CHAPTER 1

THE EVOLUTIONARY HISTORY OF BIOSEMIOTICS

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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).

A PERSONAL PRELUDE: MY STROLL THROUGH THE WORLDS OF SCIENCES AND SIGNS

Having spent the last six 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.*

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. For the 1990s were declared (by fiat of an actual act of Congress) to be "The Decade of the Brain" in the United States – and, reservations about the seriousness of such self-aggrandizing hyperbole aside, this period did indeed see a great explosion of ideas and energy emanating out of such newly minted hybrid research projects

M. Barbieri (ed.), Introduction to Biosemiotics, 1–67.

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 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 for it a satisfactory answer.

For with the object of study itself being invariably conceptualized either in a modified Cartesian sense (i.e. – "mind" as a 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 to 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, Fuster 2003) were suggesting interesting syntheses that, although not phrased this way by their proponents, attempted to preserve the interdependent reality of both sign relations and material relations in their explications of the phenomenon of "mind."

These searches still, however, proceeded from the yet too partial understanding that somehow "the mind produces sign relations" – when, in point of fact, 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. And 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 discusses the concept of self-reference in a system. This he compares to 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 Gathering in Biosemiotics.

Researchers from 18 different countries were present at that initial Gatherings, with backgrounds ranging from physics and molecular biology to animal ethology, robotics, evolutionary psychology and philosophy of semiotics and of mind. And since entering the interdisciplinary project that this group was in the process of creating, I have since 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.

For even 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) and that "most neuroscientists and philosophers now take for granted that all biological phenomena, including consciousness, are *properties of matter*" as writes Nobel Prize winner Eric Kandel at the conclusion of his authoritative *Principals of Neural Science* (2000:1318, italics mine). "Is the 'problem of consciousness' *real*, however?" he then asks, noting far too accurately that "some philosophers and *many neuroscientists* believe that *consciousness is an illusion*" (ibid).

And so the question accordingly arises: How did modern science – the communal knowledge-generating system *par excellence* – arrive at this sterile

impasse whereat the investigation of individual knowledge-generating systems *as* knowledge-generating systems *per se* came to be seen, at best, as a vexingly paradoxical riddle and, at worst, as falling outside the scope of legitimate scientific inquiry entirely?

It is in the hope of providing at least partial illumination of the historical processes by which this particular explanatory Gordian knot was tied, that the first half of this history of biosemiotics begins.

A BRIEF HISTORY OF THE TYING OF A GORDIAN KNOT

The resistance to studying "subjective experience" *qua* "subjective experience" (and not just studying the interactions of its material substrate) has a long and principled history in science – and it precisely this history that we need to understand first, if we are ever to understand how something as oddly named as "biosemiotics" is not only not an anti-science nor a pseudo-science, but is genuinely a proto-science aimed at scientifically distinguishing and explaining the use of sign relations both between and within organisms.

Accordingly, it might seem at first that an examination into the uniquely influential works of René Descartes (1596–1650) would be a logical place to start this discussion – Descartes' work being emblematic of the "bifurcation" between modernity and pre-modernity in both the sciences and in philosophy, as well, of course, as the bifurcation between the mental and material "realms" that we continue to travel, 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.

Like all of us, however, Descartes too played his role informed by a set of prior narratives that are themselves contingent products of history as well. So if we are to understand the relationship of biosemiotics to the modern science from which it proceeds and 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, rather, to continue it, re-tooled for the very challenges that the enterprise itself entails, if not demands.

The same cannot be said of the relation of modern science to its parent traditions of ancient Greek thought and medieval scholasticism however. For the founders of modern science, as again we shall see shortly, were adamant in their declarations

that all such older traditions were to be renounced wholesale and were to be replaced with something "entirely new". And so, if we are to make sense of the narrative that is the history of biosemiotics only within the larger narrative that is the history of science, we now find that yet an even earlier history and an even larger embedding narrative has to be recounted here. Thus, if we are to understand the history of science, it will be critical to understand the intellectual traditions from which modern science, and the whole modern age of the 16th and 17th centuries, was self-consciously rebelling. But to understand what joins those two older traditions, one first and foremost has to understand Aristotle.

And what better place to begin a history of biosemiotics than with the West's first genuine biologist? For 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, we may at last begin to get a clearer view of the conceptual entanglements between signs and nature that Descartes sought to resolve not with a yet more entangled synthesis, but with an Alexandrain cleaving that would leave the two halves disconnected and the thread that once was their unity forever cut.

And as it is the job of biosemiotics to begin 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 a knot out of the naturally occurring continuum bearing humans, nature, animals and culture.

PHASE ONE: SEMIOTICS WITHOUT SCIENCE

It is said that the ancient Greeks had no real vocabulary for, nor philosophical interest in, discussing the distinction between "natural" and "cultural" signs. Rather, reports historian John Deely (2001), even up until the Roman period, σημείο (L: *semeion*) for the Greeks remained primarily a medical term – roughly akin to the modern concept of *symptom* – that referred only to the outward manifestations of an internal condition or overall 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"[2]– proceeds.

We can notice at the outset, however, that a close association between something present and observable (pallor, a rash, a swelling of the ankles) with either something else that is present and unobservable (an organ malfunction or a tapeworm within) or with something else that is non-present and unobservable (overindulgence of food and drink, an accident that happened previously) imbue this notion of *semeion* with at least the two following characteristics: (1) The phenomenon of *relation* is inextricable from the concept; the *semeion* is always a symptom "*of* " something other than itself or just itself (and is so, presumably, whether or not any physician or patient is looking at it, as it necessarily pre-exists both of their awarenesses of it). (2) Something "unobservable" is being *educed* in the process of observing.

AUGUSTINE: THE "NATURAL" AND "GIVEN" SIGNS

These two broad characterizations alone will be sufficient for several centuries worth of "realist" versus "idealist" debate arising, self-consciously or not, from the question of whether (2) or (1) should be given primacy in one's understanding of what it is to be a "sign." And this is a debate whose lack of historical resolution deeply informs our own difficulties with the concept of a "sign" today. Paralleling our own deepening understanding in biosemiotics, perhaps, Augustine of Hippo (354–430) in his treatise of 387 known as *De Dialectica*, first assigned ontological priority to the second of these two characteristics, by codifying the extra-medical notion of the sign (the Latinized *signum*) as constituting "anything *perceived*, which in so doing, causes something other than itself to come into *awareness* (*Signum est quod se ipsum sensui et praeter se aliquid animo ostendit*)."

Returning to the topic twelve years later, however, in *De Doctrina Christiana* (398), Augustine refined his definition by emphasising the first of the sign relation's two aspects. There, he writes that "*a sign is something* which, offering itself to the senses, conveys something other to the intellect (*Signum . . . est res praeter speciem quam ingerit sensibus, aliud aliquid ex se faciens in cogitationem venire*)." The shift in emphasis from the semiotic capacity of the agent to the semiotic capacity of the sign vehicle *per se* is a subtle one, but as Deely (2001:215) notes, the implication of Augustine's general formulation is that there exists a mode of actuality in the real world that contains and is thus a higher-order category of both "mind-dependant relations" and "mind-independent relations" – i.e., the category of relations *qua* relations. And this actually constitutes the first recorded consideration of "sign relations" *per se*. Yet this was not the implication that was taken up and developed subsequently, but turned out to be exactly that most potentially fruitful part of Augustine's formulation that lay dormant for the majority of the Middle Ages, and, indeed, for most of modernity as well, as we shall see.

Rather, and unfortunately, it was not Augustine's posit of the sign relation's unification – but of its distinctions – that would turn out to be perplexingly consequential for the history of sign study. For it is in Augustine, too, that we first find the beginning of the philosophic tradition that distinguishes between "natural signs" (*signa naturalia*) and what might be called "cultural signs" – but that Augustine himself calls "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" – one might think of the relations of physical contiguity, such as the relation of smoke to fire, or of the footprint in the ground to the animal that made it, or of a fossil. "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" – such as, presumably, talk and gestures and the marks on this page and Augustine's *Confessions*.[3]

Subsequent inquirers into the notion of sign relations will come to realize, however, that Augustine's distinctions raise as many questions as they propose

to answer. And among these many questions are: *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? And 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 "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?

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 (2003) writes, "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."[4]

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 (one which just so happens to be constituted as 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.

ARISTOTLE: *ON LIFE* AND *ON INTERPRETATION*

The contingencies actualized by history have *not* been otherwise, however, and thus the understandings about sign relations that came to be most generally accepted next are ones that were to have dire consequences for subsequent centuries' attempts at incorporating the resulting notion of "sign" relations with the modern project of science. For that version of the scientific project that we have inherited today, of course, proceeds in a fairly straight line from the experimentalist instrument of Francis Bacon's *Novum Organon* – which is itself an historically situated reaction to what had been the primary "instrument of logic" and investigation about the natural world for the scholastics of the medieval world – i.e., 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 until 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.

For 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 natural 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 C.E. These six books on logic, thought to have been collected by Andronicus around 40 B.C. 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 *comes out of and fits in with* the logic of the natural world (a 'biosemiotic' understanding, as it were) – these 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 – without the corresponding Aristotelian texts on nature and biology – meant that 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.

This latter notion – 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*, the first six centuries of monastic scholars, however, 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 a 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. Because 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 ψῦχή (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 – so much so that 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"* and the basics of his hylomorphism to state that *the biological "form" of such life is the product of its (for us: 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: (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 organisms' actions upon the world (which subsequently change that world) are both enabled by and constrained by the organism's systemic biological constitution, including its perceptual capacities (anticipating von Uexküll); and (3) it follows that as the result of (1) and (2) there is a 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)*.[5]

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 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 later) 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 (cf. 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 twentieth century. For the result of the ever-widening bifurcation in the scholastic period between the investigations of bio-logic and the investigation of semeiologic 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, in that understanding the essence of a "sign" *per se* to be an object that is mediated through the mental experience of human beings, conflates what is merely one example of the superordinate category of "sign relations" into the definition of the entire category itself. Doing so thus accomplishes a logical conflation and an explanatory reduction at one 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 only centuries later would be reclaimed the evolutionarily coherent notion that the appearance of humans with their unique kind of "mental experience" is itself the product of a legacy of sign relations arising out of animals' interactions with each other and with the external world. And that in order for even these most primitive multicellular animals to come into being, processes of organization whereby living cells could co-ordinate their interactions with each other (and, again, with the external environment that they had to somehow come to negotiate in order to survive), proto-semiotic "substitution relations" – biologically instantiated processes whereby detection of the presence of x becomes a reliable indicator of y – had to evolve.

SIGN DIVERGENCE AND CONVERGENCE IN THE LATE MIDDLE AGES

This is not to say, however, that the Middle Ages was entirely bereft of thinkers dedicating their considerable intellects to an examination of the role of sign relations in life. Indeed, both Roger Bacon (1214–1293) and his contemporary Robert

Kilwardby (1215–1279) 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). Both projects floundered, 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"[6] that, not surprisingly, failed to satisfactorily account for the possibility of *any* sign relations emerging out of the world of nature at all.

Yet thus did almost all investigations into the nature of "sign relations" throughout the Middle Ages take as the object of their inquiry not a triad of relations bringing together the extra-mental world of agents, actions and objects in the first instance, but a triad of relations joining "mental speech" (*oratio mentalis*) and its relations to the rest of the intellect (*intellectus*) on the one hand, and to the grammar of the spoken word (*vox verbi*) on the other. Propositions, human mentation, psychological states, linguistic relations and their resulting (and often unacknowledgedly linguaform) conceptual understandings – these were the first principles and paradigmatic assumptions from which the "sign sciences" of the Middle Ages – and, indeed, of most of the modern age – set forth but could not proceed.

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, has not truly occurred yet). Not surprisingly, then, did William of Ockham (1287–1347) exacerbate the incipient dualism between extra-mental relations and sign relations by asserting that the universal properties of things were merely the universalizing mental *signum* (signs) of human minds. In such ground did the seeds of an increasingly mentation-centric *nominalism* flourish, and the self-reinforcing "humanification of the sign" progress.[7]

Indeed, it was only towards the absolute twilight of scholasticism and the dawn of the modern period that a minority of 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 – and this conclusion was only reached through their hermeneutic reconsideration of Augustine's original assertion that "a sign, in every case, imports 'something relative to something else' (*aliquid stans pro alio*)" (Deely 2001:426).

It was proceeding from this investigation that 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, italics mine).

In ways which we will have both time and need to expand upon more fully later in this history, Poinsot's understanding of the sign as being something that is in its very essence a triadic *relation* of *x* as *y* to *z* in its first instance[8] – and only derivatively any actually instantiated realization of such a relation (e.g., of a mental sign to a human knower, or a odorant molecule to an opossum, or in the exchange of Ca+ as a second messenger in the incessant interaction between living cells) – resuscitates 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.

Thus, philosopher historian John Deely claims that Poinsot's muddle-clearing "identification of *signs* with pure relations as such [constitutes] medieval semiotics' highest point of development . . . as the question of whether signs can be identified with any definite class of things able to exist [independently], whether as physical or as psychological realities, is definitely answered in the negative" (2001:434). Rather, writes Deely, "in every case, the sign as such, *consisting in the relation* between sign-vehicle and object-signified, is something suprasubjective" to the yet necessary participation of them both, in any system capable of acting upon the "things" of the material world so as to be able to actively transform them into the "objects" of triadic relation (2001:434).

This means, claims Deely, that "those 'things' or 'perceived objects' that we [mistakenly] *call* "signs" – things such as traffic lights, barber poles, words, [thoughts], and so on, are not, technically speaking, *signs* but the *vehicles* of signification" (ibid) – an understanding which, if adopted widely, would 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.

Instead, the discoverable relevant relations of system *x as well as* those of entity, state or event *y during the course of interaction* whereby *y* is acted upon as a sign of *z* for *x* becomes the focus of investigation – and 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, 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 system has to include in its account:

> Hence a physicist would define an affection of soul differently from a dialectician . . . the latter assigns the material conditions, the former the form or formulable essence . . . Thus 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*).

And from Poinsot's formulation to our current understanding about the generative, recursive dynamics of autopoetic systems, it is only one small step to realizing that one of the implications Aristotle's assertion about the "double character" of "enmattered formulable essences" is 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 what today calls itself "biosemiotics". Yet having progressed the 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-dependent relations from everything else.

Such a discontinuous and divisive posit would itself constitute a schism between the classic-scholastic tradition of thinking and, well, everything else. 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."[9]

So wrote René Descartes in 1641, expressing his resistance to the prospect of becoming a biosemiotician, right at the outset of modernity – a modernity that this particular resistance not only helped to shape, but to actually 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).

And, indeed, so absolutely ordinary does it feel to us as the inheritors of Descartes' 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 – that it often goes unnoticed that smuggled into the very terms of this debate, the latter stands in relation to the former as a kind of impotent Platonic shadow or blind mendicant – and the mind becomes the glass through which we see the world darkly, rather than face-to-face.

This understanding, like all others, no matter how infrequently considered, has a history of its own, for 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.

DESCARTES: BIFURCATING THE NATURAL WORLD INTO BODY AND SPIRIT

For by 1641, both the scholastic tradition and the hegemony of Aristotelian explanation of 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: in an exponentially individualistic and mercantile society, the calculus of utilitarian efficiency trumps 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 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 burgeoning 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*).[10]

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.

Thus convinced of the need to reject the *entirety* of received opinion from the past – as well as to renounce 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., in "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 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. That feeling had been growing, rather, at least since Petrarch retroactively designated the 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 mercantilism and the rapid advancement of printing, lens and machine technologies, all played their parts in laminating this retrospective construction of a "backwards" time from which humanity was finally emerging – 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 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 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 that 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-medieval thinker 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 *objects of experience* become not a partial revelation of surrounding nature and culture, but a screen separating the mind from things" (Deely 2001:520, italics mine). But Descartes, of course, was not alone in seeing the need for a "radical surgery" that would separate *res cogitans* off from the rest of *res extensa* and come to see it as inhabiting its own little private world – an immaterial world that would quickly be recognized as a scientifically unexaminable world, no less, and yet the only world, supposedly, in which something as equally ghostly 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]). This is 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]). Here, again, 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.[11]

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 from the human repertoire out entirely.[12] "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' 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 succeed 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 the science of Descartes' time have 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 vindicated by Robert Boyle's (1627–1692) foundation of "public science" and the establishment of the Royal Society 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 be admitted by Isaac Newton (1643–1727), thereby rightly vindicating Descartes. Thus armed with the error-correcting mechanisms of 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' 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 – 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 happening as variously and as species-specifically as does every other biological universal), but because our very *idea* 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 equate "mind" and "knowing" *only* with our particular form of adaptation to this universal biological need.[13] And this, of course, presents us with a two-fold 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 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 swims safely away? Are we to say that the self-reflexive ability to symbolize its own experience and articulate that set of symbols to another *constitutes 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 essentially the input/output automatons that Descartes claimed they are.

The second problem that this raises, of course, 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* 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" – *and*

sees to the organization of all the animal's 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 well knew!).

Finally, the unexamined conflation of "mind" with "human mind" leaves the entire question of the species-specific peculiarity *of* that kind of human "mindedness" untouched. *If* we are 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" (as Charles Peirce would say), 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 ever since.

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 pursue the issue, an increasing lack of need to consult, or eventually to even be conversant in, science. In short, 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 ẽxplanatorily 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 made possible by Leeuwenhook's deployment of the microscope, 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 all were relatively amenable to the then-available physical and chemical understandings. It is only with Wilhelm Johannsen's (1857–1927) introduction of the "gene" concept in 1909 that "information" *per se* becomes 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 pregiven 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.[14] 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 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 in what just 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 a 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) while for Claude Shannon and Warren Weaver, "information" was the diminution of uncertainty in a system absolutely without regard to cognitive 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 matter and anti-matter. Because the rationality driving Crick's, and Shannon and Weaver's denials is based upon the assumption all "true meaning" is *symbolic* meaning – the 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, neither nucleotides nor electronic pulses along a length of wire in themselves have any "*symbolic* meaning." Why, then, use this strange word "information" to describe them?

The move made here – as with the concepts "signal" in molecular biology, "message" in neuroscience and "communication" in animal ethology – is 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" (cf. Griffith 2001; also Barbieri 2003a and this volume). But in all three instances, the question reasserts itself – a metaphor for what? "Processes we do not yet understand," certainly. But what *kind* of processes? Ultimately,

informational, representative, and meaningful ones – so once again, we are back to having to confront the existence, in the *biological* world, or genuinely *semiotic* processes.

And the refusal to cross this 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 living under the same physical conditions who have evolved from virtually the exact same genetic processes, and who have developed myriad other capabilities, but just not those particular ones last listed – *and* one denies 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 are *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 twentieth 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) 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) it is the subjective experiences of these agents that *leads* 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). Yet all generatively and recursively 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 be really be to say the most committed – members of these two groups started pushing back against their respective fields' Cartesian boundaries and began scouting around in distant coastlines in an effort to more effectively redraw the inherited, but prohibitively unrealistic, map.

It is to just that 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

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 of 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 describe the many and various disciplinary sites of origin spanning across biochemistry and philosophy departments, dynamic systems research labs and anthropological field sites, and the lifelong private research investigations of individual scholars, many of whose final destinations are, as of this writing, unknown.[15]

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.

JOINING SIGN SCIENCE WITH LIFE SCIENCE: THOMAS A. SEBEOK

While a growing number of isolated scholars working in widely-separated disciplines were all toiling 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.*[16]

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 signaling behaviour in and across animal species" (1963).[17]

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 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 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 SCHOLARSHIP 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 an 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 unnaturally 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 acknowledging his debt of understanding to both 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 was virtually unknown of in the West.[18]

It 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 Semiosfere* for translation and publication in the West (Sebeok 1998).[19] 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 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*[20] – to describe a *necessary* concept for understanding our species-specific use of, and immersion in, a world of materially consequential sign relationships – but not 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 1986: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.

Thus Sebeok continued his own decades-long study into animal communication both via the majority of research literature then extant and through his hands-on work with zoobiologist Heini Hediger (Sebeok 2001a). 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, anthropomorphisms and machino-morphisms being then attributed to animal cognition (e.g. Sebeok 1977, 1980, 1988, 1990).

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 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).[21] 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 (or brief flash, as it were) of this, one of the two main sources of incandescence illuminating Sebeok's biosemiotic vision.[22]

A scientist by training and by temperament, "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, bought 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), and here only schematically the uncoupling of the unified force, which results in the generation of quarks that then makes possible to 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 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, 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. Here, 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 (i.e., of sensations *to* perceptions, and of perceptions *to* other perceptions) become representable *as signs* in their own right (e.g., as in musical notation, mathematical notation, linguistic notation, etc), the malleable conventionality of *thirdness* becomes available to living organisms for the re-contextualization 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 himself 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 "bafflingly murky" and "beyond doubt over his 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 some truth in this characterization, as we shall see. For in his rediscovery of von Uexküll, Sebeok felt that he had not only found the long missing piece of the puzzle that he had been looking for – but he 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 *and* 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 was not privileged, of course, 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).[23] 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 1999c). 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.

It can be seen, however, that von Uexküll was working very much within a nineteenth century Romantic intellectual culture that was still vibrant in Estonia, while the science of Darwin's England was increasing utilitarian, mechanistic and Malthusian. Thus, the original quote in the paragraph 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 same concept of proximate, systemic interaction towards homeostatic optima observable in all living organisms that I have substituted for it in the brackets above.

However, and as Hoffmeyer notes, just as Darwinism needed Mendelian genetics for its full coherence, "it is only through *integration with* the theory of evolution that [von Uexküll's] *umwelt* theory can truly bear fruit" (1996:58). For just as 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 – 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) – needs to be supplemented with a theory of how such subjects themselves have come to be so peculiarly 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 and, *sic passim*, "nature's sovereign plan" (1934/1957:80).

An epigone of Peirce himself, however, Sebeok 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 organisms – as enabled 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 *Theoretische 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 upon the "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* 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.

But Barbieri's charge of "proselytization" is on the whole a fair one – though happily enough, as it turns out, for many of the scholars laboring in the fields of biosemiotics today, many of whom find von Uexküll's articulation of *umwelt* to be a manifestly helpful terminological tool – and many of whom were, quite directly, brought to this realization in the person of Thomas Sebeok himself.

For "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 – semiotics. The number of "converts" he made for semiotics in this way are innumerable" (Danesi 2002).

Thus, in 1977, 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 (*BMJ* 2004), 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 1999 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 "proselytization" 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 and 2000, Deely 1995, Pertrilli and Ponzio 2001, and 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 entire

undertaking 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, his 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 of this coalescence and where that history will lead remain, of course, 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).

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. Most of these scholars have found their way into the field through their own unique and surreptitious pathways, and many 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 Scandinavia and 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)[24] 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 (1982, 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.[25]

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 1966–1969 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 were 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 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

Trained and hired as a biochemist by the University of Copenhagen in 1968, Hoffmeyer had been active in Danish public life since his days as a student activist in the mid-1960s. 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, "by the 1980s, Jesper Hoffmeyer had become one of the most visible intellectuals in the debate on technology and society in Denmark" write his biographers (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 nineteenth century scientist-philosopher Charles S. Peirce.

By 1985, Hoffmeyer was committed to the idea of developing "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 – can emerge from a universe that was not [so] organized and meaningful from the very beginning" (Emmeche et al 2002:41).

And in this, 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, more importantly, the kind of 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.[26] 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, 1982).

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)[27]– while 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 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. 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 1998, 2000, 2001).

In 1993, Jesper Hoffmeyer published his definitive work on biosemiotics *En Snegl Pa Vejen: Betydningens naturhistorie (A Snail on the Trail: The Natural History of Signification)*, was later translated into English the book that 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 in nature without 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 languages, the English language publication of Hoffmeyer's *Signs of Meaning* was enthusiastically reviewed (1998) and remains as 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 (a tale 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 to a successor.

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.[28]

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 of the peer-reviewed *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.[29]

CONTRIBUTIONS FROM OUTSIDE THE COPENHAGEN-TARTU NEXUS

One of the approaches that does not come strictly out of the Copenhagen-Tartu lineage is represented at these conferences 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,[30] 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. Indeed, 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). Working biologists "just like any others," Cvrčková and Markoš's work yet reminds us never to lose sight of Korzybski's admonition that "the map is not the territory" – lest we find ourselves taking seriously such 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*?).

Yağmur Denizhan and Vefa Karatay (1999, 2002), a dynamic systems engineer and a molecular biologist, respectively, from Boğaziçi University in Istanbul, 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.

Physicists Edwina Taborsky (1998) and Peder Voetmann Christensen (2000), almost alone among biosemioticians, have sought to explicate Peirce's own understanding of his semeiotic as a 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 a rich mine for physicists, as well as for biosemioticians, and Taborsky and Christensen are among the first to be blazing this trail.

And 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, to 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 concepts 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 – the ultimate research question of biosemiotics (see Pattee 2005 and this volume).

DEVELOPMENTS AND CHALLENGES 2001–2005

Indeed, it would require a book-length monograph of its own to detail the interdisciplinary research interests and data presented at the annual International Gatherings in Biosemiotics, all of which, in one way or the other, are devoted to this central question of the non-mystical role of "representation" and its "meaning" in the

organization and interactions of living organisms. In lieu of that, I will merely direct the reader to pursue on his or her own the representative list of cited publications corresponding to some of the more regular attendees to the annual Gatherings as referenced below.

In the areas of animal studies, ethology and zoology, Dominque Lestel (2002), Timo Maran (2003), Mette Böll (2002), Dario Martinelli (2005) and Aleksei Turovski (2000) are all pursuing biosemiotic lines of investigation in their work. Examination into the relations of intercellular signaling processes are molecular biologists Luis Emilio Bruni (1997, 2001), Mia Trolle Borup (2005), Mogens Kilstrup (1997) and Abir Igamberdiev (1999), as well as immunologist Marcella Faria (2005), embryologists Johannes Huber and Ingolf Schmid-Tannwald (2005), and pharmacologist Sungchul Ji (2002).

Researchers into dynamic systems theory who are incorporating biosemiotics into their models include Hernán Burbano (2005), Stephen Pain (2002), Toshiyuki Nakajima (2005), Assen Dimitrov (2004), Wolfgang Hofkirchner (2002), João Queiroz (2005), Charbel Niño El-Hani (2005), László Hajnal (2003), and Karel Kleisner (2004).

"Neurosemiotic" approaches to brain research and consciousness studies have been proposed by Andreas Roepstorff (2004), Anton Fürlinger (1998), Sidarta Ribeiro (2003), Alessandro Villa (2005) and the author (Favareau 2001, 2002); while a biosemiotically informed approach to Artificial Intelligence and cognitive robotics has been undertaken by Tom Ziemke (2003) and Noel and Amanda Sharkey (1999, 2002).

Maricela Yip (2005), Pierre Madl (2005), and Almo Farina (2004) all apply a biosemiotic approach to their research into sustainable ecosystems, Yair Neuman (2003) applies it to theoritical immunology while anthropologists Myrdene Anderson (1999), Thierry Bardini (2001), Cornelius Steckner (2004), Andreas Weber (2002), and Mark Reybrouck (2005) focus on the cultural semiotics of human-to-human interaction.

Enriching and informing all of this discussion is the work of semioticians and linguists Tuomo Jämsä (2005), Sergey Chebanov (1994) and Adam Skibinski (2004), Han-Liang Chang (2005) and Juipi Chien (2003), philosopher Giinter Witzamy (2000), biosemiotic theorists Andres Luure (2002), Aleksei Sharov (2002) and Kaie Kotov (2002), Gregory biographer Peter Harries-Jones (1995), and archivist for the Jakob von Uexküll Institute for *Umweltforschung*, Torsten Rüting (2004).

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 earlier was officially founded; and in the same year, the first issue of the international *Journal of Biosemiotics* appeared.

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. No longer can it be assumed that

a self-identified "biosemiotician" necessarily believes that the semiotic categories of Peirce – or even the *Umweltforschung* of von Uexküll – are the optimal starting points on which to build a scientific articulation of sign processes in biology.

Rather, in the five 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, and forthcoming) and Stefan Artmann (2005, and this volume) 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 . . .") resulting from a lack of familiarity with the field.

For as productive as these Gatherings have been for the exchange of ideas and the development towards a common goal, equally important is the fact the international biosemiotic conferences and journal articles have also resulted in a series of penetrating 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 name "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 psuedo-science), these internally informed even as they critiques highlight both the existing shortcomings as well as the possibly inherent problematics in the current articulation of the biosemiotic project *per se*, even as they point to alternative possible ways to develop a semiotically-informed biology without reliance on 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 the 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.[31]

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 itself" while in continuous interaction with its 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 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 "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 – it 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.[32]

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).

"The cell is the unity of life," claims Barbieri, "and biosemiotics can become a science only if we prove that the cell is a semiotic system."[33] 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 mind from body – and in so doing introduced an impossible dualism incompatible with the biological reality of interacting levels of organization.

For, argues Barbieri, "the very definition of phenotype leads us 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, "the real distinction between genotype and phenotype is based 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) and *whatever it is that 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 a *semantic theory of evolution* necessary, along with a s*emantic 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 of 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 ribosoid* 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)

In what would be considered to be a revolutionary re-thinking of both the origin of cellular life and of its ongoing internal relations even today, in 1985 Barbieri expanded upon these ideas in a work entitled *The Semantic Theory of Evolution* that was enthusiastically received both by mathematician René Thom (1923–2002) and by philosopher of science Sir Karl Popper (1902–1994). Eighteen 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 for the existence of a whole array of organic codes that he postulated in the earlier work, including RNA splicing codes (97–100), intercellular signal transduction and integration codes (101–108), cellular migration and adhesion codes (112–114), and 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 seem 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" (2006: forthcoming).

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" (2002: 291–292).

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"), not does they 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).[34]

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*).

A PARTING PROLOGUE: 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 us 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.[35]

Whether or not this day will come, only the history written *after* this history can tell. 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.

Yet many working scientists do not feel comfortable toiling 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, fields that may already be well into their third and fourth re-articulations, as in physics. Yet 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," Marcello Barbieri reminds us 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 processes, 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. For there again, an *observation* – about familial sameness – led to an *intuition* – about material transmission – that had to be articulated – as the "theoretical unit of heredity" (*whatever* that might turn out to be ... and some candidates were: cell, protein, blood, vapor and many others) – to be called, for *articulatory* purposes – a "gene" – *before* researchers started conducting experiments to find out if this so-called "unit of heredity" 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, 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 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 *is* "reproduction between organisms."

Precisely analogous to this is the current state of neurobiological research with which we opened this discussion on page one. There – as in genetics, as in pharmacology, as in animal behavior study – if one is not *looking for* the biological construction of a "sign relation" within the set of material interactions that is brain activity, one can "see" all the chemical-electrical activity there is to be seen – but one will never know how to explain it *as* any particular *instance* of "sign activity"

until one has a provisional theory – or *articulation* – of in just what a "biological sign category" consists. The microscope can only *present* – it cannot "make sense of " or explanatorily "reveal." That takes a theory – which is an articulation, based on intuition and observation – which is then subject to rigorous experiment.

For a neuron will remain a neuron no matter what, and 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 this particular neuron's activation is functioning as part of an indexical circuit, an iconic one, or a symbolic one – to this *kind* of question, 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.

Yet 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 questions about sign processes in biology to the point that they become taken up by the larger scientific community as being legitimate questions to ask. For many of these questions are often yet intuited as being "not quite legitimate" questions to ask, even now – and even with the continual insistence of virtually everyone involved in 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. Biosemiotics has thought these matters through from both their biological and their semiotic sides and as come to the conclusion that the problem is not in the phenomena, but in the unnecessary restrictiveness of the informing theory.

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 – and that this 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 agent-object-action relations of a biological organism. For a system that is alive must maintain itself in a constant state of self-reconstruction – this means that it must simultaneously and incessantly negotiate the ordering of both of its own internal set of intra-system relations as well as its macro-system level interactions with an externality that is constituted by a whole other set of internal relations of its own. To do this, with a third set of "mediating" relations at the interface between the two becomes necessary. 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 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.*

But again: because biosemiotics is *not* challenging in any way the absolute need for, and manifest success of, examining the material aspects of these phenomena *qua* those material (and not "material and also relational") aspects, doing lab experiments now will not "advance" the biosemiotic understanding any further. 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 DNA before there is a coherent theory of genetic inheritance in place. The results of lab experiments will always be the same for both of us in our capacities as "object-ive" observers, and thus the burden of proof, quite rightfully, is now on the biosemioticians to articulate why the biosemiotic insistence that the same phenomenon must also be explicated from the "subject-ive" 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, and 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/object knowledge synthesis in order to explain *nature's* genuine subject/object syntheses. But whether or not anyone currently working in the field of biosemiotics can actually accomplish this, of course, remains to be seen. Thus far, the majority of our effort has 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 (2001) 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 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 this project and a member of this community is welcome all our readers to this thriving young interdiscipline and, on behalf of my colleagues in biosemiotics everywhere, invite you to actively contribute to its ongoing history.

NOTES

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

[3] Augustine: *De doctrina christiana* II, 2 (1963: 34) in: *Sancti Augustini Opera*, ed. W. M. Green, CSEL 80, Vienna. Cited in Meir-Oeser (2003).

[4] Meir-Oeser Stephan, "Medieval Semiotics" *The Stanford Encyclopedia of Philosophy (Winter 2003 Edition)*, Edward N. Zalta (ed.). Available at: *http://plato.stanford.edu/archives/win2003/entries/semiotics-medieval*.

[5] A more comprehensive comparison between Aristotle's ideas and those of biosemiotics, however, is the project of another day. Interested readers are heartily encouraged to begin this investigation on their own, however, and note that the project to resuscitate a wholly non-spiritual, non-mystical, scientific notion of local *system teleology* based on Aristotle's subtle and widely-misunderstood notion of *formal causation* is one that Stanley Salthe (1993, 2006) has been pursuing for some time. (See also Jesper Hoffmeyer's notion of *semiotic causation,* this volume, as well as John Deely's penetrating discussion of Aristotelian "relation" in 2001:226–231)

[6] This wonderfully insightful phrase is from Terrence Deacon's equally insightful *The Symbolic Species* (1997:53), a highly recommended entry point into biosemiotics – for although Deacon does not identify himself as a biosemiotician *per se*, many biosemioticians draw inspiration from his work.

[7] It is germane to note here that Deely observes 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)

[8] More precisely: *x* registered simultaneously both as itself (i.e., *x* and not nothing; *x* and not *y*) and as a significate pointing to something other than itself (non-*x*, or *x* not only as *x*, but as *y*) – even if that y is "other instances of *x*", as in the iconic organization of categorical perception.

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

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

[11] Note, too, that 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 – that 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 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).

[12] 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 2001a), 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."

[13] This 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?"

[14] 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.

[15] 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. And 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 text. This is not to say, however, that the works of these researchers is 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 inter-disciplinary movement resulted from these individual efforts, I have made the purely editorial decision to refrain from any in-depth discussion of them here. 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 Sebeok (1998, 2001) and Kull (1999, 1999a, 1999b, 2005).

[16] 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 1999 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.

[17] 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 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, 2001).

[18] 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 1997:27–8). 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. (Cf. Sebeok 1998, Kristeva 1994 and Kull 1999b).

[19] 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 Systems Studies*, Volume 33.1

[20] 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 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 1999b.

[21] 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.

[22] 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: *http://members.door.net/arisbe/arisbe.htm*

[23] We pass over here, in the interest of space, 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).

[24] "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.

[25] 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.

[26] 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).

[27] 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).

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

[29] This history would not be complete without mentioning those related researchers who, while 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 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."

[30] This movement also includes biologist and philosopher of science Zdeněk Neubauer, systems theorist Ervin Laszlo, cognitive scientist Ivan Havel 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.

[31] 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).

[32] 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.

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

[34] 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.

[35] 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.

WORKS CITED

Anderson, Myrdene. (1990). "Biology and semiotics." In *Semiotics in the Individual Sciences*. W.A. Koch (ed.), 254–281. Bochum: Universitätsverlag Dr. N. Brockmeyer.

Anderson, Myrdene; Deely, John; Krampen, Martin; Ransdell, Joseph; Sebeok, Thomas A. and Thure von Uexküll (1984). "A semiotic perspective on the sciences: Steps toward a new paradigm", *Semiotica* 52–1/2, 7–47.

Aristotle. *De Anima.* (330 BC /1941) Translator: J. A. Smith. In McKeon, Richard. *The Basic Works of Aristotle,* New York, Basic Books, pp. 533–603.

Aristotle. *De Interpretatione*. (330 BC /1941) Translator: E. M. Edghill. In McKeon, Richard (1941). *The Basic Works of Aristotle,* New York, Basic Books, pp. 38–61.

Aristotle. *De Sensu et Sensibilius.* (c350 /2004). Translator: J.I. Beare. Available online as e-book at: http://etext.library.adelaide.edu.au/a/aristotle/sense/

Artmann, Stefan. (2005). "Biosemiotics as a structural science: Between the forms of life and the life of forms." *Journal of Biosemiotics 1*, pp. 229–265.

Artmann, Stefan. (*forthcoming*). "Computing codes versus interpreting life: Two alternative ways of synthesizing biological knowledge through semiotics." *Journal of Biosemiotics* (to appear).

Augustine of Hippo: (387 /1975) *De dialectica*, ed. Jan Pinborg, translation with introd. and notes by B. Darrel Jackson, Dordrecht: Reidel.

Augustine of Hippo (389 /1963): *De Doctrina Christiana*. In *Sancti Augustini Opera*, ed. W. M. Green, CSEL 80, Vienna. Cited in Meir-Oeser (2003).

Aquinas, Thomas (1252 /1965). "De Ente et Essentia (On Being and Essence)." In Bobik, Joseph (Trans.) *Aquinas on Being and Essence: A Translation and Interpretaion*. Notre Dame: Notre Dame University Press.

Bacon, Francis. (1620 /1863). *Novum Organum*. In James Spedding, Robert Leslie Ellis, and Douglas Denon Heath in Francis Bacon's *Works (Vol. VIII)* Boston: Taggard and Thompson. Available Online at: http://www.constitution.org/bacon/nov_org.htm

Baer, Eugen. (1987). "Thomas A. Sebeok's Doctrine of Signs." In Krampen, Martin (Ed). *Classics of Semiotics*. New York, Plenum Press, pp.181–210.

Barbieri, Marcello (1981). "The ribotype theory of the origin of life." *Journal of Theoretical Biology* **91**: 545–601.

Barbieri, Marcello. (1985). *The Semantic Theory of Evolution*. New York: Harwood Academic.

Barbieri, Marcello. (2002). "Has biosemiotics come of age?" *Semiotica, 139*(1/4), 283–295.

Barbieri, Marcello. (2003). *The Organic Codes: An Introduction To Semantic Biology*. Cambridge, UK.; New York: Cambridge University Press.

Barbieri Marcello. (2003a). "Biology with information and meaning." *History and Philosophy of the Life Sciences*, 25, 243–254.

Barbieri Marcello. (2005). "Life is artifact-making." *Journal of Biosemiotics 1*, 107–134.

Bardini, Thierry. (2001) *Bootstrapping: Douglas Engelbart, Coevolution, and the Origins of Personal Computing*. Stanford: Stanford University Press.

Bateson, Gregory. (1973). Steps To An Ecology Of Mind; Collected Essays In Anthropology, Psychiatry, Evolution, And Epistemology. San Francisco,: Chandler Pub. Co.

Bentele, Günter. (1984). Zeichen und Entwicklung: Vorüberlegungen zu einer genetischen Semiotik. Tübingen: G.Narr.

Bernard, Jeff (2001) *Obituary: Thomas A. Sebeok November 9, 1920 – December 21, 2001.* Available at the website for the International Association for Semiotic Studies page: http://www.uni-ak.ac.at/culture/withalm/semiotics/AIS/sem-people/sebeok/TASebeok-obit.html

Bickhard, Mark. H. (1999). "Representation In Natural and Artificial Agents." E. Taborsky (Ed.) *Semiosis. Evolution. Energy: Towards a Reconceptualization of the Sign.* (15–25). Aachen: Shaker Verlag.

Bickhard, Mark. H. (2003). "The Biological Emergence of Representation." In T. Brown, L. Smith (Ed.) *Emergence and Reduction: Proceedings of the 29th Annual Symposium of the Jean Piaget Society.* (105–131). Erlbaum.

Böll, Mette (2002). *The evolution of empathy in social systems.* Paper Presented at the International Gatherings in Biosemiotics Conference 2, the University of Tartu, Estonia. June 14–17.

Brent, Joseph. (1993).*Charles Sanders Peirce: A Life.* Bloomington: Indiana University Press.

Brier, Søren ed. (1995). "Cyber-semiotics: On autopoesis, code-duality and sign games in biosemiotics. *Cybernetics and Human Knowing 3* (1), pp. 3–14.

Brier, Søren ed. (1998). "Cyber-semiotics: A transdisciplinary framework for information studies." *Biosystems* 46, pp. 185–191.

Brier, Søren ed. (2001). "Cybersemiotics and Umweltlehre." *Semiotica 134* (1/4), pp. 779–814.

Brier, Søren ed. (2003), "Thomas Sebeok and the Biosemiotic Legacy.", Special Memorial Issue of *Cybernetics and Human Knowing* 10.1.

British Medical Journal. (2004) "Obituary: Thure von Uexküll." (October 30) 329:1047. Available at: *http://bmj.bmjjournals.com/cgi/content/full/329/7473/1047*

Brooks, Rodney. (1999). *Cambrian Intelligence: The Early History of the New AI*. Boston: MIT Press.

Bruni, Luis Emilio. (1997). "Cultura, determinismo económico y la confusión del mapa con el territorio." *Venezuela Analitica Revista Electrónica Bilingüe 13.* Available at: http://www.analitica.com/archivo/vam1997.03/lit2.htm

Bruni, Luis Emilio. (2001). "Biosemiotics and ecological monitoring." *Sign System Studies 29*(1), 293–312.

Burbano, Hernán A. (2005). *Determinism, Indeterminism and Semiotic Election.* Paper Presented at the International Gatherings in Biosemiotics Conference 5, Urbino University, Italy. July 20–24.

Campbell, Donald T. (1974). "Evolutionary Epistemology." In P. A. Schilpp (Ed.) *The Philosophy of Karl R. Popper*, LaSalle, IL: Open Court. pp. 412–463.

Cariani, Peter (2001). "Symbols and dynamics in the brain." *Biosystems*. Vol 60, pp. 59–83.

Chalmers, David (1995). "Facing Up to the Problem of Consciousness" *Journal of Consciousness Studies* 2(3):200–19.

Chang, Han-liang. (2002). *Is Language a Primary Modeling System?–On Juri Lotman's Semiosphere*. Paper presented at the International Conference on *Cultural Semiotics: Cultural Mechanisms, Boundaries, Identities* University of Tartu, Estonia, February 26 – March 2, 2002.

Chang, Han-liang. (2005) "Biosemiotics: Nature in Culture or Culture in Nature?" *Chung Wai Literary Monthly* 34 (7).

Chebanov, Sergei V. (1994). "Man as participant to natural creation: Enlogue and ideas of hermeneutics in biology." *Rivista di Biologia 87*(1), 39–55.

Chekhov, Anton. (1904). *Teatr I iskusstvo*. No. 28, 11 July, p. 521.

Chien, Juipi Angelina (2003): *Diagramming as a Convergence of C. S. Peirce, Jakob von Uexküll, and E. Gombrich.* Paper Presented at the International Gatherings in Biosemiotics Conference 3, University of Copenhagen, Denmark. July 11–14.

Christiansen Peder Voetmann (2000) Macro and Micro-Levels in Physics In *Downward Causation: Minds, Bodies and Matter.* Peter Bøgh Andersen, Claus Emmeche, Niels Ole Finnemann and Peder Voetmann Christiansen (Eds). Århus: Aarhus University Press. pp. 51–62.

Churchland, Paul. (1984) "Eliminative Materialism" in *Matter and Consciousness.* Cambridge, Mass: MIT Press. pp. 43–49.

Churchland, Patricia. S. (1986). *Neurophilosophy: Toward A Unified Science Of The Mind-Brain*. Cambridge, Mass.: MIT Press.

Churchland, Patricia. S. (2002). *Brain-Wise: Studies In Neurophilosophy*. Cambridge, Mass.: MIT Press.

Clark, Andy. (1997). *Being There: Putting Brain, Body, And World Together Again*. Cambridge, Mass.: MIT Press.

Colapietro, Vincent. (1989). *Peirce's Approach to the Self: A Semiotic Perspective on Human Subjectivity State*. Univ of New York Press.

Colapietro, Vincent and Thomas Olshewsky. (1996). (Eds.) *Peirce's Doctrine of Signs*. Berlin: Mouton de Gruyter.

Collier, John (1999) "The Dynamical Basis of Information and the Origins of Semiosis.", in Edwina Taborsky (ed) *Semiosis. Evolution. Energy Towards a Reconceptualization of the Sign*. Aachen: Shaker Verlag:111–136

Crick, Francis. (1958). "On Protein Synthesis." *Symposium for Experimental Biology XII,* pp. 139–163.

Crick, Francis. (1988). *What Mad Pursuit: A Personal View of Scientific Discovery*, New York, New York: Basic Books.

Csikszentmihalyi, Mihaly. (1977). *Creativity: Flow and the Psychology of Discovery and Invention.* New York: HarperCollins.

Cvrčková, Fatima (2002). "The Darwinian purpose enters the post-genomic era: A case study." In Havel, Ivan and Markoš, Anton (Eds.) *Is There a Purpose in Nature? How to Navigate Between the Scylla of Mechanism and the Charybdis of Teleology*. Czech Republic: Vesmir. pp. 175–184.

Cvrčková, Fatima and Markoš, Anton. (2005). "Beyond bioinformatics: Can similarity be measured in the digital world?" *Journal of Biosemiotics 1*, pp. 87–105.

Damasio, Antionio. (1994). *Descartes' Error: Emotion, Reason, And The Human Brain*. New York: Putnam.

Danesi, Marcel. (1998). (Ed.) *The Body in the Sign: Thomas A. Sebeok and Semiotics.* Ottawa: Legas.

Danesi, Marcel. (2002). "Thomas A. Sebeok (1920–2001) Remembered." *SIGN Journal*, Vol 3.1, Available at: http://vicu.utoronto.ca/courses/semiotics/SIGN_Danesi_TAS.htm

Danesi, Marcel. (2000). "The biosemiotic paradigm of Thomas A. Sebeok." In Tarasti, E. *Commentationes in Honorem Thomas A. Sebeok Octogenarii.* Imatra:ISI. pp. 5–29.

Deacon, Terrence. W. (1997). *The Symbolic Species: The Co-Evolution Of Language And The Brain*. New York: W.W. Norton.

Deacon, Terrence. W. (2003). "The heirarchic logic of emergence: Untangling the interdependence of evolution and self-organization." In B. H. W. a. D. J. Depew (Ed.), *Evolution and Learning: The Baldwin Effect Reconsidered* (pp. 273–308). Cambridge, Mass.: MIT Press.

Deely, John. (1990). *Basics of Semiotics*. Bloomington: Indiana University Press.

Deely, John. (1995). *Thomas A. Sebeok: Bibliography 1942–1995*. Bloomington: Eurolingua.

Deely, John. (2001). *Four Ages Of Understanding: The First Postmodern Survey Of Philosophy From Ancient Times To The Turn Of The Twenty-First Century*. Toronto: University of Toronto Press.

Deely, John. (2004) "Thomas Albert Sebeok, "Biologist Manqué.", *International Association for Semiotic Studies 2004 World Congress, Lyon*. (Sebeok Memorial Essay) available at: http://carbon.cudenver.edu/~mryder/itc/sebeok.html

Deely, John N., Williams, B. and Kruse, F.E. (eds.) (1986). *Frontiers in Semiotics*. Bloomington: Indiana University Press.

Deledalle, Gérard. (2000) *Charles S. Peirce's Philosophy of Signs.* Bloomington: Indiana University Press.

Denizhan, Yağmur and Karatay, Vefa. (2002). Evolution of the "window." *Sign System Studies 30*(1), pp.259–270.

Depew, David. (1996). *Darwinism Evolving: Systems Dynamics and the Genealogy of Natural Selection.* Boston: MIT Press.

Descartes, René. (1637 /1973). "Discourse on the Method of Rightly Conducting the Reason." In *The Philosophical Works of Descartes*, translated by E. Haldane and G. Ross, Cambridge: Cambridge University Press, pp. 79–130.

Descartes, René. (1641 /1973). "Meditations on First Philosophy." In *The Philosophical Works of Descartes*, translated by E. Haldane and G. Ross, Cambridge: Cambridge University Press. pp. 131–200.

Dimitrov, Assen I. (2004). *Intelligence: Not Seeking Algorithm, But Meaning*. Faber: Bulgarian Academy of Sciences.

Donald, Merlin. (1991). Origin of the Modern Mind: *Three Stages in the Evolution of Culture and Cognition.* Cambridge: Harvard University Press.

Edelman, Gerald. (1992). *Bright Air, Brilliant Fire: On The Matter Of The Mind.* New York, N.Y.: BasicBooks.

Edelman, Gerald & Tononi, Guilio. (2000). *A Universe Of Consciousness: How Matter Becomes Imagination*. New York, NY: Basic Books.

Elsasser, Walter M. (1998). *Reflections on a Theory of Organisms*. Baltimore: The Johns Hopkins University Press.

Emmeche, Claus. (1991). "A Semiotical Reflection on Biology, Living Signs and Artificial Life." *Biology & Philosophy, 6*(3), 325–340.

Emmeche, Claus. (1994). *The Garden In The Machine: The Emerging Science Of Artificial Life*. Princeton, N.J.: Princeton University Press.

Emmeche, Claus. (1998). "Defining life as a semiotic phenomenon." *Cybernetics & Human Knowing, 5*(1), 3–17.

Emmeche, C. (1999). The biosemiotics of emergent properties in a pluralist ontology. In E. Taborsky (Ed.), *Semiosis, Evolution, Energy: Towards a Reconceptualization of the Sign*. Aachen: Shaker Verlag, pp. 89–108.

Emmeche, Claus. (2000a). "Closure, Semiosis, Autopoiesis, and Autocatalysis – Closure, Function, Emergence, Semiosis, and Life: The Same Idea? Reflections on the Concrete and the Abstract in

Theoretical Biology." *Annals of the New York Academy of Sciences, 901*, 11.
Emmeche, Claus. (2000b). "Transdisciplinarity, theory-zapping and the growth of knowledge." *Semiotica, 131*(3/4), 217–228.
Emmeche, Claus. (2001). "Does a robot have an Umwelt? Reflections on the qualitative biosemiotics of Jakob von Uexküll." *Semiotica* 134 (1/4): 653–693.
Emmeche, Claus. (2002). "Taking the semiotic turn, or how significant philosophy of biology should be done." *Sats, The Nordic Journal of Philosophy, 3*(1), 155–162.
Emmeche, Claus and Hoffmeyer, Jesper (1991). "From language to nature: the semiotic metaphor in biology." *Semiotica* 84(1/2), 1–42.
Emmeche, Claus; Kull, Kalevi and Stjernfelt, Frederik (2002). *Reading Hoffmeyer, Rethinking Biology.* Tartu: Tartu University Press.
Faria, Marcella (2005). *RNAs as code makers: A biosemiotic view of RNAi and cell immunity.* Paper Presented at the International Gatherings in Biosemiotics Conference 5, Urbino University, Italy. July 20–24.
Farina, Almo (2004): *Eco-field versus habitat: Shifting a paradigm in developing a cognitive ecology.* Paper Presented at the International Gatherings in Biosemiotics Conference 4, Charles University, Prague. June 1–5.
Favareau, Donald (2001). Beyond self and other: The neurosemiotic emergence of intersubjectivity. *Sign Systems Studies,* 30 (1), pp. 57–101.
Favareau, Donald (2001a). "Phenomenal Epiphenomena: Deconstructing the Fallacy Fallacy." Invited seminar presentation, *First International Gatherings in Biosemiotics*, University of Copenhagen, Denmark. May 24–27.
Favareau, Donald. (2002). Constructing representema: On the neurosemiotics of self and vision. *Semiotics, Evolution, Energy and Development Journal* 2 (4), 1–39.
Florkin, Marcel (1974). "Concepts of molecular biosemiotics and of molecular evolution." In *Comprehensive Biochemistry* 29A, 1–124.
Freeman, Walter. J. (2000). *Neurodynamics: An exploration in Mesoscopic Brain Dynamics*. London; New York: Springer.
Fürlinger, Anton. (1998). "Locomotion and Cognition: From fish to hominids." *Proceedings of the 26th Goettingen Neurobiology Conf. 1998* Vol 1
Fuster, Joaquin. M. (2003). *Cortex And Mind: Unifying Cognition*. Oxford; New York: Oxford University Press.
Griffith, Paul.E. (2001). "Genetic Information: A Metaphor in Search of a Theory." *Philosophy of Science*, 68, 394–412.
Hajnal, László (2003): *A new model for biology?* Paper Presented at the International Gatherings in Biosemiotics Conference 3, the University of Copenhagen, Denmark. July 11–14.
Harries-Jones, Peter. (1995). *A Recursive Vision: Ecological Understanding and Gregory Bateson*. Toronto: University of Toronto Press.
Havel, Ivan and Markoš, Anton (2002). *Is There a Purpose in Nature? How to Navigate between the Scylla of Mechanism and the Charybdis of Teleology* Czech Republic: Vesmir.
Hoffmeyer, Jesper. (1984). *Naturen I Hovedet. Om Biologisk Videnskab*. København: Rosinante.
Hoffmeyer, Jesper. (1988). Bioinformation techniques and the view of nature. In Thill, G., and Kemp, P. (eds). *The Triumph of Biotechnologies: The Domestication of the human Animal.* Namur: Presse Universitaires de Namur. pp. 107–115.
Hoffmeyer, Jesper. (1992). "Some semiotic aspects of the psycho-physical relation: The endo-exosemiotic boundary." In T. S. a. J. U. Sebeok (Ed.), *Biosemiotics: The Semiotic Web* (pp. 101–124). Berlin: Mouton de Gruyter.
Hoffmeyer, Jesper. (1996). *Signs Of Meaning In The Universe*. Bloomington: Indiana University Press.
Hoffmeyer, Jesper. (1998). "Semiosis and Biohistory: A Reply." In *Semiotics in the Biosphere: Reviews and Rejoinder.* Special issue of *Semiotica* Vol. 120. no. 3/4, pp. 455–482, 1998.
Hoffmeyer, Jesper. (2000a). "The Biology of Signification." *Perspectives in Biology and Medicine, 43*(2), 252–268.
Hoffmeyer, Jesper. (2000b). "Life and reference." *Bio systems, 60*(1), 8.

Hoffmeyer, Jesper. (2001). "Seeing virtuality in nature." *Semiotica, 134*(1–4), 18.
Hoffmeyer, Jesper. (2002). "Code Duality Revisted." *Semiotics, Evolution, Energy and Devlopment Journal* Vol 2 (1), pp. 98–117
Hoffmeyer, Jesper and Emmeche, Claus (1991). "Code-duality and the semiotics of nature." *On Semiotic Modeling*, Myrdene Anderson and Floyd Merrell (eds.), 117–166. Berlin, Mouton de Gruyter.
Hofkirchner, Wolfgang (2002) "The Status of Biosemiotics." *Semiosis, Energy, Evolution And Development Journal* 3, pp. 4–15
Hofstadter, Douglas. (1979). *Gödel, Escher, Bach: An Eternal Golden Braid.* Middlesex: Penguin.
Huber, Johannes and Schmid-Tannwald, Ingolf. (2005). *Epigenetic mechanisms following mammalian fertilization reveal basic principles of constructivist epistemology.* Paper Presented at the International Gatherings in Biosemiotics Conference 5, Urbino University, Italy. July 20–24.
Igamberdiev, Abir. (1999). "Foundations of metabolic organization: Coherence as a basis of computational properties in metabolic networks." *BioSystems* 50(1): 1–6.
Jämsä, Tuomo (2005). *Language and Nature.* Magisterial Lecture Presented at the International Gatherings in Biosemiotics Conference 5, Urbino University, Italy. July 20–24.
Ji, Sungchul (2002). "Microsemiotics of DNA." *Semiotica* 138 (1/4):15-42.
Kandel, Eric; Schwartz, James and Jessell, Thomas. (2002). Principles of Neural Science. New York: McGraw-Hill.
Karatay, Vefa and Denizhan, Yağmur. (1999). "The non-decreasing character of complexity: A biological approach." *Proceedings of the Third International Conference on Computing Anticipatory Systems.* Volume 5. Liège: Belgium.
Kauffman, Stuart. (1995). *At Home In The Universe: The Search For Laws Of Self-Organization And Complexity*. New York: Oxford University Press.
Kauffman, Stuart. (2000). *Investigations*. Oxford; New York: Oxford University Press.
Kilstrup, Mogens. (1997). "Biokemi og semiotik: Molekylær biosemiotik." In: *Anvendt Semiotik*, pp. 97–123.
Kleisner, Karel (2004): *GENES – MEMES – SEMES. Towards the new concept of mimicry.* Paper Presented at the International Gatherings in Biosemiotics Conference 4, Charles University, Prague. June 1–5.
Kotov, Kaie. (2002)."Semiosphere: A chemistry of being." *Sign Systems Studies,* 30 (1), pp. 41–56.
Krampen, Martin (1981). "Phytosemiotics." *Semiotica*, 36.3/4, 187–209; reprinted Deely, Williams and Kruse. 96–103.
Kristeva, Julia. (1994). "On Juri Lotman." *Publications of the Modern Language Association 109* (3), pp. 375–376.
Kull, Kalevi. (1998). "Organism as a self-reading text: anticipation and semiosis." *International Journal of Computing Anticipatory Systems* 1, 93–104.
Kull, K. 1998. "On semiosis, Umwelt, and semiosphere." *Semiotica* 120(3/4), 299–310.
Kull, Kalevi (1999). "Biosemiotics in the twentieth century: a view from biology." *Semiotica* 127(1/4), 385–414.
Kull, Kalevi (1999a). "On the history of joining bio with semio: F.S.Rothschild and the biosemiotic rules." *Sign Systems Studies* 27, 128–138.
Kull, Kalevi (1999b). "Towards biosemiotics with Yuri Lotman." *Semiotica* 127(1/4): 115–131.
Kull, Kalevi (1999c). "A Teleology of the Estonian Research Tradition" talk given for the Baltic and Finnish Studies Association at Indiana University, November 9, 1999. Summary here: http://www.iub.edu/~bafsa/articles.html
Kull, Kalevi. (2000a). "An introduction to phytosemiotics: Semiotic botany and vegetative sign systems." *Sign Systems Studies, 28*, 326–350.
Kull, Kalevi. (2000b). "Organisms can be proud to have been their own designers." *Cybernetics & Human Knowing, 7*(1), 45–55.
Kull, Kalevi. (2000c). "Part V Closure, Information, and Thermodynamics – Active Motion, Communicative Aggregations, and the Spatial Closure of Umwelt." *Annals of the New York Academy of Sciences, 901*, 8.
Kull, Kalevi. (2001). "Jakob von Uexküll: An introduction." *Semiotica* 134(1/4): 1–59.

Kull, Kalevi. (2001). "Living forms are communicative structures, based on the organic codes." *Cybernetics and Human Knowing* 8(3): 91–94.

Kull, Kalevi (2003). "Thomas A. Sebeok and biology: Building biosemiotics." *Cybernetics and Human Knowing* 10(1): 47–60.

Kull, Kalevi. (2005). "A brief history of biosemiotics." *Journal of Biosemiotics* Vol 1 pp. 1–34.

Küppers, Bernd-Olaf. (2000). Information and the Origin of Life. Cambridge: MIT Press.

Lagerspetz, Kari. (2001): Jacob von Uexkull and the origins of cybernetics. *Semiotica 134* (1–4): 643–651.

Latour, Bruno. (1987). *Science in Action: How to Follow Scientists and Engineers through Society.*. Harvard University Press. Cambridge. Mass.

Latour, Bruno. (1999). *Pandora's Hope: Essays on the Reality of Science Studies*. Harvard University Press. Cambridge. Mass.

Lestel, Dominique. (2002). "Human/animal communications, language and evolution." *Sign Systems Studies, 30*(1), 201–212.

Lewontin, Richard. (1992). "The Dream of the Human Genome." *New York Review of Books,* May 28, pp. 31–40.

Llinás, Rodolfo. R. (2001). *I Of The Vortex: From Neurons To Self* (1st ed.). Cambridge, Mass.: MIT Press.

Lotman, Juri. (1984 /2005). "On the Semiosphere." *Sign Systems Studies, 33*(1), 215–239.

Lorenz, Edward. (1963). "Deterministic nonperiodic flow." *Journal of Atmospheric Sciences*. Vol.20 : 130–141.

Luure, Andreas. (2002). "Understanding life: Trans-semiotic analogies." *Sign Systems Studies,* 30 (1), pp. 315–326.

MacIntyre, Alisdair C. (1974 /1980). "Epistemological crises, dramatic narrative, and the philosophy of science." In G. Gutting (Ed.), *Paradigms and Revolutions: Appraisals and Applications of Thomas Kuhn's Philosophy of Science.* (pp. 54–74). Notre Dame: University of Notre Dame.

Maran, Timo (2003). "Mimesis as a phenomenon of semiotic communication." *Sign Systems Studies* 31.1, pp. 191–215.

Margulis, Lynn, & Sagan, D. (1987). *Microcosmos: Four Billion Years Of Evolution From Our Microbial Ancestors*. Boston: Allen &Unwin.

Markoš, Anton. (2002a). "Evolution, purpose, teleology." In Havel, Ivan and Markoš, Anton (Eds.) *Is There a Purpose in Nature? How to Navigate Between the Scylla of Mechanism and the Charybdis of Teleology*. Czech Republic: Vesmir. pp. 113–128.

Markoš, Anton. (2002b). "Purpose and biology." In Havel, Ivan and Markoš, Anton (Eds.) *Is There a Purpose in Nature? How to Navigate Between the Scylla of Mechanism and the Charybdis of Teleology*. Czech Republic: Vesmir. pp. 42–64.

Markoš, Anton. (2002c). *Readers Of The Book Of Life: Contextualizing Developmental Evolutionary Biology*. Oxford; New York: Oxford University Press.

Martinelli, Dario (2005). "A whale of a sonata – Zoomusicology and the question of musical structures." *Semiosis, Energy, Evolution And Development Journal* 2005 (1), p. 2–29.

Matsuno, Kochiro & Swenson, R. (1999). "Thermodynamics in the Present Progressive Mode and its Role in the Context of the Origin of Life" *BioSystems* 51, 53–61.

Maturana, Humberto & Varela, Francisco ([1st edition 1973] 1980). "Autopoiesis and Cognition: the Realization of the Living." Robert S. Cohen and Marx W. Wartofsky (Eds.), *Boston Studies in the Philosophy of Science* 42. Dordecht: D. Reidel Publishing Co.

McCord Adams, Marilyn. (1987). *William Ockham*. Notre Dame: Notre Dame Press.

McGinn, Colin. (1999). *The Mysterious Flame: Conscious Minds in a Material World.* New York: Basic Books.

Meier-Oeser, Stephan (2003), "Medieval Semiotics.", *The Stanford Encyclopedia of Philosophy (Winter 2003 Edition)*, Edward N. Zalta (ed.). Available at: http://plato.stanford.edu/archives /win2003/entries/semiotics-medieval.

Merrell, Floyd (1996). *Signs Grow: Semiosis and Life Processes*. Toronto: University of Toronto Press.

Miller, Stephen A. and John P. Harley. (1994) *Zoology.* 2nd Ed. Dubuque, Iowa: Wm. C. Brown Publishers.

Minsky, Marvin. (1988). *Society of Mind.* New York: Simon and Schuster.

Nakajima, Toshiyuki (2005). *Managing uncertainty of events by semiosis in living systems.* Paper Presented at the International Gatherings in Biosemiotics Conference 5, Urbino University, Italy. July 20–24.

Ockham, William. (1323 /1991). *Quodlibetal Questions,* Alfred J. Freddoso and Francis.

E. Kelley, trans., 2 vols., *Yale Library of Medieval Philosophy*, New Haven: Yale University Press, 1991.

Neuman, Yair (2003) *Processes and Boundaries of the Mind: Extending the Limit Line.* New York: Kulwer Academic.

Oyama, Susan (1985). The Ontogeny of Information: Developmental Systems and Evolution. Cambridge: Cambridge University Press.

Pain, Stephen (2002) - *Introduction to biorhetorics: applied rhetoric in the life sciences.* Paper Presented at the International Gatherings in Biosemiotics Conference 2, the University of Tartu, Estonia. June 14–17.

Parmentier, R. J. (1994). *Signs In Society: Studies In Semiotic Anthropology*. Bloomington: Indiana University Press.

Pattee, Howard. (1965). Experimental Approaches to the Origin of Life Problem. In F.F. Nord (ed.) *Advances in Enzymology, Vol. 27.* New York: Wiley. pp. 381–415.

Pattee, Howard (1969). "The physical basis of coding and reliability in biological evolution." in *Towards a Theoretical Biology* 1, C. H. Waddington, ed. Edinburgh Univ. Press, pp. 67–93.

Pattee, Howard (1972). "Laws and constraints, symbols and languages." in *Towards a Theoretical Biology* 4, C. H. Waddington, ed., Edinburgh Univ. Press, pp. 248–258.

Pattee, Howard. (1977). "Dynamic and Linguistic Modes of Complex Systems." *International Journal for General Systems.* 3: 259–266.

Pattee, Howard. (1982). "The need for complementarity in models of cognitive behavior." In W. Weimer and D. Palermo (Eds.), *Cognition and the symbolic process*, Vol 2 (pp. 21–34). Hillsdale, NJ: Erlbaum.

Pattee, Howard. (1982a). "Cell psychology: An evolutionary approach to the symbol-matter problem." *Cognition and Brain Theory* 5(4), 325–341.

Pattee, Howard. (1988). "Simulations, realizations, and theories of life." In C. Langton (Ed.), *Artificial Life* (pp. 63–77). *Santa Fe Institute Studies in the Sciences of Complexity*. Reading, MA: Addison-Wesley.

Pattee, Howard (2001). "The Physics of Symbols: Bridging the Epistemic Cut." in *BioSystems* 60, 5–21.

Pattee, Howard (2005). "The physics and metaphysics of biosemiotics." *Journal of Biosemiotics 1*, 281–301.

Peirce, Charles. S. (1931–1935). *Collected papers of Charles Sanders Peirce* (Vol. 1–6). Cambridge, MA: Harvard University Press.

Peirce, Charles. S. (1958). *Collected papers of Charles Sanders Peirce* (Vol. 7–8). Cambridge, MA: Harvard University Press.

Petrilli, Susan, and Ponzio, Augusto (2001). *Thomas Sebeok and the Signs of Life*. Great Britain: Icon Books.

Ponzio, Augusto. (1990). *Man as a Sign: Essays on the Philosophy of Language.* Berlin: Mouton de Gruyter.

Poinsot, John (1632 /1985). *Tractatus de Signis.* With English translation by John Deely. Berkeley: University of California Press.

Prigogine, Ilya. (1969), *Structure, Dissipation and Life. Theoretical Physics and Biology*, Versailles, 1967. North-Holland Publ. Company, Amsterdam.

Prigogine, Ilya, & Stengers, I. (1984). *Order Out Of Chaos: Man's New Dialogue With Nature*. Toronto; New York, N.Y.: Bantam Books.

Queiroz, João, Emmeche, Claus and El-Hani, Charbel Niño (2005). "Information and Semiosis in Living Systems: A Semiotic Approach." *Semiosis, Energy, Evolution And Development Journal* (1), p. 60–90.

Reybrouck, Mark (2005). *The musical code between nature and nurture: Biosemiotic and ecological claims.* Paper Presented at the International Gatherings in Biosemiotics Conference 5, Urbino University, Italy. July 20–24.

Ribeiro, Sidarta, Queiroz, João, and Ivan de Araújo (2003): *The emergence of referential symbolic process in non-human primates communication: A zoosemiotic analysis based on the Peircean extended theory of sign*. Paper Presented at the International Gatherings in Biosemiotics Conference 3, the University of Copenhagen, Denmark. July 11–14.

Robert E. Ulanowicz (1986) *Growth and Development: Ecosystems Phenomenology*. San Jose, CA: Excel Press.

Rocha, Luis M. (2001). "Evolution with Material Symbol Systems." *Biosystems*. Vol. 60, pp. 95–121. LAUR 00–1604.

Roepstorff, Andreas. (2004) "Cellular Neurosemiotics: Outline of an interpretive framework." In Joachim Schult (ed.) *Studien zur Theorie der Biologie*, Vol. 6: *Biosemiotik - Praktische Anwendung und Konsequenzen für die Einzeldisziplinen*. VWB - Verlag für Wissenschaft und Bildung. Berlin.

Rosen, Robert (1991). *Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life*. New York: Columbia University Press.

Rothschild, Friedrich S. (1962). "Laws of symbolic mediation in the dynamics of self and personality." *Annals of New York Academy of Sciences* 96: 774–784.

Rüting, Torsten. (2004) *Jakob von Uexküll: Theoretical Biology, Biocybernetics and Biosemiotics*. Available at: www.math.uni-hamburg.de/home/rueting/UexECMTB.doc.

Rüting, Torsten (2003): *Uexküll's "Institut für Umweltforschung" - Biosemiotics in action?* Paper Presented at the International Gatherings in Biosemiotics Conference 3, the University of Copenhagen, Denmark. July 11–14.

Salthe, Stanley N. (1993). *Development and Evolution: Complexity and Change in Biology*. Cambridge (Mass.): The MIT Press.

Salthe, Stanley N. (2006). "Purpose in Nature." Available online at: http://www.nbi.dk/~natphil/salthe/Purpose_In_Nature.pdf.

Savan, David (1976). *Peirce's Semiotic*. Toronto: Victoria College.

Sebeok, Thomas A. (1963). "Communication among social bees; porpoises and sonar; man and dolphin." *Language* 39: 448–466.

Sebeok, Thomas A. (1969). "Semiotics and ethology." In: *Approaches to Animal Communication*, Thomas A. Sebeok and Alexandra Ramsay (eds.), 200–231. The Hague: Mouton.

Sebeok, Thomas A (1976). *Contributions to the Doctrine of Signs*. Lisse, Netherlands: The Peter de Ridder Press.

Sebeok, Thomas A. (1977). "Ecumenicalism in semiotics." In *A Perfusion of Signs*, Thomas A. Sebeok (ed.), 180–206. Bloomington: Indiana University Press.

Sebeok, Thomas A., ed., (1977). *How Animals Communicate* (Bloomington, IN: Indiana University Press).

Sebeok, Thomas A. (1977). "Neglected figures in the history of semiotic inquiry: Jakob von Uexkull." In *The Sign and Its Masters* (pp. 187–207). Lanham, MD: University Press of America.

Sebeok, T. A. (1980). *Speaking of Apes: A Critical Anthology of Two-Way Communication with Man*. New York: Plenum Press.

Sebeok, Thomas. A. (1986). *Encyclopedic Dictionary Of Semiotics*. Berlin; New York: Mouton de Gruyter.

Sebeok, Thomas A. (1986). *I Think I Am A Verb: More Contributions To The Doctrine Of Signs*. New York: Plenum Press.

Sebeok, T. A. (1988). 'Animal' in biological and semiotic perspective. In T. Ingold (Ed.), *What is an Animal?* (pp. 63–76). London: Unwin Hyman.

Sebeok, Thomas A. (1990) *Essays in Zoosemiotics*. Toronto: Toronto Semiotic Circle.

Sebeok, Thomas A. (1990a). "Sign science and life science." In J. Deely (Ed.), *Semiotics 1990* (pp. 243 – 252). Lanham, MD: University Press of America.

Sebeok, Thomas A. (1995). Into the rose-garden. In J. Deely (Ed.) *Thomas A. Sebeok: Bibliography 1942–1995* (pp.116–125). Bloomington: Eurolingua.

Sebeok, Thomas A. (1998). "The Estonian connection." *Sign Systems Studies* 26, 20–41.
Sebeok, Thomas A. (1999). "Biosemiotica I." ed. with "Biosemiotica II." guest-ed. Jesper Hoffmeyer and Claus Emmeche, Special Issue *Semiotica* 127-1/4.
Sebeok, Thomas A. (2001). "Biosemiotics: Its roots, proliferation, and prospects." *Semiotica, 134*(1), 18.
Sebeok, Thomas A. (2001a) *The Swiss Pioneer: In Nonverbal Communication Studies, Heini Hediger (1908–1992)*. Ottawa: Legas Press.
Sebeok, Thomas A. and Umiker-Sebeok, Jean, (1980). *Speaking of Apes: A Critical Anthology of Two-Way Communication with Man*. New York: Plenum.
Sebeok, Thomas A. and Rosenthal, Robert, eds., (1981). *The Clever Hans Phenomenon: Communication with Horses, Whales, Apes, and People*. New York: The New York Academy of Sciences.
Sebeok, Thomas A and Umiker-Sebeok, Jan. (eds.) (1992). *Biosemiotics: The Semiotic Web 1991.* Berlin: Mouton de Gruyter.
Sercarz, Eli E., Celada, Franco, Mitchison, N. Avrion and Tada, Tomio (eds.) (1988). *The Semiotics of Cellular Communication in the Immune System*. Berlin: Springer.
Shannon, Claude and Weaver, Warren. (1949): *The Mathematical Theory of Communication*. Urbana: University of Illinois Press.
Sharkey, Amanda J.C. (1999) *Combining Artificial Neural Nets: Ensemble and Modular Multi-Net Systems*. Springer-Verlag.
Sharkey, Noel. E. (2002), "Biologically Inspired Robotics." In M.Arbib (Ed), *Handbook of Brain Theory and Neural Networks*, Cambridge: MIT press.
Sharov, Aleksei. (1992). "Biosemiotics: A functional-evolutionary approach to the analysis of the sense of information." In *Biosemiotics: The Semiotic Web 1991*, T.A.Sebeok and J.Umiker-Sebeok (eds.), 345–373. Berlin: Mouton de Gruyter.
Sharov, Aleksei. (2002). "Pragmatics and biosemiotics." *Sign System Studies 30* (1), pp. 245–258.
Skibinski, Adam. (2004). "Metalogy: A Commentary on Mind, Recursion and Topological Inference." *Semiosis, Energy, Evolution And Development Journal* 2004 (1), p. 70–90:
SLIS Press News (2002) *Thomas A. Sebeok, Senior Fellow at SLIS, Passes On.* School of Library and Information Science News, Indiana University. Available at: http://www.slis.indiana.edu/news/story.php?story_id=364.
Sonea, Sorin (1992). "Half of the living world was unable to communicate for about one billion years." In: *Biosemiotics: The Semiotic Web 1991*, T.A. Sebeok and J. Umiker-Sebeok (eds.), 375–392. Berlin: Mouton de Gruyter.
Spade, Paul Vincent, (1994). *Five Texts on the Mediaeval Problem of Universals: Porphyry, Boethius, Abelard, Duns Scotus, Ockham*. Indianapolis, Ind.: Hackett. Includes a complete translation of Ockham's discussion of universals from *Sent*. I.2.4–8.
Steckner, Cornelius (2004): *Environmental misfit in vision and grasp.* Paper Presented at the International Gatherings in Biosemiotics Conference 4, Charles University, Prague. June 1–5.
Stepanov, Yuri S. (1971). *Semiotika*. Moscow: Nauka.
Stjernfelt, Frederik (1992). "Categorical perception as a general prerequisite to the formation of signs." In: *Biosemiotics: The Semiotic Web 1991*, T.A. Sebeok and J. Umiker-Sebeok (eds.), 427–454. Berlin: Mouton de Gruyter.
Stjernfelt, Frederik. (2000). "Mereology and semiotics." *Sign Systems Studies, 28*, 73–98.
Stjernfelt, Frederik. (2002). "Recollections." In Emmeche, Claus; Kull, Kalevi and Stjernfelt, Frederik (eds). *Reading Hoffmeyer, Rethinking Biology.* Tartu: Tartu University Press. pp. 57–60.
Taborsky, Edwina. (1998). *Architectonics Of Semiosis* (1st ed.). New York: St. Martin's Press.
Taborsky, Edwina. (2001a). *The internal and the external semiosic properties of reality*, from http://www.library.utoronto.ca/see/SEED/Vol1-1/Taborsky-Journal1.html.
Taborsky, Edwina. (2001b). "What is a sign?" *Journal of Literary Semantics, 30*(2), 12.
Thom, Rene (1989) *Structural Stability and Morphogenesis an Outline of a General Theory of Models*. Boulder, Co.: Westview Press.
Thompson, D'Arcy Wentworth (1917). *On Growth and Form*. Cambridge: University Press.
Thorndike, Edward. L. (1898). "Animal Intelligence: An Experimental Study of the Associative Processes in Animals." *Psychological Review, Monograph Supplements*, No. 8. New York: Macmillan.

Tochon, François V. (2000). "Review of The Swiss Pioneer in Nonverbal Communication Studies: Heini Hediger (1908–1992) by Thomas A. Sebeok." *International Journal of Applied Semiotics*, Volume 3, Number 1, pp. 137–143.

Trolle Borup, Mia (*nee* Krause, Mia) (2005) *Genotype-phenotype relations. On the modeling of biological phenomena in genetics and molecular biology.* Doctoral Dissertation, Niels Bohr Institute, University of Copenhagen.

Turovski, Aleksei. (2000). "The semiotics of animal freedom." *Sign Systems Studies, 28*, 380–387.

Umerez, Jon (2001). "Howard Pattee's theoretical biology: a radical epistemological stance to approach life, evolution and complexity" *Biosystems*. Vol 60, pp. 159–177.

Varela, Francisco J.; Maturana, Humberto R.; & Uribe, R. (1974). "Autopoiesis: the organization of living systems, its characterization and a model." *Biosystems* 5 187–196.

Vehkavaara, Tommi. (2002). "Why and how to naturalize semiotic concepts for biosemiotics." *Sign Systems Studies 30* (1), pp. 293–313.

Vehkavaara, Tommi. (2003). "Natural self-interest, interactive representation, and the emergence of objects and *Umwelt*: An outline of basic semiotic concepts for biosemiotics." *Sign Systems Studies 31* (2), pp. 547–587.

Vehkavaara, Tommi. (forthcoming). "Limitations on applying Peircean semeiotic." *Journal of Biosemiotics.* (to appear).

Villa, Alessandro E.P. (2005). *The Neuro-Heuristic paradigm.* Paper Presented at the International Gatherings in Biosemiotics Conference 5, Urbino University, Italy. July 20–24.

Von Foerster, Heinz (1982) *Observing Systems.* Intersystems Publications.

von Glasersfeld, Ernst (1987) *Construction of Knowledge.* Intersystems Publications.

von Uexküll, Jakob. (1905). *Leitfaden in das Studium der Experimentellen Biologie der Wassertiere.* Weisbaden: J.F. Bergmann Verlag.

von Uexküll, Jakob. (1909). *Umwelt und Innenwelt der Tiere.* Berlin: Julius Springer Verlag.

von Uexküll, Jakob. (1926). *Theoretical Biology.* Trans. By D.L. Mackinnon. London: Kegan Paul.

von Uexküll, Jakob. (1928). *Theoretische Biologie (Second Edition.)* Berlin: Julius Springer Verlag.

von Uexküll, Jakob. (1934 /1992). "A stroll through the worlds of animals and men: A picture book of invisible worlds." In *Semiotica* 89(4), 319–391.

von Uexküll, Jakob. (1940 /1982). "The theory of meaning." *Semiotica, 42*(1), 25–87.

von Uexküll, Thure. (1986). Medicine and Semiotics. *Semiotica* 61:201–217.

Waddington, Conrad Hal, 1905–1975, ed. *Towards a theoretical biology. An IUBS Symposium.* Chicago: Aldine Pub. Co. 1968–1972.

Weber, Andreas. (2001). "Cognition as expression: The autopoetic foundations of an aesthetic theory of nature." *Sign Systems Studies, 29*(1), 153–168.

Weber, Bruce & Deacon, Terrence. (2000). "Thermodynamic cycles, developmental systems, and emergence." *Cybernetics & Human Knowing, 7*(1), 21–43.

Witzany, Günther (2000) *Life: The Communicative Structure. A New Philosophy Of Biology*. Norderstedt: Libri Books.

Yip, Maricela and Madl, Pierre (2005). *Semiosis aspects of ecosystems of the invasive Caulerpa taxifolia.* Paper Presented at the International Gatherings in Biosemiotics Conference 5, Urbino University, Italy. July 20–24.

Ziemke, Tom (2003). "Robosemiotics and embodied enactive cognition." *Semiosis, Energy, Evolution And Development Journal* (3), p. 112–124:

Ziemke, Tom and Sharkey, Noel (2001). "A stroll through the worlds of robots and men: Applying Jakob von Uexkull's theory of meaning to adaptive robots and artificial life." *Semiotica* 134 (1/4): 701–746.