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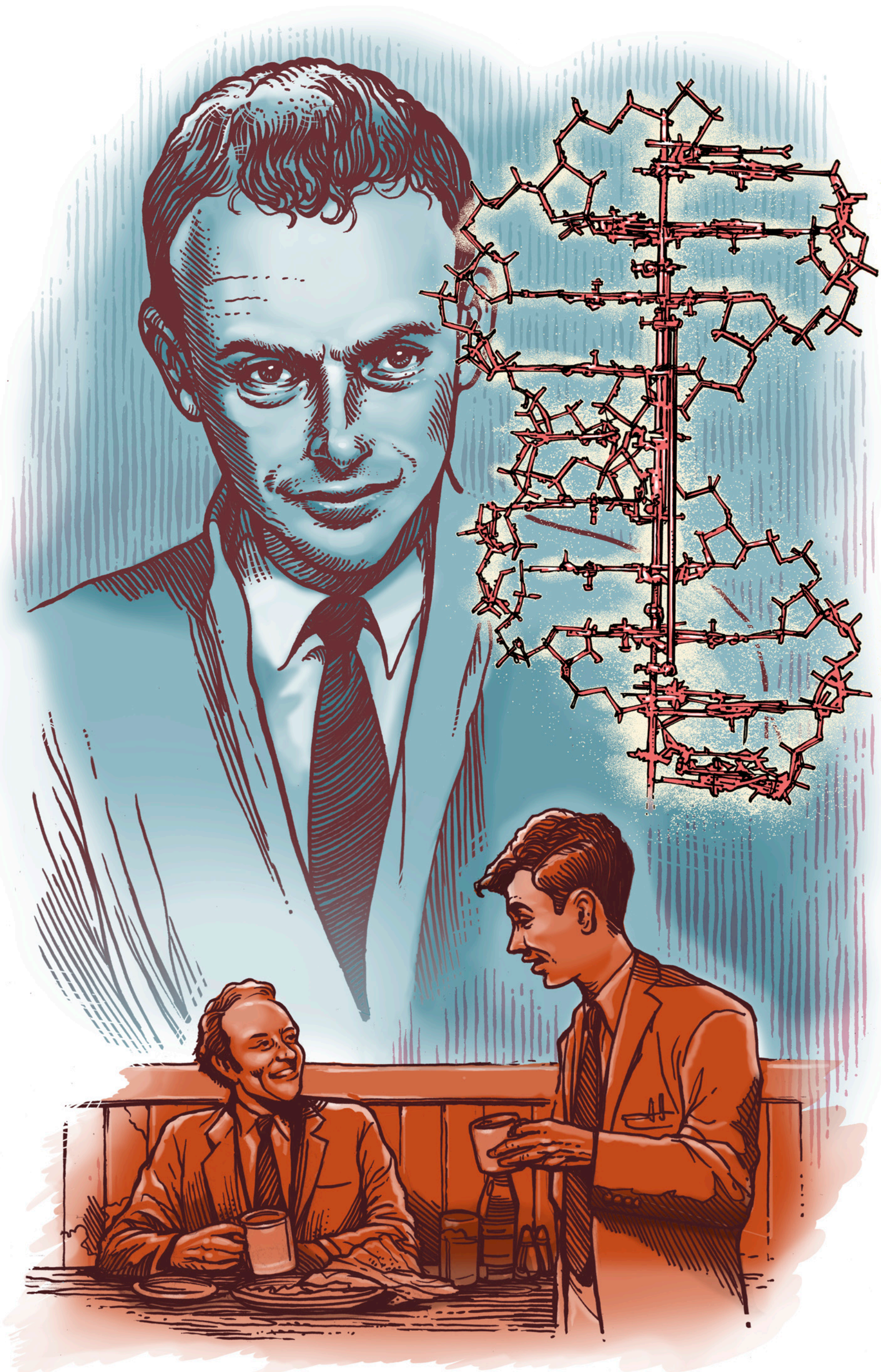


Dave Cheng (https://www.instagram.com/smiley_dafe/)

The Evangelist of Molecular Biology

Algis Valiunas

James D. Watson is the most famous American scientist since J. Robert Oppenheimer, and he wouldn't have it any other way. That his name will roll throughout history in tandem with that of Francis Crick, his English collaborator at the Cavendish Laboratory in Cambridge, does not diminish its luster, and may even enhance it somewhat. For an achievement like the 1953 discovery of the structure and basic function of DNA, there is glory enough to go around.

It might indeed be too much for a single man to shoulder. Watson and Crick are certainly an inseparable pair in the public mind, and the association has even confused some persons who clearly ought to know better. In 1955, shortly after Nevill Francis Mott had become the new head of the Cavendish, Crick said he'd like to introduce him to Watson, who had recently returned to Cambridge from Caltech. Mott was flummoxed. "Watson? Watson? I thought your name was Watson-Crick."

It did take some time for the momentous discovery to make the rounds, even among distinguished scientists. But in due course it became common knowledge of a sort. As Crick relates in his memoir *What Mad Pursuit*, the physical chemist Paul Doty was traveling to New York around 1960, when lapel buttons had become the latest thing, and, in amazement, he saw one for sale proclaiming "DNA." Certain that this was some fashionable slogan unknown to him—something quite different from what the letters signified to scientists—he asked the sidewalk vendor what it meant. "Get with it, Bud," the salesman replied. "Dat's the gene."

Watson, with characteristic acerbic brio and uncharacteristic self-effacement, said nearly fifty years after the discovery that it was Bill Clinton and O. J. Simpson who made DNA really famous. In a similarly modest mood years before, Crick had declared that he and Watson had not made DNA; it had made them. As one reviewer of Watson's 1968 memoir *The Double Helix* wrote, "The Watson-Crick paper on the structure of DNA sent to *Nature* on 2 April 1953 is of a very small class. Which class includes, say, Galileo to Paolo Sarpi of 16 October 1604 on the law of falling bodies, Einstein's papers of 1905, Dirac's theory of the electron…."

Algis Valiunas *is a* New Atlantis *contributing editor and a fellow at the Ethics and Public Policy Center. His writings are collected at AlgisValiunas.com.*

The Watson–Crick discovery inaugurated the transformation of biology, from what Watson caustically dismissed as the idle agglomeration of pointless boring facts to the fruitful search for "the secret of life." "To truly understand life, we must pursue genetics at the molecular level," Watson once wrote. And of the Human Genome Project that he would direct until 1992, he predicted it would "find out what being human is." He had been saying so for years, the foremost champion since his early twenties of molecular biology as the one true biological faith and the hope of mankind's earthly salvation. He continues in that role even now, in his late eighties.

In Watson's eyes, science is "the highest form of human achievement." In his early adolescence, excited by his love of birdwatching, the thought of a career as a naturalist had inspired him. But to pursue such a course, he later came to understand, would be to dabble in trifles. For among the sciences, molecular biology is peerless: Creatures, or to call them by their less poetic name, organisms, become worthy of the most serious interest only when they're taken apart to their elemental components.

Watson's view of molecular biology describes an intellectual—and moral—adventure that is just getting underway. The potential of molecular biology for making human existence more agreeable and more complete—more fully human, one might say, not to say trans-human—seems nearly boundless.

Thus Watson eloquently promotes and prophesies. He is our most forceful spokesman for what René Descartes called "knowledge which is most useful in life," which will "make ourselves, as it were, masters and possessors of nature," conducing "principally [to] the preservation of health, which is undoubtedly the first good, and the foundation of all the other goods of this life." Like Descartes, Watson feels a moral obligation to spread the word about the new beneficial possibilities of the everlasting truth put to good use.

Unlike Descartes, Watson is no philosopher, nor a writer of genius, but he is a writer of distinction about his particular branch of science, and a prolific one at that. In *The Writing Life of James D. Watson*, Errol C. Friedberg registers his amazement that Watson does not regard the DNA structure as his nonpareil accomplishment: "When asked what he considers his greatest achievement, Watson's response is unhesitating: It is, he has said firmly, 'my writing.'" For Watson epitomizes the scientist as public intellectual: He is the evangelist of molecular biology, whose mission is to inform the public of the specialized work being undertaken for their sake.

Watson considers himself responsible for educating both government and populace, and is particularly concerned with the workaday taxpayer who will fund the expensive scientific machinery. Yet it is not only the technological benefits of molecular biology that he wants the public to appreciate; he proselytizes for the disinterested nobility of the scientific calling too. As he wrote in 1976:

> As scientists, we shall have to spend more time educating the public, not only about our idealistic dreams, say to conquer the common cold or cancer, but also with regard to the old-fashioned idea on which I was brought up, that the pursuit of knowledge about the nature of life and about the universe in which it exists is a glorious endeavor that should be undertaken for its own sake.

Yet this endeavor, in its detail, lies far beyond the public's powers of understanding. Watson approaches the layman who comes unequipped to contend with the arcana of scientific research and wins him over with candor, and with gentle but decisive nudging toward appreciation for the recondite. Frequently he mingles his sketches of the scientific process with anecdotes of personal quirk and foible, and with reflections on the social significance of the advancement of learning, to borrow a phrase from Bacon.

From his young manhood, Watson nurtured the desire to write not just like an elegant scientist but indeed like a superior artist. In an essay titled "Striving for Excellence," he wrote, "When I was 23, I went through a phase where I wanted to understand how Linus Pauling thought well enough so I could write a paper in his style. And several years later I read *The Great Gatsby* and I began to dream that I might produce a novel with the class of Fitzgerald." Watson never did write a book to rival *Gatsby*. Yet of *The Double Helix*, his account of the discovery of DNA's structure, the formidably learned English crystallographer J. D. Bernal could exclaim, "It is an astonishing production, I could not put it down. Considered as a novel of the history of science, as it should be written, it is unequalled."

The Double Helix, not in fact a novel, has been a million-seller translated into more than twenty languages, and it has reached a larger audience, Errol Friedberg writes, than any other "story about scientific discovery." The Modern Library, which goes in for literary rankings, listed it at number seven of the hundred most important books of the twentieth century. In 1987 Watson's book was even adapted for the screen, with Jeff Goldblum as the hero.

Not every scientist shared Bernal's excitement over *The Double Helix*, but Watson can boast a number of other successful entries. These include two more memoirs in the *Helix* vein, the too often drearily confessional *Genes, Girls, and Gamow* (2001) and the more serious and successful *Avoid Boring People: Lessons from a Life in Science* (2007); the textbook *Molecular Biology of the Gene* (1965), which won nearly universal acclaim and is now in its seventh edition; *DNA: The Secret of Life* (2003), a valuable introduction to the reader with no scientific training, and the most clearly, forcefully, and gracefully written of his books, most likely thanks to its coauthor, geneticist Andrew Berry; and the essay collection *A Passion for DNA: Genes, Genomes, and Society* (2000), which provides an important view of Watson's opinions on the social implications of genetic research.

Then there is *Father to Son: Truth, Reason, and Decency* (2014), a Watson family history, focusing on the intellectual and moral legacy bequeathed to him by his father, James D. Watson, Sr. The loving memoir details the decisive yet unpredictable interplay of nature, nurture, and chance that shapes a life story. It points toward a richer understanding of human character and fate than is suggested by Watson's famous, perhaps notorious, emphasis on genetic destiny—the theme commonly seen as Watson's own principal legacy.

Through the trove of these writings, we learn that, like Descartes, Watson stands in the distinguished line of descent from Francis Bacon, who enthused, "Only let mankind regain their rights over nature, assigned to them by the gift of God, and obtain that power, whose exercise will be governed by right reason and true religion." To Watson, sound reason will be all the religion mankind needs. He needn't pay lip service to orthodox proprieties as Bacon did. The twentieth-century scientist embodies the orthodoxy of the new dispensation, and he takes the future with him.

Figuring Out a Focus

Born in 1928, James Dewey Watson, Jr. grew up in the bungalow belt on Chicago's South Side, rather nearer to the U.S. Steel South Works than to the University of Chicago, as he enjoyed remembering. Watson's mother had had to drop out of the university for want of tuition money, and she worked as a secretary there. His father had flunked out of Oberlin College after a serious illness had laid him low, and he worked as a bill collector.

Both his parents were of Scots-Irish stock, his father a one-time Episcopalian, his mother a practicing Roman Catholic. After his own confirmation at age eleven, Watson gave up church-going with his mother for

Sunday birdwatching excursions with his father. The brutal religiosity of Generalissimo Francisco Franco informed young Watson's dim view of the Church, and the son took naturally and by nurture after his dad, who he said "couldn't stand religion." The great philosophers supplied Watson Sr.'s desire for the transcendent, and the house was full of serious books. Watson Jr. learned to avoid the philosophers himself, and went in for books loaded with hard facts instead, favoring the *World Almanac*.

Watson thought of himself as a striver rather than a natural-born brainiac: Taking a forbidden glance at his IQ score on the teacher's desk, he found it was an unexceptional 120, so that he was deficient in what is ordinarily considered the essential genetic endowment for work of genius. He was determined to make his mark with what mental powers he had, and did rather well for himself after all.

At fourteen he appeared for three weeks on the national hit radio show *Quiz Kids*, in which children too smart for their own good competed in answering questions ranging from math to literature. After a successful run, Watson was stumped by Shakespeare and the Old Testament, and he would say he appeared on the show at all only because the producer was a next-door neighbor. He spent his prize money on a pair of ornithological binoculars.

At fifteen Watson entered the University of Chicago under the early admission protocol instituted by President Robert Maynard Hutchins, who found American high schools so desolate and deforming that he believed intelligent youth ought to flee them as soon as possible. Chicago under Hutchins's presidency was perhaps the signal glory in the history of American college education. It was the college of Great Books, and Watson delighted in reading the original scientific sources, though he abhorred the mandatory readings in philosophy—an aversion he would never get over.

The Chicago style of intellectual exchange had little to do with the social graces. The readiness for combat it instilled would hone the unmannerly edge of Watson's manner for the rest of his life: "I had learned the need to be forthright and to call crap crap," he would write in *Avoid Boring People*. Some of those dismembered by the buzzsaw of his contempt might have wished he had gone instead to gentlemanly Yale or Princeton. Most importantly, Watson learned to despise the triviality of so much in academic life—an indispensable Hutchins lesson—and to be ever on the alert for the most significant question, the intellectual main chance that would mark a scientific breakthrough and ensure a lasting reputation. Immersed in the greatness of the most renowned minds, he sought greatness for himself—and that meant both sterling achievement and worldly recognition. "Don't think about unimportant things," he exhorted himself, and set about becoming an important figure.

His adolescent yen for ornithology would not serve. To fulfill his early ambition to become an avian curator at a great museum would be ignominious now. Birds on the wing or on the dissecting table did not line the path to glory. The big excitement awaited altogether elsewhere, and in 1945, Watson happened upon the text that would re-direct the course of his life: the 1944 book *What Is Life?* by Erwin Schrödinger, an Austrian quantum physicist then living in exile in Dublin. (The book also made converts to biology of Francis Crick and Maurice Wilkins, both English physicists who would go on to share the 1962 Nobel Prize with Watson.)

Schrödinger had a physical scientist's nervy understanding of biology, unnerving to traditional practitioners and revelatory to those daring to venture beyond the sharply differentiated boundaries of the disciplines. "How can the events *in space and time* which take place within the spatial boundary of a living organism be accounted for by physics and chemistry?" he wrote. Yet "the obvious inability of present-day physics and chemistry to account for such events is no reason at all for doubting that they can be accounted for by those sciences."

Schrödinger's understanding of the role of chromosomes is strikingly prescient to modern ears, so associated have many of the ideas become with the DNA double helix, a discovery still waiting to be made by his impressionable reader. Schrödinger wrote:

> It is these chromosomes, or probably only an axial skeleton fibre of what we actually see under the microscope as the chromosome, that contain in some kind of code-script the entire pattern of the individual's future development and of its functioning in the mature state.... In calling the structure of the chromosome fibres a code-script we mean that the all-penetrating mind, once conceived by Laplace, to which every causal connection lay immediately open, could tell from their structure whether the egg would develop, under suitable conditions, into a black cock or into a speckled hen, into a fly or a maize plant, a rhododendron, a beetle, a mouse or a woman.

Henceforth, to understand as much of the genetic marvel as his mind could hold, to come as close as possible to the view of the all-penetrating mind, became the unrelenting spur in Watson's flank. *What Is Life?* prompted him to sit in on a course taught by the estimable physiological geneticist Sewall Wright, who spoke as if specifically to Watson. Wright described the pathbreaking but then little-regarded work of Oswald

Avery at the Rockefeller Institute. Avery had showed that the hereditary fundamentals do not lie in complex proteins, as most scientists—including Schrödinger—believed. Rather, they lie in DNA, or deoxyribose nucleic acid (now called deoxyribonucleic acid), a chemical that seemed far too simple to bear such immense responsibility. In a 1992 symposium speech, Watson recalled that Wright's lectures left him with three questions: "What is the gene?...How is the gene copied?...How does the gene function?" A life's work in embryo.

At nineteen Watson had charted the course of his career. It could easily have gone otherwise. In *Avoid Boring People*, he talks up the advantage of knowing as soon as you can the work you want to devote yourself to. That he was "initially excited by virtually all aspects of biology" could have diverted him from "the most thrilling problem of all—the DNA structure." He adds, "If I had not figured out my focus so early, I very likely would have gone to a [graduate] school such as Cornell or Berkeley that had great programs in biology but not in genetics."

Taking the next step in his education, Watson again landed in the right place, Indiana University, after Caltech rejected him and Harvard offered him a place but no stipend. All for the best: At Harvard, genetics were piffling; at Caltech, the Linus Pauling cult of personality engulfed graduate students in the master's preoccupations. Indiana was both strong in genetics and hospitable to a young man with a lot of catching up to do in his new specialty. At Indiana, Watson's deficiency in mathematics was stoutly remediated, enabling him to take on the demanding physics at the heart of the new biology, especially "the forces at work in three-dimensional molecular structures [that] could not be described except with math."

But Watson's primary mentor would be the Italian-born Salvador Luria, a medical doctor by training, and another physicist drawn to innovative biology, whose expertise lay in the use of bacteriophage viruses to study the gene. Watson got a particular thrill from Luria's talk of his long collaboration with Max Delbrück, the German-born physicist whose thoughts on genetics had been the basis of Schrödinger's *What Is Life?* "In learning how phages multiply," Watson wrote, they "thought the fundamental mechanism of how genes are copied would also become known." This is the all-consuming question Watson had come to pursue: "We were thinking about nothing but the gene," Luria would reminisce years later. That suited Watson perfectly. He earned his Ph.D. in 1950 with a dissertation on "the biological properties of x-ray inactivated bacteriophage." He was 22.

Luria and Delbrück thought the next stage for Watson should include Europe and biochemistry, and they helped to arrange a fellowship for him to work with Herman Kalckar in Copenhagen. Kalckar turned out to have little interest in DNA, and, in any case, biochemistry was not the thing for Watson.

A conference in Naples, however, enlivened him greatly. There Watson heard a talk by Maurice Wilkins on his DNA research, which included an X-ray diffraction photograph of the molecule. Watson tried his best to convince Wilkins to take him on in his lab, but Wilkins did not know what to make of this bumptious American, and turned him aside. The best available place for Watson, then, was the Cavendish Laboratory in Cambridge, where the finest X-ray crystallography of macromolecules was being done. Luria exploited his connection with a Cavendish friend and Watson was on his way.

Honorable Ambition

For the discovery of the structure of DNA we turn now to Watson's own account in *The Double Helix*. The book provides a privileged view of how science is done at the very highest level, and is quite unlike any account before it.

While many loved the book, a number of distinguished scientists took offense at Watson's intellectually libertine confessions. Crick was furious at first, and one can see why. "I have never seen Francis Crick in a modest mood" is the book's opening sentence, and the tone of slick irreverence runs throughout the work, often descending to sneering and cat-calling at lesser mortals. Watson is indeed baiting Crick here, but he is also leading with the suggestion that there are men, and minds, who have nothing to be modest about. And there is a disarming immodesty to the observation that marks the writer as every bit Crick's equal in self-regard. The story will demonstrate that Watson is right to think so well of himself—but then, it is Watson telling the story.

Well before the historic discovery, Crick exuded an atmosphere of thrilling anticipation. Great things were always just around the corner, even when on the last turn he'd hit a brick wall:

> Often he came up with something novel, would become enormously excited, and immediately tell it to anyone who would listen. A day or so later he would often realize that his theory did not work and return to experiments, until boredom generated another attack on theory.

This is the mental rhythm of a life structured by the tendency Nietzsche found in himself—"to make knowledge the most *powerful passion.*" Although Crick was still working on his doctorate at 35, trying to figure out hemoglobin, his mind did not take to the routine work that satisfies run-of-the-mill scientists.

Watson broaches the matter of pride in one's intellectual rank as a primary fact of scientific life. This pride made smaller creatures, protective of their territory, wary of Crick. He showed no mercy for the mediocre, who overran even the brain-rich preserve of Cambridge. Crick claimed the university was "dominated by pedantic, middle-aged men incapable of either amusing or educating him in anything worthwhile." And Cambridge was hardly alone in elevating the inept. To Crick, "One could not be a successful scientist without realizing that, in contrast to the popular conception supported by newspapers and mothers of scientists, a goodly number of scientists are not only narrow-minded and dull, but also just stupid."

As soon as Watson met Crick, he knew Cambridge was his rightful intellectual home. "Finding someone…who knew that DNA was more important than proteins was real luck," writes Watson. And it was lucky for Crick too. For all his prowess, without Watson his intellect would have gone to waste. Enter the catalytic hero, who aroused his new colleague to the questions that ought to set the most serious scientific career aflame with passion. "Before my arrival in Cambridge, Francis only occasionally thought about deoxyribonucleic acid (DNA) and its role in heredity. This was not because he thought it uninteresting. Quite the contrary." Rather, Crick was just beginning to be adept with proteins—the former physicist had been a biological researcher for only two years.

Moreover, DNA was, "for all practical purposes, the personal property of Maurice Wilkins," Crick's friend at King's College London. "The combination of England's coziness—all the important people, if not related by marriage, seemed to know one another—plus the English sense of fair play would not allow Francis to move in on Maurice's problem." In America they ordered things differently. "One would not expect someone at Berkeley to ignore a first-rate problem merely because someone at Cal Tech had started first. In England, however, it simply would not look right."

This English innocence American experience would correct, and perhaps corrupt; Henry James is Watson's favorite novelist, and Watson inverts the terms of James's characteristic transatlantic moral education. Watson would convince Crick that self-seeking in the pursuit of honorable ambition is as important to scientific advancement as the disinterested pursuit of the truth. English colleagues at King's College whom Watson immediately understood to be rivals would learn the hard way that scientific discovery is as competitive as politics, money-making, or any Olympic sport: "You did not move cautiously when you were holding dynamite like DNA." Watson might fracture his metaphor here, but he is on to a significant truth. Wilkins was all too cautious, and his diffidence would prevent him from claiming the prize that bolder hands would grasp.

Watson and Crick suffered no such hesitation. "Our lunch conversations quickly centered on how genes were put together. Within a few days after my arrival, we knew what to do: imitate Linus Pauling and beat him at his own game." Crick schooled Watson in the triumphant modus operandi of Pauling, the chemist without peer.

Reading Pauling's paper on the alpha-helix structure of proteins thrilled Watson, even though he lacked the knowledge to judge "whether it made sense. The only thing I was sure of was that it was written with style." Watson, who didn't shrink from displaying his mental doodling, became infatuated by the thought of one day being accomplished enough to display his own intellectual aplomb:

> Again [Pauling's] language was dazzling and full of rhetorical tricks. One article started with the phrase, "Collagen is a very interesting protein." It inspired me to compose opening lines of the paper I would write about DNA, if I solved its structure. A sentence like "Genes are interesting to geneticists" would distinguish my way of thought from Pauling's.

There is of course leg-pulling here, but the emulation of Pauling, and not only of his divine style, would prove to be dead earnest. And Pauling was not only Watson's inspiration, but would soon become his most feared competitor.

Pauling's secret was "his reliance on the simple laws of structural chemistry." He had found the alpha-helix structure of proteins not "by only staring at X-ray pictures; the essential trick, instead, was to ask which atoms like to sit next to each other. In place of pencil and paper, the main working tools were a set of molecular models superficially resembling the toys of preschool children."

What worked with proteins for Pauling ought to work with DNA for Watson and Crick. Their understanding of Pauling suggested a trial-and-error method for their own research. "All we had to do was to construct a set of molecular models and begin to play."

The Race Is to the Swift

Following Pauling's method, simplicity seemed to be the order of the day. Yet even the simple facts presented theoretical difficulties. It was obvious right away that determining the structure of DNA was a much tougher proposition than Pauling's discovery of the alpha-helix structure of proteins. The alpha helix involved but a single chain of amino acids, held in its helical shape by hydrogen bonds. But the greater diameter of the DNA molecule indicated the presence of more chains of nucleotides, constituting a compound helix, with the chains wrapping around each other.

Deciphering how the chains of DNA formed a compound helix was hard enough, but each chain of DNA presented its own complications. DNA contains four different types of nucleotides, with four different nitrogenous bases: two purines (adenine and guanine) and two pyrimidines (cytosine and thymine). DNA "was not a regular molecule but a highly irregular one." Indeed, it *had* to be irregular, for "if the base sequences were always the same, all DNA molecules would be identical and there would not exist the variability that must distinguish one gene from another."

Yet there was still some regularity to DNA. While the four nucleotides had different bases, each was also composed of sugar and phosphate, and only these sugar and phosphate groups were involved in the junctions between nucleotides. In part based on this regularity and in part as a simplifying guess, Watson and Crick decided to assume that the nucleotides were all linked together by the same type of chemical bond, and that the variability between different DNA molecules came from differences in the sequences of the bases.

X-ray diffraction data on the crystalline form of DNA would speed the model-building process, first by ruling out a good many structural possibilities. The published literature had "one half-good photograph" taken five years earlier, but Watson and Crick knew that Wilkins had his own photos, and better ones. Being able to use the photos would save them a lot of time and effort. The gentlemanly boundaries of English scientific propriety would have to be violated.

Wilkins, it turned out, was surprisingly agreeable to discussing his findings and speculations. On the basis of his X-ray evidence, he hypothesized a triple helix. But he believed that better pictures would have to be taken before anything useful could come of model-building.

Enter Rosalind Franklin, the X-ray diffraction expert in Wilkins's laboratory. Wilkins had run afoul of Franklin, who guarded her province with dagger drawn. Though Wilkins was her nominal superior, she intimidated him, and pressed him not to take any more DNA photos of his own.

In the hope of continuing his own diffraction work and preserving a modicum of self-respect, Wilkins had struck a bargain with Franklin that worked out badly for him: He gave her all the good crystalline DNA he had been using. The DNA she permitted him to keep, he discovered, did not crystallize at all. None of this mollified her. "The point had been reached where Rosy would not even tell Maurice her latest results."

Watson's notoriously gossipy recollections in *The Double Helix* are most striking when he describes Franklin. He presents her as a dour, mannish virago, and uses the nickname "Rosy," a diminutive her colleagues used behind her back and which she hated. At one point, his condescension becomes something worse: "There was not a trace of warmth or frivolity in her words. And yet I could not regard her as totally uninteresting. Momentarily I wondered how she would look if she took off her glasses and did something novel with her hair."

Franklin was a stern empiricist, with lofty disdain for highly theoretical model building. In Watson's telling, her insistence on experiment and abstruse mathematical formulation kept her from exploring the luminous theoretical possibilities that would eventually win the day. "It was downright obvious to her that the only way to establish the DNA structure was by pure crystallographic approaches.... The idea of using tinker-toy-like models to solve biological structures was clearly a last resort." As for Pauling's own success with this approach, "only a genius of his stature could play like a ten-year-old boy and still get the right answer."

Since Watson was barred from any privileged access to Franklin's work, his only avenue was a public talk at which she would be presenting her recent findings. He read up on crystallography and went to hear Franklin in mid-November 1951. Content with her circumscribed mastery, she was quick to discount any mode of attack but her own. Nothing much could be expected of DNA research, she assured the audience, until superior diffraction results disclosed the truth. Her hard-faced authority put a chill on the listeners:

> Maybe their reluctance to utter anything romantically optimistic, or even to mention models, was due to fear of a sharp retort from Rosy. Certainly a bad way to go out into the foulness of a heavy, foggy November night was to be told by a woman to refrain from venturing

> an opinion about a subject for which you were not trained. It was a sure way of bringing back unpleasant memories of lower school.

Watson himself is seriously unpleasant here, crude and sexist. Yet it may seem that, as the end results would prove, there is some truth in his criticism of the limitations of her approach (more about this controversy later).

In the meantime, however, Watson would have to endure being treated as a fool by Franklin, and rightly so. For Watson, who is famously disinclined to take lecture notes—he is known for reading the newspaper while listening to complex presentations—simply did not know enough crystallography to take in and remember salient facts of Franklin's talk. So when Watson later repeated to Crick the water content of her DNA samples, he was flagrantly wrong. Their initial model was consequently a hopeless wreck of a triple helix, with the sugar–phosphate backbones in the center and the bases facing outward. Their consternation was complete when a troupe from King's College accepted an invitation to come examine the premature marvel. Watson had fumbled the water numbers badly. The correct model, as Franklin pointed out, would have to account for ten times as much water as their laughable failure, and with that revised water content a crushing superabundance of DNA models suddenly became possible.

Watson and Crick's fiasco appeared decisive to Sir William Lawrence Bragg, then the director of the Cavendish Laboratory. A 1915 Nobel laureate for his pioneering work in crystallography, Bragg knew little and cared less about DNA. But he recognized a waste of time when he saw it, and imposed a ban on their project. Crick was to return to his doctoral study of hemoglobin, Watson to see what he could make of tobacco mosaic virus.

But thought is free, as Stephano observes in *The Tempest*, and Bragg lacked the resources at Prospero's disposal to keep the boys from their mischief. Conversation over lunch at The Eagle, their pub of choice, naturally turned to DNA, as they pondered the mistakes they had made and contrived to set them right the next time. They kept themselves apprised of developments in London, where Franklin was more certain than ever before that DNA was not a helix. "Rather than build helical models at Maurice [Wilkins]'s command, she might twist the copper-wire models about his neck." In fact, Wilkins was no longer proceeding with model-building—and Watson was encouraged that progress at King's College had stalled.

The Competition

As Watson and Crick ground on with their forced labor, the flow of revelatory talk about DNA continued, not only between the two of them but with others. Watson told Crick about the findings of Erwin Chargaff, a Columbia University biochemist and world authority on DNA, that there were "some curious regularities" in "the relative proportions of [DNA's] purine and pyrimidine bases. In all their DNA preparations, the number of adenine (A) molecules was very similar to the number of thymine (T) molecules, while the number of guanine (G) molecules was very close to the number of cytosine (C) molecules." Chargaff didn't know what to make of these findings, and at first neither did Watson or Crick. In due course, furious brainstorms would produce a deluge of novel speculation.

Talking with the chemist John Stanley Griffith over beers after an astronomer's evening lecture on the perfect cosmological principle, Crick "popped out with the idea that the perfect biological principle was the self-replication of the gene—that is, the ability of a gene to be exactly copied when the chromosome number doubles during cell division." Griffith countered Crick's like-produces-like scheme with an alternative procedure in which the gene was duplicated by "the formation of a complementary (negative) image where shape was related to the original (positive) surface like a lock to a key. The complementary negative image would then function as the mold (template) for the synthesis of a new positive image." Crick and Griffith knew they were rehearsing a thirty-year-old argument conducted by genetic theoreticians, and neither was pleased with his own or the other's lack of originality.

Originality would appear by and by, in unexampled connections. Crick had "the feeling that DNA replication involved specific attractive forces between the flat surfaces of the bases." In a conversation at the Cavendish tea queue some days later, Griffith reinforced Crick's hunch by telling him that "a semi rigorous argument hinted" at just such forces binding adenine to thymine and guanine to cytosine. At this point, Crick vaguely but enthusiastically recalled Watson telling him of Chargaff's base proportions. Watson confirmed those data at lunch, and although Crick hesitated to make too much of the possibility just yet, it seemed not impossible that "Chargaff's regularities had their origin in the genetic code. In some way specific groups of nucleotides must code for specific amino acids. Conceivably, adenine equaled thymine because of a yet undiscovered role in the ordering of the bases."

Watson and Crick would have the dubious privilege of meeting Chargaff on his visit to Cambridge, when they told the distinguished guest of their DNA work and were subjected to his self-delighted mockery. Crick fell before the withering fire of Chargaff's ridicule when he could not remember the fundamental chemistry of the bases and said he could always look it up in a book. Pompous as a maharajah, disagreeable as barbed wire—many who encountered him found him insufferable—Chargaff would memorialize the upstarts, in his little-read memoir, as "two pitch-men in search of a helix." But they would discern the significance of his experimental data as he could not, and in Watson's memoir he would become a minor comic figure made to last.

For a good long while, however, Watson and Crick even stopped discussing DNA at lunch. The momentary impetus given them by the potential connection between the Chargaff data and the gene's replication soon dwindled. They fiddled intermittently with their models but had made no substantial progress in the year since their debacle. In London, meanwhile, Franklin had announced she was leaving King's College for J. D. Bernal's lab at Birkbeck College, and abandoning DNA altogether. Once she had written up her DNA results for publication, she would head off, and the reanimated Maurice Wilkins intended to mount his own offensive on the structure as soon as she was gone.

Then Linus Pauling entered the competition. His son Peter was now a Cavendish officemate of Watson and Crick's, and in December 1952 he showed them a letter from Linus saying he had a structure for DNA. "Francis then began pacing up and down the room thinking aloud, hoping that in a great intellectual fervor he could reconstruct what Linus might have done. As long as Linus had not told us the answer, we should get equal credit if we announced it at the same time."

By the first week of February 1953 they got Linus's answer. Peter Pauling and lab director Lawrence Bragg each received a manuscript copy of Linus's soon-to-be-published paper. Watson and Crick felt the sharp bite of chagrin when Peter told them his father's model was a triple helix with the sugar–phosphate backbone in the center—"so suspiciously like our aborted effort of last year that immediately I wondered whether we might already have had the credit and glory of a great discovery if Bragg had not held us back."

Watson yanked the manuscript out of Peter's coat pocket and got right down to the essential figures. They were inexplicable. Each phosphate group, which ought to be negatively charged, was not ionized; a hydrogen atom bound to the phosphate gave it no charge whatsoever, and these hydrogens were indispensable to keeping the three conjoined helical chains from coming unglued. "If a student had made a similar mistake, he would be thought unfit to benefit from Cal Tech's chemistry faculty." This legendary grand master had gotten the structure so far wrong that Watson and Crick had to wonder for a moment if Pauling hadn't based his model on some monumental discovery—"a revolutionary re-evaluation of the acid-base proportions of very large molecules." But there was no such discovery. Linus had botched the job.

Yet once Pauling's paper would be published and he would be made to realize his mistake, Watson and Crick feared he would be driven to work on the problem until he got it right. "We had anywhere up to six weeks before Linus again was in full-time pursuit of DNA." Too excited to work any more that day, Watson and Crick retired to The Eagle, "to drink a toast to the Pauling failure. Instead of sherry, I let Francis buy me a whiskey. Though the odds still appeared against us, Linus had not yet won his Nobel."

Closing In

The hunt resumed with renewed energy. The great man's pratfall reinvigorated Watson and Crick with hope of surpassing him.

Several days later Watson went to London to tell Wilkins the news. But as Wilkins was otherwise engaged when Watson arrived, the visitor dropped in on Franklin first. When he told her how Pauling had stumbled, she grew annoyed, "for she knew that Pauling was wrong the moment I mentioned a helix. Interrupting her harangue, I asserted that the simplest form for any regular polymeric molecule was a helix." Franklin fulminated: If only he would study her X-ray photos, he would see clearly how stupid he was being. Watson had in fact heard from Wilkins months before that her photos gave plain evidence of a helix, and he replied that she must be inept at her work. "If only she would learn some theory, she would understand how her supposed antihelical features arose from the minor distortions needed to pack regular helices into a crystalline lattice."

Suddenly Franklin advanced upon the startled Watson with blood in her eye. Fearing for his skin, Watson hastened for the door, where he ran into Wilkins. They went off together, but Watson's clash with Franklin set the stage for the indispensable revelation. "My encounter with Rosy opened up Maurice to a degree that I had not seen before. Now that I need no longer merely imagine the emotional hell he had faced during the past two years, he could treat me almost as a fellow collaborator rather than as a distant acquaintance."

The freshly forthcoming Wilkins invited Watson to look at a photo Franklin had taken of "a new three-dimensional form of DNA. It occurred when the DNA molecules were surrounded by a large amount of water.… The instant I saw the picture my mouth fell open and my pulse began to race." This well-hydrated form of DNA showed the helical structure unmistakably, and "mere inspection of its X-ray picture gave several of the vital helical parameters. Conceivably, after only a few minutes' calculation, the number of chains in the molecule could be fixed." This time Watson took in each detail and held it fast. On the way back to Cambridge he opted for the double-helix model over the triple. "Francis would have to agree. Even though he was a physicist, he knew that important biological objects came in pairs."

Crick was hung over that morning and slow to appreciate Watson's burst of enthusiasm. But when Watson told him the photo indicated the diameter of the helix, the thickness of the bases, their arrangement one atop the other, and their orientation perpendicular to the helical axis, Crick was on the alert. He still had his doubts, however, about the double helix, and thought it best to keep the triple in mind as well. Watson did not argue, but "would of course start playing with two-chain models."

But first, Watson had his moment of reckoning with Professor Bragg. Appealing to his sense of national and institutional honor, emphasizing the peril of letting Pauling work away feverishly while the Cavendish dawdled, the American hell-bent on glory made the English grandee understand that the instant must be seized. Bragg was more than agreeable, urging Watson to build all the models he needed.

Now seriously at play, Watson ran into more and more difficulties with the model featuring a central sugar–phosphate backbone, and figured he might as well see what he could do with some outer-backbone alternatives. The result conformed happily to the crystallographic evidence, and the backbone-out model was there to stay.

They were getting close. Watson believed for a spell that he had the answer with "two intertwined chains with identical base sequences," adenine with adenine and so on, joined by hydrogen bonds. The promising idea would make one chain the template for the synthesis of the other, thus neatly answering the question of how genes replicate; but it was wrong nonetheless. The crux of the problem was that Watson and Crick initially believed that, for each DNA base, there were roughly equal proportions of different tautomeric forms—minor molecular variants that feature hydrogen atoms at different positions. Using a standard organic chemistry textbook as his guide, Watson was led astray. The American chemist Jerry Donohue, another officemate and a recognized wizard in the subject of hydrogen bonds, set Watson straight: "In fact, organic-chemistry textbooks were littered with pictures of highly improbable tautomeric forms." With the real forms in place, the like-with-like structure was an impossibility.

Getting this impossibility out of the way was a major step toward triumph. Work continued the next morning, as Watson used cardboard representations to try out pairs of bases joined by hydrogen bonds:

> When Jerry came in I looked up, saw that it was not Francis, and began shifting the bases in and out of various other pairing possibilities. Suddenly I became aware that an adenine-thymine pair held together by two hydrogen bonds was identical in shape to a guanine-cytosine pair held together by at least two hydrogen bonds. All the hydrogen bonds seemed to form naturally; no fudging was required to make the two types of base pairs identical in shape.

He asked Donahue if there was anything to disapprove of in this combination. Donahue could see nothing wrong with it.

This was it. The bases and their bonds were a perfect fit. Everything was a perfect fit:

> Two irregular sequences of bases could be regularly packed in the center of a helix if a purine always hydrogen-bonded to a pyrimidine. Furthermore, the hydrogen-bonding requirement meant that adenine would always pair with thymine, while guanine could pair only with cytosine. Chargaff's rules then suddenly stood out as a consequence of a double-helical structure for DNA. Even more exciting, this type of double helix suggested a replication scheme much more satisfactory than my briefly considered like-with-like pairing. Always pairing adenine with thymine and guanine with cytosine meant that the base sequences of the two intertwined chains were complementary to each other. Given the base sequence of one chain, that of its partner was automatically determined. Conceptually, it was thus very easy to visualize how a single chain could be the template for the synthesis of a chain with the complementary sequence.

When Crick came in, Watson proclaimed that "the answer to everything" was about to be theirs. Crick was slow to celebrate; but after he had tried numerous variations on base-pair connections and found that only the AT and GC pairs worked, he was all but convinced. And then, displaying his terrific ability to visualize in three dimensions, Crick observed that the way the bases were bonded to the sugar backbone showed that "both pairs could be flipflopped over and still have their glycosidic bonds [those joining the base and sugar] facing in the same direction. This had the important consequence that a given chain could contain both purines and pyrimidines. At the same time, it strongly suggested that the backbones of the two chains must run in opposite directions."

The work was not over yet. The definitive model still had to be built. But the celebration was on. A discovery of this magnitude called for a rich flow of emotion and words to match; decorous understatement would not do. Despite Watson's misgivings, "at lunch Francis winged into the Eagle to tell everyone within hearing distance that we had found the secret of life."

The hard thing about the model—besides building it—was telling Wilkins about it. A note from Wilkins had informed Crick that the Londoner was now going to power down on DNA. Watson and Crick asked somebody else to call Wilkins and tell him to come look at their discovery. "Maurice needed but a minute's look at the model to like it." Watson had feared that Wilkins would be downcast at his own missed opportunity. In the event, he acted not like a defeated contender but rather like an estimable colleague uplifted by the implications of the discovery. Soon after arriving back in London, Wilkins called to say that his and Franklin's X-ray data verified the diffraction pattern that the model predicted.

Franklin reacted similarly. "Rosy's instant acceptance of our model at first amazed me. I had feared that her sharp, stubborn mind, caught in her self-made antihelical trap, might dig up irrelevant results that would foster uncertainty about the correctness of the double helix." In fact, even before their launch, she had been coming around to believing in the helix. And she was quite over her ferocious personal distaste for Watson and Crick. Collegial, even warm, she treated them as equals for the first time. "Obviously affecting Rosy's transformation was her appreciation that our past hooting about model building represented a serious approach to science, not the easy resort of slackers who wanted to avoid the hard work necessitated by an honest scientific career."

So elegant in form, so simple, so sleek, so ideally suited to its function, the double helix convinces one of its truth by its very beauty. Drawn schematically, "the structure resembles a spiral staircase with the base pairs forming the steps." In a sentence that could rival anything Pauling wrote for its concise rhetorical effectiveness, Watson and Crick conclude their April 1953 paper in *Nature* announcing their discovery, "It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material."

To replicate itself, the DNA unzips down the middle, forming two separate strands, each with a sugar–phosphate backbone joined to a series of bases; then each strand synthesizes its only possible complement, so that there are two identical double helices where one had been before. The importance of this insight, hinted at in the conclusion of the Watson–Crick paper, cannot be overstated. Faithful copying is essential for any gene-bearing molecule. But the unzippable helix of paired bases also suggested a way in which DNA could serve as the "code-script" that Schrödinger said controlled the life of cells. The sequence of bases is a template not only for copying itself, but also for the sequence of amino acids in the many proteins that make up a living cell.

Before the discovery of DNA's structure, it was a mystery how this mostly chemically inert molecule could be responsible for anything, let alone the whole of an organism's hereditary nature. But Watson and Crick's double helix showed scientists how to think about genetics as a code in the four letters of DNA's bases. DNA's molecular structure and its function henceforth became inseparable.

The Double Helix and Its Discontents

Watson was a distinguished Harvard professor when Harvard University Press leapt at the chance to publish *The Double Helix.* Complications soon ensued. As Watson sent Crick early drafts of his book in 1966 and 1967, Crick responded with heat, insisting Watson not publish it. Crick objected to Watson's scanting the science in favor of gossip, declared the book "misleading because it does not in fact accurately convey the atmosphere in which the work was done," derided the "poor taste" of the style, pleaded a gross invasion of privacy, and protested the inexcusable "violation of friendship."

Watson could not placate Crick, but never wavered in his resolve to publish. But then Crick, joined by Wilkins, had their attorneys write to the president of Harvard, Nathan Pusey, howling lawsuit. Errol C. Friedberg, author of *The Writing Life of James D. Watson*, points out that they did not mention libel, so the basis of their legal threat was hazy. Nevertheless, the menacing Nobel laureates scared Pusey off, and he canceled publication. Watson promptly found another publisher, the newly founded Athenaeum Press, and he would later take satisfaction in writing of how much Harvard had lost in royalties.

He could take satisfaction as well in the glowing reviews his book received from accomplished figures (many of which are collected in the Norton Critical Edition of the book). Richard Lewontin, professor of biology at Chicago and later at Harvard, praised Watson's frankness about the competitive aspect of science. "What every scientist knows, but few will admit, is that the requirement for great success is great ambition. Moreover, the ambition is for personal triumph over other men, not merely over nature." Jacob Bronowski, of the Salk Institute for Biological Studies, delighted in the very style that Crick so deplored, finding in it "a quality of innocence and absurdity that children have when they tell a fairy story. The style is shy and sly, bumbling and irreverent, artless and good-humored and mischievous, so that the book leaves us with the spirited sense of intellectual knockabout of a novel by Kingsley Amis."

Peter Medawar, a Nobel laureate and pioneer in immunology, wrote, "It is simply not worth arguing with anyone so obtuse as not to realize that this complex of discoveries is the greatest achievement of science in the twentieth century." Watson has told his part of that story with uncommon skill, and his readers will be changed by hearing it. "No layman who reads this book with any kind of understanding will ever again think of the scientist as a man who cranks a machine of discovery. No beginner in science will henceforward believe that discovery is bound to come his way if only he practices a certain Method, goes through a certain well-defined performance of hand and mind."

There were, however, distinguished detractors besides Crick and Wilkins, and certain reviews amounted to enemy action. The irrepressible Erwin Chargaff damned Watson and Crick as characteristic specimens of the "new kind of scientist," who "could hardly have been thought of before science became a mass occupation, subject to, and forming part of, all the vulgarities of the communications media." To Chargaff, *The Double Helix* exhibited the grubby vices of the lower journalism and dishonored the scientific vocation: "I believe it is only recently that such terms as the stunt or the scoop have entered the vocabulary of scientists."

Biologist Robert Sinsheimer of Caltech found both the scientist and the private man unworthy. "This story is of such interest that one can overlook its atypical aspects, that Watson and Crick were relying upon cadged data from the X-ray studies of Franklin and Wilkins—overheard in seminars, pried out in conversations.... Or the somewhat bogus suspense provided—repeatedly—by the synthetic race with the demigod Pauling." Sinsheimer clearly does not overlook those unsavory aspects, but rather savors their repugnant taste. As for "the private world of J. D. Watson...

this is unbelievably mean in spirit, filled with the distortions and cruel perceptions of childish insecurity. It is a world of envy and intolerance, a world of scorn and derision. This book is filled with character assassination, collective and individual, direct and indirect."

Some of the harshest dissent came from the defenders of Rosalind Franklin. As Brenda Maddox writes in the 2002 biography *Rosalind Franklin: The Dark Lady of DNA*, "Since Watson's book, Rosalind Franklin has become a feminist icon, the Sylvia Plath of molecular biology, the woman whose gifts were sacrificed to the greater glory of the male." Maddox cuts through both Watson's misprision and the fashionable agitprop, and portrays Franklin as a dedicated and accomplished scientist who was a congenial and generous colleague when she was treated with the respect she deserved, as she was not by Maurice Wilkins, or by Watson.

In the 1975 book *Rosalind Franklin and DNA*, Franklin's friend Anne Sayre prepares a cool and judicious brief against Watson's treatment of her. Sayre contains her nonetheless evident outrage and makes a cogent case for Watson's gross misrepresentation of Franklin's scientific work. What Watson makes of Franklin's November 1951 lecture is not only obnoxious about her person but also simply wrong about her findings:

> Rosalind's notes for this November lecture say, "*Conclusion: Big helix in several chains, phosphates on outside, phosphate-phosphate inter-helical bonds disrupted by water. Phosphate links available to proteins.*" She underlined it.
>
> This does not in itself provide the structure of DNA. But it contains some essential clues, without which the structure of DNA could not have been determined at the time at which it was.

Franklin's experimental data were indispensable to Watson and Crick's successful model-building. "Anyone hoping to build a model was obliged to have this information in order to know how many chains there were in the molecule," Sayre continues. "Without it, Crick and Watson cheerfully produced a three-chain model. The same was true of the location of the sugar-phosphate backbone, and this Rosalind also demonstrated."

That Franklin did not try to build a DNA model was not proof of her distaste for the slacker boys and their molecular toys, as Watson contends. She had in fact built a model of graphite in her earlier research, and she did not do so with DNA because she thought the groundwork was not complete. As it turned out, she did miss a promising opportunity that might have led to lasting glory. The preponderance of glory went to others, and Watson's famous book ensured that Franklin's contribution to the glorious work has been slighted, even while it made her name more widely known.

Sayre acknowledges, nevertheless, that Watson and Crick merit the acclaim their discovery has brought them. "Nobody denies, and I do not deny, that Watson and Crick found the structure of DNA, and a very beautiful piece of work it was. They, and no one else, deserve full credit for perceiving the nature of the base pairing; biologically speaking, this is what counts; and to have done this is in itself a very high and unarguable claim to glory." However, Sayre goes on to say that "the evidence for the rest of the structure lay in Rosalind's data which they received unorthodoxly," and by all rights they ought to have offered her joint authorship of their momentous paper.

Watson's impugning of Franklin's personality, moreover, was unfair and demeaning. And Franklin could not defend herself against Watson's belittling of her contributions or her character. She died in 1958, at the age of 37, of ovarian cancer, before *The Double Helix* and the Nobel Prize for DNA. Speculation continues about how she would have answered Watson had she lived, and whether she rather than Wilkins would have shared the Nobel with Watson and Crick. (Nobel Prizes are not awarded posthumously, and they are not shared by more than three recipients.) There is some measure of justice in her rehabilitation by sympathetic biographers, and even in Watson's own smarmy epilogue to *The Double Helix*, in which he admits that his personal and scientific judgments of her "were often wrong," and does what he can to correct his own record, though it is too little, too late.

Newfound Fame

Watson's Harvard teaching and research career was notably and typically tempestuous and transformative. As biographer Victor K. McElheny writes in *Watson and DNA*, from his arrival as an assistant professor in 1956, he rallied around him "a small group of scientists who were determined to move biology at Harvard beyond nineteenth-century-style description and classification, and, through reductionism, to focus on specific pieces of the puzzle of life that were amenable to experiment." Watson undertook to remake biology in his own image, and Harvard groaned but succumbed in the end.

One of his peers at Harvard was the entomologist, and later sociobiologist, E. O. Wilson. In his memoir *Naturalist*, Wilson recalls that Watson deployed the heroic prestige the double helix gave him to condemn the antiquated ways of conventional biology and to establish unequivocally in its place "a science directed at molecules and cells and rewritten in the language of physics and chemistry. What had gone before, 'traditional biology'—*my* biology—was infested by stamp collectors who lacked the wit to transform their subject into a modern science."

Lavish and brazen in his contempt, "the Caligula of biology" and "the most unpleasant human being" Wilson had ever known, Watson littered Harvard Yard with mauled corpses and bloody footprints. "He was given license to say anything that came to his mind and expect to be taken seriously. And unfortunately, he did so, with casual and brutal offhandedness." In 1958, when Wilson was granted tenure ahead of Watson, the scalded assistant professor was heard screaming obscenities as he climbed the stairs. Watson and his supporters made sure he got his promotion fast, and by 1967 Harvard had its own Department of Molecular Biology and Biochemistry, while the traditionalists formed a separate department all their own.

To his acolytes and admirers, this monster was sacred. The laboratory he headed made breakthroughs in the roles DNA and RNA play in protein synthesis. Watson generally left his own name off the published work, so that lesser-known colleagues could get world-class respect. He also turned his attention to cancer-causing viruses, which he would later call "the next big hard problem" after DNA. And with *Molecular Biology of the Gene*, he wrote the textbook designed to put an end to the vaporing of the mysterians—Crick's term for the vitalists who attribute some singular essence to living matter—and to shape a new clear-thinking generation of biologists:

> The growth and division of cells are based upon the same laws of chemistry that control the behavior of molecules outside of cells. Cells contain no atoms unique to the living state; they can synthesize no molecules which the chemist, with inspired, hard work, cannot some day make. Thus there is no special chemistry of living cells.

In 1968, Watson became director of the Cold Spring Harbor Laboratory (CSHL) on Long Island, for decades a premier institution that was now pitiably down-at-heel and in danger of extinction. When Wilson heard of the appointment, he said Watson could run a lemonade stand into the ground, but Watson proved a supremely capable administrator. "In ten years he raised that noted institution to even greater heights by inspiration, fund-raising skills, and the ability to choose and attract the most gifted researchers," Wilson would write. Watson took on the directorship as a side job, to be done in the time Harvard allowed its professors for outside consulting. In 1976 he would resign his professorship and head

Cold Spring Harbor full-time, later becoming its president and then its chancellor, until he retired in 2007.

As at Harvard, "he proved adept at exploiting fame," according to McElheny. Though he might sometimes have had the air about him of a social nudnik, and was in perpetual peril of saying precisely the wrong thing with fatal vehemence, he could be surprisingly gracious and talk convincingly with people he needed, from trustees to scientific recruits to building contractors. He used the press shrewdly in his surge toward heightened visibility and funding for the Laboratory, promoting the new emphasis on cancer research and telling a *New York Times* reporter he was "looking for someone who would like to give $5 million to cancer and restoring old buildings."

Saul Bellow has written that "money surrounds you in life as the earth does in death," and few know that suffocating feeling better than scientists trying to do cutting-edge research. Watson never had Pauling's smoothness in dealing with the money men, but he got the millions needed to turn the place around and make it thrive. He also proved adept at expanding the CSHL Press imprint, boosting the reputations of young researchers and the lab's income. "Surpluses from book sales provided so much money for renovation that CSHL could be regarded as the lab that books rebuilt," McElheny reports.

The best scientists came to work at Cold Spring Harbor, however, not because they stood to get rich, but because of Watson's prestige, and because he was known for demanding and getting the best work from the best people. McElheny writes that Watson saw the potential to expand what had been a narrow, short-sighted medical research program into an immense theoretical project that would in fact speed the desired practical solution: "Cancer research, hitherto so focused on treating existing illness, would extend into 'pure science,' Watson reflected. 'The solution to cancer lies in a fuller understanding of what happens after viruses enter cells.'" And the cancer work would also "speed up the transition of molecular biology—the field he helped define and advertise—from studying tiny, simple bacteria to tackling animal and plant cells many thousands of times more complex."

The Powers of the New Biology

One of the most important innovations to which Cold Spring Harbor contributed, and the most controversial, was recombinant DNA, sometimes known as DNA cloning or molecular cloning. This is the technique that allowed scientists "to move DNA freely from one species to another," in McElheny's succinct summation. Restriction enzymes, discovered in the early 1970s, would cut the targeted DNA into segments, and ligase enzymes would stitch the segments together in the desired configurations, to be inserted into bacteria. As the bacteria multiplied into colonies of billions of genetically identical microorganisms, the pieces of "recombinant" DNA that had been inserted into them would multiply with them, allowing scientists to mass-produce specific DNA sequences.

Twenty years after the discovery of the double helix, molecular biology was beginning to realize the powers modern men like Bacon and Descartes had longed to possess. As Watson writes in *DNA: The Secret of Life*:

> Phase 2 of the molecular biology revolution was thus under way. In phase 1 we aimed to describe how DNA works in the cell; now, with recombinant DNA, we had the tools to intervene, to manipulate DNA. The stage was set for rapid progress, as we spied the chance to "play God." It was intoxicating: the extraordinary potential for delving deep into the mysteries of life and the opportunities for making real progress in the fight against diseases like cancer.

Not everyone—not even every molecular biologist—relished the thought of this quasi-divine power in the hands of mere mortals. It made many reasonable people tremble, and Watson himself publicly confessed to misgivings about potential biological hazards, even catastrophes, that accidents might cause. Watson even signed the 1974 moratorium letter calling for scientists everywhere to suspend the most dangerous kinds of experiments—such as those that might introduce antibiotic resistance into new bacterial strains—"until the potential hazards of such recombinant DNA molecules have been better evaluated or until adequate methods are developed for preventing their spread."

Almost immediately, however, he began to regret his caution, which he suspected was not prudence so much as cowardice. Any biohazards were only potential, unproven, after all, and might be pure phantasms. His maledictions against pusillanimity and retrograde religiosity, and his exhortations to boldness, struck the customary note of medical emergency. The Asilomar Conference of one hundred and forty scientists in February 1975 saw Watson trying to restrain perfervid colleagues from "defer[ring] research on the basis of unknown and unquantifiable dangers. There were desperately sick people out there, people with cancer or cystic fibrosis—what gave us the right to deny them perhaps their only hope?" Moderation seemed to carry the day, "with coherent recommendations allowing research to continue on disabled, non-disease-causing bacteria and mandating expensive containment facilities for work involving the DNA of mammals."

The scientists hadn't counted on the power of the press. Reporting from and after Asilomar played up the prospect of uncontrollable plagues unleashed upon the innocent citizenry by scientists virtually malevolent in their unconcern. In response, know-nothing politicos dreamed up bogeymen to terrify the know-nothing public. The mayor of Cambridge, Massachusetts, proud nemesis of Harvard and MIT, wrote in 1977 to the National Academy of Sciences retailing newspaper stories of a bizarre orange-eyed half-man and a hairy nine-foot-tall creature sighted on public thoroughfares, and calling for an investigation into recombinant DNA experiments that might have spawned these monstrosities. Edward Kennedy, lion of the Senate, understood molecular biology to be as dangerous as atomic energy. In 1976, he pressed Gerald Ford for federal control of industrial and academic DNA research, and sponsored legislation to constrain all such work severely.

Scientists bit back. In a passionate exchange at Cornell, cited by McElheny, Watson declared that he "would eat grams of any K-12 strain carrying recombinant DNA rather than be licked by any neighbor's dog." In 1978, he proclaimed that it was "time to bury Asilomar." And Asilomar was buried shortly thereafter. Harvard lobbied Senator Kennedy strenuously, warning of the damage that medical research, a leading state industry, would suffer in the event of his bill's passage. The lion surrendered, purring. Molecular biologists made up for lost time.

Among the recombinant DNA innovations that Watson champions are genetically modified, or GM, agricultural crops. In *DNA: The Secret of Life*, he promotes the adoption of a tactic used by organic farmers to guard plants from insect infestation. The bacterium *Bacillus thuringiensis*, or Bt, produces a toxin that paralyzes the guts of crop-destroying caterpillars and beetle and fly larvae. It has been employed as a natural pesticide since 1938, when French farmers introduced its use. Since the mid-1990s, genetic engineers have inserted genes from the bacillus into the genomes of corn, potato, cotton, and soybean, producing "a whole range of Bt designer crops." Thus chemical pesticide use, with its dangers to human health and its devastation of harmless insects, has been heroically reduced.

Biotechnology can also put in what nature left out, thereby "enhancing the nutrient profile of crop plants, compensating for their natural shortcomings as sources of nourishment." The predominantly vegetarian diet that most people in the developing world eat of necessity is characteristically short of vital amino acids, and genetic modification can make good this deficit. And the widespread childhood blindness caused by lack of Vitamin A has been alleviated by the production of "golden rice," which adds beta-carotene, a crucial vitamin precursor, to the plant. "It is here that we see the broader promise of GM agriculture to diminish human suffering."

Big Money for Small Scientists

The capstone to Watson's career was the Human Genome Project: the sequencing of "the entire set of genetic instructions in the nucleus of every cell," as he describes it. Once again great ambition moved Watson, at a time when such an ambition seemed outlandish to many scientists. "It was like suggesting to a Victorian balloonist that he attempt to put a man on the moon."

An old antagonist of Watson's, the biologist Robert Sinsheimer, by then chancellor of UC Santa Cruz, sought to take advantage of an immense foundation windfall to establish a top-dollar institution for biologists that would rival physicists' supercolliders and astronomers' telescopes in grandeur and exorbitance. The U.S. Department of Energy, which investigates the health risks of nuclear power, had been studying the genetic damage done to Hiroshima and Nagasaki survivors and their descendants. To home in on radiation-induced mutations, the knowledge of the full human genome would be invaluable. The head of the National Institutes of Health scoffed that the DOE could think of such a project, but in the end both government agencies would play a significant role in the Human Genome Project coalition, with the NIH at the vanguard.

In the spring of 1986, Watson convened a meeting on the project at the Cold Spring Harbor Laboratory, and discussion grew contentious after Harvard biochemist Walter Gilbert declared that sequencing three billion base pairs would cost three billion dollars. The scale of the project, some complained, threatened to swallow whole the careers of numerous scientists, who would devote their entire energies to "the endless tedium of sequencing, sequencing, sequencing," Watson writes. But he emerged with the conviction that this "was destined soon to become an international scientific priority," and he devoted his own unflagging energies to getting the colossal enterprise underway.

He was a leading member of the fifteen-person exploratory committee of the National Academy of Sciences that met throughout 1987 and published its report the next year. It expected the project to take fifteen years and the full three billion dollars to complete. At first, sequencing of simpler organisms' smaller genomes—*E. coli*, baker's yeast, nematode, fruit fly—would prepare the way for sequencing the human genome.

Watson's role in the project would be to exercise his formidable administrative abilities. Hitting Congress up for $30 million to start the NIH on the genome track, he accentuated the potential that genomic knowledge had to help cure dread diseases. "Lawmakers, like the rest of us, have all too often lost loved ones to diseases like cancer that have genetic roots.... In the end we got $18 million."

In September 1988, it was announced that Watson would head the NIH's part in the genome program. When that part expanded under the enhanced title of the National Center for Human Genome Research, he was the natural choice to lead it. He was a budget hawk, taking command of the purse-strings, ensuring that the project's monies be held separate from the general NIH budget, and deciding to set aside three percent of the budget for "exploring the ethical, legal, and social implications" of the project. (Later, under political pressure, this portion was increased to five percent.)

Watson insisted that the project never fall into the hands of bureaucrats. "We are all small scientists. Big science is no good. We have to give the money to bright people. The program has to be run by scientists, not by NIH administrators." He enlisted an international consortium of scientists to take part in the work, though the bulk of the labor would be handled by the Americans. When the U.K.'s Medical Research Council, which had overseen the double-helix discovery, was reduced to a small role because of "Mrs. Thatcher's myopically stingy funding policies," Watson tapped the more generous privately funded Wellcome Trust, which built a sequencing operation near Cambridge.

He made himself unpleasant in the extreme to the head of the Japanese end of the project, demanding that Japan devote at least $300,000 a year to it or pack the whole show up. He got the required commitment, though a goodwill ambassador had to be dispatched in his wake to mollify the hard feelings. Watson shrugged off the international incident: "I've found you never get anywhere in the world by being a wimp."

At home, fearing chaos and cost overruns if too many labs were involved, he distributed the work among a half-dozen centers at major universities. Bringing the cost of sequencing down from ten dollars to fifty cents per base pair was a major priority. It issued in the development of the polymerase chain reaction, a method for purifying and mass-producing DNA segments under scrutiny, and an improved sequencing machine that could sequence half a million base pairs daily. "It was ultimately this technology that made the genome project doable."

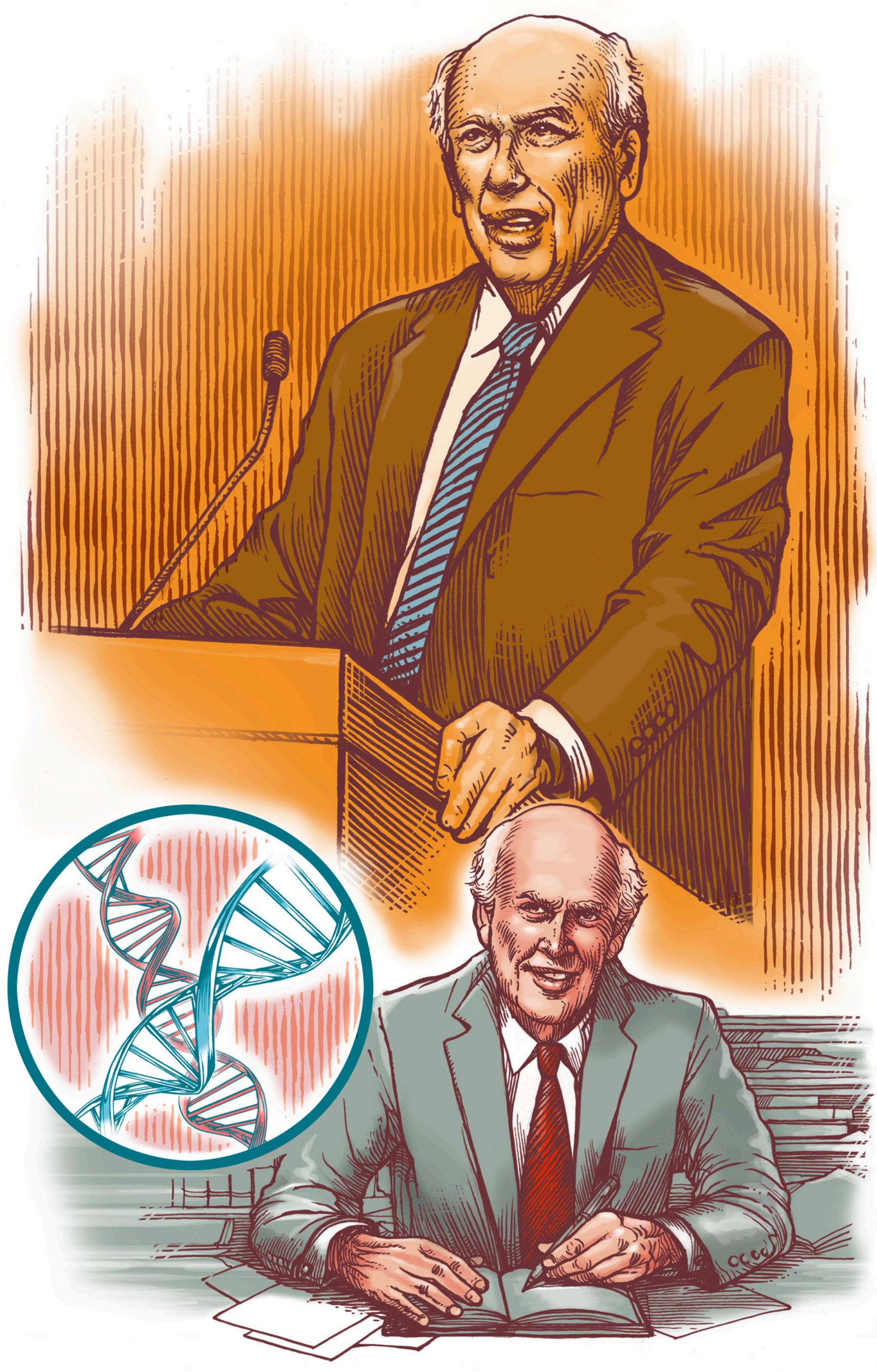
Watson lasted as director until 1992, when he was compelled to resign. A dispute had gathered force about the proposed patenting of strings of DNA known as "expressed sequence tags" or ESTs, which provided a useful shortcut for gene sequencing by allowing scientists to skip some of the onerous steps of locating genes on chromosomes. Fledgling biotech entrepreneur Craig Venter sought patents, and the new director of the NIH, Bernadine Healy, supported the move. Watson called the proposal "sheer lunacy," for patenting ESTs "could not pass the legal requirement for utility," as McElheny tells the story in his 2010 book *Drawing the Map of Life: Inside the Human Genome Project.* Watson helped to ignite a furor among his fellow scientists, and in time the U.S. Patent and Trademark Office disallowed the patents.

Healy was soon looking for an excuse to get rid of Watson, and he gave her one. In 1991 the entrepreneur Frederick Bourke tried to pry loose a pair of Watson's most esteemed researchers from the genome project and lure them to his Seattle start-up. Watson lit into Bourke. He convinced the British—one of the researchers was in England—to come through with the funds needed to keep his man on the job. Bourke protested to Healy, pointing out that Watson owned shares in several biotech firms and arguing that he had acted as a business rival. At the beginning of his term, Watson had been granted a waiver by the NIH that allowed him to keep these shares. But Healy now suspected conflicts of interest and forced Watson out.

He would continue as a highly effective lobbyist for the project. And he would return to the subject repeatedly in his writings. In June 2000, President Clinton honored the successful completion of the first draft of the Human Genome Project, proclaiming, "Today, we are learning the language in which God created life.... With this profound new knowledge, humankind is on the verge of gaining immense new power to heal."

For Moral Good and Ill

When Watson convened the meeting at Cold Spring Harbor in the spring of 1986 to discuss the feasibility of sequencing the human genome, he and his wife, Elizabeth, told arriving conferees that the previous day their sixteen-year-old son Rufus had made good his threat to run away from a psychiatric hospital. He had been committed there after trying to break a window in the World Trade Center to jump to his death. Two days after



Dave Cheng (https://www.instagram.com/smiley_dafe/)

his escape, Rufus was found wandering in some woods. The probable diagnosis was schizophrenia.

In the 2016 book *The Gene: An Intimate History*, the oncologist Siddhartha Mukherjee writes, "To Watson, a firm believer in the genetic basis for the disease, the Human Genome Project had come home—literally." Victor McElheny recounts Watson's memories years after the episode, his customary missionary zeal for human betterment amplified by a wounded father's love. Helping Rufus meant understanding the genetic basis for his sickness, "and the only way we could do that was to get the genome." Success in the most ambitious genetic project ever could mean personal salvation: "My son might have some of his life at a normal level."

The genes had to be found, and in the 1986 essay "Moving on to Human DNA," Watson couches rhapsodic hope in sensible pedestrian tones:

> Although initially it was possible to talk about good and bad genes largely only in the abstract, the arrival of recombinant DNA procedures…has transformed the field of human genetics into a virtual beehive of activity. Each week more and more genes are being mapped to precise chromosomal locations, and long-intractable genetic problems such as epilepsy, schizophrenia, and manic-depressive syndromes may be resolved over the next decade.

But the decades have come and gone, with no resolution in sight. Watson later wrote that "the genetic culprits of mental illness have so far proved particularly elusive. A recent study reveals that as many as twelve chromosomes—half the total—have been shown through mapping analysis to contain genes contributing to schizophrenia.…The history of this research is full of high hopes brought low." That was written fourteen years ago, but any genetically based treatment continues to be far from possible. In his mid-forties now, Rufus Watson still cannot have the normal life his father has hoped for, and worked for.

Watson is understandably impatient, and his impatience extends to those unbelievers in his project who object on religious grounds to "attempts to develop procedures for curing genetic diseases using DNA therapy. Also behind much of this hesitation is the feeling of many people that the DNA within us is not the result of stochastic [random] processes, but of design, and that we have no right to interfere with the destiny that lies behind our individual existences." To intervene medically in the DNA of a genetically doomed sufferer, for some religious believers, would be to tamper with a divinely appointed fate. To Watson, on the other hand, genetic disaster for an individual or a family is the product of the sequence of random variables that constitutes all animal and vegetable life. To minds and hearts that crave order and purpose, this randomness to human existence is the most distressing feature of Watson's historic discovery—too much to bear for persons who need to know they suffer for a justifiable reason, even a supernatural one.

In Watson's eyes the problem of natural evil has nothing supernatural about it, and demands something better than consolation: It demands a solution. Religion sanctifies suffering; philosophy steels one to endure it; but genetically informed medical science may render it, so far as possible, unnecessary. In *DNA: The Secret of Life*, Watson calls for "a form of genetic alteration, a correction of the genes that cause the problem." There are two options: "somatic gene therapy," the alteration of cells in a patient's body, and "germ-line therapy," the alteration of sperm or egg cells to prevent the disease in future generations. The idea of genetically altering offspring has often been controversial, to say the least, but for Watson, "germ-line therapy is in principle simply putting right what chance has put horribly wrong." At the time he was writing, germ-line therapy was yet beyond the technical powers of scientists, and life continued to guard its powers like a jealous god. But today these powers are tantalizingly close.

Watson himself has never stopped working for his cause. In a 1994 essay on the ethical implications of the Human Genome Project, Watson swiftly makes his case:

> To alleviate this current suffering and to help prevent many future victims of genetic injustice from being created, we need to find and study the genes that give rise to these diseases. Once we have found the genetic culprits, we can rationally search for pharmaceutical cures as well as [try] to develop curative genetic therapies. And for those individuals who want to use them, we can provide…screening techniques to tell prospective parents whether a fetus carries a gene whose possession will strongly impair its potential for meaningful life.

Although Watson has no patience for the notion of divine design underlying an individual life or life in general, he embraces here the idea of "genetic injustice." The phrase does have an undeniable moral gravity, but that is attributable strictly to rhetorical flair. Watson knows how to fire up the crowd, and to coax the unwilling to come over to his side. Simply speaking of evolutionary accidents here would blunt the desired effect.

Yet Watson goes on later in the piece to dismiss those who believe

> that all human life is a reflection of God's existence and should be cherished and supported with all the resources at human disposal. Such individuals believe that genetically impaired fetuses have as much right to exist as those destined for healthy, productive lives. But such arguments present no validity to those of us who see no evidence for the sanctity (holiness) of life, believing instead that human as well as all other forms of life are the products not of God's hand but of an evolutionary process operating under the Darwinian principles of natural selection.

This passage opens with a declaration of moral toxicity. According to a ruthless cost–benefit analysis, certain damaged, unhealthy, unproductive human beings evidently do not have a right to exist; they impose an undue burden on the society that keeps them alive.

Yet Watson goes on to argue for the primacy of compassion in the matter of abortion. Here it is clear that there is no justice or injustice to genetic matters; nature proceeds by concatenation of accident, and there is no dressing up that implacably cold fact. Such moral warmth as might exist in the world, Watson continues, comes from compassion applied to human will. Against the intractable believers in the inviolable sanctity of all human life, he sets those other pious people whom he considers more amenable to reason, who "are bound to ask themselves whether the words of God, as then interpreted, are more important than the health of their children or those of their friends."

What Watson recognizes, and what the intractable believers refuse to acknowledge, is that there are lives so crippled and agonizing that no children should have to endure them in the name of their parents' God. Above all, he honors and protects here the suffering child, whose torment, in all decency, ought to outweigh a parent's belief in a God who tolerates such torment. That said, he leaves to parents the question of whether to abort a fetus suffering profound genetic damage. The state is never to be the arbiter in such affairs, whether by requiring abortion or by proscribing it.

The problem for Watson's moral scheme is that a list of lives deemed not worth living will come to include not only extremely painful and fatal genetic diseases, but also milder mutations. In *DNA: The Secret of Life*, Watson delicately maneuvers around the matter of aborting fetuses that show the genetic abnormality for Down syndrome. He remarks that, although people with Down tend to acquire "a depressing familiarity with the insides of hospitals, [they] generally enjoy life, and have brightened many a family. The condition is perhaps tougher on their parents, who must adjust to caring for someone with special medical needs, as well as to the knowledge that their child will, in many ways, never really grow up." A hardship, then—which falls largely on the parents, and is borne in the name of love—but rarely an unbearable ordeal.

Yet the majority of women who discover their child will be born with Down choose abortion. Data collection in the United States is inexact, but the most reliable studies over the last two decades found between 60 and 93 percent of fetuses diagnosed with Down syndrome were aborted. A report this year by CBS News found that in Denmark the rate has reached 98 percent; in Iceland it is nearly 100. As Watson writes, "We are seeing an ever-decreasing proportion of Down babies." Despite the care with which he handles the issue, one cannot escape the suspicion that he would consider a world with a zero incidence of Down syndrome, practically achievable by prenatal testing and abortion, a significant improvement. Is a world where children who "brightened many a family" are deemed unworthy of life really a world worth making with our new genetic powers?

What, too, of those suffering from schizophrenia, like Rufus Watson? The suicide rate among schizophrenics, as among depressives and manic-depressives, is fearsome—they generally cannot be said to enjoy life. In his youth, in the throes of madness, Rufus wanted to die. But he has chosen to live, and only he can say whether his life has been worth living. His father would have spared him suffering if only he could have, but would he rather his son had never lived at all? One is inclined, given the paternal love Watson has shown in taking care of Rufus, to suspect not. A world without schizophrenia would indeed be a significant improvement. But as we await its arrival we must recognize that many lives that normal people might consider unendurably blighted are nevertheless endured willingly by the sufferers who choose to go on living them.

To his discredit, Watson has at times been less ambivalent about another use of human genetics: the categorization and ranking of different groups of human beings. Media reports erupted in the fall of 2007 over an interview Watson gave in which he said that he is "inherently gloomy about the prospect of Africa," for "all our social policies are based on the fact that their intelligence is the same as ours—whereas all the testing says not really." He added that, though he hopes everyone is equal, "people who have to deal with black employees find this not true." As if this poison were scientifically justified, he continued that "our wanting to reserve equal powers of reason as some universal heritage of humanity will not be enough to make it so."

These words have dogged Watson ever since, even more so because they unavoidably sound like a nod to the era of eugenics and scientific racism that is the legacy of early genetics. Watson's own Cold Spring Harbor Laboratory had been, decades before he got there, a hub of eugenic organizing and proselytizing. It housed the notorious Eugenics Record Office, which stored and analyzed data on American families and their supposedly hereditary traits, such as "feeblemindedness," leading to the forced sterilization of thousands in the United States. And race pseudoscience provided a noxious rationalization for the subjugation of millions.

Watson has denounced eugenics programs led by governments, but he thinks it a matter of common sense that when our society gains the power to control the human gene, individuals should choose to create a better race through their offspring. In one of his essays, Watson offers a brief, and dispassionate, history of genetics and eugenics, writing that just "because of Hitler's use of the term 'Master Race,' we should not feel the need to say that we never want to use genetics to make humans more capable than they are today." Watson continues, "If your life is going nowhere, shouldn't you seize the chance of jump-starting your children's future?....Here we must not fall into the absurd trap of being against everything Hitler was for." At least some of Hitler's eugenic aims were laudable, the trouble was just in the implementation.

Watson says he is careful not to be mistaken for "a closet eugenicist" in support of "class and race-based discriminatory practices." But, leaving aside his evidently mixed personal views on race, he seems altogether too optimistic that choices about humanity's genetic future made by individuals rather than governments will not also lead to barbarism. "For us as individuals to feel comfortable making decisions that affect the genetic makeup of our children, we correspondingly have to become genetically literate." Worry not: Once you know the science, morality will take care of itself.

Enduring Fate

Ours is the world begotten in the minds of Machiavelli, Bacon, and Descartes—the world in which human virtue consists in the overcoming of unfortunate impediments to our natural and ordinary desires, in which man's estate needs all the relief it can get, in which human will strains to break the hold over life and death once given to God and now blamed on inhuman nature. Watson is the steward of these founders' legacy, the fulfiller in no small measure of their dreams, and he may yet be responsible for transforming the world even more profoundly than they did.

We, in turn, are the beneficiaries of this legacy. Often we are unhappy that our share of the wealth is not as generous as promised, and are envious of the generations to come, who we expect will inherit more handsomely than we have. Where is the brave new world, the one without cancer or hemophilia or cystic fibrosis or muscular dystrophy or osteogenesis imperfecta or Huntington disease or schizophrenia or Alzheimer's? We have as much right to it as any men and women of the future, and cannot be expected to wait calmly while science dithers. In the meantime we suffer genetic injustice, and all the more acutely because we have been assured the remedy is closer than ever before.

Alternatively, some are anxious that the immense windfall surely on its way may unman us, dehumanize us as it trans-humanizes us, make us bored and slack with our too readily acquired comforts and diversions, deprive us of pains and exertions that have always been the salutary opportunities to demonstrate our love and grace and courage, gnaw away at our gratitude for the inexplicable chance to live as we do for a brief time here, and make us come to regard death either as an insufferable insult or as the inconsequential termination of an inconsequential interval of existence. To the new worldview, such honorable misgivings are legitimate to an extent, but do tend to be overstated. Life will always be hard enough to satisfy all but the most exigent moralists.

For Watson, the glorious future cannot arrive fast enough. He finds it hard to believe that truly reasonable people might resist his blandishments. He knows that most people want what he wants, that once the goods become generally available everybody will want them, and all of them, and right away. Genetic enhancement will one day be commonplace, and not to worry. The holdouts who might pass up the chance to make themselves or their offspring smarter, stronger, handsomer, healthier, happier—who are these people? Modernity's rejects, who claim in their delusion that *they* have rejected *it*—religious fanatics, bound to a cruel and strictly imaginary Father.

Even the severe doubters such as these, however, do not disavow the Watsonian project plain and simple. Almost no one would turn his back on gene therapy that would cure melanoma or lung cancer or glioblastoma. Almost no one who knows what schizophrenia is would stand against genetic manipulation to remove the taint from the bloodline, even if it should cost the world a potential van Gogh or Strindberg. For now, such marvels remain beyond our reach. With cancer, hopes are always high and almost always disappointed. Watson remains confident nonetheless that soon the war on cancer will be conducted with the requisite genetic knowledge to make a cure more than mere hope, and many researchers and practitioners share that informed confidence.

As for schizophrenia, even in the foreseeable future, and well down the line, such treatment looks highly unlikely. The guilty genetic endowment is too far-flung, scattered across so many chromosomes, and differing markedly from one sufferer to another. Watson's son Rufus will almost certainly die with the disease, and any children he or his healthy brother might father must consider themselves in peril, unless and until genetic testing clears them of the fear. One hopes and (dare one say) prays that medical genius will eventually realize Watson's waking dream to abolish mental illness. But the dim prospect for the middle distance is bitter indeed for a man such as Watson, who has so poignant a personal stake in the genetic project to redraw the boundaries of the tragic.

But then we all have a stake in it, and must decide how to live with the new knowledge and the incomplete project to put it to use. And the project will almost certainly never be complete to humanity's full satisfaction. Death shall have its dominion, whatever the poet or the visionary medicine men might urge to the contrary. Human life will always have more than its share of tragedy.

The most powerful tragic drama of the twentieth century is the simplest, the starkest, the most elemental, the most nearly Sophoclean in its sense of inexorable fate: John Millington Synge's one-act *Riders to the Sea*, first performed in 1904. It tells of the day when Maurya, the matriarch of a family of Aran Islands fishermen, who has already lost five sons and her husband to the sea, loses her last remaining son. Maurya speaks the final line of the play, and it sears with pathos and resignation at once desperate and heroic: "No man at all can be living for ever, and we must be satisfied." Though Watson finds little enough to entice him in Christianity or stoicism, one trusts that he cannot fail to recognize the truth to this old woman's Christian stoicism. Loss is universal, the end is inevitable, and they will always come hard.

And the fact is that fewer and fewer are satisfied with the immemorial tragic wisdom. Life ought to be easier and longer than it is, the feeling goes, and as mankind contracts death's dominion to an ever more manageable size, the very existence of that part of the dominion left unconquered will be ever harder to bear. One cannot fault cancer patients, schizophrenics, or those given a diagnosis of Alzheimer's for wanting—for demanding—an end to suffering like theirs. The promise has been vouchsafed, and patience wears thin. And yet stoical patience under hard circumstances—fortitude indeed—is required of virtually everyone at some point; and this is a dwindling virtue, as the tragic sense of life becomes increasingly unacceptable.

Our time and the time to come belong to Watson and those like him. One must be more than grateful for the medical, agricultural, and industrial achievements his genius and tenacity have made possible. One can only be hopeful that his project for the alleviation of human suffering will flourish and change the lives of billions for the better. Watson stands as nothing less than the preeminent intelligence of the era. He has done more than any other contemporary to define the principal concerns of civilized men and women for the foreseeable future.

And yet the gospel according to James D. Watson, who represents the stunning brilliance of science at the cutting edge, and who speaks with the inspired ardor of the happy prophet honored in his own time, fails to touch some of the deepest human needs. For while we await Watson's predicted millennium, and even once the millennium arrives, there remains and will remain the need for the wisdom found in the philosophic and religious masterpieces that Watson has never had time for, and that instruct us in what must be borne, body and soul, as long as we inhabit the earth.