lin) the discovery by Leonor Michaelis of organic free radicals which led to the principle of the transfer of single electrons via flavins to the cytochromes and finally to oxygen.

MacMunn's discoveries (1884) of the absorption bands of the "histohematins" are reviewed in chapter 6. Keilin believes that MacMunn's work was neglected by his contemporaries because of the lack of evidence that the absorption spectrum changes could be correlated with reversible redox reactions in living tissues and the possibility that these bands might be related to myoglobin and its decomposition products.

In a most exciting chapter Keilin tells how, during a relatively few years, around 1925, he came to rediscover the "histohematins" while seeking to find out how the bot fly decomposed ingested hemoglobin. To avoid problems of contamination with hemoglobin or myoglobin, Keilin chose the adult wax moth as biological material for further study. Through the wing muscle of this insect he observed the appearance of a four-banded absorption spectrum when the wings were in active motion and the disappearance of the bands when the wings were at rest. He also found the same absorption bands in suspensions of a bacillus and of yeast when oxygen was used up, and the disappearance of the bands in the presence of air. Then, with the use of the specific poisons, urethane and cyanide, with differential heating of the cells, and with extraction methods, he was able to demonstrate that the four-banded spectrum actually represented three distinct heme proteins within the cells which he designated as cytochromes *a*, *b*, and *c*. His intimate knowledge of the current literature led him to a connection between the dehydrogenases, the cytochromes, and oxygen.

It is worthwhile asking how Keilin came to make all of these fundamental findings in the amazingly brief time that he did. I suggest three reasons: (i) Keilin had an astute, analytical mind; (ii) he was a biologist with a broad base of knowledge of biological material; and (iii) he was an excellent experimenter in biology. Biological phenomena are highly complex. In investigating such phenomena it is important to use simple rapid methods of analysis so that one can make numerous observations with a large number of samples under varying conditions. To make numerous rapid observations of the cytochrome bands Keilin used a small dispersion spectroscope mounted on a microscope. With this device he could examine a clear solution, or an opalescent suspension, or a thick tissue slice within a few minutes. His knowledge of biological material permitted him to survey the cytochromes from the bacteria all the way up to mammalian tissues. Thus, he was able to show that the cytochromes are components of most cells.

In succeeding chapters the experiments that further revealed the properties of the cytochromes are described. At liquid air temperatures, the absorption bands of the cytochromes sharpen and shift in wavelength. In 1955 Keilin and Hartree, using this property, were able to establish the presence of a new cytochrome c_1, which at room temperature overlapped the bands of cytochrome *c*. The studies on cytochrome *a* showed that it was an insoluble complex consisting of two heme protein components *a* and a_3 as well as a copper-containing component. Whether oxygen is activated by cytochrome a_3 or by the copper is still not known.

The last part of chapter 9 is a polemic that I mention merely because it may aid in the sale of this important book. This section contains a criticism of Warburg's criticisms of Keilin's interpretations during the years 1924 to 1932. It is evident that Warburg failed to recognize the significance of Keilin's discoveries on the cytochromes. Humans, even those with a scientific background, will delight in this tiff between two intellectual giants, although, physically, both men were of small stature. Perhaps the lesson we may gain here is that a scientist must think arrogantly, but write with humility. But how inhuman is this combination of qualities!

The great achievements of Keilin and his co-workers at Cambridge have revealed much about cellular respiration. However, a problem early perceived, the interaction of the cytochromes, is far from solution. Actually, this problem evolved into three major problems of present-day biochemistry: the spatial interaction of component cytochromes organized in juxtaposition on a lipoprotein membrane; the coupling of electron transport with the formation of high energy phosphate bonds; and the activation of oxygen to accept four electrons, one at a time, from cytochrome *c*. Here are problems to challenge even new young Keilins and Warburgs.

Biochemistry is changing so rapidly that the useful lifetime of books in this field is only several years. David Keilin's monograph will become a classic of biochemistry and will be read by many generations of students. It is well printed and bound. It costs $17.50 and is well worth the price.

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Oceanography

Marine Geochemistry (Narragansett Marine Laboratory, University of Rhode Island, Kingston, 1965. 380 pp.), edited by David R. Schink and James T. Corless, is a paperback collection of papers presented in a symposium at the marine laboratory of the University of Rhode Island in 1964, dealing primarily with trace elements and isotopes in marine geochemistry. Most of the papers are reports of research in progress rather than completed investigations. The following notes are a sampling of the topics covered, but by no means a complete summary.

Variations in deuterium and oxygen 18 are the subject of a long paper by H. Craig and L. I. Gordon and of a shorter one by A. C. Redfield and I. Friedman. In both studies it is demonstrated that isotope concentrations have characteristic values in the major deep water masses, and hence can serve as tracers for water movements. Craig and Gordon discuss in detail the equilibrium and kinetic factors involved in the partial separation of isotopes during movements of water across interfaces between sea and air and between sea and ice.

F. T. Manheim, in a long article with an 11-page bibliography, describes manganese-iron accumulations in shallow marine environments and relates these to the better known manganese-iron nodules from the deep sea. He concludes that both major and minor metals in the nodules must come largely from the continents, and that the weathering of submarine volcanic products can be important as a source of metal only locally.

Preliminary results of a study of iodine, bromine, and chlorine in the air-sea-sediment system, using neutron activation as a method of analysis, are

described in a paper by J. W. Winchester and R. A. Duce. Relations of the three halogens show many surprises, and the paper is eloquent testimony to our present lack of detailed knowledge about the geochemical behavior of these elements.

K. K. Turekian and D. F. Schultz present current results in a continuing study of trace-element economy in the oceans. One interesting conclusion from their data is the demonstration that the supply of trace elements to the deep sea by continental runoff is importantly supplemented by underwater volcanism in the Pacific Ocean and by glaciation in Antarctica.

The volume is a useful, if somewhat uneven, survey of current work and thinking in an active area of research. As might be expected, it raises far more questions than it answers. Many of the papers convey a sense of excitement over unexpected results fresh out of the laboratory and not yet assimilated into the main body of scientific thought. Unfortunately, the book contains no record of the discussions that must have enlivened the symposium.

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Introductory Geology Textbook

In response to the need of nonscience students for some contact with the broad spectrum of scientific knowledge, many colleges have condensed physical and historical geology into a one-semester survey course. This book, **Geology—An Introduction** (Heath, Boston, 1966. 367 pp., $7.20), by R. L. Bates and W. C. Sweet, is a suitable textbook for such a course.

The best possible organization of the topics of physical geology has been accomplished. Consideration of weathering, transportation, and deposition processes precedes the chapter on sedimentary rocks. Discussions of rock deformation, metamorphism, and mountain-building are grouped together. Superposition, geologic time, and correlation are introduced early in the book. The weakest sections are those on minerals and igneous rocks. There are no mineral identification tables and no discussion of physical properties of minerals, so the book must be supplemented by a good laboratory manual. Possibly the best chapters in the first half of the book are those on downslope movements and ground water.

Post-Precambrian physical history of North America is presented on the basis of five cycles, each bounded by major marine regressions. Generalized rock types and thicknesses for each Paleozoic and Mesozoic system are presented by means of isopach-lithofacies maps (after Sloss, Dapples, and Krumbein, 1960). The history of animal and plant development is discussed separately, and the emphasis is very strongly on vertebrate animals. Very few invertebrates are illustrated and these mostly by photographs of museum reconstructions.

In covering all major topics of introductory geology and still realistically staying within the limits of a semester course, the authors ran into some problems of misleading oversimplifications and omission of some material that others would consider important (for example, stream piracy, initial dip, and possible causes of ice ages). New terms are placed in heavy type where they are first defined. However, several terms that will not be familiar to nonscience students are introduced without definition (for example, natural glass, ion, angle of repose, and suture). Almost all of the photographs are well chosen, but about 20 percent of them show low contrast or appear to be somewhat out of focus. A brief list of suggested readings follows each chapter.

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The Mathematics of Space Exploration (Holt, Rinehart, and Winston, New York, 1965. 160 pp., $1.96), by Myrl H. Ahrendt, was produced for teachers and nonspecialists who want to know how to use a little mathematics to sketch our activities in space. Fifty-two formulas concerned with mechanics, astronomy, and rocketry are introduced and used in examples designed to demonstrate their utility. There are 185 "Space Flights," imaginative problems for the reader to solve, and the answers are thoughtfully provided. There is a three-page index, a one-page bibliography, four pages of natural logarithms, and 20 pages of powers, roots, and reciprocals of numbers from 1 to 1000, to six significant figures. Nevertheless, all of the examples and problems are expected to involve no more than slide-rule accuracy.

I recommend this book to anyone who can handle mathematical and physical ideas with ease. Neither the mathematics nor the physics is difficult, but there are a few printed errors that may trap the naive or unwary reader. Of course not all of the errors are important—for example, the use of *infers* for *implies* (p. 56) and the amusing instruction: "Fill in the other empty blanks" (p. 94). The half dozen typographical errors will not trouble an experienced reader.

The author seems a little unsure in discussing centrifugal force in connection with orbits and weightlessness. Early in the work, he correctly calls it an inertial reaction to the action of a centripetal force, but this upright stand gradually droops into a balance of the two forces to explain weightlessness. On page 99, he states that the expression for the speed of a body at any point in an elliptical orbit is beyond the scope of the book, and then he introduces it on page 105. This is a very useful expression and may be rearranged to show the relation between kinetic, potential, and total energy throughout an orbit. The needed space could have been made available by deleting Figure 5-1 which contains no information, turning Figure 5-2 the necessary 90° counterclockwise, and deleting the confusion on pages 101 and 102 which exists because Kepler's Third Law was not properly explained and the velocity expression was not used.

In general, the figures exhibiting the earth are stylized and show no relation between coordinates and the sketched maps. A few of them are confused and indicate poor rapport between the author and artist; all of them should have been controlled by a science editor.

A review that points out errors may make the book look worse than it is, and this review should serve only as a caveat to the reader. The grade on this work is almost A$^-$, and the book deserves a place on the desk of teachers and nonspecialists who need such a volume.

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