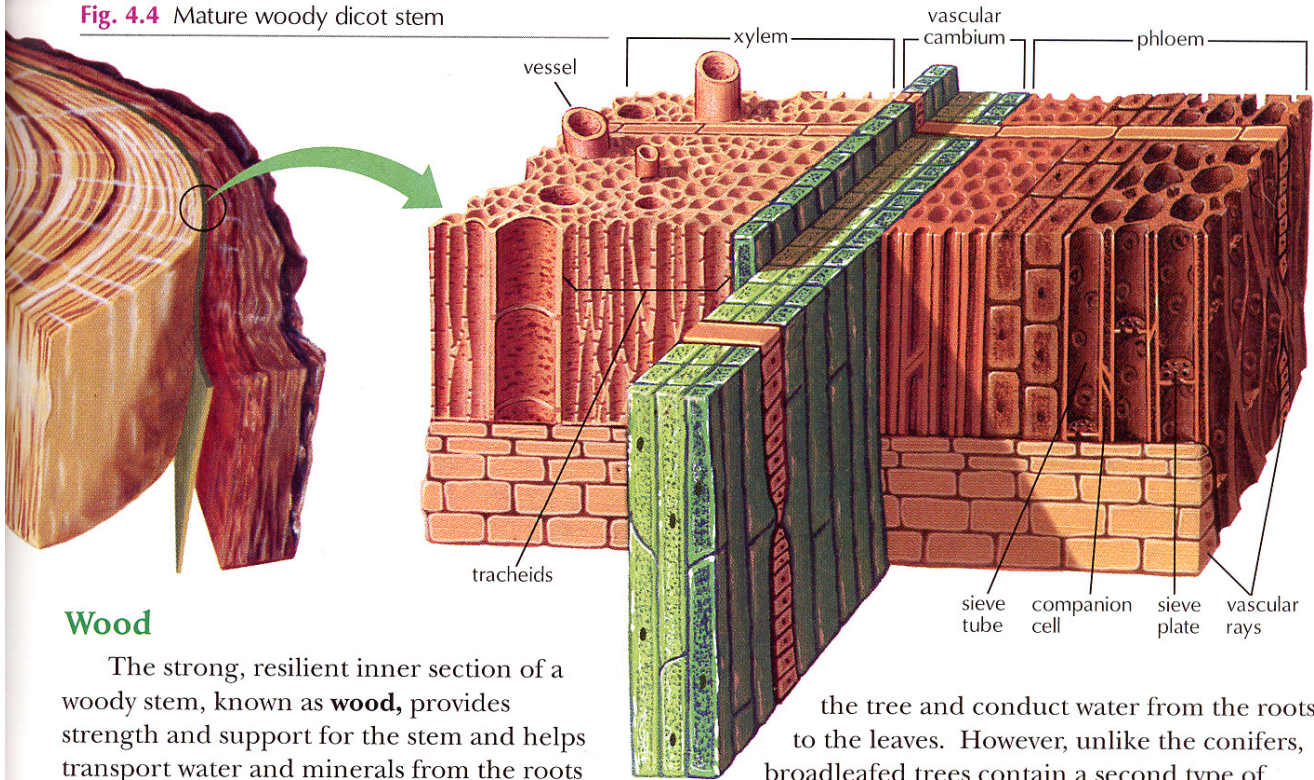


Fig. 4.4 Mature woody dicot stem



Wood

The strong, resilient inner section of a woody stem, known as **wood**, provides strength and support for the stem and helps transport water and minerals from the roots to the leaves. Wood consists mostly of long, narrow, tubular cells with thick cellulose walls stiffened by a substance called *lignin*. These cells, which are arranged in long, water-conducting pipes, compose the *xylem* of the tree (the tissues of the tree that conduct sap upward from the roots to the leaves).

Conifers (cone-bearing trees) such as pines and firs contain special water-conducting cells called **tracheids** [trā'kē-īdz]. Tracheids are long, narrow, rod-shaped cells that often have tapered ends. Tracheids have very strong, thick walls that impart great strength and a limited amount of flexibility to the tree. When a tracheid cell matures, it is designed to cease functioning and break down, leaving its sturdy walls behind as an empty tube that can then freely conduct water. Each tracheid has several dozen small holes in its walls, allowing water to flow in and out. By flowing to the top of one tracheid, then out the side into the bottom of an adjoining tracheid, and so on, water climbs from the roots of the tree, up through the stem, and into the leaves.

Like pines and firs, *broadleafed trees* such as oaks and maples contain tracheids that give strength to

the tree and conduct water from the roots to the leaves. However, unlike the conifers, broadleafed trees contain a second type of xylem tube called **vessels**. Vessels are considerably larger than tracheids; whereas tracheids are generally visible only under a microscope, vessels can sometimes be seen with the naked eye as tiny pores in a piece of cut wood. Vessels are composed of relatively short, wide, often barrel-shaped cells joined end to end like concrete pipes in a culvert. Like tracheid cells, vessel cells are designed to cease functioning and break down when mature, leaving their thick walls behind to form a segmented pipe. The large diameter and straight walls of vessels allow water to be transported through them much faster than through tracheids. Because vessels are not as strong or resilient as tracheids, broadleafed trees have extra reinforcement fibers extending through the xylem to give the wood strength. Because these fibers tend to make the wood hard, rigid, and dense, broadleafed trees are often called *hardwoods*.

Tracheids, vessels, and the other parts of wood all make up the xylem tissue. **Xylem and wood are essentially the same substance.** Tracheids and vessels are types of xylem tubes. Together, the xylem and phloem cells are the **vascular tissue** that forms the "circulatory system" of the plant.

Some woody stems contain additional circulatory structures in addition to tracheids and vessels. For example, most mature trees contain *vascular rays*, microscopic structures that radiate outward from the center of the trunk like the spokes of a bicycle wheel. Vascular rays transport water, food, and waste products between the center and edges of a tree. Many softwood trees such as pines also contain *resin ducts*, special tubes lined with resin-producing cells. If the bark of the tree is damaged, the resin seeps out of the wood and forms a protective seal against insects and fungi.

Pith, Heartwood, and Sapwood

At the center of a woody stem in a young plant is the **pith**. This area of the stem, often only a few millimeters across, is softer than wood and is made up of thin-walled cells. Pith cells are packed loosely together and function mostly as *water storage cells*. The pith becomes less important as the plant grows; it is hardly noticeable in the cross section of a mature tree, and sometimes disappears altogether.

As a tree ages, its oldest xylem tubes (those near the center of the tree) gradually become clogged with debris and waste products from the tree's living cells. When xylem tubes become clogged, they are sealed off and no longer conduct sap from the roots to the leaves. This older, inner wood, known as **heartwood**, is then useful only as support for the stem. The accumulation of resins and oils gives the heartwood a darker color than the rest of the wood in the xylem.

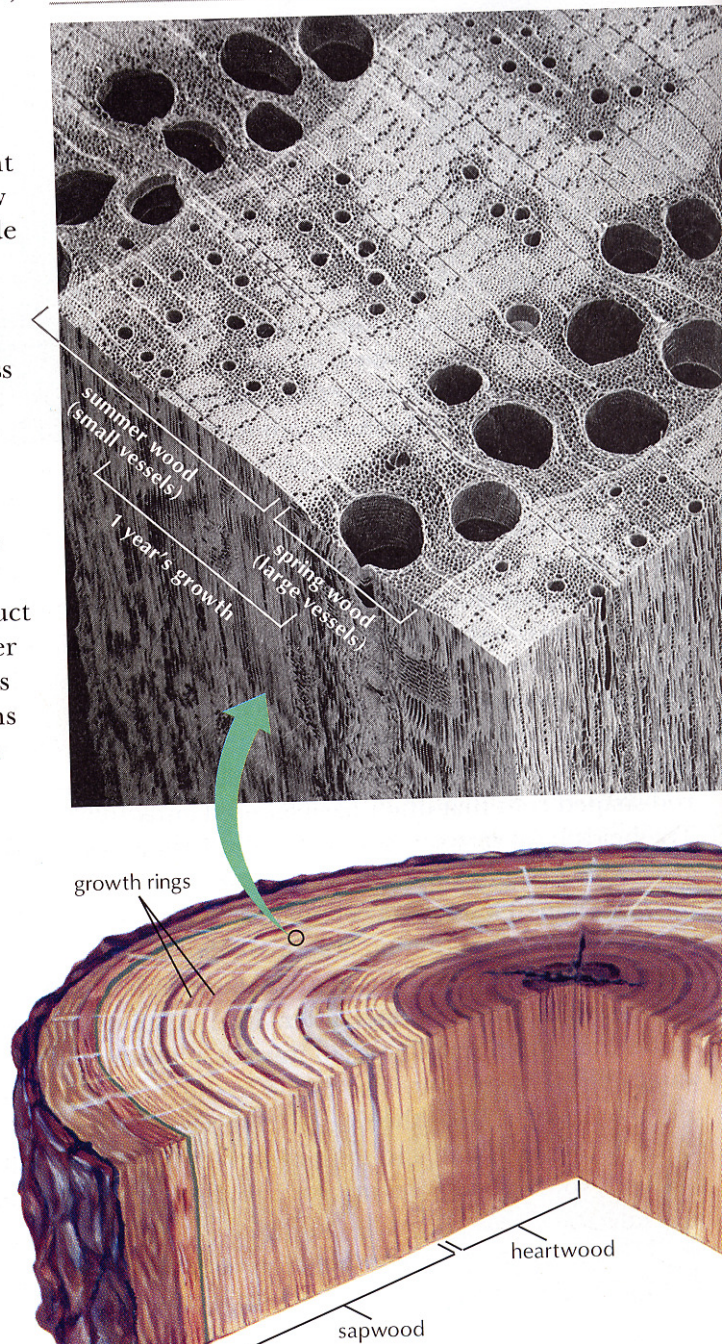
As a result of this process, in a tree that is several years old, only the younger xylem (that farthest from the center of the tree) conducts water and minerals from the roots to the leaves. This younger, functioning xylem tissue is called **sapwood**. Sapwood is lighter in color than the other wood and is the outer part of the wood.

Annual rings

New wood (xylem) is formed by the vascular cambium layer in the same manner that new phloem is produced. As can be expected, the production of new wood leads to an increase in the thickness of the tree trunk; this growth in width is called

secondary growth. Cells of the vascular cambium are very active when growing conditions are good, but they slow down during droughts, cold weather, or whenever conditions are not conducive to growth. In *deciduous* trees, the cambium cells become less active in the fall, remain dormant over winter, and start to grow rapidly again in the spring. This pattern of growth results in distinct

Fig. 4.5 Heartwood, sapwood, and growth rings



layers of xylem which are called **annual growth rings**. Much new wood is formed in the spring; less is formed in the summer. *One layer of spring and summer wood taken together makes up a single annual growth ring.* The age of trees can be estimated by counting their growth rings.

In the northern temperate zone, most stem growth is completed by early summer. Spring wood of a given annual growth ring is located toward the center of the stem; wood toward the outside of a ring is summer or fall wood. *Spring wood is light in color* because xylem vessels are large to conduct the large amount of water necessary for spring growth. *Summer wood is darker in color*

because the xylem vessels are smaller. These two areas make up the **grain** of the wood, and when wood is stained, the two parts absorb the stain differently. This results in the light and dark streaks (the beautiful grain of the wood) which appear in the finished wood.

A tree does not have to be cut down in order for one to examine its rings. Foresters use a device called an *increment borer* to remove a plug of wood from a tree for examination. This device is a kind of hollow drill which can be used to bore into the center of a tree for collecting a thin, rodlike plug of wood which shows the tree's growth rings.