Unit: Protozoa	1 Introduction

PROTOZOA

Traditionally the animal kingdom has been divided into two subkingdoms; Protozoa* and Metazoa* .

Protozoa are the most abundant animals in the world in terms of numbers and biomass. Their principal importance is as consumers of bacteria (*PROKARYOTES*). Bacteria play a vital role in maintaining the earth as a suitable place for inhabitation by other forms of life and protozoa play a vital role in controlling their numbers and biomass. Protozoa are also important as parasites and symbionts* of multicellular animals.

Protozoa are defined as single-celled eukaryotic* organsims, that feed heterotrophically* and exhibit diverse motility mechanisms. However, it is impossible to draw a line between unicellular animals (consumers), plants (producers) and fungi (decomposers) and it is customary to speak of the Protista* as a separate kingdom of unicellular eukaryotes that embraces *both* heterotrophic protozoa and autotrophic algae.

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Protozoan diversity

Protists exhibit an enormous range of body form, even though they are largely microscopic, mainly ranging in size from 10-200 μm. Over 60,000 species have been described although you can be sure this is only a fraction of the total number of protist life forms.

In multicellular animals and plants complexity of body form has evolved through division of labour among cells. Complexity in protists has evolved through specialisation of different parts of the cell - organelles and the cytoskeleton* in particular.

The most striking differences among protozoa at the light microscope level are in the locomotory structures and the traditional classification of protozoa, found in most zoology textbooks and used within this unit, is based on these differences.

Protozoa may occur singly or in colonies (e.g. *Volvox* ); may swim freely or be in contact with a substratum or be sedentary; may be housed in a shell (lorica) (e.g. foraminferans  , clothed in scales or other adhering matter, or be naked; they may or may not be pigmented. They may be parasitic (e.g. *Trypanosoma* ) or symbiotic living attached to or inside other organisms (e.g. *Joenia* ), even inside their cells.

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Protozoan classification

Four major groups of protozoa are recognised and often given the status of phylum* . Note, however, that in the animal kingdom proper (Metazoa*), phyla are distinguished on their different body plans and that no comparable body plans are found in Protozoa.

The groups are:

- flagellates (or Mastigophora)
- amoebae (or Sarcodina)
- sporozoans (or Sporozoa, Apicomplexa) and
- ciliates (or Ciliophora).

The above classification represents a convenient filing system. We now know from molecular data (especially *RIBOSOMAL RNA* gene sequencing), that the different groups of flagellates and amoebae are not closely related and that there may be much greater genetic distance between two groups of flagellates than between flowering plants and vertebrates.

The above classification is not therefore phylogenetic* (i.e. reflecting the course of evolution). It is at present premature to try to construct a phylogenetic classification of protists, and for purposes of identification the above traditional classification is a starting point.

Flagellates

Also known as Mastigophora, the organisms are distinguished by their use of *FLAGELLA* as locomotory organelles and, in common with amoebae, usually multiply by longitudinal binary fission* .

Some flagellates have a characteristic arrangement of the flagella, *DINOFLAGELLATES* for example.

Many flagellates are able to feed autotrophically* as well as heterotrophically* , and dinoflagellates are important primary producers (photosynthesisers) in lakes and oceans, yet they can also ingest prey and feed in an animal-like fashion.

This makes them difficult to classify and until recently flagellates were divided into plant-like Phytomastigophora* and Zoomastigophora* .

Probably the most structurally complex flagellates are those which live symbiotically in the guts of *WOOD-EATING INSECTS* (e.g. termites and wood roaches).

Amoebae

Amoebae move  by means of flowing cytoplasm* , usually with the production of pseudopodia* . The pseudopodial morphology has been used in classification of amoebae.

Note that some amoebae live in shells from which the pseudopodia are extruded.

The Sarcodina (amoebae) are divided into two major groups or classes on the form of their pseudopodia.

- *RHIZOPODA* have unsupported pseudopodia (lobopodia  , filopodia  or reticulopodia ).
- *ACTINOPODA* have radiating microtubule-supported axopodia  .

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Sporozoans

These protozoa have no locomotory extensions of the body and all species are parasitic. Their motile stages move by bending, creeping and gliding and usually have an *APICAL COMPLEX* at their anterior end.

Most sporozoans are intracellular parasites or at least part of their life-cycle takes place inside a host cell. The apical complex seems to be structurally designed to assist host cell penetration.

Sporozoans reproduce by multiple fission* and because they do not form true spores but all possess an apical complex the name Apicomplexa is often preferred. Malaria parasites (*Plasmodium* ) and coccidians are among the most important sporzoan parasites.

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Ciliates

Ciliates form an extremely large group distinguished by the possesion of *CILIA* , two different types of *NUCLEUS* and transverse fission* of the organism when it divides (c.f. flagellates and amoebae).

Ciliates usually have their cilia arranged in rows called *KINETIES* .

All cilia beat with their effective stroke in the same direction and the waves of ciliary bending give the appearance of a wheat field blown by gusts of wind. This co-ordination is brought about by hydrodynamic drag-forces.

Other similar examples of metachronal rhythym* in animals e.g in the walking legs of millipedes or the segmental contractions of earthworms - are under nervous control.

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Consortia & Serial Endosymbiosis

The evolutionary origin of mitochondria* and chloroplasts* , from symbiotic bacteria is now widely accepted. This serial endosymbiosis theory* for the origin of eukaryotic organelles gains much support from the ease with which protozoa can be seen to enter into symbiotic* relationships with bacteria.

With the transfer of genes from the symbiont's nucleus to that of the host, the relationship becomes obligate and the symbiont becomes an organelle - no longer capable of independent existence.

New consortia between protozoa and bacterial symbionts are being described all the time, and appear to be the rule rather than the exception in free-living forms.

Examples of symbiotic consortia include

- *CILIATES*
- *HETEROTROPHIC FREE-LIVING PROTOZOA*
- *MARINE PROTOZOA*

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Evolution & the Fossil Record

One of the first criticisms levelled against Darwin's theory of evolution through natural selection was that many simple organisms have been observed to remain largely unchanged over long periods of geological time.

The Foraminfera* represent an important group of amoeboid* protozoa that live in shells that have been preserved in sedimentary rocks since the Cambrian* and indeed are a major constituent of chalk and limestone rocks. They are often cited as simple organisms that have not evolved. This citation however, was the result of a fundamental misunderstanding of the nature of natural selection, which does not have to be in some direction or other. Foraminifera have remained unicells from their first appearance, but they have *EVOLVED* .

In particular, large foraminiferans appear to have evolved over and over again. The large living foraminifera appear to owe their size to symbiotic relationships with intracellular photosynthetic protists (unicellular algae or dinoflagellates) once again illustrating the importance of symbiosis in evolution.

The adaptive significance of most foram shell shapes is not understood and so possible reasons for convergent evolution in forams of different geological eras are hard to find!

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Key Features of Protozoa

- Protozoa are unicellular organisms belonging to a number of different phyla.
- Most are motile and heterotrophic.
- Food is digested within a food vacuole.
- Excess water is eliminated by means of a contractile vacuole.

Features of flagellates

- Flagella are the locomotor or food-capturing organelles.

Features of amoeba

- Pseudopodia are the locomotor or food-capturing organelles.
- Skeletal structures are highly developed in this group.

Features of sporozoans

- Ringlike, tubular, and filamentous organelles at the apical end of the body are a distinguishing feature of these parasitic protozoa.

Key Features of Protozoa

Features of ciliates

- Cilia are present at some stage in the life cycle.
- Two types of nuclei are present: macronucleus and micronucleus.

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