What (if anything) are plants and where did they come from?

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EVOLUTION
Chemicals ➔ Cells ➔ Slimy lower forms of life ➔ Plants and Animals ➔ Humans
Kingdom Plantae

- chlorophylls a and b, carotenoids
- store starch inside chloroplast
- cellulose
- form phragmoplast during cell division

Characteristics suggest a common ancestor in the Chlorophyta, Class Charophyceae

- the most advanced charophytes (e.g. Chara, Coleochaete) are most similar to the higher plants

Kingdom Plantae

Bryophytes
- Phylum Hepatophyta (liverworts)
- Phylum Anthocerophyta (hornworts)
- Phylum Bryophyta (mosses)

Vascular plants

Seedless vascular plants
- Phylum Lycopsodiophyta (lycophytes)
- Phylum Pteridophyta (ferns and their allies, the whisk ferns and horsetails)

Seed plants
- Phylum Cycadophyta (cycads)
- Phylum Ginkgophyta (ginkgo)
- Phylum Coniferophyta (conifers)
- Phylum Gnetophyta (gnetophytes)
- Phylum Anthophyta (angiosperms)
Key events:
• acquisition of chloroplasts
• colonization of land

Reconstruction of these events:
• fossils
• genes

Phylogenetic thinking
What are phylogenies?
• genealogies extended over evolutionary time
• views evolution as descent from common ancestors
• phylogenetic reconstruction permits the assessment of relationships and the study of evolutionary events in the past
So plants form one of many eukaryotic groups of organisms

Where did eukaryotes come from?
(from prokaryotes)

Presumed Chronology:
• earth formed around 4.5 billion years ago
  • oldest rocks around 3.8 bya
  • oldest fossil cells 3.2 - 3.5 bya
• divergence of prokaryotes (eubacteria/archaea)
• divergence of archaea and ancestors of eukaryotes

Archaea, bacteria and eukaryotes
• In 1977 Carl Woese compared ribosomal RNA sequences of representatives of prokaryotic and eukaryotic groups
• found that the prokaryotic groups are enormously diverse and form two ancient lineages
  ARCHAEA
  BACTERIA
• also found that eukaryotes shared common ancestry with archaeans
Most Bacteria, some Archaea

Organic compounds

Chemoheterotrophs or Heterotrophs

A few Bacteria and many Archaea

CO₂

Chemoautotrophs or Lithotrophs

Inorganic compounds, e.g. H₂, NH₃, NO₂, H₂S

CO₂

Some Purple and Green Bacteria

Photoheterotrophs

Light

Organic compounds

Some Purple and Green Bacteria

Photoautotrophs

Light

CO₂

Cyanobacteria, some Purple and Green Bacteria

Prokaryotic modes of nutrition

<table>
<thead>
<tr>
<th>Nutritional Type</th>
<th>Energy Source</th>
<th>Carbon Source</th>
<th>Examples</th>
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<tbody>
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<td>Photoautotrophs</td>
<td>Light</td>
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Complex eukaryotic cells are symbiotic associations
• earliest cells were mergers of archaean and bacterial genomes (discovered very recently)
• mitochondria and plastids arose by endosymbiosis (an old idea confirmed by studies done by Lynn Margulis)

Ancestors of green plants (green algae) and other photosynthetic eukaryotes (brown algae, red algae, etc.) diverged from common ancestors very early (over 1 billion years ago)
• each acquired plastids independently
Based on molecular data (and some fossil evidence):

- cyanobacteria origin at 2.56 billion years ago (Ga)
- eukaryotes originate at around the same time (fossils at 1.9 Ga)
- “Great Oxidation Event” (mass extinction) 2.3 Ga
- mitochondrial symbiosis at 1.85 Ga
- plastid endosymbiosis at 1.5 Ga

- Oxygen produced by photosynthetic cyanobacteria changed the atmosphere from reducing to oxidizing
  - rocks older than about 2.3 bya have reduced forms of iron, sulfur, etc.
  - younger have oxidized forms
  - would have led to an enormous mass extinction
Fossil microorganisms both prokaryotic and eukaryotic
- bacterial fossils similar in appearance to present-day bacteria (fig of cyanobacteria)
- eukaryotes found in 1.5 by fossils (red algae at 1.2 by)
- molecular data suggest a much earlier origin
- both prokaryotes and eukaryotes remain unicellular for a billion years (so multicellularity is hardly an inevitability)

Multicellular life forms in fossils date from the Precambrian
- ~ 630 mya
- soft-bodied animals
- Cambrian animals a little later (550 mya)

First land plants
- earliest land plants represented by spores and sporangium fragments date from 470 mya
- macrofossil plants in fossil record (Cooksonia) date from 430 mya
• conductive tissues of some sort (earliest ones were similar to mosses, with hydroids and leptoids)
• required water for fertilization (plant ‘amphibians’)
• most similar to present-day mosses, liverworts and ferns

Carboniferous landscapes dominated by seedless vascular plants (ferns and lycophytes)
• remains mined today as coal
• present-day diversity is low, except for the ferns
Seed plants first seen in the late Devonian
- air-transported pollen grains
- internal fertilization
- covered ovule, which develops into a seed
- no need for liquid water for fertilization
- biologically equivalent to ‘reptiles’ (amniotes)
First flowering plants seen in the Cretaceous (125 mya)

- flowers modified from shoot apices produce fused microsporangia (stamens) and ovules inside an ovary
- double fertilization (also seen in some gymnosperms)
- seeds develop inside fruits
1. What are plants?
2. When do the first ‘plants’ appear on the planet?
3. What is the significance of plants to the history of life on the planet?
4. When do these grade-level groups of ‘plants’ appear?
   - Cyanobacteria
   - Green algae
   - Vascular land plants
   - Seed plants
   - Flowering plants