Topic One: **From the First Plants to the Age of Dinosaurs**

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

Botany lesson: Ancient Oceans and the Beginnings of Life

The primeval atmosphere did not have much oxygen — it was thick and acrid from volcanic activity. The first organisms in the ancient oceans were single-celled. The first bacteria consisted of an outer membrane and a few primitive proteins. Some bacteria acquired the ability to capture energy from sunlight — the first photosynthetic bacteria. The earliest photosynthesis was different from what we see today: for 300 million years these original photosynthetic bacteria produced sulfurous gases rather than oxygen.

Oxygen accumulated in the air after the development of the early cyanobacteria, which perform photosynthesis but are not part of the Plant Kingdom. These organisms, which originated 2.7 billion years ago, pumped oxygen into the atmosphere over a period of one billion years. You probably learned in school that photosynthesis captures energy from sunlight and converts carbon dioxide and water to sugar and oxygen. This process was the key to plant and animal evolution and is still the basis of life on our planet today. At one time, the oxygen in the atmosphere rose to 35%, before settling back to the 21% we have today (about 250 million years ago). Oxygen is the third most abundant element in the universe.

The cyanobacteria were joined by other photosynthetic organisms — the red, brown, and green algae. The algae whose cells had both a nucleus and chloroplasts became the earliest members of the Plant Kingdom. A chloroplast is the body within a cell where photosynthesis occurs. The simple ocean plants known as “phytoplankton” became so successful that they still occur in every ocean in the world today and are key players in the global ecosystem and food chain.

For the complete story from which these paragraphs are summarized, see the book *Kingdom of Plants* by Will Benson, Chapter One.

Bonus material: Ocean Plants Today

Let’s take a look at some ocean plants that we find today.

First we will consider the floating *Sargassum* seaweed found in the “Sargasso Sea” in the mid-Atlantic. This is a brown algae and not a member of the Plant Kingdom. The Sargasso Sea is surrounded by strong ocean currents and known for the high visibility in its waters — up to 200 feet. There is also a large amount of man-made trash dropped there by the currents. This type of seaweed also has planktonic (free-floating) species. In my childhood, I remember reading an

article about the Sargasso Sea in *National Geographic* magazine. It has been prominent in folklore and fiction for hundreds of years.

Kelp is another type of seaweed, a large group of brown algae species. They are not part of the Plant Kingdom either. Kelps evolved around 5 to 23 million years ago and thus were not part of the ancient oceans. Kelp grows in underwater "kelp forests" and can reach a length of 100 to 260 feet. In nineteenth-century Scotland, kelp was harvested and burned as a source of the industrial chemical "soda ash" (sodium carbonate, also called washing soda).

The plants that grow in salt marshes and fresh-water lakes are often closely related to land plants, but the plant life of the oceans has a different ancestry.

Group discussion

Have you ever seen an underwater kelp forest? What was the location? Have you ever eaten seaweed at a restaurant, perhaps a Japanese restaurant? Did you like it?

Group inquiry

Does anyone know what "diatomaceous earth" is? What is it used for? Where does it come from? What is a "diatom"?

Botany lesson: the first land plants

Some green algae were washed up on to the land, and these became the ancestors of land plants. Over time, some algae developed a waxy cuticle on their surfaces and a capsule around the embryo of a developing plant. These became the bryophytes which were the first land plants, during the Ordovician period 470 million years ago. (See Table XXX about geologic time.) They were primitive land plants, short in size and dependent on a moist environment for reproduction (this is still true of bryophytes living today).

Botany lesson: A Nature Walk and Plant Evolution

If you go on a nature walk in temperate North America, you will see many kinds of land (terrestrial) plants. We will select four types to investigate here: lichens, mosses, *Lycopodiums* (clubmosses or ground pines), and *Equisetums* (horsetails or scouring rushes). Let's take a look at these plants and how they fit into plant evolution.

For starters, we will look at lichens. Lichens are not in the Plant Kingdom.

Here is a description of lichens as you might see them on a nature walk:

You might see lichens as ruffled rosettes of light green, blue, or grey on the bark or branches of a tree. In cities, bright yellow "candleflame" lichens are common.

Many lichens form light green/grey communities at the bases of forest trees – look at them with a hand lens! Other lichens look like light grey plain splotches on rocky outcrops, and if you look closely you might find their fruiting bodies – they look like a tiny grey or black pizza! If you look closely at a mossy log, you might see some light grey stalks or grey "pixie cups" growing among mosses – these are *Cladonia* lichens.

Bonus material: Fun facts about lichens

Fungus + alga = lichen? Not exactly.

First of all, only specialized fungi can associate with a photosynthesizing organism to form a lichen. (Not all fungi can do it!)

Secondly, lichens sometimes have algae in their tissues, sometimes cyanobacteria, and sometimes both! Sometimes one lichen will be a parasite on another lichen and take over its algae or cyanobacteria.

Finally, we just found out in 2016 that often lichens have more than one kind of fungus! They also harbor a diverse "microbiome" of smaller microorganisms.

Even though many lichens are pollution-sensitive, some lichens can grow in the centers of urban areas, including Central Park, NYC and City Hall, Philadelphia. Lichens can also grow on a huge array of substrates, including glass, cars, benches (wood or plastic), bones, (and of course trees and rocks).

You can grind up lichen to dye wool! You can even eat some lichens (including "rock tripe").

Some Biblical scholars think that the "manna in the wilderness" was lichen growing on rocks in the Sinai Desert.

Lichens grow on every continent, including Antarctica.

Lichen rhizoids penetrate rock surfaces and, combined with secretions such as oxalic acid, this helps to weather rock surfaces and release minerals needed by plants.

Botany lesson: Nature Walk, continued

Mosses, along with liverworts and hornworts, are relatives of the oldest land plants — they have no xylem or phloem or roots, no flowers or pollen, and no seeds.

Here is a description of mosses as you might see them on a nature walk: clumps of light or dark green color on rocks, tree trunks or stream banks — short and close to the ground or the bark (See Figure XX and Figure XX). If you pick up a clump in your hand it is soft and damp — green on top and brown on bottom (no

roots). Mosses are primitive non-vascular plants that evolved prior to the advent of coastal colonies of vascular land plants in the Silurian period and the evolution of the first pollen-bearing plants in the Devonian period. More about that in Topic Two: *Gymnosperms and Angiosperms.*

There are about 1,000 species of moss in North America — it grows in moist, acidic soil in heavy shade. If you want to discourage moss in your lawn, you can incorporate dry, bulky organic material into the soil and apply pelletized limestone (calcium carbonate).

Mosses, liverworts, and hornworts are bryophytes, which after 450 million years on Earth have remained small and inconspicuous — about 10,000 species living today. They do, however, have important ecological roles such as nutrient cycling in the tropics and insulating the permafrost in the arctic.

Group inquiry

What is sphagnum moss? Why are environmentalists trying to protect it? How is it used commercially? Are we harvesting too much?

Botany lesson: Nature Walk, continued

Lycopodiums, or lycopods, (also called clubmosses) are the oldest living vascular plants, descended from the early plants that colonized dry land in coastal areas during the Silurian period. See photos in Figure XX and Figure XX that show modern *Lycopodiums* you can see today on the floor of the temperate forest. They are also called “ground pine,” “running pine,” or “creeping cedar.” They reproduce by spores and spread horizontally by means of creeping stems called rhizomes. They do not transplant well, so don’t try to dig them from the woods to put them in your garden or woodlot.

When you find an *Equisetum* on the side of a road or pull it from your garden, you are visiting a plant that was formerly king of the forest. For about 100 million years, *Equisetums* dominated the understory of the Devonian, Carboniferous, and Permian forests (reaching heights of 100 feet). Wow! *Equisetums* are related to ferns, including the huge tree ferns of the dinosaur age. See photos of typical modern *Equisetums* in Figure XX and Figure XX.

Equisetums contain silica, which is why they were used as “scouring rushes” to clean pots and pans. Your instructor might be able to pass around some *Equisetums* so you can feel this for yourself — the stems feel gritty when you crush them in your hand. Silica is a mineral material similar to beach sand.

Botany lesson: the first forests

As years passed, the clubmosses (*Lycopodiums* and their relatives), horsetails (*Equisetums*), ferns, and tree ferns, in sizes much larger than we see today, formed tropical forests. The tremendous proliferation of new plant forms in the

Devonian period is called the “Devonian Explosion.” The 12,000 species of ferns we see today are descended from these Devonian forests and fern savannas. In time these plants gave way to the gymnosperms and angiosperms (see Topic Two).

For the sake of simplicity, I do not discuss the drift of continents across the surface of the Earth. As the land masses and oceans shifted, the evolution of plants continued. For example, when the Andean-Saharan Ice Age occurred between 450 and 420 million years ago, what we now know as South America and West Africa were close to the South Pole. The ice ages occurred as part of climate cycles and changes in levels of atmospheric carbon dioxide and methane. Throughout these cycles, the diversification and extinction of plant and animal species continued, with many ups and downs.

Another factor in mass extinctions of species was changes in the composition of seawater, including low levels of oxygen (anoxia) and high levels of toxic sulfur compounds and heavy metals (euxinia). Even the experts do not agree on the specifics of how these extinctions occurred, so we will move on to simpler topics.

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