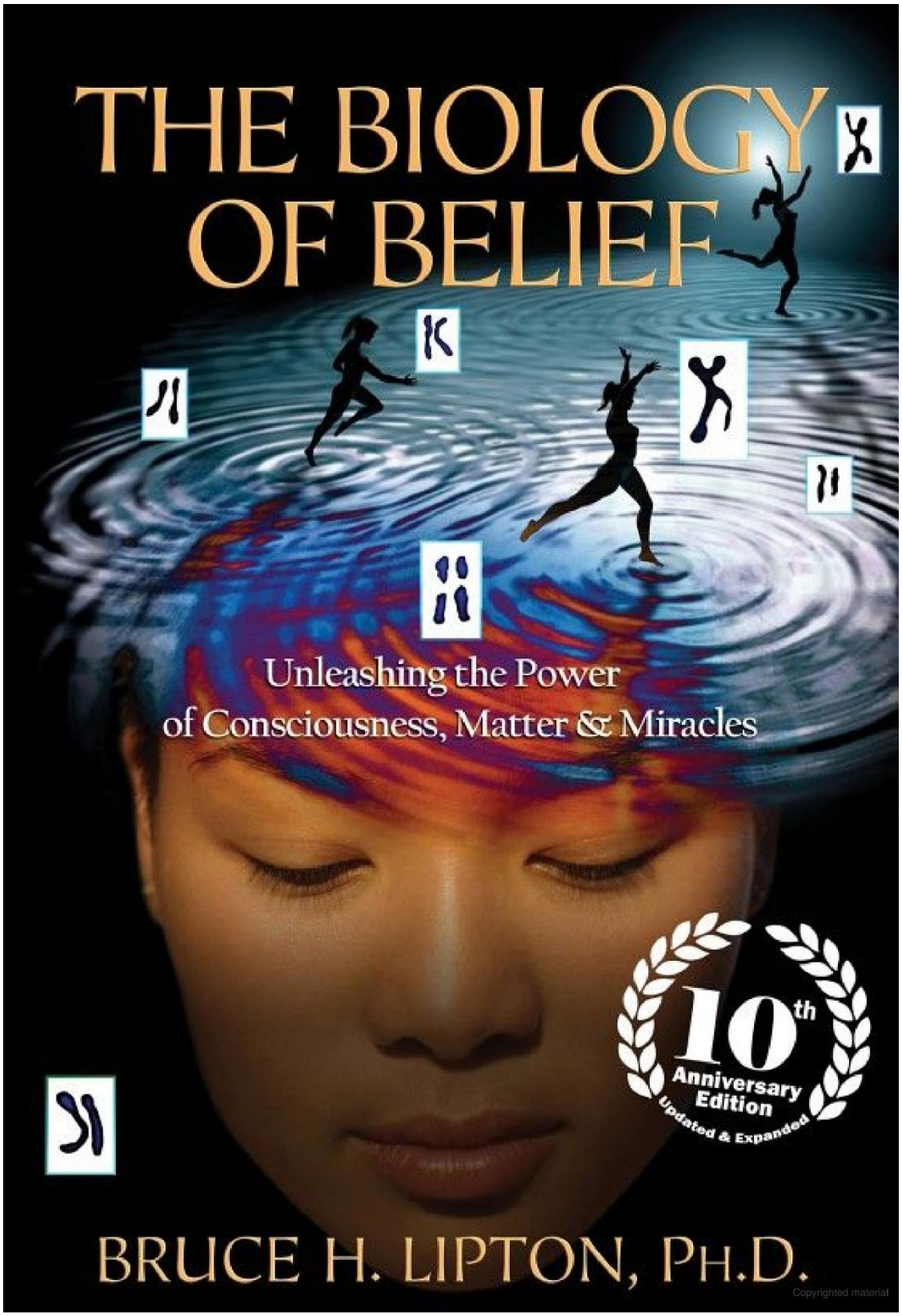
THE BIOLOGY OF BELIEF
Unleashing the Power of Consciousness, Matter & Miracles
10th Anniversary Edition
Updated & Expanded
BRUCE H. LIPTON, PH.D.
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Contents

Prologue

"If you could be *anybody*, who would you be?" I used to spend an inordinate amount of time pondering that question. I was obsessed with the fantasy of changing my identity because I wanted to be anybody *but* me. I had a good career as a cell biologist and medical school professor, but that didn't make up for the fact that my personal life was, at best, a shambles. The harder I tried to find happiness and satisfaction in my personal life, the more dissatisfied and unhappy I became. In my reflective moments, I resolved to surrender to my unhappy life. I decided that fate had dealt me a bad hand, and I should simply accept it. Que sera, sera.

In the fall of 1985, my depressed, fatalistic attitude changed in one transformational moment. I had resigned my tenured position at the University of Wisconsin's School of Medicine and was teaching at an offshore medical college in the Caribbean. Because the school was so far from the academic mainstream, I had the opportunity to think outside the rigid parameters of *belief* that prevail in conventional academia. Far from the ivory towers, isolated on an emerald island in the deep azure Caribbean Sea, I experienced a scientific epiphany that shattered my *beliefs* about the nature of life.

My life-changing moment occurred while I was reviewing my research on the mechanisms by which cells control their physiology and behavior. Suddenly I realized that a cell's life is fundamentally controlled by the physical and energetic environment with only a small contribution by its genes.

Genes are simply molecular blueprints used in the construction of cells, tissues, and organs. The environment serves as a "contractor" who reads and engages those genetic blueprints and is ultimately responsible for the character of a cell's life. It is a single cell's "awareness" of the environment that primarily sets into motion the mechanisms of life.

As a cell biologist I knew that my insights had powerful ramifications for my life and the lives of all human beings. I was acutely aware that each of us is made up of approximately 50 trillion single cells. I had devoted my professional life to better understanding single cells because I knew then and know now that the better we understand single cells the better we can understand the community of cells that comprises each human body and that if single cells are controlled by their awareness of the environment so too are we trillion-celled human beings. Just like a single cell, the character of our lives is determined not by our genes but by our responses to the environmental signals that propel life.

On the one hand, this new understanding of the nature of life was a jolt. For close to two decades I had been programming biology's Central Dogma—the *belief* that life is controlled by genes—into the minds of medical students. On the other hand, my new understanding was not a complete surprise. I had always had niggling doubts about genetic determinism. Some of those doubts stemmed from my eighteen years of government-funded research on cloning stem cells. Though it took a sojourn outside of traditional academia for me to fully realize it, my research at that time (1985) offered incontrovertible proof that biology's most

cherished tenets regarding genetic determinism were fundamentally flawed.

My new understanding of the nature of life not only corroborated my stem cell research but also, I realized, contradicted another *belief* of mainstream science of that time. I had been propounding to my students—the *belief* that allopathic medicine is the only kind of medicine that merits consideration in medical school. By finally giving the energy-based environment its due, it provided for a grand convergence uniting the science and practice of allopathic medicine, complementary medicine, and the spiritual wisdom of ancient and modern faiths.

On a personal level, I knew at the moment of insight that I had gotten myself stuck simply by *believing* that I was fated to have a spectacularly unsuccessful personal life. There is no doubt that human beings have a great capacity for sticking to false *beliefs* with great passion and tenacity, and hyper-rational scientists are not immune. Our well-developed nervous system, headed by our big brain, is testament that our awareness is far more complicated than that of a single cell. When our uniquely human minds get involved, we can choose to perceive the environment in different ways, unlike a single cell whose awareness is more reflexive.

I was exhilarated by the new realization that I could change the character of my life by changing my *beliefs*. I was instantly energized because I realized that there was a science-based path that would take me from my job as a perennial "victim" to my new job as "co-creator" of my destiny.

It has been thirty years since that magical night in the

Caribbean when I had my life-changing moment of insight and ten years since I published the first edition of *The Biology of Belief*. In the intervening years, and particularly in the last decade, biological research has corroborated the knowledge I gained on that early morning in the Caribbean. We are living in exciting times, for science is in the process of shattering old myths and rewriting a fundamental *belief* of human civilization. The *belief* that we are frail, biochemical machines controlled by genes is giving way to an understanding that we are powerful creators of our lives and the world in which we live.

The times are indeed changin', which is why I'm particularly excited about this tenth-anniversary edition of *The Biology of Belief.* In fact, I thought about a new title for this edition: *The Biology of Belief and Hope*. However, I reconsidered because I like the alliteration of the original title! Nevertheless, during this time of change (despite, I can't deny, a slew of negative news headlines), I am filled with hope.

Hope because the size and enthusiasm of the audiences for my lectures about *The Biology of Belief*, which has been published in thirty-five countries, have grown exponentially.

Hope because more and more professionals, who agree that biomedicine needs to change its drug-focused ways, are coming to my lectures and engaging me in spirited debate.

Hope because I've met so many people who "get" that *The Biology of Belief* isn't just about *individual* empowerment, and it certainly isn't just about me. I was deeply honored to receive the Goi Peace Award in 2009, and I was also thrilled that the

President of the Goi Peace Foundation, Hiroo Saionji, made it so clear that though I was the recipient, the award was actually for the "new science" outlined in *The Biology of Belief*: "[This] research . . . has contributed to a greater understanding of life and the true nature of humanity, empowering wide layers of the public to take control of their own lives and become responsible co-creators of a harmonious planetary future."

It is also my sincerest hope that everyone who reads *The Biology of Belief* recognizes that many of the *beliefs* that propel their lives are false and self-limiting. You can take control of your life and set out on the road to health and happiness, and you can band together with others you meet on that road so that humanity can evolve to a new level of understanding and peace.

As for me, I am ever thankful for that moment of insight in the Caribbean, which enabled me to create my now wondrous life. In the last decade, I've traveled around the world several times teaching the New Biology, written two more books —*Spontaneous Evolution* (2009) and *The Honeymoon Effect* (2013) —become a grandfather three times over, and, oh, become a septuagenarian. Instead of slowing down with age, I feel more and more energized by the life I've created, the connections I've made with those who are also dedicated to creating a harmonious planet, and the continuing honeymoon I'm enjoying with Margaret Horton, my best friend, my life partner, my love, as I described her in the first edition's dedication and still describe her now. In short, my life is so much richer and more satisfying that I no longer ask myself:

If I could be anybody, who would I be? For me, the answer is a nobrainer. I want to be *me*!

Introduction

The Magic of Cells

I was seven years old when I stepped up onto a small box in Mrs. Novak's second-grade classroom, high enough to plop my eye right onto the lens and eyepiece of a microscope. Alas, I was too close to see anything but a blob of light. Finally I calmed down enough to listen to instructions to back off from the eyepiece. And then it happened, an event so dramatic that it would set the course for the rest of my life. A paramecium swam into the field. I was mesmerized. The raucous din of the other kids faded, as did the back-to-school smells of freshly sharpened pencils, new waxy crayons, and plastic Roy Rogers pencil cases. My whole being was transfixed by the alien world of this cell that, for me, was more exciting than today's computer-animated special-effects movies.

In the innocence of my child mind, I saw this organism not as a cell but as a microscopic person, a thinking, sentient being. Rather than aimlessly moving around, this microscopic, single-celled organism appeared to me to be on a mission, though what kind of mission I didn't know. I quietly watched over the paramecium's "shoulder" as it busily comported itself in and around the algal mat. While I was focusing on the paramecium, a large pseudopod of a gangly amoeba began to ooze into the field.

Just then my visit to this Lilliputian world ended abruptly

when Glenn, the class bully, yanked me off the step and demanded his turn at the microscope. I tried to get Mrs. Novak's attention, hoping that Glenn's personal foul would get me another minute at the microscope free-throw line. But it was just minutes before lunch time and the other kids in line were clamoring for their turn. Immediately after school, I ran home and excitedly relayed my microscopic adventure to my mother. Using my best second-grade powers of persuasion, I asked, then begged, then cajoled my mother into getting me a microscope, where I would spend hours mesmerized by this alien world that I could access via the miracle of optics.

Later, in graduate school, I advanced to an electron microscope. The advantage of an electron microscope over a conventional light microscope is that it is a thousand times more powerful. The difference between the two microscopes is analogous to the difference between the 25¢ observation telescopes used by tourists to observe scenic vistas and the orbiting Hubble telescope that transmits images of deep space. Entering the electron microscopy suite of a laboratory is a rite of passage for aspiring biologists. You enter through a black revolving door, similar to the ones separating photographic darkrooms from illuminated work areas.

I remember the first time I stepped into the revolving door and began to turn it. I was in darkness between two worlds, my life as a student and my future life as a research scientist. When the door completed its rotation, I was deposited into a large, dark chamber, dimly lit by several red photographic safelights. As my eyes adapted to the available light, I

gradually became awed by what stood before me. The red lights were reflecting eerily off the mirrored surface of a massive, foot-thick chromium steel column of electromagnetic lenses that rose to the ceiling in the center of the room. Spreading out on either side at the base of the column was a large control console. The console resembled the instrument panels of a Boeing 747, filled with switches, illuminated gauges, and multicolored indicator lamps. Large tentacle-like arrays of thick power cords, water hoses, and vacuum lines radiated from the base of the microscope like tap roots at the base of an old oak tree. The sound of clanking vacuum pumps and the whir of refrigerated water recirculators filled the air. For all I knew, I had just emerged onto the command deck of the *U.S.S. Enterprise.* Apparently, it was Captain Kirk's day off, for sitting at the console was one of my professors, who was engaged in the elaborate procedure of introducing a tissue specimen into a high-vacuum chamber in the middle of the steel column.

While the minutes passed, I experienced a feeling reminiscent of that day in second grade when I first saw a cell. Finally, a green fluorescent image appeared on the phosphor screen. The presence of darkly stained cells could barely be discerned in the plastic sections, which were enlarged to about thirty times their original size. Then the magnification was increased, one step at a time. First 100X, then 1000X, and then 10,000X. When we finally hit warp drive, the cells were magnified to over 100,000 times their original size. It was indeed *Star Trek,* but rather than entering outer space, we were going deep into inner space where "no

man has gone before." One moment I was observing a miniature cell, and seconds later I was flying deep into its molecular architecture.

My awe at being at the edge of this scientific frontier was palpable. So was my excitement when I was made honorary co-pilot. I put my hands on the controls so that I could "fly" over this alien cellular landscape. My professor was my tour guide, pointing out notable cellular landmarks: "Here's a mitochondrion, there's the Golgi body, over there is a nuclear pore, this is a collagen molecule, that's a ribosome."

Most of the rush I experienced came from my vision of myself as a pioneer, traversing territory that had never been seen by human eyes. While the light microscope gave me an awareness of cells as sentient creatures, it was the electron microscope that brought me face to face with the molecules that were the very foundation of life itself. I knew that buried within the *cytoarchitecture* of the cell were clues that would provide insight into the mysteries of life.

For a brief moment, the microscope's portholes became a crystal ball; in the eerie green glow of its fluorescent screen I saw my future. I knew I was going to be a cellular biologist whose research would focus on scrutinizing every nuance of the cell's ultrastructure to gain insights into the secrets of cellular life. As I had learned early on in graduate school, the *structure* and *function* of biological organisms are intimately intertwined. By correlating the cell's microscopic anatomy with its behavior, I was sure to gain insight into the nature of Nature. Throughout graduate school and postdoctoral research, and into my career as a medical school professor,

my waking hours were consumed by explorations into the cell's molecular anatomy. For locked within the cell's structure were the secrets of its functions.

My exploration of the "secrets of life" led me into a research career studying the character of cloned human cells grown in tissue culture. Ten years after my first close encounter with an electron microscope, I was a tenured faculty member at the prestigious University of Wisconsin School of Medicine, internationally recognized for my research on cloned stem cells, and honored for my teaching skills. I had graduated to more powerful electron microscopes that allowed me to take three-dimensional CAT-scan-like rides through organisms where I had the opportunity to directly experience the molecular anatomy that provided for the magic of life. Though my tools were more sophisticated, my approach hadn't changed. I had never lost my seven-year-old conviction that the lives of the cells I studied had purpose.

Unfortunately, I had no such conviction that my own life had a purpose. I didn't believe in God, though I confess that on occasion I entertained the notion of a God who ruled with an extremely honed perverse sense of humor. I was after all a traditional biologist for whom God's existence is an unnecessary question: life is the consequence of blind chance, the flip of a friendly card, or, to be more precise, the random shake of genetic dice. The motto of our profession, since the time of Charles Darwin, has been: "God? We don't need no steenking God!"

It's not that Darwin denied the existence of God. He simply

implied that chance, not Divine intervention, was responsible for the character of life on Earth. In his 1859 book, *The Origin of Species,* Darwin said that individual traits are passed from parents to their children. He suggested that "hereditary factors" passed from parent to child *control* the characteristics of an individual's life. That bit of insight set scientists off on a frenzied attempt to dissect life down to its molecular nuts and bolts, for within the structure of the cell was to be found the heredity mechanism that controlled life.

The search came to a remarkable end fifty years ago when James Watson and Francis Crick described the structure and function of the DNA double helix, the material of which genes are made. Scientists finally figured out the nature of the "hereditary factors" that Darwin had written about in the nineteenth century. The tabloids heralded the brave new world of genetic engineering with its promise of designer babies and magic bullet medical treatments. I vividly remember the large block print headlines that filled the front page on that memorable day in 1953: "Secret of Life Discovered."

Like the tabloids, biologists jumped on the gene bandwagon. The mechanism by which DNA controls biological life became the Central Dogma of molecular biology, painstakingly spelled out in textbooks. In the long-running debate over nature vs. nurture, the pendulum swung decidedly to nature. At first DNA was thought to be responsible only for our physical characteristics, but then we started believing that our genes control our emotions and behaviors as well. So if you are born with a defective

happiness gene, you can expect to have an unhappy life.

Unfortunately, I thought I was one of those people victimized by a missing or mutant happiness gene. I was reeling from a relentless barrage of debilitating emotional roundhouse punches. My father had just died after a long, pain-fraught battle with cancer. I was his principal caretaker and had spent the previous four months flying back and forth between my job in Wisconsin and his home in New York every three or four days. In between stays at his deathbed, I was trying to maintain a research program, teach, and write a major grant renewal for the National Institutes of Health.

To further compound my stress levels, I was in the midst of an emotionally draining and economically devastating divorce. My financial resources were rapidly depleted as I tried to feed and clothe my new dependent, the judicial system. Economically challenged and homeless, I found myself living pretty much out of a suitcase in a most abysmal "garden" apartment complex. Most of my neighbors were hoping to upgrade their living standards by seeking accommodations in trailer parks. I was particularly scared of my next-door neighbors. My apartment was broken into, and my new stereo system was stolen in my first week of residence. A week later, six-foot tall, three-foot wide Bubba knocked on my door. Holding a quart of beer in one hand and picking his teeth with a ten-penny nail held in the other, Bubba wanted to know if I had the directions for the tape deck.

The nadir was the day I threw the phone through the glass door of my office, shattering the "Bruce H. Lipton, Ph.D.,

Associate Professor of Anatomy, U.W. School of Medicine" sign, all the while screaming, *"Get me out of here!"* My meltdown was precipitated by a phone call from a banker, who politely but firmly told me he couldn't approve my mortgage application. It was like the scene from *Terms of Endearment* when Debra Winger aptly responds to her husband's hopes for tenure: "We don't have enough money to pay the bills now. All tenure means is we won't have enough money forever!"

The Magic of Cells—Déjà Vu

Luckily, I found an escape in the form of a short-term sabbatical at a medical school in the Caribbean. I knew all my problems would not disappear there, but as the jet broke through the gray cloud cover above Chicago, it felt that way. I bit the inside of my cheek to prevent the smile on my face from evolving into audible laughter. I felt as joyful as my seven-year-old self, first discovering my life's passion, the magic of cells.

My mood lifted even more on the six-passenger commuter plane that took me to Montserrat, a mere four-by-twelve-mile dot in the Caribbean Sea. If there ever was a Garden of Eden, it probably would have resembled my new island home, erupting out of the sparkling aquamarine sea like a giant multifaceted emerald. When we landed, the gardenia-laced balmy breezes that swept the airport's tarmac were intoxicating.

The native custom was to dedicate the sunset period as a time of quiet contemplation, a custom I readily adopted. As each day wound down, I looked forward to the heavenly light show. My house, situated on a cliff fifty feet above the ocean, faced due west. A winding path through a tree-covered fern grotto led me down to the water. At the bottom of the grotto, an opening through a wall of jasmine bushes revealed a secluded beach, where I enhanced the sunset ritual by washing away the day with a few "laps" in the warm, gin-clear water. After my swim, I would mold the beach sand into a comfortable recliner, sit back, and watch the sun set slowly into the sea.

On that remote island, I was out of the rat race and free to see the world without the blinders of civilization's dogmatic beliefs. At first my mind was constantly reviewing and critiquing the debacle that was my life. But soon my mental Siskel and Ebert ceased their thumbs up/thumbs down review of my forty years. I began to re-experience what it was like to live in the moment and for the moment. To became reacquainted with sensations last experienced as a carefree child. To again *feel* the pleasure of being alive.

I became more human and more humane while living in that island paradise. I also became a better cell biologist. Almost all of my formal scientific training was in sterile, lifeless classrooms, lecture halls, and laboratories. However, once I was immersed in the Caribbean's rich ecosystem, I began to appreciate biology as a living, breathing, integrated system rather than a collection of individual species sharing a piece of the Earth's turf.

Sitting quietly within garden-like island jungles and snorkeling among the jeweled coral reefs gave me a window into the island's amazing integration of plant and animal species. All live in a delicate, dynamic balance, not only with other life forms but with the physical environment as well. It was life's harmony—not life's struggle—that sang out to me as I sat in the Caribbean Garden of Eden. I became convinced that contemporary biology pays too little attention to the important role of cooperation because its Darwinian roots emphasize life's competitive nature.

To the chagrin of my U.S. faculty colleagues, I returned to Wisconsin a screaming radical bent on challenging the sacred foundational beliefs of biology. I even began to openly criticize Charles Darwin and the wisdom of his theory of evolution. In the eyes of most other biologists, my behavior was tantamount to a priest bursting into the Vatican and claiming the Pope was a fraud.

My colleagues could be forgiven for thinking a coconut had hit me on the head when I quit my tenured position and, fulfilling my life's dream to be in a rock 'n' roll band, took off on a music tour. I discovered Yanni, who eventually became a big celebrity, and produced a laser show with him. But it soon became clear that I had a lot more aptitude for teaching and research than I did for producing rock 'n' roll shows. I wound down my midlife crisis, which I'll describe in more agonizing detail in a later chapter, by giving up the music business and returning to the Caribbean to teach cell biology again.

My final stop in conventional academia was at Stanford University's School of Medicine. By that time I was an

unabashed proponent of a "new" biology. I had come to question not only Darwin's dog-eat-dog version of evolution but also biology's Central Dogma, the premise that genes control life. That scientific premise has one major flaw—genes cannot turn themselves on or off. In more scientific terms, genes are not "self-emergent." Something in the environment has to trigger gene activity. Though that fact had already been established by frontier science, conventional scientists blinded by genetic dogma had simply ignored it. My outspoken challenge of the Central Dogma turned me into even more of a scientific heretic. Not only was I a candidate for excommunication, I was now suitable for burning at the stake!

In a lecture during my interview at Stanford, I found myself accusing the gathered faculty, many of them internationally recognized geneticists, of being no better than religious fundamentalists for adhering to the Central Dogma despite evidence to the contrary. After my sacrilegious comments, the lecture room erupted into shouts of outrage that I thought meant the end of my job application. Instead, my insights concerning the mechanics of a new biology proved to be provocative enough to get me hired. With the support of some eminent scientists at Stanford, especially from the Pathology Department's chairman, Dr. Klaus Bensch, I was encouraged to pursue my ideas and apply them to research on cloned human cells. To the surprise of those around me, the experiments fully supported the alternative view of biology that I was postulating. I published two papers based on this research

and left academia, this time for good. (Lipton, et al, 1991, 1992)

I left because, despite the support I got at Stanford, I felt that my message was falling on deaf ears. Since my departure, new research has consistently validated my skepticism about the Central Dogma and the primacy of DNA in controlling life. In fact, *epigenetics*, the study of the molecular mechanisms by which the environment controls gene activity, is today one of the most active areas of scientific research. The newly emphasized role of the environment in regulating gene activity was the focus of my cell research twenty-five years ago, long before the field of epigenetics was even established. (Lipton 1977a, 1977b) While that is gratifying for me intellectually, I know that if I were teaching and researching in a medical school, my colleagues would still be wondering about those coconuts because in the last decade I have become even more of a radical by academia's standards. My preoccupation with a new biology has become more than an intellectual exercise. I believe that cells teach us not only about the mechanisms of life, but also how to live rich, full lives.

In ivory tower science, that kind of thinking would no doubt win me the wacky Dr. Dolittle award for anthropomorphism or more precisely cytopomorphism—thinking like a cell—but for me it is Biology 101. You may consider yourself an individual, but as a cell biologist, I can tell you that you are in truth a cooperative community of approximately 50 trillion single-celled citizens. Almost all of the cells that make up your body are amoeba-like, individual

organisms that have evolved a cooperative strategy for their mutual survival. Reduced to basic terms, human beings are simply the consequence of "collective amoebic consciousness." As a nation reflects the traits of its citizens, our human-ness must reflect the basic nature of our cellular communities.

Living the Lessons of Cells

Using these cell communities as role models, I came to the conclusion that we are not victims of our genes, but masters of our fates, able to create lives overflowing with peace, happiness, and love. I tested my hypothesis in my own life after a nudge from my audiences, who asked me why my insights hadn't made me any happier. They were right: I needed to integrate my new biological awareness into my daily life. I knew I had succeeded when, on a bright Sunday morning in the Big Easy, a coffee-shop waitress asked me: "Honey, you are the happiest person I ever did see. Tell me child, why are you so happy?" I was taken aback by her question, but nevertheless I blurted out, "I'm in Heaven!" The waitress shook her head from side to side mumbling, "My, my," and then proceeded to take my breakfast order. Well, it was true. I was happy, happier than I had ever been in my life.

A number of you critical readers may rightly be skeptical of my claim that Earth is Heaven. For by definition, Heaven is also the abode of the Deity and the blessed dead. Did I really think that New Orleans, or any other major city, could be part

of Heaven? Ragged homeless women and children living in alleys; air so thick that one would never know if stars really existed; rivers and lakes so polluted that only unimaginable "scary" life forms could exist in them. This Earth is Heaven? The Deity lives here? He *knows* the Deity?

The answers to those questions are: yes, yes, and I believe I do. Well, to be completely honest, I must admit that I don't know all of the Deity personally, for I don't know all of you. For God's sake, there are over six billion of YOU. And to be more fully honest, I don't really know all of the members of the plant and animal kingdom either, though I believe they also comprise God.

In the immortal words of Tool Time's Tim Taylor: "Baaaaack the truck up! Is he saying that *humans* are God?"

Well . . . yes, I am. Of course I am not the first to have said that. It is written in Genesis that we are made in the image of God. Yes, this card-carrying rationalist is now quoting Jesus, Buddha, and Rumi. I have come full circle from a reductionist, scientific take on life to a spiritual one. We are made in the image of God, and we need to put Spirit back into the equation when we want to improve our physical and our mental health.

Because we are not powerless biochemical machines, popping a pill every time we are mentally or physically out of tune is not the answer. Drugs and surgery are powerful tools when they are not overused, but the notion of simple drug fixes is fundamentally flawed. Every time a drug is introduced into the body to correct function A, it inevitably throws off function B, C, or D. It is not gene-directed hormones and

neurotransmitters that control our bodies and our minds; our beliefs control our bodies and our minds, and thus our lives . . . Oh ye of little belief!

The Light Outside of the Box

In this book I will draw the proverbial line in the sand. On one side of the line is a world defined by neo-Darwinism, which casts life as an unending war among battling, biochemical robots. On the other side of the line is the "New Biology," which casts life as a cooperative journey among powerful individuals who can program themselves to create joy-filled lives. When we cross that line and truly understand the New Biology, we will no longer fractiously debate the role of nurture and nature because we will realize that the fully conscious mind trumps both nature and nurture. And I believe we will also experience as profound a paradigmatic change to humanity as when a round-world reality was introduced to a flat-world civilization.

Humanities majors, who may be worried that this book offers an incomprehensible science lecture, have no fear. When I was an academic, I chafed at the three-piece, itchy suit, the constricting tie, the wing-tip shoes, and the interminable meetings, but I loved to teach. And in my post-academia life, I've gotten plenty of teaching practice; I have presented the principles of the New Biology to thousands of people all around the world. Through those lectures, I have honed my presentation of the science into easy-to-

understand English illustrated by colorful charts, many of which are replicated in this book.

In Chapter 1, I discuss "smart" cells and why and how they can teach us so much about our own minds and bodies. In Chapter 2, I lay out the scientific evidence to show you genes do not control biology. I also introduce you to the latest discoveries of epigenetics, a booming field of biology that is unraveling the mysteries of how the environment influences the behavior of cells without changing the genetic code. It is a field that is uncovering new complexities in the nature of disease, including cancer and schizophrenia.

Chapter 3 is about the cell's membrane, the "skin" of the cell. You no doubt have heard more about the DNA-containing nucleus of the cell than you have about its membrane. But frontier science is revealing in ever greater detail what I concluded more than thirty years ago: that the membrane is the true brain of the cellular operation. And the latest research suggests that one day, this knowledge will lead to awesome medical breakthroughs.

In Chapter 4, I talk about the mind-bending discoveries of quantum physics. Those discoveries have profound implications for understanding and treating disease. Tragically, the conventional medical establishment has not yet incorporated quantum physics into its research or medical school training. (However, judging from my audiences, more and more insiders are hungry for new modalities.)

In Chapter 5, I explain why I named this book *The Biology of Belief.* Positive thoughts have a profound effect on behavior

and genes, but *only* when they are in harmony with subconscious programming. And negative thoughts have an equally powerful effect. When we recognize how these positive and negative beliefs control our biology, we can use this knowledge to create lives filled with health and happiness.

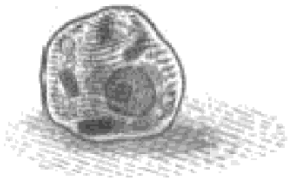
Chapter 6 reveals why cells and people need to grow, how fear shuts down that growth, and how love, the opposite of fear, promotes growth.

Chapter 7 focuses on conscious parenting. As parents, we need to understand the role we play in programming our children's beliefs and the impact those beliefs have on our children's lives and thus the evolution of human civilization. This chapter is important even if you are not a parent, for as a former child, you'll find the insight into your own programming quite revealing!

In the Epilogue, I review how my understanding of the New Biology led me to realize the importance of integrating the realms of Spirit and Science, which was a radical shift from my background as an agnostic scientist. I am humbled to say that *Watkins Mind Body Spirit,* a magazine published by London's oldest esoteric bookshop, has named me one of the 100 Most Spiritually Influential Living People every year since it started the list in 2011. I am humbled that the list has put me in the same company as the Dalai Lama, Desmond Tutu, Wayne Dyer, Thich Nhat Hanh, Deepak Chopra, Gregg Braden, and my publisher, Louise Hay, to name just a few. What an incredible honor for someone who used to study only the mechanistic, material world!

Are you ready to consider an alternate reality to that provided by the medical model—a reality in which the human body is not simply a biochemical machine? Are you ready to use your subconscious and conscious minds to create a life overflowing with health, happiness, and love without the aid of genetic engineers and without addicting yourself to drugs? There is nothing to buy, and there are no policies to take out. It is just a matter of temporarily suspending the archaic beliefs you have acquired from the scientific and media establishments so you can consider the exciting new awareness offered by leading-edge science.

CHAPTER 1



LESSONS FROM THE PETRI DISH:

In Praise of Smart Cells and Smart Students

On my second day in the Caribbean, as I stood in front of more than a hundred visibly on-edge medical students, I suddenly realized that not everyone viewed the island as a laid-back refuge. For these nervous students, Montserrat was not a peaceful escape but a last-ditch chance to realize their dreams of becoming doctors.

My class was geographically homogeneous, mostly American students from the East Coast, but there were all races and ages, including a sixty-seven-year-old retiree who was anxious to do more with his life. Their backgrounds were equally varied—former elementary school teachers, accountants, musicians, a nun, and even a drug smuggler.

Despite all the differences, the students shared two characteristics: One, they had failed to succeed in the highly competitive selection process that filled the limited number of positions in American medical schools. Two, they were "strivers" intent on becoming doctors—they were not about

to be denied the opportunity to prove their qualifications. Most had spent their life savings or indentured themselves to cover the tuition and extra costs of living out of the country. Many found themselves completely alone for the first time in their lives, having left their families, friends, and loved ones behind. They put up with the most intolerable living conditions on that campus. Yet with all the drawbacks and the odds stacked against them, they were never deterred from their quest for a medical degree.

Well, at least that was true up to the time of our first class together. Prior to my arrival, the students had had three different histology/cell biology professors. The first lecturer left the students in the lurch when he responded to some personal issue by bolting from the island three weeks into the semester. In short order, the school found a suitable replacement who tried to pick up the pieces; unfortunately he bailed three weeks later because he got sick. For the preceding two weeks, a faculty member, responsible for another field of study, had been reading chapters out of a textbook to the class. This obviously bored the students to death, but the school was fulfilling a directive to provide a specified number of lecture hours for the course. Academic prerequisites set by American medical examiners have to be met in order for the school's graduates to practice in the States.

For the fourth time that semester, the weary students listened to a new professor. I briefed them on my background and my expectations for the course. I made it clear that even though we were in a foreign country, I was not going to

expect any less from them than what was expected from my Wisconsin students. Nor should they want me to because to be certified all doctors have to pass the same Medical Boards, no matter where they go to medical school. Then I pulled a sheaf of exams out of my briefcase and told the students that I was giving them a self-assessment quiz. The middle of the semester had just passed, and I expected them to be familiar with half of the required course material. The test I handed out on that first day of the course consisted of twenty questions taken directly from the University of Wisconsin histology midterm exam.

The classroom was deadly silent for the first ten minutes of the testing period. Then nervous fidgeting felled the students one by one, faster than the spread of the deadly Ebola virus. By the time the twenty minutes allotted for the quiz were over, wide-eyed panic had gripped the class. When I said, "Stop," the pent-up nervous anxiety erupted into the din of a hundred excited conversations. I quieted the class down and began to read them the answers. The first five or six answers were met with subdued sighs. After I reached the tenth question, each subsequent answer was followed by agonizing groans. The highest score in the class was ten correct answers, followed by several students who answered seven correctly; with guesswork, most of the rest scored at least one or two correct answers.

When I looked up at the class, I was greeted with frozen, shell-shocked faces. The "strivers" found themselves behind the big eight ball. With more than half a semester behind them, they had to start the course all over again. A dark

gloom overcame the students, most of whom were already treading water in their other, very demanding medical school courses. Within moments, their gloom had turned into quiet despair. In profound silence, I looked out over the students and they looked back at me. I experienced an internal ache—the class collectively resembled one of those Greenpeace pictures of wide-eyed baby seals just before heartless fur traders club them to death.

My heart welled. Perhaps the salt air and sweet scents had already made me more magnanimous. In any case, unexpectedly, I found myself announcing that I would make it my personal commitment to see that every student was fully prepared for the final exam, if they would commit to providing matching efforts. When they realized I was truly committed to their success, I could see the lights flash on in their previously panicked eyes.

Feeling like an embattled coach revving up the team for the Big Game, I told them I thought they were every bit as intelligent as the students I taught in the States. I told them I believed their stateside peers were simply more proficient at rote memorization, the quality that enabled them to score better in the medical college admissions tests. I also tried very hard to convince them that histology and cell biology are not intellectually difficult courses. I explained that in all of its elegance, nature employs very simple operating principles. Rather than just memorizing facts and figures, I promised they were going to gain an understanding of cells because I would present simple principles on top of simple principles. I offered to provide additional night lectures,

which would tax their stamina after their already long lecture- and lab-packed days. The students were pumped up after my ten-minute pep talk. When the period ended, they bolted from that classroom snorting fire, determined they would not be beaten by the system.

After the students left, the enormity of the commitment I had made sank in. I started having doubts. I knew that a significant number of the students were truly unqualified to be attending medical school. Many others were capable students whose backgrounds had not prepared them for the challenge. I was afraid that my island idyll would degenerate into a frenetic, time-consuming academic scrimmage that would end in failure for my students and for me as their teacher. I started thinking about my job at Wisconsin, and suddenly it was beginning to look easy. At Wisconsin, I gave only eight lectures out of the approximately fifty that made up the histology/cell biology course. There were five members of the anatomy department who shared the lecturing load. Of course I was responsible for the material in all of the lectures because I was involved in their accompanying laboratory sessions. I was supposed to be available to answer all course-related questions asked by the students. But knowing the material and presenting lectures on the material are not the same thing!

I had a three-day weekend to wrestle with the situation I had created for myself. Had I faced a crisis such as this back home, my type A personality would have had me swinging from the proverbial chandeliers. Interestingly, as I sat by the pool, watching the sun set into the Caribbean, the potential

angst simply morphed into an exciting adventure. I began to get excited about the fact that for the first time in my teaching career, I was solely responsible for this major course and free from having to conform to the style and content restrictions of team-taught programs.

Cells as Miniature Humans

As it turned out, that histology course was the most exhilarating and intellectually profound period of my academic career. Free to teach the course the way I wanted to teach it, I ventured into a new way of covering the material, an approach that had been roiling in my brain for several years. I had been fascinated by the idea that considering cells as "miniature humans" would make it easier to understand their physiology and behavior. As I contemplated a new structure for the course, I got excited. The idea of overlapping cell and human biology rekindled the inspiration for science I had felt as a child. I still experienced that enthusiasm in my research laboratory, though not when I was mired in the administrative details of being a tenured faculty member, including endless meetings and what, for me, were torturous faculty parties.

I was prone to thinking of cells as human-like because, after years behind a microscope, I had become humbled by the complexity and power of what at first appear to be anatomically simple, moving blobs in a petri dish. In school you may have learned the basic components of a cell: the

nucleus that contains genetic material, the energy-producing mitochondria, the protective membrane at the outside rim, and the cytoplasm in between. But within these anatomically simple–looking cells is a complex world; these smart cells employ technologies that scientists have yet to fully fathom.

The notion of cells as miniature humans that I was mulling over would be considered heresy by most biologists. Trying to explain the nature of anything not human by relating it to human behavior is called anthropomorphism. "True" scientists consider anthropomorphism to be something of a mortal sin and ostracize scientists who knowingly employ it in their work.

However, I believed that I was breaking out of orthodoxy for a good reason. Biologists try to gain scientific understanding by observing nature and conjuring up a hypothesis of how things work. Then they design experiments to test their ideas. By necessity, deriving the hypothesis and designing the experiments require the scientist to "think" how a cell or another living organism carries out its life. Applying these "human" solutions, i.e., a human view of resolving biology's mysteries, automatically makes these scientists guilty of anthropomorphizing. No matter how you cut it, biological science is based to some degree on humanizing the subject matter.

Actually, I believe that the unwritten ban on anthropomorphism is an outmoded remnant of the Dark Ages, when religious authorities denied any direct relationship existed between humans and any of God's other creations. While I can see the value of the concept when

people try to anthropomorphize a lightbulb, a radio, or a pocketknife, I do not see it as a valid criticism when it is applied to living organisms. Human beings are multicellular organisms—we must inherently share basic behavioral patterns with our own cells.

However, I know that it takes a shift in perception to acknowledge that parallel. Historically, our Judeo-Christian beliefs have led us to think that *we* are the intelligent creatures who were created in a separate and distinct process from all other plants and animals. This view has us looking down our noses at lesser creatures as nonintelligent life forms, especially those organisms on the lower evolutionary rungs of life.

Nothing could be further from the truth. When we observe other humans as individual entities or see ourselves in the mirror as an individual organism, in one sense, we are correct, at least from the perspective of our level of observation. However, if I brought you down to the size of an individual cell so you could see your body from that perspective, it would offer a whole new view of the world. When you looked back at yourself from that perspective you would not see yourself as a single entity. You would see yourself as a bustling community of more than 50 trillion individual cells.

As I toyed with these ideas for my histology class, the picture that kept recurring in my mind was a chart from an encyclopedia I had used as a child. Under the section on humans, there was an illustration with seven transparent plastic pages, each printed with an identical, overlapping

outline of the human body. On the first page the outline was filled in with an image of a naked man. Turning the first page was like peeling off his skin and revealing his musculature, the image within the outline on the second page. When I turned the second page, the overlapping images of the remaining pages revealed a vivid dissection of the body. Flipping through the pages I could see in turn, the skeleton, the brain and nerves, blood vessels, and organ systems.

For my Caribbean course, I mentally updated those transparencies with several additional, overlapping pages, each illustrated with cellular structures. Most of the cell's structures are referred to as organelles, which are its "miniature organs" suspended within a jelly-like cytoplasm. Organelles are the functional equivalents of the tissues and organs of our own bodies. They include the nucleus, which is the largest organelle, the mitochondria, the Golgi body, and vacuoles. The traditional way of teaching the course is to deal first with these cellular structures, then move on to the tissues and organs of the human body. Instead, I integrated the two parts of the course to reflect the overlapping nature of humans and cells.

I taught my students that the biochemical mechanisms employed by cellular organelle systems are essentially the same mechanisms employed by our human organ systems. Even though humans are made up of trillions of cells, I stressed that there is not one "new" function in our bodies that is not already expressed in the single cell. Virtually every eukaryote (nucleus-containing cell) possesses the functional equivalent of our nervous system, digestive system,

respiratory system, excretory system, endocrine system, muscle and skeletal systems, circulatory system, integument (skin), reproductive system, and even a primitive immune system, which utilizes a family of antibody-like "ubiquitin" proteins.

I also made it clear to my students that each cell is an intelligent being that can survive on its own, as scientists demonstrate when they remove individual cells from the body and grow them in a culture. As I knew intuitively when I was a child, these smart cells are imbued with intent and purpose; they actively seek environments that support their survival while simultaneously avoiding toxic or hostile ones. Like humans, single cells analyze thousands of stimuli from the microenvironment they inhabit. Through the analysis of this data, cells select appropriate behavioral responses to ensure their survival.

Single cells are also capable of learning through these environmental experiences and are able to create cellular memories, which they pass on to their offspring. For example, when a measles virus infects a child, an immature immune cell is called in to create a protective protein antibody against that virus. In the process, the cell must create a new gene to serve as a blueprint in manufacturing the measles antibody protein.

The first step in generating a specific measles antibody gene occurs in the nuclei of immature immune cells. Among their genes are a very large number of DNA segments that encode uniquely shaped snippets of proteins. By randomly assembling and recombining these DNA segments, immune

cells create a vast array of different genes, each one providing for a uniquely shaped antibody protein. When an immature immune cell produces an antibody protein that is a "close" physical complement to the invading measles virus, that cell will be activated.

Activated cells employ an amazing mechanism called *affinity maturation* that enables the cell to perfectly "adjust" the final shape of its antibody protein, so that it will become a perfect complement to the invading measles virus. (Li, et al, 2003; Adams, et al, 2003) Using a process called *somatic hypermutation,* activated immune cells make hundreds of copies of their original antibody gene. However, each new version of the gene is slightly mutated so that it will encode a slightly different shaped antibody protein. The cell selects the variant gene that makes the best-fitting antibody. This selected version of the gene also goes through repeated rounds of somatic hypermutation to further sculpt the shape of the antibody to become a "perfect" physical complement of the measles virus. (Wu, et al, 2003; Blanden and Steele 1998; Diaz and Casali 2002; Gearhart 2002)

When the sculptured antibody locks on to the virus, it inactivates the invader and marks it for destruction, thus protecting the child from the ravages of measles. The cells retain the genetic "memory" of this antibody, so that in the future if the individual is again exposed to measles, the cells can immediately launch a protective immune response. The new antibody gene can also be passed on to all the cell's progeny when it divides. In this process, not only did the cell "learn" about the measles virus, it also created a "memory"

that will be inherited and propagated by its daughter cells. This amazing feat of genetic engineering is profoundly important because it represents an inherent "intelligence" mechanism by which cells evolve. (Steele, et al, 1998)

The Origins of Life: Smart Cells Get Smarter

It shouldn't be surprising that cells are so smart. Single-celled organisms were the first life forms on this planet. Fossil evidence reveals they were here within 600 million years after the Earth was first formed. For the next 2.75 billion years of the Earth's history, only free-living, single-celled organisms—bacteria, algae, and amoeba-like protozoans—populated the world.

Around 750 million years ago, these smart cells figured out how to get smarter when the first multicellular organisms (plants and animals) appeared. Multicellular life forms were initially loose communities or "colonies" of single-celled organisms. At first, cellular communities consisted of from tens to hundreds of cells. But the evolutionary advantage of living in a community soon led to organizations comprised of millions, billions, and even trillions of socially interactive single cells. Though each individual cell is of microscopic dimensions, the size of multicellular communities may range from the barely visible to the monolithic. Biologists have classified these organized communities based on their structure as observed by the human eye. While the cellular communities appear as single entities to the naked eye—a

mouse, a dog, a human—they are, in fact, highly organized associations of millions and trillions of cells.

The evolutionary push for ever-bigger communities is simply a reflection of the biological imperative to survive. The more awareness an organism has of its environment, the better its chances for survival. When cells band together they increase their awareness exponentially. If each cell were to be arbitrarily assigned an awareness value of X, then each colonial organism would collectively have a potential awareness value of at least X times the number of cells in the colony.

In order to survive at such high densities, the cells created structured environments. These sophisticated communities subdivided the workload with more precision and effectiveness than the ever-changing organizational charts that are a fact of life in big corporations. It proved more efficient for the community to have individual cells assigned to specialized tasks. In the development of animals and plants, cells begin to acquire these specialized functions in the embryo. A process of cytological specialization enables the cells to form the specific tissues and organs of the body. Over time, this pattern of *differentiation*, i.e., the distribution of the workload among the members of the community, became embedded in the genes of every cell in the community, significantly increasing the organism's efficiency and its ability to survive.

In larger organisms, for example, only a small percentage of cells are concerned with reading and responding to environmental stimuli. That is the role of groups of

specialized cells that form the tissues and organs of the nervous system. The function of the nervous system is to perceive the environment and coordinate the behavior of all the other cells in the vast cellular community.

Division of labor among the cells in the community offered an additional survival advantage. The efficiency it offered enabled more cells to live on less. Consider the old adage: "Two can live as cheaply as one." Or consider the construction costs of building a two-bedroom single home versus the cost of building a two-bedroom apartment in a hundred-apartment complex. To survive, each cell is required to expend a certain amount of energy. The amount of energy conserved by individuals living in a community contributes to both an increased survival advantage and a better quality of life.

In American capitalism, Henry Ford saw the tactical advantage in the differentiated form of communal effort and employed it in creating his assembly line system of manufacturing cars. Before Ford, a small team of multiskilled workers would require a week or two to build a single automobile. Ford organized his shop so that every worker was responsible for only one specialized job. He stationed a large number of these differentiated workers along a single row, the assembly line, and passed the developing car from one specialist to the next. The efficiency of job specialization enabled Ford to produce a new automobile in ninety minutes rather than weeks.

Unfortunately, we conveniently "forgot" about the cooperation necessary for evolution when Charles Darwin

emphasized a radically different theory about the emergence of life. He concluded 150 years ago that living organisms are perpetually embroiled in a "struggle for existence." For Darwin, struggle and violence are not only a part of animal (human) nature but the principal "forces" behind evolutionary advancement. In the final chapter of *The Origin of Species: By Means of Natural Selection, Or, the Preservation of Favoured Races in the Struggle for Life,* Darwin wrote of an inevitable "struggle for life" and that evolution was driven by "the war of nature, from famine and death." Couple that with Darwin's notion that evolution is random and you have a world, as poetically described by Tennyson, that can be characterized as "red in tooth and claw," a series of meaningless, bloody battles for survival.

Evolution Without the Bloody Claws

Though Darwin is by far the most famous evolutionist, the first scientist to establish evolution as a scientific fact was the distinguished French biologist Jean-Baptiste Lamarck. (Lamarck 1809, 1914, 1963) Even Ernst Mayr, the leading architect of "neo-Darwinism," a modernization of Darwin's theory that incorporates twentieth-century molecular genetics, concedes that Lamarck was the pioneer. In his classic 1970 book, *Evolution and the Diversity of Life,* (Mayr 1976, page 227) Mayr wrote: "It seems to me Lamarck has a much better claim to be designated the 'founder of the theory of evolution,' as indeed he has by several French historians . . .

he was the first author to devote an entire book primarily to the presentation of a theory of organic evolution. He was the first to present the entire system of animals as a product of evolution."

Not only did Lamarck present his theory fifty years before Darwin, he offered a much less harsh theory of the mechanisms of evolution. Lamarck's theory suggested that evolution was based on an "instructive," cooperative interaction among organisms and their environment that enables life forms to survive and evolve in a dynamic world. His notion was that organisms acquire and pass on adaptations necessary for their survival in a changing environment. Interestingly, Lamarck's hypothesis about the mechanisms of evolution conform to modern cell biologists' understanding of how immune systems adapt to their environment as described above.

Lamarck's theory was an early target of the Church. The notion that humans evolved from lower life forms was denounced as heresy. Lamarck was also scorned by his fellow scientists who, as creationists, ridiculed his theories. A German developmental biologist, August Weismann, helped propel Lamarck into obscurity when he tried to test Lamarck's theory that organisms pass on survival-oriented traits acquired through their interaction with the environment. In one of Weismann's experiments, he cut off the tails of male and female mice and mated them. Weismann argued that if Lamarck's theory were correct, the parents should pass on their tailless state to future generations. The first generation of mice was born with tails. Weismann

repeated the experiment for twenty-one more generations, but not one tail-less mouse was born, leading Weismann to conclude that Lamarck's notion of inheritance was wrong.

But Weismann's experiment was not a true test of Lamarck's theory. Lamarck suggested that such evolutionary changes could take "immense periods of time," according to biographer L. J. Jordanova. In 1984, Jordanova wrote that Lamarck's theory "rested on" a number of "propositions" including "the laws governing living things have produced increasingly complex forms over immense periods of time." (Jordanova 1984, page 71) Weismann's five-year experiment was clearly not long enough to test the theory. An even more fundamental flaw in his experiment is that Lamarck never argued that every change an organism experienced would take hold. Lamarck said organisms hang on to traits (like tails) when they need them to survive. Although Weismann didn't think the mice needed their tails, no one asked the mice if they thought their tails were necessary for survival!

Despite its obvious flaws, the study of the tail-less mice helped destroy Lamarck's reputation. In fact, Lamarck has been mostly ignored or vilified. Cornell University evolutionist C. H. Waddington wrote in *The Evolution of an Evolutionist* (Waddington 1975, page 38): "Lamarck is the only major figure in the history of biology whose name has become to all intents and purposes, a term of abuse. Most scientists' contributions are fated to be outgrown, but very few authors have written works, which, two centuries later, are still rejected with indignation so intense that the skeptic may suspect something akin to an uneasy conscience. In point

of fact, Lamarck has, I think, been somewhat unfairly judged."

Waddington wrote those prescient words thirty-five years ago. Today Lamarck's theories are being re-evaluated under the weight of a body of new science that suggests that the oft-denounced biologist was not entirely wrong and the oft-lauded Darwin not entirely correct. The title of an article in the prestigious journal *Science* in 2000 was one sign of glasnost: "Was Lamarck Just a Little Bit Right?" (Balter 2000)

One reason some scientists are taking another look at Lamarck is that evolutionists are reminding us of the invaluable role cooperation plays in sustaining life in the biosphere. Scientists have long noted symbiotic relationships in nature. In *Darwin's Blind Spot* (Ryan 2002, page 16), British physician Frank Ryan chronicles a number of such relationships, including a yellow shrimp that gathers food while its partner gobi fish protects it from predators and a species of hermit crab that carries a pink anemone on top of its shell. "Fish and octopuses like to feed on hermit crabs, but when they approach this species, the anemone shoots out its brilliantly colored tentacles, with their microscopic batteries of poisoned darts, and stings the potential predator, encouraging it to look elsewhere for its meal." The warrior anemone gets something out of the relationship as well because it eats the crab's leftover food.

But today's understanding of cooperation in nature goes much deeper than the easily observable relationships. "Biologists are becoming increasingly aware that animals have coevolved and continue to coexist, with diverse

assemblages of microorganisms that are required for normal health and development," according to a recent article in *Science* called "We Get By with a Little Help from Our (Little) Friends." (Ruby, et al, 2004) The study of these relationships is now a rapidly growing field called "Systems Biology."

Ironically, in recent decades, we have been taught to wage war against microorganisms with everything from antibacterial soap to antibiotics. But that simplistic message ignores the fact that many bacteria are essential to our health. The classic example of how humans get help from microorganisms is the bacteria in our digestive system, which are essential to our survival. The bacteria in our stomach and intestinal tract help digest food and also enable the absorption of life-sustaining vitamins. This microbe-human cooperation is the reason that the rampant use of antibiotics is detrimental to our survival. Antibiotics are indiscriminate killers; they kill bacteria that are required for our survival as efficiently as they kill harmful bacteria.

Recent advances in genome science have revealed an additional mechanism of cooperation among species. Living organisms, it turns out, actually integrate their cellular communities by sharing their genes. It had been thought that genes are passed on only to the progeny of an individual organism through reproduction. Now scientists realize that genes are shared not only among the individual members of a species but also among members of different species. The sharing of genetic information via *gene transfer* speeds up evolution since organisms can acquire "learned" experiences from other organisms. (Nitz, et al, 2004; Pennisi 2004;

Boucher, et al, 2003; Dutta and Pan 2002; Gogarten 2003) Given this sharing of genes, organisms can no longer be seen as disconnected entities; there is no wall between species. Daniel Drell, manager of the Department of Energy's microbial genome program told *Science* (2001 294:1634) "we can no longer comfortably say what is a species anymore." (Pennisi 2001)

This sharing of information is not an accident. It is nature's method of enhancing the survival of the biosphere. As discussed earlier, genes are physical memories of an organism's learned experiences. The recently recognized exchange of genes among individuals disperses those memories, thereby influencing the survival of all organisms that make up the community of life. Now that we are aware of this inter- and intra-species gene transfer mechanism, the dangers of genetic engineering become apparent. For example, tinkering with the genes of a tomato may not stop at that tomato but could alter the entire biosphere in ways that we cannot foresee. Already there is a study that shows that when humans digest genetically modified foods, the artificially created genes transfer into and alter the character of the beneficial bacteria in the intestine. (Heritage 2004; Netherwood, et al, 2004) Similarly, gene transfer among genetically engineered agricultural crops and surrounding native species has given rise to highly resistant species deemed superweeds. (Milius 2003; Haygood, et al, 2003; Desplanque, et al, 2002; Spencer and Snow 2001) Genetic engineers have never taken the reality of gene transfer into consideration when they have introduced genetically

modified organisms into the environment. We are now beginning to experience the dire consequences of this oversight as their engineered genes are spreading among and altering other organisms in the environment. (Watrud, et al, 2004; Biello 2010)

Genetic evolutionists warn that if we fail to apply the lessons of our shared genetic destiny, which should be teaching us the importance of cooperation among all species, we threaten human existence. We need to move beyond Darwinian Theory, which stresses the importance of *individuals*, to one that stresses the importance of the *community.* British scientist Timothy Lenton provides evidence that evolution is more dependent on the interaction among species than it is on the interaction of individuals within a species. Evolution becomes a matter of the survival of the fittest *groups* rather than the survival of the fittest individuals. In a 1998 article in *Nature,* Lenton wrote that rather than focusing on individuals and their role in evolution "we must consider the totality of organisms and their material environment to fully understand which traits come to persist and dominate." (Lenton 1998)

Lenton subscribes to James Lovelock's Gaia hypothesis that holds that the Earth and all of its species constitute one interactive, living organism. Those who endorse this hypothesis argue that tampering with the balance of the superorganism called Gaia, whether it be by destroying the rainforest, depleting the ozone layer, or altering organisms through genetic engineering, can threaten its survival and consequently ours.

Recent studies funded by Britain's Natural Environment Research Council provide support for those concerns. (Thomas, et al, 2004; Stevens, et al, 2004) While there have been five mass extinctions in the history of our planet, they are all presumed to have been caused by extraterrestrial events, such as a comet smashing to Earth. One of the new studies concludes that the "natural world is experiencing the sixth, major extinction event in its history." (Lovell 2004) This time though, the cause of the extinction is not extraterrestrial. According to one of the study's authors, Jeremy Thomas, "As far as we can tell this one is caused by one animal organism—man."

Walking the Talk of Cells

In my years of teaching in medical school, I had come to realize that medical students in an academic setting are more competitive and backbiting than a truckload of lawyers. They live out the Darwinian struggle in their quest to be one of the "fittest" who stagger to graduation after four grueling years in medical school. The single-minded pursuit of stellar medical school grades, without regard for the students surrounding you, no doubt follows a Darwinian model, but it always seemed to me an ironic pursuit for those who are striving to become compassionate healers.

But my stereotypes about medical students toppled during my stay on the island. After my call to arms, my class of misfits stopped acting like conventional medical students;

they dropped their survival of the fittest mentality and amalgamated into a single force, a team that helped them survive the semester. The stronger students helped the weaker and, in so doing, all became stronger. Their harmony was both surprising and beautiful to observe.

In the end, there was a bonus: a happy Hollywood ending. For their final exam, I gave my students exactly the same test the students in Wisconsin had to pass. There was virtually no difference in the performance of these "rejects" and their "elite" counterparts in the States. Many students later reported that when they went home and met with their peers who attended American medical schools, they proudly found themselves more proficient in their understanding of the principles governing the life of cells and organisms.

I was of course thrilled that my students had pulled off an academic miracle. But it was years before I understood *how* they were able to do it. At the time, I thought the format of the course was key, and I still believe that overlapping human and cell biology is a better way to present the course material. But now that I've ventured into what I told you would be considered by some as wacky Dr. Dolittle territory, I think a good part of the reason for my students' success was that they eschewed the behavior of their counterparts in the United States. Instead of mirroring smart American medical students, they mirrored the behavior of smart cells, banding together to become even smarter. I didn't tell my students to pattern their lives after the lives of the cells, because I was still steeped in traditional, scientific training. But I like to think that they went in that direction intuitively after

listening to my praise of cells' ability to group together cooperatively to form more complex and highly successful organisms.

I didn't know it at the time, but I now believe that another reason for my students' success was that I did not stop at praising cells. I praised the students as well. They needed to hear they were first-rate students in order to believe that they could perform as first-rate students. As I will detail in future chapters, so many of us are leading limited lives not because we have to but because we *think* we have to. But I'm getting ahead of myself. Suffice it to say that after four months in paradise, teaching in a way that clarified my thinking about cells and the lessons they provide to humans, I was well on my way to an understanding of the New Biology, which leaves in the dust the defeatism of genetic and parental programming as well as survival-of-the-fittest Darwinism.

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When I first wrote this chapter, I had to search hard for the first glimmerings that the much-maligned Jean-Baptiste Lamarck would finally be credited for his insights about evolution. Nevertheless, proverbial optimist that I am, as you read above, I included a reference to an article with the tentative headline, "Was Lamarck Just a Little Bit Right?" I'm happy to report that my optimism was warranted. A decade later, it's a lot easier to find Lamarck supporters who believe that he was more than "just a little bit" right, that, in fact, he was a seer! Nearly 200 years after his death, epigenetic research, one of the hottest fields in science today, is

corroborating over and over Lamarck's oft-ridiculed belief that organisms adapt to their environment and can pass on those adaptations to future generations. Consider this definitive (no question mark!) headline I quickly came across during my research for this anniversary edition: "The Rebirth of Lamarckism (The Rise of Epigenetics)." (Rogers 2009)

Of course, Lamarck did not have any insight into the molecular nature of genes and their relationship to organismal expression (neither did Darwin), so I can't argue that he was actually an epigeneticist. It has taken the high-tech labs of modern researchers to uncover the subtle chemical modifications to DNA and DNA-associated proteins that enable organisms to adapt to their environment and pass on those adaptations to their offspring without changing the structure of DNA molecules. Lamarck's theory of the inheritance of acquired characteristics, cited as the primary reason to debunk Lamarck, has now been found to be a valid hereditary mechanism. (Morris 2012) Frontier research is not only helping rehabilitate Lamarck's reputation, it is also undermining our culture's belief in genetic determinism, which, as you know by now, is one of the major themes of *The Biology of Belief*—the genes we inherit from our mothers and our fathers are not our fate!

I don't want to oversell the scientific community's shift to Lamarckism. When it comes to the mechanisms that drive evolution, there is still a lot of debate. For example, when the theory of "adaptive mutation," which holds that mutations occur in response to specific stresses, was first brought to academic attention in the 1980s by eminent physician and

molecular biologist Dr. John Cairns, he was called a heretic, and this theory is still controversial today. (Cairns, et al, 1988) Adaptive mutation conflicts with neo-Darwinism's focus on chance alterations in heredity based on *natural selection*, a process that was described by Darwin as the "struggle for life most severe" and that came to be known as "survival of the fittest." (Though it's a catchy phrase, survival of the fittest is actually a tautology, an obvious truth that is not an apt way of describing the driving forces of evolution. By definition, *fittest* means "most capable of survival," so the phrase can be rewritten as "survival of the most capable of surviving." No argument there!)

Neo-Darwinism attributes mutations to accidental copying mistakes in replicating the genes; if the genetic error enhances the organism's survivability, the mutation is selected to propagate. This suggests that the direction of evolutionary advancement is accidental and unpredictable . . . how's that for a tautology! In response to the perennial questions "How did we get here?" and "Why are we here?" neoDarwinian theory would lead us to believe we evolved through a few billion years of "lucky" genetic accidents. In contrast, Lamarckian theory implies that evolution-producing mutations arise from an organism's "need" to adapt to life-threatening environmental stresses, so they are not random and to a large degree are environmentally predictable.

This seemingly arcane scientific debate is important because adaptive mutations imply purposefulness in biological evolution—the purpose being to conform to

prevailing conditions in the surrounding environment, which includes the entire community of life. Eventually, I believe the theory of adaptive mutations will prevail and provide more support for the view that the web of life and the process of evolution are the result of a highly organized, symbiotic *collaboration* among all living organisms.

The fascinating research of biologist and mathematician Martin A. Nowak, Director of Harvard's Program for Evolutionary Dynamics, already provides support for the crucial role of cooperation in evolution. Using mathematical and computer simulations, Nowak divided populations into "cooperators," those who support others, and "defectors," those who do not support others even after accepting help from others. Nowak found that in the several thousand papers scientists have published on how cooperators, ranging from bacteria to human beings, prevail in evolution, all the scenarios fall into five categories. (Nowak 2012)

One category, for example, is "spatial selection," in which cooperators and defectors are not uniformly distributed in a population. In these populations with "patches of cooperators," helpful individuals band together and prevail against defectors. Another category is what Nowak calls the "I'll scratch your back, and someone will scratch mine," in which an individual decides to be a cooperator because of the person in need's reputation. He uses the example of Japanese macaques: low-ranking monkeys that groom high-ranking ones may improve their reputations (and receive more grooming) by being seen with the high-ranking monkeys Nowak calls "the top brass."

Nowak found that cooperation-defection works on several levels—an individual can simultaneously be a cooperator and a defector. The example Nowak uses is a group of employees at a company who compete ruthlessly against one another for promotions but also cooperate with one another to ensure that their company beats the performance of other companies. That insight about the complex nature of cooperation-defection is in alignment with the principles of systems biology—another field that has boomed in the last decade—which recognizes that biological insights emerge best from studying the dynamics of interacting systems rather than focusing on only one system. One case in point: medical science once attempted to understand heart disease by focusing on the function and structure of the heart. However, fundamental breakthroughs in cardiac disease were only recognized when the heart's function was studied in relation to the influence of other systems, such as the nervous, neuroendocrine, immune, and digestive systems.

Nowak's models also confirm what everyone who is agonizing over the current dismal state of our planet has noted—that cooperation is "intrinsically unstable": there are cycles when defection prevails. However, he also offers the good news that "the altruistic spirit always seems to rebuild itself." Nowak's sums up what he has discovered through his simulations, with the conclusion that "life is not just a struggle for survival but also a snuggle for survival."

Now more than ever, we need more research on the cooperative snuggle for survival lest we fall into a defection cycle during which we destroy ourselves and our planet. I

believe we have been brought to the brink by our misunderstanding of evolution as simply a continuous struggle and quest for individual fitness (as measured by the number of one's "toys"). Human civilization has bought into the warning couched in the subtitle of Darwin's *Origin of Species* book: *The Preservation of Favoured Races in the Struggle for Life*—in other words, that life is an all-out struggle wherein the riches go to the fittest, regardless of the means by which they are attained.

According to this "scientific" principle, the less fit genetically deserve only what's left over . . . if anything. That mentality has brought us continuous wars over material possessions, overconsumption that has led to unsustainable resource exploitation, and increasingly unequal wealth distribution as well as an obviously ailing planet. The Darwinian focus on the fitness of the individual de-emphasizes the significance of communal cooperation in evolution.

One of the most striking areas where we have ignored the importance of cooperation among organisms is in our own bodies. In the decade since I decried our "war against microorganisms with everything from antibacterial soap to antibiotics," a wealth of damaging evidence has emerged about the toll this war is taking on our bodies.

The fact is that hundreds of trillions of microbial "invaders," mostly in our gut, are absolutely necessary for our survival, and there are ten times more of them than cells in the human body. Because the body cannot survive without its microbes (collectively called the "microbiome"), they are

the functional equivalent of any of our other vital organ systems. In (belated) recognition of the importance of the microbiome, humans and most other organisms are now properly defined as superorganisms (complex organisms composed of many smaller organisms). (Saey 2013A) Again in belated recognition of the microbiome's importance, in 2007, the National Institutes of Health created the Human Microbiome Project to study it. Those scientists reported that humans and other animals form a life-sustaining bond with their gut microbes. Researchers have found that human genes influence the genetics of the microbiome, and the microbiome's genes (that make up 99 percent of the unique genes in our body!) regulate genes in our cells. (Saey 2013B)

In his alarming new book, *Missing Microbes: How the Overuse of Antibiotics Is Fueling Our Modern Plagues*, Dr. Martin J. Blaser, Director of the Human Microbiome Program at New York University, warns not only about antibiotic resistance but also about the declining diversity of the human microbiome that is increasing our susceptibility to chronic conditions from allergies and asthma to diabetes and obesity. For example, type 1 diabetes has been doubling in incidence about every twenty years in the industrialized world; in Finland, the incidence has risen 550 percent since 1950. Blaser writes that these modern epidemics are "not only diseases but also external signs of internal change." Recent studies have found that "otherwise normal individuals have lost 15 to 40 percent of their microbial diversity and the genes that accompany it" mostly due to the overprescription of broad-spectrum antibiotics that kill microbes

indiscriminately. Yet Blaser, who has studied the microbes that populate our bodies for thirty years, calls them and their 20 million genes the "guerrilla warriors" that help us fight disease. (Blaser 2014)

While Blaser is warning about the declining diversity of our microbiome, other scientists are pointing with alarm to the declining diversity of our planet, where animal populations and species are decreasing at an alarming rate. Stanford scientists have tracked species abundance and population numbers over a period of time and found that extinction rates are up to a thousand times higher than they would be if people weren't in the environment generating pollution, deforesting, monocropping, and overharvesting. (Dirzo, et al, 2014) Many environmental scientists believe we have crossed the threshold for a major environmental collapse and are in the throes of the sixth mass extinction event to hit this planet.

Environmentalists have long known that the structure of localized ecological systems can shift abruptly and irreversibly from one state to another when stressed to critical thresholds. Evidence now indicates that the entire global ecosystem can react in the same abrupt way and is, in fact, currently in danger of doing so. Anthony Barnosky, a professor at the University of California, Berkeley's Department of Integrative Biology, and others argue that we are at a planetary "tipping point" because human activities are inducing Mother Earth to express a critical global transition. (Barnosky, et al, 2012) A recent study by NASA confirms that global industrial civilization is heading toward

collapse in coming decades (i.e., soon!). (Ahmed 2014)

Civilization did not create global climate change (the planet has already been through five ice ages), but our behavior and technology are generating environmental stressors that exacerbate the impact of the climate change crisis. The process of societal rise-and-collapse has been a cyclical phenomenon throughout history, and in some cases, those collapse periods have lasted for centuries. While previous collapses primarily impacted localized human social systems, the coming collapse has already had a profound global impact on the health of the planet.

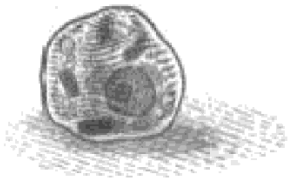
We now live in an era known as the Anthropocene, which emphasizes that human activities are causing massive changes to our natural world at an unprecedented rate. Not one location on our planet, from the southern tip of Antarctica to the heights of Mt. Everest, has remained untouched by human influence. For example, fossil fuel burning has left an imprint on our immediate environment while the thin veil of the Earth's atmosphere carries it to all portions of the globe. This reminds us of the following: (1) that we are all connected; (2) that we all leave an imprint; and (3) that the Earth that sustains us is finite. Today's global crises are warnings that we must stop exploiting the abundance and vitality of our living home and begin to reconnect and honor the planet as many traditional societies have done for eons.

Well, that's a cheery picture! However, as a flagrant optimist, I prefer to consider the positive side of Nature's resiliency. In 1883, a series of eruptions on Krakatoa in

Indonesia led to new volcanic islands arising out of the sea. Lava flows on one of the islands in 1960 eliminated all life forms and left the island in a condition scientists actually refer to as a state of "sterilization." Surveys and studies monitoring the rise of flora and fauna on the islands for over five decades documented the abundance of an incredibly diverse ecology that has been thriving on these "sterile" islands since that time. In the aftermath of its catastrophic disturbance, the island's vital and thriving ecological paradise has since become more robust, expressing a diverse plasticity that enhances its ability to resist environmental stress. (Whittaker, et al, 1989) This lesson from Nature emphasizes the old adage, "What doesn't kill you will make you stronger."

I also take heart from the fact that organismal cooperation is not a nagging exception to the rule of evolution but instead one of its primary architects and that humans are (though it's hard to believe sometimes!), in Nowak's words, "supercooperators." Collectively, the cooperative accomplishments of human civilization have taken us to the Moon and beyond, and I hope our collective accomplishments will also take us to a restored planet, a restored microbiome, and beyond. After all, I have personally seen the dramatically positive changes that can occur when the cooperative behavior among my Caribbean medical students helped them evolve to become better humans, and more importantly, compassionate healers.

CHAPTER 2



IT'S THE ENVIRONMENT, STUPID

I will never forget a piece of wisdom I received in 1967, on the first day I learned to clone stem cells in graduate school. It took me decades to realize how profound this seemingly simple piece of wisdom was for my work and my life. My professor, mentor, and consummate scientist Irv Konigsberg was one of the first cell biologists to master the art of cloning stem cells. He told me that when the cultured cells you are studying are ailing, you look first to the cell's environment, not to the cell itself, for the cause.

My professor wasn't as blunt as Bill Clinton's campaign manager, James Carville, who decreed, "It's the economy, stupid," to be the mantra for the 1992 presidential election. But cell biologists would have done well to post, "It's the environment, stupid," over our desks, just as the "It's the economy, stupid" sign was posted at Clinton headquarters. Though it wasn't apparent at the time, I eventually realized that this advice was a key insight into understanding the nature of life. Over and over I learned the wisdom of Irv's advice. When I provided a healthy environment for my cells,

they thrived; when the environment was less than optimal, the cells faltered. When I adjusted the environment, these "sick" cells revitalized.

But most cell biologists knew nothing of this wisdom of tissue culture techniques. And scientists moved sharply away from considering environmental influences after Watson and Crick's revelation of DNA's genetic code. Even Charles Darwin conceded, near the end of his life, that his evolutionary theory had shortchanged the role of the environment. In an 1876 letter to Moritz Wagner he wrote: "In my opinion, the greatest error which I have committed has been not allowing sufficient weight to the direct action of the environments, i.e., food, climate, etc., independently of natural selection . . . When I wrote the *Origin,* and for some years afterwards, I could find little good evidence of the direct action of the environment; now there is a large body of evidence." (Darwin, F 1888)

Unfortunately, Darwin's followers perceived that his return to Lamarckian "thinking" was a sign of Darwin's aging and now addled mind. Rather than following their master's revised vision, Darwinian evolutionists chose to remain more Darwinian than Darwin! The problem with the Darwinian underemphasis on the environment is that it led to an overemphasis on "nature" in the form of genetic determinism —the belief that genes "control" biology. This belief has not only led to a misallocation of research dollars, as I will argue in a later chapter, but, more importantly, it has changed the way we think about our lives. When you are convinced that genes control your life and you know that you had no say in

which genes you were saddled with at conception, you have a good excuse to consider yourself a victim of heredity. "Don't blame me for my work habits—it's not my fault that I've been procrastinating on my deadline . . . It's genetic!"

Since the dawning of the Age of Genetics, we have been programmed to accept that we are subservient to the power of our genes. The world is filled with people who live in constant fear that, on some unsuspecting day, their genes are going to turn on them. Consider the masses of people who think they are ticking time bombs; they wait for cancer to explode in their lives as it exploded in the life of their mother or brother or sister or aunt or uncle. Millions of others attribute their failing health not to a combination of mental, physical, emotional, and spiritual causes but simply to the inadequacies of their body's biochemical mechanics. Are your kids unruly? Increasingly the first choice is to medicate these children to correct their "chemical imbalances" rather than fully grappling with what is going on in their bodies, minds, and spirits.

Of course there is no doubt that some diseases, like Huntington's chorea, beta thalassemia, and cystic fibrosis, can be blamed entirely on one faulty gene. But single-gene disorders affect less than 2 percent of the population; the vast majority of people come into this world with genes that should enable them to live a happy and healthy life. The diseases that are today's scourges—diabetes, heart disease, and cancer—short circuit a happy and healthy life. These diseases, however, are not the result of a single gene, but of complex interactions among multiple genes and

environmental factors.

What about all those headlines trumpeting the discovery of a gene for everything from depression to schizophrenia? Read those articles closely and you'll see that behind the breathless headline is a more sober truth. Scientists have linked lots of genes to lots of different diseases and traits, but scientists have rarely found that *one* gene causes a trait or a disease. In the realm of human diseases, defective genes acting alone only account for about 2 percent of our total disease load. (Strohman 2003)

The confusion occurs when the media repeatedly distort the meaning of two words: correlation and causation. It's one thing to be linked to a disease; it's quite another to cause a disease, which implies a directing, controlling action. If I show you my keys and say that a particular key "controls" my car, you at first might think that makes sense because you know you need that key to turn on the ignition. But does the key actually "control" the car? If it did, you couldn't leave the key in the car alone because it might just borrow your car for a joy ride when you are not paying attention. In truth, the key is "correlated" with the control of the car; the person who turns the key actually controls the car. Specific genes are correlated with an organism's behavior and characteristics. But these genes are not activated until something triggers them.

What activates genes? The answer was elegantly spelled out in 1990 in a paper entitled *Metaphors and the Role of Genes and Development* by H. F. Nijhout. (Nijhout 1990) Nijhout presents evidence that the notion that genes control biology

has been so frequently repeated for such a long period of time that scientists have forgotten it is a hypothesis, not a truth. In reality, the idea that genes control biology is a supposition, which has never been proven and, in fact, has been undermined by the latest scientific research. Genetic control, argues Nijhout, has become a metaphor in our society. We want to believe that genetic engineers are the new medical magicians who can cure diseases and while they're at it create more Einsteins and Mozarts as well. But metaphor does not equate with scientific truth. Nijhout summarizes the truth: "When a gene product is needed, a signal from its environment, not an emergent property of the gene itself, activates expression of that gene." In other words, when it comes to genetic control, "It's the environment, stupid."

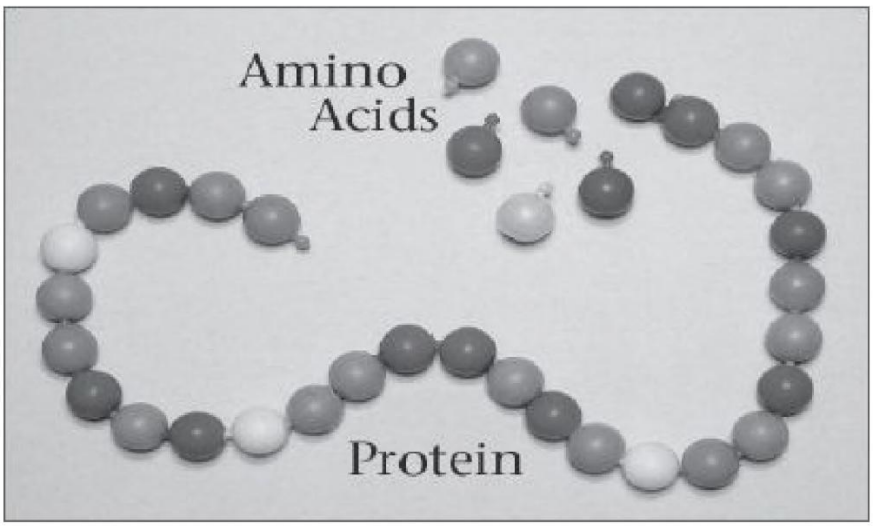
Protein: The Stuff of Life

It is easy to understand how genetic control became a metaphor as scientists with ever-greater excitement zeroed in on the mechanisms of DNA. Organic chemists discovered that cells are made up of four types of very large molecules: polysaccharides (complex sugars), lipids (fats), nucleic acids (DNA/RNA), and proteins. Though the cell requires each of the four molecular types, proteins are the most important single component for living organisms. Our cells are, in the main, an assembly of protein building blocks. So one way of looking at our trillion-celled bodies is that they are protein machines, although, as you know, I think we are more than

machines! It sounds simple, but it isn't. For one thing, it takes over 100,000 different types of proteins to run our bodies.

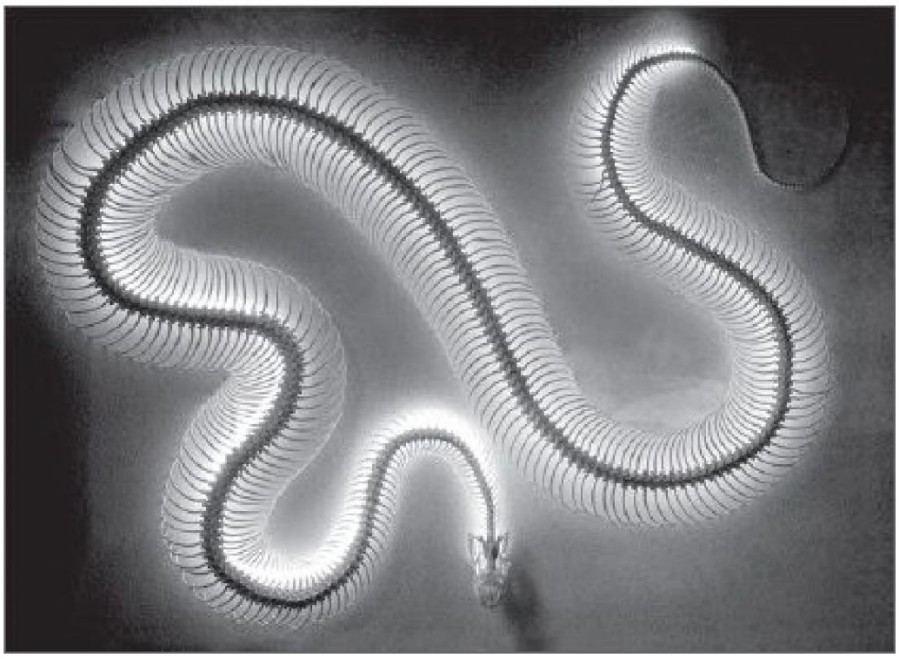
Let's take a closer look at how our cells' ~100,000 proteins are assembled. Each protein is a linear string of linked amino acid molecules, comparable to a child's pop bead necklace, as illustrated at the top of the following page.

Each bead represents one of the twenty amino acid molecules used by cells. Though I like the pop bead analogy because everyone is familiar with it, it is not an exact one because each amino acid has a slightly different shape. So to be completely accurate, you should think of a pop bead necklace that got mangled a bit in the factory.

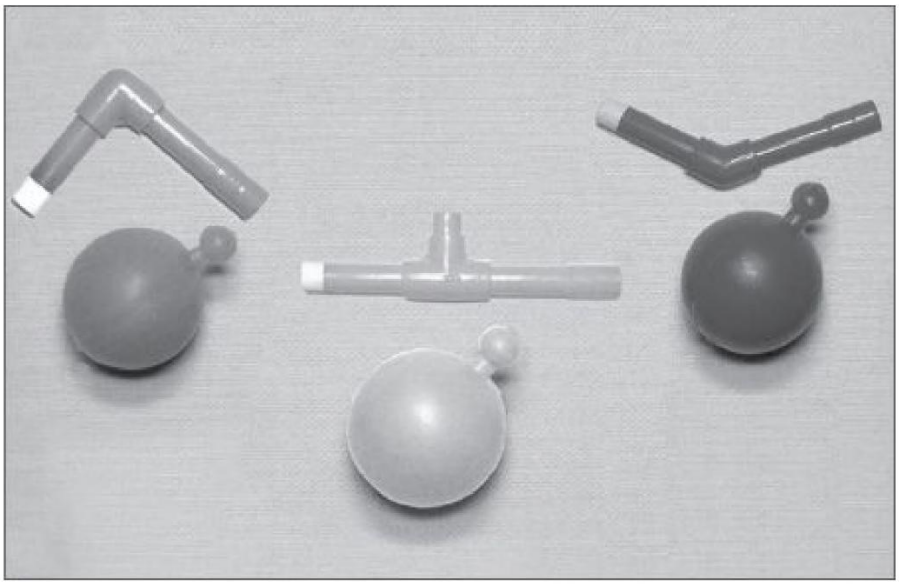


And to be even more accurate, you should know that the amino acid necklace, which forms the "backbone" of the cells' proteins, is far more malleable than a pop bead necklace, which falls apart when you bend it too much. The structure and behavior of the linked amino acids in the protein

backbones better resemble that of a snake's backbone, as shown below. (©Warren Jacobi/Corbis) The spine of a snake, made up of a large number of linked subunits, the vertebrae, is capable of coiling the snake into a wide variety of shapes, ranging from a straight rod to a knotted "ball."

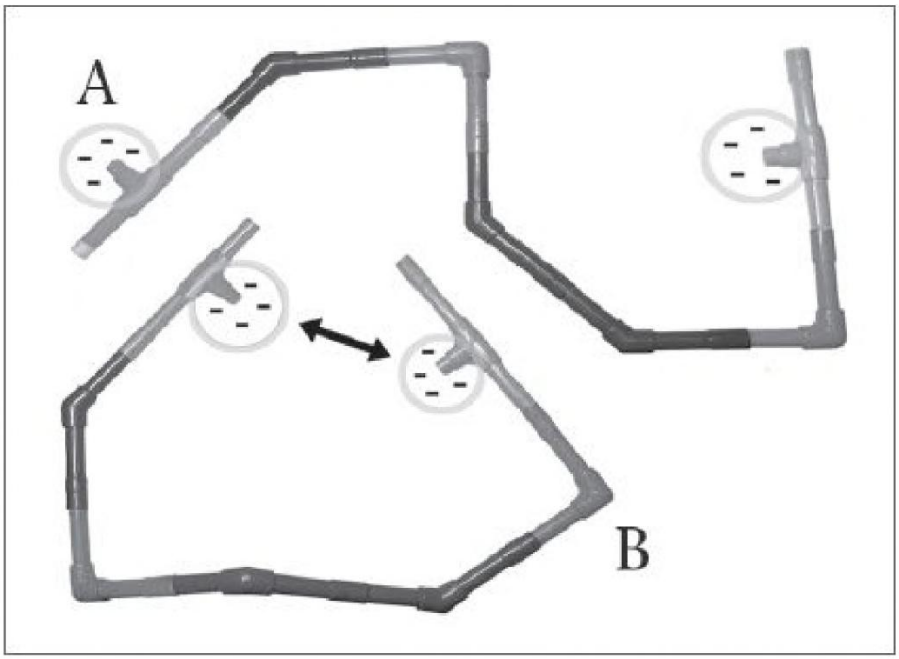


The flexible links *(peptide bonds)* between amino acids in a protein backbone enable each protein to adopt a variety of shapes. Through the rotation and flexion of their amino acid "vertebrae," protein molecules resemble nano-snakes in their ability to writhe and squirm. There are two primary factors that determine the contour of a protein's backbone and therefore its shape. One factor is the physical pattern defined by the sequence of differently shaped amino acids comprising the pop-bead-like backbone.



Unlike uniform-shaped pop beads, each of the twenty amino acids comprising protein backbones has a unique shape (conformation). Consider the differences between the character of a "backbone" made from identically shaped pop beads and one assembled from the differently shaped pipe fittings illustrated above.

The second factor concerns the interaction of electromagnetic charges among the linked amino acids. Most amino acids have positive or negative charges, which act like magnets: *like* charges cause the molecules to repel one another, while *opposite* charges cause the molecules to attract each other. As shown on the following page, a protein's flexible backbone spontaneously folds into a preferred shape when its amino acid subunits rotate and flex their bonds to balance the forces generated by their positive and negative charges.



The protein backbones shown in A and B have the exact same amino acid (pipe fitting) sequence but reveal radically different conformations. Variations in the backbone's shape result from differential rotations at the junctions between adjacent pipe fittings. Like the pipe fittings illustrated above, the protein's differently shaped amino acids also rotate around their junctions (peptide bonds), allowing the backbone to wriggle like a snake. Proteins shape-shift though they will generally prefer two or three specific conformations. Which of the two conformations, A or B, would our hypothetical protein prefer? The answer is related to the fact that the two terminal amino acids (pipe fittings) have regions of negative charges. Since like charges repel each other, the farther apart they are, the more stable the conformation. Conformation A would be preferred because the negative charges are farther apart than they are in B.

The backbones of some protein molecules are so long that they require the assistance of special "helper" proteins called

chaperones to aid in the folding process. Improperly folded proteins, like people with spinal defects, are unable to function optimally. Such aberrant proteins are marked for destruction by the cell; their backbone amino acids are disassembled and recycled in the synthesis of new proteins.

How Proteins Create Life

Living organisms are distinguished from nonliving entities by the fact that they move; they are *animated*. Cells harness the energy of protein movements to do the "work" that characterizes living systems, such as respiration, digestion, and muscle contraction. To understand the nature of life, one must first understand how protein "machines" are empowered to move.

The final shape, or *conformation* (the technical term used by biologists), of a protein molecule reflects a balanced state among the electromagnetic charges of the amino acids comprising the backbone. However, if the protein's positive and negative charges are altered, the protein backbone will dynamically twist and adjust itself to accommodate the new charges. The distribution of electromagnetic charges within a protein can be selectively altered by a number of processes including the binding of other molecules or chemical groups such as hormones, the enzymatic removal or addition of charged atoms (ions) in the backbone's amino acids, or interference from electromagnetic fields such as those emanating from cell phones. (Tsong 1989)

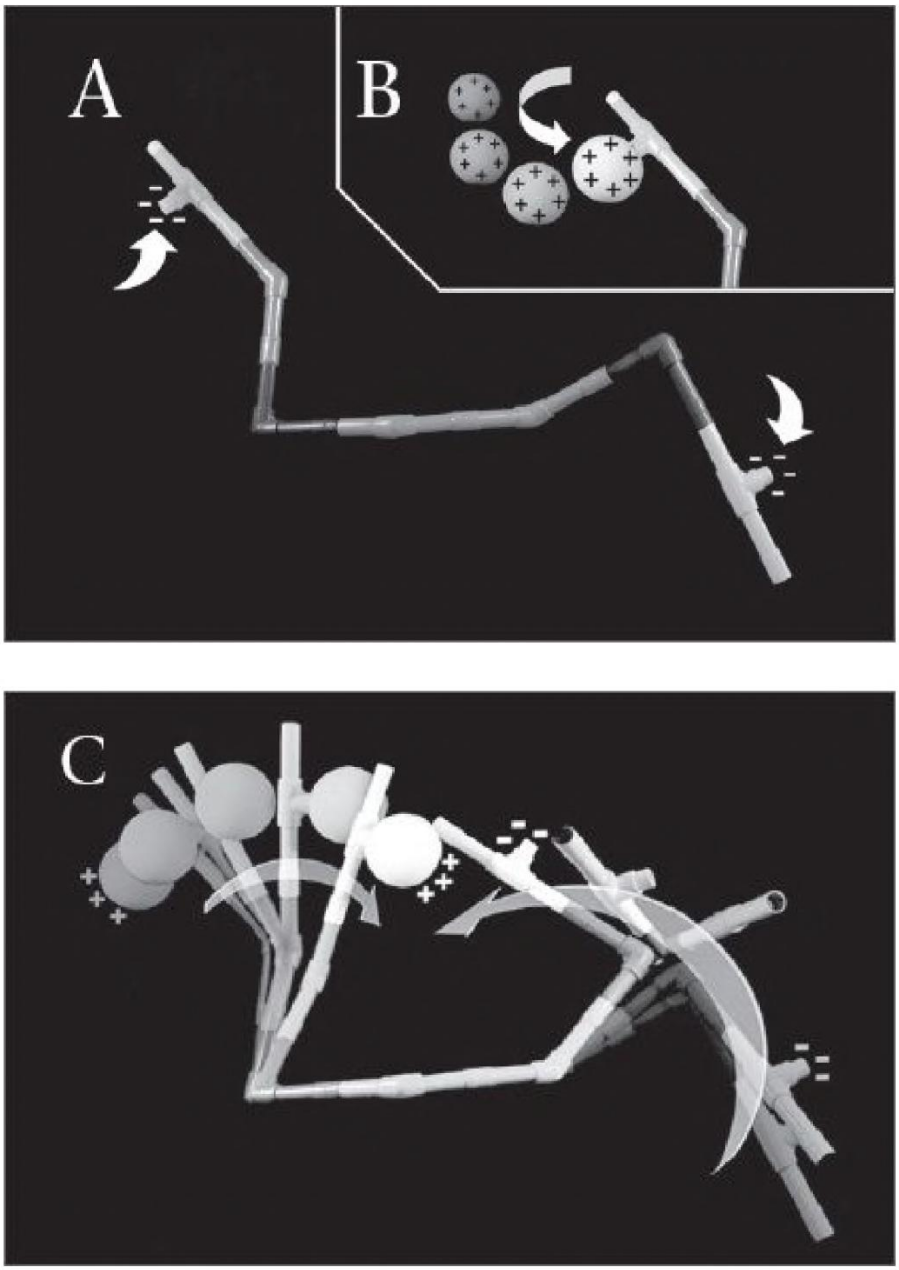
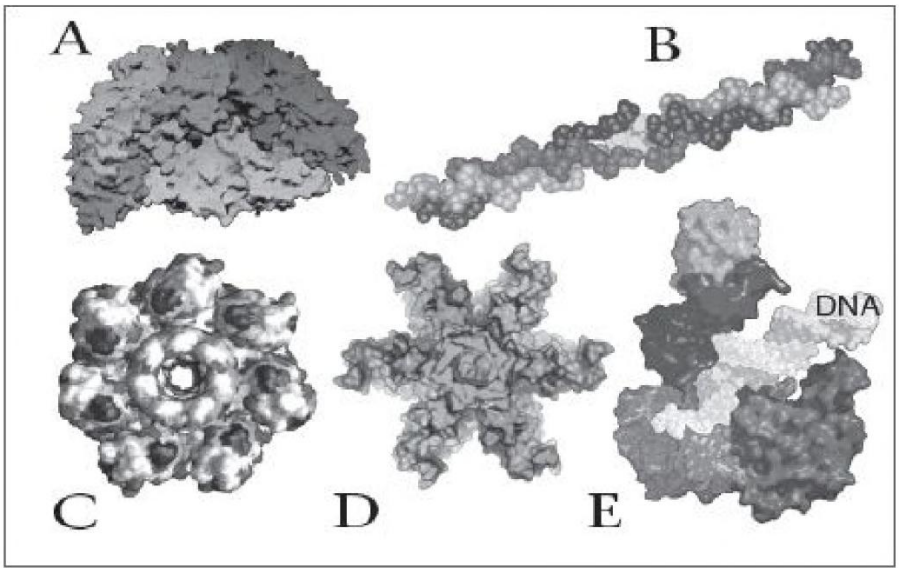


Figure A shows the preferred conformation of our hypothetical protein backbone. The repelling forces between the two negatively charged terminal

amino acids (arrows) causes the backbone to extend so that the negative amino acids are as far apart as possible. Figure B shows a close-up of an end amino acid. A signal, in this case a molecule with a very positive electric charge (white sphere), is attracted to and binds with the negative site on the protein's terminal amino acid. In our particular scenario, the signal is more positive in charge than the amino acid is negative in charge. After the signal couples with the protein, there is now an excess positive charge at this end of the backbone. Since positive and negative charges attract one another, the backbone's amino acids will rotate around their bonds so that positive and negative terminals will come closer together. Figure C shows the protein changing from conformation A to conformation B. Changing conformations generates movement and the movement is harnessed to do work, providing for such functions as digestion, respiration, and muscle contraction. When the signal molecule detaches, the protein returns to its preferred extended conformation. This is how signal-generated protein movements provide for life.

The shape-shifting proteins exemplify an even more impressive engineering feat because their precise, three-dimensional shapes also give them the ability to link up with other proteins. When a protein encounters a molecule that is a physical and energetic complement, the two bind together like human-made products with interlocking gears, say an eggbeater or an old-fashioned watch.

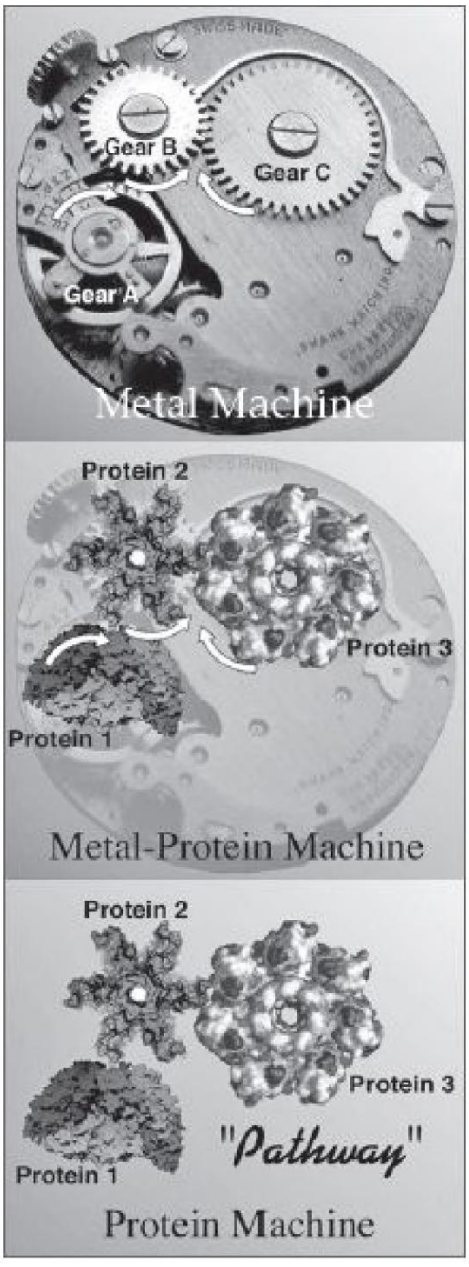
Examine the following two illustrations. The first shows five uniquely shaped proteins, examples of the molecular "gears" found in cells. These organic "gears" have softer edges than machine-shop-manufactured gears, but you can see that their precise, three-dimensional shapes would enable them to securely engage with other complementary proteins.



Protein Menagerie. Illustrated above are five different examples of protein molecules. Each protein possesses a precise three-dimensional conformation that is the same for each copy of itself in every cell. A) Enzyme that digests hydrogen atoms; B) Woven filament of collagen protein; C) Channel, a membrane-bound protein with hollow central pore; D) Protein subunit of "capsule" that encloses a virus; E) DNA-synthesizing enzyme with attached helical DNA molecule

In the second illustration (p. 35), I chose a wind-up watch to represent the workings of the cell. The first picture shows a metal machine, revealing the gears, springs, jewels, and case of the watch model. When Gear A turns it causes Gear B to turn. When B moves it causes Gear C to turn, etc. In the next image, I overlay the human-made machine gears with softer-edged organic proteins (magnified millions of times in proportion to the watch) so that it becomes visually conceivable that proteins could be like the watch's

mechanism. In this metal-protein "machine," one can imagine Protein A rotating and causing Protein B to revolve, which in turn causes Protein C to move. Once you see that possibility, you can look to the third figure in which the human-made parts are removed. Voilà! We are left with a protein "machine," one of the thousands of similar protein assemblies that collectively comprise the cell!



Cytoplasmic proteins that cooperate in creating specific physiologic functions are grouped into specific assemblies

known as *pathways.* These assemblies are identified by the functions they perform, such as respiration pathways, digestion pathways, muscle contraction pathways, and the infamous, energy-generating Krebs cycle, the bane of many a science student who has to memorize every one of its protein components and complex chemical reactions.

Can you imagine how excited cell biologists were when they figured out how the protein machines work? Cells exploit the movements of these protein assembly machines to empower specific metabolic and behavioral functions. The constant, shape-shifting movements of proteins—which can occur thousands of times in a single second—are the movements that propel life.

The Primacy of DNA

You'll notice that, in the above section, I didn't discuss DNA at all. That's because it is the changing of the proteins' electromagnetic charges that is responsible for their behavior-generating movement, not DNA. How did we get to the widespread and often-cited notion that genes "control" biology? In the *Origin of Species,* Darwin suggested that "hereditary" factors were passed on from generation to generation, controlling the traits of the offspring. Darwin's influence was so great that scientists myopically focused on identifying that hereditary material, which, they thought, controlled life.

In 1910, intensive microscopic analyses revealed that the

hereditary information passed on generation after generation was contained in chromosomes, thread-like structures that become visible in the cell just before it divides into two "daughter" cells. Chromosomes are incorporated into the daughter cell's largest organelle, the nucleus. When scientists isolated the nucleus, they dissected the chromosomes and found that the hereditary elements were essentially comprised of only two kinds of molecules, protein and DNA. Somehow the protein machinery of life was entangled in the structure and function of these chromosome molecules.

The understanding of the chromosome's functions was further refined in 1944 when scientists determined that it was DNA that actually contained hereditary information. (Avery, et al, 1944; Lederberg 1994) The experiments that singled out DNA were elegant. These scientists isolated pure DNA from one species of bacteria—let's call it Species A—and added the pure DNA to cultures containing only Species B bacteria. Within a short time, Species B bacteria began to show hereditary traits that were formerly seen only in Species A. Once it was known that you needed nothing other than DNA to pass on traits, the DNA molecule became a scientific superstar.

It was now left to Watson and Crick to unravel the structure and function of that superstar molecule. DNA molecules are long and thread-like. They are made from four nitrogen-containing chemicals called bases (adenine, thymine, cytosine, and guanine, abbreviated as A, T, C, and G). Watson and Crick's discovery of DNA's structure led to the fact that the sequence of the A, T, C, and G bases in DNA spells

out the sequence of amino acids along a protein's backbone (Watson and Crick 1953). Those long strings of DNA molecules can be subdivided into single genes, segments that provide the blueprint for specific protein backbones. The code for recreating the protein machinery of the cell had been cracked!

Watson and Crick also explained why DNA is the perfect hereditary molecule. Each DNA strand is normally intertwined with a second strand of DNA, a loosely wrapped configuration known as the "double helix." The genius of this system is that the sequences of DNA bases on both strands are mirror images of each other. When the two strands of DNA unwind, each single strand contains the information to make an exact, complementary copy of itself. So through a process of separating the strands of a double helix, DNA molecules become self-replicating. This observation led to the assumption that DNA "controlled" its own replication . . . it was its own "boss."

The "suggestion" that DNA controlled its own replication *and* served as the blueprint for the body's proteins led Francis Crick to create biology's Central Dogma, the belief that DNA rules. The dogma was so fundamental to modern biology it was essentially written in stone, the equivalent of science's Ten Commandments. The dogma, also referred to as "the Primacy of DNA," is a fixture of almost every scientific text.

In the dogma's scheme of how life unfolds, DNA perches loftily on top, followed by RNA. RNA is the short-lived Xerox copy of the DNA. As such, it is the physical template encoding the amino acid sequence that makes up a protein's backbone.

The Primacy of DNA diagram provides the logic for the Age of Genetic Determinism. Because the character of a living organism is defined by the nature of its proteins and its proteins are encoded in the DNA, then by logic, DNA would represent the "first cause," or primary determinant of an organism's traits.

The Central Dogma's assumption of a one-way flow of information from DNA to RNA to protein is profoundly important. Since proteins represent the physical body, the dogma implies that your physical body, and your life experiences cannot send information back and alter the DNA. According to the Dogma, DNA controls your life and you cannot influence your DNA!

The Human Genome Project

After DNA achieved superstar status, the remaining challenge was to create a catalog of all the genetic stars in the human firmament. Enter the Human Genome Project, a global scientific effort begun in the late 1980s to create a catalog of all the genes present in humans.

From the outset, the Human Genome Project was a massively ambitious one. Conventional thought held that the body needed one gene to provide the blueprint for each of the 100,000-plus different proteins that make up our bodies. Add to that at least 20,000 regulatory genes, which orchestrate the activity of the protein-encoding genes. Scientists concluded that the human genome would contain a minimum of 120,000

genes located within the twenty-three pairs of human chromosomes.

But that wasn't the whole story. A cosmic joke was unfolding, one of those jokes that periodically unsettle scientists convinced they have discovered the secrets of the universe. Consider the impact of Nicolaus Copernicus' discovery published in 1543 that the Earth was not the center of the universe, as was thought by the scientist-theologians of the day. The fact that the Earth actually revolved around the sun and that the sun itself was not the center of the universe undermined the teachings of the Church. Copernicus' paradigm-busting discoveries launched the modern, scientific revolution by challenging the presumed "infallibility" of the Church. Science eventually displaced the Church as Western civilization's source of wisdom for understanding the mysteries of the universe.

Geneticists experienced a comparable shock when, contrary to their expectations of over 120,000 genes, they found that the entire human genome consists of fewer than 25,000 genes. (Pennisi 2003a and 2003b; Pearson 2003; Goodman 2003) Over 80 percent of the presumed and *required* DNA does not exist! The missing genes proved to be more troublesome than the missing eighteen minutes of the Nixon tapes. The one-gene, one-protein concept was a fundamental tenet of genetic determinism. Now that the Human Genome Project has toppled the one-gene for one-protein concept, our current theories of how life works have to be scrapped. No longer is it possible to believe that genetic engineers can, with relative ease, fix all our biological dilemmas. There are

simply not enough genes to account for the complexity of human life or of human disease.

The Central Dogma. The dogma, also referred to as the Primacy of DNA, defines the flow of information in biological organisms. As indicated by the arrows, the flow is only in one direction, from DNA to RNA and then to protein. The DNA represents the cell's long-term memory, passed from generation to generation. RNA, an unstable copy of the DNA molecule, is the active memory that is used by the cell as a physical template in synthesizing proteins. Proteins are the molecular building blocks that provide for the cell's structure and behavior. DNA is implicated as the "source" that controls the character of the cell's proteins, hence the concept of DNA's primacy that literally means "first cause."

I may sound like Chicken Little shouting that the genetics sky is falling. However, you don't have to take my word for it. Chicken Big said the same thing. In a commentary on the

surprising results of the Human Genome Project, David Baltimore, one of the world's preeminent geneticists and a Nobel Prize winner, addressed the issue of human complexity (Baltimore 2001): "But unless the human genome contains a lot of genes that are opaque to our computers, it is clear that we do not gain our undoubted complexity over worms and plants by using more genes.

"Understanding what does give us our complexity—our enormous behavioral repertoire, ability to produce conscious action, remarkable physical coordination, precisely tuned alterations in response to external variations of the environments, learning, memory, need I go on?—remains a challenge for the future."

As Baltimore states, the results of the Human Genome Project force us to consider other ideas about how life is controlled. "Understanding what does give us our complexity . . . remains a challenge for the future." The sky *is* falling.

In addition, the results of the Human Genome Project are forcing us to reconsider our genetic relationship with other organisms in the biosphere. We can no longer use genes to explain why humans are at the top of the evolutionary ladder. It turns out there is not much difference in the total number of genes found in humans and those found in primitive organisms. Let's take a look at three of the most studied animal models in genetic research, a microscopic nematode roundworm known as *Caenorhabditis elegans,* the fruit fly, and the laboratory mouse.

The primitive *Caenorhabditis* worm serves as a perfect model for studying the role of genes in development and

behavior. This rapidly growing and reproducing organism has a precisely patterned body comprised of exactly 969 cells and a simple brain of about 302 cells. Nonetheless it has a unique repertoire of behaviors and, most importantly, it is amenable to genetic experimentation. The *Caenorhabditis* genome consists of approximately 24,000 genes. (Blaxter 2003) The human body, comprised of over 50 trillion cells, contains only about 1,000 more genes than the lowly, spineless, thousand-celled microscopic worm.

The fruit fly, another favored research subject, has 15,000 genes. (Blaxter 2003; Celniker, et al, 2002) So the profoundly more complicated fruit fly has 9,000 fewer genes than the more primitive *Caenorhabditis* worm. And when it comes to the question of mice and men, we might have to think more highly of them or less of ourselves; the results of parallel genome projects reveal that humans and rodents have roughly the same number of genes!

Cell Biology 101

In retrospect, scientists should have known that genes couldn't provide the *control* of our lives. By definition, the brain is the organ responsible for controlling and coordinating the physiology and behavior of an organism. Conventional science, as revealed in a recent publication by the U.S. Department of Health and Human Services (2005), perceives that the nucleus is "basically the cell's brain": "It contains the equivalent of the cell's gray matter—its genetic

material, or DNA. In the form of genes, each with a host of helper molecules, DNA determines the cell's identity, masterminds its activities and is the official cookbook for the body's proteins."

Since genes were presumed to "control" the traits of the cell and the nucleus is the organelle that contains virtually all the cell's DNA, considering the nucleus as the "brain" of the cell made sense.

But is the nucleus truly the cell's brain? If our assumption that the nucleus and its DNA-containing material is the "brain" of the cell, then removing the cell's nucleus, a procedure called enucleation, should result in the immediate death of the cell.

And now, for the big experiment . . . (Maestro, a drumroll if you please).

The scientist drags our unwilling cell into the microscopic operating arena and straps it down. Using a micromanipulator, the scientist guides a needle-like micropipette into position above the cell. With a deft thrust of the manipulator, our investigator plunges the pipette deep into the cell's cytoplasmic interior. By applying a little suction, the nucleus is drawn up into the pipette, and the pipette is withdrawn from the cell. Below the nucleus-engorged pipette lies our sacrificial cell—its "brain" torn out.

But *wait!* It's still moving! My God . . . the cell is still *alive!*

The wound has closed and like a recovering surgical patient, the cell begins to slowly stagger about. Soon the cell is back on its feet (okay, its pseudopods), fleeing the microscope's field with the hope that it will never see a

doctor again.

Following enucleation, many cells can survive for up to two or more months without genes. Viable enucleated cells do not lie about like brain-dead lumps of cytoplasm on life-support systems. These cells actively ingest and metabolize food, maintain coordinated operation of their physiologic systems (respiration, digestion, excretion, motility, etc.), retain an ability to communicate with other cells, and are able to engage in appropriate responses to growth and protection requiring environmental stimuli.

Unsurprisingly, enucleation is not without side effects. Without their genes, cells are not able to divide, nor are they able to reproduce any protein parts they lose through the normal wear and tear of the cytoplasm. The inability to replace defective cytoplasmic proteins contributes to mechanical dysfunctions that ultimately result in the death of the cell.

Our experiment was designed to test the idea that the nucleus is the "brain" of the cell. If the cell had died immediately following enucleation, the observations would have at least supported that belief. However, the results are unambiguous: enucleated cells still exhibit complex, coordinated, life-sustaining behaviors, which imply that the cell's "brain" is still intact and functioning.

The fact that enucleated cells retain their biological functions in the absence of genes is by no means a new discovery. Over a hundred years ago, classical embryologists routinely removed the nuclei from dividing egg cells and showed that a single, enucleated egg cell was able to develop

as far as the blastula, an embryonic stage consisting of forty or more cells. Today, enucleated cells are used for industrial purposes as living "feeder" layers in cell cultures designed for virus vaccine production.

If the nucleus and its genes are not the cell's brain, then what exactly is DNA's contribution to cellular life? Enucleated cells die, not because they have lost their brain but because they have lost their reproductive capabilities. Without the ability to reproduce their parts, enucleated cells cannot replace failed protein building blocks, nor replicate themselves. So the nucleus is not the brain of the cell—the nucleus is the cell's gonad! Confusing the gonad with the brain is an understandable error because science has always been and still is a patriarchal endeavor. Males have often been accused of thinking with their gonads, so it's not entirely surprising that science has inadvertently confused the nucleus with the cell's brain!

Epigenetics: The New Science of Self-Empowerment

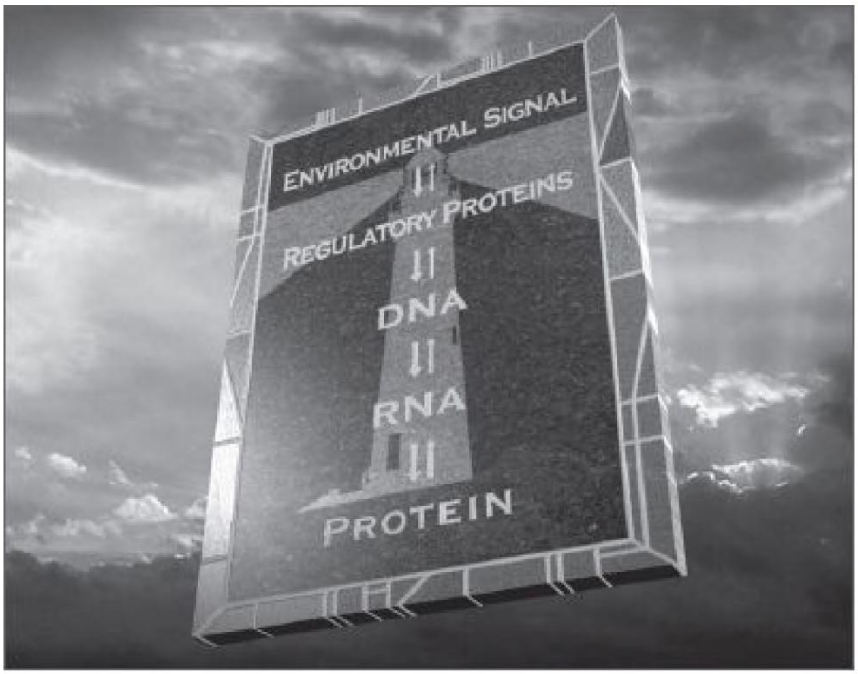
Genes-as-destiny theorists have obviously ignored hundred-year-old science about enucleated cells, but they cannot ignore new research that undermines their belief in genetic determinism. While the Human Genome Project was making headlines, a group of scientists were inaugurating a new, revolutionary field in biology called *epigenetics.* The science of epigenetics, which literally means "control above

genetics," profoundly changes our understanding of how life is controlled. (Pray 2004; Silverman 2004) In the last decade, epigenetic research has established that DNA blueprints passed down through genes are not set in concrete at birth. Genes are not destiny! Environmental influences, including nutrition, stress, and emotions, can modify those genes without changing their basic blueprint. And those modifications, epigeneticists have discovered, can be passed on to future generations as surely as DNA blueprints are passed on via the double helix. (Reik and Walter 2001; Surani 2001; Watters 2006; Cloud 2010)

There is no doubt that epigenetic discoveries have lagged behind genetic discoveries. Since the late 1940s, biologists have been isolating DNA from the cell's nucleus in order to study genetic mechanisms. In the process they extract the nucleus from the cell, break open its enveloping membrane, and remove the chromosomal contents, half of which is made up of DNA and half of which is made up of regulatory proteins. In their zeal to study DNA, most scientists threw away the proteins, which we now know is the equivalent of throwing the baby out with the bathwater. Epigeneticists are bringing back the baby, by studying the chromosome's proteins, and those proteins are turning out to play as crucial a role in heredity as DNA.

In the chromosome, the DNA forms the core, and the proteins cover the DNA like a sleeve. When the genes are covered, their information cannot be "read." Imagine your bare arm as a piece of DNA representing the gene that codes for blue eyes. In the nucleus, this stretch of DNA is covered by

bound regulatory proteins, which cover your blue-eye gene like a shirtsleeve, making it impossible to be read.



Primacy of Environment. The new science reveals that the information that controls biology starts with environmental signals that, in turn, control the activity of regulatory proteins on the DNA. Regulatory proteins direct the activity of genes. The DNA, RNA, and protein functions are the same as described in the Primacy of DNA chart. Note: the flow of information is no longer unidirectional. In the 1960s, Howard Temin challenged the Central Dogma with experiments that revealed RNA could go against the predicted flow of information and rewrite the DNA program. Originally ridiculed for his "heresy," Temin later won a Nobel Prize for describing reverse transcriptase, the molecular mechanism by which RNA can rewrite the genetic code. Reverse transcriptase is now notorious, for it is used by the AIDS virus' RNA to commandeer the infected cell's DNA. It is also now known that epigenetic changes in the DNA molecule, such as adding or removing methyl chemical groups, influence the binding of regulatory proteins. Proteins must also be

able to buck the predicted flow of information, since protein antibodies in immune cells are involved with changing the DNA in the cells that synthesize them. The size of the arrows indicating information flow are intentionally not the same. There are tight restrictions on the reverse flow of information, a design that would prevent radical changes to the cell's genome.

How do you get that sleeve off? You need an environmental signal to spur the "sleeve" protein to change shape, i.e., detach from the DNA's double helix, allowing the gene to be read. Once the DNA is uncovered, the cell makes a copy of the exposed gene. As a result, the activity of the gene is "controlled" by the presence or absence of the ensleeving proteins, which are in turn controlled by environmental signals.

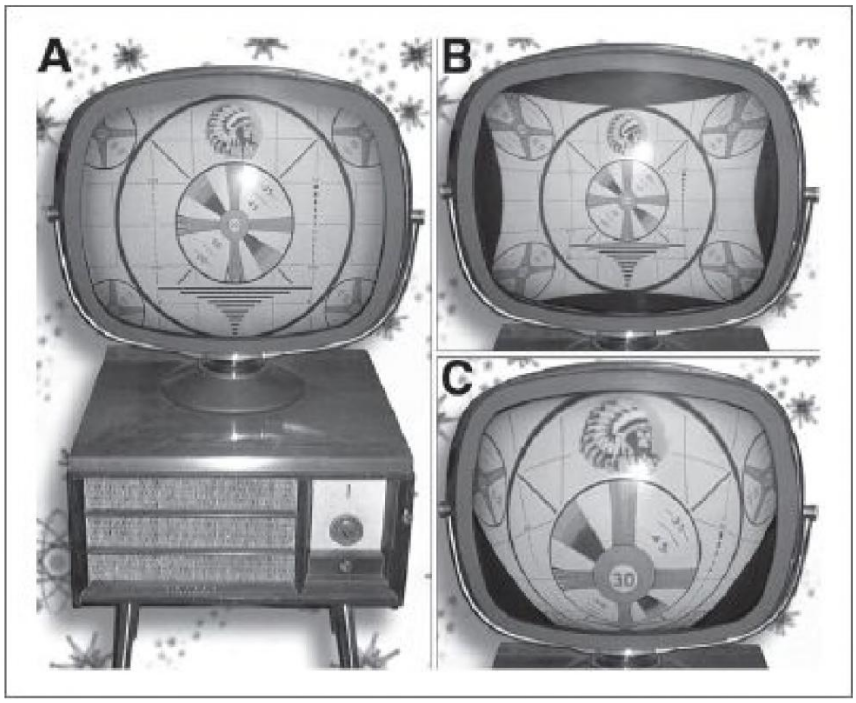
The story of epigenetic control is the story of how environmental signals control the activity of genes. It is now clear that the Primacy of DNA chart described earlier is outmoded. The revised scheme of information flow should now be called the "Primacy of the Environment." The new, more sophisticated flow of information in biology starts with an environmental signal, then goes to a regulatory protein and only then goes to DNA, RNA, and the end result, a protein.

The science of epigenetics has also made it clear that there are two mechanisms by which organisms pass on hereditary information. Those two mechanisms provide a way for scientists to study both the contribution of nature (genes) and the contribution of nurture (epigenetic mechanisms) in human behavior. If you only focus on the DNA blueprints, as scientists have been doing for decades, the influence of the

environment is impossible to fathom. (Dennis 2003; Chakravarti and Little 2003)

Let's present an analogy that hopefully will make the relationship between epigenetic and genetic mechanisms clearer. Are you old enough to remember the days when television programming stopped after midnight? After the normal programming signed off, a "test pattern" would appear on the screen. Most test patterns looked like a dartboard with a bull's eye in the middle, similar to the one pictured on the following page.

Think of the pattern of the test screen as the pattern encoded by a given gene, say the one for brown eyes. The dials and switches of the TV fine-tune the test screen by allowing you to turn it on and off and modulate a number of characteristics, including volume, color, hue, contrast, brightness, and vertical and horizontal holds. By adjusting the dials, you can alter the appearance of the pattern on the screen, while not actually changing the original broadcast pattern. This is precisely the role of regulatory proteins. Studies of protein synthesis reveal that epigenetic "dials" can create 2,000 or more variations of proteins from the same gene blueprint. (Bray 2003; Schmuker, et al, 2000)

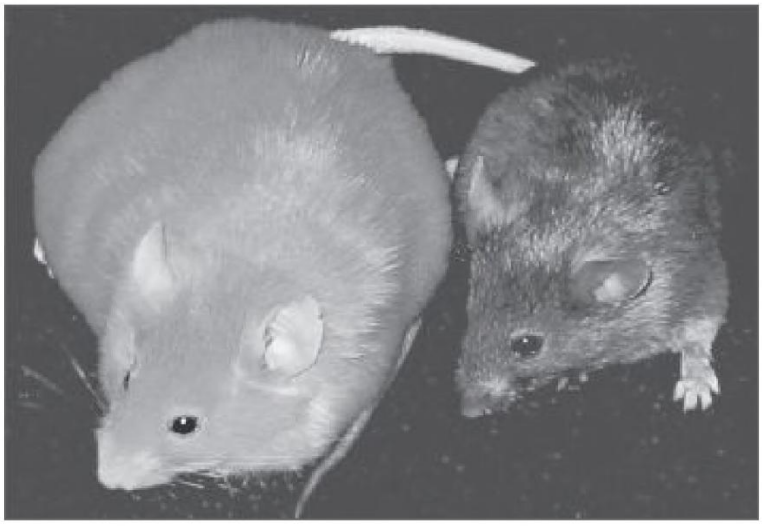


In this epigenetic analogy, the test pattern on the screen represents the genetic code (program). While the TV's controls can change the appearance of the pattern (B and C), they do not change the original pattern of the broadcast (i.e., the gene). Epigenetic control modifies the readout of a gene without changing the DNA code.

Parental Life Experiences Shape Their Children's Genetic Character

We now know that the environmentally influenced fine-tuning described above can be passed from generation to generation. A landmark Duke University study published in the August 1, 2003 issue of *Molecular and Cellular Biology* found

that an enriched environment can even override genetic mutations in mice. (Waterland and Jirtle 2003) In the study, scientists looked at the effect of dietary supplements on pregnant mice with the abnormal "agouti" gene. Agouti mice have yellow coats and are extremely obese, which predisposes them to cardiovascular disease, diabetes, and cancer.



Agouti Sisters. One-year-old female genetically identical agouti mice. Maternal methyl donor supplementation shifts coat color of the offspring from yellow to brown and reduces the incidence of obesity, diabetes, and cancer. (Photo courtesy of Jirtle and Waterland©)

In the experiment, one group of yellow, obese, agouti mothers received methyl-group-rich supplements available in health food stores: folic acid, vitamin B12, betaine, and choline. Methyl-rich supplements were chosen because a number of studies have shown that the methyl chemical

group is involved with epigenetic modifications. When methyl groups attach to a gene's DNA, it changes the way regulatory chromosomal proteins bind to the DNA molecule. If the proteins bind too tightly to the gene, the protein sleeve cannot be removed and the gene cannot be read. Methylating DNA can silence or modify gene activity.

This time the headlines "Diet Trumps Genes" were accurate. The mothers who got the methyl-group-rich supplements produced standard, lean, brown mice, even though their offspring had the same agouti gene as their mothers. The agouti mothers who didn't get the supplements produced yellow pups, which ate much more than the brown pups. The yellow pups wound up weighing almost twice as much as their lean, "pseudo-agouti" counterparts.

The University's photo, shown above, is striking. Though the two mice are genetically identical, they are radically different in appearance: one mouse is lean and brown and the other mouse is obese and yellow. What you can't see in the picture is that the obese mouse is diabetic while its genetically identical counterpart is healthy.

Other studies have found epigenetic mechanisms to be a factor in a variety of diseases, including cancer, cardiovascular disease, and diabetes. In fact, only 5 percent of cancer and cardiovascular patients can attribute their disease directly to heredity. (Willett 2002; Silverman 2004) While the media made a big hoopla over the discovery of the BRCA1 and BRCA2 breast cancer genes, they failed to emphasize that 95 percent of breast cancers are not due to inherited genes. The malignancies in a significant number of cancer patients are

derived from environmentally induced epigenetic alterations and not defective genes. (Kling 2003; Jones 2001; Seppa 2000; Baylin 1997) Recently, eminent scientist and physician Dean Ornish revealed that by just changing diet and lifestyle for ninety days, prostate cancer patients switched the activity of over 500 genes. Many of their gene changes inhibited biological processes critical in the formation of their tumors. (Ornish, et al, 2008)

The epigenetic evidence has become so compelling that some brave scientists are even invoking the "L" word for Jean-Baptiste Lamarck, the much-scorned evolutionist, who believed that traits acquired as a result of environmental influence could be passed on. Philosopher Eva Jablonka and biologist Marion Lamb wrote in their 1995 book *Epigenetic Inheritance and Evolution—The Lamarckian Dimension:* "In recent years, molecular biology has shown that the genome is far more fluid and responsive to the environment than previously supposed. It has also shown that information can be transmitted to descendants in ways other than through the base sequence (code) of DNA." (Jablonka and Lamb 1995; Kaiser 2005)

We're back to where we started in this chapter, the environment. In my own work in the laboratory, I saw over and over the impact a changed environment had on the cells I was studying. But it was only at the end of my research career, at Stanford, that the message fully sank in. I saw that endothelial cells, which are the blood vessel–lining cells I was studying, changed their structure and function depending on their environment. When, for example, I added inflammatory

chemicals to the tissue culture, the endothelial cells rapidly became the equivalent of macrophages, the scavengers of the immune system. What was also exciting to me was that the cells transformed even when I destroyed their DNA with gamma rays. These endothelial cells were "functionally enucleated," yet they completely changed their biological behavior in response to inflammatory agents, just as they had when their nuclei were intact. These cells were clearly showing some "intelligent" control in the absence of their genes. (Lipton 1991; Butler, et al, 2010)

Twenty years after my mentor Irv Konigsberg's advice to first consider the environment when your cells are ailing, I finally got it. DNA does not control biology, and the nucleus itself is not the brain of the cell. Just like you and me, cells are shaped by where they live. In other words, it's the environment, stupid.

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The exploding field of epigenetic research has not only made Jean-Baptiste Lamarck look like a seer, it has made my professor and mentor Irv Konigsberg, who inspired the title for this chapter, look like more of one as well. More than forty years later, it's still the environment, stupid!

Consider a Stanford study touted in the media with headlines that sound like *The Biology of Belief*! (I'll try to restrain myself from pointing out over and over that the newest research supports the conclusions of the first edition of *The Biology of Belief,* though that's hard for me because I've felt so many times like a voice in the wilderness.) From *U.S.*