How the Brain Creates the Mind

We have long wondered how the conscious mind comes to be. Greater understanding of brain function ought to lead to an eventual solution

By Antonio R. Damasio

At the start of the new millennium, it is apparent that one question towers above all others in life sciences: How does the set of processes we call mind emerge from the activity of the organ we call brain? The question is hardly new. It has been formulated in one way or another for centuries. Once it became possible to pose the question and not be burned at the stake, it has been asked openly and insistently. Recently the question has preoccupied both the experts—neuroscientists, cognitive scientists and philosophers—and others who wonder about the origin of the mind, specifically the conscious mind.

The question of consciousness now occupies center stage because biology in general and neuroscience in particular have been so remarkably successful at unraveling a great many of life's secrets. More may have been learned about the brain and the mind in the 1990s—the so-called decade of the brain—than during the entire previous history of psychology and neuroscience. Elucidating the neurobiological basis of the conscious mind—a version of the classic mind-body problem—has become almost a residual challenge.

Contemplation of the mind may induce timidity in the contemplator, especially when consciousness becomes the focus of the inquiry. Some thinkers, expert and amateur alike, believe the question may be unanswerable in principle. For others, the relentless and exponential increase in new knowledge may give rise to a vertiginous feeling that no problem can resist the assault of science if only the theory is right and the techniques are powerful enough. The debate is intriguing and even unexpected, as no comparable doubts have been raised over the likelihood of explaining how the brain is responsible for processes such as vision or memory, which are obvious components of the larger process of the conscious mind.

I am firmly in the confident camp: a substantial explanation for the mind's emergence from the brain will be produced and perhaps soon. The giddy feeling, however, is tempered by the acknowledgment of some sobering difficulties.

Nothing is more familiar than the mind. Yet the pilgrim in search of the sources and mechanisms behind the mind embarks on a journey into a strange and exotic landscape. In no particular order, what follows are the main problems facing those who seek the biological basis for the conscious mind.

The first quandary involves the perspective one must adopt to study the conscious mind in relation to the brain in which we believe it originates. Anyone's body and brain are observable to third parties; the mind, though, is observable only to its owner. Multiple individuals confronted with the same body or brain can make the same observations of that body or brain, but no comparable direct third-person observation is possible for anyone's mind. The body and its brain are public, exposed, external and unequivocally objective entities. The mind is a private, hidden, internal, unequivocally subjective entity.

How and where then does the dependence of a first-person mind on a third-person body occur precisely? Techniques used to study the brain include refined brain scans and the measurement of patterns of activity in the brain's neurons. The naysayers argue that the exhaustive compilation of all these data adds up to *correlates* of mental states but nothing resembling an *actual mental state*. For them, detailed observation of living matter thus leads not to mind but simply to the details of living mat-

MULTIMEDIA MIND-SHOW occurs constantly as the brain processes external and internal sensory events. As the brain answers the unasked question of who is experiencing the mind-show, the sense of self emerges.

SLIM FILMS

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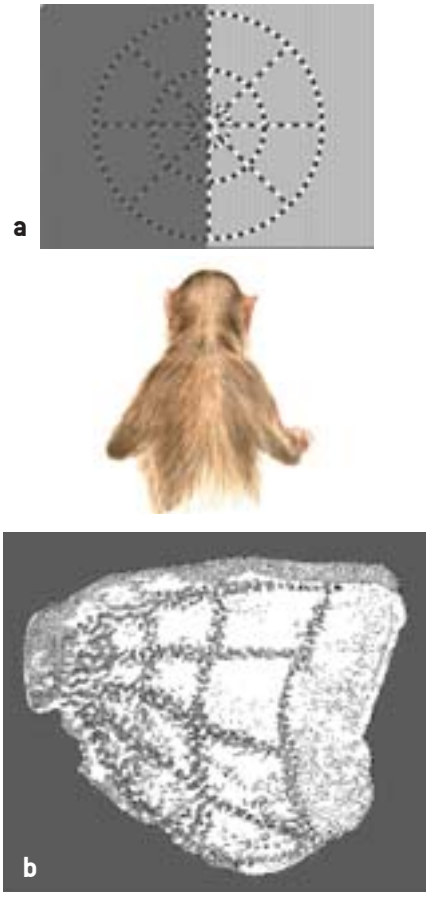
ter. The understanding of how living matter generates the sense of self that is the hallmark of a conscious mind—the sense that the images in my mind are mine and are formed in my perspective—is simply not possible. This argument, though incorrect, tends to silence most hopeful investigators of the conscious mind.

To the pessimists, the conscious-mind problem seems so intractable that it is not even possible to explain why the mind is even *about* something—why mental processes represent internal states or interactions with external objects. (Philosophers refer to this representational quality of the mind with the confusing term "intentionality.") This argument is false.

The final negative contention is the reminder that elucidating the emergence of the conscious mind depends on the existence of that same conscious mind. Conducting an investigation with the very instrument being investigated makes both the definition of the problem and the approach to a solution especially complicated. Given the conflict between observer and observed, we are told, the human intellect is unlikely to be up to the task of comprehending how mind emerges from brain. This conflict is real, but the notion that it is insurmountable is inaccurate.

In summary, the apparent uniqueness of the conscious-mind problem and the difficulties that complicate ways to get at that problem generate two effects: they frustrate those researchers committed to finding a solution and confirm the conviction of others who intuitively believe that a solution is beyond our reach.

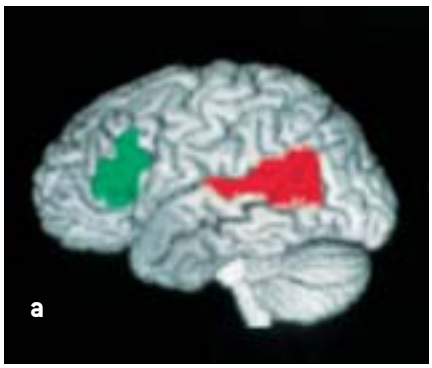


BRAIN'S BUSINESS is representing other things. Studies with macaques show a remarkable fidelity between a seen shape (*a*) and the shape of the neural activity pattern (*b*) in one of the layers of the primary visual cortex.

Evaluating the Difficulties

THOSE WHO CITE the inability of research on the living matter of the brain to reveal the "substance of mind" assume that the current knowledge of that living matter is sufficient to make such judgment final. This notion is entirely unacceptable. The current description of neurobiological phenomena is quite incomplete, any way you slice it. We have yet to resolve numerous details about the function of neurons and circuits at the molecular level; we do not yet grasp the behavior of populations of neurons within a local brain region; and our understanding of the large-scale systems made up of multiple brain regions is also incomplete. We are barely beginning to address the fact that interactions among many noncontiguous brain regions probably yield highly complex biological states that are vastly more than the sum of their parts.

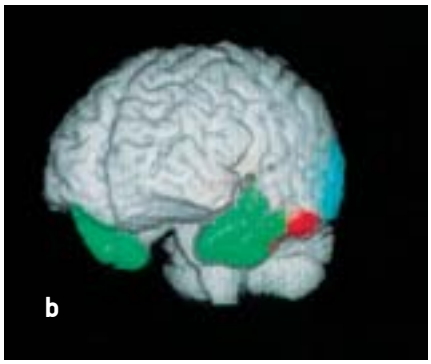
In fact, the explanation of the physics related to biological events is still incomplete. Consequently, declaring the conscious-mind problem insoluble because we have studied the brain to the hilt and have not found the mind is ludicrous. We have not yet fully studied either neurobiology or its related physics. For example, at the finest level of description of mind, the swift construction, manipulation and superposition of many sensory images might require explanation at the quantum level. Incidentally, the notion of a possible role for quantum physics in the elucidation of mind, an idea usually associated with mathematical physicist Roger Penrose of the University of Oxford, is not an endorsement of his specific proposals, namely that consciousness is based on quantum-level phenomena occurring in the microtubules—constituents of neurons and other cells. The quantum level of operations might help explain how we have a mind, but I regard it as unnecessary to explain how we *know* that we own that mind—the issue I regard as most critical for a comprehensive account of consciousness.

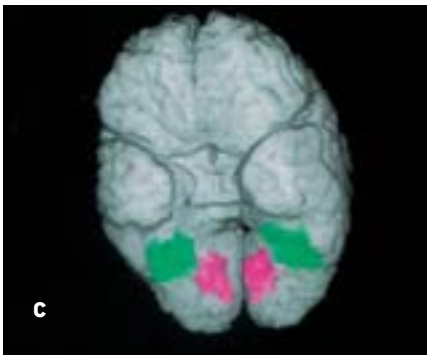


NEUROSCIENCE continues to associate specific brain structures with specific tasks. Some language regions are highlighted in *a* and *b*. Color-processing (*red*) and face-processing (*green*) regions are shown in *c*. One's own body sense depends on the region shown in *d*.

The strangeness of the conscious-mind problem mostly reflects ignorance, which limits the imagination and has the curious effect of making the possible seem impossible. Science-fiction writer Arthur C. Clarke has said, "Any sufficiently advanced technology is indistinguishable from magic." The "technology" of the brain is so complex as to appear magical, or at least unknowable. The appearance of a gulf between mental states and physical/biological phenomena comes from the large disparity between two bodies of knowledge—the good understanding of mind we have achieved through centuries of introspection and the efforts of cognitive science versus the incomplete neural specification we have achieved through the efforts of neuroscience. But there is no reason to expect that neurobiology cannot bridge the gulf. Nothing indicates that we have reached the edge of an abyss that would separate,

DIMITRY SCHIDLOVSKY; SOURCE: TOOTELL ET AL., IN *JOURNAL OF NEUROSCIENCE*, MAY 1988 (*left*); HANNA DAMASIO (*above* and *opposite page*)





in principle, the mental from the neural.

Therefore, I contend that the biological processes now presumed to correspond to mind processes in fact *are* mind processes and will be seen to be so when understood in sufficient detail. I am not denying the existence of the mind or saying that once we know what we need to know about biology the mind ceases to exist. I simply believe that the private, personal mind, precious and unique, indeed *is* biological and will one day be described in terms both biological and mental.

The other main objection to an understanding of mind is that the real conflict between observer and observed makes the human intellect unfit to study itself. It is important, however, to point out that the brain and mind are not a monolith: they have multiple structural levels, and the highest of those levels creates instruments that permit the observation of the other levels. For example, language endowed the mind with the power to categorize and manipulate knowledge according to logical principles, and that helps us classify observations as true or false. We should be modest about the likelihood of ever observing our entire nature. But declaring defeat before we even make the attempt defies Aristotle's observation that human beings are infinitely curious about their own nature.

Reasons for Optimism

MY PROPOSAL for a solution to the conundrum of the conscious mind requires breaking the problem into two parts. The first concern is how we generate what I call a "movie-in-the-brain." This "movie" is a metaphor for the integrated and unified composite of diverse sensory images—visual, auditory, tactile, olfactory and others—that constitutes the multimedia show we call mind. The second issue is the "self" and how we automatically generate a sense of ownership for the movie-in-the-brain. The two parts of the problem are related, with the latter nested in the former. Separating them is a useful research strategy, as each requires its own solution.

Neuroscientists have been attempting unwittingly to solve the movie-in-the-brain part of the conscious-mind problem for most of the history of the field. The endeavor of mapping the brain regions involved in constructing the movie began almost a century and a half ago, when Paul Broca and Carl Wernicke first suggested that different regions of the brain were involved in processing different aspects of language. More recently, thanks to the advent of ever more sophisticated tools, the effort has begun to reap handsome rewards.

Researchers can now directly record the activity of a single neuron or group of neurons and relate that activity to aspects of a specific mental state, such as the perception of the color red or of a curved line. Brain-imaging techniques such as PET (positron emission tomography) scans and fMR (functional magnetic resonance) scans reveal how different brain regions in a normal, living person are engaged by a certain mental effort, such as relating a word to an object or learning a particular face. Investigators can determine how molecules within microscopic neuron circuits participate in such diverse mental tasks, and they can identify the genes necessary for the production and deployment of those molecules.

Progress in this field has been swift ever since David H. Hubel and Torsten Wiesel of Harvard University provided the first clue for how brain circuits represent the shape of a given object, by demonstrating that neurons in the primary visual cortex were selectively tuned to respond to edges oriented in varied angles. Hubel and Margaret S. Livingstone, also at Harvard, later showed that other neurons in the primary visual cortex respond selectively to color but not shape. And Semir Zeki of University College London found that brain regions that received sensory information after the primary visual cortex did were specialized for the further processing of color or movement. These results provided a counterpart to observations made in living neurological patients: damage to distinct regions of the visual cortices interferes with color perception while leaving discernment of shape and movement intact.

A large body of work, in fact, now points to the existence of a correspon-

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dence between the structure of an object as taken in by the eye and the pattern of neuron activity generated within the visual cortex of the organism seeing that object [*see illustration on page 6*].

Further remarkable progress involving aspects of the movie-in-the-brain has led to increased insights related to mechanisms of learning and memory. In rapid succession, research has revealed that the brain uses discrete systems for different types of learning. The basal ganglia and cerebellum are critical for the acquisition of skills—for example, learning to ride a bicycle or play a musical instrument. The hippocampus is integral to the learning of facts pertaining to such entities as people, places or events. And once facts are learned, the long-term memory of those facts relies on multicomponent brain systems, whose key parts are located in the vast brain expanses known as cerebral cortices.

Moreover, the process by which newly learned facts are consolidated in long-term memory goes beyond properly working hippocampi and cerebral cortices. Certain processes must take place, at the level of neurons and molecules, so that the neural circuits are etched, so to speak, with the impressions of a newly learned fact. This etching depends on strengthening or weakening the contacts between neurons, known as synapses. A provocative finding by Eric R. Kandel of Columbia University and Timothy P. Tully of Cold Spring Harbor Laboratory is that etching the impression requires the synthesis of fresh proteins, which in turn relies on the engagement of specific genes within the neurons charged with supporting the consolidated memory.

These brief illustrations of progress could be expanded with other revelations from the study of language, emotion and decision making. Whatever mental function we consider, it is possible to identify distinct parts of the brain that contribute to the production of a function by working in concert; a close correspondence exists between the appearance of a mental state or behavior and the activity of selected brain regions. And that correspondence can be established between a given macroscopically identifiable region (for example, the primary visual cortex, a language-related area or an emotion-related nucleus) and the microscopic neuron circuits that constitute the region.

Most exciting is that these impressive advances in the study of the brain are a mere beginning. New analytical techniques continuously improve the ability to study neural function at the molecular level and to investigate the highly complex large-scale phenomena arising from the whole brain. Revelations from those two areas will make possible ever finer correspondences between brain states and mental states, between brain and mind. As technology develops and the ingenuity of researchers grows, the fine grain of physical structures and biological activities that constitute the movie-in-the-brain will gradually come into focus.

Confronting the Self

THE MOMENTUM of current research on cognitive neuroscience, and the sheer accumulation of powerful facts, may well convince many doubters that the neural basis for the movie-in-the-brain can be identified. But the skeptics will still find it difficult to accept that the second part of the conscious-mind problem—the emergence of a sense of self—can be solved at all. Although I grant that solving this part of the problem is by no means obvious, a possible solution has been proposed, and a hypothesis is being tested.

The main ideas behind the hypothesis involve the unique representational ability of the brain. Cells in the kidney or liver perform their assigned functional roles and do not represent any other cells or functions. But brain cells, at every level of the nervous system, represent entities or events occurring elsewhere in the organism. Brain cells are assigned by design to be *about* other things and other doings. They are born cartographers of the geography of an organism and of the events that take place within that geography. The oft-quoted mystery of the "intentional" mind relative to the representation of external objects turns out to be no mystery at all. The philosophical despair that surrounds this "intentionality" hurdle alluded to earlier—why mental states represent internal emotions or interactions with external objects—lifts with the consideration of the brain in a Darwinian context: evolution has crafted a brain that is in the business of directly representing the organism and indirectly representing whatever the organism interacts with.

The brain's natural intentionality then takes us to another established fact: the brain possesses devices within its structure that are designed to manage the life of the organism in such a way that the internal chemical balances indispensable for survival are maintained at all times. These devices are neither hypothetical nor abstract; they are located in the brain's core, the brain stem and hypothalamus. The brain devices that regulate life also represent, of necessity, the constantly changing states of the organism as they occur. In other words, the brain has a natural means to represent the structure and state of the *whole* living organism.

But how is it possible to move from such a biological self to the sense of ownership of one's thoughts, the sense that one's thoughts are constructed in one's own perspective, without falling into the trap of invoking an all-knowing homunculus who interprets one's reality? How is it possible to know about self and surroundings? I have argued in my book *The Feeling of What Happens* that the biological foundation for the sense of self can be found in those brain devices that represent, moment by moment, the continuity of the same individual organism.

Simply put, my hypothesis suggests

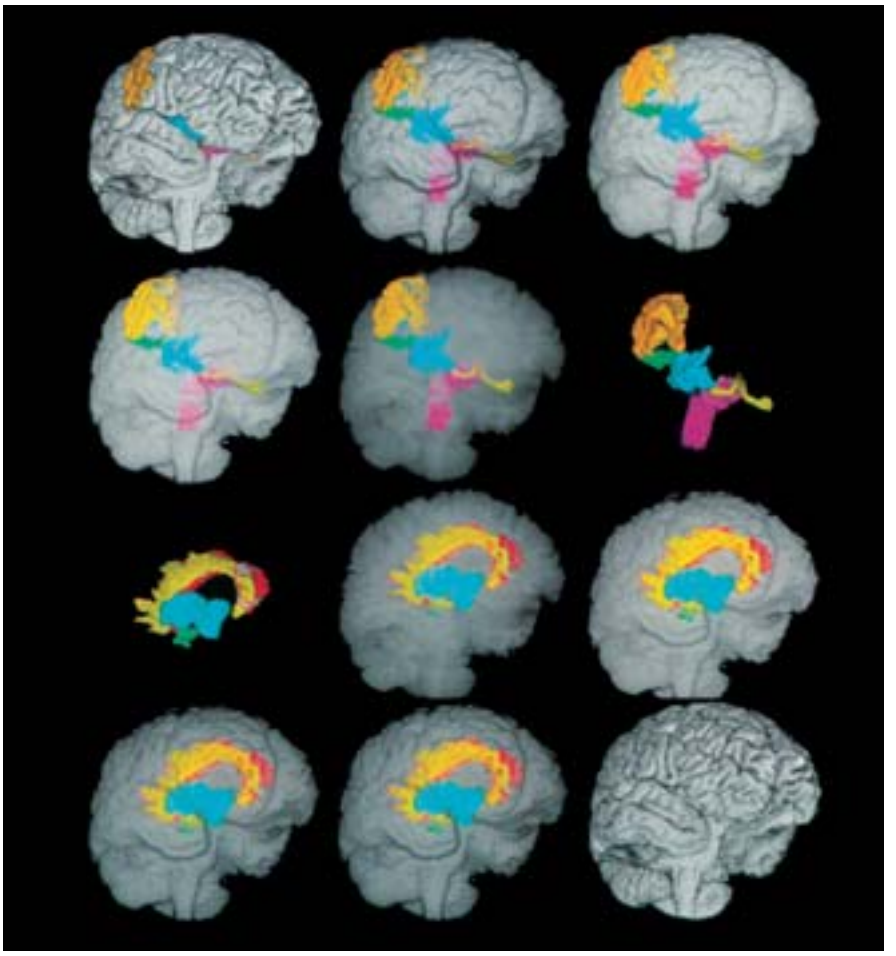
The pilgrim in search of the mechanisms of the mind journeys into A STRANGE, EXOTIC LANDSCAPE.

that the brain uses structures designed to map both the organism and external objects to create a fresh, second-order representation. This representation indicates that the organism, as mapped in the brain, is involved in interacting with an object, also mapped in the brain. The second-order representation is no abstraction; it occurs in neural structures such as the thalamus and the cingulate cortices.

Such newly minted knowledge adds important information to the evolving mental process. Specifically, it *presents* within the mental process the information that the organism is the owner of the mental process. It volunteers an answer to a question never posed: To whom is this happening? The sense of a self in the act of knowing is thus created, and that forms the basis for the first-person perspective that characterizes the conscious mind.

Again from an evolutionary perspective, the imperative for a sense of self becomes clear. As Willy Loman's wife says in Arthur Miller's *Death of a Salesman*: "Attention must be paid!" Imagine a self-aware organism versus the same type of organism lacking it. A self-aware organism has an incentive to heed the alarm signals provided by the movie-in-the-brain (for instance, pain caused by a particular object) and plan the future avoidance of such an object. Evolution of self rewards awareness, which is clearly a survival advantage.

With the movie metaphor in mind, if you will, my solution to the conscious-mind problem is that the sense of self in the act of knowing emerges *within* the movie. Self-awareness is actually part of the movie and thus creates, within the same frame, the "seen" and the "seer," the "thought" and the "thinker." There is no separate spectator for the movie-in-the-brain. The idea of spectator is constructed within the movie, and no ghostly homunculus haunts the theater. Objective brain processes knit the subjectivity of the conscious mind out of the cloth of sensory mapping. And because the most fundamental sensory mapping pertains to body states and is imaged as feelings, the sense of self in the act of knowing emerges as a special kind of feeling—the feeling of what happens in an organism caught in the act of interacting with an object.



THE SENSE OF SELF has a seat in the core of the brain. Stripping away the external anatomy of a human brain shows a number of deep-seated regions responsible for homeostatic regulation, emotion, wakefulness and the sense of self.

The Future

I WOULD BE FOOLISH to make predictions about what can and cannot be discovered or about when something might be discovered and the route of a discovery. Nevertheless, it is probably safe to say that by 2050 sufficient knowledge of biological phenomena will have wiped out the traditional dualistic separations of body/brain, body/mind and brain/mind.

Some observers may fear that by pinning down its physical structure something as precious and dignified as the human mind may be downgraded or vanish entirely. But explaining the origins and workings of the mind in biological tissue will not do away with the mind, and the awe we have for it can be extended to the amazing microstructure of the organism and to the immensely complex functions that allow such a microstructure to generate the mind. By understanding the mind at a deeper level, we will see it as nature's most complex set of biological phenomena rather than as a mystery with an unknown nature. The mind will survive explanation, just as a rose's perfume, its molecular structure deduced, will still smell as sweet. SA

MORE TO EXPLORE

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