Beyond Darwin Systems Dynamics Issues in Adaptation and Speciation

Dr. Jon C. Cawley, Roanoke College Environment Program, Salem, Virginia

ABSTRACT

Darwin had only the merest physical access to the work of Mendel (which he did not apply to his theory or mechanisms). Nor did he have access to present-day concepts of adaptation, nor of the systems dynamics of Prigogene, the memes of Dawkins, endosymbiontic synthesis of Margulis, or holographic assemblage (as exemplified by Gabor's or Pribrim's work), among other present-day tools. This paper explores a few of the ideas and implications of such 20th Century systems-related concepts which must now advise Darwin's seminal work. In it, we caution against debating Darwin or any other 19th Century scientific work "Chapter and Verse" without depth of more modern contexts. This discussion includes an explorative Systems Dynamics definition of "species" as "a functional (reproductive) set of genetics at dynamic equilibrium within the adaptive context of its local ecosystem." Such a definition implies that a species only exists within the context of its environment, that it must be conserved or examined as an extension of that ecosystem, and that it is only as genetically stable as the controlling parameters of that ecosystem.

INTRODUCTION

The discourse between the doctrine of Creationism and the science of Biology has continued virtually unabated for 150 years, with no signs of a solution, even with the advent of new generations. The difficulty with examining this topic is the polarity demanded within an essentially political debate. For one party, the denial of Darwinian concepts poses as a required article of Faith. Within the second group, genetically-controlled natural selection is the accepted basis of a powerful (and often lucrative) modern biological paradigm. We recognize first that it is a caricatured Darwin which is usually discussed; the issue tends to be simplified to suit those who debate it (i.e. Gish 1992). It is not unusual to hear those who argue creationism or intelligent design say, "we may have no problem with adaptation, but our faith says that Evolution–the accidental, spontaneous change or creation of species, does not happen." Meanwhile, many of the learned biologists who staunchly promote Darwinism might be the samevoices who would push upon us a technology of patented, genetically modified organisms. Science without restraint is profane. In the end, it is control of the popular will which is primarily at stake.

Much of the successful popular argument against original Darwinian Evolution is that it seems to imply a Victorian idea of Orthogenesis, where species progress "upward" through time, from primitive to complex, in a natural order. This would occur in the anthropogenic universe, where human-kind represents the most perfect form. Are you ascended from a mere ape? It is an old button to push.

This is partially the fault of the way we still teach science: A child learns an inanely simple version of a food chain in grade school. In high school, the matter is revisited, and the understanding expands to a food web concept, a more complex, although still fairly simplified approximation of reality. If and when the student pursues an advanced degree, then a more complex and complete study of the interactions of the ecosystem might happen. The majority of trained biologists understand that a modern jellyfish is just as distant through time and development from the Ordovician as is a human. The modern biologist has for the most part abandoned teleology; the Victorian simplification that every jellyfish has an undeniable urge to evolve upward toward being human. (In fact, the jellyfish is better adapted to its own lifestyle and ecosystem than a human would be—the sinking of any modern ship is a good illustration; in general, a human fares about as well when dropped into the deep ocean as a jellyfish does when dropped in the middle of a London street.)

To argue The Origin of Species (Darwin 1859) “chapter and verse” one falls prey to the same flaw by which the 1545 Council of Trent locked the Church into the trap of becoming a medieval authority on modern scientific matters. Scientific notes and papers are never intended to be static, and hardly any scientific document of 1859 vintage is still applied verbatim in the 21st Century. Darwin, basically a descriptive naturalist, says traits are selected for or against by the environment; strong traits survive to breed, weaker ones die and disappear. New traits occur at random intervals. It is recognized here that Darwin didn’t even know about genetics. In fact, it was not until fairly late in the 20th Century that genetics became the over-riding paradigm of how traits, mutation, selection and adaptation occur.

My colleague, Duncan Porter, of the Darwin Correspondence Project points out that in Darwin’s library collection, there still exists Darwin’s own journal copy containing Mendel’s paper on genetic traits of pea plants. Weknow that Darwin read the journal because Darwin always made copious margin notes on papers he read. The issue in question is filled with margin notes, but not, however, Mendel's paper--he apparently skipped it...... it is interesting to realize that Darwin held in his hand Mendel’s work, but seemingly did not perceive its importance or apply it to his work.

Darwin also did not know about dynamic systems, feedback, or cybernetics—concepts not widely known until the late 20th Century. To discuss Evolution in the 21st Century, we must have a basic understanding of how systems dynamics applies to change, complexity, emergence, and selection. Such a discussion begins with the Nobel prize-winning work of Ilya Prigogene. Prigogene “turned the second law of thermodynamics on its head.” The old law stated that energy in the Universe was winding down. All systems became less energetic and organized as entropy took its toll. Creationists asked how Evolution could ‘accidentally’ create complexity, life, or a species, all of which went against entropy, without the direct intervention of God.

Prigogene showed that the physics of Entropy is multi-scalar (Prigogine 1980)—that is, a flow of energy from high to low potential spawns complex systems on more local scales. He speaks of local ordered structures in the sense of the small whirlpools that form along the edge of a canoe paddle in a lake. As the paddle moves, as energy flows, small intensely ordered systems are created. Not occasionally, but consistently—they are stable, and—this is important-- follow certain specific physical laws. Such large and tiny organized “whirlpools” seem to make up the structure of everything, from atoms and matter, to ecosystems—And as long as energy flows through them, they are both Real, and relatively stable. It is this emergent creation of orderly, complex systems which is the wider issue we must take to task.

Well beyond Darwin, we now have scientific mechanisms and guidelines for how complex systems tend to assemble, and also mathematical rules by which they are governed (Minorsky 1962; Mandelbrot 1977; Umez-Eronini 1998). To say that such assemblages are either random or “accidental” is simply incorrect. To invoke inaccessible mysticism is also at this point fairly silly. Let’s pursue this study with scientific analysis. To be fair, however, this may still indeed be a picture of God Creating a Universe from Scratch, which makes it all the more interesting. Dynamic systems are those whose stability and function is autopoetic (in other words, possessing a dynamic equilibrium): much like a bathtub with water flowing both in through the tap and out through the drain--energy is flowing through the system constantly (an "entropy pump" if you like that analogy)--but the state of the system remains relatively constant. If we mathematically look at such a system through time, we can graph and analyze its structure, and measure its stability. Any dynamic system is controlled by two forces: Positive feedback (Novelty), which pushes the system toward its extremes (more water into the proverbial bathtub than normal, or more water out), and Negative feedback (Goal-seeking), which pushes the system closer toward its average state.

A dynamic system, because of the interplay between positive and negative feedback, will always oscillate--or, show a stochastic range through time. The central tendency which is tracked by the system may be considered (in the language of Chaos mathematics) as the system's "strange attractor." If the physical conditions of the system remain constant, then the oscillation will "fine-tune" itself to the strange attractor, and the oscillation can become very consistent, and predictable, with a balanced interplay between Novelty and Goal-seeking. In a dynamically-stable system, the oscillation approaches a natural harmonic which is self-strengthening-- the oscillation of a dynamic system may be considered a resonance phenomenon. The parameters of a given system adapt directly to changes in the energy and resonant stability of their own system—Biological denizens of an ecosystem adapt to changes in the energy and resonant stability of their system as well, and this gives new implication or context to Darwin's concept of "fittest."

The outer boundary of a dynamic system's stable range is called a threshold. Any value which occurs outside the threshold (i.e. when the bathtub is full, and overflows its edge) is no longer controlled by the rules of that system. States pushed beyond the system threshold (by positive feedback) are on their own, and subject to chaotic effects. Such a condition does not wander "outside" for long--it may revert to 'true' equilibrium ("death")--or it may track a different (emergent) strange attractor or central tendency, and regain some new stability under different rules. The concept of "survival of the fittest" might be recast as *"Emergence, tested against Sustainability."* A *sustainable* new trait, species, or sub-system will match or strengthen the resonance of its system, supporting or improving its continuance. An *unsustainable* emergence will either destructively interfere and dampen itself out (negative feedback), or produce constructive interference (positive feedback), overshooting fatally beyond a threshold.(This implication seems poignant when applied to present human endeavors on this planet.)

When genetics are considered as an autopoetic system, the system is controlled by parameters of the local environment or ecosystem ("strange attractor"), including the genetics, social structures, and behavior of individuals. So long as an individual's genetic string, and its behaviors lie within the thresholds of functionality, then it can survive. Goal-seeking suggests, that the closer to the "norm" the more effective survival within the given environment will be. Individuals outside any of the many threshold parameters of the system are potential "monsters" which most often reach equilibrium ("die") or at least do not successfully breed. By generating both inliers and outliers, the population is then tuned by selection for its particular environment. The resulting dynamically-stable system of a genetic sequence, its outward physical expression, its social behavior, its niche, *and* its environment then define a species. Notice that "species" is contextual-- that is, it is only relevant or stable in the context of its given environment. It is the local ecosystem which provides thresholds defining its “fitness” and its survival. Within the system, the species population procreates in a stable way, and its genetic stability should approximate Hardy-Weinberg equilibrium. If you have a creature's genetic material frozen in liquid nitrogen--or only a set of individuals in a cage, you do not, cannot have a species--outside of the context of its environment. This also implies that in wildlife and biodiversity conservation, it is necessary to address the specific ecosystem along with the species. Otherwise, the species is not a species, and is not *"saved"* at all.

I am told by Aaron Conrad (formerly of the National Cheetah Preserve in Namibia) that if you take a breeding population of cheetahs from the grasslands, and put them into a zoo, some large number of them, perhaps 80%, will die of cirrhosis of the liver. Running and activity is how they maintain liver function. If the surviving ones breed, in the next generation fewer of them will die, perhaps 40%. And in the third generation very few would die of liver problems—the problem is being selected out. However, supposedly, if you release those individuals into the wild, the third generation apparently cannot run well either. In this hypothetical example, it has taken only three generations for the cheetahs to begin "looking like" their new cage. It can be argued that these are still cheetahs, members of the species because they may still breed with each other, and because they still look to our eye like "a cheetah." Their genetic string after only three generations is very similar. But --is a cheetah who cannot run still a ‘significant’ cheetah—that is, would it survive or breed in its original habitat, or would it be quickly selected out instead?

Only when the ecosystem itself changes significantly will the entire population begin to adapt and shift to match the new environmental circumstance. And only when that shift is genetically significant (enough to preclude breeding with other populations), and stable, might we choose to recognize the population as a new species. The rate and tempo of such changes are assumed to be controlled by slow (or more rapid) environmental changes across geologic stretches of time (i.e. McLean 1991). This is likely the pattern recognized in Niles Eldredge and Stephen Gould's punctuated equilibrium (Eldredge and Gould 1972; Gould 1980). Such breaking of a resonant pattern, short re-adaptation, and re-establishment of a different stable pattern should produce a "punctuated" change, in the sense of Gould.

Richard Dawkins recognizes that ideas also are emergent, are systematic in nature, and are capable of moving through and affecting a population in adaptive ways similar to genetic factors. Dawkins refers to these, emergent, virus-like ideas as ‘memes’ (Dawkins 1976). Such memes begin as an emergent trait of an individual, and are then communicated to other members of the population. If the meme is useless or indifferent, it is soon damped out. If the idea triggers unwarranted positive feedback, it becomes unstable and unsustainable, and also quickly runs its course. If the meme turns out to be stable and sustainable, then the idea is adopted by the majority. With time, the meme becomes ubiquitous social behavior, and eventually acts as a system parameter which may eventually help direct physical or genetic expression of the group.

A population of organisms dropped into a new ecosystem begins a game of “Survivor.” In the first time period, the individuals must simply survive to see the next day. Having accomplished this, the surviving individuals must then develop behaviors which allow them to interact with their ecosystem—to feed themselves, find shelter. These experimental behaviors move quickly into the realm of memes—the individual and the group learn from both spectacular successes, and spectacular failures. As the socialization process continues, the memes take the form of a) strategies, and b) heuristics. Briefly, heuristics are behavioral shortcuts which become programmed responses because they are useful in a majority of situations encountered. (If a large shadow falls over you in the jungle, Scientific Method would say to discover if the large shadow was friend or foe, and then to react accordingly with either greeting or flight—the heuristic says, “jump first, and worry about the identification later.”) Very often, a good heuristic means that one consistently survives to another day.

In the next period, the group must reproduce. A second generation is born and raised in the new environment—educated within the experience of the group: while the first generation is always an outsider, the second generation has already begun to adapt socially and behaviorally to look like its new cage. In short, it has adopted a useful set of memes upon which to build and expand. A third or fourth generation becomes more and more finely-tuned to the local ecosystem. In a few generations the genetics of the group has already begun to be physically selected for specific traits—and over a very long term, perhaps the social behavior or the physical drift of the local group may preclude it from breeding with outside parties—here is traditional divergent evolution, although with a behavioral component.

Now, if a number of discrete real-time individual systems interact, they do so complexly, acting as additive positive or negative feedback in a larger scale system. That is, the effects of individual sub-systems act to produce interference patterns, or *causal loops.* These patterns are observable, contain specific information, and are recordable. All physical science is based on such observations, followed by attempts to deduce causal mechanisms. In this way earth systems interact within the earth's atmosphere to produce climate (Morowitz 1979). In the same way, cells interact to produce tissues, tissues to organs, organs to organ systems, and organ system to an organism (and organisms to a cultural group). Complex interacting systems produce holographic effects and outcomes. This term, "holographic" deserves special attention: A hologram consists of light energy flowing through a film with information preserved on it (Wenyon 1978). The interference patterns between individual light rays (via positive or negative feedback) produce a 3-dimensional image. The hologram is based upon Nobel Prize winner Dennis Gabor's theory about interference patterns. Gabor theorized in (Gabor 1948) that each crest of the wave pattern contains the whole information of its original source, and that this information could be stored on film and reproduced.

What is most interesting about a hologram is that the image produced contains more information than does the film it is recorded on—by orders of magnitude in some cases. Additionally, one can analyze the film quantitatively without finding the image physically in the film. The reality of the image ONLY exists in the context of energy flow through the system. Mathematically this is something of a paradox—the seeds of a miracle, if you so wish. There is a scalar or geometrical disconnect between the subsystems and the final result: The product is emergent, due to complex combinations of positive and negative interference: it is more than the sum of its parts.

According to the present scientific paradigm, evolutionary changes in traits stem from random, or accidental mutations of genes; incomplete transcription, faulty encoding, physical damage or irradiation. Creationists object to such "accidents" being at the root of physical change. They also point out that theoretical mutation rates are not high enough to account for the biodiversity we see in the world. This is probably true, but it also relies on a simplification. We now know that the genetic code is neither so rigid nor so complex as science once thought. It is *emergent* interactions between genes that cause traits. And we now know that viruses and bacteria recombine and alter genetic materials (Rokyta, et. al 2006) at prodigious rates. Even partial pollination between plant species is now known to allow genetic materials to slip between species gene pools (Heinemann and Traavik 2005). The larger genetic mix –with its causal loop interactions and interference patterns is proving to be both emergent and exceedingly dynamic. And these alterations are partially or wholly decoupled from simple theoretical rates of 'accidental' mutation.

Science is good at dissecting the "photographic film" of reality. But it is such scalar disconnects which often leave the intelligent layman to find scientific explanations unsatisfying. Faith senses that the hologram effect is real and important by its own right. A miracle might be defined as (awe- inspiring) transcendence across holographic scales, where the whole is more than the sum of the parts. Here we finally begin to have the language to recognize that a concerto is something of a miracle that goes much beyond its individual musical notes played on a keyboard.

As the great ecologist Eugene Odum used to say, "How many bees does one have to dissect to find the hive?" And the answer is that you can dissect all of them, and still never find the hive, because it exists on a different *level* of organization. Even though each bee has individual behavior and apparent free will, the hive actually occurs and behaves on a different, and somewhat decoupled level. Swarm Intelligence is now seen as a viable algorithm for finding best-case solutions to certain kinds of design problems, based mathematically upon natural behaviors of bee and ant colonies (Kennedy and Eberhart 2001; Gray 2006). Here search behaviors are governed by very simple heuristic rules—the individual "bee" or "ant" program follows very simple mathematical rules of novelty and goal-seeking. Darwin-like selection is used to winnow unsuccessful solutions from the hive, while "winning" solutions are rewarded. The algorithm, however does not work successfully when only "survival of the fittest" is invoked—optimal progress is made only when there is a healthy component of exploration and novelty. The solution is always an emergent one, dependent on all members of a population interacting dynamically with themselves and their environment.

One of the most interesting applications of a holographic approach is by Karl Pribram, formerly of Radford University in Virginia, now at George Washington University. His holographic theory of mind (Pribrim and Wilber 1982) asks how many neurons, or how much genetic DNA does Science have to look at or dissect to find the mind or the soul? And the answer is, none of them, or all of them. The trans-substantiation lies in the interactions.

We must also include in this mix Lynn Margolus' idea of endosymbiosis, in which the eukaryotic cell is posited to be a multiple symbiont composed of one or more prokaryotic hosts (Margulis 1991, 1998). which eventually became mutualistic with other prokaryotic entities, each with varying skills, varying genetics, and varying attributes. Within the new eukaryotic "community," a bluegreen alga merged to become a symbiotic chloroplast; a spirochete became a symbiotic flagella; an energetic prokaryote became a symbiotic mitochondria. The interactions among members of this community lead to a very different, eukaryotic cell. One with holographically-emergent properties. If the eukaryotic cell is recognized as emergent, then there are profound implications yet to be recognized about the simple "fitness" and selection of its individual precursor components (Dyer and Obar 1994). Even the single-point origin of life, seen in this light, is not necessarily unassailable.

Our paper has explored some of the systems-related concepts which must now advise Darwin's original work. Our discussion includes an explorative Systems Dynamics definition of "species" as "a functional (reproductive) set of genetics at dynamic equilibrium within the adaptive (and holographic) context of its local ecosystem." Such a definition implies that a species only exists within the context of its environment, that it must be conserved or examined as an extension of that ecosystem, and that it is only as genetically stable as the controlling parameters of that ecosystem.

"Emergence is tested against Sustainability."

*****

REFERENCES

Darwin, Charles. 1859, 1923 reprint. On the origin of species by means of natural selection: or the preservation of favoured races in the struggle for life. New York, London: Humphrey Milford, Oxford University Press.

Dawkins, Richard. 1976, 1989. The selfish gene. London: Oxford University Press.

Dyer, Betsy and Robert Obar. 1994. Tracing the history of eukaryotic cells: the enigmatic smile. New York: Columbia University Press.

Eldredge, Niles, and Stephen Gould. 1972. Punctuated equilibria: an alternative to phyletic gradualism. In: Models in paleobiology. T. J. M. Schopf, ed. San Francisco: Freeman, Cooper and Company

Gabor, D. 1948. A new microscopic principle. Nature 161:771.

Gish, Duane. 1992. Dinosaurs by design. Green Forest, AR: Master Books. Gould, Stephen. 1980. The Panda's Thumb. New York: W.W. Norton Co.

Gray, Adam. 2006. Swarm intelligence optimization: techniques and applications. Salem, VA: Roanoke College Honors Thesis.

Heinemann, J., and T. Traavik. 2005. Problems in monitoring horizontal gene transfer in field trials of transgenic plants. Nature Biotechnology 23 no.4: 1105.

Kennedy, James and Russell Eberhart. 2001. Swarm Intelligence. San Francisco: Morgan Kaufmann Publishers.

McLean, Dewey. 1991. A climate change mammalian population collapse mechanism. In Kainlauri, et al., eds., Energy and Environment. Atlanta, GA: ASHRAE.

Mandelbrot, Benoit. 1977 The fractal geometry of nature. New York: W.H. Freeman and Company.

Margulis, Lynn. 1991. Symbiogenesis and symbionticism. In L. Margulis and R. Fester, eds., Symbiosis as a source of evolutionary innovation. Cambridge, MA: MIT Press.

Margulis, Lynn. 1998. Symbiotic planet: a new look at evolution. New York: Basic Books. Minorsky, Nicholas. 1962. Nonlinear oscillations. Princeton: D. Van Nostrand Company, Inc. Morowitz H. 1979. Energy flow in biology. Woodbridge, CT: Ox Bow Press.

Pribrim, Karl and Ken Wilber, ed. 1982. The holographic paradigm. London: Shambala Press.

Prigogine, Ilya. 1980. From being to becoming: the new science of connectedness. New York: W.H. Freeman.

Rokyta, D., C. Burch, S. Caudle and Wichman, H. 2006. Horizontal gene transfer and the evolution of microvirid coliphage genomes. Journal of Bacteriology 188, no. 3: 1134-1142Umez-Eronini, Eronini. 1998. Systems dynamics and control. Pacific Grove: ITP/Brooks/Cole Publishing Company.

Wenyon, Michael. 1978. Understanding holography. New York: Arco Publishing Company.