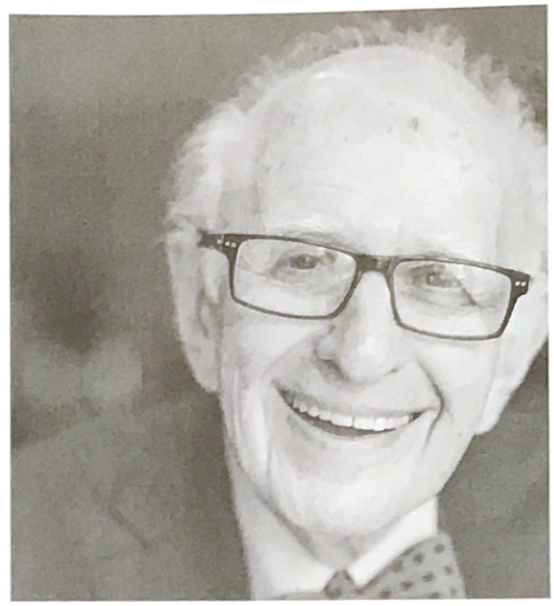
ERIC
# KANDEL

## *The Problem of Consciousness*



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**ERIC KANDEL** (b. 1929) was born in Vienna, Austria, but when the Nazis annexed Austria in 1939, his parents realized that they were at risk because Jews were being persecuted and killed. They abandoned their small toy and luggage store and sailed to the United States. With relatives in Brooklyn, Kandel, at age 9, began grade school at a yeshivah and then attended public high school at Erasmus Hall in Brooklyn, where he was a track star. At the suggestion of a teacher, he applied to Harvard University and was accepted; he graduated with a major in modern European history. However, his interest in the studies of the mind began while he was an undergraduate as a result of his friendship with a young woman whose parents were Freudian analysts.

In 1952, Kandel entered New York University's School of Medicine and began a career that led him into the field of psychiatry. Eventually, he began research in neurobiology that centered on the question of how memory works. In 1957, he joined the Laboratory of Neurophysiology at the National Institutes of Health. Some of the ongoing research postulated that the hippocampus, a structure deep in the brain, is a center of memory storage, but the complexity of the hippocampus made it difficult to study directly. After his residency in psychiatry, Kandel went to Paris to study research with Ladislav Tauc (1926–1999), who was working with a simple sea animal called *Aplysia*. Eventually, Kandel also centered his work on the sea slug *Aplysia*, which is one of the simplest animals capable of learning. This animal was particularly easy to work with because the ganglia and axons that help form memory are large enough to manipulate and study.

On his return from Paris, Kandel became a professor in the departments of physiology and psychiatry at the New York University Medical School. He set up a laboratory to continue his studies of *Aplysia* and, in 1974, moved his lab to Columbia University as the founding director of the Center for Neurobiology and Behavior. As his work progressed, he was winner of many prestigious awards, such as the Lasker Award (1983), National Medal

From *In Search of Memory: The Emergence of a New Science of Mind.*

of Science (1988), Wolf Prize in Medicine (1999), and the Nobel Prize in Physiology or Medicine (2000), which he shared with two other researchers.

*In Search of Memory: The Emergence of a New Science of Mind* (2006) is an award-winning book by Kandel aimed at a large audience. Kandel begins with his own memories of his life in Austria and his immigration to the United States. He remembers his early education and the help he had in deciding to go to Harvard. His book also goes on to present the current research and understanding of the cellular nature of the brain and its operations in memory. It represents a major introduction to the state of the art in memory research. Kandel begins one cell at a time and continues until he presents his thoughts on the problem of consciousness in the selection that follows.

## KANDEL'S RHETORIC

The purpose of Kandel's essay is to inform the reader about the ongoing research into the nature of consciousness. Although he admits that the interest in consciousness has been evident since Hippocrates in the fifth century B.C.E., most of his attention is paid to what has been going on since he began his studies. He begins, in paragraph 2, to define consciousness as "a state of perceptual awareness, or selective attention writ large." Much of the rest of the essay expands on this definition.

Although Kandel does not use an enumerative structure, he does begin with an effort to understand the nature of the problem and explain why it is so difficult to solve. Because the problem of consciousness has not been solved — and may not be solved anytime soon — Kandel brings to our attention a wide range of work done by the most important current scientists working on the problem. He begins with the most well-known of modern genetic researchers, James Crick, who discovered the nature of the gene. After he identified the important aspects of the structure of the gene, Crick devoted himself to trying to solve some of the most difficult aspects of the problem of consciousness.

In the process of his review of what is known, Kandel summarizes the position of René Descartes and his view that the mind is immaterial, like the soul, and therefore cannot be studied. Gilbert Ryle (p. 514) also reviews Descartes's ideas, stating they are false. Kandel then reviews modern philosophers and finds a variety of opinions. Eventually, he considers a recent consensus that ascribes "two characteristics to the conscious state: unity and subjectivity" (para. 10). He describes unity as the easy problem, whereas subjectivity is the hard problem of consciousness. But even the easy problem has some great difficulty, as in the case of a bisected brain that, then, has "two conscious minds" that perceive a uniform experience.

Kandel then goes on to discuss issues such as perception, as when he is in his rose garden in Riverdale both seeing and smelling flowers. He asks how the mind creates the unity of experience that he perceives in that setting. "How is it that I respond to the red image of a rose with a feeling that is distinctive to me?" (para. 15). That question is one of subjectivity and, for him, represents the "hard problem of consciousness" (para. 20).

From that point, Kandel moves into the biology of the brain and observes the activity of brain cells during periods of people's awareness and consciousness of feeling. His interest in emotions parallels some of Robert Nozick's (p. 528) interest, but from the point of view of the physiologist. Most of Kandel's essay on consciousness is part of the study of the physiology of the brain while the mind is conscious. However, he also includes observations of the brain and the mind's activity while unconscious. In this way, he links his early training as a psychiatrist with his later training as a neurologist. He also connects the subject of his research with the work of Freud (p. 477), who postulated that in the future his psychological research would probably be clarified by studies of the physiology of the brain.

Thus, Kandel leaves us with the sense that our understanding of consciousness will come not only from philosophical studies or religious studies, but also from neurological studies that are in progress now and that continue to confront still massive challenges to our understanding.

## PREREADING QUESTIONS: WHAT TO READ FOR

The following prereading questions may help you anticipate key issues in the discussion of Eric Kandel's "The Problem of Consciousness." Keeping them in mind during your first reading of the selection should help focus your attention.

1. What is the unity problem of consciousness?
2. What is the hard problem of consciousness?
3. How does Eric Kandel define consciousness?

# The Problem of Consciousness

Psychoanalysis introduced us to the unconscious in its several forms. Like many scientists now working on the brain, I have long been intrigued by the biggest question about the brain: the nature of consciousness and how various unconscious psychological processes relate to conscious thought. When I first talked with Harry Grundfest[1] about Freud's structural theory of mind—the ego, the id, and the superego—the central focus of my thinking was: How do conscious and unconscious processes differ in their representation in the brain? But only recently has the new science of mind developed the tools for exploring this question experimentally. 1

To develop productive insights into consciousness, the new science of mind first had to settle on a working definition of consciousness as a state of 2

[1] **Harry Grundfest (1904–1983)** Professor of neurology at Columbia University and Eric Kandel's teacher.

perceptual awareness, or selective attention writ large. At its core, consciousness in people is an awareness of self, an awareness of being aware. Consciousness thus refers to our ability not simply to experience pleasure and pain but to attend to and reflect upon those experiences, and to do so in the context of our immediate lives and our life history. Conscious attention allows us to shut out extraneous experiences and focus on the critical event that confronts us, be it pleasure or pain, the blue of the sky, the cool northern light of a Vermeer painting, or the beauty and calm we experience at the seashore.

Understanding consciousness is by far the most challenging task confront- 3
ing science. The truth of this assertion can best be seen in the career of Francis Crick,[2] perhaps the most creative and influential biologist of the second half of the twentieth century. When Crick first entered biology, after World War II, two great questions were thought to be beyond the capacities of science to answer: What distinguishes the living from the nonliving world? And what is the biological nature of consciousness? Crick turned first to the easier problem, distinguishing animate from inanimate matter, and explored the nature of the gene. By 1953, after just two years of collaboration, he and Jim Watson[3] had helped solve that mystery. As Watson later described in *The Double Helix*, "at lunch Francis winged into the Eagle [Pub] to tell everyone within hearing distance that we had found the secret of life." In the next two decades, Crick helped crack the genetic code: how DNA makes RNA and RNA[4] makes protein.

In 1976, at age sixty, Crick turned to the remaining scientific mystery: the 4
biological nature of consciousness. This he studied for the rest of his life in partnership with Christof Koch,[5] a young computational neuroscientist. Crick brought his characteristic intelligence and optimism to bear on the question; moreover, he made consciousness a focus of the scientific community, which had previously ignored it. But, despite almost thirty years of continuous effort, Crick was able to budge the problem only a modest distance. Indeed, some scientists and philosophers of mind continue to find consciousness so inscrutable that they fear it can never be explained in physical terms. How can a biological system, a biological machine, they ask, feel anything? Even more doubtful, how can it think about itself?

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[2] **Francis Crick (1916–2004)** Nobel Prize–winning geneticist who helped to crack the genetic code.

[3] **Jim Watson (b. 1928)** Co-discoverer with Crick of the double helix structure of the gene.

[4] **DNA and RNA** Deoxyribonucleic acid, which contains instructions for the gene; ribonucleic acid, which helps carry out the DNA instructions.

[5] **Christof Koch (b. 1956)** Chief Scientific Officer of the Allen Institute for Brain Science in Seattle, known for his work in consciousness.

These questions are not new. They were first posed in Western thought 5
during the fifth century B.C. by Hippocrates[6] and by the philosopher Plato, the founder of the Academy in Athens. Hippocrates was the first physician to cast superstition aside, basing his thinking on clinical observations and arguing that all mental processes emanate from the brain. Plato, who rejected observations and experiments, believed that the only reason we can think about ourselves and our mortal body is that we have a soul that is immaterial and immortal. The idea of an immortal soul was subsequently incorporated into Christian thought and elaborated upon by St. Thomas Aquinas[7] in the thirteenth century. Aquinas and later religious thinkers held that the soul—the generator of consciousness—is not only distinct from the body, it is also of divine origin.

In the seventeenth century, René Descartes[8] developed the idea that human 6
beings have a dual nature: they have a body, which is made up of material substance, and a mind, which derives from the spiritual nature of the soul. The soul receives signals from the body and can influence its actions but is itself made up of an immaterial substance that is unique to human beings. Descartes' thinking gave rise to the view that actions like eating and walking, as well as sensory perception, appetites, passions, and even simple forms of learning, are all mediated by the brain and can be studied scientifically. Mind, however, is sacred and as such is not a proper subject of science.

It is remarkable to reflect that these seventeenth-century ideas were still 7
current in the 1980s. Karl Popper,[9] the Vienna-born philosopher of science, and John Eccles,[10] the Nobel laureate neurobiologist, espoused dualism all of their lives. They agreed with Aquinas that the soul is immortal and independent of the brain. Gilbert Ryle,[11] the British philosopher of science, referred to the notion of the soul as "the ghost in the machine."

Today, most philosophers of mind agree that what we call consciousness 8
derives from the physical brain, but some disagree with Crick as to whether it can ever be approached scientifically. A few, such as Colin McGinn,[12] believe that consciousness simply cannot be studied, because the architecture of the

[6] **Hippocrates (460–375 B.C.E.)** Regarded as the greatest ancient physician.

[7] **St. Thomas Aquinas (1225–1274)** A Dominican friar and follower of Aristotle and Plato. *Summa Theologica* is his major work.

[8] **René Descartes (1596–1650)** French philosopher who in his meditations proposed the idea of mind-body dualism.

[9] **Karl Popper (1902–1994)** Austrian-British philosopher of science.

[10] **John Eccles (1903–1997)** Australian neurophysiologist and winner of the Nobel Prize for work on the brain's synapses.

[11] **Gilbert Ryle (1900–1976)** British analytic philosopher. See p. 514.

[12] **Colin McGinn (b. 1950)** British philosopher who has contended that the human mind cannot solve the problem of consciousness.

brain poses limitations on human cognitive capacities. In McGinn's view, the human mind may simply be incapable of solving certain problems. At the other extreme, philosophers such as Daniel Dennett[13] deny that there is any problem at all. Dennett argues, much as neurologist John Hughlings Jackson[14] did a century earlier, that consciousness is not a distinct operation of the brain; rather, it is the combined result of the computational workings of higher-order areas of the brain concerned with later stages of information processing.

9 Finally, philosophers such as John Searle and Thomas Nagel[15] take a middle position, holding that consciousness is a discrete set of biological processes. The processes are accessible to analysis, but we have made little headway in understanding them because they are very complex and represent more than the sum of their parts. Consciousness is therefore much more complicated than any property of the brain that we understand.

10 Searle and Nagel ascribe two characteristics to the conscious state: unity and subjectivity. The unitary nature of consciousness refers to the fact that our experiences come to us as a unified whole. All of the various sensory modalities are melded into a single, coherent, conscious experience. Thus when I approach a rosebush in the botanical garden at Wave Hill near my house in Riverdale, I sniff the exquisite fragrance of the blossoms at the same time that I see their beautiful red color—and I perceive this rosebush against the background of the Hudson River and the cliffs of the Palisade mountain ridge behind it. My perception is not only whole during the moment I experience it, it is also whole two weeks later, when I engage in mental time travel to recapture the moment. Despite the fact that there are different organs for smell and vision, and that each uses its own individual pathways, they converge in the brain in such a way that my perceptions are unified.

11 The unitary nature of consciousness poses a difficult problem, but perhaps not an insurmountable one. This unitary nature can break down. In a surgical patient whose brain is severed between the two hemispheres, there are two conscious minds, each with its own unified percept.

12 Subjectivity, the second characteristic of conscious awareness, poses the more formidable scientific challenge. Each of us experiences a world of private and unique sensations that is much more real to us than the experiences of others. We experience our own ideas, moods, and sensations directly, whereas we can only appreciate another person's experience indirectly, by observing or

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13 **Daniel Dennett (b. 1942)** Professor of philosophy at Tufts University and a noted atheist.

14 **John Hughlings Jackson (1835–1911)** British neurologist who has done influential work in epilepsy and aphasia.

15 **John Searle and Thomas Nagel** John Searle (b. 1932) is a philosopher at University of California, Berkeley, and Thomas Nagel (b. 1937) is a philosopher teaching at New York University. Both have written about the mind.

hearing about it. We therefore can ask, Is your response to the blue you see and the jasmine you smell—the meaning it has for you—identical to my response to the blue I see and the jasmine I smell and the meaning these have for me?

The issue here is not one of perception per se. It is not whether we each see a very similar shade of the same blue. That is relatively easy to establish by recording from single nerve cells in the visual system of different individuals. The brain does reconstruct our perception of an object, but the object perceived—the color blue or middle C on the piano—appears to correspond to the physical properties of the wavelength of the reflected light or the frequency of the emitted sound. Instead, the issue is the significance of that blue and that note for each of us. What we do not understand is how electrical activity in neurons gives rise to the meaning we ascribe to that color or that wavelength of sound. The fact that conscious experience is unique to each person raises the question of whether it is possible to determine objectively any characteristics of consciousness that are common to everyone. If the senses ultimately produce experiences that are completely and personally subjective, we cannot, the argument goes, arrive at a general definition of consciousness based on personal experience. 13

Nagel and Searle illustrate the difficulty of explaining the subjective nature of consciousness in physical terms as follows: Assume we succeed in recording the electrical activity of neurons in a region known to be important for consciousness while the person being studied carries out some task that requires conscious attention. For example, suppose we identified the cells that fire when I look at and become aware of a red image of the blossoms on a rosebush at Wave Hill. We have now taken a first step in studying consciousness—namely, we have found what Crick and Koch have called the neural correlate of consciousness for this one percept. For most of us, this would be a great advance because it pinpoints a material concomitant of conscious perception. From there we could go on to carry out experiments to determine whether these correlates also meld into a coherent whole, that is, the background of the Hudson River and the Palisades. But for Nagel and Searle, this is the easy problem of consciousness. The hard problem of consciousness is the second mystery, that of subjective experience. 14

How is it that I respond to the red image of a rose with a feeling that is distinctive to me? To use another example, what grounds do we have for believing that when a mother looks at her child, the firing of cells in the region of the cortex concerned with face recognition accounts for the emotions she feels and for her ability to summon the memory of those emotions and that image of her child? 15

As yet, we do not know how the firing of specific neurons leads to the subjective component of conscious perception, even in the simplest case. In fact, according to Searle and Nagel, we lack an adequate theory of how an objective 16 phenomenon, such as electrical signals in the brain, can cause a subjective experience, such as pain. And because science as we currently practice it is a reductionist, analytical view of complicated events, while consciousness is irreducibly subjective, such a theory lies beyond our reach for now.

According to Nagel, science cannot take on consciousness without a signif- 17
icant change in methodology, a change that would enable scientists to identify and analyze the elements of subjective experience. Those elements are likely to be basic components of brain function, much as atoms and molecules are basic components of matter, but to exist in a form we cannot yet imagine. The reductions performed routinely in science are not problematic, Nagel holds. Biological science can readily explain how the properties of a particular type of matter arise from the objective properties of the molecules of which it is made. What science lacks are rules for explaining how subjective properties (consciousness) arise from the properties of objects (interconnected nerve cells).

Nagel argues that our complete lack of insight into the elements of subjec- 18
tive experience should not prevent us from discovering the neural correlates of consciousness and the rules that relate conscious phenomena to cellular processes in the brain. In fact, it is only by accumulating such information that we will be in a position to think about the reduction of something subjective to something physical and objective. But to arrive at a theory that supports this reduction, we will first have to discover the elements of subjective consciousness. This discovery, says Nagel, will be enormous in its magnitude and its implications, requiring a revolution in biology and most likely a complete transformation of scientific thought.

The aim of most neural scientists working on consciousness is much more 19
modest than this grand perspective would imply. They are not deliberately working toward or anticipating a revolution in scientific thought. Although they must struggle with the difficulties of defining conscious phenomena experimentally, they do not see those difficulties as precluding all experimental study under existing paradigms. Neural scientists believe, and Searle for one agrees with them, that they have been able to make considerable progress in understanding the neurobiology of perception and memory without having to account for individual experience. For example, cognitive neural scientists have made advances in understanding the neural basis of the perception of the color blue without addressing the question of how each of us responds to the same blue.

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What we do not understand is the hard problem of consciousness—the mystery of how neural activity gives rise to subjective experience. Crick and Koch have argued that once we solve the easy problem of consciousness, the unity of consciousness, we will be able to manipulate those neural systems experimentally to solve the hard problem.

The unity of consciousness is a variant of the binding problem first identified in the study of visual perception. An intimate part of my experiencing the subjective pleasure of the moment at Wave Hill is how the look and the smell of roses in the gardens are bound together and unified with my view of the Hudson, the Palisades, and all the other component images of my perception. Each of these components of my subjective experience is mediated by different brain regions within my visual and olfactory and emotional systems. The unity of my conscious experience implies that the binding process must somehow connect and integrate all of these separate areas in the brain. 21

As a first step toward solving the easy problem of consciousness, we need to ask whether the unity of consciousness—a unity thought to be achieved by neural systems that mediate selective attention—is localized in one or just a few sites, which would enable us to manipulate them biologically. The answer to this question is by no means clear. Gerald Edelman,[16] a leading theoretician on the brain and consciousness, has argued effectively that the neural machinery for the unity of consciousness is likely to be widely distributed throughout the cortex and thalamus. As a result, Edelman asserts, it is unlikely that we will be able to find consciousness through a simple set of neural correlates. Crick and Koch, on the other hand, believe that the unity of consciousness will have direct neural correlates because they most likely involve a specific set of neurons with specific molecular or neuroanatomical signatures. The neural correlates, they argue, probably require only a small set of neurons acting as a searchlight: the spotlight of attention. The initial task, they argue, is to locate within the brain that small set of neurons whose activity correlates best with the unity of conscious experience and then to determine the neural circuits to which they belong. 22

How are we to find this small population of nerve cells that could mediate the unity of consciousness? What criteria must they meet? In Crick and Koch's last paper (which Crick was still correcting on his way to the hospital a few hours before he died, on July 28, 2004), they focused on the claustrum, a sheet of brain tissue that is located below the cerebral cortex, as the site that mediates unity of experience. Little is known about the claustrum except that it connects to and exchanges information with almost all of the sensory and motor regions of the cortex as well as the amygdala, which plays an important role in emotion. Crick and Koch compare the claustrum to the conductor of an orchestra. Indeed, the neuroanatomical connections of the claustrum meet the requirements of a conductor; it can bind together and coordinate the various brain regions necessary for the unity of conscious awareness. 23

The idea that obsessed Crick at the end of his life—that the claustrum is the spotlight of attention, the site that binds the various components of any 24

[16] **Gerald Edelman (1929–2014)** Neuroscientist who won the Nobel Prize in Physiology or Medicine. He was professor at the Scripps Research Institute in California.

percept together—is the last in a series of important ideas he advanced. Crick's enormous contributions to biology (the double helical structure of DNA, the nature of the genetic code, the discovery of messenger RNA, the mechanisms of translating messenger RNA into the amino acid sequence of a protein, and the legitimizing of the biology of consciousness) put him in a class with Copernicus, Newton, Darwin, and Einstein. Yet his intense, lifelong focus on science, on the life of mind, is something he shares with many in the scientific community, and that obsession is symbolic of science at its best. The cognitive psychologist Vilayanur Ramachandran,[17] a friend and colleague of Crick's, described Crick's focus on the claustrum during his last weeks:

> Three weeks prior to his death I visited him in his home in La Jolla. He was eighty-eight, had terminal cancer, was in pain, and was on chemotherapy; yet he had obviously been working away nonstop on his latest project. His very large desk—occupying half the room—was covered by articles, correspondence, envelopes, recent issues of *Nature*, a laptop (despite his dislike of computers), and recent books on neuroanatomy. During the whole two hours that I was there, there was no mention of his illness—only a flight of ideas on the neural basis of consciousness. He was especially interested in a tiny structure called the claustrum which, he felt, had been largely ignored by mainstream pundits. As I was leaving he said: "Rama, I think the secret of consciousness lies in the claustrum—don't you? Why else would this tiny structure be connected to so many areas in the brain?"—And gave me a sly, conspiratorial wink. It was the last time I saw him.

Since so little is known about the claustrum, Crick continued, he wanted 25
to start an institute to focus on its function. In particular, he wanted to determine whether the claustrum is switched on when unconscious, subliminal perception of a given stimulus by a person's sensory organs turns into a conscious percept.

One example of such switching that intrigued Crick and Koch is binoc- 26
ular rivalry. Here, two different images—say, vertical stripes and horizontal stripes—are presented to a person simultaneously in such a way that each eye sees only one set of stripes. The person may combine the two images and report seeing a plaid, but more commonly the person will see first one image, then the next, with horizontal and vertical stripes alternating back and forth spontaneously.

17 **Vilayanur Ramachandran (b. 1951)** Neuroscientist professor at the University of California, San Diego. He is the director of the Center for Brain and Cognition and author of *Phantoms in the Brain* (1999).

Using MRI, Eric Lumer[18] and his colleagues at University College, London 27
have identified the frontal and parietal areas of the cortex as the regions of the brain that become active when a person's conscious attention switches from one image to another. These two regions have a special role in focusing conscious attention on objects in space. In turn, the prefrontal and posterior parietal regions of the cortex seem to relay the decision regarding which image is to be enhanced to the visual system, which then brings the image into consciousness. Indeed, people with damage to the prefrontal cortex have difficulty switching from one image to the other in situations of binocular rivalry. Crick and Koch might argue that the frontal and parietal areas of the cortex are recruited by the claustrum, which switches attention from one eye to the other and unifies the image presented to conscious awareness by each eye.

As these arguments make clear, consciousness remains an enormous 28
problem. But through the efforts of Edelman on the one hand, and Crick and Koch on the other, we now have two specific and testable theories worthy of exploration.

As someone interested in psychoanalysis, I wanted to take the Crick-Koch 29
paradigm of comparing unconscious and conscious perception of the same stimulus to the next step: determining how visual perception becomes endowed with emotion. Unlike simple visual perception, emotionally charged visual perception is likely to differ between individuals. Therefore, a further question is, How and where are unconscious emotional perceptions processed?

Amit Etkin,[19] a bold and creative M.D.-Ph.D. student, and I undertook a 30
study in collaboration with Joy Hirsch,[20] a brain imager at Columbia, in which we induced conscious and unconscious perceptions of emotional stimuli. Our approach paralleled in the emotional sphere that of Crick and Koch in the cognitive sphere. We explored how normal people respond consciously and unconsciously to pictures of people with a clearly neutral expression or an expression of fear on their faces. The pictures were provided by Peter Ekman[21] at the University of California, San Francisco.

Ekman, who has cataloged more than 100,000 human expressions, was able 31
to show, as did Charles Darwin before him, that irrespective of sex or culture, conscious perceptions of seven facial expressions—happiness, fear, disgust, contempt, anger, surprise, and sadness—have virtually the same meaning to everyone (figure 1). We therefore argued that fearful faces should elicit a similar response from the healthy young medical and graduate student volunteers

[18] **Eric Lumer** British neuroscientist.

[19] **Amit Etkin (b. 1976)** Stanford University psychiatrist.

[20] **Joy Hirsch** Professor at Columbia University, studying neurological disorders.

[21] **Peter Ekman** American photographer.

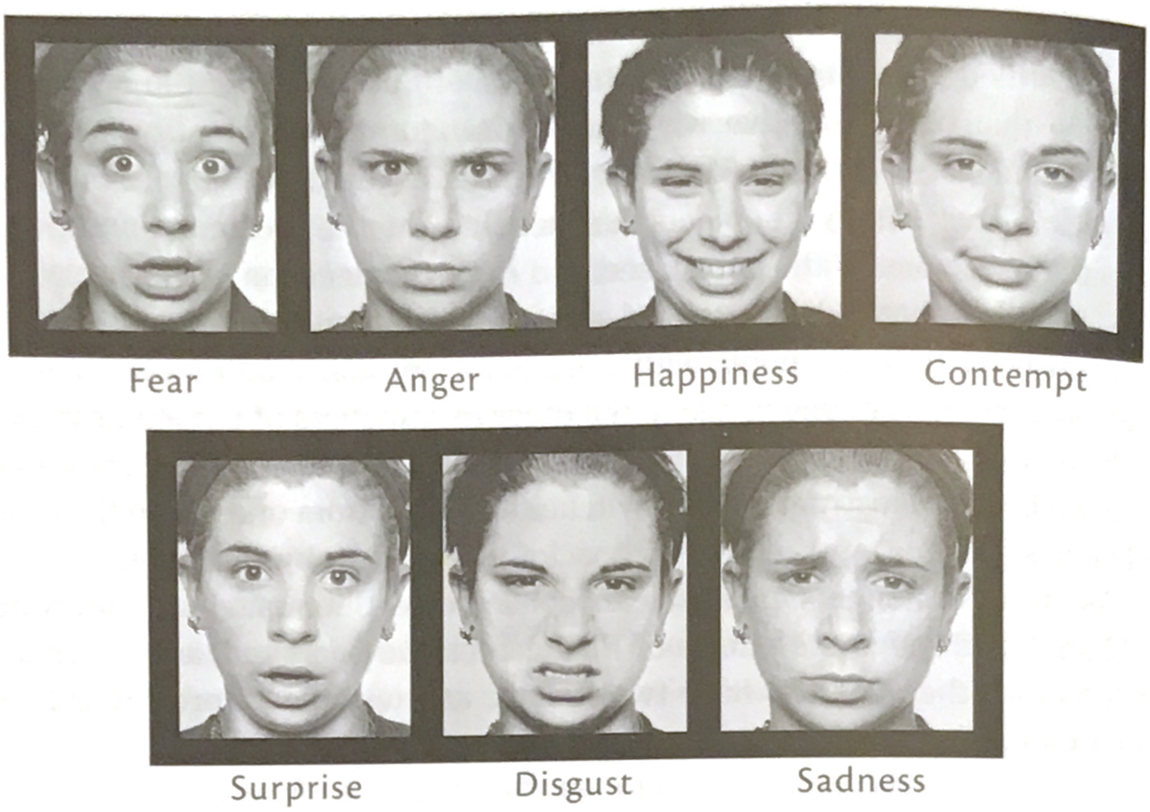


**Fig. 1** Ekman's seven universal facial expressions. (© Paul Ekman 2003.)

in our study, regardless of whether they perceived the stimulus consciously or unconsciously. We produced a conscious perception of fear by presenting the fearful faces for a long period, so people had time to reflect on them. We produced unconscious perception of fear by presenting the same faces so rapidly that the volunteers were unable to report which type of expression they had seen. Indeed, they were not even sure they had seen a face!

Since even normal people differ in their sensitivity to a threat, we gave all 32
of the volunteers a questionnaire designed to measure background anxiety. In contrast to the momentary anxiety most people feel in a new situation, background anxiety reflects an enduring baseline trait.

Not surprisingly, when we showed the volunteers pictures of faces with 33
fearful expressions, we found prominent activity in the amygdala,[22] the structure deep in the brain that mediates fear. What was surprising was that conscious and unconscious stimuli affected different regions of the amygdala, and they did so to differing degrees in different people, depending on their baseline anxiety.

Unconscious perception of fearful faces activated the basolateral nucleus. 34
In people, as in mice, this area of the amygdala receives most of the incoming sensory information and is the primary means by which the amygdala

[22] **amygdala** Small almond-shaped nuclei, one in each hemisphere of the brain, associated with emotional responses and the processing of memory.

communicates with the cortex. Activation of the basolateral nucleus by unconscious perception of fearful faces occurred in direct proportion to a person's background anxiety: the higher the measure of background anxiety, the greater the person's response. People with low background anxiety had no response at all. Conscious perception of fearful faces, in contrast, activated the dorsal region of the amygdala, which contains the central nucleus, and it did so regardless of a person's background anxiety. The central nucleus of the amygdala sends information to regions of the brain that are part of the autonomic nervous system—concerned with arousal and defensive responses. In sum, unconsciously perceived threats disproportionately affect people with high background anxiety, whereas consciously perceived threats activate the fight-or-flight response in all volunteers.

35 We also found that unconscious and conscious perception of fearful faces activates different neural networks outside the amygdala. Here again, the networks activated by unconsciously perceived threats were recruited only by the anxious volunteers. Surprisingly, even unconscious perception recruits participation of regions within the cerebral cortex.

36 Thus viewing frightening stimuli activates two different brain systems, one that involves conscious, presumably top-down attention and one that involves unconscious, bottom-up attention, or vigilance, much as a signal of salience does in explicit and implicit memory in *Aplysia* and in the mouse.

37 These are fascinating results. First, they show that in the realm of emotion, as in the realm of perception, a stimulus can be perceived both unconsciously and consciously. They also support Crick and Koch's idea that in perception, distinct areas of the brain are correlated with conscious and unconscious awareness of a stimulus. Second, these studies confirm biologically the importance of the psychoanalytic idea of unconscious emotion. They suggest that the effects of anxiety are exerted most dramatically in the brain when the stimulus is left to the imagination rather than when it is perceived consciously. Once the image of a frightened face is confronted consciously, even anxious people can accurately appraise whether it truly poses a threat.

38 A century after Freud suggested that psychopathology arises from conflict occurring on an unconscious level and that it can be regulated if the source of the conflict is confronted consciously, our imaging studies suggest ways in which such conflicting processes may be mediated in the brain. Moreover, the discovery of a correlation between volunteers' background anxiety and their unconscious neural processes validates biologically the Freudian idea that unconscious mental processes are part of the brain's system of information processing. While Freud's ideas have existed for more than one hundred years, no previous brain-imaging study had tried to account for how differences in people's behavior and interpretations of the world arise from differences in how they unconsciously process emotion. The finding that unconscious

perception of fear lights up the basolateral nucleus of the amygdala in direct proportion to a person's baseline anxiety provides a biological marker for diagnosing an anxiety state and for evaluating the efficacy of various drugs and forms of psychotherapy.

In discerning a correlation between the activity of a neural circuit and the 39
unconscious and conscious perception of a threat, we are beginning to delineate the neural correlate of an emotion—fear. That description might well lead us to a scientific explanation of consciously perceived fear. It might give us an approximation of how neural events give rise to a mental event that enters our awareness. Thus, a half century after I left psychoanalysis for the biology of mind, the new biology of mind is getting ready to tackle some of the issues central to psychoanalysis and consciousness.

One such issue is the nature of free will. Given Freud's discovery of psy- 40
chic determinism—the fact that much of our cognitive and affective life is unconscious—what is left for personal choice, for freedom of action?

A critical set of experiments on this question was carried out in 1983 by 41
Benjamin Libet[23] at the University of California, San Francisco. Libet used as his starting point a discovery made by the German neuroscientist Hans Kornhuber.[24] In his study, Kornhuber asked volunteers to move their right index finger. He then measured this voluntary movement with a strain gauge while at the same time recording the electrical activity of the brain by means of an electrode on the skull. After hundreds of trials, Kornhuber found that, invariably, each movement was preceded by a little blip in the electrical record from the brain, a spark of free will! He called this potential in the brain the "readiness potential" and found that it occurred 1 second before the voluntary movement.

Libet followed up on Kornhuber's finding with an experiment in which he 42
asked volunteers to lift a finger whenever they felt the urge to do so. He placed an electrode on a volunteer's skull and confirmed a readiness potential about 1 second before the person lifted his or her finger. He then compared the time it took for the person to will the movement with the time of the readiness potential. Amazingly, Libet found that the readiness potential appeared not after, but 200 milliseconds before a person felt the urge to move his or her finger! Thus by merely observing the electrical activity of the brain, Libet could predict what a person would do before the person was actually aware of having decided to do it.

This finding has caused philosophers of mind to ask: If the choice is deter- 43
mined in the brain before we decide to act, where is free will? Is our sense of willing our movements only an illusion, a rationalization after the fact for what

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23 **Benjamin Libet (1916–2007)** A professor of neurology at the University of California, San Francisco; winner of the first Virtual Nobel Prize in psychology.

24 **Hans Kornhuber (1928–2009)** Professor at the University of Freiburg, Germany.

has happened? Or is the choice made freely, but not consciously? If so, choice in action, as in perception, may reflect the importance of unconscious inference. Libet proposes that the process of initiating a voluntary action occurs in an unconscious part of the brain, but that just before the action is initiated, consciousness is recruited to approve or veto the action. In the 200 milliseconds before a finger is lifted, consciousness determines whether it moves or not.

Whatever the reasons for the delay between decision and awareness, 44
Libet's findings also raise the moral question: How can one be held responsible for decisions that are made without conscious awareness? The psychologists Richard Gregory and Vilayanur Ramachandran have drawn strict limits on that argument. They point out that "our conscious mind may not have free will, but it does have free won't." Michael Gazzaniga,[25] one of the pioneers in the development of cognitive neuroscience and a member of the American Council of Bioethics, has added, "Brains are automatic, but people are free." One cannot infer the sum total of neural activity simply by looking at a few neural circuits in the brain.

[25] **Michael Gazzaniga (b. 1939)** Heads the Sage Center for the Study of the Mind at the University of California at Santa Barbara. He has done extensive work on the split brain. See p. 784.

## QUESTIONS FOR CRITICAL READING

1. How do modern scientists explore the question of consciousness experimentally?
2. What is the relation of the conscious mind to the unconscious mind?
3. How does the conscious mind go beyond just the experience of pleasure and pain?
4. Is consciousness biological?
5. What did René Descartes believe about the mind?
6. Why have we made little headway in understanding consciousness?
7. To what extent may it be possible to identify consciousness with molecular activity?

## SUGGESTIONS FOR CRITICAL WRITING

1. Kandel mentions several parts of the brain: the hippocampus, the frontal and parietal lobes, and the amygdala. Research these parts of the brain, and write a brief essay that explains their functions to someone who may not have read this essay. Try to bring your reader up to date on the most contemporary knowledge about these neurological features and how they function.

2. James Crick thought that "the secret of consciousness" (para. 24) was in the claustrum, a little studied portion of the brain. Research the claustrum online and in your library. What functions does it perform in the brain? Crick discusses his understanding of neurobiology in his last book *The Astonishing Hypothesis* (1994). What has been learned about the claustrum since Crick became interested in it?

3. When discussing Descartes, Kandel reviews a position that sees the mind as separate from the brain. Gilbert Ryle (p. 514), on the other hand, sees the mind as a function of the brain. Given what you have understood from your reading on this matter, where do you stand? In a brief essay, relying on the evidence of your reading and/or your research, decide what the status of consciousness is. Is it a product of physiology, or is it a product of something else? What is the primary evidence that convinces you? Make an argument to convince others of your views.

4. In paragraph 37, Kandel talks about conscious and unconscious awareness of a stimulus. He says, "the effects of anxiety are exerted most dramatically in the brain when the stimulus is left to the imagination rather than when it is perceived consciously." What are the chief forms of imagination in your own experience? Would film or literature constitute stimuli of imagination? How responsive are you to your imagination? When do you sense that imagination has produced anxiety? What is the relationship between imagination and consciousness?

5. In paragraphs 41 and 42, Kandel refers to experiments by Libet and Kornhuber that track the path of a person's movement of his or her finger from the person's decision to move the finger to the activity of the brain that moves the finger and, finally, to the actual movement of the finger. Kandel says this experiment calls into question whether or not we have free will. Review what Kandel writes on this subject and then check the literature to see what the current thinking is. Search "Benjamin Libet's experiment." Where do you stand on the question of free will? Is the unconscious mind sometimes dominant over the conscious mind? What does that mean for us?

6. When discussing the possibility that we may not have free will, Ramachandran and his researchers say that although we may not have free will, we have "free won't" (para. 44). What does that really mean? Explore this issue and write a brief essay that explains how "free won't" helps to qualify the question of whether or not people have free will and are responsible for their actions. If, in fact, the unconscious directs our action, should we be held responsible for things we do that we are not consciously aware of doing? What are the legal implications?

7. **CONNECTIONS** With reference to Robert Nozick's (p. 528) ideas about emotions, how does the information presented in Kandel's essay, in paragraphs 29 to 37, about the conscious and unconscious perception of emotions help

us understand Nozick's ideas? How would Nozick react to the experiments by Amit Etkin and Joy Hirsch as well as to the photographs by Peter Ekman? How do you respond to the expressions on the faces illustrating emotions? Do you agree that each face is properly labeled with the emotion ascribed to it? If possible, take some photographs of yourself consciously expressing a range of emotions. Label each as you take the photo (so you don't forget) and see if others can identify the emotion you are expressing. Do you support Kandel's conclusions about the perception of emotions on people's faces?