The Career of a Methodology

Ratio Scaling of Psychological Magnitude. In Honor of the Memory of S. S. Stevens. STANLEY J. BOLANOWSKI, JR., and GEORGE A. GESCHEIDER, Eds. Erlbaum, Hillsdale, NJ, 1991. xvi, 324 pp., illus. $49.95. From a conference, Syracuse, NY, July 1989.

Progress in psychology, as in other disciplines, proceeds in an uneven fashion, with periods of rapid growth spurred sometimes by new ideas but more often by new methods and the data they generate. During the 1950s and 1960s the Harvard psychologist S. S. Stevens (1906–1973) developed a set of techniques for the study of the intensity of sensations that quite transformed that field of study. The present volume presents the proceedings of a conference held in 1989 in honor of Stevens's achievements.

For many years it had been believed that the strength of sensations was nonlinearly related to the intensity of the stimuli that produced them, but the nature of that nonlinearity was largely a matter of speculation. In the mid-19th century it was proposed, in what came to be called Fechner's law, that sensation was logarithmically related to stimulus intensity, but little evidence could be produced to support that or any alternative view, because no methods more powerful than simple categorizing had been developed to estimate the magnitude of sensations. Everyone knew, for example, that the loudness of a tone grew as sound pressure was increased, and it was also apparent that it grew more slowly than the energy of the signal, but what was the exact form of the function?

It was Stevens who discovered that listeners could describe the loudness of signals presented for judgment with greater precision than was implied by simple categories such as "soft," "loud," and "very loud." Rather than limit his subjects to such insensitive categories, Stevens encouraged them to pick values on a continuous scale, such as number, and discovered that they had little hesitation in making fine distinctions with their numerical judgments and that those judgments consistently followed a power function in relation to the tones presented. This power law was subsequently confirmed for dozens of different perceptual continua, ranging from such straightforward cases as brightness, heaviness, and sweetness to such unusual instances as the apparent intensity of coffee odor, the perceived intensity of electric shock applied to the fingertips, and the felt roughness of sandpaper. In each case, the judged magnitude of the sensation grew as a power function of the stimulus intensity, confirming the generality of the power law. Even more provocative was Stevens's discovery that the exponent for this power relation varied substantially among the various continua he studied. Though the judgments of some sensations (such as loudness) grew more slowly than did the strength of the signal, in other cases (such as electric shock) subjects reported their sensations growing as the square or even the cube of the stimulus strength.

Prior to Stevens's pioneering work, students of sensory systems had largely confined their psychological investigations to the study of very weak signals, and measures of detectability were relied upon almost exclusively. With the advent of Stevens's new methods it became possible to study the whole range of sensory experience, from the very faint to the painfully strong, and there followed an outpouring of new and useful information about the function of the various sensory systems. Much of what we now know about the perception of taste, smell, pain, skin pressure, and effort was learned by means of Stevens's techniques and variants of them. And the already large body of knowledge about hearing and vision has been increased in important and surprising ways because of these methods. As an unexpected dividend, these methods have proved readily applicable to a wide variety of perceptual continua in which the sensory components are multidimensional, such as size and distance, and even to subjective judgments where there is no simple metric for the associated physical correlate, such as the intensity of stage fright, phobic fear, and seriousness of criminal acts. Like the methods developed by B. F. Skinner (a colleague of Stevens's, for many years with a laboratory in the same building), techniques developed by Stevens in connection with problems in basic science have proved suitable for application to a host of practical questions in everyday life.

But, perhaps inevitably, following Stevens's death, the pace of new discovery has slowed considerably, and much of the work that continues to be done with his methods has more to do with the nature of these methods, the problems and biases that afflict them, and the variations of them that may succeed in avoiding those difficulties. (If it hasn't already been done, it might be useful to construct an index of productivity for scientific methods: the ratio of new published knowledge resulting from the use of a given method to the amount of published research about the method itself. As the ratio drops toward and even below unity, as seems to be the case for Stevens's scaling methods, it may be cause for concern.) It was therefore a timely and appropriate idea to bring together 20 experts in the field for a retrospective look at Stevens's techniques and an assessment of their present value.

I cannot say that the results of this assessment are very encouraging. Though a few of the participants had new and interesting findings to report, many could only provide reviews of past successes, and the theoretical and methodological papers provide a glimpse into the very considerable conflict about the best ways to address the serious problems that have surfaced in recent years. And, I think, the gravity of these problems may have been underestimated in a group of largely like-minded participants. A useful concluding chapter by the editors provides an interesting summary of the main issues raised in the individual papers as well as a final general discussion, but there remains much uncertainty about what lies ahead. The history of science yields many examples of new, and for a while productive, methods that were eventually abandoned. In psychology, the once-popular memory drum and its computerized successors have disappeared. On the other hand, tests of mental abilities, having run the gauntlet of searching criticism, have emerged in substantially new form and promise to play a continuing role in the study of human intellectual capacity. Whether Stevens's ingenious methods will undergo a comparable rejuvenation and stimulate a renewed flow of important knowledge about human perception remains to be seen. The interested reader can find in the present volume an account of some obstacles to that goal and some ideas about how to overcome them.

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Before and After Phage

The Emergence of Bacterial Genetics. THOMAS D. BROCK. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, 1990. xxii, 346 pp., illus. $55.

Bacterial genetics is a field that grew out of studies of bacteria and bacterial viruses prior to 1940 and then began a meteoric rise to its prominent place in the history of molecular genetics owing to seminal work carried out principally in the 1940s and 1950s. Although books have been written about various parts of this story, until now no single treatise has covered the emergence of bacterial genetics in its entirety.

Thomas Brock's *The Emergence of Bacterial Genetics* will be regarded as the definitive treatment of the history of the science behind the development of bacterial genetics as we know it today. It is as remarkable for its completeness as for its deft interweaving

of the themes behind the conceptual advances in the field. For example, one chapter details the roots of bacterial genetics in classical genetics and the following chapter its roots in bacteriology. Rather than presenting a personalized view of key players in the story, this book focuses on the science itself. It divides the development of the field into topics (mutation, mating, phage, lysogeny, transduction, transformation, gene expression and regulation, from bacterial genetics to recombinant DNA) and then traces the history of each, going back to the 19th century.

Perhaps the best way to understand the scope of *The Emergence of Bacterial Genetics* is to look at how a typical section is organized. In the chapter "Phage," Brock begins with the early history of phage research, discussing the discovery, by Frederick Twort in England in 1915 and Felix d'Herelle in France beginning in 1917, of a virus that attacked bacteria and the skepticism of the Belgian immunologists Gratia and Bordet regarding d'Herelle's interpretation. The studies of Burnet and of Northrop in the 1930s are reviewed as a prelude to a detailed account of Max Delbrück's entry into the field and the profound influence he had on modern phage research. Delbrück is one of the most important figures in early phage and bacterial genetics research, and it is fitting that a significant part of this chapter is devoted to his biography, the influences on his thinking that led him from physics into biology, and the effect he had on students and postdoctoral researchers who became pioneers in their own right. The chronological account of how each scientific paper and advance fitted into the development of the phage field represents the strength of this book. Delbrück's collaboration with Luria and their involvement with Cold Spring Harbor Laboratory, the work of Hershey, and the first steps in phage genetics are covered, and some of the key experiments are analyzed in detail, with tables reprinted from the original research papers. The Hershey-Chase experiment is given a particularly detailed treatment. Benzer's classic work on genetic fine structure is also nicely summarized. A consideration of the biochemistry of phage replication, including the prejudice of the phage group against biochemistry, and a treatment of the restriction–modification phenomenon close out the chapter.

One of the pleasures of reading the book lies in the treasure house of experiments that are not widely appreciated today. For instance, even though I myself have worked with the *lac* system of *Escherichia coli* for almost 25 years, I had not previously realized that in 1951 Joshua Lederberg had actually isolated the first constitutive (I^-) mutants, in which the *lac* enzymes were synthesized without the aid of an inducer. Lederberg had isolated mutants that could grow on the sugar neolactose, since it was thought that the specificity of β-galactosidase was such that neolactose was not cleaved by this enzyme. In reality, neolactose (somewhat in analogy to the sugar more widely used today, phenyl β, D-galactoside) is a good substrate for β-galactosidase, but it is not recognized as an inducer by the *lac* repressor. Therefore, mutants that could utilize lactose turned out to have high constitutive levels of β-galactosidase. The account of Lederberg's experiments is also interesting because of Brock's argument that they might be considered forerunners of the work by Jacob and Monod.

It should be stressed that the value of this book does depend somewhat on the audience. As a thorough and exhaustively referenced history of bacterial genetics through the beginning of the 1960s it is indispensable for the serious student of the history of this field. It is less accessible to the casual reader, however, because of its very completeness. As a work for students, it appears to be at the graduate level. In my opinion, it would require several modifications, most notably the inclusion of additional explanatory figures, to be considered as a supplementary text for an undergraduate course.

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Reprints of Books Previously Reviewed

The Emperor's New Mind. Concerning Computers, Minds, and the Laws of Physics. Roger Penrose. Penquin, New York, 1991. xiv, 466 pp., illus. Paper, $12.95. *Reviewed* **245**, 880 (1990).

Mind, Brain, and Adaptation in the Nineteenth Century. Cerebral Localization and Its Biological Context from Gall to Ferrier. Robert M. Young. Oxford University Press, New York, 1990. xxvi, 278 pp. $39.95. History of Neuroscience, no. 3. *Reviewed* **173**, 1013 (1971).

Science as a Process. An Evolutionary Account of the Social and Conceptual Development of Science. David L. Hull. University of Chicago Press, Chicago, IL, 1990. xiv, 586 pp., illus. Paper, $19.95. *Reviewed* **242**, 1182 (1988).

Books Received

Current-Induced Nonequilibrium Phenomena in Quasi-One-Dimensional Superconductors. Reinhard Tidecks. Springer-Verlag, New York, 1990. x, 341 pp., illus. $89. Springer Tracts in Modern Physics, vol. 121.

The Curse of Icarus. The Health Factor in Air Travel. F. S. Kahn. Routledge (Routledge, Chapman, and Hall), New York, 1990. xiv, 180 pp., illus. $19.95.

Cytochromes c. Evolutionary, Structural and Physicochemical Aspects. Geoffrey R. Moore and Graham W. Pettigrew. Springer-Verlag, New York, 1990. xvi, 478 pp., illus. $98. Springer Series in Molecular Biology.

Density Functional Theory. An Approach to the Quantum Many-Body Problem. R. M. Dreizler and E. K. U. Gross. Springer-Verlag, New York, 1990. xii, 302 pp., illus. $89.

Field Geology of High-Grade Gneiss Terrains. C. W. Passchier, J. S. Myers, and A. Kröner. Springer-Verlag, New York, 1990. x, 150 pp., illus. Paper, $19.50. From a workshop, Kandy, Sri Lanka, Aug. 1987.

The Fine Structure of the Nervous System. Neurons and Their Supporting Cells. Alan Peters, Sanford L. Palay, and Henry deF. Webster. 3rd ed. Oxford University Press, New York, 1991. xx, 494 pp., illus. $65.

Four Neotropical Rainforests. Alwyn H. Gentry, Ed. Yale University Press, New Haven, CT, 1991. xvi, 627 pp., illus. $57.50. From a symposium, Columbus, OH, Aug. 1987.

Fractional Statistics and Anyon Superconductivity. Frank Wilczek. World Scientific, Teaneck, NJ, 1990. x, 447 pp., illus. $68; paper, $28.

Handbook of Pesticide Toxicology. Wayland J. Hayes, Jr. and Edward R. Laws, Jr., Eds. Academic Press, San Diego, CA, 1990. 3 vols. xlvi, 1576 pp., illus. $395.

Imaging Anatomy of the Newborn. Ernst Richter and Werner Lierse. Alan E. Oestreich, Transl. Ed. Urban and Schwarzenberg, Baltimore, MD, 1991. xii, 280 pp., illus. $175.

Mathematical Models of Hysteresis. I. D. Mayergoyz. Springer-Verlag, New York, 1991. xx, 207 pp., illus. $59.50.

Protein Purification Applications. A Practical Approach. E. L. V. Harris and S. Angal, Eds. IRL (Oxford University Press), New York, 1990. xiv, 179 pp., illus. Spiral bound, $54; paper, $36. Practical Approach Series.

Proto-Oncogenes in Cell Development. Greg Bock and Joan Marsh, Eds. Wiley, New York, 1990. x, 295 pp., illus. $63.50. Ciba Foundation Symposium 150. From a symposium, London, Sept. 1989.

Quantitative Methods in Landscape Ecology. The Analysis and Interpretation of Landscape Heterogeneity. Monica G. Turner and Robert H. Gardner, Eds. Springer-Verlag, New York, 1991. xvi, 536 pp., illus. $98. Ecological Studies, vol. 82.

La Science pour Tous. Sur la Vulgarisation Scientifique en France de 1850 à 1914. Bruno Béguet, Ed. Bibliothèque du Conservatoire National des Arts et Métiers, Paris, 1990. 168 pp., illus. Paper, F 230.

The Scientific Letters and Papers of James Clerk Maxwell. Vol. 1, 1846–1862. P. M. Harman, Ed. Cambridge University Press, New York, 1990. xxviii, 748 pp., illus., + plates. $195.

The Second Fifty Years. Promoting Health and Preventing Disability. Robert L. Berg and Joseph S. Cassells, Eds. National Academy Press, Washington, DC, 1990. xii, 332 pp., illus. $29.95.

Semantic Structures. Ray Jackendoff. MIT Press, Cambridge, MA, 1990. xiv, 322 pp., illus. $34.95. Current Studies in Linguistics, 18.

Shaping the Earth. Tectonics of Continents and Oceans. Readings from *Scientific American* Magazine. Eldridge Moore, Ed. Freeman, New York, 1990. x, 206 pp., illus. Paper, $11.95.

The Silent Countdown. Essays in European Environmental History. P. Brimblecombe and C. Pfister, Eds. Springer-Verlag, New York, 1990. xii, 265 pp., illus. $78. From a workshop, Bad Homburg, F.R.G., March 1988.

Spectral and Scattering Theory for Wave Propagation in Perturbed Stratified Media. Ricardo Weder. Springer-Verlag, New York, 1991. viii, 188 pp. $39. Applied Mathematical Sciences, vol. 87.

Spores of the Pteridophyta. Surface, Wall Structure, and Diversity Based on Electron Microscope Studies. Alice F. Tryon and Bernard Lugardon. Springer-Verlag, New York, 1991. xii, 648 pp., illus. $98.

Stars and Planets. The Sierra Club Guide to Sky Watching and Direction Finding. W. S. Kals. Sierra Club, San Francisco, CA, 1990. viii, 244 pp., illus. Paper, $14.95.

Statistical Inference and Analysis. Selected Correspondence of R. A. Fisher. J. H. Bennett, Ed. Clarendon (Oxford University Press), New York, 1990. xviii, 380 pp., illus. $90.

Women, the State, and Welfare. Linda Gordon, Ed. University of Wisconsin Press, Madison, WI, 1991. xii, 311 pp. $35; paper, $12.95.

The World of Pastoralism. Herding Systems in Comparative Perspective. John G. Galaty and Douglas L. Johnson, Eds. Guilford, New York and Belhaven, London, 1990. x, 436 pp., illus. $45.