Lecture 18. Mini-review and Secondary Phloem

- **Secondary Stem Growth** – secondary phloem

### Reasons for secondary growth in stems vs. roots

1. Method of satisfying the demand during growth
2. In dicot perennials & gymnosperms new yearly leaves & needles need new vascular systems
3. Greater herbage (topside) requires greater support

### Type of secondary growth

- Continuous vascular cylinder (most common - angiosperms)

  a) Leftover procambium produces cells - becomes fascicular cambium
  b) Parenchyma between bundles becomes interfascicular cambium
  c) Both fascicular and interfascicular cambium produce secondary phloem and secondary xylem - they become or behave as a vascular cambium

### Distribution of secondary vascular tissues

A. Usually 5x more xylem produced than phloem
B. More xylem because of high demand for water
C. Xylem in trees forms conspicuous rings because the vascular cambium produces different sized cells (small in the Fall and large in the Spring)
D. Phloem doesn't form distinguishable rings because it doesn't form a secondary wall - old phloem gets squashed
E. Vascular system last for only one year - then an new system is provided
The cambial zone: theoretically thought to be one layer

A. Axial system
1. Vascular cambium: gives rise to tracheids & sieve cells, vessels & sieve tube members - fibers and sclerids come out of this too
2. Fusiform initials - make axial phloem (usually sieve cells) and xylem (usually tracheids) elements
3. Sometimes a fusiform initial can become a ray initial

B. Transverse (ray) system
1. Ray initials - make xylem and phloem rays as well as ray parenchyma
2. Purposes of ray system
   a) Storage (starch grains)
   b) Produce tyloses
   c) Absorb air bubbles
   d) Produce callose

The Vascular Cambium

Definitions
AXIAL: Along the axis of the organ, or organism
RADIAL: At right angles to the axis, i.e., along a radius
Tangential: At right angles to a radius.

Ray initial: Meristematic cambial cell. Forms a file of cells (one or more wide) that is composed of parenchyma. Orientated ALONG a RADIUS. Contributes to the RADIAL transport system
Fusiform Initial: Meristematic cambial cell. Forms new secondary xylem and secondary phloem and associated cells. Contributes to the AXIAL transport system.

Robinia cambium: tangential section

Axial vs. Radial directions

The vascular cambium is unlike the primary meristems of the plant (root and shoot apex) in that:
• It produces new cells and tissues which add to the axial system (i.e. the conducting system) as well as to the radial system (i.e. the lateral transport pathways), whereas the apical meristems of the shoot and root add only to the axial system.
• Thus the cells of the vascular cambium do not fit the regular concept of meristematic cells (i.e. small dense, with large nuclei, and of isodiametric shape).
• Cambial cells are usually highly vacuolate and occur in two forms, namely fusiform cells and ray cells.
1. The term fusiform implies that the cell is shaped like a spindle, but it is approximately prismatic and wedge-shaped at both ends.
2. Ray cells on the other hand, are short squat cells.
3. Tangentially, both cell types are wider than they appear in radial section or view.
4. These two different cell types (fusiform and ray cells) have unique functions.
   * Fusiform cells usually only produce cells associated with the axial system that is they produce either new elements of the xylem, or elements of the phloem, and thus add to the AXIAL conducting system
   * Ray cells on the other hand, produce under normal circumstances, ONLY ray cells and thus add to the RADIAL system of the plant
Division planes

Development of secondary vascular tissues

During primary growth, the vascular bundles produce PRIMARY vascular tissue. These are the primary phloem (proto + meta) and primary xylem (proto and meta). The fascicular cambium separates the two tissues.

Remember: a fascicle is a vascular bundle.

1. Development commences at the fascicular cambium

First activity is in the vascular bundle

2. FCZ = fascicular cambial zone

Secondary xylem and phloem are produced by the fascicular cambium

3. The interfascicular regions begins to develop a cambium.

A widening band of secondary vascular tissue results.
The ring of secondary tissue is Complete. The interfascicular and fascicular cambia together form a vascular cambium.

Cambial activity in the root. Typical Dicot Root. End of primary growth (cambial activity in Gymnospermous roots is very similar).

Formation of the cambium. Stage 1.

Formation of the cambium. Stage 2.

Cambial cells differentiate more rapidly at the junction of the metaxylem and primary phloem. Outward pressure caused by the addition of new cells continues, effectively rounding out the ring of secondary vascular tissue. Primary phloem strands become crushed, lose functionality.
Remnant of primary phloem strands – completely crushed, non-functional

Remnant of primary phloem strands – completely crushed, non-functional

$E = \text{endodermis}$

$P = \text{pericycle}$

$2X = \text{secondary xylem}$

$2P = \text{secondary phloem}$

$P = \text{pericycle}$

$E = \text{endodermis}$

The root will retain its primary xylem, which will be visible and may be functional.

$Araucaria (gymnosperm)$

All Stems are divided into...

- a cortex
- A zone of vascular tissue
- A pith (parenchymatous in young stems like this one)

Primary phloem fibers - derived from the protophloem. This forms the outer tissue (these cells should be stained red in the Fabri section) of each vascular bundle - they may be hardly visible in your section.

The protophloem is formed first.

Metaphloem - small cells (stained blue) lying between the phloem fibers and the xylem. Note very small, deeply-stained companion cells and the rather wider sieve tubes.

Secondary Growth in Dicots

Cross Section of the Shoot
5 Year Old Woody Dicot Stem

Periderm (cork)
Cortex
Secondary phloem
Vascular Cambium
One annual ring
5 Years of Secondary Xylem

Three Year Old Tree