Topic 2: **Gymnosperms and Angiosperms**

[This is an early draft — strictly a work-in-progress.]

Botany lesson: The history of vascular plants (tracheophytes)

Some of the descendants of the bryophytes (the first land plants) developed xylem, phloem, and structural fibers. The xylem carries water and water-borne mineral nutrients, and the early forms of xylem were made up of tracheids. The phloem carries sugars and other compounds made by the plant, and the early forms of phloem were made up of sieve cells. These were the first vascular plants — their numerous descendants, including the gymnosperms and angiosperms, dominate all terrestrial plant life on Earth today.

The ability to transport fluids and a greater structural strength meant that vascular plants could grow to greater heights and occupy ecological niches away from the marine and freshwater coastlines. The first vascular plants reproduced by means of spores, not seeds, and are represented in the world today by clubmosses, spikemosses, and quillworts. The clubmosses, which make up the genus *Lycopodium,* were discussed in Topic One (see photos of modern *Lycopodiums* in Topic One). These plants were followed by other spore-producing vascular plants that we can still find today: horsetails, whisk ferns, grape ferns, marattioid ferns, and leptosporangiate ferns. The latter group is what we would recognize as the ferns we see in our North American woodlands and gardens. See the discussion and photos of horsetails, the genus *Equisetum,* in Topic One.

Botany lesson: The seed plants (spermatophytes)

And then what happened? Well, then the Plant Kingdom really cut loose with the development of seed plants. Humans, and the mammals that they hunted and domesticated, could never have evolved without the seed plants — the gymnosperms and angiosperms.

The seed ferns, which are now extinct, may have been the ancestors of all seed plants. See Figures XX and XX of what seed ferns must have looked like.

The gymnosperms came first. So, what the heck is a gymnosperm anyway? The seeds of gymnosperms develop on the surface of leaves or on the scales of a cone such as a pine cone or spruce cone. Sometimes gymnosperm seeds occur singly as in yew bushes, ginkgo trees, and *Torreya.* The soft covering of a yew or ginkgo seed is not a “fruit” in the true sense. See Figures XX and XX of yew and ginkgo seeds.

The dinosaurs ate gymnosperms such as cycads and conifers (see photos of cycads in Figures XX and XX). The gymnosperms developed in the late Carboniferous period and replaced the previous forests of giant clubmosses, horsetails, ferns, tree ferns, and the now-extinct seed ferns. This was not a smooth and steady development — there was a little climatic hiccup called "The Karoo Ice Age." This ice age began 360 million years ago and lasted until 260 million years ago, spanning part of the Carboniferous period and part of the Permian period. As the climate became cold and dry, ice caps and large glaciers spread from certain geographic centers. About 95% of species of plants and animals became extinct. Wow. Life as we know it, and the DNA that keeps it going, were almost wiped out. That was a close call. You have probably seen drawings of the dinosaur age showing a brontosaurus in a swamp or something like that. That was during the Jurassic period, AFTER the Karoo Ice Age was over. See Table XXX of the periods of time in the correct order.

The gymnosperms living today fall into four groups: the cycads (338 species), the ginkgos (one species), the gnetophytes (95-100 species) and conifers (600-630 species). These numbers add up to only a fraction of the number of species of flowering plants — the angiosperms. The angiosperms have 416 families, 13,164 genera, and 295,282 species. Wow. In terms of square miles covered, the conifers (a type of gymnosperm) make a respectable showing due to large temperate and subarctic forests (pine, spruce, fir, hemlock, and so forth). See photos of typical conifers in Figures XX, XX, and XX, a photo of a gnetophyte in Figure XX and a photo of a ginkgo tree in Figure XX.

<u>Group activity</u>
Pass around some edible pine nuts (see Topic 5 for more about pine nuts).
Are there any other gymnosperm foods you can think of?

Along with the evolution of seeds came another innovation (during the Devonian period) called "pollen," which in the development of the Plant Kingdom was a Really Big Deal. The spores of ferns and horsetails could travel pretty far, but the sex cells of these plants (the gametes) traveled only short distances. This means that genes were not mixed between different groups of the same species.

Let me explain. You have probably heard about "cross-pollination" and "out-crossing." Perhaps you have come across varieties of apple trees or blueberry bushes that need to be pollinated by another variety of the same species. Or maybe you have heard about purebred dogs that had hip problems because of "inbreeding." The upshot is that mixing genes of two parents that are dissimilar is good for the offspring — hence the term "hybrid vigor." If you are tree A of a species and your pollen is carried by the wind to tree B of the same species a mile away, then that is good for the offspring and future generations of that tree species (more variation and more ability to adapt). To make a long story short, this was a great improvement over the spore-bearing plants. If you are tree A and your pollen and your seeds are *both* carried long distances, then BINGO — you win the evolution sweepstakes! In fact, this is just what we see in the Plant Kingdom all around us — pollen that moves long distances and seeds that travel tremendous distances.

We will come back to the subject of pollen later in this topic, and then again in Topic Six, when we delve into the work of Gregor Mendel and other geneticists.

<u>Botany lesson: Angiosperms</u>

So, where the heck did the angiosperms come from? In the modern world, they are common in every conceivable ecological niche. The time and place of the origin of angiosperms is not known. Charles Darwin referred to the sudden appearance of angiosperms in the fossil record as "the abominable mystery." Well, we have found a lot of fossils since Darwin's time, and we have many more analytical tools at our disposal. We know a lot more about the origin of angiosperms than Darwin did, but not the full story. They diverged from the gymnosperms about 202 million years ago, appeared in the fossil record about 160 million years ago, became widespread about 120 million years ago, and replaced conifers as the dominant trees between 100 and 60 million years ago. The non-woody (herbaceous) angiosperms evolved later.

Angiosperm seeds are enclosed, not "naked seeds" as in the seeds of gymnosperm ancestors. You probably remember diagrams of flowers with the seed or seeds developing at the base of the female parts of the flower. No doubt you have seen a cucumber or tomato plant when the fruit (the edible part) is just beginning to develop as a swelling at the base of the faded blossom. A tremendous variety of seeds, fruits, and seed dispersal mechanisms have evolved, often in conjunction with the evolution of animals. Since Topics Three, Four, Five, and Six and mostly about angiosperms, we can leave the story there for now.

<u>Botany trivia: plant nutrients</u>

This is a review topic for the Master Gardeners out there. There are sixteen chemical elements required for plant life, including these nine major ones: Carbon (C) and Oxygen (O) come from the air (from carbon dioxide) and Hydrogen (H) and Oxygen again come from water. The next three are the N-P-K of fertilizer bag labels: Nitrogen (N), Phosphorous (P) and Potassium (K). These are the main nutrients that plants need from the soil — there is plenty of Nitrogen in the air but plants cannot use it in that form. Some plants can "fix" atmospheric Nitrogen by harboring bacteria adjacent to their roots. The final three of the big nine are Calcium (Ca), Magnesium (Mg), and Sulfur (S). Gardeners are familiar with Calcium and Magnesium compounds used to increase the alkalinity of the soil, and Sulfur or aluminum sulfate to increase acidity. In addition to adjusting alkalinity and acidity, these elements are also essential to plant nutrition.

Bonus material: Biogeography

Let's set botany aside for a moment and consider the question: why don't kangaroos live in North America? Perhaps they can't live in this climate. No, that can't be true because we have kangaroos in zoos and wildlife parks.

Maybe marsupials never came to North America. But we have native opossums that are marsupials. Opossums, skunks, and raccoons have adapted well to suburban life. The answer must be geographical — kangaroos did not arrive on this continent in prehistoric times. They might have arrived and then died out — perhaps they could not compete with the animals that were already here. But, the fossil record shows no evidence of that.

The distribution of plants and animals is called "biogeography." Guess what? That was one of the ways that evolution was discovered — every family of plants and animals was geographically connected to a common ancestor. It's true. There were sometimes "jumps" due to ocean currents or upper-atmosphere winds, but every one of them had an explanation. Sometimes the explanations are bizarre and fascinating, but they are never far-fetched. Pretty amazing, no?

In August of the year 1883 the island of Krakatau, thirty miles off the west coast of Java (now part of Indonesia), blew up in a huge volcanic eruption that affected weather worldwide for the following five years. The remaining crescent of bare rock was named "Rakata" and subsequently studied by naturalists who examined the plant and animal life that returned to the island. Author David Quammen, in *The Song of the Dodo: Island Biogeography in an Age of Extinctions,* describes the island plant life as follows (page 143):

"In 1934, a half century after the new beginning, Rakata and its companion islets held 271 species of plants. One botanist has given us an informed guess as to how each of those species arrived. About forty percent came on the wind. Almost thirty percent floated across the sea. Most of the others had probably been carried by animals. They all possessed good dispersal ability, but the means were various."

The people who discovered evolution were not looking for it — they had originally set out to glorify God by studying His Creation. However, they kept finding evidence that did not fit the old theories (Noah's flood, for example). Biogeography was a key part of that evidence! The distribution of plants and animals on islands played a major role in the discovery of evolution — not just the Galapagos and the Falklands but many others as well. The early evolutionary biologists Alfred Russel Wallace and Joseph Hooker made extensive studies of island life and arrived at startling conclusions. Charles Darwin was an island biogeographer before he was an evolutionist. Darwin and Wallace both reached similar conclusions about evolution independently of each other.

Biographical trivia
Alfred Russel Wallace (1823-1913) was a naturalist, explorer, poet, writer, and advocate for social reform. He shares with Charles Darwin credit for first developing the idea of evolution-by-natural-selection, which is only part of the modern concept of evolution (see Topic 6). His 1887 visit to Denver, Colorado, was hosted by the distinguished Canadian-American botanist Alice Eastwood (1859-1953).

Bonus material: Pollen studies in paleobotany and archaeology

Paleobotany is the field we have been discussing — the origin and development of plants throughout geologic time. Let's take a break from paleobotany and turn to something more recent — archaeological studies of human communities of the near and distant past.

Palynology is the study of pollen, which in our time has developed into a precise and revealing science. Using light microscopes, scanning electron microscopes, and other analytical methods, it is possible to identify pollen grains and determine the species of plant from which they came. Isn't that amazing?

Pollen studies are often useful to archaeologists. Here are some examples:

1) Pollen grains embedded in adobe bricks from Spanish Colonial buildings reveal the spread of European plants in places such as California. Often the date of the construction of the building (and thus the date of the bricks) is a known date, and the pollen studies can be correlated with when imported plant life became common in a certain area.
2) For a village site or nomadic campsite that has been occupied and abandoned several times over the years, excavations of pollen grains can determine when cultivated plants were present and when wild plants were present. This can help construct a precise timeline of occupation and abandonment.
3) In more recent history, pollen excavated from gardens at Mount Vernon and Williamsburg reveal what plants were grown and when.

Pollen studies are pretty nifty, no? From these examples, you can imagine how fossil pollen can be used to reconstruct a Jurassic swamp or a Cretaceous forest. Wow.

Intergenerational activity (for a senior citizen and young person to do together).

The instructor will bring in a bunch of old retail and mail-order nursery catalogs of woody ornamental plants (trees and shrubs). Alternatively, participants can search online nursery catalogs. Avoid nurseries that have a limited specialty such as conifers, heathers, or roses. The drawback to wholesale catalogs is that common names are not given. Label each shrub or tree as "Gymnosperm" or "Angiosperm." Then count up the totals and see which number is greater. There is an alphabetical list of gymnosperm genus names as an appendix to this chapter — all others are angiosperms. Or, you can look them up yourself on a mobile device with Internet access. Compare your totals with other teams, or perhaps the instructor can post the totals for all to see. A large catalog or online listing can be split between two or more teams. There may be some plants such as ferns that are neither gymnosperms nor angiosperms — your instructor can assist in identifying which ones they are.

[End of first draft of Topic Two. There is more to be added.]