THE ELEMENTARY PRINCIPLES OF GENERAL BIOLOGY

BY

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"BEFORE the great problems [of Biology], the cleft between Zoölogy and Botany fades away, for the same problems are common to the twin sciences. When the zoölogist becomes a student not of the dead but of the living, of the vital processes of the cell rather than of the dry bones of the body, he becomes once more a physiologist and the gulf between these two disciplines disappears. When he becomes a physiologist, he becomes, *ipso facto*, a student of chemistry and physics."

D'ARCY THOMPSON, — "Magnalia Naturæ."

PREFACE

In this book I have endeavored to present in an elementary way some of the fundamental generalizations that are the product of modern research in biology. The artificial division between the study of plants and that of animals is one that is becoming increasingly difficult to maintain, inasmuch as some biological principles are best illustrated by phenomena in the plant world, others by those of the animal world. I have tried, therefore, to utilize both aspects of the subject and to draw my illustrative material impartially from both kingdoms.

The practice that insists upon the student getting his knowledge of natural science at first hand needs nowadays no justification. The laboratory method of study has shown itself to be not only the best means of acquiring a concrete and accurate knowledge of the science studied but also a primary prerequisite for those habits of thought that are essential to what has come to be known as the "scientific method." Nevertheless in Biology the field is so broad and so varied that the student is very likely to lose sight of the fundamental principles that underlie all living nature. Moreover, these principles do not grow out of the laboratory work so obviously nor are they so easily demonstrated by experiment as is the case with such sciences as chemistry and physics. This book is accordingly planned to supply a background for a laboratory course in Biology and to supplement the facts acquired in such a course, the exact nature of which will depend upon the convictions or preliminary training of the individual instructor.

On the other hand, it is believed that the general reader also will find here a simple statement of the fundamentals of General Biology, a subject that is becoming increasingly important in our everyday life.

In covering so much ground I have been compelled to condense many subjects to paragraphs that might well have deserved whole chapters to themselves. The wide-awake teacher, I think, will have no difficulty in amplifying those portions that he esteems most important or in which he is most interested. I am conscious, too, of the fact that many generalizations have been stated in a much less cautious way than would have been the case if condensation had not seemed so essential a feature. But, apart from this, I think that it is preferable, pedagogically, that a student should get a few clean-cut fundamental ideas which perhaps require subsequent qualification than that he should have vague notions in which exceptions to rules figure as largely as the rules themselves. For instance, it is best that he should acquire the fact that the division of chromosomes in mitosis is equal and that in consequence the number of chromosomes in an individual or a species is constant, leaving any consideration of the accessory chromosome, important as it may be, to a time when the former concept shall have taken firm root.

A chapter on Animal Behavior was projected but was abandoned when it was found that its inclusion would have increased the size of the volume unduly. For the same reason no apology need be offered for the constant reference by name without comment to the various groups of animals and plants. The first-hand knowledge of the types in the laboratory will have supplied the descriptive details for which there is no room in the present work, although text-figures have been freely used to illustrate the forms mentioned.

In such a book as the present one, little can be claimed for originality except the manner of presenting the subject. I have sought counsel and criticism in those fields in which my personal knowledge is least dependable, and I hope that such errors as may have crept in will not be significant ones. I am particularly indebted to Professor George T. Moore, Director of the Missouri Botanical Gardens, who read the whole book in manuscript, and to Professor Walter E. Garrey, who read the proof of the first four chapters. Acknowledgments are also due to the following for the use of clichés or permission to copy figures: to Herr Gustav Fischer, Jena, for permission to use figures 7, 13, 34, 55, 60, and 82; to Messrs. Henry Holt and Co., for the use of figures 8, 22, 49, 92, 94, 100, 106, and 112; to Messrs. Ginn and Co., for the use of figures 31 and 103; to the American Book Co., for the use of figures 2, 52, 97, and 109; to Messrs. G. P. Putnam's Sons, for the use of figure 16; to Messrs. D. Appleton and Co., for the use of figures 19, 58, 62, 67, 70, 90, 93, 95, 96, and 113; to Messrs. Longmans, Green, and Co., for the use of figure 23; to Messrs. P. Blakiston's Son and Co., for the use of figure 64; to Professor C. B. Davenport and the Editors of the *Popular Science Monthly*, for the use of figure 71; to Professor Davenport and Messrs. John Wiley and Sons, for the use of figure 73; to the Columbia University Press, for the use of figure 110; to Professor John Schaffner, for permission to copy figure 66; to Professor C. C. Curtis, for the use of figures 51 and 107; to the Editors of the *American Review of Reviews*, for the use of figure 108; and to Sir E. Ray Lankester, for permission to copy figure 112. For photographs from which were made figures 85, 98, and 99 I am indebted to the kindness of Professor S. M. Coulter. All the other illustrations, with the exception of figures 6, 10, 24, 25, 37, 40, 42–44, 50, 54, 56, 57, 63, 74, 77, 88, 89, and 114, are from publications of The Macmillan Co.

J. F. A.

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GENERAL BIOLOGY

CHAPTER I

LIVING SUBSTANCE

Biology, the "science of life," includes in its broadest aspects the investigation of all that pertains to the structure and functions of living things. The observing and recording of the wonderful variety of Nature will always have a fascination not only for the poet, but for the scientist as well. But the latter is more especially concerned with the meaning, the analysis, or the explanation of natural phenomena. Philosophy tells us that science can never hope to get the ultimate explanation of anything which it observes. All that it can do is to reduce the complexities to simpler expression, to find the common denominator for things that seem at first glance unrelated, in the same way that the mathematician by processes of factoring reduces elaborate and complex algebraic expressions to simple statements of relation. And, just as in mathematics, the greater the number of variables we have to deal with, the more involved and difficult becomes our computation, so in physical and biological science the greater the number of unknown factors there may be, the greater becomes our difficulty in reducing them to fundamental principles. This is why biology is so strikingly an "inexact" science in comparison with physics or inorganic chemistry. Yet, it is not necessary even for the physicist or the chemist to know what is the ultimate nature of matter or force or electricity or atoms in order to study such things and formulate general laws based on such observation; nor is it necessary for the biologist to concern himself with the meaning or nature of life in order to find out what principles govern in the world of living things.

The study and comparison of the structures of plants and animals, of their methods of growth and reproduction, their relation to each other and the world about them, has revealed the fact that there is an underlying unity in nature that makes it possible for us to sum up our observations in general principles, incompletely understood, of course, but more or less applicable to all living things. The consideration of these general principles forms the basis for a General Biology in the sense in which it will be taken in the present work.

Although we shall not attempt to elucidate life in any philosophical sense, it is of interest, notwithstanding, to discover at the start just how much science can tell us of the nature of life, or of living things as a whole.

Living and Non-living. — If a biologist should ask the average layman whether he could tell the difference between something alive and something that is not, he would hardly be taken seriously. Yet, if such a layman should be pressed to define just what he meant by "being alive," he might be hard put. It might be assumed that some characteristic chemical compounds are to be found in living matter which are absent in non-living matter. But thousands of exact chemical analyses have been made of every sort of living thing and no element or compound has ever been found which is essentially different from what may exist in the non-living world. Long ago a distinction used to be made between "organic" and "inorganic" substances, — the former being the product of living "organisms." But such a distinction has broken down. It is possible to synthesize substances in the test tube, identical in chemical composition with those formed in Nature's laboratory, — the tissue of plant and animal. Indeed, the ability to artificially reproduce natural products in this way has proved of great value commercially, and artificially synthesized indigo, camphor, etc., now supplement in large measure Nature's meager store of such things.

Nor is it easier to discover any unique physical phenomena in living things. So far as we can observe, — and the more our observations are extended, the more is the conclusion confirmed, — living matter obeys the same physical laws that obtain in the rest of the universe. Again, living things grow: but so do crystals and clouds. They reproduce themselves, but, as we shall see later, this is but a discontinuous form of growth, and may be paralleled, perhaps, in other "inorganic" bodies.

Life and Death. — If we find it so difficult to point to any one thing as the touchstone of living matter contrasted with non-living matter, what shall we say of the difference between that which is alive and that which has been, but is no longer, — in other words between living matter and dead matter? A turtle may justly be called a dead turtle if we cut off its head, yet, if we cut out the heart of such a decapitated turtle and suspend it on hooks in a moist chamber, wet with a weak solution of common salt, such a heart will go on beating rhythmically for days. So long as it beats we are forced to consider the substance composing it as living matter.

We must make a distinction, then, between *general life and death*, which affects the whole organism and *elemental life and death*, which affects only the elements or tissues. This distinction is much more apparent in animals than in plants on account of the greater degree of specialization in the former. Ordinarily, decay and disintegration in the tissues promptly follow general death, but experimentally we may avoid this contingency if we exclude bacterial invasion,[1] and such a piece of tissue may be kept passively "alive" for a considerable interval of time, regaining its functions when replaced in a living organism. In this way sections

[1] See Chapter IV.