

# Biology, Peirce, and Biosemiotics: Commentaires ‘Cénoscopique’ d’un Biologiste

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## Introduction

When John Deely invited me to review *Peirce and Biosemiotics* I was enthusiastic and flattered. For many reasons I have become (once again), in mid-life, seriously more interested in emergence in living systems and the universe than in top-down phenomena. A naturalist since childhood, I was educated in evolutionary ecology and molecular biology. I am an evolutionary biologist and unapologetic Neo-Darwinist<sup>1</sup> and pluralist.

Peircean logic is clearly formidable (Lane [chap. 4]) and its application to such issues as the intelligibility of the universe vis-a-vis cosmology in Nathan Houser’s essay (chap. 2) is particularly eye opening. However, where application to Biology is concerned Prof Fernandez’s assessment (chap. 5: 80) is indeed correct: “rather oblique and peculiar.” Biology is not immature Biosemiotics (Hoffmeyer 2008). Biosemiotics has yet to engage Biology on a

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<sup>1</sup> Neo-Darwinism is the melding of Darwin’s conclusions with Gregor Mendel’s observations as verified by R. A. Fisher, J. B. S. Haldane, Sewall Wright, et al., in the early twentieth century. In so doing a robust and testable Theory of Evolution by Natural Selection was erected. Decades of subsequent empirical evidence and enumerable arguments later, Neo-Darwinism makes no philosophical, theological, or spiritual statements about anything. All modern biologists are products of Neo-Darwinism.

large scale, and some statements and sentiments expressed in this volume make me skeptical. However, C. S. Peirce makes a sweeping and brilliant attempt.

When biologists think, test, or write about evolution we do so as a Theory of Evolution by Natural Selection (TENS) per se. TENS is the organizational framework of all of the life sciences, including medicine; without which we are left a disorganized cornucopia of facts about nature. For example, imagine predicting viral flu outbreaks without the ability to estimate rates of viral gene mutation and disease transmission grounded in evolutionary models of population equilibria. Characterizations of traditional or modern Biology as mere mechanistic reductionism (e.g., da Silveira and Gonzalez [chap. 8]: 165) are rather simplistic and naive at best. Reference to Peirce's comments regarding ax chopping and science in general (e.g., Romanini and Fernandez [chap. 1]) imply that Biology has had little interest in emergence or synthesis, outside of systems ecology. Nothing could be further from the truth. Current interest in phenomena and 'language' at the genome level is indeed intense; Hoffmeyer's (2014) appeal for the construction of a semiome may be premature.

Colapietro (chap. 7) and da Silveira and Gonzalez (chap. 8) in particular have written thought provoking chapters that not only illustrate the magnitude of the problem but may also provide fertile ground for a bridge, if not eventual synthesis, between aspects of Biosemiotics and Biology. It is important however (because Biosemiotics deals directly with *living organisms*), that the "budding discipline of biosemiotics still searching for a unified theoretical framework" (Fernandez [chap. 5]: 92) clearly understands the language, evidence for, and historical development of biological ideas. Herein I will briefly summarize the relevant high points of evolutionary biology, elucidate problems for Biosemiotics, and comment on Peirce and Biosemiotics.

## **Painting the Theory of Evolution by Natural Selection Using Some Broad Brush Strokes**

In his famous treatise, *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*, Charles Darwin (1859) made five poignant observations in proposing a theory of evolution by natural selection:

1. Some forms (individuals) are better adapted to current conditions than others (*Variability*).
2. Some of that variability is passed to the next generation (*Heritability*).
3. Organisms produce more offspring than their environments can support, and than actually survive to mature and reproduce (*Natural Selection*).

4. Those forms that are better adapted will leave more offspring and thus increase in frequency in a population (*Adaptation and Reproductive Fitness*).
5. As environments change over time, new forms may become better adapted and increase in frequency (*Natural Selection*); thus, new species may ultimately form (*Descent with Modification*).

Darwin's eminently testable hypotheses aside, evolutionary theory has matured and come far. During the early twentieth century Darwin's theory provided a credible mechanism of inheritance by the late discovery of Gregor Mendel's experiments and the elucidation of its cellular and structural parts.<sup>2</sup> The theory was made robust over thirty to forty years when R. A. Fisher, J. B. S. Haldane, Sewall Wright, and others, empirically showed TENS to operate in a Mendelian framework in what is now referred to as the Modern Synthesis or Neo-Darwinism. Non-Mendelian forms of inheritance are now known and biologists today function in a Neo-Darwinist framework. TENS has been modified over the past 150+ years and much of that modification is based not only in new discovery (DNA, genome structure, etc.) but also in synthesis of those discoveries into a coherent body of explanation.

Evolution is defined as the change in allele frequency *between* generations, and almost by necessity biologists are fixated on reproduction. Individuals reproduce and *develop*. Populations *evolve*. How is information (some portion of Darwin's variability) transmitted from one generation to the next? What information is transmitted, and under what circumstances? Is there a measurable unit in nature, common to all living organisms, that reproduces and is subject to selection under local conditions? In other words, at what level (molecule, individual, 'kin' unit, 'group', species, ecosystem, etc.) does natural selection occur?

In 1908 G. H. Hardy and Wilhem Weinberg separately put within-population variability into Mendelian perspective (Ewens 2004), in what has come to be known as Hardy-Weinberg equilibrium. Simply, for an ideal diploid population at a single genetic locus, where  $p$  = a dominant allele,  $q$  = a recessive allele, and  $p + q = 1.0$ , the population will be at equilibrium (i.e., allele frequencies will remain constant and variability will be maintained) when:

$$p^2 + 2pq + q^2 = 1$$

[ $p^2$  = homozygous dominant,  $q^2$  = homozygous recessive,  $2pq$  = heterozygous]

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<sup>2</sup> Darwin got heritability wrong and believed in a 'blending' theory of inheritance in which variability has been mathematically shown to be lost quickly from a population.

Five conditions must be met:

1. No mutation
2. No natural selection
3. No genetic flow (migration or gamete transfer)
4. Random mating
5. Large population size (no genetic drift)

Virtually all populations violate these conditions in varying degrees and combinations and much of evolutionary biology is about teasing out and documenting their effects.

Biologists widely agree that the source of *de novo* variability is mutation (e.g., nucleotide substitution, chromosomal rearrangement, etc.) and in 1968 the Japanese population geneticist Motoo Kimura introduced the Neutral Theory of Molecular Evolution. Among other consequences the Neutral Theory predicts that

1. Of those mutations that are *not* deleterious,<sup>3</sup> their effect is almost always neutral.
2. The *rate* of molecular evolution is equal to the *rate* of mutation.

That is, of those mutations that make it into the next generation, almost all are neutral with respect to effects on fitness; there are very few selectively advantageous mutations. Population size and natural selection, mathematically, play virtually no role. The Neutral Theory spawned vociferous rounds of debate and experimentation among biologists. Neutralists attributed the majority of population effects to genetic drift and Selectionists attributed the same to natural selection. In other words, both camps attribute deleterious mutations to natural selection, while Selectionists invoke natural selection to explain all of the variability we see in populations around us. The Neutral Theory was subsequently modified in the early 1990s by Kimura's protégé, Tomoko Ohta, as the Nearly Neutral Theory of Molecular Evolution (Ohta 2002) that predicts a significant impact of population size. In the end, for strict Neutralism, supported in some experimental cases, natural selection is not as unimportant as Kimura thought; nor, is natural selection nearly the universal driver that strict Selectionists championed.

The last half of the twentieth century has witnessed the emergence of some not-so-trivial theoretical questions and proposals as well as important testable

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<sup>3</sup> Biologists agree that the vast majority of mutations are deleterious and never enter a population. No one has ever espoused *pan-neutralism* where the effects of ALL mutations are neutral with respect to fitness.

solutions. Two are particularly relevant to our discussion. As mentioned above, at what level does natural selection operate? Is there a real (measurable) and basic entity in nature such as a *species*, and what is its significance?

For at least three centuries, individual species have been described or identified on the basis of morphological or typological criteria. In the 1960s–1970s Ernst Mayr (1963, 1970) formulated the Biological Species Concept (BSC) where a species is defined as groups of interbreeding populations that are *reproductively isolated* from other such entities, thus placing ‘species’ in the conceptual framework of population genetics and reflecting a shared or common ancestry. Other species concepts exist (e.g., morphological, ecological, phenetic) but the BSC is the most inclusive and is far and away the concept that permeates the life sciences today. The predominant species concepts agree on three points:

1. Species are groups of interbreeding populations
2. Species are fundamental units of evolution
3. Species are evolutionarily independent

Differences among species concepts usually center on establishing the criteria for evolutionary independence. That is, what is the unit within which migration, mutation, selection, and drift act? Or, where and what is the boundary for the spread of alleles? For the BSC that criterion is reproductive isolation. No species concept, however, is universal, and asexual organisms (e.g., bacteria), fossil forms, hybridization, and polyploidy present complex and partly unresolved problems.

The latter part of the last century also generated a highly and publicly visible debate over natural selection from which modern biology has been characterized as mechanistic, reductionistic and deterministic. Popularized in books like *The Selfish Gene* (Dawkins 1976) and *The Extended Phenotype* (Dawkins 1982), proponents of the gene centric view of evolution argue that the only relevant units of selection are genes themselves. Thus genes (or more accurately physical segments of DNA) promote and enhance their own evolutionary success by manifesting a phenotype that interacts with the environment. This view is hardly universal and such luminaries as Ernst Mayr, Stephen Jay Gould, David Sloan Wilson, and Elliott Sober have made the case for other selection units, including multilevel selection (Lieberman and Vrba 2005, and references therein). Gould (2002) was particularly vocal in arguing against a gene centric view.

In an attempt to explain social interactions and altruism<sup>4</sup> Wynne-Edwards (1962) also proposed a Theory of Group Selection wherein individuals will act (i.e., sacrifice some portion of their own reproductive fitness) for the good of the group. In an elegant dismantling of selection at the group level, W. D. Hamilton (1964a, b) proposed the concept of *inclusive fitness* wherein individual reproductive fitness is shown to consist of two components: direct fitness (the actual contribution of offspring that an individual makes to the next generation) and indirect fitness (that portion of an individual's genetic makeup contributed to the next generation through cooperative behavior directed at relatives). That is, an allele (or mutation) for altruistic behavior would be expected to spread in a population if,

$$Br - C > 0$$

where,

B = Benefit to the recipient

C = Cost to the actor

r = degree of relatedness between actor and recipient

Hamilton's contribution to evolutionary theory was as controversial as it was enormous, but pivotal in the establishment of Kin Selection Theory and sociobiology. Empirical tests, including field studies, in the ensuing decades, have shown that interactions among groups of individuals that appear to be altruistic are virtually *always* directed toward relatives. Some workers still posit strong empirically based disagreement (Alonso 1998, Alonso and Schuck-Paim 2002), and arguments for Reciprocal Altruism<sup>5</sup> exist (Trivers 1971)—albeit invoking complex mechanisms that apply almost exclusively to primates (Hemelrijk 1994, Lee 1987). The question of natural selection is patently complicated and not fully settled.

My own view is that *generally* natural selection acts on individuals, and with the exception of groups of genetically related individuals (kin), does not act on groups, real or construed. Individuals produce gametes, experience environmental conditions, find nourishment and mates, and transmit genomes of information to the next generation as a package—not as un-integrated chunks

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<sup>4</sup> Interactions are those that occur between members of the same population or species, not *between* species. For example, behavioral interactions between dogs and humans, or dolphins and humans, characterized as altruistic are not included in group selection theory.

<sup>5</sup> Selection can favor Reciprocal Altruism (RA) if, the cost to the actor is < or = benefit to the recipient and cheaters are punished. RA groups should exhibit the following characteristics: (1) individuals repeatedly interact with the same set of individuals, (2) many opportunities exist for altruism in an individual's lifetime, (3) individuals have good memories, (4) altruists interact roughly symmetrically.

of nucleic acids with potentially competing interests. Because they encode and influence the development phenotypes, genomes are *de facto* significant.

In the end, reproduction, variability and plasticity are key signatures of living systems (Darwin 1859: 490):

There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning **endless forms most beautiful and most wonderful** have been, and are being, evolved.

## Evolutionary Theory: What Biology Does and Does Not Say

It would be fair to say that I am the biologist to whom Hoffmeyer (2008) refers in the opening paragraph of *Biology Is Immature Biosemiotics*. I have long sensed an *élan vital* in nature, or a “spirit behind the letter ... that hovers behind the text as unsaid” (Ibri [chap. 3]: 34). It has motivated but not necessarily informed my science. Colapietro’s observation (chap. 7: 134) of a shift in interest from knowledge acquisition to understanding is also acknowledged and well taken.

Why indulge in the preceding historical recitative of elementary evolutionary biology? For one thing, given that the universe is knowable, it is the job of science, and biological science in particular, to describe the living world accurately and in the fewest coherent, and verifiable, statements possible. These are the *facts*, or causes and effects, to which Hulswit and Romanini (chap. 6: 107) refer. Natural selection is fact, regardless of what form it takes, and its causes and effects are generalizable.<sup>6</sup> Those *generalizations* are no more reductionist than a dissection of abduction (da Silveira and Gonzalez [chap. 8]), a discussion of ‘kinds’ of signs (Nöth [chap. 9]), or descriptions of Peircean sign and symbol semantics (Lane [chap. 4]). What biologists have thus far discovered of carbon-based life (extinct and extant) on this planet is, to put it mildly, diverse to a mind-boggling degree. Biology simply has exponentially more parts to account for than Biosemiotics has thus far realized.

By way of example, I am going to use comments written by John Collier (chap. 10: 195–196) to illustrate the mindset toward evolution, selection, and Neo-Darwinism, that permeates Peirce and Biosemiotics (*italics mine*):

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<sup>6</sup> I would prefer to consider natural selection as *reality*. However, the same authors point out that to Peirce, “reality is purely a matter of events”, not facts (p. 107). I am wary of engaging philosophers in debates about *reality*.

According to the *widely adopted* optimality theory in neo-Darwinism, every trait is already *optimally adapted*, so it could not be better. ... The problem with this view is that it assumes that genetic and environmental changes are slow enough to allow selection to produce optimal adaptation. Biologists I work with tell me that this is seldom the case. If genetic and environmental changes are too fast, then there is room for self-organization within the genetic and trait space and the information of adaptation can increase indefinitely (Collier 1998). This is still a controversial area, with traditional neo-Darwinists holding that *progress in evolution is a mistaken idea*, whereas self-organization theorists see it as both possible and actual.

There are two fundamental points in this quoted text that need to be examined—firstly, optimality; and secondly notions of progress. Let us consider each in turn.

### I. Optimality

Indeed, Prof. Collier's biologist colleagues are correct. But, Neo-Darwinism simply does *not* "widely adopt optimality theory". Darwin himself highlighted the variability between individuals of the same species. In fact, a major consequence of his work was to eventually erase, or at least considerably ease, typological—or, optimal—concepts in the fields of phylogenetic and taxonomic study. Basic Hardy-Weinberg approaches discussed above also model the reality of populations that are most often composed of anything *but* optimal phenotypes and genotypes. A trait evolved to optimality would imply such instability that any slight change in environment, or natural selection pressure, would result in population extinction instead of future generation adaptation (and change in allelic frequency) based in population level genotypic diversity. Sewall Wright (1932) proposed the idea of an adaptive landscape as a metaphor for thinking about the relationship between genotype and reproductive fitness. With multiple peaks and mountains, Wright's (1932) landscape was static, but ecological geneticists have extended the model to a dynamic seascape of rolling and changing waves that represent constantly changing biological and physical conditions (Merrell 1994). There are not stable optimal peak heights or wave crests; there is continual flow and change, or what Peirce might call *reality*.<sup>7</sup> In short, natural selection does not result in individuals that are optimally adapted to their environments. It usually results in a population of individuals with a range of traits; many combinations that are 'good enough' to survive.

The likes of John Maynard Smith (*d.*2004) (whom I never met) aside, I have yet to meet any biologist in four decades that labors in the trenches of the

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<sup>7</sup> Ibid.



laboratory or field that is completely gene-centric, or that utilizes optimality criteria other than to question *why* systems *do not* approach optimality. The prevailing view is decidedly 'evolutionary pluralism' (Merrell 1994) where adaptation and natural selection are concerned. Opinion and evidence range from criticisms of adaptationism (i.e., selectionism) (Gould and Lewontin 1979), the acknowledgement of exaptation (Gould and Vrba 1982), the elucidation of the role of development in evolution called Evo-Devo (see Mallarino and Abzhanov 2012 for review), to an extreme gene-centrism (Maynard Smith and Szathmáry 1999). In the last 15 years biologists have begun to pay particularly close attention to genotype-by-environment interactions at numerous levels (Herron and Freeman 2014). Clearly the drumbeat in nature is and has always been variability-plasticity-diversity.

Phenotypic plasticity and genetic variability *may* get at notions of habit (Hulswit and Romanini [chap. 6]: 97) or vagueness and generality (Lane [chap. 4]: 63–65) with which Peirce himself seemed to wrestle. A problem for modern biology is now explaining both plasticity and variability. A species' collective genome is variable as a whole and phenotypes are plastic with respect to which parts of the genome are expressed *under different conditions* and how those factors interact. Each individual or population passes on only part of that variability and not *all* phenotypic expression, or potential expression, is a result of heritable genomic-DNA expression (e.g., epigenetics). Variability changes from generation to generation with the introduction of new mutations, most of which never drift nor are selected *to fixation*. *Drift they do*.

## 2. Progress, Purpose, Complexity, and Causation

Some words need to be said first about progress, purpose, and complexity. Evolution is not progressive in the sense of producing complexity over time. Lets look at parasites for example, and the tapeworm in particular. If we look at the distribution of parasitic taxa over any large phylogenetic tree<sup>8</sup> of extant organisms we see that they occupy positions at the tips of the branches—*terminal taxa*, in my language. If we read the tree from its terminal tips, down through the branches, we also see that they share a common ancestor with many forms that are free-living (i.e., non-parasitic). Parasitic forms do not give rise to free-living forms. In the case of the highly successful tapeworm, it has

<sup>8</sup> Although we construct bifurcating phylogenetic trees out of computational and statistical necessity, biological thinking has actually proceeded from tree, to bush, to web, to *network*. Many genome projects and experimental results have shown that the degree of genetic horizontal transmission is much greater than biologists ever suspected. For example Herron and Freeman (2014: 674) report that 24 percent of the genes in a single Eubacterium (*Thermotoga maritima*) were laterally acquired from the Archaea, a separate domain of life. Over half of the human genome is composed of mobile elements, some of which are retroviral in origin.

'lost' its digestive system. It is anatomically less complex than its free-living cousins and its inferred common ancestor. Why? An evolutionary explanation (or hypothesis) would tell us that this makes sense from the standpoint of reproductive fitness or success. True, the tapeworm has no 'need' of a digestive system, because its host provides all of its essential nutrients. However, the tapeworm is highly streamlined and efficient at egg laying. We (biologists) would say that in the transition from free-living to parasite some individuals of variable populations of ancestors laid more eggs (more copies of themselves and their genetic proclivity to lay many eggs) than others. Over time those forms that committed the most resources to egg production came to predominate. 'Need' per se has nothing to do with it. Resources committed to digestion (anatomical, physiological, etc.) were committed to egg making. By sheer numbers and probabilities alone a parasitic form morphologically less complex than its ancestor came to predominate over time.

Yes, we biologists have had problems with the concept of need. These problems stem mostly from our narrow interpretation, modern misunderstanding, and application of teleology, and from our history with Mr. Lamarck. I prefer to think about *teleonomy* rather than needs, or *teleology*. Teleonomy references verifiably developmental processes occurring in nature (Deely 2001: 65–66). Organisms do not evolve out of some need<sup>9</sup> or to fulfill some future unknown purpose. Natural selection is only purposeful in the sense that individuals are selected (survive) that best fit conditions at the time. Again, it is important to note that 'best' fit does not mean 'optimally' fit. Losses of complexity, and/or loss of characteristics, are apparently as much a part of the adaptive seascape as gains. If this is what Winfried Nöth (chap 9: 175) means when he says

*Purpose* is a characteristic of life. The biological *purpose* of any organism is to survive both individually and as a species.

Then, so be it. The point is mostly semantic from a biological standpoint.

More relevant and useful, for biologists, than a concept of purpose, is Peirce's conception of causation as explained by Hulswit and Romanini (chap. 6: 104–105) in terms of efficient, final, and chance components. *Final causes* are *general possibilities*, not future events (*probabilities* or *likelihoods* in my language), that are realized in the process of *efficient causation* or *blind compulsion*. They are dependent upon each other and, together with an element of *objective chance*, are all three *interdependent*. Hulswit and Romanini (chap. 6: 105) explain:

Moreover, according to Peirce, every event (as part of a process) is characterized not only by an aspect of final causation and an aspect of efficient

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<sup>9</sup> Organisms with dire 'needs' go extinct.

causation, but also by an aspect of *objective chance*. Each process involves an aspect of irreducible novelty or objective chance at every stage of the process, which cannot be reduced to efficient or final causation.

It is relatively simple to apply the reasoning to the events in the process of meiosis (reduction/division of the nuclear genome from diploid to haploid in the formation of gametes), for example.

Now, what of our friend<sup>10</sup> the tapeworm's genome? Recently, Tsai et. al. (2013) have produced a high-quality reference sequence and analysis of the genomes of four tapeworm species that are neglected tropical diseases, two of which are prioritized by the World Health Organization (WHO). It is significant that comparison to other invertebrate genomes shows extreme losses of genes that are ubiquitous in other animal taxa. Homeobox genes are involved in body plan symmetry of which approximately 100 are conserved across bilaterally shaped (Bilateria) invertebrates. Of 96 homeobox gene families believed to have been present in the Bilaterian ancestor, 34 no longer exist in tapeworms. Further (Tsai et. al. 2013), tapeworms no longer possess 3 ParaHox genes for through-gut development (tapeworms have no gut). Progressive? Or, adaptation, specialization and natural selection?

Genomes are hardly static entities, nor do they read like a book. The system does not begin at base pair (bp) 1, reading on until the 3.2 billionth base pair, and then somehow produce a human copy, akin to itself, for example. Rather, genomes are dynamic and, significantly, self-interactive. Why *not* a book or a linear code? Why instead a strange (to us) conversation embedded within a unique communication system? Because if chapter 3 in this book is read it might rearrange chapters 61–67. Reading chapter 34 may well change the ending of chapter 18, or eliminate chapters 6, 17, and 101; and so on. The book metaphor doesn't work, because the genome regulates itself from *within* and is regulated by other factors *within the nucleus* and cell but *outside* of the genome. It also is regulated by factors outside of the cell and outside of the individual. In turn, the genome itself may (or may not) encode and regulate all of those factors. The conversation is continual and complex.

We can divide any genome into two parts, coding and non-coding. Coding regions make all of the things we know of an organism's phenotype (appearance, physiology, instructions for all known life processes, etc.). We generally don't know what non-coding regions do, except that they are necessary and important. We are reasonably certain that some non-coding regions regulate coding regions. Oddly, if we look across the genomes of multicellular organisms we see that less than 10% is coding. Vertebrate genomes contain

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<sup>10</sup> Friend only if you are not infected with a tapeworm.

significantly less coding DNA, with the human genome consisting of about 3 percent (Lee et. al. 2001). Nor, does genome size have anything whatever to do with our perceived notions of complexity: the Japanese canopy plant genome size = 150 billion bp, human = 3.2 billion bp, fruit fly = 180 million bp (Herron and Freeman, 2014, p. 583).

Indeed the devil is in the details and theory needs to account for those spirits. There is no governing (imposed or otherwise) gene-centric paradigm in evolutionary theory. There is no over-arching optimality paradigm. There isn't "*the genome*". There is an adaptive seascape of ecological genetics (Peircean fact *and* reality if you will), revealed in the myriad genome projects themselves.

In concluding this section, I will end with a cautionary note intended for linguists penned by John Maynard Smith in his review of Daniel Dennett's *Darwin's Dangerous Idea* (1995). Regarding Noam Chomsky, Maynard Smith (1995) writes (*italics mine*):

Why does Chomsky not wish to think about evolution? Dennett, who is as puzzled as I am, has an interesting idea. Chomsky, he suggests, would readily accept an explanation of linguistic competence in terms of *some general physical law*, but not in terms of *messy, ad hoc, contingent* engineering design, which is *the best that natural selection can do*. If so, he is not alone in his taste for general, elegant explanations. My friend Brian Goodwin, the developmental biologist, cannot bear the idea that the explanation for development may be a series of ad hoc contrivances, and another friend, the Japanese evolution theorist Motoo Kimura, sadly now dead, once rejected an idea of mine with the words, "It is possible, but it would be so inelegant." *But I fear that the world is inelegant*. There is a lesson which Chomsky's students, if not the great man himself, will have to learn. *Science is a unity. Biology cannot ignore chemistry, much as I wish it could; for the same reason, linguistics cannot ignore biology.*

Evolutionary theory may well be inelegant. But, biosemioticians wanting to explain biology cannot afford to ignore or misunderstand evolutionary theory.

## **Necessity, Contingency, Entanglement, and Cenoscropy**

I am neither physicist nor philosopher, but from the point of view of evolutionary biology the Peircean principles of Tychism and Synechism make sense. If the evolution of life on earth is so, then absolute chance or indeterminism is an evident operational factor (e.g., gene drift). Phenomena such as extended droughts or shifts in continental land mass are not anticipated by populations of organisms that experience the result [much less the sizeable Chicxulub bolide that ultimately ended dinosaur dominance at the KT boundary (65 Ma) and gave mammals the opportunity to exploit previously occupied niches (adaptive radiation)]. These are rare and random events from the perspective

of individual organisms. To misquote Prof. Einstein, God does indeed play dice with the universe.

Eliseo Fernandez (chap. 5: 91) cites the concept of *extended criticality* where “organisms can be envisioned as complex, far-from-equilibrium systems permanently undergoing an uninterrupted flow of continuous *phase transitions* ... where old *symmetries are constantly broken* and new ones simultaneously created” (italics mine). The near universality of introns<sup>11</sup> among the Eukaryotes and their virtual absence among the prokaryotic Eubacteria is certainly one example of contingency and symmetry-breaking in the evolution of living systems. The origins and evolution of introns is a major mystery in biology.

At this juncture in the history of science we mostly live in an Einsteinian world. Were I to fill an empty container with balls, an Aristotelian view would tell me that I had done exactly that. An Einsteinian view would look at the container and balls and make two observations: objects tell space how to fold, and space tells objects how to move. Even in a perfect vacuum the ‘space’ is still a something. The point is that we live in a “relational” if not “entangled” universe (Wegter-McNelly 2012).

Nathan Houser (chap. 2: 29) comments on Peirce’s cosmology:

Regardless of whether Peirce’s cosmology<sup>12</sup> is accepted whole, it has proved itself useful to modern cosmologists as we have seen, especially for its pioneering embrace of chance and evolution of physical law. But Peirce’s synechism and agapasm have yet to be discovered by modern science. It remains to be seen how future science will regard Peirce’s generalized view of life and mind and how it will fit into more inclusive future modern cosmologies.

Indeed, Biosemiotics may be one starting point for that future inclusivity, synthesis or clarity that I especially infer from comments of Profs. Houser,

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<sup>11</sup> The origin and evolution of introns is a major unresolved issue in evolutionary biology. Introns are sequences of non-coding DNA, containing short conserved consensus sequences, between protein coding sequences, or exons. When coding sequences are ultimately transcribed into mature messenger RNAs, (that will be translated into proteins at some point) introns are a major part of the mechanism that splices together the correct exons, in the correct order, to make a particular RNA transcript. Living organisms are divided into three domains: Eubacteria, Archaea, and Eukaryotes. The Eukaryotes contain introns while the Eubacteria by and large do not. The Archaea and Eubacteria, together make up the prokaryotes. Some Archaea use a small number of introns. Recent analyses support an origin of the Eukaryotes within the Archaea, from an archaeon host lineage containing the inferred mitochondrial endosymbiont (Williams et al. 2013).

<sup>12</sup> Houser (chap. 2: 29) goes on to point out that “Peirce believed in three principle kinds of evolution which he called agapasm, tychasm, and anancasm (but Peirce held that there is no sharp line of demarcation between them). Agapasm was evolutionary growth driven by attraction or sympathy—Peirce said it was evolution by *creative love* (emphasis mine). Tychasm was evolution driven by fortuitous variation and anancasm was evolution driven by mechanical necessity”.

Fernandez, and Colapietro. I admit that Peirce (and several chapters in this volume) appeal to the spiritual *élan vital* and naturalist in me. Much like my understanding and interpretation of Teilhard de Chardin, *we know that we know*. Answers to large questions are rarely found in either/or solutions, but commonly in both/and approaches. Creativity and insight are frequent gifts that arise from *tension*. It would enrich biologists interested in the emergent phenomena of nature to read Peirce and *Biosemiotics: A Guess at the Riddle of Life*. Much like theologians that have engaged physical and life scientists proactively, it behooves biosemioticians to do the same with biologists who have made some scientific sense of messy, contingent, and regularly conflicting observations.

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