

Relevant excerpts from:

Life of faith, life of science

*William T. Newsome, Ph.D.
Professor of Neurobiology
Stanford University School of Medicine
Stanford, CA 94305*

Correspondence to: bill@monkeybiz.stanford.edu

Evolution and the “Imago Dei”

The scientific discovery that has proven most contentious in certain religious and scientific circles during the past century has been Darwin’s theory of evolution by natural selection. At first glance, the central Darwinian vision of the gradual and unpredictable evolution of life (through the interaction of random biological variation and selective environmental pressure) appears to be at odds with the biblical assertion that God created human life intentionally in his image. How can a process that depends on chance and is fundamentally unpredictable be an intentional, creative act of God?

I would argue first that dependence of a process on random events does not speak to the matter of intentional creation one way or the other. The use of random events is sufficiently important in modern scientific investigation that the design of computer algorithms for generating random numbers has become a high art. Random, or probabilistic, events are intentionally harnessed for scientific purposes in innumerable contexts, including the rapidly emerging field of quantum computing. There is no deep contradiction between the evolutionary mechanism of chance mutation and the religious notion that God intentionally created human life.

Secondly, we must be clear concerning what, exactly, is “unpredictable” about evolution. What biologists generally mean by this is that evolution is, in the words of Stephen Jay Gould, highly “contingent.” A specific random mutation in one species in a particular environmental context can have a major impact on survival and thus on the future development of entire ecosystems in the future. The identical random mutation occurring in another species or in the same species in a different environmental context, however, may have little or no impact on survival and the ensuing configuration of species in the environment. The potential interactions between chance mutation, environmental pressure and individual survival are so numerous and complex as to constitute a system whose future states are impossible to predict. Gould argues that contingent events exert such an enormous effect in evolution that if we were able to rewind the history of the earth to a point, say three billion years ago, and let history unwind all over again, it is grossly unlikely that a creature exactly like *homo sapiens* would emerge—a predator

with frontally directed eyes, bilaterally symmetric body plan, and a central nervous system organized on the current mammalian configuration.¹

Two aspects of Gould's argument deserve comment. First, the scientific evidence itself provides grounds for doubting the argument. The counterargument has been made particularly forcefully by the Cambridge paleontologist Simon Conway Morris who changed his original views, which were similar to Gould's, after life-long study of the fossil record of the Cambrian explosion.² Succinctly, Morris is far more impressed by the "convergence" that occurs within evolutionary history than by "contingency." Morris argues that certain body plans and adaptive features (particular points in the entire space of possible animal morphologies) recur independently in evolution with sufficient frequency that they must be regarded as uniquely adaptive to life on this planet. For example, Morris cites the fact that dolphins, which have evolved from dog-like mammals, are shaped similarly to fish because there is an optimal shape and strategy for moving through water.³ Thus, Morris argues, if the tape of evolution were to be rewound and allowed to play out again, it is likely that these evolutionary "solutions" to the challenge of living on earth, or very similar ones, would emerge once again.

Since the critical experiment that could resolve this issue is impossible to perform, we may never know the actual answer. From a religious point of view, however, arguments about physical morphology are not critical. The important question is what it means to be created in the "image of God." Is God a visually directed predator with a bilaterally symmetric body plan and a mammalian central nervous system? I doubt it. Rather, the religious insight of Genesis is directed toward the emergence of a creature with intelligence, with sensitivity to right and wrong, and with the freedom to choose between them. Would such a creature likely re-emerge if the earth's history were rewound by three billion years, even if its physical appearance were extremely different from *homo sapiens*? I, along with Conway Morris, think that the answer is yes. My view on this matter might be chalked up to religiously motivated wishful thinking, but ironically, I claim as my ally the noted evolutionary theorist Richard Dawkins, certainly no friend to religion. In his book, *The Blind Watchmaker*, Dawkins states:

My personal feeling is that once cumulative selection has got itself properly started, we need to postulate only a relatively small amount of luck in the subsequent evolution of life and intelligence. Cumulative selection, once it has begun, seems to me powerful enough to make the evolution of intelligence probable, if not inevitable.⁴

These are strong words, but my gut feeling is that Morris and Dawkins, who appear to be in essential agreement on this point, are correct. The selective advantages of advanced intelligence are so vast that its emergence in this particular universe, which itself appears uniquely hospitable to life, may indeed have been inevitable once the evolutionary process was started. In this sense, then, the emergence of intelligent, morally responsive life can reasonably be thought to have been an integral feature of our universe from its inception. Certainly no scientific findings argue compellingly against this point of view. As Kenneth Miller has eloquently argued in his recent

¹ S.J. Gould, *Wonderful Life: The Burgess Shale and the Nature of History* (Norton: New York, 1989)

² S.C. Morris, *The Crucible of Creation: The Burgess Shale and the Rise of Animals*. (Oxford University Press: Oxford)

³ See the fascinating exchange between Morris and Gould, "Showdown on the Burgess Shale", available at www.stephenjaygould.org/library/naturalhistory_cambrian.html.

⁴ R. Dawkins, *The Blind Watchmaker* (W.W. Norton: New York, 1987), p. 146 (page number is from the 1987 paperback edition.)

book,⁵ evolution, properly understood, is no enemy of religion. Despite the continued objections of a vocal minority, most Christians do not see evolution as major point of dispute between science and religion. As Richard Dawkins has observed, the emergence of the theory of evolution in the 19th century “made it possible to be an intellectually fulfilled atheist”⁶. It had relatively little effect, I think, on the possibility of being an intellectually fulfilled theist.

Human freedom

A central tenet of Christianity and most other religions is that human beings have a meaningful degree of freedom to make moral choices. We can make loving, divinely inspired choices in how we interact with others, or we can act in ways that are utilitarian, exploitative, or at worst overtly hateful. The issue of human freedom is an increasingly vexing point of tension between religious and scientific world views. What are we to make of human freedom when, from a scientific point of view, all forms of behavior are increasingly seen as the causal products of cellular interactions within the central nervous system, which themselves are substantially influenced by the toss of genetic dice that occurred when each of us was conceived? To frame the issue in an everyday context, can I really choose to have fish or chicken for dinner this evening, or do events already in motion reduce me to a predetermined course of action? More disturbing yet, if our sense of choice is illusory, can anyone reasonably be held responsible for his or her actions?

The issue of human freedom is a tricky one. Some modern thinkers find refuge from strict determinism in quantum mechanics, which describes events probabilistically rather than deterministically. While quantum mechanics does imply that we live in a fundamentally unpredictable world, I am not yet convinced that it offers substantial insight into human freedom. Quantum mechanics can establish probabilities for the occurrence of specific events, but within the constraints of those probabilities events occur randomly. It is not clear to me that randomness provides an understanding of human freedom that is any more meaningful than that of strict determinism.⁷ Our intuitive understanding of human freedom is that we have some meaningful degree of *self-determination*. While we are certainly influenced by random events (in the quantum mechanical sense) and by strictly determined events (in the Newtonian sense), we are at the complete mercy of neither.

⁵ K.R. Miller, *Finding Darwin's God* (HarperCollins: New York, 1999). Miller's excellent book provides a detailed critique of the uses and abuses of the theory of evolution by conservative Christian creationists on the one hand, and a scientific establishment that largely adheres to an ideology of reductive materialism on the other.

⁶ R. Dawkins, *The Blind Watchmaker*, p. 6.

⁷ A deeper argument for the relevance of quantum theory to the notion of human freedom is provided by Henry Stapp (see H.P. Stapp, *Mind, Matter and Quantum Mechanics*, Springer-Verlag, Berlin, 1993). In a nutshell, the argument is that quantum theory, which is our most sophisticated and far-reaching physical theory of the universe, requires the existence of an "observer" to ask questions of nature (i.e. to pose experiments) who lies outside the causal system of physics. Because the observer lies outside the causal system described by the wave equations of quantum mechanics, the observer is free of constraints in a manner that conforms to intuitive ideas of human freedom. I am intrigued by this argument because it appears to be profoundly required by the best available physical theory of the universe, but the biologist in me finds it difficult to swallow. For the biologist, the "observer" asking questions of nature cannot lie outside of nature; she/he is a human being who operates wholly within the natural system of life on earth. The nagging suspicion of the biologist is that quantum theory (or at least some prevailing interpretations thereof) just doesn't have it right yet!

Some of my scientific colleagues seem to feel that the notion of human freedom must be tolerated as a practical matter in order to maintain a functioning society, but that human freedom is likely to prove illusory in the final analysis. Brains are extremely complex neurochemical machines, and their behavior will ultimately be understood in the same mechanical terms that any other machine is understood. While notions of human freedom are convenient, and probably even necessary to get along in everyday life, our subjective experience of freedom itself is no more than the result of machine-like activity within specific regions of the central nervous system.⁸

What this point of view fails to realize, however, is that the sense of human freedom is just as important for scientific understanding as for everyday understanding of the world. Thorough-going determinism becomes entangled in profound logical difficulties in science no less than in everyday life. J.B.S. Haldane put the matter succinctly:

If my mental processes are determined wholly by the motions of the atoms in my brain, I have no reason to suppose that my beliefs are true...and hence I have no reason for supposing my brain to be composed of atoms.⁹

Haldane's point is that the entire enterprise of science depends upon the assumption that scientists have freedom to evaluate evidence rationally and make reasoned judgments about the truthfulness of particular hypotheses and results. If, however, the scientist's rational judgments, and his beliefs about the validity of the scientific method, simply reflect an inevitable outcome of the atomic, molecular and cellular interactions within a particular physical system, how can we take seriously the notion that his or her conclusions about the world bear any relation to objective truth? (Ironically, the ardent determinist becomes an intellectual bedfellow of the ardent deconstructionist.) And if we cannot believe that the scientific approach leads to some approximation of truth, how can we take seriously the scientifically based assertion that mechanical determinism is the correct way to think about the world? The attempt to adopt a thorough-going determinism is like sawing off the limb of a tree upon which one is sitting; the result is intellectual freefall.

Like it or not, then, achieving a meaningful understanding of human freedom is profoundly important for science, for society, and for each individual person. We are all aware that our freedom is quite sharply limited. I am not free, for example, to play the violin like Itzhak Perlman or basketball like Michael Jordan. My freedom is limited by my biology—by the biology of my central nervous system no less than by the biology of muscle and bone. The remarkable studies of “identical twins raised apart”¹⁰ emphasize the pervasive influence of our genetic composition on surprisingly varied aspects of behavior from basic temperament to small behavioral tics; we are not free to escape many aspects of our genetic heritage. Nevertheless, our subjective experience, the mores of responsible living within a society of other persons, and the enterprise of science itself all suggest (demand?) that we have a meaningful degree of personal

⁸ But as Charles Jennings has observed, throw a rock through the living room window of the most reductionistic neurophilosopher and you will probably find out just how quickly the dispassionate notion of behavioral determinism evaporates! (Editorial, *Nature Neuroscience* 1:535-536, 1998)

⁹ J.B.S. Haldane. *Possible Worlds*. (London: Transaction Publishers) p. 209.

¹⁰ See, for example: K.S. Kendler, “Twin studies of psychiatric illness: current status and future directions.” *Arch. Gen. Psychiatry* 50:905-915, 1993; G.E. McClearn, B. Johansson, S. Berg, N.L. Pedersen, F. Ahern, S.A. Petrill and R. Plomin. “Substantial Genetic Influence on Cognitive Abilities in Twins 80 or More Years Old.” *Science* 276:1560-1563, 1997.

choice and freedom within the constraints of our biology. Understanding how that freedom, or self-determination, arises from the central nervous system should ultimately be a primary goal of the neuro-behavioral sciences.

A compelling answer to this question does not appear to be close at hand, but I suspect that success will ultimately lie in a deeper understanding of emergent behavior within complex systems. This is a somewhat slippery concept and has been used in different ways by different authors. By “emergence”, I mean that complex assemblies of simpler components can generate behaviors that are not predictable from knowledge of the components alone and are governed by logic and rules that are independent of, although constrained by, those that govern the components. Many authors have cited examples of emergent behavior, a favorite example being the unicellular organism. The existence of unicellular organisms permits an enormous number of new phenomena that could not be predicted from knowledge of macromolecules alone and that operate on principles that go well beyond those that govern macromolecules: cellular motility, foraging for resources, competition with other organisms, and adaptation to environmental pressure by means of mutation, to name but a few. Each of these phenomena must be identified and described in-and-of-themselves, and their internal logical rules worked out, before rigorous links can be made to lower level mechanisms.

It is critical to be very clear on one point: the concept of “emergence” does not imply magic or mysticism.¹¹ As far as we know, nothing about the life of unicellular organisms violates the laws of physics or the chemical laws that govern the behavior of macromolecules. The cell cannot behave in any way that is not permitted by the lower levels of organization of its constituent parts; the behavior of the cell is thus *constrained* but not *determined* by the lower levels.

Obviously, the crucial distinction here is between the words “constrained” and “determined.” This distinction comes into clearest relief for me when considering the operation of the computer program that is running right now on my laptop computer. If I want to understand how Microsoft Word operates, I can tackle the problem at the mechanistic level of transistors, resistors, capacitors and power supplies, or I can tackle the problem at the level of the software—the logical instructions that lie at the heart of the process of computing. It seems clear to me that the most incisive understanding of Microsoft Word lies at the higher level of organization of the software. One wants to understand the logical relationships that comprise

¹¹ My discussion here will search for an understanding of human freedom that does not postulate brain events that violate known physical principles. More than anything else, this reflects my biological intuition that the human brain, as a product of the natural evolution of the universe in general and life on earth in particular, will generally operate in a manner consistent with (i.e. constrained by) known physical laws. As a theist, however, I do believe in the existence of a nonphysical being (God) who created and sustains our orderly physical universe. As a Christian, I believe that very special events, probably involving exceptions to known physical law, occurred in the life of Jesus. Nevertheless, my working assumption is that the normal functioning of the human brain does not involve such events and that a proper understanding of human freedom must be sought within the overall picture of nature that conforms to known physical law. Although it is certainly conceivable, and perhaps likely, that that some aspects of human and animal consciousness will never be satisfactorily understood from the point of view of the reductive sciences (see, for example, T. Nagel, “What is it like to be a bat” *Philosophical Review* 83:435-450, 1974), one doesn't want to throw in the towel until absolutely forced. If Copernicus and Galileo, for example, had shrugged their shoulders and accepted contemporary theological explanations of celestial motion, progress in understanding our solar system would have been severely stunted. As many writers have pointed out, eager acceptance of extra-physical accounts for a particular phenomenon is “giving up” from a scientific point of view, and it is far too early in the history of neuro-behavioral science to entertain the thought of giving up.

computation: for-loops, if-statements, and the like. The logic of the computation exists independently of the physical system of electronics that make up the computer (the software can be transferred to another computer) and operates according to its own rules that cannot be predicted from knowledge of the hardware alone. Again, nothing magical or mystical is occurring here. The software is constrained by the hardware; the software cannot abrogate the laws of physics nor the principles that govern the behavior of electronic circuits. Nevertheless, the behavior of the computer as I type this manuscript is *determined* at a higher level of organization—the software—not by the laws of physics or the principles of electronic circuitry.

Although this computer example emphasizes the critical distinction between “constraint” and “determination”, it is *not* an example of emergence because the software did not evolve from a natural process of self-assembly but was designed by human programmers. A better example of emergence in the computing world lies in the relatively new field of neural networks. In a neural net, multiple layers of “neuron-like” computing units are linked to each other in a hierarchical manner such that the behavior of units in each lower layer influences units in the next highest layer. The influence of any given lower level unit upon units in the next higher level is governed by a set of “weights” that determines the effectiveness of the link between each pair of units. In the initial state of the network, the weights governing the many links are chosen randomly. An input is then provided to the lowest level of the network, and an output emerges at the highest level. A “teacher” (a software entity) recognizes whether the actual output is similar to the desired output (the correct answer) and adjusts all of the weights of the links between computing units accordingly. After many iterations of the input-output-adjustment cycle, the network “learns” to produce the correct output for a given input.

Neural networks can perform remarkable feats that are extremely difficult to accomplish by traditional computing methods which employ mathematically precise algorithms specified by a programmer. Some of the most impressive examples lie in the arena of voice and character recognition and in the arena of robotics. Yet a remarkable intellectual quandary is often encountered in the neural network field: a network can be trained to solve a fiendishly difficult problem, and in the end, the human operator who designed the network and orchestrated the training procedure may have little or no insight into *how* the problem has actually been solved! The scientist can show us the final pattern of weights between the individual computing units that somehow embodies the solution, but we frequently remain embarrassingly ignorant concerning the algorithmic principle(s) the network has “discovered” in solving the problem. A close colleague of mine at Stanford refers derisively to these networks as “know-nothing networks” because at the end of the exercise, the scientist still may not *understand* the solution that has been achieved.

This example comes closer to the meaning of emergence. We *do* understand the physical principles by which the neural network operates. We know all about the electronic components of the computer, the software that specifies the neural network model, the learning procedure that enables the network to “solve” a problem, and the connection weights that comprise the final state of the network. Yet a higher level of organization emerges within the network during the “learning” process that goes beyond connection weights. We *must* understand this higher level of organization, which involves formal computational logic, to be intellectually satisfied with the result. This higher level of organization has its own rules and logical integrity that must be grasped in-and-of-themselves. Although the higher level behavior of the network is certainly constrained by the lower level hardware and software (there is no magic involved), analysis of the lower levels alone does not produce insight that comprises *understanding*. One might even

argue that the network, by virtue of its learning rules and its ability to interact with its environment, is "free" in some sense to discover solutions to problems and to make judgments about its environment independently of guidance from the human programmer!

I do not wish to push the neural net analogy too far in the context of a discussion of human freedom. Certainly one may still consider the interaction of the neural net with its environment to be a quasi-deterministic system at a larger scale. Nevertheless, the central point remains: an entity that is capable of interacting with its environment and *learning* as a result of the interaction, can enter into novel realms of operation—or existence—that transcend (are not encompassed or determined by) the lower levels that define its constituent parts.

The human brain, of course, is infinitely more complex than our most sophisticated network models, and it seems inevitable that the emergent (or transcendent?) properties of the human brain will be substantially more sophisticated and surprising than those of neural networks. Although my examples of emergence are at best heuristic in the current context, my hunch is that this is the general arena in which a deeper understanding of human freedom will ultimately develop. I am not optimistic about being around to witness this "new emergence" personally. Genuine progress toward this level of understanding of the human person, as well as its implication for the spiritual quest, will be measured in decades or perhaps centuries, not in years. If we still have difficulty identifying the higher order principles "discovered" by artificial neural networks, how much more challenging will it be to discern those "discovered" by the unfathomably complex networks within the brain? In the meantime, however, I continue to believe steadfastly in the reality of human freedom, and in the integrity and responsibility this freedom bestows upon each person, upon society, and upon science itself.

.....

Emergent behaviors of even simple learning systems are often surprising and deeply perplexing, yet they can "get in touch with" realities whose deeper foundations we struggle to discern long after we accept the validity of the behavior. Thus "emergence" becomes a pivotal concept for interpreting the reality of human life in all its complexity, from scientific endeavor to personal morality to religious understanding. Although emergence is a notoriously difficult phenomenon to study rigorously, few areas of study are likely to prove as intellectually and practically consequential in the long run.