BIOSC 041

PROTISTS!

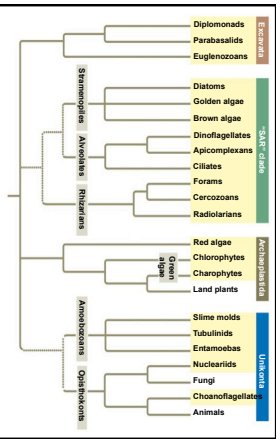
Reference: Chapter 28

Outline

- General characteristics of protists
- Our understanding of the relationships among protist groups continues to change rapidly!
- One hypothesis divides all eukaryotes (including protists) into four supergroups:
  - Excavata
  - "SAR" clade
  - Archaeplastida
  - Unikonta
- Roles in Ecological Communities
  - Producers
  - Consumers
  - Parasites & pathogens

What is a Protist?

- Everything that is not something else
- But definitely not an animal
- The one-time kingdom of Protista has been abandoned
- Protists are now recognized as **polyphyletic**
  - Some lineages of protists recognized as kingdoms
- Protist remains the informal name for highlighted taxa
- **"Protozoa"** are animal-like protists

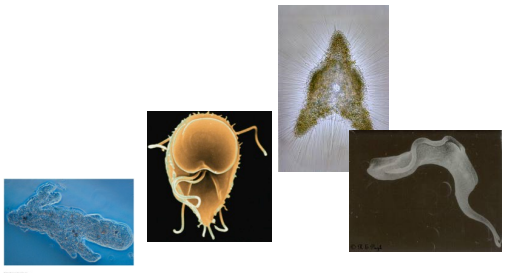


The Protists exhibit more structural and functional diversity than any other group of eukaryotes

- Include unicellular, colonial, and multicellular taxa

Most protists are unicellular, and small…

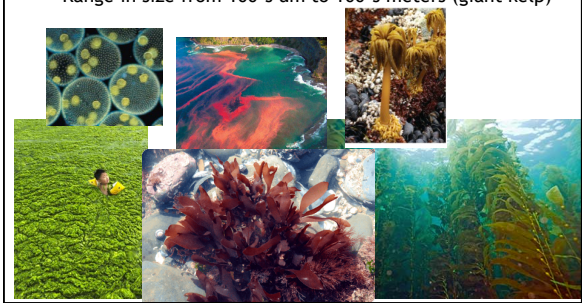
- Single-celled protists can be very complex, as all biological functions are carried out by organelles in each individual cell
  - Most range in size from <1-200 µm



…but there are many exceptions…

- *Galatheammina* (Xenophyophore)
- Benthic (deep sea) protozoan, ~10 cm in diameter
- Single-celled(!!)
  - "ruffled" surface increases surface area for gas/nutrient exchange

- The Protists also include colonial and multicellular taxa- particularly **algae**
- Algae are considered protists because they don't meet the complex tissue criteria of true plants
  - Range in size from 100's um to 100's meters (giant kelp)

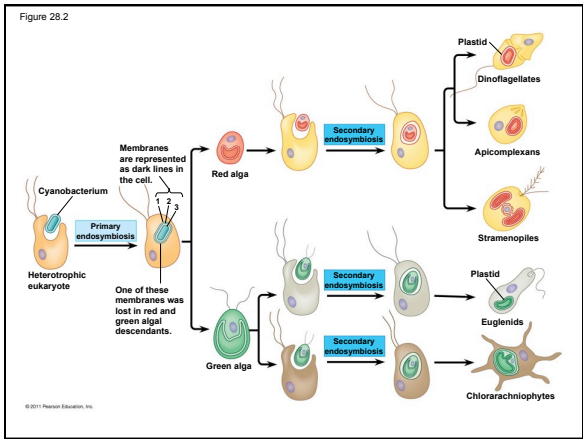


Nutritional and reproductive diversity

- **Nutrition**
  - **Photoautotrophs**
    - Contain chloroplasts
    - Obtain energy from the sun and carbon from CO_2
  - **Heterotrophs**
    - Obtain both energy and carbon from organic molecules, absorbed from the environment or through ingestion of other organisms
  - **Mixotrophs**
    - Combine photosynthesis and heterotrophic nutrition
- **Reproduction**
  - Sexual, asexual, or both!

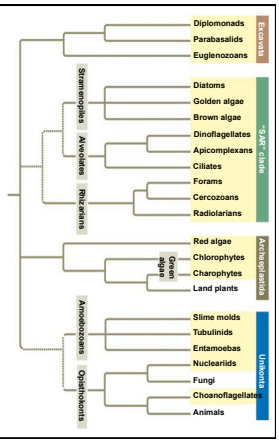
Endosymbiosis in Eukaryotic Evolution

- Protists owe their diversity to **endosymbiosis-** a unicellular organism engulfs another cell, which becomes an **endosymbiont** and then an organelle in the host cell
  - Review:
    - Mitochondria evolved by endosymbiosis of an aerobic heterotrophic bacterium
    - Chloroplasts evolved by endosymbiosis of photosynthetic cyanobacterium
- The plastid-bearing protists evolved into red and green algae **(**DNA of plastid genes in red algae and green algae closely resemble DNA of cyanobacteria)
- During eukaryotic evolution, red and green algae also underwent **secondary endosymbiosis**, in which they were ingested by a heterotrophic eukaryote



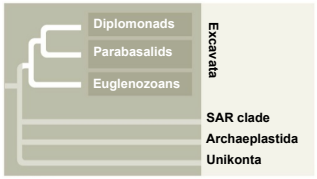
Five Supergroups of Eukaryotes

- Our understanding of the relationships among protist groups continues to change rapidly
- One hypothesis divides all eukaryotes (including protists) into four supergroups



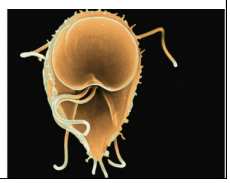
Supergroup #1: Excavates

- Include protists with modified mitochondria and protists with unique flagella
- The clade **Excavata** is characterized by its cytoskeleton
- Some members have a feeding groove
- This diverse group includes
  - Diplomonads
  - Parabasalids
  - Euglenozoans



Excavata: Diplomonads and Parabasalids

- These two groups lack plastids, have modified mitochondria, and most live in anaerobic environments
- ***Diplomonads***
  - Have modified mitochondria called mitosomes
  - Derive energy from anaerobic biochemical pathways
  - Have two equal-sized nuclei and multiple flagella
  - Are often parasites, for example, *Giardia intestinalis* (also known as *Giardia lamblia*)

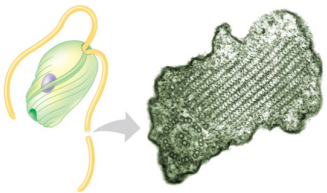


Parabasalids

- Have reduced mitochondria called **hydrogenosomes** that generate some energy anaerobically
- Include *Trichomonas vaginalis*, the pathogen that causes a type of vaginal infection in human females

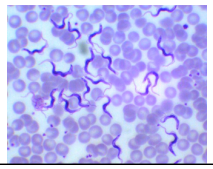
Euglenozoans

- **Euglenozoa** is a diverse clade that includes predatory heterotrophs, photosynthetic autotrophs, and parasites
- Distinguishing feature
  - A spiral or crystalline rod of unknown function inside their flagella
- This clade includes the
  - Kinetoplastids
  - Euglenids



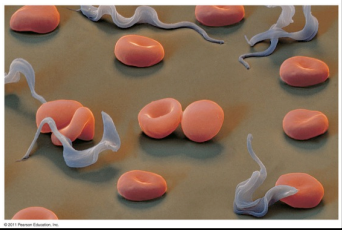
Euglenozoa - Kinetoplastids

- **Kinetoplastids** are distinguished from other protozoa by the **kinetoplast-** a single mitochondrion containing an organized mass of DNA (kDNA) that comprises several copies of the mitochondrial genome
- Include free-living consumers of prokaryotes in freshwater, marine, and moist terrestrial ecosystems
- Also include some pathogens
  - *Trypanosoma*, which causes sleeping sickness in humans
  - Another pathogenic trypanosome causes Chagas' disease



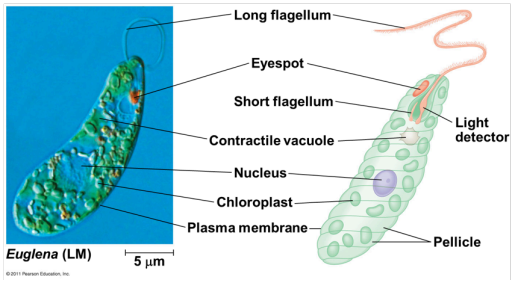
More about trypanosomes

- Trypanosomes evade immune responses by switching surface proteins
- A cell produces millions of copies of a single protein
- The new generation produces millions of copies of a different protein
- These frequent changes prevent the host from developing immunity



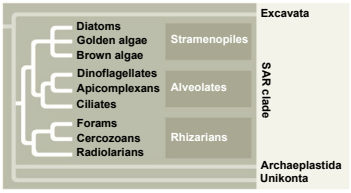
Euglenozoa - Euglenids

- **Euglenids** have one or two flagella that emerge from a pocket at one end of the cell
- Some species can be both autotrophic and heterotrophic



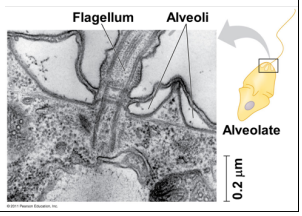
Supergroup #2: SAR clade

- A highly diverse group of protists defined by DNA similarities
- The **"SAR" clade** is a diverse monophyletic supergroup named for the first letters of its three major clades Stramenopiles, Alveolates, and Rhizarians
- This group is the most controversial of the four supergroups (sometimes split to give 5 subgroups)
- Stramenopiles covered in Biosc 42



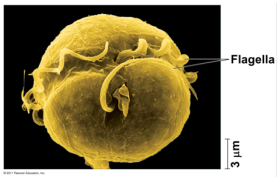
Alveolata

- Members of the clade **Alveolata** have membrane-bounded sacs (alveoli) just under the plasma membrane
- The function of the alveoli is unknown
- The alveolates include
  - Dinoflagellates
  - Apicomplexans
  - Ciliates



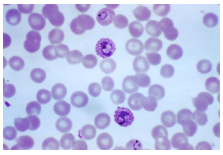
Dinoflagellates

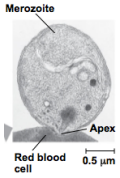
- **Dinoflagellates** have two flagella and each cell is reinforced by cellulose plates
- They are abundant components of both marine and freshwater phytoplankton
- They are a diverse group of aquatic phototrophs, mixotrophs, and heterotrophs
- Toxic "red tides" are caused by dinoflagellate blooms



Apicomplexans

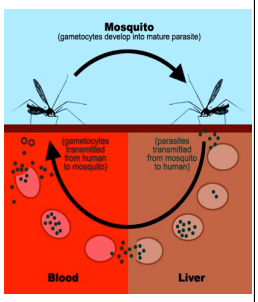
- **Apicomplexans** are parasites of animals, and some cause serious human diseases
- No movement, no free-living forms (obligate parasites)
- Complex intracellular structures and lifecycles (spread through host as infectious cells called sporozoites)
- One end, the apex, contains a complex of organelles specialized to penetrate host cells and tissues
- Most have sexual and asexual stages that require two or more host species for completion

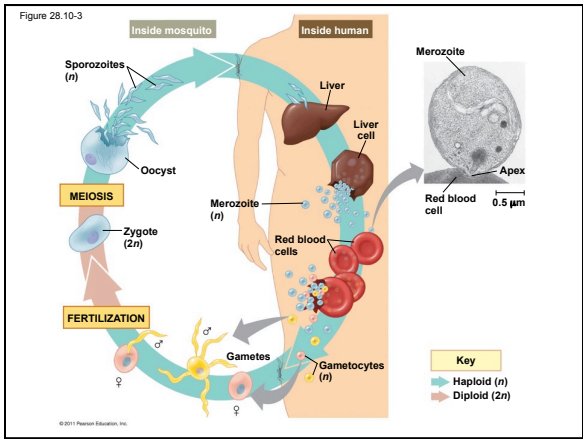




More about Apicomplexans

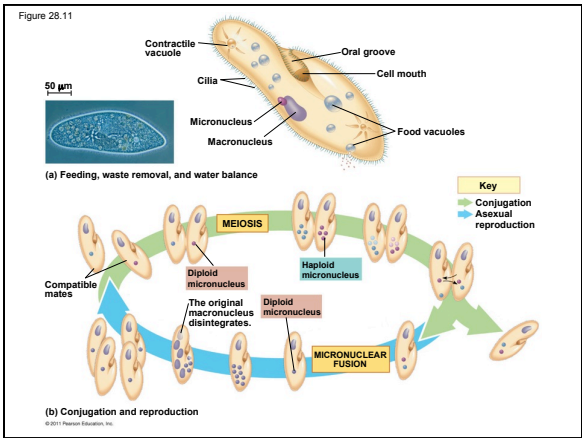
- Responsible for some of the most serious human disease – Malaria (*Plasmodium*), Toxoplasmosis
- *Plasmodium* requires both mosquitoes and humans to complete its life cycle
- ~900,000 people die each year from malaria
- Efforts are ongoing to develop malaria vaccines





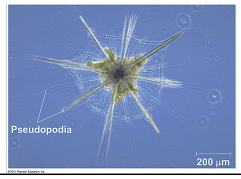
Ciliates

- **Ciliates**, a large varied group of protists, are named for their use of cilia to move and feed
  - *Paramecium caudatum* is a good example of a ciliate
- Have large macronuclei and small micronuclei
- Genetic Variation
  - Exchange of haploid micronuclei via sexual conjugation
- Reproduction
  - Asexual- binary fission



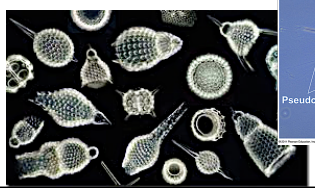
Rhizarians

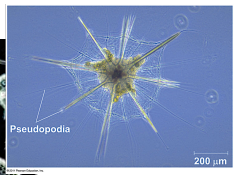
- DNA evidence supports **Rhizaria** as a monophyletic clade (so it sometimes is split from SAR into its own supergroup)
- Rhizaria includes some groups of amoebas (**"testate** ameobas"= with shells), including radiolarians, forams, and cercozoans
- Amoebas are protists that move and feed by **pseudopodia**, extensions of the cell surface
- Rhizarian amoebas differ from amoebas in other clades by having threadlike pseudopodia



Radiolarians

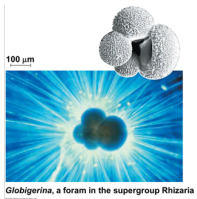
- Marine protists called **radiolarians** have tests fused into one delicate piece, usually made of silica
- Radiolarians use their pseudopodia to engulf microorganisms through phagocytosis
- The pseudopodia of radiolarians radiate from the central body





Forams

- **Foraminiferans**, or **forams**, are named for porous, generally multichambered shells, called **tests**
  - Organic material hardened with $CaCO_3$
- Pseudopodia extend through the pores in the test
- Foram tests in marine sediments form an extensive fossil record
- Many forams have endosymbiotic algae



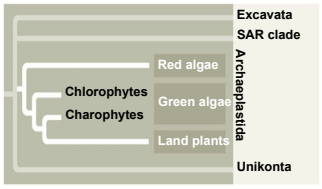
Cercozoans

- **Cercozoans** include most amoeboid and flagellated protists with threadlike pseudopodia
- They are common in marine, freshwater, and soil ecosystems
- Most are heteroptrophs, including parasites and predators

Imbricatea

Supergroup #3: Archaeplastida

- Covered in detail in Biosc 42
- Includes red algae, green algae, and land plants

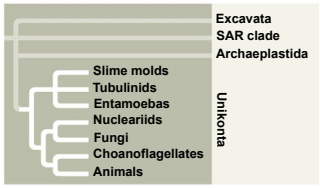


Dulse (*Palmaria palmata*)

(a) *Ulva*, sea lettuce

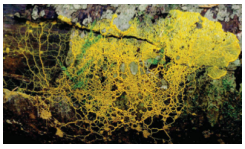
Supergroup 4: Unikonts

- Includes animals, fungi, and some protists (that are closely related to fungi and animals)
- This group includes two clades: the **amoebozoans** and the **opisthokonts** (animals, fungi, and related protists)
- The root of the eukaryotic tree remains controversial
- It is unclear whether unikonts separated from other eukaryotes relatively early or late



Amoebozoans

- **Amoebozoans** are amoeba that have lobe- or tube-shaped, rather than threadlike, pseudopodia- and no shell
- They include slime molds, tubulinids, and entamoebas



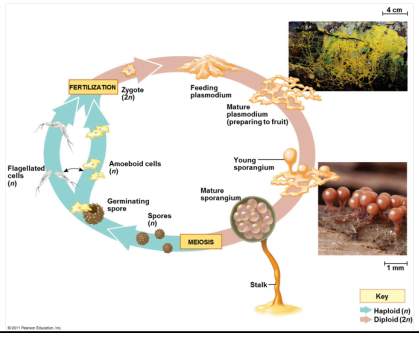
A unikont amoeba

Slime Molds

- Slime molds (mycetozoans) once thought to be fungi
- Molecular systematics places slime molds in the clade Amoebozoa
- Two types:
  - **Plasmodial** (no cell membranes, but many nuclei)
  - **Cellular** (cell membranes present)
  - Give clues to evolution of multicellularity

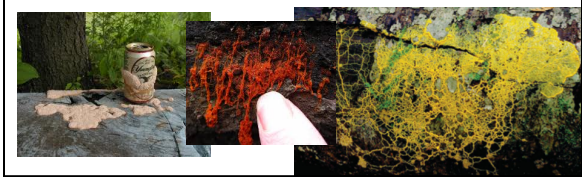
Plasmodial Slime Molds

- Many species of **plasmodial slime molds** are brightly pigmented, usually yellow or orange



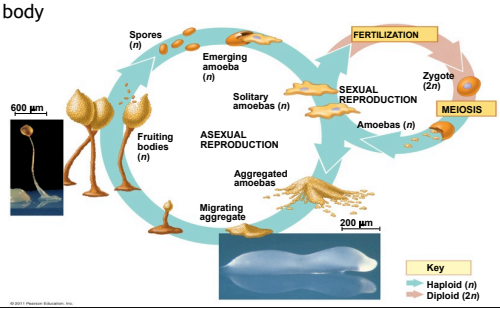
Plasmodial Slime Molds

- At one point in the life cycle, plasmodial slime molds form a mass called a **plasmodium** (not to be confused with malarial *Plasmodium*)
- The plasmodium is not multicellular
- It is undivided by plasma membranes but contains many diploid nuclei
- Extends pseudopodia through decomposing material, engulfing food by phagocytosis



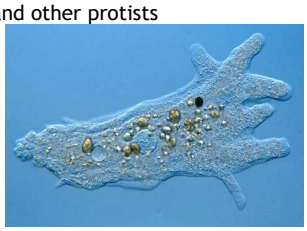
Cellular Slime Molds

- **Cellular slime molds** form multicellular aggregates in which cells are separated by their membranes
- Cells feed individually, but can aggregate to form a fruiting body



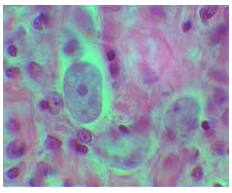
Tubulinids

- Have lobe or tube-shaped pseudopodia. Typical "amoeboid" movement
- Common unicellular amoebozoans in soil as well as freshwater and marine environments
- Most are heterotrophic and actively seek and consume bacteria and other protists



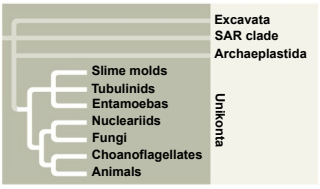
Entamoebas

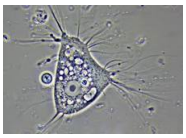
- Entamoebas are parasites of vertebrates and some invertebrates
- *Entamoeba histolytica* causes **amebic dysentery**, the third-leading cause of human death due to eukaryotic parasites

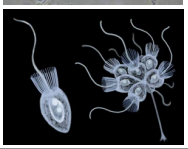


Opisthokonts

- **Opisthokonts** include animals, fungi, and several groups of protists
  - Nucleariids (amoeba more similar to fungi)
  - Choanoflagellates





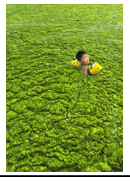


Protists play key roles in ecological communities

- Protists are found in diverse environments
  - Aquatic, marine and terrestrial
- Protists are found in all trophic levels
  - Producer (photoautotrophs)
  - Various types of consumer (heterotrophs feeding on photoautotrophs or other heterotrophs)
  - Parasites (including human pathogens)
  - Detritovore
    - Important in recycling nutrients

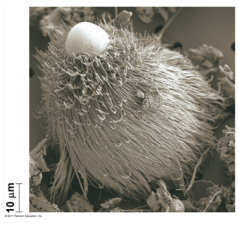
Photosynthetic Protists

- Many protists are important **producers** that obtain energy from the sun
- In aquatic environments, photosynthetic protists and prokaryotes (cyanobacteria) are the main producers
- In aquatic environments, photosynthetic protists are limited by nutrients
  - Primarily N and/or P, sometimes Fe
- These populations can explode (bloom) when limiting nutrients are added



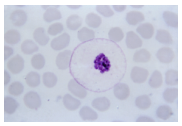
Symbiotic Protists

- Some protist symbionts benefit their hosts
  - Dinoflagellates (***zooxanthellae***) photosynthesize to provide food for coral polyps that build reefs
  - Wood-digesting protists digest cellulose in the gut of termites



Parasitic Protists

- *Plasmodium* causes malaria

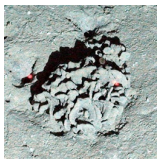


- *Pfiesteria shumwayae* is a dinoflagellate that causes fish kills

- *Phytophthora ramorum* causes sudden oak death

A Protist as Ecosystem Engineer?

- *Galatheammina* (Xenophyophore- giant unicellular organism)
- Can form very dense populations on undersea plains
- Stirs up sediment and creates structure with slime secretions
  - Creates habitat for other bottom-dwelling organisms
    - Populations of crustaceans and worms much higher where *Galatheammina* is present
  - Plays key role in circulating C & N back into the water column



Global warming and phytoplankton

- Phytoplankton form the basis for marine and aquatic food webs (most phytoplankton are protists)
- Biomass of photosynthetic protists has declined as sea surface temperature has increased
- If sea surface temperature continues to warm due to global warming, this could have large effects on
  - Marine ecosystems
  - Fishery yields
  - The global carbon cycle

Figure 28.UN06

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