PROTOCTISTA

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Contents

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 $2/m^3$.

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 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 pray 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 lyses, 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.

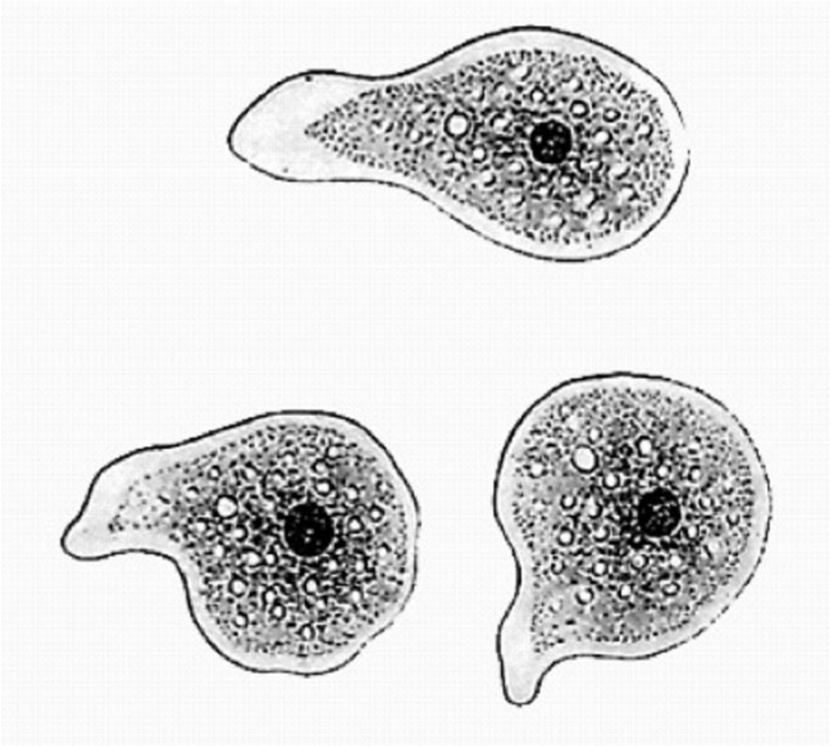

Figure 1. *Entamoeba histolytica*

***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 proboscidae: 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.

2.3. Rhizopoda

Meaning: Gr. '*root footed*'. The phylum Rhizopoda includes a large group of protozoa, more than 5 000 species, with pseudopods, which are extensions of the cytoplasm, simple or branched, passing by wide bases into the general surface. Pseudopods are never radial, nor they fuse into complex networks. While many Rhizopods have a simple cell organization, some forms do construct a simple shell named test or theca, with the skeleton absent. Reproduction is by binary fission; by division or abstriction of buds after the body has become multi-nucleate; or by the resolution of the body into numerous uninucleate zoospores which may conjugate as gametes; encystment in resting cysts (hypnocysts).

Most Rhizopods use their pseudopods to capture prey but also for locomotion. Rhizopods are heterotrophic, feeding on a wide range of bacteria, algae and other protists.

Figure 2. *Amoeba proteus*

Amoeba proteus: The word 'Amoeba' comes from a Greek word meaning "change", because as they move they show different forms. They are typically bottom dwellers in fresh and salt waters, damp soils and foul materials. Usually they range from 300-600 μm in length. Floating in this cytoplasm all kinds of cell bodies can be observed. The most obvious is the nucleus, which is uninucleate discoid to polymorphic, often biconcave, and ranges from 30-35 μm in diameter. Apart from the nucleus, the cell may contain water expelling vesicles and all kinds of inclusions (digested food). Many species of amoeba also bear small crystals. They form thick-wallet spherical cysts. Pseudopods are ridged and do not meld at bases during polypodial locomotion. They have uroid or posterior protoplasmic mass, often distinct from the rest of the body by a constriction. An *Amoeba proteus* can move at the rate of about 5 mm per minute. They move by extending and retracting pseudopods (false feet) over the surface. They are carnivores, in that they eat (engulf) bacteria and other small creatures.

An important group of amoeba makes a protective shell called 'test'.

Arcella. A fresh water species, make delicate tests, and measures from 30-100 μm. They construct chitinous tests, which lack attached or embedded material. Tests are areolar, transparent, yellow to brownish black, circular from aboved, domed-like on top, concave on bottom with central incurved aperture. The amoeba does not fill the test but is attached to its inner surface by many filaments (epipodia). It has two nuclei.

***Difflugia* spp.** Has a test or shell composed of small pebbles in a protein based gel. The amoeba constructs the test by ingesting small pebbles, particles of sand etc. and extruding them into the protein gel by gluing tiny bits of inorganic detritus together. They are different fresh water species, with sizes ranging go from 100-600 μm. The test is round with a nipple at the base and a flared rim at the aperture. It is completely covered with sand grains looks like a pile of sand grains.

Others testacean amoebas are: *Euglypha strigosa* and *Nebela dentistostoma.*

Figure 3. *Difflugia*

2.4. Mycetozoa

Species of this phylum are commonly referred as slime molds. Their characteristics are mitochondria with tubular cristae; lacking of cell wall and cellulose in spore walls. Reproduction: Vegetative reproduction by means of a myxamoebae; sexual reproduction by sporangium spores or resting spores (cysts).

Although presently classified as Protozoans, in the Kingdom Protista, slime molds were once thought to be fungi (=kingdom Mycetae) because they produce spores that are borne in sporangia, a characteristic common to some taxa of fungi. However, the assimilative stage in slime molds is morphologically similar to that of an amoeba. This assimilative stage has been designated a myxamoeba, which as is the case of the amoeba, is a uninucleate, haploid cell, not enclosed in a rigid cell wall, and ingests its food by means of phagocytosis. During this mode of ingestion, the food particles, usually bacteria, become surrounded by the pseudopodia of the myxamoeba. Once the food has been engulfed in this manner, it is surrounded by a membrane or food vacuole where hydrolytic enzymes are secreted that will digest the food. In fungi, the assimilative stages are mycelium and yeast, both of which are surrounded by a rigid cell wall and obtain their food by means of absorption. These are some of the reasons why mycologists no longer recognize slime molds as being fungi. However, organisms in this group continue to be studied in mycology as a matter of tradition and not because they are thought to be related to fungi. There are approximately 850 species of Mycetozoa. They are found on moist soil, decaying wood, and dung. Cosmopolites.

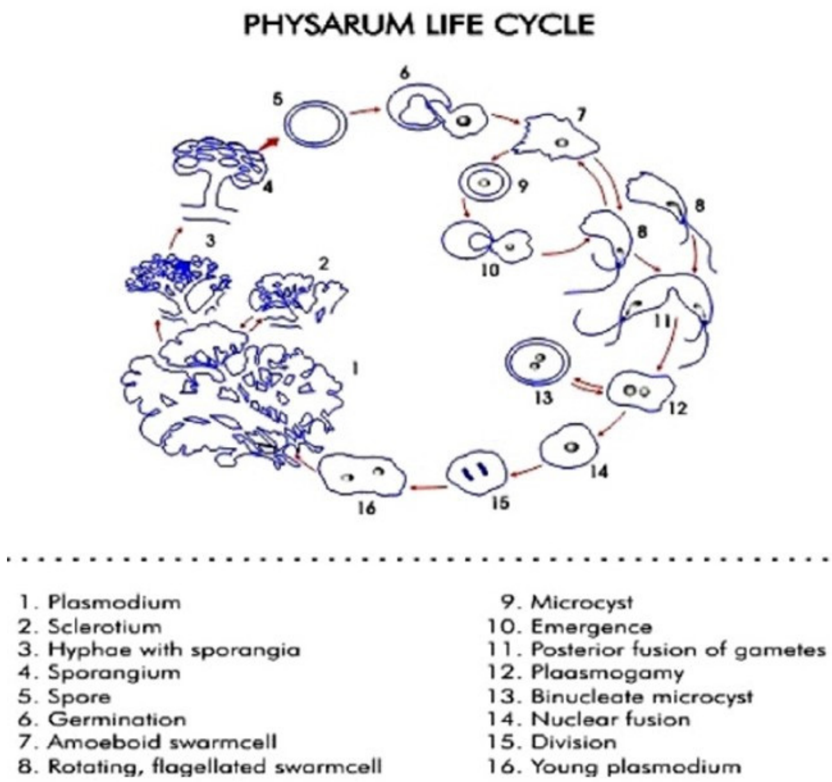

Figure 4. Life Cycle of *Physarum polycephalum*

The plasmodium is the main vegetative phase of the life cycle. The appearance is a bright yellow, slimy structure. Usually diploid, it is a large syncytium (multiple nuclei in a common cytoplasm). This is the actively migrating stage and also assimilative stage that consumes food by phagocytosis. Such plasmodia cease to migrate when they encounter a fresh source of nutrition. When unfavorable conditions prevail, the plasmodium forms a protective, brittle layer and becomes dormant. This dormant stage is termed a sclerotium. It is composed of a number of smaller multinucleate cells called macrocysts. Upon return of favorable conditions, each macrocyst can give rise to a new plasmodium. During favorable conditions, the plasmodium will migrate and feed for a period of time before being converted to numerous sporangia. Spore formation comes about with the formation of cell walls around the diploid nuclei. The nucleus in each spore will undergo meiosis to produce four haploid (n) nuclei. Thus, only one myxamoebae results from each spore. As the myxamoebae feed and grows, they will reproduce, asexually, by mitosis and cytokinesis.

Other species are: *Dictyostelium; Trichia and Nematostelium*.

2.5. Foraminifera

Meaning: (Lat. *Foramina*: pores; *Ferre*: to bear) bearing pores, studded with pores.

The phylum Foraminifera is single-celled amoeboid protozoa. The largest phylum in the kingdom includes 45,000 species. The principal characteristics of the taxon are: the life history characterized by an alteration of sexual and asexual generations with meiosis associated with the asexual reproduction, typical of heterotrophic eucaryotes; threadlike anastomosing pseudopodia bearing granules that reveal constant bi-directional streaming of the cytoplasm (granuloreticulopodia) and the presence of a test (shell). The test can be composed of biogenic calcium carbonate (calcareous), cemented foreign particles such as quartz and sand grains, other material as sponge spicules, an agglutinated or organic theca composed of polysaccharides. Some foraminifera have lost the test. The test is generally formed by a succession of two to many chambers (locula) connect by means of large pores (foramina), with variation in chamber size, shape, and arrangement (growth plan) resulting in an incredible variety of final shapes and forms. They inhabit a wide range of marine environments, from the intertidal zone to the deep sea in all regions. They either live on the sea bottom (benthic) or float in the upper water column (planktonic). A few benthic species have been recorded from terrestrial environments including ground water. In favorable environments, their abundance can reach many thousands of tests per cubic centimeter of sediment.

The size of the foraminiferan test, typically, ranges from 0.05 mm to 0.5 mm although some may be as large as several centimeters with a recorded maximum of 18cm in diameter. The cytoplasmic threads, the thinnest of which are <1µm across, may reach a distance of up to 25 times their test diameter.

Foods of the foraminifera are variable: dissolved free amino acids, bacteria, unicellular algae, and even metazoans, such as copepods. In tropical euphotic waters, where trophic resources are highly competitive and sunlight is plentiful, several families of benthic and planktonic foraminifera harbor unicellular algae. The latter provide the foraminiferan hosts with carbohydrates. Foraminifera host a variety of photoautotrophs: dinoflagellates, diatoms, green algae, red algae and eventually chrysophytes and prymnesiophytes. Owing to the diversity of endosymbiont photopigments, the symbiont-bearing foraminifera are successful in utilizing a wider range of the light spectrum and water depths.

Foraminifera are the food of many small marine invertebrates and fish. Scaphopod mollusks are specialized in eating this group. The foraminifera are a key group in the marine food chain: they feed on small prey mostly inaccessible to the macrofauna and are prey of the latter. Predation by macrofauna is not the only way the ecosystem utilizes foraminiferal production. The cytoplasm of replicating adults, is ultimately released together with the offspring and thus become available to suspension-feeders or is simply included in the pool of organic detritus.

Ulitlization of Foraminifera: The petroleum exploration industry has for a long time been a major stimulus for foraminiferal research. Foraminifera are the first microfossil group to be used extensively for age assessment of strata encountered during drilling, and are the major microfossil for subsurface exploration. This is because foraminiferal tests survive inside the millimeter-sized rock chips produced by rotary drilling, whereas larger fossils, such as molluscs, are obliterated.

The fossil record of benthic foraminifera is ancient, dating to more than 550 MY, while the fossil record for the planktonic is about 190 MY. The abundance of their shells in ancient sediments, their wide distribution and their sensitivity to changes in environmental conditions make them valuable indicators of past climate change. Because the length of time a foraminifera's species exists is geologically brief (ca. 5-15 MY), the shells are also very useful for determining the age of sediments in which they occur.

Planktonic foraminifera are the only extant group in which all species are preserved as fossils in the geologic record. Their shell remains contribute to the oceanic carbonate sediment in about 70% of the ocean area, which is, therefore, a global source of studies of planktonic foraminifera. The species composition of sediment assemblages reflects the relative intensity of shell production and preservation of the individual species under prevailing environmental and taphonomic conditions. Environmental conditions include physical, chemical, and biological factors. Some information on their ecologic preferences can be extracted from geographic patterns of their relative abundance.

Foraminifera are ideal subjects for testing various aspects of evolutionary theory, because large populations of individuals, whose characteristics can be measured and treated statistically, can be obtained from closely spaced rock samples at carefully selected localities, to provide an evolutionary time series. It is then possible to show how distribution of a particular character changes over time within successive populations. Some examples are: *Cibicide*s sp., a calcareous benthic foraminiferan and *Globigerina* sp., calcareous planktonic foraminifera. Foraminifers, with calcite tests, are the most numerous and diverse, and include bottom-dwelling benthic and floating species. In some instances calcareous foraminifers become so abundant to become sediment formers. *Globigerina* ooze, formed beneath tropical and subtropical waters of the world's oceans, is an example of such sediment. A further example is represented by *Clavulina* sp., agglutinated benthic foraminifera. Agglutinated foraminifers, with tests of cemented grains, are also widespread in marine environments, but tend to be most abundant under restricted conditions such as low salinity. They probably are ancestral to the calcareous forms.

2.6. Heliozoa

Meaning: (Gr *helios:* sun, *zoon*: animal). These protozoa are unicellular phagotrophics with radiating axopods. They live at shallow depths in freshwater, brackish or marine environments. Most species are free-living, floating just above solid substrates or rolling among aquatic plants. They are never found in turbid water, which cause retraction of the cytoplasmic extensions used for feeding. Reproduction is generally asexual but, sexual processes with production of amoeboid or flagellate gametes have been described.

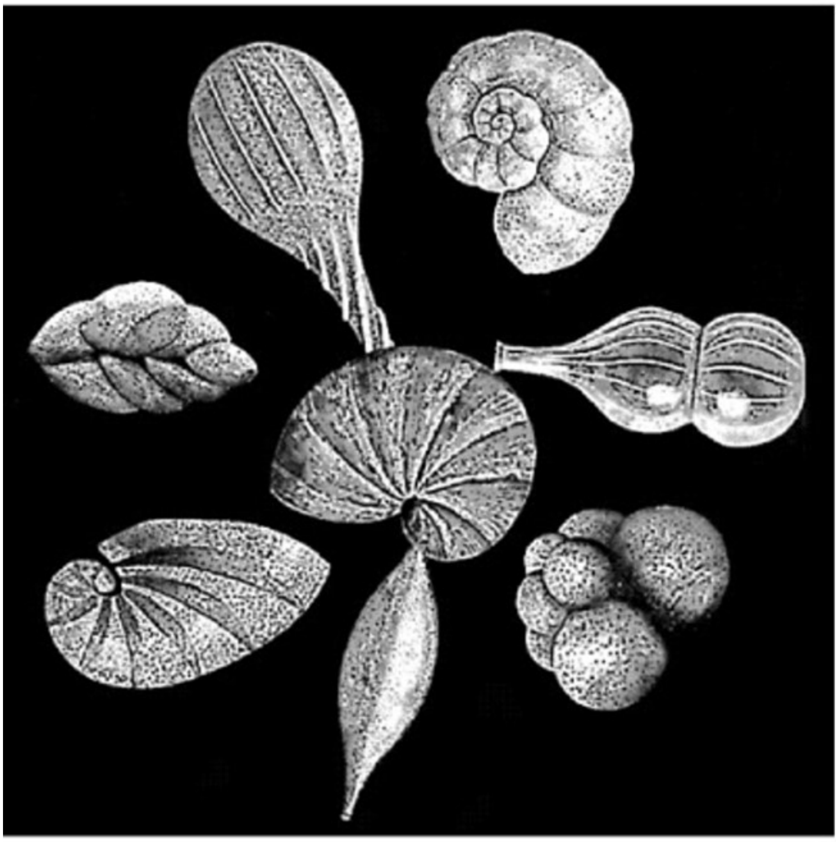

Figure 5. Several foraminifera.

Of the 100 species of Heliozoa most are spherical, measuring 0.05–0.5 mm in diameter, although some are more complex, comprising a cytoplasmic base bearing a contractile stalk and an oval head. The cell membrane is covered with a mucous coat that can include dispersed mineral or organic scales and spicules. The cytoplasm of heliozoans is never enclosed in a central capsule as it is in radiolarians. Long, granule-studded processes known as axopods radiate from the cell body. Axopods are slender extensions that project 0.04–0.8 mm from the cell body into the surrounding water and are involved in many physiological functions, including recognition of environmental stimuli, cell contraction, locomotion and food capture. Axopods are stiffened by a rigid, though labile, axial rod, which consists of a complex assembly of parallel microtubules and crosslinking bridges. They are strengthened by highly ordered bundles of unstable microtubules that radiate from one central mass of fibrillar-granular material in the cell body, or from multiple sites associated with the nuclear envelope. The microtubule-based cytoskeleton is seen to be organized in specific and complex patterns when viewed in cross-section. One of the distinctive features of the axopods is their sensitivity to a variety of physical stimuli, such as mechanical or electrical shocks, ultrasound, cold, high pressure and chemical agents.

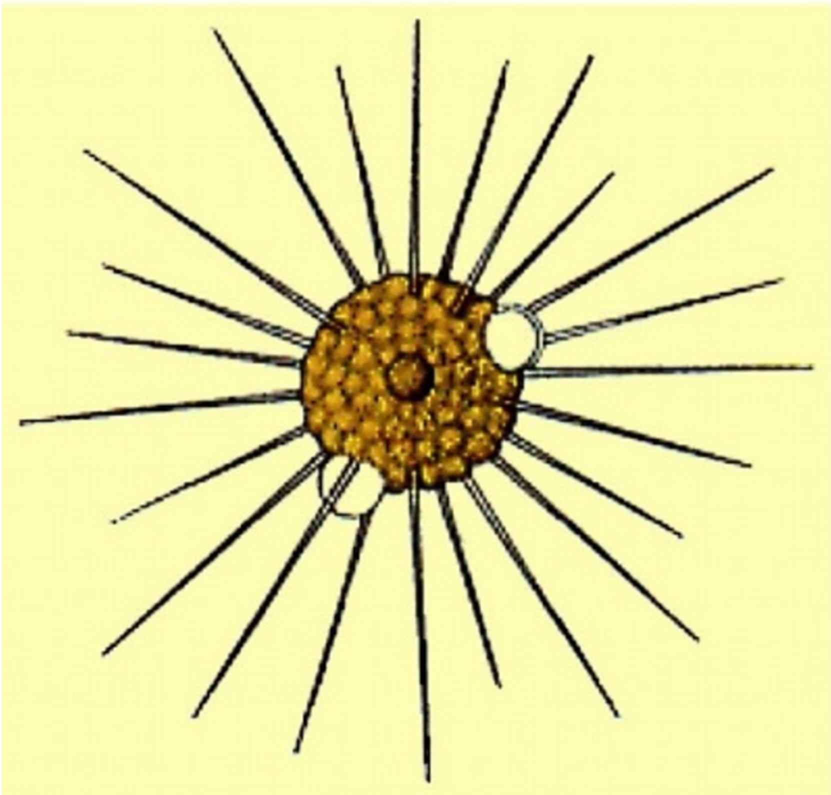

Figure 6. *Actinophrys*

The cytoplasm includes microtubule organizing centers, one or several nuclei and, in some species, endosymbiotic algae. They use extrusive organelles in prey capture, and digest them in food vacuoles. Heliozoa contain membrane-bound extrusive organelles (0.2–0.8 μm in diameter), including mucocysts and kinetocysts involved in cell coat formation and prey capture. These organelles arise from the Golgi apparatus. Mucocysts contain a homogeneous, mottled or flocculent matrix. Kinetocysts include a dense pointed missile-like core embedded in a fuzzy material. Mature organelles are found in the superficial cytoplasm and axopods, and are linked to the cell membrane by proteinaceous particles. In the presence of prey organisms, they move in both directions along the axopodial axis at a velocity of about 0.5 $\mu m\ s^{-1}$. They stop moving in the absence of stimulation. Heliozoa are passive predators. Prey organisms colliding with the axopods are liable to stick to the cell membrane as the result of exocytosis of adhesive substances by mucocysts. The prey becomes entangled and progressively paralysed. It is then translocated towards the cell body. Some heliozoan species have a strict diet, but most feed on a variety of prey organisms, such as bacteria and cyanobacteria, colored flagellates, and ciliates. Binary and multiple fissions are very common processes of asexual reproduction. Multiple fission occurs through repeated divisions of the parent nucleus and formation of many daughter cells, each with one nucleus. Sexual reproduction has been observed in a few heliozoans.

Some genera are *Actinosphaerium*, *Echinosphaerium*, *Actinophrys*, *Camptonema*.

2.7. Radiozoa

These protozoa are holoplanktonic, widely distributed in the oceans. They occur throughout the water column from near surface to depths of hundreds of meters. Their abundance in a geographical region is related to the quality of the water mass, including such variables as temperature, salinity, productivity, and available nutrients.

They are largely non-motile organisms, and their general morphology clearly reflects an adaptation for a floating existence. Various structures in the cytoplasm enhance buoyancy, including bubble-like alveoli in the peripheral rhizopoda of some species and lipid lobules localized in the dense central cytoplasm or dispersed within the surrounding complex cytoplasmic network.

The most widely recognized morphological feature of the radiolaria is the elaborate glassy skeletons. The delicateness of form and diversity of space-enclosing structures, include perforated spheres, ornate geodesic polyhedral lattices, and seemingly endless variations of combinations of solid geometric designs. They have a high adaptive plasticity. The solitary forms vary considerably in size from 30 µm to 2mm diameter. There are macroscopic colonies consisting of hundreds of radiolarian cells interconnected by rhizopodial strands and enclosed within a translucent, gelatinous envelope form (*Spumellaria*). The colonies may be spherical, varying in diameter from several millimeters to a centimeter or larger. Other colonies are cylindrical to filiform, with lengths varying from under a centimeter to several meters. Some of the colonial *Phaeodaria* form more complex aggregates of several shells joined by their spines or otherwise held together by simple siliceous networks.

The radiolaria skeleton is encased in the soft cytoplasm. The bulk of the test usually lies in the ectoplasm, with filopoda. Thus, the hard parts are never in direct contact with the seawater, so that the skeleton of living organisms is never subjected to dissolution in the aqueous environment. Innermost portions of the test may lie within the endoplasm in the central capsule, which also contains the nucleus. The membrane of the central capsule separates the inner endoplasm from the outer ectoplasm. This is a characteristic that distinguishes radiolarians from other protozoa.

Radiolarians apparently feed on various kinds of planktonic organisms including microflagellates and other protozoans, diatoms, and possibly forms as large and active as copepodes. Symbiotic algae like zooxanthellae, also contribute to radiolarian nutrition. Radiolaria are actually some of the most complex extant protozoans. Some genera of this phylum include: *Sphaerostylus:* Sphere of skeleton 175 µm with long opposite spines. Thysocyrtis*:* 350 µm skeleton of two to several chambers with many pores as it grows.

2.8. Percolozoa

These protozoans live in soil, freshwater, brackish, and seawater environments and have both anaerobic and aerobic representatives. They are biflagellate cells with mitochondria, discoid cristae and lack a cell wall. The vegetative reproduction is a myxamoebae uninucleate, haploid with lobose pseudopodia which develop upon spore germination. This stage forms microcysts under adverse conditions. Sexual reproduction is unknown. The aggregation of myxamoebae forms a non-migratory pseudoplasmodium. The culmination of pseudoplasmodium results in the formation of sorocarp; all its cells are able to germinate. Sorocarps (350 µm to 3.5 mm tall) may be stalked with a terminal cluster of spores in a ball or in chains or columns. The spores or cysts emit small amebas that repeat the cycle.

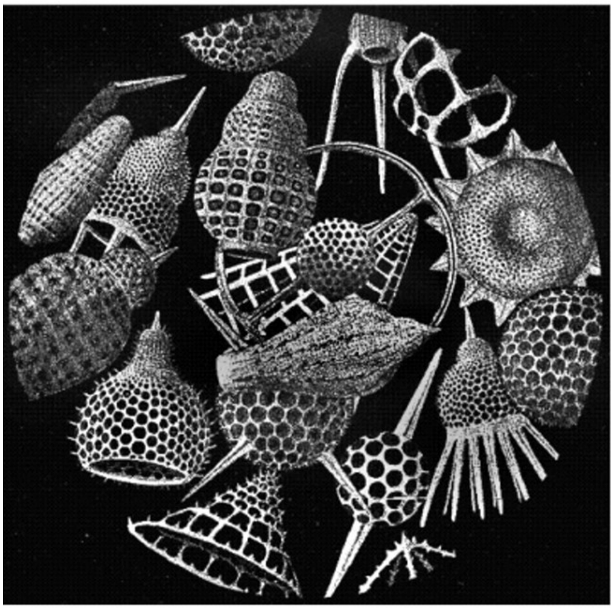

Figure 7. Radiolaria

The most commonly species, of the 100 species reported, is *Acrasis rosea*, which has a number of distinguishing features from the well-known cellular slime mold *Dictyostelium discoideum (*Phylum Mycetozoa). *Acrasis* amoebae are much larger, have pseudopodia lacking subpseudopodia, and move much more rapidly. Aggregation in *Acrasis* involves individual cells and small groups of cells moving towards an aggregation center; it involves no aggregation streams and does not produce mobile pseudoplasmodia or slugs. The stalk cells in *Acrasis* fruiting bodies are viable, while those in *Dictyostelium* are not. Finally, although the spores and stalk cells in *Acrasis rosea* are distinguishable from each other, they are not as highly differentiated, as is the case in *Dictyostelium discoideum*.

2.9. Euglenozoa.

Euglenoids are mostly free-living and autotrophic (1000 species), but there are also heterotrophic and a few parasitic species (600). They are usually unicellular but some are colonial. They used to be placed with green algae because some have green chloroplasts. (see *Algae*). Species reproduce by longitudinal fission. They form a cyst when the conditions are unfavorable and they can elongate their bodies. The flagellate species without chloroplast are the zooflagellata. The free-living forms are mostly holozoic while the parasitic ones are saprozoics.

The more common genera of colorless flagellata include: *Peranema*. This flagellate is common in waters rich in organic nutrients, i.e., waters in which much decay is taking place. Perhaps counter intuitively, the single flagellum projects straightforward, and a rapid twirling of its extreme end pulls the *Peranema* smoothly through the water. Its body can undergo extreme contraction and distortion as it proceeds. *Peranema*, have to consume other organisms to survive. A prominent feeding apparatus, composed of two rods, is located at the flagellated (anterior) end of the cell. *Peranema* sometimes hunt in "packs" and rip away at prey cells, tearing holes in them and sucking out cell contents. Like other euglenoids, these organisms are actually biflagellate (having two flagella), but only one is easily viewed through the microscope, being thinner and shorter. Beating often occurs only at the tip of the visible flagellum. *Peranema* is said to absorb nutrients through its outer pellicle, and it can also ingest quantities of detritus, bacteria, algae and even other organisms of its own size by expansion of the cytostome, a cavity that lies at the base of the flagellum. It is a continuously active predator and scavenger.
Others genera of free-living zooflagellata are: *Chilomonas, Bodo, Astasia*

The most important species from the human health standpoint are trypanosomes and leishmanias. These are blood parasites of humans and others vertebrates, and are characterized by the kinetoplast, a fibrous network of DNA, which constitutes 20-25 percent of the total parasite DNA, and which is in located in the mitochondria.

One of the most important of such parasites is *Trypanozoma cruzi*. The flagellum is connected to the basal body and emerges from a specialized invagination, the flagellar pocket which is apparently involved in the ingestion and uptake of nutrients of the external medium. The outdated concept that the adhesion of the flagellum to the cell body was due to the existence of a virtual membrane has been abandoned, but the mechanism of this connection remains uncertain. Recent observations by electron microscope and freeze fracture strongly suggest that particle clusters distributed at regular spaces, or in a linear array, observed in the flagellum and the plasmalemma of trypomastigotes may represent "rudimentary desmosomes" that participate in the adhesion process. Another general characteristic of trypanosomatids is the presence of subpellicular microtubules, which are organized as a cytoskeleton, but also play a role in other more complex functions, such as the process of cellular differentiation, motility and tissue migration. Very little is known about the structure of the *T. cruzi* cytoskeleton, but recently actin filaments and a - and b - tubulins associated with the microtubules have been reported. Interestingly, the flagellar pocket is deprived of subpellicular microtubules, but contains pinocytotic vesicles which incorporate macromolecules and other substances from the external medium and the host cell cytoplasm. The cytostome, an invagination of the cell membrane, is another region in which incorporation of pinocytotic vesicles and larger particles occurs. In addition to the above structures and organelles, which are more specific to trypanosomatids, this group of protozoa shares with the eucariotic cells the endoplasmic reticulum, ribosomes and Golgi complex. The presence of peroxisomes, defined as membrane-bound cytoplasmatic organelles containing enzymes such as catalase and oxidases, have been reported on *T. cruzi*, however, their activity seems to be significantly lower than that taking place in mammalian cells, probably because of a lower concentration of these enzymes. Because, *T. cruzi* has to accomplish an intracellular cycle in the vertebrate host (which implicates an interaction with a number of different cells), and since a strong immune response is present in the infected host mostly induced by surface antigens, the plasma membrane of *T. cruzi* has been intensively investigated in many laboratories. A large number of surface macromolecular complexes, (glycoproteins, polysaccharides and lipids), have thus become known and are now used for diagnosis, immuneprotection and immunopathology investigations.

Trypanosomiasis.

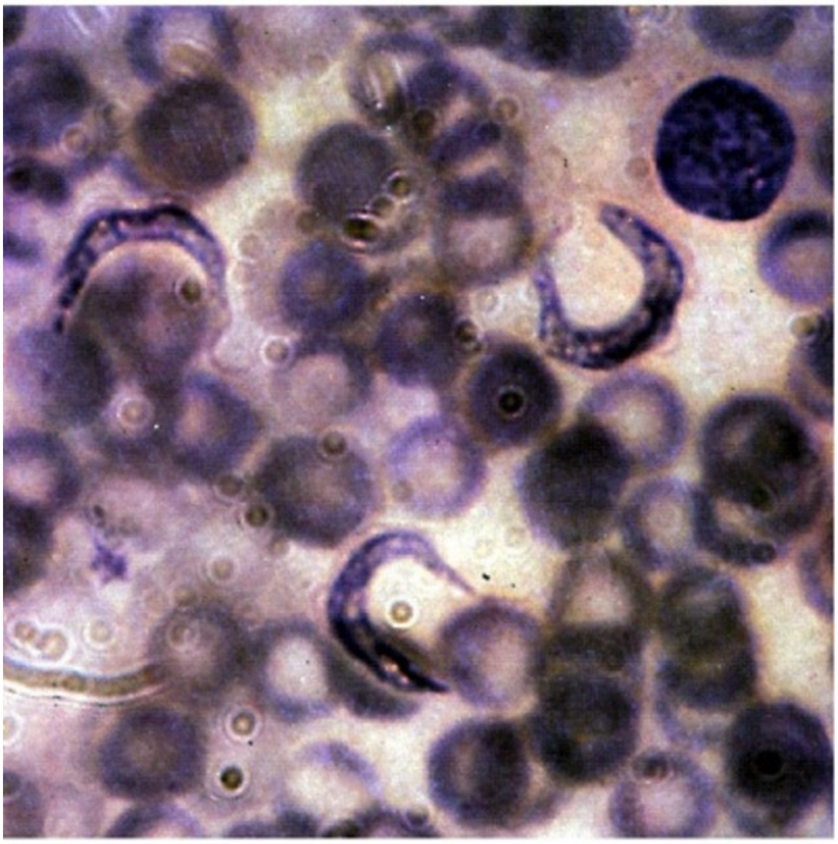

Figure 8. *Trypanosoma*

The three variations of the disease that predominate in humans are transmitted by an insect vector: two types of African sleeping sickness are caused, respectively, by *Trypanosoma rhodesiense* and *T. gambiense*, both transmitted by the bite of the tsetse fly. South American trypanosomiasis, or Chagas' disease, is caused by *T. cruzi*, which is the most common cause of heart disease in South America. It is transmitted by certain species of triatoma (blood-sucking insects); the parasite enters the skin when infected insect feces are rubbed into the site of the bite. The characteristic symptoms of Chagas' disease are edema; hard, red nodular outbreaks of the skin; and damage to the heart muscle. There is no effective treatment. Symptoms of African sleeping sickness may appear at once, after several weeks, or even after years in the Gambian type. Early disturbances include inflammation at the site of the bite, intermittent fever, and enlargement of the spleen. In the Gambian variety, the lymph nodes are enlarged. Subsequent signs of heart damage, personality changes, and headache develop. The final stages are marked by tremor, disturbed speech and gait, emaciation, and a prolonged comatose state. African trypanosomiasis is treated with suramin sodium and other drugs as pentamidine, which are most effective when injected during the early stages of the disease. Such drugs also provide protection against infection for two months or more, but organ damage appears irreversible. Even with treatment, the disease is often fatal and the prognosis becomes grave after the nervous system is invaded. Prevention involves the use of insecticides and the clearing of vegetation that harbors the tsetse fly.

Other parasites include *Leishmania donovani,* which cause Kal-azar, a common disease in India, China, and parts of Africa and South America. It is transmitted by sand flies. *L. brasiliensis* that causes espundia. This malignant leishmaniasis progresses from the skin to mucous membranes of the nose, eroding and disfiguring the face.

2.10. Dinozoa

The term "dinoflagellate" means "with whirling flagella". Dinoflagellates have a pair of unequal flagella. Both flagella lie in grooves: the sulcus, in the body axis and the cingulum, which is flattened and ribbonlike, and lies transverse to the axis. The nutrition is either phototrophic, saprobic or holozoic. Photosynthetic dinoflagellates have eyespots, light-sensitive organelles composed of lipid droplets packaged within stacked layers of membranes. These contain carotenoid compounds, which are light- excitable, allowing the organism to detect the direction of the light source. A few rare species have a more complex structure, the ocellus, which uses a refracting lens to focus a projected image on the retinoid lining membrane. Many dinoflagellates produce defensive trichocysts, often hundreds per cell. These are discharged upon rapid hydration, ejecting long rod-shaped protein filaments similar to those found in ciliates like *Paramecium*. The effect is much like an exploding can of spray-string. In those dinoflagellates capable of photosynthesis, there is a triple-membraned plastid, which contains the photosynthetic machinery. This plastid may contain its own nucleus. Dinoflagellataes are widely distributed (in marine, brackish, and fresh waters). Some may have xanthophyll pigments (yellow or golden brown color).

Of the 4 600 species some may be unarmored, or armored, and some are bioluminescent as *Noctiluca*, *Gonyaulax* and *Pyrocystis*.

The armored dinoflagellates have two major cellulosic plates regions composed of two to 100 individual plates. The edges of the plates overlap, sliding apart as the cell increases in size and allowing the cell to expand. The plates come in many varied shapes, from spherical forms, as in *Peridinium*, to elongate horn-like forms such as in *Ceratium.* The structures of an armored species can be seen in the diagram depicted in figure 9.

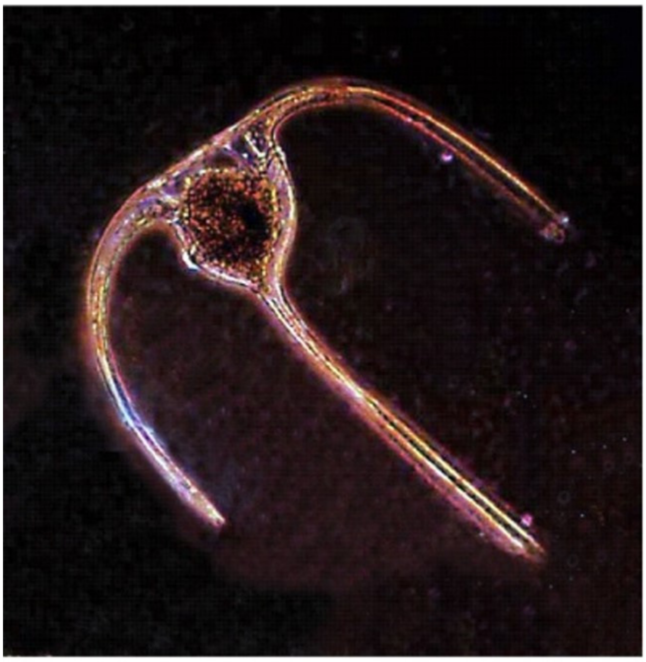

Figure 9. *Ceratium* structures

Marine species of the genera *Gymnodinium* (naked) and *Gonyaulax* (armored) are responsible for the outbreaks of the red tides of many coasts of the world, along continental shelves. They poison many fish that eat them, by producing a toxin, which acts on the CNS of animals, causing death. Red-tide outbreaks coincide with high concentrations of nutrients, especially iron and high temperatures.

Ciguatera, first recognized in 1550 in the Caribbean, is a form of ichthyotoxism caused by the consumption of mainly reef fish contaminated with the ciguatoxin, a class of lipid soluble toxins. An estimated 50 000 victims worldwide, are reported annually, with 20 000-30 000 cases, in Puerto Rico and U.S. Virgin Islands alone.

The primary vector, the dinoflagellate *Gambierdiscus toxicus*, an epiphyte living on a range of calcareous macroalgae and other substrates on coral reefs, has been identified as the producer of toxins causing ciguatera. *G. toxicus* is widely distributed on coral reefs and lagoons but is most prolific in shallow waters (3-15 m) away from terrestrial influences. Herbivorous reef fish browsing on reef algae ingest *G. toxicus* and concentrate the ciguatoxins in the gut and muscle tissue. Piscivorous reef fish may then become toxic through the consumption of herbivorous fishes and the concentration of the toxins increases up the food chain. Other benthic dinoflagellates such as *Prorocentrums*, *Ostreopsis* and *Coolia* are also linked to ciguatera outbreaks. Ciguatoxins are not destroyed by cooking and no routine tests are performed to identify contaminated fish, or to predict the timing or occurrence of ciguatera outbreaks on reefs. Ciguatera poisonings are characterized by a range of often severe gastrointestinal and neurological symptoms. Intoxicated individuals may experience diarrhea, vomiting, lethargy, numbness, reversal of temperature perception, itching, tingling and muscular pains. Some of these symptoms such as itching and muscular pain may persist for several months. A recurrence of neurological symptoms may be brought on by consumption of alcohol or certain foods such as other fish, fish-flavored food products, peanut butter, and meat such as chicken and pork. Untreated, ciguatera is usually a self-limited disease lasting one to two months. However, symptoms can persist months to years, causing great anguish. Mannitol is believed to alleviate, if not abate, the clinical symptoms of ciguatera fish poisoning. Preliminary evidence suggests that the earlier a victim is diagnosed and treated, the more likely the success with mannitol.

2.11. Metamonada

This group of 300 species comprises oval and elongated forms with two to eight flagella, a delicate pellicle permitting much change of form and often parabasal bodies and axostyles; they have hydrogenosomes in place of mitochondria. They include curious bilaterally symmetrical flagellates with double structures: nuclei, axostyles, groups of flagella, etc. Reproduction occurs by longitudinal fission.

Many species are typically digestive tract parasites, that are transmitted to humans through insect vectors. *Giardia* and *Cryptosporidium* are microscopic parasites. *Giardia* are often found in human, beaver, muskrat, and dog feces. Cattle feces appear to be the primary source of *Cryptosporidium*, although these parasites have also been found in humans and other animals. Sources of drinking water can become contaminated when feces containing the parasites are deposited or flushed into water.

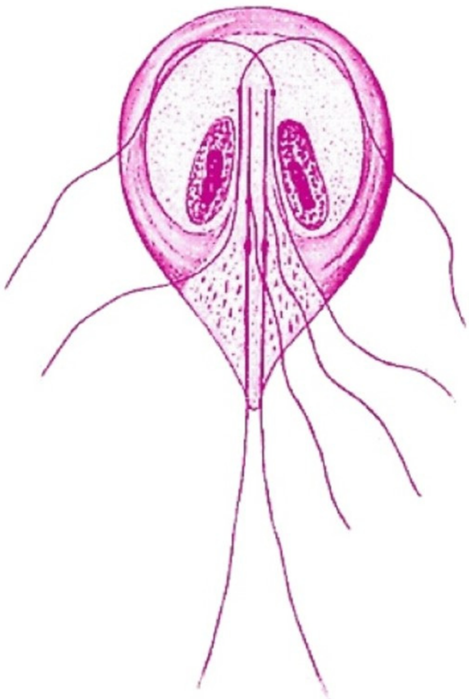

Figure 10. *Giardia*

Giardia causes an intestinal illness called Giardiasis or "beaver fever." *Cryptosporidium* is responsible for a similar illness called cryptosporidiosis. Both parasites produce cysts that are very resistant to harsh environmental conditions. When ingested, they germinate, reproduce, and cause illness. After feeding, the parasites form new cysts, which are then passed in the feces. Diarrhea, abdominal cramps, gas, malaise, and weight loss are the most common symptoms caused by *Giardia*. Vomiting, chills, headache, and fever may also occur. These symptoms usually surface six to 16 days after the initial contact and can continue as long as one month. The symptoms of cryptosporidiosis are similar; the most common include watery diarrhea, abdominal cramps, nausea, and headaches. These symptoms occur within two to 25 days of infection and usually last one or two weeks; in some cases they persist for up to a month. *Giardia* is usually cleared from healthy people without treatment, within a month. *Cryptosporidium* will also usually disappear from healthy people within a month without treatment. Anti-diarrhea drugs and rehydration therapy may be used if diarrhea becomes severe. No drugs to treat the illness have been approved, though many are now being tested.

2.12. Parabasala

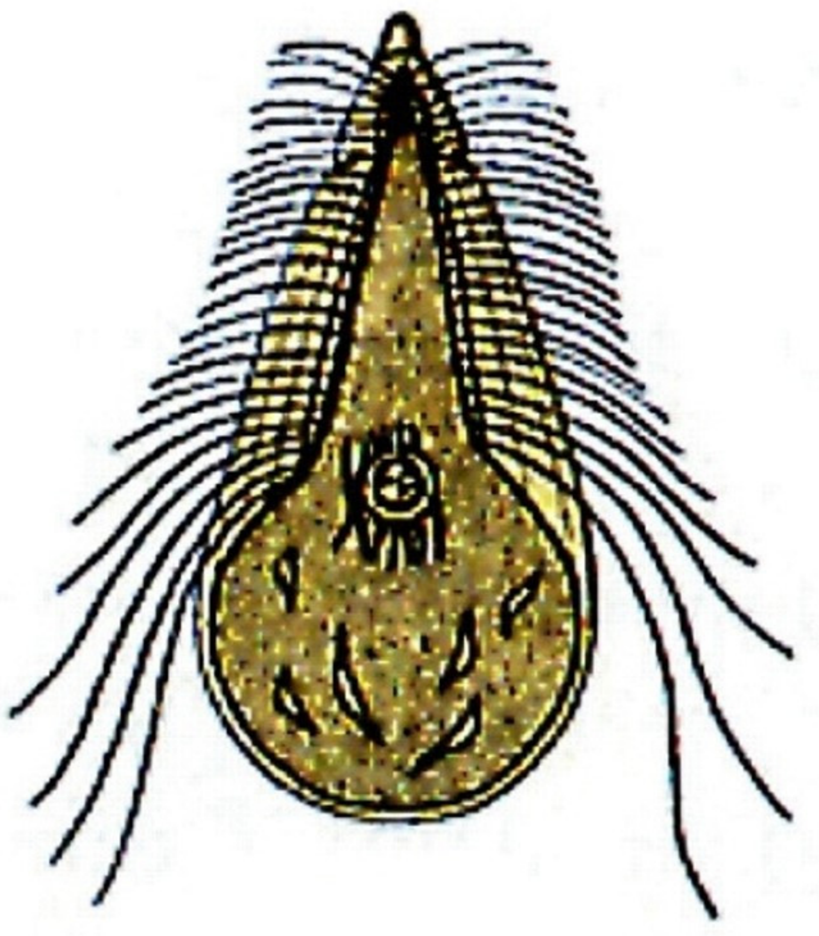

Figure 11. *Trichonympha*

These are the most complex mastigophorans. With more than 400 species, all are symbionts, either parasites or commensals, occurring with a wide variety of vertebrate and invertebrate hosts. Multiflagellated forms are amitochondriate, and with striking parabasal (Golgi) apparatus.

The xylophagous simbionts like as *Trichonympha* (meaning they eat wood), inhabit the hindguts of some termites and roaches, where they are necessary for the chemical digestion of the cellulose in the insect's diet. Trichonympha campanula is commensal with the western damp wood termite. *Zootermopsis angusticollis* live commensaly in the intestines of termites, cockroaches and wood roaches. There is a mutual dependence between host and flagellate. The flagellate digests the cellulose in termite guts and Trichonympha, in turn, gains from the host protection from desiccation and predation.

Trichomonas vaginalis parasitizes the human vagina, male urethra and prostate gland. Typically with 4-6 flagella, the key structural feature is a mastigont system (kinetosome, undulating membrane, parabasal body or Golgi apparatus, axostyle and nucleus). Reproduction only by binary fission.

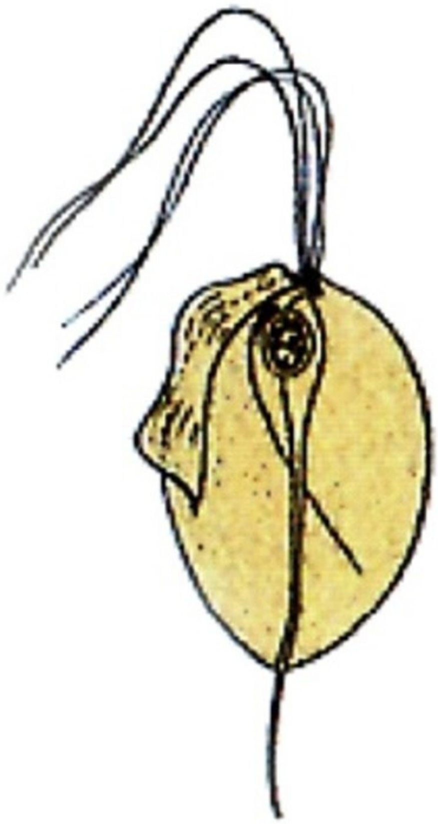

Figure 12. *Trichomonas vaginalis*

Trichomonas vaginalis is a sexually transmitted disease (STD), although transmission by other routes (such as soiled towels) has been documented. There is no cyst in the life cycle, so transmission is via the trophozoite stage. Most people infected with trichomoniasis are asymptomatic. Symptomatic infections are characterized by a white discharge from the genital tract and itching. Diagnosis depends on finding trophozoites in secretions of the genital tract in either, men or women.

2.13. Apicomplexa

In former classifications, most parasitic protists were placed in the class Sporozoa. Now the members of Phylum Apicomplexa include many of the parasitic protists which have the following characteristics: an apical complex of microtubules within the cell and bottle-shaped extrusomes (rhoptries) involved in penetration of or attachment to host. Always have a vesicular nucleus with no cilia or flagella, except in flagellated microgametes in some groups. There are more than 5,000 known species and no known fossil apicomplexans.

However, this group is a very important part of the living biota. Apicomplexans infect both invertebrates and vertebrates; they may be relatively benign or may cause serious illnesses. Species of the genus *Plasmodium* cause malaria in humans and other animals. Other apicomplexans cause serious illnesses, such as coccidiosis and toxoplasmosis, in humans and domestic animals. On the other hand, apicomplexans that infect insects have been used experimentally to control populations of insect pests. Apicomplexans have complex life cycles, and there is much variation among different groups. Both asexual and sexual reproduction are involved.

The most harmful to humans are the Haematozoa, which are endoparasites with an obligatory alternation between the blood of intermediate vertebrate hosts and the gut and body cavity of final arthropod hosts. They have a reduced apical complex. In malaria (*Plasmodium* spp.), cells injected by mosquitoes invade vertebrate liver cells and develop into large (1 mm) schizonts, which divide by multiple asexual fission (schizogony) into thousands (up to 20 000) of merozoites that are released into the bloodstream. Merozoites invade erythrocytes (red blood cells) and undergo further schizogony, producing more merozoites. Merozoites ingest hemoglobin by phagocytosis and ultimately cause the erythrocytes to lyse. Synchronous release of merozoites from erythrocytes produces cell fragments and pigment bodies that cause periodic fever and other symptoms. After about 10 days, some merozoites develop into male and female gamonts. After ingestion with a mosquito's blood meal, gamonts produce micro- and macrogametes in the insect's intestine. Fertilization occurs in the intestine and the motile zygote (ookinete) invades the intestine wall and is encapsulated. The encapsulated ookinete undergoes multiple asexual divisions (sporogony) to produce large numbers of slender sporozoites**.** Sporozoites become infective agents after bursting out of the capsule and migrating via the hemolymph to the mosquito's salivary glands, to await injection again. Some species of *Plasmodium* which cause malaria in humans are*: falciparum; malariae; vivax*. The World Health Organization estimates that more than 2 billion people (about 40 per cent of the world’s population) in 100 countries are at risk. There are at least 300 million cases of acute malaria each year. About 2.7 million people die from malaria each year, most of whom are children. Other high risk groups include pregnant women, non-immune travelers, refugees, displaced persons, or labour forces entering into endemic areas. Countries in tropical Africa bear the brunt of malaria, accounting for more than 90 per cent of the 300 million annual cases of malaria. Malaria is estimated to cost Africa more than US$12 billion annually.

Other parasitic species include: the gregarines, such as *Monocystis:* common parasite of earthworm's receptacles. These parasites live in the gut of annelids and arthropods.. *Toxoplasma* invades cats as final hosts; humans may be infected as intermediate hosts via cat feces or raw meat; pathological symptoms include lymph node diseases and, via infection of pregnant women, severe or fatal toxoplasmosis of the fetus. *Perkinsus* is one of the primary factors that adversely affects the abundance and productivity of the oyster *C. virginica*. Proliferation of the parasite causes systemic disruption of connective tissue and epithelial cells and is correlated with warm summer water temperatures (higher than 20 °C) when mortalities are highest. Mortalities of up to 95 percent have occurred in eastern oysters during the second summer following transfer to disease enzootic areas.

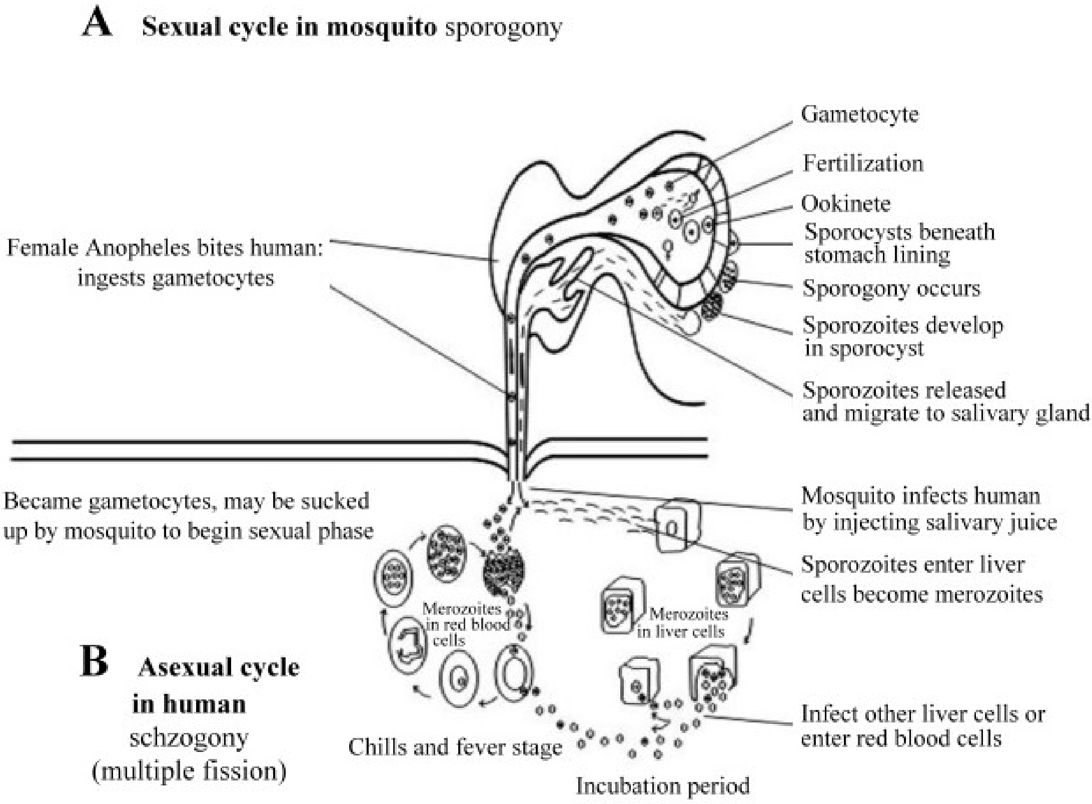

Figure 13. *Plasmodium* life cycle

3. Ciliophora

One of the largest protozoan phyla with 8 000 species. Relatively large from 30 mμ to 2 mm; all or partly covered with cilia identical in fine structure to eucaryote undilopodia. Complex infraciliature of units called kinetids composed of basal bodies (kinetosomes) and rootlets (kinetodesmal fibrils and microtubules). Macro and micronuclei (the latter divide by mitosis). Permanent oral and anal openings. Asexual reproduction via transverse fission and sexual reproduction by conjugation. Chiefly single-celled and heterotrophic. Benthic and planktonic marine, freshwater and soil dwelling, including extreme environments such as Antarctic ice and hot springs. Major subdivisions of ciliates (superclasses and classes) are based chiefly on details of infraciliature structure.

The most important subgroups included in this phylum are:

The heterotrichs: *Stentor*, *Spirostomum* which are often very large, up to 2 mm long; marine and freshwater dwelling, with extensive right-winding oral membranelles. Often contractile and brightly pigmented.

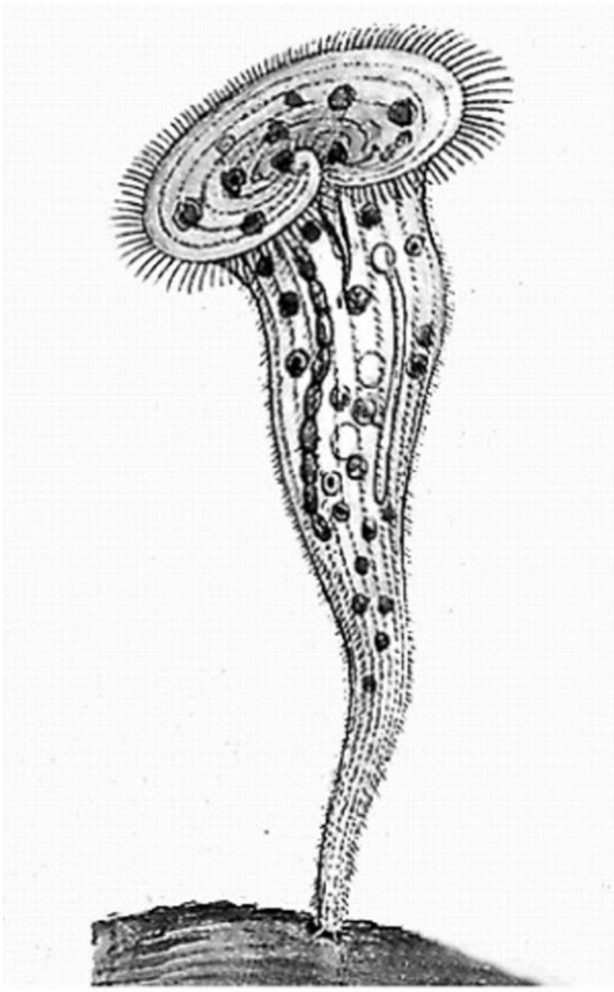

Figure 14. *Stentor*

The oligotrichs: *Halteria, Tinntinus Tintinnopsis.* Mainly marine planktonic; important bacterivores in marine food webs. The cilia are largely restricted to well-developed oral membranelles for feeding and locomotion. Cytoproct absent. Many species are semi-autotrophic or mixotrophic via cultivation of chloroplasts from ingested algae. One subgroup, the tintinnids, produces a protective organic lorica that incorporates foreign particles (e.g., sediment grains, coccoliths); they have a fossil record dating to the Ordovician.

The hypotrichs: *Euplotes, Stylonychia* and *Oxytricha.* Typically flattened ciliates with oral membranelles and ventral locomotor cirri (tufts of cilia fused together to form stiff, motile structures that move as legs).

Figure 15. *Stylonychia*

The haptorids: *Didinium, Dileptus.* Mainly predatory forms with microtubular bundles that strengthen the cytostome. They have extrusive toxicysts.

The trichostomatids are endosymbionts in animal intestines, including ruminants; endobiotic bacteria permit digestion of cellulose. Cilia dense around cytostome, reduced to zones on body. Often bizarre body shapes stabilized by a conspicuous layer of microfilaments. Cytological differentiation sometimes extreme. Mitochondria replaced by hydrogenosomes that produce hydrogen. *Balantidium colli* lives in human cecum and colon, may cause balantidial dysentery.

The suctorians: *Acineta* and *Podophyra.*

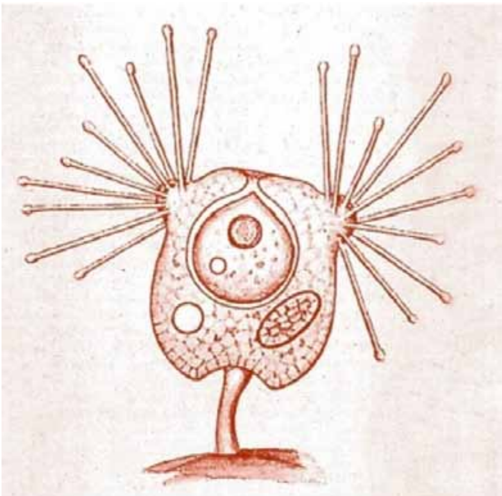

Figure 16. *Acineta*

Chiefly freshwater, often stalked, prey on ciliates and other suctorians. Adults lack cilia; swarmers budded from mother cells have cilia. Knob-tipped feeding tentacles pierce prey cells; prey is "sucked" into tentacles via microtubule activity.

The peniculids: *Paramecium, Tetrahymena.* Present an oral apparatus consisting of a small elastic slit surrounded by a complex of small membranelles. *Paramecium* is probably the most studied protozoan genus, one of its must notorious characteristics is the water expelling vesicles that have a star form.

Figure 17. *Paramecium*

The peritrichs: *Vorticella, Zoothamnium, Carchesium.* Have oral membranelles in wreath around oral end, which can contract and withdraw. Reduced body cilia. Most are stalked, some colonial, some loricate. Often ectosymbionts on marine and freshwater invertebrates.

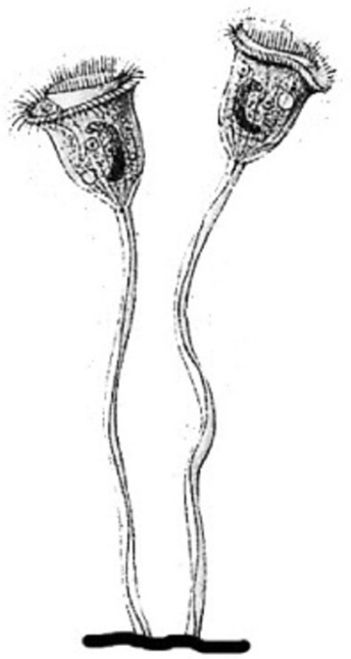

Figure 18. *Vorticella*

Glossary

Axostyle: Internal supporting rod in *Trichomonas* and other zooflagellates.

Binary fission: Duplication of an individual and separation into two individuals by apparent division.

Cilia: Motile hair-like extensions that enable certain protozoa (ciliates) to move.

Commensal: Organisms sharing a common food supply.

Conjugation: Temporary fusion of cells with micronuclei exchange and recombination.

Cyst: A resistant capsule protecting an inactive protozoan.

Cytokinesis: The phase in mitosis or meiosis that involves the division of cytoplasm.

Cytoproct: The anal opening of a protozoan; cytopyge.

Desmonemes: A specialized structure with a threadlike tube coiled like a corkscrew and closed at one end.

Dictyosome: Organelle found in plant cells and functionally equivalent to the Golgi apparatus of animal cells.

Endosymbiotic: Organism living inside an organism of a different species; may be intracellular or intercellular.

Euphotic zone: The surface layer of a body of water in which light is sufficient for photosynthesis. In the sea, the average depth is 100 fathoms.

Filopoda: Thin, faintly granular, branched extensions of cytoplasm that do not fuse to form a network, and extend outward to encase any protruding spines.

Flagella: Relatively long extensions of mastigophorans cells for propulsion by undulations through water.

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