ROOTS

Background Information

Roots are plant parts that grow downward and, in most cases, anchor land plants in the soil. Roots absorb water and dissolved nutrients and transport these to parts of the plant where they are needed. They do not, generally, produce leaves or buds.

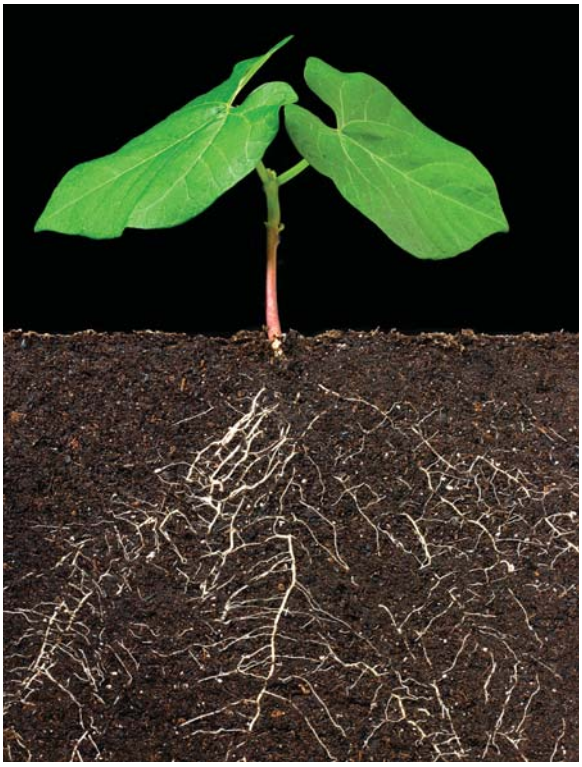
Most plants have roots, but there are some exceptions. The exceptions are bryophytes and the groups of green algae that are classified as plants. Bryophytes have root-like structures called rhizoids for absorbing water, but because rhizoids lack vascular tissue they are not considered roots.

The first root of a plant, called the **primary root**, arises from a part of the seed called the **radicle**, and emerges when the seed **germinates** — when it emerges from its dormant state and begins to grow. As the roots develop, they form one of two types of root systems:

- A taproot system forms when the primary root grows directly down into the soil and becomes the main root, or **taproot**. Smaller roots, known as **secondary roots** or **lateral roots**, branch from the primary root. Most dicotyledons such as beans, carrots, and oak trees have taproots.

- A fibrous root system forms when the primary root is replaced by a number of roots, all of similar thickness. These roots look like a mass of fibers growing into the soil in all directions. Monocotyledons such as grasses and corn have fibrous roots.

Taproot



Fibrous root

Did you know?

If a gardener wishes to move a plant from one part of a garden to another, it is important that he or she first establishes which type of root system the plant has — a taproot or a fibrous root system. Plants with fibrous roots transplant fairly easily as they have many roots and, if some are damaged, they can rely on others to absorb water and nutrients. Plants with taproots are far more difficult to transplant because they rely solely on one root and that root often penetrates deep into the ground, making it very difficult to remove without severely damaging it. Moving even a young oak tree, for example, can be challenging, as a 6 ft (1.8 m) tree may have a taproot of almost the same length.

The main functions of most roots are:

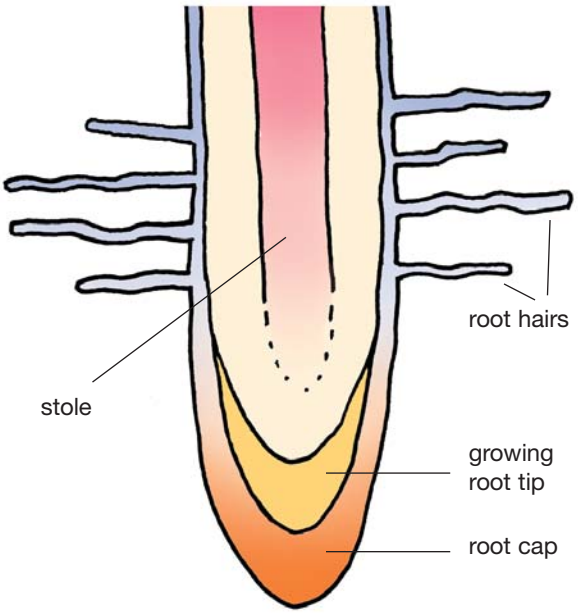
- to absorb water and dissolved nutrients from the soil
- to transport water and dissolved nutrients to other parts of the plant
- to anchor the plant so that it does not fall over

The structure of a root is, like all things in nature, related to its function. This means roots must have a structure suitable for absorbing moisture and they must grow continuously. Through growing, roots not only anchor the increasingly heavy plant in more soil, but also reach new supplies of nutrients or moisture when the area surrounding them becomes dry or depleted of nutrients.

The part of the root associated with growth is the root tip, and this is covered and protected by the **root cap**, which is made of tiny cells that are constantly rubbed off and replaced as the root penetrates new areas of soil. Scientists have shown that, apart from protecting the root tip, these cells play an important role in causing roots to grow downward.

The parts of the root associated with absorbing water and dissolved nutrients are the **root hairs**, tiny hair-like outgrowths that grow from the outer surface of the root behind the root cap. Root hairs dramatically increase the surface area of the root, creating a large area for absorbing water and nutrients from the soil. Inside the root is a core of vascular tissue called the **stele**, that helps transport water and dissolved nutrients from the roots to other parts of the plant.

Structure of a root tip



Roots anchor plants in soil by growing between the soil particles and pressing outward. As the upper parts of the plant grow, so the roots grow to compensate for the increasing height and weight of the above-ground plant. Roots do this effectively when the soil has structure and strength, but they are less effective when the soil is either waterlogged or very sandy, which explains why trees in these types of soil can sometimes blow over in heavy winds. Even the roots of floating aquatic plants function to keep the plants upright by hanging downward, stabilizing the plants in the water, so the leaves face up toward the light.

In addition to anchoring plants and absorbing water and nutrients, some plants have special roots modified to perform functions such as storing food and water, breathing, or adding extra support to the plant. Each of these functions is an **adaptation**, a development that helps organisms survive in the environment where they live.

Storage roots are modified for storing food or water, a modification that allows a plant such as a carrot or a beet to survive dormant periods. Storage roots may be one of three shapes:

- conical, or cone shaped e.g., carrots and parsnips
- **napiform**, meaning they are broader than they are long e.g., turnip
- **fusiform**, meaning they are swollen in the middle and tapered at both ends e.g., white radishes

Tuberous roots are also storage roots, but unlike carrots and beets where the whole root is modified for storage, tuberous roots involve the swelling of only part of the root. Sweet potatoes are an example of a plant with a fibrous root system that produces tuberous storage roots. (Note: potatoes are modified stems, not roots, because potatoes produce buds.)

Conical root

Napiform root

Fusiform root

Tuberous root

Breathing roots are produced by plants that grow in waterlogged soil where oxygen is scarce. For most plants, waterlogged soil is a serious problem that can kill them. Plants such as mangrove trees inhabit swampy areas and solve this problem by producing breathing roots called pneumatophores. **Pneumatophores** grow upward from the submerged roots and have pores that allow for gases to pass between the submerged roots and the atmosphere.

Many plants have **aerial roots** that arise above the ground, are either partly or fully exposed to the air, and which serve one of several purposes. Examples of plants with aerial roots include corn, orchids, trees in rainforests, and **dodder**, a yellowish **parasitic plant** — a plant that grows on another plant and harms it. Dodder has thread-like stems that wind around crops such as alfalfa and potatoes.

Corn plants and palm trees grow tall and slender and may produce aerial roots called **prop** or **stilt roots**, which arise from the stem and grow down into the soil to help anchor and stabilize the plant. Large trees growing in rainforests, or any area where the soil is shallow, sometimes produce **buttress roots**, which are strong, woody, plank-like roots that provide extra support for the trees by functioning to make the base of the trees wider.

Orchids are **epiphytic plants** that grow on other plants, but do not obtain food, moisture, or nutrients from the host plants, and do not harm them. Epiphytes typically grow in humid areas and unbranched aerial roots grow down from the plant toward the ground. The function of these aerial roots is twofold; to absorb moisture from the atmosphere and to anchor the epiphyte to the host plant.

Like epiphytic plants, parasitic plants grow on other plants, but unlike epiphytes, parasitic plants harm the host plants. Parasitic plants produce structures called **haustoria** that penetrate the host plant and absorb food and moisture from the host. Although not all haustoria are roots, the haustoria of dodder are modified roots.

All aerial roots and most fibrous roots are known as **adventitious roots**, meaning they are roots that do not arise from the primary root but, instead, roots that arise from stem tissue or sometimes from leaf tissue. The ability of many plants to grow roots from leaf and stem tissue is used by **horticulturists**, people involved in plant cultivation, to grow new plants from cuttings of existing plants.

aerial roots

prop roots

buttress roots

Summary of root types

Root type	Definition	Example
primary root	the root that grows from the radicle	the first root produced by all germinating seeds
secondary or lateral roots	roots that grow from the primary root	small side-roots extending from carrots or beets
taproot system	a root system where a single main root develops from the primary root	most dicots e.g., carrot, beet, oak tree
fibrous root system	a root system where many roots of similar thickness replace the primary root	most monocots e.g., corn, grass
storage roots	roots that store food and moisture	taproots e.g., carrot and tuberous roots
tuberous roots	storage roots that develop when parts of secondary roots thicken	sweet potatoes
pneumatophores	breathing roots	mangroves
adventitious roots	roots that do not arise from the primary root	aerial roots, prop roots, some haustoria
aerial roots	roots that grow from the stem or leaves and are partly or completely exposed to the air	orchid
prop or stilt roots	aerial roots that grow down into the ground to help support the plant	corn, some palms
buttress roots	strong, woody support roots of some large trees	many large trees e.g., spruce, beech
haustoria	modified roots of some parasitic plants that absorb moisture and food from the host plant	dodder

The following table presents a summary of the functions of taproots, fibrous roots, and modified or adaptive roots.

Summary of root functions

Function	Description	Example
anchoring and stabilizing	anchors the plant to its substrate e.g., soil or rock	taproots, fibrous roots
absorbing	absorbs water and dissolved nutrients	all roots
transporting	transports water and nutrients to other parts of the plant	all roots
storing	stores food and water	tuberous roots, many taproots
extra support	provides additional support to tall slender plants, or plants growing in shallow soil	prop and buttress roots
breathing	allows plants growing in waterlogged soils to exchange gases with the atmosphere	pneumatophores
absorbing food	absorbs food and moisture from the host plant	haustoria

Self-testing review sheet: Roots

The following example shows part of a self-testing sheet teachers can create for students to review roots. The sheet can be created using the template in the Templates for Teachers section of this manual.

Student name: _____ Date: _____

1. Cover the right-hand column before you start.
2. Complete each of the sentences in the left-hand column by writing the missing words in the spaces provided.
3. Uncover the right-hand column to check your answers.

Roots are the parts of plants that _____ and _____ water and dissolved nutrients.	absorb, transport
Roots generally grow _____ (direction). They _____ the plant in the soil.	downward, anchor
Roots do not, as a rule, produce _____ or _____ .	leaves, buds
Rhizoids are the root-like structures of bryophytes, but are not considered roots because they lack _____ tissue.	vascular
When a seed germinates, the first root arises from the _____ and grows into the _____ root.	radicle, primary
A root system with a single dominant root is called a _____ system.	taproot
A root system where all roots are a similar thickness is called a _____ _____ system.	fibrous root
The part of the root that covers the growing tip is called the _____ _____ .	root cap

Self-testing review sheet: Modified roots

The following example shows part of a self-testing sheet teachers can create for students to review modified roots. The sheet can be created using the template in the Templates for Teachers section of this manual.

Student name: _____ Date: _____

1. Cover the right-hand column before you start.
2. Complete each of the sentences in the left-hand column by writing the missing words in the spaces provided.
3. Uncover the right-hand column to check your answers.

Modified roots are roots that have _____ to perform special functions.	adapted
Conical, napiform, and fusiform are names of modified _____ that function as _____ roots.	taproots, storage
Roots such as the white radish that are swollen in the middle and tapered at both ends are called _____ roots.	napiform
Sweet potatoes are an example of a _____ storage root, where only part of the root is modified for storage.	tuberous
Pneumatophores are roots modified for _____ . They are found on plants such as mangroves that grow in _____ soil.	breathing, waterlogged (or wet)
Aerial roots are roots that arise _____ the ground.	above
Adventitious roots are roots that do not arise from the _____ root, but from stem or leaf tissue.	primary
Epiphytic plants such as orchids grow on other plants, but do not _____ them. Orchids have unbranched _____ roots that hang down toward the ground and absorb moisture from the _____ .	harm, aerial, atmosphere (or air)

Resources

There are many excellent student-based resources about roots. Here are some examples:

- Ganeri, Anita. *What's inside Plants?* Hong Kong: Simon and Schuster Young Books, 1993.
- Hughes, Meredith S. *Buried Treasure: Roots and Tubers*. Minneapolis, MN: Lerner Publications, 1998.
- Legg, Gerald. *The World of Plant Life*. Milwaukee, WI: Gareth Stevens Publishing, 2002.
- Taylor, Barbara. *Incredible Plants*. Willowdale, ON: Firefly Books, 1997.
- Gibson, Arthur, C. "Types of roots." <http://www.botgard.ucla.edu/html/botanytextbooks/generalbotany/typesofroots/index.html>
- Royal Botanic Garden, Kew. <http://www.kew.org/ksheets/pdfs/b3plant.pdf>

Note to the teacher – Preparing for Activity 1 and Experiment 1

Activity 1 and Experiment 1 use young plants that have been growing for two weeks prior to the activity date.

Prepare two trays of seedlings for Activity 1 and two smaller containers of seedlings for Experiment 1 as follows:

- Plant one package of commercially prepared bean seeds in a seed tray containing good potting soil. Follow the instructions on the seed package, and ensure the seeds are planted far enough apart, so their roots do not entwine.
- Repeat the process using a package of commercially prepared corn seeds. The students will examine and compare the roots of the bean and corn plants.
- Plant two bean seeds and two corn seeds in each of two, smaller containers. The students will use these plants to demonstrate that roots absorb moisture from the soil.
- After two weeks the plants should be ready for harvesting.

EXPERIMENT 1

Demonstrating that Roots Absorb and Transport Moisture

Note to the teacher – Watering plants

For watering seedlings, rather than using a watering can or jug, provide a plastic bottle with a small nozzle for controlling water flow. Clean, squeeze-type mustard bottles, for example, work well.

Purpose

To show that roots absorb moisture from the soil and transport it to other parts of the plant.

Material

Two containers each holding four seedlings.

Water bottle with water.

Stick-on labels.

Felt marker.

Experiment templates (one for each student).

Botany journals and pencils.

Presentation

- Most Montessori teachers present this concept in Years 4 and 5.
- Announce that the students will have the opportunity to perform an experiment to show that roots function to absorb moisture from the soil and transport it to other parts of the plant.
- Introduce the two small containers each with four seedlings.
- Ask the students to examine the plants. The leaves should be green and healthy, and should show no sign of wilting.
- Ask the students to suggest how they might prove, using the two containers of seedlings, that roots take up moisture. (There are at least two possible answers: The students would place both containers in a warm, bright spot in the classroom and water the soil of one plant, but not of the other plant. After a period, they would observe the plants. If the plant in the soil without moisture has wilted due to lack of water, this would prove that the roots, which are the only parts of the plant in the soil, have not had any water to absorb from the soil and transport up the plant. Alternatively, the students could water the containers well and then cover them with plastic so no water can evaporate. After four or five days they could remove the plastic and feel the soil to determine if it is still wet. If the soil is dry, this suggests the roots absorbed it, as this is the only way the water could have been removed from the pot.)
- Ask the students to place a stick-on label on the side of each container, and to use the felt marker to write Water on one label and No Water on the other label. Explain that the container labeled water is the control. Review experimental controls with the students, if necessary.

- Ask the students to place both containers in a warm, bright spot in the classroom, and to use the watering bottle to moisten the soil in the container labeled Water. The soil in the other container must not be moistened. The seedling containers will stay in the same place for about one week.

- Demonstrate the Experiment Template and ask the students to use this to begin writing up their experiment. Some students may be familiar with the template from the lower elementary sciences.

- In the observations section of the template, ask the students to draw a three-column table and to head the first column Date, the second column Water, and the third column No Water.

- Set aside a time each day when the students can check the moisture content of the soil in the two containers and add water to the container labeled Water, if necessary. They can test the soil by simply feeling the surface with their fingertips.

- Continue the experiment until the experimental plant is visibly wilted.

- Invite the students to make daily recordings in the three-column table, noting whether the soil is wet or dry and whether the leaves look healthy or wilted. (Note: In the unlikely event that the plant without water is not wilted after seven days, continue the experiment until it does wilt.)

- On the final day, discuss the results of the experiment with the students and ask them to draw conclusions. The experimental plant has wilted from lack of water, whereas the control plant is healthy. The only difference between the two plants is that the roots of the experimental plant did not have access to water, whereas the roots of the control plant did have access to water. In the control plant, the leaves do not wilt because they do not dry out, and the only way they could obtain water is if the roots absorbed it from the soil and transported it to the stem. As the roots of the experimental plant did not have access to water, no water reached the leaves and they wilted.

- On the final day of the experiment, ask the students to draw a labeled diagram of each plant in their botany journals.

Extension

- Prove that roots take up water using the alternative method. Cover the pot of a well-watered plant with a clear plastic bag, and secure this around the plant stem so water cannot evaporate. Leave the pot in a warm, bright spot for about five days, then remove the bag and check the soil for moisture. If the soil is less wet than it was when the bag was placed around the pot, the roots must be responsible for removing moisture from the soil because they are the only part of the plant in the soil.

ACTIVITY 1

Examining Root Systems and Functions

Purpose

To examine fibrous and taproot systems and to understand the basic functions of roots.

Material

One tray of bean seedlings.

One tray of corn seedlings.

Magnifying glass.

Bucket filled two thirds with tepid water.

Unprinted newspaper or absorbent towel.

Plastic forks.

Photographs or diagrams of fibrous root and taproot systems.

Diagram, Structure of a root tip.

Books and pictures of roots.

Self-testing review sheet: Roots.

Botany journals and pencils.

Presentation

- Most Montessori teachers present this concept in Years 4 and 5.
- This activity is divided into parts and can be presented over several days.
- Announce to the students that in this activity they will have the opportunity to show that roots absorb moisture from the soil and to examine the roots of bean and corn plants. They will examine special types of roots in the next activity.

PART 1: DISCUSSING THE STRUCTURE AND FUNCTION OF ROOTS

- Review the main characteristics of roots and explain why the rhizoids of bryophytes are not classified as roots.
- Describe how roots develop. Begin with the germinating seed, and explain how taproot systems and fibrous root systems develop. Use photographs or diagrams to illustrate the difference between the two systems.

- Ask the students if they can name the three basic functions of roots: absorbing water and dissolved nutrients, transporting water and nutrients to other parts of the plant, and anchoring the plant (or stabilizing aquatic plants). Discuss these functions.

- With the students, examine the diagram, Structure of a root tip, and the diagrams or photographs of the root systems. Discuss how the structure of the whole root system and of individual roots helps roots perform their basic functions.

- Ask the students to use their journals to draw a diagram of the structure of a root tip and to list the basic functions of roots.

PART 2: EXAMINING A FIBROUS ROOT SYSTEM AND A TAPROOT SYSTEM

- Place the two trays of seedlings, beans and corn, on the table facing the students.

- Demonstrate using a plastic fork to carefully remove one plant from each tray without damaging the roots.

- Place the plants on a piece of paper, and take the paper and plants to the bucket of water.

- Carefully pick up one plant, and rinse the roots in the bucket to remove the soil. Do not rub the roots. Replace the plant on the paper to drain.

- Ask the students to work in pairs, and give each pair a piece of paper for supporting and draining the roots. Ask them to take turns to remove one plant from each tray, beans and corn, and to rinse the roots.

- When all the pairs have two seedlings, ask the students to examine and compare the root systems of the two plants. Suggest the students use the magnifying glass to examine the root tips. Can they see the root hairs?

- Ask the students to use their journals to create a table with two columns, one labeled Bean Roots and the other labeled Corn Roots. In each column, ask the students to write notes about their observations of the two root systems.

- Ask the students to draw labeled diagrams of the two seedlings showing the differences in the root systems.

- Demonstrate the resource material and the self-testing review sheet. Encourage the students to complete a review sheet.

- Ask the students to use their journals to write two or three paragraphs explaining how the structure of root systems and of roots helps roots perform their three main functions.

ACTIVITY 2

Investigating Modified Roots

Purpose

To investigate modified roots and their functions.

Material

Examples of storage roots: radish, carrot, turnip, sweet potato.

Orchid with aerial roots.

Pictures of plants with prop roots and buttress roots.

Pictures of dodder, or a live specimen, if possible.

Labels: taproot system; fibrous root system; storage roots; conical root e.g., carrot; napiform root e.g., turnip; fusiform root e.g., radish; tuberous root e.g., sweet potato; prop roots; buttress roots; haustoria; epiphyte; aerial roots; pneumatophores.

Chart, Summary of root functions.

Chart, Summary of root types.

Whiteboard and marker.

Self-testing review sheet: Modified roots.

Books and pictures of plant roots.

Botany journals and pencils.

Presentation

- Most Montessori teachers present this concept in Year 5.

- Announce to the students that they will have the opportunity to explore various types of modified roots and the functions these roots perform for the plant.
- Review the three main functions of roots with the students.
- Explain that in addition to these functions, some roots are specially adapted to perform other functions, such as storing food and water, supporting the plant, helping other roots breathe, or even parasitizing other plants.

PART 1: STORAGE ROOTS

- Introduce the four storage roots, placing them on a table in front of the students. Arrange the roots so that all the taproots are placed together. Above the four roots, place the label, Storage roots.
- Discuss the three types of storage taproots: conical, fusiform, and napiform. Place the appropriate labels next to each specimen. Repeat with the tuberous root.

- Discuss why the plants have storage roots, and then discuss how humans use these roots.

PART 2: ROOTS WITH SPECIAL FUNCTIONS

- Introduce the orchid and place it next to the storage roots. Explain the nature of epiphytic plants. Define and discuss aerial roots. Place the label Aerial Roots above the orchid, and the label Epiphyte, next to the orchid.
- Introduce, one at a time, the other examples of aerial roots with specific functions.
- Discuss the functions of these roots and how they benefit plants. Place the appropriate label next to each specimen or photograph. Encourage the students to practice saying new words as they are introduced.
- On the whiteboard, write the term adventitious roots. Pronounce it clearly for the students and invite them to repeat it.
- Define and discuss the term, adventitious roots (roots that do not arise from the primary root) with the students. Ask the students to indicate examples of adventitious roots from the specimens and photographs on display.

- Demonstrate the chart, Summary of root types, and review with the students the terminology used to describe roots.
- Demonstrate the chart, Summary of root functions. Explain that this chart lists most of the functions that roots can perform for a plant. These include the three basic functions, as well as the specialized functions of modified roots.
- Leave the display of modified roots on the table and encourage the students to visit it over the next couple of days.
- Demonstrate the resource material and the self-testing review sheet on modified roots. Encourage the students to complete a review sheet.
- Ask the students to use their journals to write three illustrated paragraphs, each describing a different type of modified root and how it helps the plant survive.

Extensions

- Prepare edible storage roots to sample.
- Do a research project on one type of modified root such as buttress roots or pneumatophores.
- Find and prepare a soup using edible storage roots.