ANATOMY AND PHYSIOLOGY OF TREES[1]

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The objective of this presentation is to help you understand how you apply the science of arboriculture in your everyday activities, and hopefully better prepare you to make decisions relating to your arboricultural practices. I will limit it to the anatomy and physiology; anatomy relating to the structure of the plant and physiology to the chemical reactions occurring in the plant.

Anatomy

The basic building block of trees is the cell, with all cells formed by division from other cells. Don't ask me where the first one came from! The work performed by cells is amazing; they store energy from the sun by producing sugars, use the energy for growth and development by consuming the sugars, and in between they store them. Cells produce enzymes, hormones, and new cells; everything accomplished by plants is done at the cellular level.

Cells are surrounded by a semi-permeable membrane. It allows water to pass through freely but substances dissolved in the water (solutes) are selectively passed through. Water will move from an area with a low concentration of dissolved materials to an area with a high concentration of dissolved materials. Those dissolved materials may be salts, such as deicing salt. When salts are sprayed over the roadside plantings of white pine, those pines are damaged, if not killed, because the water in the leaf cells of the plants is literally sucked out by the salt. The other thing that happens is the road salt washes into the root zone of the plant, and if not leached away rapidly, damages cells in the roots. Taking this principle one step further, damage caused by overfertilization is also nothing more than salt damage.

Cells are joined together to form tissues. One group of tissues are the conductive tissues which are called xylem and phloem. Xylem is mainly involved with the upward movement of water and minerals from the roots to the shoot. The phloem is used to move sugars, hormones, and other growth substances down from the shoot to the roots. It is located just under the bark and is more susceptible than the xylem to damage by such things as insects, canker diseases, automobiles, bulldozers, dogs chained to trees and unknowing humans with knives or hatchets. But girdling, removing the bark and phloem in a ring completely around a tree, does not kill the tree immediately. The xylem, which is located deeper in the tree, in most cases will continue to supply water and nutrients to the stems and leaves until the sugar reserves in the roots are used up. When those reserves are depleted the roots die and that is the end of the tree. Trees may survive for one or two years after girdling, allowing arborists the time to save them by bridge grafting the damaged area.

The lifespan of xylem cells is different from that of phloem cells. Phloem cells function one season or less and then are crushed into the bark by the growth of the tree. Xylem cells are not crushed, they are the cells that form the "wood" of the tree and may continue conducting water for years. Exactly how water gets from the roots to the shoots is open to debate, but the best answer at present is the "transpirational pull' theory. According to this theory there is a continuous column of water reaching from the tips of the roots to the tips of the shoots. As water moves out of the leaves during transpiration a vacuum is created and water is pulled up through the xylem to fill it. Everything works well until the column is broken, after which water can not be pulled up until the column is restored by lateral movement of water in the stem. This is a slow process and accounts for the difficulty in injecting liquids into the trunks of trees. The injection hole breaks the column and results in a low flow rate.

The roots, stems, and leaves are made up of groups of tissues and are the organs of a tree.

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Roots supply the shoots with raw materials, mainly water and mineral elements, and the shoots supply the roots with stored energy in the form of sugars. A tree allowed to grow undisturbed will reach a balanced root to shoot ratio in which each part is able to meet the needs of the other. Serious problems result if an imbalance in this ratio is created. If there are not enough roots to supply the shoot with water, the plant will wilt and possibly die. This imbalance is created when a tree is transplanted or when there is construction around a tree. When this occurs, the best thing that can be done for the tree is to prune it and try to return an acceptable root to shoot ratio. Also, high nitrogen fertilizers which promote shoot growth should not be applied at planting.

Physiology

This discussion of plant physiology will briefly include nutrition, hormones, photosynthesis, and respiration. Plant nutrition involves the uptake of mineral elements by the roots and their distribution throughout the plant. For a mineral to be absorbed it must be present in the root zone and in a form the plant can use. Nitrogen is an example of a nutrient that is abundantly present around plant roots, but in most cases is in an unavailable form. Nitrogen is in the air as a gas, but roots can not absorb nitrogen gas. They can only absorb nitrogen that is in the ammonia or nitrate form. These forms occur naturally as a product of the decomposition of organic matter or can be produced from the nitrogen gas in the air by bacteria in the soil or in the roots of legumes such as honeylocust, black locust, and yellowwood. Nitrogen fertilizers are also chemically produced in great quantities by man.

Another example of an element that is often present in a form unavailable to plants is iron. Many plants in soils with a high pH will be iron deficient because iron is in an insoluable form at high pH levels. Though most plants can extract enough iron for proper growth, some plants, notably pin oak in this part of the country, can not. The deficiency symptoms can range from slight chlorosis to severe dieback, depending on the pH of the soil and the ability of the individual plant to absorb iron at high pH levels.

A key to identifying nutrient deficiency symptoms in a plant is understanding that some nutrients are more mobile than others. For example, nitrogen and potassium are mobile elements and will move from old tissues to tissues being formed if the plant is deficient in them. For this reason nitrogen and potassium deficiency symptoms will appear on old leaves before appearing on new growth. The opposite is true for iron and manganese which are relatively immobile. Iron and manganese deficiency symptoms appear on new growth first and are virtually indistinguishable from one another.

This leads us to another principle in nutrition — nutrient balances. The uptake and utilization of all nutrients are strongly interrelated. The relative levels of calcium, potassium, and magnesium are presented on soil test results because excessive levels of one may depress the uptake of one or both of the others. Applying fertilizer or lime containing one of the elements that was already present in excessive amounts would be worse than adding no fertilizer at all. Another example of a critical nutrient balance is that of iron and manganese. Excessive levels of either one will depress the uptake of the other, and since their deficiency symptoms are identical the problem is often aggravated by the addition of the wrong element. To determine the element actually deficient you can send leaf samples to a laboratory to be analyzed. This will take several weeks and cost $25-$50. An inexpensive, fast, and simple alternative is to mix solutions of iron, manganese, and a combination of iron and manganese and spray them on individual, carefully labelled branches of the tree. In 3 to 10 days you should be able to tell which solution corrected the problem.

Hormones. Hormones are substances that are produced in the plant in very small amounts and translocated to another part where they greatly affect growth and development of that part. The most common hormones are auxins, cytokinins, gibberellins, and ethylene. The first three control cell division and increase in cell size, while ethylene is related to the abscission of plant parts.

The most important example of hormone action to arborists is the principle of apical dominance. Auxins are produced in the tips of branches and are translocated downward to lateral buds, where they inhibit the development of those buds. Trees develop central leaders because the tip of the tree has a stunting effect on its lateral branches. Pruning the tip of a branch removes the source of the inhibitor and results in the active growth of a series of lateral buds, giving the new branch tip a bushy appearance. Eventually one of them becomes "dominant" over the others and begins to inhibit their growth, re-establishing apical dominance.

Auxins are also very important in the propagation of many plants because they promote the formation of roots on cuttings. In many cases rooting is very poor or does not occur at all without the application of hormone preparations to the cutting.

Geotropism is a term relating the fact that roots grow down and stems grow up to gravity. This response is believed to occur because auxins will settle to the bottom of roots or stems due to gravity, resulting in higher auxin concentrations in the bottoms of these plant parts. Since stem cell growth is stimulated by auxins, the cells on the lower side of the branch elongate more than the cells on the upper side, resulting in an upward curvature. Root cells respond in the opposite manner and their elongation is reduced by high auxin concentrations. Therefore growth is greater on the top side of a root than the bottom, resulting in a downward curvature. Notice that auxins promote root initiation in cuttings, but inhibit elongation of the cells once they are formed.

Ethylene is the most unusual of the hormones, as it is able to move from plant to plant. A simple demonstration of ethylene action occurs when an apple is placed in a plastic bag with an unripe banana. Ethylene produced by the apple will cause the banana to ripen much faster than an unripe banana placed in another plastic bag alone. In arboriculture ethylene is important because it is related to the abscission of plant parts. It is used in nurseries to promote leaf drop so that fall digging can be started earlier. Caution must be used here to assure that there is no chance of additional new growth being initiated that season. Ethylene can also be used to cause abscission of flowers to prevent the setting of unwanted fruits on trees such as ginkgo.

Photosynthesis and Respiration. Photosynthesis is the conversion of carbon dioxide and water to sugars, using sunlight as an energy source. That energy is stored in the sugars and is released in the process of respiration. The following equations are simplified representations of the processes.

Photosynthesis

carbon dioxide + water + sunlight = sugar (stored energy) + oxygen

Respiration

sugar (stored energy) + oxygen = carbon dioxide + water + energy

Plants can't use the energy in sunlight directly. It must first be converted to sugars in the leaves, then translocated to the site of growth and released through respiration.

In recent years many people have made the claim that plants "purify" the atmosphere by removing carbon dioxide from the air and returning oxygen. This does occur during photosynthesis, but note that during respiration the exact opposite happens. Some carbon is tied up in the wood of plants, but as soon as it is burned or decomposed it is returned to the air. So plants really have little effect on the overall balance of carbon dioxide and oxygen in the atmosphere.

Finally, roots must also carry on respiration to obtain the energy needed for growth. This means that they must have oxygen in the soil around them and that they will grow where the air-water relationships is best suited for root growth. Many tree problems occur because the air-water relationship is changed after the root system has been established. Factors that interfere with respiration in the roots by changing the amounts of oxygen available to them include grade changes, paving, compaction, water table changes, drainage pattern changes, and natural gas leaks.

Summary

All of the arboricultural practices that you perform in your everyday work have a scientific basis behind them. Understanding them will make you better prepared to face the problems and answer the questions constantly occurring in this complex business of arboriculture.

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