Evolution of Seed Plants

Extraordinary success of the seed plants can be attributed the "seed habit". This encompasses evolutionary trends and innovations in life history traits; in life cycle. The particularly important structures in this aspect of plant macroevolution are:

- gametophytes
- pollen
- seeds

Seed plant life cycles in evolutionary context
Recent research indicates that ferns, by far the most speciose lineage of seedless vascular plants, are closest living relatives to seed plants.

In non-tracheophyte lineages, such as mosses, gametophyte is larger, persists longer, and supports the sporophyte.

In non-seed tracheophyte lineages, such as ferns, the gametophyte and sporophytes are unattached; the gametophyte is reduced in terms of size.

In seed plant lineages, gametophyte is highly reduced -- to a small population of cells.

**Evolutionary trend in Plantae from “ancient” to “recent” lineages: gametophyte reduction.**

“Reduction” variously refers to:

- reduced size and conspicuousness of gametophyte
- reduced independence of gametophyte (support, nutrition)
Moss gametophytes with capsule-topped sporophytes growing from them. Copyright Claudia Mills/BPS.

Above: Heart-shaped gametophyte of a fern; hairlike rhizoids extend from the midrib region of lower surface. SEM. Copyright John N. A. Lott/BPS.

Below: Oak ferns (Gymnocarpium dryopteris), understory of temperate rain forest; coast of British Columbia, Canada. Copyright Alejandro Frid/BPS.

Family Iridaceae: blue flag (Iris missouriensis); Front Range, CO. Copyright Pollock/BPS.

Sori on underside of a frond of western sword fern (Polystichum munitum). Each sori consists of a cluster of sporangia (spore producing organs) Copyright John N. A. Lott/BPS.
Ecological and Evolutionary importance of seeds lie in their adaptations to dessication-resistance, dispersal and dormancy

- In seed, embryo is protected by an extra layer of sporophyte tissue creating the ovule
- During seed development, this tissue hardens to produce the seed coat
- Seed coat also enhances dispersal ability
- Seeds have the physiological capability for dormancy; the seed introduces a dormant phase into the plant life cycle that allows the organism to delay growth and physiological activity until environmental conditions are favorable

Seed plants are heterosporous; the two specialized spores produce two - male and female -- gametophytes

Male and female gametophytes are highly reduced; each consists of only a few cells

The entire male gametophytes -- pollen grains -- travel to female gametophytes by wind or pollinator - in seedless plants, sperm moves to female

Female gametophyte develops within the ovule

- In angiosperms ("enclosed seed"). ovules are completely enclosed in, and following fertilization, seeds develop in, chambers called ovaries (fruit = "ripened ovary"

- In gymnosperms, ovules are not completely enclosed in chambers (ovaries); "gymno-sperm"="naked seed"

Adaptive radiation of seed plants is related to a suite of adaptations that collectively can be called the "seed habit", which begins, evolutionarily, with reduction of megasporangium to a single functional megaspor
First seed plants probably arose about 425 mya, perhaps from spore-bearing "progymnosperms".

- Progymnosperms and modern gymnosperms share several characters: secondary xylem and phloem; leaves (in some).
- Many paleobotanists believe that seed plants evolved from heterosporous Middle Devonian plants like the progymnosperms.
- Since the "seed habit" begins with the reduction to a single functional megaspore in each megasporangium, heterospory seems like a logical intermediate step.

gymnosperms
mostly cone-bearing seed plants;
the ovules of gymnosperms are not completely enclosed by sporophyte tissue at pollination.

conifer = “cone-bearer”.
A cone is a tight cluster of scales or leaves specialized for reproduction.
megaspores and microspores are produced in separate seed and pollen cones.

Female (ovulate) cones of ponderosa pine before seeds have been released.

Cones of ponderosa pine opened by heat in a fire; wings of seeds being released are visible.

Wind transfers pollen from male to female strobili of larch (Larix decidua).

Cloud of conifer pollen in springtime wind (most conifers are wind-pollinated).

Pollen grains (male gametophytes) of red pine (Pinus resinosa), each with two large wings.
Sago palm (*Metroxylon sagus*), an edible cycad; New Guinea. Copyright BPS.

Welwitschia mirabilis, one of the three genera of gnetophytes (Raven et al. 2002).

Ginkgo biloba, the maidenhair tree, with leaves ready to fall in autumn. Copyright BPS.

Branch of male Ginkgo biloba with clusters of pollen-producing microsporophylls. Copyright BPS.

Branch of female Ginkgo biloba with leaves and ovules. Copyright Alfred Owczarzak/BPS.
Gnetophyta

Ephedra viridis (Mormon tea or joint fir) with cones; Arizona. Copyright Pollock/BPS.
Family **Taxaceae**: Pacific yew tree (*Taxus brevifolia*); source of cancer-fighting drug taxol.

Family **Araucariaceae**: the monkey puzzle tree (*Araucaria araucana*); alpine south-central Chile.

Family **Cupressaceae**: California juniper (*Juniperus californica*); Joshua Tree National Park, CA.

Family **Pinaceae**: **Pinus ponderosa**, ponderosa pine, is widespread in the American West.

Family **Pinaceae**: Colorado blue spruce (*Picea pungens*).
Family Pinaceae: *Pinus aristata*, the bristlecone pine, may live for thousands of years.

Slash pines, *Pinus palustris*, in Florida, are representative of the Coniferophyta, the largest phylum of gymnosperms (Raven et al 2002).

Family Taxodiaceae: coastal redwood (*Sequoia sempervirens*) in a California national park.
The pollen grain is the male gametophyte; as it germinates, it produces pollen tubes to reach the egg.

Embryo in protective seed coat.

Meiotic event in sporophytic megasporangium gives rise to megaspore which, through mitosis, will give rise to female gametophyte.

Female gametophyte forms a sex organ - a female gametangium or archegonium - in which it produces eggs. The archegonium is enclosed in sporophytic tissue that will later develop into seed coat.

The pollen grain is the male gametophyte; as it germinates, it produces pollen tubes to reach the egg.

Life cycle of a pine, illustrating gymnosperm reproduction and alternation of generations.

The ovule is a sporophytic structure; it includes the megasporangium, the integument in which it lies (integument will later form seed coat) and the tissue attaching integument to sporophyte.
Cones of ponderosa pine opened by heat in a fire; wings of seeds being released are visible.

Fruit-like "berry" of yew (Taxus sp.).
**Evolutionary perspective: Angiosperm reproductive biology**

Decline of some woody plants; rise of herbaceous plants

Extinction of some plant species

Expansion of extensive grasslands and deserts; decline of forests

Flowering plants continue to diversify

Spread of forests; flowering plant communities expand

Flowering plants dominant

Semi-tropical vegetation – flowering plants and conifers widespread

Rise of flowering plants

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**Floral Organs: Structure and Function**

- Flowers develop from compressed shoots, from four whorls of modified leaves
- Flowers consist of **four organs**,
  - Non-reproductive floral organs
    - Sepals
    - Petals
  - Reproductive floral organs
    - Stamens
    - Carpels
  - Reproductive organs contain **sporangia** – chambers in which gametophytes develop:
    - Male gametophyte: pollen grain
    - Female gametophyte: embryo sac

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**Idealized Flower**

- **Carpels**; triploid endosperm; seeds in fruit
- **Vessel elements**
- **Carpels fused by tissue connection**
- **Pollen with three grooves**

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**Lily**