The Mysterious Epigenome

What Lies Beyond DNA

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Introduction

The New Frontier. Those words rang out in political speeches during the fall of 1960 as a 43-year-old presidential candidate began to stir the United States with a vision of courage and initiative, a vision of untapped possibilities and beckoning adventure. John F. Kennedy had struck a rhetorical nerve and the phrase resonated widely. Historians routinely refer to President Kennedy's administration as the "New Frontier." Yet they note that after Kennedy's election and inauguration, the idea of a "new frontier" seemed to be widely embraced across the political spectrum. Its spirit transcended party politics. At its root, it captured a much broader narrative of America facing and seizing the challenges that loomed on the horizon.

One of the US's greatest scientific challenges burst onto the world scene on April 12, 1961, just 83 days after Kennedy took office. Russia, which had been "first in space" in October, 1957 with their launch of Sputnik, scored a second spectacular first on that day. This time they beat the US in the manned exploration of space, placing Yuri Gagarin in orbit around the earth. In the six weeks that followed, the President worked closely with NASA officials and drew up a comprehensive plan of expanded space exploration. This master plan was presented to a joint session of Congress on May 25, 1961. In his most famous line, the President said that America would set the goal of placing a man on the moon before the end of the decade.

Many readers will remember watching on television as that goal was reached in July of 1969 when Neil Armstrong jumped from the ladder of the lunar module and landed on the dusty surface of the Sea of Tranquility. In the years since that historic milestone, the US has tackled many other frontiers of science and technology. One of the most ambitious and promising projects was the Human Genome Project which was launched in 1990. The Human Genome Project was aimed at elucidating the entire DNA library of humankind, right down to the complete text bearing the exact sequence of As, Ts, Cs and Gs along the double helix. This herculean task—somewhat parallel to the goal of a moon landing—took nearly a decade of labor by thousands of scientists and the expenditure of billions of federal dollars.

The first major goal was reached in 2000 when President Clinton called a news conference to announce that a rough draft of the genome had been assembled. After more years of refining and cross-checking the data, the completion of this colossal project came in 2003. That was the year a final draft of the genome was published. At last, scientists had delivered a complete map of our human DNA—right down to the positioning of tens of thousands of genes on the different chromosomes. Thanks to the coordinated labors of geneticists around the globe, anyone could directly access online the exact spelling of the entire 3.1 billion letter DNA database for *Homo sapiens.*

By most standards of scientific discovery, this project was a magnificent success. However, some of the practical promise of this project remains unfulfilled. For example, there has been little success in the so-called "gene therapies" that were expected in the days when the project was being organized. The headline of a recent front page article in the *New York Times*, announced, "A Decade Later, Genetic Map Yields Few New Cures."

In this article by Nicholas Wade, disappointment was a dominant theme, since medicine had "yet to see any large part of the promised benefits." He added, "For biologists, the genome has yielded one insightful surprise after another. But the primary goal of the $3 billion Human Genome Project—to ferret out the genetic roots of common diseases like cancer and Alzheimer's and then generate treatments—remains largely elusive. Indeed, after 10 years of effort, geneticists are almost back to square one in knowing where to look for the roots of common disease."

So the Human Genome Project was an undeniable success in advancing our knowledge of the programming of the DNA hard drive, but its payout in terms of *health-enhancing strategies* seems to have fallen far short of the expectations raised in the early 1990s. How could this be? Is not the human genome a prime example of a new frontier that has been faced and conquered? How could this achievement produce such minimal results in terms of medical breakthroughs?

Spelling out the encyclopedic text of our DNA is indeed a major scientific breakthrough. Of this there can be no doubt. Yet perhaps what's been missing in the payoff, at least in the connection with human health, is that biological science had been overlooking the equal importance of another genome-related frontier—one that lies "beyond DNA," and one that we now see coming into focus in front of us.

It may come as something of a shock, but in probing the operation of DNA, scientists have learned much more about a second biological encyclopedia of information that lurks above the primary information store within our DNA. In other words, researchers have discovered that a complex system in the cell situated *beyond DNA*, a sophisticated software that directs DNA's functions, is responsible for our embryonic development, and in the differentiation of a single fertilized egg cell into over 200 different cell types in a mature body. Also, this higher informational system is implicated in aging processes, in cancer, and in many other diseases. This system guides the expression of DNA, telling different kinds of cells to use different genes, and to use them in the precise ways that meet the needs of those different cells. This "information beyond DNA" plays a crucial role each hour of each day, in each of our sixty trillion cells, telling the genes exactly when, where, and how they are to be expressed. Welcome to biology's strangest new frontier—the *epigenome.*

How could this huge key to the function of DNA have remained so hidden for so long? President Kennedy himself once said, *"The greater our knowledge increases, the more our ignorance unfolds."* This truth applies just as powerfully here in the world of biology and genome research as it does to physics or political theory. In any academic field, scholars are continually poking and probing into the crannies of the unknown, and in doing so they not only find out new truth, they also realize how much ignorance they harbored before the search began. In the case of DNA's depths of complexity, each discovery seems to raise fresh questions and new opportunities to see *what we don't know.*

Thus in *Beyond the Genome* we are focusing our study on two revolutionary arenas. First, we will explain the latest news in the *world of DNA* which is curled up like a chemically-encoded hard drive in the nucleus of all plant and animal cells. Each month seems to bring yet another remarkable discovery of unexpected richness of information embedded in the DNA. We find these discoveries too exciting and too important not to share.

Second, interwoven with the first story of DNA discovery we will tell how science has stumbled upon the master control system that sits above our genetic riches—the wondrous epigenome that now is being diligently mapped and catalogued. Much of this system resides very close to our genes; it is dynamically connected to the double helix in the form of a multi-layered system of tiny chemical tags. So the term *epigenome* commonly refers to these control tags that are in a close relationship with DNA. Yet, in our journey through the epigenome, we will be using the word in a slightly broader sense. We will include all layers and levels of cell memory and stored information that is found beyond DNA itself.

One might view the genome of DNA as a sailing ship that sits in calm waters, tied up to a dock, ready for a journey. When the winds arise, and the captain wants to venture out to sea, he wisely and intelligently sets the sails that catch the wind and moves the rudder that directs the ship to its destination. The captain, the sails and the rudder, in our analogy, is the multi-layer epigenome. In our book, we want to explore and understand every part of the biological “ship-at-sea,” including the all-important DNA, as well as every dimension of the cell’s epigenetic programming that directs the expression of DNA.

As tour guides, we have chosen to emphasize the theme of human health, especially in relation to discoveries of the epigenome. Undoubtedly the most exciting aspect of this explosion of epigenetic information is the potential for our proactive role in reprogramming our epigenome—to some extent at least—so as to allow for improved health for all of us. Amazingly, some aspects of this epigenetic improvement can even be passed on to future generations.

We have spent several years studying the new revolutionary picture of the genome and epigenome emerging from lab research, and the deeper we penetrated into this realm the more we sensed that the time was ripe for a guided tour of both of these frontiers of biology. Our interest and qualifications for writing on this topic are linked to our work as research scientists (in specialties of ophthalmology and scientific rhetoric and argumentation) and as science writers. We previously collaborated on one book, *Darwinism under the Microscope*, and also published other science books on our own. Dr. James P. Gills, the co-author who originated this project, is an ophthalmologist who completed his MD at Duke University and residency at Johns Hopkins University. He is a pioneer in cataract surgery and founder of St. Luke’s Cataract and Laser Institute in Tampa Bay (www.stlukeseye.com). On the side, in addition to writing books on medical topics like astigmatism, Dr. Gills has become a researcher, lecturer and author on the Darwin/design controversy. In addition, he is a prolific author on a variety of other topics.[1]

The other author, Dr. Tom Woodward, is Research Professor at Trinity College of Florida teaching in the areas of the history of science and apologetics. He is the founder and director of the C. S. Lewis Society (www.apologetics.org), and is author of two historical surveys on the intense debate over Darwinism and design theory. A graduate of Princeton University in history, he completed his doctorate at the University of South Florida in the rhetoric of science, a field of communication theory. His PhD dissertation at the University of South Florida, “Aroused from Dogmatic Slumber,” was published by Baker Books as

Doubts about Darwin: A History of Intelligent Design. A sequel, *Darwin Strikes Back*, was released by Baker in 2006.

We wish to thank the many persons whose help in research, reflection and editing made this book possible. Special thanks go to Gary Carter of St. Luke's Cataract and Laser Institute, to Joseph Condeelis for his amazing visual illustrations, and to Dennis Hillman and the editors at Kregel Publications. We also thank our wives for their great patience and encouragement throughout the entire process. Lastly, we wish to acknowledge the scientific review and counsel of many biologists and geneticists, including Dr. Jonathan Wells and Dr. Ralph Seelke, without whose guidance this book would have not been possible. We would also thank the many other biological researchers and experts on the epigenome, whose names we are not at liberty to mention due to the point of view of this book—sympathetic to intelligent design theory. May the day come soon when these questions of biological origins can be discussed with a calm, clarity, and rhetorical balance that they deserve.

Our hope for you, the reader, is that this book will be but the start of an awe-inspiring journey: exploring the wonder, the newest frontier that is our genome, our epigenome . . . and beyond!

Chapter One

Science's Supreme Quest

Unraveling our Master Codes

DNA, the master code of life, is flashing an impish smile. She has been a bit coy and evasive recently. Now we know why. She's been harboring some shocking scientific secrets.

During the past two decades, this delicate spiral molecule has played a game of genetic hide-and-seek with scientists. Fortunately, she has whispered some helpful hints, and scattered clues on the finger-like landscape of her chromosomes. One by one, those clues have started to fall into place. You can almost glimpse her nodding in delight as her sequestered mysteries are pried open.

Researchers have been stunned by many of these findings. One is the discovery of a sophisticated "splicing code" which has been found embedded within the familiar DNA code. This set of instructions enables a single gene to perform the feat of knitting together a bewildering variety of different gene products—numbering in the hundreds and even thousands. It is like a brilliant chef producing a single "super-recipe" from whose instructions cooks can produce three thousand different sumptuous dishes.

Another shock came in June of 2007 when the combined efforts of dozens of laboratories were published. This ambitious project, called "ENCODE," turned up something totally unexpected. Previously, vast stretches of our genome had been described as "junk DNA." (See the "The Riddles of DNA" on page . . . .) Textbooks said that as much as 90 percent or more of our genetic sequences may be sheer useless gibberish. Unlike our functional genes, these odd sequences were never opened up and translated into RNA copies. If this vast quantity of junk DNA were graded in terms of its vital function, it would receive an "F." It was classed as useless debris—damaged goods that accumulated during the long eons of evolution.

The ENCODE study, however, showed that this picture is radically false. The exact opposite is now shown to be the case. These stretches of humble DNA are anything but junky. Much of this mysterious code is in fact being read and copied. Scientists are beginning to grasp many of the vital functions of this genetic black box, but much is yet to be learned. One thing is certain: the credibility of the junk DNA doctrine has been heavily damaged, almost certainly beyond repair, and textbooks are being rewritten to accommodate this surprise.

A Life-Code . . . Beyond DNA?

One of the key DNA discoveries concerns a mysteriously intertwined "dance partner" in the elegant waltz of cellular life. The discovery of this chemical partner presents mind-boggling implications for our physical health and spiritual well-being. In a nutshell, we now have learned that our DNA responds to cues from a higher control system written into the cell, and the programming of this system can even change over time. Thus our own healthy (or not-so-healthy) life habits can affect the way DNA is processed in our cells.

This may come as quite a surprise, since our DNA library, known as the "genome," is viewed as an ironclad inheritance for each of us. Yet thankfully, that's not the end of the story. Scientific sleuths have uncovered a sophisticated genetic control system which they call the *epigenome*. We can think of it as a molecular computer code that had been lurking quietly inside living cells—*beyond our DNA*.

This built-in director, found in all of our cells, sits above our DNA and carefully controls how genes are expressed. This has been compared to a skilled musical director waving a baton in front of an orchestra. This remarkable system actually has several layers or levels, which we will explore in later chapters, but they all seem to be tightly coordinated into one smooth system. Let's sketch a few of the key discoveries that have been confirmed as scientists plumbed the depths of the epigenome.

First, if one envisions the epigenome's role as the orchestra director of DNA, this is a director with metaphorical "eyes and ears." This biochemical conductor is sensitive to his biological environment; the quality of his directing can be changed as he picks up signals that tell him what is happening in the body's tissues and organs. He can be strengthened in his daily work with a sensible diet, leading to brilliant DNA-directing, or he can be damaged and poisoned through binging, which leads to sloppy and even fatal waving of his wand. In fact, there appear to be a myriad of life habits that can either strengthen or damage the DNA-director. We will return to this in a moment.

Second, we've learned much about the clever mechanics that enable this system work so efficiently. The director's functions are cleverly woven together in a chemical software program with its own set of codes comprised of tiny signals and switches. At the heart of our book, we've placed detailed images to show how these chemical signals might appear if we could see them directly through a nano-scale microscope.

Two of these epigenetic codes are embedded very close to the DNA in a double-tiered library of instructions—a database which oversees or governs the DNA-library hard drive. This epigenetic dual-library differs from cell type to cell type, so that the brain cell epigenome would be noticeably different from a muscle cell epigenome, and from each of the other two hundred or so cell types. If we could zoom in to the intricate nooks of the DNA's molecular landscape, we could see millions of these chemical switches. Some epigenetic signals are hard to spot—they're very tiny and are written onto the double helix itself. A second epigenetic code involves five different markers; they are attached to the spools that DNA is coiled onto. (Scientists have a name for this "coiled-up DNA" material: chromatin. This "packaged DNA" material, which makes up our chromosomes and is buried deep inside the nucleus, is the focus of much epigenetic research.)

Also, several lines of evidence suggest that additional layers of quietly coded information are built into other parts of the cell, including the cell wall and even the interior structural members of a cell. This strange new realm of functional information written into parts of our cells that are distant from DNA can be startling when one hears of it for the first time. It's a bit like the surprise one might feel upon being told that the digital memory in your computer is not confined just to the hard drive, but that millions of bits of vital data are also inscribed in other specialized languages and codes, and are embedded in the keyboard, screen, outer casing, and dozens of other pieces of the computer besides the hard drive.

Just as this higher control-library has been dubbed the *epigenome*, so also the study of this complex system is called *epigenomics* or more commonly *epigenetics*. (See table 1.1, which compares genetics with epigenetics.) A growing network of researchers is probing the mysteries of the epigenome, and the complexity of the system they're searching out seems to grow with each passing month.

Table 1.1. Genetics vs. Epigenetics

Field of Study	Genetics	Epigenetics (Epigenomics)
Complete Library	Genome	Epigenome
Function	Codes for RNA & Proteins	Controls DNA Expression
Informational Format	DNA Language (in genes)	(1) Methyl tags on C-letters (2) Tagging of histone tails
Variation from Cell Type to Cell Type	None: Genome = Identical in all cell types	Much variation: 200+ cell types, so . . . 200+ different epigenomes
Heritable Changes	Yes: mutations in germ cells are inherited	Yes: epigenetic tweaking can be passed on to other generations
Changes by lifestyle	No	Yes – many ways

Reprogramming Family Health for Generations

As we mentioned above, perhaps the most sobering discovery that has emerged from this research is that crucial changes in any person's epigenetic code *can be inherited by succeeding generations.* In other words, scientists are finding that our system of epigenetic control is not only tweaked and re-edited by our own lifestyle, but these changes can also be locked in; they can be passed down to our children, and even to our grandchildren and beyond. One fascinating study was published by Dr. Lars Bygren of the Karolinska Institute, a highly regarded research facility in Stockholm. Bygren focused on the health histories of 99 families in a tiny village in a remote agricultural region called "Norrbotten" in the northernmost part of Sweden.

As Bygren studied the life patterns in this village, where his own father grew up, he uncovered a stark reality. A pattern of binge-eating in years of abundant harvests seems to have dealt a devastating blow as it reprogrammed the human epigenetic system of young boys that lasted for many decades. By studying the patterns of diet and longevity in these lineages, Bygren found that an average of 32 years were cut from the average lifespan of the next two generation of farmers through experiencing the single year of gluttony.

This research, which was reported originally in prestigious science journals, was laid out starkly in John Cloud's cover story in *Time* magazine ("Why Your DNA Is Not Your Destiny," January 2010) which surveyed the explosion of epigenetics research.

The potential of influencing one's own efficiency of DNA function—and especially reshaping the DNA health of our succeeding generations—is clearly headline news in the world of science. Yet it is much more than that. These discoveries are bringing us to the edge of a scientific revolution in the biology of inheritance. Several lines of evidence, summarized in various books and research articles, have shown that many of our own patterns of daily living—including diet, stress, smoking, exercise and more—have the power to partially reprogram our epigenetic system and that of our offspring. How widespread is the fruit of any such epigenetic changes (for good or ill) in the generations that follow? How many generations can reap the effects of these epigenetic tweaks? Answers so far are sketchy. This is a focus of much current research. *One thing is clear: our epigenome is somewhat malleable and moldable.* We can literally influence our epigenetic code, and as the tiny chemical markers are modified, this can produce either a positive or negative impact on our posterity. The quality of our great grandchildren's life can be influenced by the way we live our life now. As Cloud said at the close of his *Time* article, "It will take geneticists and ethicists many years to work out all the implications, but be assured: the age of epigenetics has arrived."

Of course, scientists have not downgraded the role of DNA and genetics itself in the day to day workings of cells. In one sense, DNA is still king; it is just as central to life today as it's always been. The library of DNA still plays a key role in ruling or shepherding the process of growth of a single fertilized cell into a gigantic sequoia, or a mighty blue whale, or a healthy adult human body. Rather, what is emerging now in molecular studies of genetics is a dual focus. First, we must track the intricate toiling of DNA in its ruling or shepherding process itself. Second, we must also track the higher control system which we call the *epigenome—the ruler of the DNA ruler, and the shepherd of the DNA shepherd.* Scientists will continue to probe the incredible genome, even as they explore and come to understand the mysterious epigenome.

It bears repeating: Because epigenetic inheritance weaves such deep changes in life and health, (something that does not easily happen in DNA itself) this new double-focus in biology is opening a huge window of opportunity for improved human health for generations to come.

Sidebar: The Riddles of DNA

Over the past decade, based on an explosion of new data, scientists have had to revise their most basic notions of the double helix. Much of what was taught as "fact" about DNA in biology classes a few years ago is now tossed into history's bin of discarded myths.

A radically revised picture of life is taking shape. We glimpse a panorama that is far richer and much more complex than the simple sketch inherited from the biological revolution that roared to life in 1953. That's when DNA pioneers James Watson and Francis Crick announced that they had uncovered her elegant double-helix structure.

Six decades of feverish research into DNA have passed since then. During this time Watson and Crick continued to play a key role in ongoing research. Watson even helped launch the Human Genome Project in the early 1990s, which by the year 2000 had produced a complete draft of all 3.1 billion letters in the miniaturized DNA hard drive found in human cells.

Until 2007, scientists assumed that only 3 percent of our DNA contains recognizable genes. These genes serve as digital files (construction templates or recipes) for assembling the complex protein molecules that do most of the work in our cells. Teachers commonly asserted that over 90 percent of human DNA, devoid of gene patterns for proteins, was apparently broken or useless. Since it did little harm, it was passed along through the eons. This mysterious and disparaged DNA was described as "junk DNA."

Then came the shock. By June of 2007 a global project called ENCODE had completed an extensive exploration of the human genome and published a pattern of DNA activity that was entirely unexpected. Far from our possessing a genome that was "jammed with junk," it turned out that the opposite is true. Between 74 percent and 93 percent of the DNA spiral-ladder in human cells seems to be opened up routinely in our cells. It is read and then copied into the half-ladder RNA format. Then, many of these mysterious RNA molecules—including some quite tiny ones—spring into action, and are used in a variety of vital functions. (We note that some researchers sympathetic to intelligent design had predicted in the 1990s that functions would be found for some junk DNA.) One scientist focusing on the collapse of the "junk DNA" model has estimated that our human genome may contain as many as 450,000 RNA genes—a vast lurking load of DNA information that was virtually invisible a few years ago.

Our Goal: To Probe and Question

Our purpose in writing *Beyond the Genome* is to recount the discoveries which have opened up a transformed picture of our genome and its crucial companion, the epigenome. In a clear and accessible way we will survey the nuts and bolts of these systems. As we sketch a picture of what this molecular landscape looks like, we will highlight recent findings about the cellular hard drive of DNA, and we'll show how the epigenome's switches and gadgets work, with the help of complex machinery.

To complete this tour of discovery, we will take the reader on a fictional field trip to a high tech cellular display, along with a pair of trips into the cell using a miniaturized exploration sub. With the help of a bit of imagined "frame-shifting technology," your submarine will zip right into the cell's spherical DNA-packed nucleus. These journeys and field trip are portrayed in the setting of a new biological research laboratory in Chicago. Although this lab is entirely fictional, it is inspired by the very real Biologic Institute, a research facility near Seattle, Washington associated with the Discovery Institute. Of course, characters in these chapters are fictional. However, we can assure you that the scientific information in these sections is as accurate as a geneticist's lab report.

Since we are dealing with such foundational discoveries, we want to ask the relevant "So what?" questions throughout the book. First, what is the impact of these new truths on our own physical health and practical way of life? How can we live life to the fullest—and at the same time insure that our lifestyle promotes not only our own wellness but also that of family members who will inherit our epigenetic code? Because of the urgency of these questions, we will devote space to the emerging picture of the health and fitness implications of the epigenome.

Equally important—ultimately, more important by far—is the question of how these findings impact our spiritual health. How does the new breathtakingly complex view of the genome/epigenome system impact our view of origins? How do these discoveries reopen old questions as to whether life is "designed with a purpose in mind"? After reviewing the newest scientific evidence, we will ask *what* or *who* designed this massive multi-level system. It would be a simple failure of nerve if we did not delve into the theological implications that flow from this scientific vista. If the highly integrated system of complex information is at the root not only of our body but also our marvelous gifts of intelligence, creativity and love, the idea of "purpose" simply cannot be ignored. Because this kind of question moves into the smoke-filled terrain of the debate over Darwinism and intelligent design, such scientific questions and controversies excite the mind but they also have the potential to rev up our emotions.

Darwin or Design?

Because of this built-in emotional factor, we will approach with special care the issue of how cellular complexity arose. Our goal is to bring a maximum of light and a minimum of heat. This can be difficult, since in the minds of many in the Western world, "Darwin" and "Darwinism" have come to symbolize such cherished values as scientific enlightenment, critical reasoning and educational progress. The moment one sets forth deep empirical problems with Darwinian theory (which we will do at times) one risks being instantly dismissed or marginalized. Even some leading Evangelicals have argued that we should make peace with the Darwinian scenario of life's development. They claim that the evidence for Darwinian evolution is solid.[2] Yet is this claim plausible? Can a proclamation of the "triumph of Darwin" stand in the light of the experimental evidence that is set forth in such works as *The Edge of Evolution* by biologist Michael Behe or *Signature in the Cell* by philosopher Stephen Meyer? We think not.

These developments, and much more, have posed a deep and formidable challenge to Darwinian theory. More scientists than ever, not only in the Americas but also in Europe and Asia, are asking if is it truly plausible that mindless, undirected processes of nature were responsible for building all of the cell's high-tech hardware and its *software codes* as well. This is precisely what Darwinism claims to have shown, and those claims are now under enormous stress from the weight of new data. Using Darwin's own words, is it possible that evolutionary theory will be found "not fit to survive" the onslaught of evidence? Is the handiwork of a brilliant designer now on display for all to see?

Darwin himself had no way to glimpse the tiny machines and digital libraries that modern science has uncovered in the past century of biochemistry. He and his contemporaries viewed the cell as a fairly simple substance. (See the sidebar, "Darwin's View of the Cell." But when one moves in fast forward from Darwin's day to the twenty-first century, there is a drastic change in perspective. Biologists and geneticists are working in concert to penetrate the mysteries and intricacies of the cell, and in recent months such phrases as "staggering complexity" and "infinite complexity" have appeared in the literature.[3] The bizarre nano-world of unexpected sophistication that has opened in front of them has been endlessly exciting. Yet, so very often it has greeted scientists with shocking discoveries.

One shock we've already seen is the collapse of the textbook doctrine that a mere "three percent of DNA" is a true functioning code, with junk DNA scattered everywhere else in the genome. Now we must reckon with much more of our DNA as functional after all (and little junk anywhere). Yet at a more fundamental level, we must also see the DNA code itself as dependent upon the masterful direction of a higher code. The epigenome, that submerged part of our cell's informational iceberg, is now being brought to light and displayed in all its glory. So DNA is more information-packed than we had imagined—and it is tethered to a high-tech software system that lies "beyond DNA."

In recent years, a cascade of evidence has put stress on cherished assumptions. It has raised exciting new questions about the origin of cellular complexity. What is nature saying to us all? Let us go and see.

Sidebar: Darwin's Limitations; Darwin's Revisionists

Let's note an irony about Darwin's monumental *Origin of Species*, published over 150 years ago. Darwin's book, brilliantly argued and clearly revolutionary for its time, was nevertheless hamstrung with a blurred and simplistic view of the complexity of life. Today, when researchers question the adequacy of Darwinian theory, with its great stress on the role of natural selection in explaining the rise of complexity, they are asking the hard questions. Instead of asking simply, "What did Darwin discover about the development of life?" they are also now asking, "What didn't he know about the basic structures of life's complexity, that we now have to face?"

Armed with an inquisitive, brilliant mind, Darwin was nevertheless aided only by inferior quality instruments for observing life under the microscope. As a result, when viewing a cell, he and his colleagues concluded that it was a relatively simple object. One of his contemporaries, Ernst Haeckel (1834–1919), an eminent German embryologist and devout Darwinist, agreed with this assessment. He called the cell a "simple little lump of albuminous combination of carbon"—in other words, just a tiny sack of gray biological goo.[4] These conclusions caused Darwin and scientists of his day to misunderstand the cell's significance as the hyper-complex building block of all forms of life. Seeing the cell as a simple entity, they attributed it to purely material factors.

Chapter Two

What Biologists Know About DNA

(And Darwin Didn't)

Several dozen adults and teenagers gathered in the spacious, wood-paneled lobby of a new scientific research facility on the northwest side of Chicago. Flanked by large oak trees, the two-story modern building presented a handsome façade of beige stone punctured with pairs of dark tinted windows. Between the building and a winding suburban road sat a small crescent-shaped pond. A crisp breeze was stirring a pile of leaves that huddled by a sign built of dark grey concrete. In brushed aluminum letters, the sign read, "The Institute for the Study of Biological Design."

The institute had become famous for its unique approach as a biological research facility. On the one hand, the institute was typical in many ways. Its scientists conducted dozens of experiments, prying into the nooks and crannies of living cells, uncovering the details of exquisitely complex systems. On the other hand, what made it stand out as unique (and controversial) was that its fourteen research scientists had made no secret of their strong sympathies with intelligent design theory.

In media coverage of the grand opening two years earlier, this unique perspective triggered some positive reactions from sympathetic Chicagoans, along with negative comments from two local biology professors. One article on the ribbon-cutting quoted a biochemist at a nearby college, who declared: "Intelligent design is not science!" The reporter counterbalanced that jab with a puzzling quote from a local physics professor who is also an avowed agnostic: "Modern intelligent design theory is actually on pretty solid scientific grounds, and has some good arguments, but I'm taking a wait-and-see attitude as to the existence of a cosmic designer."[v]

One local columnist sneered that a biological think tank using intelligent design theory was like NASA announcing that it would begin hiring astrologers to work alongside its astronomers. He suggested that the public call the institute the "God Lab." Fortunately, that nickname didn't stick. Another reporter who covered the opening of the facility wrote that the name "Institute for the Study of Biological Design" was so long, a cumbersome mouthful, that he would dub the lab with an acronym—ISBiD. To his surprise, his name stuck immediately and was used by everyone, including the institute's scientists.

The lobby of ISBiD, with its circle of overstuffed leather couches, was a refuge from the brisk, chilly Saturday morning outside. On one side of the lobby a gas-lit fireplace contributed its cheery flicker of light and a welcome token of warmth. A dozen local college students, all taking an introductory "Biology and Ecology" course, chatted with their bearded professor wearing a purple turtleneck pullover. Opposite the glass entryway was the double-door entrance to a bowl-shaped auditorium. Above the doors was a brass sign that read, "The Incredible Cell."

Suddenly the auditorium doors opened and a tall young man in a white lab coat strode into the lobby, sporting close-cropped black hair and wire-rimmed glasses. The young scientist smiled warmly and announced, "Greetings to all of you, and welcome to ISBiD. I'm Curt Grantham, and I'm one of the staff scientists here. It's a pleasure to welcome you today to our new exhibit and multimedia program, 'Journey into the Incredible Cell.' You all will be the first group to experience our new electronically animated model of the nucleus. Today is the official debut of our multimedia show. Follow me!" He disappeared through the doors, and the group quickly followed him into the bowl-shaped auditorium.

Twenty minutes later, Curt Grantham was winding up his introductory briefing. Gesturing to the tall closed curtain behind him, he added, "In just a few minutes, we'll open the curtain and you'll be treated to a visual electronic feast. You will see a precisely accurate 3-D scale model of a human cell which fills the equivalent of one half of a high school gymnasium. After we point out the main components, we'll welcome you up onto the stage, and you can explore our cell-model up close. Along the way, I'll involve the audience in some quiz questions. I'll also be glad to take your questions, so write down anything you want to ask."

"First, to prep you for the up-close tour inside our cell, we'll invite you to meet some animatronic models of a bacterium called *E. coli*. These guys live happily inside of our intestines—by the billions—and do us a great service, helping us in our digestion. Come and see!"

As the group moved up to the front of the stage, a switch was thrown, opening up a narrow trap door and triggering a motor which raised into view a glass tank that resembled an oversized aquarium. Inside the tank five battery-driven models of E. coli were floating gently in the water like a school of exotic fish taking a nap. "These high tech models have been crafted to portray the shape and dimensions of these famous bacteria. Keep this in mind: the actual size of E. coli is two millionths of a meter, so at our model's size, this is what they would look like if you could shrink yourself by a factor of a hundred thousand and do a close-up inspection."

An onlooker spoke up, "What are those long hairs that sprout from one end of the cell models?"

"Well, let's see if we can get them in motion first." Curt clicked a remote control switch and the long hairs began to wiggle and twirl. In a few seconds the hairs were rapidly rotating like long thread-like propellers. "Those long rotating whips," said Curt, "are amazing machines. Each one is called a *flagellum* and is machine-driven down at their base in the cell membrane. In fact, each flagellum is connected to a complex rotary engine that powers it. So these are essentially miniature outboard motors, complete with rotors, stators, bushings, universal joint, drive shaft and propeller. Together, they propel the *E. coli* through liquid like a tiny submarine. You are looking at one of the great wonders of microbiology!"

As the group moved closer to the tank, they noticed that the bacteria models, which previously resembled oversized cucumbers floating in a bath tub, had now taken on a new look with their multiple propellers twirling. They looked more like hungry fish, cruising around the tank on the prowl for food. Curt added, "Each flagellum of these creatures involves about forty parts, with each part having its precise structure encoded in digital form in 40 separate genes. Speaking of genes, even bacterial cells need lots of digital information to run all of their chemical factories. It's incredible how much digital information is programmed along the spine of this tiny critter's DNA."

Curt walked over and pointed to a three-foot row of books lined up on the desk beside the tank. "Here we have over two dozen average sized books—a few novels by Nobel Laureate Toni Morrison, J.R.R. Tolkien's Lord of the Rings trilogy and twenty published novels of Stephen King. In their sheer content of individual letters, these twenty-five books contain the same total of letters that are packed into one *E. coli* cell: about 4.5 million pairs of DNA letters. If you think of this database in terms of computer files on a C-drive, that comes to 4.5 megabytes of information in this tiny critter, with over 4,000 files. Now, compare that to the human genome's size—nearly a thousand times larger. The human genome has a bit over 3.1 billion letter-pairs—the equivalent of about 14,000 books of 250 pages each! Now, look carefully above the tank."

A button was pressed behind the tank and in the empty space above the tank, there flashed something like a Fourth of July fireworks display, with accompanying sound effects of explosions. Several psychedelic sprays of colored sparks exploded, over and over, until one massive explosion of sparks began to swirl crazily in a vibrating whirlpool of color, which then converged into a single holographic image of an elongated bluish-hued cell.

One of the college students said, "Cool! A 3-D hologram!"

Curt smiled, "In fact, you are looking at the newest experimental type of holography. Watch carefully."

The large cell, seemingly hovering in mid-air above the tank, grew in size until it was slightly larger than the tank and the fine texture of its exterior surface came into view. In seconds, the cell membrane disappeared, and the crowded cell interior was opened to view. The moving hologram revealed complex structures that resembled a 3-D maze of thick cables and tubes stretching out in every direction. Visible in the middle of the maze was a large, thick loop. As the zooming effect of the hologram continued, the loop grew in size, and one could see that the loop was made of carefully woven threads of DNA, that were coiled up like hundreds of tiny loops or kinks in a rope.

"We invite you to take a deep breath," said Curt. "Try to get your mind around an emerging picture of cellular complexity. We will first zoom in on the genetic library that is composed entirely of DNA. Does anyone know what term biologists use for the DNA library found in every living cell?"

A blond teenager raised her hand and ventured, "Is it the *genome*?"

"That's right! Many of us have read about the Human Genome Project. As it turns out, every plant or microbe that has ever lived on earth has possessed a unique genome, and has been totally dependent on this storehouse of precisely written instructions"

The hologram of the bacterial loop of DNA was now so enlarged that the individual rungs in the spiral ladder were plainly visible. "You can now see the familiar twisting ladder structure of the strands of DNA," said Curt. "But there is one major difference in the way it is packaged. Bacterial DNA isn't packed into a spherical *nucleus*. It's woven together carefully in the shape of a loop."

After the animation cruised around the edge of the loop of DNA, it moved in to one spot in the double helix, so that the individual rungs of the ladder became visible. "Notice that each of these DNA ladder rungs you see is formed from a pair of chemical letters. When we call these units *letters* we're not just using a crude analogy. This is how biologists describe it. DNA is not just *like* a code; DNA *is* a code. Now look carefully at the hologram!"

As the bacteria's DNA helix grew ever larger in size, a single colorful stretch of rungs came into view. The dimensions resembled an oversized household stepladder. "We compare the four-letter alphabet of the DNA language with the 26 letters of the English alphabet, or the 32 letters in the Cyrillic alphabet used in Russia. The four letters in DNA's alphabet are A, T, C and G. Sometimes, scientists call these four letters the four *bases*. A single rung in the twisting ladder of DNA has two paired DNA letters, so it is said to contain a *base pair*. This model you're looking at has twenty rungs, so how many base pairs does it have?"[vi]

After a slight pause, several students blurted out, "Twenty!"

"Right again!" said Curt. "Look carefully at the holographic animation and you'll see that A, T, C and G are the first letters of the names of the chemicals. Maybe some of you had to memorize these names in school. A stands for *adenine*, T for *thymine*, C for *cytosine* and G for *guanine*. Now I want to show you our little memory trick for recalling the four letters and their pairing system. As I turn off the hologram, look up—toward the ceiling."

Curt pushed a button on the console and from high up in the ceiling a twisting-ladder plastic DNA model, some forty feet in length, was lowered by a trio of narrow aluminum arms until it was suspended ten feet above the stage. With a flick of another control switch, roughly half of the colored rungs in the DNA ladder began to glow like Christmas bulbs—in bright colors of red and green—thanks to their embedded miniature LED lights.

Curt went on, "In our DNA models, we use a color code that makes it easy to remember the letters. We symbolize 'C' using the color *crimson*—another word for red. Then, the DNA letter 'G' is pictured by the color *green*. Just as crimson and green go together—you can think of them as the Christmas colors—so 'C-G' always go together in DNA."

A second switch was clicked and the C-G lighted rungs were turned off, and seconds later, the remaining ladder rungs on the model began to glow brightly in combinations of orange and blue. Curt continued, "Now you can see the other pairs of letters, the A-T letters, which also have colors linked to them. We had to get creative here. The DNA letter 'A' is represented by *azure*, another word for blue. For comparison, the Spanish word for blue is *azul.* The letter that is always paired with A is T, and we picture DNA's letter 'T' by the color *tangerine*, which of course is a synonym for orange. So the 'A-T' pairing of letters in DNA are shown by letter duos of azure-tangerine. If it helps, you can think of them as the colors of the Gators—the University of Florida."

One student raised his hand and added, "My dad went to Auburn and I think that those are also the Auburn's colors, too."

"True—and they're also the colors of the Universities of Illinois and Virginia, and they're complementary colors on the color wheel. Now, it's time to light up our entire DNA model."

All of the helix's ladder rungs began to glow, showing off the gorgeous crimson-green and azure-tangerine pairings. As the entire double helix began slowly spinning, a recording of soft music began playing and a woman narrator began, "You're now looking at the world's largest model of a single human gene."

The narration paused as the crimson-green DNA rungs began to flash in an alternating sequence with the azure-tangerine rungs. In sync with the strobe-like flashing of the colored rungs, an energetic melody of synthesized music sprang to life. As the visitors took in the view of the strangely-colored twisting necklace, the taped narration continued: “With four hundred fifty color-coded rungs in our forty-foot DNA ladder, this model actually represents one of the shortest genes known to lurk in the human genome.”

Sidebar: DNA, Superstar

DNA: is it as famous as a superstar? Perhaps. You are probably familiar with the use of DNA by the FBI and other law enforcement agencies to identify the guilt or innocence of alleged perpetrators of crime. So DNA can discern the truth of past events, but it is also famous as a predictor of the future. Samples taken from a fetus are analyzed in order to detect or predict genetic diseases.

DNA’s superstar status is sometimes carried to an extreme. Some evolutionary theorists elevate DNA almost to the level of an all-powerful (if unconscious) deity, controlling our every move. One who has nearly deified DNA is Richard Dawkins, the evolutionary biologist who has become an evangelist for atheism. He wrote in River Out of Eden: “The universe we observe has precisely the properties we should expect if there is, at bottom, no design, no purpose, no evil and no good, nothing but blind, pitiless indifference. . . . DNA neither cares nor knows. DNA just is. And we dance to its music.”

But by Dawkins’s view, can we then be truly free to explore the truth about ourselves, the universe, or God? Or by this view, would not our beliefs be mere mirages served up to us by our DNA, as we “dance to its music”? In other words, how can evolutionary biology itself, as a belief that is part of DNA’s dance that we perform, escape this self-refuting view of reality?

Another aspect of DNA is superstar-famous: the iconic image of DNA’s double helix—in the form of a twisting ladder. As a visual help to grasp DNA’s intricacies, we encourage you to purchase (or watch on youtube.com) the acclaimed documentary DVD, “Unlocking the Mystery of Life” by Illustra Media. The DVD, now in 26 languages, features brilliant 3-D computer graphics of DNA and the other long-chain molecules—RNA and proteins. Superb special effects show the construction of a protein chain with the help of a ribosome machine (which we will encounter in chapter three). For pictures of the macromolecules in this film, see pages . . . ..

One “sweet way” to build a DNA model at home or school is to employ colored gum drops (also marketed as “spice drops”) for the four letters. The ‘C-G’ letter pairs are shown by crimson gum drops paired with green ones; likewise ‘A-T’ pairs are shown by azure drops paired with tangerine ones. To complete the connecting DNA side chains, use marshmallows: large ones for DNA sugars, and small ones for the phosphates. All are connected together with tooth picks, as pictured on page . . . For details, see this note.[vii]

The music faded and Curt explained that for better visibility, the gene model had been enlarged to a much greater degree than the cell model. In fact, it was magnified an extra thousand times in size beyond the enlargement scale of the cell. “Now, you may wonder how many genes—programmed strings of DNA—inhabit any given cell. For example, how many genes does our bacterial friend E. coli have? Since humans have somewhat over twenty thousand genes, it may surprise you that E. coli has over four thousand distinct genes.”

“Genes can be thought of as unique little booklets—or you can think of them as important files on a computer. They are housed within the genome, and yet these 4,000-plus genes of E. coli, so vital in carrying out the huge number of functions of the cell, are so tightly condensed, they fit into a space ten thousand times smaller than the period at the end of a sentence. Scientists have concluded that no entity in the known universe stores and processes information as efficiently as the DNA molecule.”

"Now," said Curt, "in a moment we'll take a look at how DNA functions in a living cell. The double helix reigns currently as the superstar of all the molecules that inhabit a cell. Yet DNA doesn't work alone. He depends on two other partners, which are also long-chain macromolecules. Does anyone here know what the other two are called?"

A teen raised his hand and ventured, "Are the other two the RNA and protein molecules?"

"Right—and I think that makes the audience three for three in answering my quiz questions. I think it's time to celebrate, so you all are invited to enjoy a complimentary beverage of your choice at our café before you leave. It's on us—and I can personally recommend our incredible cappuccino!"

Curt explained, "What I've described as the three *long-chain molecules*—the *DNA*, *RNA* and *proteins*—are sometimes called the three *macromolecules,* since they typically contain many hundreds or even tens of thousands of chemical letters linked together in each chain. Now, before I show you what they look like, let's stop and take a question or two."

Spotting the professor, he said, "Yes, sir—you're the one I briefly spoke to earlier—was it Dan?"

"Yes, I'm Dan Ross, and I teach biology at Westlake College just down the road. I keep reading conflicting reports about how much 'junk DNA' is in our genome. And second, I understand that our genome is not the largest animal genome, right? Don't some animal and plant species have even more DNA in their cells that we do?"

"If you can hold on to that first question," said Curt, "let me cover the issue of *junk DNA* in a few minutes when enter the cell model. On the other question—it is certainly true that the size of the human genome is dwarfed by other species!" said Curt. "Many plants have higher quantities of DNA, per cell, than what we find in the human genome. A Japanese plant, *Paris japonica,* holds the plant record at 149 billion letters per cell. Even species of wheat have nearly sixteen billion letters per cell—that's more than *five times* as much DNA as we find in each human cell. So that should give you some extra respect for your next slice of bread since it was made from wheat cells whose genome puts ours to shame—at least in sheer size.

"Human genomes are also tiny compared to many species in the animal kingdom. Many salamander and newt species have genomes that are gargantuan—from ten billion up to one hundred twenty billion letters of DNA per cell—and the marbled lungfish has 140 billion letters per cell! Perhaps strangest of all, the record-holders for 'DNA per cell' are totally unexpected. Who would have thought that the first- and second-place records would be held by a pair of humble single-cell species—*Amoeba proteus*, which has 290 billion letters, and the incredible *Amoeba dubia* which harbors about 670 billion letters of DNA. To put this in perspective, we can say that humble *Amoeba dubia*, which hardly grows bigger than a poppy seed, is comparable to a laptop computer with a 670 gigabyte hard drive, or an IPOD programmed with 20,000 songs! Now, are there any more questions?"

A hand of a lady shot up near the back and was quickly recognized. "I'd like to know what Darwin knew about all of this. Even though he didn't know about DNA itself, he knew about genes, right?"

"Actually, Darwin had no knowledge of the kind of biological complexity we're talking about here. In fact, he knew literally nothing about the details of the genetic inheritance carried within cells. He did not even know about Mendel's momentous discovery of dominant and recessive genes. Many scientists conclude that his ignorance of the most fundamental facts of inheritance contributed to his faulty picture of the complexity of the cell. This in turn paved the way for his simple theory of nature-driven incremental change. In his mind, any new body structure could be developed step-by-infinitesimal-step, over long eons of time. In the view of our scientists, the history of science reveals in Darwin's case that scientific ignorance can contribute to a rejection of a highly reasonable explanation for life's digital complexity—namely, *intelligence*. That same ignorance led to a simple materialistic explanation—the idea that nature's unguided and unintelligent forces were the sole cause that shaped the world of biology.[viii]"

Curt paused for a moment. "If there are no more questions, it's time to open up what you've been waiting for: the Incredible Cell." He reached down, pushed a button, and glanced behind him as silent motors opened the tall curtains, revealing something strange, almost surreal and other-worldly in appearance. The audience gasped as the lushly decorated, oversized model of the interior of a living cell was presented to their sight. The enormous space was as large as a three-story oversized hotel lobby. It was a huge reddish cavern whose walls curved like the interior of a bubble. Its surface was slightly undulated, as if a scarlet pond with its ripples had been suddenly frozen in place. The walls, ceiling and floor were populated by all sorts of strangely-shaped objects. Majestic orchestral music began to flow and the lights were lowered on the whole scene. A taped narration began, and one by one, each of the key parts of the cell was identified. As each part was named, that object was lit brightly by carefully aimed spotlights that switched on.

"Now," said Curt, "the time has come to meet the other stars in DNA's trio—the RNA half-ladders, and the absolutely amazing workhorses of life, the *proteins*. Follow me now into the Incredible Cell, and I'll literally let you shake

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Introduction

1 For a complete listing, go to stlukeseye.com, and click the link to "Dr. Gills' Books."

Chapter 1. Science's Supreme Quest

2 For example, in *The Language of God*, by evangelical Christian and former Human Genome Project director Francis Collins, the intelligent design theory is described as a ship that is not "headed to the promised land" but is headed "to the bottom of the sea." We will have occasion to return to Dr. Collins's vigorous defense of Darwinism a bit later, and we will point out serious scientific problems with this chapter, but it is enough here to note that he is merely the most visible (and well known) member of a movement of scientists and Christian leaders, many of them associated with the Biologos website, who call on Christians to cease their questioning of the *scientific claims* of Darwinian evolution. We view this development as educationally and empirically astonishing, in the light of the crucial void of evidence for a vast creative power of the mutation-selection mechanism. Leaving theological questions aside, why should Christian theists make peace with a theory that is scientifically in tatters?

3 See the articles, from crev.info news blog, which are archived at apologetics.org. Click on the home page link to "Beyond the Genome: Key Resources."

4 Michael Behe, *Darwin's Black Box*, p. 93, endnote 10 chapter 5

Chapter 2. What Biologists Know About DNA

v The idea of a scientist who is an atheist coming to the defense of intelligent design is not imaginary. The comments from the imaginary physicist here are based on factual reality. In early 2010 one of us (Woodward) interviewed on the weekly "Darwin or Design" radio program a professor of the philosophy of physics, Bradley Monton, who teaches at the University of Colorado at Boulder. He did his PhD in that field at Princeton University, and has become renowned as a *secular defender of the legitimacy of design theory as scientific.* His new book, *Seeking God in Science: An Atheist Defends Intelligent Design*, presents a balanced and sober evaluation of a wide array of ID arguments—both in biology and physics. Monton feels that a number of these arguments, especially the ones in physics and cosmology, carry some weight and could prove to be right in the long run, although he personally is not yet convinced to abandon his atheism.

vi For a picture of two hand-held models of DNA we've developed, one shorter one with 21 rungs and a longer 10-foot model with 75 rungs, see page . . .

vii Construction directions are found on the apologetics.org website on the page entitled "How to Build a Sweet DNA Model."

viii Behe, p. 255