How a Tree Works

Have you ever stopped to think about what goes on inside a tree? We know that the roots of a tree take up water and minerals from the soil and transport them to the leaves where some of the water is used in photosynthesis to combine with carbon dioxide from the air to make sugars, starches and cellulose.

But the roots are 30 feet below the top of the average Hill Country tree, and there are many trees that are several times that tall. How does the water get up to the leaves? Trees don't have hearts. They don't really even have a closed circulatory system. So how does it work?

Just under the bark of a tree are three structures that are involved with the transportation of fluids within the tree. The outermost structure is the phloem (pronounced flow-em), just inside that is the cambium and then the xylem. The xylem and the phloem structures are made up of many long cells connected end to end in a chain that reaches from the roots to the leaves and which form rings of living tissue just under the bark.

The xylem, running from the finest root hairs to the tallest leaf is where water and minerals from the soil are transported to the leaf. But how does it get there? If we were designing such a system, we would use a pump, which would require an external energy source. The tree doesn't have a pump.

It turns out that there is an unbroken column of water from the roots to the top leaf, from one xylem cell to another all the way to the top. The water molecules are attached to each other in this column of water by adhesive and cohesive molecular forces. On the underside of the leaves are microscopic structures called stoma which open and close with temperature and humidity and from which droplets of water evaporate.

When a water molecule evaporates from a leaf, in a process called evapotranspiration, its place is taken up by the next molecule below it, which pulls up the molecule below it and so on and so on all the way down to the roots. Thus water flows from the roots to the leaves through the xylem cells.

When the leaves make sugars from carbon dioxide and water, not all of these sugars are used to make starches and cellulose for the leaves. The roots have to grow too, and they can't make their own sugars. So sugar solution made in the leaves (sap) is transported down to the roots through the phloem structures under the bark. The sugar molecules are the building blocks for starches and cellulose, the former being energy stores and the latter being structural components (wood) of the plant.

How does a tree make its first leaves of spring when it doesn't have any leaves as yet to carry out photosynthesis? The answer is that sugars are transported from where they were stored in the roots for the winter back up the phloem to make the new leaves. So at different times, sugar solution can flow both directions in the phloem. How does it do that?

The energy to drive that process is called osmotic pressure, in which water in the xylem flows into cells with high sugar concentrations, forcing the sugar solution into the phloem which then flows through the phloem into cells with lower sugar solutions. Thus sugar is transported from areas of high concentration to areas of low concentration. In the summer and fall the leaves have higher concentrations of sugar than the roots, but in the early spring the roots have the higher concentration, and these concentration gradients drive the flow of sap from where it is not needed to where it is.

By the way, the process of storage of starches in the roots is where we get our potatoes, carrots, radishes, turnips and beets, and the sap flow in early spring gives us maple syrup.

Most of the growth of trees is at the tip of the branches as the tree grows taller and longer branches. But the trunks also grow a little in diameter each year as older xylem becomes sapwood and older phloem becomes bark and are replaced by new layers produced in the cambium. This process is revealed in the growth rings of trees.

Until next time…

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