

organ systems. Likewise, the bibliographies appear to have been shortened, and their effectiveness as an introductory source to the primary literature is thus reduced. In my opinion, only the chapter on the central nervous system has overcome these handicaps. Its broad but detailed coverage will make it a useful reference for neurophysiologists and other investigators studying the central nervous system.

Although the basis of each chapter in *Biology of the Reptilia* is a review of the literature, each author has been instructed not only to synthesize the literature but to add new data and interpretations where possible and to indicate clearly the problem areas. The editors have enabled the authors to accomplish this difficult task by permitting them unlimited space and finely dividing the organ system into easily handled units that encompass the main research interests of the authors. The first volume contains chapters on the origin of reptiles, histology of bone, epiphyses and sesamoids, dentition, vertebrae and ribs, and turtle shell. The second volume covers the cephalic sense organs—eye, nose and Jacobson's organ, ear, and pit organs—and contains a chapter on taxonomic literature.

In addition to providing the first survey of bone histology, Enlow, in his chapter entitled "The bone of reptiles," alerts readers to two frequently held misconceptions. There is a tendency to interpret growth annuli of bones as a product of annual growth and thus use the annuli as an accurate age indicator. Enlow clearly demonstrates that reptile bones grow by periosteal deposition and endosteal resorption, that bone growth and remodeling occur at different rates and at different positions on the same bone, and that bone growth is not always accompanied with lamellar deposition. All these characteristics make age determination hazardous. The biogenetic law is no more applicable to the skeletal system than to any other organ system. The patterns and types of bones reflect the effect of functional and developmental factors upon the genetic mold of a particular species. In addition, the variability of osseous structures is as great in reptiles as in mammals. Although the osseous structure does not provide direct clues to the evolution of bone, it may be helpful in determining the physiology of extinct reptiles, since there are correlations between bone structure and physiology.

Presentation of new interpretations is not confined to Enlow's chapter but is characteristic of most of the chapters. The one on turtle shell contains a new subordinal classification of turtles based on the different levels of organization of the shell. This classification is not cladistic but based on grades. It provides neat pigeonholes, but I doubt that it will enable us to construct a better phylogeny of turtles. The chapter on snake pit organs interweaves structure and physiological function, whereas most of the other chapters or subjects have not reached that level of integration.

As a whole, I believe the *Biology of the Reptilia* to be superior to the *Traité de Zoologie* volume. However, the audience to which each is directed readily explains its depth of coverage. The *Traité* is directed primarily at students and instructors who wish a general survey of reptilian anatomy. In contrast, the *Biology* volumes will be used more by incipient or active investigators.

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## Psychophysics as Physics

**The Measurement of Sensation.** A Critique of Perceptual Psychophysics. C. WADE SAVAGE. University of California Press, Berkeley, 1970. xiv, 578 pp., illus. \$15.

The topic is an old one: are there measurable perceptual dimensions distinct from physical ones, and if not, exactly what are psychophysicists doing when they claim to be measuring sensations and formulating laws relating these measures to physical measures? Savage's answer is that the only measures we have and need in psychophysics are physical and that psychophysicists are—or at least should be—determining the perceptual abilities of observers, not measuring sensations and establishing psychophysical laws. The argument is long and detailed and, to simplify its presentation, is worked out for only one important dimension, sound.

Savage first examines N. R. Campbell's position that fundamental measurement is possible when, and only when, both an empirical ordering and an empirical addition exist which satisfy the by now familiar axioms of exten-

sive measurement. If this is so, few if any psychological dimensions are measurable. Many question the necessity and even the adequacy of extensive measurement for physics, let alone other fields. Savage attacks Campbell's position at length, but because he does not provide any explicit alternative measurement scheme his point is blunted. He hints at ones not resting on physical addition, and he clearly senses the importance of standard sequences in constructing numerical measures, but not one example is provided. Yet examples exist. Probably their omission relates to the fact that in a bibliography of some 300 items only 14 are dated later than 1963, the year of Savage's Ph.D. thesis, of which this volume is an outgrowth. None of the 14 items includes any of the measurement work carried out or made more accessible during that period.

Next, Savage explores the view of S. S. Stevens, which was developed in response to Campbell, that "measurement is the assignment of numerals to objects or events within a dimension according to some consistent rule or set of rules" (p. 164). Ultimately, Savage rejects it as too broad. The limits of what is generally called measurement seem to lie between the two extremes, and he formulates the concept as: "Measurement is a procedure of assigning numerals to objects within a dimension by means of an empirical process of comparing these objects with a dimension unit or units" (p. 197). Although units probably are crucial to effective measurement, this definition is hardly adequate either; it fails to emphasize the point, central to Stevens's and Campbell's definitions, that the empirical operations must be shown to satisfy a system of laws adequate to construct a numerical homomorphism. That the author underestimates the importance of this is forcefully illustrated by his proposals for the measurement of loudness and pitch.

In chapters 2 and 3 Savage takes some pains to argue that the concept of a "sound," although possibly distinct from that of a wave in air, is nonetheless a physical, not a psychological, one. Sounds, he argues, are "out there" in a way that sensations such as pains or afterimages are not. In chapters 6 and 7, he further argues that the loudness and pitch of sounds, although possibly distinct from intensity and frequency, are physical, not psychological, dimensions; and he

proposes ways to measure each of them which, he alleges, are on a par with physical measurement of length, mass, and the like. For loudness, select a number of faint tones that are deemed equally loud (presumably under some sort of standardized listening conditions). Without providing any evidence, Savage seems to believe that different observers with normal hearing will agree on these judgments. The loudness of any other tone is then the number of these "unit" tones which when played simultaneously are judged (approximately) as loud as the given one.

If my system of loudness measurement satisfies each of these axioms [those of extensive measurement], perhaps we can safely conclude that it does permit the application of arithmetical statements to loudness. It is noteworthy, then, that there do not seem to be any experimental facts indicating that all or even some of these axioms are not satisfied by the system proposed . . . [p. 239].

This last statement is bizarre. One consequence of the axioms is that any pair of unit tones must be just as loud as any other pair. Consider four unit tones which have the same frequency but of which the first pair is in phase and the second 180 degrees out of phase; the two sums are not equally loud. More generally, composite sounds created from unit tones of different frequencies may beat and not have a constant loudness. For pitch, Savage's scheme is an implicit form of difference measurement based on unit intervals rather than on unit objects. It rests on the ability of at least some people consistently to equate half-note differences. The issue of axioms adequate to permit the construction of a difference representation—such axiom systems exist—and whether they are empirically satisfied is hardly mentioned. Measurement entails difficult formal and experimental problems to which the author is little sensitive.

Given these schemes, Savage concludes that the resulting measures are physical. It seems odd to refer to an objective measure as "physical" when it plays no role in physical theory but is potentially important in psychology. Should we also say that "rate of money flow" is a physical rather than an economic measure?

The remainder of the book is a detailed critique of the psychophysics of G. T. Fechner (and incidentally of L. L. Thurstone) and of Stevens. Much of the criticism is exceedingly careful and useful. The ultimate conclusion is

that, whatever is involved in their work, it is not measurement in the sense meant in the other sciences. What, then, are Stevens's methods getting at? Perhaps, as the name of one of them suggests, they yield estimates of some internal magnitude, of some physiological process. Even this is rejected, in part, by means of a splendid non sequitur:

. . . one way of emphasizing that [the observer] perceives no retinal, nerve, or brain processes is to point out that an observer who has never heard of retinas, optic nerves, or brains could function quite as well in [a magnitude estimation] experiment as a professional physiologist [p. 375].

Although he never comes right out with it, Savage evidently feels that Stevens's methods are without merit. Psychologists cannot help being sad to relinquish the innumerable neat formulations of regularities that are so easily uncovered in this way—and I rather doubt that they will relinquish them. One can agree that magnitude estimation and related methods do not constitute a form of fundamental measurement without, however, rejecting them as important sources of data.

The book concludes with the author's "radical view" of perceptual psychophysics, namely that it is "the science of perceptual abilities." Radical? Perhaps if you accept that "Psychophysics is traditionally defined as the science of relations between psychological dimensions . . . and physical dimensions" (p. 531), but most people called psychophysicists in fact study, and know they study, perceptual abilities—discriminability, sensitivity, and so on—and not so-called psychophysical laws. It should amuse these conservatives of psychology to be told that what they do is radical.

Because no other systematic and detailed philosophical critique of fundamental measurement in psychology exists, it is most unfortunate that this one is so deeply flawed. That which is good in it should not be lost because of its failures. It is at its best, although not most gracious, when it is critical; it fails utterly to convince when it attempts to be positive; and its ignorance of both elementary empirical facts and the modern measurement literature surely will not enhance the prestige of philosophical criticism among psychophysicists or measurement theorists.

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