Book Reviews

Listening in the Dark. The acoustic orientation of bats and men. Donald R. Griffin. Yale University Press, New Haven, 1958. xviii + 413 pp. Illus. + plates. $7.50.

Under this title D. R. Griffin of Harvard has produced an outstandingly thorough and able survey of the problem of echolocation in animals. The problem of how a bat flying in the dark can avoid collision, not merely with cliffs, trees, and walls but even, in darkened rooms, with quite fine wires, has intrigued naturalists since the time of Spallanzani (1729–99).

One of the most attractive features of the present work is the thorough and appreciative account it contains of Spallanzani's experiments—an account which shows him to have been not only an incisive thinker but a master of the experimental method long before his time. The suggestion that the bats might, in fact, be navigating by some form of echolocation was indeed foreseen by Spallanzani, who suggested that the sounds of bats' wingbeats might perhaps be heard after reflection from obstacles.

It was not until 1912 that Sir Hiram Maxim, unaware of Spallanzani's suggestion, put forth the idea that bats could successfully avoid obstacles by means of sounds of about 15 cycles per second—that is, below the human auditory range, this frequency being roughly that of the wingbeat of some of the smaller bats. As we now know, it is the opposite end of the spectrum which is involved, and in 1920 the English physiologist Hartridge, as a result of the developments of underwater sound signalling after World War I, suggested that bats might use sounds of high frequency and short wavelength in their avoidance of obstacles. This was a suggestion only, without any experimental support. Indeed it was not certain whether Hartridge had in mind high auditory frequencies, 15 to 20 kilocycles, or frequencies above the range of the human ear; but, as Griffin points out, he was certainly the first to appreciate and emphasize the great advantage that a bat might be expected to gain by using high frequencies and short wavelengths. The development of radar in World War II was, incidentally, an important factor in bringing the author of this work to the subject, and 1944 saw the publication of the first of an important series of papers by him and his associates.

Hartridge returned to the subject in 1945 and 1946. It has since been the chosen field of several able sensory physiologists, but among these Griffin himself has been outstanding, and—partly because he is also a first-rate naturalist—it is primarily to him that we owe the development of one of the most surprising and absorbing recent chapters in zoology. Many problems remain for further investigation and innumerable byways offer themselves for exploration, but the main lines of the story now seem to be established beyond doubt. The conclusion is that all groups of bats except the Megachiroptera, which are primarily visual animals, control their flight by emitting brief pulses of sound, either well above the human auditory range or at least containing strong supersonic components. These pulses are often highly directional, so that with them the bat can scan its surroundings as one might do with the beam of an electric torch, and where—as in many species—the pulses are of very high intensity, they enable the bat to perceive, follow, and catch flying insects solely by the echoes which return to it from the insect's body. It is extraordinarily difficult for us human beings, visual animals that we are, to imagine ourselves into this world of sound, but Griffin's descriptions are so vivid and lively that he succeeds in familiarizing us with the acoustic world of the bats where many others would fail.

Much of the book is highly technical. Many of the chapters contain material not previously published and perhaps more appropriate for scientific journals than for a book intended for the general zoologist; but the whole is so well done and the story is such an exciting one that even the reader quite ignorant of acoustics and radar is likely to emerge not merely much better educated but an enthusiastic student of the natural history and physiology of bats. The story of Griffin's work on the bats must certainly take its place as one of the major developments in natural history of the present period.

But of course it is not only bats that achieve echolocation; there are also absorbing chapters on the echolocation methods of fish, marine mammals, and, above all, birds. Griffin himself has established beyond doubt that the "oilbird" or "guacharo" (*Steatornis caripensis*), the extraordinary vegetarian nightjar of South America, finds its way in its home caves by just the same method, save that the sounds used probably do not contain important supersonic components. There is now strong circumstantial evidence that swifts of the genus *Collocalia* also have the same ability.

Finally, not the least of the merits of Griffin's book is that it makes clear the problems yet to be tackled. How is it that many bats can undertake long-distance homing and migration flights at night under circumstances in which echolocation can be of little, if any, use? How do the fish-eating bats perceive echoes from fish beneath the surface of smooth water, a surface which must be almost completely reflecting even to the intense high-frequency sounds of bats? How indeed do bats avoid collision with smooth water surfaces when drinking? In some way they must overcome the difficulties caused by specular reflection. These and many other points remain to be worked out, and we have little doubt that Griffin will continue to be a pioneer in their study.

This distinguished book ends with a number of chapters on general problems and prospects raised by these studies, not least of which is the likelihood that some of the methods bats employ might be effectively harnessed for the service of the human blind. Blind persons, as is now well known, may become remarkably proficient at avoiding collision by means of the perception, often unconscious, of echoes of footsteps and of such sounds as the tapping of a stick, as these come back to them.

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Volumetric Analysis. vol. III. *Titration Methods: Oxidation-Reduction Reactions.* I. M. Kolthoff, R. Belcher, V. A. Stenger and G. Matsuyama. Interscience, New York, 1957. ix + 714 pp. $15.

This long-awaited volume completes the three-volume series on volumetric analysis by Kolthoff and his associates. Volume I, *Theoretical Fundamentals,* was issued in 1942 and volume II, *Titration Methods: Acid-Base, Precipitation, and Complex-Formation Reactions,* was issued in 1947. The third volume is of the same high quality as the

earlier works and is an outstanding contribution to analytical literature.

The subject matter is presented in 14 chapters. The initial chapter on reactions, indicators, and general techniques is followed by chapters on potassium permanganate as both a volumetric and an oxidimetric reagent employed in methods for the determination of many inorganic and organic substances. Similar chapters cover the oxidimetry and use of ceric salts, potassium dichromate, iodine, iodates, periodates (Malaprade reaction), bromates, and hypohalites. In addition, there are chapters on the determination of water with the Karl Fischer reagent and on miscellaneous oxidizing and reducing titrants—for example, ferric salts and arsenious oxide.

The text material is up to date and is presented in the clear, orderly style characteristic of the senior author and his associates. The book is well-indexed. Cross references throughout the text will enable the reader to pin-point desired information readily—a very useful aid to those searching for reliable and thorough information when carrying on analytical operations. The student, teacher, and experienced chemist will find a great amount of information in this text with which their objectives can be more quickly and easily attained.

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Studies on Fossil Vertebrates. Presented to David Meredith Seares Watson. T. Stanley Westoll, Ed. University of London, Athlone Press; Essential Books, Fair Lawn, N.J., 1958. xii + 263 pp. Illus. $5.60.

This series of papers, honoring D. M. S. Watson on his retirement from the University of London, includes interesting, authoritative, and well-written theoretical studies, review articles, and discussions of new material in many of the fields Watson himself investigated.

Five chapters deal with fossil fish. Dorothy H. Rayner discusses the problems in determining the life habitats of fossil fish. Fish remains are very rare in modern dredging except in areas of low oxygen content, which suggests that the abundance of fossil fish in any environment may be inversely related to their abundance as living fish.

Errol I. White concludes that the evidence indicates that the original home of the craniates or Vertebrata was salt water, not fresh. Evidence for a freshwater origin often involves fish which lived in fresh water at some unspecified time after their origin, but this has no bearing on where the origin actually was. Perhaps the problem is complicated by there being no universally accepted definition of the precise point at which organisms became vertebrates. White cites zoological, geologic, and paleogeographic evidence, indicating that craniate conditions were achieved in marine (presumably coastal) waters, though the vertebrates may soon have entered fresh water.

T. S. Westoll concludes that, in early fishes, there was probably never "an ancestral type with continuous paired finfolds with segmented endoskeleton and segmental muscles," but that "there was a paired line of potential skin-folding, from which keel-like structures could develop," and that such structures developed several times among the early vertebrates, the invasion by muscles being independent in the different groups. The general homology of paired fins is indicated by the similarity of blood supply and innervation in the cephalaspids and sharks.

A new restoration of *Lasanius* accompanies F. R. Parrington's discussion of the Anaspida. Resemblances to cyclostomes are striking, suggesting the presence of similar gill sacs. These organisms probably buried their heads in the mud for feeding and pumped water in and out of the gill pouches for respiration.

The head of another anaspid, *Birkenia,* is restored by Anatol Heintz, who believes that the mouth and feeding habits were like those of *Amphioxus* rather than of cyclostomes.

Three papers summarize important aspects of the evolution of higher vertebrates: the stratigraphy, fauna, and environment of the Texas Permian, by A. S. Romer; evolutionary trends among Triassic tetrapods and indications of the similarity of Triassic and Cretaceous extinctions, by Edwin H. Colbert; and annotated faunal lists of the fossil vertebrates of Australia, which, E. Sherborn Hills states, show that Australia has always had closer faunal relationships with Europe than with South America or Africa.

The remaining three chapters are more theoretical. Causation in evolution, correlation of structure and function, relationships of internal and external environment, and evolutionary rates and directions are discussed by W. K. Gregory, Sir Gavin de Beer and W. E. Swinton stress paedomorphism (that is, the younger stages of the ancestor prophesy the adult stages of the descendant) in fossil sequences, both vertebrate and invertebrate. The neo-Darwinian basis of major evolutionary changes is questioned by James Brough, who feels that families and smaller units may arise by natural selection but that orders and higher groups have arisen very rapidly, due both to a former much higher mutation rate and to directional mutations. He observes that no new animal phyla have arisen since the Cambrian, and no new classes (except birds and mammals) since the Paleozoic, and concludes that "evolution is almost or quite spent as a major creative force."

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Quantum Mechanics. Non-relativistic theory. L. D. Landau and E. M. Lifshitz. vol. 3, of *Course of Theoretical Physics.* Translated by J. B. Sykes and J. S. Bell. Pergamon Press, London; Addison Wesley, Reading, Mass., 1958. xii + 515 pp. $12.50.

This volume is the second to appear in a projected series of nine volumes on theoretical physics by these authors. It is in many ways an excellent introduction to the ideas and the applications to atomic phenomena of nonrelativistic quantum mechanics.

The strong point of this text is the completeness with which it treats atomic problems. There is an almost exhaustive discussion of angular momentum and spin on an elemenatry level. Of particular interest are the detailed computations of matrix elements for angular momentum problems and the introduction and use of spinors in the discussion. The treatment of the semiclassical (Wentzel-Kramer-Brillouin) approximation is far more detailed and interesting than that given in comparable available texts and includes, for example, a little-known calculation by Landau of the matrix elements in this approximation.

It is difficult to show restraint in praising the chapters on elementary many-body systems. Besides the usual self-consistent field analysis, a good account is given of the Thomas-Fermi model of the atom. Following these more or less general methods there is a long exposition of results for the diatomic molecule. The chapter on polyatomic molecules is preceded by a very readable introduction to the theory of groups, particularly as it relates to the representation of molecular symmetry. These ideas are then applied in discussion of the vibrational properties of the polyatomic molecule.

The concluding chapters are devoted to the theory of scattering, both elastic and inelastic. The authors make very effective use of the semiclassical approximation in scattering problems. They make mention of the Gelfand-Levitan recipe for deriving the potential energy from the phase shifts but do little more than quote it.

It seems to me that this text is not as good as many now available as a general