

ionic regulation, on which Lockwood is a recognized authority. Respiration and metabolism are dealt with in chapter 6, while related subjects of energy input into an organism, feeding and digestion, are not discussed until chapter 9. Chapters on the neuromuscular system and the sense organs intervene. This arrangement is not too distracting, however, since each chapter is independent. By and large the illustrations are adequate though not exciting. I would buy this book for my own library, but I question its basic value to the student.

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Cosmological Theory

Relativity and Cosmology. H. P. ROBERTSON and THOMAS W. NOONAN. Saunders, Philadelphia, 1968. xxxiv + 460 pp., illus. \$16.50.

In an excellent tribute to the late H. P. Robertson, his lecture notes have been edited and augmented by one of his students as "co-author." Many physicists and former friends of the Caltech mathematical physicist will find this book a useful summary of his important contributions and an outstanding textbook for advanced courses. The introductory pages, including a foreword by William A. Fowler, give some impression of the "senior author," but neglect his work for the armed forces in England and France during and after World War II, and the now famous Robertson Panel on Unidentified Flying Objects. Except for a 10-line excerpt from his lecture notes on the rotating-disk paradox, the humorous side of Robertson's character does not show in the text (as it did on the wall decorations of his kitchen, or in his salty remarks on poker games after a hard day's work on Air Force photographs).

However, I suspect that Robertson, a meticulous mathematician, would have preferred to keep his theoretical work serious, brief, and to the point, in the manner in which Noonan presents it in this book. The rigorous treatment, in vector and matrix notation, starts with Euclidean space and classical electromagnetism, and proceeds with special relativity and Riemannian geometry to general relativity and a detailed treatment of its consequences. These include the three classic tests (advance of planetary orbit peri-

helion, gravitational deflection, and gravitational redshift of light), the Poynting-Robertson effect on small particles (updated to include the effect of the solar wind), gravitational waves, the effects of changing stellar mass, and several experiments possible with artificial satellites (orbital precession, clock rate differences, and others). All of these are expressed in specific equations derived rigorously, often with numerical values compared with actual or possible observational results, and clear indication of approximations made or unknown parameters in the most general formulation.

Although the history of the development of special relativity is outlined in more detail than is known to most modern physicists (experiments by Fizeau, Hoek, Hammer, Sagnac; Thomas precession; the Michelson-Morley, Kennedy-Thorndike, and Ives-Stillwell experiments; the Minkowski universe; and Birkhoff's gravitational theory), nothing is said about Milne's kinematical relativity or the recent Brans-Dicke scalar theory. However, the upper limit of velocity of material particles (c) set by the principle of causality is noted—the recently popular "Tachyon theory" of E. Sudarshan and others thus being eliminated.

The text generally emphasizes mathematical rigor, occasionally to the detriment of physical insight. For instance, the Lorentz transformation can be derived without complex mathematics from the relativity principle and the postulate that light has velocity c relative to any inertial frame, but the authors omit this conceptually simple derivation (and the diagram showing observers O and P, each considering himself at the center of a spherical wave front resulting from a light pulse released as they passed each other with relative velocity v). In the conceptual vein, Robertson and Noonan dispose of the twin paradox by using a simple Minkowski diagram showing the 18-year gap in the journeying twin's time scale as that twin reverses velocity ($0.6c$) 15 light-years away. Similar, notable demonstrations are given of the gravitational redshift, the inconsistency of gravitation and special relativity, the equivalence of gravitation and acceleration, the generalized Doppler effect and Planck's constant, cosmological constant and curvature, and cosmological distances.

In the last five chapters, all dealing with cosmology, Noonan augments Robertson's notes very effectively and

follows his mentor's efforts to find observational tests of the various relativistic models. He uses observational data as of 1965 (and notes 1967 additions in an appendix), including the Hubble constant 100 km/sec-Mpc, quasars with redshift of 2, and the background 3°K radiation, but does not note all their implications (for instance, the "disproof" of steady-state theory by the 3°K background).

The metrics and geometries of eight cosmological models are derived and summarized in a table. Astronomically observable quantities (redshift, bolometric distance, angular size, and counts to various limiting magnitudes) are related to cosmological parameters and discussed briefly, and the inescapable conclusion is drawn that observations to date cannot confirm any one cosmological model.

Most of the calculations are illustrated with schematic diagrams that add greatly to the clarity. One of the more detailed diagrams that I found particularly interesting illustrates the trajectories of test particles and photons near the Schwarzschild singularity. There are a useful list of symbol definitions, a good bibliography, and an excellent ten-page abstract of the text, chapter by chapter, in an appendix designed to help the reader find particular topics and to follow the line of reasoning. I am sure that Robertson would be proud of this product of the many years he devoted to relativity and cosmology.

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Some Aquatic Animals

Australian Inland Waters and Their Fauna. Eleven Studies. A. H. WEATHERLEY, Ed. Australian National University Press, Canberra, 1967. xvi + 287 pp., illus. \$A10.50.

Australian Freshwater Life. The Invertebrates of Australian Inland Waters. W. D. WILLIAMS. Sun Books, Melbourne, 1968. x + 262 pp., illus. Paper, \$A2.50.

Australia remains, as the editor of *Australian Inland Waters and Their Fauna* has noted, terra incognita as far as biology is concerned. This book, which includes contributions from ten Australian specialists, is valuable in reducing our ignorance of the

interesting fauna and environment of Australia's limited and often ephemeral inland waters. It has three main divisions covering environment, faunal surveys, and some of the consequences of man's presence.

There still remains a paucity of limnological data on Australia, and the first two chapters summarize physical and chemical information concerning this exceedingly dry land. As might be expected on the world's driest continent, many lakes have very high salinity. W. D. Williams has summarized the varied chemical characteristics by region in very useful fashion. In Queensland, for example, sodium is the dominant cation instead of calcium or magnesium. In northern and southern Australia at salinities over 4000 parts per million sodium also dominates. A general classification of aquatic environments is proposed by I. A. E. Bayly which is based on the calanoid copepods, whose representatives cover the whole range of salinity encountered. A useful new term, "athalassic," is proposed for lakes whose waters are not derived in any direct fashion from the sea yet which show a biological unity despite their variable chemical nature.

The faunal survey includes Australian decapod Crustacea, Mollusca, Amphibia including anurans, and the principal fish of the major river system in New South Wales. J. A. Bishop provides interesting zoogeographic speculation as to probable origin and dispersal. D. F. McMichael presents simple keys to bivalves and gastropods, with useful illustrations. M. J. Littlejohn deals with patterns of speciation at two levels which may be considered as divergence following a postglacial fragmentation of amphibian ranges and differentiation in earlier glacial phases. In search of distinct regional faunas he reviews 51 forms of southeastern Australian anuran amphibians. This chapter is complemented by one on life histories, evolution, and ecology of anurans by A. A. Martin.

The faunal survey section concludes with a review of principal fish of the Murray-Darling River system. This system, despite the length of the rivers (2600 and 2700 kilometers, respectively), has the smallest runoff of any large river system in the world. The fish fauna is characterized by few species and remarkable resilience in extremes of drought and flood.

The first chapter of the final section of the book, by the editor and J. Slake,

deals with the nine introduced species which are "at liberty" in Australia. Introductions of exotic species are often criticized by biologists, and Australia has had some particularly unfortunate examples. Fish introductions appear to have met with more welcome. The trout, which are confined by temperature to the eastern highlands, have probably been the most successful. The suggestion that any future introduction be examined carefully by "authorities" rather than "authoritative administrators" is well taken in the chapter by W. D. Williams.

The concluding chapter, a particularly interesting example of applied limnology, deals with zinc pollution of the Molonglo River, which supplies Lake Burley Griffin in the city of Canberra. The zinc, which originates from abandoned mining operations upstream, is in "ionic" and "nonionic" form. In the river there is a depression of the number and variety of invertebrates. The suggestion of indirect effects on the primary producers would lend itself to useful additional study, and further work is certainly necessary on toxicity in fish.

In summary, although the book would be somewhat disappointing to limnologists seeking information on the physical and chemical aspects of inland waters of Australia or some study of the productivity or population structure of the plankton, the taxonomist and zoogeographer will find the book to be of considerable interest.

W. D. Williams in *Australian Freshwater Life* provides a useful guide to the invertebrates found there. The author intended the volume for readers with little biological knowledge, and it is written in a popular style. For such an audience the grouping of animals included in chapters 2, 3, and 4 seems unfortunate, since the basis for this classification is not clearly explained. Williams' primary subdivision separates "the Lowest Groups," namely, Protozoa, Porifera, and Coelentera (chapter 2) from the other animals on the basis of their "lacking bilateral symmetry," without mentioning that the last two groups are predominantly radially symmetrical. The higher Metazoa (with bilateral symmetry) are then subdivided on the basis of presence or absence of a coelom, which the author defines in the strict sense as "an internal body cavity developing within embryonic mesoderm." No mention is made of another internal body cavity which is only partly enclosed by mesoderm (and

not lined by peritoneum), namely the pseudocoel. This should be noted because four of the six major groups dealt with in chapter 3, "The Bilateral groups without a coelom," do have a pseudocoel (Nematoda, Nematomorpha, Rotifera, and Gastrotricha). The other two, Platyhelminthes and Nemertea, of course lack a body cavity within the mesodermal packing and hence may properly be called acoelomate. The reader may be confused to find acoelomate and pseudocoelomate groups thus combined in the same chapter.

References are included at the end of each chapter and a short glossary and a well-developed index are included.

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Chemical Systems

Radical Ions. E. T. KAISER and L. KEVAN, Eds. Interscience (Wiley), New York, 1968. x + 800 pp., illus. \$30. Reactive Intermediates in Organic Chemistry.

This is a collection of 13 papers that deal with the recent developments in the chemistry of radical ions. The first eight chapters cover the theoretical and experimental aspects of organic radicals in solution. Although there is no apparent attempt to present these chapters from a systematic point of view, the topics chosen do seem to give a fairly good, up-to-date, overall perspective of the radicals. Since electron paramagnetic resonance (EPR) is uniquely suited for investigation of these systems, most of the discussions are based on the interpretation of the EPR spectra. Recent important developments such as theoretical calculation of spin densities, electronic structure of anion and cation radicals, ion-ion-pair equilibria, and molecular conformation studies are treated in considerable detail. The other five chapters are devoted to the chemistry of inorganic radical ions as well as ions produced in rigid media by high energy irradiation. Here again the reader will find that EPR is the dominant experimental tool, although optical methods are also discussed.

The chapters are highly specialized and tend to reflect the interests of the authors, and a sound knowledge of EPR is essential for understanding most of the discussions. The presentations are clear and well organized, and the mate-