PROTOCTISTA

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Summary

The kingdom Protozoa is considered to be part of the protoctists and is defined as single-celled eucaryotic organisms that feed heterotrophically and exhibit diverse motility mechanisms. Their principal importance is as consumers of bacteria as they play a vital role in controlling bacterial numbers and biomass. Protozoa are also important as parasites and symbionts of multicellular animals and they 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 of protozoa have been described. In multicellular animals and plants, complexity of body form has evolved through division of labor among cells. Complexity in protozoa, however, has evolved through the specialization of different parts of the cell, organelles and the cytoskeleton in particular (with specialization at protoplasmic level). Protozoa may occur singly or in colonies; may swim freely or be in contact with a substratum or be sedentary; may be housed in a shell, clothed in scales or other adhering matter, or be naked; they may or may not be pigmented. Polluted waters often have rich and characteristic protozoan fauna. The relative abundance and diversity of protozoa are used as indicators of
organic and toxic pollution along with their ecological distribution with respect to parameters such as amount of organic material and oxygen levels. Although protozoa are frequently overlooked, they play an important role in many communities where they occupy a range of trophic levels. As predators upon unicellular or filamentous algae, bacteria, and micro fungi, protozoa play a role both, as herbivores and as consumers in the decomposer link of the food chain. As components of the micro- and meiofauna, protozoa are an important food source for micro invertebrates. Thus, protozoa play a significant ecological role in the transfer of bacterial and algal production to successive trophic levels.

1. Introduction

The Kingdom Protoctista (Greek protos, very first; ktistos, to establish), is polyphyletic since it is an assemblage of unicellular eucaryotic organisms. This group represents an important step in early evolution, evolving from procaryotes and eventually giving rise to the entire line of eucariotes. The first probably evolved from simple groups of prokaryotic cells, 1.7 billion years before present (MYBP), 2.3 billion years after the origin of life on Earth.

Lynn Margulis explains the use of protoctist rather than protist: “Since the nineteenth century, the word protist, whether used informally or formally, has come to connote a single celled organism. In the last two decades, however, the basis for classifying single-celled organisms separately from multicellular ones has weakened. It has become evident that multicellularity evolved many times from unicellular forms - many multicellular organisms are far more closely related to certain unicells than they are to any other multicellular organisms. For example, the ciliates, what are unicellular include at least one species that forms a sorocarp, a multicellular spore-bearing structure; euglenoids, chrysophytes, and diatoms also have multicellular derivatives”. In recent years some authors have been using both terms, protist and protoctista.

Protoctists are aquatic: primarily marine, some primarily freshwater, and some in watery tissues of other organisms. Nearly every animal, fungus and plant, and perhaps every species, has protoctists associates. Some protoctists phyla include hundreds of species, all of which are parasitic on other organisms. The protoctists’ number is not definitively known, although it has been suggested that, at the turn of the XX century, there were more than 250 000 described species. Thousands have been described in the biological literature, in general; plant parasites and water molds have been described by the mycological literature, parasitic protozoa by the medical literature, algae by the botanical literature and free-living protozoa by the zoological literature.

The protoctists represent an incredibly diverse group. Most are unicellular, some are colonial, and other are simple multicellular organisms closely related to various multicellular kingdoms.

Protoctists are the simplest eukaryotic cells, containing membrane-bound nuclei and endomembrane systems, as well as numerous organelles. Movement is often provided by one flagellum or more, and cilia are often present on the plasma membrane as sensory organelles. As is typical of eucaryotes, the protoctistan flagella consist of a 9+2
pattern of microtubules. Unlike procaryotes, protoctistan nuclei contain multiple DNA strands, though the total number of nucleotides is significantly less than in more complex eucariotes. Protoctists can reproduce mitotically, and some are capable of meiosis for sexual reproduction. Cellular respiration is primarily an aerobic process, but some protoctists, including those that live in muddy pond sediments or in animal digestive tracts, are strict or facultative anaerobes.

Increasing knowledge about the ultrastructure, genetics, life cycle, developmental patterns, chromosomal organization, physiology, metabolism and protein amino-acid sequences of the protoctists has revealed many differences between them and the animals, fungi, and plants.

Protozoologists consider the protoctists, as an integrated group composed of a number of separate kingdoms, where the algae, are autotrophic photosynthesizers, while the rest, named Protozoa, are heterothrophic and eat bacterial or other protoctistan cells, or small organic particles suspended or dissolved in water.

**Kingdom Protozoa**

The protozoa are placed here in their own kingdom, comprising those generally minute and predominantly unicellular eukaryotic organisms that are mostly heterotrophic (phagotrophic or osmotrophic) in their nutrition, often independently motile (by means of pseudopodia, flagella or cilia), without chlorophyll and lacking cellulosic cell walls, and with tubular mitochondrial cristae. If mastigonemes are present on flagella, they are never rigid or tubular. The kingdom includes 14 phyla. Numerous members of two major phyla Euglenozoa and Dinozoa are capable of photosynthetic activities (but many are also mixotrophic). Their plastids are unique among phototrophic organisms in being cytosolic with stacked thylakoids, no stored starch, and surrounded by three, rather than two, membranes. The number fossil species is around 50 000, mostly foraminifera with some radiolarians.

The protozoa range in size by four orders of magnitude, from around 1 μm up to 10 mm or more. They are cosmopolites and can be found in all types of habitats where free water is available: in freshwaters, seawater and in soils and sediments, as well as being found as parasites in animals of all types and, to a lesser extent, in plants. The need for free water relates to the fact that active protozoa have an area of naked membrane through which water would be easily lost. Some species tolerate a remarkably wide range of habitats, temperature and pH. However, many protozoa produce resting stages, cysts or spores, protected by a secreted wall that is usually waterproof, and such resting stages may be found in dry habitats as well as wet ones, and even floating in the air at densities averaging 2/m³.

Within a single cell membrane, protozoa possess a variety of organelles, which perform all of their necessary life functions. As is the case in animals, they must take in organic molecules in some form or other. They do so either as soluble molecules that pass through the membrane, or in particulate form by formation of a food vacuole within which the food particle is digested. The organic molecules taken in are partly converted to body structures and partly broken down in respiratory processes, which in aerobic
Protozoa involve mitochondria, to release energy in a form that can be used to drive metabolic processes in the cell. The enzymes that perform these processes, as well as the structural molecules of the cell, are polymerized in the cytoplasmic ribosomes, many of which are associated with membranes of the endoplasmic reticulum system. Smaller protozoa contain a single nucleus and a single (haploid) or double (diploid) set of chromosomes, according to the species and the stage in the life cycle. Many larger protozoa contain additional nuclear material, either as multiple haploid or diploid nuclei, as polyploid nuclei or as multiple nuclei of different types, such as the diploid micronuclei and polyploid macronuclei of ciliates; it seems likely that there is some limit to the amount of cytoplasm which a single set of genes can control. The endoplasmic reticulum and a specialized part of it called the Golgi complex, forms a compartment within the cell that has functions in secretion and membrane synthesis, including the packaging of digestive enzymes in lysosomes for delivery to food vacuoles.

Most protozoa are motile and thus possess specialized organelles of motility. All protozoa probably have both contractile elements based on microfilaments and those based on microtubules. The former, are responsible for various cytoplasmic movements, ranging from slow shape changes and the formation of food vacuoles, to some exceedingly rapid contractions, and the latter are used for the movement of chromosomes during nuclear division as well as the bending of cilia and flagella, and some other shape changes.

Protozoa often contain symbiotic organisms or organelles of one sort or another. Frequently these symbionts are bacteria whose influence on the life of the host cell is unknown, although some have been shown to play important roles in the oxidative metabolism of anaerobic protozoa. In other cases, endosymbionts are other protists, or the remnants of protists. Notable among these, are, the symbiotic algae that aid the nutrition of various green or brown ciliates and amoebae, and the plastids derived from remnants of symbiotic algae acquired by the ancestors of photosynthetic euglenids and dinoflagellates. Finally, the cells of protozoa may contain structural elements deposited as an internal skeleton or as a thickened pellicle under the plasmalemma, or they may secrete a protective shell, testa or theca, adhering tightly to the outside of the cell or a looser protective lorica. Few protozoa are visible without the aid of a microscope, but their study began as soon as early microscopes enabled the observation of natural water samples. Protozoa were then found in all samples studied, in ponds, rivers, the sea, soils, and in various tissues and body spaces of other animals. A body of knowledge about these organisms was established which led, during the XIX century, to the publication of specialized books about protozoa, signaling, effectively, the birth of the science of protozoology. Most people today have heard of amoebae. Protozoa are regarded generally as organisms of little importance compared, for example, with insects, birds or mammals. However, they affect our lives as agents of disease infecting humans and domestic animals – plasmodial malaria is considered by some, to be the second most common cause of human deaths world-wide and it is now known that protozoa contribute to processes that are essential to ecosystem function. It is not just the intrinsic attraction of these microscopic organisms, which draws people to study them, but also their impact on our lives.
2. Classification

The Kingdom Protozoa includes the 14 Phyla described in this section.

2.1. Archamoeba

The archamoeba is a small group of amoeboid protozoa lacking both mitochondria and dictyosomes and could represent either a premitochondrial eucaryote, or be the result of secondary loss of mitochondria. No fossils are known.

This group is very heterogeneous and includes organisms that live in diverse habitats. It is deduced from 16S-RNA sequencing that they have a common phylogenetic origin. Members of this anaerobic phylum live in temperate habitats in the Northern Hemisphere. They are found on the bottom of freshwater, swampy/marshy water and freshwater mud. They are large up to 1 mm and are primarily scavengers.

This group includes several species:

*Pelomyxa carolinensis* (Alternative names: Amoeba carolinensis, Chaos chaos). Pelomyxa, the giant amoeba, usually 500-800 μm but occasionally passing 3 mm in length. This species is found in the mud at the bottom of freshwater streams, and can tolerate very low oxygen levels, lacks mitochondria, but contain several types of symbiotic bacteria that fulfill the same function (see Biological Science Fundamentals). They are cylindrical in shape, with a single hemispherical pseudopod at the front and a semipermanent bulb called the uroid at the back, which is usually covered in thin non-motile extensions. The cytoplasm streams forward through the center of the organism and back along the outside, allowing the creature to slide along the substratum. Each cell can contain from two to several hundred nuclei, which undergo mitosis independently of cell division. *Pelomyxa* are full of vacuoles containing whatever food they encounter along with sand and other debris, although their preferred prey is *Paramecium caudatum*. There are several other species of *Pelomyxa*, the most notable is *P. palustris*.

*Entamoeba histolytica*, water-borne pathogen, cosmopolite, can cause diarrhea or a more serious invasive liver abscess. When in contact with human cells, these amoebae are cytotoxic. There is a rapid influx of calcium into the contacted cell, which quickly stops all membrane movement save for some surface blobbing. Internal organization is disrupted, organelles lyse, and the cell dies. The amoeba may eat the dead cell or just absorb nutrients released from the cell.

The life cycle of *Entamoeba histolytica* involves trophozoites (the feeding stage of the parasite) that live in the host's large intestine and cysts that are passed in the host's feces. Ingesting cysts, most often via food or water contaminated with human fecal material, infects humans. The trophozoites can destroy the tissues that line the host's large intestine. Therefore, of the amoebae infecting the human gastrointestinal tract, *E. histolytica* is potentially the most pathogenic. In most infected humans the symptoms of "amoebiasis" (or "amebiasis") are intermittent and mild (various gastrointestinal upsets, including colitis and diarrhea). In more severe cases the gastrointestinal tract
hemorrhages, resulting in dysentery. In some cases the trophozoites will enter the circulatory system and infect other organs, most often the liver (hepatic amoebiasis), or they may penetrate the gastrointestinal tract resulting in acute peritonitis; such cases are often fatal. As with most of the amoebae, infections of *E. histolytica* are often diagnosed by demonstrating cysts or trophozoites in a stool sample. An estimated 40 million people develop intestinal disease or liver abscess annually; 40,000 die from amoebiasis annually.

*Naegleria fowleri*: Commonly found in lakes, swimming pools, tap water, and heating and air conditioning units and causes opportunistic infections. Enters via nasal passages from water, invades the central nervous system (CNS) and causes fatal meningoencephalitis. *Naegleria fowleri* is found in nature in warm water bodies as amoeboid and ameboflagellate trophozoites. Cysts also occur in nature, but not in human infections. Infection occurs during swimming or diving with the parasites gaining access, through the olfactory neuroepithelium, to the brain.

![Figure 1. Entamoeba histolytica](image)

*Acanthamoeba* spp.: Occur in the same environments, as *Naegleria* but are also found in soil and dust as well as more restricted liquid environments such as humidifiers and dialysis units. (They can also be cultured from the upper respiratory tract of some healthy individuals). *Acanthamoeba* spp. does not have an ameboflagellate form, and cysts can be found in human infections.

Infections due to *Acanthamoeba* spp. occur more frequently in debilitated or chronically ill individuals, and reach the central nervous system by hematogenous dissemination from foci in the lungs, skin, or sinuses.
Several species of *Acanthamoeba* are implicated, including *A. culbertsoni*, *A. polyphaga*, and *A. castellanii*, (opportunistic infection, corneal ulcers, common but not life-threatening, occasional death through invasion of CNS). Other species are: *A. astronyxis*, *A. hatchetti*, and *A. rhysodes*.

### 2.2. Neomonada

A group of often small, free-living, marine heterotrophic flagellates and amoeboflagellates. Species few in number. This group includes:

**Apusomonas proboscideae**: Heterotrophic flagellates free-living: marine, freshwater and terrestrial. Includes flattened gliding flagellates in which the anterior flagellum emerges from a projecting mastigophore. There are two flagella, and both insert near the projecting end of the mastigophore. The second flagellum runs backwards to lie under the cell and usually cannot be seen. The mastigophore beats slowly as the cell moves. Species in this genus eat bacteria, with the food being ingested taken ventrally. Temporary cysts may be formed, and the genus is cryptobiotic - i.e. the organism survives drying out. The genus is common in soils (world-wide) and has also been reported in fresh-waters. The opalozoan Apusomonas is related to the common ancestor of animals, fungi, and choanoflagellates.

**Cryothecomonas scybalophora**: Lives in coastal waters. Its life style is solitary and size ranges from 5-20 µm. The cells have a prominent anterior nucleus and are surrounded by debris outside the theca.

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**Biographical Sketches**

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