Protists

Chapter 28

- Objectives
  - Explain why the kingdom Protista is no longer considered a legitimate taxon
  - Explain the process of endosymbiosis and state what living organisms are likely relatives of mitochondria and plastids
  - Distinguish between endosymbiosis and secondary endosymbiosis
  - Name the five supergroups, list their key characteristics, and describe some representative taxa

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A World in a Drop of Water

- Even a low-power microscope can reveal an astonishing menagerie of organisms in a drop of pond water
  - These amazing organisms belong to the diverse kingdoms of mostly single-celled eukaryotes informally known as protists
- Advances in eukaryotic systematics have caused the classification of protists to change significantly

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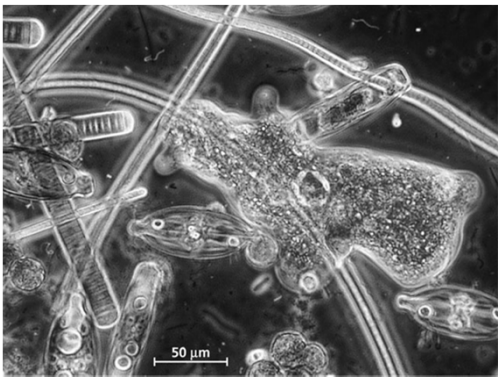

Introduction to Protists

- Protists are an extremely diverse assortment of eukaryotes
- Protists are more diverse than all other eukaryotes and are no longer classified in a single kingdom
- Most protists are unicellular and some are colonial or multicellular

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- Protists, the most nutritionally diverse of all eukaryotes, include:
  - Photoautotrophs, which contain chloroplasts
  - Heterotrophs, which absorb organic molecules or ingest larger food particles
  - Mixotrophs, which combine photosynthesis and heterotrophic nutrition

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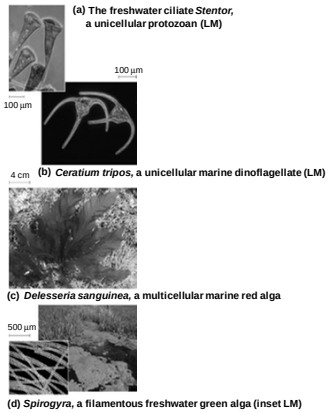

(a) The freshwater ciliate *Stentor*, a unicellular protozoan (LM)

(b) *Ceratium tripos*, a unicellular marine dinoflagellate (LM)

(c) *Delesseria sanguinea*, a multicellular marine red alga

(d) *Spirogyra*, a filamentous freshwater green alga (inset LM)

- Protist habitats are also diverse
  - Most are aquatic, including freshwater and marine species
- Reproduction and life cycles are also highly varied among protists, with both sexual and asexual species

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Eukaryote Phylogeny

- Our understanding of the relationships among protist groups continues to change rapidly
- It is no longer thought that amitochondriates (lacking mitochondria) are the oldest lineage of eukaryotes
- A tentative phylogeny of eukaryotes divides eukaryotes into many clades
  - One hypothesis divides all eukaryotes (including protists) into four supergroups

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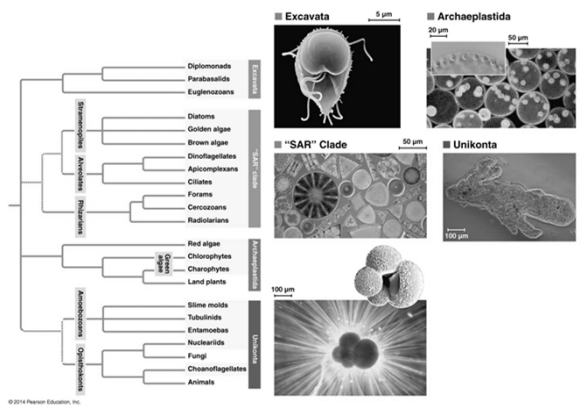

Endosymbiosis in Eukaryotic Evolution

- There is now considerable evidence that much of protist diversity has its origins in endosymbiosis
  - The plastid-bearing lineage of protists evolved into red algae and green algae
  - On several occasions during eukaryotic evolution red algae and green algae underwent secondary endosymbiosis, in which they themselves were ingested

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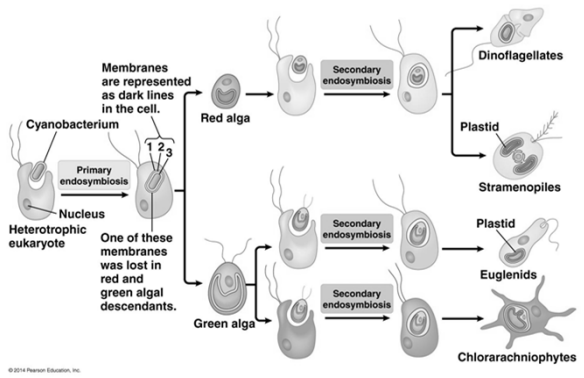

The Excavata

- The clade Excavata is characterized by its cytoskeleton
  - Some members have a feeding groove
- This controversial group includes the diplomonads, parabasalids, and euglenozoans

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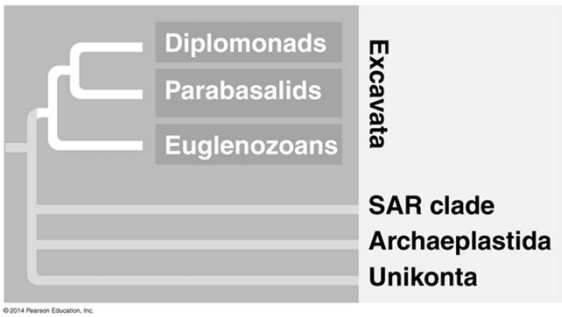

Diplomonads and Parabasalids

- Diplomonads and parabasalids are adapted to anaerobic environments
  - Lack plastids
  - Have mitochondria that lack DNA, an electron transport chain, or citric-acid cycle enzymes

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- Diplomonads
  - Have modified mitochondria called mitosomes
  - Derive energy anaerobically, for example, by glycolysis
  - Have two equal-sized nuclei and multiple flagella
  - Are often parasites, for example, *Giardia intestinalis*

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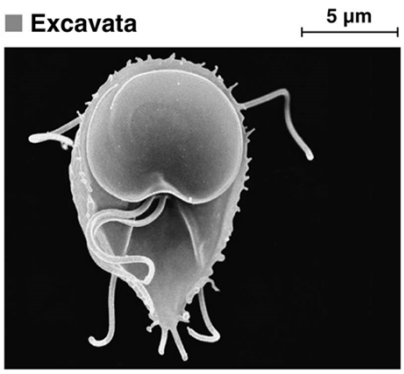
■ **Excavata**



***Giardia intestinalis*, a diplomonad parasite**

- Parabasalids
  - Move by means of flagella and an undulating part of the plasma membrane
  - Have reduced mitochondria called hydrogenosomes that generate some energy anaerobically
  - Include *Trichomonas vaginalis*, the pathogen that causes yeast infections in human females

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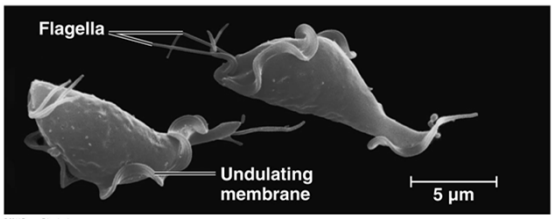

Euglenozoans

- Euglenozoa is a diverse clade that includes predatory heterotrophs, photosynthetic autotrophs, and pathogenic parasites
- The main feature that distinguishes protists in this clade is the presence of a spiral or crystalline rod of unknown function inside their flagella

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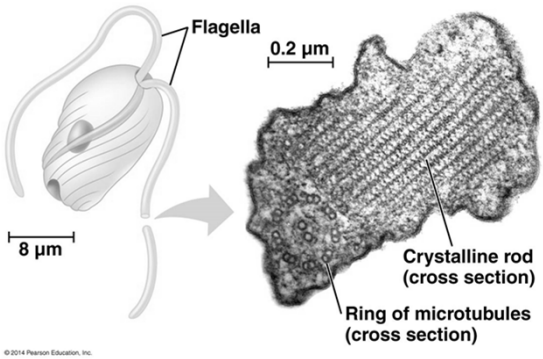

Kinetoplastids

- Kinetoplastids have a single, large mitochondrion that contains an organized mass of DNA called a kinetoplast
  - the clade includes free-living consumers of bacteria in freshwater, marine, and moist terrestrial ecosystems
  - The parasitic kinetoplastid Trypanosoma causes sleeping sickness in humans
  - Another pathogenic trypanosome causes Chagas' disease

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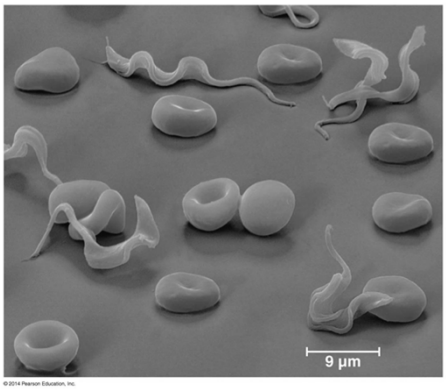

Euglenids

- Euglenids have one or two flagella that emerge from a pocket at one end of the cell
  - They store the glucose polymer paramylon
  - Some species can be both autotrophic and heterotrophic (mixotrophic)

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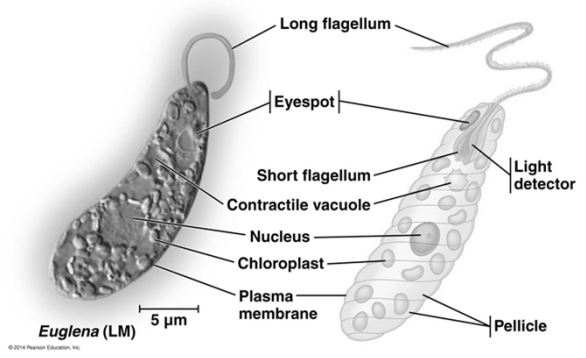

The "SAR" Clade

- The **"SAR" clade** is a diverse monophyletic supergroup named for the first letters of its three major clades stramenopiles, alveolates, and rhizarians
  - Based on whole-genome DNA analysis
- This group is one of the most controversial of the four supergroups

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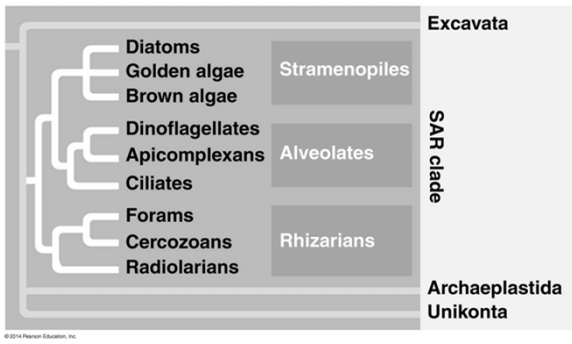

Stramenopila

- The clade Stramenopila includes several groups of heterotrophs as well as certain groups of algae
  - Most stramenopiles have a “hairy” flagellum paired with a “smooth” flagellum

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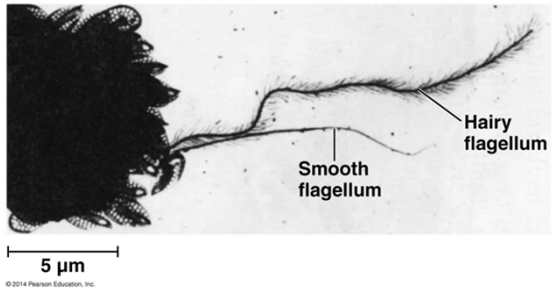

Diatoms

- Diatoms are unicellular algae with a unique two-part, glass-like wall of hydrated silica
- Diatoms usually reproduce asexually, and occasionally sexually
- Diatoms are a major component of phytoplankton and are highly diverse

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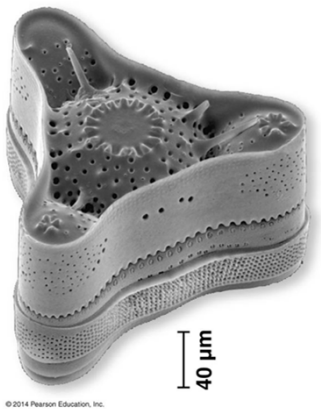

- Accumulations of fossilized diatom walls compose much of the sediments known as diatomaceous earth

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Golden Algae

- Golden algae, or chrysophytes ,are named for their color, which results from their yellow and brown carotenoids
- The cells of golden algae are typically biflagellated, with both flagella attached near one end of the cell
- Most golden algae are unicellular but some are colonial

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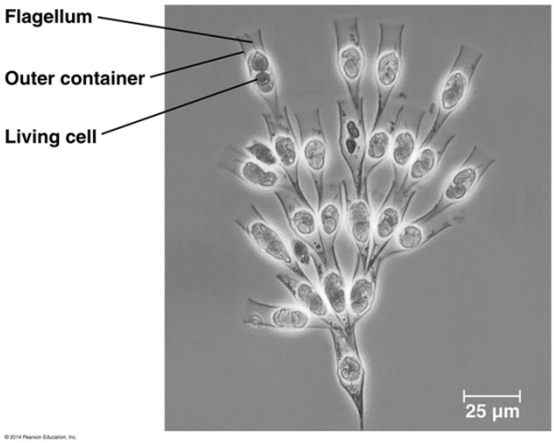

Brown Algae

- Brown algae, or phaeophytes are the largest and most complex algae
  - Are all multicellular, and most are marine
- Brown algae include many of the species commonly called seaweeds
- Seaweeds have the most complex multicellular anatomy of all algae
- Kelps, or giant seaweeds live in deep parts of the ocean

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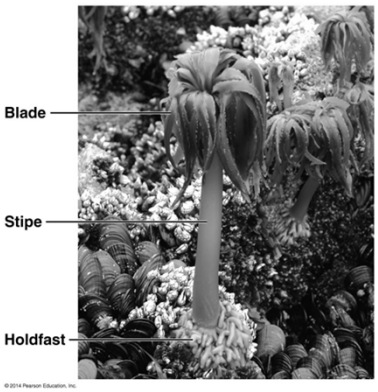

Alternation of Generations

- A variety of life cycles have evolved among the multicellular algae
- The most complex life cycles include an alternation of generations
  - The alternation of multicellular haploid and diploid forms
  - Heteromorphic generations are structurally different, while isomorphic generations look similar

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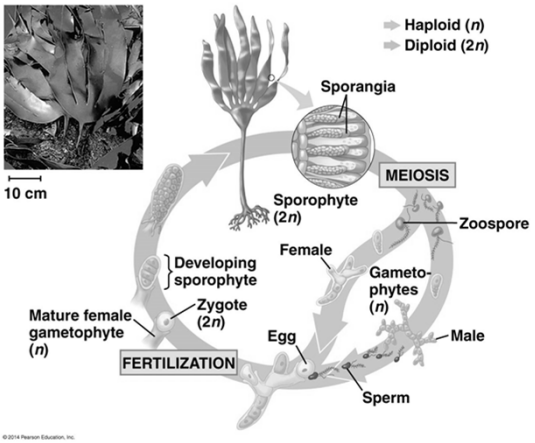

Oomycetes (Water Molds and Their Relatives)

- Oomycetes include water molds, white rusts, and downy mildews
  - Once were considered fungi based on morphological studies
- Most oomycetes are decomposers or parasites
  - Have filaments (hyphae) that facilitate nutrient uptake

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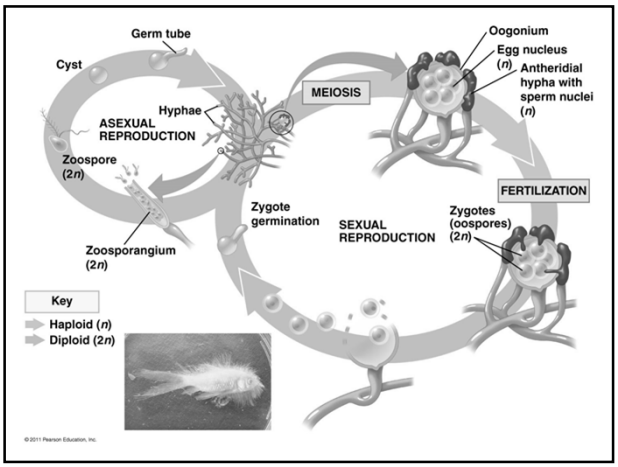

- The ecological impact of oomycetes can be significant
  - *Phytophthora infestans* causes late blight of potatoes
  - *Phytophthora cinnamomi* causes cinnamon root rot in American chestnut
  - *Phytophthora ramorum* causes sudden oak death

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Alveolates

- Members of the clade Alveolata have membrane-bounded sacs (alveoli) just under the plasma membrane
  - Includes photosynthetic flagellates (Dinoflagellates), parasites (apicomplexans) and ciliates

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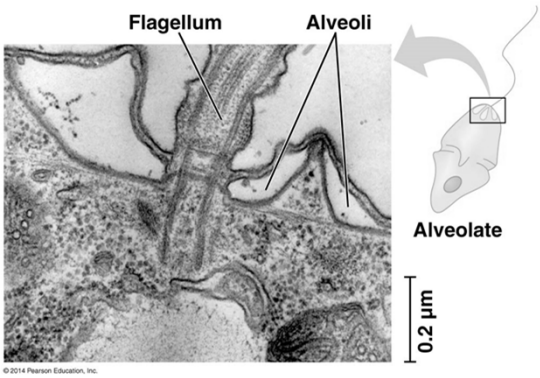

Dinoflagellates

- Dinoflagellates are a diverse group of aquatic photoautotrophs and heterotrophs
  - They are abundant components of both marine and freshwater phytoplankton
- Each has a characteristic shape that in many species is reinforced by internal plates of cellulose
- Two flagella make them spin as they move through the water

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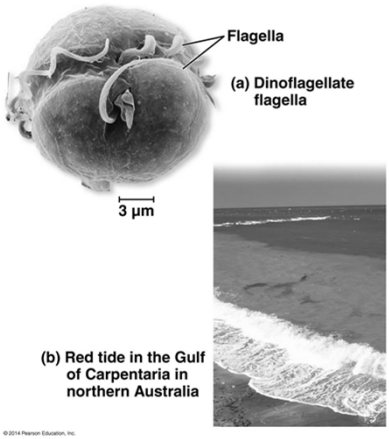

- Rapid growth of some dinoflagellates is responsible for causing “red tides,” which can be toxic to humans

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Apicomplexans

- Apicomplexans are parasites of animals and some cause serious human diseases
  - They are so named because one end, the apex, contains a complex of organelles specialized for penetrating host cells and tissues
  - Have a nonphotosynthetic plastid, the apicoplast

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- Most life cycles with both sexual and asexual stages that require two or more different host species for completion
  - The apicomplexan *Plasmodium* is the parasite that causes malaria
    - *Plasmodium* requires both mosquitoes and humans to complete its life cycle
    - Approximately 2 million people die each year from malaria
    - Efforts are ongoing to develop vaccines that target this pathogen

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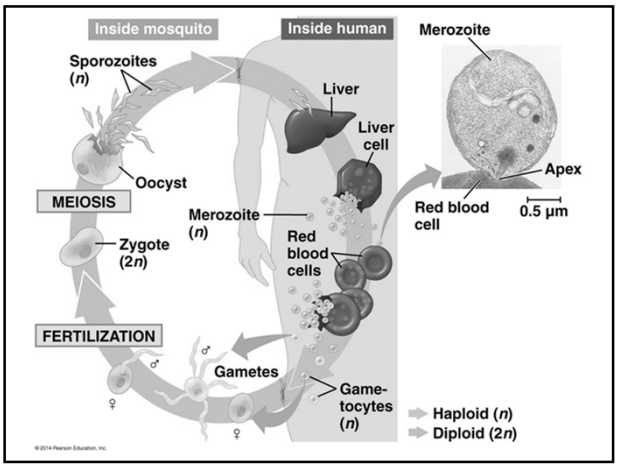

Ciliates

- Ciliates, a large varied group of protists are named for their use of cilia to move and feed
  - Have large macronuclei and small micronuclei
- The micronuclei function during conjugation, a sexual process that produces genetic variation
- Conjugation is separate from reproduction which generally occurs by binary fission

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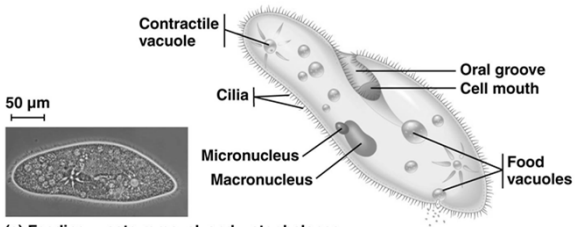
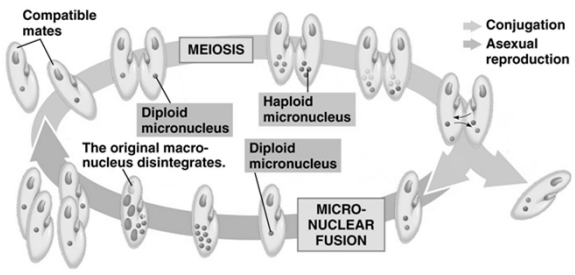


(a) Feeding, waste removal, and water balance.



(b) Conjugation and reproduction.

Rhizarians

- Many species in the rhizarian clade are amoebas
- Amoebas are protists that move and feed by pseudopodia, extensions of the cell surface
  - Rhizarian amoebas differ from amoebas in other clades by having threadlike pseudopodia
- Rhizarians include radiolarians, forams, and cercozoans

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Radiolarians

- Radiolarians are marine protists whose tests are fused into one delicate piece, which is generally made of silica
  - They feed by phagocytosing microorganisms with their pseudopodia
- The pseudopodia of radiolarians, known as axopodia, radiate from the central body

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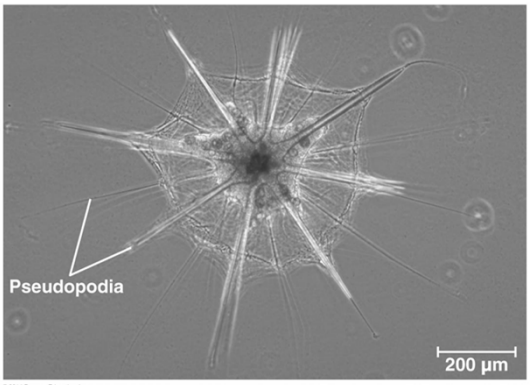

Foraminiferans (Forams)

- Foraminiferans, or forams are named for their porous, generally multichambered shells, called tests
  - Pseudopodia extend through the pores in the test

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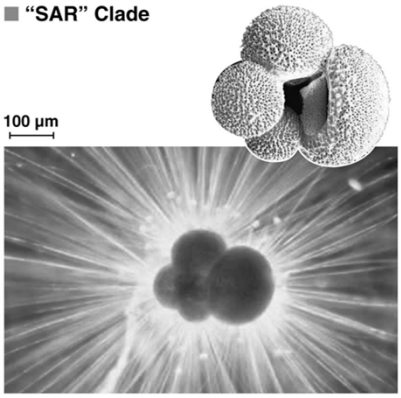
■ **"SAR" Clade**



***Globigerina*, a rhizarian in the SAR clade**

- Foram tests in marine sediments form an extensive fossil record

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Cercozoans

- Cercozoans include most amoeboid and flagellated protists with threadlike pseudopodia
  - They are common in marine, freshwater, and soil ecosystems
- Most are heterotrophs, including parasites and predators
  - *Paulinella chromatophora* is an autotroph with a unique photosynthetic structure called a chromoatophore
    - This structure evolved from a different cyanobacterium than the plastids of other photosynthetic eukaryotes

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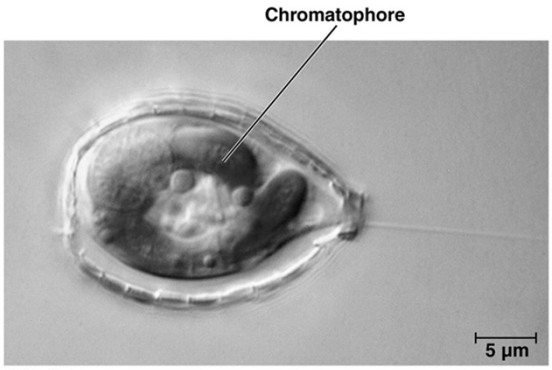

Archaeplastida

- Over a billion years ago, a heterotrophic protist acquired a cyanobacterial endosymbiont
  - The photosynthetic descendants of this ancient protist evolved into red algae and green algae
- Land plants are descended from the green algae
- Archaeplastida is a supergroup used by some scientists and includes red algae, green algae, and land plants

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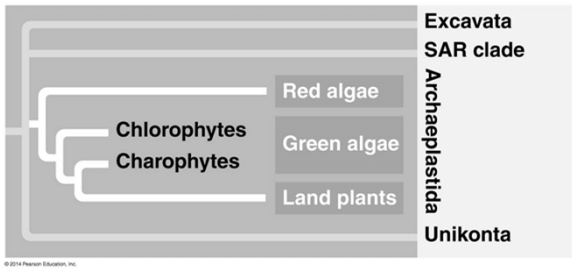

Red Algae

- Red algae are reddish in color due to an accessory pigment call phycoerythrin, which masks the green of chlorophyll
- Red algae are usually multicellular; the largest are seaweeds
  - They are the most abundant large algae in coastal waters of the tropics

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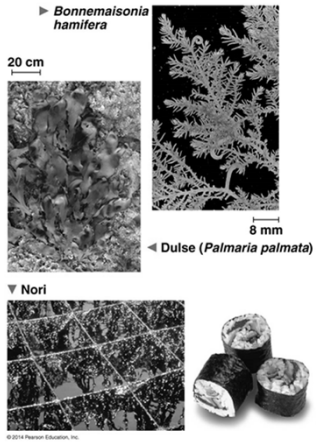

Green Algae

- Green algae are named for their grass-green chloroplasts
  - The clade is divided into two main groups: chlorophytes and charophyceans
  - They are closely related to land plants
- Most chlorophytes live in fresh water, although many are marine
  - Other chlorophytes live in damp soil, as symbionts in lichens, or in snow

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- Chlorophytes include unicellular, colonial, and multicellular forms

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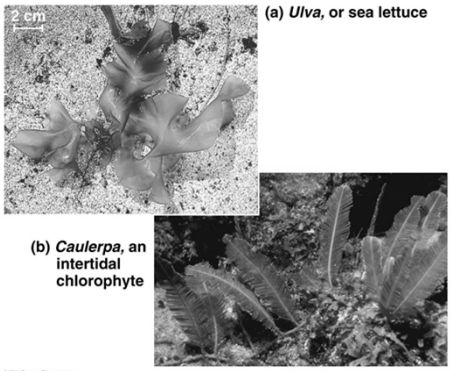

- Most chlorophytes have complex life cycles with both sexual and asexual reproductive stages

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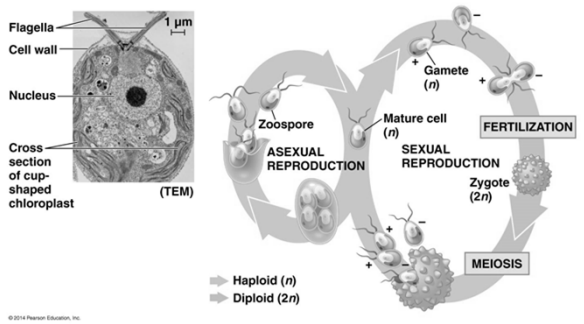

Unikonta

- The supergroup Unikonta includes animals, fungi, and some protists
  - This group includes two clades: the amoebozoans and the opisthokonts (animals, fungi, and related protists)

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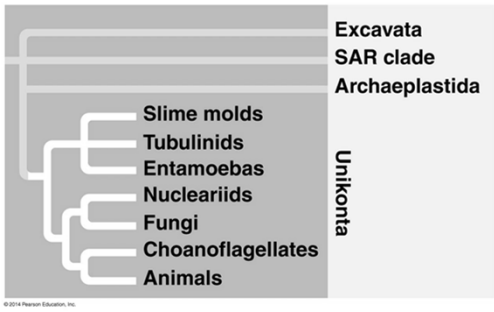

- The root of the eukaryotic tree remains controversial
  - It is unclear whether unikonts separated from other eukaryotes relatively early or late

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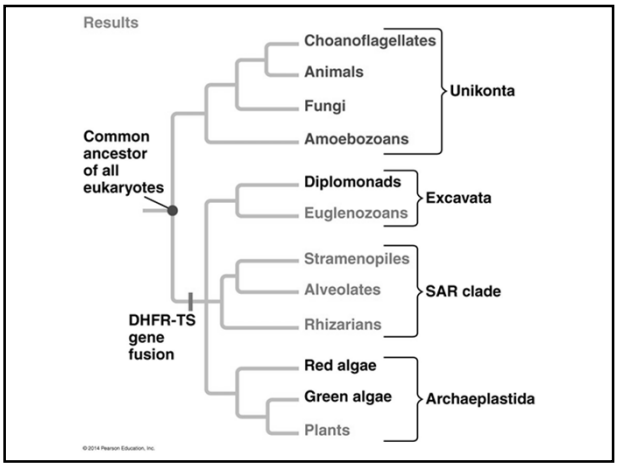

Amoebozoans

- Amoebozoans are amoeba that have lobe-shaped, rather than threadlike, pseudopodia
  - Includes tubulinids, entamoebas, and slime molds

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Slime Molds

- Slime molds, or mycetozoans were once thought to be fungi
  - Molecular systematics places slime molds in the clade Amoebozoa

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Plasmodial Slime Molds

- Many species of plasmodial slime molds are brightly pigmented, usually yellow or orange
- At one point in the life cycle they form a mass called a plasmodium
  - The plasmodium is undivided by membranes and contains many diploid nuclei
- The plasmodium extends pseudopodia through decomposing material, engulfing food by phagocytosis

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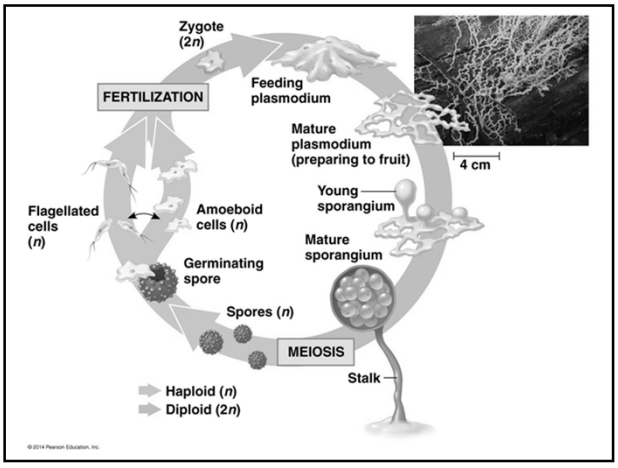

Cellular Slime Molds

- Cellular slime molds form multicellular aggregates in which the cells remain separated by their membranes
  - Cells feed individually, but can aggregate to form a fruiting body
- Dictyostelium discoideum has become an experimental model for studying the evolution of multicellularity

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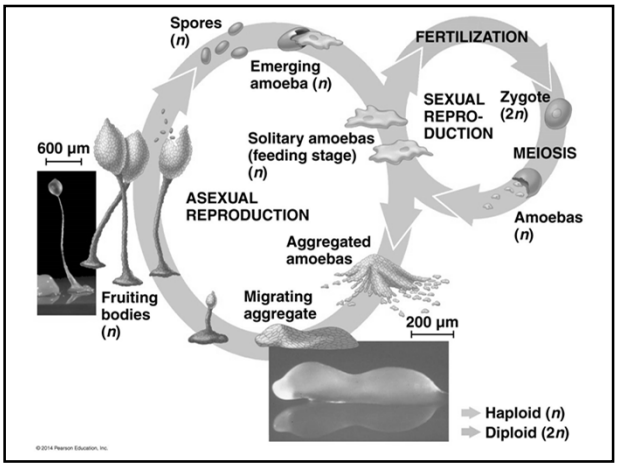

Tubulinids

- Tubulinids are common unicellular amoebozoans in soil as well as freshwater and marine environments
- Most tubulinids are heterotrophic and actively seek and consume bacteria and other protists

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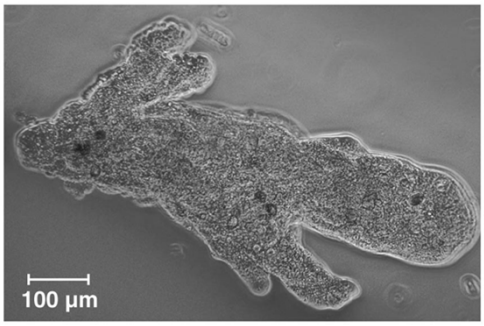
Unikonta



A unikont amoeba

Entamoebas

- Entamoebas are parasites of vertebrates and some invertebrates
  - *Entamoeba histolytica* causes amoebic dysentery in humans

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Opisthokonts

- Opisthokonts include animals, fungi, and several groups of protists

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Ecological Roles of Protists

- Protists are found in diverse aquatic environments
- Protists often play the role of symbiont or producer

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Symbiotic Protists

- Some protist symbionts benefit their hosts
  - Dinoflagellates nourish coral polyps that build reefs
  - Hypermastigotes digest cellulose in the gut of termites

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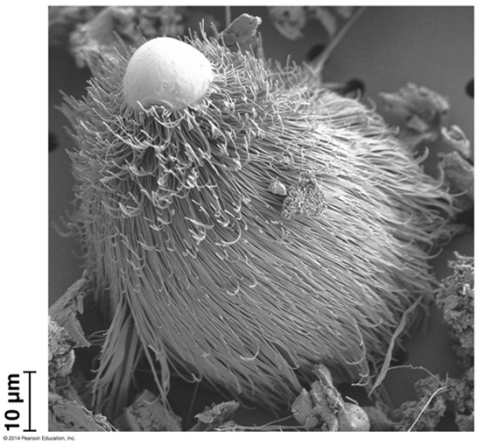

- Some protists are parasitic
  - *Plasmodium causes* malaria
  - *Pfesteria shumwayae* is a dinoflagellate that causes fish kills
  - *Phytophthora ramorum* causes sudden oak death

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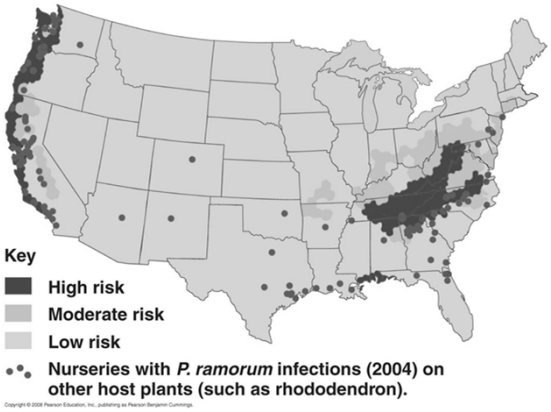

Photosynthetic Protists

- Many protists are important producers that obtain energy from the sun
- In aquatic environments, photosynthetic protists and prokaryotes are the main producers
- The availability of nutrients can affect the concentration of protists

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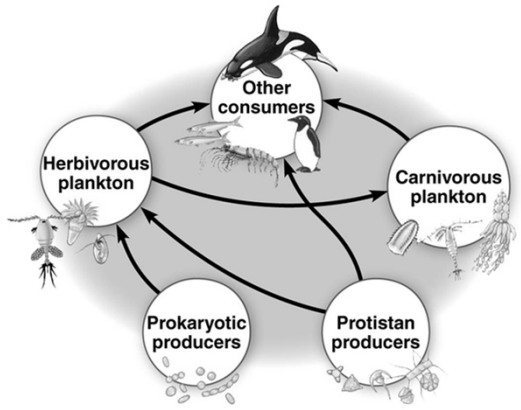

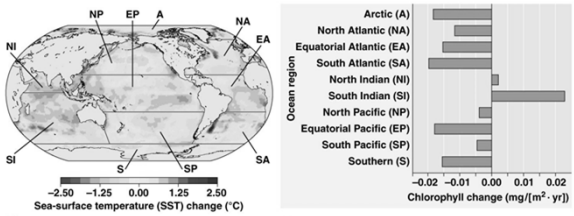

Eukaryote Supergroup	Major Groups	Key Morphological Characteristics	Specific Examples
Excavata	**Diplomonads and parabasalids**	Modified mitochondria	*Giardia, Trichomonas*
	Euglenozoans Kinetoplastids Euglenids	Spiral or crystalline rod inside flagella	*Trypanosoma, Euglena*
"SAR" Clade	**Stramenopiles** Diatoms Golden algae Brown algae	Hairy and smooth flagella	*Phytophthora, Laminaria*
	Alveolates Dinoflagellates Apicomplexans Ciliates	Membrane-enclosed sacs (alveoli) beneath plasma membrane	*Pfiesteria, Plasmodium, Paramecium*
	Rhizarians Radiolarians Forams Cercozoans	Amoebas with threadlike pseudopodia	*Globigerina*
Archaeplastida	**Red algae**	Phycoerythrin (photosynthetic pigment)	*Porphyra*
	Green algae	Plant-type chloroplasts	*Chlamydomonas, Ulva*
	Land plants	(See Chapters 29 and 30.)	Mosses, ferns, conifers, flowering plants
Unikonta	**Amoebozoans** Slime molds Tubulinids Entamoebas	Amoebas with lobe-shaped or tube-shaped pseudopodia	*Amoeba, Dictyostelium*
	Opisthokonts	(Highly variable; see Chapters 31–34.)	Choanoflagellates, nucleariids, animals, fungi