Figure 3.5 The radial path ...

3.2.4 Root pressure

If the stem of a well-watered herbaceous plant is cut off just above the soil, xylem sap will exude from the cut surface. Exudation of sap indicates the presence of a positive pressure in the xylem. The magnitude of this pressure can be measured by attaching a *manometer* to the cut surface. This pressure is known as *root pressure* (term coined by Stephen Hales) because the force that gives rise to the exudation originate in the root. The root pressure can be as high as 0.5 MPa. Roots generate positive hydrostatic pressure by absorbing ions from the dilute soil solution and transporting them into the xylem. The buildup of solutes in the xylem sap leads to a decrease in the xylem water potential. This lowering of the xylem water potential provides a driving force for water absorption, which in turn leads to a positive hydrostatic pressure in the xylem.

Root pressure is most likely to occur when soil water potentials are high and transpiration rates are low. When transpiration rates are high, water is taken up so rapidly into the leaves and lost to the atmosphere that a positive pressure never develops in the xylem.

3.3 Ascent of sap

Water and minerals from the soil enter the plant through the epidermis of roots, radially cross the root cortex, and pass into the xylem. From there the xylem sap, the water and dissolved minerals in the xylem, moves upward. It is vitally important for a plant to transport water and minerals from the soil to its uppermost leaves. The upward movement of minerals and water against gravitational force from root to aerial parts of the plant through xylem is called as *ascent of sap*.

... end walls, vessels provide a very efficient low-res... In rooted plants, transport of water and minerals through xylem is essentially *unidirectional*, from roots to the stems.

3.3.2 Mechanism of ascent of sap

Unlike animals, plants do not have a heart or a circulatory system to move water from the soil to the leaves. Despite this, the upward flow of water through the xylem occurs at fairly high rates. How is this movement accomplished? A longstanding question is whether water is *pushed* or *pulled* through the plant.

As we mentioned previously some roots develop root pressure, a positive hydrostatic pressure in their xylem. However, root pressure is typically less than 0.1 MPa and disappears when the transpiration rate is high, so it is clearly inadequate to move water up a tall tree. It is also not a universal phenomenon. Instead, water at the top of a tree develops a large tension (a negative hydrostatic pressure), which *pulls* water through the xylem.

Most researchers agree that water is mainly pulled through the plant, and that the driving force for this process is *transpiration* from the leaves. Transpiration generates a negative pressure in the xylem of leaves, which pulls the water upward. The most accepted theory for upward movement of water in the xylem is the **cohesion-tension theory** (also known as *transpiration pull*). This theory was proposed by *Dixon* and *Jolly*. Some physical properties of water support the formation of water column in xylem vessel and their upward movement are described below:

1. *Cohesion*: it is mutual attraction between water molecules.
2. *Adhesion*: it is attraction of molecules to the hydrophilic walls of tracheary elements.
3. *Surface tension*: water molecules are attracted to each other in the liquid phase more than to water in the gas phase.

These properties give water high *tensile strength* (i.e. an ability to resist a pulling force) and high *capillarity* (i.e. the ability to rise in a thin tube). In plants, capillarity is aided by the small diameter of the tracheary elements - the tracheids and vessel elements.

Due to the fact that transpiration 'pulls' the sap from the soil to the leaves, water in the xylem is in a state of tension. In this state, negative pressures in the xylem water may cause *cavitation* (embolisms) in the xylem. Cavitation is the appearance of a gas bubble within the liquid phase. It is more common in wide vessels than in tracheids and can occur during drought stress or when xylem sap freezes in winter. Such cavitation can block water transport and lead to severe water deficits in the leaf. However, the impact of xylem cavitation on the plant is minimized by several means. The principal mechanism for minimizing the effect of cavitation is a structural one. The end walls of vessels and the pores prevent the bubble from spreading from tube to tube.