**Lecture 8**

**Secondary xylem:**

It is formed by the vascular cambium, therefore composed of two systems, **the axial (vertical)** composed from cells with their long axes oriented parallel in the stem or the root and the **radial (horizontal)** system which composed of cells oriented horizontally regard to the axis of the stem or root. The complex nature of secondary xylem will be addressed by considering first the less complex wood of gymnosperms, varied wood found in the angiosperms.

\*  **Gymnosperm wood (conifer and Ginkgo wood)**

 In conifer woods (and gymnosperms generally), the **axial** water conducting system is composed largely of:

**1-** **Tracheids** (imperforate cell involved in water transport, i.e. with intact pit membrane between it and adjacent cell). They formed during the flush of spring growth are usually **wider radially** than those formed later in the growing season. It is normally easy to see the extent of thickness of a growth increment for this reason.

**2-** The torus (a central thickening on the pit membrane) which is **characteristic of tracheid pits in confers**. It acts like a plug, closing against the pit aperture if there are potentially damaging changes in pressure between adjacent tracheids. Inthis way, the spread of air embolisms may be controlled and reduced.

**3-** Thickened areas between the pits termed **bars of Sanio**. These are **characteristic of conifer wood**.

**4-** There are **no vessel elements**.

**5-** Fibres are **not normally** found in conifer woods; if present, they run

alongside the tracheids, axially.

**6- Axial parenchyma cells are rare**; the cells are narrow, elongated axially, are situated alongside the tracheids, and have square end walls. Members of the **Pinaceae (except *Pseudolarix*)** and ***Sequoia*** spp. of Cupressaceae have **axial resin ducts**.

The **radial (ray) system** in gymnosperms consists of

**1-** Parenchymatous cells, which are, on the whole, procumbent.

**2-** Some genera have radial **tracheids (ray tracheids**) as well, and some Pinaceae have **radial resin ducts**.

**3-** The wall pitting and thickenings of ray tracheids may also be of a characteristic form, for example, the **‘dentate’ ray tracheids** of *Pinus* species.

**\*Angiosperm wood:**

**1-**The cell types of dicot wood include vessel elements, fibres and parenchyma cells.

**2-** Tracheids are rare in dicots, but occur in some species such as oaks and chestnuts.

**3-** Two types of fibres are common in dicot wood: fibre tracheids and libriform fibres , Fibre tracheids have thick walls with bordered pits.

**4-** The **intercellular spaces or ducts** in angiosperm woods contain secondary plant products such as gums and resins. They occur in both the axial and the radial systems**.**

The wood of angiosperms can be **classified differently**, one of them according to **its complexity** and this is due to the great variation in kind, size, form, and arrangement of its elements.

**1-** The most **complex angiosperm woods**, such as that of **oak**, may **contain vessel elements, tracheids, fiber-tracheids, libriform fibers, axial parenchyma, and rays of different sizes.**

**2-** Some angiosperm woods contain **only fiber-tracheids** among the imperforate nonliving cells like **Juglandaceae**.

**3- The vesselless angiosperms** (Amborellaceae, Tetracentraceae, Trochodendraceae, Winteraceae) appears so similar to that of conifers that it has at times been erroneously interpreted as conifer wood. Vesselless angiosperm woods can, however, be distinguished fromconifer wood by their **tall broad rays.**

**\*Classification of angiosperm woods according to porosity:**

The word **porous** is used by the wood anatomist to refer to the appearance of the vessels in transverse sections:

**1- Diffuse-porous** woods are woods in which the vessels, or **pores**, are rather uniform in size and distribution throughout a growth ring**.**

**2- Ring-porous** woods the pores of the earlywood are distinctly larger than those of the latewood, resulting in a ring-like zone in the earlywood. The ring-porous condition appears to be highly specialized and occurs in relatively few woods , most being species of the north temperate zone.

**\*Growth Rings:**

It is resulted from the periodic activity of the **vascular cambium** which is a seasonal phenomenon in temperate regions related to changing day lengths and temperatures, produces **growth increments**, or **growth rings** in the secondary xylem. There are types of growth rings:

**1- Annual ring**:

 It such a growth layer represents one season’s growth.

2- **False annual ring**:

 It is additional ring in a given year which produced **either by changes** in available water and other environmental factors **or injuries** by insects, fungi, or fire. **false annual ring** and the **annual growth** rings consisting of **two or more rings** is termed a **multiple annual ring**. Sometimes, it is difficult to judge the age of such trees as in very **suppressed** or **old trees** the lower portions of the stem or of some branches may fail to produce xylem during a given year. Thus, the estimatation of age may be **inaccurate** as some rings are “missing” or if false annual rings are present. Trees that exhibit **continuous cambial activity**, such as those in **wet tropical rainforests**, may **lack growth rings entirely.**

**\*Heartwood and sapwood:**

**Heartwood**: It is **darker part of the woody stem** filled with **resinous materials and polyphenols**, this happens after a variable number of years, cavitation occurs in most of the vessels and tracheids and the rest of the xylem cells in the growth ring die resulting to this while the outer, water-conducting part of the stem is called **sapwood**. In many species, as sapwood is converted to heartwood, air-filled vessels in the sapwood are often sealed off by the intrusive growth of surrounding parenchyma cells. These intrusions are called **tyloses** and, together with the resinous materials, serve to prevent fungal growth in the empty vessel lumens. The outer, conducting part of the stem is called sapwood.

**Secondary thickening in monocots**

The majority of monocots are **herbaceous**, which means that the primary xylem has to fulfil **all the requirements of water transport** that the plant may encounter throughout its lifetime. However, some monocots do undergo **thickening of the primary stem** like in **bamboos** and other **monocot species with wide stems**, a broad region of mitotic activity, called the **primary thickening meristem**, is **responsible** for **radial and tangential expansion of the primary stem**. Very few examples exist of truly woody monocots. In woody monocot genera such as **Yucca** and **Dracaena**, **the activity of a secondary thickening meristem in the outer cortex of the stem is responsible for** **anomalous secondary growth**.

**Water transport**

Despite a large amount of research on this topic, the precise mechanism of water transport in plants is still debated. The experimental evidence strongly suggests that **water transport** in plants is driven by a **gradient of water potential** that exists between the **air surrounding the leaves** at one end and the water that **surrounds the roots at the other**. These two extremes are connected by the xylem, which supports a water column that extends from the roots to the leaves.

**The upward movement of the water column is counteracted by three forces:**

 **1**- The weight of the water column.

**2-** Adhesion of water to the cell walls of tracheary elements.

**3-** Adhesion of the water to soil particles.

The upward movement of the water molecules in each tracheary element will cause **tension** in the water column, causing it to become narrower. During times of **high transpiration**, the negative pressure inside tracheary elements can become **strong enough to cause these cells to collapse inward.** Vessel elements and tracheids possess secondary **thickened walls** that serve **to reinforce the walls and prevent inward collapse** under the tremendous forces produced inside the tracheary element.

**\*Senescence (Programmed Cell Death)** **of tracheary elements:**

Tracheary elements undergo **autolysis** at the completion of secondary wall deposition and lignification. Its steps which are:

**1-** **Soon** after the initiation of secondary thickening, hydrolytic enzymes (**DNAases, RNAases and proteases**) start accumulating in the vacuole.

2- **The autolytic process** is initiated when the tonoplast ruptures, causing the hydrolytic enzymes to spill out into the cytoplasm.

**3- The complete degradation** of the cell contents and partial digestion of the unprotected regions of the primary wall. Only regions covered by lignified secondary wall material are protected from degradation.

**4-** **The end walls** of differentiating vessel elements are degraded at the perforation sites to allow direct cell-to-cell movement of water and nutrients.

**5- Pit membranes** are often partially degraded to leave mats of cellulose fibrils. This enhances the movement of water through pit-pairs, which is the only way water can enter and leave tracheids.