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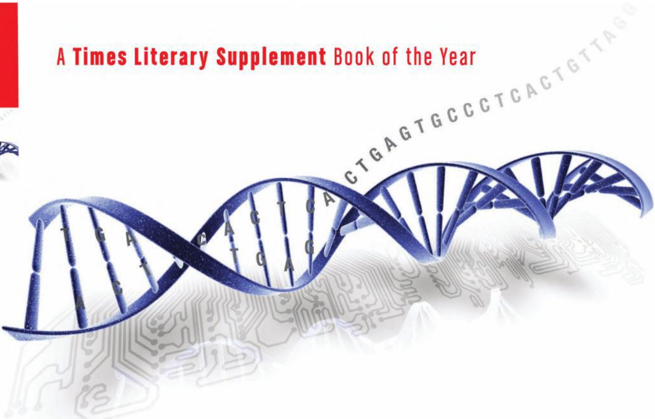

SIGNATURE IN THE CELL

DNA AND THE EVIDENCE FOR INTELLIGENT DESIGN

STEPHEN C. MEYER

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Signature in the Cell

DNA and the Evidence for Intelligent Design

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Prologue

"Dad, that's you!" my fourteen-year-old son exclaimed as he looked at the newspaper while we stood waiting to check out at the tiny general store. His shock at seeing my face in the front section of the *Seattle Post-Intelligencer*, when he just went to look for baseball scores, was no doubt compounded by his awareness of our location.[1] The general store on Shaw Island, one of the most remote in the San Juan chain north of Puget Sound, was the only commercial establishment on the island. This irony was not lost on my wife, whose raised eyebrow said it all. "I thought we were coming here to get away from all of this." We were. But then how was I to know that the local Seattle paper would rerun the previous day's front-page story from the *New York Times* about the program of scientists I directed and the controversy surrounding our work?[2]

The controversy about the origin of life and whether it arose from an undirected material process or from some kind of designing intelligence is not new. It goes back in Western civilization at least as far as the ancient Greeks, who produced philosophers representing both schools of thought. But the controversy over the contemporary theory of intelligent design (ID) and its implied challenge to orthodox evolutionary theory became big *news* beginning in 2004 and 2005. And, for better or worse, I found myself right in the middle of it.

Three events sparked intense media interest in the subject. First, in August 2004, a technical journal housed at the Smithsonian Institution in Washington, D.C., called the *Proceedings of the Biological Society of Washington* published the first peer-reviewed article explicitly advancing the theory of intelligent design in a mainstream scientific periodical. After the publication of the article, the Smithsonian's Museum of Natural History erupted in internal controversy, as scientists angry with the editor—an evolutionary biologist with two earned Ph.D.'s—questioned his editorial judgment and demanded his censure. Soon the controversy spilled over into the scientific press as news stories about the article and editor's decision appeared in *Science, Nature, The Scientist,* and the *Chronicle of Higher Education*.[3]

The media exposure fueled further embarrassment at the Smithsonian, resulting in a second wave of recriminations. The editor, Richard Sternberg, lost his office and his access to scientific samples and was later transferred to a hostile supervisor. After Sternberg's case was investigated by the U.S. Office of Special Counsel, a government watchdog organization, and by the U.S. House Committee on Government Reform, a congressional committee, other questionable actions came to light.[4] Both investigations found that senior administrators at the museum had interrogated Sternberg's colleagues about Sternberg's religious and political beliefs and fomented a misinformation campaign designed to damage his scientific reputation and encourage his resignation.[5] Sternberg did not resign his research appointment, but he was eventually demoted.

As word of his mistreatment spread, the popular press began to run stories about his case. Ordinarily, my reaction to such reports might have been to shake my head in dismay and move on to the next story in the news cycle. But in this case, I couldn't. As it happened, I was the author of the offending article. And some of the reporters interested in Sternberg's mistreatment were coming to me with questions. They wanted to know more about the theory of intelligent design and why it had provoked such alarm among establishment scientists.

Then in December 2004, two other events generated worldwide interest in the theory of intelligent design. First, a renowned British philosopher, Antony Flew, announced that he had repudiated a lifelong commitment to atheism, citing, among other factors, evidence of intelligent design in the DNA molecule.[6] Flew noted in his announcement that his views about the origin of life bore a striking resemblance to those of "American design theorists." Again, intelligent design was in the news. But what was it? This time I found myself on the BBC debating a prominent evolutionary biologist about the theory.

Later in the month, the American Civil Liberties Union (ACLU) announced a suit against a school board in the western Pennsylvania town of Dover. The school board had just announced its intention to let high school students learn about the theory of intelligent design. To do this, it proposed to inform students about the existence of a book in the school library—one that made the case for intelligent design in opposition to the standard evolutionary theories presented in the existing biology textbooks. When the ACLU announced its own intentions to sue, the national media descended upon the town en masse.

The press corps covering the story no doubt already knew about the 1925 Scopes "monkey trial" from the fictionalized Spencer Tracy movie *Inherit the Wind,* if from no other source. In Dover they sensed they had the makings of a sequel. During 2005, all the major American network and cable news programs ran segments about the theory of intelligent design, the Dover controversy, or both. Stories not only appeared in major U.S. newspapers, but in papers around the world, from the *Times* of London, *Sekai Nippo* (Tokyo), the *Times* of India, and *Der Spiegel* to the *Jerusalem Post.*

Then in August 2005, just as an end to the media buzz seemed near, a number of political and religious leaders—including figures as diverse as the Dalai Lama, President George W. Bush, and the pope—made public statements supportive of either intelligent design or allowing students to learn about the controversy surrounding it. When *Time* magazine followed suit with a cover story about the controversy, our phones started ringing all over again.

As summer was drawing to an end, my wife and I decided it was time for our family to get away after friends offered us the use of their island cabin. But in the two-week period corresponding to our vacation, the *New York Times* ran its two front-page stories about our program at the Discovery Institute, the *Washington Post* broke a story about the latest developments in the Sternberg case, and the *New York Times* editorial page offered criticism of Sternberg in its main staff-written editorial.[7] After Sternberg decided to appear on *The O'Reilly Factor* to tell his side of the story, we knew it was time to head back to Seattle.[8]

My temporary notoriety provided something my colleagues and I sorely needed—a platform for correcting much of the misinformation circulating about the theory of intelligent design. Many news articles and reports confused intelligent design with biblical creationism and its literal reading of the book of Genesis. Other articles echoed the talking points of our critics and portrayed our work as either "giving up on science" or a sneaky attempt to circumvent the legal prohibitions against teaching creationism in the public schools that the Supreme Court had enacted in 1987.

Yet I knew that the modern theory of intelligent design was not developed as a legal strategy, still less as one to abet creationism. Instead, it was first considered in the late 1970s and early 1980s by a group of scientists—Charles Thaxton, Walter Bradley, and Roger Olsen—as a possible explanation for an enduring mystery of modern biology: the origin of the digital information encoded along the spine of the DNA molecule.[9]

As I explained repeatedly to reporters and cable-news hosts, the theory of intelligent design is not based on a religious text or document, even if it does have implications that support theistic belief (a point to which I will return in Chapter 20). Instead, intelligent design is an evidence-based scientific theory about life's origins that challenges strictly materialistic views of evolution.

Indeed, the theory of intelligent design challenges a specific tenet of contemporary evolutionary theory. According to modern neo-Darwinists such as Oxford's Richard Dawkins, living systems "give the appearance of having been designed for a purpose." But, to Dawkins and other contemporary Darwinists, that appearance of design is entirely illusory, because wholly undirected processes such as natural selection and random mutations can produce the intricate design–like structures in living systems. In their view, natural selection can mimic the powers of a designing intelligence without being guided or directed in any way.

In contrast, the theory of intelligent design holds that there are telltale features of living systems and the universe that are best explained by an intelligent cause—that is, by the conscious choice of a rational agent—rather than by an undirected process. Either life arose as the result of purely undirected processes, or a guiding intelligence played a role. Advocates of intelligent design argue for the latter option based on evidence from the natural world. The theory does not challenge the idea of evolution defined as change over time or even common ancestry, but it does dispute the Darwinian idea that the cause of all biological change is wholly blind and undirected. Even so, the theory is not based on biblical doctrine. Intelligent design is an inference from scientific evidence, not a deduction from religious authority.

Despite the opportunity I had been given in the media to clarify our position, my experiences left me with a sense of unfinished business.

By 2005, I had devoted nearly twenty years of my life to developing a case for intelligent design based upon the discovery of the information-bearing properties—the digital code—stored in the DNA molecule. I had written a series of scientific and philosophical articles developing this idea,[10] but these articles were neither particularly accessible nor gathered into one volume. Now I repeatedly found myself in the position of having to defend an argument in sound bites that my audience did not know well enough to evaluate. How could they? Perhaps the central argument for intelligent design, the one that first induced me to consider the hypothesis, had not been explained adequately to a general, scientifically literate audience.

Of course, by 2005 many excellent books and articles—including several important peer-reviewed books—had already been published on different aspects of the theory of intelligent design. In 1996, Lehigh University biochemist Michael Behe made a detailed case for intelligent design based upon the discovery of nanotechnology in cells—such as the now famous bacterial flagellar motor with its thirty-part rotary engine. Behe's *Darwin's Black Box* sold over a quarter of a million copies and almost single-handedly put the idea of intelligent design on the cultural and scientific map. In 1998, William Dembski, a mathematician and philosopher with two Ph.D.'s (including one from the University of Chicago), followed suit by publishing a groundbreaking work on methods of design detection. Dembski's work, *The Design Inference,* published by Cambridge University Press, established a scientific method for distinguishing the effects of intelligence from the effects of undirected natural processes. His work established rigorous indicators of intelligent design, but did not make any specific argument for intelligent design based on the presence of these indicators in living organisms.

These were seminal works, but I had become convinced of intelligent design by another route. Over the years, I began to develop a related, but largely independent, case for intelligent design. Unfortunately I had a penchant for writing long, dense essays in obscure journals and anthologies. Even my article in the *Proceedings of the Biological Society of Washington* attracted more attention because of the controversy at the Smithsonian than because of controversy over the argument itself, though there had been more than a bit of that in some scientific circles.[11]

In any case, when the national media came calling, I simply could not get them to report why I thought DNA pointed to intelligent design. Reporters refused to cover the argument in their articles or backgrounders; debate partners scrupulously avoided responding to it, but instead continued to recite their talking points about the dangers of "intelligent design creationism." Even the judge in the Dover case decided the scientific validity of intelligent design without considering the DNA evidence.

Though I wasn't too keen on having federal judges decide the merit of any scientific argument, let alone one that I favored, the Dover trial and its associated media coverage made me aware that I needed to make my argument in a more prominent way. Many evolutionary biologists had acknowledged that they could not explain the origin of the first life. Leading theories failed in large measure because they could not explain where the mysterious information present in the cell came from. So it seemed there were no good counterarguments to the case I wanted to make. Yet various avoidance strategies continued to work because the argument did not have sufficient public prominence to force a response. Too few people in the public, the scientific community, and the media even knew about it. And yet it provided—arguably—one of the most important and fundamental reasons for considering intelligent design.

None of this was actually too surprising. Since World War II, scientists have stressed the importance of publishing their work in specialized peer-reviewed journals, but throughout the history of science "paradigm-shifting" ideas and theories have typically been presented in books, including many that we might now call "trade press" (rather than academic) books.

There are a couple of reasons for this. First, books allow scientists to make sustained and comprehensive arguments for synthetic new ideas. As the Italian philosopher of science Marcello Pera has shown, scientists often *argue* about competing interpretations of the evidence.[12] Although this is sometimes done successfully in short articles—as Einstein did in making his case for special and general relativity and Watson and Crick did in their nine-hundred-word article proposing a double helix structure for DNA—books have often been the go-to genre for presenting and evaluating new arguments for synthetic interpretations of a relevant body of evidence.

Perhaps the best-known example of this form of scientific discourse was provided by Charles Darwin himself, who famously described his work in *On the Origin of Species by Means of Natural Selection* as "one long argument."[13] There, Darwin proposed a comprehensive interpretation of many diverse lines of evidence. He also argued for the superior explanatory power of his theory and its two key propositions: (1) the creative power of natural selection and (2) the descent of all life from a common ancestor. As part of his case, he also argued against the explanatory adequacy of rival interpretations of the evidence and refuted arguments for them. Other scientists such as Newton, Copernicus, Galileo, and Lyell as well as a host of lesser figures have used books to advance scientific arguments in favor of novel and comprehensive interpretations of the scientific evidence in their disciplines.

There are other reasons that books are used to advance paradigm-shifting ideas. New scientific theories often synthesize a broad range of evidence from many related disciplines or subdisciplines of science. As such, they are often inherently interdisciplinary in scope. *On the Origin of Species* incorporated data from several disciplines, including embryology, paleontology, comparative anatomy, and biogeography. Modern scientific journals, typically focused as they are on topics within a narrowly defined subdiscipline, rarely permit the kind of comprehensive review and assessment of evidence that the advancement of a new interpretive framework requires.

Additionally, by creating a larger audience for a new idea, a book, and particularly a popular trade book, can go over the heads of an entrenched establishment to force the reevaluation of an established theory by creating wider interest in its standing. Darwin did this by publishing *On the Origin of Species by Means of Natural Selection* with John Murray, a prominent trade press in Victorian England. Michael Behe has done this as well. By making a case for intelligent design based upon various examples of nanotechnology in the cell, Behe's book focused international attention on the problem that complex systems have posed for neo-Darwinism. It also gave the theory of intelligent design public and, arguably, scientific standing.

This book makes a case for that same idea. It does so, however, on the basis of a different class of evidence: the information—the digital code—stored in DNA and the other large biological molecules.

The case I make for intelligent design is less well known than Professor Behe's and, therefore, to many completely new. Even so, it is not based upon a new discovery. It is, instead, based upon one of the most famous breakthroughs of modern biology: the discovery in 1953 of the information-bearing capacities of the DNA molecule, what I call the "signature in the cell."

In 2005, when I was repeatedly placed in the position of defending the theory of intelligent design in the media, the argument that I most wanted to make in its favor had little public standing. I have written this book to remedy that deficiency. This book attempts to make a comprehensive, interdisciplinary argument for a new view of the origin of life. It makes "one long argument" for the theory of intelligent design.

Before coming to work full-time at the Discovery Institute, I worked for twelve years as a college professor. In teaching I've found that it is often easier to understand a scientific theory if one can follow the historical progression of thought that led to its formulation. Following a story of discovery is not only more engaging, it can also illuminate the process of reasoning by which investigators came to their conclusions. For this reason, I've chosen to present my case for intelligent design in the context of a larger historical and personal narrative.

Thus, *Signature in the Cell* does not just make an argument; it also tells a story, a mystery story and the story of my engagement with it. It tells about the mystery that has surrounded the discovery of the digital code in DNA and how that discovery has confounded repeated attempts to explain the origin of the first life on earth. Throughout the book I will call this mystery "the DNA enigma."

A brief word about the organization of the book: in Chapters 1 and 2 I define the scientific and philosophical issues at stake in the DNA enigma and give some historical background about the larger origin-of-life debate. In Chapters 3, 4, and 5 I describe the mystery surrounding DNA in more detail in order to establish what it is that any theory of the origin of life must explain. After a short interlude in Chapters 6 and 7 in which I examine what scientists in the past have thought about biological origins and how scientists currently investigate these questions, I examine (in Chapters 8 through 14) the competing explanations for the origin of biological information. Then, in Chapters 15 and 16, I present a positive case for intelligent design as the best explanation for the origin of the information necessary to produce the first life. Finally, in Chapters 17 through 20, I defend the theory of intelligent design against various popular objections to it. In the Epilogue, I show that intelligent design offers a fruitful approach to future scientific research. Not only does it illuminate some very recent and surprising discoveries in genomics, but it also suggests productive new lines of scientific investigation for many subdisciplines of biology.

My interest in the DNA enigma stretches back nearly twenty-five years. And though there were times (particularly in 2005) when I was frustrated with myself for not having already produced this work, my protracted production schedule has had at least two unintended advantages. First, it has given me the opportunity to engage in both private conversation and public debate with some of the leading scientific figures involved in this controversy. That has made it possible for me to present what I hope is an unusually thorough analysis of the competing explanations for the origin of the information in living cells.

Second, because of the timing of its release, this book may contribute to the ongoing assessment of Darwin's legacy just when many scientists, scholars, reporters, and others will be doing so. This year marks the 200th anniversary of Darwin's birth and the 150th anniversary of the publication of *On the Origin of Species.* In the *Origin,* Darwin accomplished many things. He introduced a new framework for understanding the history of life. He identified a new mechanism of biological change. And, according to many scholars and scientists, he also refuted the scientific argument for design. He did this by explaining away any presumed vestiges of an actual designing intelligence, showing instead that these "appearances of design" had been produced by a purely undirected process—indeed, one that could mimic the powers of a designing mind. As evolutionary biologist Francisco Ayala has recently explained, Darwin explained the appearance of design without recourse to an actual designer. He gave us "design without a designer."[14] But is this really true? Even if we grant Darwin's argument in the *Origin,* does it really follow that he refuted the design hypothesis? This book will present a fresh perspective on this question by examining one of the most enduring mysteries of modern biology.

1

DNA, Darwin, and the Appearance of Design

When James Watson and Francis Crick elucidated the structure of DNA in 1953, they solved one mystery, but created another.

For almost a hundred years after the publication of *On the Origin of Species* by Charles Darwin in 1859, the science of biology rested secure in the knowledge that it had explained one of humankind's most enduring enigmas. From ancient times, observers of living organisms had noted that living things display organized structures that give the appearance of having been deliberately arranged or designed for a purpose, for example, the elegant form and protective covering of the coiled nautilus, the interdependent parts of the eye, the interlocking bones, muscles, and feathers of a bird wing. For the most part, observers took these appearances of design as genuine. Observations of such structures led thinkers as diverse as Plato and Aristotle, Cicero and Maimonides, Boyle and Newton to conclude that behind the exquisite structures of the living world was a designing intelligence. As Newton wrote in his masterpiece *The Opticks:* "How came the Bodies of Animals to be contrived with so much Art, and for what ends were their several parts? Was the Eye contrived without Skill in Opticks, and the Ear without Knowledge of Sounds? . . . And these things being rightly dispatch'd, does it not appear from Phænomena that there is a Being incorporeal, living, intelligent . . . ?"[1]

But with the advent of Darwin, modern science seemed able to explain this appearance of design as the product of a purely undirected process.

In the *Origin,* Darwin argued that the striking appearance of design in living organisms—in particular, the way they are so well adapted to their environments—could be explained by natural selection working on random variations, a purely undirected process that nevertheless mimicked the powers of a designing intelligence. Since then the appearance of design in living things has been understood by most biologists to be an illusion—a powerfully suggestive illusion, but an illusion nonetheless. As Crick himself put it thirty-five years after he and Watson discerned the structure of DNA, biologists must "constantly keep in mind that what they see was not designed, but rather evolved."[2]

But due in large measure to Watson and Crick's own discovery of the information-bearing properties of DNA, scientists have become increasingly and, in some quarters, acutely aware that there is at least one appearance of design in biology that may not yet have been adequately explained by natural selection or any other purely natural mechanism. Indeed, when Watson and Crick discovered the structure of DNA, they also discovered that DNA stores information using a four-character chemical alphabet. Strings of precisely sequenced chemicals called nucleotide bases store and transmit the assembly instructions—the information—for building the crucial protein molecules and machines the cell needs to survive.

Crick later developed this idea in his famous "sequence hypothesis," according to which the chemical parts of DNA (the nucleotide bases) function like letters in a written language or symbols in a computer code. Just as letters in an English sentence or digital characters in a computer program may convey information depending on their arrangement, so too do certain sequences of chemical bases along the spine of the DNA molecule convey precise instructions for building proteins. Like the precisely arranged zeros and ones in a computer program, the chemical bases in DNA convey information in virtue of their "specificity." As Richard Dawkins notes, "The machine code of the genes is uncannily computer-like."[3] Software developer Bill Gates goes further: "DNA is like a computer program but far, far more advanced than any software ever created."[4]

But if this is true, how did the information in DNA arise? Is this striking appearance of design the product of actual design or of a natural process that can mimic the powers of a designing intelligence? As it turns out, this question is related to a long-standing mystery in biology—the question of the origin of the first life. Indeed, since Watson and Crick's discovery, scientists have increasingly come to understand the centrality of information to even the simplest living systems. DNA stores the assembly instructions for building the many crucial proteins and protein machines that service and maintain even the most primitive one-celled organisms. It follows that building a living cell in the first place requires assembly instructions stored in DNA or some equivalent molecule. As origin-of-life researcher Bernd-Olaf Küppers explains, "The problem of the origin of life is clearly basically equivalent to the problem of the origin of biological information."[5]

Much has been discovered in molecular and cell biology since Watson and Crick's revolutionary discovery more than fifty years ago, but these

Figure 1.1. James Watson and Francis Crick at the Cavendish Laboratory in Cambridge. *Courtesy of Barrington Brown/Photo Researchers, Inc.*

discoveries have deepened rather than mitigated the enigma of DNA. Indeed, the problem of the origin of life (and the origin of the information needed to produce it) remains so vexing that Harvard University recently announced a $100 million research program to address it.[6] When Watson and Crick discovered the structure and information-bearing properties of DNA, they did indeed solve one mystery, namely, the secret of how the cell stores and transmits hereditary information. But they uncovered another mystery that remains with us to this day. This is the DNA enigma—the mystery of the origin of the information needed to build the first living organism.

In one respect, of course, the growing awareness of the reality of information within living things makes life seem more comprehensible. We live in a technological culture familiar with the utility of information. We buy information; we sell it; and we send it down wires. We devise machines to store and retrieve it. We pay programmers and writers to create it. And we enact laws to protect the "intellectual property" of those who do. Our actions show that we not only value information, but that we regard it as a real entity, on par with matter and energy.

That living systems also contain information and depend on it for their existence makes it possible for us to understand the function of biological organisms by reference to our own familiar technology. Biologists have also come to understand the utility of information, in particular, for the operation of living systems. After the early 1960s advances in the field of molecular biology made clear that the digital information in DNA was only part of a complex information-processing system, an advanced form of nanotechnology that mirrors and exceeds our own in its complexity, storage density, and logic of design. Over the last fifty years, biology has advanced as scientists have come to understand more about how information in the cell is stored, transferred, edited, and used to construct sophisticated machines and circuits made of proteins.

The importance of information to the study of life is perhaps nowhere more obvious than in the emerging fields of genomics and bioinformatics. Over the last decade, scientists involved in these disciplines have begun to map—character by character—the complete sequence of the genetic instructions stored on the human genome and those of many other species. With the completion of the Human

Genome Project in 2000, the emerging field of bioinformatics entered a new era of public interest. News organizations around the world carried President Clinton's announcement of the project's completion on the White House lawn as Francis Collins, scientific director of the project, described the genome as a "book," a repository of "instructions," and the "book of life."[7] The Human Genome Project, perhaps more than any discovery since the elucidation of the structure of DNA in 1953, has heightened public awareness of the importance of *information* to living things. If Watson and Crick's discovery showed that DNA stores a genetic text, Francis Collins and his team took a huge step toward deciphering its message. Biology has irrevocably entered an information age.

In another way, however, the reality of information within living things makes life seem more mysterious. For one thing, it is difficult to understand exactly what information *is*. When a personal assistant in New York types a dictation and then prints and sends the result via fax to Los Angeles, some *thing* will arrive in L.A. But that thing—the paper coming out of the fax machine—did not originate in New York. Only the information on the paper came from New York. No single physical substance—not the air that carried the boss's words to the dictaphone, or the recording tape in the tiny machine, or the paper that entered the fax in New York, or the ink on the paper coming out of the fax in Los Angeles—traveled all the way from sender to receiver. Yet something did.

The elusive character of information—whether biological or otherwise—has made it difficult to define by reference to standard scientific categories. As evolutionary biologist George Williams notes, "You can speak of galaxies and particles of dust in the same terms because they both have mass and charge and length and width. [But] you can't do that with information and matter."[8] A blank magnetic tape, for example, *weighs* just as much as one "loaded" with new software—or with the entire sequence of the human genome. Though these tapes differ in information content (and value), they do not do so because of differences in their material composition or mass. As Williams concludes, "Information doesn't have mass or charge or length in millimeters. Likewise matter doesn't have bytes. . . . This dearth of shared descriptors makes matter and information two separate domains."[9]

When scientists during the late 1940s began to define information, they did not make reference to physical parameters such as mass, charge, or watts. Instead, they defined information by reference to a psychological state—the reduction of uncertainty—which they proposed to measure using the mathematical concept of probability. The more improbable a sequence of characters or signals, the more uncertainty it reduces, and thus the more information it conveys.[10]

Not surprisingly, some writers have come close to equating information with thought itself. The information technology guru George Gilder, for example, notes that developments in fiber optics have allowed more and more information to travel down smaller and smaller (and lighter and lighter) wires. Thus, he notes that as technology advances, we convey ever more thought across ever less matter—where the numerator in that ratio, namely, thought, corresponds precisely to information.[11]

So should we think of information as thought—as a kind of mental chimera etched in stone or burned onto compact discs? Or can we define information less abstractly as, perhaps, just an improbable arrangement of matter?

Whatever information is—whether thought or an elaborate arrangement of matter—one thing seems clear. What humans recognize as information certainly *originates* from thought—from conscious or intelligent activity. A message received via fax by one person first arose as an idea in the mind of another. The software stored and sold on a compact disc resulted from the design of a software engineer. The great works of literature began first as ideas in the minds of writers—Tolstoy, Austen, or Donne. Our experience of the world shows that what we recognize as information invariably reflects the prior activity of conscious and intelligent persons.

What, then, should we make of the presence of information in living organisms? The Human Genome Project, among many other developments in modern biology, has pressed this question to the forefront of public awareness. We now know that we do not just create information in our own technology; we also find it in our biology—and, indeed, in the cells of every living organism on earth. But how did this information arise? And what does the presence of information in even the simplest living cell imply about life and its origin? Who or what "wrote" the book of life?

The information age in biology officially began in the mid-1950s with the elucidation of the chemical structure and information-bearing properties of DNA (deoxyribonucleic acid)—the molecule of heredity. Beginning in 1953 with their now famous communication to the British scientific journal *Nature,* James Watson and Francis Crick identified DNA as the molecular repository of genetic information.[12] Subsequent developments in the field of molecular biology confirmed this idea and showed that the precisely sequenced bases attached to the helical backbone of DNA store the information for building proteins—the sophisticated enzymes and machines that service the cells in all living things.

Though the discovery of the information-bearing properties of DNA dates back over a half century, the recognition of the full significance of this discovery has been slow in coming. Many scientists have found it difficult to relinquish an exclusive reliance upon the scientific categories of matter and energy alone. As George Williams (himself an evolutionary biologist) notes, "Evolutionary biologists have failed to realize that they work with two more or less incommensurable domains: that of information and that of matter. . . . The gene is a package of information, not an object. The pattern of base pairs in a DNA molecule specifies the gene. But the DNA molecule is the medium, it's not the message."[13]

Yet this recognition begs deeper questions. What does it mean when we find information in natural objects—living cells—that we did not ourselves design or create? As the information theorist Hubert Yockey observes, the "genetic code is constructed to confront and solve the problems of communication and recording by the same principles found . . . in modern communication and computer codes." Yockey notes that "the technology of information theory and coding theory has been in place in biology for at least 3.85 billion years," or from the time that life first originated on earth.[14] What should we make of this fact? How did the information in life first arise?

Our commonsense reasoning might lead us to conclude that the information necessary to the first life, like the information in human technology or literature, arose from a designing intelligence. But modern evolutionary biology rejects this idea. Many evolutionary biologists admit, of course, that living organisms "appear to have been carefully and artfully designed," as Richard Lewontin puts it.[15] As Richard Dawkins states, "Biology is the study of complex things that appear to have been designed for a purpose."[16] Nevertheless, Lewontin and Dawkins, like evolutionary biologists generally, insist that the appearance of design in life is illusory. Life, they say, looks designed, but was not designed by an actual intelligent or purposive agent.

Darwin's Designer Substitute

Why do evolutionary biologists so confidently assert that the appearance of design in living organisms is illusory? Of course, the answer to this question is well known. Evolutionary biologists have a theory that can apparently explain, or explain away, the appearance of design without invoking an actual designer. According to classical Darwinism, and now modern neo-Darwinism, the mechanism of natural selection acting on random variations (or mutations) can mimic the effects of intelligence, even though the mechanism is, of course, entirely blind, impersonal, and undirected.[17]

Figure 1.2. English naturalist Charles Robert Darwin (1809–82), age seventy-two. *Courtesy of SPL/Photo Researchers, Inc.*

Darwin developed his principle of natural selection by drawing on an analogy with artificial selection: the process of selective breeding to change the characteristics (whether anatomical, physiological, or behavioral) of a group of organisms. For example, a farmer might observe that some of his young stallions are faster than others. If he allows only the fastest of these to breed with the fastest mares, then, after several generations of selective breeding, he will own a small group of speedy "thoroughbreds" suitable for racing on the Downs.

Darwin realized that nature could imitate this process of selective breeding. The presence of unusually fast predatory wild cats would imperil all but the fastest horses in a wild herd. After several generations of such predatory challenge, the speed of the remaining herd might exhibit a discernible increase. Thus, environmental forces (predators, changes in weather, competition for food, etc.) could accomplish the work of a human breeder. By causing a population to adapt to its environment, blind forces of nature could come to mimic, over time, the action of a selecting or designing intelligence.

Yet if natural selection, as Darwin called this process, could improve the speed of a horse or an antelope, why couldn't it also produce those animals in the first place? "Reason," wrote Darwin "ought to conquer . . . imagination"[18]—namely, our incredulity about the possibility of such happenings and our impression that living things appear to have been designed. According to Darwin, if given enough time, nature's selective power might act on any variation perfecting any structure or function far beyond what any human could accomplish. Thus, the complex systems in life that we reflexively attribute to intelligence have wholly natural causes. As Darwin explained, "There seems to be no more design in the variability of organic beings, and in the action of natural selection, than in the course which the wind blows."[19] Or as evolutionary biologist Francisco Ayala explains, "The functional design of organisms and their features would . . . seem to argue for the existence of a designer. It was Darwin's greatest accomplishment [however] to show that the directive organization of living beings can be explained as the result of a natural process, natural selection, without any need to resort to a Creator or other external agent."[20] Thus, Ayala and other Darwinian biologists not only affirm that natural selection can produce "design without a designer," they also assert that it is "creative without being conscious."[21]

The Appearance of Design

To many outside evolutionary biology, the claim that design arises without a designer may seem inherently contradictory. Yet, in theory at least, the possibility that life is not what it seems represents nothing particularly unusual. Science often shows that our perceptions of nature do not match reality. A straight pencil appears bent when inserted in a glass of water; the sun appears to circle the earth; and the continents appear immobile. Perhaps, living organisms only appear to be designed.

Even so, there is something curious about the scientific denial of our ordinary intuition about living things. For almost a hundred and fifty years, since its putative explanation by Darwinian theory, this impression of design persists as incorrigibly as ever. Public opinion polls suggest that nearly 90 percent of the American public does not accept the full-fledged neo-Darwinian account of evolution with its denial of any role for a purposeful creator.[22] Though many of these people accept some form of evolutionary change and have a high view of science generally, they apparently cannot bring themselves to repudiate their deepest intuitions and convictions about the design of the living world. In every generation since the 1860s, scientific critics of Darwinism and neo-Darwinism have arisen marshaling serious evidential objections to the theory. Since the 1980s a growing number of scientists and scholars have expressed deep reservations about both biological and chemical evolutionary theory, each with their implicit denial of design. And even orthodox evolutionary biologists admit the overwhelming *impression* of design in modern organisms. To quote Francis Crick again, "Biologists *must constantly keep in mind* that what they see was not designed, but rather evolved."[23]

Perhaps more curiously, modern biologists can scarcely describe living organisms without resorting to language that seems to imply the very thing they explicitly deny: intentional and purposive design. As philosopher of science Michael Ruse notes, biologists ask about "the *purpose* of the fins on the back of the stegosaurus" or "the *function* of the bird's feathers" and discuss whether "the Irish elk's antlers did or did not exist *in order* to intimidate rivals." "It is true," Ruse continues, "that during the nineteenth century [some physicists] suggested that the moon exists in order to light the way home of lonely travelers, but no physicist would use such language today. In biology, however, especially evolutionary biology, this kind of talk is commonplace." He concludes, "The world of the evolutionist is drenched in the anthropomorphism of intention." And yet "paradoxically, even the severest critics" of such intentional language slip into it "for the sake of convenience."[24]

In theory, at least, the use of such metaphor in science derives from ignorance. Physicists talk about gravitational "attraction," because they don't really know what causes action at a distance. Metaphors reign where mystery resides. Yet, on these grounds, we might have expected that as biology advanced, as new discoveries explicated the molecular basis of biological functions, biology's reliance upon the language of purpose, upon teleological metaphor, might have diminished. Yet the very opposite has taken place. The advent of the most reductionistic subdiscipline of modern biology—molecular biology—has only deepened our dependence on teleological language.

In fact, molecular biologists have introduced a new "high-tech" teleology, taking expressions, often self-consciously, from communication theory, electrical engineering, and computer science. The vocabulary of modern molecular and cell biology includes apparently accurate descriptive terms that nevertheless seem laden with a "metaphysics of intention": "genetic code," "genetic information," "transcription," "translation," "editing enzymes," "signal-transduction circuitry," "feedback loop," and "information-processing system." As Richard Dawkins notes, "Apart from differences in jargon, the pages of a molecular-biology journal might be interchanged with those of a computer-engineering journal."[25] As if to underscore the point, University of Chicago cell biologist James Shapiro describes the integrated system of proteins that constitutes the mammalian blood-clotting system "as a powerful real-time distributed computing system." In the same context he notes that many biochemical systems within the cell resemble "the wiring diagram for an electronic circuit."[26] As the historian of biology Timothy Lenoir observes, "Teleological thinking has been steadfastly resisted by modern biology. And yet in nearly every area of research, biologists are hard pressed to find language that does not impute purposiveness to living forms."[27]

Thus, it seems that an acquaintance with biological organisms, to say nothing of the molecular biology of the cell, leads even those who repudiate design to use language that seems incompatible with their own reductionistic and Darwinian perspective—with their official denial of actual design. Although this may ultimately signify nothing, it does at least raise a question. Does the persistence of our perception of design, and the use of incorrigibly teleological language, indicate anything about the origin of life or the adequacy of scientific theories that deny (actual) design in the origin of living systems?

As always, in science the answer to such questions depends entirely on the justification that scientists can provide for their theories. Intuitions and perceptions can be right or wrong. It might well be, as many in biology assure us, that public and even scientific doubts about evolutionary theory derive solely from ignorance or religious prejudice, and that teleological language reflects nothing more than a metaphor of convenience, like saying the sun has set behind the horizon. Yet the persistence of dissenting scientific opinion and the inability of biologists to avoid the language of purpose raise a pardonable curiosity. Have evolutionary biologists discovered the true cause of the appearance of design in living systems, or should we look for another? Should we trust our intuitions about living organisms or accept the standard evolutionary account of biological origins?

The Origin of Biological Information

Consider the following sequence of letters:

AGTCTGGGACGCGCCGCCGCCATGATCATCCCTGTACGCTGCTTCACTTGT-
GGCAAGATCGTCGGCAACAAGTGGGAGGCTTACCTGGGGCTGCTGCAGG
CCGAGTACACCGAGGGGTGAGGCGCGGGCCGGGGCTAGGGGCTGAGTCC-
GCCGTGGGGCGCGGGCCGGGGCTGGGGGCTGAGTCCGCCCTGGGGTGCGCG
CCGGGGCGGGAGGCGCAGCGCTGCCTGAGGCCAGCGCCCCATGAGCAGCTTCAG-
GCCCGGCTTCTCCAGCCCCGCTCTGTGATCTGCTTTCGGGAGAACC

This string of alphabetic characters looks as if it could be a block of encoded information, perhaps a section of text or machine code. That impression is entirely correct, for this string of characters is not just a random assortment of the four letters A, T, G, and C, but a representation of part of the sequence of genetic assembly instructions for building a protein machine—an RNA polymerase[28]—critical to gene expression (or information processing) in a living cell.

Now consider the following string of characters:

010101110110100001100101011011100010000001101001011
011100010000000111010001101000011001010010000000100
00110110111101110101011100100111001101100101001000
000110111101100110001000000011010000111010101101101
011000001011011100010000001100101010111011001100101
0110111001110100011100110010000000110100101110100

This sequence also appears to be an information-rich sequence, albeit written in binary code. As it happens, this sequence is also not just a random array of characters, but the first words of the Declaration of Independence ("When in the course of human events . . .")[29] written in the *binary conversion* of the American Standard Code for Information Interchange (ASCII). In the ASCII code, short specified sequences of zeros and ones correspond to specific alphabetic letters, numerals, or punctuation marks.

Though these two blocks of encoded information employ different conventions (one uses the ASCII code, the other the genetic code), both are complex, nonrepeating sequences that are highly specified relative to the functional or communication requirements that they perform. This similarity explains, in part, Dawkins's observation that, "The machine code of the genes is uncannily computer-like." Fair enough. But what should we make of this similarity between informational software—the undisputed product of conscious intelligence—and the informational sequences found in DNA and other important biomolecules?

Introduction to an Enigma

I first encountered the DNA enigma as a young scientist in Dallas, Texas, in 1985. At the time, I was working for one of the big multinational oil companies. I had been hired as an exploration geophysicist several years earlier just as the price of oil had spiked and just as I was graduating from college with degrees in physics and geology. My job, as the Texas oilmen put it, was to "look for *awl* out in the *guff*."

Though I had been a physics and geology student, I had enough exposure to biology to know what DNA did. I knew that it stored the instruction set, the information, for building proteins in the cell and that it transmitted hereditary traits in living things using its four-character chemical alphabet. Even so, like many scientists I had never really thought about where DNA—or the information it contained—came from in the first place. If asked, I would have said it had something to do with evolution, but I couldn't have explained the process in any detail.

On February 10, 1985, I learned that I wasn't the only one. On that day I found myself sitting in front of several world-class scientists who were discussing a vexing scientific and philosophical question: How did the first life on earth arise? As recently as the evening before, I had known nothing about the conference where this discussion was now taking place. I had been attending another event in town, a lecture at the Southern Methodist University by a Harvard astronomer discussing the big-bang theory. There I learned of a conference taking place the following day that would tackle three big scientific questions—the origin of the universe, the origin of life, and the nature of human consciousness. The conference would bring together scientists from competing philosophical perspectives to grapple with each of these issues. The next morning I walked into the downtown Hilton where the conference was being held and heard an arresting discussion of what scientists knew they didn't know.

I was surprised to learn—contrary to what I had read in many textbooks—that the leading scientific experts on the origin of life had no satisfactory explanation for how life had first arisen. These experts, many of whom were present that weekend in Dallas, openly acknowledged that they did not have an adequate theory of what they called "chemical evolution," that is, a theory of how the first living cell arose from simpler chemicals in the primordial ocean. And from their discussions it was clear that DNA—with its mysterious arrangements of chemical characters—was a key reason for this impasse.

The discussion changed the course of my professional life. By the end of that year, I was preparing to move to the University of Cambridge in England, in part to investigate questions I first encountered on that day in February.

On its face, my change of course looked like a radical departure from my previous interests, and that's certainly how my friends and family took it. Oil-company geophysics was a highly practical, commercially relevant form of applied science. A successful study of the subsurface of the earth could net the company millions of dollars of revenue from the resulting discovery of oil and gas. The origin of life, however, was a seemingly intractable—even arcane—theoretical question, with little or no direct commercial or practical import.

Nevertheless, at the time, the transition seemed entirely natural to me. Perhaps it was because I had long been interested in scientific questions and discoveries that raised larger philosophical issues. In college, I had taken many philosophy courses while pursuing my scientific training. But perhaps it was what I was doing at the oil company itself. By the 1980s looking for oil required the use of sophisticated computer-assisted seismic-imaging techniques, at the time a cutting-edge form of information technology. After sending artificial seismic waves down into the earth, geophysicists would time the resulting echoes as they traveled back to the surface and then use the information from these signals to reconstruct a picture of the subsurface of the earth. Of course, at every stage along the way we depended heavily on computers and computer programs to help us process and analyze the information we received. Perhaps what I was learning about how digital information could be stored and processed in machines and about how digital code could direct machines to accomplish specific tasks made life itself—and the digital code stored in its DNA—seem less mysterious. Perhaps this made the problem of the origin of life seem more scientifically tractable and interesting. In any case, when I learned of the enigma confronting origin-of-life researchers and why DNA was central to it, I was hooked.

A controversy that erupted at the conference added to my sense of intrigue. During a session on the origin of life, the scientists were discussing where the information in DNA had come from. How do chemicals arrange themselves to produce code? What introduced drama into what might have otherwise been a dry academic discussion was the reaction of some of the scientists to a new idea. Three of the scientists on the panel had just published a controversial book called *The Mystery of Life's Origin* with a prominent New York publisher of scientific monographs. Their book provided a comprehensive critique of the attempts that had been made to explain how the first life had arisen from the primordial ocean, the so-called prebiotic soup. These scientists, Charles Thaxton, Walter Bradley, and Roger Olsen, had come to the conclusion that all such theories had failed to explain the origin of the first life. Surprisingly, the other scientists on the panel—all experts in the field—did not dispute this critique.

What the other scientists did dispute was a controversial new hypothesis that Thaxton and his colleagues had floated in the epilogue of their book in an attempt to explain the DNA enigma. They had suggested that the information in DNA might have originated from an intelligent source or, as they put it, an "intelligent cause." Since, in our experience, information arises from an intelligent source, and since the information in DNA was, in their words, "mathematically identical" to the information in a written language or computer code, they suggested that the presence of information in DNA pointed to an intelligent cause. The code, in other words, pointed to a programmer.

That was where the fireworks started. Other scientists on the panel became uncharacteristically defensive and hostile. Dr. Russell Doolittle, of the University of California at San Diego, suggested that if the three authors were not satisfied with the progress of origin-of-life experiments, then they should "do them." Never mind that another scientist on the panel who had favored Thaxton's hypothesis, Professor Dean Kenyon, of San Francisco State University, was a leading origin-of-life researcher who had himself performed many such experiments. It was clear that Doolittle regarded the three scientists, despite their strong credentials, as upstarts who had violated some unspoken convention. Yet it was also clear, to me at least, that the authors of the new book had seized the intellectual initiative. They had offered a bold new idea that seemed at least intuitively plausible, while those defending the status quo offered no plausible alternative to this new explanation. Instead, the defenders of the status quo were forced to accept the validity of the new critique. All they could do was accuse the upstarts of giving up too soon and plead for more time.

I left deeply intrigued. If my sense of the scientific status of the problem was accurate—if there was no accepted or satisfactory theory of the origin of the first life—then a mystery was at hand. And if it was the case that evolutionary theory could not explain the origin of the first life *because it could not explain the origin of the genetic information in DNA,* then something that we take for granted was quite possibly an important clue in a mystery story. DNA with its characteristic double-helix shape is a cultural icon. We see the helix in everything from music videos and modern art to science documentaries and news stories about criminal proceedings. We know that DNA testing can establish guilt, innocence, paternity, and distant genealogical connections. We know that DNA research holds the key to understanding many diseases and that manipulating DNA can alter the features of plants and animals and boost food production. Most of us know roughly what DNA is and

Figure 1.3. Charles Thaxton. *Printed by permission from Charles Thaxton.*

what it does. But could it be that we do not know anything about where it came from or how it was first formed?

The controversy at the conference served to awaken me to the strange combination of familiarity and mystique that surrounds the double helix and the digital code it contains. In the wake of the conference, I learned that one of the scientists who participated in the origin-of-life discussion was living in Dallas. It was none other than Charles Thaxton, the chemist who with his coauthors had proposed the controversial idea about an intelligence playing a role in the origin of biological information. I called him, and he offered to meet with me. We began to meet regularly and talk, often long after work hours. As I learned more about his critique of "origin-of-life studies" and his ideas about DNA, my interest in the DNA enigma grew.

These were heady and exciting days for me as I first encountered and grappled with these new ideas. If Thaxton was right, then the classical design argument that had been dismissed first by Enlightenment philosophers such as David Hume in the eighteenth century and then later by evolutionary biologists in the wake of the Darwinian revolution might have legitimacy after all. On a visit back home to Seattle, I described what I had been learning to one of my earlier college mentors whose critical faculties I greatly respected, a philosophy professor named Norman Krebbs. He surprised me when he told me that the scientific idea I was describing was potentially one of the most significant *philosophical* developments in three hundred years of Western thought. Could the design argument be resuscitated based upon discoveries in modern science? And was DNA the key?

As intriguing as this new line of thinking was for me, I had a growing list of questions. I wondered, what exactly is information in a biological context? When biologists referred to the sequences of chemicals in the DNA molecule as "information," were they using the term as a metaphor? Or did these sequences of chemicals really function in the same way as "code" or "text" that humans use? If biologists were using the term merely as a metaphor, then I wondered whether the genetic information designated anything real and, if not, whether the "information" in DNA could be said to point to anything, much less an "intelligent cause."

But even if the information in DNA was in some important sense similar to the information that human agents devise, it didn't necessarily follow that a prior intelligent cause was the only explanation of such information. Were there causes for information that had not yet been considered at the conference that day? Maybe some other cause of information would be discovered that could provide a better explanation for the information necessary for the origin of life. In short, I wondered, is there really evidence for the intelligent design of life, and if so, just how strong is that evidence? Was it, perhaps, scientifically premature or inappropriate to consider such a radical possibility, as Thaxton's critics had suggested?

My concerns about this were heightened because of some of the things that Thaxton and his colleagues had written to justify their conclusion. *The Mystery of Life's Origin* had made the radical claim that an intelligent cause could be considered a legitimate *scientific* hypothesis for the origin of life. To justify this claim Thaxton and colleagues argued that a mode of scientific inquiry they called *origins science* allowed for the postulation of singular acts of intelligence to explain certain phenomena. Thaxton and his colleagues distinguished what they called "origins sciences" from "operation sciences." Operation sciences, in their view, focus on the ongoing operation of the universe. These sciences describe recurring phenomena like the motions of the planets and chemical reactions that can be described by general laws of physics and chemistry. Origins sciences, on the other hand, deal with unique historical events and the causes of those events—events such as the origin of the universe, the formation of the Grand Canyon, and the invention of ancient tools and agriculture. Thaxton and his colleagues argued that inferring an intelligent cause was legitimate in *origins science,* because such sciences deal with singular events, and the actions of intelligent agents are usually unique occurrences. On the other hand, they argued that it was not legitimate to invoke intelligent causes in operations sciences, because such sciences only deal with regular and repeating phenomena. Intelligent agents don't act in rigidly regular or lawlike ways and, therefore, cannot be described mathematically by laws of nature.

Though their terminology was admittedly cumbersome, it did seem to capture an intuitively obvious distinction. But still I had questions. Thaxton had argued that theories in the operation sciences are readily testable against the repeating phenomena they describe. Regularity