Land Plant Evolution: Algae to Angiosperms

The greatest adaptive radiation...

- is the largest radiation of plants
- involves series of dramatic adaptations to the problem of life on land and being non-mobile
- exhibits successive rounds of speciation and subsequent extinction
- sets the stage for the development of a land-based ecosystem with fungi and animals

Angiosperms or Flowering Plants

the phylum Magnoliophyta

Angiosperms - Flowering Plants

Angiosperms focus of the course
- comprise the phylum Magnoliophyta
- vast majority of plant diversity

What are the non-angiosperm land plants?
- DNA evidence has clarified much but not all of the relationships of other phyla (= divisions)

See first pages of Chpts 1 & 3 for more detail (Plant Systematics)

Fungi?

- Fungi collectively are not a natural group
- More closely related to animals than to plants
**Fungi?**

Traditional view of eukaryotic relationships

*Fungi are here*  *Green Plants are here*

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**Charales - stoneworts**

- Green algal lineage
- Closest relatives to land plants

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**Extinct Land Plants - the first plants**

- Green algal lineage
- Closest relatives to land plants

Extinct Land Plants - the first plants

- First evidence of land life at 460 mya

- Microfossils of spores with sporopollenin (degradation resistant material like lignin) and similar to modern day bryophytes such as liverworts

- Found worldwide in shales that were deposited at the marine-terrestrial interface
bryophytes

- earliest land plants - non vascular
- gametophyte dominant, 16000 species
- 3 lineages — they are not a natural group

Liverworts - Marchantiophyta
Mosses - Bryophyta
Hornworts - Anthocerotophyta

Extinct Land Plants - first vascular plants

<table>
<thead>
<tr>
<th>Paleozoic Era</th>
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<tbody>
<tr>
<td>Cambrian</td>
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<tr>
<td>Ordovician</td>
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<tr>
<td>Silurian</td>
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<tr>
<td>Devonian</td>
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<td>Mississippian</td>
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<td>Pennsylvanian</td>
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<tr>
<td>Permian</td>
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Early Devonian Period (410 - 390 mya)

Rhynia seen in the early Devonian (Rhynie Chert fossil) is one of first vascular plants.
20 cm tall, no roots, no leaves, primitive vascular tissue

Lycopodiophyta - club mosses

- 3 families, 1150 species
- sporophyte dominant, vascular, free sporing
- they are sister to all other vascular plants
Extinct Land Plants - the first ferns

Late Devonian Period (390 - 360 mya)

‘First true ferns (Protopteridium) - free sporing with complex sporangia & megaphylls

Polypodiophyta - ferns

• 11000 species
• immense variation in habit and habitat
• spores produced in specialized sporangia
• need a lot of systematic work - tropics!

Polypodiophyta - ferns

• includes the horsetails as unusual ferns!
• 15 species in Equisetum
• vascular plants, reduced leaves, terminal sporangia

Polypodiophyta - ferns

• includes the strange whish ferns!
• 6 species in 2 genera
• vascular plants, leafless green stemmed, lateral sporangia

Psilotum habit  Psilotum branch  Psilotum sporangia
Late Devonian Period (390 - 360 mya)

First "seeds" - "seed ferns" [Archaeosperma]

Plants fern-like with dissected compound leaves, but produce naked seeds (embryo within protective coverings)

Permian Period (286 - 245 mya)

Extinct Land Plants – first gymnosperms

Pinophyta - gymnosperms

- 870 species
- seed plants but seeds naked
- often divided into 4 phyla
- is one closer to angiosperms?

conifers

- pine
- spruce
- juniper

Cycads

- male strobilus
- female strobili
**Pinophyta - gymnosperms**

- 870 species
- Seed plants but seeds naked
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- Is one closer to angiosperms?

**Extinct Land Plants – first flowering plants**

- Cretaceous Period (146 - 65 mya)
- Near the Jurassic/Cretaceous border, the first Angiosperms are seen

**Magnoliophyta - angiosperms**

- 275,000 + species
- Seed plants with seeds encased in ovary
- Flowers a “key innovation”
Angiosperms - Flowering Plants
• tremendous adaptive radiation on land (and back into water)

- **Eucalyptus regnans** (Myrtaceae) over 100m tall and 19m dbh

- **Wolffia microscopica** (Araceae) less than 1mm long

- **Rafflesia arnoldii** (Rafflesiacae) from New Guinea, up to 1m across and 20lbs
Angiosperms - Flowering Plants

- tremendous adaptive radiation on land (and back into water)
- largest inflorescence
  *Amorphophallus titanum* (Araceae)

**Magnoliophyta classification**

- previously divided into two classes — dicots and monocots
- artificial!
  - we will use Angiosperm Phylogeny Group (APG III) classification system of 2009

The Flower — Why Important?

1. unlike anything else in other plants & extremely variable & co-evolved with animals
2. floral features used in describing and id’ing
3. plant specimens (herbarium) must include flowers or derived features
4. classification of angiosperms relies on flowers

**Calochortus** - fairy lanterns & mariposas (images: T. Givnish)
The Flower — What is it?

- specialized shoot = stem + leaves (folia)
- shoot is highly modified and determinate (ceased to grow)

The Flower — What is it?

- “foliar theory” of flower - J.W. von Goethe in “Attempt to Interpret the Metamorphosis of Plants” (1790)

The Flower — What is it?

- developmental/evolutionary origin of the flower still debated
  1. Euanthial theory - (foliar theory) - single shoot
     - anthers
     - ovules
  2. Pseudanthial theory - compound shoot or cone

The Flower — What is it?

- thus, a flower is a specialized shoot that:
  1. is determinate (vs. indeterminate)
  2. has a modified stem with compressed internodes
  3. possesses modified leaves with various functions, these determined by gene arrays (e.g., ABC model)
The Flower — What is it?

The 'ABC' model of floral part identity

sepals petals stamens carpels

The Plant Cell, 2010

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   4. often clustered in an inflorescence (larger branch)

The Flower — What is it?

The 'ABC' model of floral part identity

The Plant Cell, 2010

1st half deals with vegetative features - we will cover in lab 2 next week
2nd half deals with flowers/ fruits - lab 3 following week

read chpt 9 in Plant Systematics!
1. Peduncle: floral stalk, the stem supporting the flower; sometimes referred to as the pedicel.

2. Receptacle: modified floral stem or axis from which arise the floral appendages or modified leaves.

3. Sepal: the outer whorl of leaves, green and protective; collectively called the calyx.

4. Petal: the second whorl of leaves, typically brightly colored, attracting pollinators; collectively called the corolla.
5. Perianth: collective term for sepals and petals

6. Filament: slender stalk of the stamen supporting the anther; permits exsertion of anther with pollen out of flower

7. Anther: fertile portion of stamen that dehisces to release pollen grains; composed of anther sacs

8. Stamen: the male structure of flower comprising filament and anther; collectively, stamens are the androecium (= "house of males")
• stamens can be leaf-like in primitive angiosperms!

Nectaries often near base of stamens - produce nectar reward for visitors who will move pollen ('pollinators')

• all pistils (1 or more) are referred to as the gynoecium (= 'house of females')

12. Stigma: receptive portion at top of style that receives and recognizes pollen
11. Style: slender stalk of pistil above ovary that the pollen tubes must pass through to reach eggs in ovules.

13. Pistil: flask-shaped, female structure comprising three main parts — often referred to as carpel(s) —

9. Ovary: basal portion of pistil that contains ovules; at maturity becomes fruit with seeds.

10. Ovules: fertile portions of pistil that contain a female gametophyte (embryo sac); develop into seeds after fertilization.

Pollination biology: Study of the pollen, its transfer, and movement down the style.
The Flower

Pistil vs. carpel

How do you know?
- 3 examples
Carpels not fused
1. Monocarpic
2. Apocarpic
Carpels fused
3. Syncarpic

The Flower

Monocarpic

1 floral "leaf" in gynoecium. Folded "leaf"
1 carpel = 1 pistil
This gynoecium is monocarpic (one carpel)

The Flower

Apocarpic
- If 6 leaves separately form carpels,
- then the flower has 6 carpels and 6 pistils,
- gynoecium is apocarpic (separate carpels)

The Flower

Caltha palustris - Marsh marigold
6 fruits (pistils) from 1 flower
Gynoecium is apocarpic with 6 carpels or 6 pistols
3 floral "leaves" in gynoecium fuse

The Flower

Syncarpic

3 carpels = 1 pistil
3 styles
This gynoecium is syncarpic

3 carpels = 1 pistil
1 style
This gynoecium is syncarpic

The Flower

Syncarpic

tomato = 2 carpels
passion fruit = 3 carpels
starfruit = 5 carpels

* number of fused carpels is often clear in a cross section of the fruit

The Flower

Placentation types - arrangement of ovules, provides hints to the number of carpels

tomato = 2 carpels
passion fruit = 3 carpels
starfruit = 5 carpels

* number of fused carpels is often clear in a cross section of the fruit

= placenta tissue

The Flower

Placentation types - arrangement of ovules, provides hints to the number of carpels

Marginal - found in almost all monocarpic or apocarpic pistils

Axile - found in some syncarpic pistils
The Flower
Placentation types - arrangement of ovules, provides hints to the number of carpels

Parietal - found in some syncarpic pistils

Free-central - found in a few syncarpic pistils

Basal - found in some monocarpic, apocarpic, or syncarpic pistils

Numerical plan - merosity, arrangement of perianth
- not necessarily stamens or carpels

perianth spiralled
Common in primitive angiosperms

perianth 5-merous
Common in eudicots
The Flower

Numerical plan: merosity, arrangement of perianth
- Not necessarily stamens or carpels

Perianth 4-merous
Occasional in eudicots

Perianth 3-merous
Common in monocots & some primitive angiosperms

The Flower

Symmetry plan: perianth arrangement important in pollination biology

Flowers radially symmetrical
Flowers actinomorphic

Flowers bilaterally symmetrical
Flowers zygomorphic

The Flower

Connation: fusion of floral parts from the same whorl

- Fusion of carpels
- Sympetalous pistil

Fusion of stamens
- Staminal tube

Fusion of petals
- Corolla tube

The Flower

Adnation: fusion of floral parts from different whorls

- Simple adnation
  - Stamens fused onto inner surface of fused (connation) petals

- Complex adnation
  - Sepals, petals, and stamens fuse to form a hypanthium
Adnation: fusion of floral parts from different whorls

No adnation!

Connation (fusion of similar parts) may or may not occur

e.g., Drimys & sandwort

Adnation of calyx, corolla, & stamens = hypanthium

Ovary superior
Flower hypogynous
No hypanthium

Ovary superior
Flower perigynous
Hypanthium present

Ovary inferior
Flower epigynous
Hypanthium present

Adnation: fusion of floral parts from different whorls

e.g., cherry & rose

Adnation: fusion of floral parts from different whorls

e.g., horse gentian & fuchsia

Adnation: fusion of floral parts from different whorls
The Flower

Adnation: fusion of floral parts from different whorls

- calyx, corolla, stamens
- ovary
- hypanthium
- pedicel

Ovary superior
Flower perigynous
Hypanthium present

Ovary inferior
Flower epigynous
Hypanthium present

Floral formula - shorthand notation

\[ CA^4 \ CO^4 \ A^8 \ G^4 \]

- 4 sepals (CA\text{lyx})
- 4 petals (CO\text{rolla})
- 8 stamens (Androecium)
- 4 carpels (Gynoecium)

- Carpels fused = 1 pistil

- Oenothera biennis
- Evening primrose
- Onagraceae

Carpels fused = 1 pistil
- Ovary inferior
**The Flower**

Floral formula - shorthand notation

\[
\text{CA}^4 \text{CO}^4 \text{A}^8 \text{G}^{1}
\]

- 4 sepals (CALyx)
- 4 petals (CO rol l a)
- 8 stamens (Andr oecium)
- 4 carpels (Gynoecium)
- Carpels fused = 1 pistil
- Ovary inferior

\* Hypanthium (+ hypanthium tube)

**Oenothera biennis**
Evening primrose
Onagraceae

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