troscopy of gases, have been deliberately excluded. The contributions are authoritatively written, and most include clear introductions and extensive bibliographies, with some references as recent as 1975. A general introduction by N. Bloembergen helps to unify the volume and to place the subsequent contributions in their proper topical and historical context.

The volume consists of two parts. Almost two-thirds of part A is devoted to a discussion of nonlinear susceptibilities, which can be used to describe and characterize any nonlinear optical phenomenon in a given material. The rather detailed and highly mathematical article by C. Flytzanis on the theory of these susceptibilities covers both the macroscopic phenomenological aspects and the microscopic theory, using quantum mechanical perturbation theory up to third order and progressing from rarified media to anisotropic solids. The subsequent article by S. K. Kurtz on the experimental determination of these parameters and their numerical values in a variety of materials is more limited in scope, restricting itself essentially to second-order susceptibilities in crystals, which are important for sum or difference frequency generation or parametric conversion of light waves.

The remainder of part A presents discussions of a number of nonlinear optical phenomena that are primarily of spectroscopic interest. All these contributions achieve a balance between theory and experimental material. They include a review of two-photon absorption spectroscopy by H. Mahr, which emphasizes electronic transitions in solids, a review of stimulated Brillouin scattering in gases, liquids, and solids by I. L. Fabelinskii, and a relatively short update on stimulated Raman scattering by C.-S. Wang, which emphasizes transient effects. Some less widely known and used spontaneous and stimulated parametric scattering processes are discussed in a paper by C. L. Tang.

Readers with more practical interests may find part B even more useful. It consists of three papers on the application of nonlinear optical phenomena to the generation of coherent light at new wavelengths. The first paper, by S. A. Akhmanov, A. I. Kovrygin, and A. P. Sukhorukov, gives a detailed account of the theoretical and practical aspects of optical harmonic and sum-frequency generation. The second, by R. L. Byer, is a comprehensive review of optical parametric oscillators. And the third, by J. Warner, is devoted to difference frequency generation and upconversion. The first two papers are notable for a valuable collection of equations, diagrams, tabulated data, and references, which are sometimes hard to find elsewhere.

By selecting topics that have reached a certain maturity, the authors and editors of this volume have minimized the danger of instant obsolescence. And by presenting a few topics in depth rather than attempting a general survey of nonlinear optics, the volume succeeds not only in conveying the spirit of the field to the novice or graduate student, but in offering valuable reference material to the specialist.

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Aerial Locomotion

Insect Flight. Proceedings of a symposium. R. C. RAINEY, Ed. Halsted (Wiley), New York, 1976. xii, 288 pp., illus. + plates. $47.50. Symposia of the Royal Entomological Society of London, No. 7.

The evolution of a successful flight mechanism by insects was one of the great events in the development of life on Earth. It enabled the group to undergo a radiation not equaled before or since and to dominate the biological scene without rival until the recent advent of man. Insects account for three-quarters of animal species, living and fossil, and are estimated currently to number 10^{18} individuals with a biomass of about 10^{13} grams.

Insect Flight is a collection of a dozen articles by as many authors. In these days of specialization, the book is unusual and appealing in its attempt to give a broad perspective on the phenomenon of flight and its biological implications without undue sacrifice of sophistication. The topics treated range from sensory and muscular adaptations (J. W. S. Pringle) and central nervous mechanisms (B. Mulloney) through navigation (M. Lindauer) to population movements and atmospheric conditions (R. C. Rainey).

Among the highlights is an account of night migrations given by G. W. Schaefer. Developments in radar technique have made possible the detection of individual insects at distances of 3.1 kilometers (swarms to 70 kilometers) in densities down to ten per cubic kilometer with some species identification from wingbeat frequencies. This capability reveals that "great masses of insect migrants become airborne after dark, regularly assume a common orientation related to wind-direction or compass bearing, climb actively for hundreds of meters to reach altitudes of apparently optimum temperatures and winds, continue to fly for periods of hours, and finally land after travelling tens or hundreds of kilometers, repeating this behavior night after night." The extent and general biological role of small aerial fauna are poorly understood, but such migrations are certainly critical in pair formation, dispersal, and location of suitable reproductive and foraging areas and, of course, for insect control.

A thought-provoking resuscitation of the gill theory of the evolution of flight is offered by V. B. Wigglesworth. The currently most widely held theory envisages the progressive extension of paranotal thoracic "flaps," first as a parachute in retarding descent, then as a gliding mechanism, then as movable steering vanes during gliding, and ultimately for actual flapping flight. After reviewing the structure of vibratile gill plates on the abdomen of Ephemeroptera (mayflies), Wigglesworth suggests that similar appendages on thoracic segments could have evolved into wings. The ecological basis is viewed as an attempt by aquatic insects, under seasonal or long-term drying conditions, to disperse to damper areas. The interesting parallel is indicated between this theory and Romer's theory of the evolution of terrestrial locomotion in fishes, also during the Devonian.

T. Weis-Fogh provides an analysis of wing aerodynamics and recent developments in our understanding of events during nonsteady airflow conditions of slow and hovering flight. Initiation of lift by flow across an airfoil normally involves establishment of a bound vortex and shedding of a "starting vortex." Disruption of smooth flow causes stalling, a severe problem with a wing that not only is moving but must frequently reverse direction. Two partial solutions, "flip" and "fling," are employed by insects. In the latter, the wings are pressed together at the top of the stroke and peeled apart at the leading edge to create two lift-generating bound vortices immediately without any starting vortex. The mechanism is independent of size and could also be used by birds, in which case it might create an audible clap. Such a clap is produced at the start of flight by some pigeons, as Virgil (*Aeneid*, book V) noted.

The volume suffers from some imbalance. About a third of it is concerned with population movements, and in-

sufficient attention is given to the role of the flight period in the life cycle or to the features of free flight by individuals. No readily discernible logic underlies the sequence of topics. Considering the range of the book, some articles have too much jargon and too little perspective. And inevitably, some are already seriously dated (from summer 1974).

On the whole, though, the synthetic, as opposed to reductionist, approach of this volume is very attractive and should have widespread appeal to those interested in insects, behavior, and biology.

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Invertebrate Structure

A Functional Anatomy of Invertebrates. V. FRETTER and A. GRAHAM. Academic Press, New York, 1976. viii, 590 pp., illus. $31.

The vast domain of invertebrate zoology, rich in tradition and largely untainted by economic necessity, stands today as a testament to the power of the comparative method in phylogenetic reconstruction championed a century ago by T. H. Huxley. Those groups that menace man, notably the parasitic worms and the insects, have largely seceded from the invertebrates as we know them in undergraduate classes, leaving us with a long parade of diverse animals, many of them obscure, most of them very beautiful, the delight of connoisseurs. They are the stuff of courses that range from the worst of pickled assemblages to the highest delights of marine stations.

Textbooks for such diverse material can be thick catalogs, packed with anatomical details that define systematic position, enlivened with some bits of biology, and held together with phylogenetic speculation. An alternative approach takes function as the primary theme, but it is difficult to fit texts of that type, excellent though they may be, into courses that follow a systematic sequence.

A compromise solution is now offered by Fretter and Graham in *A Functional Anatomy of Invertebrates*. Groups are presented in systematic order, with recourse where appropriate to Huxley's method of describing a representative type in detail. Structure is presented with emphasis on what it does and how it does it. Successive phyla are treated in 14 closely written, informative essays that cover broad classification, organization of a type, and such topics as feeding and digestion, locomotion, excretion, osmoregulation, and reproduction. All are beautifully illustrated with sensitive, lively line-and-stipple diagrams that are models of clarity even when they are printed smaller than they deserve. They shine in comparison with those of comparable textbooks and will be the most attractive feature of the book to many readers. It is a delight to see the illustrative style adopted by these eminent authorities on the Mollusca extended to other groups, especially the annelids, which are superbly treated.

No single volume of reasonable size can be expected to give adequate coverage to all invertebrate phyla. Emphasis necessarily reflects personal taste, but it is a disappointment, at least to one with admittedly arthropocentric attitudes, to find that whereas annelids receive 100 pages and mollusks 80 the land arthropods are disposed of in 18, of which barely 30 lines concern the arachnids. A break with tradition is the unexplained exclusion of the lower chordates. This may be justifiable on the grounds of phylogenetic relationships, but the functional anatomy of these animals is best considered in an invertebrate context.

Manton's views on arthropod evolution are admirably epitomized; the emphasis on polyphyletic pathways and grades is reflected in the absence throughout of evolutionary trees. A serious error is perpetuated in opening the section on arthropods with the statement that the cuticular exoskeleton is composed of chitin. The cuticle is in fact composed of sclerotized protein, variably strengthened with chitin fibrils as in fiber glass. Variations in the composition of the cuticle provide some of the marvels of functional anatomy, and the book is the poorer for ignoring them. It is the lipid component of the cuticle, not the degree of tanning as stated, that serves the function of waterproofing.

As might be expected, Mollusca provide the high points of the volume, though the cephalopods get scant attention.

A pervasive shortcoming in a book that in its preface celebrates the bioengineering approach is the virtual absence of any such analyses beyond the level of bioplumbing. Quantitative treatments are rare. Ciliary action is touched on in the account of protozoan locomotion, but the emphasis is on microstructure rather than mechanics. The discussion of the arthropod cuticle includes no significant account of its profoundly important mechanical properties, especially in relation to flight; resilin, the remarkable animal rubber, is not mentioned. An account of the hydrodynamics of cephalopod locomotion could well have displaced some material of lesser functional significance in the mollusk chapter.

The functional approach of the book is used to justify a somewhat flaccid approach to systematics that will cause confusion to students. The authors properly emphasize the arbitrariness of units in the hierarchical classification but thus justify bald listings of taxonomic groupings at the end of each chapter without any indication of hierarchical level other than degree of indentation. Fortunately, these pages provide ample white paper for annotation.

In summary, this is a book notable for the general quality of its discursive essays on invertebrate structure and its admirable illustrations, but one that falls short of its proclaimed goal of bioengineering functional anatomy.

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Insect Behavior

Evolution of Instinct. Comparative Ethology of Hymenoptera. KUNIO IWATA. Translated from the Japanese edition (Kanagawa Prefecture, 1971). Amerind, New Delhi, 1976 (available as PB257052 from National Technical Information Service, Springfield, Va.). xii, 536 pp., illus. Cloth, $13; microfiche, $3.

Kunio Iwata has been studying the behavior of wasps and bees for half a century, beginning, he notes, shortly after the appearance of the Japanese translation of Fabre's *Souvenirs Entomologiques*. His *Comparative Studies on the Habits of Solitary Wasps*, published in 1942, provided a needed synthesis of studies up to that date and stimulated many young investigators (including this one) to enter this field of research. Two of Iwata's trademarks were already evident in this earlier work: his practice of including a great many data in tabular form, permitting quick comparison; and his use of behavioral formulas, in which individual behavioral elements are indicated by a single letter, so that the sequence of behavioral acts can be quickly compared in different genera.

The present book is in a sense an expansion and updating of the 1942 monograph, though the organization is much different and the coverage broader. *Evolution of Instinct* was published in Japa-