

CHAPTER 35: PROTISTS

CHAPTER SYNOPSIS

Eukaryotes likely arose through the process of endosymbiosis. *Pelomyxa* is a model for the first eukaryote as it is unlike any other eukaryote. It lacks mitochondria, though it contains two other kinds of bacteria that perform the same function. To a great extent it resembles archaebacteria more than it does eukaryotes. Early eukaryotes probably engulfed symbiotic, aerobic eubacteria similar to today's nonsulfur purple bacteria. Mitochondria possess two membranes, the outer one derived from the host's endoplasmic reticulum. Chloroplasts are another result of endosymbiosis, but with a photosynthetic bacteria as the source. As there are three distinct classes of chloroplasts, they may have evolved through different symbiotic events.

The kingdom Protista is the most diverse kingdom of living organisms. Certain of its groups have historically been placed in the plant, animal, or fungal kingdoms. The traditional arrangement for the protists has been artificial with all algae grouped together as photosynthesizers, all heterotrophs grouped as protozoa, and the absorbers grouped together as fungus-like protists. Some protists are surrounded by only a plasma membrane, others form glassy shells of silica around themselves. Many have flagella or cilia, others move by pseudopodia. Some protists form cysts to survive inhospitable conditions. Many are phototrophic making their own food through photosynthesis. Heterotrophs obtain energy from organic sources and are classified as phagotrophs or osmotrophs. Most protists reproduce regularly by asexual processes, utilizing sexual reproduction only in times of stress. The fifteen phyla of protists are presented here in five groups arranged by several factors including: presence or absence of cilia or flagella, presence of and kinds of pigments, types of mitosis, kinds of cristae in the mitochondria, molecular genetics of the ribosomal "S" subunit, presence and kinds of inclusions, overall body form, presence of body armor, and the modes of nutrition and locomotion.

The phyla Rhizopoda, Foraminifera, and Actinopodia are included in the group of heterotrophs lacking locomotor apparatus. The

rhizopods include the familiar *Amoeba* and are most notable for their characteristic pseudopodia. These large, blunt cytoplasmic projections are involved in locomotion and obtaining food. Actinopodia, on the other hand, have needlelike pseudopodia that project through their glassy skeletons. Foraminifera also have tests made of organic and inorganic materials and are riddled with pores. Cytoplasmic extensions called podia extrude through the pores. They are used in swimming, gathering inorganic materials for the test, and for feeding.

There are numerous photosynthetic protists. Flagellated forms include the Pyrrhophyta (dinoflagellates) and the Euglenophyta (euglenoids). The former have a distinctive biochemistry and protective plates composed of a cellulose-like material. Some forms are symbionts in animals, while others cause the periodic red tides. Euglenoids are mostly small, freshwater organisms with a thin, flexible pellicle and characteristic eyespot. The silica-shelled diatoms are members of the phylum Chrysophyta. They are grouped based on the radial or bilateral symmetry of their shells. These organisms undergo unique forms of asexual and sexual reproduction. The algae include the phyla Rhodophyta (red algae), Phaeophyta (brown algae), and Chlorophyta (green algae). Chloroplasts containing chlorophyll *a* and *b* and carotenoids are found in euglenoids and green algae, the likely ancestor of all plants. Red algae possess chloroplasts with chlorophyll *a*, carotenoids, and phycobilins that are distinctly related to cyanobacteria. Brown algae, diatoms, and dinoflagellates possess chlorophyll *a* and *c*, carotenoids, and yellow-brown pigments.

The Zoomastigophora are heterotrophic protists with flagella. Some are free-living, others are parasitic, many cause disease in humans. Some are found in the gut of wood-eating insects, while choanoflagellates appear to be ancestors of sponges, and likely all animals. Ciliates are members of the phylum Ciliophora and are readily characterized by their hairlike cilia. Ciliates have a tough outer pellicle and possess

specialized vacuoles involved in food ingestion and water regulation. Members of this group have specialized organelle systems with a complexity rivaling that of multicellular organisms. The classic ciliate is *Paramecium*. Sporozoans are non-motile spore-formers that belong to the phylum Apicomplexa, a group with extremely complex life cycles with alternating sexual and asexual phases. Many members of this phylum cause diseases, most notably *Plasmodium*, which causes malaria. Sporozoans produce thick-walled cysts that enable them to survive in very inhospitable environments.

Three phyla are grouped as heterotrophs with restricted mobility. The Oomycota include water molds, white rusts, and downy mildews. They have been mistaken for fungi due to their characteristic hyphae. The cellular slime molds (Acrasiomycota) are more closely related to amoebas than to fungi. They have a distinct life cycle that makes them ideal for studying differentiation. The plasmodial slime molds (Myxomycota) consist of a streaming plasmodium that engulfs bacteria and organic matter. They form distinctive sporangia under adverse conditions and exposure to light.

CHAPTER OBJECTIVES

- ä Explain how endosymbiosis is involved with the evolution of eukaryotic organisms.
- ä Understand why the protists are the most diverse eukaryotic kingdom.
- ä Know the nine major shared characteristics of the five groups of protists.
- ä Indicate the major characteristics of Rhizopoda, Foraminifera, and Actinopodia.
- ä Contrast the flagellated Pyrophyta and Euglenophyta to other photosynthetic protists.
- ä Compare the diatoms and golden algae in terms of anatomy, cell wall composition, and chloroplasts.
- ä Describe the primary characteristics of the brown and red algae.
- ä Explain the development of multicellularity using members of the phylum Chlorophyta as examples.
- ä Delineate the three types of chloroplasts and the group(s) of Protists with which they are connected.
- ä Understand the importance of the Zoomastigophora and the Ciliophora.
- ä Indicate the major characteristics of Sporozoa.
- ä Know why the Acrasiomycota are unique among the protists.
- ä Explain why Myxomycota and Oomycota are significantly different from members of the Fungi.

KEY TERMS

antheridium
binary fission
budding
conjugation
cyst
cytoproct
food vacuole
gametangium (gametangia)
gametic meiosis
gametocyte
gametophyte
holozoic feeder
hypha (hyphae)
intermediary meiosis
kelp

macrocyst
macronuclei
merozoite
micronuclei
oocyst
oogonium
oospore
osmotroph
pellicle
phagosome
phagotroph
phototroph
plasmodium
podia
pseudopod

reservoir
saprobe
saprozoic feeder
schizogony
sorocarp
sporangium
sporophyte
sporozoite
stigma
test
zoospore
zooxanthellae
zygospore
zygotic meiosis

CHAPTER OUTLINE

35.0 Introduction

- I. PROTIST EVOLUTION REPRESENTED A VERY DIFFERENT KIND OF LIFE fig 35.1
 - A. First Fossils Appear in Rocks 1.5 billion years old
 - B. Eukaryotes Are Flexible and Adaptable

35.1 Eukaryotes probably arose by endosymbiosis

- I. ENDOSYMBIOSIS
 - A. A Model for the First Eukaryote
 - 1. *Pelomyxa palustris* fig 35.2
 - a. Single-celled, nonphotosynthetic organism
 - b. Larger than bacteria, contain complex system of internal membranes
 - 2. Cells are unlike any other eukaryote
 - a. Lacks mitochondria, does not undergo mitosis
 - b. Nuclei divide by pinching apart, like bacteria
 - c. Contains two kinds of bacteria that may play same role as mitochondria
 - 3. Assigned own phylum, Caryoblastea
 - 4. Resembles archaebacteria more than eukaryotes
 - B. Origin of Eukaryotic Mitochondria fig 35.3
 - 1. Were symbiotic, aerobic eubacteria engulfed by eukaryote ancestors
 - 2. Characteristics of mitochondria
 - a. Sausage-shaped, bacteria-sized organelles, 1 to 3 micrometers long
 - b. Bounded by two membranes
 - 3. Closest relatives today are nonsulfur purple bacteria, carry out oxidative metabolism
 - 4. Derivation of mitochondrial membranes
 - a. Outer membrane is smooth, from host's endoplasmic reticulum
 - b. Inner membrane is folded like membranes of nonsulfur purple bacteria
 - c. Oxidative metabolism proteins embedded within inner membrane
 - 5. Mitochondrial genome
 - a. Most genes transferred to chromosomes of host cell over 1.5 billion years
 - b. Few genes retained on circular mitochondrial molecule of DNA
 - 1) Similar to bacterial DNA
 - 2) Encode proteins for oxidative metabolism
 - 3) Transcribed within mitochondrion, using mitochondrial ribosomes
 - 6. Replication of mitochondria
 - a. Divide by simple fission like bacteria
 - b. Process directed by nuclear genes
 - c. Unable to grow mitochondria in cell-free culture
 - 7. Theory of endosymbiosis well-accepted as established fact
 - C. Evolution of Eukaryotic Mitosis
 - 1. Different forms exist, mechanism did not evolve all at once
 - a. Process in some fungi and protists is unusual
 - 1) Nuclear membrane does not dissolve
 - 2) Mitosis confined to nucleus
 - b. Process may be intermediate or just different
 - 2. No appropriate fossils exist

D. Endosymbiosis Is Not Rare

1. Chloroplasts are another example of symbiosis with bacteria
 - a. Derived from symbiotic photosynthetic bacteria
 - b. Possess complex inner membranes and circle of DNA
2. Centrioles resemble spirochete bacteria
 - a. Associated with assembly of microtubules
 - b. Possess bacteria-like DNA that directs production of centriole structural proteins
3. Chloroplasts may have evolved through different symbiotic events
 - a. Three distinct classes of chloroplasts resemble different bacterial ancestors
 - 1) Red algae pigments are similar to cyanobacteria
 - 2) Plant and green algae resemble *Prochloron* bacteria
 - 3) Brown algae and other photosynthetic protists resemble third group
 - b. Compare DNA of chloroplasts
 - 1) Suggest single origin of chloroplasts
 - 2) Different postendosymbiotic histories
 - 3) Different genes relocated to nucleus, lost or modified

35.2 The kingdom Protista is by far the most diverse of any kingdom

I. THE CHALLENGE OF CLASSIFYING THE PROTISTS

A. Most Diverse of the Four Kingdoms

1. Contains unicellular, colonial, and multicellular groups
2. Is considered an artificial group, lumped together by convenience
 - a. Not representative of any evolutionary relationships
 - b. Phyla are distinctly related at most
3. Molecular examination providing new insights into relationships
4. Still in great deal of flux as to classification

B. Will Consider Protista as One Diverse, Unified Group

1. Protist relationships are becoming more evident
2. Traditional arrangement will likely be replaced within a few years

fig 35.4

II. GENERAL BIOLOGY OF THE PROTISTS

A. Unity Due to Negative Characteristic

1. Not classified as plant, animal, or fungus
2. Are mostly unicellular and microscopic
 - a. May be colonial or multicellular
 - b. Some as large as trees
3. Represent all symmetries, exhibit all types of nutrition

fig 35.5

B. The Cell Surface

1. Amoebas are surrounded only by plasma membranes
2. Algae and molds encased in strong cell walls
3. Diatoms and forams secrete glassy shells of silica

C. Locomotor Organelles

1. Many move by flagellar motions
 - a. Some have one or more flagella
 - b. Others have banks of multiple flagella called cilia that create water currents
2. Others exhibit pseudopodial movement
 - a. Pseudopodia in amoeba are large blunt extensions of cell body called lobopodia
 - b. Thin branching pseudopods are called filopodia

- c. Long, extremely thin pseudopods are called axopodia
 - 1) Supported by axial rods of microtubules
 - 2) Can be extended or retracted
 - 3) Tips can adhere to adjacent surfaces
 - 4) Cell moves by a rolling motion

D. Cyst Formation

- 1. Cysts formed to survive inhospitable conditions
 - a. Dormant form of cell with resistant outer covering
 - b. Cell metabolism is nearly completely shut down
- 2. Parasitic amoeba resistant to gastric juices, but cannot survive drying or heat

E. Nutrition

- 1. Phototrophs are photosynthetic autotrophs
- 2. Heterotrophs obtain energy from organic molecules
 - a. Phagotrophs or holozoic feeders ingest visible particles of food
 - b. Osmotrophs or saprozoic feeders ingest food in soluble form
- 3. Phagotrophs produce intracellular vesicles: Food vacuoles or phagosomes
 - a. Fuse with lysosomes containing digestive enzymes
 - b. Digested molecules absorbed across vacuole membrane
 - c. Food vacuole decreases in size

F. Reproduction

- 1. Generally reproduce asexually
- 2. Sexual reproduction occurs only in time of stress
- 3. Asexual reproduction involved mitosis, but may be quite different from that of animals
 - a. Nuclear membrane may persist throughout mitosis
 - b. Microtubular spindle forms within nucleus
- 4. Asexual reproduction may involve spore formation or fission
 - a. Most common kind of fission is binary fission, production of two equal cells
 - b. Called budding if one is larger "parent" and other is small and grows to adult size
- 5. Multiple fission is called schizogony
 - a. Fission preceded by several nuclear divisions
 - b. Produces several individuals simultaneously
- 6. Sexual reproduction may include gametic meiosis
 - a. Includes ciliates and some flagellates
 - b. Occurs just before gamete formation
- 7. Zygotic meiosis occurs in sporozoans
 - a. Occurs directly after fertilization
 - b. All individuals are haploid until next zygote is formed
- 8. Intermediate meiosis occurs in algae
 - a. Produces alternation of generation similar to plants
 - b. Significant portions of life cycle spent as haploid and diploid

35.3 Protists can be categorized into five groups

I. FIVE GROUPS OF PROTISTS

A. Fifteen Distinct Phyla of Protists

- 1. Historical, traditional artificial arrangement
 - a. Photosynthesizers = algae
 - b. Heterotrophs = protozoa
 - c. Absorbers = fungi-like protists

2. Present protists in five groups by major shared characteristics fig 35.6
 - a. Presence or absence of cilia or flagella
 - b. Presence and kinds of pigments
 - c. Type of mitosis
 - d. Kinds of cristae present in mitochondria
 - e. Molecular genetics of ribosomal "S" subunit
 - f. Presence and kinds of inclusions
 - g. Overall body form
 - h. Presence of shell, test, or other body armor
 - i. Modes of nutrition and movement
- B. Other Classification Schemes Are Possible
1. Molecular analysis presents clearer picture
 2. More suitable groupings will arise with further research
 3. Major characteristics of 15 phyla tbl 35.1

II. HETEROTROPHS WITH NO PERMANENT LOCOMOTOR APPARATUS

- A. Rhizopoda: The Amoebas
1. Fresh and salt water specimens, abundant in soil, parasites of animals
 2. Reproduction by fission, direct division into two cells
 3. Lack cell walls, flagella, meiosis, and sexual reproduction
 4. Undergo mitosis, have typical eukaryotic spindle apparatus
 5. Locomotion via pseudopods fig 35.7
 - a. Cytoplasmic projections that also engulf food particles
 - b. Involved with microfilaments of actin and myosin
 - c. Form at any point, can move in any direction
 6. Parasitic species may form resistant cysts
 - a. *Entamoeba histolytica* : Causes amoebic dysentery
 - b. Cysts resist digestion by host
 - c. Mitotic divisions occur in cysts, release four, eight, or more amoebas
 - d. Primary infection in intestines, moves to liver and rest of body
 - e. Cysts dispersed in feces, transmitted via food, water, flies, direct contact
 - f. Spread of disease limited by proper sanitation and hygiene
- B. Actinopoda: The Radiolarians
1. Member of phylum Actinopodia secrete glassy skeletons of silica
 2. Organisms have distinct bilateral or radial symmetry
 3. Pseudopodia extrude along spiky projections of the skeleton fig 35.5
 4. Cytoplasmic projections supported by microtubules
- C. Foraminifera: Forams
1. Heterotrophic, marine organisms
 2. Variable in size
 3. Possess pore-studded shells called tests
 - a. Organic matter reinforced with inorganic material
 - b. Use sand grains, echinoderm plates, spicules from sponges
 - c. Shells may appear quite different from one another
 4. Most live in sand or attach to other organisms, 2 families are free-floating, planktonic
 - a. Tests are usually multichambered, often spiral shaped
 - b. Cytoplasmic extensions called podia extrude through pores in test fig 35.9
 - c. Podia used for swimming, gathering material for test, feeding
 - d. Eat a wide variety of organisms
 5. Complex life cycles with sporic meiosis

6. Provides extensive fossil record
 - a. Used as geological markers
 - b. Used as guide to oil-bearing strata
7. Form limestone structures like White Cliffs of Dover fig 35.10

III. PHOTOSYNTHETIC PROTISTS

A. Pyrrhophyta: The Dinoflagellates

1. Unicellular, photosynthetic, with 2 flagella, mostly marine organisms
2. Some planktonic forms are luminescent
3. Distinctive flagella, coat, and biochemistry are distinctive
 - a. Not directly related to other protists
 - b. Protective plates composed of a cellulose-like material fig 35.11
 - c. Two flagella beat in grooves formed at junction of plates
 - 1) One encircles body like a belt, other is perpendicular to first
 - 2) Organism spins like a top as flagella beat in grooves
4. Most have chlorophyll *a* and *c* along with carotenoids
 - a. Resemble diatoms and brown algae in chloroplast biochemistry
 - b. May have formed through endosymbiotic relationships with those groups
5. Some forms are symbionts in animals
 - a. Sea anemones, mollusks, and corals
 - b. Called zooxanthellae, lack characteristic cellulose plates and flagella
 - c. Provide hosts with nutrients
 - d. Primary factor for high productivity of corals in nutrient poor water
6. Periodic population explosions cause blooms and red tides
 - a. Pigments in individual cells responsible for color of water
 - b. Produce toxins harmful to many vertebrates
 - c. *Pfiesteria piscicida* is a carnivorous, ambush predator
 - 1) Stuns fish with its toxins
 - 2) Feeds on prey's body fluids
7. Reproduce primary by asexual cell division
 - a. Sexual reproduction does occur under starvation conditions
 - b. Mitosis is unique as it occurs within nucleus
 - 1) Chromosomes are permanently condensed
 - 2) Divide longitudinally within permanent nuclear envelope
 - 3) After chromosome duplication, nucleus divides into 2 daughter nuclei
 - c. Unique chromosome: DNA not complexed with histone proteins
 - 1) In other eukaryotes, DNA is complexed with histones, forms nucleosomes
 - 2) Unknown how dinoflagellates maintain chromosome integrity

B. Euglenophyta: The Euglenoids

1. Mostly fresh water organisms
2. Group has characteristics of plants and animals
 - a. Some specimens have chloroplasts and are photosynthetic
 - b. Others lack chloroplasts and are heterotrophic
 - c. Some can transform from autotrophs to heterotrophs and back, depending on light
3. Small size with variable form
 - a. Thin flexible pellicle lies within cell membrane
 - b. Composed of interlocking proteinaceous strips
4. Reproduction via mitotic cell division
 - a. Nuclear envelope remains intact through entire process
 - b. No known sexual reproduction
5. Model specimen is *Euglena* fig 35.12
 - a. One short, one long flagellum attached to flask-shaped reservoir

- 1) Long flagellum has row of short hairlike projections along one side
- 2) Short flagellum does not emerge from reservoir
- b. Contractile vacuoles collect excess water, pump it out reservoir
- c. Has light sensitive stigma
- d. Has numerous small chloroplasts with chlorophylls *a*, *b*, and carotinoids
 - 1) Probable common origin of chloroplasts of euglena and green algae
 - 2) Euglena may have acquired chloroplasts by ingesting green algae

C. Chrysophyta: The Diatoms and Golden Algae

1. The Diatoms

- a. Diatoms are photosynthetic, unicellular organisms
 - 1) Double shells of opaline silica
 - 2) Resemble box with lid
- b. Chloroplasts resemble that of dinoflagellates and brown algae
 - 1) Chlorophylls *a* and *b*, carotinoids
 - 2) Groups are dissimilar, probably do not share immediate common ancestor
- c. Produce unique carbohydrate called chrysolaminarin along with golden algae
- d. Well-represented in living and fossil specimens
 - 1) Fossils produce thick sediments of diatomaceous earth
 - 2) Used as abrasive or paint additive
- e. Occur in plankton and attached to submerged objects in shallow water
- f. Some move by secretions produced from groove along each shell
- g. Grouped by radial or bilateral symmetry fig 35.13
 - 1) Shells are rigid
 - 2) Asexual reproduction separates shell halves
 - 3) Each half produces new shell within old one
 - 4) Organisms and shells get smaller with each consecutive division
 - 5) When size is too small, cell slips shell and grows to full size, makes new shell
- h. Individuals are diploid, meiosis occurs more frequently under starving conditions
 - 1) Marine diatoms produce multiple sperm or single egg
 - 2) Freshwater diatom gametes are amoeboid and similar in appearance

2. The Golden Algae

- a. Named for yellow and brown carotenoid pigments, xanthophyll accessory pigments
- b. Unicellular, often colonial, found in freshwater
- c. Have two flagella, both attached to same end of cell
- d. Form resistant cysts when ponds dry out in summer, viable cells emerge when wetter

D. Rhodophyta: The Red Algae

1. Most common coastal seaweeds
2. Chloroplasts related to cyanobacteria
 - a. Possess phycoerythrin, phycobilin pigment
 - b. Chlorophyll *a* and phycobilins, like cyanobacteria
 - c. Cyanobacteria were likely candidates for symbiotic events
3. Primarily multicellular
4. Body form composed of complex, interwoven filaments
5. Often incorporate sulfated polysaccharides like agar, carrageenan
6. Economic importance
 - a. Agar used as laboratory medium, base for cosmetics
 - b. Prevent baked goods from drying out, temporary preservative for meat and fish
 - c. Carrageenan stabilizes paints, cosmetics, and ice cream
 - d. Nori cultivated for human consumption
7. Complex life cycles involve sporic meiosis
8. Completely lack flagella, cilia, and centrioles at all stages
9. May be one of most ancient groups of eukaryotes, along with fungi

E. Phaeophyta: The Brown Algae

1. Mostly multicellular marine organisms
2. Conspicuous seaweeds, include kelps fig 35.14
 - a. Fast growing and photosynthetically productive
 - b. Possess flattened blade, stalks, and anchoring base
3. Largest specimens in genera like *Macrocystis*
 - a. Some specimens grow as large as 100 meters in length
 - b. Flattened blades help kelp float on top of water
 - c. Base anchored tens of meters below
 - d. *Sargassum* also ecologically important
 - e. Exhibit complex internal differentiation of conducting tissues
4. Exhibit alternation of generations
 - a. Diploid sporophyte: Large, conspicuous kelp-like form
 - b. Haploid gametophyte: Small, filamentous form
 - c. Sporophytes produce sporangia, after meiosis produces spores
 - d. Spores divide by mitosis, give rise to gametophytes
 - e. Two different gametophytes, produce either male or female gametes
 - f. Gametes fuse producing a zygote that becomes the sporophyte

F. Chlorophyta: The Green Algae

1. Varied group
 - a. Represented by aquatic and semiterrestrial habitats
 - b. Unicellular and multicellular forms
 - c. Generally microscopic with few macroscopic forms, like *Ulva* fig 35.16
2. Ancestors of all plants were multicellular green algae
 - a. Have similar chloroplasts
 - b. Contain chlorophylls *a* and *b*, carotinoids
3. Well-known genus is *Chlamydomonas* fig 35.15
 - a. Microscopic, unicellular, and biflagellated
 - b. Light sensitive eyespot orients cell for swimming
 - c. Most individuals are haploid
 - d. Reproduces asexually by cell division
 - e. In sexual reproduction two fuse to form diploid zygote with four flagella
 - 1) Zygote forms resting stage called zygospore
 - 2) Meiosis occurs at end of resting stage, produces four haploid cells
4. Evolutionary specialization in *Chlamydomonas*-like cells
 - a. Nonflagellated *Chlorella*
 - 1) Reproduces only asexually
 - 2) Possible use as food source for humans and other animals
 - b. Motile, colonial forms leading to *Volvox* fig 35.1
 - 1) Specialized reproductive cells give rise to new colonies
 - 2) Have definite anterior and posterior ends
 - 3) Flagella beat to rotate colony clockwise
 - 4) Division of labor among different types of cells in colony
5. Other growth forms
 - a. Filamentous algae: *Spirogyra*
 - 1) Differ substantial from rest of green algae
 - 2) Sometimes placed in separate phylum, new research very revealing
 - b. Sheet-like algae: *Ulva* fig 35.16
 - 1) Attaches to substrate with basal cell protuberances
 - 2) Exhibits sporic meiosis and alternation of generations fig 35.16
 - 3) Haploid gametophytes and diploid sporophytes resemble one another

- c. Stoneworts: *Chara* and *Nitella*
 - 1) Complex forms, have whorled branches
 - 2) Reproductive gametangia are complex and multicellular
 - 3) Abundant in brackish water, common fossils

IV. HETEROTROPHS WITH FLAGELLA

- A. Zoomastigophora: The Zoomastigotes
 - 1. Unicellular, heterotrophic, highly variable in form fig 35.17
 - 2. Possess one to thousands of flagella
 - 3. Free-living and parasitic forms
 - 4. Many reproduce only asexually, some reproduce sexually
 - 5. One group alternates between amoeboid and flagellated stages
 - 6. Order kinetoplastids includes pathogens like *Trypanosoma* and *Crithidia* fig 35.17c
 - 7. Many trypanosomes are human pathogens fig 35.18
 - a. Cause sleeping sickness, East Coast fever, Chagas' disease
 - b. Spread by various insects, such as sand flies, tsetse flies, and assassin bugs
 - c. Attempts to produce vaccine via genetic engineering
 - 1) Difficult due to constant changes in glycoprotein coat
 - 2) Caused by gene recombination during asexual cycle
 - d. Release sterile flies to impede reproduction of populations
 - e. Cow-scented, cloth traps are laced with insecticide
 - 8. Other species inhabit guts of wood-eating insects
 - a. Possess enzymes capable of digesting wood
 - b. Provide food for host
 - 9. Choanoflagellates are ancestors of sponges and likely all animals
 - a. Possess single flagellum, funnel-shaped contractile collar
 - b. Feed on bacteria strained out by collar
 - 10. Hiker's Diarrhea
 - a. Caused by *Giardia lamblia*, found throughout world fig 35.19
 - 1) Occurs in water, infects wild and domesticated animals, humans
 - 2) May appear in city water supplies, requires boiling water to kill
 - b. May cause nausea, cramps, bloating, vomiting, diarrhea
 - 1) No longer thought to be harmless
 - 2) May infect 16 million Americans
 - c. Lives in upper small intestine of host
 - 1) Form is motile, cannot live outside body
 - 2) Spreads as cysts in feces, can survive for months in cool water
 - 3) Resistant to treatment with chlorine and iodine
 - 4) Spread by human pollution
 - 5) Good sanitation necessary when in wilderness
 - a) Dogs should be kept out of pristine areas, contract and spread disease
 - b) Must filter drinking water with micropore filter or boil for one minute
- B. Ciliophora: The Ciliates
 - 1. Unicellular and heterotrophic
 - 2. Have large numbers of characteristic cilia fig 35.20
 - a. Arranged in longitudinal rows or spirals
 - b. Coordinated beating provides motility to cells
 - c. Often fuse to form structures modified for feeding or locomotion
 - 3. Outer pellicle is tough but flexible
 - 4. Two types of nuclei fig 35.21
 - a. Micronuclei contain normal diploid chromosomes
 - 1) Divide by meiosis

- 2) Undergo genetic recombination
- b. Macronuclei contain genes for routine cellular activities
 - 1) Derived from certain micronuclei in complex series of steps
 - 2) Divide by elongating and constricting
- 5. Specialized vacuoles ingest food and regulate water fig 35.21
 - a. Food enters through gullet and passes into vacuoles
 - b. Digestion occurs, wastes empty via cytoproct
 - c. Contractile vacuoles function to regulate water balance, expand and contract
- 6. Non-sexual reproduction by transverse fission fig 35.22a
- 7. Sexual reproduction in *Paramecium* called conjugation fig 35.22b,c
 - a. Two different mating types (*odd* and *even*) exchange pair of haploid micronuclei
 - b. Macronucleus in each individual disintegrates
 - c. New diploid micronucleus undergoes mitosis, forms 2 identical micronuclei
 - d. Replications of one of the micronuclei reconstitutes macronucleus
- 8. Progeny undergo 50 asexual divisions before they can conjugate
 - a. Biological clocks are then restarted for next conjugation event
 - b. After 600 asexual divisions, proteins around gullet lost
 - c. Can no longer recognize sexual mating partner
 - d. Death follows 100 divisions later
 - e. Events unknown, associated with accumulation of a protein

V. NONMOTILE SPORE-FORMERS

A. Apicomplexa: The Sporozoans

- 1. Nonmotile, spore-forming animal parasites
- 2. Exhibit fibrils, microtubules, vacuoles, and organelles at one end
- 3. Have complex life cycles with sexual and asexual phases
 - a. Exhibit both haploid and diploid generations
 - b. Both generations also reproduce by mitosis to increase numbers
 - c. Fusion of gametes produces a thick-walled cyst, the oocyst
 - d. Meiotic divisions in oocyst produce infective haploid spores, sporozoites
- 4. Common example, *Plasmodium* causes malaria fig 35.23
 - a. Sporozoite stage carried by *Anopheles* mosquito
 - b. Sporozoites injected into bloodstream, travel to liver, divide asexually
 - c. Become merozoites and reinvade liver cells or return to bloodstream
 - d. Invade red blood cells, cause them to rupture, release toxic substances
 - e. Some merozoites develop into male or female gametocytes
 - f. Extracted by mosquito, produce sperm or eggs
 - g. Fuse, form oocysts that undergo mitosis to form new sporozoites
- 5. Malaria
 - a. One of the most serious diseases in the world, 500 million infected at any one time
 - 1) Kills most children who contract it, 2 million humans die each year
 - 2) Symptoms include chills, fever, sweating, enlarged spleen, confusion, thirst
 - 3) Victim may die of anemia, kidney failure, brain damage
 - 4) May be controlled by victim's immune system, drugs
 - b. Eradication of malaria
 - 1) Elimination of mosquito vectors by use of DDT
 - a) Cannot use DDT in U.S.
 - b) Effectiveness is dropping
 - c) Potential environmental problems
 - 2) Development of drugs to poison parasites
 - 3) Development of vaccines
 - c. Large number of new cases due to drug resistant strains
 - d. Genetic engineering has developed antibodies to parasites

6. Vaccines against malaria
 - a. Three stages of *Plasmodium* make three antigens, sensitive to three antibodies
 - b. Vaccine against sporozoites may not make very effective vaccine
 - 1) Travel rapidly to liver, no longer exposed to antibodies
 - 2) Multiply readily, even one will cause disease
 - c. Compound vaccine most effective, hard to develop
 - d. Experimental vaccine developed in 1997
 - 1) Induces immune system to produce defenses to destroy parasite in future infections
 - 2) Six out of seven vaccinated individuals did not get malaria when exposed

VI. HETEROTROPHS WITH RESTRICTED MOBILITY

A. Oomycota

1. Include water molds, white rusts, and downy mildews
2. Parasites or saprobes
3. Mistakenly classified with fungi
 - a. Cell walls are composed of cellulose or similar polymers
 - b. Fungi cell walls composed of chitin
 - c. Gametic meiosis produces a diploid phase (unlike fungi)
 - d. Exhibit normal mitosis (mitosis in fungi is unusual)
4. Possess filamentous structures called hyphae
5. Live in freshwater or soil, many are plant or animal parasites
6. Exhibit unique sexual reproduction
 - a. Zoospores have two unequal flagella, one directed forward, other backward
 - b. Spores produced asexually in sporangium
 - c. Female gametangium called oogonium with one to eight eggs
 - d. Male gametangium called antheridium with numerous male gametes
 - e. Fusion produces zygote that becomes thick-walled oospore
7. Typical water mold: *Saprolegnia* fig 35.24
8. Important plant pathogens
 - a. Downy mildew of grapes
 - b. Late blight of potatoes caused Irish potato famine

B. Acrasiomycota: The Cellular Slime Molds

1. Once thought to be related to fungi
 - a. Most closely related to amoebas
 - b. Have certain characteristics that make them distinct
2. Common in fresh water, damp soil, rotting vegetation
3. Important group for studies on differentiation fig 35.25
4. Presentation of life cycle
 - a. Individuals behave as individual amoebas
 - b. At certain phase, cells aggregate into motile slug
 - c. Transforms into sorocarp, amoebas encyst as spores
 - d. Some amoebas fuse sexually forming macrocysts with diploid nuclei
 - e. Zygotic meiosis occurs in macrocysts after a short period
 - f. Other amoebas released directly to reaggregate into new slug
5. Study chemical signals in development and differentiation in *Dictyostelium*
 - a. Aggregation occurs when bacteria in area are eaten and starvation ensues
 - b. Induced by pulses of cyclic adenosine monophosphate (cAMP) secreted by cells
 - c. Spores differentiate in terminal portion of sorocarp
 - d. Spores released, can release new amoebae to reinitiate cycle

- C. Myxomycota: The Plasmodial Slime Molds
1. Consist of streaming plasmodium fig 35.26
 - a. Feeding phase may be yellow, orange, or other color
 - b. Cytoplasm exhibits conspicuous streaming
 - c. Engulf and digest bacteria, yeasts, bits of organic matter
 - d. Lack dividing cell walls, thus multinucleate
 2. Nuclei undergo mitosis in synchrony, nuclear envelop breaks down in late anaphase or telophase
 3. Lack centrioles
 4. No strong evidence indicating they are related to cellular slime molds
 5. Forms sporangium under adverse conditions fig 35.27
 - a. Spores may be diploid or haploid
 - 1) If diploid, meiosis occurs within 24 hours of formation
 - 2) Three of four nuclei disintegrate, leaving one haploid nucleus
 - b. Resistant spores survive years if dry
 - c. With favorable conditions, release amoeboid or flagellated gametes (protoplasts)
 - d. Gametes fuse to produce diploid plasmodium

INSTRUCTIONAL STRATEGY

PRESENTATION ASSISTANCE:

One can determine the previous taxonomic associations of protists by examining the phylum/division suffix. "Mycota" relates to fungi, "phyta" refers to plants.

Differentiate between true multicellularity and simple colonialism. Some green algae and diatoms are good examples of the latter. Stress the evolutionary diversity of the unicellular protists and the advanced multicellular forms that evolved from them.

Diatomaceous earth is used to filter various liquids and is often used in swimming pool filters. Few organisms are small enough to get through the holes in the diatom shell. The shells are also very useful in determining the optical quality of the lenses of light microscopes.

Discuss the significance of algae blooms and pollution, especially as related to runoff of fertilizers and phosphate detergents. Excessive growth of certain protists can deplete lakes, ponds, and rivers of large quantities of oxygen, which ultimately kills all other forms of life.

VISUAL RESOURCES:

Light micrographs show the various colors exhibited by protists, especially those that are photosynthetic. Electron micrographs of hard-walled forms (diatoms, dinoflagellates, forams) are especially impressive.

A petri dish is an excellent example of a radially symmetrical diatom.