prenatal call sounds before they can develop a preference for the quite different sounds of their mother's call (Gottlieb 1981). It is important to underline here, as Lehrman did and Gottlieb repeated, "that these sorts of facts do not show that all traits are 'learned.' They show, rather, that reliable developmental outcomes occur because of reliable interactions between the developing organism and its environment" (in Griffiths and Gray 1994: 280).

A consequence of this increased emphasis on the importance of the non-genetic resources in the expression of "genetic traits" is that Weismann's doctrine becomes directly misleading. For not only is the postulated separation between the germ cell line and the somatic cell lines, as we have seen, the exception rather than the rule in the biosphere – but even in those cases where it does apply, it cannot really be said to play the exclusively decisive role ascribed to it by many geneticists.

Rather, it appears that the supposed "dead-end" organisms – i.e. the phenotypes – via their interaction with the environment and with their offspring, yield a rich causal input to the welfare of the next generation. In order to include this richer conception of causality to our understanding of evolution, Griffiths and Gray suggest that neither genes *nor* individuals should be seen as units of evolution, and that such a role should be ascribed rather – if at all – to the whole life cycle:

> the individual, from a developmental systems perspective, is a process – the life cycle. It is a series of developmental events which forms an atomic unit of repetition in a lineage. Each life cycle is initiated by a period in which the functional structures characteristic of the lineage must be reconstructed from relatively simple resources. At this point there must be potential for variations in the developmental resources to restructure the life cycle in a way that is reflected in descendant cycles (Griffiths and Gray 1994: 296).

Within the framework of such a process perspective, the whole replicator/interactor distinction becomes rather misleading, for it is based on the unnatural dichotomization of the developmental process into "genes" and "all the rest." Dawkins, for instance, says that "when we are talking about *development*, it is appropriate to emphasize non-genetic as well as genetic factors. But when we are talking about *units of selection* a different emphasis is called for, an emphasis on the properties of *replicators*" (Dawkins 1982: 98, italics added).

But this so idea only makes sense if one disregards the fact that many of those factors that, in the course of the life-cycle, are responsible for the success of an individual, are replicas of factors that were responsible for the success of the life-cycle of its parents. A DNA segment – to stay within the terminology of Dawkins – is not even itself a "replicator" in the strict sense of "something that is capable of replicating itself." For the replication of DNA-segments cannot take place without the cellular machinery of proteins and membranes that – considered as topologically ordered structures – are in themselves extra-genetic hereditary factors. And a range of other developmental resources are likewise furthermore required for the life-cycle to be realized in a viable way.

Griffiths and Gray therefore conclude that: "If we insist that a replicator have the intrinsic power to replicate itself, there will be only one replicator, the life cycle. But if we allow the status of 'replicator' to anything that is reliably replicated in development, there will be many replicators" (Griffiths and Gray 1994: 300).

Developmental systems theory is largely consistent with a biosemiotic conception of ontogenesis and evolution, and probably the most radical consequence of DST is that the dichotomizing into organism and environment is severely challenged. For in the traditional view, evolution is due to the exposure of individual variants to selective forces caused by an independently existing milieu. But according to DST, such variants (here: life-cycles) are by necessity already deeply integrated into the environment, and the thus conception of differential success is therefore no straight forward matter:

> One variant does better than another, not because of a correspondence between it and some preexisting environmental feature, but because the life cycle that includes interaction with that feature has a greater capacity to replicate itself than the life cycle that lacks that interaction (Griffiths and Gray 1994: 300).

Griffiths and Gray therefore suggest that:

> Life cycles still have fitness values, but these are interpreted not as a measure of a correspondence between the organism and its environment, but as measures of the self-replication power of the system. Fitness is no longer a matter of 'fittednes' to an independent environment. (Griffiths and Gray 1994: 301).

And this conception is not too distant from the concept of *semiotic fitness,* that I suggested in 1997:

> Instead of genetic fitness, evolutionary biology should try to develop a concept of *semiotic fitness*. After all, fitness depends on a relation, something can be "fit" only in a given context. Genes may be fit only under certain environmental conditions, or environments might perhaps be said to be fit in the sense that their self-sustaining dynamic capacity has been adapted to the actual genotype resources offered to them. But if genotypes and envirotypes (Odling-Smee and Patten 1994) reciprocally constitute the context on which fitness should be measured, it seems we should rather talk about the fit in its *relational* entirety, that is as a semiotic capacity. The evolutionarily relevant fitness concept of "semiotic fitness" *should ideally measure the semiotic competence or success of natural systems in managing the genotype-envirotype translation processes*. The optimization of semiotic fitness results in the continuing growth and depth of interpretative patterns accessible to life (Hoffmeyer 1997).

Genes are Indeed Special

Returning to our point of departure: Although Weismann's doctrine certainly is not waterproof in its substantial sense, it did at least illuminate an important aspect of evolution that is still in need of much clarification. This aspect concerns the general role of digital codes in evolution.

Because Weismann and several generations of biologists after him have reified the digital code – first as germ cells, then as chromosomes or genomes, and now, as DNA-segments or replicators – it has been thought that this reified code could carry the weight of exerting efficient causality in the evolutionary process. And by framing this strange efficient causality as that of a "transport process" (where the transported goods was called *information*), the mystification had finally been made complete. The missing substance in the concept of "genetic information transport" has been thoroughly analyzed by Sahotra Sarkar (1996, 1997) who points out that cracking the genetic code was the result of brilliant experimental work and was not, to any significant extent, helped by information-based reasoning,[25] "At the very most," Sarkar says, the concept of a code carrying information "provides a succinct look-up table on the basis of which one can predict the sequence of the polypeptide chain that would be determined by a particular DNA chain provided at least five conditions, discovered since 1966, are fulfilled. Unfortunately, if prediction is the goal, these conditions are quite debilitating" (Sarkar 1996, 1997) For further details see Emmeche (1999).

I claimed in Chapter 2 that the digital code appeared with the first living systems as a mechanism for the description of central constituents of the holistic arrangement in prebiotic systems. This description (in DNA-code) implied a self-reference in the absence of which a living system could not become a "self" (in the sense of a system possessing a stable coupling of self-reference to alter-reference). The role of the digital code is connected, then, to the vertical (temporal) continuation of the self-specifying capacity of life. And in this chapter, we have seen that towards this end, the digital code manifests three important characteristics: temporal stability (memory), rich potential for combinatorics (renewal) and capacity for abstraction (formation of meta-messages).

Digital codes, in our understanding, are therefore something special, and we bear attention to the fact that there may yet hide a potential misunderstanding in the DST conception of complete parity between the genes and other resources of the developmental process. We certainly support the dethronement of genes from their relatively

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[25] I agree with Sarkar (1996) in his demonstration of the inconsistencies inherent in the *information concept* of molecular biology. From this, however, Sarkar draws the conclusion that we had better stick to strictly chemical-biological terminology. Biosemiotics draws the opposite conclusionand introduces an explicitly *semiotic* understanding, seeing *information* as the exchange of signs or sets of signs, i.e., coded messages. A thorough discussion of this understanding is given in Emmeche (1999). Sharov (1992) also has recommended a semiotic understanding of biological information, and Jablonka (2002), as we saw in Chapter "The Logic of Signs", uses a concept of information that is nearly indistinguishable from the Peircean sign concept.

uncontested position as deterministic executants of control within the ontogenetic process. But on the other hand, their role as digitally coded sign systems provide them with a unique status that ought to be recognized. And by seeing life, as suggested here, as being based on the incessant semiotic interactions between code-dual systems – organisms in life-cycles – it is possible to respect the special role that genes do in fact play, without thereby privileging them relative to all other factors that contribute semiotic control within the life-cycles of the biological world.

Decoupled from the dynamics of cellular life, the genome is in one and the same time conservative and promiscuous. From the one side it is protected against changes, and from the other side, it becomes recombined all the time under the formation of new genetic combinations. In the next chapter, we shall have a closer look at such genetic semiotics.

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Chapter 20
Information and Semiosis in Living Systems: A Semiotic Approach

Claus Emmeche (1956–), João Queiroz (1963–), and Charbel El-Hani (1968–)

Introduction and Commentary: Claus Emmeche

> *When I first tried to apply Peirce, I found many different interpretations of his work that were essentially misinterpretations – interpretations having the idea that* 'the mind' *is the name of some kind of mysterious* entity *that somehow imputes meaning upon the sign is a very common, and a very Cartesian misinterpretation of Peirce. Peirce, from what I can tell, would reject this kind of reified, non-processural view of 'mind.' So this makes relevant the whole question of the supposed 'locus' of* meaning*: Is 'meaning' the* kind *of thing that is physically 'located' at a certain place? Is it – as people often say –* in the mind*? Or is it possible that talking about* 'the mind' *is really not the right way to phrase the whole question of* meaning*?*
>
> C. Emmeche (2008: 19–20)

At the Ninth World Congress of the International Association for Semiotic Studies in 2007, molecular biologist Jesper Hoffmeyer recalls the impetus leading to the founding of "biosemiotics" as a research agenda in Denmark by himself and Claus Emmeche in 1985 thusly:

> After the discovery of the genetic code, many of my fellow scientists started talking about a new 'Information Age' that we were supposed to be entering. And yet one of the things that became most clear to me was that, in the discourse of Biology, one had a deeply incoherent notion of 'information' being used all the time, one wherein nobody really knows, *or* attempts to explicitly define, what exactly the term 'information' means. Therefore, as a biologist, it appeared to me that a very deeply informed concept of 'information' would become central to the study of life processes. And, indeed, the *word* 'information' at any rate, did become very central to Biology in those years. But, as I say, the necessary explanatory concepts behind the promiscuous kind of 'placeholder' use of this word were lacking. So, around 1985, Claus Emmeche and I started wondering what exactly *information* means in living systems, and we collaborated together a lot [in this investigation]in the early days of biosemiotics (Favareau et al. 2008: 3)

Twenty-five years have elapsed since the time that Hoffmeyer recounts above – and as the following selection by Claus Emmeche and his colleagues João Queiroz and Charbel Niño El-Hani makes abundantly clear, the notion of "information" is still used both promiscuously and without precise conceptual grounding in the life sciences today. Now, as then, the goal of Emmeche and his colleagues is "not to get rid of" the term *information* in biology "but rather to clarify it by using a proper theoretical framework" (2005: 60).

D. Favareau, *Essential Readings in Biosemiotics*, Biosemiotics 3,
DOI 10.1007/978-1-4020-9650-1_20,

Having helped birth the "semiotics of nature" movement that would later be rechristened "biosemiotics" with Jesper Hoffmeyer at the University of Copenhagen in 1985, Claus Emmeche traces his own interest in biology back to his elementary school days "touring around with a little local club of naturalists, a youth faction of amateur field biologists called 'Natur & Ungdon' [Nature & Youth] and founded by the Danish Nature Conservation Union back in the year of the Russian Revolution" (2009: p.c.). Fourteen years Hoffmeyer's junior, Emmeche recalls first coming across a book by Hoffmeyer during his first summer after high school, just before he was about to begin his undergraduate studies in the Department of Biology at the University of Copenhagen in 1975. "What I found in his *Dansen om Guldkornet* [roughly: "The Idol Worship of (Science's) Gold" (1975)]," recalls Emmeche, "was an intriguing combination of history of biology, political ecology, philosophical anti-reductionist thinking and much more that I had never seen before. . .[and] it provoked my conception of the topic I was going to study" (2002: 47).

Emmeche's undergraduate studies, however, took him down the more traditional route of biological training – "with strong emphasis on the rich details of comparative vertebrate anatomy, botanical morphology, and other hot stuff like the taxonomy of kormophytes" he recounts (*ibid*) – while Hoffmeyer at that time was already known throughout Copenhagen as a public intellectual, author, and founder of a critical leftist journal on science and technology. Recalling the intellectual atmosphere of this period in a contribution to a Hoffmeyer *festschrift* published in 2002, Emmeche comments upon the often under-appreciated fact that a post-1968 West European student culture of "immanent critique" – wherein students (and their more radical professors) sought to deconstruct the ideology and challenge the assumptions of the very fields that they were actively studying – was pervasive in Denmark at this time – and that what would later be called "biosemiotics" also has some of its historical and philosophical roots in this ground (2002: 36–41, 48–50).

By the time that Emmeche finished his Master's Degree in biology in 1984, Hoffmeyer had already re-oriented the emphasis of his research away from the experimental biochemical research he had been doing, and towards the investigation of the then emerging fields of "biotechnology" and "information technology" – fields that the philosophically-inclined Emmeche also had an interest in. In 1985, Emmeche secured a grant to have Hoffmeyer as his Ph.D. supervisor, and together they embarked on the project to formulate a richer notion of *information* for use in biology. The result of this collaboration was their seminal paper on "code-duality" that was written in 1988, and published in two parts three years later (Emmeche and Hoffmeyer 1991; Hoffmeyer and Emmeche 1991).

In this paper, inspired both by cybernetician Gregory Bateson's distinction between the nature of digital and analog codes (Bateson: 1972, 1979), as well as physicist Howard Pattee's parallel distinction between time-independent descriptions and time-dependent dynamics (Pattee: 1969, 1972), Emmeche and Hoffmeyer developed a theory of code-duality wherein life on any biological level is characterized by "the recursive and unending exchange of information between analog and digital coding surfaces" (Hoffmeyer 2008: 80). Critically, and in contradistinction to the often reified and undefined "placeholder" use of the term *information* in biology, Emmeche and Hoffmeyer make clear their very specific, and very different, conception of this term's meaning right at the outset of their paper, whose first words, appearing in carefully chosen bold face header, are: "Biological information is not a substance" (1997: 117). Instead, when Emmeche and Hoffmeyer claim that "life on any biological level is characterized by the recursive and unending exchange of information between analog and digital coding surfaces" they are talking neither about the physical transfer of some mysterious "meaning"-bearing matter-energy packets, much less about the emission and absorption of any form of any (even more unlikely) self-conscious "knowledge" or ideas at the level of the cell. Rather, their "recursive in-form-ation" refers to precisely the functional process phenomenon – found only in living beings – whereby form and substance are mutually modified by their incorporation sign processes.

Hoffmeyer expands upon the implications of his and Emmeche's code-duality framework at some length in Chapter Nineteen of this volume, (to which the interested reader is now directed). However, it is relevant to an even fuller reading of the following selection to consider the introductory paragraphs of the seminal "code-duality" paper here, so as to conceptually ground one's understanding to the developed to that will be in considerably more detail by Emmeche and his colleagues in the selection that follows.

> The biological discipline of *morphology* derives its name from the Greek word 'morph.' According to the etymological dictionary, the Romans probably took over this word from the Greek, but in a distorted way. Thus, in Latin 'morph' became 'form.' From this Latin word arose the verb *informare:* To bring something into form. And this again is the root of the now fashionable word *information*. In spite of this likely etymological relationship between *morphology* and *information,* however, the two areas occupy nearly antagonistic positions in modern biology: While the study of the anatomical forms of organisms (morphology), is now a rather outmoded discipline, the study of 'biological information' (in DNA or RNA) is one of the most flowering specialties of present biology. Clearly, in the 20th century, the term 'information' has been substituted for the term 'form' as the preferred key to unlocking the fundamental problems of biology. It should be realized, however, that the old dilemma of *form* and *substance* is not at all explained away through the introduction of this new concept *information*. The dilemma merely assumes a new disguise.
>
> Reading contemporary texts on biology – at whatever level it may be – one cannot escape feeling, that the very notion of biological information serves to circumvent diffculties which are in fact not solved. Thus, we are told, for instance, that in the fertilized egg of any animal is carried 'a programme' specifying how this particular animal should be formed. Although nobody claims detailed knowledge as to how this programme actually works, it is understood that its creation is no serious mystery. Natural selection acting on the endless succession of minor changes in the DNA-sequence (i.e. mutations) will do. The details remain to be worked out, of course, but the main lines are firmly established. Essentially this explanation amounts to a claim, that the actual *forms* of the organisms in this world can be explained through the *functionality* of the genetic 'programmes' carried in the DNA of these organisms. At first sight this explanation may look sound enough. But the problem circumvented through this kind of reasoning is the following: *What is the relation between DNA and the 'programme'? How does this scheme take into account the eventual logic of the programme itself?* And, above all, *who is the subject to whom this programme makes sense?*
>
> Thus, the metaphor of a programme or of information serves to shift the attention from the actual life-forms to the more invisible and badly understood level of latent life-forms which, one assumes, is somehow 'coded' in the DNA of the fertilized egg. And here the whole dilemma of form and substance suddenly disppears. DNA (a substance) and programme

> (information/or potential form) is treated as one and the same thing. The evolutionary flexibility of DNA is seen as the basis for the evolutionary flexibility of the genetic programme. This identification of *substance* and *form* at the lowest level explains the otherwise rather astonishing easiness by which neo-Darwinism derives the form of biological structures from their function. But biological information is not identical to genes or to DNA (any more than the words on this page are identical to the printers ink visible to the eye of the reader). Information, whether biological or cultural, is *not* a part of the world of substance. It nevertheless depends on that world, since it has to do with the pattern of substance, the way substance is organized or formed.

> We suspect that the confusion of *form* and *substance* brought about through this rather ill-considered use of the concept *information* lies at the root of fundamental problems of present biology. And it is the aim of this paper to show, that if the concept of information is not used to conceal the distinction between *form* and *substance*, it might be possible to change the central perspective of biology in a fruitful way. The dynamics of biological information belongs to another level of analysis than the dynamics of DNA molecules. Biological information is expressed through *signs* and should be studied as such, i.e. as a special case of semiotics, which we shall term the *semiotics of nature* (Hoffmeyer and Emmeche 1991: 117–119).

Since the writing of this paper in 1988, Claus Emmeche and Jesper Hoffmeyer have, both individually and collectively, developed these ideas considerably. Subsequent to the association that they would make with Thomas A. Sebeok and his colleagues a few years later, and with the formation of a Danish Society for the Semiotics of Nature that brought together such kindred local scholars as Frederik Stjernfelt, Mogens Kilstrup, Søren Brier and Peder Voetmann Christiansen, both Hoffmeyer and Emmeche saw the need for incorporating the sign logic of Charles Sanders Peirce more deeply and more extensively into their investigations of the roles that sign processes play in life processes.

Emmeche, in particular – after completing his Ph.D. with Hoffmeyer and going on to become an associate professor and the Director of the Center for the Philosophy of Nature and Science Studies at the University of Copenhagen's Niels Bohr Institute – augmented his later investigations into the "semiotics of nature" (now called "biosemiotics") with Peircean-influenced investigations into Artificial Intelligence, neural networking, self-organizing complex-adaptive systems and Artificial Life (Emmeche 1992, 1992a, 1994, 1997, 2000, 2003). Having also an intense interest in the philosophy of science, Emmeche made the acquaintance of Brazilian philosopher of biology Charbel Niño El-Hani (1968–) at a meeting of the International Society for the History, Philosophy and Social Studies of Biology in 1997. El-Hani and Emmeche were both extremely interested in the notions of "emergence" and "downward causation" that were coming out of systems theory at that time, and together discussed the possibility of testing the applicability of such notions in biology. In 1999, they authored the first of several papers together on this topic, and eventually began collaborating with the Peirce scholar and cognitive scientist João Queiroz (1963–), who joined El-Hani as a professor of Semiotics and Cognitive Science in the Graduate Studies Program in History, Philosophy and Biology Teaching at the Federal University of Bahia not long after.

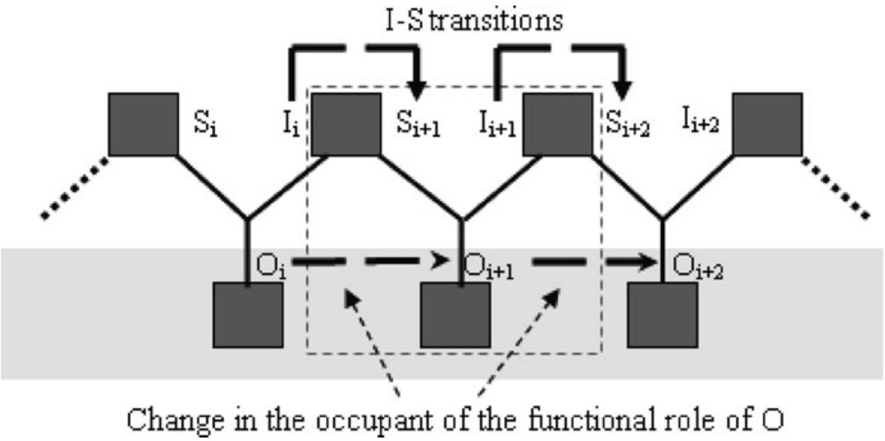

Fig. 20.1 A schematic depiction of Peircean triadic sign action. The triadic relation forms a chain of triads. The grey area at the bottom of the figure shows that all signs in the chain of triads ultimately refer back to the same one dynamical object through a series of increasingly sophisticted 'immediate (last)' sign objects. The hooked arrows on top show the ever-mediating (last) interpretant to (next) sign vehicle transitions that produce these ever-more precisely contextualized sign interpretations. [Figure from El-Hani, Argyris and Queiroz 2007, reprinted with permission the authors]

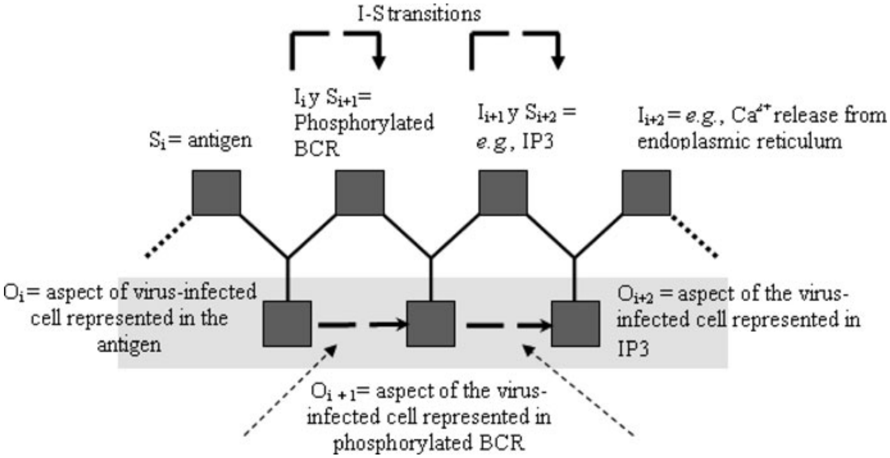

Fig. 20.2 The Peircean triadic sign action of immunological response. A model of one of the signaling pathways triggered by activated B-cell antigen receptor (BCR) as a chain of triads. Notice the interpretant-sign above transition and the changes in the occupants of the functional role of object below, corresponding to the Fig. 20.1's schematic of the sign. In both cases, veridical yet generative *referentiality* in a signaling pathway is modeled in terms of these changes of occupants, which show how the reference to the same external entity or process is maintained throughout the signaling process. [Figure permissions as above]

Emmeche, El-Hani and Queiroz have continued to collaborate on the project of investigating life processes from a complex-adaptive systems approach that incorporates Peircean sign-logic for the explication of such biological phenomena as immunological response, genetic expression and signal transduction (2005, 2006, 2007, 2008). In 2009, El-Hani, Queiroz and Emmeche published a full-length monograph of their work, entitled *Genes, Information, and Semiosis*. In it, they reveal the fruitfulness of applying Peirce's sign-logic for the explication and understanding of the complex, multi-leveled processes of sign activity by which a system of internal relations (i.e., an organism) both maintains itself as a system distinct from – and yet simultaneously maintains veridical relations with – the larger set of external relations from where it emerged and where it now has its (semi-autonomous) being.

The Figs. 20.1 and 20.2, from a 2007 paper with systems scientist Arnellos Argyris (1974–), clearly illustrate the effectiveness of the strategy taken by Emmeche and colleagues in *Genes, Information, and Semiosis*, and its improvement over the naïve (i.e., either mechanical or cognitive-mystical) notions of *information* decried in the original "code-duality" paper of 1991, as well as building upon that paper's nascent discussions regarding the unique biological relations of mutually adaptive *substance* and *form*. Accordingly, in the following selection, Emmeche and colleagues discuss the contemporary role of the *information* concept in the sciences, and provide a more in-depth understanding of the unique explanatory benefits afforded by the Peircean approach.

Information and Semiosis in Living Systems: A Semiotic Approach (2005)

Abstract During the 1950s and 1960s, genetics and cell and molecular biology have been swamped by terms borrowed from information theory. This "information talk" still pervades these fields, including widely used terms such as "genetic code", "messenger RNA", "transcription", "translation", "transduction", "genetic information", "chemical signals", "cell signaling" etc. As the concept of information and its plethora of associated notions were introduced in biology, several problems emerged, with which the tradition of biology was unprepared to cope. Instead of deepening the discussion about "information talk", the trend in the biological sciences was one of treating "information" as merely sequence information in DNA or proteins. Today, a number of researchers consider information talk as inadequate and "just metaphorical", expressing a skepticism about the use of the term "information" and its derivatives in biology as a natural science. We disagree with this position, claiming instead that the notion of information and other related ideas grasp some fundamental features of biological systems and processes that might be otherwise neglected. Our problem is not to get rid of information talk, but rather to clarify it by using a proper theoretical framework. We intend to show that the use of semiotic concepts and theories to interpret information talk can contribute to the construction of a precise and coherent account of information in biology. For this purpose, we introduce here a model of information as semiosis, grounded on Peircean semiotics. Peirce's formal science of signs provides an analytic framework in which information can be modeled as a pragmatic triadic dependent process that irreducibly connects signs, objects, and interpretants (effects on interpreters). According to the model developed in this paper, information is treated as semiosis, i.e., the communication of a form or habit from an object to an interpretant through a sign, so as to constrain (in general) the interpretant as a sign or (in biological systems) the interpreter's behavior. We employ this treatment of information for building an account of genes as signs and genetic information as semiosis.

Introduction

"Information" is a concept which is very important but problematic in biology (see Oyama 2000, Stuart 1985, Sarkar 1996, Griffiths 2001, Jablonka 2002). The concept of information in biology has been recently a topic of substantial discussion (See, e.g., Maynard 2000, Godfrey-Smith 2000, Sarkar 2000, Sterelny 2000, Wynnie 2000, Jablonka 2002, Adami 2004). Furthermore, the evolution of new kinds of information and information interpretation systems in living beings has received a great deal of attention recently (See, e.g., Jablonka 1994, Jablonka and Szathmáry 1995, Maynard and Szathmáry 1995, 1999, Jablonka and Avital 1998). It is even the case that the evolution of different ways of storing, transmitting, and interpreting "information" can be treated as a major theme in the history of life (Maynard and Szathmáry 1995, 1999, Jablonka 2002).

As Griffiths (2001) wrote recently, “genetic information” is a metaphor in search of a theory. We think the same can be said, in general terms, of the current use of the term “information” and its derivatives in biology. After all, a number of researchers consider all information-talk as inadequate, taking a skeptical view towards the very use of the term “information” and its derivatives in biology as a natural science (e.g., Stuart 1985, Sarkar 1996). Among the reasons for this skepticism, is the fact that the use of that term in biology is not as precise as in the mathematical theory of communication. Second, although the standard account of genetic information refers to an alleged semantic property of genes, it is not clear if and how any genuinely intrinsic semantics is involved.

One possibility for building a theory of information in biology is to rely on the mathematical theory of communication. The mathematical theory of communication is a branch of mathematics that arose out of communication theory. As Shannon and Weaver defined it, “[t]he fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point” (1949: 31). According to Adams (2003: 472), “at the foundation of information theory is the development of methods to measure the amount of information generated by an event or events, and mathematical treatments of the transmission characteristics of communication channels”. It relies on the theory of probability to model information sources, flow, and communication channels. The amount of information is measured in terms of the *unexpectedness* of the sequence of signals, written $H=\Sigma\, p_i \log(1/p_i)$, where p is the probability of the ith form of signal.

This theory allows one to define the amount of information as the measure of the probability of selection of a particular message among the set of all possible messages. The probabilistic measure of information provided by this theory is non-semantic, indifferent to meaning (Shannon and Weaver 1949: 31, Cover and Thomas 1999, Jablonka 2002). Despite the fact that the meaning-free concept of information theory can be invaluable in biological research for several purposes (Adami 2004), controversy continues about a non-semantic understanding of information in biology and whether it is sufficient for a theoretical understanding of information in biology. Jablonka (2002), for instance, argues that this concept is not sufficient by pointing out that, for instance, a DNA sequence encoding a functional enzyme and a same-length sequence coding for a completely non-functional enzyme would contain, according to the above-mentioned measure, the same amount of information. It is obvious, however, that these two messages don’t mean the same thing to the cell. This indicates the necessity of a definition of information in biology which includes a semantic and a pragmatic dimension.

We think that a semantic and pragmatic notion of information and its derivatives grasp some fundamental features of biological systems and processes that might be otherwise neglected. In particular, the concepts of “code”, “information”, “signals”, “message”, “signaling”, “transduction”, and so on must be regarded as necessary for an understanding of the organization of relations in living beings in order to make clear that what happens in such beings is much more than simple chemistry (for details, see Emmeche and Hoffmeyer 1991, Emmeche 1991, El-Hani et al.

forthcoming). For instance, understanding control and regulation in cellular systems without understand cell signaling is not possible. Bray argues that as "about 50% of the genome of a multicellular organism may code for proteins involved in cell signaling, – organisms can be viewed as complex information-processing systems, where molecular analysis alone may not be sufficient" (cited by Williams 1997: 476–477). Ideker and colleagues (2001: 343) consider that one of the consequences of the Human Genome Project has been a strengthening of the view that "biology is an informational science", and even argue that biological research needs cross-disciplinary scientists which should be educated through teaching of biology as an informational science (p. 365).

The task of building a theory of information in biology becomes more and more important as our knowledge about the structural and functional complexity of living beings increase. In our view, the use of semiotic concepts and theories to interpret information talk can significantly contribute to a precise and coherent formulation of the notion of information in biology. Our aim here is to introduce a model of information as semiosis, grounded on Peircean semiotics. In the next section, we will examine the interrelationships between the concepts of signs, semiosis, and information in Peirce's formal science of signs.

Information and Semiosis in Peirce's Science of Signs

Peirce's conception of Semiotics as the "formal science of signs" has had a deep impact in philosophy, psychology, theoretical biology, and cognitive sciences (see Queiroz and Merrell 2005, Freadman 2004, Fetzer 2001, Houser 1997, Deacon 1997, Hoffmeyer 1996, Tiercelin 1995, Freeman 1983, Brunning 1997).[1] Peirce defined semiosis (meaning process) as an irreducible triadic relation between sign-object-interpretant (S-O-I) (EP 2.171, CP 2.274). That is, according to Peirce, any description of semiosis involves a relation constituted by three irreducibly connected terms, which are its minimal constitutive elements (MS 318: 81; CP 2.242):

> "My definition of a sign is: A Sign is a Cognizable that, on the one hand, is so determined (i.e., specialized, *bestimmt*) by something *other than itself*, called its Object, while, on the other hand, it so determines some actual or potential Mind, the determination whereof I term the Interpretant created by the Sign, that that Interpreting Mind is therein determined mediately by the Object" (CP 8.177. Emphasis in the original).

Peirce conceives a "Sign" or "Representamen" as a "First" which stands *in such a genuine triadic relation* to a "Second", called its "Object", so as to be capable of "determining a Third", called its "Interpretant", to assume the same triadic relation to its Object in which it stands itself to the same Object (CP 2.274. See also CP 2.303, 2.242, 2.92, 1.541). The term "Sign" was used by Peirce to designate the

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[1] Readers wishing to learn more about Peirce's philosophy and logic of semiotic should consult Murphey 1993, Nöth 1995, Parker 1998, and Peirce 1931–1935, 1967, 1976, 1998, and 1982–2000, as detailed in our Reference List.

irreducible triadic relation between S, O and I, as well as to refer to the first term of the triad (sometimes "Representamen"). Some commentators propose, then, that we should distinguish between "Sign in a broad sense" and "Sign in strict sense" (e.g, Johansen 1993: 62). We will systematically use the term "Sign" in this paper to refer to the first term of the triad, and "semiosis", to refer to the whole triad. The triadic relation between S, O and I is regarded by Peirce as *irreducible*, in the sense that it is not decomposable into any simpler relation:

> . . . by 'semiosis' I mean – an action, or influence, which is, or involves, a cooperation of three subjects, such as a sign, its object, and its interpretant, this tri-relative influence not being in any way resolvable into actions between pairs (CP 5.484).

Semiosis entails the instantiation of chains of triads. As Savan (1986: 134) argues, an interpretant is both the third term of a given triadic relation and the first term (sign) of a subsequent triadic relation. This is the reason why semiosis cannot be defined as an isolated triad; it necessarily involves chains of triads (see Merrell 1995) (see Fig. 20.3).

Indeed, one of the most remarkable characteristics of Peirce's theory of signs is its dynamical nature. According to Merrell (1995: 78), "Peirce's emphasis rests not on content, essence, or substance, but, more properly, on dynamic relations. Events, not things, are highlighted." The complex (S-O-I) is the focal-factor of a dynamical process (Hausman 1993: 72). As a process thinker, it was quite natural that Peirce conceived semiosis as basically a process in which triads are systematically linked to one another so as to form chains. Throughout this paper, it is also important to avoid losing from sight the distinction between the *interpreter*, which is the system which interprets the sign, and the *interpretant*. The interpreter is described by Peirce as a "Quasi-mind" (CP 4.536), a description which demands, for its proper interpretation, a clear recognition of Peirce's broad concept of "mind" (Ransdell 1977, Santaella-Braga 1994). It is far from being the case that only conscious beings can be interpreters in a Peircean framework. Rather, a transcription machinery synthesizing RNA from a string of DNA or a membrane receptor recognizing a given hormone, or an ant recognizing a leaf among several other objects in a garden (and so on) can be regarded as interpreters in such a framework. A basic idea in a semiotic understanding of living systems is that these systems are interpreters of signs, i.e., that they are constantly responding to selected signs in their surroundings. In

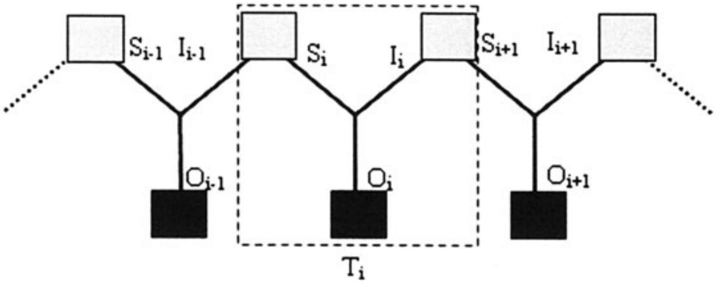

Fig. 20.3 The triadic relation S-O-I forming a chain of triads

short, the interpreter does not have to be a conscious being, not even an organism, as it may be some part or subsystem within an organism or a humanly-designed product.[2]

We also need to consider here Peirce's distinctions regarding the nature of objects and interpretants.[3] He distinguishes between the immediate and the dynamical objects of a sign as follows:

> We must distinguish between the Immediate Object – i.e., the Object as represented in the sign – and – the Dynamical Object, which, from the nature of things, the Sign *cannot* express, which it can only *indicate* and leave the interpreter to find out by *collateral experience* (CP 8.314. Emphasis in the original).

Or else:

> . . . we have to distinguish the Immediate Object, which is the Object as the Sign itself represents it, and whose Being is thus dependent upon the Representation of it in the Sign, from the Dynamical Object, which is the Reality which by some means contrives to determine the Sign to its Representation (CP 4.536).

We should also take into account his distinction between the following two kinds of interpretants:[4]

> The *Immediate Interpretant* is the immediate pertinent possible effect in its unanalyzed primitive entirety. [. . .]. The *Dynamical Interpretant* is the actual effect produced upon a given interpreter on a given occasion in a given stage of his consideration of the Sign (MS 339d: 546–547. Emphasis in the original).

Let us consider, first, Peirce's distinction between the immediate and the dynamic objects of a sign. The immediate object of a sign is the object as it is immediately given to the sign, the dynamical object in its semiotically available form. The dynamical object is something which the sign can only indicate, something that the interpreter should find out by collateral experience (EP 2.498; CP 8.178). In turn, Peirce defines the dynamical interpretant as the actual effect of a sign, while the immediate interpretant is the "range of interpretability" of a sign – the range of possible effects that a sign is able to produce (see Johansen 1993: 166–167). The dynamical interpretant is the instantiation of one of the possible effects established in the immediate interpretant. As the effect of the sign upon the interpreter (or upon some interpreting system), the dynamical interpretant can be treated as

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[2] When a part or subsystem of a system is the interpreter, its actions as an interpreter will be typically subordinated, i.e., regulated by the system as a whole (that we will call, in this case, a "global" interpreter). We can call, as Jablonka (2002), the subordinated interpreters "interpretative systems" within a global interpreter. It can happen that a system loses its control over one or more of its included interpreters. In this case, dysfunctional states may result from the interpretation of signs in that system. These are misinterpretation events. By "misinterpretation", we mean the interpretation of a sign that does not lead to a successful coping with its circumstances, i.e., that does not contribute to the maintenanceof the dynamic stability of a system in a given context.

[3] For a review of these topics, see Savan (1987), Liszka (1990), Short (1996).

[4] In the context of our analysis, we will not employ the concept of Final Interpretant. It will not play an important role in our current arguments, and, thus, we think we can leave it to subsequent works.

being essentially equal to the significance of the sign when seen in a dynamic and process-oriented perspective.

The notions of "meaning", "information", "semiosis" intersect and overlap in different ways (see Johansen 1993). Peirce (see Fitzgerald 1966: 84, Bergman 2000) *defined* meaning as connected to the triadic relation as a whole (EP 2:429), as well as to different correlates of a triad – e.g., object (MS 11, EP 2:274), interpretant (EP 2:496, EP 2:499; CP 4:536). For Debrock (1996), Peirce defined "information" at least ordinarily (CP 2.418), metaphysically (CP 2.418), as a connection between form and matter, and logically (W 1.276), as the product of extension and intension of a concept. Peirce described the function of a sign as that of "conveying" a form from an object to an interpretant (EP 2:391):

> . . . a Sign may be defined as a Medium for the communication of a Form. –. As a medium, the Sign is essentially in a triadic relation, to its Object which determines it, and to its Interpretant which it determines. –. That which is communicated from the Object through the Sign to the Interpretant is a Form; that is to say, it is nothing like an existent, but is a power, is the fact that something would happen under certain conditions (EP2, p. 544, n.22).

Accordingly, in the biosemiotic approach to the notion of information we are developing, significantly inspired by Peirce, *information* is conceived as the communication of a *form* from O to I through S (Fig. 20.4). The communication of a form amounts to the transference of a *habit* embodied in the object to the interpretant, so as to constrain (in general) the interpretant as a sign or (in biological systems) the interpreter's behavior

Or, to put it in more detailed terms, the production of an effect of the sign on the interpreter results from the communication of the form of the object (as a regularity), via sign, to the interpretant. The interpretant then becomes itself a sign which refers to the object in the same manner in which the original sign refers to it (i.e., there is an invariance in the reconstruction of the form of the object by the interpreter).[5]

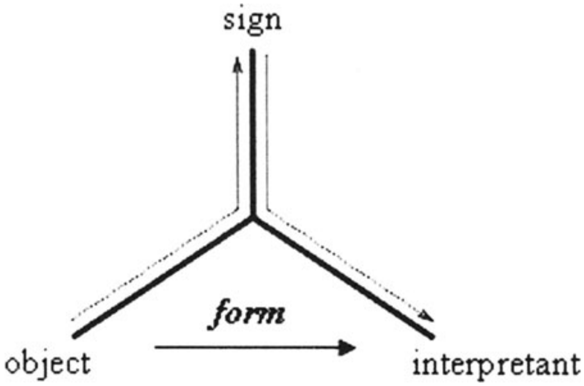

Fig. 20.4 Semiosis as the communication of a form from the object to the interpretant through the mediation of the sign

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[5] It should be clear at this point that by "communication" we mean more than mere transmission of a form.

According to this approach, “information” can be strongly associated to the concepts of “meaning” and “semiosis”. Peirce spoke of signs as “conveyers”, as a “medium” (MS 793), as “embodying meaning”.

If we consider that Peirce defined a sign both as “a Medium for the communication of a Form” and as “a triadic relation, to its Object which determines it, and to its Interpretant which it determines”, we can say that semiosis is a triadic process of communication of a *form* from the object to the interpretant by the sign mediation. Therefore, in this framework, we can say that semiosis is information, if we define this latter concept as above.

But what is a Form? Form is defined by Peirce as having the “being of predicate” (EP 2.544) and it is also pragmatically formulated as a “conditional proposition” stating that certain things would happen under specific circumstances (EP 2.388). For Peirce, it is nothing like a “thing” (De Tienne 2003), but something that is embodied in the object (EP 2.544, n. 22) as a habit, a “rule of action” (CP 5.397, CP 2.643), a “disposition” (CP 5.495, CP 2.170), a “real potential” (EP 2.388) or, simply, a “permanence of some relation” (CP 1.415). We can say that Peirce follows a *via media* in which ‘form’ has both the character of firstness and thirdness. This is in accordance with Bergman’s (2000: 236) proposal of communicated *form* as a *First* of a *Third*. Form can also be defined as *potentiality* (“real potential”, EP 2.388). If we consider this definition, we will also come to the conclusion that form can show the nature of both firstness and thirdness. Consider that potentiality is not the same as mere *possibility*. For the sake of our arguments, consider Peirce’s treatment of Quality as a “mere abstract potentiality” (CP 1.422). Quality has the nature of firstness, being essentially indeterminate and vague. But we can also talk about a generality of Quality. In this case, we are beyond the domain of pure firstness, as generality refers to some law-like tendency, and thus to the nature of thirdness. Peirce works in this case with a merging of firstness and thirdness. As an abstract potentiality, Quality is closer to a blend of firstness and thirdness than to pure firstness. Such a treatment seems to be compatible with Peirce’s categorical scheme, since, as Potter (1997: 94) stresses, “the categoreal structure which Peirce uses is [. . .] highly subtle and complex, admitting of various combinations”.

An understanding of information as a communication of a form or habit embodied in the object to the interpretant through the sign, which brings about a constrained set of effects on the interpreter, can be fruitfully connected to Rosenthal’s (1997) pragmatic approach to meaning, but with some qualification. Rosenthal argues that meaning is an emergent relational pattern of behavior. Information, when conceived as the communication of a form from O to I through the mediation of S, can be seen as a process working as a constraining factor of possible patterns of interpretative behaviors or processes. As meaning is also defined by Peirce as something communicated in semiosis (NEM 4:309), we will opt here for explaining meaning as being associated with the interpretant, which, after all, embodies the reconstructed form of the object.

Peirce (CP 8.177) writes that a sign determines an interpretant in some “actual” or “potential” Mind (in other passages, a “quasi-mind”. See CP 4.536). We take this suggestion to introduce in our analysis a differentiation between “potential” and "effective" semiosis. Potential semiosis is defined as a triadically-structured process which is not taking place, which is only in potency. Effective semiosis, in turn, is a sign in effective action, i.e., a sign which, by being actualized, has an actual effect on the interpreter.

Following the distinction between potential and effective semiosis, we can define potential information as a process of communicating a form which could be realized in a given moment, while effective information is the communication of a form from an object to an interpretant through the sign, i.e., a *sign in effective action*. The notion of information as form communicated from O to I through the mediation of S allows us to conceive it in a processual way, as a constraining factor of possible patterns of interpretative behavior. When applying this general semiotic approach to biological systems, information will most often be an *interpreter-dependent objective process*. It cannot be dissociated from the notion of a situated (and actively distributed) communicational agent (potential or effective). It is interpreter-dependent in the sense that information *triadically* connects representation (sign), object, and an effect (interpretant) on the interpreter (which can be an organism or a part of an organism). In turn, the habit or form which is communicated in information is embodied in the object, treated in the Peircean framework as (dynamically) the primary constraining factor of interpretative behavior.[6] Thus, the form – as a regularity in the object – acts as constraint on the interpreter's behavior, but the interpreter always reconstructs the form of the object when interpreting a sign. Nevertheless, the interpreter does so in such a manner that an invariance is retained, which makes it possible, in fact, the very act of interpretation.

In sum, according to our interpretation of Peirce's remarks quoted above, information has a processual nature: information is the process of communicating a form from the object to the interpretant through the sign. A framework for thinking about information as a process can be built in Peircean terms by employing the following definitions:

[Information = semiosis] A triadic-dependent process through which a form embodied in the object in a regular way is communicated to an interpretant through the mediation of a sign. [Potential information = potential semiosis] A process of communicating a form from an object to an interpretant through the mediation of a sign that could take place in a given moment, changing the state of the interpreter. [Effective information = effective semiosis] The process by which a sign effectively exerts an effect (interpretant) on some system (an interpreter) by making the interpretant stands in a similar relation to something else (the object of the sign) as that to which the sign stands, thus mediating the relation between object and interpretant. The sign effectively communicates, thus, a form from the object to the interpretant, changing the state of the interpreter.

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[6] The irreducibility of the triadic relation S-O-I is a logical property. Therefore, while it makes no sense to sort out a primary constraining factor in such a logical relation, dynamically it makes sense to sort out the dynamical object as the primary constraining factor of semiosis (for a detailed discussion about this issue, see Short 1998: 31).

To formulate the above definitions in a sufficiently clear way, we should define what we mean by "process". We follow here Rescher in his definition of a process as "... a coordinated group of changes in the complexion of reality, an organized family of occurrences that are systematically linked to one another either causally or functionally" (Rescher 1996: 38). These definitions certainly raise several questions and face a number of difficulties when they are seen against the background of other accounts of information. We shall leave to a subsequent paper, however, a discussion about how they relate to and result in controversies concerning a number of ideas about what is information expressed by different authors.

A Biological Example: A Semiotic Analysis of the Genetic Information System

As we argued above, the concept of information has been playing an important role in the biological sciences since the mid-20th century, but it remains a problematical notion, to which biologists have ascribed a metaphorical role. Understandably, it is a controversial issue whether the concept of information and its derivatives should be maintained or eliminated from biology. We assume that they should be kept in the biological conceptual framework, but a semantic/pragmatic theory of information in biology should be built, in order to ascribe precise meanings to those concepts and to articulate them in proper explanations of sign processes in biological systems. As a way of contributing to this endeavor, we have been using semiotic concepts and theories to build an account of genes as signs and genetic information as semiosis grounded on Peircean semiotics (El-Hani et al. forthcoming). As an example of our application of the conceptual tools introduced in the previous section, we will present here part of the results we obtained so far.[7]

When applying Peirce's semiotics to understand the nature of genetic information, it is inevitable to engage in interpretation about how to see, for instance, the relationship between what molecular biologists and biophysicists call forms of information processing (i.e., production and interpretation of signs) in a complex living system such as the cell and forms of causality in that system. So, the analysis of the genetic information system given below is not the only way to apply Peircean semiotics to this particular case; and some might object to the particular way we addressed the problem. We also acknowledge that there are peculiar features of the genetic information system which do not exactly conform to any standard Peircian framework. Nevertheless, we think that we have been faithful both to the basic insights and concepts of semiotics and to the findings of molecular biology, and that the few changes we have made in specific semiotic conceptions (as we shall explicate below) are necessitated by the growth of scientific knowledge about the system analyzed.

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[7] For more details, we refer the reader to El-Hani et al. (forthcoming).

Some Basic Notions About the Genetic Information System

First, we should briefly introduce some basic notions about the genetic information system.[8] Let us consider a very simple model of the process of gene expression (Fig. 20.5). During the synthesis of pre-mRNA (transcription), the four-base language of DNA (as a sequence of nucleotides including the bases adenine, A, guanine, G, cytosine, C, and thymine, T) is copied or "transcribed" into the four-base language of RNA (with uracil, U, replacing T).

The effects of a protein-coding gene on a given cell or organism are regulated mainly by control of gene expression at the level of transcription initiation. The

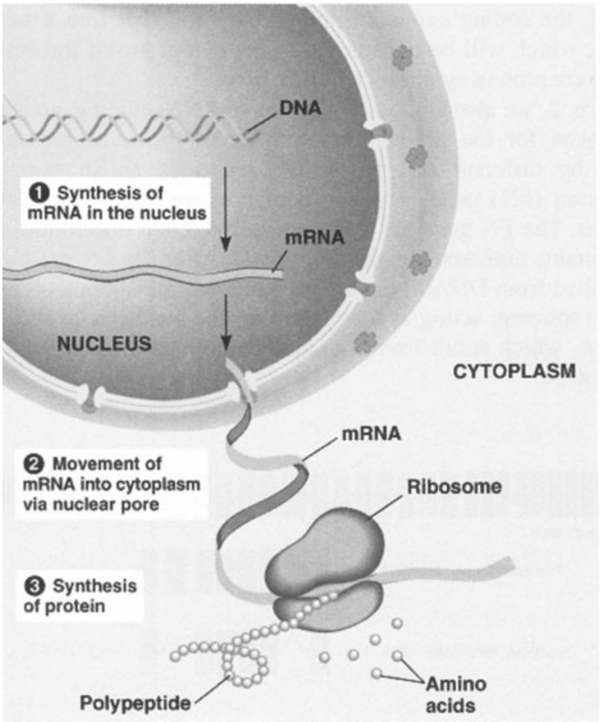

Fig. 20.5 A model of the steps of gene expression (From Campbell and Reece 2002). Many details are omitted, for the sake of simplicity

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[8] We will deliberately avoid introducing a large number of details, which can be easily found in any molecular and cell biology textbook (e.g., Lodish et al. 2003, Cooper and Haussman 2003, Alberts et al. 2002, Lewin 2000). These books are also the basic sources in this section, unless otherwise noticed. As the following paragraphs only summarize some elementary ideas in cell and molecular biology, any reader who doesn't feel any need of perusing these notions can simply skip them.

transcription of a gene can be either *repressed*, when the corresponding mRNA and encoded protein or proteins are synthesized at low rates or not synthesized at all, or *activated*, when both the mRNA and encoded protein or proteins are, *ceteris paribus*, produced at much higher rates. Through the control of gene expression, only a subset of all genes present in any cell type in a multicellular organism is really expressed. Thus, from all the potential protein products a given cell type might exhibit, only a specific number and variety will be present. This is the fundamental basis for cell differentiation in multicellular organisms. In the end of the 1970s, it was found that eukaryotic genes are split into pieces of coding sequence, named "exons", separated by non-coding segments, named "introns" (after Gilbert 1978). The vast majority of genes in multicellular eukaryotes contain multiple introns and the presence of such introns allows for the expression of multiple related proteins from a single stretch of DNA by means of a process known as "alternative splicing" (see below).

In eukaryotic protein-coding genes, introns are excised from a long "primary transcript" (precursor mRNA or pre-mRNA), i.e., the RNA copy of an entire DNA sequence containing both exons and introns, in a process known as RNA "processing", which includes other events not described here. After the introns are excised, the coding exons are joined back together into a functional mRNA, which will be transported to the cytoplasm of the eukaryotic cell, where protein synthesis will take place. The effects of genes on the functioning of a cell or organism can also be regulated by means of alternative pre-mRNA splicing, so as to produce different gene products from the same pre-mRNA. Alternative RNA splicing is an important mechanism for the production of different forms of proteins (isoforms) by different cell types. The fibronectin (FN) gene, for instance, generates more than 20 different FN isoforms. The FN gene has approximately 75,000 nucleotides (75-Kb) and contains numerous exons. After the FN pre-mRNA is transcribed from DNA, it undergoes cell type-, development – and age-specific splicing. Each FN isoform is encoded by a differently, alternatively spliced mRNA, and, therefore, each isoform results from a unique combination of exons found in the FN gene (see Fig. 20.6).

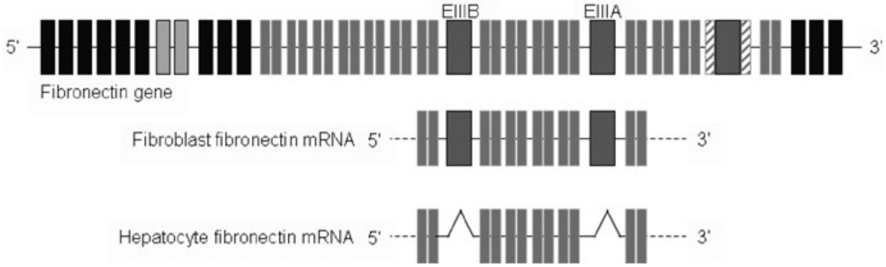

Fig. 20.6 Cell type-specific splicing of fibronectin pre-mRNA in fibroblasts and hepatocytes. The 75-kb FN gene (*top*) contains multiple exons. Introns are shown in the diagram as *thin lines* and are not drawn to scale. Most of the introns are much longer than any of the exons. The FN mRNA produced in fibroblasts includes the EIIIA and EIIIB exons, whereas these exons are spliced out of FN mRNA in hepatocytes (from Lodish et al. 2003. Available at http://www.ncbi.nlm.nih.gov/PubMed/)

Consider, for instance, the splicing of FN pre-mRNA in fibroblasts and hepatocytes. In fibroblasts, splicing of the FN pre-mRNA results in mRNAs containing exons EIIIA and EIIIB. The fibroblast FN isoform contains amino acid sequences that bind tightly to proteins in the plasma membrane. This specific FN isoform contributes to the adhesion of fibroblasts to the extracellular matrix. In hepatocytes, the major cell type in the liver, cell-type specific splicing results in functional FN mRNAs lacking exons EIIIA and EIIIB. FN secreted by hepatocytes does not adhere tightly to fibroblasts or most other cell types, freely circulating in the blood stream. When the wall of a vase is ruptured, hepatocyte FN plays a fundamental role in the formation of blood clots, due to the presence in the protein of fibrin-binding domains, amino acid sequences that bind to fibrin, one of the main constituents of blood clots. When hepatocyte FN is bound to fibrin, it interacts with integrins, cell-adhesion protein molecules found in the membranes of activated platelets. As a result, the blood clot is expanded through the addition of platelets.

Finally, translation is an essential part of protein synthesis, consisting in the process by which the nucleotide sequence of an mRNA serves as a template for the synthesis of a polypeptide chain, i.e., for a series of events in which amino acids are ordered and joined to form the primary structure of a protein. Three types of RNA molecules are involved in translation, performing different but cooperative functions. mRNAs are the “vehicles” of the genetic information transcribed from DNA. The “message” at stake is “written” in the form of a series of three-nucleotide sequences, called “codons”, each of which specifying a particular amino acid. tRNAs play a fundamental role in the process of deciphering the codons in mRNA. Each type of amino acid has its own subset of tRNAs. They act as transporters, binding amino acids and carrying them to the growing end of a polypeptide chain in response to specific codons in the mRNA. The reason why the correct tRNA with its attached amino acid is selected at each step in protein synthesis lies in the fact that each specific tRNA molecule contains a three-nucleotide sequence, called an “anticodon”, that base-pairs with its complementary codon in the mRNA. In this manner, for each specific codon in mRNA a specific amino acid, carried by a specific tRNA, is included in a polypeptide chain, according to the rules expressed in the almost universal “genetic code”. Along with 100 different proteins, several types of rRNA are components of ribosomes, the complex and large macromolecular structures that act, so as to say, as guides to coordinate the assembly of the amino acid chain of a protein. In fact, a rRNAs (a ribozyme), and not a protein, is probably the catalyst involved in the formation of peptide bonds in protein synthesis.

Recognition of a codon in mRNA specifying a given amino acid by a particular tRNA is, in fact, the second step in “decoding” the genetic “message”. The first step is the attachment of the appropriate amino acid to a tRNA in a reaction catalyzed by a specific aminoacyl-tRNA synthetase. The specificity of the attachment between amino acids and tRNAs results from the capacity of each one of these enzymes of recognizing *one* amino acid and *all* its compatible, or “cognate”, tRNAs.

Therefore, the rules captured in the genetic code ultimately depend on the recognition activity of aminoacyl-tRNA synthetases. Although the terms “translation” and “protein synthesis” are usually employed interchangeably, this is not correct, since, although translation is obviously an essential step in protein synthesis, this process involves further steps. Polypeptide chains undergo post-translational folding and often other changes, as, for instance, chemical modifications and association with other polypeptide chains, that are required for production of functional proteins. All these steps in protein synthesis can undergo regulation.

A Semiotic Analysis of Genes and Genetic Information

If we take Peirce’s concepts of sign and semiosis as bases for analyzing what is a gene, it will be the case that the action of a gene as a sign will have to be understood as a relationship between three elements (Fig. 20.7). Given the account of information developed in this paper, genetic information can be described as a semiotic process. In these terms, there’s more to genetic information than just sequences of nucleotides in DNA.

In this picture, a string of DNA (say, the FN gene) is treated as a sign. As a protein-coding gene, the FN gene, for instance, stands – in a triadic-dependent relation – for a specific sequence of amino acids (immediate object) – one of the FN isoforms, translated out of a mature mRNA after alternative splicing (which, as the figure shows, can take place or not, depending on the string of DNA we are

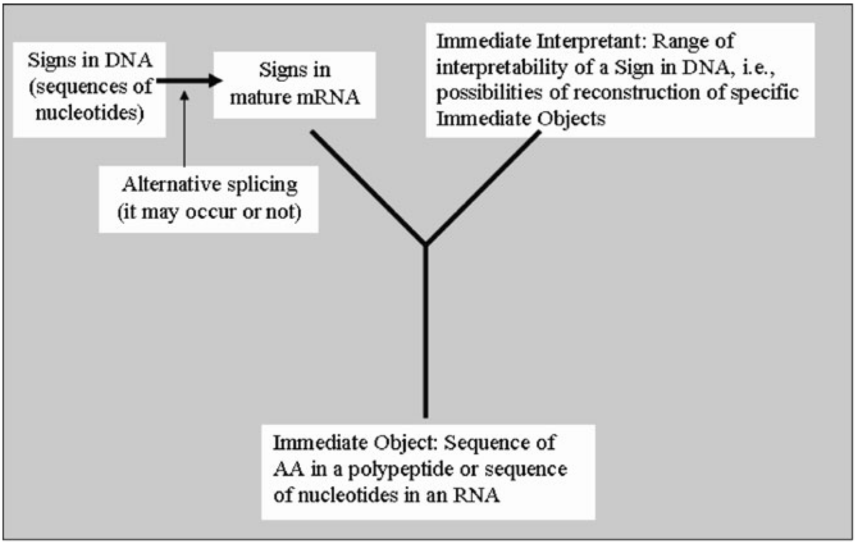

Fig. 20.7 A semiotic analysis of the gene as a sign

analyzing)[9] – through a process of reconstruction of a specific form (interpretant).[10] Given that a sign is the mediating element in a semiotic process through which a form is communicated from an object to an interpretant, we treat the interpretant here as the reconstruction of a form (habit) which was embodied in an object. To be more explicit, we defined above information as the communication of a form from the object to the interpretant, and we also argued that such a communication will in turn constrain the behavior of the interpreter. What we mean by "reconstruction" here is a process by which the form of a protein in a cell generation is communicated through signs in DNA (in potency) to a cell in a subsequent generation. Thus, a regularity obtains (with possible evolutionary consequences) in the three-dimensional structure and function of proteins along generations.

We will introduce the qualifiers "composite" and "simple" to incorporate a part-whole relationship in our semiotic analysis of genes, referring to a stretch of DNA or mature RNA as a whole as a composite sign, formed by clusters of simple signs, codons. We can now introduce in our analysis the distinction between immediate and dynamical object, and immediate and dynamical interpretant. In a Peircean framework, the immediate object can be understood as the characteristics selected in the sign as a means of indicating the dynamical object. It is not the case, in this framework, that the immediate object is a condition of possibility for the dynamical object. Nevertheless, in the case we are analyzing here the interpreter creates a dynamical object of a given class (showing a given habit) on the grounds of indications present in the sign. A cell uses signs in DNA as a basis for synthesizing a dynamical object sufficiently resembling a past dynamical object which does not exist anymore but resulted in successful, adaptive experiences. This is the reason why we claim that, in this case, the immediate object establishes conditions of possibility for the dynamical object.

The dynamical object of a gene is a functional, folded, and chemically modified protein, which is often not entirely specified in the sequences of nucleotides or amino acids, but it is rather indicated by such sequences.[11] Functional proteins

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[9] If alternative splicing does not occur, it will be the case that signs in DNA and signs in mature mRNA will be equivalent.

[10] In the case of genes, the objects at stake are entities, as described above. Nevertheless, it is important to bear in mind that, in Peirce's framework, it is not the case that the object of a sign should necessarily be an entity, a thing, or even an existent. Consider, for instance, the following passage: "The Objects – for a Sign may have any number of them – may each be a single known existing thing or thing believed formerly to have existed or expected to exist, or a collection of such things, or a known quality or relation or fact, which single Object may be a collection, or whole of parts, or it may have some other mode of being, such as some act permitted whose being does not prevent its negation from being equally permitted, or something of a general nature desired, required, or invariably found under certain general circumstances" (CP 2.232).

[11] To be more precise, we should consider that some proteins acquire their mature conformation spontaneously. These proteins show the property of self-assembly. In this case, the three-dimensional structure of a protein simply follows from its primary sequence of amino acids, and, therefore, the immediate Object directly determines the dynamical Object. (Here we find yet another peculiar feature of the genetic information system, when compared to the standard Peircean

are not always simply translated out of nucleotide sequences by a cell, but they are rather found out through resources the cell acquire by collateral experience, i.e., by habits that a cell acquire in its development towards the states characteristic of a given cell type, and can be traced back to evolutionary processes.[12] A functional FN isoform, for instance, is a dynamical object. The composite immediate object of a protein-coding gene is the sequence of amino acids of a polypeptide, as this is the object represented in the gene's vehicle, a string of DNA. Each amino acid, in turn, is a simple immediate object. If we consider the sequence of amino acids of a specific FN isoform, we will say, in the terms of our analysis, that such a sequence is an immediate object of the FN gene. It is important to bear in mind, however, that it is *an* immediate object, not *the* immediate object. After all, the FN gene codes more than 20 different FN isoforms, all of them being possible immediate objects of the FN gene as a sign in DNA.

The sequence of amino acids, the composite immediate object, is the dynamical object in its semiotically available form. The sequence of amino acids of each FN isoform amounts to a specific protein coded – in its semiotically available form – in a mature RNA which results, after splicing, from a pre-mRNA transcribed from the FN gene. The immediate object, a sequence of amino acids, can indicate a range of possible functional proteins, dynamical objects, as a single amino acid sequence can be folded in different ways in different cellular contexts. But we should not lose from sight, however, that such an indication by the immediate object plays a fundamental role in the reconstruction of the dynamical object, since it is not the case that any three-dimensional protein can be produced from a given amino acid sequence.[13]

The immediate interpretant of a codon as a simple sign is the range of interpretability established by the rules of base pairing by which specific nucleotides in DNA determine specific nucleotides in mRNA, or the range of interpretability of three-nucleotide sequences in mature mRNA as established in the genetic code, a set

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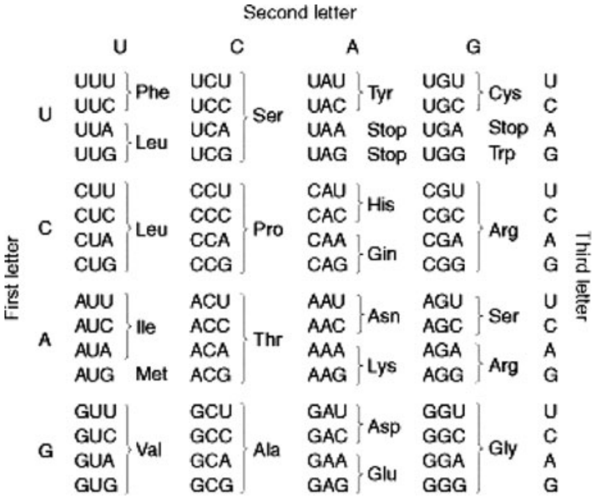
framework). There are a number of proteins, however, that cannot self-assemble and should be assisted by proteins called "chaperones" in order to acquire their proper structures. In this case, the sequence of amino acids, the Immediate object, only indicates the functional protein, the dynamic object. In the text, we are dealing particularly with this case, which fits Peirce's understanding of the relationship between immediate and dynamical objects. "Chaperones" can be treated, in these terms, as part of the habits cells acquired in evolution.

[12] Symptomatically, Godfrey-Smith (1999) and Griffiths (2001) argue that developmental information is not stored in the genetic code, because the formal coding relation between codons in DNA and amino acids in polypeptides specifies only the primary structure of proteins.

[13] In a Peircean framework, the immediate object can be understood as the characteristics selected in the sign as a means of indicating the dynamical object. It is not the case, in this framework, that the immediate object is a condition of possibility to the dynamical object. Nevertheless, in the case we are analyzing here the interpreter creates a dynamical object of a given class (showing a given habit) on the grounds of indications present in the sign. A cell uses signs in DNA as a basis for synthesizing a dynamical object sufficiently resembling a past dynamical object which does not exist anymore but resulted in successful, adaptive experiences. This is the reason why we claim that, in this case, the immediate object establishes conditions of possibility to the dynamical object.



	Second letter								
First letter	U		C		A		G		Third letter
U	UUU	Phe	UCU	Ser	UAU	Tyr	UGU	Cys	U
	UUC		UCC		UAC		UGC		C
	UUA	Leu	UCA		UAA	Stop	UGA	Stop	A
	UUG		UCG		UAG	Stop	UGG	Trp	G
C	CUU	Leu	CCU	Pro	CAU	His	CGU	Arg	U
	CUC		CCC		CAC		CGC		C
	CUA		CCA		CAA	Gln	CGA		A
	CUG		CCG		CAG		CGG		G
A	AUU	Ile	ACU	Thr	AAU	Asn	AGU	Ser	U
	AUC		ACC		AAC		AGC		C
	AUA		ACA		AAA	Lys	AGA	Arg	A
	AUG	Met	ACG		AAG		AGG		G
G	GUU	Val	GCU	Ala	GAU	Asp	GGU	Gly	U
	GUC		GCC		GAC		GGC		C
	GUA		GCA		GAA	Glu	GGA		A
	GUG		GCG		GAG		GGG		G

Fig. 20.8 The genetic code. Sets of three nucleotides (codons) in an mRNA molecule are translated into amino acids during protein synthesis according to the rules shown in the table above (from Griffiths et al. 1999. Available at http://www.ncbi.nlm.nih.gov/PubMed/)

of rules by means of which nucleotide sequences determine the addition of specific amino acids to a growing polypeptide chain (Fig. 20.8).[14] The dynamical interpretant of a codon as a simple sign amounts, then, to the realization of one of the rules of base pairing or of the genetic code. A composite sign in DNA determines a range of possible composite immediate objects. It is true that there are cases in which a stretch of DNA codes for only one protein product. In this case, the composite sign in DNA determines only one immediate object. Nevertheless, in eukaryotic cells at least, most stretches of DNA codes for several distinct proteins, as in the case of the FN gene. Therefore, we can define the immediate interpretant of a composite sign as the range of interpretability of that sign in DNA, i.e., as the possible immediate objects, the possible sequences of amino acids, that can be produced from that sign in DNA. Alternative RNA splicing is understood, in these terms, as one of the processes that enrich the range of interpretability, the immediate interpretant, of a stretch of DNA. In the case of the FN gene, its immediate interpretant comprises more than 20 possible composite immediate objects.

This analysis is in accordance with the definition of a sign as medium for communicating the form of an object to an interpretant. The interpretant can be seen, thus, as a reconstruction of the form of an object. It follows that the immediate interpretant of a stretch of DNA or mRNA as a composite sign, i.e., its range of interpretability, amounts to the diversity of possibilities of reconstruction of the form of the composite immediate object, the sequence of amino acids in a polypeptide. The dynamical

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[14] By "coding", we mean here a system of constraints which establishes a range of possible effects of a sign (see Nöth 1995: 210).

interpretant of a stretch of DNA or mRNA as a composite sign corresponds to the effective reconstruction of a sequence of amino acids. In an alternatively spliced gene, such as the FN gene, this realization involves the instantiation of a specific splicing pattern in a given cell type, at a given developmental stage. Thus, one of the possibilities established in the range of interpretability of a stretch of DNA, in its immediate interpretant, is actualized. In a fibroblast, for instance, when a specific immediate object is synthesized, the fibroblast-specific FN isoform, this means that, from the range of possible sequences of amino acids that might be made out of the FN gene – its immediate interpretant – a specific sequence was reconstructed – its dynamical interpretant.

After it is actualized, an immediate object indicates a particular dynamical object – say, a specific FN isoform. It is the dynamical object, then, that has an effect on the cell as a global interpreter. We can define, then, a dynamical interpretant of the dynamical object, a particular effect on a cell, among a range of possible effects – the immediate interpretant of the dynamical object. This dynamical interpretant is the actualization of one of the possible effects that a composite sign might have on the interpreter. Its range of interpretability is the immediate interpretant of the composite sign. This analysis faces the potential problem that it seems to treat the sign as the primary constraining factor in semiosis, while this role is reserved for the dynamical object in Peirce's theory of signs. After all, we are describing here how S (a sequence of nucleotides in DNA) determines O (a sequence of amino acids in a polypeptide) through I (a range of possibilities of reconstruction of sequences of amino acids).[15] We accommodate this description into a Peircean framework by examining the constraining action of the object in evolutionary terms (see Fig. 20.9). Consider two different generations of a population, in times t_1 and t_2, and a protein (dynamical object) in t_1 that increases the likelihood of successful, adaptive experiences of organisms possessing it. Therefore, that protein increases the likelihood

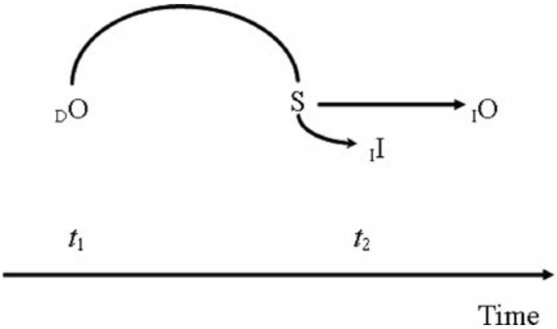

Fig. 20.9 The dynamical object (functional protein) as the primary constraining factor of semiosis in the genetic information system. S, sign; $_{D}O$, dynamical object, $_{I}O$, immediate object; $_{I}I$, immediate interpretant; t, generation time

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[15] In this picture, it is important to take in due account that we are not claiming that DNA causes or brings about the protein as an object, since DNA is a set of data (or, as we prefer, signs) rather than a program, a source of materials rather than a master agent in the cell. It is the DNA processing system that produces the proteins. We are not claiming, therefore, that the sign causes the object.

that a gene (sign) encoding it will be present in high frequencies in the next generation, in t_2. Indeed, the sequence of a gene is determined, by past natural selection, because of the effects it produces (Maynard 2000: 177). This gene, in turn, will bring to the next generation the potency to produce that protein, as a dynamical object, by indicating it through its semiotically available form, its immediate object. Signs in DNA will carry to future generations the potentiality of reconstructing the form of that protein in generations to come. This means that that gene, as a sign, exerts a determining influence on the range of possibilities of reconstructing sequences of amino acids in the next generation. If we follow this set of ideas, we will be able to see how, in evolutionary terms, O determines I through S, in conformity with Peirce's account of semiosis. Nevertheless, the role of O as the primary constraining factor of semiosis depends, in the genetic information system, on the role of S, in a given generation, in determining O through I. We can say, in short, that the fact that S determines O through I in a given population in t_2 is itself determined by the fact that O determined I by increasing the likelihood of S being present in a high frequency in t_2, by means of its involvement in successful experiences in t_1.

The relationship between signs in DNA and the sequence of amino acids of a protein (the composite immediate object) is established by a complex mechanism of interpretation, involving transcription, RNA processing and translation. Thus, to interpret a string of DNA, more than one interpretative system is required, including, for instance, RNA polymerases, involved in the transcription of DNA into RNA, and ribosomes, involved in the translation of mRNA into proteins. These interpretative systems are parts or subsystems of a cell as a global interpreter, and their actions are subordinated to the latter. That ultimately the whole cell participates in the network necessary for the interpretation that is demanded for the effect of a gene product to take place (cf. Emmeche and Hoffmeyer 1991) is shown by the impressive array of signaling pathways regulating the interpretation of Signs in DNA.

Symptomatically, a Peircean approach to the gene concept entails that genetic structures should not be seen in isolation from the larger system by which they are interpreted. From this perspective, the meaning of a gene to its interpreter, the cell, or, to put it differently, the biological meaningfulness of a gene, is found not only in DNA sequences in a chromosome. After all, according to this approach, there is more to genetic information than just a sequence of nucleotides in DNA. We will have to include the effect of the gene-as-a-sign on the cell or organism, and, in fact, the very role of cellular subsystems as interpreters of strings of DNA, in such a way that they relate signs to specific dynamical objects, proteins which play a function inside the cellular system and have an effect on it or on the organism of which the cell is a part.

In sum, the semiotic analysis of the genetic information system developed above leads to the following conclusions:

(i) Genes should be regarded as signs in DNA, which can only have any effect on a cell through a triadic-dependent process (semiosis);
(ii) This process is genetic information and involves more than just genes as signs in DNA but also objects and interpretants;

(iii) Genetic information is the process by means of which a form in a dynamical object (a functional protein) is communicated to an interpretant (the reconstruction of a specific sequence of amino acids in a cell) by means of signs in DNA.[16]

Concluding Remarks

There is controversy about the prospects of the non-semantic understanding of information offered by the mathematical theory of communication for developing a theory of information in biology. Despite the usefulness of this theory for several purposes in biological research, there is still doubt whether it is sufficient for the understanding of biological information. We believe that biology needs a semantic/pragmatic account of information. Throughout this paper, we argue that semiotic concepts and theories, and, in particular, C. S. Peirce's formal science of signs, can lead to a precise and coherent formulation of the notion of information in biology.

Toward this end we have developed a model of information as semiosis, grounded on Peircean semiotics. According to this model, information is conceived as the communication of a form or habit from O to I through S, so as to constrain (in general) the meaning of the interpretant as a sign or (in biological systems) the interpreter's behavior. Or, to put it differently, information is the same as semiosis, i.e., a triadic-dependent process through which a form embodied in the object in a regular way is communicated to an interpretant through the mediation of a sign.

The treatment of information in biology based on Peircean semiotics leads to an account of genes as signs and genetic information as semiosis. According to this account, genetic information is a triadic relation between a (composite) sign in DNA, i.e., the sequence of nucleotides of a gene; an immediate object, i.e., the sequence of amino acids of a polypeptide (or the sequence of nucleotides of a RNA); and an immediate interpretant, i.e., the possibilities of reconstruction of specific immediate objects, which amount to the range of interpretability of a (composite) sign in DNA. Genetic information has, thus, a processual nature and should not be identified with sequence information in a nucleic acid. Rather, it is a process by means of which a form in a dynamical object (a functional protein) is communicated to an interpretant (the reconstruction of a specific sequence of amino acids in a cell) by means of signs in DNA.

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[16] In another paper, we substantiate and elaborate these conclusions by means of a more detailed analysis of some processes in the genetic information system, namely, transcription and translation. For this analysis, see El-Hani et al. (forthcoming).

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Chapter 21
Excerpts from *Readers of the Book of Life*

Anton Markoš (1949–)

Introduction and Commentary: Anton Markoš

> *What kind of creature is hidden under the notion of* "hermeneutic biologists"? *What do their working hours look like? Well, you will not recognize them by their doings – they are busy performing standard biology like anyone else. Maybe in the introductions and discussions of their papers you will recognize slightly different accents and suggestions for opening new realms within the framework of the current paradigm – but no revolutionary zealots changing current paradigms! They know that plurality of view is the most precious gem in the quest for wisdom.*
>
> A. Markoš (2002: 221)

At the time of his attendance at the first annual Gatherings in Biosemiotics conference in 2001, experimental cellular physiologist and philosopher of science Anton Markoš had just completed a groundbreaking treatise entitled *Readers of the Book of Life* – a book that called for the development of a "biohermeneutic" understanding of sign processes in living systems that proceeded not from a Peircean or Uexküllian perspective, but from a grounding in the existential hermeneutics of philosopher Hans-Georg Gadamer (1900–2002). Thus it was Markoš's paper presentation at that inaugural conference that led to the incorporation of the 'biohermeneutic school' of inquiry into contemporary biosemiotics.

Born on March 20, 1949 in the small mountain town of Kremnica, Czechoslovakia, Anton Markoš studied cellular physiology at the Charles University in Prague, receiving his undergraduate degree in that subject in 1972, and his CSc (the then Czech equivalent of the Ph.D.) in 1977. From 1977 to 1994, Markoš worked as both a professor and as an experimental scientist in cell physiology at Charles University, focusing particularly on energy metabolism and differentiation in the protistan parasite *Trypanosoma brucei*, as well as in trichomonads and slime molds. "In the air of a shortage of everything and bureaucratic bonds everywhere," reports Markoš about Soviet-era Czechoslovakia, "the most common chemicals had to have been ordered two years in advance, and there was no real new equipment. Thus, because I could do only a very limited range of science, I focused my attention to reading and teaching" (2009: p.c.).

Seeking increased opportunities for research, Markoš secured himself short-term fellowships at the Institute for Cell Pathology in Brussels, the Max-Planck

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Institute for Biology in Germany, and at Rockefeller University in New York. In 1994, he entered the Charles University and the Czech Academy of Sciences Center of Theoretical Study, where he was part of a four-year interdisciplinary workshop bringing together biologists, philosophers, physicists, and historians of science – and where he first became acquainted with the hermeneutic philosophy of Hans-Georg Gadamer, whose application to the intransigent problems of biology immediately became clear to him.

An additional event critical, too, to his later development of the project of biohermeneutics, recalls Markoš, took place "after the political turn of 1989, when a group of previously underground philosophers and scientists, headed by Zdeněk Neubauer, got the chance to establish a small Department of Philosophy and History of Science in the Faculty of Sciences at Charles University, with the goal of giving apprentice scientists some insights into the existence of other corners of human knowledge" (*ibid*). In 1998, Markoš was invited to enter this interdisciplinary department, which he presided over from 2002 to 2008, and where he teaches still. Subsequently, articles on biohermeneutics written by Markoš and his colleagues in the department have been appearing regularly in biosemiotics journals, and in 2009, Markoš co-authored a volume on biohermeneutics for the Springer Book Series on Biosemiotics entitled *Life as its own Designer*, together with his colleagues Drs. Filip Grygar, László Hajnal, Karel Kleisner, Zdeněk Kratochvíl and Zdeněk Neubauer.

There, as throughout so much of Markoš's biohermeneutic work, writes biosemiotician Marcello Barbieri, the starting point of Markoš's *biohermeneutics* is the problem of "novelty":

> Do genuine novelties exist in nature? Did real novelties appear in the history of life? In classical physics, as formulated for example by Laplace, novelty was regarded a complete illusion ... [for Prague biohermeneutician Anton Markoš] this is precisely what Darwin's revolution was about. It was the introduction of *contingency* in the history of life, the idea that all living organisms, and not just humans, are *subjects*, individual *agents* which act on the world and which take care of themselves. . . .[Thus,] according to Markoš, the present version of Darwinism that we call Modern Synthesis, or Neodarwinism, is a substantial manipulation of the original view of Darwin, because it is an attempt to explain the irrationality of history with the rational combination and recombination of chemical entities. Cultural terms like *information* and *meaning* have been extended to the whole living world, but have suffered a drastic degradation in the process. Information has become an expression of statistical probability, and meaning has been excluded *tout court* from science. Darwin has shown that the history of life is as contingent as the history of man, and Heidegger has shown that man can create genuine novelties because he can *interpret* what goes on in the world. From these two insights, Markoš. . .argues that we should go back to the basic concepts of the humanities and study the history of life as a 'narrative', precisely as we study the history of human affairs (Barbieri 2009: 228).

When asked about the biohermeneutic project during a panel discussion in 2007, Markoš himself framed the project this way:

> If you look at the last two hundred years of the history of Biology, you can always find minor groups of dissidents claiming that "There is something more to life than is being accounted for in the standard science." You find this especially in the major works of literature. But who alone succeeded in actually establishing this case? Only one single person succeeded.

> It was Darwin. Darwin brought 'story' – i.e., 'history' – into Biology, and into the sciences. And it took a hundred and fifty years to push story back out of Darwinian evolution to make neo-Darwinism! But because, in fact, there are only two histories, or 'stories' that have been allowed into science. One is the Big Bang, where the whole story is effectively condensed into the first one-tenth to the minus forty-two seconds of the universe – after which you then just have normal functioning, the mechanical, clockwork functioning of the universe. So that story already finished long ago. But the second story – that of biological evolution – is still going on. Well, we've found the (his)'story' in life again. But since we see that in two hundred years, only one single person was successful in synthesizing history and working science, well . . . we must be careful in our optimism! (2008: 16–17)

"History", "story", "narrative", "reading" and "text" are critical concepts in Markoš's biohermeneutics project, for, with Gadamer, Markoš asserts that "the nature of knowledge" – all knowledge, whether mentally conceptualized or biologically embodied – "is hermeneutical and is rooted in experience, history and in structures" (2008: p.c.). He therefore eschews the idea that formalized equations between "digital signs and bodily (or analog) entities can be reduced to an unequivocal correspondence" (Cvrčková and Markoš 2005: 87). Instead, claims Markoš, scientists' maps – of cell fate, of immunological response, of neuronal activity, and even of protein synthesis – are at best helpful marks made by scientists' for their own orientation, but they are never to be confused with the vastly different multidimensional territory wherein the objects of the biologists' study must orient themselves according to very different sets of signs and meanings than those that the scientist crudely attempts to translate into the language of human symbolic terms (2002: 120).

What often become obscured by such a procedure, observes Markoš, is the fact that, for the majority of more complex organisms – and certainly for mammals – the action of interpretation upon a sign is "its own shortest description" and cannot thus be algorithmically compressed (cf. Kauffman 2000). As a result, argues Markoš' wife and collaborator, fellow cell physiologist Fatima Cvrčková (1966–), all attempts to reduce this historically situated, though ever presently unique, realm of living-acting-perceiving-and-signifying onto the "necessarily incomplete, reduced, and flattened" descriptions of the contemporary objectivist scientific model cannot help but to obscure, instead of clarify, the very phenomenon that is a living systems' defining characteristic – i.e., its ability to self-preservatingly "read" its own immediately present situation, and to actively choose its response from among a repertoire of available possibilities (Cvrčková, in Markoš 2002: 184).

These embodied repertoires, claims Markoš, have developed over the long history of evolutionary time in the manner of biological "texts" that have been literally "inscribed" in organisms and are now "ready to hand" for them, in the Heideggerian sense. Accordingly, organisms creatively *use* such embodied inscriptions as interpretative resources for negotiating the current condition that they find themselves in. Such an understanding is the conceptual inverse of that of the genetically "programmed" organism that is at the mercy of the biological text (or code), which controls it like the execution of a computer program stored inside an automaton. Here, instead, it is the organism itself that is the ultimate "reader of the book of life" that it inherits, on the one hand, and that it must perpetually "read" anew, on the other.

Yet, notes Markoš, for much of contemporary biology, "the genome is often taken for a *sui ipsius interpres* (or self-interpreting text). According to this view, the "interpretation" of a genetic script would mean simply decoding according to a known key" (2002: 34). Markoš devotes a substantial portion of *Readers of the Book of Life* (2002) to showing how gross and misleading an oversimplification of the actual processes instantiating genetic expression is expressed in such a claim. Instead, he argues, a more realistic analogy for life processes than that of mechanical decoding, would be that of genuine *hermeneutic reading*, which is "not merely a matter of *deciphering* meaning – as such a method would simply reveal what is already pre-existing – but rather, it is the very act of *acquiring* knowledge . . .and *creating* meaning, as both knowledge and meaning will *arise* in the very process [of the reading]" (2002: 35).

Markoš points us towards a quote from Hans-Georg Gadamer's classic hermeneutics text *Truth and Method* (1996) regarding written texts that, mutatis mutandis, provides us with a fruitful new heuristic for thinking about the reading (and the writing) of genetic texts:

> The written word and what partakes of it is the intelligibility of mind transferred to the most alien medium. Nothing is so purely the trace of the mind as writing, but nothing is so dependent on the understanding mind either. In deciphering and interpreting it, a miracle takes place: the transformation of something alien and dead into total contemporaneity and familiarity. This is like nothing else that comes down to us from the past . . . That is why the capacity to read, and to understand what is written, is like a secret art, even a magic, that frees and binds us. In it, time and space seem to be superceded (Gadamer 1996: 163–64).

Similarly can one "read", with scientifically trained eyes, the implications for our understanding of evolutionary biology in Gadamer's remarks that "*understanding* is not to be thought of so much as an action of one's subjectivity, but as the placing of oneself within a process of tradition, in which past and present are constantly fused," and thus the "working out [of] appropriate projections, anticipatory in nature, to be confirmed 'by the things' themselves, is the constant task of understanding" (Gadamer 1972: 267, 1975: 258).

For as Markoš shows us in the following selection, the living organization of an organism changes the way it "reads" itself and its environment on a moment-to-moment (as well as on an evolutionary) basis in a way that no machine logic or mathematical formalization could ever predictively account for – and it is this very embodiment of a possibility-collapsing "bio-logic" that allows a living system to effectively explore and to creatively exploit novel state spaces, giving it "the characteristics of a field, a culture, a statement, and of course, [but only] sometimes, also of a machine" (2002: 163).

Thus, like many biosemioticians, Anton Markoš finds himself attempting to establish a scientifically viable and explanatorily more complete framework for the understanding of biological being that "navigates between the Scylla of mechanism and the Charybdis of teleology" (Havel and Markoš 2002). And as the epigraph that begins this commentary indicates, he emphatically does not wish to "do away with" the traditional and infinitely valuable way of doing biological laboratory science.

He wishes, instead, to augment it, after the fashion of Gadamer's perspective-widening "fusion of horizons" and Bateson's knowledge-generating method of "double-description" – i.e., with the realization that the laboratory scientist's perspective *is* a perspective, and that the object of the biological laboratory scientist's investigation is a subject with a perspective of its own. The dialogic viewpoint that emerges from this understanding Markoš refers to as an exploration into *the hermeneutics of the living*. The following selection well represents this enterprise, in what has now firmly been established as one of the most vibrant and promising areas of inquiry in biosemiotics.

Excerpts from *Readers of the Book of Life (2002)*

> The difference between meaning in a formal system and in a language is a very important one. . . It is in this: in a language, when we have learned a meaning for a word, we then make new statements based on the meaning of the word. In a sense the meaning becomes *active*, since it brings into being a new rule for creating sentences. This means that our command of language is not like a finished product: the rules for making sentences increase when we learn new meanings. . . [I]n a formal system, the theorems are predefined, by the rules of production. We can choose "meanings" based on an isomorphism between theorems and true statements. But this does not give us the license to go out and add new theorems to the established theorems. – Douglas R. Hofstadter

Why This Book?

The reader may ask why, when the neo-Darwinian paradigm seems to be invincible, I wish to discuss branches of biology that are in concealed or open conflict with it. Most such alternatives are without doubt "contaminated" by the humanities. Why not adopt the view of Kováč, who sees them as dwelling in the tenets of Aristotelian truths, eye-catching, intellectually extremely expressive but, alas, untrue? Why not reject all alternative views with a resignation similar to that in the following passage by Gould (1996) on Lamarckism?

> We deny our preferences all the time in acknowledging nature's factuality. I really do hate the fact of personal death, but will not base my biological views on such distaste. Less facetiously, I really do prefer the kinder Lamarckian mode of evolution to what Darwin called the miserable, low, bungling, and inefficient ways of his own natural selection – but nature does not give a damn about my preferences, and works in Darwin's mode, and I therefore chose to devote my professional life to this study. (p. 37)

The reason for my apparently foolish task is my conviction that the neo-Darwinian theory, like any other, reflects only a certain set of ideas and values. Those who have espoused these ideas and values have focused their attention on certain properties of living beings and generalized them into a viable theory. These undoubtedly truthful and very efficient filters help us to put our understanding of reality in order. I am, however, convinced that there may be other filters, other theories that would allow us to discover different aspects of living beings. I must confess to a "postmodern" heresy that it is we who construct truth in order to find an orientation in *our* world. Competition between several truths is more important than the hegemony of a single Truth, however invincible it might look to us and our contemporaries.

I do not believe that knowledge elaborated by the natural sciences is different in principle from other forms of knowledge, just because science has found a way to cumulatively improve the truth, whereas the humanities have just wandered in an endless vicious circle for the last 2,500 years. I maintain that *any* knowledge is both cumulative *and* circular. The circle, however, is not an erratic whirling, but a hermeneutic activity. Because of this, it is useful also to retain knowledge of half-forgotten, abandoned alternatives, dead ends, and even frauds of the past – if for no other reason then simply as a corrective for the overly confident and pompous judgments of some protagonists of the theory reigning at a given time, as an antidote against ideology. Neo-Darwinism is a beautiful edifice of the human spirit, and heuristically it is invaluable. However, we should venture into different regimes of thought and seek for phenomena that are ignored, neglected, or even rejected by the leading theory.

I see a hermeneutic approach as a good alternative in biology. If there are calls for the unification of knowledge, why not undertake the enterprise "democratically," from different angles and by different methods? Life on Earth arose as a result of certain chemical and physical conditions in force on the virgin planet. Such conditions opened – or better, created – new realms that had never been present before. Because of this, life is, and at the same time is not, explicable by chemistry, thermodynamics, and physics. The existence of replicators enabled one particular kind of evolution. New realms came into existence because of that very fact, and they, too, both are and are not explicable in terms of the "selfish" replicator.

In this part of the book I present a survey of some biological theories that profoundly influenced the development of biological science in the twentieth century. I maintain a scheme similar to that in part I, where we moved from objectivism to hermeneutics. In this part, the ground will be delimited by two extremes. One is the postulate that the phenotypic characters (structure, physiology, and behavior) of the organism can be derived from a basic, digital level of description, that is, from information implemented in the molecule of DNA. Neo-Darwinism, the leading paradigm of contemporary biology, lies close to this end of the scale. The opposite extreme stresses the importance of bodily experience, history and environmental contingencies and sees genetic makeup as a necessary but far from sufficient precondition. Close to this end of the scale belong the theories of biological field, epigenetics, and superorganism and what I call the language metaphor of life. Between lie biological structuralism, vitalism, and also the theoretical background of what became Lysenkoism. I follow the struggle to conciliate the contradictory demands of the "living state" with objectivist science.

Mechanism Versus Organism

During the last 200 years, this topic has been treated ad nauseam by myriad works of theoretical biology. Whole careers have been devoted to various stands on the conflict, and elaborate philosophical systems have been developed, just to reach the conclusion that either (1) living beings are *nothing but machines* or (2) living beings *are not machines* and need some element in addition. Thus, the centuries-old dispute addresses the single question of whether the living (the "organic") can be identified with the mechanism. If not, how to characterize it? One of the greatest frustrations of biology lies in the fact that it is not able, despite incessant effort, to break through this "Aristotelian barrier" (see Chapter 1 for this concept) and provide a clear resolution to this seemingly simple conflict.

The modern (Cartesian) tradition of thought. with its stress on strict causality, has of course resisted any attempts to support the existence of anything other than unequivocal causal chains and has instead proposed a machinelike conception of life. Despite this, the problem of organicity has tendency to resurface again and again. Abram (1996) has reflected it as follows:

> First, the "mechanical philosophy" suggests that matter, itself, is ultimately inert, without any life or creativity of its own. The great worth of the machine metaphor is that it implies that the material world is, at least in principle, entirely predictable. According to this metaphor, the material world operates like any machine according to fixed and unvarying rules; laws that have been built into the machine from the start. It has no creativity, no spontaneity of its own. (pp. 234–235) A machine always implies someone who invented the machine, a builder, a maker. A machine cannot assemble itself. . . . If we view nature as machine, then we tacitly view it as something that has been built, something that has been made from outside. (p. 242)

Abram, of course, only restates a classic problem for our times. Almost identical formulations can be found in Kant's *Critique of Judgement* (1790). Also, for Kant, organic beings *should* be distinguished from mechanical devices. In contrast to machines, they possess one principal property: all their parts are at one and the same time the cause and the effect of their form.

On the part of mainstream biology, now as in the past, the whole mechanism versus organism problem has been declared a pseudoproblem or, in the milder form of rejection, put aside with a comment that it is beyond the powers of contemporary knowledge to solve it. In both cases, it is considered advisable to concentrate on more relevant problems (e.g., modern, successful, mechanistic science) instead of wasting time on metaphysical speculations. This advice has usually been followed – biologists do not protest against a mechanistic understanding of their subject. The prerequisite for understanding life in this framework is a linear and unidirectional (i.e., mechanical) relationship between the genetic text as the cause and the phenotype pattern as the effect of the process. The absence, in recent decades, of any alternative approaches has been balanced by the rocketing progress of mechanistic theory, which is most often called modern or neo-Darwinian synthesis.

The Reproduction of the "Living Machine"

Suppose that a device exists that is executing a program in a constant environment. This device has two functions: writing a copy of the program and building a copy of itself. This is the essence of so-called von Neumann interstellar automaton; here on Earth the cells of asexual microorganisms grown in a chemostat may be close to such a scenario. Both functions are carried out by metabolic subroutines, which serve both the production of construction parts and their compilation into an identical copy of the interpreter. A machine functioning in this manner could build a copy of itself in one of three ways (or a combination thereof):

1. By building the new machine *de novo* from construction parts it has produced: either they will self-assemble, or the mother machine will help to do this
2. By dividing into two nonidentical parts and completing them from the store of construction parts (modules) synthesized in advance (semi-conservative reproduction)
3. By growth and subsequent division into two identical copies of the original machine
   The task is, in the strict sense, fulfilled only in the first case – in other cases, the original phenotype in fact goes through changes, and there must be a loop in its states that will reestablish the starting position. It is symptomatic that the first alternative is not present in living beings.[1]

Whatever the means of reproduction of our machine, two complications will inevitably arise even in the absence of disturbances from the environment: copy errors (owing to the fact that analogue magnitudes cannot be measured with absolute accuracy) and attrition. The parts – but also the sensors and standards for space, mass and other measures – will be subject to wear and tear, and consequently they will not be able to produce an ideal copy of themselves. It could be argued that one of the program's subroutines might detect and replace the damaged parts, but for this sensors are needed, which themselves are parts of the device. The demand can therefore be satisfied only to some extent – by the high turnover of all parts of the device, including those that execute the turnover. Replacement will become a stochastic process, which necessarily is also prone to error. There are two ways out of this vicious circle, both requiring an external source of information:

1. Invariant factor(s) in the environment that can serve as calibration standard(s): ontogeny and physiology provide many examples of "bootstrapping" in the background of life cycles. The surrounding world thus interferes with the functioning of the machine.
2. The number of replicas of the system is high: those differing from the norm (due to errors) will be incompatible with their environment and will be eliminated. In this case, there is no need for the environment to contain invariant factors. Even in a variable environment, some variants in the progeny *will* cope with the environmental demands.

If we compare both ways, we see that the first is more or less applied in ontogeny; the second is at the core of the Darwinian evolutionary paradigm. In both cases, even

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[1] At this point, many readers may argue that viruses are such an example, but this argument could take us too far. First: is a virus alive? What Is its phenotype during periods when the virus itself does not "exist," when it is reduced to a piece of viral nucleic acid incorporated into a host cell? What is the boundary of the viral organism? We could come to the conclusion that a virus is a very atypical machine that incorporates a large part of the biosphere. We can, of course, pretend that we "know" what a virus is, but the textbook definition does not fulfill the basic criterion of a self-reproducing machine, that is, self-reproduction.

a simple hypothetical system, with a constant genetic program and in a constant environment, will necessarily produce variations. The whole developmental loop will therefore require corrections from the environment (external or internal). But again: Is an organism a machine?

Genotype and Phenotype

If the metaphor of organism as a machine is encountered frequently, it may be worth delineating the boundaries within which it has a heuristic value and beyond which it becomes a caricature. Every biology textbook begins with a statement that organisms have a timeless, enduring component. This is the one-dimensional genetic script, a digital code easily reproducible in a form implemented with nucleic acids and transposable into other media (i.e., magnetic disk or a sheet of paper). The nucleic acid can also be removed from the cell, stored, amplified in vitro, or inserted into cells of virtually any biological species. Copying is highly accurate, and for all practical reasons copies can be considered identical to the original. Mutations – changes in the script – may occur either because the maintenance machinery is not absolutely error-proof or because of external causes. Everything else, the story goes on, in a living cell or an organism is of a corporeal, phenotypic, and therefore ephemeral nature. Living beings embody a tension between an (eternal) genetic code and a (transitory) pattern, or, more precisely, it is we who feel such a tension.

With contemporary biological techniques, it is much easier to study the lasting genetic message than to study phenotypes. This is why the body of (scientific) information concerning the genetic message is much more voluminous than is that concerning phenotypes. It is no wonder, then, that there is a well-established theory that considers genetic script both a necessary and a sufficient *cause* of a phenotype. The theory is based mainly on the observation that a single, nondifferentiated cell (e.g., a zygote) can give rise to a plethora of cell phenotypes, and that these – in the case of multicellular organisms- will build the entire body. Such phenomena, of course, do not necessarily mean causality; causality enters the field only when an *assumption* is introduced that the totality of functioning, differentiation, and ontogeny is a function of the digital information in the form of a linear string of symbols (bases).

Proteins can be considered as connecting links between the genetic information and the body: The machinery of transcription and translation can, to a great extent, be considered as constant and indifferent to whichever part of the information is being read, what proteins are being built, and what proteins were built in the past: The development of the whole system can be seen as an analogue of a computer program: each step of the reading will modify the existing protein context, which will modify the next decision as to which subroutines will be switched on, and so forth. Differentiation and morphogenesis can then be understood as higher steps – reiterations on other levels – of this simple successive program of differential protein synthesis in different daughter cells arising from the zygote (see, e.g., Stubblefield 1986).

If development always starts from a zygote (or a spore) with an identical setup, the genome could be indeed considered a *cause* of the resulting phenotype. Such causality can be proved, for example, by mutations of the genetic text. If everything remains the same, a change in the sequence of bases will (or *may*) elicit a change in the function of a particular protein. This will or may result in a change in the phenotype of a cell (organism), even up to the activation of programs that are normally not in use or even forbidden. In similar cases, the direct causal relationship between the genetic text and the phenotype should be obvious. Hindrances to the construction of an artificial cell able to realize developmental program(s) would then be technical only and would not exist in principle. E. 0. Wilson (1998: 91) compared the task with the Moon mission in 1969: no new principal discoveries were necessary for its accomplishment, only money and technical skill. The "Jurassic Park Fallacy" – the conviction that the knowledge of the complete sequence of DNA of an individual is wholly sufficient for its "production" (resurrection, creation?) – reemerges periodically, not because of science fiction writers, but from the proclamations of serious scientists (at least two such projects of resurrection were announced in 1999 for the Tasmanian wolf and the Siberian mammoth).

But a strictly mechanistic approach may not be satisfactory. Even at the level of transcription and translation, the above model will seem oversimplified. Genetic information is a necessary but not sufficient condition to assign shape, localization and function to a protein that is synthesized. This fact was proved when the first attempts were made to synthesize commercially or medically important eukaryotic proteins in bacteria (genetically transformed with the gene for the particular protein). Transcription or translation generally proceeded without problems, but outside the context of their "maternal" cells, many proteins collapsed into nonfunctional denatured chunks. We are now well aware of the fact that proper reading of the genetic text is a function of a context constituted from hundreds of proteins and other structures. The external and internal environments are sources not only of physical and chemical "forcing" but also of signs, hints corning from other cells and organisms. The receiver will recognize such signals and interpret and evaluate them in the context of other signals and its own experience. All this, together with the high interspecies similarity of genetic texts (recall, e.g., the genetic proximity of humans and chimpanzees), suggests that species-specific morphologies will depend not only on genetic but also on epigenetic interpretation processes. They are "cultural" achievements – results of a "tradition" perpetuated in a given line, as well as of active care on the part of an individual. If we accept such a notion, then life in all its manifestations becomes a hermeneutic achievement.

Where is the "Information" Hidden?

Owing to its usage in many different connotations, the word "information" has become largely devoid of meaning. To avoid misunderstanding, I will try to describe how it is used here. First of all, I maintain, together with Hofstadter (1979), that information as such does not exist objectively. Anything that can become information will do so only if the interpreter can distinguish it from the background *as* a message and is able to interpret it. Hofstadter distinguished three levels of information:

(1) The *frame message* is a clue, a trigger signaling to the interpreter the need for a decoding device. Hofstadter gives the example of a sealed bottle washed up on the seashore, with a piece of paper in it. A learned interpreter will instantaneously recognize it among junk on the beach, as something to be decoded. Note the effort required even in such a simple example. Those able to receive the message as a message must know that a bottle is an artifact and not something commonly encountered on the beach. They must know the common use for bottles – they will not pay attention to an empty bottle or a bottle full of seawater. They should know something about the specific properties of bottles (that bottles will not dissolve in seawater, will float if sealed empty. etc.). They must know the use of paper and distinguish writing from simple dirt. They probably know that messages used to be sent in bottles. All this will arouse a receiver's willingness to focus attention on bottle and its message, and then a second level of deciphering can take place.
(2) To understand the *outer message* means to know how to get an adequate decoding mechanism to read the message proper. In Hofstadter's example, the message *is* in Japanese. The receivers, even if they cannot read Japanese. should be able to decipher that it is in Japanese and act accordingly to find a translator, The message itself cannot serve as a source of information for decoding – the *way of decoding* should be deciphered independently of what the message contains.
(3) The *inner message* is the message proper, which can reveal the meaning. This level is the closest to a receiver, but first the receiver must go through the first two levels of recognition, taking cues from outer characteristics of the information medium. The *experience of the receivers* plays a decisive role here – they must distinguish the message from the background and choose the adequate decoding procedure. Similarly, if genetic messages are to be the *cause* of anything, there must exist a receiver (mechanism, device, "subject") that is able to decipher them *as* such and interpret them. The outcome of such an effort can be, for example, the selection of a particular program and its execution.

But if we take the phenotype as a decoding mechanism, we immediately find ourselves in a difficulty, because the very act of reading the message may – and usually does – change the interpreting device itself. The execution of the developmental program means entering the physical world. This would lead to an endless expansion of new phenotypic variations, which are also subject to change owing to changes in their environment. An incompatibility of the phenotype with the environment would arise, quickly followed by the breakdown and death of our "device." As one of the key programs is the simple command "copy me," which ensures error-free copying of the message itself, we would very soon witness the collapse of the prerequisite of the whole process – the message.

The only way to avoid such a catastrophe is to provide a loop in the program after some steps of execution, leading to the reestablishment of the initial conditions, that is, a copy of the genetic message and of the original reading (interpreting) device – the phenotype. The loop may be reset in several ways. One of them is a limited choice of degrees of freedom – phenotypes- following one after another in an invariable sequence and ending up back in the starting position. One example of such a simple loop is the life cycle of a unicellular organism, for example, a bacterium, which switches periodically between a vegetative cell and a unicellular spore. Environmental factors act as triggers for switching between states, or the organism itself generates endogenous cues (rhythms). If cells of a common origin can cooperate, then cellular phenotypes can arise that do not return to the initial state and die without leaving descent. If there is at least one cell line that can close the loop, there is nothing to prevent the generation of many abortive specialized cell lines, which will help to ensure that the loop is closed by the single line that is able to do so.

In multicellular sexually reproducing organisms *all* cell lines are abortive, and the line of the *organism* can be saved only by fusing two gametes (which themselves are abortive). Hence, an individual comes into existence from a *newly formed* cell line equipped with a specific version of both genetic information and structures. A new generation starts not from a precisely recreated initial state, but with a mélange of genetic programs and construction elements: both the message and the interpreting device are unique. A species will be characterized by an endless number of variants (dialects) of the genetic message – genotypes – and with a similar plethora of interpreting devices. What, then, makes the whole process "species specific" in each individual?

Genidentity

Faced with the enormous variability of living beings, we are confronted with the question of what is that *sameness* that we can recognize in all manifestations of life, and what is the essence of their unity in time? Is it a precisely copied genetic message, a controlled network of relations, or genealogical lines? A very useful concept here might be that of *genidentity*, introduced in 1922 by Kurt Lewin. He posed a seemingly trivial question: How we can know that a thing in time t_1 is the same thing in time t_2? The stone on my desk, or a star in the skies, remains the same despite the possibility that it may undergo some change during the observation period. Surprisingly, says Lewin, it is not easy to explain how we recognize the identity of two objects a and b in two times (a_1, a_2, or b_1, b_2), and why we prefer the relation a_1–a_2 and not a_1–b_2. Even when an object remains relatively stable in shape and material (e.g., a stone, or test tubes in a rack), we often have to rely on a label put on the specimen. It is this identity in time (stone a_1 to stone a_2) that Lewin called "genidentity." The relation of genidentity is not a logical one: from the logical point of view, the object *could* have changed – acquired scrapes and cracks or changed its color, or grew from child to adult, and so forth. This means that the relation of simple identity (*Gleichheit*) does not hold here. Nor can genidentity be reduced to a mere sequence of changes to the object in time or of causal sequences (here the relationship is open: genidentity and causality mayor may not mean the same). Genidentity is the very precondition for the existence of physics or chemistry.

In the case of living beings, determining genidentity is of course not an easy task: How can we assess the genidentity between a chicken and the hen it has grown into? Here, again, if we cannot be absolutely sure (e.g., by witnessing the development of *the* chicken into *the* hen), we have to rely only on labels – for example, a ring on the leg or a DNA fingerprint (and, of course, to believe in the genidentity of such labels).

But what is the essence of the genidentity of two texts, if one is a copy of another and may, moreover, contain typing errors or even word deletions? What is the genidentity of different descriptions of the same thing, landscape, or situation? Such questions become important in the reconstruction of genealogical lines where no label can be placed on the predecessors, and we are left with learned guesses based on paleontology and other traces. A similar situation is encountered in comparative biology. We must believe the experts who have been initiated into a given field, who are able to immerse themselves in the essence of the thing under investigation; that is, we need a hermeneutic task. What, then, connects "the same" in different times and situations? One answer comes from the concept of eidetic biology.

Eidetic Biology

A corollary to both biological structuralism and hermeneutics of the living is the "eidetic biology" developed and pursued by Neubauer (1996, 1997, 2001). The central concept refers to the ancient Greek word *eidos*, which in the vernacular of that time meant something like semblance, likeness, shape, kind. (In Czech texts, Neubauer uses the word *podoba*.) *Eidos* refers to self-presentation or display of a living being to the surrounding world: what it looks like. We recognize a primrose, a lizard, a snowflake, a composition by Mozart, or a person by their *eidos*, the internal characters they communicate to the outside world. We do recognize them at repeated encounters, despite the fact that none of these "specimens" remains the same (see also genidentity, above, and Chapter 3). No two absolutely identical snowflakes have ever been formed: an encounter with any snowflake is in fact different from that with any other. It is its *eidos* that makes us recognize something as *something* – not only by being the same but also by being different. *Eidos* also endows us to recognize – on the background of similarities – *differences*, individual features. Thus, eidetic biology refers to everyday experience (with perception and self-perception, knowledge, memory, etc.) to understand the nature of the living.

Eidos uplifts a mere thing to the realm of both being-like *and* being-different from other specimens of the kind. It allows us to see "the difference that makes the difference" (Bateson's definition of information, 1988) and what is important – ignore irrelevant differences. Such knowledge concerns the very being of the entity in question (I would say, along with Ruyer, that it somehow invites us to participate in its being, instead of only observing what is *objectively* visible, measurable, classifiable from outside).

Eidos thus refers to the essence or identity of a thing, consisting of the unique way in which it *is related* to everything else. This general relatedness makes up both its being and its being-known by others. *Eidos* is what knowledge – and any kind experience – is about. It is the "format" in which the information is received, stored, and processed. This format is the prerequisite of the organic wholeness and any reasonable, meaningful behavior.

One might suspect that *eidos* is simply a disguised Platonic idea. Neubauer's background ontology, however, is somewhat different. The difference, may be illustrated by the English usage of the term "idea." In sayings such as "I have no idea," "It is a good idea," and so forth, the word "idea" belongs to the natural, dynamic sort of being that eidetic biology ascribes to all living existence. The ideas of our everyday experience are being conceived and born *here*. They grow, differentiate, recombine, adapt, compete, survive with fertility, or become extinct. (It is in this sense Bateson speaks about the ecology of ideas.) And, most important, they are not inert rules to obey: they are the very process of self-imitation through inside formation – *in-formation* for short.

That is exactly what *eidos* – the nature of living beings, forms, and processes – is like. Their likeness takes a form of relation of similarity, correspondence, analogy; complementarity. The relation of likeness rests on a reference: whenever we say that something is like something else, we must also state in *what respect*. To see the likeness among things requires us to *under- stand* in what sense they are similar, correspondent, alike. In Neubauer's words, how they are fitted and oriented in the eidetic space. To *know* something means to understand its *eidos*, to enter its eidetic field, and to see in what respect diverse phenomena are related, are but different aspects, cases, versions of the same thing. The eidetic space, once understood, is open for exploration for new possibilities (eidetic variations), following known rules of transformation or discovering new ones.

Understanding, orientation, discovering of new possibilities is knowledge gained by interpretation – that is, a genuine hermeneutic feat. Eidetic biology understands life processes precisely in these terms. It views living beings as eidetic spaces or semantic fields of formative causation. Like knowledge and learning, development and evolution are based on the interpretation of the embodied living experience stored as *eidos*, that is, as a specific formative strategy; way of formation – information, interpreted by imitation within the current context.

At first glance, such an approach to living beings as mindlike existences might seem to be in sharp contrast to the traditional view, according to which the bodily existence is reducible to a particular composition of material parts filling the inert geometrical space. For eidetic biology, the elements of life are elements of meaning rather than chunks of Cartesian space; a mechanism is merely a projection of *eidos* into a geometrical space. But any mechanism is by definition an *eidos* (purpose, strategy; instruction) implemented in a special way of mechanistic causation (as an abacus is an implementation of numbers into strings of beads). To make use of a device – mechanical or not – means to understand it.

Is such a shift of perspective as preposterous as orthodox scholarship holds it to be? In the foreword written for the Czech version of this book (Markoš 2000), Neubauer points out that such a switch of perspective had actually taken place within the womb of the most orthodox and prevailing stream of recent biology – in the neo-Darwinian theory of evolution. The spectacular and celebrated shift from organisms to genes (so-called genocentric revolution; see Chapter 4) meant not just a shift in scale dimension from macroscopic bodies to the molecular level: unwittingly, it was accompanied by a deeper, *ontological* transition, from a material (geometrical, mechanical) existence to the informational one. From the gene's point of view, the competition that is the driving force of evolution takes place not among different living forms, but among different *instructions*, that is, formative strategies, ways of life. Information does not increase through multiplication (redundancy): it is the success to *prevail* – irrespective of the survival of its carriers (vehicles). Information *is* selfish. But its selfishness does not concern quantity, volume, or number of copies, but rather quality, meaning, semantic content.

What is really being selected through natural selection, then, is *eidos*: the form of evolutionary experience stored. *Eidos* is implemented not only in the genetic text, but also in the way the text is used, that is, how it is understood. It refers to its semantic context. The Darwinian struggle for survival corresponds to the "conflict of interpretations" (Ricoeur 1976). A successful interpretation amounts to "fitness" – ability to fit into the given context of relations and communications, to make use of the polysemy of the *eidos*.

> The very nature of Life *as* Life cannot be "survival." A species (*eidos* in Greek, *species* in Latin; in both cases semblance, appearance, expression) is nothing but the "eidetic space" open for any individual to reveal its individuality and originality; in the way an artist, a poet, or a scientist does. Not only are most living beings equipped by a unique version of genetic information, they also represent a unique interpretation of their genetic thesaurus. Any given interpretation – a decision among possible readings – discloses novel possibilities of interpretation (a hermeneutic space), curtailing or excluding the others. Hence, an organism is not merely a passive result of the realization of its "genetic program," but an active expression, an incarnation, a manifestation of a certain interpretation (application) of a genetic recipe. The recipe, in its turn, has also arisen from the mutual competition of different variants of reading. (Neubauer 1996: 21)

Neubauer's eidetic biology puts the established scientific tradition into a larger context of European thought. To disclose and select the link between mechanistic, structuralist, and informatic (syntactic) tradition in biology on the one hand, and the eidetic and semantic side of life on the other, it is necessary to recur to the concepts, notion, and terminology of hermeneutics.

Organisms and the Art of Being Acquainted with the World

I now return to the metaphor of living beings as a natural language and attempt a hermeneutic view. We should be able to work with phenomena such as understanding, memory, forgetting and remembering, invention and intentionality. My approach will stress the historical, that is, the diachronic nature of living beings and their ability of mutual communication (given either by their common origin or by relations that have been constantly enacted). This view does not reject the levels described by neo-Darwinists or structuralists. There is no doubt that natural languages possess means that make it possible both to be highly precise and to save time: various automatisms, phrases, idioms, quotations, styles, and so forth. The point is that these levels are not the *only* means of expression.

"Objective information does not exist without a system, which "accepts" it," states Fiala, who continues:

> Does the system, then, accept information or not? We are so entangled in object language that we invite such questions. Information does exist – we can point to any library. But in what sense does it exist? The text in a book does not in itself carry any information. If you wish to persuade me of the contrary, you will remove the book from the shelf and ask me to read it. Fine: in this instant information receives its "existence," but this existence does not reside in "that information": but in my own structure as an observer. In this sense, there is no such thing as a text without its reader. (p. 46)

To sum up some results of my quest so far: the genetic text, structure, and genidentity are necessary but not sufficient preconditions for the hermeneutics of the living. What, then, do we need in addition? The answer is language, with its discourse. Not computer language with its unequivocally defined concepts, but a natural language with all that it can encompass: its ability to express things in very precise terms, but also its metaphors, ambiguous propositions, wit, and so forth.

What, then, is the Language, and Who is the Speaker?

If the original presuppositions concerning living beings become more and more complicated, if we need more and more new assumptions, additions, and exceptions, their heuristic value becomes obscure. In such a situation, there are two possible outcomes: either to believe that intensive research in the chosen direction will lead to a new level of unification, a new paradigm, or to resign and look for different views, images, and parables. The hermeneutic approach may be one of the options to hand. The conformation of a single protein, the state of a protein network, cell differentiation, an individual – all these can be understood as statements in a given semantic field. To take this approach, however, we must rid ourselves of mechanistic conceptions:

> Are the principles which determine and control the life process at the molecular level, indeed mechanical? I doubt it. We know today that the laws of classical physics describing the behavior of mechanic systems are nothing but averaged demonstrations of the situation in the microworld. The rules of the microworld are anything but mechanical. When speaking of a single molecule of an enzyme whose state is determined by single atoms and particles, to speak of "averaging" is nonsense. In what sense, then, can we speak about "machines"? Yes, we speak of a proton turbine, sodium pump, hydrogen bridges, electron cascades, single and double bonds, but we always should remember that these are examples and conceptions applied to a reality of a completely different order. (Neubauer 1990: 144)

Even if the language metaphors seem strange, the "machine" ones are by no means more natural. I therefore suggest forgetting about inveterate icons of, say, a protein molecule as a very long, intricately folded yardstick of amino acids, of the lock-and-key models depicting binding the ligand, and so forth. Why not take it as a field of force, holonomic and nonlocal? In such a view, conformational changes would become results of reshuffling of the field, expressions of Neubauer's *eidos*. Through a similar prism, we can also observe other "hierarchical" levels and come to a conclusion that, at all levels, living beings have the nature of a semantic field that encompasses all of them. The fields can combine into higher order fields, or disappear- collapse into a mosaic. At some levels – for example, ecosystems – the field character can become suppressed (or simply obscured?); at other levels, it may become obvious.

Whatever happens to living beings is interpreted by experience that is present as a field of different orders; episodes of life become parts of the overall field. The fate of such imprints can vary: they may disappear quickly, become diluted, change their meaning because of a different reading; they may be even absolutized by natural selection as the "only reading allowed."

Science has not paid attention to intentionality, because research was directed from the perspective of large numbers: the phenomena that were studied were those that could be generalized and averaged, and if this was not immediately possible, *standard conditions* were created. From such standardized conditions, science attempted to explain the world. It is obvious that much of what has been found under standard conditions can be also applied to everyday practice: bridges are solid and do not collapse, planes can fly, the Pathfinder will land on Mars, chemical reactions can be reproduced in any laboratory with the proper equipment, inbred mice look and behave identically. All this, however, is no justification for an inductive claim that the world is as it is described. And here science once again comes up against the second branch of human knowledge- call it humanities – which has never ceased to stress the conditional nature of our knowledge. Physicists lived through this encounter some hundred years ago, and biology is (I hope) on the edge of rediscovering it today.

My main effort in this direction is to stress the idea of the semantic field combined with the intentionality of the living, which is the subject of Part III of this book. I ask such questions as, What happens if we try to appoint as the standard observer not the scientist, but living organisms belonging to a given species, with a consensus on how to interpret the genetic text? What happens if we replace the observer with all species on a biotope and determine the consensus to be the behavior of the community? What if we take cells in a multicellular organism as observers, and the consensus as the morphogenetic pathway? My quest proceeds in these directions.

The Speech of Proteins

> When seen from outside, much of biology appears to be the building of data bases – making the "whole life catalog." Sometimes, in a pensive mood, I fancy that to biologists the living world is a vast set of book collections held in interconnected libraries. In this dream, the

> biologists are like competent librarians who devise the most intricate classification of every new library they discover but never read the books. They sense that something is missing from their lives, and this feeling intensifies as new collections of books grow hard to find. I see the biologists expressing an almost palpable sense of relief when joined by molecular biologists who dare to start the even greater task of classifying the words the book contains. It means that the search for the answer to the awesome question of what the books are about can be put off until the new and infinitely detailed molecular classification is complete. – James E. Lovelock

> Cells detect extracellular signals by allostery and then give those signals meaning by "regulated localization." We suggest that this formulation applies to many biological processes and is particularly well illustrated by the mechanisms of gene regulation. Analysis of these mechanisms reveals that regulated localization requires simple molecular interactions that are readily used combinatorially. This system of regulation is highly "evolvable," and its use accounts, at least in part, for the nature of the complexities observed in biological systems. – Mark Ptashne and Alexander Gann

The focus of this chapter is the linear strings of digital molecular symbols, that is, nucleic acids. These molecular sequences are often compared to a code or an algorithm – a program. Here I explore the possibility that they might represent genuine written texts. If so, then how are they read and who is the reader? The metaphor can be formulated in two ways:

(1) The weaker variant will take the set of DNA sequences coding for proteins for a dictionary of "words." The cell is "consulting" the dictionary saved as the sequence of DNA, selecting appropriate words (i.e., synthesizing proteins), putting these words (i.e., proteins) into a proper grammatical form, and embedding them into "sentences" or longer "utterances" that will constitute the phenotype – *parole*. Note the distinction from the more common metaphor of coding sequence: an entry in the dictionary is not the code of a given word.
(2) In the stronger variant, the string of DNA is a genuine text that is read and interpreted by the cell. The cell will behave according to how it interprets the text; the interpretation is based on previous understanding, momentary contexts and/or layout for the future. This metaphor is again in opposition to the metaphor of the genetic script as a program or an algorithm. A text written in natural language is not an algorithm: it requires a reader, not hardware.

Both metaphors stimulate the top-down analysis rather than the more common bottom-up procedures of molecular biology. They offer a complementary view that might, I believe, contribute to a better understanding of what living beings *are*. I appeal to the reader not to take the preceding sentence as an empty phrase: complementarity of the discrete (digital) with the continuous (analogue) may lie at the very heart of understanding the living; their superposition may be the only way to glimpse the *being-in-the-world* of living beings. We instinctively turn toward the digital because it is more easily reproducible, measurable, apprehensible. We tend to forget that the digital text needs a reader whose nature is *not* "digital."

At this point, I take a short digression for those who are not acquainted with molecular biology.

Proteins

A molecule of protein is huge compared to “ordinary” small molecules (a protein molecule can be from several thousands up to millions of daltons in size; compare this with 2 daltons for a hydrogen, 18 for water and 180 for glucose). The function of practically any protein resides basically in two areas: (1) specific binding of ligand(s) (i.e., a small molecule or a small region on a macromolecule) and (2) performing some specific action after the ligand is bound (or released). Any molecule or part thereof can serve as a ligand; the binding takes place in a special region of the protein molecule called the binding site (every ligand requires a specific binding site). The protein molecule can bear several binding sites for different ligands, each usually situated on a different region – the domain – of the protein molecule. The performance of the protein molecule resides in its ability to change its conformation (shape) upon binding of its ligand(s).

This new constellation brings about a specific function for which the protein has evolved. It may help a specific chemical transformation of the bound ligand(s) (as in enzymes), transport of the ligand from one compartment to another (as in translocators), binding of antigen (in antibodies), signal transmission (receptors), and so forth. The given function may require not just one but several identical or different protein molecules that are part of a higher order structure. Such spatiotemporal structures (networks) are typical for both inside the cell and the extracellular space. It is true that many proteins will maintain their specific conformations even when isolated and in a homogeneous suspension, but such conditions are highly artificial. Such a homogeneous space (if it exists at all) is very limited inside the cell – perhaps the content of vacuoles and similar cisternae may be close to it. The cytoplasm; however, is by no means homogeneous,[2] and the same holds for the extracellular space (Fig. 21.1). Space inhabited by bacteria is also highly structured: coatings, sediments, mats, soil particles, and so forth, have a very complicated structure of biogenic origin.

The protein molecule is primarily a: polypeptide, that is, a linear, nonrandom polymer of hundreds to thousands of amino acids. Twenty species of amino acids are being regularly inserted into the protein chains synthesized in cells. This means that within a chain of, say, 500 amino acids, the number of theoretically possible strings is 20^{5OO} -obviously, only a tiny fraction of all possibilities ever came into existence. Only strings that are able to pack into a specific spatial conformation compatible with function were selected during evolution; mutation in the protein

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[2] See, for example, Goodsell (1991), Porter et a1. (1983), Hess and Mikhailov (1995,1996), Ovádi (1995), Schaff et al. (1997), Clegg (1992), Welch and Easterby (l994), Shapiro and Losick (1997), Matthews and White (1993), and Westerhoff and Welch (1992).

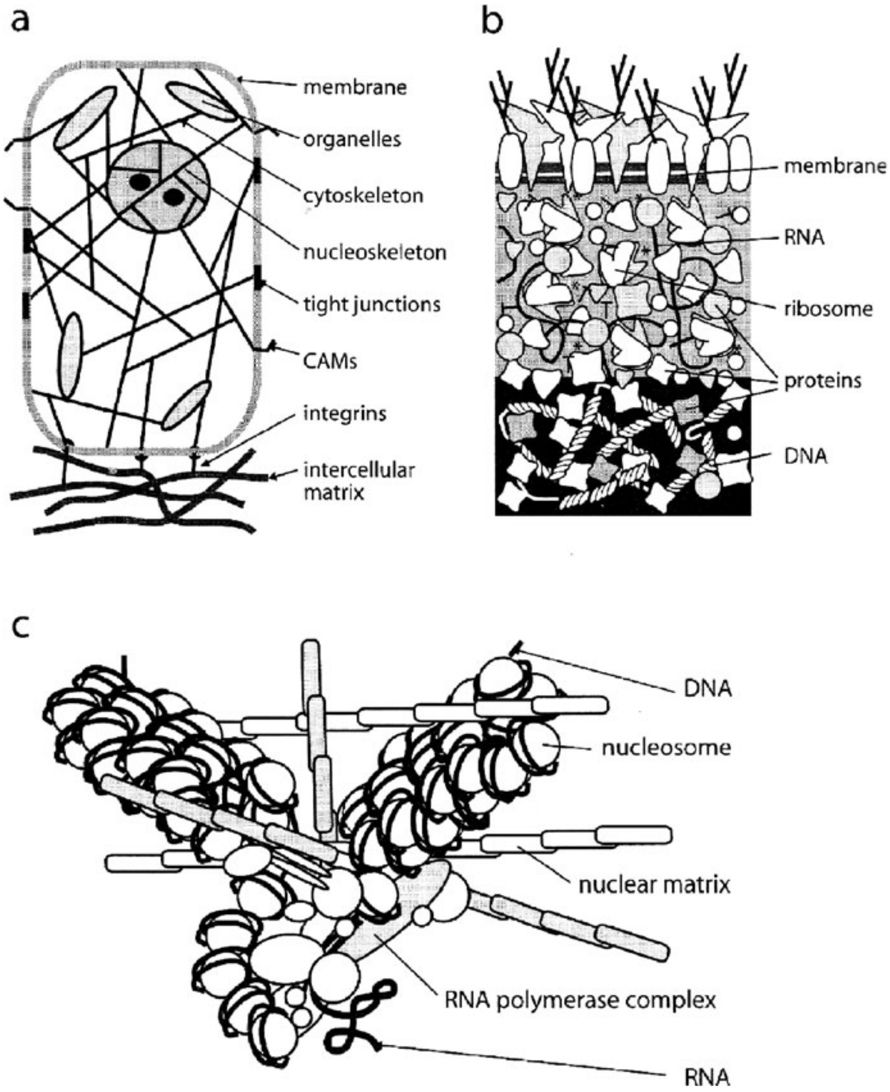

Fig. 21.1 Ultrastructure of the "living matter." (**a**) Ultrastructure (highly schematic view) of an animal cell. Note the interconnected network of cytoskeleton, nucleoskeleton, extracellular matrix, and membranous cisternae of various origins and functions. (**b**) Schematic insight into bacterial cytoplasm. (**c**) The structure of chromatin. Regular "spools" represent nucleosomes with rolled-on DNA. In the foreground there is a segment of DNA freed from such a regular matrix – it may contain a gene that is being transcribed. Round and oval symbols represent the service proteins necessary for such a function (for a more detailed scheme, see Fig. 21.4); beamlike formations symbolize the nucleoskeleton

sequence (deletion, insertion, or replacement of amino acids) can lead to incompatibility with the function of the protein. A protein molecule is not a replicator; that is, the proper succession of amino acids when producing new strings of the kind must be ensured by a medium different from the protein itself. I return to this point further below.

To attain the specific conformation, however, may not be a matter of course for a given string: virtually endless numbers of possible packings of a given polymer exist. Despite this, in a living cell the protein has only a small number of typical, strictly defined conformations that enable it to perform its specific function. Nonfunctional conformations either do not appear or, if they do, are actively detected and either repaired or destroyed. The question of how to ensure that the protein is confined to functional conformations lies at the core of the so-called Levinthal paradox (Ruddon and Bedews 1997; Bryngelson et al. 1995; Bohr et al. 1996): if the functional conformation were sought by a random walk through all possible conformational states, then a chain of the size of an average protein domain (i.e., about 100 amino acids long) would require an astronomical time to do this. A newly synthesized protein, however, attains the conformation required with a half-life of several seconds, either spontaneously or with the assistance of other proteins.

The importance of cellular environment becomes obvious when we compare naturally occurring half-lives of packing with those necessary when proteins are synthesized in vitro. Such molecules either cannot attain the "natural" conformation at all, or can do so only after several hours and only in very dilute protein solutions (fewer than 10 μg/ml; Ruddon and Bedews 1997). In much denser protein suspensions that (to some extent, perhaps) simulate the situation within a living cell, the protein is unable to reach the functional conformation at all – in such a chaotic environment, rapid aggregation and denaturation will occur. It should therefore be postulated that the cellular structures into which the new protein has been born play a key role in the process.[3] But even the time necessary, for in vitro packing is only a negligible fraction of that calculated from the Levinthal paradox. It follows that the primary sequence of amino acids should be considered one of the major determinants of the final shape: at least some protein molecules "know," even if removed from the cellular context and left to themselves, a shorter path to the goal than random searching through endless conformation space.

The function of a protein, and the evolution of this function, is a compromise between two trends concerning the rigidity of conformation(s) required: higher affinity for the ligand can be attained only by more rigid conformation. Rigidity, however, goes at the expense of the performance that depends on ability to switch rapidly between working conformations (see, e.g., Gillespie 1991). Upon finding its ligand, the protein molecule can change between "allowed" conformations either spontaneously or by the action of various specific or nonspecific agents

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[3] If we transform bacterial cells by, for example, mammalian genes, very often we get precipitates of denatured protein. The bacterial cell will truly perform the synthesis of the polypeptide chain, but it is unable to provide conformation information provided by the mammalian cell.

present in its cellular environment. Escapes into abnormal conformations are not allowed.

The Buildup of a Protein Molecule

The textbook icon of protein synthesis – transcription and translation – is summarized in Fig. 21.2a. The shape of the molecule is the function of the sequence of amino acids in the chain; the chain, in turn, was gained by unequivocal decoding (in the process of translation) of another sequence – that of bases in the molecule mRNA. The molecule of mRNA, finally, is nothing but a one-to-one transcription of a special piece in the much longer molecule of DNA. It follows that the sequence of amino acids in a newly synthesized protein molecule is largely, and in some cases (especially in bacteria) even unequivocally, determined by the sequence of bases in the coding sequence in DNA. A decoding machinery providing the task – transcription and translation – must be present in the cell. Side by side with the icon is the "central dogma of molecular biology," that the flow of information is unidirectional, from nucleic acids (DNA or RNA) to proteins. Only DNA is *the* replicator.

The icon is beautiful, economical, and elegant. It enables the construction of causal chains and loops by assuming that a single level – that of DNA texts – is the formative cause of epigenetic structures and processes. These emerge automatically because they are *totally* contained in the genetic text, and the system, led by cues from its environment, is channeled toward one of alternative decoding pathways (i.e., development). The model is compatible with the neo-Darwinian theory of evolution and has indeed become part of its reification.

A more realistic view of the whole process is shown in Fig. 21.2b, which demonstrates that the definition of the coding sequence on the molecule of DNA and making it available for transcription are not trivial tasks. Before RNA polymerase starts with the transcription, dozens of proteins must bind to the whole area of the string containing the coding sequence in question. The binding sites often extend thousands of bases upstream and downstream of the coding sequence.[4] The process, hence, requires change of the whole higher order structure, of which DNA is but one constituent (in eukaryotes, the structure is called chromatin: Fig. 21.1c). Thus, the very beginning of the whole process – the identification and selection of a particular DNA string to be read – can be apprehended as a hermeneutic act of the body searching over the genetic text. A related activity is the determination of the quality of the primary transcripts, that is, the selection of those parts of the gene, which will be transcribed into RNA. The genetic text may sometimes start at different positions (promoters) and end at various termini; in such cases we are confronted, in fact, with a set of (partially) overlapping sequences (see also

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[4] This is why I try to avoid the word "gene." We may define it as that part or the string which is transcribed into RNA – in that Case, however, the definition will not include all the flanking labels. Or we include these regions into consideration, at the price that we cannot sharply delineate the boundaries of the gene.

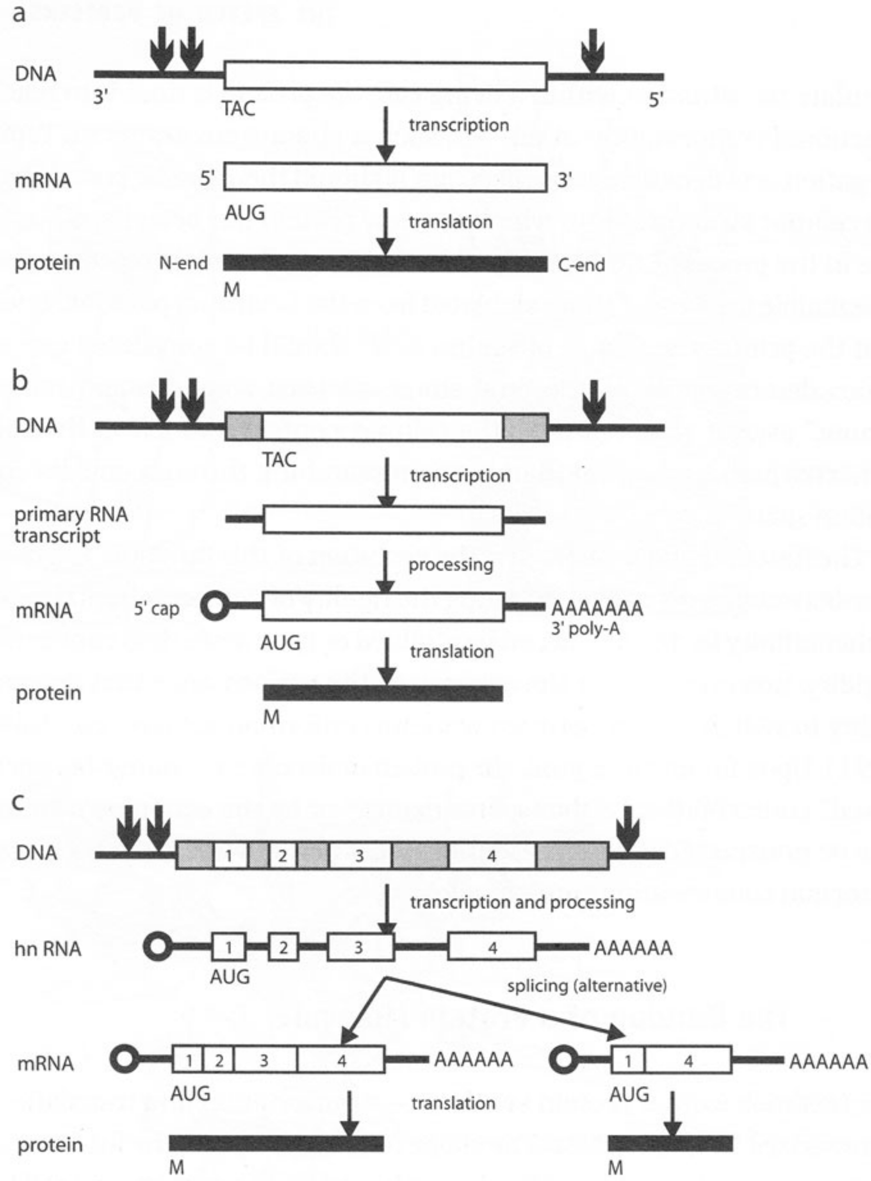

Fig. 21.2 The path from DNA to protein. (**a**–**c**) The first line, 3′ to 5′, is a short piece of a much longer DNA molecule, with the part transcribed into RNA highlighted as a rectangle. In RNA molecules, rectangles highlight parts that will be translated into the amino acid chain of protein. TAC (AUG), initiation codon for the first amino acid methionine (M). Arrows on the DNA symbolize sites for attachment of the transcription complex (*left*; see Fig. 21.4) and the site of its release from DNA (*right*), (**a**). An idealized state: the sequence of amino acids in protein directly corresponds, via mRNA, to the sequence of nucleotides in DNA. Both transcription and translation proceed from left to right. (**b**) The coding sequence is only part of the gene, flanked by transcribed

Fig. 21.3a, b). It must therefore be decided *how* the text will be read. Of course, the ratio of different variants, as well as the rate of the whole process, can also be precisely set.

The primary transcript (i.e., the RNA molecule) may enter into a complicated decision process in which exons (i.e., the parts that will finally become components of the resulting molecule of mRNA) are designated. The rest of the chain – multiple and often very long strings (introns) – is cut out of the transcript and discarded (Fig. 21.2c). Its important to note that the definition of exons and introns in a transcript depends on the cell type and its functional context. Different variants of mRNA – hence different proteins can be obtained from a single species of primary transcript (see, e.g., Barnier et al. 1995; Kornblihtt et al. 1996).

There is no need at this point to go into all the subtleties of RNA manipulation. Instead, I invite the reader to visit a small corner of the protein zoo, which is depicted in Fig. 21.3. Schemes of two related genes, CREB and CREM, are shown in Fig 21.3a. The genes code for a family of similar proteins that are engaged in performing a plethora of regulatory functions in the cell. Even the layman will recognize the similarity of both genes and will come to the conclusion that resulting proteins will probably display similar qualities.

The protein are able – as homo- or heterodimers $(CREB)_2$, $(CREM)_2$ and CREB-CREM – to bind to specific regions of DNA and thus control the expression of great variety of genes. Each kind of dimer can bind to different parts of DNA, thus regulating expression of a different set of genes. Now consider a situation in which only genes CREB and CREM were transcribed from the whole family, and the product of each gene is only a single species of protein. Simply by manipulating the ratio of CREB to CREM, the occurrence of particular dimers would differ substantially and so would the intensity the transcription regulated by a particular dimer. Now imagine the real potential of creating dimers not with two but with the whole set of proteins produced. Figure 21.3b shows some of possible transcripts of the CREM gene. But the story does not end here. Figure 21.3c shows an example of protein products obtainable by further chemical modifications of a single *domain* of protein (see below).

Nursing the Neonate Protein

As discussed above, native protein produced by translation is seldom ready-made, and the site of its synthesis may not be its final location. Usually it is in a "pre-pro" form that requires further processing by a variety of other proteins. Even in

Fig. 21.2 (continued) but untranslated regions. The primary transcript becomes mRNA after derivatization on both ends. (**c**) Standard situation in eukaryotes: the coding sequences (exons, numbered) are interrupted by noncoding sequences (introns). The primary transcript (hnRNA) is processed to mRNA by excising introns and splicing the exons. The splicing can lead to multiple varieties of mRNA, that is, to manifold different proteins that all are products of a single gene (only two shown here)

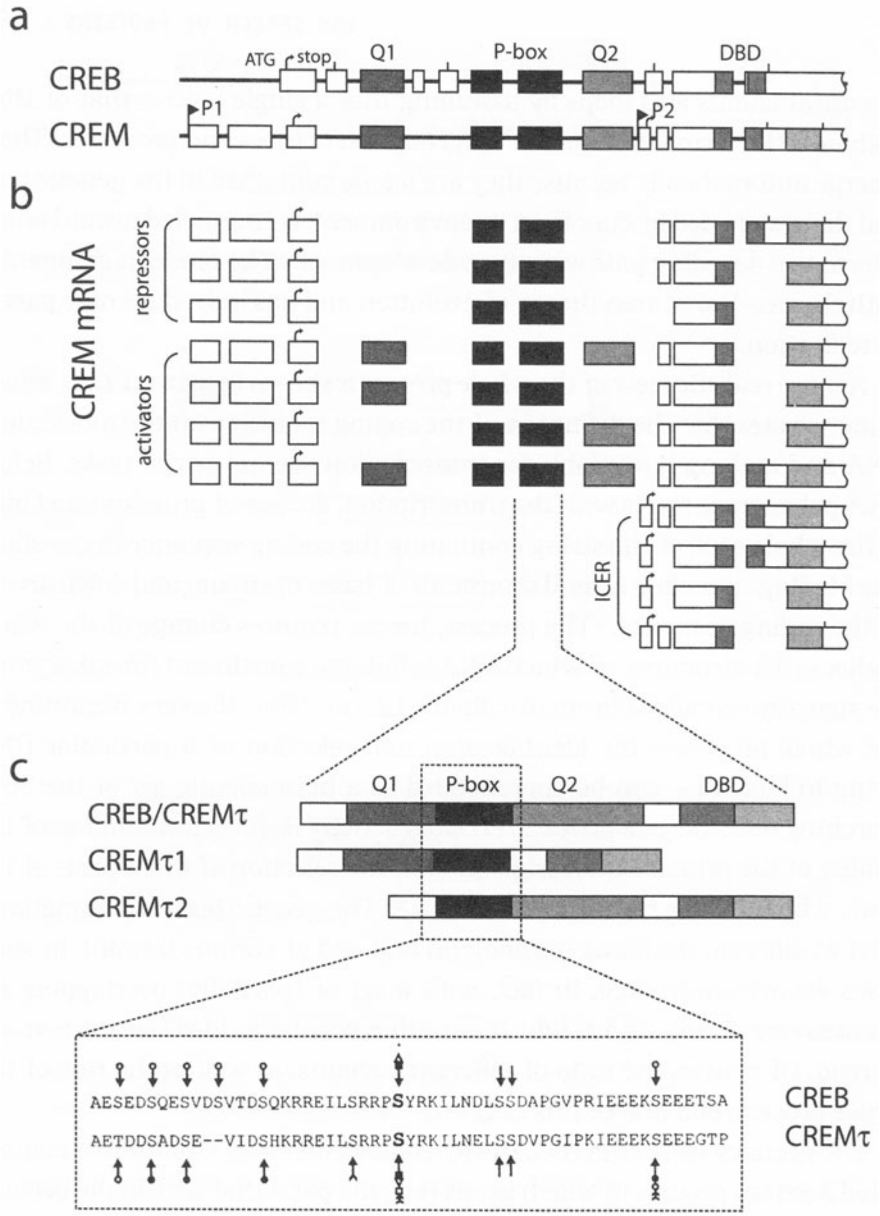

Fig. 21.3 Heterogeneityof transcription, demonstrated for one "family" of regulatory proteins, CREB and CREM. (**a**) Schematic outline of the genes. Note two starting positions PI and P2 in CREM. (**b**) The repertoire of CREM products. Primary transcripts are submitted to processing and splicing, which leads to multiple variants of mRNA owing to the selection of exons. Some known variants of CREM and lCER mRNAs are shown here; the set is, of course, fluid both for a given cell type and over time. (**c**) Regulation of protein activity by reversible

cases when no chemical modification is required, the molecule may not be able to attain the conformation required: help of specific processing proteins – “chaperones” – is necessary. Other proteins will supply post-translational modifications of the native molecule, for example, creation of disulfide bridges, attachment of prosthetic groups,[5] excision of parts of the polypeptide chain, or derivatization of amino acyl residues by glycosylation, lipidation, hydroxylation, sulfatation, phosphorylation, and so forth.[6] Such processing will bring enormous micro heterogeneity to the set of products synthesized according of a single type of mRNA (Fox 1991; Kobata 1992). It will result, in turn, in subtle modification of the function of a particular molecule. The derivatization process may continue throughout the whole lifetime of the protein molecule.

The protein molecule must be also recognized at the site of its synthesis (cytoplasm) and subsequently transported and inserted to target compartment (i.e., mitochondria or the extracellular matrix).[7] The process of localization often starts at the level of mRNA, which may be anchored at a specific site in the cell or even transferred from cell to cell (e.g., in oogenesis of *Drosophila*). Similarly, the newly synthesized protein must be quickly and efficiently transferred to the compartments for which, it is designed. The rapid delivery is ensured by various types of “addresses,” that is, cues on the molecule that are deciphered by the service machinery.

In the development of latent genetic information into the body of the protein, then, we must presume the presence of cellular machinery (or field?) able to perform and control the whole process of proteosynthesis and subsequent embedding of the new protein into the functional context. The very presence of the new protein may change the state of the whole network, and as a result the network may start reading different genetic texts, and so forth. Does the description above differ from that given in any modern textbooks? At the first sight, no. And yet the expression “genetic control” was never used in our story.

◄

Fig. 21.3 (continued) phosphorylation. Above, the protein CREB and three variants of the protein CRBM, each containing the domain called P-box. Below, detail of the sequence of this domain (each letter is a symbol for one amino acid, e.g., S for serine). Arrows point to positions that can be phosphorylated (and dephosphorylated – the modifications are reversible); symbols with arrows designate different protein kinases known to be able to phosphorylate the particular site (protein phosphatases not shown). Adapted from Foulkes and Sassone-Corsi (1996)

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[5] Attachment of prosthetic groups refers to attachment of chemical moieties that are not amino acids and that enable the proper function of the given protein (e.g., RNA in ribonucleoprotein, hemin in respiratory enzymes. etc.).

[6] See, for example, Alix and Hayes (1983), Huttner (1987), Gordon et al. (1991), Lis and Sharon (1993), and Wallis (1995).

[7] See, for example. Shapiro and Losick (1997), Zimmermann (1998), Gorlich and Mattaj (1996), Pfanner (1998), and Pfanner et al. (1997).

Reversible Controls: Chemistry Yields to Semiosis

The system of the epigenetic regulation of a protein molecule has been perfected by the reversible control of protein conformation, which can proceed in parallel in many parts of the molecule. The control can be applied in two ways. The first is *allosteric regulation* by regulatory ligands that bind to specific binding sites on the protein. A second possibility is *chemical modification* of specific groups on the molecule, most frequently phosphorylation and dephosphorylation by a large set of special enzymes – protein kinases and protein phosphatases. These regulatory enzymes are, in turn, also subject to such regulation (Fig. 21.3c).

In the case of allostery, the regulatory ligand can simply be taken as just another ligand that can finely adjust the processes dependent on other binding sites on the protein molecule. Yet there is an important difference here. Regulatory molecules do not belong to the set of common nutrients as do, for example, glucose or oxygen. Nutrients are "utilized" by all cells in a more or less similar fashion. The most prominent property of regulatory molecules is that they play the role of *signs*. The function of a sign may be carried simply by the amount of the signaling molecule, its concentration gradient in the space, fluctuation of its concentration in time, combination with other signs, and so forth. The signaling molecule, therefore, is not a pointer to itself, as in the case of metabolites: it represents something else. This "something else," the *meaning* carried by the molecule, is to be deciphered, interpreted by the cell. And because the signaling molecule refers to something other than itself, it can mediate different meanings to different cells in the body; thus, for example, epinephrine will evoke different responses in the heart, liver or blood vessels. As in the case of reading, genetic texts, here also the specific interpretation has been won by the experience of the cell, organism, lineage, species. There, as here, the given interpretations may be strictly unequivocal, but they can be also flexible, exploratory, putting to trial several possibilities. . . sometimes detrimental, sometimes favorable for the interpreter.

The covalent modification (introduced by specific enzymes) is even more impressive. By this process, a genuine *mutation* is introduced into the protein molecule (e.g., the serine residue in the chain of amino acids is replaced by phosphoserine), with all the consequences such a mutation can bring about to the function of the protein. The number of protein building blocks may thus rise from the initial twenty to many tens of different amino acid residues. What is more important, such "mutations" are to a great extent reversible by the action of other proteins, The protein network thus influences the shape and performance of an individual protein at any given moment (Fig. 21.3c).

The advantage of the above-mentioned regulation is obvious. Instead of harboring many paralogous genes coding very similar, redundant, proteins, only a single crude, half-finished product is coded for. The particular form required is being finely adjusted in the process of protein synthesis (transcription, RNA processing, translation) and ontogeny (noncovalent and covalent modification, addition of functional group, e.g., coenzymes, etc.).

Does not the whole process resemble genuine reading and writing, expressing the right grammatical tense, article, prefixes, and suffixes appropriate for the context, instead of blind decoding the genetic message?

Redundancy: Synonyms in Cellular Functions

Despite the possibility of fine epigenetic adjustment of protein function, many cellular functions are also secured by a high degree of redundancy, that is, by harboring similar paralogue genes. Redundancy, then, is secured either by paralogue proteins expressed concurrently, or by producing a "backup" protein version whenever the primary function aborts. In the first arrangement, the products of different but similar genes will perform different functions, but if one gene of the set is turned down (e.g., by a mutation), the cognate proteins will often take over the missing function and save the normal course of affairs in the cell. In contrast, backup genes remain silent if the master copy is functioning: they become activated only in case of the breakdown of its function (of course, what is backup in one context may be the master function in another). Note that redundancy is typical for regulatory proteins – bypasses in metabolic functions are not that common (Fig. 21.3a; see, e.g., Nasmyth et al. 1991; Brookfield 1997a, b; see also discussion of homeotic genes in Chapter 13).

In language terms, the same meaning can be expressed by synonyms and circumlocutions when the right expression is not at hand.

It is estimated that an average mammalian cell expresses about 10,000 genes (i.e., about one quarter of its genetic thesaurus). About one tenth of them, the so-called housekeeping genes, are engaged in maintaining basic functions – they are uniformly expressed in every cell. The rest of the set differs from one cell in the body to another, depending on its type, differentiation state, and momentary needs. The number of protein forms attained in the way described above may be, as I have shown above, much higher and, moreover, subject to continual qualitative and quantitative rebuilding.

At the microscopical level, the microheterogeneity of both space and time in the cell is enormously complex. This is why it is hard to apply classical chemistry terms requiring high numbers of identical entities (molecules) to environments in the living body. Even magnitudes such as concentration, pH, and so forth, can be defined only very vaguely for such environments. This leads to uncertainties regarding the functional parameters of proteins in their natural environment. Perhaps what is needed is not a chemical theory of life, but a theory of cellular protein neural networks capable of learning, adaptation, memory trace construction, forgetting, and so forth. Such a model could serve as a starting point toward a deeper understanding of the life of the cell. Bray (1995) considers all short-term behavior of an organism to be a result of the activity of the protein neural network; I would go further and apply this to longer time scales. One example of such a subnetwork of an "ordinary" transcription unit is shown in Fig. 21.4.

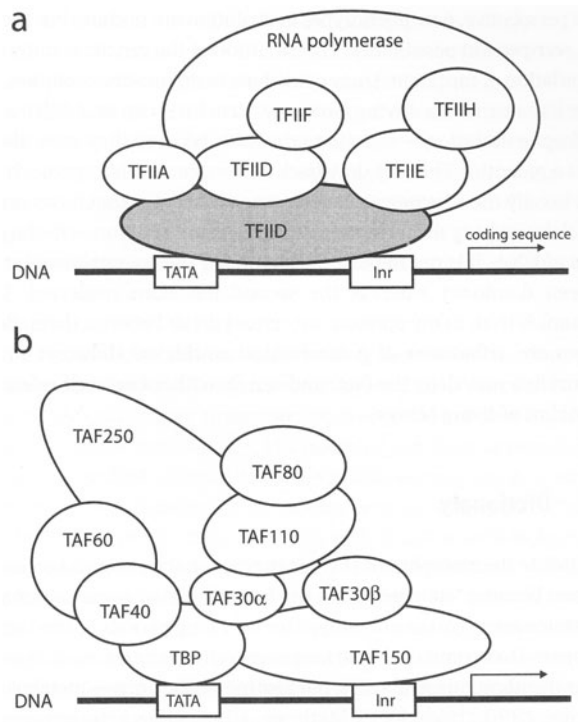

Fig. 21.4 Transcriptioninitiation complex. To start transcription of a coding sequence, RNA polymerase must be brought to a very specific context in chromatin, which is ensured by several protein complexes. Regulatory sequences TATA box and Inr help anchoring the whole complex upstream of the coding sequence to be transcribed. (**a**) Schematic view of the RNA polymerase complex. (**b**) Detail of the factor TFIID, which is itself a complex of several proteins. The whole ensemble is embedded into, and constitutes a part of, chromatin (see Fig. 21.1c)

The scheme, however, is misleading in two respects. First, it gives an impression that the whole protein complex can be neatly distinguished, excised from the cell, and studied as such. In reality, such schemes are our abstraction from the cellular field of which the protein complex is normally part. Second, proteins occurring in the nodes of such a network or field should be taken not as points but as fields in themselves. What is more, the field has been around as long as life itself. The whole edifice, then, can be taken as the semantic field of the cell. Such a field does not implicate the existence of a source, a center of emanation as I have shown in Gurwitschian speculations. The reader could object that the "field" is but a metaphor and that strict determination of cellular function has not been ruled out. No one would deny that *some* strictly deterministic processes do occur in the cell, and that *they* should be taken as the starting point of all the reasoning. I only maintain that automatisms should be considered not a *basic* state from which all extrapolations are to be made but, on the contrary, a highly derived and extreme case. I try to justify this view in the next section.

Note that the whole molecular-biological reasoning could easily be turned upside down to provide a synchronous structuralist model with its network of interactions leading toward phenotypic attractors (faithfully and blindly, as in the preceding case). Here the *structure* becomes the formative cause of living processes, and genes become mere parameters of canalizing functions. In such a perspective, new phenotypes in evolution are nothing but the discovery of ever-present possibilities. The evolution of the genetic text (by, e.g., the accumulation of mutations) may contribute to organismic evolution, but it is neither its cause nor its driving force: new structures can establish themselves even despite mutation – selection processes, because they have always existed as a potential. The only drawback of the structuralist approach is its inability to reify the *structures*, whereas genetics believes that it has performed the trick by reifying the formative principle – information – in the gene, as a piece of DNA. It is not important that one of these complementary views has been dominant whereas the second has been neglected. What is important is that, in my opinion, we cannot *decide* between them. Both are, furthermore, tributaries of a mechanical worldview (however much the structuralists may deny the fact) and can do without any self-reference, intentionality, of living beings.

Dictionary

If we stick to the metaphor of DNA as the dictionary, proteins become words that then become “statements” in the form of higher organizational units. Some statements remain unchanged for very long periods of time and could be compared to various clichés in language (cell structures, such as centrioles or some membranous structures, but also metabolic units – metabolons; see, e.g., Srere 1990; Ovádi 1995; Mathews 1993). Others can be compared to the dynamic and ever-changing flow of speech. An example of the second case may be the short-term coalitions of proteins evoked by the presence of growth factors (see, e.g., Pawson and Scott 1997).

The classic iconography of biochemical textbooks presents a protein molecule as a spatial distribution of beads connected by cords of different strength. In such a representation, a conformational change is coupled with a local disruption of some bonds and the creation of new ones. The word “local” is fundamental in this context, suggesting a final number of interactions, with a conformational change being a process of *gradual* manipulation with each of them separately. The transition between two stable “minima” is thus understood as a passage through a continuum of a great number of intermediary states (defined by their energy content). Problems with this model start when it is declared to be reality itself and serves as a background for generalizing theses concerning cell regulations, differentiation, evolution, and so forth. Moving in such a direction can only end with a machine conception of the cell’s “functioning”:

I suggest an alternative view that I believe will reveal aspects unknown or underestimated by the classic model. Here the protein plays the role of a field with internal, nonlocal rules of conformational transition (it follows that discrete intermediates do not exist). Different shapes (conformations) represent “grammatical forms” obedient to the species-specific “grammar” of the cell. As I have shown, the speaker (i.e., the cell) reigns over an extensive selection of different “words” and “grammatical figures” present as a plethora of protein patterns, of their modifications, and of multiprotein structures. When necessary, new basic forms of "words" can be retrieved from the dictionary (i.e., the genetic thesaurus) and modified in the process of "speech" according to reigning grammatical rules. Elementary protein utterances then assemble into higher order fields (discourses).

Consider, as an illustration, that the word "dog" has many meanings in the English language. First of all, it denotes a familiar domesticated animal. The meaning is then carried over to any carnivore of the family Canidae or, more precisely, the male of such species. The meaning can then be transferred to denote various kinds of unattractive or despicable persons and even to something worthless or of extremely poor quality, or to an utter failure. The word can also be used for mechanical tools. As a verb, it can be used as a synonym of tracking and chasing or for performing perfunctory actions ("dogging"). One can lead a "dog's life" and learn to "let sleeping dogs lie." Add constellations (Canis Minor and Major), hot dogs, dog days, sundog, and dogfish. The word "dog" can have various conformations (dogs, doggy, dogging. . . but, e.g., "doggation" is not allowed in English). Redundancy is ensured by using many synonyms (hound, bitch, mongrel, etc.). The word "dog" bears a "dictionary" semantic field that represents an average value of all meanings; different semantic fields from dog breeding, zoology, poetic language, suburb slang, and so forth, are superposed over the dictionary entry. Still other nuances can be found in individual usage. In the act of discourse, individual higher order semantic fields are constructed. Understanding the meaning of the word as used in a given discourse is a hermeneutic task that will cause the field to "collapse" into a single meaning.

Now, it is true that a language is a kind of "agreement" among the speakers. In English, one can imagine replacement of the word dog by, say, *Hund* or *pes* ("dog" in German and Czech, respectively) or even some invented word like *lihue* (of course, not any word would do, the unpronounceable *ksfrachs* would not be accepted). Perhaps such a replacement would even work, but it would leave a terrible scar on the language for a long time before new bonds to "hot dog," "sun-dog," and the like become established. Isomorphism does exist in other languages – the Polish *dog* and the Czech *doga* for mastiff can be easily recognized, and the same holds for the French *doguin*(*e*) for pug or Czech *buldok* for a bull-dog; in all such cases, however, the transferred word, lacks the original semantic field it had in English and enters the semantic field of the language in question, with completely different grammatical conformations. Finally, one has to learn that the word "dogma" has nothing in common with dogs.

The whole problem of characterizing living processes may perhaps reside in the emphasis that is placed on "processes" rather than on "living." Such a functionalist approach is typical of our civilization and spreads into life, science, medicine, world views, and so forth.

Many of us became totally disgusted by the lessons in our mother tongue at primary school. In my experience with Czech and Slovak schools, through these lessons the language became transformed into "language processes" and required endless grammar exercises and dictations; there was almost no time left for discussion and essays. The teacher unequivocally prescribed the "hermeneutics": she knew how to interpret the text, and the pupils were required only to memorize it.

The situation is similar to many in biology, where specific interpretations found in the textbooks are supposed to be the only ones allowed to be taken into account.

The situation can be compared with that of foreigners learning some words and grammar and being able to compose grammatically correct sentences. These words and sentences may even be fully comprehensible to native speaker but will still look very strange to them, and native speakers would never utter those phrases themselves. (e.g., native English speakers living in Czech Republic are always surprised by the phrase "We shall slowly go." They hear it from Czech visitors who are about to leave. Of course, it is a translation of the Czech phrase used at such occasions. In this case, Native English speakers will even *understand* it, yet they would never *use* it.) Similarly; we move in science into an unknown language with unknown grammar and try, with a dictionary in our hands, to compose grammatically correct sentences.

In the quest to understand living processes, proteins were removed from their cellular context, and their properties have been corroborated in minute detail. Experiments under controlled conditions create a context-free "grammar," similar to giving all the tenses of a verb in a language textbook. Moreover, most knowledge of proteins came from the study of common metabolic enzymes: they occur in high concentrations, can be easily extracted, and remain stable upon extraction, and their properties can be easily studied. These proteins have the same role that grammatical standards play in linguistics and all newly studied proteins are studied in the light of such standards. This approach was, and is, invaluable, especially in the study of the common metabolic enzymes. At the same time, we tend to prescribe only a single "reading frame" for natural "speech acts": only those that were *created* in the laboratory are taken as legitimate.

In the language metaphor, the description of the molecular functioning of cells as relying on automatisms is comparable with the world of laws, public notices, directions for use, recipes and manuals, and, of course, scientific definitions. In all such cases, we tend to encounter simple language, precisely defined meanings of words, and simple sentence structures. The languages of such text forms (of course, only when written carefully) are not problematic, but this comes at a high cost: the meaning can be totally changed or even destroyed by a single typographical error, incorrectly situated negation, or improper synonym. Closer examination would reveal how much effort, processing of the meaning of words, and conceptual refinement has come from the past. What is seemingly simple and uncomplicated carries with it much local and historical context and often cannot be translated to other loci, times, or languages. It is fascinating to consider the presuppositions that should be fulfilled for us to be able to understand far more complex texts, for example, Euclidean theorems.

Even more illustrative is a thesis by Umberto Eco devoted to the genre of comic strips, for which he uses as a sample case one of the earliest comics: reading *Steve Canyon* confronts us with an autonomous genre based on the existence of code shared by the readers. The author of *Steve Canyon* has recourse to this code whenever he has to articulate the message addressed to the intelligence, imagination, or taste of the readers (Eco 1964). Transfer of such structures into a community that does not know them or accepts only some of their facets leads to endless misunderstandings and conflicts and long-winded explanations. Such abbreviations of linguistic, historical, and local contexts, however, represent only a marginal aspect of the natural language. Language is rather characterized by the intentional fuzziness of the means used and, above all, high redundancy of messages. This is why the context will usually smooth over small stumbles; omitted words or spelling mistakes in texts can usually be tolerated without the breakdown of the message.

Metabolic pathways usually proceed automatically – it is a good measure of credibility that they always work in the expected manner. The cell does not have to bother with an accurate study of the situation or go through a laborious decision-making process – things have already been settled and are part of a shared *code*. Automatic reactions save time; they are quick and usually correct. Because of the very existence of the code, the cell can set aside the trivialities of everyday working arid pay more attention to things that *are* truly important. Automatic reactions are characteristic of all levels of living (e.g., cleavage of an egg, gait, instincts, conditioned reflexes, or driving a car). Sometimes there is no way back, and the whole behavior is locked in automatisms (e.g., insect instincts). Sometimes controls allow intervention when necessary (as in driving).

Classic biochemistry came into existence as a description of a biochemical automaton driven by energy potentials, with feedback from the concentrations of metabolites. All the nuances that followed (e.g., regulation of protein function) were absorbed into *this* original conception and became the starting point for expansion to other functions (signaling pathways) and for the description of a cell as such. This approach was conditioned by the existence of defects in the elementary protein grammar, for example, by mutations changing the meaning of the "sentence" (e.g., metabolic diseases such as sickle cell anemia), which is fairly comparable to a typing error in codified sentences in language.

The situation is analogous to the above-mentioned language of notices, comics, road signs, and gestures, where no redundancy is allowed. They represent incredibly efficient abbreviations, but they work "for free" only in the community of users that developed them. Other mutations are not visible at the first sight, but they may supply material for evolutionary modifications.

A protein catalyzing a given reaction or transporting a given ion across a membrane does not usually have many degrees of freedom: it must fulfill the needs of a particular reaction. Different forms of the same protein are usually interpreted as adaptations to a different environment. Two or three replacements of amino acids may be interpreted as a *cause* of why the species inhabits a niche different from that of a closely related species.[8] But living beings need not sit back and wait for an adaptational change delivered by a mutation. A good example of this was recently found in yeast. The yeast cell harbors two types of glucose transporter in its membrane. Changing the ratio of the proteins can optimize the glucose intake in

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[8] See, for example. Gillespie (1991), Zimmermann (1998), Graves et al. (1983), Graves and Somero (1982), and Watt (1977, 1983).

standard environments. In the case of special needs, however, the cell can produce multiple copies of both genes and perform recombination among the "slave" copies (leaving the "master" copies untouched), providing a whole spectrum of transport proteins. The cell is able to experiment with such special copies without changing the "master" copy (Brown and Rosenzweig 1998). Large-scale recombinations taking place in bacteria are described in Chapter 14. In multicellular organisms, similar processes allow, for example, the construction of genes for antibodies and T receptors. But above all, it is in the massive recombination in gametogenesis that new versions of the dictionary are produced. The dictionary does allow adjustments! Another way of achieving an optimal setup is redundancy of performance, that is, a higher degree of freedom, of regulatory pathways, allowing them to express "the same" by different constituents of the pathway or by different pathways.

Proteins Emancipated

The main objective of hermeneutic biology should be to get rid of the genocentric view that takes the genome as a recipe for building the body. It should pose questions about the *builder*, who takes the genome as a mere dictionary of the language in which the recipe is written. Proteins – "words" uttered in the language – enter into complicated syntactic and semantic relations, which constitute the cellular *parole*. The cell is thus a materialized *parole*.

From this viewpoint, we can pose methodological questions about what understanding can be gained from the contemporary genomic era, which is witnessing the acquisition of complete sequences of genomes. The genome is understood as a complete dictionary and source book of a cell, an individual, a species. Comparative analyses will undoubtedly lead to a deeper understanding of the richness and evolutionary position of a given language. But now another step is needed: to proceed from the dictionary to utterances. The field of grammar is being mapped very extensively – for example, regulatory and metabolic networks. A new move in the field is the interconnection of gene dictionaries with protein utterances, as illustrated by the KEGG database (Kanehisa 2000). The semantics of new science is no longer a Cinderella, even if it is still hidden under names such as "mechanisms of the regulation of gene expression."

The utterances of the protein continuum themselves may; in turn, appear to be a higher order dictionary for the ontogeny of a multicellular organism. This aspect is treated in Chapter 13.

The Text and Its Reader

In the 1950s and 1960s, living beings were seen mainly in terms of biochemical pathways and chemical (equilibrium) thermodynamics. Their functioning was limited by energy resources and concentrations of inputs, intermediates, and outputs. Cells were described as machines driven by the difference in the free energy of inputs and outputs. Moreover, the whole image was strictly cyclical. From these cyclical events extrapolations were made to acyclical ones, and ontogeny became a process that is highly controlled by a deterministic genetic program. There is no need to give a full summary here: it can be found in current textbooks and monographs on the topic.

As mentioned above, the older concept of cells as bags full of enzymes and driven by a program was later replaced by the idea of an elaborate network of structures and information flows. Cells have active access to their genetic thesaurus: they select from it and interpret it in an unceasing confrontation with their own time and space (i.e., coordinates within the tissue or organism) and with inputs from their environment. This work with the "source code" is dependent on the quality of the text itself and the "tuning" of the cell (the above-mentioned coordinates. physiology, morphology, and history) and is indeed to be viewed as a hermeneutic task. A medium for this interpretative work, the "search for meaning," is to hand in the form of nonlocal morphogenetic fields, concentration gradients, complicated dynamic networks of macromolecules (extracellular matrix, cytoskeleton, nucleoskeleton), and morphological structures of higher orders and longer duration.[9] DNA is thus far from being the algorithm prescribing how the body will look and how it will behave. It is a genuine text to be read by an *informed* (or better initiated) reader. The cell, the body, is an in-formation of experience (Chapter 3). Information is in fact "contained" in the whole cell, a multicellular body equipped with temporal, spatial, internal, and external cues and rules as to how to decipher the meaning of a great variety of signals. Changes in the interpretation of any of this multilayered information accumulated over billions of years can also be considered mutations and may even result in misinterpretations ending in aberrant development, or tumors, but from time to time also to a new morphological variant.

In the quest to recognize the ultimate and simple causes of life, biology became fascinated by a single kind of molecule: those able to perpetuate their structure – nucleic acids, molecules that can serve as a medium for digital encoding of strings of signs. But, strangely, the situation is reversed: whereas *all* molecules in the cell can indeed be perpetuated over generations, in the case of the molecule of DNA this is not true – owing to recombination processes in gametogenesis! Neubauer, in the foreword to the Czech edition of this book (Markoš 2000), commented:

> What is the difference between the replication of nucleic acids, and repeated chemical production of other molecules? Why only in the first case we have a need to stress the identity and continuity? Is it in the fact that all molecules are "produced" by other molecules, whereas DNA is a product of DNA as its faithful replica?. . . No: nucleic acids must be built enzymatically as any other biomolecules. And they themselves participate in many organic syntheses having nothing to do with production of their own copies. From the chemical and molecular-biological perspective the participation of DNA on its self-replication is of little importance, and all the emphasis given to prefixes "self-" and "auto-" only play on words. The conception that the "cell controls its own replication" describes the cell division

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[9] See, for example, Edelman et al., (1990), Müller (1996), Gilbert (1994), and Wolpert et al. (1998).

> truly; in contrast, the phrase that "DNA controls its replication" will hardly do justice to the essence of replication. (p. 18)

The difference is in the different order of being. Bodies and their parts (cells, organs) do appear again and again in each generation, as do molecules, but they can only more or less resemble each other, whereas molecules can be absolutely identical. This is because bodies are from the order of Neubauerian *eidos*, whereas simple molecules are from the order of *structures*. Individual but identical molecules will – under given conditions – behave uniformly; the rule does not hold for individual living bodies. I maintain that proteins are of the order of bodies, not structures or molecules in the sense in which the term was developed for particles of simple chemical species. A lot of effort must be developed in the laboratory to restrain their hermeneutic properties and to study them as *molecular* entities.

Epilogue

I am deeply convinced that a single objective and noncontradictory view of the world is impossible, and that for this reason we cannot limit ourselves to a single preferred image of the world. By "we" I mean all cognizant beings – not only humans with their culture and history, but all living beings. We all learn, on short time scales, to breathe in this world, into which we were thrown as the smallest branches of the tree of life, which has lasted for four billion years. Our "thrownness" is based on the fact that our predecessors left at our disposal a digital text-the inscription of experience – that is to be confronted with the world we belong to. They also left behind their experience, embodied as our nature, our bodies – or rather, the knowledge of how to build them. The environment, the frame for our thoughts and behavior, ideas about what is adequate (equity, *epieikeia*, decorum), belong to another class of legacy. Because of these two kinds of tradition, we feel at home in our world. But "being at home" is not an obvious and automatic state – it requires a high degree of hermeneutic effort. The common world in which we all participate often requires a radical change in our system of values. Nothing is "made" forever, "so that": cultures that relied on the constancy of the world collapsed in the first breeze that came from an unexpected direction. The same holds for species, which in this book I have compared to cultures. We do not live in a gradualist world lasting for millions of years, which has brought about a perfection of forms and physiology, tending toward perfect harmony! The game is still going on here and now; with all the equipment at hand. Species – cultures that cannot revalue their being according to the demand of time – must yield to other, more flexible outlines. The past and the future serve as prompts. The sociobiologists (sorry: evolutionary ethologists) are right in that we carry with us all sorts of ballast that – *once, and in certain contexts*- appeared to be useful. But the Golden Age with a constant environment never existed – in the past, as now, hypotheses about the world were in mutual conflict, and to be able to decide between them was, and is, a hermeneutic task (or art). We carry past layouts, and in the context of the present instant we reappraise, modify, recall or forget, pick up or throw them away, sometimes with fatal consequences, sometimes with an aspiration to reach the stars.

The hermeneutic endeavor is very demanding of intellect, time, and resources. But what kind of creature is hidden under the notion of "hermeneutic biologists"? What do their working hours look like? Well, you will not recognize them by their doings-they are busy performing standard biology like anyone else. Maybe in the introductions and discussions of their papers you will recognize slightly different accents and suggestions (see, e.g., the slight wording modifications illustrated in the introduction to part III) opening new realms within the framework of the current paradigm – no revolutionary zealots changing current paradigms! They know that plurality of view is the most precious gem in the quest for wisdom.

I strongly believe that an organism cannot be defined solely in terms of thermodynamic, biochemical, and information magnitudes. If we want to understand the difference between living beings and machines (however complicated), then meaning (i.e., an internal interpretation of the situation, not forced on us from outside) should become the central focus of our interest. It is here that, in my opinion, the border between the living and nonliving lies. Understanding the hermeneutic situation present in us, in all living beings, is one of the first steps on our long path in such a direction.

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Chapter 22
The Cybersemiotic Model of Communication: An Evolutionary View on the Threshold between Semiosis and Informational Exchange

Søren Brier (1951–)

Introduction and Commentary: Søren Brier

> *In establishing a new framework, I also hope to create a third culture, one that transcends the incommensurability between C.P. Snow's two cultures: science-technology, and the humanities versus social sciences. I am trying to draw a map onto which a multitude of viewpoints can be plotted and their subject areas characterized and compared with other approaches. By erecting this framework, I hope to expand the dialogue between sciences, the humanities, the social sciences, philosophy, and the existential quest to broaden our concept of* reason *in accordance with my stance towards making common frames for the open and systematic pursuits of knowledge and meaning.*
>
> S. Brier (2008: 13)

Because the domain of investigation that biosemiotics encompasses – i.e., the investigation of sign use, as it may be observable in the activity of any living system, at any level of its organization – is so diverse and complex, the accomplishment of interdisciplinary synthesis and the search for unifying explanatory principles have become increasingly pressing concerns. Having devoted over twenty years to a focused attempt at synthesizing insights from first- and second-order cybernetics theory, ethology, sociology, embodied cognitive science and philosophy of mind within a framework of Peircean sign logic, Danish biosemiotican Søren Brier has articulated a *cybersemiotic* framework for the understanding of animal and human evolution, communication, and cognition.

Winner of the prestigious Warren McCulloch Award from the American Society of Cybernetics in 2008, Søren Brier has long been recognized as one of biosemiotic's most interdisciplinary thinkers. Born in Copenhagen, Denmark, on July 12, 1951, Brier undertook his Master's Degree studies in biology from the University of Copenhagen supplemented with courses in psychology and brain processes, comparative psychology, and philosophy of science, earning his degree with a thesis entitled "A critical and historical examination of ethology's explanatory concepts of perception, motivation and action" (*Adfærdens årsager*) that foreshadowed much of his later writings in biosemiotics. Indeed, Jesper Hoffmeyer's early writings in Danish had inspired much of Brier's own thinking at this time, and Hoffmeyer himself was a member of Brier's evaluation committee. Awarded a gold medal in psychology for his essay on "the usefulness of hierarchical and probabilistic

D. Favareau, *Essential Readings in Biosemiotics*, Biosemiotics 3,
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models of motivation" Brier was simultaneously awarded a research fellowship at the Psychological Laboratorium at the University of Copenhagen from 1981 to 1983, in order to continue research into the evolution of human cognition, signification and communication. His participation in the variety of interdisciplinary discussion groups then revolving around such topics led him into the orbit of Jesper Hoffmeyer's nascent biosemiotic community (which was then meeting under the name of the Danish Society for the Semiotics of Nature) in 1986.

That year also, Brier founded the interdisciplinary journal *Paradigma*, which, through his collaboration with his colleague Ib Ravn, expanded Danish interest in second order cybernetics and autopoiesis theory. Brier was editor of this transdisciplinary journal, which attained a circulation of over one thousand copies per issue in Denmark, until 1990, when the journal came to the attention of American Society for Cybernetics president Fred Steier. The overwhelmingly positive reception that his idea received at the ASC led eventually to Brier replacing *Paradigma* with the founding of the peer-reviewed quarterly *Cybernetics and Human Knowing* in 1992, with the collaboration of Steier. Supported by researchers such as Humberto Maturana, Francisco Varela, Heinz von Foerster, Niklas Luhmann, Dirk Baecker, Thomas Sebeok, Claus Emmeche and Jesper Hoffmeyer, Brier he continues to edit *Cybernetics and Human Knowing* to this day.[1]

In 1994, Brier earned his Ph.D. in Philosophy of Information Science at the Institute for the Study of Mathematics and Physics at Roskilde University, Denmark. He was awarded the terminal D. Phil degree in 2006, and is currently a Professor in the Semiotics of Information, Cognition and Communication Sciences at the Department of International Culture and Communication Studies at Copenhagen Business School. Since 1979, Brier has published over 170 scholarly articles, as well as six books in Danish, and one in English (2008). This latter volume is entitled *Cybersemiotics: Why Information is Not Enough* and is the culmination of his thirty year effort to forge a scientifically viable interface between cybernetic information science, autopoiesis, system theory, epistemology, and a Peircean based biosemiotics.

Christening this explanatory and investigative framework "*Cybersemiotics*," Brier's work proceeds from a grounding in the cybernetic theory of complex, adaptive systems, as it has developed from Norbert Wiener's (1894–1964) mechanically-inspired feedback models – or "first-order" cybernetics – through the observer-implicated "second order cybernetics" of Gregory Bateson (1904–1980) and Heinz von Foerster (1911–2002), and as it has later been extended specifically into the biological realm by Humberto Maturana (1928–) and Francisco J. Varela's (1946–2001) concepts of *autopoiesis*. Maturana and Varela understood their 'autopoietic'

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[1] Brier's editorial and committee work – like his scholarly output – is prodigious, as he also serves on the Editorial Board of the journals *System Research and Behavioral Sciences Biosemiotics, The Journal of Trans-person Studies, Triple C: The Journal of Cognition Communication and Cooperation* and *Signs*, and on the Board of the Science of Information Institute, the Foundation of Information Science, and the Sociocybernetic Research Group of the International Sociological Association.

framework as an attempt to explicate the ways in which an organism continually self-organizes and self-maintains itself, yet remains ‘structurally coupled’ to its environment. Niklas Luhmann (1827–1998), in turn, built upon Maturana and Varela’s ideas in an attempt to understand both social communication and the structure of the individual human psyche as semi-autonomous systems that are yet deeply inter-connected through the process of mutually inter-penetrative structural coupling.

After having worked within this broad “cybernetic” tradition for many years, however, Brier comes to the conclusion that – for all of their otherwise critically important explanatory power in addressing the very real phenomena of decentralized, emergent organization in complex systems – neither any of the existing “first-order” *nor* “second-order” cybernetic frameworks (including the systems theory of Luhmann) can satisfactorily account for the phenomena of genuine signification and *subjectivity* in the natural world – much less for that species-specific variety of subjectivity that manifests in the multi-leveled cybernetic organization of human beings as “first-person experience.”

Yet because the biological specificity of animal subjectivity plays such an important role in the co-evolution of species, however – and because the semiotic specificity of human subjectivity is inextricable from even the most “objective” scientific explanations of phenomena (as physicists such as Einstein and Heisenberg remind us) – Brier, along with many another biosemiotician, understands that one of biosemiotics’ most important tasks at this time is to rehabilitate and to restore to the concepts of signification, meaning and “subjectivity” as a naturalistically understandable and scientifically examinable phenomenon.

Accordingly, Brier finds both Charles S. Peirce’s semiotic triadic logic and Jakob von Uexküll’s *Umweltlehre* to be particularly helpful correctives to the explanatorily unsatisfactory “two-valued logic” of organism-environment duality still endemic to much cybernetic theory. For example: Maturana and Varela, he notes,

> see autopoietic living systems as ‘closed’ in their spatial and temporal organization and reproduction. They are only ‘open’ to the world through their structural couplings with it. Multicellular organisms are second order couplings among cells, and societies are third order couplings among organisms. Luhmann turns this into a view of social organizations as autopoietic systems created by communication … [Yet, he, too] has conceptualized the three biological, psychological and socio-communicative levels as closed systems. Although they are all present in the human being and functioning between them, there is no direct ‘inner connection’ between them (2001: 798–799).

Understanding the inter-penetration taking place between such multiply embedded and interdependent systems is the project of Brier’s *cybersemiotics*, which weds insights from second-order cybernetic theory with insights from Jakob von Uexküll’s *Umweltlehre* and from Charles S. Peirce’s systemic logic of sign relations. Uexküll’s *Umweltlehre,* notes Brier, does not artificially separate organism and environment – and by so not doing, provides the framework for an “intrasemiotic” understanding whereby *meaning* can and does arise from the interactional “closure” afforded by the generative functional cycle of perception, action and consequence. Truer to the always subject-implicated processes of biological organization than are the machine-like descriptions of traditional cybernetic theory, Uexküll's *Umweltlehre* insights constitute a necessary but not sufficient emendation to the very real insights that cybernetics gives us into how complex systems work. Accordingly, Brier updates and expands upon Uexküll's "cryptosemiotic" concept of *Umwelt* within a Peircean and biosemiotic evolutionary paradigm, rechristening the expanded concept, a "signification sphere" (2008: 32–34 *et passim*).

Yet, because Uexküll's *Umweltlehre* is itself grounded in a Kantian metaphysics, notes Brier, it can no more account for the veridicality of sign relations than can Kantian epistemology. "The conflict," John Deely writes succinctly, "is between an idealist perspective – in which the mind knows only what it constructs – and the semiotic perspective, in which what the mind constructs and what is partially prejacent to those constructions interweave objectively to constitute indistinctly what is directly experienced and known" (1990: 122).

To accomplish this final "organizational closure" between organisms and environment (including, in the human case, the environment of "culture," or symbolic reference, as described by Terrence Deacon in Chapter Eighteen in this volume), Brier finds that the incorporation of Peircean pragmatic realism is needed in order to naturalistically explain both how veridical, real-world knowledge is possible and how such knowledge is and must always be, just as Peirce affirmed, "doubly grounded" – with one foot firmly rooted in the existing patterns of mind-independent reality, and the other just as inextricably planted in the observer-specific *umwelt* of inherited and ongoing biological constitution, epistemological history, and interpersonal social practice. Within such a framework, Brier introduces the technical terms "pheno-semiotics", "thought-semiotics," "inter- and intra-semiotics" and "sign games" – the latter of which supplies a semiotic foundation for understanding both Winfried Nöth's "ecosemiotics" as well Ludwig Wittgenstein's (1889–1951) more restricted anthropocentric concept of "language games".

In sum, for over twenty five years, Søren Brier has labored upon the development of "a philosophical framework for a trans-disciplinary information science or semiotic doctrine" that is deeply informed by, yet cognizant of the limitations inherent in, the wide variety of "mechanical-materialistic, pan-informational, Luhmanian second order cybernetic, Peircian biosemiotic and pan-semiotic approaches" that have been developed thus far (2003: 71). The result of that labor is Brier's original construction of a five-levelled *cybersemiotic* framework consisting in: "(1) a level of Peircean Firstness [cybernetic 'difference'], (2) a level of mechanical matter, energy and force [Peircean Secondness], (3) a cybernetic and thermodynamic level of *information*, (4) a level of sign games [broadly conceived] and (5) [in humans,] a level of conscious language games" (*ibid*).

As is the case with all of our other authors, however, there is not space here to explicate, even in summary fashion, Brier's entire explanatory and investigative conceptual framework for the examination of the role of meaning in nature and in culture. Rather, and has been the practice throughout the rest of the volume, we have chosen to reprint here a brief selection that introduces one small part of the author's larger explanatory framework, in the hopes that that will inspire the reader to consult the larger corpus. Brier's 2008 monograph *Cybersemiotics: Why Information is Not Enough,* presents the Cybersemiotic framework in its fullest and most current form to date, but here we have chosen his 2003 article, *The Cybersemiotic model of communication: An evolutionary view on the threshold between semiosis and informational Exchange* to introduce the reader to Brier's work. In this paper, Brier develops the framework of "intra-semiotics" for use in the study of the necessary acts of inter-penetration taking place within the multiple autopoetic systems (i.e., ontological, biological, cultural-communicative, and phenomenological) that organisms are both themselves, and are immersed in – and the subsequent emergence of those overlapping "signification spheres" wherein alone *meaning* can be made.

The Cybersemiotic Model of Communication: An Evolutionary View on the Threshold between Semiosis and Informational Exchange (2006)

Abstract This paper discusses some of the various suggestions that have been put forth for a philosophical framework for a trans-disciplinary information science or a semiotic doctrine. These are: the mechanical materialistic, the pan-informational, the Luhmanian second order cybernetic approach, Peircian biosemiotics and finally the pan-semiotic approach. The limitations of each are analysed. The conclusion is that we will not have to choose between either a cybernetic-informational or a semiotic approach. A combination of a Peircian-based biosemiotics with autopoiesis theory, second order cybernetics and information science is suggested in a five-levelled cybersemiotic framework. The five levels are (1) a level of Firstness, (2) a level of mechanical matter, energy and force as Secondness, (3) a cybernetic and thermodynamic level of information, (4) a level of sign games and (5) a level of conscious language games.

These levels are then used to differentiate levels of information systems, sign and language games in human communication. In our model Maturana and Varela's description of the logic of the living as autopoietic is accepted and expanded with Luhmann's generalization of the concept of autopoiesis, to cover also to psychological and socio-communicative systems. Adding a Peircian concept of semiosis to Luhmann's theory in the framework of biosemiotics enables us to view the interplay of mind and body as a sign play. I have in a previous publication (see list of references) suggested the term "sign play" pertaining to exosemiotics processes between animals in the same species by stretching Wittgenstein's language concept into the animal world of signs.

The new concept of intrasemiotics designates the semiosis of the interpenetration between biological and psychological autopoietic systems as Luhmann defines them in his theory. One could therefore view intrasemiotics as the interplay between Lorenz' biological defined motivations and Freud's Id, understood as the psychological aspect of many of the natural drives. In the last years of the development of his theory, Lorenz worked with the idea of how emotional feedback introduced just a little learning through pleasurable feelings into instinctive systems because, as he reasoned, there must be some kind of reward of going through instinctive movements, thus making possible the appetitive searching behaviour for sign stimuli. But he never found an acceptable way of modelling motivation in biological science.

Here I am suggesting a cybersemiotic model to combine these approaches, defining various concepts like thought-semiotics, phenosemiotic and intrasemiotics, combining them with the already known concepts of exosemiotics, ecosemiotics, and endosemiotics into a new view of self-organizing semiotic processes in living systems. Thus a new semiotic level of description is generated, where mind-body interactions can be understood on the same description level.

Introduction

What are information, cognition, meaning, intelligence, mind and communication? How did mind emerge out of natural evolution? What is the difference between animal, human and machine intelligence and communication? What is the difference between physical and informational interaction? And, further, between the informational and the semiotic (sign level) and again language interactions. What and where are the thresholds?

This article deals with the threshold problem in semiotics and information science in the broader context of the attempts to make general scientific theories of information, cognition and communication as we see, for instance, in the cognitive sciences' information processing paradigm (Brier 1992). The foundation of information science international transdisciplinary group (FIS) has for more than ten years discussed possible ways of making a broad philosophical framework to understand basic concepts in a transdisciplinary information science. I am one of the few biosemioticians in this group.

The purpose of these transdisciplinary theories is to help us frame the problems of understanding man-machine interface, intelligence and linguistic interaction amongst other things by clearing up the epistemological problems of the difference between how digital machines work, and how living systems perceive, think and communicate. Furthermore, it is to find out what the physical, chemical, biological, psychological, and social foundations of communication are.

I want to discuss the question of threshold in a broader epistemological and ontological context of the metaphysics of knowledge systems and further in a philosophy of science context, taking into consideration Peircian semiotics, cybernetics and information science (Brier 2000a, b, c). The relation and conflict between informational and semiotic approaches comes into focus in this context. As we shall see later, the semiotic threshold discussion is very similar to the problem of whether objective information exists in nature, as required by the pan-informational paradigm.

I view the threshold discussion as situated at the crossroad of the scientific worldview and its cybernetic theory of information, general epistemology, the biopsychological theory of cognition and semiotic theory of signification. It is a most interesting point where our conception of nature/reality, cognition, communication and the nature of knowledge, and our understanding of the human mind and the relation of mind to matter are all involved at the same time. The threshold discussion has also been going on for some time within the context of the informational paradigm (Ruech/Bateson 1987: 67). Both the informational and the Peircian semiotic paradigms are transdisciplinary paradigms (Deely 1990) suggesting solutions to our scientific problems of making a unified theory of nature, cognition and mind. This is contrary to the traditional mechanistic scientific paradigm, where the concept of mind as inner life has to be outside of the theory.

In their pan-version (everything is information or everything is signs) they both suggest that the connection between mind and nature is either informational or semiotic, which are in our mind as well as in nature. The pan-views make radical changes in our conceptions of both mind and nature

1. The informational paradigm makes nature full of information and understands our mind as a computer. But it cannot encompass a theory of meaning and signification.
2. The semiotic paradigm makes all nature signs but tends to deplete the living of any special significative abilities, and it tends to remove the idea of an independent reality from physical nature.

On the other hand, the original mechanistic framework of classical physics did not encompass concepts of information and meaningful signs at all. In previous papers I have pointed out how pan-informational and pan-semiotic paradigms seem to compete in covering the same subject area with a new transdisciplinary framework (Brier 1992, 1999a, 2000a), each with specific advantages and drawbacks. I have attempted to develop a non-reductionistic framework encompassing them both called Cybersemiotics (Brier 1995, 1998a, b). This approach tries to deal with the profound epistemological problems whose importance phenomenological philosophy (Kirkeby 1997) has shown. By working it out, an attempt to make a framework for studies of human cognition, understanding and language is launched, which at the same time attempts to state the prerequisites for any scientific endeavour as such (Brier 2000d). Peircian semiotics, with its blend of phenomenology and pragmatics, is therefore one of its foundations.

On this basis, I want to show how Cybersemiotics, through a series of models, can describe the differences and continuity between inanimate and animate systems, between living and socio-linguistic systems, and between those and mechanical and cybernetic informational digital systems (mostly machines).

Previous Paradigms of Mater, Mind and Meaning

To clarify the problems, let us start by analysing paradigms that attempt to explain the whole area from the foundation of nature to human intelligence, consciousness and communication, or put in another way, explaining from the laws of nature to the meaning of humans in culture. I will then discuss the limitations of such enterprises in general. Then I will look at the shortcomings of every paradigm. I will then construct a coherent framework, building on the viable parts of each (cybersemiotics). Finally, I will present a model of the prerequisites for human communication, concentrating on the informational, semiotic and linguistic aspects of embodied human communications.

At present, I can see six basic significant models within science trying to cover the whole range, from the basic patterns, laws and forces of inanimate nature to the phenomena of life and consciousness within one paradigm and a few all-encompassing basic concepts

1. *The mechanical materialistic metaphysics* that refuses to talk about information and signs in nature including animals. It often presumes that the phenomenon of thinking in meaningful signs, within humans, is not connected to consciousness or sometimes not even to intentionality. These understandings are often grounded in the view that these phenomena are illusory (eliminative materialism) [references, e.g., Rorty, Paul Churchland]. This means that they do not consider intentionality, free will and consciousness to have any real causal effects on things in the physical/real world, including our own bodies. The difference between the physical, the chemical and the biological level of reality is only seen as a consequence of organisational levels.
2. Pan-informational metaphysics where information is seen as an objective part of all nature and culture like matter and energy. Already in 1929 Szilard suggested a converse relationship between information and entropy, referring to Boltzmann's thermodynamics, or statistical mechanics. Shannon and Weaver (1949), in fact, referred to entropy in their own work as well, mainly because of similarities with the equations that dealt with statistical events – equations originally written to describe the outcomes of games of chance. But it was Norbert Wiener (1961) who took the full step and declared that information not only is not matter or energy, but that thermodynamic entropy is the opposite of the statistical concept of information (Brier 1992) defined as neg-entropy. This approach was supported by Schrödinger (1967) in his book from 1942 What is life? (which places him before Wiener, Shannon and Weaver) and later by Ruesch and Bateson (1987, org. 1967), carried into Bateson's (1973) Steps to an Ecology of Mind, and further developed by Tom Stonier (Stonier 1997) just to mention a few important figures. The result of all this was that information came to be viewed as the opposite of entropy. Information could be understood as constructing order in the face of disorder. Prigogine's (Prigogine/Stengers 1984) self-organizing, dissipative structures can be seen as gathering not only organized energy, but information, and simultaneously dissipating energy and making entropy grow.

   Thus, the concepts of energy, order, and information, on the one hand, and entropy, disorder, and loss of information on the other, became connected in such a way that we perceive information as having something to do with patterned organization and the reduction of uncertainty (Combs/Brier 2001). Information is then seen as the organizational aspect of nature. Stonier (1997) even talks about "the infon" as a basic constituent of nature, much like MacKay (1969) SAW "the logon" as the unit of destruction in the physical case.[2]

   This approach is most often developed within a first order cybernetics metaphysics, which sees the world coming into being as a self-organized system consisting of other self-organized systems. For Wiener and Bateson the breakthrough was to unite the theory of information with the Bolzmanian interpretation of thermodynamics and thereby overcoming the Cartesian duality of

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[2] Thanks to John Collier for pointing out MacKay to me and for his most valuable critique of an earlier version of the manuscript.

mind and matter, but they did not manage to develop this into a full-fledged metaphysics.

Many other cyberneticians working with this general model clearly take inspiration from Bertallanffy's General Systems Theory. Here the anti-dualistic view is based on an organismic evolutionary worldview including a theory of emergence and holism with a belief in some kind of continuity between mind and matter that is quite close to Peirce's, but lacking his triadic philosophy. This metaphysical aspect seems to be overlooked by many modern theorists, such as Stonier, but not by Jantsch (1980), Lazslo (1995) and Goerner (1993), where a new kind of eco-system-spiritualism or objective idealism seems to be developed as a holistic interpretation of the modern scientific results in Cosmology and quantum field theory. But how can such a notion dealing with the creation of form say anything interesting about the nature of discourse?

3. *The Luhmannian second order cybernetics approach* where nature is seen as a source of enumerable differences. Here the cybernetic system decides which difference should make a difference and become information in the organism and its social communication in the human society. Somehow there is a situation in which a cybernetic autopoietic system makes the first distinction by making a difference between the system and its surroundings. Luhmann (1995) never explicates the nature of this Firstness before the first distinction as Peirce does or as phenomenologists like Heidegger and Blanchot's work with. Still, his idea is originally based on Spencer-Brown, who seems to work with a Buddhist inspired theory of the Void or Emptiness, which seemingly contains the potentiality of both mind and matter. But this aspect seems to be lost in Luhmann's theory. Inspired by Husserl, Luhmann embraces concepts of intentionality and meaning, but in a Hegelian kind of functionalism minus the spirit. This paradigm, in my view then, is close to the Peircian semiotic view except that it does not have a collapsed triadic theory of the sign vehicle and lacks a developed theory about the biological systems' contribution to the generation of meaning (Brier 1999b).
4. *Peircian (bio)-semiotics* is specific from other semiotic paradigms in that it not only deals with intentional signs of communication but also encompasses non-intentional signs such as symptoms of the body and patterns of in-animate nature. It then encompasses both nature and culture. Peircian semiotics breaks with the traditional dualistic epistemological problem of first order science by framing its basic concept of cognition: – *Signification* – on a triadic semiotic philosophy. The triadic semiotics is integrated with a theory of continuity between mind and matter (*Synechism*) where the basic three categories (*Firstness, Secondness and Thirdness*) are not only inside the perceiver's mind, but also in the nature perceived. This is connected to the second important ontological belief in Peirce's philosophy, namely *Tychism* that sees chance or chaos as basic characteristics of Firstness. This is finally cornbined with an evolutionary theory of mind (*Agapism*) where mind has a tendency to take habits in nature. Chaos or chance is seen as a First, which is not to be explained further (for instance by regularities). It is the basis of habit taking and evolution. The chaos of Firstness is

> not seen as the lack of law as in mechanicism and rationalism, but as something full of potential qualities to be manifested individually in Second ness and as general habits and knowledge in the dynamic objects and semiosis in Thirdness (Peirce 1992). This is the deep foundation of Peirce's pragmatism. With chaos as spontaneity at the foundation no laws will in reality be exact. There will always prevail a little spontaneity on both the level of Secondness and Thirdness. As a result of the initiative and work of Thomas Sebeok (1976, 1989), Peirce's semiotics is now interpreted as covering all living signifying systems in a biosemiotic approach.

In the biosemiotic interpretation based on *the Peircian triadic semiotic philosophy*, semiosis thus works on a triadic basis in an evolutionary and pragmatic view. The unmanifest Firstness is seen as chaos of qualia, basic form and feeling with a tendency to take habits, which manifests through Secondness and Thirdness. Matter is seen as "effete mind". Matter and mind are united in the continuum of Firstness and develop through "Evolutionary love" into Secondness' manifestations of resistance, force, dualistic concreteness and impenetrability of objects. Secondness provides constraints on perception and cognition in the Thirdness of true triadic sign processes. The term, quasi-semiotic objects then recognizes systems in nature and culture, working with differences, often in a form of coding, instead of physical causality on one hand and meaningful semiosis on the other. In nature, we are in this context dealing with systems of Secondness that have established an information level above the energetic and causal level of nature. The area, thus delimited from true semiosis, is part of what classical first order cybernetics considered its subject area: goal oriented machines and pattern forming self-organized processes in nature based on information. Still the exact role of the living systems in establishing true semiosis is not very clear in Peirce's theory and neither is the description of the special biological qualities that make this happen. According to Santaella Braga (1999), Peirce was on the track though recognizing chance-spontaneity in the nerve cells as "the outward aspect of that which within itself is feeling" (Peirce CP 6. 265).

The *pan-semiotic metaphysics* claims further that all environmental phenomena are ultimately semiotic in their essence. The universe is perfused with signs as the famous quote from Peirce goes. Peirce's three categories are universal. Semiosis is everywhere; either because everything is semiosis in its nature or because the only way we can know anything is through semiosis. The latter is a pan-semiotic constructivism encompassing both culture and nature. The construction of reality is done by the human societies through living together in language. This kind of bio-social constructivism takes this approach very close to Maturana's bio-constructivist development of the autopoiesis theory from a cybernetic perspective. Thus it is close to becoming a human-centred metaphysics (a subjective idealism) with no explicit idea of what nature could be in itself or, to put it another way, what kind of external source there could be for the signs of nature.

The other version is the modern version of pan-semiotics claiming that signs are as real as atoms and energy, actually that latter are also signs. These signs grow by themselves as made clear in Merrell's book (1996): *Signs grow; Semiosis of life processes*. Reading Merrell, and Emmeche's (2000) critique of him, it is clear that Merrell is viewing signs as independent living beings growing by themselves. The pansemiotic interpretation takes Peirce's statements of teleonomy in causality and that the universe is perfused with signs to mean that whenever there is Thirdness there is semiosis. Then there is also semiosis in inanimate nature. *Physio-semiotics*, as Deely (1992, 1997, 1998, 2001) calls it, suggests that semiosis is the core of evolution. This means that although there are physical laws so rigid that they are almost pure Secondness, in most laws in evolving nature there is a basic telonomy, which has existed throughout evolution. Here classical physical laws are seen as universal, exact, and deterministic. Thermodynamic laws are by some (Prigogine/Stengers 1984) accepted as genuine statistical and biological "laws" much more teleonomic and semiotic in nature. The fundamental question is if Thirdness really has to bee seen as physiosemiosis?

Most modern versions of pan-semiotics are an interpretation of C.S. Peirce's semiotics, as he is the only philosophic semiotician to include natural signs in his theory. One way to perceive the consequences of his triadic metaphysics and his broad theory of mind, when placed in his theory of continuity (synechism) and evolution, is to accept physiosemiosis, which John Deeley (op. cit.) was the first to do. This kind of realistic (objective idealistic) semiotic metaphysics certainly makes the emergence of life and mind through self-organized new complexities of semiosis much easier to accept but also raises new threshold problems. We will have to define the qualitative differences between physiosemiosis, phytosemiosis, zoosemiosis and antrophosemiosis. Biosemiotics has so far only wanted to encompass the last three of them. There are some profound similarities between Peircian pansemiotics and the organismic view of Bertalanffy's general system theory that also refused mechanism as a possible basis for a scientific theory of evolution. Prigogine's work and his fierce debate with mainstream mechanicists has shown that this is a central problem. The difference between the biosemiotic interpretation and a pan-semiotic one is that the biosemiotic interpretation is limiting the ability of true semiosis to living systems. Biosemiotics considers machine processes and pattern/signal interaction in nature only as quasi-semiotic (not true triadic) processes.

As we can see from the short descriptions of the five basic views above then the central distinction to be discussed are the threshold between living and "dead" nature, and between living and mechanical systems, such as computers, and further the difference between information and meaning. Another important part of this discussion will be between the modern scientific approaches that deal with meaning and the phenomenological part of reality on the one hand, and on the other to deal with the demands on science to deliver true explanations of an independent reality. This demand has increased ever since our religious and mythical frameworks were challenged by the world view of the classical mechanical sciences, the rationality and historical thinking of the Enlightenment, Darwinian evolution, the psychology of modernity and finally the linguistic turn. It seems to place truth and meaning in opposite camps. Let me therefore start with a short history and philosophy of science perspective (based on Brier 2000d) on this matter.

The Explanatory Quest of the Sciences Since Religion Lost Power

Ever since Galileo, through experiments and theories of an earthly science combined with his enforcement of Copernicus' view of the heavens, confronted the Catholic Church's worldview, religion as the upholder of a meaningful world has been challenged. The evolution of classical (mechanical) physical science and its concept of universal mechanical natural laws were some of the most important instruments to break the Church's worldview and our view of our own place in it. The worldview of the Catholic Church was one of the core foundations of the culturally produced meaningfulness of the individual's personal life. It told us where we came from, where we could go and the meaning of our lives.

Further, since the philosophers of the Enlightenment and later Marx and Engels broke the view of the social order as "heavenly sent", a further disturbance in our belief in that everything in our social order was "as it should be" was created. Darwin destroyed our belief in man coming from a higher and meaningful place and thus being endowed with a meaningful destiny, accordingly. He partly destroyed the idea of the human soul as descended into our body from the "divine above". Freud spoiled our idea of being perfectly conscious and rational beings in control of our language and ourselves and own drives. Nietzsche finally declared God "dead", and he and other philosophers left us in a nihilistic vacuum with no universal meaning and values left.

Since then man has increasingly looked to science for new explanatory stories of himself. It has lead to what Ilya Prigogine and Elisabeth Stengers called "World Formula Thinking"; the belief that final explanations can be found through science, especially through algorithmic approaches such as in artificial intelligence, the search for "the algorithms of the book of life" in the genes and in the Grand unification theories of physics, the last attempt of which was the super string theory (Brier 2000d). Descartes' dualism attempted to save the human soul from the mechanistic grip of science, but his own followers' experiments with brain lesions in doves and the later reflexiological view in brain and behavioural science, further developed with learning theories of "conditioning" by behaviourism, entrenched the human mind and behaviour into the scientific subject area. Cybernetics, information theory and science, plus the theory of artificial intelligence, have produced functionalistic approaches of our understanding of cognition and communication (Brier 1992). These approaches are now combined in the transdisciplinary program of the information-processing paradigm of cognitive science. It is promoting a paradigm of cognition as a software program based on algorithms in the brain's neurological hardware (Brier 2000d). At the same time quantum mechanical field theories get more attention as possible tools to explain the continuum character of consciousness (Penrose 1995).

Through science we have also learned to be sceptical towards systems that tend to explain too much. Such systems are religious, mythical-magical or ideological-political systems of belief and power. Still by the end of the 20th century modern science encompasses attempts to combine evolutionary, historical and developmental theories of the environment, the living systems, individual conscience and socio-cultural linguistic meaning and values into one big scientific narrative, completely ignoring the post modernistic warnings against the deceptiveness of grand narratives.

These stories are Grand Evolutionary Theories (GET) wanting to combine Big Bang cosmology of the self-organization of energy and matter, and the evolution theory of the living. Modern science attempts to explain life from physics and chemistry by computational A-life simulations, and through manipulating genes and other chemicals. The final proof of such a theory could be the artificial construction of life through an independent synthesis of macromolecules and a combination of them, creating the organelles within artificially created membranes producing a living cell. This is being planned as I write.

As we in the sciences expect to explain matter as a specific form or organization of energy, matter is then expected to provide the foundation for an explanation of life as a unique organization of matter. The grand evolutionary story attempts to explain them all in one story starting with energy from a quantum vacuum field turning into matter, time and space. By process of self-organization information and life is supposed to emerge, and later again central nervous systems, social organization, semiosis, communication, language, culture and consciousness.

Modern Big Bang cosmology combined with unified field and super string theory delivers the materialistic story about the reality we inhabit, which we now call the Universe. It also tells the story about the evolution from radiation to subatomic particles, further how the atoms of the basic chemical elements were created through "cooking in the stars" and supernova's explosions, and finally the creation of the multitude of molecules, climaxing in the macromolecules that are the essential chemical components of living systems. This is then often combined with theories of objective information, which perceive energy as self-organizing into patterns and systems of matter in the expanding universe and further on to living systems, cognitive systems, linguistic and conscious systems in culture. Often this story is combined with Richard Dawkins' theory of the selfish gene, and of culture as a collection of selfish memes (Dawkins 1989, Blackmore 2000). Growing up in a culture, the child's mind is infected with the memes of culture and its worldviews. They program its mind with unitary ideas and causalities. This explanatory narrative of reality and meaning is most often performed through religion in the pre-scientific and its pre-industrial societies, but in the modern industrialized cultures, the scientific rationality and worldview is more and more taking over.

I have here in a very general way outlined the character of these explanations. But I doubt:

1. That such a grand story is scientifically possible.
2. That it is the true nature of science to construct this type of explanation.
3. That we will ever be able to provide in generally accepted shared language, universal explanations that combine the four basic constituents of human existence (energy/matter, embodied life, language and conscious inner life) in one discourse.

I suggest that natural science, social science, arts and humanities, practical sciences, philosophy and any other systematic search for public knowledge starting with: 1. Embodiment: our body is at least a main source of life and cognition. 2. Consciousness: consciousness is the source of an inner life of cognition, volition, feeling and perceptual qualities (qualia). 3. Situated in meaning: In semiosis meaning is constructed through language in a social and cultural network of other living, linguistic conscious systems. 4. Relatively autonomous environment: Placed in an environment that seems partly independent of our perception and being (Brier 2000d).

As analysed above, humans are embodied, feeling and knowing cultural beings in language. My point then is that this makes us live in four different worlds

1. Embodiment: Our body hood and our sharing of body hood with other living species.
2. Inner Mental World: Our inner world of emotions and thoughts manifesting as mind and consciousness.
3. Physical nature: The physico-chemical aspect of ourselves and of the environment of the natural world.
4. Culture: The cultural world of language and meaning.

I think that each of the four worlds calls on its own type of narrative. Physicists and chemists tend to see the universe as basically consisting of matter, energy and meaningless information. Biologists tend to end up seeing the universe basically as a living being, the social and cultural sciences tend to see the world as constructed from our social linguistic interpretations (unless they are dualistic and accept that nature is as science describes it and only culture is constructed by man). Those dealing with the phenomenological aspect of our being tend to be rather anti-scientific and anti-realistic often viewing the world as a product of consciousness as product of a linguistic system. But, like Peirce, I see the semiotic mind at the heart of all four worlds. One of the strengths in Peirce's semiotic philosophy is that qualia and mind – as semiosis – are installed in the whole metaphysics from the beginning. They cannot be explained as such because they can only be inferred as a necessary prerequisite for producing the knowledge we want to discuss!

My main problem with the standard materialistic scientific evolutionary paradigm is that I cannot see how physics – as an external science – on the basis of the present definitions of matter, energy and deterministic law can ever alone furnish us with the final understanding of our inner lives and how consciousness arises. If you work from an evolutionary view, combining the Big Bang theory with self-organizing thermodynamics and chemistry adding Darwinism for biology systems, and proceed with a somewhat materialistic theory of the development of man and the history of language and culture, there is a severe problem of explaining life and consciousness as this inner quality of perception, feeling, volition and cognition that we all experience. I do not see quantum physics, the relativity theory or non-equilibrium thermodynamics as being of any particular help concerning this problem although they may be helpful to explain the physical aspect of consciousness.

I am, therefore, hesitant to put the understanding of Peirce's semiotic philosophy into a scheme, explaining life and consciousness from the development of inanimate nature. The standard view of today combines an evolutionary view with a materialist ontology based on energy as the ultimate concept (in quantum physics, general relativity theory and thermodynamics), hoping to explain life as a phenomenon of chemical organization. When realizing that this is not enough, often the aid by some kind of objectivistic information concept is sought, although this adds fundamental new concepts, entities and ideas of organization to the paradigm that is foreign to its basic metaphysical conceptions. The idea of my figure, and the epistemological turn it is illustrating, is to escape the great explanatory burden of reductionistic mainstream science, wanting to explain both life and consciousness from the basic assumption of energy and mechanistic mathematical laws. The cybersemiotic view sees scientific explanations as going from our present state, of socio-linguistically based conscious semiosis in self-organized autopoietic systems, towards a better understanding of the prerequisites of language and the self-conscious being. The reduction made in any of the four directions has to remain consistent with the point of departure in the middle.

Science only to a limited degree explains the world or our place in it beyond our existential questions such as what is life, reality and meaning – not to talk of good and bad. We had knowledge before we had science. Knowledge – which can be defined as the combination of qualia, objects and interpretants in semiosis – is one of the big mysteries of the world. Being in the world in language, in body hood, in a meaningful social context we always have to start "in medias res". We will always be bound to make some metaphysical presumptions based on our present understanding and they will always show later to be too limited. But Peirce's semiotics is a very good non-reductionistic framework to start from since its point of departure is the semiotic mind.

Somehow we will have to enlarge the conceptual framework within which we do science if we want to make a connection, also to the phenomenological aspect of reality and deal with the experience of meaning. Our task is to explain and understand all four aspects of reality and our explanations of any of the corners will only be one aspect of the explanation. My suggestion is that we start in the middle and extrapolate toward the four corners. Trying to explain all from one corner is reductionism, no matter then in which corner we will end. For instance, I see social constructivism as the same reductionistic totalitarism as physicalism and the pan-informational paradigms.

Peirce's insistence on Secondness as an independent existence revealing itself in the end as the dynamic object for the final interpretant is an insurance against all sorts of (overly radical constructivism) too radical kinds of constructivism that loose their grip in reality and transform into either subjective or collective idealism. One way to deal with this paradoxical problem would be to be less ambitious about the explanatory demands on science for the big scheme of things as Peirce shows in his deep integration of science, religion and philosophy with semiosis (Brier 2004). Science gives a good economic understanding of certain processes often in a way that allows prediction with a wanted precision within certain circumstances.

But it does not give universal explanations of the construction of reality, energy, information, life, meaning, mind and consciousness.

Semiotics starts with the process of knowledge; how signification is taking place in living systems making perception and cognition possible. Peirce's semiotics unites our explanatory schemes of deduction and induction through abduction within the process of semiosis. Peirce suggests that we look at triadic semiosis as the fundamental process of reality. Consciousness is built from semiotic processes. In biosemiotics, semiosis is an essential part of all living systems. But again the problem of total explanation arises: can we go on from here to a pan-semiotic view without wanting to explain too much? My answer is that I doubt it. Instead I have argued that it seems fruitful to accept and work with five different levels of interaction in nature, but not necessarily assume any evolutionary causal links between them, i.e. indications that one level is supposed to give rise to the other assuming a one way up-causality:

1. A non-manifest level with hypercomplex interactions. The concept of vacuum in Quantum field theory is one attempt from science to describe this state but without a synechistic frame.
2. An energy level with energy based causal interaction by natural forces.
3. An informational level with signal and/or code causality.
4. A semiotic level with sign game causality within and among living systems.
5. A linguistic level with language-game-causality based on meaning between conscious social systems.

Critique of Current Approaches

The point then is that the description of these levels did exist in different areas of modern science, but they have never been connected in one theoretical or even paradigmatic framework, although this is what mainstream eliminative mechanistic science tries to accomplish but on an insufficient philosophical background. Or to be more precise, the present and past attempts have all had different problems and inconsistencies:

1. Although classical mechanistic physics could describe certain connections, forces and regularities in nature mathematically, and later with the help of quantum mechanics the stability of matter, it is very difficult to think of actual evolution in a mechanistic worldview with rigid deterministic universal laws and a Newtonian reversible time (Prigogine/Stengers 1984).
2. This is solved in the thermodynamic atomistic view based on complexity, self-organizing dissipative structures and irreversible time. But here it is still difficult to understand how information and cognition can arise and self-organize from pure physical matter and energy.
3. In the pan-informational paradigm information as organizing power is present from the start. This makes self-organization and the emergence of cognition more

understandable especially when it is established in general systems theory that has an organismic and emergent evolutionary worldview. But in this view it is still difficult to understand how living systems can arise as individual beings, how they treat information differently from mechanical cybernetic systems, and also what is the special quality of the semiotic creativity of self-conscious linguistic embodied beings.

4. In second order cybernetics and autopoiesis theory, the idea of closure on the biological, psychological and social communicative level explained by the concept of autopoiesis: living systems' self-organising, self-maintaining and self-producing ability, much clarifies the special self-preserving ability and cognition as well as the creation of an individualistic point of view. The conception – especially of Maturana and Varela and also von Foerster – also comes close to Jacob von Uexküll's Umweltslehre (Brier 2001a). They all represent some kind of bio-constructivism. Unfortunately it tends to be rather idealistic, sometimes even solipsistic in certain formulations while, at the same time, it "paradoxically" insists on the material reality of a biologic(al) observing system.
5. In Peircian semiotic philosophy these levels can be bound together by Synechism, Tychism and Agapism combined with the evolutionary view of the interaction of Firstness, Secondness and Thirdness. The view of Firstness as a blend of mind and matter qualities and as containing qualia and living feeling with a tendency to take habits is crucial to understand the self-organizing capabilities of nature and how, what seem as "dead" matter, through self-organization in evolution can become autopoietic and alive and has cognitive/semiotic abilities and feelings (Brier 1999a). Re-interpreting Uexküll on this foundation creates a biosemiotics that is much more suited to encompass the phenomenological aspect of life and cognition, which is now conceptualised as signification (Brier 2001a). Still, aspects of the development of embodiment, which Uexküll did not think of, are partly missing. Concepts of closure and self-organization of biological, psychological and social systems and their differentiation, developed in second order cybernetics and autopoiesis theory, need to be integrated (Brier 2000a). Both Hoffmeyer and Emmeche do work with these aspects in the theory development, which is already transgressing the original limits of biosemiotics.

These are some of my reasons for being sceptical about totalitarian and reductionistic explanatory paradigms like mechanicism, pan-informationalism and a pan-semiotic without thresholds, but also too radical forms of constructivism that are out of touch with any non-linguistic reality. This is why the discussion of the semiotic threshold in a Peircian framework becomes so crucial.

The cybernetic thinking of self-organization and system closure has, in my opinion, made an important contribution to our understanding of living systems. Already Jacob von Uexküll used some basic cybernetics in his "Funktionskreis". We can see the foundation laid both for biosemiotics and biocybernetics (second order cybernetics and autopoiesis theory) in Uexküll's work. But a combination of Peircian semiotics and modern cybernetics is necessary to make the theory broad enough in order to cover what is now called biosemiotics and to make the framework develop beyond the present stage, encompassing the understanding of the problem of the semiotic threshold, which is a core-epistemological problem. Biosemiotics, in name and scope, is partly neglecting or ignoring the contribution of second order cybernetics and autopoietic theory. However, the cyberneticians, even as their work is combined and further developed into the area of human social communication as in Luhmann's work, instead tend to ignore the semiotic component too much (Ort/Marcus 1999). In my view, to be able to combine the fruitful work of both camps a broader foundation is needed. This is why I call my work Cybersemiotics.

The *cybersemiotic approach* that I am working on, attempts to unite cybernetic, systemic informational and semiotic approaches to deal with the problems of self-organization, intentionality, selection of differences and constructivism avoiding solipsism and idealism. This is – among other things – done by giving decisive attention to the role of body hood in the construction of meaning using the viable parts of the above-described five views by combining informational, cybernetic and Peircian biosemiotic approaches in non-totalitarian or non-pan versions.

The cybersemiotic approach thus ascribes to a Peircian and Uexküllian biosemiotics and combines it with the theories of second order cybernetics (von Foerster) and autopoiesis (Maturana and Varela 1980 and Luhmann 1995) that are already visible in Uexküll's "Funktionskreis" (Sebeok 1986). It uses a Peircian and ethological extension of Wittgenstein's pragmatic language theory to distinguish between the sign games of biological systems and the language games of humans. It acknowledges the independent being of Firstness and Secondness (what would normally be called the "physical world" but is now based in Peircian metaphysics). Finally it underlines that the cybernetic machines, such as computers and robots are not truly semiotic, but quasi or proto-semiotic (Nöth 2002). Machines lack autopoiesis, reproduction, code-duality and inner organization of membranes (Hoffmeyer 1998) and thus an individually and species based motivation and intentionality (Brier 1995 and 1998a). Combining the results of modern science with Peircian biosemiotics the cybersemiotic framework operates with five levels of existence:

1. A primary chaotic level of continuity, quality and potentiality with a tendency to take habits (Firstness). This goes beyond the physical conception of vacuum fields that are still pure materialistic, but may be included as an aspect.
2. A "causal" level of matter, energy and causality by natural forces. This is Secondness that has, as its inner aspect, will and mental force.
3. An informational cybernetic system level of informational signals, which encompasses the goal-oriented mechanical systems described by first order classical cybernetics. Described from a cybersemiotic view, concepts of information as signals of differences only make sense as quasi signs (see Nöth 2002 for an analysis).
4. The semiotic level belonging to all living systems (biosemiotics), which are so far the only systems capable of true triadic semiosis (producing signification spheres in sign games). This level encompasses the work of Uexküll (1934) and

the ethologists such as Lorenz (1970–1971 and 1973) and Tinbergen (1973) in a broader semiotic framework (Brier 1999b).

5. The level of conscious languaging systems (language games, arguments), to our knowledge so far only occupied by humans.

Sign-making is thus immanent in nature, but only manifest in full triadic semiosis in living systems. Cybersemiotics has, so far, sided with biosemiotics in not accepting physio-semiotics as a full-fledged semiosis.

The Cybersemiotic Epistemology

Ever since Umberto Eco formulated the problem of the "semiotic threshold" in 1976, semiotics, especially Peircian semiotics, has developed even further into the realm of biology. The efforts of Thomas Sebeok (1976, 1989), in particular, has lead to the development of a biosemiotics encompassing all living systems as sign users – including plants and microorganisms. This semiotics has even moved into the organisms describing semiosis between body cells and in the cells (*endosemiotics*) (Uexküll et al. 1993).

The question that is now becoming essential for the whole debate about the possibility of a transdisciplinary information/signification science is, if the biosemiotic Peircian framework that includes and reformulates Jacob von Uexküll's theoretical biology will comprise un-interpreted "natural" objects as signs. Most obvious phenomena are autocatalytic and dissipative structures that emerge by the spontaneous generation of order and patterns in nature. These objects were originally described in physio-chemical terms. Now some of the pan-informational paradigm adherents, such as Stonier, want to explain them in purely informational terms.

From a Peircian view these phenomena are protosemiotic, or quasisemiotic when compared to the semiosis of living systems, as they are only displays of Secondness (Nöth 2001). To distinguish the semiosis of the living systems from physiosemiosis, I have applied the term *sign games or biosemiosis* (Brier 1995). We are not talking about the situation that *any natural thing can become a sign* when placed in a meaningful context by a living system, but about the objects and their processes per se. The present quote from Peirce gives a very clear idea of the distinction between what the thermometer as a physical thing does per se, and how it works when interpreted by a doctor:

> "The acceleration of the pulse is probably a symptom of fever, and the rise of the mercury in an ordinary thermometer ... is an index of an increase of atmospheric temperature, which, nevertheless, acts upon it in a purely brute and dyadic way. In these cases, however, a mental representation of the index is produced, which mental representation is called the immediate object of the sign; and this object does triadically produce the intended, or proper, effect of the sign strictly by means of another mental sign" (CP 5.473 from Nöth 2002).

Another similar problem is the question of what machines, like computers, are processing when no humans are interpreting. Is it signs or just signals? We know that we codify the signals so they carry meaning for us in our context and therefore they are signs to us, and forwarding that sign's meaning through a pragmatic view is what they do. But doesn't this have to be in a living context where meaning is already introduced through embodied minds existence? Relating to the question of the semioticity of calculating machines, Nöth explains how Peirce coined the term "quasi-semiosis" to deal with this problem. He writes:

> "The term quasi-sign suggests an answer to the question whether there can be semiosis in a machine of the kind which Peirce knew. A quasi-sign is only in certain respects like a sign, but it does not fulfil all criteria of semiosis. While some criteria of semiosis may be present in machines, others are missing. The concept of quasi-sign thus suggests degrees of semioticity. Quasi-semiosis does not only begin with calculating machines. It can be found in processes in which much simpler instruments are involved" (Nöth 2002: 8).

Through his synechism Peirce did not believe in a separation of mind and matter in a strict dualism. Peirce's concept of mind is then extremely broad and does not need to include consciousness or intentionality but only goal directedness. The use of the term quasi-semiosis to designate "degenerated" semiosis near the shift between Secondness, in machines, and Thirdness of the biosemiotic sign games, stems first of all from a lack of a triadic object relation. Nöth writes:

> "Evidence of the quasi-semiotic nature of data processing comes from the dyadic nature of the signs involved. The view that sign processing in computers is based on dyadic relationships is implicit in a widely held theory which states that computers can only process *signals*..., i.e., mechanical stimuli followed by automatic reactions. Winograd & Flores (1987), e.g., refer to signal processing when they write: "One could describe the operations of a digital computer merely as a sequence of electrical impulses traveling through a complex net of electronic elements, without considering these impulses as symbols for anything" .... What is missing for these signs to develop from dyadic to triadic signs is an object relationship. The dyadic relations are merely dyadic relations of signification, but there is no denotation, no "window to the world" which allows to relate the sign to an object of experience ... the messages produced by a computer in the interface of humans and machines are either messages conveyed by a human sender and mediated by the computer or they are quasi-signs resulting from an automatic and deterministic extension of human semiosis" (Nöth 2002: 8).

This brings us right into cybernetics, especially Bateson's. Here information is a difference that makes a difference for a cybernetically defined "mind". This mind works primarily on differences with feedback loops based on energy. The energy is not important for the coding process per se. But the critique directed at cybernetics' concept of information and meaning has exactly been underlining that this type of system based on information theory is only functionalistic and does not have the capacity of encompassing meaning in a biological, not to say a human perspective (Brier 1992). The problems between these two transdisciplinary paradigms of information and signification seem to stem from the fact that they are coming from opposite directions of the hierarchy of science and humanities when they develop their theories of messages.

It seems to me then that if we want to get beyond just accepting that we have two incompatible paradigms, we must abandon the pan-views. In the spirit of Niels Bohr's complementarity theory we must take one step back and:

1. Give up some of our ambitions of getting "to the bottom of things" including laws and causality with our scientific approaches.
2. We must attempt to broaden our conceptual framework by – amongst other things – integrating the observer and doer in our framework.

Peirce clearly does this in his triadic model of semiosis where the interpretant is part of the theory through his concepts of the immediate and dynamic object. A similar development has been carried through in second order cybernetics and autopoiesis theory.

Maturana and Varela in their theory of autopoiesis do not apply the word information at all when cognition is to be understood from within the autopoietic system. Nothing is transferred from the environment to the living system that can be designated meaningful information. But they admit that you can say that, when you observe from the outside, it looks like the system has obtained information. A way to describe it is to say that information is created inside the autopoietic system when it receives a disturbance, which as a species it is prepared for by the creation of a structural coupling. Maturana and Varela (1980) do not view the structural coupling as an information channel because no representations are moved through it. Ethologists would say it had an instinctual perception where sign stimuli elicited an Innate Release Response Mechanism (IRM) that released a preprogrammed instinctive behaviour (see for instance Brier 2000b, 2001) Anyway, this constructivistic biological cybernetics stresses the intimate evolutionary and developmental dynamical relation between environment and organism. One can then from a cybersemiotic perspective view autopoiesis combined with Hoffmeyer's (1998) further points as a condition for differences in the environment becoming meaningful signs through the process of semiosis. But Maturana and Varela's concepts do not in themselves fit with neither concepts of information science, nor with semiotic concepts, such as semiosis as an interpretation.

It is now well established that there is an area of nature between the physical causal level and the level of biosemiosis. I have argued that this level is the area that cybernetics and information science has conceptualised. In my previous works I have argued that cybernetic information science also erases a threshold between causality and information when all nature becomes informationalised. It also ignores the level of meaning, or what we now call second order semiosis, suggested to be the subject area of biosemiosis. When information theory attempts to encompass the area of meaning and semantics it passes and destroys the semiotic threshold too, but now in the other direction, blurring the difference between informational and semiotic processes, and thereby between mechanical signal manipulation or quasi-semiotic systems and living systems. This produces all sorts of simplistic theories about intelligences that are not able to grasp the cognitive processes special for embodied living systems, not to speak of conscious socio-linguistic systems.

Even though I do not think that any of our systematic conceptual knowledge systems can fully grasp the reality. I agree with Peirce and Bohm (1983) that there must be some kind of infolded dynamic order in our reality, even though it is just potential qualia and tendency to take habits. If this were not so, then the Thirdness, which makes it possible for us to know something through the establishment of interpretants based on the perception of some kind of regularity of differences would not be possible.

My point here is to say that sign making is the threshold between cybernetics and semiotics. That to make a difference make a difference is to establish a sign for it (the interpretant) in an embodied mind. Before that it is only second order cybernetic signals or quasi-semiotic according to Peirce. *The whole subject area of cybernetic information theory is in my view then quasi-semiotic*. Underneath that is the physicochemical level that in general is best described in terms of energy, matter and causality by natural forces (Secondness), but it does have Thirdness processes over long time frames. If you want, this is a kind of semiosis over long time with the universe as subject.[3] You can then call the biosemiotic level semiosis with the species as subject and, finally, human language games as semiosis with individual cultural persons (persona) as subject.

Cybersemiotics is a development of biosemiotics using, among other things, Niklas Luhmann's work for further development. Below we will go into more detail describing a model for the levels of signification and communication in humans.

Luhmann's Triadic Autopoietic Systems

Luhmann has generalized the autopoietic concept of Maturana and Varela (1980) in order to also comprise psychological thinking systems and socio-communicative systems. He views the psyche as a silent inner system, a closed system of perception, emotions and volitions. A special linguistic system has to be created for communication to happen. Communication is again an organizationally closed system. Only communication communicates. Social systems are communicative systems with human bodies and minds as surroundings!

To Luhmann (1995) communication is a sequence of selections, namely of (1) information, (2) utterance and (3) meaning. The two first have to be made by what we traditionally call "the sender", the last one by the receiver. He chooses his understanding of the signs produced, and then one could say that a message is produced when the receiver says something that the sender chooses to understand as a confirmation of understanding of his first message. Finally, in a fourth selection the message is connected to present practice.

Although his view of information is loosely based on Shannon's concept, it differs from it in that Luhmann (1995) does not believe in its use outside of human social communication. Thus, he does not want to generalize it outside the analysis of human messages. Also Luhmann does not seem to believe that information exists in nature independently of human perception. The information concept functions as a quantitative aspect within a meaningful human context. Further he combines

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[3] The formulation is a result of a discussion with Jesper Hoffmeyer on April 3, 2001, in my office at KVL. As such it is a way to interpret Deely's physiosemiosis theory.

information with the aspects of utterance and meaning. Luhmann stresses that both the sender and the receiver have to make their choices to produce a meaningful message. I think that instinctive reactions would also count as such a choice. Information is choices related to subject matter, utterance is choices pertaining to the way to say something, and meaning is the choices of interpretation of the listener depending on his evaluation of the human context. I think that Luhmann's theory has problems producing a concept of meaning that relates deeply to the flesh, blood and life (conditions) of biological systems and the existential conditions of human consciousness. Here pragmatic language philosophy, like Wittgenstein's language game theory and Lakoff and Johnson's embodied cognitive semantics combined with ethology, all seen within Peircian biosemiotic framework (Brier 2000a), tell us that signs as concepts and classifications arise in our embodied biological and social "life forms". From our inner world we express our bodily experiences in social relations. It is especially regarding the social communicative construction of meaning that Luhmann's theory connects so well with semiotics. But Luhmann himself did not connect to semiotics in any systematic way. In the following I will reformulate this problem area from a cybersemiotic viewpoint.

The Cybersemiotic View of Cognition and Communication

One way to understand our inner mental world is to see it as a way of representing our bodily interactions with the environment through the constructions of a felt signification sphere. In this way an individual "point of view" as a centre of cognition, interest and interpretation is created. What Spinoza calls conatus, self-value and self-interest in preserving the individual's and species' self-organizing structure is basic to living systems' ability to signify. But this individual signification sphere is again perturbed by the species' specific social interactions starting with mating, rearing of the young, competing for hunting territory, and hierarchy in the group, co-operation in food gathering and hunting. These social interactive activities first generate sign games, and later in evolution, the human language games.

The construction or development of meaningful and informative messages has as a prerequisite autopoiesis, signification and conatus/motivation/intentionality. It is only within this triad that the selections of information, utterance and meaning are possible.

Viewed in this way, Luhmann's three autopoietic systems (see Luhmann 1990) are all needed to create the meaning of a message and one needs the sign concept to understand their interaction. One way of getting out of the impasse of Luhmann's functionalism, where the role of body and mind in the production and meaning of social communication has not been adequately grasped by theory, is to view the interpenetration between the three organizationally closed systems semiotically. Signs acquire meaning where the systems interpenetrate. Interpenetration is Luhmann's term for the interaction between biological autopoiesis, psychic closure and the socio-communicative system with its own closure at the social level. My hypothesis is *that sign and language games arise on the basis of the interpenetration of the three different autopoietic systems.*

Meaning is seen as being generated by the interpenetration of the systems. For example, language is a part of the socio-communicative system, but it does not really acquire meaning before it interpenetrates with the psychic system and gets to indicate differences of emotions, volitions and perceptions "putting words" on our silent inner being. But our cognitive, emotional and volitional qualities would only have a weak connection to reality if they were not connected to the survival of the living systems' organization as a body in its interaction with the environment's differences in the development of a signification sphere in the evolution of the species.

Biosemiotics and metaphor theory have argued extensively for the importance of embodiment in semiosis. In Brier (2000a), I have tried to show the connection between the biosemiotic (ethologically based) concept of motivation and the motivational concept of embodied cognitive semantics. I have shown that ethology and embodied metaphor theory have both discovered that the conception of a sign as standing for something for somebody in a particular way is controlled by some releasing mechanisms that connect motivation, perception and behaviour/action into one systemic process as already Jacob von Uexküll described in his "Funktionskreis" and, which Heinz von Foerster refers to as perceptual "eigenvalues". Instinctually, the actual IRM (Innate Release Mechanism) is chosen through the urge coming from a specific motivation. This is again based on biological expectancies and vital needs, like for food and mating. I argue that the linguistic motivation that Lakoff and Johnson claim controls the ICM (Idealized Conceptual Models) have connection to the biological motivations in many instances. This is obvious in the much-used example where a woman classifies a man as a bachelor, and therefore as a potential mating partner. It is our bio-psychological embodiment that ties these relations together.

Further I showed that a phenomenological-emotional concept was necessary to understand the production of meaning. I want to point out here that this is consistent with Peirce's placing of feeling as an attribute of Firstness. In his evolutionary theory, feeling becomes an immanent inner reality, also in matter. Knowledge systems thus unfold from our bio-psycho-socio-linguistic conscious being. Their function is to help us orient (ourselves) in the world and help us act together in the most fruitful way, but they do not explain us to ourselves. Peirce's view that we cannot with any good reasons split the concepts of mind and matter from the beginning, is a very sound and profound foundation for a transdisciplinary metaphysical framework. I do not see any good reason why the inner world of cognition, emotions and volition should not be accepted as just as real as the physical world as well as our cultural world of signs and meaning. Finally to both the spiritualist and the materialist, embodied life, even with only one cell as the body, has to be a basic part of, or a component of constructing reality. We are thinking in or maybe even with the body. The psyche and its inner world arise within and between biological systems or bodies. With Peirce one may say that there will always be some kind of psyche in any kind of biological autopoietic and code dual system. Still, a partly autonomous inner world of emotions, perceptions and volitions, only seems to arise in multicellular chordates with a central nervous system. Lorenz (1973) argues that such a system with emotions and experiences of pleasure is necessary for animals to have appetitive behaviour, searching for the objects or situations that can elicit their instinctual behaviour and release the motivational urge built up behind it. This is qualitatively different from how reflexes function on a signal, which is a proto-semiotic informational level. Instinctual sign function is on a genuine semiotic level.

Luhmann's theory of the human socio-communicative being consisting of three levels of autopoiesis can be used in cybersemiotics to distinguish between (1) the languaging (Maturana) of the biological systems, which is the coordination of coordination of behaviours between individuals of a species on the reflexive signal level, (2) the motivation driven sign games of the bio-psychological systems and, finally, (3) the well driven language games level of the self-conscious linguistic human through generalized media in the socio-communicative systems. A semiotic understanding has thus been added to Luhmann's conception, and his theory has been placed in the Peircian triadic metaphysics. In the following section, I will explain and develop this further.

Intrasemiotics

It is obvious that what we call language games arises in social contexts where we use our mind to coordinate our willful actions and urges with fellow members of our culture. Some of these language games are then about our conceptions of nature, now filtered through our common culture and language. But underneath that, we also have emotional and instinctual *bio-psychological sign games* (Brier 1995) that these function for humans as unconscious paralinguistic signs, such as facial mimics, hand movement gestures and body positions with origin in the evolution of species-specific signification processes in living systems.

Simultaneously, we also have an internal communication going on between our mind and body. In Luhmann's version it is something different from what Kull (1998) calls *psychosomatics*, as it is not a direct interaction with culture but only with the psyche. On the other hand it is not only *endosemiosis*. The terms endosemiosis and exosemiosis were probably both coined by Sebeok (1976: 3), endosemiosis denoting the semiosis that takes place inside the organisms, and *exosemiosis being the sign process that occurs between organisms*. Endosemiosis became a common term in semiotic discourse (see Uexküll et al. 1993), meaning a semiotic interaction at a purely biological level between cells, tissues and organs. Nöth and Kull (2001) introduced the term *ecosemiotics*, specifically for the signification process of non-intentional signs from the environment or other living beings that take a meaning for another organism, for instance, to a hunting animal, the scent of prey. Thus the sign signifying an organism, as a suitable prey is not intentionally emitted by the organism preyed on, and is therefore rather ecosemiotic than exosemiotic. What can we then call the internal semiotic interaction between the biological and the psychological systems?

I term the interaction between the psyche and the linguistic system *thought semiotics*. This is where our culture through concepts offers us possible classifications of our inner state of feelings, perceptions and volitions. These, in their non-conceptual or pre-linguistic states not recognized by conceptual consciousness, I call *phenosemiotic processes*. For short I just call them *phenosemiosis*.

As the interactions between the psyche and the body are internal bodily, but not pure biological as in endosemiotics, I call the semiotic aspect of this interpenetration between the biological and the psychological autopoiesis *intrasemiotics* (Brier 2000b). These different terms are coined to remind us that we deal with different kinds of semiotics. In the future, we will have to study more specifically the way semiosis is created in each instance.

Today we know that there are semiotic interactions between the hormone systems, the transmitters in the brain and the immune system and that their interactions are very important for the establishment of the autopoietic system of second order, which a multicellular organism constructs as a kind of biological self. Its parts are cells that are themselves autopoietic systems and these are again on a new level organized to an autopoietic system. But we do not know very well what the relations are between our lived inner world of feeling, volitions and intensions and this system. It seems that certain kinds of attention on bodily functions, such as imaging, can create physiological effects in this combined system. As mentioned above, this is partly carried by different substances that have a sign effect on organs and specific cell types in the body (endosemiotics). We also know that our hormonal level influences our sexual and maternal responses. Fear turns on a series of chemicals that change the state and reaction time of several body functions, and so on. This is a very significant part of the embodiment of our mind, but intrasemiotics seem to function as meta-patterns of endosemiotic processes. For example, our state of mind determines our body posture through the tightness of our muscles. There is a subtle interplay between our perceptions, thoughts and feelings and bodily state working among other things through the reticular activation system. There is still a lot we do not know about the interaction between these systems.

The nervous system, the hormonal system and the immune system seem to be incorporated into one big self-organized sign web. Now, the autopoietic description of living cybernetic systems with closure does not really open for sign production per se, and semiotics in itself does not reflect very much about the role of embodiment in creating signification. Thus, the cybersemiotic suggestion to solve this problem is that signs are produced when the systems interpenetrate in different ways. The three closed systems produce different kinds of semiosis and signification through different types of interpenetration, plus a level of structural couplings and cybernetic “Ianguaging”, as Maturana and Varela (1980) call it.

Autopoiesis theory underlines that two interpenetrating systems primarily are closed black boxes to each other. But interpenetration between them develops a coordination of coordination of behaviour that he calls languaging. Parts of these systems are inherited on reflexive and instinctual levels and are foundational for communication to develop. Then, in my opinion, it is through the reciprocal structural coupling formed between the two systems signs can be produced and exchanged. Maturana's concept of *languaging* (coordination of co-ordinations of behaviour) seems to be the bio-psychological connection between two individuals in a social species. But it is not the sign and/or language game as such; it is the underlying coqnit ive coupling that is the coordination necessary for communication to develop as a signification system with its own organizational closure. I would, therefore, suggest that we distinguish between languaging and *sign games* at the level between reflexes and instinctual movements (Brier 2000b) as already mentioned. Thus, the schooling behaviour of fish is reflexive informational but courtship communication is instinctual sign games. The perception eliciting reflexes is independent of motivation, whereas the perception of sign stimuli is motivation-dependent, which leads into the instinctual sign games. Ethologists would here point to how certain instinctual movements become ritualised and get a release value for instinctive behaviour as "sign-stimuli". As Lorenz (1973), in his last period, realized that emotions had to be connected to the performances of instinctual movements to create the motivational urge of appetitive behaviour, we here have criteria to distinguish between the two levels (Brier 2000b). We here see how the connection between signs and internal or phenomenological understanding is constructed. Lakoff (1987), and Lakoff and Johnson (1998) have shown us how this basic mechanism of bodily meaning can be explained, by metaphorical processes, to encompass socially and culturally produced signs.

Based on ethology and biosemiotics I claim that our cognition manifests itself as embodied semiosis, motivated in our biological social interest that is a powerful creator of structure and meaning in our signification sphere. Most animal behaviour is – like much of our linguistic categorizations and use of metaphors considered to be unconscious. Still ethologists had to realize that motivation is not a physiological concept (Brier 1992, 1998), emotional experiences are connected to the perception and behaviours with an instinctive basis.

Sign games are developed into language games through evolution and in the life of the infant human. As we are born and grow into human social communication the psyche is perfused with signs. Our mind is infected with language and we become semiotic cyborgs or what we call humans. We are in this view born as animals with a capacity to construct this interpenetration between the psychic and socio-communicative systems, creating internal interpretants that are meaningful to us because of the mutual structural couplings of languaging established in evolution. Meaning is seen in biosemiotics, cognitive semantics, autopoiesis theory and ethology as embodied. But with the new cybernetics and von Uexküll, I suggest that embodiment is thought of as much broader than only the structure of the nervous system, or even the integration of the neurotransmitter, the hormone and the immune systems through reaction to common sign substances that they secrete. As Fogh Kirkeby (1997) suggests, we should look at the body-mind or the body-thought as a complex phenomenological dynamical system, including the construction of the environment and the other (body-mind) systems that make it possible for signification to appear.

Realizing that a signification sphere not only pertains to the environment, but also to the perception of other members of the species in cultural and proto-cultural behaviour as well as to perceptions of own mind and body hood, I use a little “eco” as a prefix to the signification sphere, when it is the aspect of it pertaining especially to non-intentional nature and culture outside the species in question. In both inanimate nature, as well as in other species and in cultural processes, we can observe differences that signify meaning to us, although never intended by the object.

The Cybersemiotic Model of Biosemiotics

I am going to present a rather complicated model, differentiating between different levels of semiosis and signalling, pertaining to some of the questions already brought up about the basis and the thresholds of semiosis within biosemiosis, but without going to a pan-semiotic view. Ecosemiotics focuses on the part of our language that is about how all living systems represent nature in signification spheres, ending with language games in culture. Cybersemiotics points out that the basis of these eco-language games is the eco-sign games of animals, combined with a signification sphere, and created through evolution. Further, these are based on an intricate interplay between the living system and its environment, establishing what Maturana and Varela call structural couplings. The signification sphere is a workable model of nature for this living system that as a species has existed and evolved over millions of years.

This is also true for the human species, indicating that our language has a deep inner connection to the ecology of our culture. Any existing culture is a collective way of making a social system survive ecologically. As such, the cybersemiotic theory of mind, perception and cognition is a realistic one, but not a materialistic or mechanistic one. It builds on an inner semiotic connection between living beings, nature, culture and consciousness carried by the three Peircian categories in a synechistic and tychastic ontology in an agapistic theory of evolution delivering a philosophy going beyond the dualistic oppositions between ideal ism (or spiritualism) and materialism (or mechanism).

We can go back and now see that the linguistic motivation, mentioned earlier, must be placed in the area of thought-semiotics where our internal non-linguistic phenosemiotic processes of mind meet with the concepts of language and imbue them with inner meaning, whereas the animal motivation stems from the intrasemiotic area where the endosemotic processes of the body cells meet with the phenosemiotic processes of mind and awareness. Thus body, mind and language has been encompassed by a shared framework able to conceptualise their interactions on the same process level but now integrating concepts of meaning and qualia. The cybersemiotic model thus provides a new conceptual framework, in which these different levels of motivation can be represented and distinguished in a way that was not possibly in the earlier three different frameworks of biology, psychology and socio-culture. Thus, by viewing meaning in an evolutionary light, as always embodied, and seeing the body as semiotically organized in Peirce's triadic worldview, where mind as pure feeling is Firstness, a transdisciplinary framework can be constructed that supersedes some of the limitations of the earlier divisions of subject areas. This gives us hope that the cybersemiotic development of biosemiotics can contribute to a new inter- and transdisciplinary semiotic theory of mind, cognition, communication and consciousness.

Conclusion

I have now analysed the most prominent attempts of creating transdisciplinary frameworks for communication and cognition in physical nature, living nature, human culture, and in society as well as computers. They are all attempts to bridge the gap between Snow's two cultures, science-technology versus humanities and social sciences.

One major problem is how to place the mechanical, the living and the conscious system in relation to each other and how to fit this into the evolutionary framework of modern science. Another problem is how to find an all-encompassing unity without reducing one reality with another, making everything either physical, informational/computational, or semiotic.

Firstly, respecting the different nature of the physical, the informational and semiotical, how can we connect and understand the causal relations? Because we do not have a framework that integrates mind and matter, science today is not able to conceptualise how the conscious mind can causally influence the physiological processes in the body. Biosemiotic analysis of internal processing in the body (endosemiotics) and mind (phenosemiotics) in combination with systemic and cybernetic models of self-organization and closure (intrasemiotics) seems to offer an integrated approach to describing mind and bodily processes. Peircean semiotic philosophy seems to be able to deliver a philosophical and metaphysical framework without the limitations and flaws of the purely mechanical or informational approaches (including the computational information processing paradigm in cognitive science). It is now generally realized that the mechanical and the computational sciences can only describe limited and idealized aspects of reality. In both mechanical and the computational areas we can understand, control and predict systems with wonderful clarity and power. These systems, unfortunately, seem only to be tiny samples of the types of systems that make up the Universe as we know it. Recognizing that the social and psychological system of emotions, willpower and meaning are just as real as the mechanical system, although of a different nature, it is, no longer viable to model nature as pure mechanical or mind as only computational. On the basis of Peirce's philosophy, Cybersemiotic offers a different and more comprehensive foundation that encompasses the previously mentioned paradigms, but now relativized as being the most pertinent descriptions of certain levels of reality. They are parts of a greater whole where not only efficient causality (physical), but also formal causality (informational) and final (semiotic) causality work as real forces, but manifesting at different levels. The view, in short, is that semiosis is thus immanent in the universe and manifests clearly in the living systems and becomes emancipated and self-organized in social systems.

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Chapter 23
Excerpts from *The Logos of the Bios*

Günther Witzany (1953–)

Introduction and Commentary: Günther Witzany

> *Wittgenstein writes: "Is what we call 'obeying a rule' something that it would be possible for only one man to do, and only once in his life? It is not possible that there should have been only one occasion on which someone obeyed a rule. It is not possible that there should have been only one occasion on which a report was made, an order given or understood, and so on – To obey a rule, to make a report, to give an order, to play a game of chess, are customs (uses, institutions)" To which I add: One sign alone is not a sign. A sign is a sign only as part of a context of signs. In his analysis of the expression "to obey a rule", Wittgenstein provides proof that the identity of meanings logically depends on the ability to follow intersubjectively valid rules* together with at least one additional *subject.*
>
> G. Witzany (2007: 196)

As should be overwhelmingly evident from the readings that have appeared in this anthology so far, biosemiotics is an interdisciplinary reservoir of research findings and ideas that is fed by many streams. Even so, however, the trajectory of its historical development has been such that it has barely intersected with many other trends in thought that took place during the last century, such as those taking place under the general rubric of Analytical Philosophy. Quite possibly, such non-intersection is the result of the self-avowed (human) "language-centric" nature of the latter project, as inculcated at its outset by the works of Bertrand Russell and the younger Ludwig Wittgenstein in initiating the so-called "linguistic turn" in philosophy – wherein problems of "knowing" are reduced to problems in (by necessity, exclusively human) propositional language clarity. Widening this rift was the fact that this 'turn' was succeeded by analytic philosophy's post-1960s "cognitive turn" attempts at explicating a theory of (usually wholly anthropomorphic and external-reality separated) "mind." Rejecting what they see as both the unresolved nominalism and the biologically naïve anthropocentrism permeating many of these analyses, biosemioticians have traditionally been loathe to engage with the debates taking place within analytic philosophy, finding the very terms of its discourse to be a foundational roadblock to naturalistic inquiry.[1]

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[1] See Deely 2001 (especially Chapters "The Animal Mind", "A Semiotic Perspective on the Sciences: Steps to a New Paradigm", "Theoretical Biology on its Way to Biosemiotics", and "Laws

D. Favareau, *Essential Readings in Biosemiotics*, Biosemiotics 3,
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Philosopher Günther Witzany, however, has pursued the developments in contemporary analytic philosophy as they have evolved beyond the problematic premises of logical positivism and eliminative materialism, and has incorporated insights from analytic philosophy's still later 20th century "pragmatic turn" (i.e., speech act theory and action theory) to develop a "three-leveled biosemiotics" of rule-governed, sign-mediated interaction that avoids the traps of both anthropomorphism and of methodological solipsism, his naturalistic approach to the understanding of "signs."

Born in Salzburg, Austria on August 25, 1953, Günther Witzany studied philosophy, political science and ethics at the universities of Salzburg and Munich before founding the first Philosophical Practice counseling and consultation practice in Austria, in 1985. Witzany's *Telos – Philosophische Praxis,* based on the "applied philosophy" principles founded by Gerd B. Achenbach in 1982, applies philosophical inquiry and analysis to the fields of theoretical science, practical ethics (e.g., politics, business) and aesthetical appreciation and understanding.[2]

Between 1987 and 1992, Witzany was the author and editor of the nature philosophy journal, *Arche Nova*, as well as of several books on natural philosophy, music therapy, renewable energy, the problem of technocracy, and European community (all these works in German, see reference list). During this time, too, Witzany developed a philosophy of biology that he has christened "the theory of communicative nature" – the goal of which is to demonstrate how sign processes within cells, between cells, and between living individuals can be understood in their full syntactic, semantic and pragmatic dimensions. "The method is a cross-disciplinary one," writes Witzany, and it draws extensively from insights and research findings provided by "philosophy (especially philosophy of nature, philosophy of language and communication, philosophy of science), biology (and in particular microbiology, molecular biology, epigenetics, evolution and development theory, social biology) and semiotics (particularly biosemiotics, endosemiotics, and [Peircean Karl Otto Apel's] transcendental semiotics)" (2009: p.c.).

In contrast to similar frameworks such as information theory, systems theory, biohermeneutics, biolinguistics, and even other schools of biosemiotics, Witzany's theory "insists upon the primacy of pragmatics, i.e. the relation of signs and sign-using agents within those interactional contexts that alone determine the meaning of the signs used" (*ibid*). For one of the major lessons of philosophy of language's early

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of Symbolic Mediation", pp. 485–609) for an in-depth discussion contrasting modern philosophy's foundational commitments to the (human) mind-privileging "doctrine of ideas" with biosemiotics' foundational commitments to the organism-and-environment privileging "doctrine of signs" – and to the two very different explanatory pathways and destinations afforded by each.

[2] Explains philosophical practitioner Shlomit Schuster: "Gerd Achenbach [b 1947] and most of the European practitioners [of *Philosophische Praxis*] began practicing philosophy as a critique of, and an alternative to, psychotherapy and psychoanalysis. Consequently, philosophical counseling is not about 'applying philosophy', as if placing a poultice of Kant on the soul – but it is creative philosophizing itself. Unlike Marinoff's [similarly named but] Zen Buddhist and Ayn Rand inspired therapy, Achenbach's practice is derived from critical and skeptical sources, and philosophizing *with* the client remains the only ultimate goal of the practice" (2005: o.l.).

failed attempts to analyze and to formalize truth claims by the examination of their syntactic and semantic combinatorics alone, observes Witzany, is that such "context-free" analyses shift the burden of meaning-making onto the (usually lifeless) sign-vehicles, as opposed to the (always animate) sign users, where alone the processes of meaning-making have their proper being.

Inspired by the "pragmatic turn" taken by philosophers such J.L. Austin (1911–1960), John Searle (1932–), Jürgen Habermas (1929–), Karl Otto Apel (1922–), and, particularly, the later work of Ludwig Wittgenstein (1889–1951), Witzany insists that we must look to the practices (and to the history of practices) in which signs gain their meaning, in order to understand the roles that they play in the life of any given sign user or community of sign-users. Such practices, as Wittgenstein insisted, are by definition social – and thus, with Habermas and Apel, Witzany insists upon the replacement of the *solus ipses* sign-user with "an intersubjective-communicative *community* of interpretations" as the proper *subject* of knowledge – and as the object of our biosemiotics inquiries (2006: 3).

Analyzing the rules of syntactic and semantic sign-sequences can never reveal to us the rules of interaction that invest those sequences with their pragmatic use (which is to say: their semiotic "meaning" for the user), argues Witzany, and thus any investigation or analyses of sign-mediated interactions must recognize and account for the inextricable *complementarity* of *syntactic* (combinatorial), *pragmatic* (context-sensitive) and *semantic* (content-specifying) rules underlying and making possible every instance of sign use. Thus, a "three-leveled" biosemiotics is necessary, in order "to discover and to reconstruct the rule systems according to which [communities of interacting organisms] generate the contexts of interactions" wherein "things" become "signs" and gain their "meanings" (Habermas 1971: 65).

Moreover, the tripartite interaction rules themselves take place on three different – and, again, simultaneous and interdependent – levels of coordination and organization, argues Witzany. Thus, the establishment of meaning in his "three-leveled biosemiotics" relies upon the tight (and historically generated) interconnections between the processes of (1) *intra-organismic communication* (i.e., sign-mediated interactions in cells and between cells), (2) *inter-organismic communication* (sign-mediated interactions between individuals of the same or closely related species), and (3) *trans-organismic communication* (sign-mediated interactions between members of different species).

In all of these cases, writes Witzany, "the relationship of organisms to other organisms is a communicative one: their mutual behavior underlies changeable rules" that are quite distinct from the biological principles of fixed natural law underlying organisms' physiological relationships with the abiotic surround, towards which "organisms cannot develop such a 'to follow or not to follow' relationship" (2007: 209). It is for this reason, he writes, that Jakob von Uexküll's *Umwelt* concept

> cannot do justice to the fundamental differences between natural laws and rule-governed sign-mediated interactions, because this concept reduces rule-governed sign-mediated interactions to the information transmission effect – and therefore to a level of coding and decoding via an individual organism's physiological sensory organ. The intersubjective-communicative character of the rule-governed sign-mediated interactions, and therefore

> the relationship to following or not-following commonly shared rules of sign-use, does not manifest itself here. In investigating communication processes in and between organisms, it is therefore sensible to supplement the *Umwelt* [‘in-world’] concept with a *Mitwelt* [‘co-world’] concept. The *Mitwelt* concept underlines the difference between the cause-and-effect reactions in natural laws and rule-governed sign-mediated interactions: *Umwelt* thus becomes a helpful term in investigating those physiological influences on organisms that are not components of rule-governed sign-mediated interactions, and *Mitwelt* becomes the term for the integrative investigation of all rule-governed sign-mediated interactions of organisms, i.e. all intra-, inter- and meta-organismic communication processes and their developmental history.

In the series of publications written between 1995 and 2007 and appearing in print, collectively, as *The Logos of the Bios, Volumes 1 and 2*, Witzany (2006, 2007) demonstrates the fecundity of his three-leveled biosemiotics framework by applying it to current research findings regarding viruses, bacteria, fungi, animals (especially bees and corals) and plants. In the selection that follows, he highlights the difference that applying a “pragmatic turn” makes to our understanding of biological organization, interaction, and evolution.

Excerpts from *The Logos of the Bios* (2007)

Introduction

Margulis' Serial Endosymbiotic Theory explains the origin of nucleated eukaryotic cells as a merging of archaebacterial and eubacterial cells. The paradigmatic change offered by this theory is that the driving force behind evolution is not 'ramification' but 'merging'. However, Margulis describes these symbiogenetic processes in the language of mechanistic biology, using such terms as 'fusion', 'merging', and 'incorporation.'

Biosemiotics argues that all cell–cell interactions are rule-governed sign-mediated interactions – i.e., communication processes. As a discussion of plant communication will demonstrate, the biosemiotic approach is not limited to the level of molecular biology, but is also helpful in examining all sign-mediated interactions between organisms on the phenotypic level, as well. Yet if biosemiotics is going to use the terms such as 'language' and 'communication' to describe non-human sign-mediated interactions, then the underlying scientific justification of such usage should be critically considered and explained.

Towards this end, I will here briefly summarize the some of the relevant discussions that took place amongst philosophers of language between 1920 and 1980 that led to what has been called 'the pragmatic turn.' I will argue that application of this pragmatic turn to the philosophy of biology both lays the foundation for a three-leveled biosemiotics, as well as justifies it. I will also show how doing so helps to avoid 'the abstractive fallacy' which is a recurring weakness of many of today's scientific methodologies.

Therefore: In order to extend the Serial Endosymbiotic Theory through its reformulation within a biosemiotic perspective, I will proceed in the eight steps outlined below:

The first step will to be to briefly present the aims of biosemiotics. Biosemiotics investigates life processes, and more concretely, sign use within and between organisms. Biosemiotics holds that no life processes could be coordinated and organized without signs.

The second step is the outline of the Serial Endosymbiotic Theory. As Lynn Margulis plausibly demonstrates, chance mutations were not necessarily responsible for initiating the evolutionary process from prokaryotes to eukaryotes. Rather, merging processes by various prokaryotes via endosymbioses and the fusion of different organisms may have just as likely have led ultimately to a eukaryotic cell.

The third step will be to show that Margulis' 'merging processes' go beyond mere physical and chemical changes in state of these cells. I argue that the symbiogenetic integration of different genomes into a single genome is not just a chance merging or fusion process, but rather it requires precise and error-free DNA/RNA processing – i.e., not the chance integration of DNA components, but rather the integration of entire gene blocks along with their phenotypic features.

The fourth step will be to show how competent DNA-processing underlies semiotic rules. Traditionally, it has been assumed that such nucleic acid processing could only be carried out by enzyme proteins: they were known to be responsible for key DNA modification processes such as DNA splicing, RNA editing, coding, copying, major and fine repair, transcription, translation, etc. They were considered unlikely candidates for evolutionary genome editing. This would have created a paradox that there had to be a DNA that coded for proteins that changed their own DNA-template, as Watson formulated ("Enzymes cannot determine the order of the amino acids in polypeptide chains.") (Watson et al. 1992). Here, I show that this genome-editing competence, with its higher-order regulatory function, was found not in the protein-coding DNA (as it was previously thought), but in the non-protein-coding DNA (long-termed insignificant "junk DNA").

The fifth step uses the example of plants to show that the biosemiotic thesis – namely that sign-mediated interactions are the central aspect in coordinating and organizing life processes – is valid not only in the intracellular-genetic realm, but also in the intercellular organismic realm.

The sixth step demonstrates the necessity of specifying the scientific basis for using such terms and concepts as 'language' and 'communication' when referring to living nature. The history of science shows that the theoretical clarification of these two terms took place in two historical phases. The first was the 'linguistic turn' that attempted to construct a language that could be applied to formulate exact statements in the natural sciences. During the second phase, christened the 'pragmatic turn,' it became apparent that the attempt to justify such a language failed because the proponents had based their premises on an unrealistic model of language and of the subject of knowledge.

The seventh step is the application of a biosemiotic approach that requires considering all three semiotic levels of rules (i.e., sign pragmatics, sign syntax, sign semantics) to biological processes such as those studied in molecular biology, symbiogenesis, and the phenotypic communication within and between plants. In this section, I will also show how a reductionistic abbreviation of any of these three levels irrevocably leads to an abstractive fallacy, for which there are numerous examples in the history of science.

The eighth step is the attempt to symbiologically expand the self-awareness of biologists. The adoption of a pragmatic philosophy of biology could help to alter the process of self-awareness in biologists, allowing them to scientifically comprehend themselves as biological entities who are permanently involved in symbiotic processes; and reminding them that even in scientific discourse, they are dependent participants in an indefinitely ongoing dialogue within the scientific community.

1. What is the Aim of Biosemiotics?

Biosemiotics is a transdisciplinary science including theoretical and empirical studies; it investigates the use of signs within and between organisms. Signs may be signals or symbols, most of them chemical molecules. In the highly developed eukaryotic kingdoms, behavioral patterns of organisms also may serve as signs (signals and/or symbols), as for example, the dances of bees; or the signs may be phonetic, as in songbirds or humans. The signs obey semiotic rules of three types. Syntactic rules determine combinatory possibilities – physical, chemical, spatial, temporal, rhythmical. Pragmatic rules determine interactional content (e.g., regulatory pathways have significant differences with metabolic pathways). And those rules dependent on pragmatic interactional content are the semantic ones, i.e., the meaning of signs and sign sequences (e.g. in signaling pathways).

Individuals in a population share a common set of signs and a common set of rules. It can be applied to cell biology as well. Dependent on the situational context of interacting entities, one sign, or sequence of signs, can have different meanings or functions. Therefore, it is possible that different cell types come from the same genome by the interpretation of different chromosomal methylation patterns. Biosemiotics in the context of molecular cell biology includes not only sign processes used within cells, but also embraces immunological, metabolic, neurological and hormonal signaling pathways.

Zoosemiotics is considered the forerunner of contemporary biosemiotics. Corresponding to the five taxonomic kingdoms zoosemiotics has been completed by prokaryotic semiotics (bacteria), protoctist semiotics (eukaryotic microorganisms), mycosemiotics (fungi) and phytosemiotics (plants) (Nöth 2000). To many biosemioticians, the origin of life is the starting point of semiosis and vice versa (Witzany 1993; Hoffmeyer 1996; Barbieri 2001; Markos 2002; Emmeche and Hoffmeyer 2005; Pattee 2005).

So far, biosemiotic terms have been used as metaphors in molecular and evolutionary biology, as well as in genetics and ecology, the conviction being that they could ultimately be replaced by chemical and physical descriptions. As a result, the paradigmatic differences between biosemiotic and chemical/physical descriptions are becoming much more evident what enables biosemiotics to draw a clear distinction between the biotic and abiotic domains: “Life is distinguished from the nonliving world by its dependence on signs” (Pattee 2005). Thereby, it is possible to use biosemiotics to expand the perspective on biological processes. Consequently, the factors decisive for life processes do not consist only of the states of matter and their corresponding chances based on natural laws, but also of the communication and information processes within and among cells, tissues, organs, organisms. Their importance determines the success or failure to promote life, growth, development, disease and death in all living beings. Biosemiotics enables a broader understanding of the complexity of life processes which could hardly be achieved by conventional biological methods.

2. The Serial Endosymbiotic Theory

The Serial Endosymbiotic Theory is revolutionary because it reversed the evolution vector from ramification to merging. Eukaryotic cells, according to Margulis, are the result of merging several different ancestor genomes (Margulis 1996, 1999, 2004; Margulis et al. 2000; Margulis and Sagan 2002).

Margulis refers to the term *symbiogenesis* as coined by Mereschkovsky and Wallin. The authors argue that new tissues, organs, organisms and species arise by entering into long-term, permanent symbioses. Bacteria were permanently incorporated into animal and plant cells as plastids and mitochondria (Searcy 2003).

The important factor is the sequence of merging in symbiogenesis, i.e. the serial evolution. The first merger involved (1) thermoplasmic archaebacteria with motile spirochaeta-like eubacteria that (2) were able to swim, to the nucleocytoplasm. These forms were still anaerobic. This was followed by a merging with (3) aerobic organisms. This enabled them to survive the increasing oxygen concentrations. The late and final step was the merging with (4) photosynthetic bacteria. With this approach, the Serial Endosymbiotic Theory contradicts traditional theories of evolution, all of which firmly held that the direction lay in ramification and not in merging.

Cilia, the rods in the retina, the tail of sperm cells, sensory hairs and many similar appendages of nucleated cells arose during the original merging of archaebacteria and a swimming bacterium. The bodies they contain so-called "centriole-kinetosomes" arose through this archaic merger. There is also a genetic relationship between cilia and microtubules at the surface of nuclei of plants, and between microtubules and the mitotic spindles responsible for chromosome movement during cell division. Baluska et al. (2004) have convincingly reconstructed this in their *cell body*-theory. According to Margulis, the Spirochaeta are the modern, free-living relatives of these symbiogenetically merged centriole-kinetosomes,

One integrated genome was sufficient in the merger of archae and eubacterium, in the Proctista two integrated genomes were necessary, in the fungi three, in animals at least four, and in the plant kingdom (400 million years ago) at least 5, perhaps even 7 (Margulis 1996). Thus, the plant genome is the epitome of symbiogenetic evolution processes and represents the most complex integration process. Considering that the evolution of flowering plants took place only about 150 million years ago, and that their seeds and fruits provided the foundation for higher animals, then these revolutionary symbiogenetic processes are relatively young compared with evolutionary history as such (Margulis and Schwartz 1988).

The Serial Endosyrnbiotic Theory also supports her assumption by pointing out that most of the DNA found in the cytoplasm of animals, fungi, plants and protoctists comes from genes of bacteria that became organelles, and not from genetic drift or mutations. Eukaryotic genes that participate in information processing (translation, transcription etc.) show a close relationship to eubacteria. Genetic factors that control metabolic processes, however, more closely resemble those of archaebacteria.

Another advantage of the merging paradigm of the Serial Endosymbiotic Theory is that DNA elongation (from bacterium to humans: 1–1,000 mm) need not be attributed to chance, which would be highly improbable (Vollmert 1985), but rather to a merging of entire gene-blocks. This demonstrates that complex genomic make-ups can be passed on directly and that the step-by-step development via chance mutations is outdated. There are strong reasons too, that eukaryotic nucleus is of viral origin. Endogenous retroviruses are held to be competent in creating new genes in large numbers, complex and simple ones (Villarreal and DeFilippis 2000; Bell 2001; Ryan 2002; Villarreal 2004).

3. Not 'Merging', but 'Communication'

Lynn Margulis uses in the Serial Endosymbiotic Theory the classic language of mechanistic biology to describe the highly complex interactions of a symbiosis and, subsequently, symbiogenesis. This language ("merging", "fusion", "incorporation", etc.) is imprecise because it describes the altered state of matter, rather than the semiotic aspects of genome editing, i.e., the syntactic, pragmatic and semantic rules which determine combinatorial, interactional and functional aspects of the integration processes of different prokaryotic genomes into one.

In fact, a multi-leveled, generative DNA-processing rather than "fusion" is involved. Its success, however, depends on whether the necessary sign processes proceed according to rules or whether they fail. Moreover, the integration of genetic components into available genomes and, therefore, the creation of a new individual do not involve "incorporation", but rather rule-governed sign-mediated interactions between cells and cell components.

The pragmatic philosophy of biology (Witzany 1993; Witzany 2000) and the young science of biosemiotics (Kull 2005) demonstrate that life functions are always related to sign processes. More precisely, sign processes regulate and constitute life functions (Witzany 1993, 2006). If these sign processes are deformed or defective, then life processes are compromised or terminated. Sign processes regulate life processes on different levels simultaneously: intracellularly, within the cell (DNA, RNA activities, messenger substances, etc.), and intercellularly as cell–cell communication. This is the intraorganismic level. In parallel, each organism also conducts (species-specific) interorganismic and (trans-specific) metaorganismic communication processes (Witzany 1993; Hoffmeyer 1996; Barbieri 2001; Markos 2002; Emmeche and Hoffmeyer 2005; Pattee 2005; Margulis 1996, 1999, 2004; Margulis et al. 2000; Margulis and Sagan 2002; Searcy 2003; Baluska et al. 2004; Margulis and Schwartz 1988; Vollmert 1985; Villarreal and DeFilippis 2000; Bell 2001; Ryan 2002; Villarreal 2004; Witzany 2000).

Should the symbiosis lead to a symbiogenesis, to the development of a new species and, thus, to the disappearance of the formerly independent individuals, then the result is generative DNA- processing in which genetically different gene pools are combined into one genome. This requires a recombination that assimilates the foreign data set, converting the external into the internal. Which genome editing competences are able to integrate an endosymbiotic genome in a host genome? Manfred Eigen would ask how we should think about the correct rearrangement of the "molecular syntax" (Witzany 1995).

4. Symbiogenesis by DNA/RNA Processing

Over the last 25 years, tens of thousands of papers have been published in the field of molecular biology, genetics, biochemistry, epigenetics and similar disciplines. They outline in great detail the intracellular processes of recombinant DNA, splicing, RNA-editing, coding, copying, major and fine repairs, transcription, translation, RNA processing, insertion, the role of introns and exons in "reading" processes, the complementary roles of DNAs and RNAs, even the significance and indispensable structural function of non-coding DNA (Cavalier-Smith and Beaton 1999; Sternberg 2002; Jaenisch and Bird 2003; Shapiro and Sternberg 2005; Schmitt and Paro 2004; True et al. 2004; Wang et al. 2004; Baluska 2004).

Successful DNA/RNA processing requires numerous, specifically tailored enzyme proteins. In all cases, DNA/RNA-processing enzyme proteins and also interacting RNAs are involved in very precisely conducting these varied DNA-processing steps. Any mistakes here typically have grave and often lethal consequences for the organism.

Today there are strong reasons, that this processing on protein-coding DNA is overruled by the genome processing abilities of DNA coding not for proteins but for the micro-RNAs (Mattick 2001, 2003, 2005; Mattick and Gagen 2001; Spotswood and Turner 2002; Turner 2002; Shapiro and Sternberg 2005). Especially the recombination of two different genomes into one as happened in symbiogenesis we can imagine through the text processing competences of active micro RNAs.

Active micro-RNAs control and integrate large-scale structures of the chromosome. The number of different micro-RNAs is estimated to exceed several 10,000. Some of the discovered tasks of these micro-RNAs are co-suppression, suppression of transposition, position effect variegation, start–stop signals, RNA interference, imprinting; chromosomal methylation, transvection, transcriptional and post-transscriptional gene silencing along with numerous other RNA–DNA, RNA–RNA (trans-acting RNAs), RNA-protein interactions. These active RNAs are as competent as proteins in catalysing, signaling and switching.

Cellular differentiation and phenotypic variation results primarily from variations in this high order regulation, not in the proteins themselves or in their mutations. The phenotypic variation in complex organisms is the result of a different use if a set if protein-coding core components. The higher order regulation in non-protein-coding genome architecture is able to manage a larger genetic data set in its phenotypic range. As far as evolutionary processes are concerned, it is naturally much simpler to change or expand a number of very small control sequences than to duplicate an entire network of protein-coding DNA (Sternberg 2002; Shapiro and Sternberg 2005). Variations of this higher order regulation can create an enormous spectrum of different protein expression profiles and we can understand why one and the same gene can be used for multiple protein meanings. New reports suggest that the capabilities of non-coding DNA with higher-order regulatory functions descended from ancestral viral genome-editing competences that had been integrated by endogenous retroviruses. While complete genetic functions were transferred to the nucleus after the persistent retroviral infections, the regulatory LTR's (Long Terminal Repeats) which flank the protein-coding genetic dataset are integrated in non-protein-coding regions. In the human genome, several thousand such events are documented (Bell 2001; Ryan 2002; Villarreal 2004).

5. Plants' Multilevel Communication Competence

Biosemiotic aspects are not only interesting on the intracellular genetic and epigenetic level but also in analyzing sign-mediated interactions between cells of organisms, and between organismic bodies, e.g. plants. Plant scientists formerly thought of plants also in terms of mechanistic biology as automatons. Meanwhile research into the multilevel communication of plants revealed attributes like learning, memory, individuality and plasticity as an expression of so-called "plant intelligence" (Trewavas 2003, 2004, 2005). During last 5 years plant research has also shown that the old dichotomy of chemical versus neuronal-electric communication is misinterpretation. Today we know that 99% of neuronal communication is based on chemical messenger substances, and that electric action potentials serve merely to maintain the transport of messenger substances by long neuronal tracts (Trewavas 2003). Therefore, the catchword for new directions in plant biology is "plant neurobiology", not "plant physiology".

Plants represent a major success story in evolution and are the most recent organismic kingdom. Higher plants make up 99% of the eukaryotic biomass on our planet. At the same time, this success story also reflects the success of multilevel communicative actions by plants in their intra-, inter- and metaorganismic stages: it represents a crucial dependency on successful communication with microbial communities (Walker 2003; Bais et al. 2004), with fungi (especially in the rhizosphere), with animals (especially with insects), and, in parallel, the multilevel communication processes in and between cells, tissues and the whole body (Trewavas 2003).

The communication on the molecular level between plant tissue and the plant cells is exceptionally complex and encompasses nucleic acids, oligonucleotides, proteins and peptides, minerals, oxidative signals, gases, hydraulic and mechanical signals, electric signals, fatty acids, oligosaccharides, growth regulators, amino acids, numerous secondary products, simple sugars, and many other as yet unstudied aspects (Baluska et al. 2006).

6. Language and Communication: From Linguistic Turn to Pragmatic Turn

For more than 10 years, most biological disciplines have increasingly been referring to "communication" and "language" in describing and explaining interactions in and between cells, between tissues and organs, whole bodies, organisms, species-specific and trans-species interactions. The influence of a linguistic vocabulary is omnipresent and has become irreplaceable. This calls for an up-to-date definition of "language" and "communication" if we are to avoid using these terms in an uncritical, unreflected or merely metaphorical manner.

In referring to the language of life, to nucleic- and amino acid codes, and to communication in linguistic terminology in order to describe essential life processes, we can rely on an unspoken and uncritical pre-understanding of language and communication, i.e, on metaphysical and/ or reductionistic prerequisites: We can say that (1) we are working in standardized experimental setups and that theoretical preconditions are not very interesting. We can say that (2) we refer to the world of objects in the language of exact natural science whose validity claim is founded on the laws of the physical world. We might assume that (3) observed things have a direct empirical significance that need not be further questioned because the laws of physics correspond one-to-one with the material foundations of the linguistically constructive human brain (universal syntax). We might also assume (4) an overlying meta-system in which human populations represent one of the subsystems that communicates within itself and with co-systems in an information-theoretical framework (Witzany 1995, 1998; 2002).

This suddenly leaves us directly in the midst a 60-year-long theory of science discussion that extended from approximately 1920 to 1980. It consisted of two phases, and its first result was (a) the *linguistic turn* the second result being (b) the *pragmatic turn*.

(a) The *linguistic turn* was the result of an attempt to delimit the *logic of science* from philosophy and other "unscientific" cognitive methods. In the aftermath of Wittgenstein's "Tractatus logico philosophicus", the "Wiener Kreis" around Carnap, Neurath, Feigl, Waismann, Kraft, Frank, Menger, Gödel, Hahn and in further developmental stages also Russel and Tarski held that no subjective phenomenology, philosophy or similar discipline provided a suitable logic for an exact natural science; rather, only protocol propositions of observations that are reproducible in experimental setups are capable of depicting reality on a one-to-one basis; this is also valid for propositions of a language of theory, that would have to be brought into agreement with these protocol propositions.

What is required is a language that can be formalized, e.g. as logical calculations, algorithms. This language would represent universal syntax that would be universally valid (i) for the things of the external world, (ii) for the physical laws and (ill) for the material reality of the brain of humans speaking in formalizable propositions (Witzany 1995).[3] The history of science clearly documents the course of this discussion. Logical empiricism had to abandon its efforts to achieve the ultimate validity claim of a physicalistic universal language. Concepts such as empirical significance,

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[3] The conviction of the possibility of an exact language of science was so deeply embedded – and this might serve as an example of the valuation of emotions in purportedly emotion-free objectivism – that, while it was refuted and ultimately rejected in the theory of science discourse and in the history of science, it was and continues to be considered valid in many standard sciences, curricula, underlying convictions.

initial and marginal conditions, verification und falsification, but above all the disposition terms, could not be adequately derived. Even the concept of "natural law" was justifiable only under the assumption of an arbitrary experimental design that presupposed a free will. Thus, the strongest, centuries-long argument against free will – the determinism of the material world – principally needed autonomous researchers if the term "natural law" was to be used justifiable in the natural sciences (Witzany 1995).

(b) In fact, the transition from the linguistic turn to the pragmatic turn has already occurred in Wittgenstein's "Philosophical Investigations" and in his analysis of obeying (following) rules: "Is what we call 'obeying a rule' something that it would be possible for only one man to do, and to do only once in his life? (. . .) It is not possible that there should have been only one occasion on which someone obeyed a rule. It is not possible that there should have been only one occasion on which a report was made, an order given or understood, and so on – To obey a rule, to make a report, to give an order, to play a game of chess, are customs (uses, institutions). To understand a sentence means to understand a language. To understand a language means to be master of a technique" (Wittgenstein 1972).

In his analysis of the expression "to obey a rule," Wittgenstein provides proof that the identity of meanings logically depends on the ability to follow intersubjectively valid rules with at least one additional subject; there can be no identical meanings for the lone and lonesome subject. Communication is a form of social action.

Following Wittgenstein's analysis of rules, the theory-of-science discourse derived and justified scientific statements based on an intersubjective communicative concept of language and communication. At the same time, it replaced the solipsistic subject of knowledge of subjectivism and objectivism with the "ultimate opinion" of an "indefinite community of investigators" of Peirce. The content of argumentation developed by (language-game) Wittgenstein, Austin, Searle, Apel, and Habermas proved the intersubjective-communicative character of thought, experience and research (the a priori of the linguistic community) and was therefore able to avoid the omnipresent subject-object dichotomy and its unavoidable consequences, solipsism and objectivism.

Before we can consider the terms "language" and "communication", we must understand the language of discussing these terms. We understand sentences in a language in which we are linguistically competent; we understand sentences in which the speaker presents propositions interconnected with validity claims. Intersubjective validity of scientific knowledge requires therefore linguistic communication of meaning and consensus formation via statements. We do not understand the ontology of natural phenomena or empirical observations, physiological processes, systems, physical principles, but rather sentences and actions that underlie grammatical, semantic and pragmatic rules that we share with the members of a linguistic community. A prerequisite for understanding is therefore a historically evolved social lifeworld, which provides the basis for the historical development of the commonly shared language, i.e., a core set of signs which obey semiotic rules. This, however, means that problems with understanding can arise if we are unaware of the grammatical, semantic or pragmatic rules that an uttering individual is following.[4]

7. A Three-Leveled Semiotics and Classical Variations of the 'Abstractive Fallacy'

The *pragmatic turn* founded the *intersubjective-communicative character of thought, experience and research* and was therefore able to avoid the omnipresent subject-object dichotomy and its unavoidable consequences, solipsism and objectivism or how Thomas McCarthy characterized the monological (third-person) observer perspective: "The monological approach preordained certain ways of posing the basic problems of thought and action: subject versus object, reason versus sense, reason versus desire, mind versus body, self versus other, and so on" (McCarthy 1984). As opposed to the linguistic turn, the pragmatic turn enables an understanding of human language and communication that is coherent with our communicative experience and with our subjective life. Such an understanding of language and communication should allow us to describe the *intersubjective-communicative character of thought*, *experience and research* in a non-reductionistic manner, as well as to describe the everyday prerequisites for successful communication, namely:

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[4] In order to reach an understanding with another speaker and establish an interrelationship, four validity claims must be fulfilled: (1) An utterance must be *understandable*. If the partner cannot understand the utterance, then he or she cannot answer (respond) appropriately. (2) The utterance must be *correct*, i.e. the expressions used must be the correct ones to express the situation (normative rightness). (3) It must be *true* – the expressed situation must correspond with reality (propositional truth), (4) It must be *sincere*, i.e. be meant in the manner in which it was expressed.

The understanding of intersubjective acts of human communication is directed at three levels, on that of (a) linguistic utterances, (b) actions, and (c) body-embedded expressions. Linguistic utterances have an evident (locutionary) communicatory aspect. Depending on the intention, they can use this grammatically clearly visible structure to mean something different: This represents their not-immediately-evident (illocutionary) force, which prompts those who are addressed to react in one way or another *to one and the same grammatical structure* of an expression. And they are part of an (perlocutionary) action; perlocutionary acts are performed with the intention of producing a further effect.

We do not need third-person observations and experimental studies to understand how understanding functions. We can analyze the ordinary language that we ourselves use, in the first or second person, i.e., as a participant; here, we can find all the elements of linguistic and communicative action. In a first step, we can determine that utterances such as requests, orders, questions, insinuations, accusations, approval, declarations, fabrications, etc. are regulative, imperative, expressive, objectifying, innovative, etc. actions with the intention of (a) establishing a commonly held understanding about something and (b) establishing an inter subjective relationship of action that enables a common, coordinated action or appropriate division of labor (Witzany 2005 a).

- the simultaneous understanding of identical meanings in two interacting partners, as expressed in successfully coordinated activity
- the differentiation between deep and superficial grammar of a statement along with differentiation between locutionary, illocutionary and perlocutionary speech acts with which the statements are made
- the differentiation between communication-oriented action and strategic manipulation of the communicating partners
- the critical judgment of the validity being claimed when making a particular statement

Only with such an *(universal-) pragmatic* concept of language and communication, one which is neither subjectivistic nor objectivistic-naturalistic, can we sensibly determine whether similar structural features exist in the non-human realm, i.e., interactions within and between organisms which are sign-mediated (signals, symbols) (Witzany 1993, 2000, 2005a, 2005b). In the human world, as well as in non-human living nature, sign- use is not a *solus ipse* event, but needs individuals which share common set of signs and semiotic rules.

It therefore makes little sense to refer to sign use in the communication processes of plant or bacterial lifeworlds, all the while presupposing an objectivistic language and communication concept, and using an empirical methodological ideal to explain the evolution of communicative interactions from the amoeba to humans. This would lead to the dead-end of the solipsistic subject of knowledge and hopeless entanglement in the subject-object dichotomy of objectivism/ physicalism/ naturalism as described above by McCarthy.

The reverse pathway is more felicitous: beginning with humans, and human self-understanding, which must be coherent with the concepts of "language" and "communication" used.

The semiotics of Peirce is helpful in this respect. It can provide the irreducible conditions for the appropriate analyses of sign-usage and linguistic communication via a three-leveled semiotics.[5]

According to Peirce, a sign (1) designates something (2) to an interpreter (3). Semiotics is therefore an irreducible three-leveled relation of syntactic, semantic and pragmatic rules. *Each of the 3 elements of the sign junction already presupposes in its junction the other two*. According to Peirce, all those who reduce this principally irreducible three-leveled relation to two or one level, have fallen victim to an abstractive fallacy. The most common of these are (Apel 1974):

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[5] The decisive change versus Kant's solus-ipse subject of knowledge (and subsequently the objectivism in logical empiricism) is the "community of interpretation" in the "community of investigators". *Scientific knowledge does not exist for a solipsistic subject if knowledge, but only for members of a community of interpreters*. With this, Peirce adheres to the intersubjective-communicative character of thought, experience and research. (This is coherent with Wittgenstein's analyses of "obeying a rule".)

- Signs (1) without the signified (some)thing (2) and without sign interpreter (3): it yields abstraction from the a priori of the linguistic community (i.e., the intersubjective-communicative character of thought, experience and research as described above) which reflects on the world and produces propositions with validity claims. Examples are linguistic Platonism, model-Platonism of the logic of science in the linguistic turn: in which the linguistic expressions or the explanatory model are the real (some) thing.
- The sign interpreter (3) without signs (1) and without the signified (some)thing (2): it yields idealism of consciousness: abstraction from the a priori of the linguistic community (Descartes, Kant, Fichte, Hegel, Husserl): that is to say subjective/ objective reason is the real (some)thing. Language is only a secondary means of explanation; the external world exists only through reason/rationality.
- Sign interpreter (3) and sign (1) without the signified (some)thing (2): this yields semiotic idealism: sign and sign interpreters are the signified (some)thing. Everything is a sign: Pansemiotics/ metaphysical semioticisrn.
- The signified (some)thing (2) without signs (1) and without sign interpreter (3): It yields realism and materialism, preKantian ontology/metaphysics: Being is a physical–chemical law of the material world. We are part of this particular material and can at best recognize approximately, with our sense organs, partial perspectives of this material being. Sign use and sign interpretation are pre-scientific constructions that lack a correspondence in the material world (illusion).
- The signified (some)thing (2) and the sign interpreter (3) without signs (1): yields psychologism or affection-realism; Leibniz, Locke, Berkeley, Hume, positivism of the sensory data, Popper: the observational language and theoretical language of the logic of science can be brought into agreement. The material function of the sensory organs adheres to a "universal syntax" that is identical to the laws of physics and chemistry.
- The signified (some)thing (2) and the sign (1) without the sign interpreter (3): yields onto semantic realism, constructivism, systems theory, information theory. Abstraction from the a priori of the linguistic community yields subjectless, syntactic-semantic phase of a modern science of logic in Carnap, Russel, Frege, (Tractatus-)Wittgenstein, Tarski, Popper; solipsism and realism: each speaker/listener is equipped with the same syntax (depicting material reality), alleviating any need for communication about the structure of language or the structure of the world. Abstraction by the cognizant subject produces scientifically exact statements which depict, in agreement with the laws of physics and chemistry, material reality on a one-to-one basis. Subjects of knowledge only disturb this naturalism and muddy the exact cognitive process.

8. Towards a Pragmatic Philosophy of Biology: Biologists as Performative Participants

A pragmatic philosophy of biology is a philosophy of biology which integrates the irreducible three-leveled semiotics. This approach avoids the abstractive fallacy and allows us to understand language-like structured and communicatively organized living nature in a non-solipsistic, non-objectivistic manner. It can therefore methodologically anchor the perspective of *performative participants* (first/second person perspective) of a planetary communicating community of living nature.

The pragmatic philosophy of biology enables a clear distinction between life and the non-living. The unbridgable gap between a mechanistic and the communicative concept is that rule-governed sign-mediated interactions are restricted to living individuals (-in-populations) and do not underlie natural laws solely. The decisive difference between natural laws and semiotic rules is that every living being underlies natural laws in a strict sense. Semiotic rules may be followed or not, may be changed or not, may be generated or not. The fundamental difference between living nature and non-living nature is that life depends on sign-mediated interactions, i.e. communication processes which obey syntactic, pragmatic and semantic rules, whereas crystallization of water to ice, for example, requires solely natural laws rather than semiotic rules.

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Chapter 24
Biosemiotics: A New Understanding of Life

Marcello Barbieri (1940–)

Introduction and Commentary: Marcello Barbieri

> *"The* genotype-phenotype model, physicalism*, and* natural selection *are the three pillars of modem biology, and currently they are totally alien to the idea that semiosis is fundamental to life. This idea, therefore, can become part of biology only if we prove that* all *of the above concepts can be replaced by more* general *ones. That is what biosemiotics is really about. It is about a new biological paradigm that gives us (1) a new model of the cell, (2) a real alternative to physicalism, and (3) a new mechanism of evolution. These are the great novelties of biosemiotics".*
>
> M. Barbieri (2007: 578)

Since the early 1970s, Italian embryologist and theoretical biologist Marcello Barbieri has been developing a biosemiotic framework for biology based on his analysis of the cell's internal organic codes. Developing his theory of *semantic biology* in complete independence from the Sebeokian biosemioticians, but now widely recognized as a key figure in the development of 21st century biosemiotics, Barbieri proposes an alternative biosemiotic paradigm that is not organicist and qualitative in its origins, but mechanist and molecular instead – but that is just revolutionary a framework for the attempt to scientifically investigate and understand the reality of sign processes in life processes.

Born August 9, 1940 in Carpineti (Reggio Emilia), Italy, Marcello Barbieri received his undergraduate education at the Liceo Classico Muratori in Modena, and graduated from the Science Faculty of the University of Bologna with a degree in Natural Sciences in December 1964. He joined the Institute of Histology and Embryology of the Faculty of Medicine of the same University as a researcher in molecular biology and as a teacher of biophysics for medical students the following year, and in 1968 discovered how to isolate fractions of ribosome microcrystals induced in chick embryos by hypothermia. In 1970, he was invited by Nobel prize winning molecular biologist Max Perutz (1914–2002) to spend a semester at the Medical Research Council's Laboratory of Molecular Biology in Cambridge (UK), where he made the acquaintance of Francis Crick (1916–2004), Hugh Huxley (1924–) and Aaron Klug (1926–), all of whom, like Barbieri, were applying the technologies of electron microscopy and X-ray crystallography in their attempts to better understand the workings of the cell.

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In 1971, EMI announced the first scanner for computerized tomography and Barbieri began investigating its algorithms for the reconstruction of structures from projections, which seemed to provide "new models for a mathematical simulation of embryonic development" (2003: 67–91). Following this intuition, in 1972 and in 1974, Barbieri spent two semesters at the National Institute of Health in Bethesda, Maryland, where he discovered that "structures can be reconstructed from incomplete information provided that the reconstructions are performed with iterative methods that use *memory matrices* and *codes*; this suggested that *organic memories* and *organic codes* must be essential, natural features of embryonic development" (*ibid*).

This work into the embodied *logic* of embryonic development led Barbieri to continue his studies of ribosome crystallization in a new light, and from 1975 to 1980 he worked at the Max-Plack-Institute für Molekulare Genetik in Berlin, investigating the damage to the ribosome transport system in chick embryos that was causing the accumulation of ribosomes and inducing them to form microcrystals. What Barbieri discovered was that the entire process was highly dependent not on the sequences of DNA nucleotides per se, but on the particular stage of embryonic development having occurred up to the point of transport breakdown. This realization, he recounts

> convinced me that the differentiation of the ribonucleoprotein system of the cell was a *precondition* for the differentiation of the whole cell. That, in turn, required an evolutionary explanation, and I concluded that the evolution of the *ribonucleoprotein system* (i.e., the ribotype) had to be a precondition for the origin and the evolution of the cell. This idea appeared in 1981 in the *Journal of Theoretical Biology*, together with the concept that the cell is not a genotype-phenotype duality but a trinity of genotype, phenotype and ribotype. The cell, in other words, is not a biological computer made of software and hardware, but a semiotic system made of software [genotype], hardware [phenotype] and codeware [ribotype] [responsible for 'reading' as well as for 'writing' the system code] – and, thus, that evolution takes place by two distinct mechanisms , i.e., by natural *selection* and by natural *conventions*, as proposed in my 1985 book, *The Semantic Theory of Evolution* (2008: p.c.).

Barbieri's work on the two projects of prerequisite ribonucleoprotein differentiation and on the ability to reconstruct prior form out of incomplete information with the assistance of existing memory matrices and the appropriate codes, led him to the realization that mainstream genetics' unquestioning embrace of Wilhem Johannsen's 1909 posit that a living system could be exhaustively explained by viewing it as a "genotype-phenotype duality" was a Cartesian oversimplification that had long outlived its explanatory usefulness, given all that science has since discovered about the actual mechanisms of genetic and epigenetic development.

For genes do not ever manifest their proteins stereochemically, Barbieri reminds us (2008: 580). Rather, the manifestation of phenotype from genotype is, in all known cases of living being, *mediated* by the molecular "adaptor" machinery of the ribozymes, which are needed to carry out the very two different recognition processes that join specific sequences of nucleotides with specific amino acids. Francis Crick had first proposed the likelihood of such mediating "adaptor molecules" in the early 1960s, and today the translational role of ribosomal tRNA in genetic expression is scientific common knowledge. But, as Barbieri shows repeatedly throughout his work (1981, 1985, 1998, 2003, 2008) the implications that this *mediating domain* of life processes holds for our understanding of the essential bio-logic of living systems has thus far gone unrecognized, and is profound.

No physical nor chemical *necessity* links any given nucleotide sequence with any given amino acid, notes Barbieri (2008: 580), and the very notion of a "codon" itself implies a "reading sequence" that is a *determination* that, analogous to a perceptual *gestalt,* has to be actively established by the specific orientation taken towards the multiply-arrangeable materials present in a pre-given set – it is not a self-categorizing, objectively invariant entity in itself (2008: 583).

Left to themselves, these two separate domains – one of linear nucleotide bases and the other of three-dimensional proteins – would have no natural commerce. Yet, in nature as it has evolved here on Earth, a "genetic code" has arisen that ubiquitously *does* so link these disparate domains, guaranteeing biological specificity via the translation apparatus of ribosome and tRNAs. It is the nature of such a biological "code" itself – unaccounted for in Johannsen's genotype-phenotype duality and subsequently overlooked as a *general* organizing phenomenon in biology – that Barbieri argues must now be analyzed and operationalized for science.

In pointing to the need for a triadic explanation of not just genes and proteins, but of genes (as one-dimensional information sequences), proteins (as three-dimensional physical structures) and the *mediating relations* of the "codes of natural convention" that have arisen in evolution, and that continue to generate the evolutionary novelties of biology, Barbieri was not just calling for a new way of thinking about how living cells operate today – but also of how living cells came to be in the first place. Thus, he insisted, was a *semantic theory of evolution* necessary, along with a s*emantic theory of the cell* – and from 1981 to the present, Barbieri has worked incessantly to scientifically articulate them both.

In 1981, Barbieri proposed that the cell – the fundamental unit of all life – cannot be conceptually caricaturized as a simple (and biochemicaly impossible) one-to-one mapping of genotype to phenotype, but must be recognized instead as a triadically constituted entity of genotype, ribotype and phenotype (1981: 547). No known organism does or even could (to the best of our knowledge) lack these three levels of organization, argues Barbieri – yet the pace of scientific research has now become such, that progress in the clarification of our basic conceptual categories (e.g., *species, planet, information, measurement*) often lags decades, if not centuries, behind our progress in data collection and methodology. Such is the case with the habitual collapsing of the trivalent genotype-translational apparatus-phenotype relation into a dyadic (and, again, biologically impossible) genotype-to-phenotype duality. "In a way," wrote Barbieri in 1985, "this is like looking at the biological universe from a Ptolemaic point of view" (1985: 138).

Accordingly, and as an answer to the "gene first versus protein first" debates about of the origin of the cell that originated in the "replication first versus metabolism first" theories of Haldane and Oparin, respectively (and that are still going on in their more modern forms to this day) Barbieri proposes a revolutionary re-perspectivizing of the relations known to be operative in life:

> The idea that ribosomes are mere intermediaries implies that the essence of their evolution was to adapt to this role and to establish an increasingly accurate correspondence between genes and proteins. But the biochemical evidence, on the other hand, tells us that the ribosomal RNAs have changed very little during the history of life. If there is a smooth working unity between the components of the cell, and the ribosoids did not change much, clearly it was the genotype and the phenotype which had to adapt to the ribotype, and not the other way around . . . in my opinion, it does not even make sense to speak of the rest of the cell as an independent entity of genotype and phenotype. 'The rest of the cell' is simply whatever managed to integrate with the primitive ribonucleoprotein systems and form a working unity with them (1985: 137).

Such ancestral ribotypes, posits Babrieri, were, like their modern counterparts, heterogenous systems consisting of both nucleic acids and proteins. During the course of precellular evolution, he proposes, some ribosoids became particularly well-suited for base-pairing while others were more well suited for aminoacylation and for performing three-dimensional operations in space. Within this precellular collective, then, there were what could be called ribogenotypes and ribophenotypes, and "the origin of the *cell* can be summarized by saying that the genotype evolved as the extension of the ribogenotype, and the phenotype as the extension of the ribophenotype", as each of these later "speciation events" diffused out of a common prior, and less specialized and differentiated, ancestry (1985: 138)

Barbieri's gene code theory is a radical re-thinking of the relations that give rise to, and still sustain, cellular organization – yet upon careful consideration, it is just as possible, and even more in line with traditional Darwinian thinking, than its alternatives. Barbieri himself illustrates this best when, in a later work, he compares the "chicken or the egg" debate about the origins of cellular organization to the problem of trying to explain the presence of a city full of objects that are assembled according to instructions as an "instruction first" versus an "object first" dilemma – while relegating as mere instruction-object "intermediaries" the city inhabitants who are actually the entities that build the objects and who act upon yet other objects as instructions – and from whom both objects and instructions must have originally issued (2003: 154–155).

As a committed scientist and naturalist, however, Barbieri has no intention of assigning to the ribotype any kind of supernatural or anthropomorphic "agency" for its role in the bringing about and maintenance of this state of affairs. And so the question that he sets himself becomes: What kind of *natural* processes are we looking at when we observe the ubiquity of this gene-mediator-protein triad throughout all of known biology? Barbieri concludes that the laws of chemistry are at work here, of course, as well as the laws of physics, and natural selection . . . plus one more law-like phenomenon in nature that is observable everywhere in biology, and yet is still not fully recognized by biologists as such – i.e., the evolutionary phenomenon of *natural convention*, of which the "genetic code" is only one particular instance (albeit the earliest, and undoubtedly, the most vital one we know of).

"Natural conventions" (1985: 160) are characterized by their being *not* the product of strict physical and chemical necessity per se – i.e. they are regularities in nature that have been produced by evolution, not by force. But they are no less operative and consequential because of that, as the incessant and self-preserving regularity of the genetic code makes clear. Rather, the introduction of such regulatory natural conventions in the proto-biological world gave rise to the "new kind of anti-chaos" (2003: 153) that we recognize as life itself. Thus, all the major events of macroevolution (the cell, the nucleus, the diversity of species) are all the results of natural conventions, as they play out in the world of natural selection, posits Barbieri (1985: 168).

In contradistinction to physico-chemical necessity, then, 'natural conventions' consist in the evolution of coding rules that establish a causal (but again, not originally necessary) correspondence between two biological domains. These conventions Barbieri calls *organic codes,* and they are objectively discoverable by scientific examination and experimentation. The genetic code is, by far, the most well-known example, but in the following selection, Barbieri presents a list of twenty more. The unmistakable evidence that such a naturally conventional organic code is in play, claims Barbieri, is the presence of *adaptor molecules* that perform the two separate recognition processes that reliably join biological domains A and B. As stated above, "this gives us an objective criterion in the search for organic codes" in biology, writes Barbieri, "and their existence in nature therefore becomes, first and foremost, an experimental problem" (2005: 119).

The impact of Barbieri's theories on contemporary biosemiotics, and the seminal role that he now plays within the interdiscipline, are discussed in considerable detail in the 'history of biosemiotics' chapter that opens this volume. In the following article, written at the invitation of prestigious multidisciplinary science journal *Naturwissenschaften*, Barbieri offers an extraordinarily readable and concise overview of his forty years of work in developing his far-reaching *semantic biology*, drawing out just some of its major implications for biology, and bringing the reader up to date on his own current involvement in the interdisciplinary research agenda of biosemiotics. Surveying the current state of the field, it is appropriate for us to conclude this first biosemiotic anthology with the words with which Barbieri concludes his text:

"We have seen that biosemiotics has been developed independently by at least five different lines of research. . . . This makes us realize that biosemiotics is still a developing science where many issues, even important ones, remain to be settled. Yet all versions of biosemiotics, at any rate, share the idea that semiosis is fundamental to life – i.e., that all living creatures are semiotic systems, and the important point is that we already have enough experimental evidence in favor of that idea. Biosemiotics, in conclusion, is a genuine new paradigm for both biology and semiotics, but its future is unpredictable . . .Nothing has been settled yet, everything is on the move, and the exploration of the new continent of meaning has just begun" (2008: 597, 2007: 112).

Biosemiotics: A New Understanding of Life (2008)

Abstract Biosemiotics is the idea that life is based on semiosis, i.e., on signs and codes. This idea has been strongly suggested by the discovery of the genetic code, but so far it has made little impact in the scientific world and is largely regarded as a philosophy rather than a science. The main reason for this is that modern biology assumes that signs and meanings do not exist at the molecular level, and that the genetic code was not followed by any other organic code for almost four billion years, which implies that it was an utterly isolated exception in the history of life. These ideas have effectively ruled out the existence of semiosis in the organic world, and yet there are experimental facts against all of them. If we look at the evidence of life without the preconditions of the present paradigm, we discover that semiosis is there, in every single cell, and that it has been there since the very beginning. This is what biosemiotics is really about. It is not a philosophy. It is a new scientific paradigm that is rigorously based on experimental facts. Biosemiotics claims that the genetic code (1) is a real code and (2) has been the first of a long series of organic codes that have shaped the history of life on our planet. The reality of the genetic code and the existence of other organic codes imply that life is based on two fundamental processes – copying and coding – and this in turn implies that evolution took place by two distinct mechanisms, i.e., by natural selection (based on copying) and by natural conventions (based on coding). It also implies that the copying of genes works on individual molecules, whereas the coding of proteins operates on collections of molecules, which means that different mechanisms of evolution exist at different levels of organization. This review intends to underline the scientific nature of biosemiotics, and to this purpose, it aims to prove (1) that the cell is a real semiotic system, (2) that the genetic code is a real code, (3) that evolution took place by natural selection and by natural conventions, and (4) that it was natural conventions, i.e., organic codes, that gave origin to the great novelties of macroevolution. Biological semiosis, in other words, is a scientific reality because the codes of life are experimental realities. The time has come, therefore, to acknowledge this fact of life, even if that means abandoning the present theoretical framework in favor or a more general one where biology and semiotics finally come together and become biosemiotics.

Introduction

Semiotics is the study of signs, and biosemiotics can be defined, therefore, as the study of signs in living systems. This is the “literal” definition of the discipline, a version that can be referred to as *sign-based biosemiotics* because it is explicitly based on the concept of sign. Biosemiotics, however, can also be defined as the study of codes in living systems, a version that is referred to as *code-based biosemiotics*. There have been historical disputes between the two versions but, as we will see, they are not incompatible, and both share the idea that every living creature is a semiotic system, i.e., that semiosis (the production of signs) is fundamental to life. The evidence for this conclusion comes primarily from the genetic code, but modem biology has never accepted it. The discovery of the genetic code has been universally recognized as one of the greatest scientific breakthroughs of all times but not as proof that semiosis exists at the molecular level. Modem biology has not accepted-let us repeat this–that the existence of the genetic code implies that every cell is a semiotic system. And this is no accident. The rejection of the semiotic nature of life has been, and continues to be, extremely widespread because it is the logical consequence of at least three concepts that lie at the very heart of modem biology.

1. The first is the model that describes the cell as a duality of genotype and phenotype, i.e., as a biological computer where genes provide the software and proteins the hardware. The crucial point is that a computer has codes but is *not* a semiotic system because its codes come from a "codemaker", which is outside it. This makes it legitimate to say that cells too can have a code without being semiotic systems. All we need, for that conclusion, is the idea that the genetic code was assembled by natural selection, i.e., by a codemaker that is outside the cell just as the human mind is outside the computer.
2. The second basic concept is *physicalism*, the doctrine that everything in life, including signs and codes, is ultimately reducible to physical quantities. This implies that the genetic code is not a "real" code but a linguistic expression that biologists have adopted simply because it was intuitively appealing. Deep down, according to this view, the genetic code is but a metaphor because all its features must be completely accounted for by physical quantities.
3. The third basic concept of modem biology is the belief that every biological novelty has been brought into existence by natural selection. The codes, be they organic or mental, are outstanding phenomena, but as long as they are not a mechanism of evolution, they do not account for anything fundamentally new. This conclusion is reinforced by the fact that the genetic code appeared at the origin of life, whereas the codes of culture arrived almost four billion years later. They came into being respectively at the beginning and at the end of life's history and are considered, therefore, as utterly exceptional phenomena, not as ordinary biological processes.

The genotype-phenotype model, physicalism, and natural selection are the three pillars of modem biology, and they are totally alien to the idea that semiosis is fundamental to life. This idea, therefore, can become part of biology only if we prove that all the above concepts can be replaced by more general ones. That is what biosemiotics is really about. It is about a new biological paradigm that gives us (1) a new model of the cell, (2) a real alternative to physicalism, and (3) a new mechanism of evolution. These are the great novelties of biosemiotics, and this review is dedicated almost exclusively to illustrating them. More precisely, Part 1 is dedicated to the semiotic structure of the cell, Part 2 to the nature of information and meaning, Part 3 to the organic codes, and Part 4 to the mechanisms of evolution, whereas Part 5 will give a brief overview of the present state of biosemiotics.

Part 1: The Semiotic Structure of the Cell

The Code Model of Semiosis

Semiotics is usually referred to as the study of signs (from the Greek *semeion* = sign), but this definition is too restrictive because signs are always associated with other entities. A sign, to start with, is always linked to a *meaning*. As living beings, we have a built-in drive to make sense of the world, to give meanings to things, and when we give a meaning to something, that something becomes a sign for us. Sign and meaning, in other words, cannot be taken apart because they are the two sides of the same coin. Semiotics, therefore, is not just the study of signs; it is the study of signs and meanings together. The result is that a system of signs, i.e., a *semiotic system*, is always made of at least two distinct worlds: a world of entities that we call *signs* and a world of entities that represent their *meanings*.

The link between sign and meaning, in turn, calls attention to a third entity, i.e., to their *relationship*. A sign is a sign only when it stands for something that is other than itself, and this *otherness* implies at least some degree of independence. It means that there is no deterministic relationship between sign and meaning. Different languages, for example, give different names to the same object precisely because there is no necessary connection between names and objects. A semiotic system, therefore, is not any combination of two distinct worlds. It is a combination of two worlds between which there is no necessary link, and this has an extraordinary consequence. It implies that a bridge between the two worlds can be established only by conventional rules, i.e., by the rules of a code. This is what qualifies the semiotic systems, what makes them different from everything else: *a semiotic system is a system made of two independent worlds that are connected by the conventional rules of a code*. A semiotic system, in conclusion, is necessarily made of at least three distinct entities: signs, meanings, and code.

Here, at last, we have a definition where it is stated explicitly that a code is an essential component of a semiotic system. It is the rules of a code that create a correspondence between signs and meanings, and we can say, therefore, that an act of semiosis is always an act of coding, i.e., it is always a convention. More precisely, we can say that an elementary act of semiosis is a triad of "sign, meaning, and convention", whereas a semiotic system is a whole set of signs and meanings that are linked together by all the various conventions that make up a code.

Signs, meanings, and conventions, however, do not come into existence of their own. There is always an "agent" that produces them, and that agent can be referred to as a codemaker because it is always an act of coding that gives origin to semiosis. In the case of culture, for example, the *codemaker* is the human mind since it is the mind that produces the mental objects that we call signs and meanings and the conventions that link them together. We come in this way to a general conclusion that can be referred to as "the code model of semiosis": *a semiotic system is a triad of signs, meanings and code that are all produced by the same agent, i.e., by the same codemaker*.

This conclusion is highly relevant to biology because it tells us precisely what we need to prove in order to show that the cell is a semiotic system. We need to prove that in every living cell there are four distinct entities: signs, meanings, code and codemaker.

The Molecules of Life

Modem biology is based on three extraordinary experimental facts: (1) the discovery that most biological structures and functions are ultimately due to proteins, (2) the discovery that the hereditary instructions for making proteins are carried by strings of nucleotides called genes, and (3) the discovery that genes are translated into proteins by a universal set of rules, which has become known as the genetic code.

These discoveries have confirmed that genes and proteins are the key molecules of life but have also revealed something totally unexpected about them. They have shown that genes and proteins differ from all other molecules not only because of their size, shape, or chemical composition but primarily because they are produced in a totally different way. In the inorganic world, the structure of molecules is determined by the bonds that exist between their atoms, i.e., by internal factors. In living systems, instead, genes are built by molecular machines which physically stick their nucleotides together following the order of a template which is external to the growing molecule. In a similar way, proteins are made by molecular machines which bind amino acids in the order prescribed by an external template of nucleotides.

Genes and proteins, in short, are assembled by molecular robots on the basis of outside instructions. They are *manufactured* molecules, as different from ordinary molecules as artificial objects are from natural ones. Indeed, if we accept the commonsense view that molecules are natural when their structure is determined *from within* and artificial when it is determined *from without*, then genes and proteins can truly be referred to as artificial molecules, as *artifacts made by molecular machines.* This in turn implies that all biological objects are artifacts, and we arrive at the general conclusion that *life is artifact-making*.

The discovery that genes and proteins are manufactured molecules has direct implications for the origin of life because it tells us that primitive molecular machines came into existence long before the origin of the first cells. The simplest molecular machines we can think of are molecules that could join other molecules together by chemical bonds, and for this reason we may call them *bondmakers*. Some could form bonds between amino acids, some between nucleotides, others between sugars, and so on. It has been shown, for example, that short pieces of ribosomal RNA have the ability to form peptide bonds, so it is possible that the first bondmakers were RNA molecules of small or medium-size molecular weights. Among the various types of bondmakers, furthermore, some developed the ability to join nucleotides together in the order provided by a template. Those bondmakers started making copies of nucleic acids, so we can call them *copymakers*.

In the history of life, molecular copying came into being when the first copymakers appeared on the primitive Earth and started copying nucleic acids. This implies that natural nucleic acids had already been formed by spontaneous reactions on our planet, but that was no guarantee of evolution. Only the copying of genes could ensure their survival and have long-term effects, so it was really the arrival of copymaking that set in motion the extraordinary chain of processes that we call evolution. The first Major Transition of the history of life (Maynard Smith and Szathmary 1995) is generally described as the origin of genes, but it seems more accurate to say that it was the origin of molecular *copying*, or the origin of *copymakers*, the first molecular machines that started multiplying nucleic acids by making copies of them.

The Genetic Code

Proteins are the key building blocks of all living structures, as well as the engines of countless reactions that go on within those structures. For all their extraordinary versatility, however, there is one thing they cannot do. Unlike genes, they cannot be their own templates. It is simply not possible to make proteins by copying other proteins. The transition from natural to manufactured molecules, therefore, was relatively simple for genes but much more complex for proteins. Manufactured genes could be made simply by copying natural genes, and all that was required to that purpose were molecules which had a polymerase-like activity. Manufactured proteins, instead, could not be made by copying, and yet the information to make them had to come from molecules that can be copied because only those molecules can be inherited. The information for manufacturing proteins, therefore, had to come from genes, so it was necessary to bring together a carrier of genetic information (a messenger RNA), a peptide-bondmaker (a piece of rib os omal RNA), and molecules that could carry both nucleotides and amino acids (the transfer RNAs). The first proteinmakers, in short, had to bring together three different types of molecules (messenger, ribosomal, and transfer RNAs), and were, therefore, much more complex than copymakers.

The outstanding feature of the protein-makers, however, was not the number of components. It was the ability to ensure a specific correspondence between genes and proteins, because without it there would be no biological specificity, and without specificity there would be no heredity and no reproduction. Life, as we know it, simply would not exist without a specific correspondence between genes and proteins.

Such a correspondence would be automatically ensured if the bridge between genes and proteins could have been determined by stereochemistry, as one of the earliest models suggested, but that is not what happens in Nature. The bridge is always provided by molecules of transfer RNA, first called *adaptors*, that have two recognition sites: one for a group of three nucleotides (a *codon*) and another for an amino acid. In this case, a specific correspondence could still be guaranteed automatically if one recognition site could determine the other, but again that is not what happens. The two recognition sites of the adaptors are physically separated in space and are chemically independent. There simply is no necessary link between co dons and amino acids, and a specific correspondence between them can only be the result of conventional rules. Only a real code, in short, could guarantee biological specificity, and this means that in no way the genetic code can be dismissed as a linguistic metaphor.

Protein synthesis arose, therefore, from the parallel evolutions of the translation apparatus and of the genetic code, and the final machine was a *code-and-template-dependent-protein-maker* or, more simply, a *codemaker*. The second Major Transition of the history of life is generally described as the origin of proteins, but it would be more accurate to say that it was the origin of codemaking, or the origin of codemakers, the first molecular machines that discovered molecular coding and started populating the Earth with codified proteins.

The Cell as a Trinity

The idea that life is based on genes and proteins is often expressed by saying that every living system is a duality of genotype and phenotype. This model was proposed by Wilhelm Johannsen in 1909, but was accepted only in the 1940s and 1950s when molecular biology discovered that genes are chemically different from proteins and, above all, when it became clear that genes carry linear information, whereas proteins function by their three-dimensional structures. The genotype-phenotype duality is, therefore, a dichotomy that divides not only two different biological functions (heredity and metabolism) but also two different natural entities (information and energy). It is the simplest and most general way of defining a living system and has become the foundational paradigm of modern biology, the scheme that transformed the *energy-based* biology of the 19th century into the *information-based* biology of the 20th.

In the 1950s and 1960s, however, the study of protein synthesis revealed that genes and proteins are not formed spontaneously in the cell but are manufactured by a system of molecular machines based on RNAs. In 1981, the components of this manufacturing system were called *ribosoids*, and the system itself was given the collective name of *ribotype* (Barbieri 1981, 1985). The cell was described in this way as a structure made of genes, proteins, and ribosoids, i.e., as a trinity of genotype, phenotype, and ribotype.

This model is based on the conclusion that the ribotype had a historical priority over genotype and phenotype. Spontaneous genes and spontaneous proteins did appear on the primitive Earth but could not give origin to cells because they did not have biological specificity. They gave origin to copymakers and codemakers, and it was these molecular machines made of ribosoids that evolved into the first cells.

The RNAs and the proteins that appeared spontaneously on the primitive Earth produced a wide variety of ribosoids, some of which were synthetizing ribosoids, whereas others were ribogenes, and others were riboproteins (or ribozymes). The systems produced by the combination of all these molecules, therefore, had a ribotype, a ribogenotype, and a ribophenotype. Eventually, evolution replaced the ribogenes with genes and the riboproteins with proteins, but the synthetizing ribosoids of the ribotype have never been replaced. This shows not only that the ribotype is a distinct category of the cell but also that it is a category without which the cell simply cannot exist.

The ribosoids of the ribotype are the oldest phylogenetic molecules that exist on Earth (Woese 2000), and they firmly remain at the heart of every living cell. Genes, proteins, and ribosoids are all manufactured molecules, but only ribosoids can be also makers of those molecules. This concept can perhaps be illustrated by comparing the cell to a city where proteins are the objects, genes are the instructions, and ribosoids are the "makers" of both objects and instructions, i.e., the inhabitants of the city.

It is an experimental fact, at any rate, that every cell contains a system of RNAs and ribonucleoproteins that makes proteins according to the rules of a code, and that system can be described, therefore, as a "code-andtemplate-dependent-protein-maker" or more simply as a codemaker. That is the third party that makes of every living cell a trinity of genotype, phenotype, and ribotype. The genotype is the seat of heredity, the phenotype is the seat of metabolism, and the ribotype is the codemaker of the cell, the seat of the genetic code.

The Defining Feature of Signs and Meanings

A semiotic system is made of signs, meanings, code, and codemaker, and we know that there is a genetic code in protein synthesis. We also know that proteins are made by a system of ribonucleoproteins that is the physical seat of the genetic code and functions, therefore, as the codemaker of the cell. This tells us that every living cell does have a genetic code and a codemaker. But what about the other two entities? Can we say that there are also signs and meanings at the molecular level? Can these entities exist in the cell? In order to answer this question, let us examine first the traditional signs and meanings of culture and see if they have a qualifying feature that can be extended to the molecular level.

The signs and meanings that we are familiar with are often the mental representations of objects or events of the physical world. A sign, for example, can be a spoken word, and its meaning can be a mental image. The mental image of an object is normally evoked by different words in different languages, and this clearly shows that mental sounds and mental images are separable. When they are separated, however, they no longer function as signs and meanings. To a non-English speaker, for example, a word like "twitch" may have no linguistic meaning, and in this case, it would be just a sound not a sign. There is no contradiction, therefore, in saying that signs and meaning are distinct mental objects, and that they cannot be taken apart because when they are taken apart, they simply stop functioning as signs and meanings.

This makes us understand an extremely important feature of semiosis. It tells us that a mental sign, or a mental meaning, is never an intrinsic property of a mental object. It is something that the mind can give to a mental object and that the mind can take away from it.

To this conclusion, one could object that terms like mental signs and mental objects are a clear case of *mentalism*, and that this is no longer the received view, today. The important point, however, is that the conclusion remains valid even if we accept that the sounds and images of our perceptions are just the results of neuron firings, and that the mind is but a product of the brain. Even in this case, the link between the neuron firings that produce the signs and the meanings of any language is based on the rules of a code and are totally dependent upon the agent of that code, i.e., upon the codemaker of the system.

Signs and meanings simply do not exist without a codemaker and outside a codemaking process. The codemaker is the agent of semiosis, whereas signs and meanings are its instruments. We conclude, therefore, that signs and meanings are totally dependent on codemaking, i.e., they are *codemaker-dependent entities*. This is the qualifying feature that we were looking for because it is completely general and can be applied to all systems. We can say, therefore, that signs and meanings exist at the molecular level, and in particular, in protein synthesis, only if we prove that in protein synthesis there are codemaker-dependent entities.

The Sequences of Genes and Proteins

All biochemistry textbooks tell us that there is a genetic code in protein synthesis, but none of them mentions the existence of signs and meanings. At first sight, in fact, these entities do not seem to exist at the molecular level. The translation apparatus can be regarded as a codemaker because it is the seat of the code that creates a correspondence between genes and proteins, but these molecules appear to have only "objective" chemical properties, not the "codemaker-dependent" properties that *define* signs and meanings. A messenger RNA, for example, appears to be a unique and objective sequence of molecules, but let us take a closer look.

A messenger RNA is certainly a unique and objective chain of nucleotides, but in no way is it a unique sequence of co dons because different codemakers could scan it in different ways. If the nucleotides were scanned two-by-two, for example, the sequence of co dons would be totally different. The same chain of nucleotides, in other words, can give origin to many sequences of co dons, and it is always the codemaker that determines the sequence because it is the codemaker that *defines* the codons. A linear sequence of codons, in short, does not exist without a codemaker and outside a codemaking process. It is totally dependent on codemaking and is, therefore, a codemakerdependent entity, which is precisely what a sign is.

In the same way, the linear sequence of amino acids that is produced by the translation apparatus is also a codemaker-dependent entity because only a codemaker can produce it. Any spontaneous assembly of amino acids would *not* make linear chains, and above all, it would not arrange the amino acids in a specific order. Specific linear sequences of amino acids can be produced only by codemakers, but different codemakers would arrange the amino acids in different ways, which shows that the sequence of a protein is only one of the many possible "meanings" that could be given to a string of nucleotides.

The sequence of a gene and the sequence of a protein, in conclusion, are not objective properties of those molecules. They are codemaker-dependent properties because they do not exist without a codemaking process and because they would be different if the codemaker had a different structure. The sequences of genes and proteins, in short, have precisely the characteristics that define signs and meanings. They are codemaker-dependent entities made of organic molecules and are, therefore, organic signs and organic meanings. All we need to keep in mind is that *signs and meanings are mental entities when the codemaker is the mind, but they are organic entities when the codemaker is an organic system (*Barbieri 2003a).

We reach in this way the conclusion that every living cell contains all four components of semiosis (signs, meanings, code and codemaker) and is, therefore, a real semiotic system.

Two Types of Signs

Signs have been divided since antiquity into two great classes that are traditionally represented by *symbols* and *symptoms*. Augustine (389 AD) called them *signa data* and *signa naturalia*, a distinction that continues to these days under the terms of *conventional signs* and *natural signs* (Deely 2006; Favareau 2007). The conventional signs are those where there is no physical relationship between signifiers and meanings, and a connection between them can be established only by arbitrary rules, i.e., by conventions. Words, for example, are signs (because they "stand for" the named entities) and are conventional signs because they are not determined by the characteristics of the named entities. In the same way, there is no necessary connection between symbols and the entities that they stand for (between a flag and a country, for example).

In natural signs, by contrast, a physical link is always present between signifier and signified. Typical examples are the symptoms that doctors use to diagnose illnesses (spots on the skin, a fever, a swollen area, etc.), as well as a variety of cues (smoke as sign of fire, odors as signs of food, footprints as signs of organisms, etc.). In all these cases, there is a physical relationship between the visible signs and the invisible entities that they point to, and yet the relationship is underdetermined, so much so that it takes a process of learning and an act of interpretation to establish it. The diagnosis of an illness from symptoms, for example, is always an interpretive exercise, and even simple associations, such as those between clouds and rain, depend upon processes of learning and memory.

At the molecular level, we have seen that in protein synthesis, a sequence of nucleotides is used as a sign by a codemaker to produce a sequence of amino acids according to the rules of the genetic code. In that case, there is no necessary connection between the components of the two molecules and the codons of nucleotides are used, therefore, as *conventional* organic signs, i.e., as organic *symbols*.

A sequence of nucleotides, however, can also be used by a copymaker to produce a complementary copy of itself, and in that case, the relationship between the two sequences is no longer established by adaptors but by direct physical interactions between complementary regions. These interactions, however, occur between very small regions of the molecules, and that means that the first sequence provides only a limited number of physical determinants for the second. The first sequence, in other words, does have a physical relationship with the second, but such relationship is undetermined and represents, therefore, only a “cue”, i.e., a *natural* organic sign, for the second.

We conclude that the distinction between natural and conventional signs exists also at the molecular level and represents in fact a divide between two very different types of molecular processes. Sequences of nucleotides are used as natural signs in molecular copying and as conventional signs in molecular coding. The transcription of genes, in other words, is based on natural organic signs, whereas the translation of genes into proteins is based on conventional organic signs.

In both cases, a sequence of nucleotides provides “information” for the assembly of a second sequence, but the “meaning” of that information is determined by the molecular machine that actually performs the assembly. Organic information and organic meaning, in short, are not intrinsic properties of the molecules that carry them, and this raises a new problem. What kind of entities are they?

Part 2: The Nature of Information and Meaning

The Claim of Physicalism

In 1953, Watson and Crick proposed that the linear sequence of nucleotides represents the *information* carried by a gene. A few years later, the mechanism of protein synthesis was discovered, and it was found that the sequence of nucleotides in genes determines the sequence of amino acids in proteins with a process that amounts to a transfer of linear information from genes to proteins. In both types of molecules, therefore, *biological information* was identified with, and defined by, the specific sequence of their subunits.

The concept of biological information threw a completely new light on the century-old mystery of inheritance (*heredity is the transmission of information*) and quickly transformed the whole of biology from an energy-based into an information-based science. It must be underlined, however, that biological information, or *biological specificity* (as some prefer to call it), cannot be measured and cannot, therefore, be regarded as a physical quantity. So, what is it? A similar problem arises with the genetic code. The rules of a code cannot be measured and a code, therefore, cannot be a combination of physical quantities. So what is it?

According to an influential school of thought, biological information and the genetic code are simply metaphors. They are linguistic constructions that we use in order to avoid long periphrases when we talk about living systems, but no more than that. They are like those computer programs that allow us to write our instructions in English, thus saving us the trouble to write them with the binary digits of the machine language. Ultimately, however, there are only binary digits in the machine language of the computer, and in the same way it is argued that there are only physical quantities at the most fundamental level of Nature.

This conclusion, known as *physicalism*, or *the physicalist thesis*, has been proposed in various ways by a number of scientists and philosophers (Chargaff 1963; Sarkar 1996, 2000; Mahner and Bunge 1997; Griffith and Knight 1998; Griffith 2001; Boniolo 2003). It is probably one of the most deeply dividing issues of modern science. Many biologists are convinced that biological information and the genetic code are real and fundamental components of life, but physicalists insist that they are real only in a very superficial sense, and that there is nothing fundamental about them because they *must* be reducible, in principle, to physical quantities.

It has to be pointed out that the physicalist thesis *could* be true. In fact it would be rigorously true if genes and proteins were made by spontaneous assemblies because these processes are fully described by physical quantities. The point, however, is precisely that genes and proteins are *not* spontaneous molecules. They are molecular artifacts because they are manufactured by molecular machines, and this gives us a real alternative to the physicalist thesis. More precisely, we can prove that physicalism is wrong if we show that it is valid only for spontaneous objects, i.e., if we show that there is a fundamental difference between spontaneous objects and artifacts. To this purpose, we need to go back to our question about biological information and the genetic code.

Information is notoriously a difficult issue, and often biologists tend to identify it with genetic sequences, which are in fact only a particular type of information. A proper introduction to this field is undoubtedly called for, and the reader can find it in qualified publications such as those by Yockey (2005), Battail (2006), and Forsdyke (2006), in addition of course to the classic papers by Shannon (1948). Here, however, we are interested precisely in that particular type of information that is expressed by sequences and in those particular relationships that are the rules of the genetic code. Given that these entities cannot be measured, what exactly are they?

Organic Information

In genes and proteins, as we have seen, biological (or organic) information has been defined as the specific sequence of their subunits. This definition, however, is not entirely satisfactory because it gives the impression that information is a *static* property, something that molecules have simply because they have a sequence. In reality, there are countless molecules which have a sequence but only in a few cases this becomes information. That happens only when copymakers use it as a guideline for copying. Even copymakers, however, do not account, by themselves, for information. Copymakers can stick subunits together and produce sequences, but without a template, they would produce only *random* sequences, not specific ones. Sequences alone or copymakers alone, in other words, have nothing to do with information. It is only when a sequence provides a guideline to a copymaker that it becomes information for it. It is only an act of copying, in other words, that brings organic information into existence.

This tells us that organic information is not just the specific sequence of a molecule but *the specific sequence produced by a copying process.* This defmition underlines the fact that organic information is not a thing or a property but the result of a process. It is, more precisely, an "operative" definition because information is defined by the process that brings it into existence. We realize in this way that organic information is as real as the copying process that generates it, but we still do not know what kind of entity it is. How does it fit into our description of Nature?

According to a long tradition, natural entities are divided into *quantities* and *qualities*. Quantities can be measured and are objective, whereas qualities are subjective and cannot be measured. In the case of organic information, however, this scheme breaks down. Organic information is not a quantity because a specific sequence cannot be measured. But it is not a quality either because linear specificity is a feature that we find in organic molecules, and is, therefore, an objective feature of the world not a subjective one.

A scheme based on quantities and qualities alone, in short, is not enough to describe the world. In addition to quantities (*objective and measurable*) and qualities (*subjective and not-measurable),* we must recognize the existence in Nature of a third type of entities (*objective but not-measurable*). Information is one of them, and we can also give it a suitable name. Since we can describe it only by *naming* its sequence, we can say that organic information is a *nominable* entity or that it belongs to the class of the nominable entities of Nature (Barbieri 2003b, 2004).

We conclude that organic information is a new type of natural entity, but we also conclude that it belongs to the same class of objective entities that contains all physical quantities. Therefore, *it has the same scientific "status"as a physical quantity*. This, however, raises a new problem because there are two distinct classes of physical quantities: a small group of fundamental quantities (space, time, mass, charge, and temperature) and a much larger group of derived quantities. That distinction applies to all objective entities, so we need to understand whether organic information belongs to the first or to the second group.

Luckily, this problem has a straightforward solution because the sequences of genes and proteins have two very special characteristics. One is that *a change in a single component of a biological sequence may produce a sequence which has entirely new properties.* This means that although a biological sequence can be said to have "components", it is at the same time a single indivisible whole. The second outstanding feature is that *from the knowledge of n elements of a biological sequence we cannot predict the element* ($n + 1$). This is equivalent to saying that *a specific* *sequence cannot be described by anything simpler than itself,* so it cannot be a derived entity.

We conclude that organic information has the same scientific status as the physical quantities because it is an objective and reproducible entity. But we also conclude that it does not have the status of a derived physical quantity because it cannot be expressed by anything simpler than itself. This means that organic information has the same scientific status as the fundamental physical quantities, i.e., that it is a fundamental (or irreducible) entity of Nature (a similar conclusion was also described in Küppers 1990 and 1992).

Organic Meaning

A code is a set of rules, which establish a correspondence between the objects of two independent worlds. The Morse code, for example, is a correspondence between groups of dots and dashes with the letters of the alphabet, and in the same way, the genetic code is a correspondence between groups of nucleotides and amino acids. Let us notice now that establishing a correspondence between, say, object 1 and object 2, is equivalent to saying that object 2 is the meaning of object 1. In the Morse code, for example, the rule that “dot-dash” corresponds to letter “A”, is equivalent to saying that letter A is the meaning of dot-dash. In the code of the English language, the mental object of the sound “apple” is associated to the mental object of the fruit apple, and this is equivalent to saying that fruit is the meaning of that sound.

By the same token, the rule of the genetic code that a group of three nucleotides (a codon) corresponds to an amino acid is equivalent to saying that amino acid is the *organic meaning* of that codon. Anywhere there is a code, be it in the mental or in the organic world, there is meaning. We can say, therefore, that *meaning is an entity which is related to another entity by a code,* and that organic meaning exists whenever an organic code exists (Barbieri 2003a).

The existence of meaning in the organic world may seem strange, at first, but in reality, it is no more strange than the existence of a code because they are the two sides of the same coin. To say that a code establishes a correspondence between two entities is equivalent to saying that one entity is the meaning of the other, so we cannot have codes without meaning or meaning without codes. All we need to keep in mind, once again, is that meaning is a mental entity when the code is between mental objects, but it is an organic entity when the code is between organic molecules.

Modern biology has readily accepted the concept of information but has carefully avoided the concept of meaning, and yet, organic information and organic meaning are both the result of natural processes. Just as it is an act of copying that creates organic information, so it is an act of coding that creates organic meaning. Copying and coding are the processes; copymakers and codemakers are their agents; organic information and organic meaning are their results. But the parallel goes even further. We have seen that organic information cannot be measured, and the same is true for organic meaning. We have seen that organic information is an objective entity because it is defined by the same sequence for any number of observers, and that is also true for organic meaning, which is defined by coding rules that are the same for all observers. Finally, we have seen that organic information is an irreducible entity because it cannot be described by anything simpler than its sequence, and the same is true for organic meaning, which cannot be defined by anything simpler than its coding rules.

Organic information and organic meaning, in short, belong to the same class of entities because they have the same general characteristics: They both are *objective-but-not-measurable* entities, they both are irreducible, or *fundamental*, entities of Nature, and since we can describe them only by naming their components, they both are *nominable* entities (Barbieri 2003b, 2004). Finally, let us underline that they are the twin pillars of life because organic information comes from the copying process that produces genes, while organic meaning comes from the coding process that generates proteins.

Operative Definitions

Physical quantities have three fundamental properties: (1) they are objective, (2) they are reproducible, and (3) they are defined by operative procedures. This last property is particularly important because it has provided the solution to one of the most controversial issues of physics. The controversy was about the theoretical possibility that the entity which is measured may not be the same entity which has been defined. This led to the idea that there should be no difference between what is measured and what is defined, i.e., to the concept of operative (or operational) definition: *a physical quantity is defined by the operations that are carried out in order to measure it.*

It was this operational approach that solved the definition problem in physics, and it is worth noticing that we can easily generalize it. Rather than saying that a natural entity is defined by the operations that measure it, we can say that *a natural entity is defined by the operations that evaluate it in an objective and reproducible way*. The advantage of this generalized formulation is that it applies to all objective entities, so it can be used not only in physics but in biology as well. To this purpose, we only need to notice that a measurement is an objective and reproducible description of a physical quantity, just as the naming of a specific sequence is an objective and reproducible description of organic information, and just as the naming of a coded entity is an objective and reproducible description of organic meaning.

Whereas the physical quantities are evaluated *by measuring*, sequences and codes are evaluated *by naming their components*, but in both cases the entities in question are defined by the operations that evaluate them, and this is the essence of the operative approach. We may add that organic information and organic meaning can also be defined by the processes of copying and coding that bring them into existence, and that too amounts to an operative definition (Barbieri 2003b, 2004).

We conclude that organic information and organic meaning can be defined by generalized operative procedures that are as reliable as the operative procedures of physics. This means that the definitions of information and meaning should no longer be at the mercy of endless debates on terminology as they have been in the past. The operative definitions are scientific tools which are justified by their own prescriptions, so there is no point in asking whether they are right or wrong. All we can ask of them is whether they contribute or not to our description and to our understanding of Nature.

At this point, we can summarize all the above arguments with the following concepts:

1. The sequence used by a copymaker during a copying process is *organic information*.
2. The sequence used by a codemaker during a coding process is an *organic sign*.
3. The sequence produced by a codemaker during a coding process is an *organic meaning*.
4. Organic information, organic signs, and organic meanings are neither quantities nor qualities. They are a new kind of natural entities, which are referred to as *nominable* entities.
5. Organic information, organic signs, and organic meanings have the same scientific status as physical quantities because they are *objective* and *reproducible* entities that can be defined by operative procedures.
6. Organic information, organic signs, and organic meanings have the same scientific status as *fundamental* physical quantities because they cannot be reduced to, or derived from, simpler entities.

The Unexpected Properties of Artifacts

Sequences, codes, signs and meanings exist only in a world of artifacts because they are brought into existence by copying and coding, the very processes that give origin to artifacts. But can we really say that a set of artifacts is a *world*? Are there regularities and laws in such a world *in addition* to those of physics and chemistry? In order to find this out, let us start from the special case of those particular human artifacts that we call "numbers".

There is little doubt that numbers arose by counting, and that counting was favored by natural selection because it had practical advantages. The process of counting, however, produces exclusively natural numbers, but then we have discovered prime numbers, rational and irrational numbers, real and imaginary numbers, and an endless stream of mathematical theorems. All these additional entities were not produced by counting, and this is why some mathematicians say that natural numbers were *invented* by man but that all other rules of mathematics could only be *discovered*, as if they had an existence of their own. In practice, this is equivalent to saying that the world of mathematics was generated by the "genetic" rule of counting, and then it developed into an increasingly complex world full of additional or “epigenetic” properties. A world of artifacts, in short, may not be completely described by the coding rules that generate the artifacts. It may well have unexpected *rules of its own*, rules that we may call *epigenetic* because they were not present at the beginning and appeared only during a process of exploration and development.

Can we extend this conclusion to other artifacts? Today, something similar seems to exist also in the world of language, where it has been discovered that children learn to speak by using only a limited number of inputs from the environment. According to Chomsky (1975), this suggests the existence of a universal grammar, a mechanism that has the ability to retrieve the countless rules of any particular language from a limited sample of them. It is as if the brain of a child “explores” the world of language and “discovers” an unlimited number of new rules simply by applying the basic algorithm of the universal grammar.

A parallel conclusion appears to be valid also in the world of proteins. There is a universal mechanism in every cell that produces linear polypeptides from linear sequences of genes, but then the polypeptides fold up into three-dimensional proteins whose forms and behaviors are not written in the genes, and living cells appear to engage in a veritable exploration of the potentialities of the protein world.

Mathematics, language, and proteins are very different sets of artifacts, but deep down, there is something in common between them. They all have (1) a genetic algorithm that starts producing the objects of a potentially unlimited new world of artifacts (numbers, words, or proteins) and (2) an exploratory procedure that brings into existence additional or epigenetic properties of the new world that were not present at the beginning. We conclude, therefore, that many types of artifacts have unexpected properties which can be discovered only by a process of exploration, and in those cases we can truly say that we are in the presence of new explorable worlds. We also conclude that a complete description of a world of artifacts requires new fundamental entities in addition to physical quantities, and that is tantamount to saying that the claim of physicalism does not apply to the living world.

Schrödinger’s Prophecy

In 1944, Erwin Schrödinger wrote *What is Life?* – a little book that inspired generations of scientists and became a landmark in the history of molecular biology. There were two seminal ideas in that book: one was that the genetic material is like an *aperiodic crystal*, the other was that *the chromosomes contain a code-script for the entire organism.*

The metaphor of the aperiodic crystal was used by Schrödinger to convey the idea that the atoms of the genetic material must be arranged in a unique pattern in every individual organism, an idea that later was referred to as *biological specificity*. The metaphor of the code-script was used to express the concept that there must be “a miniature code” in the hereditary substance, a code that Schrodinger compared to “a Morse code with many characters”, and that was supposed to carry “the highly complicated plan of development of the entire organism”. That was the very first time that the word code was associated to a biological structure and was given a biological function.

The existence of specificity and a code at the heart of life led Schrodinger to a third seminal conclusion, an idea that he expressed in the form of a prophecy: “Living matter, while not eluding the ‘laws of physics’ as established up to date, is likely to involve hitherto unknown ‘other laws of physics’, which, however, once they have been revealed, will form just an integral part of this science as the former”. Schrodinger regarded this prophecy as his greatest contribution to biology, indeed, he wrote that it was “my only motive for writing this book”, and yet that is the one idea that even according to his strongest supporters did not stand up to scrutiny. Some 30 years later, Gunther Stent gave up the struggle and concluded that “No ‘other laws of physics’ turned up along the way (Stent and Calendar 1978). Instead, the making and breaking of hydrogen bonds seems to be all there is to understanding the workings of the hereditary substance”.

Schrödinger’s prophecy seems to have been shipwrecked in a sea of hydrogen bonds, but in reality that is true only in a very superficial sense. The essence of the prophecy was about the existence of something fundamentally new, and that turned out to be true. As we have seen, life is based on organic information and organic meaning, and these are indeed new fundamental entities of Nature. Schrödinger invoked the existence of new *laws* rather than of new *entities*, but that was only a minor imperfection and should not have been allowed to obscure the substance of the prophecy.

There is, however, one thing that Schrodinger might not have appreciated in the answer that here has been given to the question “What is Life?” Together with many other physicists, he believed that scientific truths must have *beauty*, and the answer “Life is artifact-making” might not be elegant enough to meet his criterion of truth. Luckily, there is a simple way out of this impasse because the word *artifact-making* maintains its meaning even when we drop all its letters but the first three. In this way, the statement that “Life is artifact-making” becomes “Life is art”, and that is a conclusion that even Schrödinger might have approved of.

Part 3: The Organic Codes

The Fingerprints of the Organic Codes

Codes and conventions are the basis of all cultural phenomena and from time immemorial have divided the world of culture from the world of nature. The rules of grammar, the laws of government, the precepts of religion, the value of money, the cooking recipes, the fairy tales and the rules of chess are all human conventions that are profoundly different from the laws of physics and chemistry, and this has led to the conclusion that there is an unbridgeable gap between nature and culture. Nature is governed by objective immutable laws, whereas culture is produced by the mutable conventions of the human mind.

In this century-old framework, the discovery of the genetic code in the early 1960s came as a bolt from the blue, but strangely enough it did not bring down the barrier between nature and culture. On the contrary, various “protective belts” were quickly built around the old divide with arguments that effectively emptied the discovery of the genetic code of all its revolutionary potential. The first protective belt was the argument that the genetic code is fundamentally a metaphor because it must be reducible, in principle, to physical quantities. The second protective belt was the idea that the genetic code has been an extraordinary exception, something that happened at the origin of life and was never followed by anything similar ever since.

But are we sure that the genetic code is the only organic code of the living world? Luckily, this is a problem that we can deal with, because if other organic codes exist we should be able to discover them by the standard experimental procedures of science, just as we have discovered the genetic code.

The first step, in this enterprise, is to underline the difference that exists between copying and coding, a difference that is particularly evident in transcription and translation. In transcription, an RNA sequence is assembled from the linear information of a DNA sequence, and in this case a normal biological catalyst (an RNA polymerase) is sufficient because each elementary step requires a single recognition process. In translation, instead, two independent recognition processes must be performed at each step, and the system that performs the reactions (the ribosome) needs special molecules, first called adaptors and then transfer RNAs, in order to associate codons to amino acids according to the rules of the genetic code. Without a code, in fact, a codon could be associated to different amino acids and biological specificity, the most precious of life’s properties, would be lost.

These concepts can easily be generalized. We are used to think that biochemical processes are all catalyzed reactions, but in reality we should sharply distinguish between catalyzed and codified reactions. Catalyzed reactions are processes (like transcription) that require only one recognition process at each step, whereas codified reactions require (like translation) two independent recognition processes at each step and a set of coding rules. The catalyzed reactions, in other words, require catalysts, whereas the codified reactions require adaptors, i.e., catalysts plus a code.

Any organic code is a set of rules that establish a correspondence between two independent worlds, and this necessarily requires molecular structures that act like adaptors, i.e., that perform two independent recognition processes. The adaptors are required because the two worlds would no longer be independent if there were a necessary link between them, and a set of rules is required in order to guarantee the specificity of the correspondence. In any organic code, in short, we should find three major features:

1. A correspondence between two independent worlds.
2. A system of molecular adaptors.
3. A set of rules that guarantee biological specificity.

We conclude that the adaptors are the key molecules of the organic codes. They are the molecular fingerprints of the codes, and their presence in a biological process is a sure sign that process is based on a code. This gives us an objective criterion for the search of organic codes, and their existence in Nature becomes, therefore, first and foremost, an experimental problem.

The Splicing Codes

One of the greatest surprises of molecular biology was the discovery that the primary transcripts of the genes are often transformed into messenger RNAs by removing some RNA pieces (called *introns*) and by joining together the remaining pieces (the *exons*). The result is a true assembly because exons are assembled into messengers, and we need, therefore, to find out if it is a catalyzed assembly (like transcription) or a codified assembly (like translation). In the first case, the cutting-and-sealing operations, collectively known as *splicing*, would require only a catalyst (comparable to a RNA-polymerase), whereas in the second case they would need a catalyst and a set of adaptors (comparable to ribosome and tRNAs).

This suggests immediately that splicing is a codified process because it is implemented by structures that are very much comparable to those of protein synthesis. The splicing bodies, known as *spliceosomes*, are huge molecular machines like ribosomes and employ small molecular structures, known as *snRNAs* or *snurps*, which are like tRNAs. The similarity, however, goes much deeper than that because the snRNAs have properties that fully qualify them as adaptors. They bring together, in a single molecule, two independent recognition processes, one for the beginning and one for the end of each intron, thus creating a specific correspondence between the world of the primary transcripts and the world of messengers.

The two recognition steps are independent not only because there is a physical distance between them but above all because the first step could be associated with different types of the second one, as demonstrated by the cases of *alternative splicing*. The choice of the beginning and of the end of an intron, furthermore, is the operation that actually defines the introns and gives them a meaning. Without a complete set of such operations, primary transcripts could be transformed arbitrarily into messenger RNAs, and there would be no biological specificity whatsoever.

In RNA splicing, in conclusion, we find the three basic characteristics of all codes: (1) a correspondence between two independent worlds, (2) the presence of molecular adaptors, and (3) a set of rules that guarantee biological specificity. We conclude, therefore, that the processing of RNA transcripts into messengers is truly a codified process based on adaptors and takes place with rules that can rightly be given the name of *splicing codes* (Barbieri 1998, 2003a).

The Signal Transduction Codes

Living cells react to a wide variety of physical and chemical stimuli from the environment, and in general their reactions consist in the expression of specific genes. We need, therefore, to understand how the environment interacts with the genes, and the turning point, in this field, came from the discovery that the exterual signals (known as *first messengers*) never reach the genes. They are invariably transformed into a different world of internal signals (called *second messengers*) and only these, or their derivatives, reach the genes. In most cases, the molecules of the external signals do not even enter the cell and are captured by specific receptors of the cell membrane, but even those that do enter (some hormones) must interact with intracellular receptors in order to influence the genes (Sutherland 1972).

The transfer of information from environment to genes takes place, therefore, in two distinct steps: one from first to second messengers, which is called *signal transduction*, and a second path from second messengers to genes, which is known as *signal integration*. The surprising thing about signal transduction is that there are hundreds of first messengers (hormones, growth factors, neurotransmitters, etc.), whereas the known second messengers are only of four types (cyclic AMP or GMP, calcium ions, inositol trisphosphate, and diacylglycerol; Alberts et al. 1994).

First and second messengers, in other words, belong to two very different worlds, and this suggests immediately that signal transduction may be based on organic codes. This is reinforced by the discovery that there is no necessary connection between first and second messengers because it has been proved that the same first messengers can activate different types of second messengers, and that different first messengers can act on the same type of second messengers. The only plausible explanation of these data is that signal transduction is based on organic codes, but of course we would also like a direct proof.

The signature of an organic code, as we have seen, is the presence of adaptors and the molecules of signal transduction do have the defining characteristics of the adaptors. The transduction system consists of at least three types of molecules: a *receptor* for the first messengers, an *amplifier* for the second messengers, and a *mediator* in between (Berridge 1985). The system performs two independent recognition processes, one for the first and the other for the second messenger, and the two steps are connected by the bridge of the mediator. The connection, however, could be implemented in countless different ways since any first messenger can be coupled with any second messenger, and this makes it imperative to have a code in order to guarantee biological specificity.

In signal transduction, in short, we find all the three characteristics of the codes: (1) a correspondence between two independent worlds, (2) a system of adaptors that give meanings to molecular structures, and (3) a collective set of rules that guarantee biological specificity. The effects that external signals have on cells, in conclusion, do not depend on the energy or the information that they carry, but on the *meaning* that cells give them with rules that we can rightly refer to as *signal transduction codes* (Barbieri 1998, 2003a).

The Cytoskeleton Codes

A cytoskeleton is absolutely essential for typical eukaryotic processes such as phagocytosis, mitosis, meiosis, ameboid movement, organelle assembly, and three-dimensional organization of the cell, i.e., for all those features that make eukaryotic cells so radically different from bacteria. The actual cytoskeleton, in reality, is an integrated system of three different cytoskeletons made of filaments (*microfilaments*, *microtubules*, and *intermediate filaments*), each of which gives a specific contribution to the three-dimensional form of the cell and to its mobility.

The driving force of the cytoskeleton is a very unusual mechanism that biologists have decided to call *dynamic instability*. The cytoskeletal filaments-especially microtubules and micro filaments-are in a state of continuous flux where monomers are added to one end and taken away at the other, and the filament is growing or shortening according to which end is having the fastest run. But what is really most surprising is that all this requires lots of energy, which means that the cell is investing enormous amounts of energy not in building structures but in *making them unstable*!

In order to understand the logic of dynamic instability, we need to keep in mind that cytoskeletal filaments are unstable only when their ends are not attached to special molecules that have the ability to anchor them. Every microtubule, for example, starts from an organizing center (the *centrosome*), and the extremity which is attached to this structure is perfectly stable, whereas the other extremity can grow longer or shorter and becomes stable only when it encounters an anchoring molecule in the cytoplasm. If such an anchor is not found, the whole microtubule is rapidly dismantled and another is launched in another direction, thus allowing the cytoskeleton to explore all cytoplasm's space in a short time.

Dynamic instability, in other words, is a mechanism that allows the cytoskeleton to build structures with an *exploratory strategy*, and the power of this strategy can be evaluated by considering how many different forms it can give rise to. The answer is astonishing: the number of different structures that cytoskeletons can create is potentially unlimited. It is the anchoring molecules (that strangely enough biologists call *accessory proteins*) that ultimately determine the three-dimensional forms of the cells and the movements that they can perform, and there could be endless varieties of anchoring molecules. The best proof of this enormous versatility is the fact that the cytoskeleton was invented by unicellular eukaryotes but was later exploited by metazoa to build completely new structures such as the axons of neurons, the myofibrils of muscles, the mobile mouths of macrophages, the tentacles of killer lymphocytes, and countless other specializations.

Dynamic instability, in conclusion, is a means of creating an endless stream of cell types with only one common structure and with the choice of a few anchoring molecules. But this is possible only because there is no necessary relationship between the components of the cytoskeleton and the cellular structures that the cytoskeleton is working on. The anchoring molecules (or accessory proteins) are true adaptors that perform two independent recognition processes: microtubules on one side and different cellular structures on the other side. The resulting correspondence is based, therefore, on arbitrary rules, on true natural conventions that we can refer to as *the cytoskeleton codes* (Barbieri 2003a).

The Compartment Codes

Eukaryotic cells not only produce molecules of countless different types but manage to deliver them to different destinations with astonishing precision, and this gives us the problem of understanding how they manage to cope with such an immensely intricate traffic. The first step in the solution of this mystery came with the discovery that the Golgi apparatus is involved not only in the biochemical modification of many molecules but also in the choice of their geographical destination. But the truly remarkable thing is that all this is achieved with an extremely simple mechanism. More precisely, the Golgi apparatus delivers countless molecules to their destinations with only three types of vesicles. One type has labels for the transport of proteins outside the cell and another for their delivery to the cell interior, whereas the vesicles of the third type carry no destination label and are programmed, *by default*, to reach the plasma membrane. The solution is extraordinarily efficient. With a single mechanism and only two types of labels, the cell delivers a great amount of proteins to their destinations and also manages to continually renew its plasma membrane.

The Golgi apparatus, however, is a transit place only for a fraction of the cell proteins. The synthesis of all eukaryotic proteins begins in the soluble part of the cytoplasm (the *cytosol*) together with that of a signal that specifies their geographical destination. The piece of the amino acid chain that emerges first from the ribosome (the so-called peptide leader) can contain a sequence that the cell interprets as an export signal to the endoplasmic reticulum. If such a signal is present, the ribosome binds itself to the reticulum and delivers the protein into its *lumen*. If not, the synthesis continues on free ribosomes, and the proteins are shed into the cytosol. Of these, however, only a fraction remains there because the amino acid chain can carry, in its interior, one or more signals, which specify other destinations such as the *nucleus*, the *mitochondria*, and other cell compartments. Proteins, in conclusion, carry with them the signals of their geographical destination, and even the absence of such signals has a meaning because it implies that the protein is destined to remain in the cytosol.

The crucial point is that there is no necessary correspondence between protein signals and geographical destinations. The export-to-the-nucleus signals, for example, could have been used for other compartments or could have been totally different. They and all the other geographical signals are purely conventional labels, like the names that we give to streets, to cities, to airports, and to holiday resorts. The existence of eukaryotic compartments, in other words, is based on natural conventions, and to their rules of correspondence, we can legitimately give the name of *compartment codes* (Barbieri 2003a).

A World of Codes

In the 1980s and 1990s, Edward Trifonov started a life-long campaign in favor of the idea that the nucleotide sequences of the genomes carry several messages simultaneously and not just the message revealed by the classic triplet code. He concluded that there are many overlapping codes in the genome and gave them the collective name of *sequence codes*. That conclusion rests upon Trifonov's definition that "a code is any sequence pattern that can have a biological function" or "codes are messages carried by sequences" or "a code is any pattern in a sequence which corresponds to one or another specific biological function" (Trifonov 1989, 1996, 1999).

The plurality of codes described by Trifonov is a result of his particular definition but is not necessarily limited by that, and may well be compatible with other approaches. The splicing code, for example, is a code not only according to his criterion but also according to the operative definition that a code is a set of rules of correspondence implemented by adaptors. This suggests that Trifonov's conclusion may have a general validity, and at least some of his sequence codes could well be true organic codes. For the time being, however, let us acknowledge the fact that according to Trifonov's definition, there are at least eight sequence codes in the genomes of living creatures, in addition to the classic triplet code (Trifonov 1996): (1) the *transcription codes*, (2) the *gene splicing code*, (3) the *translation pausing code*, (4) the *DNA structure code*, or *DNA shape code*, (5) the *chromatin code*, (6) the *translation framing code*, (7) the *modulation code*, and (8) the *genome segmentation code*.

Other authors have adopted different definitions of code, but this is hardly surprising because biologists are used to employing concepts without waiting for their precise definition (there are still many definitions of "species", for example, but that does not prevent biologists from using the word species in all cases). What really matters is that the experimental evidence suggests the existence of a wide variety of organic codes in Nature whatever is the criterion used for defining them. More precisely, the existence of the following has been reported:

1. The *Adhesive Code* (Readies and Takeichi 1996; Shapiro and Colman 1999)
2. The *Sugar Code* (Gabius 2000; Gabius et al. 2002)
3. The *Histone Code* (Strahl and Allis 2000; Turner 2000, 2002; Gamble and Freedman 2002)
4. The *Neural Transcriptional Codes* (Jessell 2000; Flames et al. 2007)
5. A *Regulatory Code in mammalian organogenesis* (Scully and Rosenfeld 2002)
6. A *Code of Post Translational Modifications* (Khidekel and Hsieh-Wilson 2004)
7. A *Neural Code for written words* (Dehaene et al. 2005)
8. A *Nuclear Receptors Combinatorial Code* (Perissi and Rosenfeld 2005)
9. A *Transcription Factors Code* (Tootle and Rebay 2005)
10. An *Acetylation Code* (Knights et al. 2006)
11. An *Estrogen Receptor Code* (Leader et al. 2006)
12. The *Metabolic Codes* (Bruni 2007)
13. The *RNA Codes* (Faria 2007)
14. The *Error-Correcting Codes* (Battail 2007; Gonzalez 2008)
15. The *Modular Code of the Cytoskeleton* (Gimona 2008)
16. A *Lipid-based Code in nuclear signaling* (Maraldi 2008)
17. The *Immune Self Code* (Neuman 2008)

18. The *Signal Transduction Codes* (Faria 2008)
19. The *Codes of Language* (Cowley 2008)
20. The *Musical Code* (Reybrouck 2008)

These discoveries have largely been seen as proof of the extreme complexity of life, which they certainly are, but they are also much more than that. They may look like those increasingly complex epicycles that people had to invent in order to keep the Ptolemaic system up, but in reality they raise fundamental questions and point to a new Copernican framework for biology. We have already seen that the existence of the genetic code proves that the cell is a semiotic system, and in the following sections, we will see that the existence of many other organic codes brings to light a new mechanism of evolution.

Part 4: The Mechanisms of Evolution

Molecular Change and Evolutionary Change

The mechanisms of evolution have been one of the most controversial issues in biology and the great debate about them culminated, in the 1930s and 1940s, in the Modem Synthesis, the theoretical framework where natural selection is regarded as virtually the sole mechanism of evolutionary change.

Natural selection is due to chance variations in the transmission of hereditary characters and is based, therefore, on the mechanism of molecular copying because the copying of a gene is the elementary act that leads to heredity. When a process of copying is repeated indefinitely, however, another phenomenon comes into being. Copying mistakes become inevitable, and in a world of limited resources not all changes can be implemented, which means that a process of selection is bound to take place. Molecular copying, in short, leads to heredity, and the indefinite repetition of molecular copying in a world of limited resources leads to *natural selection*. That is how natural selection came into existence. Molecular copying started it and molecular copying has perpetuated it ever since. This means that *natural selection would be the sole mechanism of evolution if molecular copying were the sole basic mechanism of life.*

As a matter of fact, this *could* have happened. If living systems could have been made entirely of RNA enzymes and RNA genes, only the copying of RNA molecules would have been necessary, and natural selection could indeed have been the sole mechanism of evolution. But that is not what happened. Long before the origin of the first cells, proteins were being made on the primitive Earth, and proteins, unlike genes, could not be made by copying.

Different Mechanisms at Different Levels

The discovery of the genetic code has proved that there are *two* distinct molecular mechanisms at the basis of life, transcription and translation, or copying and coding.

The discovery of other organic codes, furthermore, allows us to generalize this conclusion because it proves that coding is not limited to protein synthesis. Copying and coding, in other words, are distinct molecular mechanisms, and this suggests that they give origin to two distinct mechanisms of evolution because an evolutionary mechanism is but the long-term result of a molecular mechanism. More precisely, copying leads, in the long mn, to natural selection and coding to natural conventions. In order to accept this conclusion, however, we must prove that the two mechanisms are truly different, i.e., that *coding cannot be reduced to copying*. That is, therefore, our challenge. We can prove that natural conventions are a distinct mechanism of evolution only if we prove that copying and coding are two fundamentally different mechanisms of molecular change.

Copying and Coding

Copying and coding are both capable of bringing novelties into the world, but they do it in very different ways. By its very nature, the copying mechanism produces either exact copies or slightly different versions of the copied molecules. This means that natural selection produces new objects only by modifying previous ones, i.e., by making objects that are only relatively different from their predecessors. Natural selection, in short, creates *relative* novelties, not absolute ones.

In the case of coding, the situation is totally different. The rules of a code are not dictated by physical necessity, and this means that a new code can establish relationships that have never existed before in the Universe. The objects that are assembled by the rules of a new code can have no relationship whatsoever to previous objects. Natural conventions, in short, create *absolute* novelties, not relative ones.

A second difference between the two mechanisms is that copying operates on individual molecules, whereas coding involves a collective set of rules. The difference between natural selection and natural conventions, in other words, is the difference that exists between individual change and collective change. An example of this difference can be seen in any language whose evolution is due to variations that take place not only at the level of the individual words but also at the level of the collective rules of grammar.

A third difference between copying and coding is that they involve two different entities. A variation in the copying of a gene changes the linear sequence, i.e., the information of that gene. A variation in a coding rule, instead, changes the meaning of that rule. The great difference that exists between copying and coding, and, therefore, between natural selection and natural conventions, comes from the difference that exists between information and meaning.

There are, in conclusion, three major differences between copying and coding: (1) copying modifies existing objects whereas coding brings new objects into existence, (2) copying acts on individual objects whereas coding acts on collective rules, and (3) copying is about biological information whereas coding is about biological meaning. Copying and coding, in short, are profoundly different mechanisms of molecular change, and this tells us that natural selection and natural conventions are two distinct mechanisms of evolutionary change.

Different Mechanisms at Different Levels

The idea that natural selection can work at different levels of organization (genes, organisms, species) has been at the center of countless debates in evolutionary biology. Less attention has been given to the alteruative possibility that at different levels of organization there may be at work different mechanisms of evolution. There is, however, at least one case that gives us a clear example of this alteruative. It is the origin of mitochondria in the precursors of the eukaryotic cells.

For a long time, it has been assumed that mitochondria came into being by gradual evolution from within the cell, but then it was found out that they originated by the incorporation of whole cells into other cells by endosymbiosis. Those two types of cell had been in existence for millions of years before the symbiosis event, and all their components had been copied at each generation and had been subject to evolution by natural selection. Their coming together in symbiosis, however, was a process that took place *at the cellular level*. It was the cells acting as whole systems that gave origin to endosymbiosis. Their components had to be "compatible" with endosymbiosis, but in no way had been selected for that purpose. Endosymbiosis, in short, is a mechanism that exists only at the cellular level, not at the molecular level, and represents, therefore, a distinct mechanism of evolution.

In the case of the organic codes, the situation is somewhat intermediate between the molecular and the cellular level. The genetic code, for example, is at the same time a supramolecular system and a subcellular one. All its molecular components must be inherited and copied individually, and yet a code is necessarily a collective entity. The important point is that coding, like endosymbiosis, does not exist at the molecular level. Coding belongs to the supramolecular level just as endosymbiosis belongs to the cellular level. There is no doubt that copying is absolutely necessary for coding, but the crucial point is that it is not *sufficient* for it because copying is a molecular mechanism whereas coding is a supramolecular one. Coding cannot be reduced to copying because they are fundamentally different mechanisms of molecular change that operate at different levels of organization. We conclude, therefore, that evolution was not produced only by natural selection but *by natural selection and by natural conventions* (Barbieri 1985, 2003a), which in no way is a belittlement of natural selection. It is only an extension of it.

Codes and Macroevolution

The role of the organic codes in the history of life can be appreciated by underlining that their origins are closely associated with the great events of macroevolution. Any time that a new organic code came into being, something totally new appeared in Nature, something that had never existed before.

The origin of the genetic code, for example, made it possible to produce proteins with specific sequences and to pass them on indefinitely to other systems. That gave origin to biological specificity and to heredity, the most fundamental of life's properties. The origin of the genetic code, in short, was also the origin of protein-based life, i.e., of life-as-we-know-it.

Similar considerations apply to the other organic codes. The signal transduction codes, for example, allowed primitive systems to produce their own signals and, therefore, to separate their internal space from the outside environment. That was a precondition for the origin of *individuality*, and in particular for the origin of the cell.

Another great innovation was brought about by the codes of splicing because the appearance of a complete set of splicing rules brought something unprecedented into being. Splicing requires a separation in time between transcription and translation and that was a precondition for their separation in space, i.e., for the origin of the nucleus. The defining feature of the eukaryotes, in other words, was made possible by the origin of the splicing codes.

Many other eukaryotic innovations were brought into existence by other organic codes. The cytoskeleton codes, for example, allowed the cells to build their own scaffoldings, to change their own shapes, and to perform their own movements. The origin of embryos was also associated with organic codes because typical embryonic processes like *cell determination*, *cell adhesion*, *cell migration*, and *cell death* have all the qualifying characteristics of codified phenomena (Barbieri 1998, 2003a).

In the case of embryonic development, furthermore, we have entirely new codes before us. The correspondence is no longer between two types of molecules, like genes and proteins or first and second messengers, but between molecules and *cell-states*. The determination of the body axes, for example, is obtained by a liuk between molecules and *cell memory*. The body axes are the same in all triploblastic animals, but their molecular determinants are of countless different types, which shows that there is no necessary link between molecules and cell states. This means that the link between molecular determinants and cell states can only be realized by codes that we can refer to as *body pattern codes.*

The major events in the history of life, in short, went hand in hand with the appearance of new organic codes, from the first cells all the way up to multicellular life, and this suggests a very deep link between codes and evolution. It suggests that the great events of macroevolution were made possible by the appearance of new organic codes.

The Contribution of the Codes

The history of life has been "punctuated" by the appearance of new organic codes, and it has been deeply shaped by their characteristics. Five of them are particularly important.

1. *Discontinuity*. The evolution of the individual rules of a code can take an extremely long time, but the "origin" of a new code corresponds to the appearance of a "complete" set of rules and that is a sudden event. The great evolutionary novelties produced by a new code, therefore, appeared suddenly in the history of life. This is a new explanation of the discontinuities that paleontology has documented, and shows that natural selection and natural conventions had complementary roles. Natural conventions account for the discontinuities of the history of life, whereas natural selection explains the gradual transformations that took place in between.
2. *Invariance*. The genetic code appeared at the beginning of the history of life and has remained substantially the same ever since. The same apply to the deep codes that define prokaryotes and eukaryotes. Once in existence, they have not been changed despite the fact that all the molecular components of a code must be inherited and are subject, therefore, to the chance variations of the copying mechanism and to the long-term results of that mechanism, i.e., to natural selection and to neutral drift. The fact that the deep organic codes have been conserved for billion of years suggests that their conservation is *the* top priority in all living systems. Everything else can be changed except the rules of the basic codes of life. While morphological structures did rise and fall countless times, the "deep" organic codes have never been removed. This tells us that they truly are *the fundamentals* of life, the invariants that persist while everything else is changing.
3. *Additivity*. A new organic code has never abolished previous codes. The genetic code has not been removed by the signal transduction codes, and neither of them has been supplanted by the splicing codes. A new code has always been added to the previous ones, which shows that new codes do not originate by the transformation of previous codes. Once in existence, organic codes do not tend to change, and the origin of a new code is always the origin of an entirely new set of rules.
4. *Stability*. The genetic code is present in all living creatures, but the other organic codes appeared in increasingly smaller groups. The greater the number of codes, the smaller the number of species, which possess them. This shows that living systems coexist whatever is the number of their codes. Eukaryotes did not remove prokaryotes, and metazoa did not remove unicellular eukaryotes. Every organic code, in short, represents a stable form of life.
5. *Complexity*. The addition of new organic codes to a living system can rightly be regarded as an *increase of complexity* of that system. The structural complexity of some organisms did diminish in time, as many cases of simplification clearly show, but the complexity of the codes has never been lowered. Even the animals which lost or reduced the greatest number of parts, in order to lead a parasitic life, have conserved all the fundamental codes of animal life. The number of organic codes is, therefore, a new measure of biological complexity, and probably it is more fundamental than all the other parameters which have been proposed so far.

The Contribution of Natural Selection

Life is essentially a *manufacturing* activity based on the molecular mechanisms of copying and coding. This conclusion may appear to give importance only to internal factors, as if the environment had almost no role to play, but that is far from being the case. The concept that life is artifact-making gives at least three major roles to the environment.

To start with, it is the environment that provides the building blocks for the manufacturing activity of the living systems. All components of life come from the environment and eventually go back to it, which means that any living system is totally dependent on its surrounding world.

The second point is that it is the environment that decides whether the structures manufactured by copying and coding are viable or not. Copying and coding have the potential to create an unlimited number of artifacts, but not all of them actually work in the real world. Copying and coding propose, but in the end it is the environment that disposes of their products.

The third point is that the environment is not only the place where living systems exist. It is also the place that living systems tend to become adapted to. We have learned from Darwin that in a world of limited resources, not all organisms can survive, and a process of selection is bound to take place. The survival can be a matter of luck, but in general it is the degree of adaptation to the environment that gives the best chances of success, and this means that organisms tend to become more and more adapted to their environment.

The process of adaptation allows organisms to become increasingly capable to cope with the surrounding world, and, therefore, to reduce the distance that separates them from *reality*. Natural selection can be regarded, therefore, as a process that allows organisms to incorporate increasing amounts of reality into their constitution, even if the gap between internal and external reality can never be abolished.

Francois Jacob has expressed this concept with admirable clarity: “If the image that a bird gets of the insects it needs to feed its progeny does not reflect at least some aspects of reality, there are no more progeny. If the representation that a monkey builds of the branch it wants to leap to has nothing to do with reality, then there is no more monkey. And if this did not apply to ourselves, we would not be here to discuss this point” (Jacob 1982).

Common Descent

Darwin’s greatest contribution to Biology was probably the theory of Common Descent, the idea that “all the organic beings which have ever lived on this Earth may be descended from some one primordial form” (Darwin 1859). In fact, when Dobzhansky (1973) wrote that “Nothing in biology makes sense except in the light of evolution”, it was Common Descent that he had in mind. The idea that all creatures of the present are linked to all creatures of the past is indeed the greatest unifying theme in biology, the concept that we use as an Ariadne's thread to reconstruct the history of life.

Common Descent, however, is compatible with different mechanisms of evolution, and in order to find out the truth about it we need to know the actual mechanisms that gave origin to biological objects in the course of time. How did novelties appear in the history of life? Did new objects arise by natural selection alone or by natural selection and by natural conventions?

If evolution took place only by natural selection, we would have to conclude that nothing similar to the genetic code appeared again in the four billion years of life's history. But we know that many other organic codes exist in life, and this means that there have been many other *origins* because any new organic code gives origin to unprecedented structures. We have, therefore, two very different versions of Common Descent before us. Evolution by natural selection alone implies *Common Descent with a Single Origin*, whereas evolution by natural selection and by natural conventions leads to *Common Descent with Multiple Origins* (this is not the old theory that cells originated many times because the multiple origins are referred to codes not to cells).

The idea that natural conventions bring absolute novelties into existence is equivalent to saying that life has not lost its creative power in the course of time. The origin of embryos, the origin of the mind, or the origin of language, for example, do not seem to be less of a novelty than the origin of the cell. The theory of Common Descent with Multiple Origins makes us realize that absolute novelties appeared not only at the beginning but throughout the entire history of life. And that is not a belittlement of Darwin's theory of Common Descent. It is only an extension of it.

Part 5: Biosemiotics Today

Code-Based Biosemiotics

The discovery of the genetic code took place between 1961 and 1966 (Nirenberg and Matthaei 1961; Speyer et al. 1963; Nirenberg et al. 1966; Khorana et al. 1966) and inspired an approach to semiotics that can be referred to as *code-based biosemiotics* because it assumes that coding is the defining feature of semiosis.

The manifesto of this approach was written by George and Muriel Beadle in 1966 with a single simple sentence: "the deciphering of the genetic code has revealed our possession of a language much older than hieroglyphics, a language as old as life itself, a language that is the most living language of alleven if its letters are invisible and its words are buried in the cells of our bodies" (Beadle and Beadle 1966).

In 1974, Marcel Florkin coined the term "biosemiotics" for the study of this molecular language and gave the names *biosemes* and *biosyntagms* to the basic units of molecular semiosis. He emphasized, however, that meaning does not exist at the molecular level and claimed that the genetic code is a correspondence between structures and functions, not between signs and meanings: "A bioseme carries no 'bedeutung', no 'meaning', because its signifier is a molecular structure and its signified is a biological function" (Florkin 1974). The idea that semiosis can exist without meaning may seem paradoxical, today, and yet Florkin's conclusion was entirely logical because it was the consequence of two basic concepts of modem biology.

One is the idea that the cell is a duality of genotype and phenotype, i.e., a biological computer made of genetic software and protein hardware. The crucial point is that a computer contains codes but is *not* a semiotic system because its codes come from a codemaker, which is outside the system. The second basic concept is the idea that all biological novelties are generated by natural selection, i.e., by an agent, which is outside the cell just as the human mind is outside the computer. But if the cell is a biological computer assembled by natural selection, it is perfectly legitimate to say that it is not a semiotic system, and this justifies Florkin's statement that there is no real meaning in it. Ultimately, that leads to the physicalist thesis that there is no real code either at the molecular level, and that molecular semiosis is merely an illusion.

The computer model of the cell, in short, keeps semiosis out of the cell, and this is why the first true model of molecular semiosis was the idea that every cell is a trinity of genotype, phenotype, and ribotype, i.e., the idea that the cell contains an *internal* codemaker (Barbieri 1981, 1985). This was complemented by the idea that coding is not reducible to copying, and, therefore, that natural selection (based on copying) and natural conventions (based on coding) are two distinct mechanisms of evolution (Barbieri 1985, 2003a).

Another important contribution to code-based biosemiotics came from the discovery of an increasing number of organic codes. That development started with the unveiling of the sequence codes by Trifonov (1987, 1989, 1996, 1999) and has grown slowly but steadily ever since (Barbieri 2008).

The "code based" approach to biosemiotics, in short, is a road that started with the recognition of semiosis at the molecular level and worked its way up by extending the concepts of code and meaning to the higher levels of biological organization. At about the same time, however, there was also another road to biosemiotics that was being developed. A road that went exactly the other way round, i.e., that started at the higher levels and worked its way down towards the lower ones.

Sign-Based Biosemiotics

The idea that animals have feelings, psychologies, and even minds has been entertained in various ways throughout the centuries, but for a long time it has been taken almost for granted that only man is a semiotic animal, i.e., that only man makes use of signs. This idea was explicitly challenged for the first time only in 1963, when Thomas Sebeok suggested that animal communication is also based on signs and proposed the term *zoosemiotics* for the new science of animal semiosis (Sebeok 1963, 1972).

That proposal set Sebeok out on a long search for evidence of semiosis in the various fields of the life sciences, and eventually the hunt paid off. The first decisive clue came from reading, in 1976, the original German edition of *Theoretische Biologie* by von Uexkiill (1928). That book convinced Sebeok that von Uexkiill had already provided abundant evidence of semiosis in the animal world and had been in fact the unintentional founding father of zoo semiotics. The next crucial development was the extension of semiosis beyond the animal world, a generalization that took place in various stages.

In 1981, Martin Krampen argued that plants engage in vegetable semiosis (phytosemiotics), and in 1988, Sorin Sonea proposed that semiosis goes on even in the bacterial world. Still in 1988, Giorgio Prodi suggested that a primitive form of semiosis exists also in molecules and cells and gave it the name of *protosemiosis* or *natural semiosis* (Prodi 1988). The word "zoosemiotics" became increasingly inadequate, and in 1991 Sebeok replaced it with biosemiotics, a term proposed by Stepanov in 1971, but which had appeared for the first time in 1962 when Friedrich Rothschild used it to illustrate a new approach to psychology (Kull 1999).

Sebeok's greatest contribution, however, was probably the silent revolution that he brought about in semiotics itself. Up to the 1960s, semiotics was a deeply divided field, virtually on the edge of anarchy, because it was still split into two major schools, one founded by the Swiss linguist Ferdinand de Saussure (1857–1913) and the other by the American philosopher Charles Sanders Peirce (1839–1914). The main difference between them is that Saussure defined the sign as a dual entity, a combination of *signifier* and *signified* (de Saussure 1916), whereas Peirce insisted that it is a triadic relationship between a *representamen*, an *object*, and an *interpretant* (Peirce 1931–1958). According to Peirce, any act of semiosis cannot involve less than three parties because there must necessarily be a process of *interpretation* between sign and meaning. Sebeok's silent revolution effectively disposed of Saussure and put Peirce squarely at the center of semiosis. The most authoritative treatise of semiotics, published in four volumes between 1997 and 2003 by Roland Posner, Klaus Robering, and Thomas Sebeok, makes it clear that by the 1990s, semiotics had become a largely unitary field, and that semiosis was defined in unmistakably Peircean terms:

We stipulate that the following is a necessary and sufficient condition for something to be a semiosis: A interprets B as representing C. In this relational characterization of semiosis, A is the Interpretant, B is some object, property, relation, event, or state of affairs, and C is the meaning that A assigns to B. (Posner et al. 1997).

By the 1990s, in short, the Peircean approach to semiotics had become almost universally accepted, and it was taken virtually for granted that the extension of semiosis first to the animal world and then to the entire living world was nothing but the extension of Peirce semiosis to life. Sebeok expressed this concept in no uncertain terms by declaring that: "there can be no semiosis without interpretability" (Sebeok 2001).

The identification of semiosis with Peircean semiosis was also accepted by Jesper Hoffmeyer in *Signs of Meaning in the Universe* (1996), the book where he wrote his manifesto and condensed it in the statement that “the basic unit of life is the sign, not the molecule”. There was, therefore, a genuine continuity from Sebeok to Hoffmeyer, and their biosemiotics can rightly be referred to as *sign-based biosemiotics*, or more precisely, as *interpretation-based biosemiotics*.

The Role of Interpretation

In code-based biosemiotics, semiosis is defined by coding not by interpretation. This is because the rules of the genetic code have been virtually the same in all living systems and in all environments ever since the origin of life, which clearly shows that they do not depend on interpretation. In sign-based biosemiotics, instead, interpretation is a defining feature of semiosis, and there is, therefore, a sharp difference between the two approaches. But is this difference insurmountable? Could we not say, for example, that the codemaker of the cell is also an “interpreter”? Why should we not generalize the concept of interpretation and say that any act of coding is also an act of interpretation?

In principle, of course, we could, but there is a caveat. If we generalize the concept of interpretation in order to include coding, why do we not go the whole way and generalize it even further? Why do we not say, following Taborsky (1999, 2002), for example, that any function

$$f(x) = y$$

is an act of interpretation, whereby the function “f” interprets “x” as representing “y”? In this way, all physical laws expressed by functions like $f(x) = y$ would be processes of interpretation and, therefore, acts of semiosis.

This point is important because Peirce himself embraced this view and concluded that semiosis exists everywhere in the Universe. We realize in this way that if we extend the concept of interpretation, we end up with a *pansemiotic* view not a biosemiotic one. If we want to keep the biosemiotic idea that semiosis exists only in life, therefore, we must also keep the traditional concept of interpretation, and in this case, we can no longer apply the Peirce model to the cell. This does not mean, of course, that the Peirce model is wrong. It means that it is valid only for those living systems that are capable of interpretation in the traditional sense of the word, i.e., for organisms that have a nervous system.

It is likely that the behavior of the first animals was almost entirely determined by genes, but the number of hard-wired responses could not grow indefinitely, and animals started resorting to processes of learning in order to increase their behavioral repertoire. Learning how to respond to a signal, on the other hand, means learning how to interpret that signal, and this amounts to the construction of a behavioral code whose rules are *context-dependent*. At the same time, learning requires a memory where the results of experience are accumulated, and this means that interpretation is also a *memory-dependent* process. A process of interpretation, in short, is a new type of semiosis that is profoundly different from organic semiosis because it is dependent on learning, memory and context.

Systems capable of interpretation, in turn, evolved in many different ways and eventually a third type of semiosis appeared, a semiosis that was based on symbolic codes shared by all members of a community, i.e., on *language* (Deacon 1997). The evolution of semiosis was characterized, therefore, by three great innovations: (1) the origin of organic semiosis (the *semiotic threshold*), (2) the origin of interpretation (the *hermeneutic threshold*), and (3) the origin of language (the *symbolic threshold*). It was a process that started at the origin of life with context-free codes and produced codes that were more and more context-dependent. Today, our cultural codes are so heavily dependent on context that we can hardly imagine semiosis without interpretation, and yet they are distinct processes, and we need to keep them apart if we want to understand the origin and the evolution of life.

Five Schools and a Minimal Unity

In addition to code- and to sign-based biosemiotics, there are at least three other schools that have recognized the existence of semiosis in organic life. One is the school founded by Gregory Bateson who described evolution as a cosmic process of learning (Hoffmeyer 2008). Another school is the approach developed within physics by Howard Pattee who proposed, since the 1960s, that there must have been an *epistemic cut* at the origin of life (Pattee 1969, 1972, 2001). The third school was inspired by the philosophy of hermeneutics and was developed in particular by Anton Markoš (2002) who argued that biology can catch the essentials of life only by embracing the approach of the humanities.

There is no space, in this brief review, for these additional themes of biosemiotics, and the interested readers are invited to consult the literature and the historical accounts (Favareau 2007). What is important, here, is to underline not only the existence of different schools of biosemiotics but also the fact that a few small steps towards unification have already been taken.

The first came in 2004 at the fourth Gathering in Biosemiotics organized by Anton Markos in Pragne. Jesper Hoffmeyer, Claus Emmeche, Kalevi Kull, Anton Markos, and Marcello Barbieri met in a pub and decided that what was uniting them-the introduction of meaning in biology was far more important than their divisions. Up until then, Barbieri had referred to the science of biological semiosis as *semantic biology*, or *biosemantics*, whereas Markos had been calling it *biohermeneuthics*, but they accepted to give up their favorite names and to adopt the term *biosemiotics* that Thomas Sebeok had been campaigning for with so much passion and vigor. That is when biosemiotics really came of age. It happened when people decided to work together not because they had the same ideas but because they accepted to put their differences aside in the interest of a greater goal.

Today, the differences still exist, but there is also a “minimal unity” in the field because there are two basic principles, or postulates, that are accepted by virtually all biosemioticians.

1. The first postulate is the idea that semiosis is unique to life, i.e., that a real divide exists between life and inanimate matter. This sharply differentiates biosemiotics from "pansemiotics", the doctrine that accepts the existence of semiosis even in the physical world.
2. The second postulate is the idea that semiosis and meaning are *natural* entities. This sharply divides biosemiotics from the doctrine of "intelligent design" and from all other doctrines that maintain that the origin of life on Earth was necessarily the product of a supernatural agency.

Today, in conclusion, biosemiotics is not yet a unified field from an academic point of view, but it is nonetheless a field that provides a new paradigm for biology. Almost everything remains to be written, but the important point is that the main signposts of the new framework are already in place.

Conclusion

The major conclusion of this review is that biological semiosis is a reality because semiosis is based on codes, and organic codes are experimental realities. An equivalent formulation is that all living creatures are semiotic systems because organic codes exist in all of them. This conclusion is based on a variety of arguments that here have been divided, for convenience, into five parts.

1. In Part 1, we have seen that the cell can be described as a trinity of genotype, phenotype, and ribotype because it is made of three distinct types of informational molecules that have three distinct biological roles. Genotype and phenotype are, respectively, the seats of heredity and metabolism, whereas the ribotype is the system that manufactures proteins on the instructions of genes according to the rules of the genetic code. The crucial point is that the ribotype has the defining features of a codemaker, whereas the sequences of genes and proteins are codemaker-dependent entities and have the defining features of signs and meanings. This shows that the cell is a true semiotic system because it contains all the essential features of such systems, i.e., signs, meanings, and code all produced by the same codemaker.
2. In Part 2, we have faced the claim of physicalism, the conclusion that all natural entities must be reducible to physical quantities. This claim is certainly valid for spontaneous objects because all spontaneous reactions are completely accounted for by physical quantities, but genes and proteins are *not* spontaneous molecules. They are molecular artifacts that are manufactured by molecular machines by copying and coding. The crucial point, here, is that the production of artifacts requires not only physical quantities but also additional entities like sequences and codes. These entities are as real as physical quantities in the sense that they are equally necessary to the description of biological systems, and this means that in no way can we dismiss them as linguistic metaphors. Physicalism, in short, is not valid in a world of artifacts. It is valid only in a world of spontaneous

objects, and it is still popular today only because biology has not yet assimilated the idea that genes and proteins are molecular artifacts, that the whole of life is artifact-making.

3. In Part 3, we have seen that the experimental criterion which has led to the discovery of the genetic code, i.e., the presence of adaptors, allows us to prove the existence of many other organic codes. This makes us realize that the genetic code was only the first of a long list of organic codes, which appeared throughout the history of life. We realize furthermore that the appearance of new organic codes was associated with the great events of macroevolution, which is equivalent to saying that the semiotic processes of coding have been instrumental in shaping the history of life on our planet.
4. In Part 4, we have examined the central claim of the Modem Synthesis, the conclusion that natural selection is the sole mechanism that generates biological novelties. The crucial point here is that natural selection is the long-term result of molecular copying and would be the sole mechanism of evolution if copying were the sole basic mechanism of life. But there are two distinct molecular mechanisms at the basis of life, copying and coding, and both of them have long-term consequences. Copying leads in the long run to natural selection and coding to natural conventions, which means that evolution took place by two distinct mechanisms. Natural selection produces new objects by modifying previous ones, whereas natural conventions bring absolute novelties into existence. Even the evolution of life, in short, was based on semiosis because natural conventions represent a distinct mechanism of evolution.
5. In Part 5, we have seen that biosemiotics has been developed independently by at least five different lines of research. One is the Sebeok-Hoffmeyer approach that is based on Peirce's definition of sign and assumes that interpretation is a fundamental feature of semiosis. The second is the organic-codes line of research where semiosis is based on coding, not on interpretation, and the other three are the approaches developed respectively by Gregory Bateson, Howard Pattee, and Anton Markos. This makes us realize that biosemiotics is still a developing science where many issues, even important ones, remain to be settled.

All versions of biosemiotics, at any rate, share the idea that semiosis is fundamental to life, i.e., that all living creatures are semiotic systems, and the important point is that we already have enough experimental evidence in favor of that idea. Biosemiotics, in conclusion, is a genuine new paradigm for both biology and semiotics, but its future is unpredictable. It truly is like a new continent whose exploration has just begun.

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Commentary Bibliography and Further Readings

The following bibliography of primary and secondary literature consulted in the preparation of this volume is by no means exhaustive. Rather, I have here compiled a few short lists of only the most representative primary readings sufficient for the reader to attain a solid introductory grounding in each author's main ideas, and have augmented such lists with a number of suggested and easily accessible secondary readings meant to contextualize the author's works and their reception within the relevant fields of discourse. When consulting these chapter bibliographies and list of suggested further readings, please note that each reprinted selection in this anthology also contains its own original citation list that has been reprinted at the conclusion of each selection. Many of these original reference lists (e.g., Anderson et al.) reveal state-of-the-art scholarship at the time of their writing, and provide critically important bibliographic information that has not been reproduced on the following lists of suggested introductory readings. By using both sets of lists in tandem, however, and by following the trail of signs that appear as reference texts beget further reference texts, the reader should be able to proceed from the readings contained in this introductory anthology to an increasingly full acquaintance with the extant scholarship in the field. – D.F.

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