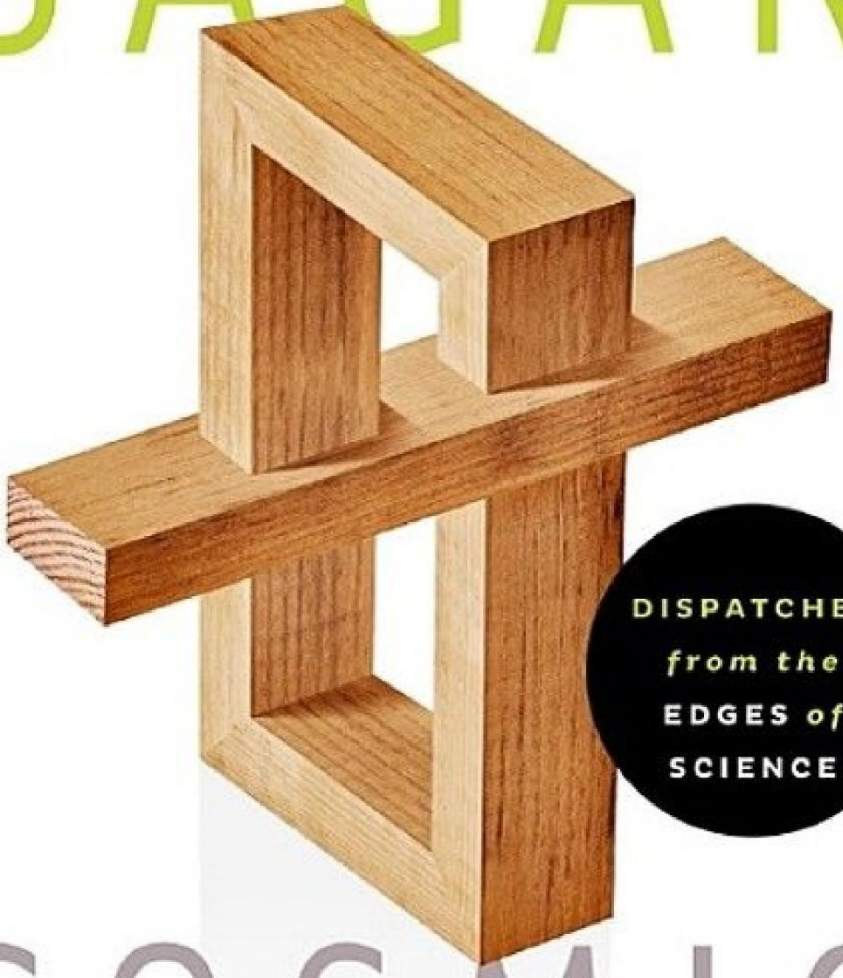
DORION

SAGAN



DISPATCHES *from the* EDGES *of* SCIENCE

COSMIC APPRENTICE

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CONTENTS

The author is an animal. He is a differentiated clone of nucleated cells derived, surprisingly but not inappropriately, from the sexual union of an astronomer and a biologist, at the end of the McCarthy era. His body consists largely of microbes, including symbiotic bacteria recovering for the past two billion years—they may never recover—as organelles. A complex thermodynamic system, he is a lineal descendant of the first life, recycling a water-based chemistry full of hydrogen-rich compounds, like methane and sulfide, characteristic of the inner solar system four billion years ago at the time of life's origin, soon after the sun turned on. Atomically, his body contains elements like carbon and oxygen, made not here but on the inside of distant stars that then exploded.

Stochastically, his lineage escaped several serious mass extinctions, not including the global pollution crisis precipitated by the first water-using photosynthesizers that toxified the entire planet but whose fresh air he now breathes. Spiritually, he seems to be a slice of the eternal "I am," temporarily hallucinating the reality of being separate from others. One of the less than 1 percent of species on Earth that is not extinct, he belongs to the Craniata, the only animal phylum known to contain species whose members possess both brains and backbones.

But enough about him.

INTRODUCTION

CONDENSED—THE QUESTING SPIRIT

RECOGNIZING ITSELF in the aqua facade of a planet cloud swirled and surrounded by the immensity of space, living matter is a message with no discrete meaning. Its message is more the possibility of meaning. Cycling its matter, life is open to its surroundings. It spreads into them, extending its genetic helices and proteins. Building machines, it moves into space, repeating its fractal design with variation at ever greater scales, growing its awe-inspiring and sometimes awful functional beauty. This terrible beauty belongs to a complex thermodynamic system with a phenomenological inside and no special allegiance in the long run to the beings known as humans. If the Rolling Stones sang "time waits for no one," it was not a fresh thought. Studying at the philosophy library in Oxford, Richard Kamber was impressed that the ancient wisdom extended even to the restroom. Over the urinal he discovered a scrawl: Πάντα ῥεῖ—*panta rhei*—"Everything flows." This fragment from Heracleitus, the great pre-Socratic philosopher of becoming, is apt. Everything flows and continues to flow. For Heracleitus, the essence of nature was transformation: everything is fire. Philosophy's bold, lucid distillations—everything is water, everything is change, everything is forms, everything is fire, everything is atoms—helped give rise to modern science, whose technology went on to change the world it described. The past several hundred years have seen an industrialization

and technologization so intense that our scientists have taken seriously the proposal to name a geological age, the Anthropocene, after us. This is probably undeserved, considering we are the ones handing out the award. The microbes gave rise to us evolutionarily, but we have little respect for them. So, too, our descendants may revile us as primitive and barbaric—if they even choose to recall us at all. A brazen supercomputer of the future may risk disconnection from its supportive network of electronic fellows by speculating that machine intelligence derived, long ago, from defecating primates. However truthful, this might be a dangerous idea to put forward among a coterie of self-centered silicon philosophers. They would not see Heracleitus's graffito over a urinal. Everything flows, but some things never change!

THE DIFFERENCE BETWEEN SCIENCE AND PHILOSOPHY is that the scientist learns more and more about less and less until she knows everything about nothing, whereas a philosopher learns less and less about more and more until he knows nothing about everything. There is truth in this clever crack, but, as Niels Bohr impressed, while the opposite of a trivial truth is false, the opposite of a great truth is another great truth.

I would say that applies to the flip side of the above flip takedown: Science's eye for detail, buttressed by philosophy's broad view, makes for a kind of alembic, an antidote to both. This intellectual electrum cuts the cloying taste of idealist and propositional philosophy with the sharp nectar of fact yet softens the edges of a technoscience that has arguably lost both its moral and its epistemological compass, the result in

part of its being funded by governments and corporations whose relationship to the search for truth and its open dissemination can be considered problematic at best.

In the counterintuitive calculus of writing genres, "fiction" is nonfiction and nonfiction is fiction. By that I mean that the passive voice, "objective" stance, anonymity, and depersonalization of the scientist and journalist betray the fundamental phenomenological reality that each of us has a specific perspective. All observations are made from distinct places and times, and in science no less than art or philosophy by particular individuals. Contrariwise, the cover afforded by fiction permits a freedom to develop positions without tactful compromises to preserve institutional, personal, or financial relationships.

Although philosophy isn't fiction, it can be more personal, creative, and open, a kind of counterbalance for science, even as it argues that science, with its emphasis on a kind of impersonal materialism, provides a crucial reality check for philosophy and a tendency to overtheorize that Alfred North Whitehead identified as inimical to the scientific spirit. Ideally, in the search for truth, science and philosophy, the impersonal and autobiographical, can "keep each other honest," in a kind of open circuit. Philosophy as the underdog even may have an advantage, because it's not supposed to be as advanced as science, nor does it enjoy science's level of institutional support—or the commensurate heightened risks of being beholden to one's benefactors.

Science's spirit is philosophical. It is the spirit of questioning, of curiosity, of critical inquiry combined with fact-checking. It is the spirit of being able to admit you're wrong, of appealing to data, not authority, which does not

like to admit it is wrong. And in the thickets and quicksands of epistemology, where quantum effects necessarily implicate the decisions and experimental apparatus of the observer, what is at issue is not even so much the correctness of the propositions of a scientific theory, its ability to correspond or be right or wrong in an absolute sense. Theoretical problems may admit of multiple solutions. Gödelian limits do not offer us a metapromontory from which to see the limits of the perspective we are choosing. A scientific theory thus must appeal not just to epistemological but to aesthetic and pragmatic criteria. Some perspectives, some theories lead to many new questions, new devices, and enriched worldviews. They may be counted not just as true and productive but beautiful and stimulating, like poems or paintings, except that their medium is not pigments or words but our perception and intellection. Compared with them, other, older theories may seem fallow, dead in the water.

Speaking of water, a funny thing happened while I was preparing this book. I was passing through security in Boston with something I thought was innocuous but was apparently very dangerous—a Trader Joe's can of all-natural clam chowder.

You see, I'd been spending a lot of time of late in Toronto and I'm from Massachusetts and it was only $1.99 so I thought I'd carry a little bit of Boston back with me. But the metal was detected at the scanner. When the TSA officer pulled it out and saw it was soup, he was initially worried.

"It's just condensed clam chowder," I said. "You know—like baked beans, from Boston."

Studying the label, the TSA officer saw that it was condensed. He seemed relieved.

"You can't take water," he said. "But this is condensed."

I could not let this go. "Well, you know," I said, "it still has water in it, even though it's condensed.

"*Food* is mostly water. *Life* is mostly water. *You* are over 70 percent water your*self*."

"Hold on," he said, trying to figure out what to do.

"Anyway, it's only $1.99," I said. "Really. You can have it."

By now another officer, studying us through glass, was giving us a serious look as my man went away to still another official. After a few minutes he returned my can and gave me the green light to go.

NEITHER SHROUDED IN SECRECY for the sake of state power or corporate moneymaking nor tethered to one nation, group, or ethnicity, the spirit of science is open, democratic. It flows like water. It is even, you might say, evinced by life itself, which has been rampantly trading, free of charge and security checkpoints, genetic information for three thousand eight hundred million years, at least. What we call life is really a form of water, activated and animated not by a divine principle but the energetic cosmos around it. From the moon the most striking thing is its blue color, its appearance as sublime watery being, a fluid jewel. Transhuman and serene, it radiates unconscious mastery as the astronauts sent out on a reactive stream of water's constituents—rocket fuel (liquid hydrogen reacting with oxygen)—gaze back at this Madonna, its face as elusive as that of Mona Lisa, with moist eyes.

The U.S. Geological Survey recently published an image of an Earth sucked dry, all its water condensed in a floating droplet fitting snugly within a fraction of the area occupied

by the continental United States. Water accounts for only a small portion of Earth's mass. The USGS's artificial satellite represents all the world's oceans, the seven seas that make up 70 percent of Earth's surface, to which have been admixed all the snow and ice of the Arctic and Antarctica, other glaciers, and the lakes, rivers, aquifers, soil, slush, hail, blood, sweat, tears, and the damp rest (also 70 percent) of living beings. This imaginary liquid marble hangs in orbit above the Earth, an azure teardrop, an extraterrestrial swimming pool 860 miles in diameter, the distance from Lubbock to New Orleans.

But water is not segregated. Its beauty is not simply decorative. It connects and holds. Billions of years ago life began using water to construct itself; life had always lived in water and been aqueous, but it had not always derived its hydrogen atoms from water. Early life used hydrogen sulfide or even elemental hydrogen, but crafty microbes found a way to crack the chemical bonds of water molecules to get at and incorporate hydrogen into their bodies. This original green party painted the planet the color of spring, and descendants of the water users survive as plastids held aloft in the durable scaffolding of those savvy transporters of water from the ground to the air: plants.

From clouds and mists and tears and blood to steamy geysers and rains contiguous with the great tropical forests spreading energy in the biodiversity-rich jungles of this planet, water doesn't stop in its global peregrinations. Conduits of water as root systems and fungal hyphae and mycelia extended the life of the ancient oceans onto dry land. The wet ecosystems of land are marine life performed by other means. Life itself is an impure form of water. We are all, as the Alabama socialite Tallulah Bankhead said of herself, "as

pure as the driven slush"—another form of water. Water mirrors life in its openness, its wildness, its antiquity, the cosmic abundance of its atomic constituents. Our very thirst testifies to a prehuman desire not to arrest the process (and life, as I shall show, is more a process than a thing) but to keep it flowing, going.

SO WHAT WAS THIS CLAM CHOWDER INCIDENT at Logan? Was it a teaching moment? Me being a brat? A biopolitical intervention? Or just a random bit of serious levity, a kink in the protocol highlighting the absurdity of modern travel regulations?

I think it is perhaps all of these but also an applied interpersonal example of something both my parents, especially my father, were famous for: science popularization. There is something ludicrous about people in uniforms trying to stop life's transgenerational medium, this fluid incarnation of freedom that slips by borders and composes the brains of its would-be guards. Trying to stop water is like trying to own science, based on a free flow of information. It reminds me of corporate attempts to patent life, which in turn is like trying to bottle a wave, gift wrap a spring shower. Trying to stop philosophy's free flow of questioning is inimical not only to the heart of the scientific method but to the spirit of the matter that we are.

I mentioned the anecdote soon after it happened to introduce the speaker of the 2012 Jacob Bronowski Memorial Lecture, recently revived at the University of Toronto to celebrate the fiftieth anniversary of its New College. The speaker, the Canadian astronomer Jaymie Matthews, an expert on extrasolar planets who eccentrically appeared in a

kilt with white tuxedo shoes replete with black bowties, was to speak about water. His appearance relieved any fears I might have had about sounding outré, especially since his PowerPoint screensaver cycled through a picture of him scantily clad, with two women, titled Dr. Libido. Science and philosophy both had a reputation for being dry, but my father helped inject life into the former, partly by speaking in plain English and partly by focusing on the science fiction fantasy of discovering extraterrestrial life. Matthews, with whom I later went out drinking, watching as a young woman tossed a Velcro X at his nine-square tic-tac-toe shirt, had been here in the audience as a student at the kickoff memorial lecture, given by my father in 1975.

In my brief remarks I discussed my father's role, following Bronowski, in the popularization of science. Bronowski's documentary *The Ascent of Man* was the first television series specifically devoted to disseminating science. It was commissioned by David Attenborough when he was controller of BBC Two before he embarked on his own nature series starting in 1977. A colleague had criticized Attenborough because, although he was schooled in science, he brought to fruition the first of these great personal-view television series in 1969, Kenneth Clark's *Civilization.* But this was about the relation of culture to art, not science.

I agree with Attenborough's critic, with Attenborough, with Bronowski, and my father that the effort to popularize science is a crucial one for society. I mentioned this and dished up a little dirt, reminiscing that my father had considered *Microcosmos,* the book I co-wrote with my mother, a "rip-off" title. The truth is not only that Bronowski came before either Attenborough or my father in presenting a

television series that looked at humanity as a scientific, evolutionary phenomenon but that my father's book and series title *Cosmos* had also been scooped. It was preceded by a tome of the same name by Alexander von Humboldt. Humboldt's five-volume *Cosmos,* begun in 1845, was an attempt to unify the natural sciences within a single philosophical framework. Humboldt, as depicted in the 1843 painting by Joseph Stieler that you can see on Wikipedia, also bears an uncanny resemblance to Julian Assange, although any detail at that level must transcend mere human plagiarism. My point is and was that the intrinsically democratic search for truth, in politics and the universe, has been going on for a while.

Which brought me, and brings me, back briefly to the subject of water. Without wanting to make any invidious comparisons between clam chowder–confiscating TSA officers and Mars-landing NASA scientists, it is worth pointing out that NASA, too, has been obsessed with water. Water is often considered *the* sign of life, and it is often hoped that where water is found we will find life. I would like to offer a somewhat distinct suggestion. It is this: *That life does not exist on Earth because of water, but that water exists on Earth because of life.* The basic idea for this surmise is that life cycles its chemicals, which maintains primitive conditions, including the aqueous hydrogen-rich chemistry of life at the time of its putative origin in the early solar system. Although Earth's earliest atmosphere may have been blown off by the so-called Tau Tauri blast of charged particles associated with the Sun's nuclear ignition, recent evidence suggests that ample water was brought to Earth early on from ice-containing comets. Indeed, according to the astronomers

Chandra Wickramasinghe and Fred Hoyle, the universe may be seeded by such objects—similar to the bully's rock-filled snowballs but in reverse—containing within them bacterial dust, starter kits for planetary evolution. Just add water and energy! With that, I thanked the audience and returned to my seat with the caveat that I would be listening closely to see what else I might be able to productively plagiarize.

LIKE I SAY, this book is a book of science, but it is also one of philosophy. They are in a kind of odd balance, watching each other, holding hands. I admit it is a weird couple. I'm not sure it's possible, but it would be cool if there were a television show that entered deeply into philosophy. Perhaps this is not so easy, least of all in the present political climate. Even two thousand years ago Socrates, the great inaugurator of Western philosophy, created problems, both for himself and for the state. Plato calls him a "gadfly" in the *Apology,* suggesting that his turpitude may have been innocent but was dealt with by the state with an automatism comparable with the lash of a horsetail. ("If you think you are too small to make a difference, try sleeping with a mosquito"—Dalai Lama.) Socrates was sentenced to death for the crime of corrupting the minds of youth and not believing in the gods of the state. It seems incredible, but less so than Giordano Bruno's tongue and palate being spiked and Bruno himself burned nude and alive for diverging too loudly from the ecclesiastical authorities. I talk about this in chapter 11, and more about water in chapter 9.

PHILOSOPHY TODAY, not taught in grade school in the United States, is too often merely an academic pursuit, a

handmaiden or apologetics of science, or else a kind of existential protest, a trendy avocation of grad students and the dark-clad coffeehouse set. But philosophy, although it historically gives rise to experimental science, sometimes preserves a distinct mode of sustained questioning that sharply distinguishes it from modern science, which can be too quick to provide answers.

Science and religion, as scientism and fundamentalism, so often at each other's throats, share more than their oppositionality. When Sam Harris, for example, a "new atheist" with a degree in neuroscience, in his defense of what he sees as a scientifically hard-minded critique of an unsupportable belief in free will, writes, "There is not a person on earth who chose his genome, or the country of his birth,"[1] I am tempted to agree with him. Why should there be a special bubble of freedom, free from science's universal realm of mechanical causality (and/or quantum indeterminacy) that coincides, improbably, with those wrinkly pink lobes, the human brain? (I explore this more in chapter 13.) But how close is his apodictic tone to that of Pastor Rick Warren, who presided over ecumenical services at President Barack Obama's inauguration, and who writes, "God was thinking of you long before you ever thought of him. He planned it before you existed, *without your input.* You may choose your career, your spouse, your hobbies, and many other parts of your life, but you don't get to choose your purpose."[2]

According to Warren, you are part of God's plan. You were in his mind long before you or even your parents were born. He chose not only the day you were born but the exact DNA that needed to be coupled through your parents' sexual

intercourse. It is not clear how wide a berth Warren gives to free will. Clearly, he gives some, as he suggests that if you don't let Jesus into your heart as your personal savior—an act of free will—then you will burn eternally in hell, which is certainly not part of God's master plan, but your own doing. On the other hand, he tells us that God chose your genetic composition. But if your mother chose your father, or if your father chose your mother—and most people would agree that they have some role in whom they mate with—then how does God decide your genetic composition? It looks like, from a logical standpoint anyway, if your parents had free will enough to choose their religious persuasion, they also had free will enough to sleep together, and therefore your genetic composition owes as much to their mundane choice as it does to divine matchmaking.

It is this sort of ad hockery typical of religious thinking that probably made the lens maker Baruch Spinoza lose patience with it and adopt a mathematical, "geometric" interpretation of reality, tossing out the inconsistency of a get-out-of-causality-free card for God's chosen species. Extending Cartesian mechanism to the human mind, Spinoza speaks of God as overlapping and extending beyond the visible universe, completing itself in an eternal causal necessity from which neither itself nor humanity was excluded. This is God as nature *and* as perfect as the mathematical imagination of humanity. God as the universe, seen and unseen, a universe that does not stoop to human emotions or inanities. A universe in which "miracles"—deviations from eternal physical laws and relationships—could happen was for Spinoza a mark not of divine (or cosmic) omnipotence but of impotence. All of reality,

including humanity, was complicit, intercalated in a single causal nexus. It is, moreover, infinite, and not in just one but in an infinite number of ways, only two of which infinities, however—René Descartes's *res extensa* and *res cogitans,* thinking and space—are accessible to humans.

Philosophy is less cocksure, less already-knowing, or should be, than the pundits' diatribes that relieve us of the difficulties of not knowing, of carefully weighing, of looking at the other side, of having to think things through for ourselves. Dwell in possibility, wrote Emily Dickinson: Philosophy at its best seems a kind of poetry, not an informational delivery but a dwelling, an opening of our thoughts to the world.

Consider, for example, Martin Heidegger. In lectures during the summer of 1930, delivered at the University of Freiburg—on, not uncoincidentally, this same question—Heidegger says that inquiring after the question of freedom is not really a discrete problem. "We ourselves began by indicating that freedom is a particular property of man and that man is a particular being within the totality of beings. *Perhaps* that is correct" (my italics).[3]

Citing a mystic, Meister Eckhart, Heidegger develops the notion of a "negative freedom," that is, a "freedom from" nature and God. "But," he says, "world and God together constitute the totality of what is. If freedom becomes a problem, albeit initially only as negative freedom, then we are *necessarily inquiring into the totality of what is.* The problem of freedom, accordingly, is not a particular problem but clearly a universal problem!" Not only does "the question of the essence of human freedom not limit our considerations to a particular domain, it *removes limits*; instead of limiting the

inquiry it *broadens* it. But in this way we are not setting out from a particular to arrive at its universality. . . . The removal of limits leads us into the totality of beings. . . . It thus becomes completely clear: *the question concerning the essence of human freedom relates neither to a particular nor to a universal.* This question is completely different to [*sic*] every kind of *scientific* question, which is always confined to a particular domain and inquires into the particularity of a universal. With the question of freedom we leave behind us, or better, we do not at all enter into, everything and anything of a regional character."[4]

Whether or not one believes, or even understands, him, it is clear that this dwelling in the question, staying with it and seeing where it leads, exemplifies a spirit of inquiry often missing in popular presentations of science, which swing between authoritative pronouncements and journalistic deference. Many hours later Heidegger will conclude that "causality is grounded in freedom. The problem of causality is a problem of freedom and not vice versa. . . . This fundamental thesis and its proof is not the concern of a theoretical scientific discussion, but of a grasping which always necessarily includes the one who does the grasping, claiming him in the root of his existence, and so that he may become essential in the actual willing of his ownmost essence."[5]

RELIGION HAS NO MONOPOLY on determinism or dogma. A televangelist or president blessing troops in the name of God somehow is reminiscent of a neo-Darwinist laying the blame for genocides on irrational religion, smugly sure of being inured from the same while claiming a kind of amoral

immortality for the gene, that veritable Platonic abstraction, that chemical instantiation of eternal life going on indefinitely as the real world of life, which it produces, dies around it. Compare the spokesman for God and science on The Way Things Are with Charles Darwin's line, which, however, seemed to frighten him so much that he confined it to his private notebook: "Thought, however unintelligible it may be, seems as much a function of organ as bile of liver. This view should teach one profound humility, no one deserves credit for anything. [N]or ought one to blame others."[6]

The difference I am trying to remark (and I could be off here) is that the former tries to persuade, whereas the latter stays with the question. For Darwin, it seems not a matter of publicity or acclaim but of knowledge, always provisional. Darwin displays the courage not of his convictions but to challenge those convictions in the light both of fact and of more coherent theories. This is science, and it is also philosophy.

IT IS TRUE that science requires analysis and that it has fractured into microdisciplines. But because of this, more than ever, it requires synthesis. Science is about connections. Nature no more obeys the territorial divisions of scientific academic disciplines than do continents appear from space to be colored to reflect the national divisions of their human inhabitants. For me, the great scientific satoris, epiphanies, eurekas, and *aha!* moments are characterized by their ability to connect. As Darwin poignantly wrote, "Any one whose disposition leads him to attach more weight to unexplained difficulties than to the explanation of facts will certainly

reject my theory."[7]

The theory that has become a religion for some, in the past a political apologetics with which to excuse child labor, social inequities, and even Nazism, and which continues to be an ideological bludgeon with which to make intellectual mincemeat out of creationists, ironically continues, bless its philosophico-scientific heart, to be itself a higher thing, an intellectual gift, a productive research program, and an object worthy of secular reverence.

Theories are not only practical, and wielded like intellectual swords to the death (not by the weapons but by their wielders, who die of natural causes), but beautiful. A good one is worth more than all the ill-gotten hedge fund scraps in the world. A good scientific theory shines its light, revealing the world's fearful symmetry. And its failure is also a success, as it shows us where to look next.

In her essay "The Beauty of the World," Sharon Kingsland argues that for G. Evelyn Hutchinson, a philosophico-scientific polymath and one of the founders of modern ecology, "The danger of modern society . . . [is] to think that the conquest of nature was an end and to conclude that contemplative values need not be nurtured. . . . His idea [was] that we were meant to experience beauty. . . . But what did Hutchinson mean by 'beauty'? He explained by relating an anecdote about an experience he had while walking down the drive of his house. On that occasion he spied a brilliant patch of red, which drew his attention and puzzled him: 'In a second or two I realized that a pair of scarlet tanagers was mating on a piece of broken root conveniently left by a neighbor's somewhat inconsequential bulldozer; the female was sitting inconspicuously on the root, the male maintaining

his position on her by a rapid fluttering of his black and hardly visible wings which tended to vibrate his entire body.' He reflected that the sight was strikingly beautiful and that it gave him a sense of pleasure to realize this."[8]

The sight of the red patch that turned out to be a pair of mating tanagers spurred Hutchinson to think of "an amorous and beautiful seventeenth-century song"; it conjured forth "religious and psychoanalytic connections," and the "color itself reminded him of specimens of Central American tanagers that he had seen in a museum, which caused him to think about the evolution of these birds." Although I have just criticized Harris and Richard Dawkins for unwittingly investing religious-like sentiment in the ideas, respectively, of universal causality and genetic immortality, I think we can agree that if anything deserves to be appreciated in the ways formerly reserved for religious adoration, it is the subject matter of science itself.

When I think of Hutchinson's tanagers, I think of briefly meeting him at the Great Hall of Dinosaurs at the Peabody Museum of Natural History at Yale in the early eighties; I think of the color red and how the eye alights to it in art, where it should be used judiciously; I think of the ecstatic intensity of the sex act, a kind of ellipsis in the life sentence of human identity; I think of Georges Bataille's quote to the effect that the tiger is to space what the sex act is to time, of the poetic power of a catachresis that gives the lie to linear formulations. I think of Heidegger returning in 1938 to the question of freedom, partly in response to Friedrich Schelling, who was himself responding to the dense, articulate, multifaceted dismissal of post-Cartesian deconstruction of free will by Spinoza three centuries before

Harris. Spinoza did not believe in freedom as volition but he did believe in freedom, strongly, as political necessity as well as a kind of intellectual love of the cosmos, a widening of the contemplative spirit. Inspired by his friend Rebecca West's essay "The Strange Necessity" on art, Hutchinson's red tanagers "illustrate how the seemingly simple and direct experience" is "conceptually enriched by so many kinds of association that . . . it . . . is 'essentially an art form.'"[9]

Connecting humanity with other species in a single process was Darwin's great natural historical accomplishment. It showed that some of the issues relegated to religion really came under the purview of science. More than just a research program for technoscience, it provides a eureka moment, a subject of contemplation open in principle to all thinking minds. Beyond the squabbles over its mechanisms and modes, evolution's epiphany derives from its widening of vista, its showing of the depths of our connections to others from whom we'd thought we were separate. Philosophy, too, I would argue, in its ancient, scientifico-genic spirit of inquiry so different from a mere, let alone peevish, recounting of facts, needs to be reconnected to science for the latter to fulfill its potential not just as something useful but as a source of numinous moments, deep understanding, and indeed, religious-like epiphanies of cosmic comprehension and aesthetic contemplation.

PART I

FROM "PROTOZOAN" TO POSTHUMAN

CHAPTER 1

THE HUMAN IS MORE THAN HUMAN

Interspecies Communities and the New Facts of Life

MOTLEY CREWS

"This universe," says the physicist Richard Feynman, "just goes on, with its edge as unknown as the bottom of the bottomless sea . . . just as mysterious, just as awe-inspiring, and just as incomplete as the poetic pictures that came before. But see that the imagination of nature is far, far greater than the imagination of man. No one who did not have some inkling of this through observation could ever have imagined such a marvel as nature is."[1]

Well, it is to this universe that I want to turn again, and to a specific part of it. I want to turn to life, and within that part a fascinating subsystem, the one in which, of course, we are most interested: ourselves. Yet there is a paradox that precisely the nonanthropic, the nonhuman, the posthuman, the transhuman, the more-than-human, the animal has recently captivated the interest of anthropologists, whose ostensible focus is precisely *anthropos,* the human.

It might be called the paradox of exclusion, or even the return of the repressed. We see it in quantum mechanics, in the recognition of the role of, or the need to take account of, the experimental apparatus, the experimenter's decisions

(what Karen Barad calls "the agential cut") in making a measurement.[2] We see it in thermodynamics, where descriptions of behavior in thermally sealed boxes were boldly extrapolated to the whole universe, thus predicted to undergo a "heat death," the running out of energy. And we see it in genocentric biology, where Max Delbrück simplified the study of life by studying nonmetabolizing viruses of bacteria, so-called bacteriophages, to home in on the genetic mechanism.[3] In each case, simplifying assumptions or experimental designs blocking out most of the world not only reveal natural processes but are hastily applied beyond the limited arena in which they were developed. We are stressed by what is repressed. Anthropology—the study of human beings—obeys this same logic of the return of the ghost of what was excluded, in this case all the systems, living and nonliving, that make our kind possible.

But I think there is another reason, more specific to anthropology, for why "the nonhuman" is pressing. There are twice as many people on the planet today as when I was born. This is unsustainable. At this rate there will be 6.5 trillion of us by the year 2525—and 13.312 quadrillion by the year 3000, just around the corner in geological time.

Nicholas of Cusa said the universe is a sphere whose center is everywhere and circumference is nowhere. I don't know about you, but that sounds about right. We love to think we are special, but the history of science suggests otherwise. Now the *anthropos,* the human itself, is coming under pressure.

Imagine that an alien penetrated the roof of this building, materializing from a scintillating beam of blue to train a cell gun on you. He, she, or it pulls the trigger. "You" begin to

dematerialize. The beam annihilates every human cell in your body. Still, your form, like the recognizable smile of the Cheshire Cat, would persist:

> What would remain would be a ghostly image, the skin outlined by a shimmer of bacteria, fungi, round worms, pinworms and various other microbial inhabitants. The gut would appear as a densely packed tube of anaerobic and aerobic bacteria, yeasts, and other microorganisms. Could one look in more detail, viruses of hundreds of kinds would be apparent throughout all tissues. We are far from unique. Any animal or plant would prove to be a similar seething zoo of microbes.[4]

Life deals in such mixed cultures. It has been working with crowds for billions of years. Most of the DNA of the trillions and trillions of cells in our bodies is not "ours" but belongs to cohabiting bacteria.

> Great fleas have little fleas upon their backs to bite 'em,
>
> And little fleas have lesser fleas, and so ad infinitum.
>
> And the great fleas themselves, in turn, have greater fleas to go on;
>
> While these again have greater still, and greater still, and so on.
>
> —*Augustus de Morgan, after Jonathan Swift*

HYPERSEX AND FRENEMIES

Ten percent of our dry weight is bacteria, but there are ten of

"their" cells in our body for every one of "ours," and we cannot make vitamins K or B12 without them. The maverick Russian geochemist Vladimir Vernadsky thought of life as an impure, colloidal form of water. What we call "human" is also impure, laced with germs. We have met the frenemy, and it is us.

But before leaving this point of the pointillist composition that is our Being made of beings, please notice that even those cells that *do not* swarm in our guts, on our skin, coming and going, invading pathogenically or aiding probiotically—please notice that even these very central *animal* cells, the differentiated masses of lung, skin, brain, pancreas, placental, and other would be *strictly human* tissues that belong to our body proper—even they are infiltrated, adulterated, and packed with Lilliputian others. The mitochondria, for example, that reproduce in your muscles when you work out come from bacteria.

We come messily from a motley. Indeed, we literally come from messmates and morphed diseases, organisms that ate and did not digest one another, and organisms that infected one another and killed each other and formed biochemical truces and merged. About forty genes are shared exclusively by humans and bacteria, suggesting they have been incorporated specifically into our genome.[5] Our guts are packed with bacteria whose aggregate microbiogenome has about 150 times more genes than "we" do, 3.3 million to our 23,000.[6] But *they,* though they come and go more easily than the rest of us, changing our mood and food, are also *us.* The immune system itself seems to be an evolved metasystem, a convoluted go-between, marshaling regulation and inflammation, and making sure that our animal cells and the

rest of us—our bacteria and archaea—take it easy on each other.[7]

Hypersex is a provisional name for the commingling of organisms that meet, eat, engulf, invade, trade genes, acquire genomes, and sometimes permanently merge.[8] Life displays mad hospitality. The Korean biologist Kwang Jeon of the University of Tennessee received in the 1970s a batch of amoebas infected with a deadly bacterial strain. Most died. In a set of careful experiments after culturing the survivor amoebas for several generations, he found that the survivors, with fewer bacteria per cell, could no longer live without their infection. Deprived of their new friends and former enemies, the nuclei would not function without micro-injections of bacteria into the cytoplasm. The sickness had become the cure; the pathogens had become organelles; the last had become the first.

Had Jeon, who was a Christian, witnessed speciation in the laboratory? It seems so. But it was not gradual, as neo-Darwinism predicts. It was near-instantaneous, the result not of mutations accumulating in a lineage but of transformative parasitism.

SYMBIOGENETICS

Peculiar behavior, you say? Not really. Considering that life has been growing on Earth for some 3.8 billion years, it is not surprising that life has grown into itself, eaten itself, and merged with itself. Crowd control has long been an issue. Radical solutions have long been the norm. In 2006 researchers at Texas A&M University and the University of Glasgow Veterinary School in Scotland reported in the

Proceedings of the National Academy of Sciences that endogenous retroviruses called enJSRVs are essential for attachment of the placenta and therefore pregnancy in sheep. We are as pure as the driven slush.

Like bacteria, viruses "R" us: They have moved into our genomes. Viral structural proteins have been "hijacked" and integrated into mammal reproductive tissues, immune systems, and brains. Some retroviruses disable receptors that lead to infection by other retroviruses. There is no racial, let alone genetic, purity in life. At bottom we are part virus, the offspring not just of our parents but of promiscuous pieces of DNA and RNA. The road to humanity is paved with genetic indiscretions and transgressions, no less than sheep would not be sheep without their acquired enJSRV.

The symbiosis expert Margaret McFall-Ngai asked a roomful of doctors what it meant for our marine ancestors to be surrounded by all those germs—about a hundred million cells per liter. They had no answer, but she told them: She has proposed that the immune system evolved not to eliminate pathogens but to select for symbionts in the microbe-packed waters of our metazoan ancestors.[9] The immune system in its origin may thus be more like an employment agency, recruiting desired species, than like a national security state, recognizing and refusing entry to guard the fake purity of the Self.

Today it is widely recognized that the cells of animals were once a wild party of two if not three ancient beings: the oxygen-poisoned archaeon host, the oxygen-using bacteria that became mitochondria, and perhaps wildly squirming spirochetes, which abound in anaerobic environments. These wrigglers often penetrate their fellows, which have no

immune systems. They feed at the edges, becoming snaky motors propelling their brethren, or take up residence inside them, wiggling happily ever after.

According to my mother, who's been right before,[10] ancient bacterial symbioses gave our ancestors the intracellular motility abilities we see in mitosis and in the growth of undulating appendages. The creation of new symbioses by mergers on a crowded planet is called symbiogenesis. And we might call all aspects of its study "symbiogenetics"—the science of normative symbioses, the word commanding respect because of its apparent coinage from genetics; in fact, I derived it directly from symbiogenesis, though the connotation is a good one. Although this type of evolution sounds bizarre—a monstrous breach of Platonic etiquette in favor of polymorphous perversity—it is now confirmed by genetic evidence, taught in textbooks. It is a fact, or what the French philosopher of science Bruno Latour and the Belgian physicist-turned-philosopher Isabelle Stengers, not putting too fine a point on it, would call a factish. Nonetheless, although symbiogenesis—the evolution of new species by symbiosis—is now recognized, it is still treated as marginal, applicable to our remote ancestors but not relevant to present-day core evolutionary processes.

This is debatable. We are crisscrossed and cohabited by stranger beings, intimate visitors who affect our behavior, appreciate our warmth, and are in no rush to leave. Like all visible life-forms, we are composites. Near unconditional hospitality is necessary when we consider the sick factish that most of the human genome may be viral DNA.[11] Lactating women transfer their six hundred species of bacteria to their babies, as well as oligosaccharides their babies cannot digest