

literature, that the reception process, which is somewhat diffuse in literature, is concentrated in mathematics. It is certainly true that a clearly delineated readership was an increasingly strong characteristic of European mathematics in the 19th century as the mathematical community was becoming professionalized. The persistence of the national stylistic differences described by Pycior and Karen Parshall notwithstanding, pure mathematics was being developed in an increasingly isolated, sharply focused, and intellectually homogeneous community; broadening the scope of its history beyond these confines may be at best unreflective of the situation and at worst impossible.

The single volume does not tell the whole story, however. In the second volume of the work, entitled "Institutions and Applications," the historical world of mathematics opens considerably; physics, education, philosophy, and mathematics intermesh so closely that the major problem is to distinguish among them. In his paper on the mathematical community in France after the Revolution, Grattan-Guinness sketches a wide variety of investigations to support his point that the designation of "applied" mathematics is too vague to be useful for describing the variety of activities it presumably encompasses. Larry Owens points to a similar variety of interpretations of mathematics and mathematical activity fought out behind the lines of the Second World War. The several papers on developments in 19th-century German education point to still other shades of meaning in the development of mathematics there. Here, at last, one finds the kind of human interaction and historical sweep often reached for but not attained in the first volume.

In spite of the marked contrast between the volumes, they are not describing two socially separable mathematical worlds; many of the same people, like Klein, appear as powerful figures in both. A persistent theme in the second volume is what the editors call the "despairingly simple question—what is applied mathematics?" McCleary's paper provides an interesting perspective from which to approach this question also. Even as he points to the focus of the mathematical readership as supporting a reception-theoretic approach, he recognizes the constant possibility of applications as a perturbing force that undercuts it. This leads to the question of the nature and legitimacy of the split in mathematics that leaves whatever goes by the name of "applied" to the mercy of the world and preserves the "pure" in a separate and sacrosanct universe. This seems to me to be the crucial question raised by these volumes overall. There is no better way to examine it

than through its history, and no better group of people to do it than those who have contributed to this impressive collection.

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Flying Machines

Bird Flight Performance. A Practical Calculation Manual. C. J. PENNYCUICK. Oxford University Press, New York, 1989. xii, 153 pp., illus., + diskette in pocket. \$49.95.

At first glance, this slim volume is a practical guide to estimating the power requirements of birds in flapping, gliding, and soaring flight. If you wish to know how far your pigeon can travel on the energy in a handful of seeds, and how fast it should fly in order to maximize this distance, then you should consult *Bird Flight Performance*. Slip the IBM-compatible, 5¼-inch diskette into your personal computer, enter the mass (0.31 kg) and wingspan (0.6 m), and within a few seconds the program will tell you that at a maximum-range speed of 15.1 m/sec your bird has a power output of about 34 watts and consumes the energy equivalent of 0.058 g of fat per kilometer (or about 34,000 miles per gallon of gasoline!). But although this book was written to provide researchers with a simple means of estimating the energy used by birds while foraging or migrating and of assaying the consequences of wing design or payload weight on flight energetics, *Bird Flight Performance* has value far beyond this narrow purpose. Colin Pennycuick, who pioneered the application of aeronautical principles to the study of bird flight and who is also a skilled pilot of many types of aircraft, has written a lucid, witty account of the engineering perspective in biology, worth reading by anyone interested in the design of organisms.

Step by step, Pennycuick leads the reader from basic physical principles through the development of equations describing the power required to overcome drag and the acceleration of gravity. These are not empirical equations that generalize measurements of energy consumption by flying birds. Indeed, the difficulty of obtaining such data on birds under natural conditions made necessary the development of equations for flight performance from first principles. To be sure, these equations have constants that must be evaluated by measurements in wind tunnels or under other experimental conditions, and some of these are quite tentative. But the greater value of the engineering

approach is that it relates flight performance directly to the design of the organism. This allows one to isolate critical design components of birds and to evaluate the impact of changes in design (primarily wing area and span) and size scaling on flight performance and power requirement. Pennycuick also relates, in detail, physiological and mechanical determinants of the power available from muscles in order to link aerodynamical considerations to other components of the flight system. For example, one learns that with increasing body size the power requirements of flight increase faster than the ability of muscle to provide power. Thus, larger birds must make greater use of soaring and gliding than smaller ones; such design constraints ultimately limit the maximum size of flying organisms.

Throughout, Pennycuick imbues *Bird Flight Performance* with a strong personal philosophy of science, in which engineering principles dictate the critical measurements of biological systems. He constantly reminds the reader of the fundamental importance of dimensional analysis and expression of variables in consistent units. One also learns that some measurements of the span and area of a bird's wing are aeronautically informative while others, including most of the traditional ones employed by ornithologists with other purposes in mind, are not. Even if one has no intention of measuring a bird or has no practical need for calculating flight performance, this book will bring considerable insight and enjoyment. Perhaps, however, the book's cover should carry a warning: after reading *Bird Flight Performance* one is likely to regard the grace and poetry of bird flight in terms of wing aspect ratios, parasite and induced power, glide polars, and thermal soaring.

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Ciliates and Universals

Pattern Formation. Ciliate Studies and Models. JOSEPH FRANKEL. Oxford University Press, New York, 1989. xviii, 314 pp., illus. \$65.

Joseph Frankel is well known among ciliatologists for three decades of work on the development of *Tetrahymena*. In chapters 2 through 9 of this 11-chapter work, he presents an account of some significant aspects of the development of *Tetrahymena*, *Paramecium*, *Euplotes*, *Stentor*, and other ciliates, which is as impressively organized as are the cell surfaces of these remarkable organisms. His ordering of the material is designed to

serve two ends. First, he writes for the non-ciliatologist; and as one of these I find the account an eminently comprehensible introduction, which can be read fast without strain. Frankel's prefatory indication that the book is too long to be read through at a single sitting is unduly modest. It took me a long weekend, but I could have read it in a shorter period.

Second, the entire account addresses the question asked as the title of chapter 11: "Can ciliates help us to find 'nontrivial universals'?" Frankel's thesis is to answer this question affirmatively, and the plan of presentation is to show (in my abbreviation from Frankel's preface): that there exists in ciliates an intracellular hierarchy of qualitatively different systems of spatial control; that these systems can be inherited cytoplasmically; and that the most global level in this hierarchy is analogous to positional information in developing embryos. This thesis denies that global organization of the structures at the cell surface can be accounted for by jigsaw-puzzle-like extension of local self-assembly. It denies also that the credo of the molecular biologist, stated by Frankel as "*omnis forma ex DNA*," can be the whole story of development.

Now I have some difficulty assessing Frankel's establishment of this thesis as critically as many biologists might wish. The importance of hidden global controls of pattern formation, communication between developing units, and the dynamic nature of these processes are to me the preconceptions or paradigms on which I have based my attempts, over 17 years, to apply physico-chemical principles to biological pattern formation. Frankel quotes my 1982 and 1987 reviews in two places in ways that are quite pleasing to me. He does not, however, resort to the mathematical language of change, the calculus, in advocating global dynamic control. (The only mathematical terminology he uses is from the field of topology. It is nicely brought in, and one needs no advance knowledge of it to understand his arguments.) Rather, Frankel addresses the biologist in biologists' language, letting the levels of pattern control emerge from a meticulously detailed account of experimental observations. But, subtly, he subdivides several sections of this account with the subheadings "statics" and "dynamics."

The scholarship of Frankel's account is admirable. The roughly 700 references cover about half a century for detailed experimental work and twice that for concepts. (But in reaching back to Whitman and Bateson in the 1890s he has omitted to go back a decade further and discover that the concept of positional information can be

attributed to Hermann Vöchting.) The section of chapter 11 in which he compares ciliate development to that of *Drosophila* is weaker because, while indicating hierarchy in ciliate controls, he does not give the hierarchical classification of *Drosophila* genes (maternal-effect, gap, pair-rule, and so on).

Chapters 8, 9, and 10 are concerned largely with mirror-image reversals of asymmetry, culminating in a cylindrical coordinate model of positional information on the cell surface. This is very similar to the polar coordinate model discussed by French, Bryant, and Bryant in 1976 for insect and amphibian limb regeneration. The model works quite well, and Frankel, while clearly liking the model, assesses its successes and deficiencies fairly. Its application to ciliates has some fascinating differences from the earlier application to animals. Intercalation of positional values occurs without growth, and these values can even be respecified as an organism shrinks.

The account of ciliates is wrapped up in the questions about universals in chapters 1 and 11. If we are to ask these, we must look outward into each other's fields, where we shall necessarily appear less expert. Thus, I do not count it a fault that there are deficiencies in Frankel's *Drosophila* account. It was important for him to make the comparison. When is any expert drosophilologist going to write a similarly outward-looking book for non-drosophilologists? Frankel has shown how a single-organism specialist can look outward, and see the stars—and wonder.

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Books Received

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