

COMPILATION OF QUOTES ON THE COMPLEXITY OF A CELL AND THE SCIENTIFIC MYSTERY OF LIFE'S ORIGIN

By Ashby L. Camp

COMPLEXITY OF A CELL

James Gray, zoologist, "The Science of Life," in C. H. Waddington, James Gray, and others, eds., *Science Today* (New York: Criterion Books, 1961), 21: "A bacterium is far more complex than any inanimate system known to man. There is not a laboratory in the world which can compete with the biochemical activity of the smallest living organism."

William Thorpe, zoologist, "Reductionism in Biology," in Francisco Ayala and Theodosius Dobzhansky, eds., *Studies in the Philosophy of Biology: Reduction and Related Problems* (Berkeley, CA: University of California Press, 1974), 117: "The most elementary type of cell constitutes a 'mechanism' unimaginably more complex than any machine yet thought up, let alone constructed, by man."

Carl Sagan, astronomer, "Life," in 10 *Encyclopaedia Britannica: Macropaedia*, 15th ed. (Chicago: Encyclopaedia Britannica, 1974), 893-894:

A living cell is a marvel of detailed and complex architecture. Seen through a microscope there is an appearance of almost frenetic activity. On a deeper level it is known that molecules are being synthesized at an enormous rate. . . . The information content of a simple cell has been estimated as around 10^{12} bits, comparable to about a hundred million pages of the Encyclopaedia Britannica.

Michael Denton, developmental biologist and genetics researcher, *Evolution: A Theory in Crisis* (Bethesda, MD: Adler & Adler, 1986), 250, 328, 342:

Molecular biology has shown that even the simplest of all living systems on the earth today, bacterial cells, are exceedingly complex objects. Although the tiniest bacterial cells are incredibly small, weighing less than 10^{-12} gms, each is in effect a veritable micro-miniaturized factory containing thousands of exquisitely designed pieces of intricate molecular machinery, made up altogether of one hundred thousand million atoms, far more complicated than any machine built by man and absolutely without parallel in the nonliving world. . . .

To grasp the reality of life as it has been revealed by molecular biology, we must magnify a cell a thousand million times until it is twenty kilometers in diameter and resembles a giant airship large enough to cover a great city like London or New York. What we would then see would be an object of unparalleled complexity and adaptive design. On the surface of the cell, we would see millions of openings, like the portholes of a vast space ship, opening and closing to allow a continual stream of materials to

flow in and out. If we were to enter one of these openings, we would find ourselves in a world of supreme technology and bewildering complexity. We would see endless highly organized corridors and conduits branching in every direction away from the perimeter of the cell, some leading to the central memory bank in the nucleus and others to assembly plants and processing units. The nucleus itself would be a vast spherical chamber more than a kilometer in diameter, resembling a geodesic dome inside of which we could see, all neatly stacked together in ordered arrays, the miles of coiled chains of the DNA molecules. A huge range of products and raw materials would shuttle along all the manifold conduits in a highly ordered fashion to and from various assembly plants in the outer regions of the cell. . . .

It would be an illusion to think that what we are aware of at present is any more than a fraction of the full extent of biological design. In practically every field of fundamental biological research ever-increasing levels of design and complexity are being revealed at an ever-accelerating rate.

James Shapiro, biochemist and molecular biologist, "Bacteria as Multicellular Organisms," *Scientific American*, Vol. 258, no. 6 (June 1988), 82: "Although bacteria are tiny, they display biochemical, structural and behavioral complexities that outstrip scientific description. In keeping with the current microelectronics revolution, it may make more sense to equate their size with sophistication rather than with simplicity."

Bruce Alberts, biochemist and former president of the National Academy of Sciences, "The Cell as a Collection of Protein Machines: Preparing the Next Generation of Molecular Biologists," *Cell*, 92 (February 8, 1998), 291:

We have always underestimated cells. . . . The entire cell can be viewed as a factory that contains an elaborate network of interlocking assembly lines, each of which is composed of a set of large protein machines. . . . Why do we call the large protein assemblies that underlie cell function protein machines? Precisely because, like machines invented by humans to deal efficiently with the macroscopic world, these protein assemblies contain highly coordinated moving parts.

Michael Denton, developmental biologist and genetics researcher, *Nature's Destiny: How the Laws of Biology Reveal Purpose in the Universe* (New York: Free Press, 1998), 212-213:

From the knowledge we now have of the molecular machinery that underlies some of their extraordinary abilities, it is clear that cells are immensely complex entities. On any count the average cell must utilize close to a million unique adaptive structures and processes -- more than the number in a jumbo jet. In this the cell seems to represent the ultimate

expression in material form of compacted adaptive complexity -- the complexity of a jumbo jet packed into a speck of dust invisible to the naked eye. It is hardly conceivable that anything more complex could be compacted into such a small volume. Moreover, it is a speck-sized jumbo jet which can duplicate itself quite effortlessly.

Paul Davies, a well-known theoretical physicist, "The origin of life. II: How did it begin?" *Science Progress* (2001), 17: "Life is more than just complex chemical reactions. The cell is also an information storing, processing and replicating system. We need to explain the origin of this information, and the way in which the information processing machinery came to exist."

Jeremy Walter, mechanical engineer, "Jeremy L. Walter," in John F. Ashton, ed., *In Six Days* (Green Forest, AR: Master Books, 2001), 17: "The most basic processes of living things are accomplished by molecular engines as complex as man's greatest inventions."

Stephen Grocott, chemist, "Stephen Grocott," in John F. Ashton, ed., *In Six Days* (Green Forest, AR: Master Books, 2001), 149:

The complexity of the simplest imaginable living organism is mind-boggling. You need to have the cell wall, the energy system, a system of self-repair, a reproduction system, and means for taking in "food" and expelling "waste," a means for interpreting the complex genetic code and replicating it, etc., etc. The combined telecommunication systems of the world are far less complex, and yet no one believes they arose by chance.

Richard Strohman, microbiologist, in David Suzuki and Holly Dressel, rev. ed., *From Naked Ape to Superspecies* (Vancouver: Greystone Books, 2004), 172: "Molecular biologists and cell biologists are revealing to us a complexity of life that we never dreamt was there. We're seeing connections and interconnections and complexity that is mind-boggling. It's stupendous. It's transcalsculational. It means that the whole science is going to have to change."

Robert M. Hazen, geophysicist, *Genesis: The Scientific Quest for Life's Origin* (Washington, DC: Joseph Henry Press, 2007), 9: "We [know] that the simplest living cell is intricate beyond imagining, because every cell relies on the interplay of millions of molecules engaged in hundreds of interdependent chemical reactions. Human brains seem ill suited to grasp such multidimensional complexity."

David Berlinski, philosopher and mathematician, interviewed by Ben Stein in the 2008 documentary *Expelled: No Intelligence Allowed*:

Stein: Darwin . . . had an idea of the cell as being quite simple, correct?

Berlinski: Yes, everybody did.

Stein: If he thought of the cell as being a Buick, what is the cell now in terms of its complexity by comparison?

Berlinski: A galaxy.

Richard Sternberg, evolutionary biologist, interviewed by Ben Stein in the 2008 documentary *Expelled: No Intelligence Allowed*:

Stein: If Darwin thought a cell was, say, a mud hut, what do we now know that a cell is?

Sternberg: More complicated than a Saturn V.

Alonso Ricardo, biochemist, and Jack W. Szostak, geneticist, "The Origin of Life on Earth," *Scientific American* (August 19, 2009), 54:

Every living cell, even the simplest bacterium, teems with molecular contraptions that would be the envy of any nanotechnologist. As they incessantly shake or spin or crawl around the cell, these machines cut, paste and copy genetic molecules, shuttle nutrients around or turn them into energy, build and repair cellular membranes, relay mechanical, chemical or electrical messages—the list goes on and on, and new discoveries add to it all the time.

THE ORIGIN OF LIFE REMAINS A SCIENTIFIC MYSTERY

George Wald, Nobel Prize-winning biochemist, "The Origins of Life," in *The Physics and Chemistry of Life* (Simon & Schuster, 1955), 270: "One has only to contemplate the magnitude of this task to conclude that the spontaneous generation of a living organism is impossible. Yet here we are -- as a result, I believe, of spontaneous generation."

Gerald Kerkut, biochemist, *Implications of Evolution* (New York: Pergamon Press, 1960), 152: "The first assumption was that non-living things gave rise to living material. This is still just an assumption. . . . There is, however, little information in favour of [a]biogenesis and as yet we have no indication that it can be performed."

Harold C. Urey, Nobel Prize-winning chemist and famous origin-of-life researcher, *Christian Science Monitor* (Jan. 4, 1962), 4: "[A]ll of us who study the origin of life find that the more we look into it, the more we feel it is too complex to have evolved anywhere. We all believe as an article of faith that life evolved from dead matter on this planet. It is just that its complexity is so great, it is hard for us to imagine that it did."

David E. Green and Robert F. Goldberger, biochemists, *Molecular Insights into the Living Process* (New York: Academic Press, 1967), 407: "[T]he macromolecule-to-cell transition is a jump of fantastic dimensions, which lies beyond the range of testable hypothesis. In this area all is conjecture. The available facts do not provide a basis for postulation that cells arose on this planet."

William Thorpe, zoologist, "Reductionism in Biology," in Francisco Ayala and Theodosius Dobzhansky, eds., *Studies in the Philosophy of Biology: Reduction and Related Problems* (Berkeley, CA: University of California Press, 1974), 116: "I think it is fair to say that all the facile speculations and discussions published during the last 10-15 years explaining the mode of origin of life have been shown to be far too simple-minded and to bear very little weight. The problem in fact seems as far from solution as it ever was."

Hubert P. Yockey, physicist and information theorist, "A Calculation of the Probability of Spontaneous Biogenesis by Information Theory," *Journal of Theoretical Biology* (Vol. 67, 1977), 396:

The 'warm little pond' scenario was invented *ad hoc* to serve as a materialistic reductionist explanation of the origin of life. It is unsupported by any other evidence and it will remain *ad hoc* until such evidence is found. . . . One must conclude that, contrary to the established and current wisdom a scenario describing the genesis of life on earth by chance and natural causes which can be accepted on the basis of fact and not faith has not yet been written.

Francis Crick, Nobel Prize-winning biochemist, *Life Itself: Its Origin and Nature* (New York: Simon & Schuster, 1981), 88: "An honest man, armed with all the knowledge available to us now, could only state that in some sense, the origin of life appears at the moment to be almost a miracle, so many are the conditions which would have had to have been satisfied to get it going."

Hubert Yockey, physicist and information theorist, "Self-Organization Origin of Life Scenarios and Information Theory," *Journal of Theoretical Biology*, Vol. 91, no. 1 (July 7, 1981), 13: "Since science does not have the faintest idea how life on earth originated . . . it would only be honest to confess this to other scientists, to grantors, and to the public at large."

Paul Davies, a well-known theoretical physicist, *God and the New Physics* (New York: Simon & Schuster, 1983), 68:

The origin of life remains one of the great scientific mysteries. The central conundrum is the threshold problem. Only when organic molecules achieve a certain very high level of complexity can they be considered as 'living', in the sense that they encode a huge amount of information in a stable form and not only display the capability of storing the blueprint for replication but also the means to implement that replication. The problem is to understand how this threshold could have been crossed by ordinary physical and chemical processes without the help of some supernatural agency.

Sir Fred Hoyle, astrophysicist and mathematician, *The Intelligent Universe* (New York: Holt, Rinehart & Winston, 1983), 23: "In short there is not a shred of objective evidence to support the hypothesis that life began in an organic soup here on the Earth."

Lewis Thomas, physician and researcher, in foreword to Robert M. Pool, ed., *The Incredible Machine* (Washington, DC: National Geographic Book Service, 1986), 7: "The events that gave rise to that first primordial cell are totally unknown, matters for guesswork and a standing challenge to scientific imagination."

Robert Gange, physicist and engineer, *Origins and Destiny* (Dallas: Word, 1986), 77:

The likelihood of life having occurred through a chemical accident is, for all intents and purposes, zero. This does not mean that faith in a miraculous accident will not continue. But it does mean that those who believe it do so because they are philosophically committed to the notion that all that exists is matter and its motion. In other words, they do so for reasons of philosophy and not science.

Andrew Scott, biochemist, *The Creation of Life: Past, Future, Alien* (Basil Blackwell: Oxford UK, 1986), 111: "In truth the mechanism of almost every major step, from chemical precursors up to the first recognizable cells, is the subject of either controversy or complete bewilderment. At the moment scientists certainly do not know how, or even if, life originated on earth from lifeless atoms."

Klaus Dose, biochemist, "The Origin of Life: More Questions than Answers," *Interdisciplinary Science Reviews* (13:4, 1988), 348:

More than 30 years of experimentation on the origin of life in the fields of chemical and molecular evolution have led to a better perception of the immensity of the problem of the origin of life on Earth rather than to its solution. At present, all discussions on principal theories and experiments in the field either end in a stalemate or in a confession of ignorance.

Paul Davies, a well-known theoretical physicist, *Cosmic Blueprint: New Discoveries in Nature's Creative Ability to Order the Universe* (West Conshohocken, PA: Templeton Foundation Press, 2004 [original: Houghton and Mifflin, 1988]), 115:

It should be stated at the outset that the origin of life remains a deep mystery. There are no lack of theories, of course, but the divergence of opinion among scientists on this topic is probably greater than for any other topic in biology.

The essential problem in explaining how life arose is that even the simplest living things are stupendously complex. The replicative machinery of life is based on the DNA molecule, which is itself as structurally complicated and intricately arranged as an automobile

assembly line. If replication requires such a high threshold of complexity in the first place how can any replicative system have arisen spontaneously?

Carl Woese, microbiologist, and Gunter Wächtershäuser, chemist and attorney, "Origin of Life" in Derek E. G. Briggs and Peter R. Crowther, eds., *Paleobiology: A Synthesis* (Oxford: Blackwell Scientific Publications, 1990), 9:

In one sense the origin of life problem today remains what it was in the time of Darwin -- one of the great unsolved riddles of science. Yet we have made progress. Through theoretical scrutiny and experimental effort since the nineteen-twenties many of the early naive assumptions have fallen or are falling aside -- and there now exist alternative theories. In short, while we do not have a solution, we now have an inkling of the magnitude of the problem.

Harold Klein, chairman of the National Academy of Sciences committee that reviewed origin-of-life research, in John Horgan, "In the Beginning," *Scientific American* (February 1991), 120: "The simplest bacterium is so damn complicated from the point of a chemist that it is almost impossible to imagine how it happened."

Werner Arber, Nobel Prize-winning microbiologist, in Henry Margenau and Roy Abraham Varghese, eds., *Cosmos, Bios, Theos* (LaSalle, IL: Open Court, 1992), 142: "Although a biologist, I must confess that I do not understand how life came about. . . . I consider that life only starts at the level of a functional cell. The most primitive cell may require at least several hundred different specific biological macro-molecules. How such already quite complex structures may have come together, remains a mystery to me."

Jay Roth, cell and molecular biologist, in Henry Margenau and Roy Abraham Varghese, eds., *Cosmos, Bios, Theos* (LaSalle, IL: Open Court, 1992), 199: "I have carefully studied molecular, biological, and chemical ideas of the origin of life and read all the books and papers I could find. Never have I found any explanation that was satisfactory to me."

Stuart Kauffman, theoretical biologist, *At Home in the Universe* (New York: Oxford University Press, 1995), 31: "Anyone who tells you that he or she knows how life started on earth some 3.4 billion years ago is a fool or a knave. Nobody knows."

Michael Denton, developmental biologist and genetics researcher, *Nature's Destiny* (New York: Free Press, 1998), 292-293: "But even if it seems very likely that the becoming of life is built in, it has to be admitted that at present, despite an enormous effort, we still have no idea how this occurred, and the event remains as enigmatic as ever."

Armand Delsemme, astrophysicist, *Our Cosmic Origins: From the Big Bang to the Emergence of Life and Intelligence* (New York: Cambridge University Press, 1998), 160: "The origin of life remains an immense problem and the gaps in our knowledge are countless."

Laura F. Landweber and Laura A. Katz, "Evolution: Lost Worlds," *Trends in Ecology and Evolution* (Vol. 13, March 1998), 93-94:

NASA's recent announcement of the formation of an Astrobiology Institute to study life's origins prompted Lenny Dawidowicz and Mitchell Sogin of the Marine Biological Laboratory, Woods Hole, Massachusetts), to organize a NASA-sponsored workshop in October on "Evolution: A Molecular Point of View." The meeting brought together researchers from diverse fields including geochemistry, paleontology, molecular biology, developmental biology, and polymer chemistry to discuss the origin and diversification of life. . . .

. . . Sherwood Chang (NASA Ames Research Center, Moffett Field, California) opened the program with the cautious reminder that any canonical scenario for the stepwise progression toward the origin of life is still just a "convenient fiction." That is, we have almost no data to support the historical transitions from chemical evolution to prebiotic monomers, polymers, replicating enzymes, and finally cells.

Christopher McKay, astrogeophysicist, "Astrobiology: The Search for Life Beyond the Earth" in Steven J. Dick, ed., *Many Worlds* (Radnor, PA: Templeton Foundation Press, 2000), 49: "The origin of life remains a scientific mystery. Despite impressive advances in the abiological synthesis of important biomolecules since the early work of Miller, the processes that lead to life have not been duplicated in the laboratory."

Paul Davies, a well-known theoretical physicist, *The Fifth Miracle: The Search for the Origin and Meaning of Life* (New York: Simon & Schuster, 2000), 17-18:

Many investigators feel uneasy about stating in public that the origin of life is a mystery, even though behind closed doors they freely admit they are baffled. There seem to be two reasons for their unease. First, they feel it opens the door to religious fundamentalists and their god-of-the-gaps pseudo-explanations. Second, they worry that a frank admission of ignorance will undermine funding, especially for the search for life in space. The view seems to be that governments are more likely to spend money seeking extraterrestrial life if scientists are already convinced that it is out there.

Nicholas Wade, science writer, "Life's Origins Get Murkier and Messier; Genetic Analysis Yields Intimations of a Primordial Commune," *New York Times*, June 13, 2000:

Everything about the origin of life on earth is a mystery, and it seems the more that is known, the more acute the puzzles get. . . .

The chemistry of the first life is a nightmare to explain. No one has yet devised a plausible explanation to show how the earliest chemicals of life – thought to be RNA, or ribonucleic acid, a close relative of DNA – might have constructed themselves from the inorganic chemicals likely to have been around on the early earth. The spontaneous assembly of small RNA molecules on the primitive earth "would have been a near miracle," two experts in the subject helpfully declared last year. . . .

. . . The best efforts of chemists to reconstruct molecules typical of life in the laboratory have shown only that it is a problem of fiendish difficulty. The genesis of life on earth, some time in the fiery last days of the Hadean, remains an unyielding problem.

Franklin M. Harold, biochemist, *The Way of the Cell: Molecules, Organisms and the Order of Life* (New York: Oxford University Press, 2001), 251: "It would be agreeable to conclude this book with a cheery fanfare about science closing in, slowly but surely, on the ultimate mystery; but the time for rosy rhetoric is not yet at hand. The origin of life appears to me as incomprehensible as ever, a matter for wonder but not for explication."

Robert Roy Britt, the senior science writer for Space.com, posted at Space.com on May 22, 2002 an article titled "The Search for the Scum of the Universe," which included:

In fact, at a meeting earlier this month of about 100 chemists, biologists, astronomers and other highly evolved thinkers interested in finding extraterrestrial life -- the scientists were said by one attendee to be the cream of the crop in their respective fields -- none could even say how the simplest life begins.

"Nobody understands the origin of life," said Ken Nealson, a geobiologist at the University of Southern California. "If they say they do, they are probably trying to fool you."

Nealson and the other scientists converged at the Space Telescope Science Institute (STScI) in Baltimore to discuss the fledgling field of astrobiology. They argued a little about how to conduct the search and whether life might be rare or common in the universe. However, they agreed on several things: They don't know how life might commence elsewhere, or whether it ever has, or what it might thrive on.

(The article is no longer available at Space.com but as of 10/15/11 could be viewed at <http://www.alaska-channel.com/blog/news/ShowArticle.asp?Id=9&num=192&nav=d.>)

European Space Agency *Bulletin* 120 (Nov. 2004) (online at <http://www.esa.int/esapub/bulletin/bulletin120/bulletin120.pdf>): "Even today, we still do not know how the self-sustaining assemblies of nucleic acids, proteins and fats at the basis of life came into existence. By identifying the likely chemical precursors that filled

the primaeval soup, Huygens will give a fresh impetus to the theories regarding the origin of life on the Earth."

Andy Knoll, paleontologist and author of *Life on a Young Planet: The First Three Billion Years of Life*, was interviewed on May 3, 2004 as part of a PBS NOVA program. He is described as a person who has "exhaustively investigated" the origin of life. Here are excerpts from an interview:

NOVA: In a nutshell, what is the process? How does life form?

Knoll: The short answer is we don't really know how life originated on this planet. There have been a variety of experiments that tell us some possible roads, but we remain in substantial ignorance.

NOVA: So at this point we're seeing the origins of life through a glass darkly?

Knoll: If we try to summarize by just saying what, at the end of the day, do we know about the deep history of life on Earth, about its origin, about its formative stages that gave rise to the biology we see around us today, I think we have to admit that we're looking through a glass darkly here. . . .

. . . We don't know how life started on this planet. We don't know exactly when it started, we don't know under what circumstances.

It's a mystery that we're going to chip at from several different directions. . . .

NOVA: Will we ever solve the problem?

Knoll: I don't know. I imagine my grandchildren will still be sitting around saying that it's a great mystery, but that they will understand that mystery at a level that would be incomprehensible to us today.

Michael Brooks, "The Mysteries of Life," *New Scientist* (September 4, 2004), 24: This article is about the ten biggest unanswered questions relating to life, and top of the list was the mystery of how life began.

July 1, 2005 issue of *Science* included in its top 25 questions facing science "How and where did life on earth arise?"

Richard Robinson, "Jump-Starting a Cellular World: Investigating the Origin of Life, from Soup to Networks," *PLoS Biology* (Nov. 15, 2005) included:

But beyond assuming the first cell must have somehow come into existence, how do biologists explain its emergence from the prebiotic world four billion years ago?

The short answer is that they can't, yet.

George M. Whitesides, chemist, "Revolutions in Chemistry," *Chemical & Engineering News* (March 26, 2007; online at <http://pubs.acs.org/cen/coverstory/85/8513cover1.html>):

The Origin of Life. This problem is one of the big ones in science. It begins to place life, and us, in the universe. Most chemists believe, as do I, that life emerged spontaneously from mixtures of molecules in the prebiotic Earth.

How? I have no idea. Perhaps it was by the spontaneous emergence of "simple" autocatalytic cycles and then by their combination. On the basis of all the chemistry that I know, it seems to me astonishingly improbable.

Robert M. Hazen, geophysicist, *Genesis: The Scientific Quest for Life's Origin* (Washington, DC: Joseph Henry Press, 2007), 241: "So we've learned a lot, but what we know about the origin of life is dwarfed by what we don't know. It's as if we were trying to assemble a giant jigsaw puzzle. A few pieces clump together here and there, but most of the pieces are missing and we don't even have the box to see what the complete picture is supposed to look like."

Gregg Easterbrook, writer, "Where did life come from?" *Wired Magazine* (February 2007), 108: "What creates life out of the inanimate compounds that make up living things? No one knows. How were the first organisms assembled? Nature hasn't given us the slightest hint. If anything, the mystery has deepened over time."

Stanley L. Miller, Nobel Prize-winning chemist and famous origin-of-life researcher, and H. James Cleaves, geochemist, "Prebiotic Chemistry on the Primitive Earth" in Isidore Rigoutsos and Gregroy Stephanopoulos, eds., *Systems Biology Volume 1: Genomics* (New York: Oxford University Press, 2007), 3:

The origin of life remains one of the humankind's last great unanswered questions, as well as one of the most experimentally challenging research areas. . . .

Despite recent progress in the field, a single definitive description of the events leading up to the origin of life on Earth some 3.5 billion years ago remains elusive.

Richard Dawkins, zoologist, interviewed by Ben Stein in the 2008 documentary *Expelled: No Intelligence Allowed*:

Stein: Well how did it start?

Dawkins: Nobody knows how it got started. We know the kind of event that it must have been, we know the sort of event that must have happened for the origin of life.

Stein: And what was that?

Dawkins: It was the origin of the first self-replicating molecule.

Stein: Right. And how did that happen?

Dawkins: I've told you, we don't know.

Stein: So you have no idea how it started?

Dawkins: No no. Nor has anybody.

Grazyna Stochel, Malgorzata Brindell, Wojcieck Macyk, Zofia Stasicka, and Konrad Szacilowski, *Bioinorganic Photochemistry* (West Sussex, England: John Wiley & Sons, 2009), 109: "Most of the (bio)chemical processes found within all the living organisms are well understood at the molecular level, whereas the origin of life remains one of the most vexing issues in chemistry, biology, and philosophy."

Edward Peltzer, chemist, in Stephen Meyer, *Signature in the Cell* (New York: HarperCollins, 2009), n.p. (endorsement in front matter): "The origin of life remains one of the great unsolved mysteries of modern science."

Anna Kushnir, virologist and science writer, gave the following report on a recent Harvard symposium on the origin of life that featured a number of leading researchers ("The Origins of Life on Earth. Really," March, 9, 2009, online at <http://blogs.nature.com/boston/2009/03/09/the-origins-of-life-on-earth-really>):

[The symposium] focused on discussing the progress made thus far in answering the most long-standing (and potentially philosophical) of all questions in science – what is life, and how did it begin? . . .

It may be difficult to believe, but there was a common theme to this seeming cacophony of scientific expertise and discovery. The theme was, "We just don't know." No one knows how life began - or even how to define 'life,' if you want to get all philosophical about it - but it's a question of such paramount interest and importance that key players in many avenues of scientific research are willing to devote their time and resources to answering it. Underneath it all, it was refreshing to hear a bunch of really smart folks say 'we don't know.' It was humbling and put things in a grandiose perspective. No one knows how we all got to be here, but the researchers in the Origins of Life initiative and beyond are trying to find out.

Jeffrey Bada and Antonio Lazcano, biochemists, "The Origin of Life," in Michael Ruse and Joseph Travis, eds., *Evolution: The First Four Billion Years* (Cambridge, MA: Belknap Press, 2009), 72: "Although there have been considerable advances in the understanding of chemical processes that may have taken place before the emergence of

the first living entities, life's beginnings are still shrouded in mystery. . . . [H]ow the transition from the non-living to the living took place is still unknown."

Michael Denton, developmental biologist and genetics researcher, "As Darwin Year ends, some seek to go beyond Darwin" (Dec. 14, 2009), online at <http://blogs.reuters.com/faithworld/2009/12/14/as-darwin-year-ends-some-seek-to-go-beyond-darwin/>:

Q: *So how did life come about?*

In the Darwinian idea, you'd first have chemistry and then a bit-by-bit accumulation of fortuitous changes. But before you get to a system that can replicate securely and yet accommodate a bit of change, you can't really have Darwinian evolution. So how do you get to the first cell? My hunch is that there is probably a unique path to the cell that exploits some unknown self-organising properties of matter. If there were many routes and they were easy to take, we would have found some by now. I think we have to postulate that the origin of life involves some as yet unknown self-organising properties of matter. That's my hunch, and if that's not true, then I think you're going to have special creation. You can quote me on that. It's either some unknown special self-organising process or it's creation.

Q: *What do you think of "intelligent design" now?*

I have some sympathy with the intelligent design movement. I can see their point. But in the end, I think natural self-organising matter plus natural selection can probably explain it. I don't like the attitude of the Darwinian establishment towards intelligent designers because one thing the Darwinist establishment certainly can't explain is the origin of life. That's for sure. Probably special creation is better than what they've got. That's almost like confessing a murder, I know, but I don't mind being quoted on that. Because I personally see so much fitness in the cosmos for the ends of life, then that it is at least compatible with a design hypothesis like Aristotle or Aquinas. I'm quite irritated by the way the Darwinists claim they have all the answers. I don't think they can explain the fitness of the universe for life. They can't explain the origin of life. So I think they should be a little bit more humble.

Timothy Kusky, geologist, *Encyclopedia of Earth and Space Science* (New York: Facts on File, 2010), 384:

Complex organic molecules including amino acids do not constitute life. After the simple amino acids form, it is no easy task to combine them into larger molecules and complex molecules necessary for life. These need additional stimuli, such as hot acidic water, or ultraviolet radiation,

or perhaps lightning. A mechanism for initiating the ability for molecules to transmit information so that they can replicate themselves is also necessary. One idea is that this may have first been done on the surfaces of clay minerals, such as those found in some submarine hot spring environments such as those along the mid-ocean ridges. Somehow, in the early Precambrian, life emerged from these complex organic molecules and simple amino acids, but the origin of life remains one of life's biggest mysteries.

Freeman J. Dyson, physicist and mathematician, *A Many-Colored Glass: Reflections on the Place of Life in the Universe* (Charlottesville, VA: University of Virginia Press, 2010), 104:

The origin of life is the deepest mystery in the whole of science. Many books and learned papers have been written about it, but it remains a mystery. There is an enormous gap between the simplest living cell and the most complicated naturally occurring mixture of nonliving chemicals. We have no idea when and how and where this gap was crossed. We only know that it was crossed somehow, either on Earth or on Mars or in some other place from which the ancestors of life on Earth might have come.

Thomas Nagel, philosopher, *Secular Philosophy and the Religious Temperament: Essays 2002-2008* (New York: Oxford University Press, 2010), 24-25:

Dawkins is not a chemist or a physicist. Neither am I, but general expositions of research on the origin of life indicate that no one has a theory that would support anything remotely near such a high probability as one in a billion billion. Naturally, there is speculation about possible nonbiological chemical precursors of DNA or RNA. But at this point the origin of life remains, in light of what is known about the huge size, the extreme specificity, and the exquisite functional precision of the genetic material, a mystery -- an event that could not have occurred by chance and to which no significant probability can be assigned on the basis of what we know of the laws of physics and chemistry.

Milton Wainwright, molecular biologist, "Musings on the Origin of Life and Panspermia," *Journal of Cosmology*, Vol. 5 (Jan. 30, 2010), online at <http://journalofcosmology.com/SearchForLife126.html>:

Are we then getting any closer to an understanding the origin of life (assuming it had one)? As ever there is much optimism that indeed we are making progress. On the other hand, it often appears as if the origin of life question has become bogged down in ever increasingly sophisticated organic chemistry. The reality is that, despite the egos of some, the existence of life remains a mystery. It is not merely that biology is

scratching the surface of this enigma; the reality is that we have yet to *see* the surface!

Kepa Ruiz-Mirazo, an origin-of-life researcher, "Open questions on the origin of life: introduction to the special issue," *Origins of Life and Evolution of Biospheres* 40 (No. 4-5, 2010), 353:

The origin of life on Earth is still a mystery, one of the greatest mysteries in science today. We are surrounded by myriads of life forms—each leaf of a tree in a forest contains billions of living cells, our body contains huge numbers of active microorganisms, we people keep living and growing, incessantly—and we do not yet know how life came about on our planet. Our ignorance about the origin of life is profound—not just some simple missing mechanistic detail. We do not know how the genetic code came about, we do not understand yet how the specific sequences of proteins or nucleic acids came about in multiple identical copies, we do not have a precise idea about the structure and functioning of the first proto-cells. This ignorance stems not only from our experimental difficulties with prebiotic chemistry, but is also conceptual, as we are not yet able to conceive on paper how all these things came about.

John Horgan, science writer, titled his February 28, 2011 article in *Scientific American* on a recent top-level origin-of-life conference "Pssst! Don't tell the creationists, but science doesn't have a clue how life began." Here are the opening paragraphs:

Exactly 20 years ago, I wrote an article for *Scientific American* that, in draft form, had the headline above. My editor nixed it, so we went with something less dramatic: "In the Beginning...: Scientists are having a hard time agreeing on when, where and—most important—how life first emerged on the earth." That editor is gone now, so I get to use my old headline, which is even more apt today.

Dennis Overbye just wrote a status report for *The New York Times* on research into life's origin, based on a conference on the topic at Arizona State University. Geologists, chemists, astronomers and biologists are as stumped as ever by the riddle of life.

Christian de Duve, Nobel Prize-winning biochemist, "Mysteries of Life: Is There 'Something Else'?" in Bruce L. Gordon and William A. Dembski, eds., *The Nature of Nature: Examining the Role of Naturalism in Science* (Wilmington, DE: ISI Books, 2011), 349: "While much has been learned, it is clear that we are still nowhere near explaining the origin of life."

Eugene V. Koonin, molecular biologist, *The Logic of Chance: The Nature and Origin of Biological Evolution* (Upper Saddle River, NJ: FT Press, 2011), 391:

The origin of life is one of the hardest problems in all of science, but it is also one of the most important. Origin-of-life research has evolved into a lively, interdisciplinary field, but other scientists often view it with skepticism and even derision. This attitude is understandable and, in a sense, perhaps justified, given the "dirty" rarely mentioned secret: Despite many interesting results to its credit, when judged by the straightforward criterion of reaching (or even approaching) the ultimate goal, the origin of life field is a failure – we still do not have even a plausible coherent model, let alone a validated scenario, for the emergence of life on Earth. Certainly, this is due not to a lack of experimental and theoretical effort, but to the extraordinary intrinsic difficulty and complexity of the problem. A succession of exceedingly unlikely steps is essential for the origin of life, from the synthesis and accumulation of nucleotides to the origin of translation; through the multiplication of probabilities, these make the final outcome seem almost like a miracle.

Stanford-educated chemist Nivaldo Tro, *Chemistry in Focus: A Molecular View of Our World*, 5th ed. (St. Paul, MN: Brooks Cole, 2012), 135:

Toward the end of his life, Stanley Miller (who died in 2007) said, "The problem of the origin of life has turned out to be much more difficult than I, and most other people, envisioned." Most origin-of-life researchers have an idea of what a viable theory should look like. Somehow, a group of molecules developed the ability to copy themselves imperfectly; that is, their "offspring" were copies of their predecessors, except for small, inheritable mistakes. Some of these mistakes gave the offspring the ability to replicate better, making them more likely to replicate and therefore to pass on the favorable mistake to the next generation. In this way, chemical evolution got its start, producing generations of molecules that slowly got better at replicating themselves. Eventually, living organisms -- very good at replicating themselves -- evolved.

The main controversy today, however, is just what these compounds were, how they formed, and how they replicated. The older origin-of-life theories suggest that these compounds were the same ones present in living organisms today, proteins and DNA (more on these in Chapter 16). However, the complexity of proteins and DNA, and the difficulty in getting them to replicate independently, have led some researchers to propose other candidates such as clays, sulfur-based compounds, or pyrite (fool's gold). None of these theories have gained widespread acceptance, and the origin of life continues to be a puzzle with which scientists grapple.

Addy Pross, Professor Emeritus of Chemistry at Ben-Gurion University in Israel, *What Is Life? How Chemistry Becomes Biology* (New York: Oxford University Press, 2012), ix-x:

[D]espite the profound advances in molecular biology over the last half-century, we still do not understand what life is, how it relates to the inanimate world, and how it emerged. True, over the past half-century considerable effort has been directed into attempts to resolve these fundamental issues, but the gates to the Promise Land seem as distant as ever. Like a mirage in the desert, just as the palm trees signaling the oasis seemingly materialize, shimmering on the horizon, they fade away yet again, leaving our thirst to understand unquenched, our drive to comprehend unsatisfied.

Paul Davies, a well-known theoretical physicist, "Are We Alone in the Universe?" *New York Times* op-ed (11/19/13), A25: "In spite of intensive research, scientists are still very much in the dark about the mechanism that transformed a nonliving chemical soup into a living cell."

Franklin M. Harold, Professor Emeritus in the Department of Biochemistry and Molecular Biology at Colorado State University, *In Search of Cell History: The Evolution of Life's Building Blocks* (Chicago: University of Chicago Press, 2014), 164:

Over the past sixty years, dedicated and skillful scientists have devoted much effort and ink to the origin of life, with remarkably little to show for it. Judging by the volume of literature, both experimental and theoretical, the inquiry has thrived prodigiously. But unlike more conventional fields of biological research, the study of life's origins has failed to generate a coherent and persuasive framework that gives meaning to the growing heap of data and speculation; and this suggests that we may still be missing some essential insight.

Alexey V. Melkikh, a biophysicist at Ural Federal University, "Paradoxes of Early Stages of Evolution of Life and Biological Complexity," *Origins of Life and Evolution of Biospheres* (June 2015, Volume 45, Issue 1), 163:

The problem of the origin of life remains largely unsolved. Although amino acids have been obtained in such experiments as the classic Miller-Urey experiment (Miller, 1953), and observations show the presence of components necessary for life in different parts of the universe (see for example Pizzarello et al. 2012; Callahan et al. 2011), the mechanism of formation of the simplest living system from these components remains unclear. Many questions are unsolved, from the appearance of chiral biological molecules to the origin of the first cells.

Science journalist Clara Moskowitz states the following in her January 1, 2016 online review for *Scientific American* of the 2015 book by Bill Mesler and H. James Cleaves II titled *A Brief History of Creation: Science and the Search for the Origin of Life*:

Here the authors chronicle the historical quest to understand how life arose from nonlife, from Aristotle's theory of the “spontaneous generation” of life, to Charles Darwin's 19th-century musing on the origin occurring “in some warm little pond,” to the latest modern-day research on the “LUCA,” or last universal common ancestor. They find that the scientific understanding of life itself has advanced considerably over the years but that the fundamental event that began it some four billion years ago is just as much a mystery as it ever has been.

James Tour is the T. T. and W. F. Chao Professor of Chemistry, as well as Professor of Computer Science and Professor of Materials Science and NanoEngineering at Rice University. He has over 680 research publications and over 120 patents. He states the following (beginning at 3:05) in his March 3, 2016 lecture titled "The Origin of Life: An Inside Story," available online here: <https://www.youtube.com/watch?v=zQXgJ-dXM4>:

We have no idea how the molecules that compose living systems could have been devised such that they would work in concert to fulfill biology's functions. We have no idea how the basic set of molecules, carbohydrates, nucleic acids, lipids, and proteins, were made and how they could have coupled into the proper sequences, and then transformed into the ordered assemblies until there was the construction of a complex biological system, and eventually to that first cell. Nobody has any idea how this was done when using our commonly understood mechanisms of chemical science. Those that say they understand are generally wholly uninformed regarding chemical synthesis. Those that say "Oh, this is well worked out," they know nothing, nothing about chemical synthesis – Nothing!

Further cluelessness – From a synthetic chemical perspective, neither I nor any of my colleagues can fathom a prebiotic molecular route to construction of a complex system. We cannot figure out the prebiotic routes to the basic building blocks of life: carbohydrates, nucleic acids, lipids, and proteins. Chemists are collectively bewildered. Hence I say that no chemist understands prebiotic synthesis of the requisite building blocks let alone their assembly into a complex system.

That's how clueless we are. I've asked all of my colleagues – National Academy members, Nobel Prize winners – I sit with them in offices; nobody understands this. So if your professors say it's all worked out, your teachers say it's all worked out, they don't know what they're talking about. It is not worked out. You cannot just refer this to somebody else; they don't know what they're talking about.

Sara Imari Walker is a theoretical physicist and astrobiologist at Arizona State University whose research focuses on the origin of life. She states in the abstract of "[Origins of Life: A Problem for Physics](#)" published at the pre-print archive on May 23, 2017:

The origins of life stands among the great open scientific questions of our time. While a number of proposals exist for possible starting points in the pathway from non-living to living matter, these have so far not achieved states of complexity that are anywhere near that of even the simplest living systems. . . . The hope is that a theory akin to our other theories in fundamental physics might one day emerge to explain the phenomenon of life, and in turn finally permit solving its origins.

Edward J. Steele is a molecular immunologist with interest in virology and evolution at the CY O'Connor ERADE Village Foundation in Australia. He and a host of coauthors declare in "Cause of Cambrian Explosion - Terrestrial or Cosmic?" published in *Progress in Biophysics and Molecular Biology* 136 (2018), 7:

The transformation of an ensemble of appropriately chosen biological monomers (e.g. amino acids, nucleotides) into a primitive living cell capable of further evolution appears to require overcoming an information hurdle of superastronomical proportions (Appendix A), an event that could not have happened within the time frame of the Earth except, we believe, as a miracle (Hoyle and Wickramasinghe, 1981,1982,2000). All laboratory experiments attempting to simulate such an event have so far led to dismal failure (Deamer, 2011; Walker and Wickramasinghe, 2015).

Franklin M. Harold, Professor Emeritus in the Department of Biochemistry and Molecular Biology at Colorado State University and Affiliate Professor of microbiology at the University of Washington, *On Life: Cells, Genes, and the Evolution of Complexity* (New York: Oxford University Press, 2021), 93-94:

A credible path to the origin of life remains to be discovered. This is an active field of research, spurred by happy talk both among scientists and in the popular press; my own take is considerably more skeptical. As I read the literature, it seems plausible that the road to life began with a small network of chemical reactions that had the capacity to reproduce itself. At its core may have been some kind of self-replicating molecule (possibly but not necessarily RNA), and it would have included ancillary reactions to supply energy and some degree of structural organization. Evolution in the direction of greater autonomy, complexity, and functional organization would have been driven, not by the classical interplay of heredity, variation, competition, and natural selection, but by the search for increased dynamic kinetic stability. The exact nature of this system and where it may have come from are entirely unknown and represent the current version of biology's black hole. However, it is not unreasonable to hope that future research into the chemistry of replicating systems will turn up suggestive examples.

Granted that such a rudiment of biological organization had somehow come to exist, there remains a huge gap between a chemical network and even the simplest protocell; and it is not at all clear how (and

even whether) evolution by small steps could bridge it. The widest of the chasms to be leapt would have been the invention of translation, the production of proteins that perform a cellular function at the behest of instructions spelled out in a nucleotide sequence. To my knowledge, no plausible scheme to accomplish this feat has yet been proposed, and there is no analog or precedent. To paraphrase a remark by J. T. Trevors and L. D. Abel, natural processes have never been observed to write prescriptive instructions. Protocells, beginning with nothing more than a prebiotic soup, must be credited with an achievement that has so far eluded the best and brightest of chemists. One cannot help wondering whether we have been missing something fundamental.