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GREAT EXPERIMENTS IN BIOLOGY

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GREAT

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IN BIO

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PREFACE

The emergence of scientific inquiry as a pervasive social force in our time has rekindled serious interest in the broader and more humanistic values of science. Awareness is growing that science and scientific thinking are no longer the exclusive domain of the professional scientist. Matters which a generation ago were laboratory problems for the specialist have become pressing questions of social and political policy. Responsible decisions by the citizen increasingly depend upon an understanding of what science is, how science grows and develops, and how science serves and affects society.

If science education is to convey this sense of the relevance of science to man's problems as a social being, it must not confine itself to the *results* of scientific inquiry, but must devote itself as well to the methodology and philosophic outlook that have led to these results. Successful training in science involves the development of a state of mind and a feeling of discovery, of participation in science, far more than the mere acquisition of factual knowledge.

This book is the outgrowth of a conviction that an important means of inculcating this awareness of science as a process lies in the presentation of scientific writings in the original. Many are the rewards of these firsthand contacts with the classic treasures of scientific writing. There is genuine excitement in seeing fundamental discoveries through the eyes of their discoverers; there is humanizing enrichment in becoming acquainted with the personalities of the scientific great—with meeting, say, the apologetic diffidence of Hardy in calling attention to the principle of equilibrium in populations, the naive zest of a Leeuwenhoek, or the lusty polemics and compelling lucidity of a Pasteur. Many insights into the nature of scientific discovery emerge: the "latent period" between fundamental discoveries and their application, the "happy accident," of which the penicillin story is perhaps the most often cited (and misunderstood) example, the manifold character of scientific methods, the often astonishing independence between the scientific value of an accurately reported experiment and its valid interpretation by the investigator himself. Our great unifying generalizations are revealed as organic historical accumulations in which progress in one area frequently depends on the convergence of ideas from isolated, unrelated fields.

The wealth of material available has inevitably imposed a measure of arbitrariness in selection. We have chosen less than a dozen areas in general biology in which significant progress has been made towards an understanding of the mechanisms underlying living activities. For each of these fields, we have selected a sufficient number of classic papers to show the milestones in the advance of knowledge starting from raw observations and the first experimental gropings to quantitative physicochemical studies of the present day.

Inasmuch as our objective has been to convey something of what science is and the way in which science grows, we have tried to present connected sequences in a chain of discovery within a field, in preference to offering representative selections ranging over that entire subject. No attempt has been made to assess priorities; our choice has often been governed by simplicity of presentation, style, or other non-historical criteria.

Citations within the chronologies should be viewed as illustrative rather than definitive. If at times there does not seem to be a smooth, logical flow in the development of a concept, the chronology has served as a reminder that science does not advance by any master plan, but has always been, as Santayana remarked, ". . . a patient siege laid to the truth, which was approached blindly and without a general, as by an army of ants. . . ."

We are grateful to the members of the library staffs of Brooklyn College, the Brooklyn Botanic Garden, and the Marine Biological Laboratory, Woods Hole, Mass., for cooperation in the use of their facilities and assistance in obtaining materials.

It is a pleasure to record our gratitude to Prof. Naphtali Lewis, Prof. Ethyle R. Wolfe, and Dr. Olga Janowitz for their assistance in the preparation of several translations.

We desire to acknowledge our indebtedness to the many authors and publishers who have kindly granted permission to reprint their publications. Each source will be found as a note preceding the article.

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CHRONOLOGY

590 B.C. Some properties of curved reflecting surfaces were investigated and recorded by Euclid.

65 A.D. Seneca reported that glass globules filled with water "will aid in seeing those difficult things that frequently escape the eye."

127–151 Ptolemy investigated the problem of magnification by means of curved surfaces.

1235 The invention of spectacles was announced by Roger Bacon in England.

1485 Da Vinci stressed the importance of using lenses for the study of small objects.

1590 Jans and Zacharias Janssen combined two convex lenses within a tube, thus constructing the forerunner of the compound microscope.

1656 Borel investigated the microscopic structure of red blood cells and accurately noted the regularity of stomatal movements.

1661 Malpighi conducted extensive investigations on the anatomy and embryology of plants and animals. He discovered the existence of capillaries—structures predicted to exist by Harvey some thirty years earlier.

1665 Hooke published the *Micrographia,* a collection of diverse essays dealing with the microscopic structure of familiar substances, among which the cellular structure of cork is fully described and illustrated.

1672 Grew published an extensively illustrated volume summarizing his detailed studies of plant anatomy.

1674 Leeuwenhoek further improved the art of polishing lenses of short focal length. He discovered and described protozoa, bacteria, rotifers, and the like.

1759 Wolff applied the microscope to the study of animal embryology and remarked that "the particles which constitute all animal organs in their earliest inception are little globules, which may be distinguished under a microscope."

1770 Hill introduced new techniques for macerating, preserving and staining woody materials. He employed alum, alcohol and carmine in preparing specimens for microscopic study.

1780 Adams and others devised slicing machines (microtomes) capable of cutting sections some $\frac{1}{2000}$ of an inch thick.

1802 Mirbel concluded from his numerous observations of plant structure that "the plant is wholly formed of a continuous cellular membranous tissue. Plants are made up of cells, all parts of which are in continuity and form one and the same membranous tissue."

1809 Lamarck investigated the microscopic structure of plants and animals. He remarked, "It has been recognized for a long time that the membranes which form the envelopes of the brain, of the nerves, of vessels, of all kinds of glands, of viscera, of muscles and their fibers, and even the skin of the body are in general the productions of cellular tissue. But no one, so far as I know, has yet perceived that cellular tissue is the general matrix of all organization and that without this tissue no living body would be able to exist, nor could it have been formed."

1824 Dutrochet further advanced the cell principle. He stated, "All organic tissues are actually globular cells of exceeding smallness, which appear to be united only by simple adhesive forces; thus all tissues, all animal (and plant) organs, are actually only a cellular tissue variously modified. This uniformity of finer structure proves that organs actually differ among themselves merely in the nature of the substances contained in the vesicular cells of which they are composed."

1830 Meyen reported his observations on algae, fungi and higher plants and concluded that ". . . each cell forms an independent, isolated whole; it nourishes itself, builds itself up, and elaborates raw nutrient materials, which it takes up, into very different substances and structures."

1831 Brown published his observations reporting the discovery and widespread occurrence of nuclei in cells.

1832 Dumortier observed the process of cell division in algae. The phenomenon had actually been reported some six years earlier by Turpin.

1835–1839 Von Mohl carefully described some details of mitosis. He recorded the appearance of the cell plate between daughter cells. He remarked, "Cell division is everywhere easily and plainly seen . . . in terminal buds and root tips."

1838 Schleiden published his *Beiträge zur Phytogenese,* an important contribution to understanding the genesis of plant tissues. He observed nucleoli but misinterpreted their significance in considering them as nuclei forming within nuclei. Schwann applied the same erroneous theory of cell formation to animal tissues but correctly emphasized that "cells are organisms and entire animals and plants are aggregates of these organisms arranged according to definite laws."

1845 Von Siebold recognized protozoa as single celled animals.

1845 Kölliker demonstrated that spermatozoa are cellular products of the organism. He also extended this finding to the ovum, from which the organism is derived by cell division.

1858 Virchow applied the cell theory to problems of pathology and disease and set forth the illuminating principle that the outward symptoms of disease are merely reflections of impairment at the level of cellular organization.

1861 Schultze established the protoplasm concept and, after noting the essential similarity between the cell contents of protozoa, plants and animals, concluded that "the cell is an accumulation of living substance or protoplasm definitely delimited in space and possessing a cell membrane and nucleus."

1880–1890 Flemming, Strasburger, Van Beneden, and others elucidated the essential facts of cell division and stressed the importance of the qualitative and quantitative equality of chromosome distribution to daughter cells.

1907 Wilson convincingly demonstrated the high level of cell individuality in phenomena of coalescence and regeneration in sponges.

1907 Harrison developed new techniques for culturing and studying isolated cells or tissue fragments apart from the intact whole organism.

The extensions flowing from the cell theory embrace the whole of modern biology. Because of their widely diverse and ramifying implications, however, they cannot be included in this section. The unifying character of the cell concept is repeatedly evidenced elsewhere in this book by the impetus and direction it has provided for the analysis of fundamental biological problems such as reproduction, sexuality, development, heredity, evolution, metabolism, coordination, growth, and a host of equally basic phenomena numerous beyond mention.

Of the Schematisme or Texture of Cork, and of the Cells and Pores of Some other such Frothy Bodies.

by ROBERT HOOKE

From *Micrographia*, London: 1665

The term cell *is but one of the legacies left by the ingenious Robert Hooke. Among other accomplishments, Hooke investigated the problem of celestial mechanics, invented the vacuum pump used by Robert Boyle, and devised the forerunner of the balance spring of the*

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