Introduction

CHRISTOF KOCH

CONSCIOUSNESS AND the problem of free will reside at the nexus of the mind–body problem. Consciousness appears as mysterious to twenty-first-century scholars as when humans first started to wonder about their minds several millennia ago. Nevertheless, scientists today are better positioned than ever to investigate the physical basis of consciousness and volition.

The researchers represented in this section take the problem of consciousness, the first-person perspective, as given and assume that brain activity is both necessary and sufficient for biological creatures to experience something. A primary goal is to identify the specific nature of the activity of brains cells that gives rise to any one specific conscious percept, the neuronal correlates of consciousness (Crick and Koch, 1990; Chalmers, 2000; Metzinger, 2000). An auxiliary goal is to determine to what extent these correlates differ from activity that influences behavior without engaging consciousness.

Almost everyone has a general idea of what it means to be conscious. According to the philosopher John Searle, "Consciousness consists of those states of sentience, or feeling, or awareness, which begin in the morning when we awake from a dreamless sleep and continue throughout the day until we fall into a coma or die or fall asleep again or otherwise become unconscious" (Searle, 1997). Some form of attention is probably necessary, but is not sufficient. Operationally, consciousness is needed for nonroutine tasks that require retention of information over seconds. Although provisional and vague, such a definition is good enough to get the process started. As the science of consciousness advances, such definitions will need to be refined and expressed in more fundamental neuronal terms. Until the problem is understood much better, though, a more formal definition of consciousness is likely to be either misleading or overly restrictive, or both. If this seems evasive, try defining a gene (Keller, 2000; Churchland, 2002).

The working hypothesis of brain scientists is that consciousness emerges from neuronal features of the brain. *Emergence* is used here in the sense that the initiation and propagation of the action potential in axonal fibers, a highly nonlinear phenomenon, is the result of, and can be predicted from, the attributes of voltage-dependent ionic channels inserted into the neuronal membrane. Although consciousness is fully compatible with the laws of physics, it is not easy to predict its properties from these interactions.

Understanding the material basis of consciousness is unlikely to require any exotic new physics but rather a much deeper appreciation of how highly interconnected networks of a large number of heterogeneous neurons work. The abilities of groups of neurons to learn from interactions with the environment and from their own internal activities are routinely underestimated. The individual neurons themselves are complex entities with unique morphologies and thousands of inputs and outputs. Humans have no real experience with such vast organization. Hence, even biologists struggle to appreciate the properties and power of the nervous system.

It would be contrary to evolutionary continuity to believe that consciousness is unique to humans. Most brain scientists assume that some species of animals—mammals, in particular—possess some, but not necessarily all, of the features of consciousness; that they see, hear, smell, and otherwise experience the world (Griffin, 2001). This is particularly true for monkeys and apes, whose behavior, development, and brain structure are remarkably similar to those of humans. Of course, each species has its own unique sensorium, matched to its ecological niche, but that is not to deny that animals can have feelings, subjective states. To believe otherwise seems presumptuous and flies in the face of all experimental evidence from split-brain patients, autistic children, evolutionary studies, and animal behavior for the continuity of behaviors between animals and humans.

The focus of much of the empirical work is on sensory forms of consciousness—vision, in particular. More than other aspect of sensation, visual awareness is amenable to empirical investigation. This is so for a variety of reasons. First, humans are visual creatures. This is reflected in the large amount of brain tissue that is dedicated to the analysis of images and in the importance of seeing in daily life. Second, visual percepts are vivid and rich in information. Pictures and movies are highly structured yet easy to manipulate using computer-generated graphics. Third, many visual illusions, such as binocular rivalry, flash suppression, or motion-induced blindness, directly manipulate visual experience while leaving the physical retinal input unchanged. Last, and most important, the neuronal basis of many visual phenomena and illusions has been investigated throughout the animal kingdom. Perceptual neuroscience has advanced to the point that reasonably sophisticated computational models have been constructed and have proved their worth in guiding experimental agendas and summarizing the data. It is not unlikely that all the different aspects of consciousness—smell, pain, vision, self-consciousness, the feeling of willing an action, and so on—employ one or perhaps a few common mechanisms. Figuring out the neuronal basis for one modality, therefore, will simplify understanding them all.

Similar to the quest to understand life, discovering and characterizing the molecular, biophysical, and neurophysiological operations that constitute the neuronal correlates of consciousness will likely help solve the central enigma, how events in certain privileged systems can be the physical basis of, or even be, feelings.

With this as background, let me briefly introduce the eight chapters. Chalmers summarizes, from the philosopher's point of view, the challenges inherent in coming to grips with the problem of consciousness. He argues for a science that catalogues and quantifies both first-person and third-person data and perspectives and shows how one relates to the other. Schiff reviews the enabling factors needed for any sensation to occur at all. Persistent vegetative states and minimal conscious states are clinical conditions in which affected patients are situated at the borderline between unconscious and consciousness and in which midline structures in the brainstem and thalamus are affected. The next two chapters, by Crick and Koch and by Dehaene and Changeux, provide conceptual frameworks and empirical data for thinking about the neural basis of consciousness. Coming from different directions and traditions (primate electrophysiology versus global workspace theory), the two sets of authors arrive at broadly similar conclusions, emphasizing unconscious processing, the all-or-none aspects of consciousness, interactions among coalitions of neurons that vie for dominance, and the bias exerted on this competition by attention. Goodale defends the two visual streams hypothesis: the idea that "vision for action" is carried out by the dorsal pathway and is quite distinct from the "vision for perception" implemented by the ventral pathway. Whereas the latter is associated with consciousness, the former can proceed without any sensation. This hypothesis explains a great deal of clinical data in neurological patients with their otherwise difficult to interpret patterns of deficits and retained abilities. Among students of the human brain, the most popular tool is functional magnetic resonance imaging (fMRI). The chapter by Rees summarizes what has been learned about the neurology of consciousness from fMRI in normal subjects and in patients, with some intriguing discrepancies that need to be resolved between the interpretation of human imaging data and the results of single-cell studies in monkeys. Split-brain patients have, historically, been of immense importance in demonstrating the brain basis of phenomenal experience, with two conscious minds living in two separate cerebral hemispheres within a single skull. Wolford, Miller, and Gazzaniga investigate the distinct nature of the sensory and more abstract processing in the left and right hemispheres. Finally, Wegner and Sparrow study the conscious perception of willing an action. The feeling of being responsible for some behavior, which forms the cognitive background to everything we do throughout the day, can, under laboratory conditions, be dissociated from its actual execution. This demonstrates that, at least under some conditions, free will is illusory.

Collectively, these studies signal the emergence of a science of consciousness, of the ability to investigate how phenomenal feelings emerge out of excitable brain matter in a rigorous, reliable, and reproducible manner. Needed now are invasive experiments that can close the gap between correlation and causation. Molecular biology is developing methods for deliberately, delicately, transiently, and reversibly dissecting individual components of forebrain circuits in mice and monkeys. The applications of such techniques, in combination with simultaneous recordings from hundreds and more neurons and functional imaging techniques, will do much to advance toward this goal.

REFERENCES

CHALMERS, D. J., 2000. What is a neural correlate of consciousness? In *Neural Correlates of Consciousness: Empirical and Conceptual Questions*, T. Metzinger, ed. Cambridge, Mass.: MIT Press, pp. 17–40.

CHURCHLAND, P. S., 2002. *Brain-Wise: Studies in Neurophilosophy*. Cambridge, Mass.: MIT Press.

CRICK, F. C., and C. KOCH, 1990. Towards a neurobiological theory of consciousness, *Semi. Neurosci.* 2:263–275.

GRIFFIN, D. R., 2001. *Animal Minds: Beyond Cognition to Consciousness*. Chicago: University of Chicago Press.

KELLER, E. F., 2002. *The Century of the Gene*. Cambridge, Mass.: Harvard University Press.

METZINGER, T., ed., 2000. *Neural Correlates of Consciousness: Empirical and Conceptual Questions*. Cambridge, Mass.: MIT Press.

SEARLE, J. R., 1997. *The Mystery of Consciousness. New York Review of Books*, New York.