CHAPTER 22 THE PROTISTS

Chapter Outline

22.1 General Biology of Protists

A. Protists are classified in the domain **Eukarya** and the kingdom **Protista.**

B. The **endosymbiotic hypothesis** explains how the eukaryotic cells arose.
   1. It proposes that aerobic bacteria became mitochondria.
   2. Cyanobacteria became chloroplasts after being taken up by eukaryotic cells.
   3. Spirochetes became flagella.
   4. Giardia has two nuclei but no mitochondria; the nucleus therefore came before the mitochondria.
   5. Although cellular, protists are highly complex.
      a. Euglenoids have both flagella and chloroplasts.
      b. Plasmodial slime molds are usually amoeboid; during drought, they produce a sporangium.
      c. Some life cycles are so complex that they require intensive lab study.
   6. Protists use asexual reproduction and, when conditions become stressful, sexual reproduction.
      a. Formation of **spores** allows free-living and parasitic protists to survive hostile environments.
      b. A **cyst** is a dormant cell with a resistant outer covering.
   7. Amoeboids and ciliates are more complex, with organelles not seen among other eukaryotes.
      a. Food is digested in food vacuoles.
      b. Excess water is expelled by contractile vacuoles.

C. Ecological Importance
   1. Some are of great medical importance in causing disease; others are ecologically important.
   2. **Plankton** float near the surface and serve as food for heterotrophic protists and animals.
   3. Plankton that photosynthesize produce much of the oxygen in the atmosphere.
   4. Many protists enter symbiotic relationships; coral reefs rely on symbiotic photosynthetic protists.

D. Evolution of Protists
   1. Multicellular algae are not plants; they do not protect their gametes and zygote from drying out.
   2. None are fungi; those that resemble fungi lack flagella and do not have chitin in their cell wall.
   3. None are animals; the heterotrophic protists do not undergo embryonic development.
   4. Due to complexity, protists may deserve more than a dozen kingdoms.

22.2 Diversity of the Protists

A. The Algae
   1. **Algae** refers to many phyla that carry out photosynthesis and the term does not represent a monophyletic taxon.
   2. At one time, algae were grouped with plants because they have chlorophyll *a* and photosynthesize.

B. The Green Algae
   1. Phylum **Chlorophyta** contains the **green algae**.
   2. They live in the ocean but are more likely found in fresh water and can even be found on moist land.
   3. Green algae are not always green; some have pigments that give them an orange, red, or rust color.
   4. Body organizations include single cells, colonies, filaments and multicellular forms.
   5. Plants are considered to be most closely related to the green algae.

C. *Chlamydomonas*, a Unicellular Green Algae
   1. *Chlamydomonas* is a unicellular green alga less than 25 m long.
   2. It has a cell wall and a single, large, cup-shaped chloroplast with a **pyrenoid** for starch synthesis.
   3. The chloroplast contains a light-sensitive eyespot (stigma) that directs the cell to light for photosynthesis.
   4. Two long whiplike flagella project from the anterior end to propel the cell toward light.
   5. When growth conditions are favorable, *Chlamydomonas* reproduces asexually with **zoospores.**
   6. When growth conditions are unfavorable, *Chlamydomonas* reproduces sexually.
      a. Gametes from two different mating types join to form a zygote.
      b. A heavy wall forms around the zygote; a resistant zygospore survives until conditions are

favorable.
    c. Some are heterogametes similar to sperm and egg that stores food, a condition called **oogamy.**
    d. In most, gametes are identical, a condition called **isogamy.**

D. *Spirogyra*, a Filamentous Green Algae
    1. Cell division in one plane produces end-to-end chains of cells or **filaments.**
    2. *Spirogyra* is a filamentous algae found on surfaces of ponds and streams.
        a. It has ribbonlike spiral chloroplasts.
        b. Two strands may unite in **conjugation** and exchange genetic material, forming a diploid zygote.
        c. The zygotes withstand winter; in spring they undergo meiosis to produce haploid filaments.

E. Multicellular Green Algae
    1. Plants are probably related to green algae because both have a cell wall with cellulose, have chlorophyll *a* and *b*, and store food as starch.
    2. The multicellular *Ulva* is called sea lettuce because of its leafy appearance.
    3. The thallus (body) is two cells thick but can be a meter long.
    4. *Ulva* has an alternation of generations life cycle, as do plants, but the generations look alike.
    5. The gametes look alike (isogametes) and the spores are flagellated.
    6. Stoneworts are green algae that live in freshwater lakes and ponds.
    7. The stonewort *Chara* forms a cell plate during cell division and has multicellular sex organs making plants most closely related to this group.
    8. Chara also has a stemlike body with nodes and internodes; the cells of the body originate from apical meristem, features that are homologous with plants.

F. *Volvox*, a Colonial Green Algae
    1. *Volvox* is a hollow sphere with thousands of cells arranged in a single layer.
    2. *Volvox* cells resembles *Chlamydomonas* cells; a colony arises as if daughter cells fail to separate.
    3. *Volvox* cells cooperate when flagella beat in a coordinated fashion.
    4. Some cells are specialized forming a new daughter colony within the parental colony.
    5. Daughter colonies are inside a parent colony until an enzyme dissolves part of a wall so it can escape.

G. The Red Algae
    1. Red algae (phylum **Rhodophyta**) are chiefly marine multicellular algae that live in warmer seawater.
    2. They are generally much smaller and more delicate than brown algae.
    3. Some are filamentous, but most are branched, having a feathery, flat, or ribbonlike appearance.
    4. Coralline algae are red algae with cell walls with calcium carbonate; they contribute to coral reefs.
    5. Red algae are economically important.
        a. Mucilaginous material in cell walls of *Gelidium* and *Gracilaria* is the source of agar used in drug capsules, dental impressions, cosmetics.
        b. In the laboratory, agar is a major microbiological media, and when purified, is a gel for electrophoresis.
        c. Agar is used in food preparation to keep baked goods from drying and to set jellies and desserts.
        d. Carrageen is an emulsifying agent extracted from *Chondrus crispus* ans used in production of chocolate and cosmetics.

H. The Brown Algae
    1. The phylum **Phaeophyta** includes the **brown algae.**
    2. They range from small forms with simple filaments to large multicellular (50–100 m long) seaweeds.
    3. Brown algae have chlorophylls *a* and *c* and a fucoxanthin that give them their color.
    4. Their reserve food is a carbohydrate called laminarin.
    5. **Seaweed** refers to any large, complex alga.
    6. Their cell walls contain a mucilaginous water-retaining material that inhibits desiccation.
    7. *Laminaria* is an intertidal kelp that is unique among protists; this genus shows tissue differentiation.
    8. *Nereocystis* and *Macrocystis* are **giant kelps** found in deeper water anchored to the bottom by their holdfasts.
    9. Individuals of the genus *Sargassum* sometimes break off from their holdfasts and form floating masses.
    10. Brown algae provide food and habitat for marine organisms, and they are also important to humans.
        a. Brown algae are harvested for human food and for fertilizer in several parts of the world.
        b. *Macrocystis* is a source of **algin**, a pectinlike substance added to give foods a stable, smooth consistency.

11. Most have an alternation of generations life cycle.
12. *Fucus* is an intertidal **rockweed**; meiotic cell division produces gametes and adult is always diploid.

I. The Diatoms
   1. Phylum **Bacillariophyta** contains both diatoms and **golden brown alga**.
   2. Some authorities place the diatoms in their own phylum, the **Bacillariophyta**.
   3. **Diatoms** are the most numerous unicellular algae in the oceans.
   4. They are extremely numerous and an important source of food and O_2 in aquatic systems.
   5. Diatom cell walls consist of two silica-impregnated halves or valves.
      a. When diatoms reproduce asexually, each received one old valve.
      b. The new valve fits inside the old one; therefore, the new diatom is smaller than the original one.
      c. This continues until they are about 30% of their original size.
      d. Then they reproduce sexually; a zygote grows and divides mitotically to form diatoms of normal size.
   6. The cell wall has an outer layer of silica (glass) with a variety of markings formed by pores.
   7. Diatom remains accumulate on the ocean floor and are mined as **diatomaceous earth** for use as filters, abrasives, etc.

J. The Flagellates
   1. Phylum **Pyrrophyta** contains the unicellular **dinoflagellates**.
   2. These algae are bounded by protective cellulose plates.
   3. Most have two flagella.
      a. One lies in a longitudinal groove and acts as a rudder.
      b. The other is located within a transverse groove; beating causes the cell to spin as it moves forward.
   4. Some species of dinoflagellates are heterotrophic; they are parasitic on their host.
   5. They are extremely numerous (30,000 per cubic millimeter) and an important source of ecosystem food.
   6. Under certain conditions, *Gymnodinium* and *Gonyaulax* increase in number enormously and cause a "red tide": they produce a powerful neurotoxin killing fish and causing paralytic shellfish poisoning.

K. The Euglenoids
   1. Phylum **Euglenophyta** includes the **euglenoids**.
   2. Euglenoids are small (10–500 μm) freshwater unicellular organisms.
   3. One-third of all genera have chloroplasts; those that lack chloroplasts ingest or absorb their food.
   4. Their chloroplasts are surrounded by three rather than two membranes.
      a. Their chloroplasts resemble those of green algae.
      b. They are probably derived from a green algae through endosymbiosis.
   5. The **pyrenoid** outside the chloroplast produces an unusual type of carbohydrate polymer (paramylon) not seen in green algae.
   6. They possess two flagella, one of which typically is much longer than the other and projects out of a vase-shaped invagination; it is called a tinsel flagellum because it has hairs on it.
   7. Near the base of the longer flagellum is a red **eyespot** that shades a photoreceptor for detecting light.
   8. They lack cell walls, but instead are bounded by a flexible **pellicle** composed of protein strips side-by-side.
   9. A contractile vacuole, similar to certain protozoa, eliminates excess water.
   10. Euglenoids reproduce by longitudinal cell division; sexual reproduction is not known to occur.

L. The Zooflagellates
   1. Phylum **Zoomastigophora** includes the **zooflagellates.**
   2. These protozoa are covered by a pellicle that is often reinforced by underlying microtubules.
   3. Many are symbiotic.
      a. *Trypanosoma brucei,* a *trypanosome* transmitted by the bite of a tsetse fly, is the cause of African sleeping sickness.
      b. *Giardia lamblia* cysts are transmitted through contaminated water; it causes severe diarrhea.
      c. *Trichomonas vaginalis* is a sexually transmitted organism that infects vagina and urethra of women and prostate, seminal vesicles and urethra of men.

4. Some scientists place all flagellates among protozoa; this would then include both photosynthetic and heterotrophic organisms.

M. Protists with Pseudopods
   1. Protists that move with pseudopods usually live in aquatic environments.
   2. They are part of the **zooplankton,** microscopic floating organisms.
   3. They engulf prey with pseudopods, cytoplasmic extensions formed as cytoplasm streams in one direction.
   4. *Amoeba proteus* is a commonly studied member.
   5. Amoeboids **phagocytize** their food; pseudopods surround and engulf prey.
   6. Food is digested inside food vacuoles.
   7. Freshwater amoeboids have contractile vacuoles to eliminate excess water.
   8. *Entamoeba histolytica* is an amoebic parasite that invades the human intestinal lining.
   9. **Foraminiferans** (phylum Foraminifera) and radiolarians (phylum Actinopoda)
      a. Both are sarcodines with a skeleton called a **test.**
      b. Foraminiferans have a multi-chambered $CaCO_3$ shell; thin pseudopods extend through holes.
   10. **Radiolaria** have a test composed of silica or strontium sulfate.
      a. Most have a radial arrangement of spines.
      b. Pseudopods (actinopods) project from an external layer of cytoplasm and are supported by rows of microtubules.
   11. Tests of dead foraminiferans and radiolarians form deep layers of ocean floor sediment.
   12. Back to the Precambrian, each layer has distinctive foraminiferans which helps date rocks.
   13. Over hundreds of millions of years, the $CaCO_3$ shells have contributed to the formation of chalk deposits (i.e., White Cliffs of Dover, limestone of the great Egyptian pyramids).

N. The Ciliates
   1. Phylum **Ciliophora** contains the **ciliates.**
   2. Ciliates move by coordinated strokes of hundreds of cilia projecting through holes in a semirigid pellicle.
   3. They discharge long, barbed **trichocysts** for defense and for capturing prey; **toxicysts** release a poison.
   4. Most are holozoic and ingest food through a gullet and eliminate wastes through an anal pore.
   5. During asexual reproduction, ciliates divide by transverse binary fission.
   6. Ciliates possess two types of nuclei—a large **macronucleus** and one or more small **micronuclei.**
      a. The **macronucleus** controls the normal metabolism of the cell.
      b. The **micronucleus** is involved in sexual reproduction.
         1) The macronucleus disintegrates and the micronucleus undergoes meiosis.
         2) Two ciliates then exchange a haploid micronucleus.
         3) The micronuclei give rise to a new macronucleus containing only housekeeping genes.
   7. Ciliates are diverse with over 8,000 different species.
      a. Members of the genus *Paramecium* are complex.
      b. The barrel-shaped didiniums expand to consume paramecia much larger than themselves.
      c. *Suctoria* rest on a stalk and paralyze victims, sucking them dry.
      d. *Stentor* resembles a giant blue vase with stripes.

O. The Sporozoans
   1. Phylum **Apicomplexa** contains the nonmotile parasitic **sporozoans**.
   2. The phylum name describes the unique apical complex of organelles.
   3. Their common name recognizes that they form spores at some point in their life cycle.
   4. *Pneumocystis carinii* causes the pneumonia seen primarily in AIDS patients.
      a. During sexual reproduction, thick-walled cysts form in the lining of pulmonary air sacs.
      b. Cysts contain spores that successively divide until the cyst bursts and the spores are released.
      c. Each spore becomes a new organism, reproduces asexually and can enter an encysted sexual stage.
   5. *Plasmodium vivax* causes one type of malaria; it is the most widespread human parasite.
      a. After bite of infected female *Anopheles* mosquito, the parasite eventually invades red blood cells.
      b. Chills and fever appear as red blood cells burst and release toxin into the blood.
      c. Malaria remains a major world disease due to insecticide-resistant strains of mosquitoes and drug-resistant strains of *Plasmodium*.

6. *Toxoplasma gondii* causes toxoplasmosis, particularly in cats but also in humans.
    a. In pregnant women, the parasite can infect the fetus and cause birth defects.
    b. In AIDS patients, it can infect the brain and cause neurological symptoms.

P. The Slime Molds and Water Molds
1. These organisms resemble fungi but all have flagellated cells that fungi never have.
2. Water molds possess a cell wall but it is made of cellulose, not chitin as in fungi.
3. Water molds produce diploid (2n) zoospores and meiosis produces the gametes.
4. The Plasmodial Slime Molds
    a. **Plasmodial slime molds** (phylum Myxomycota) exist as a **plasmodium.**
    b. This diploid multinucleated cytoplasmic mass creeps along, phagocytizing decaying plant material.
    c. Fan-shaped plasmodium contains tubules of concentrated cytoplasm in which liquefied cytoplasm streams.
    d. Under unfavorable environmental conditions (e.g., drought), the plasmodium develops many **sporangia**, called a fruiting body, that produce spores by meiosis.
    e. When mature, spores are released and survive until more favorable environmental conditions return; then each releases a haploid flagellated cell or an amoeboid cell.
    f. Two flagellated or amoeboid cells fuse to form a diploid zygote that produces a multinucleated plasmodium again.
5. The Cellular Slime Molds
    a. **Cellular slime molds** (phylum Acrasiomycota) exist as individual amoeboid cells.
    b. They live in soil and feed on bacteria and yeast.
    c. As food runs out, amoeboid cells release a chemical that causes them to aggregate into a **pseudoplasmodium.**
    d. The pseudoplasmodium stage is temporary; it gives rise to sporangia that produce spores.
    e. Spores survive until more favorable environmental conditions return; then they germinate.
    f. Spores germinate to release haploid amoeboid cells, which is again the beginning of the asexual cycle.
    g. A sexual cycle occurs under very moist conditions.

Q. The Water Molds
1. Phylum **Oomycota** includes the **water molds**.
2. Aquatic water molds parasitize fishes, forming furry growths on their gills, and decompose the fish remains.
3. Terrestrial water molds parasitize insects and plants; a water mold caused the 1840s Irish potato famine.
4. Most water molds are saprotrophic, living off dead organic matter.
5. Water molds have a filamentous body but cell walls are composed largely of cellulose.
6. During asexual reproduction, they produce diploid motile spores (2n zoospores) with flagella.
7. Unlike fungi, the adult is diploid; gametes are produced by meiosis.
8. Eggs are produced in enlarged tips called oogonia.