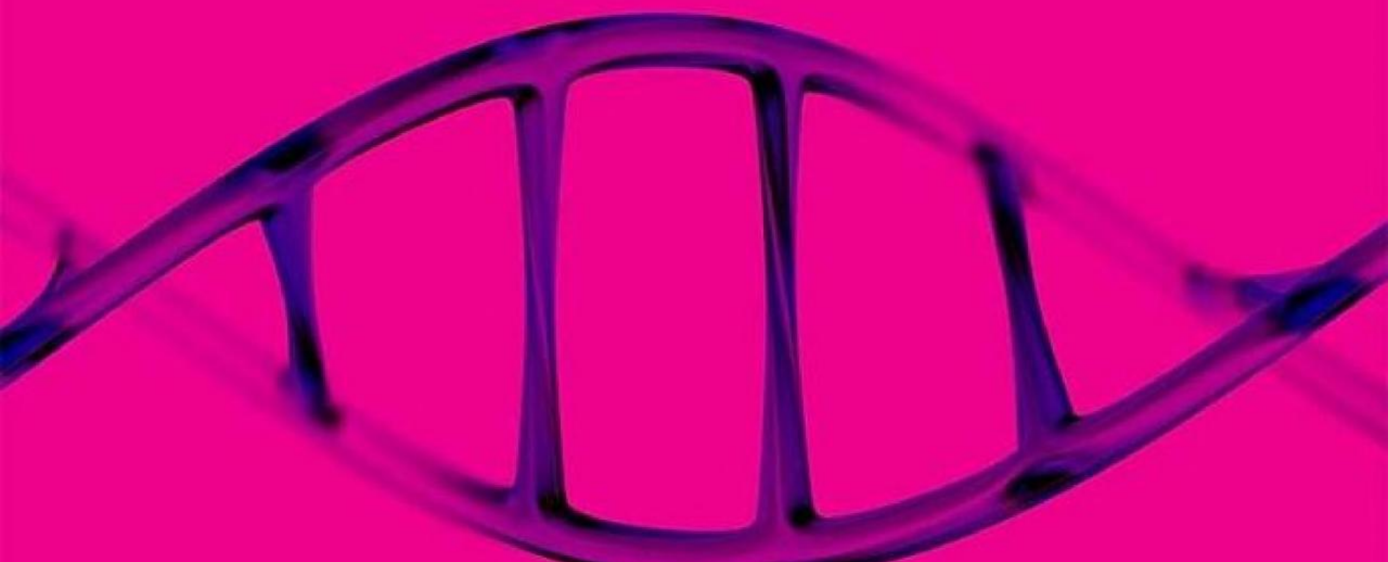
CAN SCIENCE MAKE SENSE OF LIFE?



SHEILA JASANOFF

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I am fortunate to be embedded in a family of writers who give meaning to a way of life that could strike others as isolating. That it rarely feels so to me is a tribute to the five people – Jay, Alan, Maya, Luba, and Nina – who constantly renew my wonder at what life is and what it is for.

Prologue

In February 1943, the Nobel Prize-winning quantum theorist Erwin Schrödinger delivered three lectures at Trinity College, Dublin on the advantages of borrowing terms from physics and chemistry to describe life. Published a year later, with the provocative title *What Is Life?*, the short book opened with a quote from Spinoza's *Ethics*: a free man's "wisdom is, to meditate not on death but on life." Schrödinger began his own meditation in a surprising place, with a disquisition on the smallness of atoms. He went on to speculate that life itself is organized at the molecular level in terms of regularities that explain both the variety and the relative stability of biological organisms. There must be some minimal ordering device, he suggested, capable of producing the living structures that we know and are. Two sets of chromosomes, the physicist observed, one from the mother and one from the father, "contain in some kind of code-script the entire pattern of the individual's future development and of its functioning in the mature state." How else to account for the infinite variety of life?

The term "code-script" meant for Schrödinger that some directive force in the structure of the chromosomes in a fertilized egg must determine "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" (Schrödinger 1967 [1944], 21). The miracle of biology, he suggested, is that some as yet unknown regulator inside each cell controls this wealth of living forms, as different in their diversity from the physical arrangements of periodic crystals as a Raphael tapestry is from a repeating wallpaper pattern. He likened this mechanism to a bureaucratic network operating through shared rules of the game: "Since we know the power this tiny central office has in the isolated cell, do they not resemble stations of local government dispersed through the body, communicating with each other with great ease, thanks to the code that is common to all of them?" (1967 [1944], 79).

Schrödinger's modest little book inspired a generation of young molecular biologists, most notably James Watson and Francis Crick, who cracked the code-script and so revealed the structure of life's "central office": deoxyribose nucleic acid, or DNA. But the moral implications of Schrödinger's essay lay elsewhere, in his conviction that the complex and abundant phenomenon we know as life could and would yield to material analysis at molecular levels. The code, together with the subtle laws that allow it to regulate all the stations of the body, accounts for the remarkable richness of life as we know it. In the book's concluding chapter, Schrödinger wondered about biology's ability to produce "order from order": "A single group of atoms existing only in one copy produces orderly events, marvellously tuned in with each other and with the environment according to most subtle laws" (1967 [1944], 79). But who would interpret those laws to deepen our understanding of life, and with what far-reaching consequences for the future of humanity? To those questions, Schrödinger offered no answer.

The twentieth century's great breakthroughs in the life sciences have made it increasingly more acceptable for biologists to claim ownership of the meaning of life. The origins and implications of that growing primacy deserve our attention. It is a story of arrogance in the literal, etymological sense (from Latin *ad* + *rogare*), a process of asking or claiming a terrain for oneself. Understanding how that happened and why it matters are the twin objectives of this book. The first, largely historical strand of my argument retraces the tangled pathways by which a particular way of interpreting life – that of the modern life sciences – acquired superiority over other, long-established discourses and modes of reflection. The second, more normative strand makes the case for restoring those more thoughtful ways of knowing, so that life does not devolve into just another object of conscious design, valued mainly for our ability to manipulate it, commodify it, and profit unequally from those acts of appropriation.

The beautiful simplicity of DNA's double helix provided, at first, its own compelling justification for biology's soaring status. The group of atoms Schrödinger spoke of contains, as we now know, paired bases that can be represented with just four letters: A, T, G, and C, standing, respectively, for adenine, thymine, guanine, and cytosine. If the matter of life could be broken down into these letters, so regularly coupled A with T and G with C, then the idea of an entire book written in that parsimonious script proved to be almost irresistible. References to the book of nature, in which divine laws governing the workings of life are written down, had circulated in Western thought since medieval times. Unraveling the structure of DNA's double helix gave concreteness to the idea of nature's book. Revolutionary new knowledge brings new dreams of control, as the wily serpent saw when tempting Eve in the Garden of Eden. Biology in the post-DNA age offered similar temptations. Its central project of understanding was soon reimagined as one of authorship. Life scientists, as historians have noted (Kay 2000), quickly and enthusiastically adopted the metaphors of the book and the code, claiming the power not merely to read but to edit and eventually rewrite the book's contents.

The distinguished biologist Robert Sinsheimer was an early convert. On a rainy night in Pasadena in 1965, he gave a public lecture on "The Book of Life" comparing "the genetic information to the information in a book – like a book of recipes or a manual of flower arranging" (1994, 134). Almost imperceptibly, description merged into purposiveness, with the book of life recast as a how-to guide for humble makers and doers, such as cooks and florists whose creativity lies in recombining ingredients. Despite the promise of future applications, however, molecular biology continued to be celebrated as a science, a radically new form of knowing and sense-making. Nicholas Wade, longtime science writer for the *New York Times*, wrote a series of articles under the heading "Reading the Book of Life" (2000a) on the sequencing of the human genome. His first piece hailed the event as an "achievement that represents a pinnacle of human self-knowledge." Genomics, in this telling, was a path of enlightenment, a fitting launch for a new millennium. In another article by Wade (2000b), James Watson recollected his own singular role in that journey: "I would only once have the opportunity to let my scientific career encompass a path from the double helix to the three billion steps of the human genome." With Watson in the audience, President Bill Clinton acknowledged that extraordinary achievement on the day he announced the completion of a first draft of the mapped human genome. Alluding to the famously understated language of the 1953 Watson–Crick *Nature* article on the double helix, the president said to the scientist in three equally understated words, "Thank you, sir."

Less than twenty years later, Jennifer Doudna, a co-discoverer of the CRISPR-Cas 9 technique of gene editing, titled her account of the discovery *A Crack in Creation*. A portentous subtitle claimed for biology "the unthinkable power to control evolution" (Doudna and Sternberg 2017). Her book was not the first to link molecular biology with godlike power to make, or remake, humanity's destiny. In 1979, the journalist Horace Freeland Judson published a 686-page book named *The Eighth Day of Creation* that catapulted him to fame as a historian of contemporary science, while also making his title a byword for the biological revolution. Judson spent almost ten years interviewing most of the leaders in the field for his magisterial chronicle. Understandably, his focus was on science. Yet, stories emanating from the world's leading molecular biology labs were already hinting at unprecedented possibilities for manipulating living organisms. Indeed, Judson wrote in *Harper's Magazine* as early as 1975, "I think we are afraid of the plasticity of man" (1975a, 41). That fear was not misplaced. His big book followed by a year the first certified birth of a baby conceived outside the mother's womb, Louise Brown, born in England on July 25, 1978. The first successful cloning of a mammal from the cell of an adult animal, Dolly the sheep, born in Scotland on July 5, 1996, was less than two decades away, and five more years would lead to the mapping and sequencing of the human genome.

Accounts such as Judson's, and there are many of lesser note, display a scientific field busily scripting its own near-prophetic powers, a news media mesmerized by science-driven transformations in our understanding and expectations of life, and politicians hungry to take credit for advances that might win popular acclaim. Ever since the Luddites trashed the mechanical looms of the industrial revolution, reluctance to follow the lead of science and technology has been cast as misguided and retrograde (Juma 2016). But the rhetorics of hype and hope – and occasionally fear – that accompanied the fundamental biological discoveries of this era make it easy to lose sight of the complex social and cultural contexts out of which the discoveries emerged, and which in turn shaped how the findings were turned to uses both bad and good. The capacity to rewrite the book of life proclaimed by the modern life sciences diverts attention from a history that includes darker chapters in which biology willingly partnered with state power: eugenic sterilization, racially motivated immigration laws, and Nazi experimentation, to name but the most salient few. Even Joseph Stalin's disastrous purges of Soviet genetics under the influence of Trofim Lysenko's anti-Mendelian campaign can be read as a normal chapter in the accommodation between the promises of science and the aspirations of government, although Western commentary routinely dismissed Lysenkoism as an aberration, a deviant and one-sided appropriation of science by politics (Graham 2016).

The metaphor of the book performs in this connection its own imperial simplifications. Representing the human genome as *the* book of life, written in the plain four-letter code of DNA, implicitly claims for biologists a priestly role: as the sole authorized readers of that book, those most qualified to interpret its mysteries and draw out its lessons for the human future. But the genetic book of life sits in practice alongside numerous other volumes whose authors have also been occupied, for much longer stretches of time and across more diverse cultural spaces, in asking questions about the meaning and purposes of life in general and human life in particular. Some of those other books are also scientific, from fields such as ecology or evolutionary biology that are more inclined to view their subject matter as complex and systemic, hence not open to the genetic decoder's single master key. Other books in the ancient library of human thought approach their task of sense-making from perspectives stressing less what life *is* than what it is *for*. These are the books of law, religion, political theory, and moral philosophy, in which human societies have recorded since history began their ideas about what makes lives good or worth living – and, more specifically, what makes a life human and what is special about the condition of being human.

The power of the book metaphor, moreover, resides within a theological tradition that belongs to the peoples "of the Book," or the Bible. That association draws attention away from other ancient meditations on the meaning of life and the connections between its material and spiritual dimensions that are not as centrally mediated by books or codes. We may think here of the well-known episode in the Indian Upanishads where the teacher Uddalaka instructs his book-learned son Shvetaketu in the relations between an individual life and the absolute or supreme reality of existence. The son has returned, proud of his accomplishments in having studied the Vedas, the Hindu religious texts, when the father, through a series of examples, shows him that there is an essence or unity of being that is not the same as its particular manifestations. Most famously, the father asks the son to bring him a fruit of the *nyagrodha* tree and to break it open to see what is inside. The son sees a tiny seed and the father asks him to break that seed and say what it contains. The son does so and sees nothing. The father then tells him that immaterial essence, that visible nothingness, is in truth the essence of the tree and of all material, living selves. In the widely cited Sanskrit text, Uddalaka informs his son, "*Tat tvam asi*," or "That art thou."

The point here is neither to put religious doctrines in competition with scientific theories nor to advocate for any particular dominant relationship between biology and religion or philosophy. It is far more to observe that descriptions of life have many origins and purposes, not all of them connected to unraveling or controlling the physical processes of being. Indeed, one distinction that has preoccupied Western philosophers from Aristotle through to recent and contemporary figures such as Hannah Arendt, Michel Foucault, and Giorgio Agamben is precisely the difference between bare life (Greek *zoe*), the natural, physical life of the body, and the good or active life (Greek *bios*) that exists beyond the body, usually in relation to a community, a life committed to understanding and remaking its own condition. For students of social, political, and ethical life, meaning cannot be found in the bare essence of what makes us tick as atomized biological agents. *That* life is not human in some basic sense. To begin to examine the human condition is to note, with Arendt (1958, 22), that "[n]o human life, not even the life of the hermit in nature's wilderness, is possible without a world which directly or indirectly testifies to the presence of other human beings." Meaning, the answer to questions about life's purposes, germinates in that very connectedness.

This small book aims to correct, in a sense, the elegant but over-simplified optics of Schrödinger's physics-eye vision of life as code-script. Instead of asking "What is life?" *tout court*, my purpose is to show that this question cannot easily be disentangled from the linked and inseparable question, "What is life for?" Repeatedly over the last few decades of scientific development, human societies have confronted new frontiers of meaning as it becomes possible to arrange and rearrange the fundamental units of living matter in new ways. Where does life, as we care for it, begin? Where does that life end? How is one form of life, for example the human, related to other forms, including those of close biological similarity that do not show capacities such as language that we take to be definitive of human-ness? Linked to these morally charged questions are issues of social authority and responsibility. Whose opinion counts and whose does not in addressing these fundamental concerns? Does science have any special voice in defining human progress, and if so why? Who decides when answers are contested? Put another way, which interpreters of life's meaning are entitled to the highest authority when it is not clear whether an issue properly belongs to law or to science, to politics or to expert judgment, to shared social commitments or to private religious belief?

Unsurprisingly, none of these questions has proved amenable to easy answers and so the underlying issues remain very much alive. To advance our thinking, it is time to take stock of the multiple de facto authority claims and counterclaims that have sprung up around the practices of biology and biotechnology in the post-genetic era. In keeping with this book's title question, my focus will be on the role of science in settling (or claiming to settle) the ethical, legal, and social dilemmas that swirl around definitions of life. This science does by eliding the differences between natural and social life, and hence between what life is and what it should be for. We turn first to the emergence of biology not merely as a promising area of inquiry into the nature of life, but as a force that acquired superior cultural authority to determine the scope and limits of its own advancement. We look next at several areas, most notably reproductive and synthetic biology, where struggles for authority are currently taking place between biology, biotechnology, and other social institutions such as law and ethics that also have a stake in defining life's purposes. We conclude with observations on the institutional changes that are needed to address the unresolved tensions between the *is* and the *ought* of human existence at a time when biology is arrogating to itself nothing less than the power to control the evolutionary future of humanity.

Developments in the life sciences and technologies, this book argues, are altering collective visions of desirable futures attainable through science and technology, or what we might call sociotechnical imaginaries (Jasanoff and Kim 2015), in contemporary societies. These changes run deep enough to affect constitutional understandings of who we are as human subjects and how we wish to be governed, not just as citizens of nation states but as living beings with the capacity to reflect on the value of our own existence and the meaning of our relations to nature and our earthly environment. As yet, the contours of those new understandings of science, technology, and society can be discerned only in dimmest outline. Bringing those nascent ideas into sharper focus, so that biology takes its rightful place within and not above society, is the hope and the aim of this book.

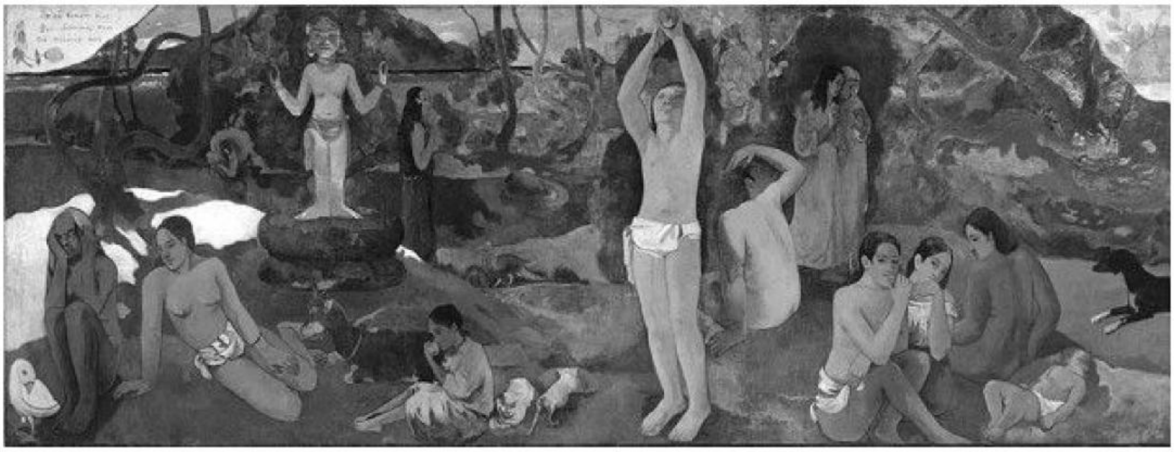

Figure 1.1 Where Do We Come From / What Are We / Where Are We Going (D'où Venons Nous / Que Sommes Nous / Où Allons Nous)

Source: Paul Gauguin, 1897

technologies increased our sense of mastery over life's processes. In turn, the manipulation of the matter of life in labs opened the door to commercial exploitation in medicine and agriculture and more ambitious plans for improving on nature's handiwork. Those shifts, the subject of this chapter, provide essential groundwork for understanding how biology positioned itself as the prime custodian of the meaning and purpose of human life and its place in the wider scheme of life on Earth.

Advances in the biological sciences fundamentally reshaped our thinking about the questions that perplexed Gauguin and his spiritual teacher: where life begins and ends; what is at stake in belonging to a species, kinship group, or family; what counts as normal or abnormal, healthy or diseased, and changeable or fixed in the natural order of things. The material descriptions of life offered by modern biology gradually took on prescriptive force, as if they were the foundation on which we should build our conceptions of good human futures, and as if those visions in turn should guide our technological interventions. Powerful new techniques for designing and redesigning life came to be seen as answers to old, value-laden questions, such as what counts as a well-lived life and who should be responsible for safeguarding lives on this planet. Science does not explicitly claim to offer full-blown answers to any of these questions, especially about the right ways to ensure life's protection and flourishing. Yet, as outlined in this chapter, biology and biotechnology have continually proclaimed themselves as humanity's most compelling instruments for making sense of life – those with the greatest power to answer the eternal questions posed by Gauguin's Tahitian masterpiece.

Origin stories: the evolution of life

From 1831 to 1836, long before Gauguin painted his enigmatic reflection on life and death, Charles Darwin undertook his famous voyage on the HMS *Beagle* to uncover in his own way one of life's basic mysteries: where do we come from? An avid beetle collector and botanist in his college years in Cambridge, Darwin acquired a passion for geology and the interpretation of strata well before setting sail on the *Beagle*. In the Galapagos archipelago, he was drawn to considering how diversity arose among living things, most famously in the finches he collected that are now named after him (Sulloway 1982). Discovery took root then; fame and adulation followed much later. Trained in theology as well as in natural history, and acutely sensitive to possible accusations of error, Darwin waited twenty years before going public in 1859 with his revolutionary work, *On the Origin of Species*.[2] Despite the outcry it provoked (and continues to provoke) in science, religion, and public culture (Wilson 2017), Darwin's claim that humans and other forms of life evolved through natural selection and adaptation proved hugely influential. Sigmund Freud, lecturing on the principles of psychoanalysis some sixty years later, called the theory of evolution the "second discontinuity," on a par with the first discontinuity of the Copernican Revolution, which decentered Earth from its anchoring place in the solar system. Darwin's research, Freud wrote, had "robbed man of his apparent superiority under special creation, and rebuked him with his descent from the animal kingdom, and his ineradicable animal nature" (1920, 247). Evolution, in other words, was one of those rare breaks with past beliefs, a true scientific revolution.

The skeptical habits of thought that allowed Darwin to question foundational presuppositions about the biological origins of life did not extend to his theories about human cultures. Yet, here too an implicit commitment to lawlike progression could be detected. The Victorian moralist observed foreign human forms and practices with a dyspeptic eye from the secure perch of his own elevated position in an enlightened society. His adventures included a ten-day stop in Tahiti in November 1835, where, unlike Gauguin, he found the women "far inferior in every respect to the men" (1860, 430). He also commended Christian missionaries for having abolished "human sacrifices, and the power of an idolatrous priesthood," while reducing "dishonesty, intemperance, and licentiousness" in the indigenous populations (1860, 440). This kind of talk presupposes a kind of universalism in the dynamics of social progress. Theorists such as Herbert Spencer soon picked up on this thread, and "social Darwinism" emerged as a popular framework in accounting for progress.

Like any other transformative idea, Darwin's theory of evolution itself had a longer history and was carried out amidst other scientific efforts that help explain its hold on the modern imagination. Evolution was already in the air as an explanation for the complexity of life forms, in particular through the work of the French natural historian, botanist, and taxonomist Jean-Baptiste Lamarck in the early nineteenth century. Lamarck is now remembered largely for his discredited theory that acquired characteristics can be inherited. Even for those who held different views about the mechanics of evolution, however, he provided inspiration that complexity and diversity among organisms were not simply matters of chance or divine will. The development of life was governed by laws, and these biological rules of inheritance could be systematically studied and deciphered. Darwin was just one of the figures, if possibly the most renowned, who took up and carried forward that invitation to decode nature's laws, including the origins of species, through scientific scrutiny.

If Lamarck and later explorers like Darwin were preoccupied with variation among species across time and space, other pioneering naturalists of that period were more interested in how species pass on their characteristics through generations of offspring. A dozen years younger than Darwin, but with an active life more or less coincident with his, Gregor Johann Mendel, an Augustinian monk in St. Thomas's Abbey in the Moravian city of Brno, began studying the effects of crossbreeding pea plants in his monastery's small experimental garden. Encouraged by his teachers and colleagues, Mendel observed what happened when common edible peas carrying one set of distinctive traits – such as for plant height, flower color, or seed shape – were crossed with plants having the contrasting trait. After years of research, he discovered that traits which disappeared in the second generation reappeared in the third, in a proportion of roughly three to one. That finding led Mendel to his breakthrough conclusion: inheritable traits are transmitted through discrete "factors," which we now think of as genes, one "dominant" and the other "recessive"; plants exhibit the recessive trait, such as the green

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