teaching of plant physiology has indeed been both "a recreation and a challenge". Conventional means, such as the provision of questions at the end of each chapter, are freely used; but it is important that the questions asked are not such as may be directly answered by turning back to the preceding text. Some thought and arrangement of ideas and facts is always called for, and it is perhaps fortunate that discussions of some of the more debatable problems are provided in an appendix. A less usual and very interesting attempt to help the student is made in a second appendix, in which are discussed some of the commoner pitfalls besetting the beginner in the interpretation of data and biological reasoning.

As their aim is at an intermediate standard, the authors have decided to touch only lightly on topics requiring more than the most elementary mathematical, chemical or physical background. Descriptive growth and transport phenomena, therefore, come in for much fuller treatment than metabolism, and photosynthesis is treated largely, though by no means exclusively, from an ecological point of view. The authors claim to consider that a critical handling of a few topics is a more effective training in scientific method than a discursive treatment of many. This attitude, long-familiar and well-tested in the 'type' system of elementary biology, is a sound basis for teaching; but it is not very clear how the present book exemplifies it. Considering its aims, its treatment must be considered as extensive and occasionally even ambulatory. It is, nevertheless, easy reading and makes a welcome and most interesting addition to the limited number of existing plant-physiology texts.

W. O. James

SLIDING SURFACES

The Friction and Lubrication of Solids

By F. P. Bowden and D. Tabor. (International Series of Monographs on Physics.) Pp. xii+337+32 plates. (Oxford: Clarendon Press; London: Oxford University Press, 1950.) 35*s*. net.

THERE can be no doubt about the importance of the subject to which this book brings such a valuable contribution. But for the surprising ease with which smooth surfaces can be made to slide over each other, even when heavily pressed together, our modern civilization would be impossible.

The use of oils and greases to reduce friction and suppress wear of sliding surfaces is an ancient practice which, with the coming of the machine age, has been developed with remarkable success by the engineer on an empirical basis of the trial-and-error approach to each problem as it arises.

Although Amontons's law, according to which friction is proportional to the loading of the bearing surfaces irrespective of their areas, was the first broad generalization on sliding and was framed so long ago as the end of the seventeenth century, its fundamental significance has only recently been appreciated. On the other hand, when, nearly two hundred years later, Osborne Reynolds propounded his hydrodynamic theory of lubrication, this attracted and held the attention of the engineer and thus dominated for many years the design of the sliding element. Under the severe conditions of modern engineering practice, however, Reynolds's thick oil film cannot always be maintained; it is often reduced to molecular dimensions and may, indeed, be broken through, so that here and there the sliding surfaces come into direct contact. This has so greatly increased the complexity of the problems associated with mechanical wear and lubrication that the empirical approach, even if guided by the hydrodynamic theory, is no longer adequate, and the implications of Amontons's law in their bearing on these changed conditions have become of enormous practical importance. The simulated model experiment or the full-scale engine trial with its many hidden and uncontrollable variables may help, at a price, to deal with the special case, but cannot take the place of the broad generalization resulting from the well-conceived scientific experiment.

The need for a scientific study of lubrication and wear seems to have been recognized more clearly in Great Britain than elsewhere, and F. P. Bowden and D. Tabor's imposing monograph is a record of the fine work done by the Cambridge research group on the physics and chemistry of rubbing solids, which for the past fifteen years has been carrying on the traditions of the earlier work of Beilby and Hardy.

Even the simplest form of sliding element consists of nine components, and most of this book is devoted to a study of four of these, namely, the metal bearing surfaces and their respective adsorbed boundary layers of lubricant. The authors have made a close and stimulating study of intermetallic welding between sliding surfaces and its consequences, and this, no doubt, has influenced them in attributing friction mainly to this source. My own view is that a sliding system in which the intermetallic component of friction makes a major contribution to the resistance to sliding is unsatisfactory. Owing to surface work-hardening during their formation, welds are more prone to shear in the body of the metal than in the plane of sliding, and th s must lead to excessive friction and severe mechanical wear. Thus it seems to me that, apart from the shearing boundary layers, the main source of friction is that due to the rubbing oxide (or sulphide, etc.) layers which are, fortunately, inevitably present on the metallic bearing surfaces. It is only when these are broken down that the bearing may be said to fail in the sense that intermetallic friction ensues. The resistance of the oxide layer to rupture is more a matter of the rigidity of the supporting metal in the regions of localized stress than a property inherent in the layer itself. I imagine that this difference of opinion is mainly one of point of view; it is only recently that the Cambridge school has begun to make use of the penetrating eye of the electron-diffraction camera. I am sure that the authors would agree with me that, but for the thin oxide film of little more than molecular thickness and its self-healing capacities, modern sliding practice would not be possible.

This is not a comprehensive text-book, nor, as we are told in the preface, is it meant to be. It deals almost wholly with the original work of the authors and their collaborators and is therefore a first-hand story of well-planned experiments and their results. This, by itself, lifts it far above the general level of other books on the subject. The engineer and the instrument maker will do well to have this book at hand. The physicist and chemist will enjoy an inspiring and well-illustrated story which tells of experimental adventure and discovery, and points the way to yet other avenues for future exploration.

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