movement is based on a single principle: the movement is from a source to a sink. A source is a plant organ that is a net producer of sugar, either by photosynthesis or by the hydrolysis of starch. Leaves are the primary sugar sources. A sink is a plant organ that uses or stores sugar. Roots, buds, stems, seeds, and fruits are all sugar sinks. It is possible for some structures to be both a source and a sink. For example, a tuber or bulb may be storing sugar or breaking down starch to provide sugar, depending on the season: tubers and bulbs act as sinks in the summer and as sources in the early spring.

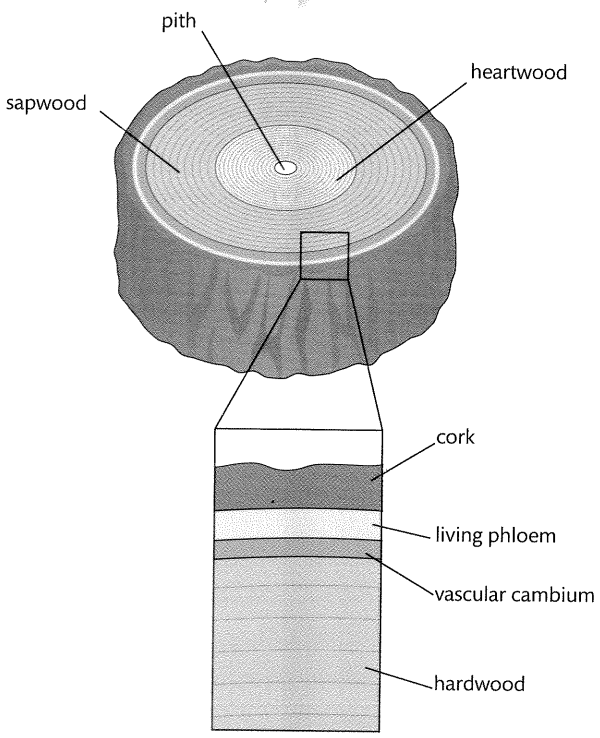

Figure 9.11 When girdling is carried out, the bark and the living phloem just below it is removed.

As early as the 1600s, it was observed that trees slowly die when a ring of bark around the trunk is removed. After the removal of the bark, called girdling, a swelling occurs just above the location of the girdle. First the bark below the girdle, and then the entire tree, dies (see Figure 9.11).

When the living phloem is removed by girdling, the flow of food from the leaves to the roots stops. The swelling is from the trapped sugar solution from the leaves. This is the cause of death of the tree. This practice has often been used to kill unwanted trees.

The movement of organic molecules in plants is called translocation. The organic molecules are dissolved in water and the solution is referred to as phloem sap. The organic molecules of the phloem sap include:

- sugars (sucrose is the most common, and sugars account for most of the phloem)
- amino acids
- plant hormones
- small RNA molecules (this is a recent finding and may explain how cells that are far apart in a plant can communicate).

Plant exudate is any fluid that moves out of the normal transport system of plants. It may include resin, saps, gums, and latex. Nectar is considered by some to be an example of a plant exudate. In some cases these exudates harden over time.

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Two relatively new techniques have allowed major developments in the analysis of phloem sap. The techniques involve the use of aphid stylets and radioactively labelled carbon dioxide. The original methods used to examine phloem contents involved studying the exudates from severed sieve tubes. However, this fluid seemed to contain many contaminants. One technique being used now involves the use of aphids. Aphids feed by inserting structures from their mouth called stylets into a sieve tube. The pressure in the sieve tube forces the contents into the stylet and insect's gut. If a feeding insect is anaesthetized, the body can be cut from the stylet with a laser. The exudate, mostly free of contaminants, can then be analysed. Another relatively new method for studying phloem sap is to use a radioactive form of carbon so that the location of carbon dioxide-fixing reactions of photosynthesis can be determined. A process called autoradiography can then be used to track the flow of the carbohydrate, usually sucrose, through the plant.

The pressure-flow hypothesis

The phloem sap can move as fast as 1 m per hour. Radioactive tracers, mentioned in the Nature of Science, can be used to study this movement, and show that more than just diffusion and osmosis are involved. The best explanation at present for the movement of phloem sap is the pressure-flow hypothesis. It includes the following processes.