lent example is its application to the case of a particular brain-damaged patient, as detailed on pages 276–282. The analysis here shows not only what the processing deficits may be in the patient but also what tests should be done to elucidate the situation. This brings home another point, namely that empirical findings can rarely be interpreted without a theoretical framework. *Image and Brain* offers a framework for making sense of hugely diverse data on visual perception and imagery that also leads to testable hypotheses and predictions, keeping it on solid evidential ground and enabling it to evolve as a more and more sophisticated instrument.

Thus the approach expounded in *Image and Brain* is a great analytical tool. But is this how the brain works? The explanation of a complex system's behavior rests heavily on the interaction of its components (W. Bechtel, *Can. J. Philos. Suppl.* **20**, 133 [1994]), and brains abound in contextually conditional states of affairs. Hence one can hardly give a global answer to this question; at best the answer can differ according to the particular processing system or systems involved.

Moreover, though the approach of *Image and Brain* has the merit of being rigorous and logical, the mechanisms used by the brain to actually solve a problem may not rely on a comparably logical series of steps. Specifically, I am referring to the possibility of "smart" mechanisms (S. Runeson, *Scand. J. Psychol.* **18**, 172 [1977]). An example is the polar planimeter, a physical device that can measure the area of an irregular shape without using any logical steps that one would ordinarily employ for that purpose, such as using a fine grid. If measuring an area were important for survival, it is possible that evolutionary pressure could have resulted in a neural operation that could likewise have been implemented by a neural network without following logical steps. Similar considerations hold for the motor system, where solutions to pressing problems could have been arrived at by a long evolutionary process of trial and error rather than by a succession of logical steps (A. P. Georgopoulos *et al.*, *Science* **237**, 301 [1987]). For example, movements of the arm involve movements of the joints, which are brought about by torques applied at the joints produced by contractions of muscles. To derive these torques, given the desired trajectory of hand in space, is a very tedious process of solving what is known as the inverse kinematics problem. Imagine the magnitude of this problem when, for example, the movement trajectories of four limbs have to be coordinated in time and space in a locomoting quadruped. And yet, the spinal cord can accomplish that feat alone. One can write down the logical steps in a series of box diagrams or in a mathematical solution of this problem, but from the fact that the problem is solved by the spinal cord it does not follow that it was solved in that particular way. It is much more plausible to suppose that the spinal cord has evolved as a neural network solving this problem without the benefit of mathematical or logical sequences. I believe that the answer to the question of how the brain actually does it lies somewhere in between, in that different processing subsystems may be involved in a given function but a number of them may implement "smart" mechanisms. But "smart" mechanisms are usually invented or discovered rather than arrived at by a logical process and therefore are much more difficult to find and identify. Keeping our eyes open is the smart thing to do.

As the book's title suggests, the theory developed in *Image and Brain* has far-reaching implications, with regard to the imagery debate. This debate during the 1970s and '80s focused on whether visual mental images are internally represented exclusively by language-like "propositional" representations or in part by "depictive" representations. In a depictive representation, shape is represented by points in a space: each point corresponds to a point on the object, and intervening points in the space correspond to intervening points on the object. The experimentally established fact that many cortical visual areas are topographically organized shows that the representations in these areas are depictive. Another recent finding is that "higher" visual areas have feedback connections to "lower," topographically organized areas. Therefore, it is reasonable to suppose, as Kosslyn proposes, that visual mental images are patterns of activation in topographically organized areas that are produced via these feedback connections. Evidence for shared mechanisms in imagery and perception is obviously relevant to the debate about the nature of images: if images share brain areas with perception, and these areas are hard-wired (that is, topographically organized) to represent shape depictively in perception, it follows that these areas represent shape depictively in imagery. This hypothesis is further supported by evidence that imagery not only activates homologous topographically organized areas in the human brain but is impaired when these areas are damaged. In summary, the central issue of the imagery debate can now be stated in concrete terms: do areas of the brain that depict visual information represent visual mental images? "Yes" is an educated answer. How are patterns of activation in these areas formed, manipulated, and used during imagery? With its schematic approach *Image and Brain* addresses these questions in a precise and challenging, yet enjoyable, way.

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Vignette: Proper Precautions

On the tiny dashboard monitor, they had a view looking straight down at the powerful body of a Tyrannosaurus rex, as it moved up the game trail toward them. Its skin was a mottled reddish brown, the color of dried blood. In dappled sunlight, they could clearly see the powerful muscles of its haunches. The animal moved quickly, without any sign of fear or hesitation.

Staring, Thorne said, "Everybody in the car."

—From *The Lost World*, a novel by Michael Crichton (Knopf)

Books Received

Aquaculture Development. Progress and Prospects. T. V. R. Pillay. Wiley, New York, 1994. x, 182 pp., illus. $59.95.

Behavioral Design. Nicholas S. Thompson, Ed. Plenum, New York, 1995. xvi, 334 pp., illus. $85. Perspectives in Ethology, vol. 11.

Publishers' Addresses

Below is information about how to direct orders for books reviewed in this issue. A fuller list of addresses of publishers represented in *Science* appears in the issue of 26 May 1995, page 1220.

Cambridge University Press, 110 Midland Ave., Port Chester, NY 10573–4930. Phone: 800-872-7423; 914-937-9600. Fax: 914-937-4712.

Comstock Press, P.O. Box 6525, Ithaca, NY 14851–6525. Phone: 800-666-2211 (outside NY state); 607-277-2211. Fax: 800-688-2877; 607-277-6292.

MIT Press, 55 Hayward St., Cambridge, MA 02142. Phone: 800-356-0343; 617-625-8569. Fax: 617-258-6779. E-mail: mitpress-orders@mit.edu.