Section B: The Origin of Land Plants

1. Land plants evolved from charophycean algae over 500 million years ago
2. Alternation of generations in plants may have originated by delayed meiosis
3. Adaptations to shallow water preadapted plants for living on land
4. Plant taxonomists are reevaluating the boundaries of the plant kingdom
5. The plant kingdom is monophyletic
1. Land plants evolved from charophycean algae over 500 million years ago

- Several lines of evidence support the phylogenetic connection between land plants and green algae, especially the charophyceans, including:
  - homologous chloroplasts,
  - homologous cell walls,
  - homologous peroxisomes,
  - phragmoplasts,
  - homologous sperm
  - molecular systematics.
• **Homologous chloroplasts** - The chloroplasts of land plants are most similar to the plastids of green algae and of eulgenoids which acquired green algae as secondary endosymbionts.

  • Similarities include the presence of chlorophyll $b$ and beta-carotene and thylakoids stacked as grana.

  • Comparisons of chloroplast DNA with that of algal plastids place the charophyceans as most closely related to land plants.
• **Homologous cellulose walls** - In both land plants and charophycean algae, cellulose comprises 20-26% of the cell wall.
  • Also, both share cellulose-manufacturing rosettes.

• **Homologous peroxisomes** - Both land plants and charophycean algae package enzymes that minimize the costs of photorespiration in peroxisomes.

• **Phagmoplasts** - These plate-like structures occur during cell division only in land plants and charophyceans.

• Many plants have flagellated sperm, which match charophycean sperm closely in ultrastructure.
• *Molecular systematics* - In addition to similarities derived from comparisons of chloroplast genes, analyses of several nuclear genes also provide evidence of a charophycean ancestry of plants.
  
  • In fact, the most complex charophyceans appear to be the algae most closely related to land plants.

• All available evidence upholds the hypothesis that modern charophyceans and land plants evolved from a common ancestor.
• The oldest known traces of land plants are found in mid-Cambrian rocks from about 550 million years ago.

• Fossilized plant spores are plentiful in the mid-Ordovician (460 million years ago) deposits from around the world.

• Some of these fossils show spores in aggregates of four, as is found in modern bryophytes, and the remains of the sporophytes that produce the spores.
2. Alternation of generations in plants may have originated by delayed meiosis

- The advanced charophyceans *Chara* and *Coleochaeta* are haploid organisms.
  - They lack a multicellular sporophyte, but the zygotes are retained and nourished on the parent.

- The zygote of a charophyceans undergoes *meiosis* to produce haploid spores, while the zygote of a land plants undergoes *mitosis* to produce a multicellular sporophyte.
  - The sporophyte then produces haploid spores by meiosis.
• A reasonable hypotheses for the origin of sporophytes is a mutation that delayed meiosis until one or more mitotic divisions of the zygote had occurred.

• This multicellular, diploid sporophyte would have more cells available for meiosis, increasing the number of spores produced per zygote.
3. Adaptations to shallow water preadapted plants for living on land

- Many charophycean algae inhabit shallow waters at the edges of ponds and lakes where they experience occasional drying.
  - A layer of sporopollenin prevents exposed charophycean zygotes from drying out until they are in water again.
  - This chemical adaptation may have been the precursor to the tough spore walls that are so important to the survival of terrestrial plants.
• The evolutionary novelties of the first land plants opened an expanse of terrestrial habitat previously occupied by only films of bacteria.

• The new frontier was spacious,

• the bright sunlight was unfiltered by water and algae,

• the atmosphere had an abundance of carbon dioxide,

• the soil was rich in mineral nutrients,

• at least at first, there were relatively few herbivores or pathogens.
4. Plant taxonomists are reevaluating the boundaries of the plant kingdom

- The taxonomy of plants is experiencing the same turmoil as other organisms as phylogenetic analyses revolutionize plant relationships.
  - The classification of plants is being reevaluated based on cladistic analysis of molecular data, morphology, life cycles, and cell ultrastructure.
  - One international initiative, called “deep green,” is focusing on the deepest phylogenetic branching within the plant kingdom to identify and name the major plant clades.
• Even “deeper” down the phylogenetic tree of plants is the branching of the whole land plant clade from its algal relatives.

• Because a phylogenetic tree consists of clades nested within clades, a debate about where to draw boundaries in a hierarchical taxonomy is inevitable.
• The traditional scheme includes only the bryophytes, pteridophytes, gymnosperms, and angiosperms in the kingdom Plantae.

• Others expand the boundaries to include charophyceans and some relatives in the kingdom Streptophyta.

• Still others include all chlorophytes in the kingdom Viridiplantae.
5. The plant kingdom is monophyletic

- The diversity of modern plants demonstrates the problems and opportunities facing organisms that began living on land.

- Because the plant kingdom is monophyletic, the differences in life cycles among land plants can be interpreted as special reproductive adaptations as the various plant phyla diversified from the first plants.