April 9 - Gymnosperms

Gymnosperm: Seed plants whose ovules and seeds are not fully enclosed in an ovary; all seed plants other than angiosperms (flowering plants).

There are **~1000*** extant (currently living) species of gymnosperms, and they are split into four lineages: (*Among credible sources, there is a remarkable lack of agreement on # of species).

1) Conifers (Phylum Coniferophyta)	**~630 spp.**
2) Cycads (Phylum Cycadophyta)	**~300 spp.**
3) Ginkgo (Phylum Ginkgophyta)	**1 sp.**
4) Gnetophytes (Phylum Gnetophyta)	**~75 spp**.

The gymnosperms first evolved ~360 mya. The identity of the gymnosperm ancestor is uncertain, and there are many extinct gymnosperms and gymnosperm-like plants and their evolutionary relatedness is not always clear. We will not discuss these extinct forms.

For our purposes, what is important to know is that the extant gymnosperms are different from seedless vascular plants (ferns and allies) in three important ways:

1) True **secondary growth** via a vascular cambium
2) Sperm that is partially or completely conveyed to the ovule by a **pollen tube** – therefore sperm are not dependent upon water for delivery. (Note pollen in *Ginkgo* and cycads is flagellated!)
   …and, perhaps most importantly…
3) Development of a **seed**

Ovule: A structure in seed plants that contains the egg, the female gametophyte (derived from the nucellus – but you don't need to know this) and a protective structure called the integument. When mature, the ovule develops into the seed.

Seed: A structure that develops from a fertilized ovule in seed plants (gymnosperms and angiosperms). Seeds contain an embryo, stored food (mostly starch, but may also contain oils and proteins), and a protective layer called the **seed coat.** The seed coat develops from the integument of the ovary.

Integument: Outermost layers of an ovule, develops into the seed coat after fertilization.

There are two main ecological advantages of seeds over spore, and which helped gymnosperms radiate into new and dryer habitats are:

1) The seed coat
2) Food supply

<u>**Conifers**</u> Conifers are cone-bearing trees. The conifer seed cone is this group's distinguishing feature. (**Tree**: A perennial and tall [>~20'] woody plant with a single thick stem, or trunk.)

- ~630 species
- Most diverse and abundant group of gymnosperms, and not surprisingly also the most ecologically and economically important as well. Conifers form dense stands that cover much of the Earth's land area, and play an important role in carbon fixation.

Overview of reproduction and the life cycle of a typical conifer

This was presented in lecture, but much of the following cone structure material below was presented in lab. Dominant stage (the large tree we see…and perhaps climb…!) is the sporophyte. Gametophytes are housed in two types of cones: male cones (pollen cones) and female cones (seed cones or ovulate cones).

Male cones (pollen cones) are structurally simple. They have a central axis and **sporophylls** (leaf-like structures that bear **sporangia**). The sporangia house spores that quickly develop into pollen grains (while still inside the sporangia). The pollen grains contain sperm (the male gamete) for fertilization. To recap: male cones contain pollen grains, which contain the male gamete (sperm). (FYI: each individual pollen grain is a male gametophyte (1n), which produces the gametes (sperm) – but you do not need to know this level of detail!).

Female cones (ovulate cones) are more complex. They have a central axis. Off of this central axis are large **scales** (these are the "woody" chip-like structures of mature female cones in the Pinaceae). Most **ovuliferous scales** that we'll encounter have a two-part symmetry and bear two seeds (developed from **ovules**), this symmetry is visible as small groves on the surface of the scale. In most conifers the bract is invisible and completely fused to the ovuliferous scale, but in some (especially Douglas-fir and bigcone Douglas-fir) the bract is still visible. (FYI: an ovule contains/is mostly the female gametophyte.)

Ovule: In seed plants, the ovule contains the egg cell and is surrounded by the integument. When mature, the ovule develops into the seed (the egg develops into the embryo, and the integument develops into the seed coat).
Micropyle: The opening in the tip of the ovule through which the pollen tube enters.
Pollination: In gymnosperms: transfer of pollen from a pollen cone directly to an ovule (ovules typically located in female cones, but sometimes not – example is *Ginkgo biloba*).
Pollen: In seed plants, a powdery substance that contains sperm (and the microgametophyte that produces the sperm). We treat pollen simply – but these grains can be complex!
Fertilization: Fusion of two gametes (sperm and egg) into a zygote.
Pollen tube: A tube that elongates from the pollen grain and carries sperm into the ovule.
Bract: A modified leaf-like structure.
Sporophyll – A sporangium-bearing, leaf-like structure
Ovuliferous scale (female cone scale): in conifers, the appendage or scale to which the ovules are attached (ovules become seeds, so the scales will ultimately bear the seeds).
Monoecious: Having both male and female reproductive parts on the same plant (we will expand our thinking on this when we discuss angiosperms…)
Dioecious: Having male and female reproductive parts on separate plants

Pollination process in conifers.

Pollen grains are released by male cones, and they blow in the wind in "hopes" of encountering a female cone. Pollen grains have a special adaptation to keep them aloft – they have air bladders that protrude out each side (they look like mickey-mouse ears). If a pollen grain lands on a female cone, at the tip of an ovule, the pollen grain produces a **pollen tube** that conveys the non-flagellated sperm into the ovule for fertilization.

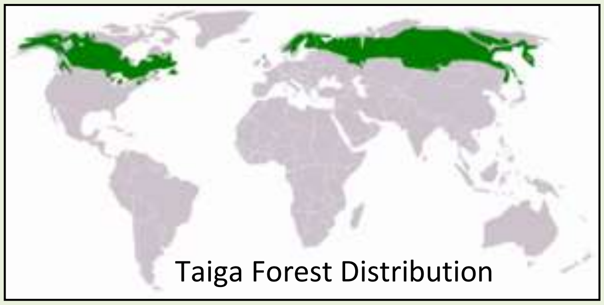
After fertilization, ovules develop into seeds and, if the parent sporophyte tree is lucky, the seeds are dispersed. Mechanisms of **seed dispersal** range from wind, small mammals (e.g., squirrels), birds (e.g., crossbills), and gravity. {VIDEO: Planet Earth: "Seasonal Forests" 1:07-5:00}

Thus, the key reproductive adaptations that allow conifers to inhabit vast areas of land are:
1) The **seed**, whose seed coat and stored energy allow offspring to disperse and begin life in dry habitats.
2) **Pollen tube**, thereby releasing conifers from the need for water to be present for fertilization.
3) **Secondary growth** – they can get very tall and dominate areas.
4) Leaves (needles) that are resistant to cold and heat (thick cuticle, sunken stomata, antifreezes, bundled into fascicles to increase protection).

Conifers and cold tolerance

Conifers are a cosmopolitan lineage, and occur on all continents except Antarctica. They are even found on relatively small islands, as evidenced by their distribution across archipelagos of Indonesia. However, conifers reach high density, blanket vast areas, and form globally important (e.g., carbon sequestration) forests across high latitudes of North America and Europe. Here, they form vast coniferous forests known as **taiga**.

Taiga (AKA boreal forests): Large expanses of coniferous forests that cover northern North America and Europe (see map at right). The most expansive forest on Earth, by most estimates comprising ~1/3rd of all forest trees and covering 11% of the land mass of the northern hemisphere. Thus important as habitat and for ATM [CO_2].



Taiga Forest Distribution

Conifers also encounter extreme cold at lower latitudes if they occur at high elevation. Clearly, conifers must have some capacity to tolerate cold temperatures if they occur at high latitude or high elevation. We had the following conversation:

<u>How cold damages plant cells/tissues:</u>
1) It's not the cold, per se, that damages plant cells, but it is the ice formation inside cells (intracellular ice) or outside cells (extracellular ice). WE DISCUSSED INTRACELLULAR ICE FORMATION.
2) Intracellular ice can physically damage cell structure, organelles etc. due to the fact that water expands as it transitions from liquid to solid. As it expands, the ice physically tears/crushes cell membranes and organelles.
3) Extracellular ice can dehydrate cells – we did NOT discuss why and you don't need to know this for exams...but can you figure out how/why extracellular ice formation could cause dehydration…based upon previous labs/conversations we've had this semester?

<u>An adaptations for avoiding ice formation in conifers:</u>
1) Antifreeze proteins (AFPs). Function by surrounding small, newly-formed, ice crystals inside cells, and thereby preventing them from behaving as nucleating agents that stimulate more expansive ice formation.

Conifer diversity

The 630 species of conifers represent some of the most impressive tress of Earth, including the oldest, largest, and tallest organisms on Earth. We discussed the following, as a small sampling of this diversity. *Know the common names and factoids of the species with asterisks*:

**Sequoia sempervirens* (coast redwood) – tallest living organims on Earth. Distributed along north coast of CA and southern OR only. Very water dependent – flattened leaves and height help strain fog (some studies suggest that up to 30% of the annual water budget is provided by fog drip). We will study this more in-depth when we talk about ecology after midterm #3.

**Sequoiadendron giganteum* (Big tree, giant sequoia) – Most massive tree on earth. Found in Sierra Nevada mountains of California.

**Pinus longaeva* (bristlecone pines) – oldest living organism on Earth. Previously discussed (in 2° growth lecture).

**Pseudotsuga menziesii* – Douglas fir. Dominant tree in the US Pacific Northwest. The most important timber tree in the US, source of many Christmas trees. Ovulate seed cones have obvious bracts that hang down.

Taxus brevifolia (Pacific yew, western yew) – bark contains taxol – used as an anti-cancer drug b/c it inhibits cell division.

Juniperus spp. (Juniper species). Widely distributed in northern hemisphere (we have four in California). Common in arid environments, common as landscape plants. Juniper “berries” – which are actually fleshy female cones - are used to flavor gin.

Pinus spp. The “pine trees”: many species (~115 worldwide). Recognized by long thin needles, often born in clusters called fascicles.

Pinus sabiniana and *Pinus coulteri* – two species of pines common in our backcountry – especially on and behind Figueroa Mountain in the San Rafael Wilderness Area. Extremely large ovulate cones – go check them out!

Abies magnifica – a “true fir”. Firs have single needles that leave a scar on braches when plucked, and their cones are upright on branches.

Araucaria spp. (includes Norfolk Island pine, bunya pine, monkey puzzle tree).

Cycads

- Cycads are woody seed plants with palm-like leaves. In fact, they are often mistaken for palms, and one commonly planted cycad (*Cycas revoluta*) has the unfortunate common name "sago palm" (but it is not a palm at all!)
- Cycads are the second-most diverse group of gymnosperms, with ~300 species known
- Cycads are dioecious – the male and female cones are on separate plants. Male cones are large and resemble conifers in structure (central axis with sporophylls) whereas the female cones are small and simple in structure.
- Relatively short, but some are tall
- Pollen is transferred via insects.
- Sperm is flagellated
- They are widely used in landscaping, and some rare species are highly sought-after by collectors and are quite valuable

Ginkgo

- Least diverse of all gymnosperms – only 1 species: *Ginkgo biloba*
- *G. biloba* is peculiar for a number of reasons(!): 1) sperm are flagellated (as in cycads), 2) leaves are broad and flat and thus more like those of a flowering plant than most gymnosperms, 3) **Deciduous** – this is rare in gymnosperms, though some conifers are also deciduous (dawn redwood, larch (genus *Larix*)); 4) female trees produce large seeds encased in fleshy "fruit" (not truly a fruit!!); 5) Represented in the fossil record up to 270 mya – *G. biloba* is a true **fossil species/living fossil**! Following are four more reasons to be impressed with *Ginkgo biloba*!
- The fleshy layer surrounding seeds contains butyric acid (aka butanoic acid) which is said to smell like rancid butter or vomit. For this reason, *G. biloba* trees planted in landscapes are almost always male.
- Used herbally to enhance cognnition and memory. It has also been suggested that *G. biloba* might reduce Alzheimer's disease and similar dementia. Scientific studies provide mixed results – often no benefits for memory or dementia are found in well-designed studies.
- *G. biloba* is an extremely hardy and durable plant – especially in urban environments. It is also quite attractive in the eyes of many, and so it is widely planted in cities (mostly male plants! – see above). Evidence of its durability is the fact that trees 1-2 km from the site of the Hiroshima nuclear bomb site were among the few (if only) macro-organisms that survived the blast – and they are alive to this day!
- *BY THE WAY (WILL NOT BE ON QUIZ OR EXAMS):* *Ginkgo* spp. (including *G. biloba*) were once widespread around the world, but by ~2mya the range of G. biloba was restricted to small pockets in China (and other *Ginkgo* spp. had gone extinct). It was first encountered by westerners in the late 1600's in temples in Japan and China – and was feared extinct in the wild. There is some suspicion that wild populations may have been cultivated by humans.

WE DID NOT COVER THIS – YOU DO NOT NEED TO KNOW IT FOR EXAMS AND QUIZZES

- *Ginkgo* pollination/fertilization is similar to conifers, and proceeds as follows:

  a) The ovule, when mature, produces a droplet that protrudes from the micropyle. This is the "pollination droplet", its purpose is to catch pollen passing by in the wind.

  b) Pollen are trapped in the pollen droplet and passed into the pollen chamber

  c) A special type of pollen tube grows into tissue surrounding the ovule, and gains nutrition from which the sperm develop.

  d) mature flagellated sperm emerge from the pollen tube, swim across the pollen chamber and fertilize an egg.

  {VIDEO: http://www.youtube.com/watch?v=kOr-XXcliHQ}

  e) Seed and a fleshy "fruit-like" seed casing develop

Gnetophytes

3 genera with ~75 species, All are very unusual gymnosperms.

Gnetum spp. = ~35 species. Mostly tropical vines that have flat, leathery leaves that resemble leaves of flowering plants.

Ephedra spp. = ~40 species. Highly branched shrubs with long, thin branches and small inconspicuous leaves. As you might expect this growth form is adapted to dry environments, where Ephedra is found throughout the northern hemisphere. Ephedra contains the alkaloids ephedrine and pseudoephedrine. *Ephedra sinensis* has been consumed in China for over 5,000 years, and other species of Ephedra have been consumed by indigenous North Americans as well as pioneers in the western USA. In the western USA, *Ephedra* is also known as "desert tea" or "Mormon tea" for this reason.

Ephedrine and pseudoephedrine stimulate the brain, increase heart rate, and expand bronchial tubes (making it easier to breathe). For this reason, ephedra is used as a PED (performance enhancing drug) by athletes, as a weight loss aid, and as a precursor to the drug methamphetamine. *Ephedra*-containing dietary supplements were popular in the USA in the 1990's and early 2000's.

Evidence of side effects began to surface in the 1990's: Ephedra can have serious side effects that include insomnia, dehydration, and vomiting, and in severe cases can cause seizures, heart attack, stroke, or death. Efforts to ban Ephedra-containing dietary supplements stalled, due largely to lobbying efforts of supplement manufacturers. In 2003, efforts to ban Ephedra picked up steam when major-league baseball player Steve Bechler died in Spring training, and a medical examiner determined that Ephedra played a "significant" role in his death. Ephedra was banned by the US FDA (food and drug administration) in 2004.

Welwitschia mirabilis (only species in genus). This plant grows only in the Namib Desert of southwestern Africa (Namibia and Angola). Each plant produces two long strap-like leaves that split along their length and appear like more than two leaves. Individual plants may be up to 1000 years old or older. (They are dioecious and pollinated by insects).