Darwin and the Origin of Life: A historical perspective

Tutorial by James Strick, February 21, 2003

What is life? Is it "the assemblage of the operations of nutrition, growth, and destruction," as Aristotle thought? Or is it "organization in action," as French physician and biologist François-Xavier Bichat defined it? Or might it be "…the continuous adjustment of internal relations to external relations," as the British philosopher and sociologist Herbert Spencer believed?

Science historian James E. Strick has studied how scientists have struggled to define life and explain its origin ever since Darwin produced his path-breaking book, *Origin of the Species*, which in 1859 set forth his theory of evolution. Strick, a Visiting Assistant Professor of Science, Technology, and Society at Franklin and Marshall College, spoke at a NASA and Templeton Foundation sponsored workshop, "Origin of Life," hosted by the Dialogue on Science, Ethics, and Religion of the American Association for the Advancement of Science.

Rather than focus on the vociferous arguments of Darwin's critics, however, Strick has closely examined the debate that took place among Darwin's supporters. "We expect a story about the new evolutionary science to include much heated objection from religious quarters," he said. "But a look at how divisive the issue was among the Darwinians themselves is an even more complex and enlightening story."

Darwin was not the first to develop a theory of evolution. More than 50 years before him the French zoologist Jean-Baptiste Lamarck proposed that the various species had not been created in their current forms all at once, as was commonly believed, but had evolved through time by natural processes. He also embraced the principle of spontaneous generation propounded by Aristotle: Living things came into being directly from nonliving matter. Lamarck supposed this occurred on a minute scale unobservable to human eyes.

Although Lamarck's theory was never widely accepted and was later proven wrong, it did influence Darwin's early mentor, Robert Grant, and fueled an ongoing controversy about spontaneous generation among scientists of Darwin's generation. For example, William Benjamin Carpenter, a professor of physiology at the Royal Institution of London, rejected spontaneous generation, arguing that nonliving matter could never organize itself into living matter except through the agency of other living matter, that is, if dead matter is consumed by a living organism and thereby transformed into living matter as that organism adds to itself. Yet because Carpenter's argument relied on a qualitative difference between what he called "vital" and nonliving forces, Strick said, it had an unexpected effect on the life sciences that Darwinist theory had inspired. "[Carpenter's arguments] seemed to prove an absolute, uncrossable divide between the living and nonliving worlds, leaving no alternative but a supernatural explanation for the first origin of life on Earth."

That was perfectly acceptable for a religious man like Carpenter, but other followers of Darwin, including T.H. Huxley and his protégé Henry Charlton Bastian, were anxious to banish from science all supernatural explanations for the origin of life. Bastian conducted a series of laboratory experiments that he thought showed cells emerging in a few short days from nonliving starting materials. By 1870 he had claimed to have generated experimental proof for spontaneous generation—and to boot, argued that this work offered important support for Darwinian theory.

Bastian's announcement forced the question of the naturalistic origin of life to its logical extreme at a time when the public was deeply divided and sensitive about the issue. Conservative Christians had from the beginning been suspicious of Darwinism, which to them implied that life had come about through nature, thereby eliminating any theoretic need for a Creator God. Bastian's claims provided new fodder for their fears—and created difficulties for many liberal Christians who, until that time, had sought an accommodation between the new evolutionary science and their religious beliefs.

Darwin himself wanted not to alienate liberal Christians, noted Strick. In the first edition of *Origin of the Species*, "…Darwin went out of his way, even misrepresenting his own views on life's origin, to use language that gave these readers some breathing room." Only one scant passage from Darwin's book even addressed the question:

> …I should infer from analogy that probably all the organic beings which have ever lived on this earth have descended from some one primordial form, into which life was first breathed.[1]

In the book's second edition, Darwin strengthened this statement by adding "by the Creator" to the end of the sentence. (He took out the entire last phrase in the book's third edition but never publicly offered in any later editions a more specific comment about how the "one primordial form" had arisen.)

Notwithstanding the comfort Darwin's studied vagueness about life's origins offered them, many liberal Christians took alarm at Bastian's 1872 book *Beginnings of Life*. Frederick Barnard, the president of Columbia University, wrote at length about how he had found Bastian's book so convincing that he felt forced to *choose* a universe with a Creator God over the godless universe of Darwin. A short excerpt reads:

> Much as I love truth in the abstract, I love my hope of immortality still more; and if the final outcome of all the boasted discoveries of modern science is to disclose to men that they are more evanescent than the shadow of the swallow's wing upon the lake,…give me then, I pray, no more science."[2]

"The reaction of Barnard and others like him can only have confirmed for Darwin how important his original choice had been to keep silent, or even at first throw a bone to Christians on the origin-of-life issue," said Strick. "Until at least the 1870s the scientists themselves stepped very carefully around the religious implications of their work."

Bastian's claims also divided and vexed Darwin's followers. Some early reviews of his book embraced Bastian's ideas and praised his experiments for bolstering Darwinist

theory by bridging the arbitrary gap between living and nonliving matter. But some Darwinists, most notably Huxley and physicist John Tyndall, tried to discredit Bastian, declaring him a careless experimenter (untrue in many ways, Strick said), and branding him and his supporters "non-Darwinians."

After years of publicly sidestepping the issue of the origin of life, Huxley delivered a famous presidential address, entitled "Biogenesis and Abiogensis," in 1870 to the British Association for the Advancement of Science (BAAS). Acknowledging that Darwinian science implied a naturalistic origin of life, Huxley posited that living organisms had arisen on the primitive Earth in a series of stages from nonliving matter. This concept he labeled "abiogenesis," to distinguish it from the principle of spontaneous generation championed by Bastian.

Judging by his private correspondence, Darwin seems largely to have concurred with Huxley's version of a naturalistic origin of life. He clearly followed with great interest the debate between Bastian and Huxley (which nearly destroyed Bastian's career). But Darwin never aired his thoughts on the subject in public.

A rebuttal of Huxley's concept of abiogenesis appeared the following year in a presidential address to BAAS by William Thomson (later Lord Kelvin). A committed anti-Darwinist and deeply religious man, Thomson offered a theory of "panspermia," the meteoric import of life to Earth. Darwinians privately derided Thomson's theory as a desperate shield thrown up against the stinging implications of abiogenesis. Huxley thought that panspermia didn't solve the origin-of-life problem at all, but only pushed it off to another planet.

Strick suggested that discussions of the origin of life are "theologically charged" to this day. He cited the work of the science historian and philosopher Iris Fry, who in *The Emergence of Life on Earth* (Rutgers University Press, 2002) traced the wide variations in Christian theology regarding the origin of life over the centuries. Even by 1997 the Pope had not fully accepted a materialistic theory of evolution, Strick noted. But apart from religious implications of the discussion, Strick emphasized, an examination of the broader historical context offers other important information about trends in how scientists in the past 150 years have defined life and thought about its origin.

Near the beginning of his 1899 article, "What is Life?" the British physician and professor of physiology F.J. Allen wrote, "Life is too complex to be described in a concise aphorism." But, Strick said, "…notwithstanding his opening caveat, Allen soon arrives at his own pet, too-concise formulation, which he calls a law: that 'every vital action involves the passage of oxygen either to or from nitrogen.'…Allen's attempt to hold on to some single *sine qua non* of life represents the deep grip of a late nineteenth century gestalt that we need to look at more closely."

From 1860 until about 1910, Strick said, scientists believed that their charge of "explaining life" required them to address every aspect of the complex problem of the nature and origin of life. Theories abounded as to the simplest living unit: Huxley

proposed "protoplasm," Darwin suggested "gemmules" of pangenesis, Nägeli offered "micelles," and Verworn, "biogen." Allen's focus on nitrogen as the defining feature of life fits within this tendency, Strick noted. Only after scientists began to perceive the complexity of the problem and tease apart its strands, did the focus of origin-of-life investigations change.

An example of this process that took place from 1910 to 1920 is the separation of the discipline of transmission genetics from the general study of embryology/development and its more inclusive notion of "inheritance." A cluster of scientists working on transmission genetics during the 1920s produced some ideas of note that shaped later research approaches. H.J. Muller, for example, published a paper in 1926, "The Gene As the Basis of Life," that embraced a "gene-centric" approach that drew in many other scientists, including Max Delbrück. A.I. Oparin, by contrast, posited a gradual chemical evolutionary process for the emergence of life. J.B.S. Haldane, although interested in the latest ideas about genes, made an early but cogent statement on what are now called "emergent properties":

> In the present state of our ignorance we may regard the gene either as a tiny organism which can divide in the environment provided by the rest of the cell; or as a bit of machinery which the "living" cell copies at each division. The truth is probably somewhere in between these two hypotheses….Unless a living creature is a piece of dead matter plus a soul (a view which finds little support in modern biology) something of the following kind must be true. A simple organism must consist of parts A,B,C,D, and so on, each of which can multiply only in the presence of all, or almost all, of the others.[3]

Particularly after Watson and Crick announced in 1953 that they had found "the secret of life," the double helix structure of DNA, Strick said, "an overwhelming majority of life scientists…believe information-carrying molecules more fundamental to life than biochemical metabolism. This, despite the fact that, ever since researchers have seen the origin of life to be predicated upon the origin of DNA, RNA, or some other… information-carrying molecule, the result has been the chicken-egg problem because of the interdependence of proteins and nucleic acids in extant cells."

Two recent books show trends in how scientists have thought about defining life in the past 40-50 years, Strick said: Freeman Dyson's 1999 *Origins of Life* (Cambridge University Press, 2nd ed., 1999) and Maynard Smith's and Eors Szathmáry's *The Origins of Life: From the Birth of Life to the Origin of Language* (Oxford University Press, 2000).

Dyson writes about the need to distinguish between replication and reproduction in order to break what Strick calls "the logical 'catch-22' deadlock that results when one considers DNA- or RNA-centered systems to be the *sine-qua-non* of life." Yet Dyson, a physicist, credits the contributions of such physicists as Schrödinger and Von Neumann to these studies but ignores the work of biologists, such as Sidney W. Fox, who emphasized the role of proteins and metabolism in the origin of life. Fox and his school were later marginalized within the research community, which was focused single-mindedly on genetic information, Strick said. "If one is constructing a forerunners'

pedigree for one's most important idea, perhaps the temptation is overwhelming to attribute that idea to winners and silently pass over losers."

Smith and Szathmáry focus on information from the very beginning of their book, raising the question of metabolism briefly, only to dismiss it, Strick noted: "Their approach clearly assumes that life is synonymous with replication."

Smith and Szathmáry write extensively of the dialectical parallel between the rise of information theory and computers, and the use of informational terms in biological analysis. "It is astute of the authors to recognize how much our cultural experience *enables* our view, especially on questions of such fundamental importance as 'What is life?' However…they seem to miss the other implication of the power of historical context. If our cultural experience enables our view, it also simultaneously *constrains* it," Strick said. "Their bias leaves us with the chicken-egg problem: If metabolism is dominated mostly by proteins, but is a prerequisite for the functioning of nucleic acid information molecules, how can a system like our current living cell, even the simplest prokaryote, with each of these two parts totally dependent upon the other, ever have evolved in the first place? (In this way, giving primacy to nucleic acids/information plays into the hands of Creationists.) The possible crucial question that gets drowned out by talk of the primacy of information (and thus of nucleic acids) is: Can there be any other central characteristic of living systems as fundamental as, or perhaps even more fundamental than, information?"

The tension between the advocates of the information approach versus those upholding the enzymatic metabolism approach to the definition of life ruled much of twentieth-centruy origin-of-life discussion. Thomas Cech's widely acclaimed 1982 discovery of catalytic RNA molecules seemed to offer a way out of the impasse by indicating that the simplest nucleic acid information molecules can also perform the enzyme role that scientists had thought to be the preserve of proteins.

But Strick suggests that scientists' hopes for RNA now seem to have been overly optimistic. "Its monomers are so difficult to form spontaneously, and are so short-lived under primitive earth conditions, that the question of how to get from an abiotic world to the RNA world is not much easier to solve than before the RNA-world transitional stage was known. Information is surely one of the fundamental issues for living systems as we know them, but we are still unclear as to whether it came first or is the *sine qua non* of the first life or its molecular predecessors."

By Nancy Ellen Roth, Science Writer

[1] Charles Darwin, *On the Origin of Species* (London: John Murray, 1859), p. 484.
[2] Frederick Barnard, "The Germ Theory of Disease and Its Relations to Hygiene," *Public Health Reports and Papers* 1:70-87 (1873), p. 80.
[3] J.B.S. Haldane, "The Origin of Life," *Rationalist Annual* (1929): 3-10, p. 6.