Root Anatomy

ARE YOU familiar with the sayings "Get to the root of the problem" or "the root of all evil"? Both these sayings suggest that the root is an essential part of something. With plants, the essential functions that a root provides are in supporting health, growth, and development.

Objective:

Describe the anatomy of roots.

Key Terms:

adventitious roots
apical meristem
Casparian strip
endodermis
epidermis
extracellular route
fibrous root system
intracellular route
lateral roots
mycorrhizal fungi
napiform root
pericycle
plasmodesmata
primary root
root cap
root hairs
seminal root
taproot system
trichomes

Roots

A plant's health is very closely tied to its roots. When roots are weak or diseased, the whole plant has difficulties. The roots need to be constantly growing in order to stay healthy.

The root system serves some important functions. The roots absorb water and minerals that a plant needs to live. The roots anchor the plant to the ground and support the above ground part of the plant. The roots store food that has been made through photosynthesis. This food can be used later when a plant needs it to grow or survive.

PARTS OF A ROOT

When a plant seed germinates, the first structure to emerge from the seed is a root. This root, initiated by a germinating seed, is called a **seminal root**. The seminal root becomes the

primary root and, on some plants, it is the most important root in the whole root system. Other roots eventually branch out from the primary root. These are called secondary or **lateral roots**.

At the tip of the root, there is an area where new cells develop, called the **apical meristem**. The apical meristem is easily damaged, and so it has a **root cap** over the top of it to protect it from damage as it grows through the large, and sometimes coarse, soil particles.

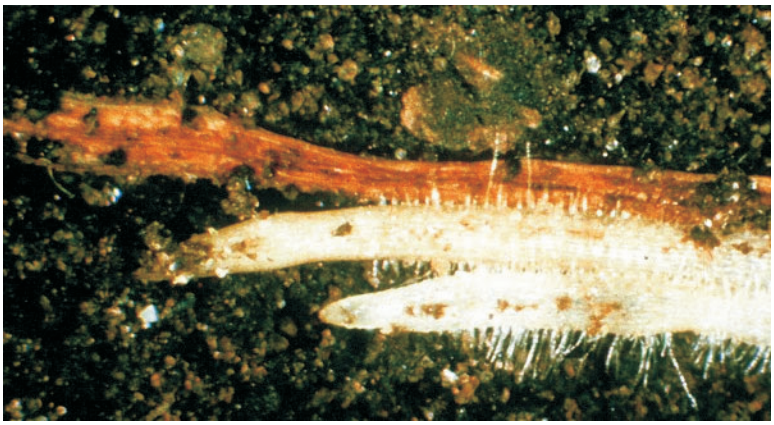

FIGURE 1. Root hairs improve the absorption of water and minerals. (Courtesy, Agricultural Research Service, USDA)

The surface of the root is covered with a skin of cells called the **epidermis**. The epidermis is where the water and minerals enter the root through osmosis and diffusion. The epidermis generates distinctive growths, or hairs, called **trichomes**. The most common type of trichome is the root hair. **Root hairs** greatly increase the surface area of the root, and thereby improve the absorption of water and minerals. Root hairs are located about 1/2 inch from the root cap. Each root hair is an individual cell. Root hairs live for only a few days and never develop into multi-cell roots. Because of their short life, roots need to grow continually.

CROSS SECTION OF A ROOT

A cross sectional view of a herbaceous dicot root reveals layers of cells.

Epidermis

Epidermal cells to the outside of the root provide protection.

Cortex

Located on the inside of the epidermis is the cortex. The cortex of herbaceous dicot roots is composed mostly of parenchyma cells. Cells of the cortex are loosely packed. There are large intercellular spaces that provide aeration for the cells. The primary function of the cortex is the storage of starches. Some examples of roots with tremendous starch storage capability are sweet potatoes, yams, turnips, carrots, and sugar beets.

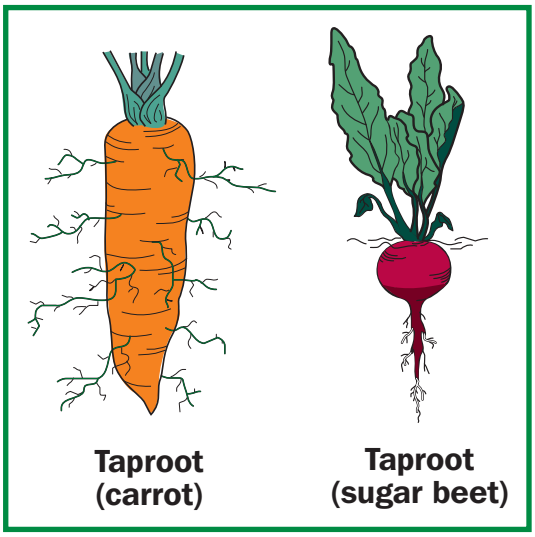

FIGURE 2. Carrots and sugar beets.

Endodermis

The innermost layer of the cortex consists of tightly fitting cells called the **endodermis**. Cells of the endodermis have a band, or strip, encircling them known as the **Casparian strip**. The Casparian strip is waterproof. It regulates the flow of water into the xylem. When water levels in the endodermis drop below that of the cortex parenchyma cells, water is allowed in and continues its flow to the xylem.

Pericycle

Another layer of cells just to the inside of the endodermis is the **pericycle**. The pericycle is important because it has meristematic properties. It is where lateral (branch) roots originate. The lateral roots forcefully grow through the other layers of cells before entering the soil. The pericycle is also involved in the secondary (woody) growth of woody plant roots.

Vascular Tissues

The vascular tissue of dicot roots is centrally located. Vascular tissue is located at the center of the root, inside the pericycle. In a dicot root, xylem tissue is at the center and, in a cross sectional view, appears like a star or an X. Lateral roots usually initiate growth at an arm. Phloem tissue that carries sugars to the roots is located between the arms of the star. Vascular cambium is located between the xylem and phloem.

Root tissues of monocot plants are similar to dicots. The epidermis, cortex, endosperm, and pericycle are roughly the same. However, the vascular tissues are arranged differently. The vascular tissues of monocots form bundles, with the xylem toward the inside. The bundles form a ring around the pith, which is centrally located.

Woody Plant Roots

Woody plants form woody roots through secondary growth. The secondary growth takes place a significant distance from the root tips. In the process, the vascular cambium gradually moves outward. It joins with part of the pericycle to form a continuous ring. Xylem is produced to the inside, phloem to the outside of the xylem, and periderm replaces the epidermis.

Types of Root Systems

Plant root systems are organized in two basic ways. The two ways have much to do with primary and secondary roots.

A root system that is composed of one main primary root and many secondary roots branching off the primary root is called a **taproot system**. Many dicot plants have taproot systems. A type of taproot highly specialized for the storage of starches is called a **napiform root**. Examples of napiform roots include radishes, beets, turnips, and carrots.

A system that has no dominant primary root but is made of many primary and secondary roots of similar size is called a **fibrous root system**. Monocot plants typically have fibrous root systems.

Some plants readily produce roots along their stems or at nodes of stems. These roots, which arise from a stem, are referred to as **adventitious roots**.

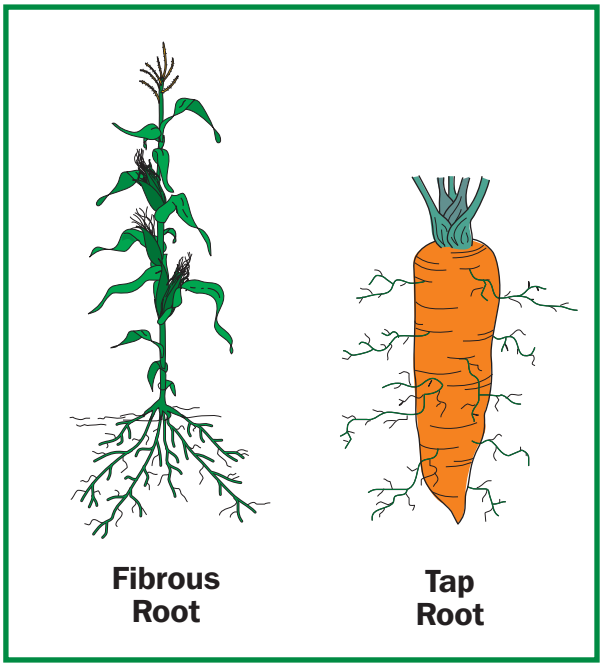

FIGURE 3. An example of a fibrous root and a taproot system.

WATER AND NUTRIENT ABSORPTION

Roots are the plant organ responsible for the absorption of water and dissolved minerals.

Water Absorption

Water enters the root through root hairs and the epidermis. It moves horizontally through the cortex, endodermis, and pericycle before reaching the xylem. Water reaches the xylem by one of two pathways. One path is through the cells between the epidermis and the xylem, and this path is called the **intracellular route**. The other path by which a greater volume of water flows through the spaces between cells is referred to as the **extracellular route**.

Water that takes the intracellular route passes through the plasmodesmata of cortex parenchyma cells between the epidermis and the endodermis. **Plasmodesmata** are cytoplasmic channels connecting adjacent cells. The channels allow for the movement of water molecules and ions.

Water does not enter the parenchyma cells of the cortex as it travels the extracellular route. Rather, it moves along the outside walls from one cell to another. Cell walls are made largely of cellulose. Cellulose has a high absorptive capacity that helps pass the water along. When the water reaches the endodermis, it enters the endodermal cells by passing through the cell membranes. It traverses the endodermis, passes through the pericycle, and enters the xylem tissues. Much of the absorption into the xylem takes place at the arms of the xylem.

Mineral Absorption

Mineral ions are absorbed into the root in the area about 1/8 inch, or 3 millimeters, above the root cap. Absorption of minerals occurs through passive and active means.

Some molecules pass through membranes by diffusion, a passive form of transport. When the mineral levels are higher outside of the root than inside the root, the minerals move into the root by diffusion.

Some nutrients are transported by an active transport mechanism. Active transport requires energy to move minerals across the cell membrane. The process begins as positively charged ions are pumped out of a cell. The displacement of these ions creates a difference in pH on either side of the cell membrane. Negatively charged ions then move into the cell. In the active

transport system, ATP is required to run the pump. The need for ATP is one of the reasons sugars are needed in the root system.

Once inside, it is believed that minerals pass through the root from cell to cell. Nutrients move through the plasmodesmata openings in cell walls and through cell membranes. Cell membranes regulate the passage of molecules.

Microbial Actions

Microbial populations in the soil greatly improve some plants' abilities to absorb nutrients. **Mycorrhizal fungi** form a mutualistic relationship with the roots of most plant species. In a mycorrhizal association, the fungus may colonize the roots of a host plant either intracellularly or extracellularly. In the relationship, the mycorrhizal fungus receives carbohydrates from the plant. The plant benefits from an enlarged surface area that improves the absorption of water and mineral nutrients from the soil.

Mycorrhizal fungi are commonly found in most soils. In some cases, it is beneficial to inoculate seeds with mycorrhizal fungi before planting.

A Healthy Root System

A healthy root system is white or nearly white in color and smells fresh. If roots are black, brown, or dark orange and smell rotten or sour, the root system is having some problems. Although a plant growing outside has a majority of roots in only the top two feet of soil, a plant in a pot should have its roots evenly dispersed throughout the soil in the pot.

Watering a plant properly is one of the most important ways to keep the root system healthy. Proper watering for most plants involves watering heavily and allowing the soil to dry slightly before watering again. Over-watering of plants is not a matter of *how much* water but of *how often* watering occurs.

FIGURE 4. Young, healthy roots are creamy white. (Courtesy, Agricultural Research Service, USDA)

Summary:

Roots absorb water and minerals, anchor the plant to the ground, and store food.

Parts of a root include the primary root, lateral roots, the apical meristem, a root cap, and root hairs.

A cross sectional view of an herbaceous dicot root reveals the epidermis, cortex, endodermis, pericycle, and vascular tissues.

Plant root systems are either a taproot system or a fibrous root system. Roots produced along stems or at nodes of stems are called adventitious roots.

Water enters the root through root hairs and the epidermis and reaches the xylem by an intracellular or an extracellular route.

Mineral ions are absorbed into the root in the area about 1/8 inch, or 3 millimeters, above the root cap. Absorption of minerals occurs through passive and active means.

Mycorrhizal fungi form a mutualistic relationship with the roots of most plant species and improve some plants' abilities to absorb nutrients.

A healthy root system is white or nearly white in color and smells fresh.

Checking Your Knowledge:

1. What are the functions of roots?
2. What are the main components of roots?
3. What are the types of root systems?
4. How are water and minerals absorbed into the roots?
5. What do healthy and unhealthy root systems look like?

Expanding Your Knowledge:

Remove a plant from a pot. Examine the roots. Determine if the root system is healthy. Remove some of the roots and view them through a magnifying glass or microscope. Look for the root hairs.

Web Links:

Plant Roots
http://facweb.furman.edu/~lthompson/bgy34/plantanatomy/plant_root.htm

Roots
http://extension.oregonstate.edu/mg/botany/roots.html

Root
http://en.wikipedia.org/wiki/Root

Roots
http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/R/Roots.html

Agricultural Career Profiles
http://www.mycaert.com/career-profiles