

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 "oil-bird" 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