On the Origins of the Mind

David Berlinski

It's all scientific stuff; it's been proved.
—Tom Buchanan in *The Great Gatsby*

At some time in the history of the universe, there were no human minds, and at some time later, there were. Within the blink of a cosmic eye, a universe in which all was chaos and void came to include hunches, beliefs, sentiments, raw sensations, pains, emotions, wishes, ideas, images, inferences, the feel of rubber, *Schadenfreude*, and the taste of banana ice cream.

A sense of surprise is surely in order. How did *that* get *here*?

If the origin of the human mind is mysterious, so too is its nature. There are, Descartes argued, two substances in the universe, one physical and the other mental.

To many contemporary philosophers, this has seemed rather an embarrassment of riches. But no sooner have they ejected mental substances from their analyses than mental properties pop up to take their place, and if not mental properties then mental functions. As a conceptual category, the mental is apparently unwilling to remain expunged.

And no wonder. Although I may be struck by a thought, or moved by a memory, or distracted by a craving, these familiar descriptions suggest an effect with no obvious physical cause. Thoughts, memories, cravings—they are what? Crossing space and time effortlessly, the human mind deliberates, reckons, assesses, and totes things up; it reacts, registers, reflects, and responds. In some cases, like inattention or carelessness, it invites censure by doing nothing at all or doing something in the wrong way; in other cases, like vision, it acts unhesitatingly and without reflection; and in still other cases, the human mind manages both to slip itself into and stay aloof from the great causal stream that makes the real world boom, so that when *it* gives the go-ahead, what *I* do is, as Thomas Aquinas observed, "inclined but not compelled."

These are not properties commonly found in the physical world. They are, in fact, not found at all.

And yet, the impression remains widespread that whoever is responsible for figuring out the world's deep things seems to have figured out the human mind as well. Commenting on negative advertising in political campaigns, Kathleen Hall Jamieson, the director of the Annenberg Public Policy Center at the University of Pennsylvania, remarked that

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"there appears to be something hard-wired into humans that gives special attention to negative information." There followed what is by now a characteristic note: "I think it's evolutionary biology."

Negative campaign advertisements are the least of it. There is, in addition, war and male aggression, the human sensitivity to beauty, gossip, a preference for suburban landscapes, love, altruism, marriage, jealousy, adultery, road rage, religious belief, fear of snakes, disgust, night sweats, infanticide, and the fact that parents are often fond of their children. The idea that human behavior is "the product of evolution," as the *Washington Post* puts the matter, is now more than a theory: it is a popular conviction.

It is a conviction that reflects a modest consensus of opinion among otherwise disputatious philosophers and psychologists: Steven Pinker, Daniel Dennett, David Buss, Henry Plotkin, Leda Cosmides, John Tooby, Peter Gärdenfors, Gary Marcus. The consensus is constructed, as such things often are, on the basis of a great hope and a handful of similes. The great hope is that the human mind will in the end find an unobtrusive place in the larger world in which purely material causes chase purely material effects throughout the endless night. The similes are, in turn, designed to promote the hope.

Three similes are at work, each more encompassing than the one before. They give a natural division of labor to what is now called evolutionary psychology.

First, the human mind is *like* a computer in the way that it works. And it is just because the mind *is* like a computer that the computer comprises a model of the mind. "My central thesis," the cognitive psychologist H.A. Simon has written, is that "conventional computers can be, and have been, programmed to represent symbol structures and carry out processes on those structures that parallel, step by step, the way the human brain does it."

Second, the individual human mind is *like* the individual human kidney, or any other organ of the body, in the way that it is created anew in every human being. "Information," Gary Marcus writes, "copied into the nucleus of every newly formed cell, guides the gradual but powerful process of successive approximation that shapes each of the body's organs." This is no less true of the "organ of thought and language" than of the organs of excretion and elimination.

Third, the universal human mind—the expression in matter of human nature—is *like* any other complicated biological artifact in the way that it arose in the human species by means of random variation and natural selection. These forces, as Steven Pinker argues, comprise "the only explanation we have of how complex life *can* evolve. . . ."

Taken together, these similes do succeed wonderfully in suggesting a coherent narrative. The ultimate origins of the human mind may be found in the property of irritability that is an aspect of living tissue itself. There is a primordial twitch, one that has been lost in time but not in memory; various descendant twitches then enlarged themselves, becoming, among the primates at least, sophisticated organs of perception, cognition, and computation. The great Era of Evolutionary Adaptation arrived in the late Paleolithic, a veritable genetic Renaissance in which the contingencies of life created, in the words of the evolutionary psychologist Leda Cosmides, "programs that [were] well-engineered for solving problems such as hunting, foraging for plant foods, courting mates, cooperating with kin, forming coalitions for mutual defense, avoiding predators, and the like." There followed the long Era in Which Nothing Happened, the modern human mind retaining in its structure and programs the mark of the time that human beings spent in the savannah or on the forest floor, hunting, gathering, and reproducing with Darwinian gusto.

Three quite separate scientific theories do much to justify this grand narrative and the three similes that support it. In the first instance, computer science; in the second, theories of biological development; in the third, Darwin's theory of evolution. At times, indeed, it must seem that only the width of a cigarette paper separates evolutionary psychology from the power and the glory of the physical sciences themselves.

The Model for What Science Should Be

If the claims of evolutionary psychology are ambitious, the standard against which they should be assessed must be mature, reasonable, and persuasive. If nothing else, that standard must reflect principles that have worked to brilliant success in the physical sciences themselves. This is more than a gesture of respect; it is simple common sense.

In stressing the importance of their subject, the mathematicians J.H. Hubbard and B.H. West begin their textbook on differential equations by observing that "historically, Newton's spectacular success in describing mechanics by differential equations was a *model for what science should be*" (emphasis added). Hubbard and West then add what is in any case obvious: that "all basic physical laws are stated as differential equations, whether it be Maxwell's equations for electrodynamics, Schrödinger's equation for quantum mechanics, or Einstein's equations for general relativity."

Equations do lie close to the mathematician's heart, and differential equations closer than most. On one side of such an equation, there is a variable denoting an unknown mathematical function; on the other, a description of the rate at which that unknown function is changing at every last moment down to the infinitesimal. Within the physical sciences, such changes express the forces of nature, the moon perpetually falling because perpetually accelerated by the universal force of gravitation. The mathematician's task is to determine the overall, or global, identity of the unknown function from its local rate of change.

In describing the world by means of a differential equation, the mind thus moves from what is local to what is global. It follows that the "model for what science should be" involves an interdiction against action at a distance. "One object," the Russian mathematician Mikhael Gromov observes, "cannot influence another one removed from it without involving local agents located one next to another and making a continuous chain joining the two objects." As for what happens when the interdiction lapses, Gromov, following the French mathematician René Thom, refers to the result as *magic*. This contrast between a disciplined, differential description of a natural process and an essentially magical description is a useful way of describing a fundamental disjunction in thought.

A differential equation, it is important to stress, offers only a general prescription for change. The distance covered by a falling object is a matter of how fast it has been going and how long it has been going fast; this, an equation describes. But how *far* an object has gone depends on how high it was when it began falling, and this the underlying equation does not specify and so cannot describe. The solutions to a differential equation answer the question, how is the process changing? The data themselves answer a quite different question: how or where does the process *start*? Such specifications comprise the initial conditions of a differential equation, and represent the intrusion into the mathematical world of circumstances beyond the mathematical.

It is this that in 1902 suggested to the French mathematician Jacques Hadamard the idea of a "well-posed problem" in analysis. For a differential equation to be physically useful, Hadamard argued, it must meet three requirements. Solutions must in the first place exist. They must be unique. And they must in some reasonable sense be stable, the solutions varying continuously as the initial conditions themselves change.

With these requirements met, a well-posed differential equation achieves a coordination among continuous quantities that is determined for every last crack and crevice in the manifold of time. And is this the standard I am urging on evolutionary psychology? Yes, absolutely.

Nothing but the best.

That the Human Mind Is Like a Digital Computer

Although evolutionary psychologists have embraced the computational theory of mind, it is not entirely a new theory; it has been entertained, if not embraced, in other places and at other times. Gottfried Leibniz wrote of universal computing machines in the 17th century, and only the limitations of 17th-century technology prevented him from toppling into the 21st. As it was, he did manage to construct a multipurpose calculator, which, he claimed, could perform the four elementary operations of addition, subtraction, division, and multiplication. But when he demonstrated the device to members of the Royal Society in London, someone in the wings noticed that he was carrying numbers by hand.

I do not know whether this story is true, but it has a very queer power, and in a discussion dominated by any number of similes it constitutes a rhetorical figure—shaped as a warning—all its own.

In 1936, the British logician Alan Turing published the first of his papers on computability. Using nothing more than ink, paper, and the resources of mathematical logic, Turing managed to create an imaginary machine capable of incarnating a very smooth, very suave imitation of the human mind.

Known now as a Turing machine, the device has at its disposal a tape divided into squares and a reading head mounted over the tape. It has, as well, a finite number of physical symbols, most commonly 0's and 1's. The reading head may occupy one of a finite number of distinct physical states.

And thereafter the repertoire of its action is extremely limited. A Turing machine can, in the first place, recognize symbols, one square at a time. It can, in the second place, print symbols or erase them from the square it is scanning. And it can, in the third place, change its internal state, and move to the left or to the right of the square it is scanning, one square at a time.

There is no fourth place. A Turing machine can do nothing else. In fact, considered simply as a mechanism, a Turing machine can do nothing whatsoever, the thing existing in that peculiar world—my own, and I suspect others' as well—in which everything is possible but nothing gets done.

A Turing machine gains its powers of imitation only when, by means of a program, or an algorithm, it is told what to do. The requisite instructions consist of a finite series of commands, written in a stylized vocabulary precisely calibrated to take advantage of those operations that a Turing machine can perform. What gives to the program its air of cool command is the fact that its symbols function in a double sense. They are symbols by virtue of their *meaning*, and so reflect the intentions of the human mind that has created them; but they are *causes* by virtue of their structure, and so enter into the rhythms of the real world. Like the word "bark," which both expresses a human command and sets a dog to barking, the symbols do double duty.

Although imaginary at its inception, a Turing machine brilliantly anticipated its own realization in matter. Through a process of intellectual parthenogenesis, Turing's ideas gave rise to the modern digital computer. And once the sheer physical palpability of the computer was recognized—there it is, as real as the rocks, the rifts, and the rills of the physical sciences—there was nothing to stand in the way of the first controlling simile of evolutionary psychology: that the human mind is itself a computer, one embodied in the human brain.

The promotion of the computer from an imaginary to a physical object serves the additional purpose of restoring it to the world that can be understood in terms of the "model for what science should be." As a physical device, nothing more than a collection of electronic circuits, the digital computer can be represented entirely by Clerk Maxwell's theory of the electromagnetic field, with the distinction between a Turing machine and its program duplicated in the distinction between a differential equation and its initial conditions. We are returned to the continuous and infinite world studied by mathematical physics, the world in which differential equations track the evolution of material objects moving through time in response to the eternal forces of nature itself.

The intellectual maneuvers that I have recounted serve to make the computer an irresistibly compelling object. But they serve, as well, to displace attention from the human mind. The effect is to endow the simile that the human mind is like a computer with a plausibility it might not otherwise enjoy.

A certain "power to alter things," Albertus Magnus observed, "indwells in the human soul." The *existence* of this power is hardly in doubt. It is evident in every human act in which the mind imposes itself on nature by taking material objects from their accustomed place and rearranging them; and it is evident again whenever a human being interacts with a machine. Writing with characteristic concision in the *Principia*, Isaac Newton observed that "the power and use of machines consist only in this, that by diminishing the velocity *we* may augment the force, and the contrary" (emphasis added). Although Newton's analysis was restricted to mechanical forces (he knew no others), his point is nonetheless general. A machine is a material object, a *thing*, and as such, its capacity to do work is determined by the forces governing its behavior and by its initial conditions.

Those initial conditions must themselves be explained, and in the nature of things they cannot be explained by the very device that *they* serve to explain. This is precisely the problem that Newton faced in the *Principia*. The magnificent "system of the world" that he devised explained why the orbits of the planets around the sun must be represented by a conic section; but Newton was unable to account for the initial conditions that he had himself imposed on his system. Facing an imponderable, he appealed to divine intervention. It was not until Pierre Simon Laplace introduced his nebular hypothesis in 1796 that some form of agency was removed from Newtonian mechanics.

This same pattern, along with the problem it suggests, recurs whenever machines are at issue, and it returns with a vengeance whenever computers are invoked as explanations for the human mind. A computer is simply an electromechanical device, and this is precisely why it is useful as a model of the human brain. By setting its initial conditions, a computer's program allows the machine to do work in the real world. But the normal physical processes by which a computer works are often obscured by their unfamiliarity—who among us *really* understands what a computer is and how it works? No doubt, this is why the thesis that the mind is like a computer resonates with a certain intellectual grandeur.

An abacus conveys no comparable air of mystery. It is a trifle. Made of wood, it consists of a number of wires suspended in a frame and a finite number of beads strung along the wires. Nevertheless, an idealized abacus has precisely the power of a Turing machine, and so both the abacus and the Turing machine serve as models for a working digital computer. By parity of reasoning, they also both serve as models for the human mind.

Yet the thesis that the human mind is like an abacus seems distinctly less plausible than the thesis that the human mind is like a computer, and for obvious reasons. It is precisely when things have been reduced to their essentials that the interaction between a human being and a simple machine emerges clearly. That interaction is naked, a human agent handling an abacus with the same directness of touch that he might employ in handling a lever, a pulley, or an inclined plane. The force that human beings bring to bear on simple machines is muscular and so derived from the chemistry of the human body, the causes ultimately emptying out into the great ocean of physical interactions whose energy binds and loosens the world's large molecules. But what we need to know in the example of the abacus is not the nature of the forces controlling its behavior but the circumstances by which those forces come into play.

No chain of causes known to date accommodates the inconvenient fact that, by setting the initial conditions of a simple machine, a human agent brings about a novel, an unexpected, an entirely idiosyncratic distribution of matter. Every mechanical artifact represents what the anthropologist Mary Douglas calls "matter out of place." The problem that Newton faced but could not solve in the *Principia* returns when an attempt is made to provide a description of the simplest of human acts, the trivial tap or touch that sets a polished wooden bead spinning down a wire. Tracing the causal chain backward leads only to a wilderness of causes, each of them displacing material objects from their proper settings, so that in the end the mystery is simply shoveled back until the point is reached when it can be safely ignored.

A chain of physical causes is thus not obviously useful in explaining how a human agent exhibits the capacity to "alter things." But neither does it help to invoke, as some have done, the hypothesis that another abacus is needed to fix the initial conditions of the first. If each abacus requires yet another abacus in turn, the road lies open to the madness of an infinite regress, a point observed more than 70 years ago by the logicians Kurt Gödel and Alfred Tarski in their epochal papers on incompleteness.

If we are able to explain how the human mind works neither in terms of a series of physical causes nor in terms of a series of infinitely receding mechanical devices, what then is left? There is the ordinary, very rich, infinitely moving account of mental life that without hesitation we apply to ourselves. It is an account frankly magical in its nature. The human mind registers, reacts, and responds; it forms intentions, conceives problems, and then, as Aristotle dryly noted, it *acts*. In analyzing action, we are able to say only, as Albertus Magnus said, that a certain power to alter things inheres in the human soul.

A simile that for its persuasiveness depends on the very process it is intended to explain cannot be counted a great success.

That the Human Mind Is Like Any Other Organ of the Body

If the computational account of the human mind cannot be brought under the control of the "model for what science should be," what of the thesis that the human mind can be comprehended by reference to the laws of biological development? Here we come to the second simile of evolutionary psychology.

"As the ruler of the soul," Ptolemy wrote in the *Tetrabiblos*, "Saturn has the power to make men sordid, petty, mean-spirited, indifferent, mean-minded, malignant, cowardly, diffident, evil-speaking, solitary, tearful, shameless, superstitious, fond of toil, unfeeling, devisors of plots against their friends, gloomy, taking no care of their body." We know the type; there is no need to drown the point in words. Some men are just rotten.

The analysis that Ptolemy offers in defense of his thesis is anything but crude. "The chronological starting point of human nativities," he writes, "is naturally the very time of conception, for to the seed is given once and for all the very qualities that will mark the adult and that are expressed in growth." It is Saturn's position that affects the seed, and the seed thereafter that affects the man.

Ptolemy's sophistication notwithstanding, no one today is much minded to study the *Tetrabiblos* as a guide to human psychology. Even if a convincing correlation could be established between the position of the planets and the onset of human rottenness, persuading us that we have identified some remote cause in nature for some human effect, that cause would quite obviously violate the interdiction against action at a distance. Ptolemy himself was sensitive to the distinction between astrological knowledge and real knowledge. In trying to construct a continuous chain between the position of the planets and the advent of human rottenness, he was at as great a loss as we are. It is for this reason that the word he employs to describe the way in which heavenly objects evoke their effects is *influence*; it is a word that does not appear, and is not needed, in the *Almagest*, Ptolemy's great treatise on astronomy.

More than 2,000 years have gone by since Ptolemy composed the *Tetrabiblos*. The stars have withdrawn themselves; their role in human affairs has been assigned to other objects. Under views accepted by every evolutionary psychologist, the source of human rottenness may be found either in the environment or within the human genome.

The first of these, the environment, has been the perpetual Plaintiff of Record in *Nurture* v. *Nature et al*. But for our purposes it may now be dismissed from further consideration. If some men are made bad, then they are not born that way; and if they are not born that way, an explanation of human rottenness cannot be expressed in evolutionary terms.

The question at hand is thus whether the path initiated by the human genome in development can be understood in terms of "the model for what science should be." A dynamical system is plainly at work, one that transforms what Ptolemy called "the seed" into a fully formed human being in nine months, and then into an accomplished car thief in less than twenty years. What evolutionary psychology requires is a demonstration that this process may itself be brought under control of a description meeting the standard that "one object cannot influence another one removed from it without involving local agents located one next to another and making a continuous chain joining the two objects."

Well, can it?

"Our basic paradigm," Benjamin Levin writes in his textbook on genetics, "is that genes encode proteins, which in turn are responsible for the synthesis of other structures." Levin is a careful and a conscientious writer. By "other structures" he means only the nucleic acids. But his "basic paradigm" is now a part of a great cultural myth, and by "other structures" most evolutionary psychologists mean *all* of the structures that are made from the proteins, most notably the human brain.

The myth begins solidly enough—with the large bio-molecules that make up the human genome. The analysis of the precise, unfathomably delicate steps that take place as the genome undertakes various biochemical activities has been among the glories of modern science. Unfortunately, however, the chain of causes that begins in the human genome gutters out inconclusively long before the chain can be continued to the human brain, let alone the human mind. Consider in this regard the following sequence of representative quotations in which tight causal connections are progressively displaced in favor of an ever more extravagant series of metaphors:

> (1) *Quantum chemistry*: "For a molecule, it is reasonable to split the kinetic energy into two summations—one over the electrons, and one over the nuclei."
>
> (2) *Biochemistry*: "Initiation of prokaryotic translation requires a tRNA bearing N-formyl methionne, as well as three initiation factors (IF1,2,3), a 30S ribosomal subunit GTP," etc.
>
> (3) *Molecular biology*: "Once the protein binds one site, it *reaches* the other by *crawling* along the DNA, thus *preserving* its *knowledge* of the orientation of the first site" (emphasis added).
>
> (4) *Embryology*: "In the embryo, cells divide, *migrate*, *die*, *stick to each other*, *send out* processes, and *form* synapses" (emphasis added).
>
> (5) and (6) *Developmental genetics*: "But genes are simply regulatory elements, molecules that *arrange* their surrounding environments into an *organism*" (emphasis added).
>
> "Genes *prescribe* epigenetic *rules*, which are the neural *pathways* and *regularities* in *cognitive development* by which the individual *mind assembles* itself" (emphasis added).

(7) *Developmental biology*: "The *pattern* of neural connections (synapses) *enables* the human cortex to *function* as the *center* for *learning*, *reasoning*, and *memory*, to *develop* the *capacity* for *symbolic expression*, and to *produce voluntary responses* to interpreted stimuli" (emphasis added).

(8) and (9) *Evolutionary psychology*: "Genes, of course, do *influence* human development" (emphasis added).

"[Genes] *created* us, body and mind" (emphasis added).

Now the very sober (1) and (2) are clearly a part of "the model for what science should be." By the time we come to (3), however, very large molecular chains have acquired powers of agency: they are busy reaching, crawling, and knowing; it is by no means clear that these metaphors may be eliminated in favor of a biochemical description. Much the same is true of (4). In (5) and (6), a connection is suggested between genes, on the one hand, and organisms, on the other, but the chain of causes and their effects has become very long, the crucial connections now entirely expressed in language that simply disguises profound gaps in our understanding.

In (7) the physical connection between morphology and the mind is reduced to wind, while (8) defiantly resurrects "influence," Ptolemy's original term of choice. It is the altogether exuberant (9)—the quotation is from Richard Dawkins—that finally drowns out any last faint signal from the facts.

These literary exercises suggest that the longer the chain of causes, the weaker the links between and among them. Whether this represents nothing more than the fact that our knowledge is incomplete, or whether it points to a conceptual deficiency that we have no way of expressing, let alone addressing—these are matters that we cannot now judge.

Curiously enough, it has been evolutionary psychologists themselves who are most willing to give up in practice what they do not have in theory. For were that missing theory to exist, it would cancel—it would *annihilate*—any last lingering claim we might make on behalf of human freedom. The physical sciences, after all, do not simply trifle with determinism: it is the heart and soul of their method. Were Boron salts at liberty to discard their identity, the claims of inorganic chemistry would seem considerably less pertinent than they do.

Thus, when Steven Pinker writes that "nature does not dictate what we should accept or how we should live our lives," he is expressing a hope entirely at odds with his professional commitments. If ordinary men and women are, like the professor himself, perfectly free to tell their genes "to go jump in the lake," why then pay the slightest attention to evolutionary psychology—why pay the slightest attention to Pinker?

Irony aside, a pattern is at work here. Where (in the first simile) computational accounts of the mind are clear enough to be encompassed by the model for what science should be, they are incomplete—radically so. They embody what they should explain. Where (in the second simile) biochemical and quantum chemical accounts of development are similarly clear and compelling, they extend no farther than a few large molecules. They defer what they cannot explain. In both cases, something remains unexplained.

This is a disappointing but perhaps not unexpected conclusion. We are talking, after all, about the human mind.

That the Human Mind Is Like Any Other Biological Artifact

Evolutionary psychologists believe that the only force in nature adequate to the generation of biological complexity is natural selection. It is an axiom of their faith. But although natural selection is often described as a force, it is certainly not a force of *nature*. There are four such forces in all: gravitational, electromagnetic, and the strong and weak forces. Natural selection is not one of them. It appears, for the most part, as a free-floating form of agency, one whose identity can only be determined by field studies among living creatures—the ant, the field mouse, and the vole.

But field studies have proved notoriously inconclusive when it comes to natural selection. After three decades spent observing Darwin's finches in the Galapagos, P.R. and B.R. Grant were in the end able to state only that "further continuous long-term studies are needed." It is the conclusion invariably established by evolutionary field studies, and it is the only conclusion established with a high degree of reliability.

The largest story told by evolutionary psychology is therefore anecdotal. Like other such stories, it subordinates itself to the principle that we are what we are because we were what we were. Who could argue otherwise? All too often, however, this principle is itself supported by the counter-principle that we were what we were because we are what we are, a circle not calculated to engender confidence.

Thus, in tests of preference, Victor Johnson, a bio-psychologist at New Mexico State University, has reported that men throughout the world designate as attractive women with the most feminine faces. Their lips are large and lustrous, their jaws narrow, their eyes wide. On display in every magazine and on every billboard, such faces convey "accented hormonal markers." These are a guide to fertility, and it is the promise of fertility that prompts the enthusiastic male response.

There is no reason to doubt Johnson's claim that on the whole men prefer pretty young women to all the others—the result, I am sure, of research extending over a score of years. It is the connection to fertility that remains puzzling. If male standards of beauty are rooted in the late Paleolithic era, men worldwide should now be looking for stout muscular women with broad backs, sturdy legs, a high threshold to pain, and a welcome eagerness to resume foraging directly after parturition. It has not been widely documented that they do.

In any case, an analysis of human sexual preferences that goes no farther than preferences is an exercise in tiptoeing to the threshold of something important and never peering over. The promise of evolutionary psychology is nothing less than an explanation of the human *mind*. No psychological theory could possibly be considered complete or even interesting that did not ask *why* men exhibit the tastes or undertake the choices they do. When it comes to sexual "preferences," what is involved is the full apparatus of the passions—beliefs, desires, sentiments, wishes, hopes, longings, aching tenderness. To study preferences without invoking the passions is like studying lightning without ever mentioning electricity.

This is one of those instances where evolutionary psychology betrays a queer family resemblance to certain theories in philosophy and psychology that (as we have seen in the case of determinism) evolutionary psychologists are themselves eager to disown. Behaviorism in psychology, as in the work of John Watson and B.F. Skinner, came to grief because human behavior is itself a contested category, and one that lapses into irrelevance once it is enlarged to accommodate the sources of behavior in the mind itself. It may be possible to analyze the mating strategies of the vole, the subject of much current research, by means of a simple assessment of what the vole does: a single genetic switch seems sufficient to persuade an otherwise uxorious male vole to become flamboyantly promiscuous. But human beings, it goes without saying, are not voles, and what *they* do becomes intelligible to them only when it is coordinated with what they are.

Despite the palpably unreliable stories that evolutionary psychologists tell about the past, *is* there, nevertheless, a scientifically reasonable structure that may be invoked to support those stories (as fine bones may support an otherwise frivolous face)?

The underlying tissue that connects the late Paleolithic and the modern era is the gene pool. Changes to that pool reflect a dynamic process in which genes undergo change, duplicate themselves, surge into the future or shuffle off, and by means of all the contingencies of life serve in each generation the purpose of creating yet another generation. This is the province of population genetics, a discipline given a remarkably sophisticated formulation in the 1930's and 40's by Ronald Fisher, J.B.S. Haldane, and Sewall Wright. Excellent mathematicians, these men were interested in treating evolution as a process expressed by some underlying system of equations. In the 1970's and 80's, the Japanese population geneticist Motoo Kimura revived and then extended their theories.

Kimura's treatise, *The Neutral Theory of Molecular Evolution* (1983), opens with words that should prove sobering to any evolutionary psychologist: "The neutral theory asserts that the great majority of evolutionary changes at the molecular level, as revealed by comparative studies of protein and DNA sequences, are caused not by Darwinian selection but by random drift of selectively neutral or nearly neutral mutants."

If Darwin's theory is a matter of random variation *and* natural selection, it is natural selection that is demoted on Kimura's view. Random variation is paramount; chance is the driving force. This is carefully qualified: Kimura is writing about "the great majority of evolutionary changes," not all. In addition, he is willing to accept the Darwinian disjunction: either complex adaptations are the result of natural selection or they are the result of nothing at all. But the effect of his work is clear: insofar as evolution is neutral, it is not adaptive, and insofar as it is not adaptive, natural selection plays no role in life.

Like his predecessors, Kimura writes within a particular tradition, one whose confines are fixed by the "model for what science should be." Thus, in trying to describe the fate of a mutant gene, Kimura is led to a differential equation—the Fokker-Planck equation, previously used to model diffusion processes. Although complicated, the equation has a straightforward interpretation. It describes the evolution of a probability distribution, tracking the likelihood over every instant of time that a specific gene will change its representation in a population of genes. Kimura is able to provide an explicit solution for the equation, and thus to treat molecular evolution as a well-posed problem in analysis.

But if the "model for what science should be" is powerful, it is also limited. Stretching it beyond its natural limits often turns out to be an exercise in misapplied force, like a blow delivered to the empty air.

As I have noted several times, the power of a differential equation to govern the flow of time is contingent on some specification of its initial conditions. It is precisely these initial conditions that anecdotal accounts of human evolution cannot supply. We can say of those hunters and gatherers only that they hunted and they gathered, and we can say this only because it seems obvious that there was nothing else for them to do. The gene pool that they embodied cannot be directly recovered.

The question very naturally arises: might that gene pool be recovered from the differential equations of mathematical genetics, much as the original position and momentum of a system of particles moving under the influence of gravitational forces might be recovered from their present position and momentum? This is the question posed by Richard Lewontin.* Writing in a recent issue of the *Annual Review of Genetics*, Lewontin observes that if Kimura's equations carry "a population forward in time from some initial conditions," then what is needed is a second theory, one "that can reverse the deductions of the first theory and infer backward from a particular observed state at present."

Lewontin is correct: this is precisely what is needed. Given the trajectory described by the solution of the Fokker-Planck equation, it *is* certainly possible to track the equation backward, past the middle ages, well past the Roman and then the Sumerian empires, and then into the era of the hunter-gatherers. There is nothing troubling about this. Kimura's equation has an explicit solution, and seeing where it led from is like running a film backward.

But whether, in running this particular film backward, we inevitably channel the temporal stream into a *unique* set of initial conditions is not altogether clear. With questions of this sort, we are in the domain of inverse problems, in which the past is contingent on the present. The solution to an inverse problem, the Russian mathematician Oleg Alifanov remarked, "entails determining unknown causes based on observation of their effects." It is this problem that evolutionary psychology must solve if its engaging stories about the Paleolithic era are to command credibility at the molecular level.

And it is this problem that Lewontin argues cannot be solved in the context of mathematical genetics. "A dynamical theory that predicts the present state generally requires that we know not only the nature and magnitude of the forces that have operated, but also the initial conditions and how long the process has been in operation." This double requirement—*know the forces*, *specify the initial conditions*—cannot simultaneously be met in going backward from the present. One item of knowledge is needed for the other.

This specific argument may now be enlarged to accommodate the general case. Inverse problems arise in mathematics when the attempt is made to run various mathematical films backward, and they are by now sufficiently well understood so that something may be said about them in a rough-and-ready way. Inverse problems are *not* in general well posed. Observing a pot of boiling liquid, we cannot use the heat equations to determine its identity. Many liquids reach the same boiling point in roughly the same time.

With inverse problems, what is, in fact, lost is the essential sureness and power of the "model for what science should be," and we are returned to a familiar world in which things and data are messy, disorganized, and partial, and in which theories, despite our best intentions, find themselves unable to peep over the hedge of time into the future or the past.

A familiar and by now depressing shape has revealed itself beneath the third and final simile of evolutionary psychology. It succeeds in meeting the demands of "the model for what science should be," but it succeeds in meeting those demands only at an isolated point. The rest is darkness, mystery, and magic.

The Origins of the Human Mind

If the chief similes of evolutionary psychology have not improved our understanding of the human mind in any appreciable sense, might we at least say that they have done something toward

* I am grateful to Robert Berwick of MIT for calling my attention to this article, and for insisting on its importance.

promoting the field's principal hope, namely, that the mind will in the end take its place as a material object existing in a world of other material objects?

This too is by no means clear. As Leda Cosmides has very sensibly observed, evolutionary psychology is more a research program than a body of specific results. As a program, it rather resembles a weekend athlete forever preparing to embark on a variety of strenuous exercises. In the literature of evolutionary psychology, there is thus no very determined effort to assess any of the classical topics in the philosophy of mind with the aim of doing more than affirming vaguely that some aspect of the mind exists because it may well have been useful. There is, in evolutionary psychology, no account of the emotions beyond the trivial, or of the sentiments, no account of action or intention, no account of the human ability to acquire mathematical or scientific knowledge, no very direct exploration of the mind's power to act at a distance by investing things with meaning—no account, that is, of any of the features of the mind whose existence prompts a question about its origins. In its great hope as in so many other respects, evolutionary psychology has reposed its confidence on the bet that in time these things will be explained. If that is so, all that we on the outside can say is that time will tell.

Yet any essay on evolutionary psychology would be incomplete if it did not acknowledge the moving power of its chief story. For that story, involving as it does our own ancestors, suggests that the human mind that we now occupy had its source in circumstances that, although occluded by time and damaged by distance, are nonetheless familiar.

The time is the distant past. "In Babylonia," the 3rd-century historian Eusebius writes in recounting the lost histories of Berossos the Chaldean, a large number of people "lived without discipline and without order, just like the animals." A frightening monster named Oannes then appeared to the Babylonians after clambering out of the Red Sea. "It had the whole body of a fish, but underneath and attached to the head of the fish there was another head, human, and joined to the tail of the fish, feet, like those of a man, and it had a human voice." The monster "spent his days with men, never eating anything, but teaching men the skills necessary for writing, and for doing mathematics, and for all sorts of knowledge."

Since that time, Eusebius adds regretfully, "nothing further has been discovered."