

ventionally—his own introspections. Hebb has said that psychological theory is usually based implicitly on long-out-of-date physiology; Konorski's physiology is at least contemporary and sometimes futuristic. Among the physiological concepts that mold his theory are centrifugal control of sensory input, hierarchical processing of information in sensory systems, lateral inhibition, the control of motivation by excitatory and inhibitory hypothalamic centers, and facilitation of cortical activity by the reticular formation.

Central to Konorski's theorizing is his view of neural organization in perception, which derives from Hubel and Wiesel's demonstration of hierarchical processing and coding of information in the visual system. First Konorski extrapolates this schema to the other sensory systems. Then, on top of the sensory hierarchies, he builds an analogous hierarchy forming the basis of cognition and learning. The theory assumes that at each level of every sensory system some neurons have a "receptive" function ("transit units") and some have a "perceptive" function ("exit units").

The transit units communicate with higher-level units in the same sensory system. The lower-order exit units may give rise, *inter alia*, to "targeting" or "orientation" reflexes, reflexes controlling sensory input, and reflexes to noxious stimuli. The higher-order exit units are "gnostic units"; they form the anatomical substrate of cognition and association. Unlike connections among transit units, connections involving gnostic units seem to be only potential at birth and are made actual when the gnostic units simultaneously receive input from the "arousal" system and from transit units. This arousal seems to be somewhat specific, since it derives from the animal's orientation to the stimulus activating the receptive units or from specific "drive centers." Gnostic units become connected with one another in a hierarchical fashion. The activation of gnostic units gives rise to "unitary" perceptions. Gnostic units are arranged in gnostic fields, identified roughly with regions of association cortex. Destruction of a gnostic field produces a specific agnosia. On the basis chiefly of human neuropathology and his own introspections, Konorski provides a catalog of gnostic fields (such as spatial relations, manipulatable objects, melodies) and diagrams of the principal associations (potential connections) among them. Emotion has its gnostic field, too, and gnostic units in it may

form connections with gnostic units in other gnostic fields. The gnostic field for emotion is roughly identified with the limbic system and receives its inputs both from other sensory systems and from the drive centers in the hypothalamus.

Konorski's treatment of the kinesthetic system is perhaps the most original and interesting aspect of his theorizing about perception. Receptors in the muscles deliver their messages to the cerebellum, where they are "translated from the language of tensions into the language of movements." Thus, the cerebellum is the "kinesthetic receptive surface." The cerebellum sends its output to precentral cortex (which is viewed as the projective area of the kinesthetic system just as postcentral cortex is the projective area of the somatosensory system). Precentral cortex then sends messages to the kinesthetic gnostic field, which is identified with premotor cortex. The kinesthetic gnostic field is somewhat different from other gnostic fields because it has direct connections with cortical motor mechanisms and it is supposed to act as their "programming device." Although the kinesthetic gnostic fields need information from the muscles for their development, once formed they are relatively independent of sensory feedback. This scheme deemphasizes the role of peripheral feedback in movement and is supported by dramatic experiments by Konorski and others which show considerable motor ability after radical deafferentation.

In Konorski's theory, both Type I (Pavlovian) and Type II (instrumental or operant) conditioning are special cases of association between gnostic fields. Classical conditioning involves association between two gnostic units (representing the conditioned and unconditioned stimuli), one of which, when activated, produces an unconditioned reflex. As with other associations, this association must be facilitated by an arousal input. In this case, the arousal arises from hunger, fear, or some other drive center. Thus, in Konorski's view of Pavlovian conditioning, unlike that of most American theorists, drive plays a central role. In instrumental conditioning, the association is between units in the gnostic field for emotion which are activated by a specific drive and kinesthetic gnostic units that control a particular motor response. In addition to this specific role, drive is again believed to provide the arousal required to establish the association.

Although this synopsis is necessarily brief and incomplete, it may convey something of the flavor of Konorski's theorizing. His English is better written and more pleasurable to read and think about than an equivalent number of pages of American journal articles on learning, perception, or physiology. His introspections are often very different from mine, but they certainly enliven the text.

Konorski's theory is open to criticism on many specific counts. The physiology is often oversimplified and usually consists of loose extrapolation rather than demonstrated mechanism. The principles of learning occasionally conflict with recent findings (as for example his claim that errorless learning is impossible). Yet such criticism is rather picaresque and irrelevant given the broad aim of the book. In spite of the scarcity of data available today, Konorski has formulated an intriguing account of how the brain is likely to work. It cannot help stimulating its readers, and it will certainly send many of them into the laboratory with new ideas or at least with a better conception of how their little experiments might fit into a larger scheme of things. Konorski's theorizing is unlikely to convert many operationally minded behaviorists who think that physiology is irrelevant to the study of learning and that elaborate diagrams of hypothetical centers and connections to "explain learning" are worthless. However, I particularly urge them to examine the chapters on learning, which constitute more than half the book. They contain many interesting and original experiments that demonstrate the heuristic value of elaborate theorizing.

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Boveri

Theodor Boveri. *Life and Work of a Great Biologist, 1862–1915.* FRITZ BALTZER. Translated from the German by Dorothea Rudnick. University of California Press, Berkeley, 1967. xviii + 165 pp., illus. \$6.

Science published a review of the original German edition of this book [by Viktor Hamburger, 136, 709 (1962)] and, later, a translation of a lecture on Boveri given by its author [144, 809 (1964)]. The latter is a tantalizing introduction to topics covered more exten-

sively in the biography. The book has merit not only as a chronicle of the life of a man but as an account of his science.

The second and more interesting half of the work describes many of Boveri's most famous experiments, demonstrating his extraordinary mastery of experimental design and objective scientific reasoning. Theodor Boveri was probably the greatest embryologist who ever lived and one of the most important geneticists as well. An embryologist viewing the current situation can feel that the period between Boveri and his contemporaries and the present has been a kind of scientific diapause from which we have not yet emerged. One reason may have been that their disciples turned to experimental embryology and lost contact with genetics. As Boveri pointed out, developmental problems will be understood only in a framework of genetics.

The remarkable feature about Boveri's experiments is that they, by themselves, suggest experiments which could be performed today with the use of modern methods. For example, molecular hybridization techniques could be applied to analyze the fragments lost during chromosome diminution in *Ascaris*. The concept of the germ plasm in eggs has been confirmed in many different embryos; study of its chemistry and effect on the nucleus is an exciting problem.

For these reasons the book should interest scientists concerned with developmental problems, as well as historians. We owe Rudnick a debt of gratitude for translating this book; perhaps she could be induced to translate some of Boveri's original articles.

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Appreciation of an Experimentalist and Philosopher

Les Concepts de Claude Bernard sur le Milieu Intérieur. An international symposium, Paris, June-July 1965. ROGER HEIM and others. Masson, Paris, 1967. vi + 423 pp., illus. 65 F.

Philosophie et Méthodologie Scientifiques de Claude Bernard. An international symposium, Paris, June-July 1965. ETIENNE WOLFF and others. Masson, Paris, 1967. vi + 170 pp. 30 F.

Catalogue des Manuscrits de Claude Bernard avec la Bibliographie de Ses Travaux Imprimés et des Etudes sur Son Oeuvre. Collège de France. MIRKO D. GRMEK. Masson, Paris, 1967. 419 pp. 40 F.

Claude Bernard and Experimental Medicine. Collected papers from a symposium, Minneapolis, April 1965, and an English translation of Bernard's *Cahier Rouge*. FRANCISCO GRANDE and MAURICE B. VISCHER, Eds. Schenkman, Cambridge, Mass., 1967. Two volumes in one; vi + 210 + vi + 120 pp., illus. Cloth, \$8.95; paper, \$4.95.

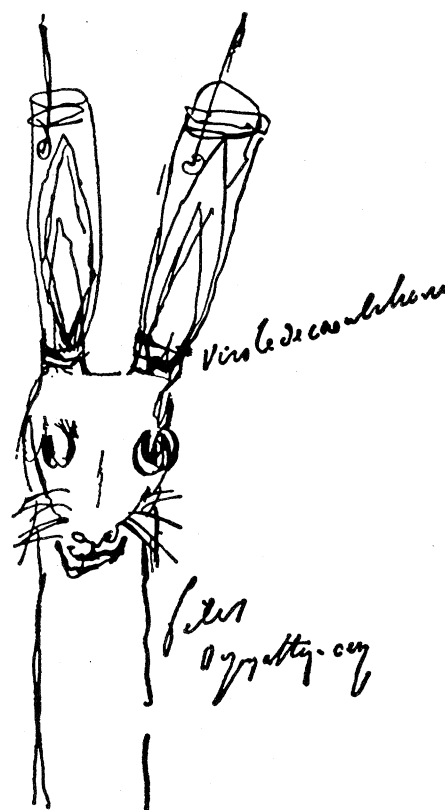
Claude Bernard et les Problèmes Scientifiques de Son Temps. JOSEPH SCHILLER. Editions du Cèdre, Paris, 1967. Paper.

Claude Bernard is justly regarded as one of the great physiologists of all time. His work in any one of the several areas in which he was engaged—physiology of digestion and the role of the pancreas, vasomotor mechanisms and blood regulation, the glyconic func-

tion of the liver, the recognition of the "internal environment"—would do credit to any life in science. But Bernard added to his mastery of experimental technique a self-consciousness about the nature of experimentation in physiology and medicine. His courses of lectures at the Collège de France and the Sorbonne were always prefaced by an explicit consideration of methodological and procedural questions, and through them the reader is able to trace the development of a philosophy of experimental biology. Finally, at mid-career in 1865, while recovering from a period of ill health, Bernard set out his *Introduction to the Study of Experimental Medicine*. In it he outlined a philosophy of scientific method, his rationale of scientific discovery, and his commitment to scientific determinism in biology. Perhaps the greatest strength of the volume was in Bernard's ability to illustrate his philosophical points by calling upon examples from his own laboratory. The book had a strong impact upon his contemporaries (for many years it served as an example of expository writing in the French schools), and has never been out of print since. The centenary of the publication of the *Introduction* has served as the occasion for several of the volumes under review.

Bernard has fared well at the hands of the symposiasts. An international colloquium called by the Collège de France gathered for several days in the early summer of 1965 to explore historical and philosophical aspects of Bernard's work and to examine the contemporary relevance of the concept of the *milieu intérieur*. The two resulting volumes, which have been published under the aegis of the Fondation Singer-Polignac, are really quite distinct. The larger of the two, *Les Concepts de Claude Bernard sur le Milieu Intérieur*, consists of a series of scientific papers organized about three regulatory functions: osmoregulation, thermal regulation, and regulation of blood pressure. A distinguished international group provides a combination of review and report on new research.

The second volume, *Philosophie et Méthodologie Scientifiques de Claude Bernard*, is devoted more directly to a discussion of Bernard, his work and influence. Mrs. J. M. D. Olmsted, who together with her late husband wrote one of the major biographical studies of Bernard, contributes a brief study of his influence on English and American



One of Bernard's sketches for experimental procedures. [From Bernard's *Cahier Rouge*. Reproduced in the English translation in *Claude Bernard and Experimental Medicine*]