Complexity Theory and Evolutionary Discourse

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The empirical method of science relies, almost to the exclusion of all other forms of phenomenological explanation, on observing and producing data that are experientially verifiable. Without empirical evidence, sensory observation, and verifiable data, science cannot function. The responsible scientist will never make claims or suggest theories that are not based in the physics of worldly operations or the grid-like laws that govern its behavior. One underemphasized characteristic of the scientific process, however, is the act of interpretation. Like the historian, the literary scholar, the philosopher, or the anthropologist, the hard scientist (and, in particular, the biologist) must interpret texts—must read the data of his or her field, convert those data symbolically, and decide what the symbols mean. This interpretive intersection—where scientific data meets the human ability to give it meaning—represents what Mark C. Taylor terms a "moment of complexity." As neither a strictly linear process of systemic order nor an act of purely artistic chaos, the interpretive acumen that scientists bring to bear on a problem of evolution is not only dictated by the laws of science and the rules of observation, but also by the impulse to supply a narrative network of meaning within the evolutionary framework. Complexity theory provides a hermeneutical tool with which to understand this critical phenomenon because it emphasizes the point where thinking transcends the grid of scientific methodology and enters the realm of creative networking.

While scientists almost universally accept the principal reality behind evolutionary theory (and one would be very hard pressed to find a biologist who did not adhere to its basic precepts at all), there is still some disagreement within the scientific community about its details. The fact that Darwin did not have a knowledge of genetics sometimes creates wrinkles in the theory,[1] for example, but, overall, natural selection is a well-established, intellectually unchallengeable explanation for both the diversity of life and the very reason for its existence. From a standpoint of intellectual history, the comprehensive Darwinian theory of evolution is relatively young, however, and this fact has given our generation an unusual vantage point for assessing its impact on Western civilization's worldview. It is perhaps difficult to overstate just how revolutionary the idea was, since it succeeded in overturning millennia of spiritually oriented explanations for the origin of life, creating whole new scientific subspecialties whose practitioners almost instantly began naming, cataloging, and interpreting the life around them in entirely new ways. More than simply giving scientists new vocational titles, however, its real influence can be felt in how the human approach to the world shifted drastically from one of mystified awe for a divine creator to one of inspired reverence for the vastness of time and matter necessary for life to coalesce from simpler—indeed, amazingly rudimentary—chemicals and energy sources.

Not only are the materials of life simple, but so is the process. In *Darwin's Dangerous Idea: Evolution and the Meanings of Life*, Daniel Dennett describes natural selection as an algorithm—a pattern of mechanical operation that requires neither an omniscient prime mover nor, in fact, a mind at all to supervise its many and disparate paths:

> No matter how impressive the products of an algorithm, the underlying process always consists of nothing but a set of individually mindless steps succeeding each other without the help of intelligent supervision; they are "automatic" by definition: the working of an automaton. They feed on each other, or on blind chance—coin flips, if you like—and on nothing else. [. . .] Can [the biosphere] really be the outcome of nothing but a cascade of algorithmic processes feeding on chance? And if so, who designed that cascade? Nobody. It is itself the product of a blind, algorithmic process. (59)

As with any algorithm, the algorithm of natural selection is a basic, predictable process of gradual—almost imperceptible—change. That the process is predictable is not to say that the outcomes are equally so. The sheer diversity of life forms this planet has produced is testament to how seemingly distinct evolutionary designs can manage to symbiotically embrace their environments. What is predictable is that organisms will change, and that those that change in a way that is beneficial (and the only criterion for benefit is survival—that is why we find so many *different* forms of life) will continue to reproduce and create offspring who in turn will continue this algorithmic process. Those organisms that do not meet this basic requirement will perish. There is overwhelming geological and biological evidence to support the reality of this process. With one brilliant, devastating idea, Darwin overturned centuries of teleological, Aristotelian presupposition about the origins of life, surgically removing from the equation the need for design and order. But his idea is perhaps even more revolutionary than we tend to give it credit for; by providing this alternate explanation, he unlocked the notion that order was, in fact, a human construct. Because thinkers had always assumed that the beauty, variety, and functionality of life was so reciprocal, so interlocked, so seemingly perfect, they had likewise assumed that its structure was far more complicated than could be explained by mere chance. Chaos, given enough matter, time, energy, and opportunities for failure, could conceivably create life along the order of *Homo sapiens*. That human life could come into existence, however, was far from a foregone conclusion.

The idea that natural selection was utterly mindless and arbitrary was too much for many people to suffer quietly. As a species, we had already been unseated from our position of primacy by Copernicus, Galileo, and Newton; were we now also to discover that not only weren't we the predetermined end of the universe, but that our existence was unintended and, given the slightest deviation in evolutionary history, even unlikely? Evolutionary theory, if seriously understood and considered, suggested a human insignificance of mind-numbing (and absolutely humbling) proportions. Given the sheer scope of Darwin's implication, and the centuries of received knowledge it threatened, it is not surprising that many simply chose to dismiss it. The paradigm shift was slow in coming—and perhaps is not, even today, fully synthesized—and for many, the willingness to relinquish old ideas would never come about. This resistance speaks to the revolutionary nature of the idea, but it also suggests that the ordering systems that we relied on were too entrenched to relinquish on the basis of a theory that seemed to many to be a mere fantasy based on a few fragmented shreds of observational evidence.

Of direct concern here is the reason for this resistance, one borne of an inability for people to accept that chaos had replaced God. The theory of evolution, in short, prompted new philosophical theories about the organizational patterns humans rely on to make sense of chaos. Through the new Continental theories about the intersection of language and society, thinkers soon discovered that developing metacognitive systems to describe chaos were only adequate insofar as they articulated the problems of rhetorical interchange, which ultimately led us down a path of meaninglessness. Since we operate in a world that we do, in fact, assign meaning to—meaning that may not "really" be there but that we must act pragmatically upon everyday nonetheless—we are left in a spiritual and intellectual void that neither allows us the comfort of the Creator nor the self-satisfaction of being the makers of our own destiny. We have, as a result, been largely unable to shake off the existential anxiety that first emerged after the import of Darwin's theory had been recognized by educated people.

In the scientific world, while we may understand the physics, the mathematics, and the chemistry that provide the foundation for the philosophy that we call science, Western civilization has not kept pace morally, socially, or humanistically with these advances. The real problem for the generations that have inherited Darwin's theory is not, as one might suspect, that there are competing theories that seriously threaten it, but that it contributes to a body of scientific knowledge that is still in its intellectually infancy. If we look at our recent history, it is clear that our track record of responsibly applying scientific knowledge to constructive ends is not a particularly polished one. The inconsistencies that arise in the perceived goals of science and the true utilization of it have left us all, on one level of consciousness or another, scrambling to make sense of the constant mental, emotional, and physical fluctuations that confront us. What we do with those discrepancies depends on our relationship to the symbols that give us meaning. For some, God is still the mind behind the operations of the universe, but today God does not enjoy the position of dominance that He once did mainly because His existence is difficult to reconcile with the scientific advances that have a more prominent hold on our daily, earthly activities. Many who still hold their faith yet wish to acknowledge the legitimacy of scientific knowledge are forced to abandon precepts and doctrines from both science and religion. Meaning becomes a matter of ideological convenience, and the complexity of conceptual reconciliation is difficult to master and implement.

Taylor has provided some key insights into the confusing intellectual phenomena that have taken shape in the last one hundred years, and he has given us a lexicon with which to describe our current state of development. Whereas linear conceptualization of our natural world was adequate to describe a Newtonian world view, the introduction of ideas like Heisenberg's Uncertainty Principle, quantum mechanics, chaos theory, and increased attention to nonlinear equations changed our outlook from one of grids and structures to one of networks and complexities. In *The Moment of Complexity*, Taylor convincingly argues that the shift between linear thinking and networking is not only necessary, but inevitable. He explains that

> [c]omplexity theory shares catastrophe theory's preoccupation with discontinuous change and chaos theory's concern with the dynamics of nonlinear systems but explores the activity of systems "far from equilibrium" or "at the edge of chaos." According to complexity theorists, all significant change takes place *between* too much and too little order. When there is too much order, systems are frozen and cannot change, and when there is too little order, systems disintegrate and can no longer function. (14)

Complexity theory occupies the nether region between order and chaos, between systems "frozen" by ordered inflexibility and systems "disintegrated" by no meaningful purpose. Those that are frozen are bound by linear dictates that allow no deviation, on a train track between predetermined points A and B, and those that have disintegrated have no binding force, flying off into space from centrifugal energy. Complexity theory helps to reconcile these extremes, not to synthesize the dialectic, but to account for the activity that takes place between order and disorder, and thus to account for systems that at once move in discernable patterns while at the same time embrace anomalous elements: "Complex adaptive systems, which always emerge at the edge of chaos far from equilibrium, are not static, but are in a state of continual evolution" (16). Moreover, complexity theory describes the intersection between our most cherished intellectual precincts—science and humanism—in a way that gives us a language of meaning for fields that have traditionally competed with one another for intellectual predominance, often to the detriment of both.

The theory of evolution is a major player in the moment of complexity that Taylor describes. Through it, we can see complex structures at work, whether through the adaptive network of chromosomal and genetic structures or through the behavior of insect colonies or through the interrelationships and development of speciation. The natural world, it seems, is intrinsically complex, and while the traditionally linear scientific urge to "reduce complexity to simplicity" (137) has yielded interesting and enlightening conclusions, the real strides in biology have taken place where complexity emerges: on the edge of chaos. As I will discuss in more detail below, the interpretive complexity used by biologists mirrors both the natural world and the rhetorical devices they use to describe it. If, for example, we understand complexity from its etymological, literal meaning—that is, to braid, twist and fold together—we can clearly see examples in the natural order of organisms (138). Looking at a model of DNA should illustrate that the twisting, interconnecting chemical basis for an organism's information system is at its very root complex. Within this seemingly simple strand resides the text for all life, and the variations of life it is capable of producing are magnificent and apparently endless. Millions of species have evolved from this complex system, and millions more have come into existence and passed silently and imperceptibly into the twilight of time.

I mentioned earlier Daniel Dennett's insight that evolutionary processes are algorithmic, that they follow a pattern of organization that may seem random, but are in fact sequenced on a scale of evolutionary magnitude. The process of natural selection that leads to the evolutionary development of a species can be viewed as a repetition of gradual change that is basically algorithmic—we can reliably predict that an organism will evolve, even if we can't predict at what rate that evolution takes place or what the outcomes will be. Taylor, likewise, describes complexity as an algorithmic pattern; the more "compressible" an algorithmic sequence is, the less complex it is: "If the insights of information theory are combined with the notion of algorithmic complexity, it is possible to conclude: *the less redundancy, the less compressibility; the less compressibility, the more complexity; the less redundancy, the more information; the more information, the less compressibility, and thus the more complexity* (139). Life, at all levels, reflects this innate complexity. Organic compounds are, in effect, networks of chemical formations that are not redundant, nor are their individual, atomistic parts randomly ordered. Each atomic link in each organic molecule has a purpose; as the complexity of the compound increases, life becomes possible, and the complexity of the chemistry begins to increase exponentially. Mere matter, especially matter comprised of single elements, is relatively simple, and therefore, relatively easy to reduce to something basic like the periodic table. As molecular structure becomes more complicated—but not redundant—the likelihood of compressibility becomes more remote. When we reach molecular structure so complex that the chemistry becomes self-enhancing, self-replicating, and self-sustaining, we have *life*. The network of life becomes increasingly complex—but not redundant—as the organism evolves. In the case of composite flora and fauna (those organisms that are not single-celled), the complexity of the systems becomes almost completely incompressible. We see the reciprocal reliance of networks within networks within networks—atoms working to form molecules working to form organic compounds working to form cell structures working to form specialized cells working to form organs working to form anatomical systems working to form the whole being—to become what Taylor refers to as "integrated wholes." "To understand life," he says, "it is necessary to analyze the structure of the complex relations that create and sustain it" (86). Michael Shermer, skeptic and regular contributor to *Scientific American*, articulates the same sentiment this way:

> Water is an emergent property of a particular arrangement of hydrogen and oxygen molecules, just as consciousness is a self-organized emergent property of simple life: prokaryote cells self-organized into eukaryote cells, which self-organized into multicellular organisms, which self-organized [. . .] and here we are.
>
> Self-organization and emergence arise out of complex adaptive systems that grow and learn as they change. As a complex adaptive system, the cosmos may be one giant autocatalytic (self-driving) feedback loop that generates such emergent properties as life. We can think of self-organization as an emergent property and emergence as a form of self-organization. Complexity is so simple it can be put on a bumper sticker: LIFE HAPPENS. (35)

Organisms become functional, "integrated" wholes over vast seas of time. But individual organisms are, of course, only one small part of the macrocosmic network of life. "Life," Taylor says, "is nothing apart from its embodiment in individual organisms, and individual organisms cannot exist apart from the global process of life" (87). The Gaia concept illustrates the interrelationship between the individual life form and the biosphere of life, viewing the earth not as a rocky ball in space that happens to be infested with millions of different, parasitic life forms, but as a living thing itself—the truly integrated whole that plays host to all other organisms living on and in it. Indeed, without the hospitality of the earth, life could not exist. Taken yet another step, its rate of spin, seasonal climate, its distance from the star it circles, the star's galactic proximity, and a host of other conditions necessary for the emergence of life—all play a role in the networks that make the functional whole functional.

It is here that we reach the theoretical bottleneck. Biologists—especially paleontologists who study the history of life and its evolution—must apply the linear scientific method they have inherited to the rather vague and often messy project of cobbling together a comprehensive picture of the geological and evolutionary past. Because paleontology is a science, it must collect physical evidence in the form of fossils, classify new fossils, clarify the time and place of the organism that left the fossil behind, and understand the fossil in relationship to other fossils that have already been put through this process. But a fossil is a shard, a mere splinter of evidence, and no matter how many fossils we find, our knowledge of evolutionary history is a fragmentary glimpse into millions of species over the course of millions, sometimes billions, of years. The paleontologist is forced to perform interpretive leaps, imaginative exercises that create a plausible story.

In this necessary leap, the evolutionist must undergo an imaginative transformation to fill in the gaps left by the scientific text. Because the evolutionary text is fragmentary, the paleontologist must supply a narrative that accounts for the missing pieces. The narrative, in this case, is formalized; that is, it must adhere to the laws of science and an empirical, rational process in order to fit the form for which it is intended. In effect, it is a fictionalized account of past events that could not be directly witnessed by human beings. That is not to say that it is "false" or "mythologized" (though once it becomes public domain, this can certainly happen—consider the popular culturalization of dinosaurs, for example). Rather, the evolutionary account, by its very nature as a science based on fragmentary evidence, functions much like historical fiction: the event was real and demonstrable, but the players in the dramatic context become abstracted. The scientist possesses particular facts, but the facts are based on artifacts that are incomplete and must stand to symbolically represent an analogy of the past.

To examine the rhetorical form of networking that the evolutionist explanation takes—a form that is at once scientific in its method and complex in its execution, relying on hard evidence and narrative embellishment, data and imagination, fact and faith—we have to understand science not as a grid, but as a network of information that relies on evidence that resists our impulse to fit it into the ordered categories we construct. We should also understand that evolutionist narratives compete, vying for aesthetic favor by telling the story that is most compelling (while remaining true to the available data—the rules that govern the form), and also how the network functions to provide the explanation that is most in keeping with the existing evidence. We should further understand that the narrative process represents a moment of complexity that supplies inroads into the cultural interchange that must take place to overcome the present impasse between science and the humanities. This impasse need not exist since it is based upon mutual assumptions about the boundaries and insights that separate disciplines place on each other, boundaries that are artificial and constructed because of motives that are more a matter of politics and economics than of the collegial sharing of knowledge.

I have already discussed, albeit briefly, the intellectual history that has brought us to the point where we recognize a need for rearticulating the theoretical framework that has guided us to our present intellectual stalemate. The stalemate is, in many ways, the result of the order/chaos dichotomy that has limited our perspective and placed undue restrictions on our ability to coordinate ideas into what Edward O. Wilson refers to as "consilience" or the "unity of knowledge." But despite the apparently sincere attention Wilson gives to the project of finding a philosophical intersection for science and the humanities, his ambition still leads him to the inevitable favoring of science as the doorway to all significant knowledge. In particular, Wilson moves toward making humanistic enterprises more *scientific* rather than supporting an intellectual climate that recognizes and uses the techniques that both approaches have to offer. He attempts this ambitious project by reducing all knowledge to a select few natural "laws," which, by definition, suggest a compressible set of basic truths. Taylor, by contrast, has truly forged a theoretical path that does not attempt to force square pegs into round holes. Rather, he has recognized that in spite of the apparent differences between science and the humanities there has always existed an implicit understanding that good scholarship embraces complexity—that it recognizes the complication of seemingly simple systems and processes, and that this is done not to carve out academic niches, but because the world is genuinely complex, requiring an internalizing of both the grid and the network.

Biologists are fine examples of this recognition because their discipline is, by its very nature, a study of the networks that make life thrive on this planet. It is no surprise, therefore, that their method should mirror their subject. Even Wilson, whose true area of expertise is ant colonies, sees and understands the validity of the network in an organizational structure so complex. Though Wilson does not explicitly acknowledge his debt to complexity theory, Taylor sees that the ant colony clearly represents the network within the network; whereas a single ant, alive and functioning, is a self-contained network of all the necessary components for life, without its colony—the macro-network of the ant world—its existence is purposeless, futile, and brief. The colony as a whole possesses remarkable intelligence, while individual ants are a part of this intelligence only insofar as they fulfill a specific function to the colony. Someone studying ant colonies must recognize this complex network of interrelationships and describe it. To describe it successfully requires that the network be represented in the description. While the biologist may order the network into successively incompressible parts (workers, queens, soldiers, and the like) the order, only has meaning in relationship to the whole. Science provides the means of classification, but the biologist provides the form of interpretation. The former requires order, whereas the latter requires a complex and imaginative rearrangement of the ordering system to give it meaning.

At the same time, scientists generally tend to favor compression if only for purposes of manageability. Scientists in general, but biologists in particular, intuitively recognize that the "real world" is infinitely complex, and that life is, as it were, "jury-rigged" to adapt to ever-changing, ever-threatening environments. When conditions in a habitat are unique and tenuous, as in, for example, a coral reef, the level of complexity increases to adapt to these surroundings but the level of redundancy does not. That is, the organisms become increasingly specialized to adjust to their surroundings, such that the slightest discrepancy in ideal conditions is fatal to a large number of species.[2] For convenience, biologists often must speak in sweeping terms in order to capture the principle that guides the interpretation of such biodiversity. The imaginative opportunity this provides should not be underestimated or undervalued; the biologist, while operating within the confines of his or her form (an inductive scientific method using ordered scientific categories) must also engage in the creative enterprise of constructing a snapshot of life, a truthful representation of the living network. Without this interpretive dimension, science is truly reduced to counting and cataloging, and the interesting, provocative, and pioneering work of imaginative momentum would never happen.

Paleontologists, even more than other biologists, necessarily have more interpretive license because their text is even more incomplete. Consider, for example, this, from the January, 2003, *Scientific American* on new evidence about the family of Mesozoic creatures called *plesiosaurs*:

> [. . .] long before whales came to preside over the ocean realms, marine reptiles called plesiosaurs were the giants that patrolled the seas. Paleontologists have long sought to understand how these enigmatic beasts, which looked like an ungainly cross between a giraffe and a turtle, captured their prey [. . .] [P]lesiosauromorphs probably cruised leisurely over long distances in search of smaller, less elusive prey. (Wong 31)

I have omitted the physical evidence that leads to this conclusion only for the sake of space; its omission does nothing to diminish the narrative nature of this interpretation, and is, of course, central to it. However, my point is less scientific and more interpretive: the scientist forwarding the interpretation summarized in the *Scientific American* news brief, F. Robin O'Keefe of the New York College of Osteopathic Medicine, has conceived this story on the basis of a fossilized text, an interpretation that understandably assumes an evolutionary complexity that not only would be known to any good paleontologist, but also to any good osteopathic specialist. Through this understanding, the narrative emerges, even though it is, in the strict critical sense, a fiction as fragmentary and inferential as the evidence that supports it. The narrative could only be formed through an overlap between induction based on a linear scientific model and a network of implied meaning based on the requirements of a plausible text. In other words, the story seems possible because it satisfies the requirements of both the scientific standards of the evidentiary process and the literary conventions of the narrative. We can picture the plesiosaur "cruising leisurely" as it "patrols" for food, partly because these are common behaviors among contemporary animals, partly because the data does not contradict this reading, and partly because the narrative structure is in keeping with our expectations. We can also picture its appearance because the author uses the simple strategy of the simile to compare the plesiosaur to a cross between more familiar animals, lending the image credibility and substance.

Another example of this interpretive license, this time from the January, 2003, issue of *National Geographic*, involves *Incisivosaurus gautheri*, a cross between a turkey and a reptile whose "beak" contains what the author, Christopher Sloan, describes as teeth that are "beaver like." This theropod—a group of meat-eating dinosaurs that lived some 128-million years ago, is an enigma to paleontologists because it contradicts the usual pattern of feeding associated with theropods: this one's teeth are designed for plants. According to the article, the fossil of *Incisivosaurus* suggests that "some early theropods experimented with vegetarian diets and occupied ecological niches not generally associated with this group" ("Geographica"). In other words, the narrative needs to be revised, at least insofar as this species is concerned, because it defies the classification system that has already been established. The description of the evolutionary process also personifies tooth-bearing, which it characterizes as "experimenting," a practice that implies deliberate and conscious effort to find the most suitable survival strategy. We know, of course, that the true process is arbitrary, and the characterization is included only for narrative convenience. Without this expository device, however, the import of the discovery might be lost on the reader, and it is likely that even professional paleontologists tend to think in terms of "experimentation" when describing such activities even though they know, intellectually, this is not what such organisms are "really" doing.

The descriptive import of the paleontologist's narrative reveals how the rhetorical form reflects the internal network of the life forms being described. It is easy to see how earlier scientific observers could make the mistake of assigning a teleological explanation to the organic networks they were studying. The rhetorical significance is one where theological ideology overlaps with scientific discovery, an error in perspective that we would do well to understand and have sympathy for. As Taylor points out, evolution has been a theological issue from the beginning, and logic was a convincing way to combat the inconsistencies natural selection exposed about scriptural doctrine: "In response to growing doubt, many theologians attempted to develop rational defenses of religious belief. The centerpiece of this program was the revival and extension of proofs of God's existence" (172). The teleological argument was the dominant favorite among the British, who preferred to challenge Darwin on the basis of the clockwork universe that was so intricate in form and function that its existence must have been the conscious design of an omnipotent Creator. The flaw in this line of argument is subtle, in my mind, but crucial to understanding why we have suffered a humanistic/scientific division, and, by extension, why the Darwinian paradigm shift has evolved so slowly.

As language-using (and, as Kenneth Burke points out, *mis*using) animals, we are, by nature and by culture, "programmed" to understand the world in an orderly fashion. Language is an ordered system, and it fails when its order is breached to the point where identification with other language-using beings is impossible. Given that our conscious minds are enveloped with ordered language systems, we must necessarily interpret everything we experience with the greater or lesser degree of order that gives those experiences linguistic form. In short, we *process* and share experiences on the basis of an ordered system that is very difficult to escape, or, if we do escape it, it is even more difficult to share what we have discovered. The teleological argument presupposes design because we are predisposed to experiencing design through our language systems. It strikes us as impossible that something so perfectly networked in form and function as an orchid could be the result of accident. But our linguistic ordering system, and the mind that it is superimposed upon, does not possess the capacity to understand the time and randomness of evolution *except as a function of imagination.*[3] Darwin's genius was that he was able to tap his imagination in a way that transcended the confines of his ordering system (or penetrated its terministic screen) yet was in keeping with the evidence he observed. Translating this idea back into an ordered language system was his rhetorical challenge.

Note also that even after Darwin had his great flash of insight, his first priority was to order the observational experience in a way that could be both communicable and verifiable. Without these properties, the theory could only exist in his own head. According to Taylor, Darwin had two imaginative "moments of illumination" that were transformed into two already existing systems: the first was the rational idea that "favorable variations would tend to be preserved, and unfavorable ones would be destroyed"; the second was the application of Adam Smith's account of the division of labor (178). Taylor describes the interpretive process this way:

> This genealogy of ideas redraws generally accepted lines of descent in the history of ideas. While the recognition of the ways in which economists have long appropriated evolutionary theory to explain economic processes is widespread, few cultural critics realize the extent to which Darwin's theory is indebted to population studies and economic speculation. [. . .] Populations, like industries and companies, must diversify and specialize to remain competitive. Fitness is not a matter of relative strength but is the ability to adapt and fit into an available niche in the competitive landscape. (178–79)

What this suggests is that, even in the imaginative leap that led Darwin to the theory of evolution, there was a necessary impulse to construct this idea using received knowledge and to report the idea using acceptable paradigms.

The problem with articulating evolutionary discourse, then, is in bridging the gulf between the expectation of order for a process that is not innately ordered without sacrificing clarity and precision in the process. Given these difficulties, it is understandable that the language of evolutionary discourse has been slow to take hold with those for whom the teleological clockwork universe makes the most "sense." This perspective makes sense, however, only within a certain limited proximity to the events that are being observed and described. Paleontologists have been trained—either implicitly or explicitly—to remember that they are only observers after the fact, functioning as evolutionary detectives who must not trust their assumptions about time and order. Yet, these same detectives must construct plausible scenarios that account, as accurately as possible, for the vastness of time and the gradualness of change in terms that have a certain intuitive reasonableness about them while also reflecting the often counterintuitive processes they must describe.[4]

Whereas rhetoricians are trained to think about all language systems that have a bearing on civilized activity, biologists and paleontologists receive no such specific instruction. Yet, the very act of textual interpretation in which they engage demonstrates a willingness to apply, and predisposition toward understanding, complexity, since complexity is reflected in the very life they study. The beauty of complexity theory is that it operates in the large gray area between order and chaos, and this has been an under-appreciated region of study for scientists and humanists alike. While good scientists are intuitively aware of the imaginative impulses of their craft (and a craft it is, for the most successful and pioneering work in science is done by masters of both the methodology and the instinct necessary to make the important discoveries), this ability embraces the very heart of complexity theory. We know this because we can look at the products of the most important science that has been done through the centuries, but it is in the discourse of science that the real manifestation of scientific creativity surfaces, because it is here that we see how people think, what motives drive their thinking, and what discursive perspectives clarify and distort their perception of the world.

Mathew Arnold once said that science provides the means, but humanities provides the "soul," of human activity. Without science, the humanities seems to embark on a long road going nowhere, recycling old ideas for the sake of knowing them, insisting on retaining knowledge without an equal emphasis on making that knowledge relevant; without humanities, science too easily dehumanizes, treating the world and its inhabitants as clockwork mechanisms helplessly knocked about by forces that make our purpose ultimately insignificant. Thanks to Mark Taylor and others who see the need for examining the complexity of our existence, our intellectual, social, and biological purpose is revalidated. One would hope that this is more than merely a trend in academe, but a bona fide resituating of our epistemological future.

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Notes

1. "Theory," in the context of evolution, is a troublesome word. Technically speaking, evolution *is* a theory insofar as it abstracts a large, even overwhelming, process for the purpose of describing both a means and an end in the biology of geological time. It has not yet, that is, been promoted to the status of a "law" like gravity or thermodynamics. Natural Selection, on the other hand, while also not normally referred to as a "law," is directly observable in a way that evolution is not. It describes the stages of the process that, taken as a whole, form species and eventually leads us to the overarching concept of "evolution." Calling evolution a "theory" is problematic because this label is often used by "creationist science" as evidence against both its legitimacy and its consensus in the scientific community, even though there is little debate among scientists about its validity. The claims of disagreement and rift within science are exaggerated, often being totally misrepresented, and are used rhetorically by creationist science to promote the political favoring of one "theory" over another, especially when it comes to teaching these theories in public schools.

2. Anyone who has attempted, as I have, to replicate a coral reef in order to keep marine fish or invertebrates understands the precarious nature of the biosphere that is their natural habitat. I have both a greater understanding of reef conditions and of adaptive structures in general as a result of keeping salt water fish. For success in this endeavor, one must keep a close watch on ammonia, nitrites, nitrates, phosphates, strontium, calcium, iodine, and heavy metals to maintain a safe environment. If any of the key chemical levels deviates even one part per million (ppm), it can be fatal to many fish. Increased stress from imperfect water conditions also leaves fish open to scores of bacteriological, viral, and parasitic threats as well as increasing the growth of nuisance algae. To counter such threats, the aquarist must purchase expensive but vital life-support equipment such as mechanical, biological, and chemical filters, protein skimmers, ultraviolet sterilizers, ozonizers, heaters, and chillers (to say nothing of the testing equipment required to monitor water conditions). In order for the fish to be truly happy, one must also make sure that the lighting is appropriate and reproduces that of the natural habitat in both intensity and duration and take into account the natural ebb and flow of tides and waves through the use of power heads and wave-makers. Oh, yes—the fish and invertebrates must also be fed, some species requiring four or five meals a day consisting of a highly specialized diet of zooplankton, brine shrimp, urchin meat, or other fare that is unique to the species' natural habitat. This example illustrates, I hope, the level of complexity that certain organisms must attain in order to survive, but it also shows the absence of redundancy because the life forms that adapt in these highly specialized ways are, in fact, very fragile. Any change in their environment, no matter how apparently insignificant, is enough to kill some species.

3. The main objection to this claim, no doubt, will be Chomskian, since it is Chomsky who—somewhat paradoxically to the notion of "deep struc-

ture"—denies the evolutionary construction of language. As Dennett notes,

> [A]lthough [Chomsky] insisted that the "language organ" was innate, this did *not* mean to him that it was the product of natural selection. [. . .] The language organ, Chomsky thought, was *not* an adaptation, but [. . .] a mystery, or a hopeful monster. It was something that *perhaps* might be illuminated some day [sic] by physics, but not by biology. (389)

The irony is that, contrary to Chomsky's rather dismissive assertion that language could not be a product of natural selection (though little evidence is supplied in support of this claim), it is difficult to imagine language developing any other way, and it is this marvel of evolution that shielded us from the idea of evolution for so long. The very development of language was a process that necessarily needed to become systematic in order for it to be useful, but this same prejudice for order is what prevented humanity from recognizing its random origins, a history of trial and error that came on the heels of the even greater evolutionary accident of human ascension. This is not to say that the emergence of language *ability* was itself preordained; rather, it makes more sense to conclude that linguistic ability arose as a progressively sophisticated response to environmental needs. Only later would it become more systematized to meet the growing intellect, curiosity, and survival strategies that *Homo sapiens* required.

4. Try to imagine 100 million years. Since it is impossible for humans to have any direct, empirical understanding of such a massive length of time, we are forced to imagine it in relationship to things for which we do have a point of reference. My grandfather, for example, is nearly ninety-six-years old. For convenience, I like to round his age to 100, which would place his date of birth in the year 1904 (something I'm sure he doesn't appreciate). One million years, then, would be the equivalent of 10,000 of my grandfather's lifetimes. Ten thousand is a relatively manageable number until you consider that 100 million years would be the equivalent of one million of my grandfather's lifetimes, and one billion years (roughly twenty percent of the earth's age and, by our best estimation, a mere eight percent of the age of the universe) would be the same as ten million of my grandfather's lifetimes. It is clear, given the imaginative leaps necessary to conceive of these time spans, why people felt more comfortable with an earth closer to 6,000 years, a mere sixty of my grandfather's lifetimes. Those are numbers we can work with.

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