PRACTICAL INVERTEBRATE ANATOMY

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PREFACE TO THE SECOND EDITION

IN 1954 de Beer * wrote: " Few . . . zoologists could have thought it possible that, in the middle of the twentieth century, all text-books of zoology should require the drastic revision of the current theory of the origin and evolution of the Metazoa. Yet that and nothing less is the situation resulting from the researches which for half a century Jovan Hadzi has made into the structure and development of the lower animals. They have led him to put forward a theory that multinuclear Protozoa evolved into Turbellaria Acoela, which latter (not the Coelenterata) would be the most primitive Metazoa." Close examination of Hadzi's theory, which de Beer explained for the first time in English, indicates that it offers what is probably the most satisfactory explanation of the facts as they are now known, and consequently this second revised edition has been prepared. Recently Hadzi has written an extended explanation of his theory in English.†

In this second edition the platyhelminths are examined before the coelenterates, the turbellarians are considered in greater detail, and in particular a description is given of the acoelan genus *Convoluta*. Within the coelenterates, the actinozoans are treated first as the most primitive class, and the terms " diploblastic " and " triploblastic " have been abandoned.

The opportunity has also been taken to include two new chapters and to introduce much extra information which, during the years, has been offered by many helpful critics. In particular I am indebted to Dr. I. Griffiths for his generous help with the descriptions of the Turbellaria and the Nemertea.

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December 1957

* de Beer, G. R. (1954), "The Evolution of the Metazoa", Chapter 2 of *Evolution as a Process*, edited by J. Huxley. London.

† Hadzi, J. (1963), *The Evolution of the Metazoa*. London.

PREFACE TO THE FIRST EDITION

THE main intention of this book is to provide brief and practical descriptions of the anatomy of those invertebrate animals which are commonly used as types in the study of zoology. Previously, such descriptions, if they existed at all, were widely scattered and not always easy either of discovery or of access. Furthermore, they were not always made from a practical point of view, or accompanied by figures which had any great practical value. To meet this situation, descriptions have been made of 122 commonly studied genera. These genera are primarily selected for their availability in the British Isles and in North America, but in most cases they, or closely related forms, also occur all over the world. In making the descriptions it was soon found that limits had to be imposed in order to keep the book to a reasonable size. Thus, it was decided to include only those features which can be demonstrated in whole specimens of adult animals, and, in particular, to exclude any consideration of prepared sections and of young or larval forms. In a few instances it has been found necessary to make exceptions, but in general this rule has been closely observed.

It is felt to be highly important that each genus studied should, as far as possible, be appreciated in its natural systematic, ecological, and functional setting. For this reason, the details of classification have been briefly inserted into the text, the description of each animal has been prefaced by a short account of its distribution and mode of life, and notes on the function and special significance of unusual organs or structures have been briefly interpolated. By these various means it is hoped that the anatomical details may assume a maximum significance and interest. In case further information should be required, references to more detailed descriptions are given wherever it has been possible to trace them, and at the ends of most of the chapters appendices are included which describe the methods of culture, where these are practical, of killing, fixing, and preserving, and of any special techniques which have proved valuable. The general appendix at the end of the book includes details of the composition of the fixatives, stains, and other solutions which are mentioned in the text.

The book is centred round, and originated with, its figures which have all been newly drawn from preparations or dissections. They were first made for the use of classes in McGill University, Montreal, when it became apparent how inadequate for practical purposes were most of the current textbook

illustrations. The figures are all semi-diagrammatic, and it should be unnecessary to state that they are in no way intended as substitutes for the student's personal drawings of his own specimens. They are designed to save time and bewilderment, and not to replace personal investigation and effort.

Many debts of gratitude have been incurred during the writing of this manuscript, and the first of these, since they concerned the beginning of the book, are to Professor N. J. Berrill and the students in the Zoology Department at McGill University. Professor Berrill did all in his power to provide the necessary facilities for the work, most of which was completed in his department, and he also readily gave his special knowledge and critical attention to the chapters on the coelenterates and the chordates. The students, of whom Mr. P. A. Orkin may be specially mentioned, formed an eager and critical group with whose help the figures, descriptions, and techniques could be tested. Also at McGill University, constant encouragement and advice were received from Professor V. C. Wynne-Edwards, who made particular comments on the chapter dealing with the echinoderms, and from Professor T. W. M Cameron, who provided much material for, and was repeatedly consulted about, the descriptions of parasitic protozoans, platyhelminthes, nematodes, acanthocephalans, and arachnids. Later, in the University of Sheffield, facilities for finishing the work were afforded by Professor L. E. S. Eastham. Also in England, much information has been gratefully received from Mr. T. Kerr on the platyhelminthes, Dr. T. B. Reynoldson on the annelids, Dr. F. Segrove on the myriapods, and Professor L. E. S. Eastham and Dr. H. Henson on the insects. Other help, which it is a pleasant duty to recall, came from Mrs. L. Terrill, who, as librarian in the Blacker Library of Zoology in McGill University, gave tireless assistance in the often difficult and tedious task of tracing important references; and from Mr. J. Hancock, who, as laboratory steward in the Sheffield Department of Zoology, has given unreservedly from his extensive knowledge of practical techniques. Finally, a special mention must be made of my wife who, in a hundred ways, has helped in the production of this book from its beginning to its end.

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University of Sheffield
December 1947

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CHAPTER I

PHYLUM **PROTOZOA**

Characteristics: Non-cellular organisms of small size which are usually motile in their main phase.

These animals possess such a uniquely simple structure that the phylum also ranks as a sub-kingdom, the other two animal sub-kingdoms being the Parazoa (sponges) and the Metazoa. They live freely in salt water, in fresh water, or in damp places on land, and many of them are parasitic. They are the simplest organisms recognised as being animals, and they are almost inseparable from the simplest plants. Many of the Mastigophora must in fact be regarded as simple plants, since they live holophytically and sometimes possess a cellulose cell wall. Such creatures may be regarded as the modern representatives of that common stock which gave rise to both the plants and the animals.

1.00. Class **Mastigophora (Flagellata)**

Characteristics: Protozoa which move by means of one or more long flagella; with a firm ectoplasmic pellicle, and therefore usually a definite body form (however, a few species may develop pseudopodia); no cilia; no macronucleus; often parasitic, but rarely intracellular.

In practice, the mastigophorans are often difficult to distinguish from the algae, on the one hand, and the rhizopods, on the other.

1.10. Subclass **Phytomastigina**

Characteristics: Mastigophora usually possessing chromoplasts and feeding holophytically (however, some, obviously closely related, have lost the chromoplasts and feed saprophytically or even holozoically); often with rigid cellulose capsules.

This subclass contains the primitive mastigophorans which cannot be separated from the algae.

1.11. Order **Euglenoidida**

Characteristics: Phytomastigina with a firm but flexible pellicle which limits movement to the type known as euglenoid; with a gullet swelling into

a reservoir into which opens a contractile vacuole; with one or more flagella emerging from the gullet; usually with numerous chloroplasts, but sometimes colourless; and with paramylum (starch) granules.

Genus Euglena

1. GENERAL ACCOUNT

a. The various species of this genus swarm in stagnant pools and ditches, especially those contaminated with dung, and they are often so abundant as to give the water a green, soup-like appearance. Feeding is mainly holo-

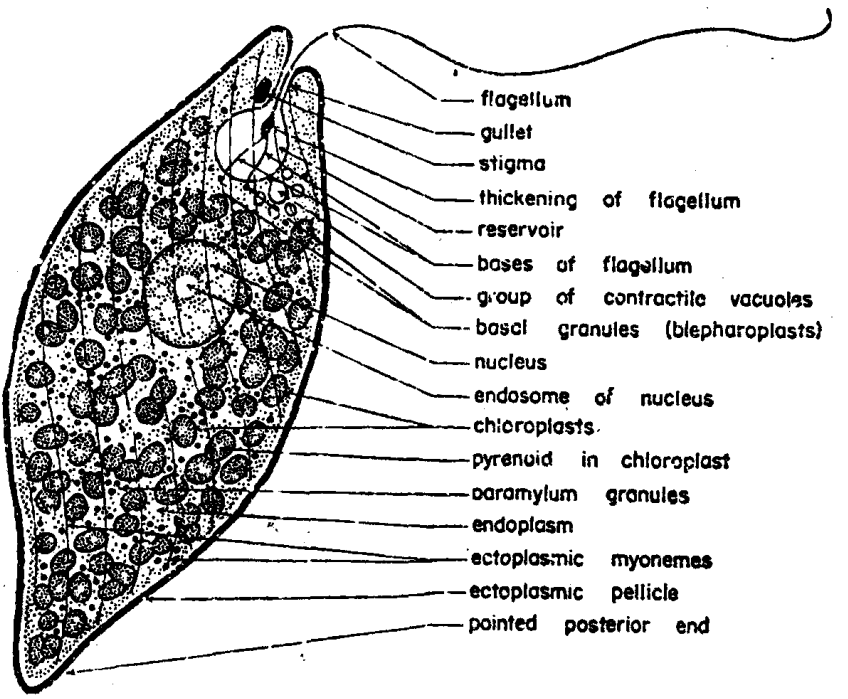

FIG. 1.—*Euglena*. A combination of the features visible in living and in stained preparations.

phytic, in the manner of a plant. However, they thrive better if amino-acids are present in the water, and, in the absence of light, some species are able to live entirely as saprophytes. They probably never feed holozoically. Reproduction is by longitudinal binary fission, and in adverse conditions, such as drought, the flagellum is withdrawn, the body becomes spherical, and a resistant cyst is secreted. The animals may be cultured by the method given on p. 34.

2. ANATOMY

a. Examine some living specimens through a low-power microscope. Notice that they are coloured green, that they twist spirally when swimming,

and that their posterior ends are pointed. Watch the euglenoid **movements** of the body, during which waves of contraction and expansion pass along the length of the animal without, however, entirely destroying its fusiform shape.

b. Arrest the animals by the agar method (described on p. 35), and study the detailed structure of the body through a high-power microscope. At the blunt **anterior end** watch closely for the single, rapidly undulating flagellum (the undulations are considered to start at the base and to travel forward). The flagellum enters the narrow gullet, which at its base enlarges into the reservoir. By the base of the gullet is a group of red pigment granules forming the stigma (this is probably light sensitive), while posterior and lateral to the reservoir is a contractile vacuole (which discharges into the reservoir, a new one being formed immediately from a ring of smaller vacuoles). The anterior end of the body contains little, if any, green colouring matter.

c. In the **central and posterior regions** of the body notice the firm pellicle (toughened outer layer of ectoplasm), beneath which, in some species, extremely fine spirally arranged myonemes (contractile fibres) can be seen; the numerous oval or elongated chloroplasts (containing chlorophyll), and within each a small refringent body, the pyrenoid (this, a protein granule, is the centre of starch formation); the refringent paramylum granules scattered throughout the granular endoplasm (according to the species these starch-like deposits are small or large discs or rods); and the nucleus with its central endosome.

d. In a permanent **stained preparation** (see method on p 36) notice again the pyrenoid in the centre of each chloroplast, and the structure of the nucleus and the endosome. In good preparations, and with the use of an oil-immersion objective, the details of the base of the flagellum may be visible. On entering the reservoir the flagellum splits into two, and at the point of splitting it is swollen. Its two basal fibres pass into the endoplasm at the posterior end of the reservoir, each joining into a tiny basal granule, or blepharoplast (these granules are regarded as nuclear extensions which are concerned with the control of flagellum movement).

e. In a rich culture, or in a permanent preparation containing large numbers of individuals, look for stages of longitudinal **binary fission** (fission is first apparent at the anterior end).

3. CONCLUSION

a. Observing the specimens, review the characteristics of the phylum, of the class, of the subclass, and of the order.

b. Notice those features which may be considered animal-like and those which may be considered plant-like.

4. REFERENCE

MAINX, F. (1928). "Beiträge zur Morphologie und Physiologie der Eugleninen." *Archiv für Protistenkunde*, Vol. 60, p. 305.

1.12. Order **Dinoflagellida**

Characteristics: Phytomastigina with two flagella lying in grooves, one directed posteriorly and the other encircling the body; either naked or encased in a shell, the theca, which is usually composed of cellulose; with green, yellow, or brown chromoplasts.

The members of this order are mostly free living, pelagic, and marine, and many are phosphorescent. However, some live in brackish water, some in fresh water, and some are parasitic (particularly in the alimentary canals of copepods).

Genus **Ceratium**

1. GENERAL ACCOUNT

a. The species of *Ceratium* all live in salt water, and nearly all are pelagic in the open seas, where their long spines offer resistance to sinking. Since their

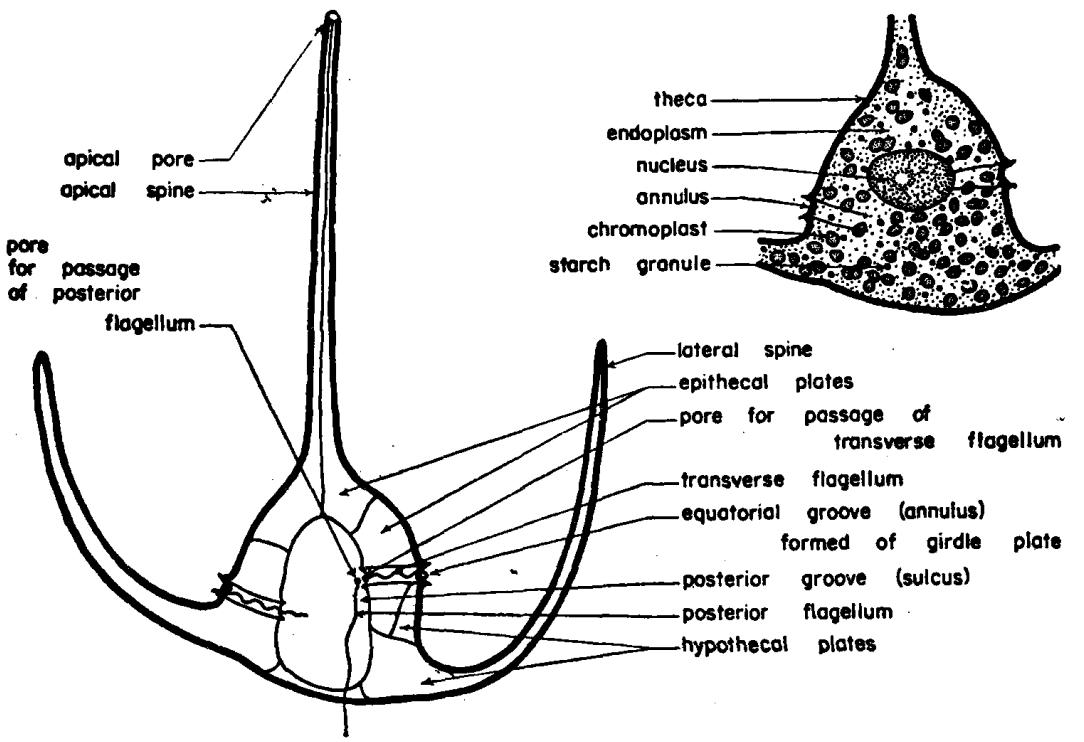

FIG. 2.—*Ceratium*. The external appearance and, on the right, a specimen seen in optical section.

two flagella are set at right angles to each other, they travel through the water with a jerky spiral movement. They live holophytically, like plants, by means of their chromoplasts, which contain chlorophyll, and because of this they occur only in the surface waters, where sunlight can penetrate. Asexual reproduction, which takes place mainly at night, is by oblique fission, each half develop-

ing those thecal plates which it lacks. Only rarely has spore formation been observed.

2. ANATOMY

a. Examine a permanent preparation of *Ceratium*. The theca enclosing the dorso-ventrally flattened body is drawn out into three hollow spines, and has a bizarre **anchor-shape**. The apical spine extends straight forwards and ends in a pore (function doubtful), while the two lateral spines curve outwards and forwards and end in closed points.

b. Examine the **external features** in detail through a high-power microscope. The deep equatorial groove, termed the annulus, almost completely encircles the body, and contains the transverse flagellum. A shallower, broader groove, termed the sulcus, runs posteriorly on one side of the body, and contains the trailing posterior flagellum. The points of emergence of the two flagella, through pores in the theca, are close together. The region anterior to the annulus is termed the epicone, while that posterior to the annulus is the hypocone. The plates covering the epicone are the epithecal plates, the groove of the annulus is formed of the girdle plate, and the hypocone is covered by hypothecal plates. The surfaces of these plates are often sculptured with tiny spines and pits.

c. Within the theca distinguish the prominent **nucleus** situated towards the centre of the mass of **endoplasm**. Also within the endoplasm are large numbers of small yellow-brown chromoplasts (containing chlorophyll) and of food-reserve granules (starch).

3. CONCLUSION

a. Observing the specimen, review the characteristics of the phylum, of the class, of the subclass, and of the order.

b. Notice those features which are particularly associated with the pelagic mode of life.

4. REFERENCE

LEBOUR, M. V. (1925). "The dinoflagellates of northern seas." Plymouth.

1.13. Order **Phytomonadida (Volvocina)**

Characteristics: Phytomastigina usually with two flagella, but with neither gullet nor grooves; body usually enclosed in a rigid cellulose capsule; usually holophytic with a single cup-shaped green chloroplast (a few are saprophytic and lack a chloroplast); starch deposits formed around one or more pyrenoids; typically solitary, but often colonial.

Of all the Protozoa, the members of this order most resemble plants, and many live symbiotically with other animals. They are found in the sea, in fresh water, and in damp places on land.