Lab IV: The Arborescent Lycophytes

Today we will examine plant fossils for the first time. The study of fossil plants presents a new challenge: plant parts are usually broken up into pieces before degrading long before they are fossilized. It is the job of Paleobotanists to give names to the pieces and figure out how the pieces go together into the fossilized organism. The pieces are called **form genera**. Once it is understood how the various pieces fit together, a name is given to the composite plant, is called the **composite genus**. Fossils are also classified by mode of preservation and there are five in all.

In order of increasing quality of preservation, they are:

1. **Casts** - three-dimensional fossil types that form in negative imprints from non-organic materials like sand or clay.

3. **Impression (or mold)** - the 2D or 3D negative imprints of organisms (e.g., animal tracks).

4. **Compressions** - fossils in which a thin film of organic carbon remains.

5.**Petrifactions** - fossils in which a mineral solution permeated the organism's cells and tissues, thereby preserving them.

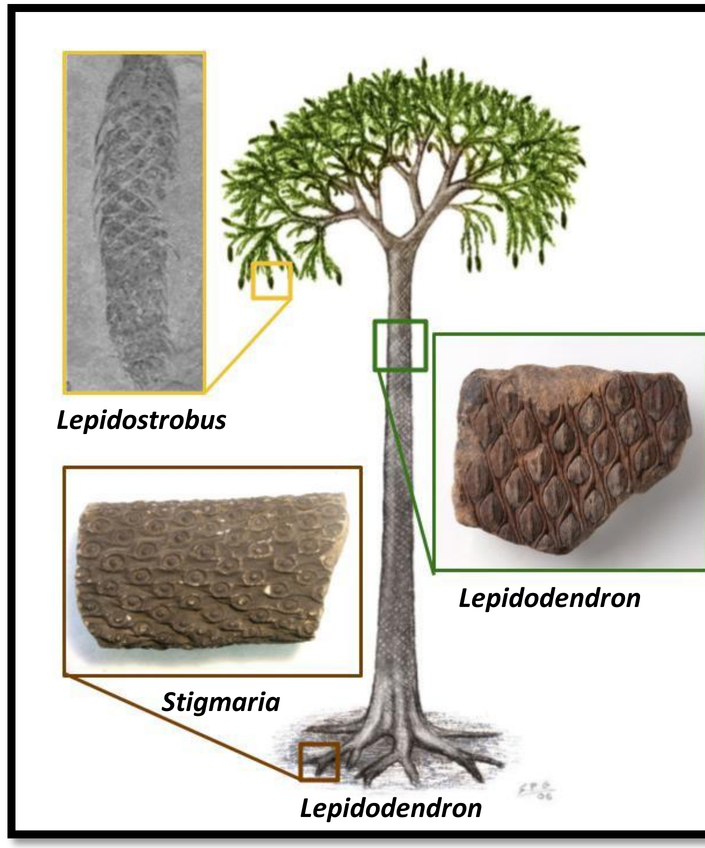


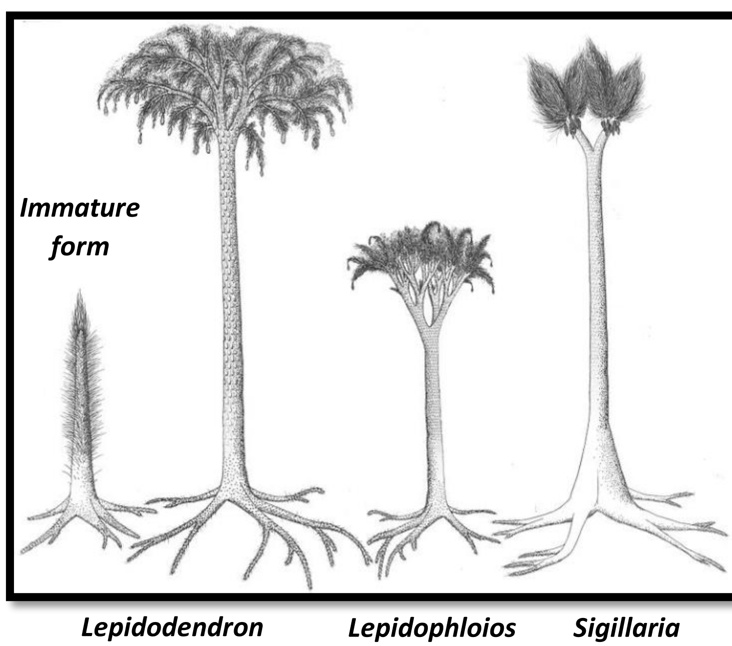
Figure 1. Composite genus *Lepidodendron* and some of its form genera: *Lepidodendron* (stem); *Stigmaria* (root); *Lepidostrobus* (strobilus).

A. Order: Lepidodendrales

This order of arborescent fossil plants was most prominent about 300 million years ago, in the Upper Carboniferous (also called Pennsylvanian). Here we will study two composite genera, organisms understood by piecing together information from form genera assumed to derive from the same plant:

Lepidodendron: much-branched crown, leaf scars in helices

Sigillaria: crown branched once or a few times, leaf scars in vertical rows.



We will spend almost all of our time with *Lepidodendron*. Also known as the scale trees, members of the composite genus *Lepidodendron* have been put together from five form genera (Figure 1):

- *Lepidophyllum* (or *Lepidophylloides*): leaves (Figure 2 & 3)
- *Lepidodendron*: trunks (Figure 4)
- *Lepidostrobus*: strobili (Figure 5)
- *Lepidocarpon*: retained megagametophyte, in place in the megasporangium, on the sporophyll
- *Stigmaria*: root-bearing axis (rhizophore) and roots (Figure 6)

1. Compressions and Impressions of Lepidophyllum

a. Look at compressions of small shoots with *Lepidodendron* leaves, classified in the form genus *Lepidophyllum* (Figure 2). The important thing to gather from these fossils is that they are microphylls, but that even these small microphylls from the top of the plant are quite large, larger than any microphylls we've seen so far.

- These fossils are **compressions** because they retain some carbon content, though they have lost their three-dimensional form.

Figure 2. Mazon creek *Lepidophyllum* in Francis Creek shale from Illinois, USA..

b. Also look at impressions of single microphylls of *Lepidophyllum* in the round, tan rocks in lab. These particular impressions are well-known to paleobotanists: they are called Mazon Creek nodules, from the place where they are found in Illinois. The nodules occur in a geologic formation called Francis Creek shale, which dates to the Middle Pennsylvanian age, approximately 309 million years ago. Apparently, the erosion of the rock that encased these fossils left the fossils intact. Presumably, the rock around the fossil did not erode because a plant exudate made it harder than the surrounding rock.

- These fossils are **impressions**: they are flattened, and no organic material remains - only the imprint of the original structure on the mud. These

c. The **microphyll** in these nodules are more interesting than the others because you can discern some of the interior structure of the leaf in the imprint. Notice that there are three ridges along the middle of the leaf. The central one is the single **vascular bundle** of the microphyll. The other two are both tubes of **parichnos**, a tissue of loosely packed cells apparently designed for providing gas exchange to the interior of the leaf.

***S1: Make a sketch of the *Lepidophyllum* leaf in the Mazon Creek nodule. Label the type of fossil its age and label the features described above.**

2. Stems of the Scale Trees (*Sigillaria*)

Now look at older stems of the scale trees. In this case, we can look at stems of two composite genera - it is by the stem pattern that the composite genera are best recognized.

a. First look at *Lepidodendron* itself. Note the **helical arrangement** of the **leaf scars** on the stems. These leaf scars are formed by the abscission of the microphyll when it falls off the stem (Figure 3). In each helical scar there is evidence of the plant's vascular tissues. In the abscised microphyll scar there is the central **vascular bundle scar**, flanked by two **parichnos scars**. On the adaxial surface of the lead are two **intrafoliar parichnos scars** and above the abscised leaf scar is the specialized cells that form the ligule pit where the ligule would have attached.

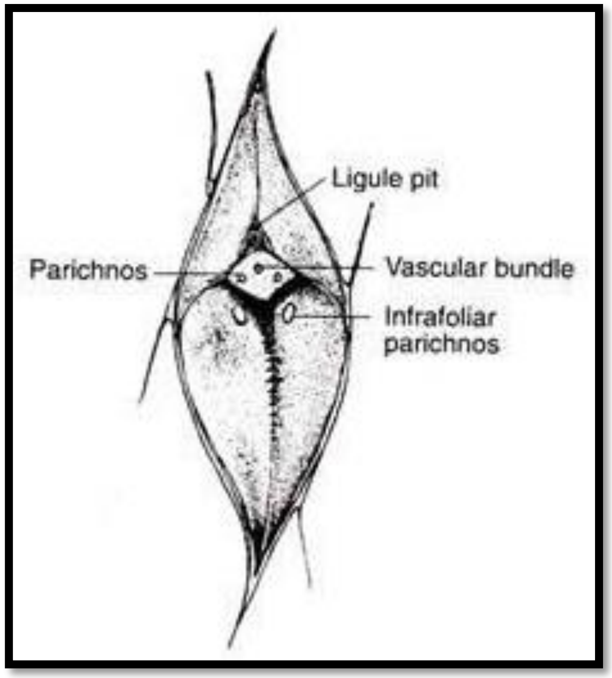


Figure 3. *Lepidodendron* leaf scar with associated vascular tissue scars.

b. Next, look at *Sigillaria* fossils; these stems have leaves separated by **vertical grooves**. Note that in fact the leaf arrangement is still helical. Note that you can make out the central vascular bundle scar and the two parichnos scars in theses fossils.

***S2: Sketch *Lepidodendron* and *Sigillaria* stem fossils and compare their differences and similarities. Use the handout from Gifford and Foster (Figure 9-42) and Figure 3 above to diagram the vascular scars left behind. Label the type of fossil and its age as well.**

3. Anatomical Structure of the *Lepidodendron* Stem

Now look at celluloid peels of a *Lepidodendron* stem. First, a note about how peels are made from coal balls. A coal ball is an accumulated mass of plant debris - the actual organic remains of the plants - completely embedded with silica. Apparently, the silica originally got into the plant parts in solution: it was dissolved in ground water and gradually precipitated out in the cavities of cells of the plants. So, a coal ball is a bunch of plant debris entombed in rock. This sort of fossil is called a **petrifaction**.

How to section a fossil:

Paleobotanists cut coal balls in half with diamond saws to reveal a flat surface with plant parts visible. Then they pour a solvent for silica (hydrofluoric acid) on the cut surface, which etches the silica away from a thin surface layer of the plant remains. Next, they wash off the acid and flood the thin layer of exposed plant parts with acetone, a solvent for celluloid film. Finally, they lay a piece of celluloid film right on the acetone. The acetone partially dissolves the celluloid film, and it settles down around the plant parts. When the celluloid has solidified in place around the plant parts, the paleobotanist peels the film away, bringing the layer of plant parts with it. The result: a peel of a thin layer of plant material exactly as it was in the parent rock (Figure 4).

Transverse section:

First look at a peel of a cross-section of *Lepidodendron* and its allied genus *Sigillaria* under a dissecting scope. You will see the actual plant parts in place in the celluloid film, though they are a bit broken down from the original phases of fossilization.

a. Begin by locating the **pith** of **parenchyma** at the very center of the **stem**. In one of our best sections, the pith is crossed by a fracture line where the coal ball was sheared after formation.Just outside of the pith is a prominent layer of **secondary xylem**. The diagnostic feature of the secondary xylem is the rows of cells radiating from the center. These are **scalariform tracheids**: each row is the product of a meristem initial in **the vascular cambium**. (The **unifacial vascular cambium** is external to the secondary xylem. Its derivatives - the cells of the secondary xylem tissue - are produced to the inside.)

b. At the outside of the section are masses of dark cells forming a dense, thick layer with some large rectangular or triangular patterns. This is the **periderm** or secondary cortex, produced by the **cork cambium**.

c. **Primary xylem** should be located at the boundary between the pith and the secondary xylem, but it is hard to distinguish in these fossils. No phloem is visible.

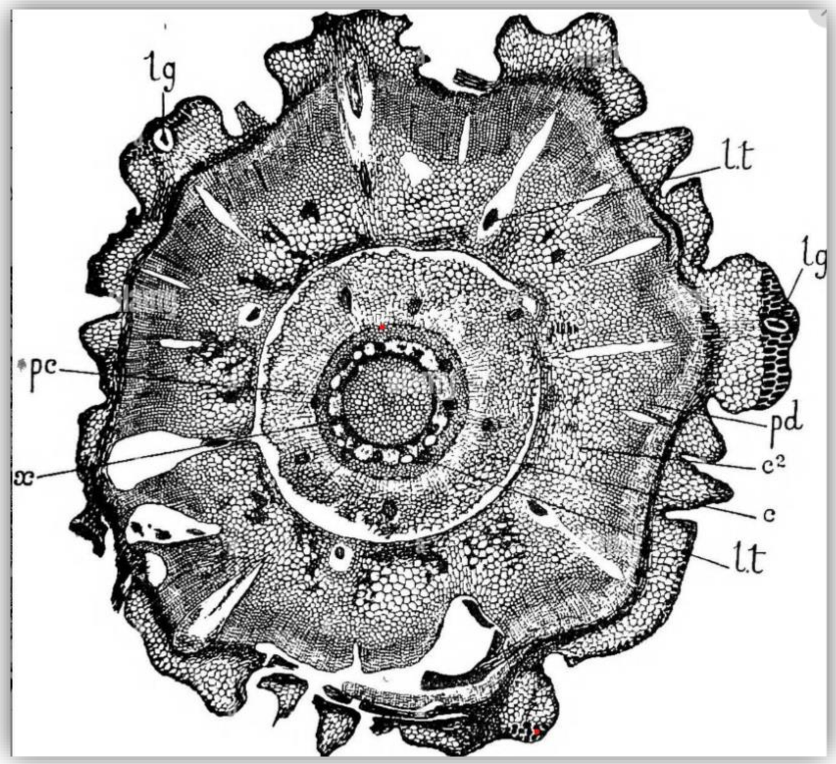


Figure 4. *Lepidodendron* transverse section of young branch, before secondary wood has formed, x, primary xylem cylinder; pc, zone of phloem and pericycle; c, inner cortex, differentiated into three layers; c2, outer cortex; pd, periderm; beyond this are the leaf bases; lg, ligule; i.t, leaf traces.

Longitudinal section:

a. Now look at peels of the *Lepidodendron* stem in longitudinal section: in these you can see the **scalariform tracheids** typical of these giant trees.

b. Remember that these stems were arborescent, that they had two lateral meristems, the **vascular cambium** and the **cork cambium**, and that it is thought they might well have been annual plants.

S3: Sketch the *Lepidodendron* or the *Sigillaria* stem in transverse AND longitudinal sections. Label the features above in each section. Label the type of fossil its age as well.

4. Strobili of *Lepidodendron*

Now look at compressions of *Lepidostrobus*, the strobilus of *Lepidodendron* (Figure 5).

a. You can see that they are typical **strobili**, just quite a bit larger than the other lycopsid strobili we've seen but they still composed of **sporophylls** that are **arranged helically** to create the body of the strobilus.

b. It will be difficult to make out sporangia but from other fossils we know that they were adaxial just like extant lycophytes.

c. There is also a peel of a transverse section of *Lepidostrobus*. Take a look at it under the dissecting scope and see what features you recognize. You should be able to see the **pith** of **parenchyma** in the center and the sporophylls arranged radially around, with **leaf traces** evident. The **sporangia** are harder to find but look for their thick **sporangial walls**.

***S4: Sketch the *Lepidostrobus* from the compression fossil AND the peel. Label the features you described above.**

Figure 5. Compressions of *Lepidostrobus* from around the Mid-Pennsylvanian age, around 300 mya.

5. *Lepidocarpon*, The Seed-Like Structure of *Lepidodendron*

Lepidodendron was heterosporous and **bisporangiate**: the strobili that you just looked at contained both microsporangia (with microspores), and megasporangia (with megaspores). The less specialized species resembled *Selaginella* in the layout of their strobili. However, some species with more complex characters had megasporangia that contained one megaspore enclosed and protected in a transformed microphyll. Look at peels of these specialized structures, which are classified in the form genus *Lepidocarpon*.

a. Look for a large central, empty area, which represents the missing **cytoplasm** that originally filled the megaspore. Then look for the **megaspore wall** surrounding the central area. This is the limit of the single cell of the **megaspore**, evidently a large cell indeed. Finally, demonstrate to yourself that the megasporangium attached by a **stalk** to a leaf (**microphyll**) that is wrapped up around the **megasporangium**. A single **vascular bundle** should be visible in the leaf.

b. These enclosed megaspores are analogous (not homologous) to the seeds of such plants as the cycads and pines, which we'll study later in the course. What we will discover by the end of the course is that megasporangia have been enclosed in vegetative tissue more than once in vascular plant evolution, once here in *Lepidodendron* and once in the seed plants.

***S5: Sketch a peel of *Lepidocarpon*, and label with the features described above.**

6. ***Stigmaria*, The Root-Bearing Stem of the Scale Trees**

Finally, consider *Stigmaria*, fossils of root-bearing axes. There are in fact three different kinds of fossils of Stigmaria in the lab, compressions, casts, and peels from petrifactions.

a. Begin with the compression. Note the relation of the roots to the **rhizophore** (the root-bearing axis).

b. Now look at the peels. These peels are of decorticated *Stigmaria* rhizophores, which means that they have lost their cortex tissues. In fact, all that remains is the **secondary xylem** and a cavity filled with debris that represents the location of the **original pith**.

c. Now look at the rhizophore fossils in lab and note the helical arrangement of the root abscission zone (Figure 6)

d. Finally, look at peels of the roots. Notice that the **vascular bundle** is suspended in **a hollow cylinder** inside of the root. This pattern is the same as you saw in *Isoetes* last week.

***S6: Sketch *Stigmaria* from the compression fossil, cast fossils, or celluloid peels. The "dimples" are the scars of the roots that broke off or rotted away prior to fossilization.**

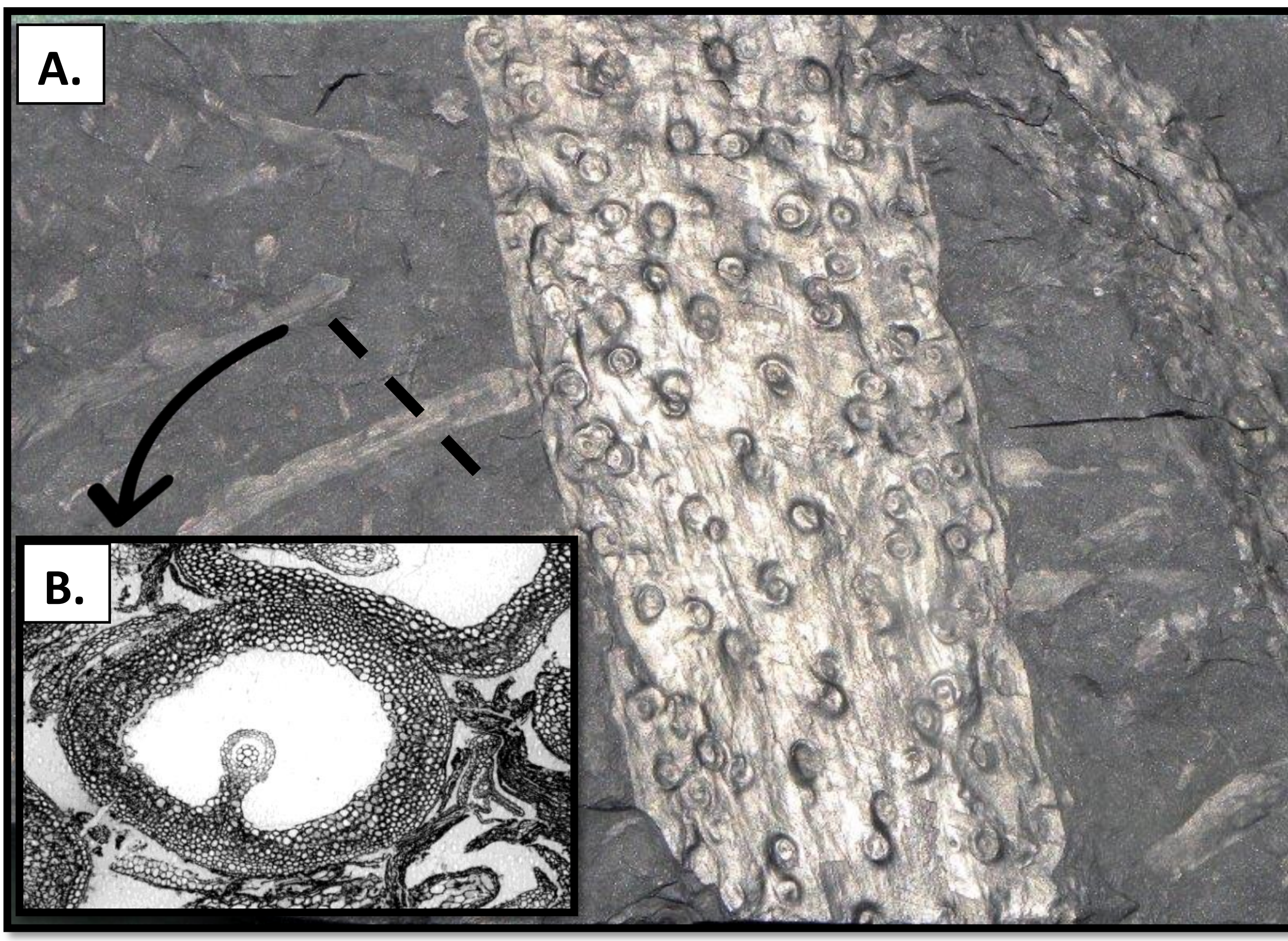


Figure 6. (A) *Stigmaria* compression fossil with helical arrangement of root abscission zones. (B) *Stigmaria* root transverse section with large central cavity and single vascular bundle.