



# Tree Physiology

by Roger C. Funk

## Learning objectives— The arborist will be able to

- explain the difference between tree anatomy and tree physiology
- describe the basic physiological functions of leaves, stems, and roots
- define respiration, transpiration, and photosynthesis

A working knowledge of how plants grow is needed to effectively implement proper methods of planting and plant care. Recognition that plants are living organisms that have physiological responses to our actions is a good first step.

The *anatomy* of the plant is really the structure, outside as well as inside, of the plant and all its various parts: leaves, flowers, seeds, stems, buds, roots and trunk. Plant *physiology* concerns the function of the plant and its parts—how it lives and grows. The structure of the plant is related to and facilitates the function. For example, the stem of the plant has a structure that enables it to carry out one of its functions, supporting the branches and leaves. This is an obvious example, but the relationship between structure and function is repeated down to the smallest parts of the plant, even to those that cannot be seen by eye.

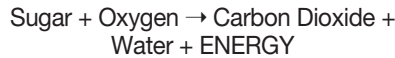
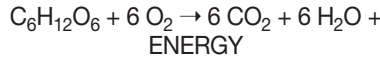
A plant is a highly organized structure. Plants consist of leaves, roots and stems—three vegetative organs, each with its own function. The leaves function in the production of food. The roots function as support, as a means to absorb mineral nutrients and water, and as a site for the storage of food. The stems function as carriers of food (from leaves and of water and nutrients from roots to all other parts of the plant), as a storage system for food, and as support for the leaves.

To grow and function properly, green plants must be supplied with oxygen, water, carbon dioxide, nitrogen and about a dozen mineral elements. All of the products and processes necessary to maintain life are derived from these chemicals.

## Function of All Living Cells

Oxygen is necessary in all living cells for respiration. *Cellular respiration* is the process in which sugars (carbohydrates) are broken down in the presence of oxygen to release carbon dioxide, water and energy. The process, which occurs in small cellular organelles called mitochondria, is

illustrated as follows:



Respiration is a constant process of converting carbohydrates into energy. If overall plant respiration exceeds overall photosynthesis (carbohydrate manufacture), the plant will decline (run out of energy) and die.

Oxygen is required for normal, aerobic respiration. The cells in tree roots under anaerobic (lacking oxygen) conditions are not capable of aerobic respiration. When the soil is compacted or flooded, oxygen is scarce and aerobic respiration is limited. If these conditions persist, cell functions are greatly reduced and cell death can occur.

Although some woody species apparently can transport oxygen for considerable distances, most oxygen is utilized at or near its entry into leaves, stems or roots. In fact, oxygen is often the limiting factor determining root depth because of restricted penetration into soil.

Water also is necessary for all living cells as the liquid within which cellular reactions occur and for the maintenance of turgidity. In addition, water is a raw material, or reagent, for photosynthesis in leaf cells and the transport liquid within xylem and phloem. Although some water may be absorbed by leaves and stem tissue, the primary source is root absorption.

Water is absorbed and moves from living cell to living cell by a process called *osmosis*. Osmosis is the movement of water across a biological or semipermeable membrane from a region of high potential (water concentration) to regions of lower water potential (Figure 1). Pure water has the highest potential; adding solutes such as mineral salts or sugar lowers the potential. Because roots have a lower water potential than soil, water moves from the soil into the root. Osmosis also occurs between living cells throughout the plant.

## Leaf Function

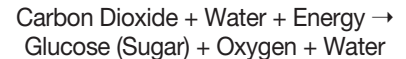
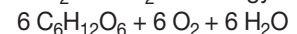
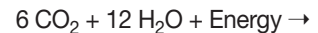
*Transpiration* is the loss of water vapor from a plant and is basically an evaporative process.

The evaporation of water from leaves creates a “transpirational pull” that moves water up through the xylem. The majority of transpiration occurs through open stomata of the leaves. The moisture loss of transpiration can be controlled by opening

or closing of stomata. Guard cells that surround the stomata regulate their opening and closing. Stomata are usually open in the light and closed in the dark. The rate of transpiration and stomata opening is influenced by environmental conditions such as light, temperature and humidity.

Transpiration also is affected by anatomical features such as cuticle thickness, presence of hairs and number of stomata.

*Photosynthesis* is the process by which green plants use light energy to build sugar molecules. Literally, photosynthesis means “putting together with light.” Photosynthesis takes place within cells that contain chloroplasts. Chloroplasts contain the light-absorbing pigment chlorophyll. Chlorophyll traps the light energy, and this energy is used to synthesize sugars with water from the soil and carbon dioxide from the air (Figure 2). A summation of the many reactions in photosynthesis is as follows:



The products of photosynthesis are sometimes referred to as photosynthates or carbohydrates. Photosynthates are the building blocks for other compounds required by the plant. Proteins, starches, fats, vitamins, amino acids and other compounds are produced from photosynthates when combined with other essential elements such as nitrogen, potassium, sulfur and iron.

The sugar, or simple carbohydrate, produced by photosynthesis is used in the leaf or transported to all other parts of the plant. Sugar that is not used immediately is stored for future growth, primarily as starch in axial and ray parenchyma cells.

The veins of a leaf are composed of two types of tissues called phloem cells and xylem cells. These cells form an efficient pipeline, with the xylem transporting water and dissolved minerals into the leaf, and the phloem transporting sugar out of the leaf. The xylem and phloem conduction cells form a continuous transport network through the leaf, through the petiole, and continuing through the stems and roots.

## Stem Function

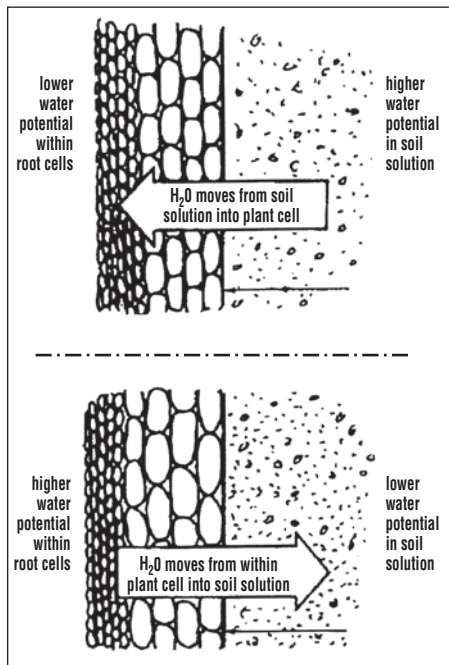
The primary function of the stem is to support the leaves in a manner that allows efficient photosynthesis and to serve as a pathway that connects the roots with the leaves.

The stem contains xylem and phloem tissue that forms an “up and down pipeline” directly connecting with xylem and phloem in the roots and leaves. The xylem cells form the “up pipeline.” Water and dissolved minerals absorbed by the roots are conducted upward through the xylem for use by all living cells in the stem and leaf tissues. The primary driving force is the gradient in water potential from soil to leaves produced by transpiration, the evaporation of water from leaves.

Phloem cells also form a pipeline that connects the phloem in the leaf veins with the roots. Carbohydrates are translocated largely as sucrose in the phloem (inner bark). The concentration in the phloem sieve tube cells is highest near production sources and declines along the pathway toward cells using or storing carbohydrates. The gradient of sucrose concentration and the resultant gradient of turgor pressure is one possible force responsible for driving phloem translocation.

### Root Function

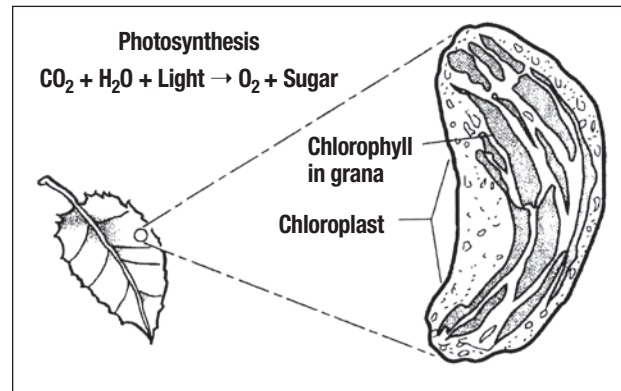
Roots anchor the plant, absorb water and mineral nutrients and provide for food



**Figure 1.** Osmosis is the movement of water across a biological or semipermeable membrane from a region of high concentration to regions of low concentration.

storage. The importance of roots is easily overlooked because they usually are not seen and are difficult to study. Because the roots of a plant are underground, their size and spread is not easily realized. The extent of the root system of a plant can be appreciated from data reported for a rye plant that was found to have 387 miles of root and 2,554 square feet of root surface area. The type of root system a plant develops—the depth, spread and degree of branching—is an inherited characteristic, influenced by the type of soil in which the plant is growing. In heavy and/or wet soils, most of the root system will be near the surface of the soil. However, these roots may spread down to ten or more feet in light and sandy soil.

Many plant roots live in a symbiotic relationship with certain nonpathogenic fungi resulting in mycorrhizal roots. Mycorrhizae are formed from both plant and fungus tis-



**Figure 2.** Photosynthesis takes place within cells that contain chloroplasts. Chloroplasts contain the light-absorbing pigment chlorophyll.

sues. In symbiosis, both organisms, the plant and fungus, benefit from the living arrangement. The mycorrhizae, or “fungus roots,” derive nourishment from the plant and aid in the absorption of water and essential mineral elements.

Water and minerals dissolved in soil water are absorbed by the roots of mycorrhizae and are pumped into the conducting cells of the roots. The energy required for growth of roots and for absorption of mineral salts by roots is obtained by oxidizing sugars in the process of respiration. Therefore, roots require oxygen, which must be available from the air in the soil.

In fact, all living cells in a tree require oxygen for respiration.

Nitrogen and other mineral elements are absorbed as ions (charged molecules or atoms) from the soil in water solution by plant roots. The exact nature of ion absorption is unknown, but most evidence indicates that (1) protein carriers cross the membrane, (2) specific binding sites on the membrane attract ions from soil solution, or (3) perhaps both explanations are valid. The internal concentration of ions is likely to regulate ion absorption and may be at least partially under hormonal control.

A high concentration of ions in the soil solution may cause plant injury. This higher concentration occurs because of decreases in water potential or unfavorable changes in pH, or because the proportion of various ions become unbalanced. Decreased water potential of the soil solution is the most likely cause of injury. This

so-called “salt effect” reduces water absorption, increases leaf water deficits, and may lead to injury to tissues from desiccation. More prolonged and severe dehydration causes stomatal closure and interferes with photosynthesis.

Practically all movement of nitrogen and minerals from roots to shoots occurs in the xylem carried by mass flow in the transpirational stream. There also is considerable lateral movement of minerals between xylem and phloem, and recirculation in the

phloem plays an important role in mineral nutrition.

Corresponding test questions for this article are available in the ISA compendium entitled “Tree Biology.” The compendium is a collection of *Arborist News* CEU articles with corresponding test questions worth a total of 8.5 CEU credits. ISA compendiums are available to purchase from the ISA online at [www.isa-arbor.com](http://www.isa-arbor.com) or by phone at 888-472-8733.

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