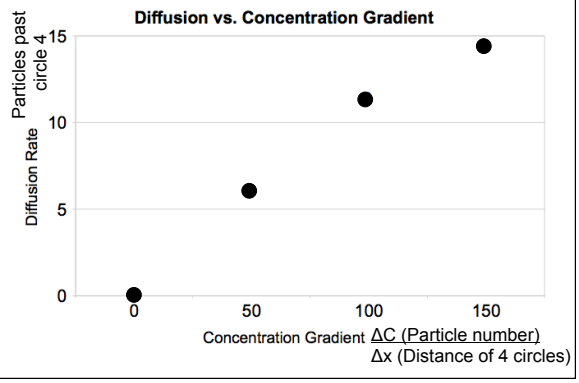
Class announcements

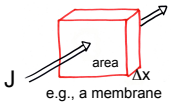
1. Next Friday – HW5. Diffusion homework due. Available at GAE homeworks link
2. Next Friday's GAE – bring 2 calculators for each group.

Simulation #3-#5 – Class results



Fick's First Law of Diffusion

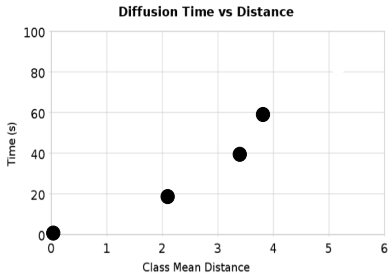
$$J = -D\frac{\Delta C}{\Delta x}$$



J = flux ("diffusion rate")
D = diffusion coefficient
ΔC = concentration difference
Δx = distance

(Negative sign means down the gradient, but biologists often drop the sign.)

Simulation #6 – Class results



Not enough data for 80 s

Two (of many) possibilities include:

1) t is directly proportional to x (the plot of t vs. x is a straight line)
2) t is directly proportional to x squared (the plot is parabolic)

Fick's Second Law of Diffusion $\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2}$

Einstein's solution - "time-to-diffuse equation"

Adapted from www.npl.co.uk/educate-+-explore/beginners-guides-posters/einstein-and-blackboard

$$t = \frac{(\Delta x)^2}{2D}$$

t = time
Δx = mean distance traveled
D = diffusion coefficient

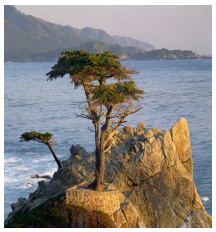
Movement of small diffusible molecules

For example, glucose -
molecular weight: 180 Da
diffusion coefficient: 7.0 x 10^{-6} cm^2/sec

$$t = \frac{(\Delta x)^2}{2D}$$

Distance (Δx)	Time (t)	Typical Structure
10 nm	100 ns	Cell membrane
1 μm	1 ms	Bacteria
10 μm	100 ms	Eukaryotic cell
300 μm	1.5 min	Sea urchin embryo
1 mm	16.6 min	Volvox
2 cm	4.6 days	Human heart wall
10 cm	82.7 days	Squid giant axon

The Evolution of Plants - They Made the Land Green



The "easy" life of an aquatic alga

- Bathed in nutrients
- Supported against gravity
- Extensive transport often not necessary
- Gametes, offspring transmitted by water
- No problem of desiccation

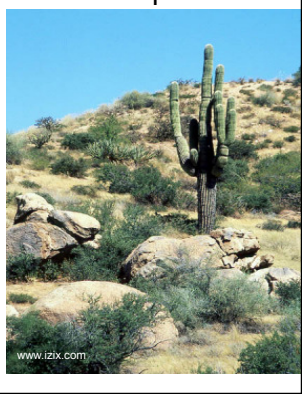
Plausible selection pressures for colonizing the land ~470 million years ago:

- More direct sun for photosynthesis (sufficient ozone for UV filtration)
- Inorganic nutrients available on land
- Initially, an absence of herbivores

The "harsh" life of a land plant

Land plants must

- _____
- _____
- _____
- _____
- _____



Where are the plants?

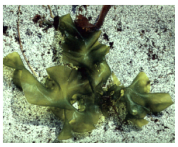
Animals fossilized in the Burgess Shale following the Cambrian Radiation 540 million years ago

Plants evolved as the conquerors of the land

Colonization of terrestrial environments

- **First** - plants evolved as a new monophyletic lineage with novel adaptations for surviving on the land.
- **Later** - existing lineages of animals modified pre-existing structures for terrestrial survival.

Did large multicellular algae "crawl" onto the land?

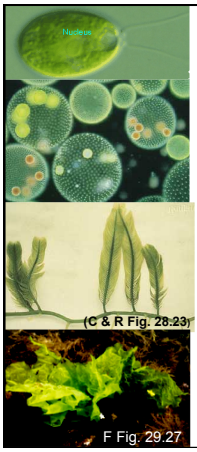


Green alga

Brown alga

Red alga

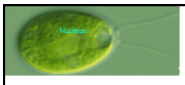
Great events in animal evolution



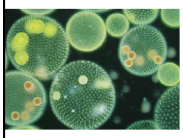
Green plants

- Two groups of modern green algae (chlorophytes and charophytes), plus land plants.
- Primitive shared features - chlorophylls *a* and *b*, cellulose cell walls, storage starch
- Great diversity of growth forms - unicells, colonies, coenocytes, filaments, and multicellular species

4 chlorophyte species



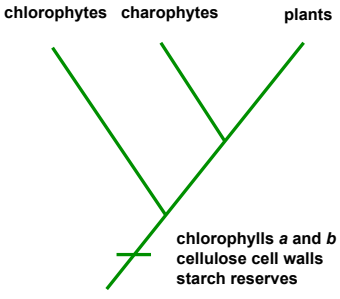
Chlamydomonas

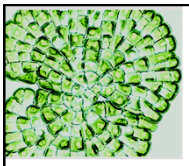


Volvox

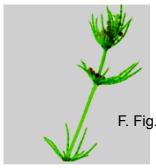
Ulva

Land Plant Origins - closest living relatives of modern land plants are green algae



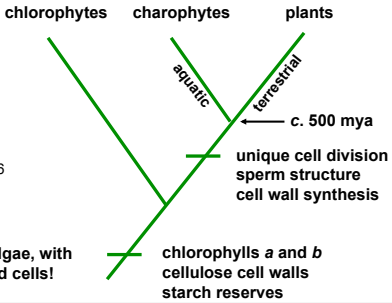


Coleochaete



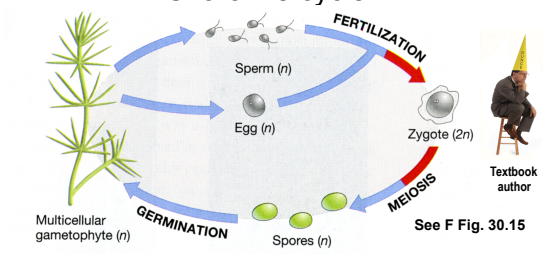
Chara

Land Plant Origins - closest living green algal relatives of modern plants are charophytes



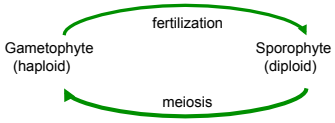
Haploid multicellular algae, with zygotes as only diploid cells!

Chara life cycle



Concept 1: The haploid generation (also called the gametophyte) of land plants retained algal-like features, including the need for external water to accomplish fertilization, except for seed plants.

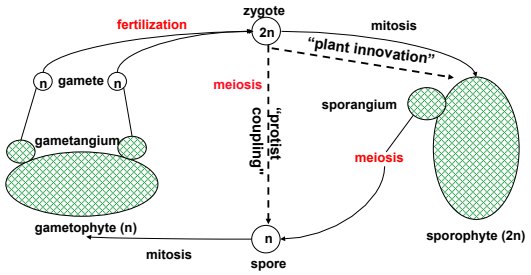
Plant life cycle - two multicellular generations



Concept 1: The haploid generation (also called the gametophyte) of land plants retained algal-like features, including the need for external water to accomplish fertilization, except for seed plants.

Concept 2: Early land plants evolved a new diploid generation called the sporophyte.

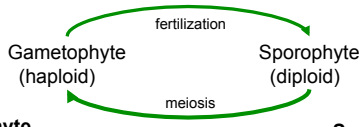
Plant life cycle - two multicellular generations

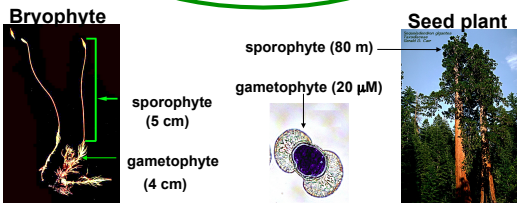


gametophyte = gamete-producing plant — sporophyte = spore-producing plant
gametangium = gamete-producing organ — sporangium = spore-producing organ
gamete = sex cell (egg or sperm) — spore = haploid product of meiosis

Concept 2: Early land plants evolved a new diploid generation called the sporophyte.

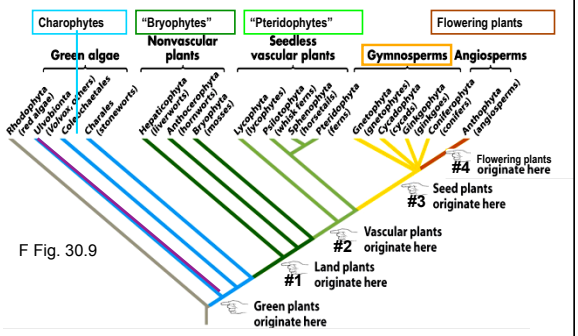
Generalized land plant life cycle





Concept 3: Almost all the adaptations to the terrestrial environment evolved as new evolutionary innovations on the land plant sporophyte - "terrestrial generation".

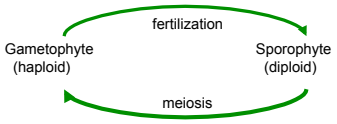
Four successive radiations of land plants



F Fig. 30.9

Concept 4: The evolution of land plants can be viewed as a series of adaptations to terrestrial challenges!

Summary - land plant life cycle



Concept 1: The haploid generation (also called the gametophyte) of land plants retained algal-like features, including the need for external water to accomplish fertilization, except for seed plants.

Concept 2: Early land plants evolved a new diploid generation called the sporophyte.

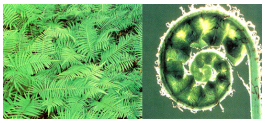
Concept 3: Almost all adaptations to land environment evolved as new innovations on the sporophyte - "terrestrial generation".

Concept 4: The evolution of land plants can be viewed as a series of major adaptations to terrestrial challenges!

.

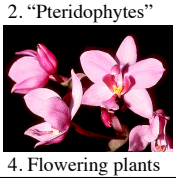
Each radiation has left living members whose sporophytes exhibit evolutionary innovations for surviving in terrestrial environments

1. "Bryophytes"



2. "Pteridophytes"

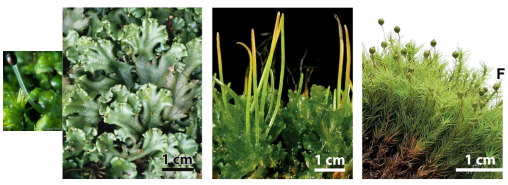
3. "Gymnosperms"



4. Flowering plants

Bryophytes - non-vascular plants

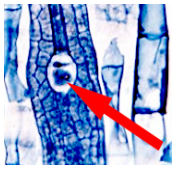
- Three phyla: liverworts, hornworts, mosses
- Abundant in moist habitats
- Persistent gametophytes, ephemeral dependent sporophytes
- Zygotes divide to form diploid embryos (young sporophytes)
- Mature sporophyte often develops three parts - capsule (sporangium producing haploid spores via meiosis), seta (stalk), and foot embedded in gametophyte for nutrition.



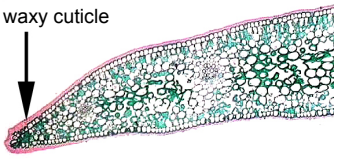
F Fig. 30.7

Liverwort **Hornwort** **Moss**

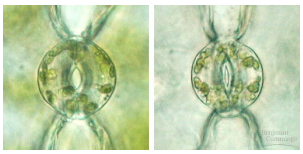
Bryophytes - three major innovations for surviving terrestrial environments



enclosed embryo



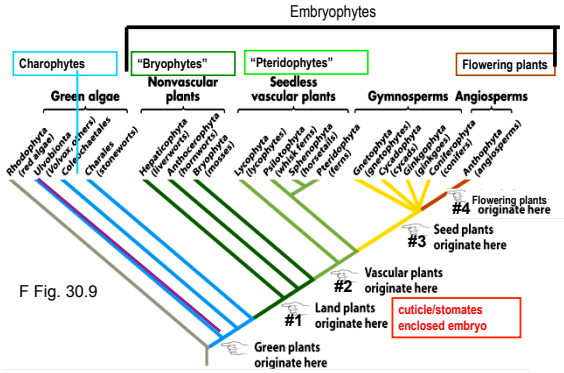
stomates



open closed

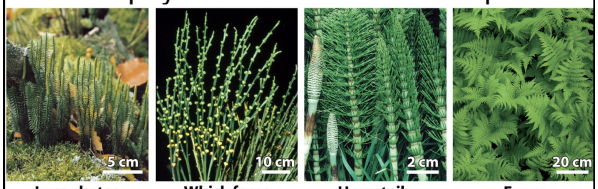
See F Fig. 30.10

1. First radiation of land plants - protection!



F Fig. 30.9

Pteridophytes - seedless vascular plants



Lycophytes Whisk ferns Horsetails Ferns

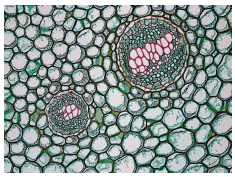
F Fig. 30.7

- major pteridophyte innovation was vascular tissue
- xylem (water and ion transport) and phloem (sugar transport)
- more efficient intercellular transport
- greater size due to the hardening agent lignin in xylem
- large sporophytes with vascular tissue
- small free-living gametophytes without vascular tissue

Pteridophytes - vascular tissue

- xylem (water and ion transport) and phloem (sugar transport)
- xylem - long, wide cells with no cytoplasm
- phloem - long, narrow cells with limited cytoplasm

stem cross-section

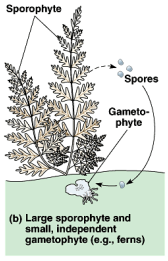


vascular bundles

C& R Fig. 29.11

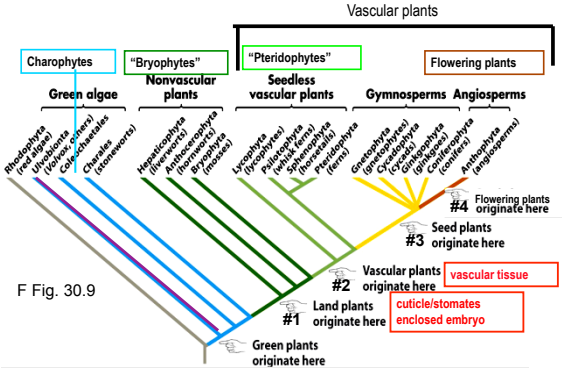
Pteridophytes are still limited by...

- the presence of a vulnerable gametophyte
- the requirement for external water to accomplish fertilization



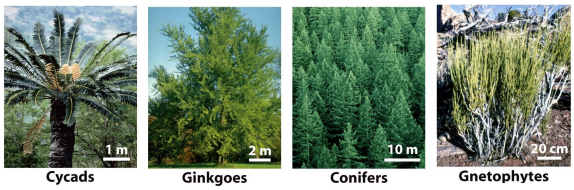
C & R Fig. 30b

2. Vascular plants - one major innovation



F Fig. 30.9

Gymnosperms - vascular plants with naked seeds

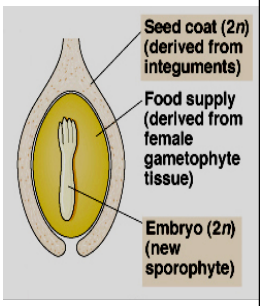


- Major innovations - seeds and pollen (with very reduced, microscopic gametophytes)
- 4 major groups with a total of 800 tree and shrub species
- Dominant tree species at high elevations and high latitudes, plus certain arid environments

F Fig. 30.7

Gymnosperms show 2 major innovations

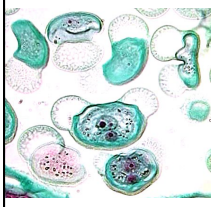
- The evolution of seeds
  - Female gametophyte (with eggs) retained on sporophyte (termed an ovule)
  - Eggs fertilized *in situ*
  - Embryo supplied with food
  - Seed (or fertilized ovule) - a three generation package deal
  - Can wait for favorable conditions!
  - Can be carried by wind or animals



See F Fig. 30.20

Gymnosperms show 2 major innovations

- The evolution of seeds
- The evolution of pollen (reduced male gametophyte)
  - Pollen can be carried by wind (et al.) to female gametophyte
  - Now free from water for reproduction!
  - Seed plants are viewed as genuine land plants



pine pollen

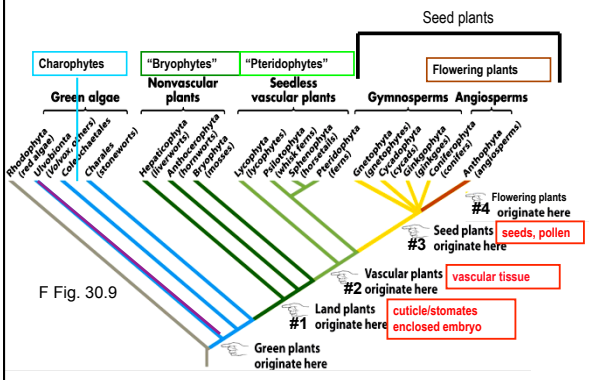
pollen cones

seed cones

Wind pollination has some drawbacks, however ...

- Inefficient … must produce lots of pollen

3. Seed plants - two major innovations



F Fig. 30.9