The Soul of Man Under Physics

David Berlinski

What is it? A sense of unease, perhaps, some persistent feeling, as the century slips into the darkness, that the larger structures of scientific thought and sentiment are disembodied, disorderly somehow. The feeling is familiar, like the taste of tea. A long moment in our collective experience is coming to an end.

The British novelist (and physicist) C.P. Snow argued in the golden 1950's that contemporary culture had acquired two contentious heads, the one scientific, the other humanistic, each unable to understand the other and both committed to commandeering the conversation. Snow's diagnosis exacerbated the disease: intellectual life seemed suddenly to divide along a fissure separating those who understood the second law of thermodynamics from those who did not. There ensued a period of comical soul-searching, as literary critics in particular realized with dismay that, just as Snow had suggested, they were incapable of following a rudimentary scientific argument. Viewed from the perspective of the present, the whole episode takes on an ineffable air of poignancy, the 1950's comprising perhaps the last years in which educated men retained the capacity to be embarrassed by their ignorance.

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Today the rich fruity preposterous discourse of the academic Left would seem to suggest that Snow's bifurcated culture has become flamboyantly fractured. Like a glass pane struck a sharp blow, the large project of the physical sciences has been shown at last to be socially regressive, or politically hegemonistic, or hopelessly gendered, or ethnically contaminated, or simply anachronistic. Quantum mechanics, after all, was anticipated—so we are told—by proud African warriors, men who in the Sudan or the marshes of the Nile conveyed Schrödinger's wave equation as an oral tradition.

The contemporary American philosopher John Searle has struck a countervailing note. Having heard out Indian philosophers convinced that in past lives they had been Pakistanis, or were destined in future lives to become Pakistanis once again, Searle affirmed magisterially that the "contemporary scientific world view is simply not up for grabs." The Darwinian theory of evolution and the atomic theory of matter are irrefragable.

It is wonderful that Searle should think to uphold two 19th-century theories that could both vanish into the void without affecting the contemporary scientific world view in the slightest. Still, he is right in his larger purpose. It is *one* culture that we now inhabit, and not two or ten thousand. Some part of the ache that today affects the human heart arises, indeed, from a kind of intellectual claustrophobia, a sense that a single and perhaps alien system of thought has somehow preempted the possibilities for the description of the universe, the consolation of the soul.

Re-creation and Revelation

SOMETIME IN the 17th century, the dry tinder of discovery, struck profitlessly throughout so many long centuries, blazed suddenly into life. The physical sciences came into creation. That is the common view, and it is completely correct. Before the 17th century there was nothing, and afterward, everything.

Myth places the miracle at the moment Isaac Newton conceived the idea that gravity might control both the fall of objects toward the center of the earth *and* the movement of the planets in the night sky. But the miracle was in fact divided, one half physical, the other mathematical, and it was the mathematical miracle that struck the deeper. Before the laws of nature could be revealed and then recorded, the real world had to be re-created in terms of the real numbers.

The real numbers—not only the natural, or counting, numbers but zero, the negative numbers, the fractions, and the irrational numbers as well—entered the Western imagination in the 16th and 17th centuries, the creation of ebullient Italian geometers and mathematicians. Creation is the right word, signifying as it does a spontaneous intellectual act, one that brings something into being. But whatever their origins, the real numbers also have a workaday identity, one that is expressible in terms of their infinite decimal expansion. The square root of two may thus be expressed as 1.41421356 . . . , with the dots indicating a continuously evolving identity as ever more numbers are added to the list. With these strange rich numbers in place, the number system is in a certain sense *complete*. The thing is contained in itself. It is whole. There are no gaps where the numbers simply lapse.

The introduction of the real numbers allowed the landscape of mathematical analysis to be suffused with a thrilling light, one akin in its own way to the light that may be seen or sensed in the great Renaissance paintings. In that lit-up landscape, the infinite was, for the first time in history, charmed into compliance. Men gained the eerie power to ask of certain processes: *suppose they go on forever, what then?*

Within the scheme of thought known as the calculus, discovered almost simultaneously by Gottfried Leibniz and Newton, they found an entirely comprehensible answer. Relationships between and among numbers could be expressed by the flexible and finely geared instrument of a function, an invention that permitted mathematicians to describe numerical patterns as if they were living processes. The concept of a limit made its first appearance on the mathematical stage, denoting the place where certain things tend and then accumulate. (As the fractions get smaller and smaller, for example, they tend inexorably toward a limit at zero.) Sequences were given voice, and strange series contemplated; hidden for centuries from human sight, an array of mathematical operations and processes became for the first time visible.

The creation of the real number system and its perfection in the calculus represented an inward explosion, one that took place against the backdrop of a larger, outward explosion: the realization by the great natural philosophers of the 17th century that these same real numbers might be assigned to physical magnitudes such as force, mass, and distance, thus creating an essentially quantitative representation of the world. To be sure, human beings since time immemorial had used the numbers to count and to measure and to reckon. As the animals trooped aboard the ark, Noah, no doubt, ticked them off on his fingertips, two by two. But the representation of the real world in terms of the real numbers was different. It was a richer and more compelling representation, one that for the very first time allowed some ineffable abstract aspect of things to be localized on a computational canvas.

It was change under the aspect of continuity, the very mutability of matter, that was captured on that canvas. Continuity is a manifestation of seamlessness: continuous processes do not break, or snap, or interrupt themselves. And continuity is a physical as well as a mathematical property. It lights up the night sky as the stars crawl solemnly across the heavens. The undulating quantum wave occupying all portions of an infinite dimensional Hilbert space is continuous, and so is the great worm of time that humps and slithers its way through the theory of relativity.

The calculus is humanity's great meditation on the theme of continuity, and the concentration on continuous change is what mysteriously lends to the calculus its diamond-hard edge, its uncanny powers of specificity.

THE REPRESENTATION that mathematics affords of the real world is not complete—no symbolic instrument is ever fully adequate to reality—but it is larger and more spacious and more commanding than any before discovered. Still, a representation can only do so much, namely, reconvey an aspect of reality, the familiar world finding itself peeping from an unfamiliar mirror. The larger promise of the physical sciences has always been that some striking *revelation* lies behind the new, the odd and unfamiliar representation, some way of coordinating appearances and enforcing a sense of order on the vagaries of things.

The world, the physical sciences affirm, is not merely depictable, but *comprehensible.* It has a rational structure. It is animated by a great plan. The catalogue of its facts may be compressed into a few infinitely pregnant laws. There is a form of words adequate to the complexity of experience.

These words mathematics does not in itself provide. They arise when the detritus of experience is sifted by a profound physical imagination—Newton, for example, discovering that all objects in the material universe attract one another in proportion to their mass and in inverse proportion to the square of the distance between them. In the tide of time, there have been only four absolutely fundamental physical theories: Newtonian mechanics; Clerk Maxwell's theory of electromagnetism; Einstein's theory of relativity; and quantum mechanics. They stand in history like the staring stone statues on Easter Island, blank-eyed and monumental.

Each theory is embedded in a continuous mathematical representation of the world; each succeeds in amalgamating far-flung processes and properties into a single, remarkably compressed affirmation, a tight intellectual knot. The supreme expression of each theory is a single mathematical law, one expressed as an equation: a statement in which something that is unknown is specified by contingencies arranged in a certain way. And each of the great theories contains far more than it states, the laws of nature fantastically compressed, as if they were quite literally messages from a timeless intellect.

The Conquest of Time

ENTERTAINING FAINT impressions from the far side of the cosmos, where the dust-clouded galaxies wink and shine forlornly, the human eye can convey a human being to the raveled edge of space. But looking anxiously into time and forever asking, *when*—when shall I find love, when happiness, when God?—the soul is shrouded, its basilisk eye unseeing. The past lies fixed and frozen back there somewhere; the future is not only indeterminate and incomplete but opaque, the horizon lit up by only a few large and gloomy certainties: death, taxes, feminism. Human beings are suspended between the unknowable and the inevitable, the place they have always occupied and the place, one suspects, they will always occupy.

The great physical theories provide an exception to this depressing human condition; they are given over to the conquest of time. Under their influence, the universe becomes temporally transparent, at least in part. The conquest of time is written into the symbolic instruments of the physical sciences, their very way of describing things. The laws of nature specify processes in the world, as when (say) a philosopher dropped from a great height accelerates toward the center of the earth, his position changing at every passing moment.

The instruments of discovery within the physical sciences are differential equations. Like equations everywhere, they express a relationship but conceal an unknown. Solving the equation is, just as in elementary algebra, a matter of uncovering the unknown, and the extraordinary feature of the calculus is that it clears a way in which such equations may *in general* be solved.

The result is an instrument of remarkable power. Galileo's law of falling bodies, for example, gives direction not only to the philosopher flying downward but to objects in free fall everywhere. That philosopher having commenced his descent by slipping (so I imagine) on a copy of Carl Sagan's *Cosmos*, one left carelessly on a narrow mountain ledge, Galileo's law controls events thereafter, predicting precisely where the philosopher will be at every subsequent moment, the law unraveling forward in time like film thread moving over sprockets, the philosopher flash-frozen frame by frame, from the moment of his initial spastic efforts to regain his balance to his comic cartwheeling in space and thence to the final ignominious wet plop some seconds later when he becomes one again with the Platonic forms which in life afforded him such satisfaction.

Nice, eh? The law of nature, I mean; and nice in the way it reveals in miniature how the physical sciences penetrate the future: by the successful combination of local circumstances—*he started out here*—with universal and deterministic processes—Galileo's law. The laws of nature are general. A local flash ties them to place and time, the contingent circumstances of the real world, whereupon they acquire prophetic powers, the specification of the particular acting as a flare illuminating an ancient text.

The *predictable future* is the exuberant manifestation of the Western scientific imagination. Eyebrows waggling and bony fingers pointing, the great scientists stand and control the flow of time, investing their calculations with a retrospective sense of inevitability, if not of moral urgency. So entrenched by now is this notion of the predictable future that it has become a category of consciousness and discourse, a familiar intellectual fixture, one derived from the very nature of description itself.

In contemporary culture, to be sure, prophecy is a debased currency, the prophets bunched up on television where they may be found offering astrological advice on love and work. But the mathematical sciences are entirely different. In physics, prophecies command a degree of accuracy that must be reckoned miraculous. Quantum electrodynamics penetrates the very heart of matter to something like twenty decimal places. It is as if, in determining the distance from New York to Los Angeles, theory and measurement would diverge by no more than the width of a single human hair.

The great theories, singular in so many ways, are singular in this as well: no other intellectual accomplishment exhibits their prophetic powers. In them, pure thought and physical experience coincide to a degree never achieved in any other domain of intellectual or practical life—coincide, that is, to a degree unparalleled in the entire experience of the race, enabling human beings to achieve a specification of points and places in the future utterly at odds with our habitual inability to say where our keys may have been misplaced, or our hearts lost.

Chaos, Randomness, Complexity

BUT NOW it is undergoing dissolution, the predictable future. Quantum mechanics served long ago to introduce a note of alien doubt into the deterministic scheme, countenancing a view of the subatomic world in which quanta bounce around for no good reason whatsoever and measurements are bound by an iron collar of uncertainty. But quantum mechanics has long been recognized as unfathomable, its formulas a series of vatic inscriptions no one can read without going blind. Current corrosives are simpler; they have nothing directly to do with the quantum world. They are chaos, randomness, and complexity.

Chaos first. The idea is very simple. Certain systems may be both deterministic *and* unstable. An example is a baseball bat balanced on its end. Left unperturbed, it may remain upright until the end of time. This is one of its destinies. Given a tiny tap, it falls over promptly, thus embracing a quite different destiny. Chaos arises when the bat is embedded in the flow of time. From where it is, there is no real saying where it is going.

More than 90 years ago, the French mathematician Henri Poincaré observed that simple but nonlinear systems might well exhibit chaotic behavior. And he drew the correct conclusion that such systems, even though governed by deterministic equations, were inherently unpredictable. His ideas were left unperturbed for a time but, given a tap in the 1940's and 1950's, became a part of common scientific currency by means of an unusual route.

The weather, Edward Lorenz suggested in 1963, might be *essentially* unpredictable (a conclusion many of us have come to on our own). Certain physical regimes—like certain households—are intrinsically chaotic; small changes in their initial states lead over time to dramatic and unsettling changes in their evolution. Beating its delicate and translucent wings in Borneo, a butterfly might bring about a tornado in Toledo. Like an upright bat, the earth's atmosphere is a system sensitively dependent on its initial conditions.

Having been read and chuckled over by a dozen or so professionals, Lorenz's paper sank promptly from sight. In the 1970's it underwent a spectacular resurrection; it is now widely regarded as prescient. Evidence of chaos has been discerned in phenomena ranging from planetary astronomy to nerve excitation in the giant squid. Outside of science as well, chaos has become an immensely fashionable term of diagnosis, an explanation for every living shambles. And why not? Both ordinary language and ordinary life seem hideously sensitive to small perturbations. An errant hiccup might have induced Gavrilo Princip to miss the Archduke entirely at Sarajevo, with Bosnia-Herzegovina becoming, over the placid decades since 1914, the Switzerland of Southern Europe.

Chaos is a cultural corrosive, one dissolving the tight connection between a deterministic mathematical model and the delivery of a predictable future. In a chaotic system, the very act of measurement induces uncertainty, for no measurement is entirely accurate; imperceptible errors grow exponentially, cascading along the system until the real world and the measured world seem utterly unlike. Chaos introduces something novel in the physical sciences, a pragmatic sense of inescapable error; it compromises the miracle of quantitative prediction, and returns the imagination to an older view of life and experience. The future *is* clouded. We *do* live amid ineradicable uncertainty.

If chaos is one corrosive, randomness is another. A trite and a tired concept, randomness denotes a statistical property of sequences, but one that is difficult to discern and even more difficult to define. The morganatic cousin of meaninglessness in French movies—as when a breathless hoodlum, ending his one chance for happiness, whimsically shoots a policeman—randomness has received a revivifying interpretation in recent years, thanks to the great Russian mathematician Andrei Kolmogorov and to the American mathematician Gregory Chaitin. Influenced no doubt by morphic resonance, Kolmogorov and Chaitin observed a sympathetic current running between randomness and the concept of complexity. The juxtaposition yields an extraordinary idea, one that captures something long sensed but never quite specified.

Here is an illustration. A painting by Jackson Pollock is complex in the sense that nothing short of the painting conveys what the painting itself conveys. As I look at those curiously compelling, variegated, aggressive streaks and slashes, words fail me. In order to describe the painting, I must display it. An Andy Warhol painting, by way of comparison, subordinates itself to a verbal formula: *just run that soup can up and down the page, Andy.*

This, however, is to remain within the realm of rhetoric. The mathematician attends not to paintings but to binary sequences—strings of 0's and 1's. Now a computer program is itself a string of symbols (binary numbers, in fact). A given string is simple, Chaitin and Kolmogorov argued, if the string may be generated by a computer program significantly shorter than the string itself; otherwise, it is complex.

This tight little declaration begins to explain the large irrelevance that now envelops the mathematical sciences. The laws of nature—those compressed and gnomic affirmations—pertain, on the one hand, to the largescale structures of space and time and, on the other hand, to the jiggling fundaments of the quantum world. Simplicity reigns amid the very large and the very small, and it is there that things may be mathematically described. And yet most strings and thus most things are not simple but complex. They cannot be more simply conveyed; they are what they are, insusceptible of compression. And this is an easily demonstrated, an indubitable, mathematical fact.

It is the world's complexity that is humanly interesting. What do we see when we look elsewhere? Stars blazing glumly in the night sky, the moons of Jupiter hanging like so many testicles, clouds of cosmic dust, an immensity of space, a spare but irritating sound track consisting of the infernal chatter of background radiation. The evidence seems inescapable that the Creator wrought the simple structures in the universe with a few swift strokes of an instrument much like a cosmic trowel. In our own corner of the composition, by contrast, He apparently set to work with a sable-tipped paintbrush, patiently fashioning a blue planet, a lush garden, creatures utterly unlike anything else in the universe, sensuous, moving, alive.

We live within the confines of that canvas. Complexity is everywhere, whether created or contrived, and compression hard to come by—in truth, the human world cannot be much compressed at all. The most we can typically do, a few resolute morals or maxims aside, is to watch the panorama unfold, surprised as always by the turbulent and unsuspected flow of things, the gross but fascinating cascade of life.

A Polytheistic Universe

THE CALCULUS is the great idealization of Western science; from within its crabbed formulas comes the master plan of equation-and-solution that makes the physical sciences possible. Yet the investiture of mathematics in things and processes weakens as one moves along the intellectual chain of command. This is a curious and disabling fact. Material objects on the quantum level may be explained as roiling waves of probability. By contrast, the attempt to discern the outlines of a coherent system of mathematical thought in the structure of biological objects—protozoa, rock stars, human beings—has been a failure.

From one perspective, the conceptual landscape of biology resembles a range of ancient foothills folded against the mathematician's high alpine peaks. The biologist employs a scheme immeasurably simpler than the one adopted by the mathematical physicist. It is, that scheme, discrete, finite, and combinatorial. No mathematics beyond finger counting.

Living systems may be understood in terms of the constituents that make them up, and of these, there are only finitely many. The dissection complete, what remains is a master molecule, DNA, which functions as a code, and the complicated proteins that it organizes and controls. No continuous magnitudes; no real numbers; no rich body of mathematical analysis. No laws, not in the sense in which physics contains laws of nature; no fantastically pregnant, compressed, and quantitative apothegms. Molecular biology should be comprehensible to someone who knows nothing of modern science, continuity, or the calculus, and who can reckon only to powers of ten—a Harvard graduate, say.

Despite the often vulgar language in which they are expressed, the concepts that animate molecular biology are old, familiar, haunting: system, information, code, language, message, organization. They often affirm a message already known: "one generation passeth away and another generation cometh." They are magical in their nature and effect. DNA, in particular, functions as a kind of biochemical demiurge, something that brings an entire organism into existence by a process akin to a casting of spells. They are often inconsistent: the role attributed to DNA is at odds with the obvious fact that the information resident in the genome is inadequate to specify the whole of a complex organism. Like a rubber band under tension, the concepts of molecular biology seem always to snap back to some earlier way of describing life, one in which *purpose* and *design* come prominently into focus.

And they seem, these concepts, often to mark the very margins of our own intellectual inadequacy. Nowhere in nature do we ever observe purely mechanical forces between large molecules giving rise to self-contained, stable, and autonomous structures like a frog or a fern, something able to carry on as a continuous arc from first to last, a physical object changing over time but remaining the *same* object at every stage, some set of forces endowing its identity with permanence so that variations remain bounded and inevitably return the object to the place from which it started. Nothing but a living system exhibits this extraordinary combination of plasticity and stability, a fact we are barely able to describe and entirely unable to explain.

Molecular biology is immune to the great idealization that marks the physical sciences; and what is more, it seems retrograde to the grand metaphysical assumptions on which the physical sciences rest. Those assumptions have passed directly into popular culture. The world, the physical sciences affirm almost with one voice, is physical and not spiritual, numinous, or mental. It is a world of matter. The doctrine of consideration in contract law and the bright bubble of consciousness are illusions. Reality contains only atoms and the void.

But if, by "physical," physical scientists mean concepts like the concepts found in physics, then the conclusion is irresistible that molecular biology is not a physical science at all, but a discipline struggling to express the properties of living systems in a vocabulary and by means of concepts unlike those needed elsewhere. What we see when we *look* at the observable universe is that one god like dark Pluto rules the quantum underworld; quite another, the biological macromolecules.

Physicists reject such a frankly polytheistic view, of course. The laws of physics are controlling, they say, and in the end everything will be made clear. That is what they always say; it is their destiny to say it. But in truth the grand vision of all of human knowledge devolving toward mathematical physics is no longer taken seriously, even by physicists who take it seriously.

"The most extreme hope for science," the physicist Steven Weinberg has written (in his *Dreams of a Final Theory*, 1993), "is that we will be able to trace the explanation of all natural phenomena to final laws *and historical accidents*" (emphasis added). Machiavelli used the word *fortuna* to describe the inexplicable adjurations of fate; it is a word that communicates a certain grave mockery. How has mathematical physics informed the human heart if the explanation for the way things are involves an appeal to fundamental laws *and* to something like a Neapolitan shrug?

Mind Over Matter

AN UNEASY sense prevails—it has long prevailed—that the vision of a purely physical universe is somehow incomplete. We are creatures with rich and various mental experiences. We live in a world of purpose, belief, intention, and meaning. We bring the future into being by the free exercise of our will, a circumstance that mathematical physics is unable to describe, let alone explain. And we are conscious, we have minds.

The great body of continuous mathematics has played no role in the explanation or description of the human mind (however much its very existence may express the powers of that mind). But within living memory a bright new world has been organized to rival the old cunning and continuous world of the physical sciences. Gone is Freud's model of the mind as a haunted house (superego/ego/id); it has been replaced by the powerful image of the mind as a computational device. Careers have been fashioned to accommodate and exploit that image. Unpleasant young people proclaim themselves weird or wired, involve themselves in trendy little magazines, and sprawl over the Internet. The descriptive resources of the English language have been altered, often to risible effect, the term "digital" emerging from the proctologist's vernacular to become a general adjective of choice. "Life is just bytes and bytes of digital information," the biologist Richard Dawkins writes obligingly in *River Out of Eden* (1995). "Pure information," a reviewer adds loyally.

The foundations of the new view were laid more than 60 years ago by a congregation of chalky logicians: the great Kurt Gödel, Alonzo Church, Emil Post, and, of course, the odd and utterly original A.M. Turing, whose lost spirit seems to roam anxiously over the second half of the 20th century like one of F. Scott Fitzgerald's sad young men. (*Fortuna*, again.)

Turing's simple model of a computing machine is the first of humanity's *intellectual* artifacts. The machine itself is a device for the manipulation of symbols, and since symbols are abstract, a Turing machine may be realized in any medium in which symbols can be inscribed. Given symbols as input, a Turing machine returns symbols as output, reading, writing, and erasing them on an infinitely extended tape. In a sense, of course, that is what lovers and lawyers do as well, the lover using his warm breath, the lawyer foolscap, each making his point by means of an inscription or exchange of symbols.

A Turing machine undertakes its transformations by means of a *program*: a fixed set of rules setting out what it may do and when it may do it. These rules are formal, in the sense that they make no appeal to the machine's emotions or thoughts, but they also reflect the ineliminable purposes of the system's programmer, enabling the machine to realize his aims or ends.

The essential elements of a Turing machine are the symbols it manipulates, the tape on which it writes, the mechanism by which it sees, and the program by which it acts; indeed, these are the essentials of the computational act itself, the process by which intelligence records its thoughts. The extraordinary, spine-chilling, contrary-to-intuition thing is that this imaginary object not only led historically to the construction of the digital computer itself—a striking example of thought bringing matter into existence—but also in some sense exhausts the very concept of rule-governed behavior. *Whatever* may be done by a discrete system moving in steps may be done by a Turing machine.

TO THE question of how best to describe change, the answer provided by the physical sciences over the course of 300 years has been a system of mathematical equations. Another answer, one new in our experience, is a program. The difference between the two is profound. A program *does* what an equation describes. Equations are indirect, they must be solved. A program is direct, it must be executed. Equations are continuous; programs discontinuous. Equations are infinite; programs finite. The elements of an equation are numbers; the elements of a program are words. An equation penetrates the future; a program does not.

As these distinctions suggest, the vision of the mind as a computational object is—no less than molecular biology—retrograde to the great movements of mathematical physics. In the physical sciences, time and space are represented by the real numbers and (therefore) have a continuous structure. A computer, by contrast, inhabits a world in which time, represented by the ordinary integers, has lost its pliant seamlessness and moves forward in jerky integral steps. A stern series of renunciations is in force. No differential equations. No connection backward to the calculus. No world-defining symmetries of space and time. No analytic continuation, as when the laws of nature conduct the physicist from the present into the future. No quantitative miracles. No miracles at all—provided one excepts the ordinary achingly human ones.

For under this new conceptual order, the prevailing direction of scientific thought has been altered and reversed. Within mathematical physics, things move dissectively, toward the fundamental objects and their fundamental properties and laws. The physical universe itself remains meaningless. The arena controlled by the fundamental laws, though vast, is sterile, the whole thing rather like a fluorescent-lit bowling alley where balls the size of quarks forever ricochet off one another in the hot and soundless night. Down there, no human voices may be heard.

But up here, things are different; they have always been different. Invoking a rich system of meaning and interpretation, human beings explain themselves to themselves in terms of what they wish and what they believe, the immemorial instincts of desire and conviction being sufficient to bring a world into being. That world is suspended in space by the chatter of human voices. A path through the chatter is not dissective, but almost always circular. A man believes that alfalfa sprouts are a cure for shingles; this is reflected in what he says, in what he does, in what he believes, and in what he wishes, each reflection explaining the one that has gone before, the circle beginning to bend back on itself.

There is no way to break the circle to reach a bedrock of physical fact, for there are no physical facts to reach. How could there be? To enter the circle, any purely physical feature of the world must be interpreted and given meaning. Once given meaning, it is no longer purely a physical feature of the world. Under the computational theory of mind, the conceptual circle is not emptied or evacuated, it is enlarged, the formal objects taking their place like guests at a wedding asked to join the dance. The states of a computer carry a significance that goes beyond physics; like words, they play a role in the economy of meaning. And meaning appears only in the reflective and interpretive gaze of human beings.

This point is evident in the simplest of devices. Call twice for the numeral "2" on a calculator and the machine returns a neoned "4." Considered simply as a physical object, the machine is shuttling among shapes, configurations of light, which it realizes by means of the way in which it is constructed: it is capable of nothing else. What makes the charming show of light an *answer* is the fact that someone has been provoked to ask a question. Question and answer belong to the circle of human voices. A purely physical process has been invested with significance, those winking ruby lights given form and content as symbols, representations. Whether the representation is made in terms of light or by the modulation of a woman's voice, the process is always the same. Some feature of the world has been made incandescent.

Consciousness

STREAMING IN from space, light reaches the human eye and deposits its information on the stippled surface of the retina. Directly thereafter I see the great lawn of Golden Gate Park; a young woman, nose ring twitching; a panting puppy; a rose bush; and beyond, a file of cars moving sedately toward the western sun. A three-dimensional world has been conveyed to a two-dimensional surface and then reconveyed to a three-dimensional image.

This familiar miracle suggests, if anything does, the relevance of algorithms to the actual accomplishments of the mind; indeed, the transformation of dimensions is precisely the kind of activity that might be brought under the control of a formal program, a system of rules cued to the circumstances of vision as it takes place in a creature with two matched but somewhat asymmetrical eyes. David Marr, for example, provides (in *Vision*, 1982) an extraordinary account of the complex transformations undertaken in the mind's cockpit in order to allow the eyes to see things stereoptically.

In a charming book entitled *Descartes' Error* (1994), Antonio R. Damasio writes of the mind as a place where neural representations, or images, arise. Having concluded correctly, say, that a football is heading toward one's nose, the mind signs off on the formal portion of its visual deliberations by means of a vibrant image (and signals the head to duck). This language of representations and images is general throughout the cognitive sciences. The mind, apparently, stores the stuff in various places and then hauls down a representation or two when the need arises.

But wait a minute. Representations? Images? As in, something seen? *In* the mind? But seen by *whom*? And just *who* is doing the representing?

These questions reverberate with a loud, flat, embarrassing bang, their innocence utterly at odds with the sophistication of the various theories they subvert. Is the mind computational? It is. Does it proceed by an application of determinate rules? It does. Very well, consider this: at the conclusion of its computations, the mind bursts into a vivid, light-enraptured awareness of the world. I open my eyes and my eyes are filled. There is a panorama to which my eyes may be partial, but it is *my* eyes that are filled, my experiences possessing both an experiencing subject—me—and the contents of that experience, the scene and its surveyor bound inseparably together as fragments in a figure.

The persistence in theory of a certain embarrassing imbroglio—the mind suddenly opens an arena in which images are thoughtfully examined, or representations are mysteriously made to represent—is evidence of the enormous difficulty entailed in accommodating consciousness within any computational view of the mind's operations.

Although most analytic philosophers have remained materialists, it is consciousness that is now on everyone's lips. Employing an argument prematurely discarded by logicians, the distinguished mathematician Roger Penrose has concluded that consciousness *cannot* be computational: a reformation of quantum theory is required to set the matter right, the transmutation of thought into action taking place in the microtubules of the cell.* Elsewhere, unorthodox quantum physicists have argued for the ubiquity of mind throughout the cosmos, with even the atoms having a say in the scheme of things.† An enterprising academic, Colin McGinn, has concluded that the problem of consciousness must forever be insoluble and has made his discovery the foundation of a far-reaching philosophical system. A few philosophers have even been observed administering discreet kicks to the corpse of mind/body dualism: *get up, you fat fool, I need you.*

Do I have anything better? Of course not. "You could not discover the limits of soul," Heraclitus wrote, "not even if you traveled down every road. Such is the depth of its form."

IT IS a fact. Among the physicists, the old quiet confidence is gone. Men with black burning eyes roam the corridors of thought. They talk of theories that will explain absolutely everything and like barroom drunks fasten on anyone to unburden themselves: *It's strings, that's what it is, I'm telling you.* There are physicists (like Stephen Hawking or Paul Davies) convinced that they are shortly to know the Mind of God, or that they have seen in the firmament secrets of a cosmic code, or discovered in the dense inaccessible equations of general relativity living proof of the Christian resurrection.**

But even as physicists add to their great creation myths, questions follow assertions in a never-ending spiral. Why do the early galaxies show so much structure? How can the universe be younger than its oldest stars? Did space and time have a beginning? A *beginning?* A beginning *in* what? Are you saying that time is relative? Then what is that business about the first three minutes? Just what are *they* relative *to*? At the margins of speculation, strange numerical coincidences haunt the imagination. And there are singularities at the beginning and end of time, places where the laws of physics simply deform themselves and then collapse.

Mathematical physics, it is sometimes said, is the cathedral constructed by our culture. The image is apt. Messy, disorganized, ideologically confused but inescapably compelling, contemporary physics resembles nothing so much as one of those strange structures designed by Antoni Gaudí. There the spooky structure sits in the somber Spanish moonlight, bats flitting about the crenellated belfry, fantastic and odd, with its thousand-and-one idiosyncratic touches, its radically asymmetrical towers, quantum mechanics on the one side, general relativity on the other, its wealth of poorly understood details set amid fearfully difficult and rebarbative mathematics, portions of the great structure incomplete, the workmen having left their tools in stupefaction, the entire glorious edifice bearing in every way the marks of its many creators, the thing deeply moving, intensely human.

It has been the hope of the physical sciences that everything might be explained by an austere, impersonal, abstract, consistent, and complete set of mathematical laws. The hope has acquired the aspect of a faith. Within the closed coffin of academic science and analytic philosophy, things are as they always were; but no one who shares a delusion, as Freud memorably remarked, ever recognizes it as such. Elsewhere, confidence is leaking from the most profound and ambitious system of secular thought ever created. Everyone feels that this is so. And everyone is right.

The prevailing world of thought is like some frozen sea, heaving and cracking, with a trickle of shy life rushing beneath its surface, carrying fragrant memories of what has long been forgotten, a world beyond the world of matter. Human beings will always need to interpret themselves in ancient and familiar terms, the intentional circle enlarging but never breaking; for the way things are, they will never find an explanation so complete and so compelling as to make their transcendental urges irrelevant. Something is going and something is gone; some aspect of conviction has been broken. In return, there is something familiar and something recaptured. *For lo, the winter is past. The rain is over and gone; the flowers appear on the earth; The time of singing is come. And the voice of the turtle is heard in our land.*

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* *The Emperor's New Mind* (Oxford, 1990) and *Shadows of the Mind* (Oxford, 1994). The first of these books was reviewed in COMMENTARY by Jeffrey Marsh (June 1990), the second by Adam Schulman (April 1995).

† Nick Herbert, *Elemental Mind* (Plume, 1994).

** See F. J. Tipler, *Physics and Immortality* (Doubleday, 1994). The generally favorable critical reception accorded this inadvertently hilarious book is itself a remarkable sign of divine grace.