SESSION OBJECTIVES
Students will be able to...

... describe the differences between haplontic, diplontic, and diplo-haplontic life cycles

... identify the synapomorphy for the Archaeplastida

... describe and draw the diplo-haplontic red algae life cycle

... define the terms filamentous, parenchymatous, and pseudo-parenchymatous

... describe the life cycle of Zygnematalean green alga, such as Spirogyra.

EUKARYOTES, in the domain Eukarya, are almost all the organisms that the public knows (plants, animals, fungi)

✔ Eukaryotes are organisms that possess membrane-bound organelles, such as a nucleus
  o Usually larger than prokaryotes
  o Unlike prokaryotes, they exhibit sexual reproduction (i.e. meiosis and fertilization)

✔ Oldest eukaryotes are algae from 1.8 billion years old

✔ "Algae" is a catch-all term (polyphyletic grouping) of photosynthetic organisms that live in aquatic environments
  o Algae range in size from unicellular (~10μm), up to 200 feet

SEXUAL LIFECYCLE REVIEW

- **Diploid** (2n): organism possesses 2 sets of chromosomes per nucleus
- **Haploid** (1n): organism possesses 1 set of chromosomes per nucleus
- **Meiosis**: a process which splits a diploid spore-mother cell (2n) into four haploid (n) cells
- **Fertilization**: a process which combines two haploid cells to create a diploid cell
- **Sporophyte**: the spore-producing phase of a plant; it is always diploid
  - Zygote: the youngest part of the diploid phase; a young sporophyte
  - Sporangium: structure that holds spores
  - Spore: a cell formed from meiosis that produces a gametophyte; spores germinate to create a young gametophyte
- **Gametophyte**: the gamete-producing phase of a plant; it is always haploid
  - Gametangium: structure that holds sperm- or eggs
  - Gamete: a reproductive cell, such as a sperm or egg; gametes fuse with another gamete during fertilization to produce a young sporophyte (=zygote)

LIFECYCLES: There are three (3) types of lifecycles found in the eukaryote domain

1. **Diplontic** Lifecycle: diploid phase is multicellular
2. **Haplontic** Lifecycle: haploid phase is multicellular
3. **Diplo-haplontic** Lifecycle: both diploid and haploid phases are multicellular

**Diplontic** lifecycle (or Gametic Meiosis - "gametes created by meiosis")

- The diploid (2n) phase is multicellular and dominant.
- This diploid phase produces sex cells through meiosis of a sporocyte to create four (4) sex cells, such as sperm or eggs.
- Sperm and egg fuse during fertilization to create a young zygote.
- Mature diploid ⇒ **meiosis** ⇒ sex cells ⇒ **fertilization** ⇒ zygote ⇒ mature diploid

Group name = focus on the lifecycle of these groups
• *e.g.* All animals, Oomycetes, Diatoms, some Brown algae

**Haplontic** lifecycle (or Zygotic Meiosis - "zygote goes through meiosis")
• A life cycle in which the haploid (1n) phase is multicellular and dominant.
• This haploid phase produces reproductive cells, such as sperm and eggs, which fuse during fertilization to create a diploid cell.
• This diploid cell, the zygote, goes through meiosis to create four (4) spores which are dispersed.
• Spores germinate into new haploid organisms.
• Mature haploid  $\Rightarrow$ sex cells  $\Rightarrow$ fertilization  $\Rightarrow$ zygote  $\Rightarrow$ meiosis  $\Rightarrow$ spores  $\Rightarrow$ mitosis  $\Rightarrow$ mature haploid.
• *e.g.* many Green algae, most Fungi (Zygomycetes, Ascomycetes, Basidiomycetes)

**Diplo-Haplontic** lifecycle (or Alternation of Generations or Sporic Meiosis - "spores created by meiosis")
• A life cycle in which both the diploid (2n) and haploid (1n) phases are multicellular.
• Since this is a lifecycle found in plants and algae, we use the term "sporophyte" for the diploid phase, and "gametophyte" for the haploid phase.
• The diploid sporophyte produces sporocytes inside a sporangium, which each will go through meiosis to create four (4) spores. For each sporocyte, meiosis will create four spores.
• These spores are dispersed and germinate into gametophytes.
• Gametophytes mature and produce sex cells: male (e.g. sperm) and female (e.g. eggs) sex cells in gametangia.
• Sex cells fuse, during fertilization, to create a young sporophyte, or zygote.
• Mature diploid  $\Rightarrow$ meiosis  $\Rightarrow$ spores  $\Rightarrow$ mitosis  $\Rightarrow$ mature haploid  $\Rightarrow$ sex cells  $\Rightarrow$ fertilization  $\Rightarrow$ zygote  $\Rightarrow$ mitosis  $\Rightarrow$ mature diploid.
• *e.g.* All land plants, Chytridiomycetes, Red algae, some Brown algae, some Green algae.

**TERMINOLOGY:** algae and plants
• **Isogamy:** gametes are all same size/shape.
• **Anisogamy:** gametes are different sizes/shapes.
  • o **Oogamy:** female gametes non-motile, male gamete motile.
• **Siphonous:** long, coenocytic cells.
• **Filamentous:** threadlike connection of cells.
• **Parenchymatous:** three-dimensional connection and communication between cells.
FOUR MAIN CLADES of Eukaryotes:
1. **Plants** or **Archaeplastida** – Red algae, Green algae, Land plants
2. **Unikonts** – Slime molds, Fungi, Animals
3. **Chromalveolates** – Water molds, Diatoms, Brown algae, and Dinoflagellates
4. **Excavates** (not covered in this class) – **Euglena** and **Giardia**

**PLANTS**, in the supergroup **Archaeplastida**, contain the Red algae, Green algae, and Land plants
- All plants possess a chloroplast that resulted from an endosymbiosis event

**Red algae** in the kingdom **Rhodophyta**, are common deep water algae
- They are autotrophs that are completely non-mobile (no flagellated cells)
  - Possess **chlorophylls a & d** as well as phycobilins (pigments) for photosynthesis
- All are multicellular and structurally complex
- Red algae are extremely diverse in marine environments
- They have cell walls made of cellulose
  - Cells are covered by agar or carrageenan, which is used as an emulsifier by humans
  - Some red algae (corallines) incorporate calcium carbonate as protection
- Some possess **toxic terpenoids**, to prevent herbivory
  - Studies have shown these chemicals have promising effects as anti-cancer drugs
- Lifecycle of red algae: example of **Polysiphonia**
  - Red algae possess a complex haplo-diplontic lifecycle with 1 gametophyte stage and 2 sporophyte stages (unique in plant world)
  - **Gametophyte stage** (1n): separate male and female gametophytes exist
    - Males produce non-flagellated sperm called **spermatia**
    - Females produce egg structure with a long stalk, called a **trichogyne**, to catch spermatia. Successful “catch” allows fertilization of spermatia and egg to create a zygote (2n)
  - **Sporophyte #1 - Carposporophyte** (2n): diploid stage that forms from fertilization
    - After fertilization, the zygote grows into the carposporophyte, which lives as an epiphyte on the female gametophyte
    - Through mitosis, it creates cloned cells, called carpospores, which are released into the water to disperse the plant
  - **Sporophyte #2 - Tetrasporophyte** (2n): diploid stage that produces haploid spores
    - The carpospores grow into multicellular plants called the tetrasporophyte
    - Spore mother cells inside the tetrasporophyte cells go through meiosis to create haploid spores. These spores are released and germinate into new gametophytes
**GREEN ALGAE**, a paraphyletic grouping of algae/plants, in the supergroup Archaeplastida

- All green algae (and land plants) are autotrophic/photosynthetic
  - Possess chlorophyll *a* & *b* (pigments) for photosynthesis
  - Store the products of photosynthesis in true starch
- Green plants have cell walls made of cellulose
- Green algae can be found in two monophyletic sister-groups
  1. **Chlorophytes**: diverse green algae group
  2. **Streptophytes**: green algae closely related to land plant

**CHLOROPHYTES**, in the phylum Chlorophyta, are monophyletic clade of many green algae groups

- We will cover the classes Chlorophyceae and Ulvophyceae

**Chlorophyceae**, are mostly freshwater or terrestrial algae

- They consist of unicellular, colonial, or filamentous forms
- During mitosis they form a phycoplast: forms cell wall parallel to cytokinesis
- *Chlamydomonas*, a unicellular motile chlorophyte is common in freshwater

**Ulvophyceae**, are mostly marine seaweeds

- They consist of filamentous, siphonous, and thalloid forms
- During mitosis they exhibit furrowing of the cell wall during cytokinesis
- *Ulva*, the sea lettuce, is a common thalloid ulvophyte eaten by many marine organisms

**STREPTOPHYTES** are a monophyletic clade, consisting of several orders including some green algae (Zygnematales, Charales), as well as the Land plants (Embryophytes)

**Zygnematales** are common freshwater weedy green algae

- They consist of unicellular, colonial, filamentous forms
- During mitosis they form a phragmoplast: forms cell wall perpendicular to cytokinesis
- These algae exhibit a haplontic lifecycle
Algae is haploid, and forms gametes which are released and fuse through fertilization.

The resultant zygote does not grow, but instead goes through meiosis to create spores.

These spores are released into water to germinate into new gametophytes.

- **Spirogyra**, the water silk, is a common filamentous green algae found in eutrophic freshwater ponds and lakes. We will look at this plant in lab.

Charophytes, are green algae in the order **Charales**, and closely related to Land plants:

- These are the most closely-related algae to Land plants
- They are mostly freshwater or terrestrial algae
- They consist of unicellular, colonial, filamentous or parenchymatous forms
- They also form a phragmoplast, like Zygnematales and Land plants
- They exhibit branched apical growth like ancestral land plants
- These algae exhibit a haplontic lifecycle
- After fertilization, the zygote is briefly retained on the female before going through meiosis
- *Chara* and *Coleochaete* are the taxa most-closely-related to Land plants

**Embryophytes:** Land plants (next week)

**Evolution of Land plants from an Algal ancestor**

- Structural evidence indicates that Land plants evolved from some ancient green algae
  - All green algae and Land plants possess **cellulose**, **chlorophyll b**, and true starch
- Land plants share specific structural and biochemical similarities with the charophyte algae:
  - Phragmoplast formation during mitosis
  - They are parenchymatous (not filamentous) with apical growth
  - The egg is encased and retained on the female gametophyte
  - Sporopollenin is found in the inner wall of zygote of algae
  - Lignin is found in the thallus of algae
- How do researchers rectify the difference in lifecycles between charophytes and plants?
  - Charophyte have a haplontic lifecycle, but Land plants possess a diplo-haplontic lifecycle.
  - During evolution, there must have been change in the behavior of the zygote (sporophyte)
    - Instead of instantly going through meiosis, the zygote was retained on the female gametophyte
    - The zygote then began to grow (through mitosis) inside the female gametophyte, deriving nutrition from the mother cells.
LABORATORY DRAWINGS

- **Spirogyra** (slide): Green algae, Zygnematales
  - LABEL: **Chloroplasts, Vegetative cells**
  - LABEL: **Conjugation tubes, Zygotes**
- **Polysiphonia** (slide): Red algae, Rhodophyta
  - LABEL: **Male gametophyte, Spermatia**
  - LABEL: **Tetrasporophyte, Tetraspores**
  - LABEL: **Carposporophyte, Carpospores, Female gametophyte, Pericarp**

QUESTIONS FOR THOUGHT:

- What is algae? What is a plant?
- Where does meiosis occur on both Polysiphonia and Spirogyra?
- Where does fertilization occur on both Polysiphonia and Spirogyra?
- Why do red algae produce toxic terpenoids?
- How is the red algae life cycle different from, and similar to, other haplo-diplontic life cycles?
- What is the function of the tetrasporophyte?
- Where does the carposporophyte reside?
- Why are the Rhodophyta red in color?
- Why are the Charophyte green algae considered the closest living relatives to the land plants?
- How is the life cycle of Spirogyra different from land plants?