Experimental Anatomy of Plant Development
Laboratory 9

Secondary Growth

Introduction

Secondary growth occurs as the result of lateral meristematic activity, and produces an increase in the girth of an organ. The two most common lateral meristems in conifers and woody dicots are the **bifacial vascular cambium**, that produces secondary xylem (wood) and secondary phloem, and the cork cambium (**phellogen**) that either produces only cork (**phellem**) to the outside, or both cork and **phelloderm** (to the inside). In contrast to primary meristems that have been undergoing continuous meristematic activity from the inception of the radicle and epicotyl in the embryo, secondary meristems are redifferentiated from cells that previously had ceased cell divisions and matured into paremchyma.

Whereas the bifacial vascular cambium is a perminant meristem, there is a succession of cork cambia redifferentiated in the primary cortex and (later) in the secondary phloem. The secondary xylem (wood) of a plant provides a permanent record of vascular cambial activity throughout the life of the plant. By contrast, the secondary phloem is constantly being displaced further-and-further out into the bark, and is eventually sloughed off with the old bark.

In the short time available for this lab, we are unable to cover the range of different types of secondary growth that occur in plants. Nor, will we go into detail about any. Rather, we will focus on the activity and products of the bifacial vascular cambium, particularly the secondary xylem. If we understand secondary xylem in relation to the activity of the vascular cambium, then we have a basis for understanding many other aspects of secondary growth.

Wood Anatomy

We should become familiar with the structure of the secondary xylem (wood), and its appearance in different sections. There are usually three planes in which wood is cut for examination. If the cut is at right angles to the long axis of the stem or root, it is a **cross** or **transverse section**. A longitudinal cut along a radius produces a **radial** section. A longitudinal slice parallel with a tangent but not along a radius is a **tangential section**.

Examine a block of wood which has been cut to expose these three sections. Note the **growth rings** in the transverse section. A growth ring is the amount of secondary xylem deposited by the vascular cambium during one growing season. The xylem elements formed in the spring are larger than those formed later in the growing season. Note the radiating lines in transverse section. These structures are vascular rays. What is the appearance of the **vascular rays** in radial section? In tangential section?

A. Pine Wood: Gymnosperms and angiosperms differ in the anatomy of the xylem, and for a typical gymnosperm we will examine pine wood (*Pinus*). You can recognize a transverse section from the configuration of the growth rings. Most of the xylem cells look like thick-walled squares or rectangles in this section. These are actually greatly elongated cells with tapered ends and are the chief water and mineral conducting cells in the pine wood. They are called tracheids. Extending along radii are elongated cells which appear to have cell contents. Unlike the dead tracheids, these cells are alive in wood that still functions in conduction. These radially elongated cells make up the vascular rays. Can you determine in which direction in your slide is the center of the stem? Can you see growth rings? What is the difference between spring tracheids and summer tracheids? In some places you will note

circular areas which are surrounded with thin-walled parenchyma cells. These areas are vertical **resin canals** which are common in many conifers.

You should be able to recognize a radial section. Since it was cut along a radius, vascular rays will show up in face view. How many cells in height is a ray? You will note that in pine one or more rows of short, dead, tracheid-like cells run along the top and bottom of a ray. These cells are called ray tracheids, but they are not found in all gymnosperms. Can you see nuclei in the thin-walled ray parenchyma cells? What is configuration of the tracheids in this section? Can you find the ends? Do you notice concentric circular markings on the radial walls of the tracheids in this section? Can you find the ends? Do you notice concentric circular markings on the radial walls of the tracheids (the walls facing you)? These are the **bordered pits**. Each half of the bordered pit consists of a dome-shaped structure with a perforation at the top of the dome. A membrane, the pit membrane, stretches between the two domes or borders. There is a thickened area in the center of the pit membrane. The outer of the three concentric circles represents the base of the dome or border. The next inner circle represents the outline of the thickened area of the pit membrane (**torus**). The smallest circle is the opening in the border or dome and is called the **pit aperture**.

Draw an area of xylem that shows the characteristic cells as seen in each of the cross, radial and tangential sections. Be sure you understand why each type of cell appears as it does in each view.

B. *Magnolia* Wood: *Magnolia* shows xylem elements found in most angiosperm woods. You will notice it differs from pine even at first glance. Probably the most conspicuous features in a transverse section are the large perforations or vessels. Each vessel element has **perforation plates** at each end. In *Magnolia* the perforation plates are on oblique end walls, and are scalariform. That is to say, they have several bars that dissect the opening or perforation. A vessel is not a cell, but consists of a vertical series of cells with the end walls missing. Thus a vessel is a long, vertical tube-like structure composed of many **vessel elements** (sometimes called **vessel members**). What would you conclude about the efficiency of such structures in water and mineral conduction? You will notice that in a transverse section of *Magnolia* there are many cells with extremely thick walls and very tiny cell cavities. These cells are wood fibers which serve to strengthen the wood. Did you see wood fibers in pine? Why is pine one of the so-called "soft woods", while oak is one of the "hard woods"? There are also tracheids in *Magnolia* which look much like those in pine in transverse section. Can you find certain cells which seem to have cytoplasm and nuclei in them? These are **xylem parenchyma** cells, which are actually vertical chains of somewhat elongated cells. Do you notice a difference between the vascular rays of magnolia and pine? What cell types found in the wood of an angiosperm like *Magnolia* are missing from a gymnosperm like pine?

You should be able to locate the radial section in the same way that you did with the pine wood. In this section you can see the vessels in longitudinal section. Note the individual vessel elements. Observe the many bordered pits on the vessel walls. Locate a tracheid, a wood fiber, a xylem parenchyma cell. How high are the vascular rays? Can you find any marginal tracheids?

As with the pine wood, draw an area of xylem that shows the characteristic cells as seen in each of the cross, radial and tangential sections. Be sure you understand why each type of cell appears as it does in each view.

Cambial Activity

Activity of the vascular cambium can be interpreted from a combination of cross sections and radial sections. Because of the limited time available for this lab, we will only look at the vascular cambium of *Pinus*, and we will use the same slides that we used for wood anatomy. Examine

the cells at the outer margin of the wood in the cross section of the *Pinus* stem. This is the cambial zone of several cell layers between mature secondary xylem and mature secondary phloem. Theoretically, only one layer is actually the vascular cambium, with the others being either immature xylem or phloem at various stages of maturation. Can you identify which layer is the vascular cambium? You should be able to see a gradation from the meristematic cells of the vascular cambium to the mature cells of the xylem and phloem. In addition to differences in cell size (particularly radial diameter), there are differences in the thickness of the cell walls (particularly in the xylem) and in the contents of the protoplasm. Draw and label the cells in a narrow wedge of the cambial zone of the pine stem.

Identify both ray initials and fusiform initials. What features of these two types of cambial cells allow you to distinguish them from each other?

Pattern of Development

The pattern of development for all of the secondary growth from the vascular cambium is recorded in the wood. In the cross section of the *Pinus* stem, identify growth rings, **spring wood** and **summer wood** (also known as early wood and late wood). What are the differences in the cells of the two types of wood? Can you identify which rays are **pith rays**, and which are wood rays (or **xylem rays**)?

Both fusiform initials and ray initials of the vascular cambium under go **addative divisions** to produce more cells in the radial rows, and also **multiplicative divisions** to increase the circumference of the vascular cambial cylinder. Each multiplicative division initiates a new radial row of cells. When a fusiform initial divides, it either produces a new radial row of tracheids, or a new ray. When ray initials under go multiplicative divisions, the width of the ray increases. Since most rays of *Pinus* are uniseriate, you are unlikely to see where a ray initial has divided. However, you should be able to find places where multiplicative divisions have occurred in fusiform initials to produce both new rows of tracheids and new rays. Draw and lebel a small area of pine wood, as seen in cross sections, that shows where multiplicative divisions have occurred to produce both new rows of tracheids and new rays.

LABORATORY – Checklist

By the end of the lab, your notebook should contain drawings of the following:

[ ] Cross, radial, and transverse sections of small squiars of the wood of *Magnolia* and *Pinus,* with the various cell types labeled..

[ ] Cross sectin of the cambial zone of *Pinus*, with the various cell types labeled.. Indicate on your drawing where the cambial zone ends and where mature xylem and phloem begin.

[ ] Cross section of a rectangle of pine wood showing growth rings, and also positions where multaplicative divisions of both fusiform and ray initials have occurred.