

PART 1 THE VASCULAR CAMBIUM

Cambial Origin and Secondary Vascular Patterns in Stems

In this program we turn our attention to the secondary vascular patterns in shoots and roots. These are produced by the vascular cambium. In leaves activity, if it occurs, usually is limited to the mid-rib, and is only in the vascular bundle. Your study of stems should enable you to interpret any secondary growth you see in leaves because of the similarity between their vascular tissues.

First we will study stems and then later on roots.

In stems there are two regions of the vascular cambium which may become active. The fascicular cambium lies between the primary phloem and xylem in each vascular bundle (fasciculus is Latin for small bundle). The interfascicular cambium arises in the ray parenchyma and links up the fascicular cambia.

Place slide 1 - the permanent mount of old Hydrangea stem on the microscope and view it with the low power objective. When you have it on the stage return to the tape.

The centre of the section is filled with large parenchyma cells - it is the pith. Around this is a ring of red stained tissue - this is the xylem. It has been stained with saffranin which stains lignin red. Immediately outside the xylem is a , non-stained region - this contains the vascular cambium and the phloem. Immediately outside the phloem are some files of cells which have also been stained - these are the periderm cells. The cells outside of those are the cortex. We will return to these cells later.

Focus on the junction of the xylem and phloem - use the 40x objective. Close to the lignified xylem cells there are very narrow cells, here lies the vascular cambium and possibly one or several undifferentiated derivatives of the vascular cambium. All the other unstained cells are the phloem and are larger in diameter. Files of cells in the secondary xylem continue through the cambium and the secondary phloem. Look along the files of phloem cells. As you get close to the outer limit the files stop and the cells become less ordered - these cells are the primary phloem and the line that separates them from the secondary phloem marks the position of the vascular cambium at the start of secondary growth. The primary phloem cells in Hydrangea appear flattened - this is because the primary phloem is often crushed as secondary tissues increase the diameter of the organ.

Now slowly traverse the xylem towards the pith. Notice that the smaller diameter cells, the fibres and the tracheids, line up in files. When vessels occur - they are the large diameter cells - they disrupt these files. As you get close to the pith see if you can find a line where the files stop and the cells become less ordered, then return to the tape

As you look down at the slide you can see, quite often in this section, some very thick walled cells - mostly fibres I suspect - just outside the primary xylem which forms a lobe pointing into the

pith. If you look at the rays you can see that they start to fan out at about the same position as the line that is formed between primary and secondary xylem. Quite often the rays can help you pick the position of the line between the primary and secondary xylem. This is particularly useful when the primary xylem is fairly diffuse and contains files of cells.

Earlier, when describing the secondary xylem of Hydrangea, you may have noted that I said - the thick walled cells - mostly fibres I suspect. Sometimes the difference between fibres and tracheids is clear in transverse section - particularly if the lumen is very very narrow and the walls very thick - phloem fibres are a very good example of this. However, often in transverse section you will not be able to distinguish between them.

Before we leave Hydrangea I want to point out one more thing - you will note that the ray parenchyma has been lignified - but they still contain cell contents - it was alive when the slides were made. Also note that the parenchyma of the rays as they fan out into the pith. and some of the pith cells. have become lignified. Do not confuse this with xylem - lignified parenchyma is often seen at the periphery of the pith.

PAUSE

Now I want to run through Figure 1 with you so you can use it when studying stem patterns. On the left-hand side (A and B) are shown three primary vascular bundles with phloem at the top and xylem at the bottom. In A. the line between the two tissues represents the fascicular cambium. In B these are shown to be linked up by a dashed line - this represents the interfascicular cambium.

When describing secondary growth the criteria used are the position of the cambium and its activity. In "C" the position of the fascicular cambium is typical but no interfascicular cambium is produced. This means that the stem will not have a complete cylinder of vascular tissue or other lignified tissue, and will not be very strong when held upright. You find this type of arrangement in sprawlers such as Cucurbita - for example pumpkin.

As secondary fascicular growth occurs the vascular bundles project further and further into the hollow in the centre of the stem - this is illustrated in diagram I. When , you look at the section of such a stem you will see the secondary growth mostly confined to the inner ring of bundles and the parenchyma of the rays has become stretched or torn as secondary growth has occurred - no division occurs in the rays.

SHORT PAUSE

An example where the only lignified tissue present is in the vascular bundles, but where the interfascicular cambium is present and produces parenchyma is illustrated in diagram J. Such an arrangement can be found in vines and lianas.

In herbaceous plants, secondary growth of an entire cylinder - involving the fascicular cambium and the interfascicular cambium - may occur, at least at the base of the stems. It leads to a pattern similar to diagram "K". The interfascicular tissue may vary however. It may be parenchyma which is lignified on the inside of the interfascicular cambium, such as in "E"; this tissue may contain

secondary vascular bundles, as in diagram "F" or secondary phloem and secondary xylem may be produced as in diagram G.

The sort of development seen in G also occurs in plants with extensive secondary growth of vascular tissues. Diagram "L" indicates the primary vascular tissue of such a plant - you will note that the vascular bundles are closer together than in herbaceous species. This may mean that most or all of the lignified tissue is of fascicular origin and that the interfascicular cambium mostly produced primary ray parenchyma - somewhat like diagram D. The succession of growth from diagram L through M to N is the type of pattern seen in shrubs and trees.

Finally, in diagram "H" is shown the typical tissue formation of a woody species - namely phloem on the outside and xylem on the inside - and this occurs in both the fascicular and interfascicular regions of the cambium, but anomalous activity in bundles causes more xylem to be produced in some bundles and more phloem to be produced in others. Diagram P illustrates the sort of pattern that can result from this. Note here that stepping of the xylem is shown at the secondary rays - it need not be confined to the primary rays. Such a cambium is said to be typical in position (in that you could not distinguish it from that in diagram "G" after a few divisions) but it is anomalous in activity.

SHORT PAUSE

Well, hopefully you are ready to tackle a range of examples of these stems. Follow the notes, view the digital images and demonstrations, and cut sections of *Callistemon*. Cutting sections and drawing map diagrams is important practice for your upcoming project. Get a demonstrator or tutor to give you feedback on your map diagram.

The Origin and Secondary Vascular Patterns in Roots

View Figure 3. The vascular cambium of roots is initiated between the phloem and xylem and in the diagram shown it is in four distinct arcs. It then links up in the pericycle outside of the protoxylem poles. Greater activity within the bays causes the cambium to become circular, similar to that in a stem. Division outside of the protoxylem poles form primary rays. Therefore, in a tetrarch root such as that in Plate 4 there will be four primary rays, and the number of primary rays is, obviously simply related to the number of protoxylem poles.

Place slide 2 - the permanent mount of Rose root on the stage of the microscope and view it under low power then return to the sound file. It appears that there are many rays, the big problem is which ones are primary rays? Follow several rays in from the outside. most of them terminate in tissues with lots of large vessels. Four of the rays terminate with very small cells - the protoxylem poles. This root has a tetrarch primary structure - can you find the four poles? If not ask for help.

Now look at slide 8 - T.S. Root of *Ricinus* - what is the main difference between it and the rose root you have studied?

We have looked at the vascular cambium in stems and roots mostly in terms of cambial activity. The cambium has been in a typical position in both stems and roots. Cambia can also be found in anomalous positions. This can cause separation of parts of the cambium or a series of cambia to be produced. A series of slides illustrating variations in position and activity have been set up for you to look at if you wish.

PART II THE PHELLOGEN

Origin and Pattern of Periderm in Stems

SHORT PAUSE

We will now look at the periderm of stems and roots.

SHORT PAUSE

A phellogen may arise superficially or in a deep-seated position in a stem or a root as illustrated in Figure 4.

In stems it may form in or close to the epidermis as illustrated by *Tilia*. Read the notes on superficial periderm in *Tilia* and view the slide. Also look at the demonstration slide of the *Sambucus* lenticel. Lenticels are believed to be , involved in the exchange of gas. When you have done this Look again at Slide 1 where the phellogen arose in a deep-seated position causing the cortex to be sloughed off. Then return to the sound file.

SHORT PAUSE

Re-examine your preparation of *Callistemon* and identify phellem, phellogen and phelloderm. Is the phellogen superficial or deep-seated? Check your answer with the demonstrator.

Bark is a non-botanical term that you will have come across - it refers to all of the tissues exterior to the vascular cambium and therefore is made up of the periderm, the phloem and cortex that may be present.

Origin and Pattern of Periderm in Roots

In roots the phellogen often arises in the pericycle and the endodermis, cortex and epidermis are sloughed off. The *Rose* and *Ricinus* roots (Slides 2 and 8) are examples of this - note that phloem fibres occur close to the periderm and that there is no clear cortical zone in these slides.

A superficial periderm may be found in aerial roots and in wetland plants. Look at the digital image of *Avicennia marina* pneumatophore and observe the superficial periderm. Also look at the section in Plate 7. A scanning electron micrograph of the periderm and a lenticel is also shown in that plate. Also have a look at the demonstration slide of *Ficus* aerial root. Many aerial roots have their vascular tissues arranged as a hollow cylinder. Can you suggest why this might be so?

PART III INTRODUCTION TO THE ANATOMY OF WOOD

The final part of this work is a brief look at the structure of wood. Wood consists of tracheids, vessels, fibres and parenchyma, as you may have guessed from your study of secondary xylem tissue. There are two types of wood porous and non-porous. Porous woods contain vessels, non-porous woods do not. However, when you look at non-porous woods, be sure not to confuse resin ducts with vessels.

We want you to look at the woods of both Gymnosperms and Angiosperms. Wood blocks of *Pinus* have been provided as an example of Gymnosperm wood together with demonstration slides of the cambial zone and of transverse, radial longitudinal and tangential longitudinal section. Complete the brief study of Gymnosperm woods as described in the notes and then return to the sound file.

Angiosperm wood may be diffuse porous or ring porous, depending on the stage during growth at which large vessels are differentiated.

Patterns in Angiosperm wood are a little more complex than gymnosperm wood, not only because of the presence of vessels but also because of the different locations that axial parenchyma can be found.

Read the notes on Angiosperm wood and view the slides of *Acacia longifolia* - one of the wattles. Each slide has three sections on it, transverse, radial longitudinal and tangential longitudinal sections. Return to the sound file when you have done this.

Acacia - also shown in Plate 10 a in your notes has diffuse vessels, and each group of vessels are surrounded by a single file of parenchyma. Rays are uniseriate in *Acacia longifolia* - I hope you looked at the lens shape in T.L.S. and brick walls of R.L.S.

The cambial zone in this species is easily seen and there are many tannin cells in the phloem tissue. Tannins are believed to be a defence mechanism against pathogens.

Whilst I do not know the succession of development of the periderm - you can see that it abuts a continuous ring of fibres. These are in the outer edge of the phloem. The rays running through the secondary tissue run out to this band suggesting that they are secondary phloem fibres, although sometimes there are thickenings to this band which line up with the primary xylem. There may, therefore, also be primary fibres present.

Well that's it for this time. I hope this program has helped you to understand how secondary growth develops so that you will be well equipped to understand secondary growth in the sections that you make in the upcoming independent project. Bye, bye.

