tions—that the politics of an issue changes as the issue matures, and our analysis must be equally dynamic. Moreover, it is worth being reminded that just as an army fights like it trains, a society innovates like it lives. If Evangelista is correct, the reactive pattern of Soviet weapons innovation in past decades has little to do with the general backwardness of the Soviet economy, and the Soviets will continue to be technological "followers" as long as they cling to highly centralized and autocratic institutions, regardless of how prosperous the Soviet economy may become. As a policy prescription, Evangelista argues that his study points toward a grand arms-control compromise. Since the U.S. strength is innovation and the Soviet forte is imitation and production in large quantities, the compromise would trade qualitative limits for quantitative reductions. This might well work if Soviet leaders also believe they are destined by their system to be technological laggards forever. That seems to be precisely what Mikhail Gorbachev fears.

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Neural Network Programs

Explorations in Parallel Distributed Processing. A Handbook of Models, Programs, and Exercises. JAMES L. MCCLELLAN and DAVID E. RUMELHART. MIT Press, Cambridge, MA, 1988. xii, 344 pp., illus., + 2 IBM PC-compatible diskettes, in pocket. Spiral bound, $29.95. Computational Models of Cognition and Perception.

This publication, produced by one of the leading neural network groups and illustrating much of their work, is a landmark. The package consists of a book and a collection of computer programs that implement many of the models discussed in the popular two-volume work *Parallel Distributed Processing* produced by the same authors and other members of the "PDP group." [For a review see *Science* **236**, 992 (1987).] The book contains an introduction to the programs, as well as exercises that illustrate important concepts about neural networks. These programs illustrate many of the popular neural network circuits, such as pattern association models, constraint satisfaction, and interactive activation and competition. A variety of learning rules is provided for some of the models, including the delta rule, back-propagation, and Hebbian learning.

For learning about neural network models, there is no substitute for experience running actual programs. The programs in this package are "user friendly" and were tested in classrooms of Carnegie-Mellon University and the University of California at San Diego. Each program contains menu-driven commands that are relatively consistent throughout the various programs. For example, the user can stimulate or inhibit different inputs to the network, as well as manipulate the strength of individual synapses. Each program can be changed in several ways. For example, the association network model includes options for different learning rules such as the delta rule or Hebbian learning, as well as various "activation" functions for determining firing properties of postsynaptic neurons. For the true enthusiasts, the source code in the programming language "C" is provided, allowing the user to make changes in any feature of the model. The inner workings of the programs are documented well enough to make this a realistic option.

The screen displays are not of the lavish quality typically found in commercial software. However, their simplicity has advantages, since the programs remain straightforward for the user to modify.

The book is not easy reading. It is hard to understand a simulation without reading the description of that network in *Parallel Distributed Processing*. The organization of the material is also difficult for readers. For each simulation, the numerous program features are described in detail in the first half of a chapter. In the second half of the chapter, there is a set of exercises that show step by step the capabilities of the network, and detailed thoughtful answers are given. Unfortunately, these exercises assume that the reader has gotten through the first half of the chapter and stored most of the information in memory. A more bite-sized tutorial approach would have been easier for those of us without photographic memories.

Not surprisingly, the book reflects the interests and opinions of its authors. Non-neurophysiologists should be aware that several of the central assumptions of these models could turn out to be dead ends for neural network research. In particular, there is emphasis in these models on the linear addition or subtraction of the "weights" of synaptic inputs that converge onto each neuron. However, we have known for decades that synaptic weights for biological neurons do not summate in the linear fashion one uses when adding resistances "in series." Instead, they summate as conductances connected in parallel. This is formalized in the Goldman equation or the parallel battery equation, well known to neurophysiologists but unfortunately neglected by many computer modelers. Rather than modeling excitation of a neuron as addition and inhibition as subtraction (as is done in the models of the PDP group), one can approximate the Goldman equation using addition to model the sodium-mediated excitation and division to model the shunting chloride-mediated inhibition. Some neural network programs, such as the medical expert system I have developed and the somatosensory models of Gerald Edelman's group, employ such "biological" nonlinearities, and these features confer stability and reasonableness on the performance of the network. Readers should be encouraged to modify the programs in this book to experiment with such nonlinearities. As Marvin Minsky and Seymour Papert demonstrated in their classic book *Perceptrons*, linear circuits are severely limited in their computational power. Computers allow us to explore beyond the territory accessible to linear algebra. It will be ironic if research on parallel processing is slowed down because of the use of serial summation of synaptic weights instead of the more powerful parallel summation.

To a neuroscientist, a second concern about methodology relates to the method of distributing "error signals" to "hidden" layers of neurons, a method known as back-propagation. Neuroscientists, who are able to "peek at the answers" to questions about biological neural networks, find little evidence for the huge network of specific back-connections needed to implement back-propagation as a common method of learning in the nervous system. Another basic problem with back-propagation is that there is no "teacher" signal for most forms of biological learning. Neuroscientists are much more excited about Hebbian learning, particularly since a molecular mechanism for such learning could exist in the voltage- and transmitter-dependence of the NMDA receptor (a ubiquitous type of neurotransmitter receptor sensitive to glutamate). Although back-propagation may be useful for setting synaptic weights in certain computer programs, readers are encouraged to focus on Hebbian learning and experiment with learning rules likely to exist in successful neural networks such as our brains. The neural network programs of Ralph Linsker and of Gerald Edelman's group are good examples of such work with Hebbian learning.

Despite such reservations, this package is extremely valuable because it includes so many different neural network models. Nature took a long time to find its favorite neural networks; one hopes it will take us less time to find successful neural networks for computers. A book like this will help by spreading ideas and source code to thou-

sands of enthusiasts. Let a thousand programs bloom; we will find ourselves a lot closer to the answers.

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Thermophysiology

Temperature Biology of Animals. A. R. COSSINS and K. BOWLER. Chapman and Hall (Methuen), New York, 1987. x, 339 pp., illus. $57.50.

Temperature is both the most pervasive of environmental variables that affect organisms and the simplest to measure. Together these facts have yielded a diverse and abundant literature, ranging from unadorned phenomenology to major advances in our understanding of organisms. Yet, although we now know more about the biology of temperature than about that of any other environmental variable, the very size of the literature has often defied attempts at summary and articulation of general principles. With this book, however, Cossins and Bowler have achieved an excellent synthesis.

The basic organization of the book differs little from that of the corresponding sections of textbooks of animal physiology and environmental physiology: chapters on the biophysics of temperature, thermal effects on animal function, thermoregulation in ectothermic and endothermic animals, and capacity and resistance adaptation. A final chapter, describing temperature effects on reproduction, development, and growth, is an unusual but welcome addition. The presentation within these chapters is what distinguishes this book from others. Although specialists will find it an excellent overview of the field, the book is intended for advanced students of physiology and for other biologists. A successful book for such an audience must strike a fine balance between facts and principles and between old data and new: too many data and the reader is overwhelmed, too much theoretical or general material and the reader becomes detached, too eclectic a selection of examples and the reader is misled. Cossins and Bowler are as much artists as scientific authors in achieving this balance. Each chapter emphasizes underlying principles and basic patterns, but every principle and pattern is illustrated by just the right number of examples. Moreover, Cossins and Bowler take pains to present alternative interpretations of data, emphasize where conclusions are tentative, and stress where additional data are needed. Taxon-by-taxon summaries of phenomenology are fortunately few. Also remarkable is the balance struck among topics. Any given topic in the book (hypothalamic mechanisms of thermoregulation in mammals, biophysics of heat exchange, and molecular mechanisms of adaptation to high temperatures, for example) could well consume an entire book; Cossins and Bowler have an exquisite sense of when to leave one topic for the next.

The text is not without deficiencies and errors (for example, that "birds and mammals have separate origins from the reptiles"), and very recent advances (concerning metabolic arrest and heat-shock proteins, for example) are understandably absent. But *Temperature Biology of Animals* is an exceptional book, the best available work on this topic for the general reader, and should serve as a model of scientific exposition for the nonspecialist or student. Ecological physiology would be well served by comparable books dealing with the other major factors affecting animal life.

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Neutrinos

Physics of Massive Neutrinos. FELIX BOEHM and PETR VOGEL. Cambridge University Press, New York, 1988. viii, 211 pp., illus. $34.50.

Neutrinos have played a special role in the theory of elementary particle physics since their existence was first postulated by Wolfgang Pauli in 1930. This is primarily because neutrinos interact only through the weak interaction, which is usually overwhelmed by the other two forces important in particle physics, the strong and the electromagnetic. In the present "standard model," which describes all known phenomena in particle physics, the weak and electromagnetic interactions are unified into one, the electroweak. As is stated in the first chapter of this book, "The study of neutrino properties is one of the few avenues which could lead to new physics beyond the standard model, and this is the chief reason why the neutrino is such an interesting particle."

According to the standard model, there are three distinct neutrinos, each with zero rest mass and each a pure, stable state. A number of speculative ideas to extend the standard model predict deviations from this picture. Since 1980 there has been a series of experiments designed to look with extreme sensitivity for indications of small neutrino rest masses or of mixing among the neutrino types. *Physics of Massive Neutrinos* was written to review this period of intense activity, both theoretical and experimental, in the area of neutrino properties.

The questions addressed in the book are of fundamental importance, and the answers draw on nuclear physics, particle physics, astrophysics, and cosmology. Do the three types of neutrinos share with the photon the property of zero mass and thus travel at the speed of light? If they have mass, do the neutrinos constitute the "dark matter" that is widely believed to provide the mass needed to close the universe? Are the neutrinos and antineutrinos distinct objects, or are they in fact just the right-handed and left-handed manifestations of the same particle? Is the observed deficit of solar neutrinos due to transformations among the various neutrino types? The authors deal with the theoretical significance of these questions, but they also take great care to explain the present status of experiments in neutrino physics and to indicate which future experiment might radically change our picture.

The reasons such a book is needed are clear. The field has expanded so dramatically in the last decade that graduate-level textbooks cannot keep up. In addition, because of the wide range of specialties related to neutrino physics, it is very difficult for someone new to the field to read the entire current literature without an organized, comprehensive review. This book provides such a review, with references to more specialized publications for those interested in pursuing particular topics. It is just the bridge needed between textbooks in nuclear or particle physics and the advanced literature.

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Books Received

Basic Environmental Engineering. Text and Disk with 80 Programs. Henry R. Bungay. BiLine Associates, Troy, NY, 1988. Variously paged, illus., + floppy disk in pocket. Spiral bound, $24.50.

Computational Physics. R. D. Kenway and G. S. Pawley, Eds. Scottish Universities Summer School in Physics, Edinburgh, 1987. x, 483 pp., illus. £24. From a school, St. Andrews, Scotland, Aug. 1987.

Disputed Parentage. The Story of the Universe. G. M. Bergman. World Studies Press, Los Angeles, CA, 1988. xvi, 238 pp., illus. $17.95.

The Engineering of Consent. Democracy and Authority in Twentieth-Century America. William Graebner. University of Wisconsin Press, Madison, 1987. xii, 262 pp., illus. $26.50.