

gramme in "Comparative Approaches to Brain and Behavior" that wedds mechanism and evolution.

Nowhere is this new approach better explicated than in *Behavioral Mechanisms in Evolutionary Ecology*. Arising from a symposium organized by Leslie Real for the American Society of Naturalists in 1992, the book has been expanded to include 19 contributions that provide broad coverage of many important topics in animal behaviour. It begins with an introductory chapter by Real, who brilliantly sketches the rationale for, and outlines of, a more unified approach to animal behaviour. The first part of the book, on "psychological and cognitive foundations", includes chapters by Kamil, Krebs and Inman, and Real, which describe how cognitive and ecological perspectives can be integrated, especially in the context of foraging. Kamil's chapter includes a thoughtful assessment of the traditional psychological approach to learning and one of the clearest expositions of the 'cognitive approach' I have read. Also in this section Dyer presents an illuminating analysis of insect orientation behaviour from a cognitive perspective.

The second part, on "communication", includes a chapter by Ryan on mechanisms of sexual selection. Ryan interweaves neuroethology and evolutionary biology and extends his "sensory exploitation" hypothesis to explain the evolution of female choice in frogs. This chapter illustrates particularly well the way in which sophisticated mechanistic analyses can contribute to important issues in behavioural ecology.

The third part, on "neural, developmental, and genetic processes", includes two chapters on bird-song development: Arthur Arnold's review of diversity in endocrine and neural control in passerines, and West, King and Freeberg's self-critical and perceptive analysis of the role of the environment in cowbirds. There are also two chapters on constraints on behavioural evolution: Stevan Arnold's quantitative genetic analysis, and Singer's case study of the evolution of diet breadth in checkerspot butterflies.

In the fourth part, on "hormonal processes", Ketterson and Val Nolen probe the mechanistic basis of life-history evolution with clever "phenotypic engineering" experiments in which they treat dark-eyed juncos with testosterone implants and then determine the consequences for fitness of variation in hormonally mediated behavioural traits. Zuk advocates a new field of "behavioural immunology" that extends psychoneuroimmunology to deal with questions of behavioural ecology. Although focusing on vertebrates, she mentions that recent findings suggest intriguing similarities between vertebrate and insect

immune systems.

The final part, on "the social context of behavior", is exclusively on primates and social insects. Seyfarth and Cheney have two goals: to infer the cognitive abilities required for primate social life and to explore ecological and social factors that select for them. It is a pleasing blend of convincing data and provocative speculation. Two chapters address a central question in insect sociobiology: how the behaviour of thousands of individual members is integrated into a smoothly running colony. Both are examples of a productive and increasingly popular refinement of the venerable 'superorganism' approach, in which a heuristic metaphor is invoked to help analyse a specific feature of colony biology. Gordon likens an ant colony to a neural network in order to guide novel empirical work on the way in which individual ants gain information on changing colony conditions. Franks and Partridge compare the predatory behaviour of army ant colonies not only to that of myxobacteria and cellular slime moulds, but to a human social construct — "Lanchester's theory of combat". This theory guided Nelson to decisive victory in the battle of Trafalgar in 1805, and it also helps Franks and Partridge to paint a coherent picture of how worker size, colony population size and self-organization contribute to ergonomic efficiency.

The book is nicely put together. Most chapters are well written, contain excellent introductions for nonspecialists and provide comprehensive reviews of the literature. Genetic themes are not as fully covered as I would have liked, and it is surprising that a chapter on kin recognition is not included, given that this phenomenon has always been investigated from a variety of perspectives. Cellular analyses of behaviour are presented only for bird song, and molecular studies are absent. This probably reflects the fact that most behavioural studies at these two levels do not yet involve a strong ecological component.

This is an important collection because it shows the promise of a more integrated approach to animal behaviour. But only a few authors in fact achieve a sophisticated blend of mechanism and evolution; most of the chapters treat one or the other superficially, and some could just have easily appeared in a book on behavioural ecology that does not purport to be integrative. Nevertheless, the volume paints a reasonable picture of current knowledge and reveals many wonderful opportunities for future research. If they are seized, the future of animal behaviour will be bright. □

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## The measure of the world

C. W. Kilmister

**Poetry of the Universe: A Mathematical Exploration of the Cosmos.** By Robert Osserman. *Doubleday*: 1995. Pp. 210. \$18.95.

JAMES L. Adams is recorded as asking the author: "How is it that mathematics is such a beautiful subject, yet students can go through four years of college taking many math courses and never find out?" They sought to rectify this with a taught course, and here is part of it. The aim differs subtly from that of popular science and so does the rather elegant result. The atmosphere is leisurely and there is more emphasis on the integration of the history of ideas in mathematics with the surrounding culture than on simplified expositions. (A slightly whimsical view of Euler, Gauss and Riemann as reflecting Bach, Beethoven and Brahms, their near-contemporaries, fits the first two pairs better than the third.)

The chosen storyline is the development of the measurement of "the world" — a term with widening connotation as the story develops. Pythagoras and Euclid lead quickly into Eratosthenes' ingenious and remarkably accurate determination of the circumference of the Earth. Map projections then bring one effortlessly to Gauss, the notion of curvature, the figure of the Earth and non-Euclidean geometry. The smooth development breaks off a little after Riemann. Maxwell, the expanding Universe and Einstein are brought in to illuminate what follows from Riemann's ideas, and the concluding modern cosmology involves topology and chaos.

Only in the final chapters is there material not to be found in many other popular accounts of mathematics, but this book never forgets to live up to its chosen title. The mathematical demands on the reader are virtually nil, but there are 25 pages of notes at the back, often very informative and some involving elementary mathematics. I particularly admired the following one-sentence definition: "The integral calculus is a mathematical technique for evaluating the cumulative effect of a continually changing quantity." □

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■ In the Beginning: The Birth of the Living Universe by John Gribbin is now published in paperback by Back Bay Books (Little, Brown) at \$12.95.