Unit 5

Water in the Soil and Plants

Watch the video titled 'Water Movement in the Soil'
https://www.youtube.com/watch?v=vmo0FRAVgkM

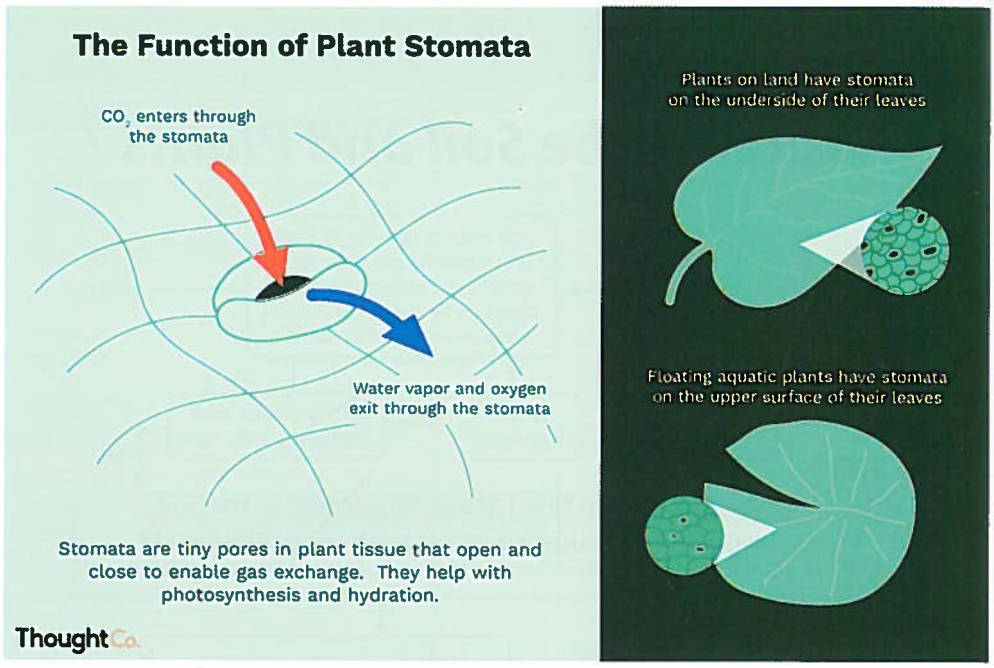
Water is a vital component of every living thing. Although it is one of nature's simplest chemicals, water has unique properties that promote a wide variety of physical, chemical and biological processes.

Water in the soil is something quite different from water in a drinking glass. Water causes soil particles to swell and shrink, to adhere to each other and to form structural aggregates. Water participates in innumerable chemical reactions that release or tie up nutrients, create acidity and wear down minerals.

Fresh plant tissues commonly contain 70% to 85% water. This is by no means inert filler since virtually most physiological processes take place in its presence. Moreover, water is one of the raw materials used in the production of substances that comprise the solids of the plant, as it is means of dissolving all the other food materials.

However, only a fraction of the water absorbed by the roots from the soil is actually used by the plant. About 99% of it escapes through the leaves and stem as water vapor during a process known as transpiration. Light affects the rate of transpiration as it causes the opening of stomata, not to mention the fact that absorbed sunlight increases the temperature of the leaf.

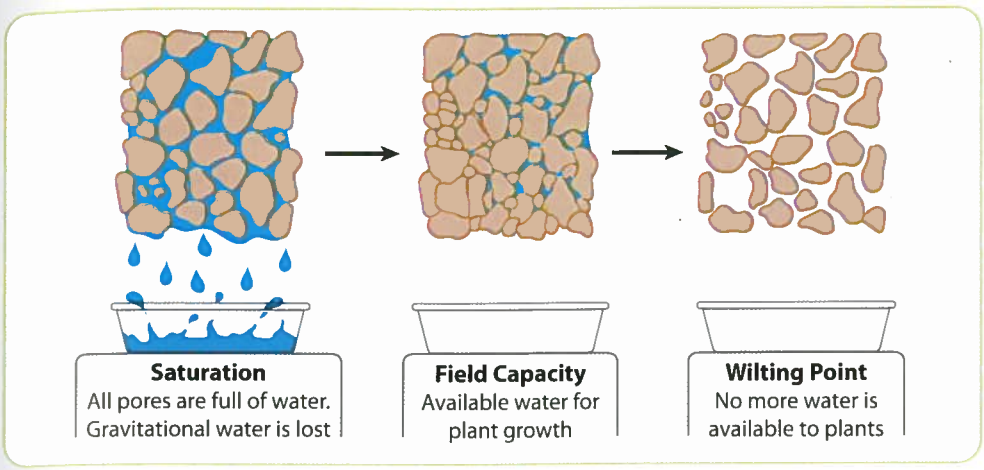
Plants normally wilt or die, not because of high temperatures but because of loss or water; this may be encountered in guttation. During guttation the water appears on the tips and margins of leaves as clear drops that are often noticed in the early morning. As the day goes on and environment temperature rises, the water can either evaporate or can be reabsorbed.



Plant Stomata Function

[Source: ThoughtCo/J.R. Bee].

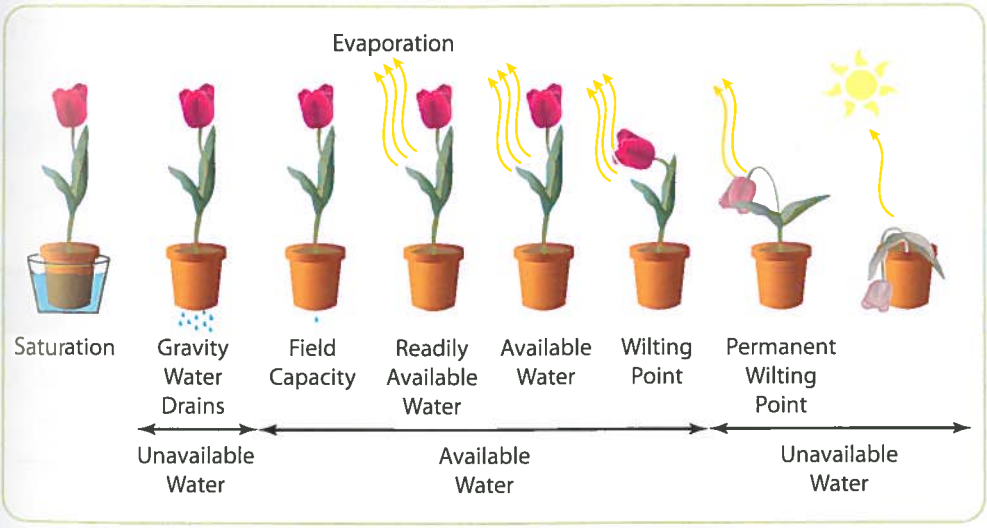
Guttation



Soil Water Status

Generally, water is supplied to plants through rain or snow. However, not all water falling in the soil is available to plants. This is true with free or gravitational water that drains away leaving a thin film surrounding and adhering to each tiny soil particle. This mass of films of water left is called capillary water. It is this capillary water, filled with dissolved food materials, which is the principal source of moisture for plants.

Soil, like a sponge, is porous. The holes in soil can be divided into two main groups; some bigger holes (called macro-pores), and some smaller holes (micro-pores). When soil is saturated with water, all the pores are filled with water and



The Range of Water Availability to Plants

there is no room for air in the soil. But if the soil is drained well, soon water drains out of the macro-pores and air takes its place. That is how plant roots can breathe. Most plants and crops die after a few days if their soil is saturated.

On the other hand, when soil moisture is lowered below the wilting point, water is unavailable to plants. As a result, plants are unable to absorb water quickly enough to replace the water lost by transpiration and eventually wilt.

Special Terms	
Capillary water	water held as a film around soil particles and in the capillary spaces.
Gravitational water	water which the soil is unable to retain against the force of gravity; free water; excess water; drainage water.
Guttation	forcing of water or cell sap from inside plants, through pores on leaves and stems out on free surfaces of plants.
Organism	a living thing, plant or animal.
Permanent wilting point	the percentage of moisture in the soil at which plants wilt and fail to recover even when placed in an atmosphere saturated with water vapor.
Physiological	referring to the functions of the organs of plants and animals.
Stoma [pl. stomata]	an opening in the epidermal layer which leads to intercellular spaces.
Transpiration	the process by which water vapor leaves the living plant body and enters the atmosphere.

Practice Tasks

Task 1 *True or False?*

1. About 80% of the water absorbed from the soil is used by a plant. [___]
2. Transpiration is the production of new substances comprising the plant solids. [___]

3. High temperature is not the major cause of plants' wilting of foliage. [__]
4. Water is one of the raw materials required for plants' substances. [__]
5. High temperatures do not affect the transpiration rate of plants. [__]
6. Guttation is a process related to water kept by plants. [__]
7. The permanent wilting point is a non-reversible state. [__]
8. Sunlight affects the rate of transpiration. [__]
9. Even if plants have reached the permanent wilting point, their placing in an atmosphere saturated with vapor is likely to reverse this state. [__]
10. Gravitational water is always retained by soil. [__]
11. Capillary water is the major source of moisture for plants. [__]
12. Water is a simple filler of plant tissues. [__]
13. All physiological processes require water to take place. [__]
14. The plant absorbs all the water from the soil. [__]
15. Plants may absorb guttation water. [__]
16. Free water is another source of water for plants. [__]
17. Plants wilt when water is replaced faster than it is lost. [__]

Task 2 *Choose one of the options to complete the sentences*

1. When water appears from inside plants through pores on leaves we refer to _____.

   a) transpiration
   b) wilting point
   c) guttation
   d) acidity

2. When water leaves the plant body and escapes in the atmosphere we are talking about _____.

   a) transpiration
   b) capillary water
   c) demand
   d) production

3. _____ water drains away from plants.

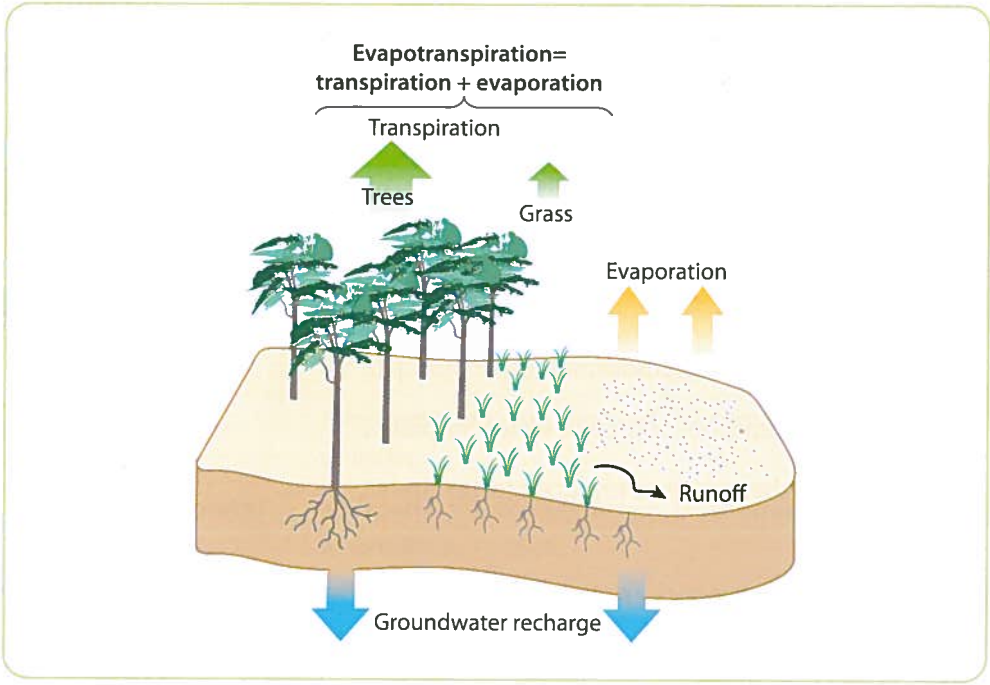
a) capillary
b) dissolved
c) physiological
d) gravitational

4. _____ water creates a thin film that surrounds the soil particles.

a) capillary
b) gravitational
c) evaporated
d) reabsorbed

5. The function of organs in plants are called _____.

a) anatomical
b) physiological
c) epidermal
d) stomatic



Evapotranspiration

Task 3 *Watch the video titled 'Water Movement in the Soil' on p. 43 and fill in the blanks*

When _____ [1] hits the earth's surface one or two things can happen, water can _____ [2] the land or often with the help of sound management practises water can move into _____ [3] to be an environmental positive rather than a negative. The soil itself has an _____ [4] on whether water runs off or moves into the soil. Here's a brief explanation of how and why soils _____ [5] water at different rates; and why you should check a soil _____ [6] when you are concerned about _____ [7], flooding, leaching or other environment hazards. Water _____ [8] in the soil is strongly influenced by soil particle size or (texture) as well as structure pore _____ [9]. Soil texture is the relative amount of sand, _____ [10] and clay sized soil particles. _____ [11] particles are the largest, silt is intermediate, and _____ [12] is the smallest. Water moves more quickly through the large open macro pores found in sandy soils than the smaller pores of silt or the much smaller flat-shaped micro pores in dense clay soils. Soil structure also impacts water _____ [13]. Water moves more quickly downward in soils with granular _____ [14] than a soil with platy structure which forces a longer, indirect path downward. Other structures include prismatic and sub-angular blocky. Water is nearly always moving in the soil and it can be in any _____ [15] simultaneously. Gravity is the dominant force that moves water _____ [16]. Restricted soil layers of compacted soil, or _____ [17], are among the reasons water moves laterally. Capillary action, the attraction of soil pores, can move water in any direction. _____ [18] is the primary water moving force in saturated soils while _____ [19] actions are the primary forces in unsaturated soils. Capillary force is greatest in soils with small pores. Water moves more slowly through these soils. Well, that's a brief explanation of what a soil scientist calls saturated hydraulic conductivity. In simpler terms the capacity of a soil to _____ [20] water. Since downward moving water carries _____ [21] and can carry contaminants into underlying water, soil percolation rates are important in choosing sites for septic fields, landfills and other _____ [22] burials, as well as other underground storage tanks and other uses. The information is critical for planning soil drainage, _____ [23] and, tillage systems, as well as other _____ [24] management practises.

Task 4 *Now read the transcript of the video and infer whether the statements are true or false*

1. When it rains, water can be used by farmers in many ways. [__]
2. Depending on the soil, rainfall water may be absorbed. [__]
3. Soil texture plays an important role in the way water moves. [__]
4. The granular structure of soil is synonymous with platy soil structure. [__]
5. Although gravity is the most important force, water can move in any direction. [__]
6. Saturated hydraulic conductivity is the same as capillary force. [__]
7. Contaminants may be transferred with rainfall in the soil. [__]
8. It is important to check the soil structure before selecting a site for landfill. [__]

Delve Deeper Into...

How does soil hold water?

INTRODUCTION

Several properties affect a particular soil's water-holding capacity and water movement within it. They include **permeability, pore space, soil adhesion,** and **soil cohesion**.

Gravitational and capillary forces affect how water moves in soil. Gravitational forces pull water downward, deeper into the soil. Capillary forces move water by adhesion and cohesion into open pore spaces or to the soil surface. Capillary forces can move water in any direction — up, down, or sideways. When gravitational and capillary forces are balanced, the soil is at **field capacity**. The purpose of this activity is to investigate soil water properties using sponges to observe different states of water and the field capacity point.

TOOL KIT

- ☐ Two sponges of the same size but different materials such as cellulose, natural sponge, or plastic foam, and with different pore space sizes
- ☐ A digital scale accurate to one-hundredth of a gram
- ☐ Bowl or container to submerge the sponges
- ☐ Bowl to hold wet sponges for weighing; weigh the bowl before starting
- ☐ Cookie sheet and cooling rack
- ☐ Oven or microwave
- ☐ Water
- ☐ A table to record weights (see below)
- ☐ Optional: third, fourth and fifth sponges

Sponge	Description (color, texture*)	Saturated Weight	Field Capacity Wt.	Wilting Point Wt.	Air Dry Weight	Oven Dry Weight
Sponge 1						
Sponge 2						
Sponge 3						

*The description ensures you are putting the correct measurement in the correct row. If in doubt, or if all the sponges are the same color, mark each sponge (1, 2, 3) with a permanent marker.

Use the scientific method to complete this activity.

- Put enough water in the bowl to submerge the sponges.
- Submerge sponge 1. Squeeze and release the sponge until it is fully soaked and no air bubbles exist.
- Remove the sponge to the container as quickly as possible so you don't lose any water before you weigh it.
- Weigh the sponge and container. Subtract the weight of the container, and record the weight of the sponge and water in the Saturated column of your chart.
- Place the sponge on the cooling rack over a cookie sheet to drain.
- Repeat the above steps (saturate and weigh) using sponge 2 and any other sponges. Repeat the following steps with additional sponges, being careful to keep track of which one you are weighing.
- Weigh the sponges when each stops dripping, and record the weight in the Field Capacity column.
- Squeeze each sponge until no more water comes out, but do not twist or wring it. Weigh the sponge, and record the value in the Wilting Point column.
- Place the sponges on the cooling rack to air-dry for a couple days. Weigh each sponge, and record the weight in the Air Dry column.
- Finally, heat the sponges at 200°F to remove all the water, or dry them in the microwave. Weigh each sponge and record its weight in the Oven Dry column.

- **Saturated** weight represents the soil as full of water as it can be. This usually occurs right after a heavy rain. Any additional water falling on saturated soil becomes **runoff**.
- Field capacity indicates the maximum amount of water that a soil can hold. Natural drainage and permeability determine a soil's field capacity.
- Plant available water: Squeezing the sponge imitates a plant removing water through its roots. As water is removed, it becomes harder to squeeze more out. The water that is squeezed out is plant available water.
- **Wilting point**: Plants can no longer pull water from the soil, so they wilt.
- Air dry soil: The only water left is a small amount attached to the sponge surfaces (not **pore space**). Soils reach this point during droughts or in areas with little rain fall. It is also called hygroscopic water.

Answer the following questions in your record book. When explaining differences, discuss the difference in pore space size, which affects adhesion vs. cohesion and gravitational forces vs. capillary forces.

1. Is there any difference between the air-dried and oven-dried weights? Explain why.
2. What force holds the water to the air-dried sponge surfaces?
3. As a percentage, how much water was lost by drainage (weight of sponge before squeezing)? See the formula below. Explain the difference between the sponges.
4. Calculate the percentage of water that was plant available water, based on the saturated weight of the sponge. Explain why there is a difference between the sponges.
5. What forces keep the water from draining completely by gravity?

Formula to calculate water content by weight:

$$\text{Percentage water content by weight} = \frac{(\text{moist weight of sponge} - \text{oven dry weight of sponge}) \times 100\%}{\text{oven-dry weight of sponge}}$$

Optional

- Find a fellow 4-H member who did the same experiment and discuss the results.
- Present the data and results, and explain the procedure at a meeting.

LIFE SKILLS

- Evaluating data
- Keeping records
- Using scientific methods

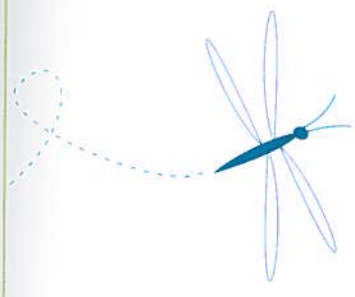
chat

Share What Happened

- What differences did you notice between the sponges?
- What effect would this have on soil drainage?

Apply: How can you apply this knowledge when you are managing your lawn, landscape, or garden?

Generalize to Your Life: How might pore size affect drainage at your house?



THE SCIENTIFIC METHOD

1. Define the problem. (Write a sentence or two.)
2. Develop your hypothesis. (What do you think can be done, and how will it help?)
3. Conduct experiments to prove or disprove your hypothesis and record your data.
4. Compare the data that you have collected.
5. Draw conclusions. What did this experiment show?