PROTOZOOLOGY

KUDO

FOURTH EDITION

PROTOZOOLOGY

By

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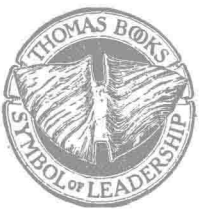
With three hundred and seventy-six illustrations

Fourth Edition



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"The revelations of the Microscope are perhaps not excelled in importance by those of the telescope. While exciting our curiosity, our wonder and admiration, they have proved of infinite service in advancing our knowledge of things around us."

LEIDY

Preface

THE fourth edition of *Protozoology* maintains its original aim in setting forth "introductory information on the common and representative genera of all groups of both free-living and parasitic Protozoa" for seniors and graduates in zoology in colleges and universities. It has been noted in recent years that students frequently wished to obtain a fuller knowledge on certain topics, organisms, processes, etc., than that which was found in the former edition. In order to meet this need without too great an expansion, references have been given to various items in the text and a list of a much larger number of literature has been appended to each chapter. Furthermore, this enlargement of references increases the usefulness of this work to advanced students, teachers of biology, field workers in various areas of biological science, veterinarians, physicians, public health workers, laboratory diagnosticians and technicians, etc.

While the chapter arrangement remains the same as before, a thorough revision has been carried on throughout the text in the light of many recently published contributions to protozoology. Good illustrations are indispensable in this kind of work, since they are far more easily comprehended than lengthy statements. Therefore, old illustrations were replaced by more suitable ones and many new illustrations have been added, bringing up the total number of the text figures now to 376. Except diagrams, all figures are accompanied by the scales of magnification. For illustrations that have been adopted from published papers, the indebtedness of the author is expressed by mentioning the authors' names.

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PART I: GENERAL BIOLOGY

CHAPTER 1

Introduction

PROTOZOA are unicellular animals. The body of a protozoan is morphologically a single cell and manifests all characteristics common to the living thing. The various activities which make up the phenomena of life are carried on by parts within the body or cell. These parts are comparable with the organs of a metazoan which are composed of a large number of cells grouped into tissues and are called **organellae** or cell-organs. Thus the one-celled protozoan is a complete organism somewhat unlike the cell of a metazoan, each of which is dependent upon other cells and cannot live independently. From this viewpoint, certain students of protozoology maintain that the Protozoa are non-cellular, and not unicellular, organisms. Dobell (1911), for example, pointed out that the term "cell" is employed to designate (1) the whole protozoan body, (2) a part of a metazoan organism, and (3) a potential whole organism (a fertilized egg) which consequently resulted in a confused state of knowledge regarding living things, and, therefore, proposed to define a cell as a mass of protoplasm composing part of an organism, and further considered that the protozoan is a non-cellular but complete organism, differently organized as compared with cellular organisms, the Metazoa and Metaphyta. Although some writers (Hyman, 1940; Lwoff, 1951) follow this view, the great majority of protozoologists continue to consider the Protozoa as unicellular animals. Through the processes of organic evolution, they have undergone cytological differentiation and the Metazoa histological differentiation.

In being unicellular, the Protozoa and the Protophyta are alike. The majority of Protozoa may be distinguished from the majority of Protophyta on the basis of dimensions, methods of nutrition, direction of division-plane, etc. While many Protophyta possess nuclear material, it is not easy to detect it in many forms; on the other hand, all Protozoa contain at least one easily observable nucleus. The binary fission of Protozoa and Protophyta is longitudinal and transverse respectively. Most of Ciliata, however, multiply by transverse division. In general the nutrition of Protozoa is holozoic and of Protophyta, holophytic or saprophytic; but there are large numbers of Protozoa which nourish themselves by the latter methods. Thus an absolute and clean-cut separation of the two groups of unicellular organisms is not possible. Haeckel (1866) coined the name **Protista** to include these organisms in a single group, but this is not generally

adopted, since it includes undoubted animals and plants, thus creating an equal amount of confusion between it and the animal or the plant. Calkins (1933) excluded chromatophore-bearing Mastigophora from his treatment of Protozoa, thus placing organisms similar in every way, except the presence or absence of chromatophores, in two different (animal and plant) groups. This intermingling of characteristics between the two groups of microorganisms shows clearly their close interrelationship and suggests strongly their common ancestry.

Although the majority of Protozoa are solitary and the body is composed of a single cell, there are several forms in which the organism is made up of more than one cell. These forms, which are called colonial Protozoa (p. 173), are well represented by the members of Phytomastigina, in which the individuals are either joined by cytoplasmic threads or embedded in a common matrix. These cells are alike both in structure and in function, although in a few forms there may be a differentiation of the individuals into reproductive and vegetative cells. Unlike the cells in a metazoan which form tissues, these vegetative cells of colonial Protozoa are not so dependent upon other cells as are the cells in Metazoa; therefore, they do not form any true tissue. The reproductive cells produce zygotes through sexual fusion, which subsequently undergo repeated division and may produce a stage comparable with the blastula stage of a metazoan, but never reaching the gastrula stage. Thus, colonial Protozoa are only cell-aggregates without histological differentiation and may thus be distinguished from the Metazoa.

An enormous number of species of Protozoa are known to man. From comparatively simple forms such as Amoeba, up to highly complicated organisms as represented by numerous ciliates, the Protozoa vary exceedingly in their body organization, morphological characteristics, behavior, habitat, etc., which necessitates a taxonomic arrangement for proper consideration as set forth in detail in Chapters 8 to 44.

Relationship of protozoology to other fields of biological science

A brief consideration of the relationship of Protozoology to other fields of biology and its possible applications may not be out of place here. Since the Protozoa are single-celled animals manifesting the characteristics common to all living things, they have been studied by numerous investigators with a view to discovering the nature and mechanism of various phenomena, the

sum-total of which is known collectively as life. Though the investigators generally have been disappointed in the results, inasmuch as the assumed simplicity of unicellular organisms has proved to be offset by the complexity of their cell-structure, nevertheless discussion of any biological principles today must take into account the information obtained from studies of Protozoa. It is now commonly recognized that adequate information on various types of Protozoa is a prerequisite to a thorough comprehension of biology and to proper application of biological principles.

Practically all students agree in assuming that the higher types of animals have been derived from organisms which existed in the remote past and which probably were somewhat similar to the primitive Protozoa of the present day. Since there is no sharp distinction between the Protozoa and the Protophyta or between the Protozoa and the Metazoa, and since there are intermediate forms between the major classes of the Protozoa themselves, progress in protozoology contributes toward the advancement of our knowledge on the probable steps by which living things in general evolved.

Geneticists have undertaken studies on heredity and variation among Protozoa. "Unicellular animals," wrote Jennings (1909), "present all the problems of heredity and variation in miniature. The struggle for existence in a fauna of untold thousands showing as much variety of form and function as any higher group, works itself out, with ultimate survival of the fittest, in a few days under our eyes, in a finger bowl. For studying heredity and variation we get a generation a day, and we may keep unlimited numbers of pedigreed stock in a watch glass that can be placed under the microscope." Morphological and physiological variations are encountered commonly in all forms. Whether variation is due to germinal or environmental conditions, is often difficult to determine. Studies on conjugation in Paramecium by utilizing the mating types first noted by Sonneborn (1937, 1938) not only brought to light a wealth of important information regarding the genetics of Protozoa, but also are revealing a close insight concerning the relationship between the nuclear and cytoplasmic factors of heredity in the animal.

Parasitic Protozoa are confined to one or more specific hosts. Through studies of the forms belonging to one and the same genus or species, the phylogenetic relation among the host animals may be established or verified. The mosquitoes belonging to the genera Culex and Anopheles, for instance, are known to transmit avian and human Plasmodium respectively. They are further infected by specific microsporidian parasites. For instance, *Thelohania legeri*

has been found widely only in many species of anopheline mosquitoes; *T. opacita* has, on the other hand, been found exclusively in culicine mosquitoes, although the larvae of the species belonging to these two genera live frequently in the same body of water (Kudo, 1924, 1925). By observing certain intestinal Protozoa in some monkeys, Hegner (1928) obtained evidence on the probable phylogenetic relationship between them and other higher mammals. The relation of various Protozoa of the wood-roach to those of the termite, as revealed by Cleveland and his associates (1934), gives further proof that the Blattidae and the Isoptera are closely related.

Study of a particular group of parasitic Protozoa and their hosts may throw light on the geographic condition of the earth which existed in the remote past. The members of the genus Zelleriella are usually found in the colon of the frogs belonging to the family Leptodactylidae. Through an extensive study of these amphibians from South America and Australia, Metcalf (1920, 1929) found that the species of Zelleriella occurring in the frogs of the two continents are almost identical. He finds it more difficult to conceive of convergent or parallel evolution of both the hosts and the parasites, than to assume that there once existed between Patagonia and Australia a land connection over which frogs, containing Zelleriella, migrated.

Experimental studies of large Protozoa have thrown light on the relation between the nucleus and the cytoplasm, and have furnished a basis for an understanding of regeneration in animals. In Protozoa we find various types of nuclear divisions ranging from a simple amitotic division to a complex process comparable in every detail with the typical metazoan mitosis. A part of our knowledge in cytology is based upon studies of Protozoa.

Through the efforts of various investigators in the past fifty years, it has now become known that some 25 species of Protozoa occur in man. *Entamoeba histolytica*, *Balantidium coli*, and four species of Plasmodium, all of which are pathogenic to man, are widely distributed throughout the world. In certain restricted areas are found other pathogenic forms, such as Trypanosoma and Leishmania. Since all parasitic Protozoa presumably have originated in free-living forms and since our knowledge of the morphology, physiology, and reproduction of the parasitic forms has largely been obtained in conjunction with the studies of the free-living organisms, a general knowledge of the entire phylum is necessary to understand these parasitic forms.

Recent studies have further revealed that almost all domestic animals are hosts to numerous parasitic Protozoa, many of which

are responsible for serious infectious diseases. Some of the forms found in domestic animals are morphologically indistinguishable from those occurring in man. *Balantidium coli* is considered as a parasite of swine, and man is its secondary host. Knowledge of protozoan parasites is useful to medical practitioners, just as it is essential to veterinarians inasmuch as certain diseases of animals, such as southern cattle fever, dourine, nagana, blackhead, coccidiosis, etc., are caused by Protozoa.

Sanitary betterment and improvement are fundamental requirements in the modern civilized world. One of man's necessities is safe drinking water. The majority of Protozoa live freely in various bodies of water and some of them are responsible, if present in sufficiently large numbers, for giving certain odors to the waters of reservoirs or ponds (p. 114). But these Protozoa which are occasionally harmful are relatively small in number compared with those which are beneficial to man. It is generally understood that bacteria live on various waste materials present in the polluted water, but that upon reaching a certain population, they would cease to multiply and would allow the excess organic substances to undergo decomposition. Numerous holozoic Protozoa, however, feed on the bacteria and prevent them from reaching the saturation population. Protozoa thus seem to help indirectly in the purification of the water. Protozoology therefore must be considered as part of modern sanitary science.

Young fish feed extensively on small aquatic organisms, such as larvae of insects, small crustaceans, annelids, etc., all of which depend largely upon Protozoa and Protophyta as sources of food supply. Thus the fish are indirectly dependent upon Protozoa as food material. On the other hand, there are numbers of Protozoa which live at the expense of fish. The Myxosporidia are almost exclusively parasites of fish and sometimes cause death to large numbers of commercially important fishes (Kudo, 1920) (p. 648). Success in fish-culture, therefore, requires among other things a thorough knowledge of Protozoa.

Since Russel and Hutchinson (1909) suggested some forty years ago that Protozoa are probably a cause of limitation of the numbers, and therefore the activities of bacteria in the soil and thus tend to decrease the amount of nitrogen which is given to the soil by the nitrifying bacteria, several investigators have brought out the fact that in the soils of temperate climate various sarcodinans, flagellates and less frequently ciliates, are present and active throughout the year. The exact relation between specific Protozoa and bacteria in