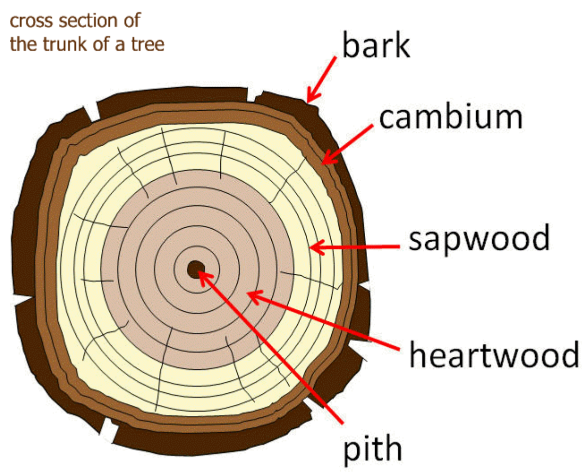
Tree Trunk Physiology

The trunk provides **support** for the branches and leaves. It also acts as the food and water **connection** between the leaves and roots. Within the trunk are many layers. The trunk supports the crown and **holds the leaves up** to the light to allow **photosynthesis** to occur. The **roots** are bathed in a **nutrient rich liquid** which **transports** these nutrients plus **moisture** to the top of the tree where it is all **consumed during photosynthesis**. The tree trunk has to ***expand as the tree grows in its search for moisture and sunlight***. If the process fails to provide water at any point, the tree will eventually **die** due to the **failure of both water and food requirements** that are necessary for life.

Trunk parts:

Inside the trunk of a tree are a number of rings. Each year of the tree's life a new ring is added so many people refer to them as the annual rings. The rings are actually made up of different parts:



A. **Bark**:

The **outside layer** of the trunk, branches and twigs of trees. Trees actually have inner bark and outer bark:

1. **Inner** bark; is made up of **living cells.** The scientific name for the inner layer of bark is **Phloem**. The main job of this inner layer is to ***carry sap full of sugar from the leaves*** to the rest of the tree.

2. **Outer** bark; is made of **dead cells**, sort of like our fingernails. serves as a ***protective layer*** for the more delicate inside wood of the tree.

A number of **handy things** are made from bark including:

- **latex**; is a sticky, milky colloid drawn off by making incisions into the bark and collecting the fluid in vessels in a process called "tapping". The latex then is refined into rubber ready for commercial processing.;

- **Cinnamon**: is a spice obtained from the inner bark of several tree species from the genus *Cinnamomum*. Cinnamon is used mainly as an aromatic condiment and flavoring additive in a wide variety of food and desert. The aroma and flavour of cinnamon derive from its **essential oil** and principal component, **cinnamaldehyde**, as well as numerous other constituents including **eugenol**.

Because bark is a protective layer for the tree, keeping it safe from insects and animals, it isn't surprising the **strong flavors, scents and toxins** can often be found in the bark of different types of trees.

B. **Cambium**:

The **thin layer of living cells** just inside the bark is called cambium. It is the part of the tree that **makes new cells** allowing the tree to **grow wider** each year.

C. Sapwood (Xylem):

The scientific name for sapwood is **xylem**. It is made up of a **network of living cells** that bring **water and nutrients up** from the roots to the branches, twigs and leaves. **It is the youngest wood of the tree** -- *over the years, the inner layers of sapwood die and become* ***heartwood****.*

D. **Heartwood**:

The heartwood is **dead sapwood** in the **center of the trunk**. It is the **hardest wood** of the tree giving it **support and strength**. It is usually **darker** in color than the sapwood.

E. **Pith**:

Pith is the **tiny dark spot** of **spongy living cells** right in the **center** of the tree trunk. **Essential nutrients are carried up through the pith**. It's placement right in the center means it is the **most protected** from **damage** by **insects**, the **wind** or **animals**.

Ascension of water through the plant (Sap Ascent)

The presence of plants outside the water environment has been related to the evolution of the **vascular system**, which allows for the ***speedy upward movement of water*** to meet the demand of transpiration from the leaves. The need for a vascular system is more evident when we observe a tree during a hot day, which demands a **large flow of water** (for example, **200 to 400 liters day-1**) to fit a transpiring surface that is situated along elevated positions, and in some species is higher than **100 meters.** The water flows from the roots to the shoot of the plant through the **xylem**. The general mechanism to explain this upward movement of water is the **cohesion-tension hypothesis.**

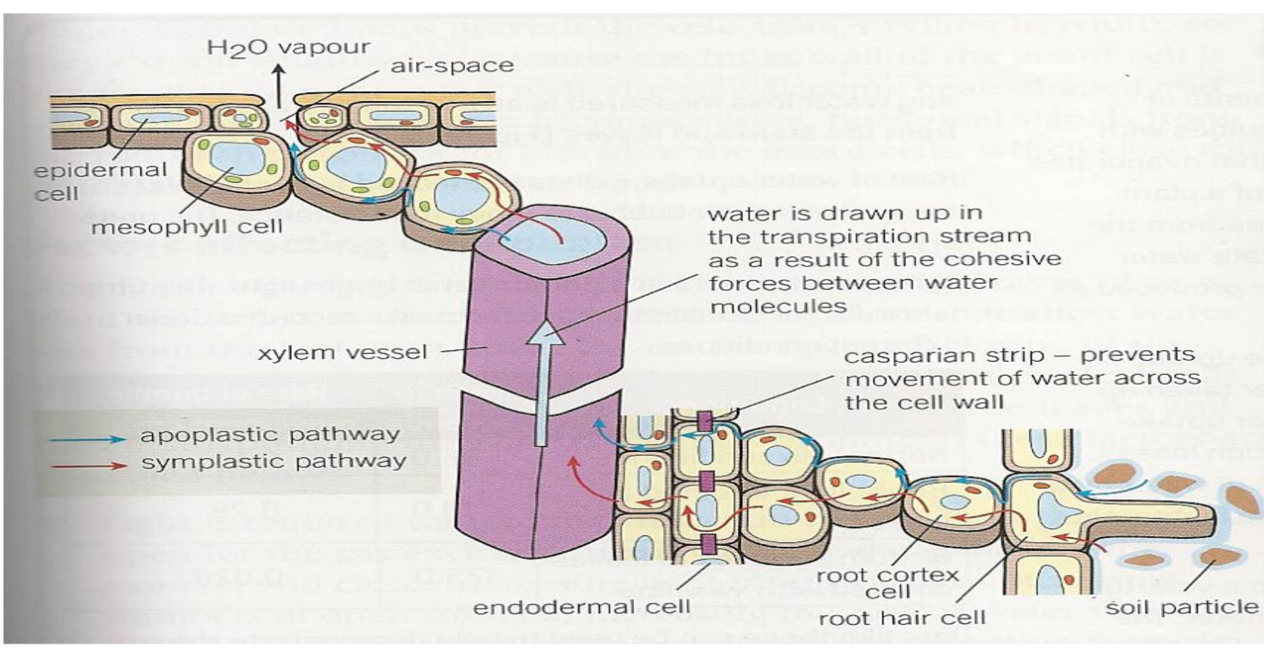
Cohesion-Tension Theory

We know that in an ordinary pipe, like that attached to a well pump, you can only "**pull**" water to a height of **10 m** with a **vacuum**. After that, **gravity** pulls on the water column and it breaks under its own weight. So if this theory is to work, we have to ***explain how a tree can violate this property?***

First off, trees don't have large diameter tubes inside. Instead, they have **tracheid** and **vessel** elements. The diameters of these cells range from **20 µ** to nearly **500 µ**, depending on species. Studies with water in capillary tubes show that ***water in small diameter tubes can withstand tensions of up to 300 bars (or 4500 psi*** (pound per square inch) tension!!).

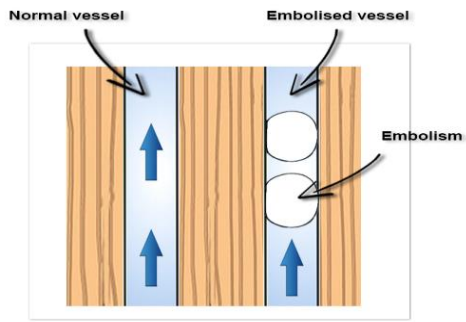
The **cohesion-tension hypothesis** is the most widely-accepted model for movement of water in vascular plants. Cohesion-tension essentially combines the process of **capillary action** with **transpiration**, water from the plant stomata and **cohesion** of water molecules.

1. **Transpiration** (evaporation) occurs because stomata are open to allow gas exchange for photosynthesis. As transpiration occurs, creating negative pressure (**tension or suction**). **The tension** created by transpiration "pulls" water in the plant xylem, drawing the **water upward** in much the same way that you draw water upward when you **suck on a straw.** Tension is simply **negative pressure**. Transpiration is caused by the evaporation of water at the leaf, or atmosphere interface; it creates **negative pressure** (**tension**) equivalent to **–2 MPa** at the leaf surface.
2. **Cohesion** (water sticking to each other) causes more water molecules to fill the gap in the xylem as the top-most water is pulled toward the stomata.
3. **Adhesion** the attraction of water molecules to the vessel and tracheid capillary tubes.



Cavitation and Embolisms

Cavitation occurs in xylem of vascular plants when the **tension of water within the xylem becomes so high** that dissolved air within water expands to fill either the vessels or the tracheid. The **blocking of a xylem** vessel or tracheid by an air bubble or cavity is called as **embolism**.



If cavitation or embolism occurs only in a **few xylem vessels or tracheid**, the upward movement of water **may continue** uninterrupted through adjacent un-emboli zed xylem vessels or tracheid bypassing the un-emboli zed ones. But, **widespread cavitation** or embolism in xylem (as under **severe water stress**) **reduces a plant's capacity to transport water** from soil to leaves. This reduction in xylem's hydraulic conductivity can **impair rate of carbon fixation** by **inducing stomatal closure to prevent further cavitation** and desiccation of leaf tissues.

Mechanisms of Embolism Formation:

1. **Water Stress-Induced Embolism:**

Under severe water stress, **tension of water in xylem becomes so high** that ***dissolved air within water expands to fill either the vessel or tracheid*** elements and cavitation occurs.

2. **Embolism Formation by Winter Freezing:**

Embolism formation by winter freezing has been observed in many plants such as sugar maple (***Acer saccharum***) and grapevine (***Vitis spp.*).** Several studies have shown that when **xylem is frozen** while under tension, extensive **embolism develops after thaw** (melting of ice) as **air bubbles forced out of solution during freezing expand and nucleate cavitation**. Embolisms may also form in frozen vessels by sublimation; is a chemical process where a solid turn into a gas without going through a liquid stage. An example of sublimation is when ice cubes shrink in the freezer.

3. **Pathogen-Induced Embolism:**

It has been known for quite some time that **vascular diseases** caused by pathogens induce water-stress in host by **reducing the hydraulic conductivity** of the xylem and formation of embolism.

Embolism Repair:

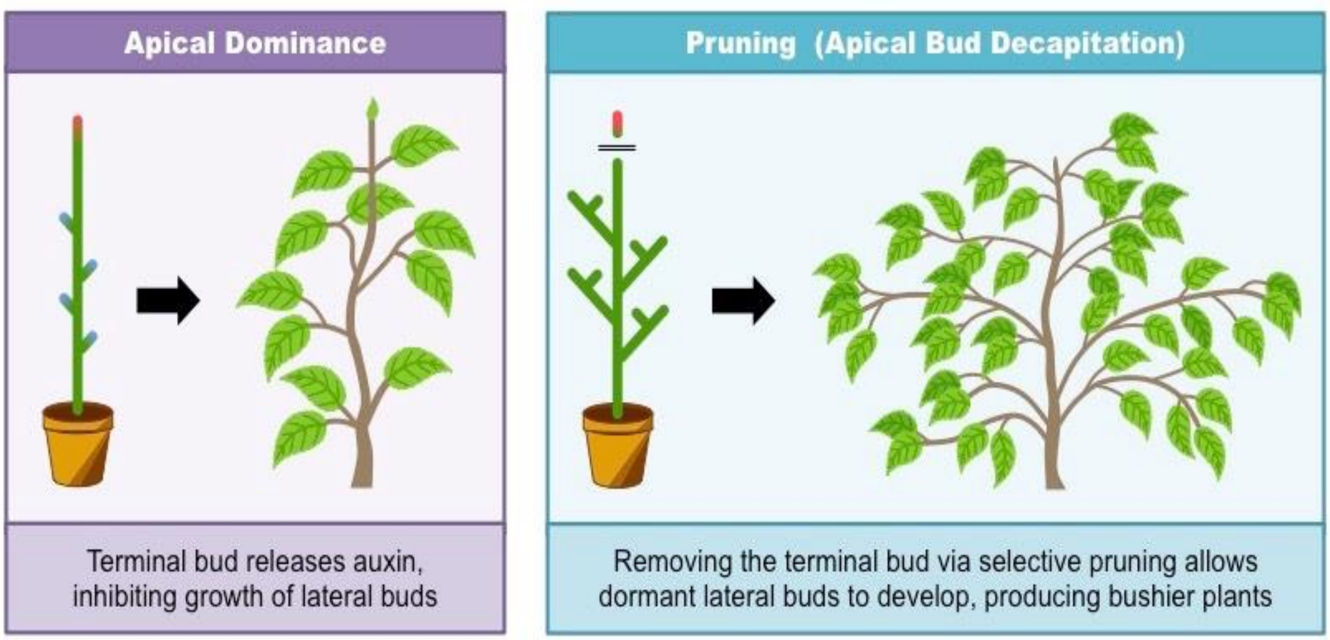
Plants adopt various strategies to avoid long term damage caused by embolism:

1. An effective method of repairing embolism in **herbaceous plants** occurs at **night** when **transpiration is low** or absent and **root pressure is high**. Under such situation, root pressure generates **positive xylem pressure** which reduces tension in xylem water and allows **air to re-dissolve** in the xylem solution. But, how embolism might be reversed in tall trees is not so clear. However, positive xylem pressures have been observed in trees such as sugar maple and woody vines in spring and those plants are known to recover from freezing- induced embolisms in spring.

2. Another effective mechanism to restore hydraulic conductivity in xylem after cavitation is to produce **new xylem** conduits in those plants which possess capacity for **secondary growth**. New xylem vessels and tracheid produced each spring in such plants (shrubs or trees) replace the older activated and non-functional xylem conduits which may fulfill the hydraulic conductivity needs of these plants.

Apical Dominance

It's the phenomenon in plants where a main shoot dominates and inhibits the outgrowth of other shoots. In plants with strong apical dominance, main shoot tip damage or shoot tip loss, caused by pruning or herbivory, leads to the outgrowth of compact embryonic shoots (axillary buds) into branches. This decapitation process can cause a relatively unbranched plant to become bushy, drastically changing its morphology.



Apical dominance is thought to be caused by the apical bud producing IAA (auxin) in abundance. This auxin is transported basipetally from the apical bud. The auxin causes the lateral buds to remain dormant.

How could a lower concentration cause lateral buds to remain dormant and a higher concentration cause the apical bud to grow?

The difference in response between the two kinds of buds is explained in their sensitivity to the auxin concentration. Clearly the lateral buds are more sensitive to auxin than the apical bud. There is a concentration of auxin at which the apical bud is stimulated to grow while the lateral buds are inhibited. When the apical bud is removed, the source of IAA is removed. Since the auxin concentration is much lower, the lateral buds can now grow.

In fact, their growth will be stimulated by a relatively small drop in auxin concentration. Thus, decapitating (pruning) a shoot will cause it to branch!