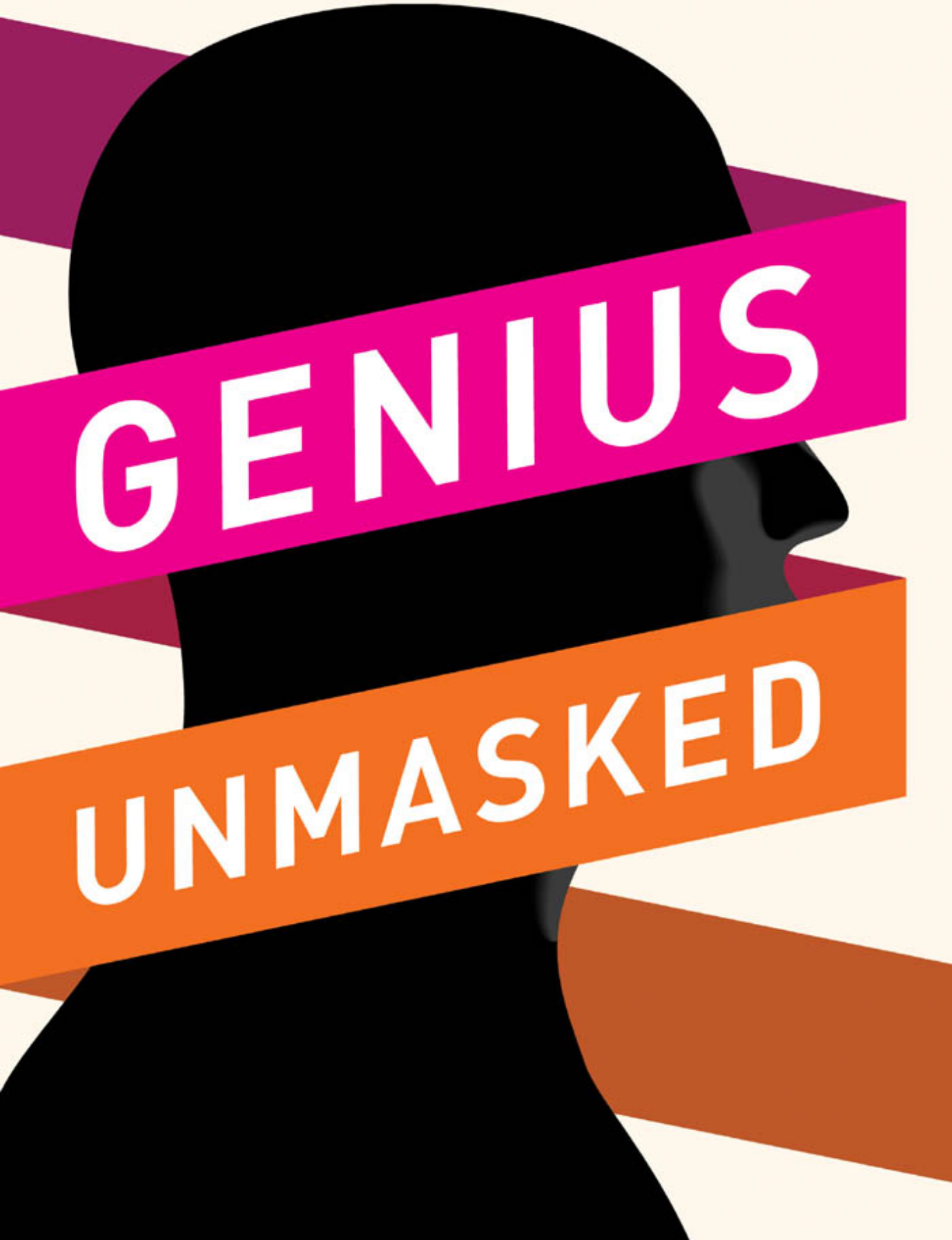
ROBERTA B. NESS



Genius Unmasked

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To David, Joel, and Sara to whom I am forever indebted
for keeping me thinking

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Hero Worship

My first encounter with inspirational thinking occurred when I was a medical intern at Bellevue Hospital in New York City. I was taking care of a 16-year-old prostitute. She came in for treatment of an infection in her heart valve that had resulted from shooting up heroin. What distinguished her from the other intravenous drug users with endocarditis that I had admitted was her unusual cleverness and optimism. She seemed eager to mend her ways. Perhaps I could convince her to escape her wayward lifestyle—to be one of the rare ones to get off the street and back to school. We talked about life and hope each day as I delivered her intravenous antibiotics. I felt sure that I was having an impact. One day, about halfway through her course of treatment, when I arrived with my miracle drugs she was gone, intravenous catheter still embedded in her arm. "A great way to shoot up," a wiser resident informed me.

Her treatment had been working—the fever had come down and the white blood count had normalized. Yet completion of such a short course of antibiotics could not have eliminated the bacteria. Going back to her pimp and the drugs meant that it was only a matter of time before she landed right back in the emergency department. Her next visit would be brutal. The unencumbered pestilence that was still inside her heart valve would have eaten away the tissue leaving only a gaping hole. The surgical residents at Bellevue had a rule in those days—they would replace a value once but never twice. An unsuccessful course of antibiotics fated the young prostitute to her first strike. And it fated me to my first failure. Hadn't my good intentions been enough?

The only person who seemed to fathom what had happened was Lewis Goldfrank, chairman of Bellevue's famed Department of Emergency Medicine. Goldfrank was, simply put, the smartest guy in the room. I remember once waking him at home at 2 A.M. because I knew he would council me through the management of a patient whose twitching muscles and dilated pupils I feared had resulted from a poisonous adventure with forest mushrooms. But Goldfrank was not just stimulating because he knew a lot. He was remarkable because he reasoned in a way that was surprising.

Goldfrank saw beyond the press of caring for the 110,000 patients with car crash injuries, drug overdoses, and gunshot wounds who poured into the Bellevue Emergency Department (ED) each year. "The purpose of a physician in the Emergency Department," Goldfrank once said, "should be to shut the place down." Accidents should never happen; medical calamities, according to him, were largely preventable. Rather than working to perfect the most fashionable emergency treatments, Goldfrank studied how to avert repeat emergency visits. He ran the New York City Poison Control Center, shifting the focus from mitigating the consequences of poisoning to thwarting toxins from ever reaching unsuspecting hands. New York City, Goldfrank believed, was full of toxins, both real and metaphorical. Speeding and drunk driving were toxins that predisposed to motor vehicle accidents. The trail of tears that preceded the prostitute's drug addiction was what had destroyed her valve. Thinking broadly, backward, and while walking in his patient's shoes—those were the unusual thought processes that Goldfrank embedded in the minds of us residents.

After Bellevue—after Goldfrank—my desire to deliver clinical care to individuals became replaced by a new passion. Public health. I now aspired to prevent disease before it ever took a toll. With seven years invested in training to be a physician, I went back to public health school to learn to be an epidemiologist, a scientist who, rather than treating disease in one patient at a time, seeks to understand patterns of illness among thousands. It was an unexpected and risky reversal of my life's path.

Lew Goldfrank, along with other remarkable scientific innovators I have known, instigated this book. The creators who populate these pages were chosen because they not only saw things differently, as did Goldfrank, but because they left the world so enriched, that their stories have transcended to legend.

Some are idols whom we all recognize—Edison, Pasteur, and Einstein. Their inventions and discoveries brought us light, health, and power—things more marvelous than our ancestors could have imagined. Others are less popularly iconic—for instance, Norman Borlaug, Russell Marker, and Paul Baran—yet within their own disciplines their claims to fame are no less imposing. Borlaug is the "father of the Green Revolution"; Marker first synthesized the chemical key to formulating oral contraceptives; Baran invented the brilliant network behind the Internet. We call these heroes "geniuses."

Genius—it is a word that invokes mystique. Such thinking is inscrutable, even though its results are recognizable as creativity on a revolutionary scale. Although the product of genius is, by definition, surprising, some of the routes taken were a series of predictable steps; other courses seemed to pop out of nowhere. Sometimes geniuses envisioned their terminus far off in the distance; other times, their destination was unforeseen. To date, however, no one—not even the autobiographical accounts written by geniuses themselves has produced satisfying insights into their thinking process. How did radical innovators think? Perhaps their minds, prepared through the providence of genetics, were simply lucked upon by chance. Or perhaps, as it sometimes seemed, their visionary insights were attained through divine intervention. But could there be an entirely different explanation? Could there be a more knowable process underlying genius?

This book seeks to unmask the nature of genius. It is designed to get inside a few inspirational minds and ask: Is genius really so magical, or does it, instead, consist of predictable patterns of imaginative thinking, no matter how transformative? Can the mental features of breathtaking creativity be revealed? What I hope to demonstrate in these pages is that genius is achieved through a thinking process that is less mystical than

it is systematic. I hope to show that even the greatest of innovative minds has used a cognitive toolbox that can be opened and understood.

Of course, such a demonstration seems like a tall order and will have to be convincing. But let's just imagine for a moment that it is true—that the activity of prodigious creativity can be discerned. Then genius actually involves a set of strategies. And those strategies can be emulated.

What is inside the scientific genius's toolbox? As their stories unfold, we find the following devices: (1) finding the right question; (2) observation; (3) analogy; (4) juggling induction and deduction; (5) changing point of view; (6) broadening perspective; (7) dissecting the problem; (8) reversal; (9) recombination and rearrangement; (10) the power of groups; and (11) frame shifting.

These tools are not magic. Together, they are techniques that have been previously described for use in teaching children and adults to be more creative. Creativity training programs that incorporate many of these instruments, as described in my previous book, *Innovation Generation: How to Produce Creative and Unusual Scientific Ideas,* have been shown to substantially improve innovation for almost anyone. Trainees from these programs, no matter their age, gender, or even intellectual prowess, generate two- to threefold more ideas on standardized creativity tests, and their ideas are more original. Professionals who complete creativity training are more productive. Their thinking is more flexible and they have a greater preference for novel problem-solving.

What this book hopes to demonstrate, then, is that some of the most creative minds in science have used devices that any of us can learn to use, and which can improve our creative abilities. Geniuses were not omnipotent and they were not divine. They were simply particularly skilled master craftsmen of creative surprise.

As we hear these stories, it is also worth asking two other questions. The first is whether there are, in fact, two subsets of scientific creators—those who worked within the rules and those who overturned the rules. The common terms for these two types of innovation are "evolutionary" and "revolutionary." All of the innovators discussed here initiated social transformation—that is, they created a state of things that was utterly

new. Yet social disruption does not always imply scientific transformation. Evolutionary innovation does not alter the very essence of science, whereas revolutionary innovation does. In business parlance, evolutionary innovations are brought about by many, incremental advances and create products that do not disrupt human (in this case, scientific) routines. Revolutionary innovations overturn the status quo; they necessitate the acceptance of radical departures from comfortable traditions.

As we shall see, the peculiarities of naming can be misleading. Darwin's evolutionary theory was not an evolutionary innovation—it was a revolutionary one that forced experts and the public to rethink assumptions about the origin of life around us and of our own human species. Conversely, the Green Revolution and the Contraceptive Revolution were not revolutionary innovations in a scientific sense but instead reflected a string of modest advances that, when applied synergistically, nonetheless produced social change on a massive scale. Naming aside, it seems reasonable to ask: Did those geniuses who contributed small steps think in the same way as those who made huge leaps?

The second question is how cognition interacts with character. Birthing radical new ideas, as we will see, is often accompanied by deep curiosity, unshakable self-belief, and dogged tenacity. Kirk Varnedoe, in his book *Fine Disregard: What Makes Modern Art Modern,* posits that the modern artists who changed art history engaged in "gratuitous rearrangement" that found the fortune to strike a cultural nerve. Modern art, he claims, was in fact instigated by people who engaged in acts that were "simple, human, and willfully contrary." Are scientific innovators also individuals with the willingness, indeed the craving, to flout convention in the service of some fascination? How common and how necessary to scientific discovery are such characteristics? Are such traits all good, or do they have an unwanted underbelly?

Every generation needs great innovators. Today, unique insights are needed to solve the greatest threats to mankind—problems such as cancer, Alzheimer's disease, obesity, emerging infections, and climate change. Yet a blue ribbon Committee of the National Academies of Science recently warned that modern American science is making slow progress toward

finding solutions. Why? Because, according to the distinguished panel, the United States is not sustaining its "creative ecosystem"—its intellectual capital. Moreover, a rash of commentaries published in *Business Week, National Review,* and the *New York Times* has decried that America is in the midst of a worrisome slowdown of innovation. Tyler Cowen's influential book *The Great Stagnation* (2010), although it applauded advances in information technology, agonized about the sluggishness of invention in many other technical and science sectors. David Brooks, a nationally syndicated columnist, reminded us that a time traveler arriving in 2011 after having blasted off in 1970 would be disappointed at the pace of progress if she expected to see advancements on par with those of the first half of the twentieth century, when horse-drawn buggies transmuted into moon rockets.

To remain healthy and prosperous, society must maximize the potential in each of us. We all hope to create something interesting and original. By understanding the methods used by eminent scientists, can we work toward useful mimicry? Can we learn from geniuses to become better innovators?

To start, we need only adopt the one trait universal among geniuses—a characteristic essential to their creativity. It is the belief that we can do whatever we seriously set out to do—that our thinking can develop. Surely, with faith in ourselves and inspirational stories as our guide, we will at the very least learn something interesting. By peeking beneath the mask of genius we may even find our own surprising capacity for ingenuity.

2

Nature versus God

Charles Darwin

Novelty often breeds controversy. If the impact of an innovative idea were ranked by its contentiousness, the theory of evolution by means of natural selection would top the list. When Charles Darwin's *On the Origin of Species* was published in 1859, it caused what has been widely described as "a sensation." Religious authorities considered it blasphemous, if not diabolical. For half a century, scientists actively contested it. Darwin himself anticipated and shied away from the maelstrom that he knew the theory could cause. With his social and scientific standing built on an impeccable record of mainstream scientific contributions, he kept the manuscript locked away in his office for 20 years, along with instructions to his wife to publish it only upon the occasion of his death. It was not until a young, entrepreneurial naturalist named Alfred Russell Wallace was about to scoop him that Darwin rushed the manuscript to press.

Darwin's theory of evolution by means of natural selection still surprises and divides the American public. Despite its profound influence on much of science—the fields of genetics, psychology, sociology, and biology, to name a few—a constant stream of books continues to challenge, tweak, or disbelieve it outright. Fewer than 20 percent of Americans surveyed in a series of recent Gallup Polls subscribe to Darwin's central tenet: human beings developed over millions of years from other life forms without the guidance of God. In contrast, about 45 percent select as true the alternative statement: "God created human beings pretty much in their present

form at one time within the last 10,000 years or so." Another 35 percent believe that humans developed slowly from other life forms but that God guided the process. Thus, 150 years after its inception, Darwin's theory departs so radically from religious teachings and is so counterintuitive that most of the American public continues to reject it.

What is the theory of evolution by means of natural selection? Let us try to absorb it, recognizing its strangeness, by breaking it into two parts. First, species are not immutable. This part of the theory has been termed "evolution," and it explains the abundance of diversity in the world's plants and animals. Within that diversity, species are the simplest units of biological classification. Commonly defined, a species is a group of organisms that can breed among themselves and produce fertile offspring. Prior to Darwin, it was commonly believed that this most basic element of life had characteristics that were absolute and unchangeable. Evolutionists, including Darwin, argued that the opposite was true: within species, alterations in both body and behavior are inevitable.

The second part of Darwin's theory is more contentious, bizarre, and earth-shattering. Darwin speculated that the driver of evolution is natural selection. "Natural selection" means that traits change because the ones that provide a reproductive advantage become more common in the population.

Random variations, Darwin argued, were the result of the mixing of traits inherited from each parent. Although "like breeds like," offspring traits were an admixture of those from each parent, which made them utterly unique. Those inherited traits that were better adapted to the environment benefitted the organism in its survival and benefitted their ability to reproduce. In the case of Galápagos finches, for example, the shape of beaks was one such trait; some beaks worked best for certain seeds, and other beaks worked better for others. A finch whose beak was most successful at opening the most common seed type was most likely to thrive. However, nature is not kind. Environmental resources are inadequate to feed or support all progeny of all species. Those individuals whose characteristics were best adapted to their environment, such as the finches with the best seed-opening beaks, were most likely to win the struggle for

survival and to produce more offspring. Over successive generations, the advantageous trait became dominant—it was selected.

Imagine that reproduction is Mother Nature's way of dealing random cards from the species deck. If a card is dealt for some characteristic that enhances the holder's hardiness in the particular environment, then that card gets dealt again to more players in the next round. On the other hand, cards that reduce hardiness get discarded. Eventually, the hardiness card becomes the most dominant in the game.

Had Darwin's logic stopped there, perhaps his theory would not have been so controversial. But he further proposed that species undergoing lengthy natural selection morphed into other species. From apes sprang man.

Darwin's later book, *The Descent of Man and Selection in Relation to Sex* (1871), argued that while humankind trended evolutionarily toward a smaller and weaker habitus, it also evolved toward superior cognition, providing complex behavioral strategies to attract mates. The image of a brute luring a beauty back to his cave was, in Darwin's mind, more literal than figurative. It was an idea almost perfectly designed to be objectionable to Victorian society.

How did Darwin hatch such a disruptive concept? Although we may remember him as a retiring aristocrat, as he was in his later years, he was anything but conventional. Early on, he rejected the upper-class expectations of his family. Rather than becoming a medic like his father, Charles dropped out of the University of Edinburgh Medical School and spent his days hunting, beetle collecting, and classifying plants. Such appetites seemed of little or no use to society. His father renounced Charles's dallying, fearing that without a shift in course, his son would become "a disgrace to yourself and all your family." That is, Charles's early exploits were not conventional and they were not reinforced by accolades. Instead, they reeked of the spontaneity, curiosity, and individuality that are characteristics so common among great innovators.

Had a letter from his former botany professor John Stevens Henslow not arrived when it did, the young Darwin would have been compelled to enter the Anglican clergy. His inclination toward genius might never have been complemented by an apprenticeship in the use of the tools

of innovation. Henslow recommended Charles as a suitable gentleman companion to Captain Robert FitzRoy on an around-the-world voyage on the *HMS Beagle*. Darwin would be the onboard naturalist on the *Beagle*'s excursion (1831–1836), which was designed to map the coast of South America. The work was not only unpaid but required self-funding. Fortunately, with the help of a respected uncle, Charles "sold" his father on the trip—giving himself five intensive years to sharpen his thinking skills.

The most prominent tool that Darwin used was *observation*. Darwin's boyhood exploits in beetle collection and plant classification had opened his naturalist's eye for characterizing the minute details that categorize species. During the voyage of the *Beagle,* his powers of observation were enhanced by the development of patience, persistence, and discipline. Crate loads of flora and fauna from South America and the South Seas arrived back in England, representing a collection whose vastness was historic. Upon disembarking from the trip in Falmouth, he was an instant scientific celebrity. He was, after all, the man who had found the fossilized bones of huge extinct mammals, including the Megatherium, a giant sloth-like creature from Patagonia.

But observation did not resolve Darwin's curiosity. Surely he had encountered a fantastic range of diversity. But how did it all fit together? Ultimately, a question took shape. It was massively ambitious—a question far more bold than those any naturalist had previously asked. "By what means," Darwin queried, "do all living things in nature come to be?"

The tool of *asking the right question* was a second fundamental step in Darwin's cognitive maturation. But his question's scope was so huge that it could only be embraced over time. In a series of notebooks that Darwin initiated soon after he arrived home, he recorded his embryonic intellectual struggles. He called his thinking on evolution "[a] most laborious, & painful effort of the mind." In these notebooks, a unique cognitive record emerges. Remarkably, Darwin documents the use of every tool in the innovator's chest.

The most sweeping of these tools was *frame shifting*. Traditionally, the accepted belief was that all living things are replicas of perfect

creations produced by God. Since there could be no alteration from this perfection, to ask how species change over time made no sense. Notably, Darwin's question about how all species originated necessarily eliminated any assumption about divine intervention. It gave him the freedom to ask whether species vary and how they vary. It gave him the freedom to produce the breakthrough that species variation occurs, and that change is driven by randomness. Rather than resulting from a perfect plan designed by a loving deity, Darwin proposed, beauty and monsters alike are created by an environment whose harshness is arbitrary.

Had Darwin trained as an Anglican minister, it is unlikely that he would have conceptualized natural selection. Prominent biologists of Darwin's time were trained first as theologians, then as scientists. God, they believed, has a hand throughout nature. In his 1802 book, *Natural Theology: Evidences of the Existence and Attributes of the Diety, Collected from the Appearances of Nature,* William Paley popularized the analogy between God and a watchmaker. His argument was: if any of us found a watch lying on the ground, we would assume that it had been made by an expert craftsman. Similarly, when we observe the perfection and variety of flora and fauna in nature, we appreciate it as the work of a master creator. Underlying this logic was the even more ancient idea, popularized by Plato, that all of life derives from a limited number of prototypes, called "natural kinds." In Plato's view, species are separate and distinct: a cat is a cat and a dog is a dog and never the twain shall meet. David Quammen, in his book *The Reluctant Mr. Darwin,* comments about creationism, "To believe otherwise was to reject an assumption that was interwoven with ecclesiastic teachings and ideas of civil order."

This is not to say that radical, anti-sectarian thinkers had not preceded Darwin. Earlier thinkers had, indeed, been so bold as to propose evolution of species and to reject creationism. Among the infamous group were Jean-Baptiste Lamark, his protégé Geoffrey Saint-Hilaire, and even Darwin's grandfather, Erasmus Darwin. Unfortunately, the brand of evolution they put forth had been forcefully refuted. In particular, these

early evolutionists proposed that evolved characteristics result from use. For example, a giraffe stretches its neck to nip at the uppermost leaves of a tree, and the act of stretching causes a somewhat longer neck. The next generation of giraffes then inherits longer necks. This was a more purposeful—and in many ways more appealing—explanation than was Darwin's. It attributed characteristics in the next generation to the hard work of parents. Unfortunately, it also led to some fairly crazy ideas, for example, that the architecture of mollusks and invertebrates had to be the same. Such extrapolations quite quickly put an end to not only Lamarkian evolution but the whole notion of variability and its origins. To make matters worse, evolution as a social construct was quickly embraced by violent social anarchists. To mainstream thinkers, evolution was a dangerous idea.

Darwin, then, did *not* propose the frame of evolution—that had already been done. He used the tool of *rearrangement* to combine the best of what had been suggested: species variability. But he replaced Lamark's notion that inherited characteristics arise out of use with his own, less self-evident idea of natural selection. Natural selection, with its randomness and arbitrariness, was Darwin's radical frame shift.

Who wouldn't be nervous, proposing an idea that opposed "ecclesiastic teachings and ideas of civil order?" Darwin struggled mightily with the development of his ideas. Early in his notebooks, he sometimes wrote down an insight and then countered it. It was his own internal battle between an emerging David and an existing Goliath. Indeed, despite having transcribed in his notebook the essence of his theory as far back as 1838, it was not until 1844 that he cautiously hinted its outline to anyone. In a letter to a new friend, the young botanist Joseph Dalton Hooker, he begins, "I have been now ever since my return engaged in a very presumptuous work that species are not (it is like confessing a murder) immutable."

The fact that, after his return home from the voyage of the *Beagle*, Darwin became a conventional landed aristocrat makes his intellectual ferment all the more extraordinary. Married to his cousin Emma in 1839, the two moved to Down House in the Kent countryside and had 10 children (two of whom died in infancy). Darwin inherited a princely sum and

invested it wisely. The family became comfortable, and their lives became routine; Darwin never again ventured far from home partially due to recurrent stomachaches, vomiting, heart palpitations, and even boils, apparently made worse by social contact. Only a strict regimen of eating, sleeping, and exercise seemed to prevent recurrences. By all appearances, Darwin had become the most tedious traditionalist.

But beneath the external trappings, an innate curiosity and intellectual independence boiled. Once Darwin had started down the path toward his theory, there was no turning back. He had already uttered the earth-shattering question and broken the existing frame. Now he took the vastness of his pondering and *dissected* it into brain-size pieces. It was like a tree, the first two branches of which constituted evolution and natural selection: (1) Do flora and fauna vary? and (2) What process orchestrates natural variability? Indeed, in his notebook, Darwin drew a tree to help visualize his theory. Further dividing the first question, he asked himself, "Why is sex so important?" The answer provided the clue that sexual assortment allows for variation. In his words, "According to this view animals, on separate islands, ought to become different if kept long enough." Thus, each question was separated into sub-questions, and each divide led to the next.

One of the sentinel characteristics of Darwin's thinking was, again, his brilliance as a keen observer. In both *On the Origin of Species* and *The Descent of Man*, he uses reams of examples, each the result of his own clear and unbiased visualizations. But Darwin also drew on the observations of others. Strongly connected to like-minded intellectuals through avid discussion and correspondence, the *power of these contemporaries* greatly influenced Darwin's thinking. For example, shortly after his return to England in 1837, he consulted with ornithologist John Gould about a collection of brown birds he had brought back from the isolated Galápagos Islands. To Darwin's surprise, Gould identified the assortment—which the collector had assumed were a mixture of orioles, grosbeaks, and wrens—all as finches. Despite a great variety of beak sizes and shapes, Gould was telling Darwin that these birds were closely related cousins. It reinforced a line of reasoning that Darwin had considered while still on the *Beagle*: If related