excitement of pulsars, quasistellar sources, gravitational collapse, Dicke's challenge to general relativity, and the cosmic microwave radiation with its implications for cosmology?

To meet the rising tide of interest in gravitation physics a number of physics departments may develop new courses in the next few years. The three volumes of *Relativity Theory and Astrophysics* would make an excellent textbook for such courses, until rapid research developments outdate them.

Each of the volumes begins with a comprehensive introduction to a major area of gravitation physics (volume 1, general relativity theory, by Alfred Schild; volume 2, galactic structure and dynamics, by Lodewyk Woltjer; volume 3, stellar structure, by Edwin Salpeter). The comprehensive introduction is then followed by in-depth reviews of the special topics of greatest recent research interest.

One of the most striking features of these volumes is the extent to which some of the reviews of special topics have become outdated in the three years since they were written. Until recently one was accustomed to thinking of gravitation physics as an area of painfully slow progress, particularly on the experimental side. However, a brief perusal of these volumes reminds one of the great changes of the last three years: (i) Volume 1 contains a beautiful description by Freeman Dyson of the *proposal* for testing general relativity by reflecting radar signals off Venus and Mercury, as they pass behind the limb of the sun. The experiment has since been carried out, confirming to an accuracy of ±20 percent the general relativistic corrections to Newtonian theory. (ii) One sentence in volume 1 mentions that if the sun's gravitational field has a quadrupole moment, that would produce part of the perihelion shift of Mercury, resulting in a discrepancy between the measured perihelion shift and the predictions of general relativity. Eighteen months ago—too late for them to get any mention in these volumes—R. H. Dicke announced the results of measurements which show the sun to be optically oblate, and by implication perhaps to have a quadrupole moment. The uproar caused by Dicke's experiment and the resultant detailed theoretical studies of rotating solar models would receive considerable attention in any review volume written in 1968. (iii) In a short (six pages) chapter Joseph Weber describes the design of a detector for gravitational waves. But of course there is no mention or detailed discussion of the strange "events" which such detectors, now in operation, have been recording roughly once a month over the last year. (iv) The theories of the origin of galaxies discussed in lectures by W. B. Bonnor are almost wholly out of date. The discovery of the cosmic microwave radiation in early 1965 (described in these volumes by James Peebles) has created deep new insights into physical conditions in the early stages of an expanding universe and into the accompanying problem of the origin of galaxies. These new insights are only now beginning to reach the pages of the *Astrophysical Journal*, and they are developing and changing so rapidly that a comprehensive review of galaxy formation will be impossible for several years to come. (v) Volume 2, on stellar dynamics, does not discuss—indeed, could not discuss in 1965—the new insights now coming from computer studies of up to 100,000 gravitationally interacting stars. (vi) The reviews of the observation and theory of quasistellar sources and x-ray sources are so out of date after three years as to be virtually useless. (This was foreseen when the articles were written; so they were kept short.) And, of course, there is no mention of the most recent mysterious class of objects, the "pulsars." (vii) These volumes do not touch on the powerful singularity theorems for gravitational collapse and cosmology, proved in 1964 through 1967 by Roger Penrose, Steven Hawking, and Robert Geroch. Those theorems and their implications are now posing deep problems of principle for theoretical physics.

I cite these examples not as an indictment of these volumes—no books written in 1965 could be more up to date—but as a measure of the excitement brewing in gravitation physics today. And I hasten to add that these examples of outdated material constitute less than 5 percent of the material in the books—albeit the 5 percent that could have been the most exciting. The remaining 95 percent of the material is so fundamental to current and future research in gravitation physics that these books belong on the shelves of everyone with a desire to follow in detail the new developments as they break.

A word of warning should be given to physicists who contemplate using these volumes as textbooks: The level of sophistication required to understand the various chapters is quite uneven. For example, the long introductory chapters of volume 2 (galactic dynamics) and volume 3 (stellar structure) should be readily understandable to any first-year graduate student in physics or astronomy. (And I must add that Salpeter's review of stellar structure is the clearest, most beautiful discussion of that subject I have ever read.) By contrast, Schild's introductory chapter on general relativity (volume 1) will be very rough going for anybody who does not know the subject in advance, at least partially. Nevertheless, it is an article well worth plowing through, since of all introductions to relativity now in print it is one of the most lucid, complete, and concise; and it is certainly the most up to date.

The greatest strength of these volumes is their uniqueness: No other book or set of books brings together with such completeness the various aspects of gravitation theory. It is here that a relativity theorist can turn for insight into stellar structure and evolution, or into the statistical mechanics of star clusters. It is here that the conventional astrophysicist can seek an understanding of general relativity or of the theory of relativistic gravitational collapse. And it is here that the young physics student can discover the many and varied aspects of gravitation theory all brought together into a quasi-coherent whole.

KIP S. THORNE
California Institute of Technology, Pasadena, and Enrico Fermi Institute, University of Chicago, Chicago, Illinois

Molecular Biology

Biological Ultrastructure. J. B. FINEAN. Academic Press, New York, 1967. viii + 384 pp., illus. $15. Second edition of the work by A. Engström and J. B. Finean (1958).

For the second edition, *Biological Ultrastructure* has been almost completely rewritten by J. B. Finean. The contents conform strictly to the dictionary definition of ultrastructure as "the invisible ultimate physicochemical organization of protoplasm"; only rarely does the subject matter reach to that commonly accepted realm of ultrastructure, the field of cytology beyond

histology that was opened up by the electron microscope. The book therefore covers a field more familiarly known as molecular biology. The book is well made; almost all the electron micrographs are excellently reproduced.

The overall coverage, though broad, is uneven. The subject of lipids and membranes, the author's principal interest, is covered *in extenso*; it is unfortunate that the present vigorous research activity relating to membranes and the conformation of proteins within membranes should have arisen while the book was being written or after. The subject of mineralization and calcification is presented succinctly and well, and its treatment fills a gap which many books of this nature have left open. The subject of striated muscle is well covered in an up-to-date manner, although little is said of smooth muscle. Nothing is said about the mitotic apparatus, although an attempt is made to resolve the present complicated picture of the mammalian chromosome structure. The structure and conformation of collagen and elastin are discussed in some detail, but no mention of cross-linking is made with respect to either protein. The structure and function of enzymes are discussed, allosterism is mentioned, and the chapter is brought right up to date by the example of the interaction of lysozyme with its substrate as defined by recent x-ray data, but no mention is made of feedback inhibition.

The book includes a summary of methods of ultrastructure research, and here too the coverage is uneven. The subject of x-ray investigation is covered in a very broad manner; in many cases the breadth exceeds that necessary to give an appreciation of the power and limitations of the method, which surely is the justification for presenting the topic. By contrast, ultracentrifugation is barely mentioned, and although electron microscopy is covered in some detail, little reference is made to freeze etching and none to the scanning microscope.

The book is intended for students as well as research workers in molecular biology, and for the needs of the former the chapters close with lists of well-chosen sources for further reading. For the research worker the lack of direct reference for many of the statements in the text is annoying; some snippets of information are given which a worker might well wish to pursue, but no reference or comment on authors is given to aid in the identification. Some such reference should be given to validate the statement that the 60*S* ribosomal subunit in mammalian cells contains two RNA molecules

In summary, this book presents an informative discussion of the roles of small molecules and macromolecules in cell function and in the building up of tissue. The fundamentals of intermolecular relationships, including the subjects of solvation and micelle formation, are discussed, and the more important methods of investigation are reviewed. The author has successfully condensed this mass of information into an easily read book of reasonable size.

PETER F. DAVISON
Department of Biology, Massachusetts Institute of Technology, Cambridge

Neuroembryology

Aspects of Neural Ontogeny. A. F. W. HUGHES. Logos Press, London; Academic Press, New York, 1968. xii + 249 pp., illus. $12.50.

Hughes deserves our gratitude for authoring the only book devoted exclusively to neuroembryology to appear in recent years. This short but fact-laden book of four chapters is concerned primarily with the interactions between the nervous system and the periphery during development of the vertebrate limb, and features Hughes's own research on amphibians. Two other subjects are discussed. One, the history of the neuron concept and description of the genesis and growth of neurons and Schwann cells, occupies the first chapter. This chapter is presumably intended to serve as a background for the following chapters, but its themes are rarely integrated into later sections. The other, the famous experiments on regeneration of cutaneous and optic nerves, is briefly summarized in the final section of chapter 4. Despite the narrow focus, Hughes has laced his account with bibliographical references to a somewhat wider field. Perhaps the best feature of the book is that it will serve as a useful guide to the literature.

Although its very uniqueness makes it valuable to the student of neuroembryology, this work has two major shortcomings. First, without being otherwise subjective, it is centered squarely upon Hughes's personal interests and provides no evaluation or even enumeration of the major problems with which neuroembryologists are grappling. Unless the reader has some background in the neurosciences, he might forget that there are other major areas of research in neuroembryology, such as the role of the nervous system in insect morphogenesis and the development of the vertebrate brain. Second, and more disappointing, although the chapters are subdivided into discrete topics which follow a logical order, the material in each subdivision is presented in an undigested manner. The contributions of individual investigations are briefly summarized, often with verbatim quotes from the publications. These summaries are strung together with virtually no evaluation or synthesis. Thus one is usually left with a puzzling assortment of hard and soft facts. Such extreme objectivity is hardly more useful than a simple bibliography. Hughes has forfeited his opportunity to advance valuable opinions or to excite the reader with interesting speculations and hypotheses.

Hughes's book is offered not only as an account of limb and spinal cord development but also as an enticement to prospective biologists to become neuroembryologists. Those students who survive the struggle with the difficult prose and the often conflicting data may emerge irritated and frustrated and aroused enough to do just that—in which case Hughes's book will have been a great success.

DOUGLAS M. FAMBROUGH
Department of Embryology, Carnegie Institution of Washington, Baltimore, Maryland

Surface Phenomena

Contact and Frictional Electrification. W. R. HARPER. Oxford University Press, New York, 1967. xii + 369 pp., illus. $11.20. Monographs on the Physics and Chemistry of Materials.

The author writes that this book is intended solely to present arguments that the charging of insulators is not due to electron movement. Nevertheless, the reader will find that it is in general an excellent review of the field as well as a significant contribution to a rather complex subject. The author has been active in the field for many years, and a considerable fraction of the experimental results presented are his own. His arguments are convincing and well thought out, though he tends to oversimplify the problem somewhat