of the cell walls. Here it seems strange to find that the well-known assimilatory cells of the Coniferae with finely invaginated walls are not classified as arm-cells, which are described separately. This, however, is only a minor point of criticism, for the classification of cell types seems otherwise to be generally acceptable. After discussing the assimilatory cells themselves the author goes on to describe their organization into tissues and the distribution of the assimilatory tissues within the plant body, and we are also told about the mode of development of assimilatory cells and the secondary changes that they undergo. Part 3 of the book is concerned with the walls of assimilatory cells and in Part 4 we pass on to the cell protoplasts and their inclusions. In Part 5, which concludes the main body of the text, the structure of assimilatory tissues is considered in relation to its physiological function and to the strains and stresses which are imposed on it by the environment. The book concludes with a bibliography occupying 10 pages, the compilation of which was closed in August 1961, and with separate indexes referring respectively to subjects, to the families and genera of plants and to authors.

The book is one for which a place should be found in all botanical reference libraries and in all laboratories where the investigation of plant structure is being actively pursued. C. R. METCALFE

OXYGENASES

Oxygenases
Edited by Osamu Hayaishi. Pp. xii + 588. (New York: Academic Press, Inc.; London: Academic Press, Inc. (London), Ltd., 1962). 125*s*.

FIFTY years have elapsed since Sir Frederick Gowland Hopkins, in his address to the British Association at Birmingham, described the life of the cell as "the expression of a particular dynamic equilibrium which obtains in a polyphasic system". As the science of biochemistry has developed since 1913, Hopkins's central idea of a dynamic state of chemical compounds in the living cell has been accepted universally. This conception in turn raised a problem: How may these unceasing biochemical transformations be reconciled with the constancy of pattern which we discern both in the chemical events themselves and in the cellular architecture, complex yet persistent in finest detail? The mechanism, as envisaged by Watson and Crick, by which the intricate molecular designs of proteins are replicated has been the inspiration of a great and increasing sector of biochemical research; and indeed we may need to remind ourselves that there still remain to be investigated many of the enzymes by which, as Hopkins also foresaw in his Birmingham address, all these metabolic reactions are catalysed. This excellent book reminds us that much of one important area of enzymology remains unexplored.

As Osamu Hayaishi remarks in a chapter which surveys the history and scope of the subject, the investigation of biological oxidation was begun by Lavoisier about two hundred years ago. Since that time, it became a firmly accepted principle of biochemistry that oxidations proceed by the removal of hydrogen atoms or electrons which may be transferred from primary substrates through carriers to molecular oxygen: in some instances, oxygen might serve as their direct acceptor, but in all cases the oxygen was converted into water or hydrogen peroxide. However, eight years ago investigations by two groups of workers associated with H. S. Mason and O. Hayaishi respectively proved, by the use of $^{18}O_2$ and $H_2{}^{18}O$, that, in the course of certain oxidations, oxygen was incorporated directly into the substrate molecule and did not act simply as an ultimate electron acceptor. These reactions are catalysed by enzymes to which the name 'oxygenase' has been given. A 'true' oxygenase incorporates two atoms of atmospheric oxygen into one molecule of substrate, as in the conversion of catechol into *cis–cis*-muconic acid; whereas a 'mixed function' oxygenase, or hydroxylase, incorporates one atom of the oxygen molecule into the substrate and requires an electron donor despite the fact that the substrate is oxidized: the second atom of oxygen is reduced to water. Mixed function oxidases that hydroxylate the benzene nucleus are reviewed in an authoritative chapter by Seymour Kaufman.

The work described in this book establishes the significance of various oxygenases in general metabolism. Hayaishi quotes a striking experiment in which he grew *Pseudomonas* with various aromatic compounds as sources of carbon and showed that 4–9 per cent of the oxygen of cell constituents was derived from atmospheric oxygen. One is reminded of the situation concerning carbon dioxide fixation in 1935 when, on the basis of very careful chemical analysis, Werkman and Wood showed that this gas could be fixed by heterotrophic bacteria, whereas it was then generally believed that this type of assimilation was confined to plants and autotrophic bacteria. The principle of heterotrophic utilization of carbon dioxide was not accepted by many biochemists at first, but by the use of isotopes of carbon it has since been proved that ability to fix carbon dioxide is possessed by practically all forms of life.

The methodology of oxygen isotopes is fully described in a chapter by D. Samuel; and it is because of findings made with this valuable technique that we must accept the fact that oxygen can be fixed biologically, despite a reluctance that might stem from our knowledge of biological oxidations built up from investigations spanning a quarter of a century. P. Nicholls considers "peroxidase as an oxygenase" which, apparently, it is not; however, this chapter takes us skilfully through the maze of contradictory findings and theories about peroxidases. One who has not worked in this field is left with the impression that this indeed is the pursuit of truth for its own sake: much has been learned about the pitfalls of enzymology, the interpretation of enzyme kinetic data and the devising of elegant techniques; but it is difficult to assess the physiological significance of peroxidases and the investigation of dihydroxyfumarate oxidase appears to be, in the words of Nicholls "the study of a chemical accident". On the other hand, there is no doubt, when one considers the carbon economy of this planet, about the significance of phenolytic oxygenases discussed by A. Mehler.

Plants lock up carbon atoms in cyclic structures and soil bacteria release them by the action of these enzymes: they are therefore essential for the continuance of life. Until four years ago it was thought that bacteria invariably open the benzene nucleus between adjacent carbon atoms bearing hydroxyl groups. It is now known that this does not always occur and that ring-fission may be catalysed by '2:3-oxygenases' which, while attacking dihydric phenols, open the benzene ring between a carbon atom bearing a hydroxyl group and one that does not. Very recent work at Bangor (Prof. W. C. Evans, private communication) has shown that such enzymes attack condensed aromatic ring compounds, which are discussed by J. W. Foster in a chapter on the bacterial oxidation of hydrocarbons; accordingly it is probable that some of the metabolic schemes presented in this chapter will shortly require modification and extension. Other chapters deal with oxygenases in lipid and steroid metabolism, phenolase, model oxygenase systems, cytochrome oxidase, hæmoglobin and myoglobin, and hæmerythrin and hæmocyanin; they are all written by acknowledged experts in the respective fields and the book is edited by Osamu Hayaishi, whose researches on the oxygenases have led to so much fruitful activity.

This book is a notable contribution to enzymology.

S. DAGLEY