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
  - Euglenozoa
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

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

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
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

<table>
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<tr>
<th>Stramenopiles</th>
<th>Alveolates</th>
<th>Rhizarians</th>
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<tr>
<td>Dinoflagellates</td>
<td>Apicomplexans</td>
<td>Ciliates</td>
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<tr>
<th>Excavata</th>
<th>Archaeplastida</th>
<th>Unikonta</th>
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<tbody>
<tr>
<td>Golden algae</td>
<td>Brown algae</td>
<td>Diatoms</td>
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</table>

Alveolata

- Members of the clade Alveolata have membrane-bounded sacs (alveoli) just under the plasma membrane
- The function of the alveolus 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

<table>
<thead>
<tr>
<th>Flagellum</th>
<th>Alveoli</th>
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<td>Ciliates</td>
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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

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

<table>
<thead>
<tr>
<th>Inside mosquito</th>
<th>Inside human</th>
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<tbody>
<tr>
<td>Sporozoite (n)</td>
<td>Liver cell</td>
</tr>
<tr>
<td>Oocyst (2n)</td>
<td>Liver cell</td>
</tr>
<tr>
<td>Gametocytes (n)</td>
<td>Liver cell</td>
</tr>
<tr>
<td>Gametocyte (n)</td>
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</tr>
<tr>
<td>Zygote (2n)</td>
<td>Liver cell</td>
</tr>
<tr>
<td>Merozoite (n)</td>
<td>Red blood cell</td>
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Figure 28.10-3
**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 amoebas" 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.

**Forams**

- Foraminiferans, or forams, are named for porous, generally multichambered shells, called tests.
  - Organic material hardened with CaCO₃.
  - Pseudopodia extend through the pores in the test.
  - Foram tests in marine sediments form an extensive fossil record.
  - Many forams have endosymbiotic algae.

**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.

**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.
Supergroup #3: Archaeplastida

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

Amoebozoans

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

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

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

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**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.

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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

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<td>SAR Clade</td>
<td>Giardia, Trichomonas, Phytophthora, Laminaria, Pfiesteria, Plasmodium, Paramecium, Globigerina, Porphyra, Chlamydomonas, Ulva</td>
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<tr>
<td>Archaeplastida</td>
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<td>Mosses, ferns, conifers, flowering plants</td>
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<td>Modified mitochondria</td>
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<td>Green algae</td>
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<td>Red algae</td>
<td>Amoebas with lobe-shaped or tube-shaped pseudopodia</td>
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<td>Land plants</td>
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<td>Amoebas with threadlike pseudopodia</td>
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<td>Float plants</td>
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<td>Phytoplankton, marine algae</td>
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