

Fundamentals of Organic Farming and Gardening Instructor's Guide



GEORGIA ORGANICS

Fundamentals of Organic Farming Instructor's Guide

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Unit 3

Unit 3

Unit Overview

A basic knowledge of plant anatomy and physiology is essential for crop management. Knowing more about plants allows management decisions that enhance their growth and development, meaning better quality and larger harvests.

[Lesson Text](#)

[Lesson Plans](#)

Teacher Demonstrations

1. Variety of plants or pictures of plants
2. Celery in a glass of colored water
3. Pictures or models of plant and animal cells
4. Plant and small chain to represent transpiration
5. Spanish moss on a branch (commensal) , a clover plant (including roots) (beneficial), and a diseased plant (parasitic). Describe the three types of symbiotic relationships represented.

Video

[Riverview Farms Video](#)

[Focus Questions](#)



Unit 3

Student Experiments and Activities

1. Plants Disassembled
2. Plant cells versus animal cells worksheet
3. Plant Hormones Worksheet
4. Vascular tissue comparison worksheet
5. Agricultural crop families

Power Point Presentations

1. [Unit 3 Presentation](#)
2. [Plant Morphology](#)
3. [Growth Regulators](#)
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Lesson Text

I. INTRODUCTION

II. BASICS OF PLANT ANATOMY

1. PLANT STRUCTURES
2. PLANT CELLS

III. BASICS OF PLANT PHYSIOLOGY

1. TRANSPORT IN PLANTS
2. PHOTOSYNTHESIS
3. TRANSPORT OF GLUCOSE
4. PLANT HORMONES
5. PLANT NUTRIENT UPTAKE

IV. PLANT TAXONOMY

V. PLANT LIFE/ SOIL LIFE RELATIONSHIPS

1. PLANT/SOIL RELATIONSHIPS
2. MANIPULATION BY PLANTS



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INTRODUCTION

While good soil management is essential to healthy plants, an understanding of the basic anatomy and physiology of plants is also important. Many management decisions are based on the knowledge of the way plants obtain water, carbon dioxide, oxygen, and mineral nutrients they need to live. Knowledge of the action of plant hormones and symbiotic relationships will inform crop management decisions. Better crops are achieved through enhancing the conditions that are conducive to plant growth and reproduction.

PLANT ANATOMY

Objectives

- 1. Identify the basic structures of plants.*
- 2. List the 3 tissue types of plants and the general functions of each.*
- 3. Name the substances that flow through the xylem and those that flow through the phloem.*
- 4. List 4 ways plant and animal cells differ.*

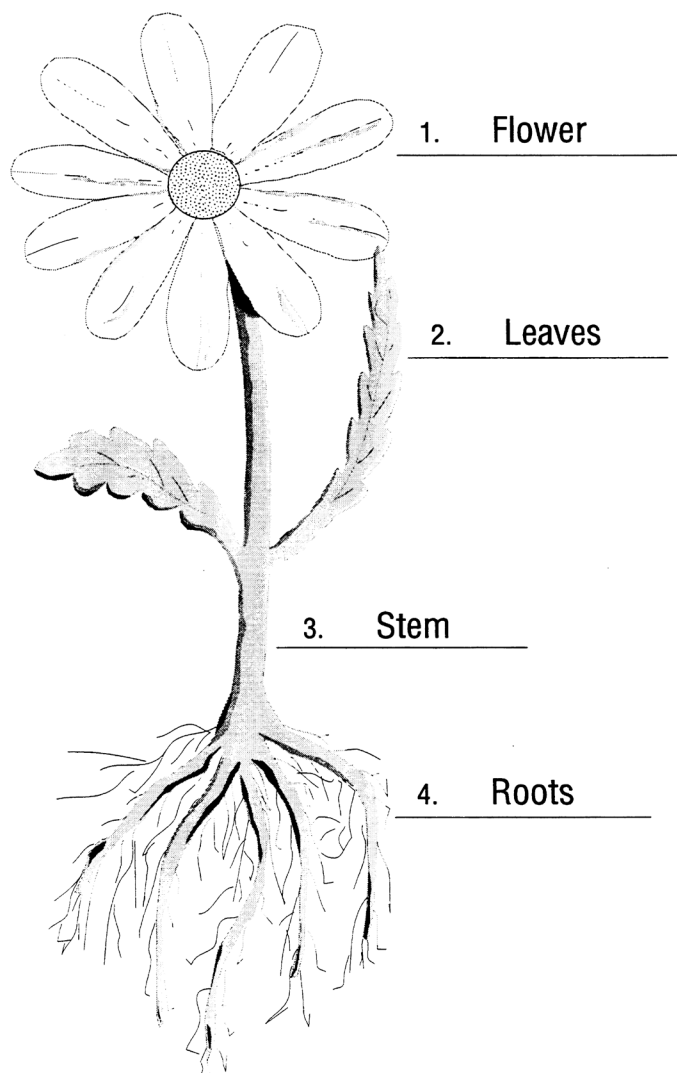
PLANT STRUCTURES

The basic plant structures in flowering plants that produce fruit and vegetables are roots, stems, leaves, flowers, fruits and seeds. The leaf, stem, and root are vegetative, or non-fruiting, structures concerned with the growth, nutrition, and development of a plant. In general, roots grow through the soil and absorb water and nutrients. The stems provide support for the plant and move nutrients from the roots to the other parts of the plant. The leaves produce food by converting light energy to sugar.



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Roots, stems, and leaves are called organs because each is composed of one or more tissues. Tissues are groups of similar cells organized to carry out one or more specific functions. Plants have only three tissue types: dermal, ground and vascular. (Flowers, fruits, and seeds are concerned with reproduction and are composed of one or more different organs.)

From Oregon State University Extension

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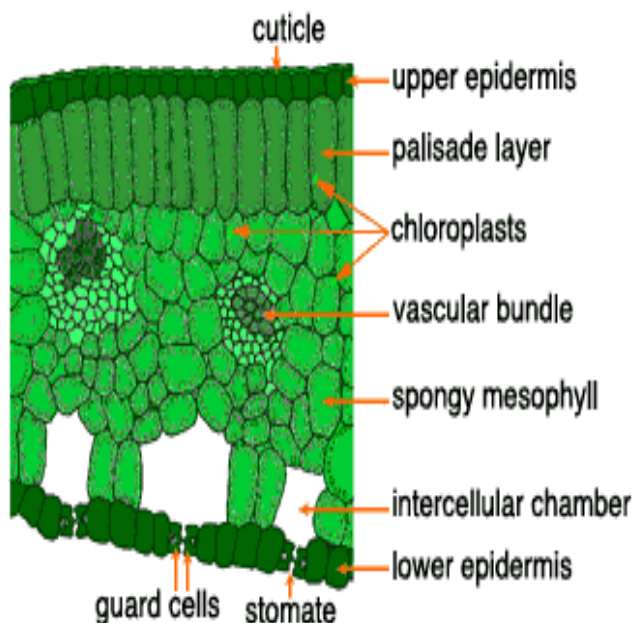


Figure 12. Leaf cross section

Dermal tissue covers the outer surface of herbaceous, or non-woody, plants. The outer layer of cells is called the epidermis. The epidermis consists of a single layer of living cells that are closely packed, which functions to protect the underlying tissues. Stomata, openings formed by guard cells, are found in the epidermis. The epidermal walls are thickened and covered with a thin waterproof layer called the cuticle. The cuticle prevents the desiccation of inner tissues and thus prevents water loss.

The stomata allow gaseous exchange for the processes of respiration and photosynthesis. These are pores, usually located on the underside of leaves, for the collection of carbon dioxide from the atmosphere. They also function as an opening through which water that has been vaporized inside the plant can be released. This acts as a cooling mechanism for the plant. The stomata have guard cells which open and close the pore.



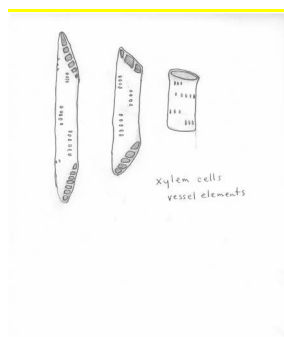
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Ground tissue is composed of small, thick-walled cells on the inside of the epidermis. These layers of cells are followed by larger thin-walled cells with intercellular air spaces. The first layer of these small, thick-walled cells strengthens the stem. The second layer stores synthesized organic food produced by the plant such as starch. Intercellular air spaces allow the exchange of gases between cells.

The vascular bundles are found scattered throughout the ground tissue. These are tube-like structures through which the fluids move inside the plant. The vascular bundles occurring nearer the outside of the stem are smaller and are closer to one another. Vascular bundles are composed of two different types of tubes: xylem and phloem.

Xylem vessels are relatively large and found within an irregular intercellular air space. Water and dissolved ions from the root system are transported to all other parts of the plant through the xylem. The xylem is a one-way transport system from the roots to other parts of the plant. Xylem tissue is composed of dead cells joined together to form long empty tubes. The ends of these cell walls are either full of holes, or are absent completely, allowing for flow. Before dying, the cells form thick cell walls containing lignin. Lignin is a woody substance that makes the xylem vessels very strong so that they don't collapse under pressure. They also help to give stems strength.

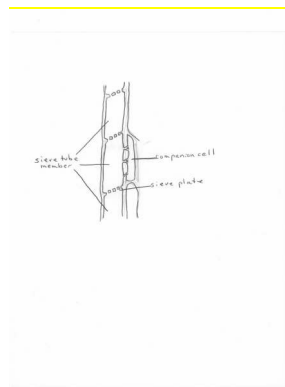


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Phloem is composed of smaller, thin-walled cells. Synthesized organic food such as carbohydrate is transported from the leaves to all other parts of the plant through the phloem. Phloem is a two-way system that can transport food and nutrients to and from each structure. Phloem tissue is composed of sieve tube cells, which form long columns with holes in their end walls called sieve plates.



These cells are alive, but they lose their nuclei and other organelles, and their cytoplasm is reduced to strands around the edge of the cells. These strands pass through the holes in the sieve plates, forming continuous filaments. The center of these tubes is empty. Each sieve tube cell is associated with one or more companion cells, normal cells with nuclei and organelles. These companion cells are connected to the sieve tube cells. They provide the phloem cells with proteins, adenosine triphosphate (ATP) and other nutrients. Additional information about ATP is provided in the section below on Photosynthesis.



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SUMMARY

Roots, stems, leaves, flowers and fruits are the basic plant structures. Roots, stems, and leaves are made up of dermal, vascular, and ground tissue. Dermal tissue provides the outside covering of the structure. Vascular tissue makes up the structures that carry water and nutrients in the plant. Ground tissue make up the bulk of the plant. Xylem carries water and minerals from the roots, while phloem carries the sugars from the leaves

Plant and animal cells differ in that animal cells do not have a cell wall and so transfer of gases between cells is different. Plant cells contain chloroplasts and vacuoles, whereas animal cells do not.

PLANT PHYSIOLOGY

Objectives:

- 1. Describe how water moves from roots to stems to leaves.*
- 2. Identify 3 factors which will effect transpiration.*
- 3. Define photosynthesis and state the location of the process.*
- 4. State the formula, in words, for photosynthesis.*
- 5. Name the plant structure which is the “source” of glucose and the structure which is the “sink”.*
- 6. Define endogenous rhythm.*
- 7. Name 5 classes of plant hormones and the general effect they have on plants.*
- 8. Describe how carbon dioxide, minerals, and water are each absorbed by plants.*



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TRANSPORT OF WATER AND NUTRIENTS

Plants don't have a circulatory system like animals but they do have a complicated system for transporting water and nutrients. This transportation system starts in the roots. Roots absorb water and dissolved salts, ions and other nutrients. These enter the xylem in the root tissue, creating a slight upward pressure called root pressure.

Root pressure is from water moving through root cells by osmosis, the diffusion of water through cell membranes. This movement of water through root cell membranes is only enough force to move the water and nutrients a few centimeters up the stem, so another force is responsible for most of the transportation.

Since the xylem tubes are made up of dead cells, no osmosis can occur within them. The driving force for the movement is transpiration, or evaporation of water from the leaves through the stomata. This creates low pressure in the leaves causing water to be sucked up the stem to replace the lost water. Because of water's unique property of cohesion, it can be "pulled up" through the stem and leaves in an unbroken stream. This is called the transpiration stream. (See unit 2, "Soil Water Management" for an explanation of the properties of water.)

As the water and nutrients pass into the leaves, they diffuse from the xylem into leaf veins. These veins transport the water and nutrients to the leaf cells where they are absorbed by through the same processes that the root cells used to absorb them into the plant to begin with. The water that is turned into vapor by the heat energy from the sun moves out of the plant through the stomata. This heat from the sun is the source of energy for all water movement in plants.



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Far more water passes through a plant by way of the transpiration stream than is used. Only 1% of the water absorbed is used by the plant cells for photosynthesis and retained in the plant. The remaining 99% evaporates from the leaves and is lost to the atmosphere. In the evening, most plants continue to absorb water, usually more than they transpire. This causes a build-up of water in the plant tissues.

There are a number of factors that affect the rate of transpiration in a plant. These are light, temperature, humidity and air movement. The stomata of a leaf react to light. They open when light strikes the leaf and close in darkness, causing the plant to lose water during the day.

The air temperature and radiant heat from the sun heating a plant's tissues also affects the rate of transpiration. As the air temperature increases and the plant's tissues are heated by radiant energy, water within the leaves turns to vapor faster and exits the plant through the stomata. This "pulls up" water from the roots at a faster rate, increasing the flow of water through the plant. If the plant gets overheated, it will wilt as a self-protective measure. Plants will wilt under these conditions even with sufficient water available in the soil.

Humidity of the atmospheric air also affects the rate of transpiration. Humidity is the amount of water vapor that atmospheric air can hold at a given temperature. When the humidity is high, there is less potential for the water vapor to diffuse into the air because it is already close to saturation. In low humidity conditions, a plant will lose more water vapor because there is a greater potential for the air to absorb it.

Air movement, or wind, is a major factor in water vapor loss from plants, increasing the rate of transpiration. Plants must keep the cells just inside the stomata moist so they can absorb the carbon dioxide necessary for photosynthesis. To do this, the leaves are slightly concave on the underside. This traps some of the water



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vapor escaping the plant through its stomata, forming what is called a “boundary layer” of near 100% humidity. A boundary layer is only a few millimeters thick or less. This high humidity boundary layer closely matches the humidity of the cells in the leaf and slows the plants’ transpiration.

When the wind blows, the boundary layer is reduced or blown away. In conditions of no wind there will be a thicker boundary layer and slower transpiration. With increasing wind, the layer will get thinner and transpiration will be more rapid. At high wind speeds, the stomata usually close to prevent the rapid water loss from the plant.

PHOTOSYNTHESIS

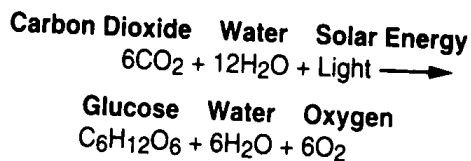
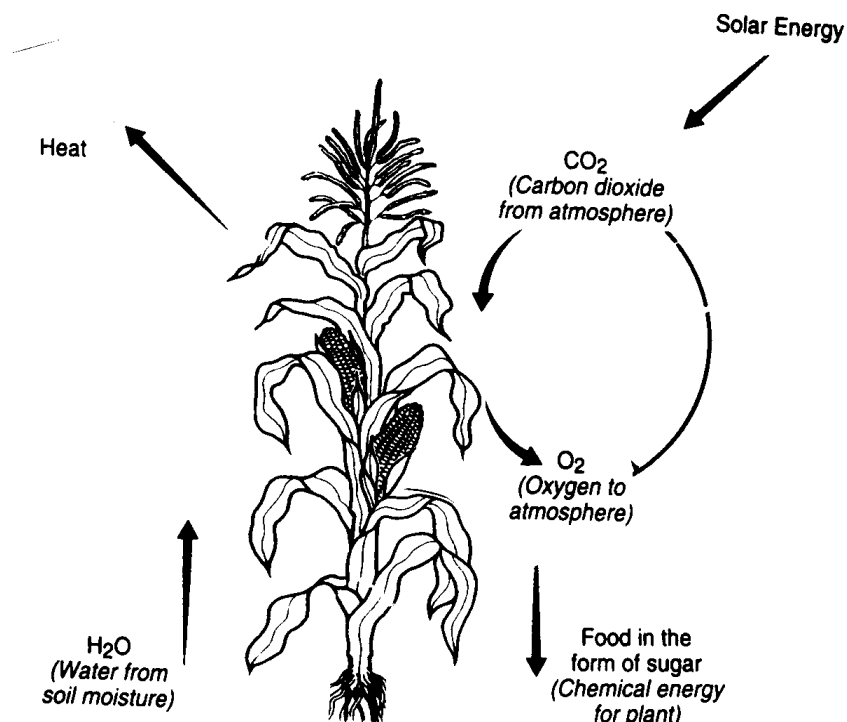
Photosynthesis is the process by which plants make their own food. This process starts in the chloroplasts. These structures are contained within the plant’s cells. A single cell may contain as many as 50 chloroplasts. The chloroplasts contain chlorophyll, a magnesium based molecule. This molecule has the unique ability to both absorb light energy and react with CO₂ and H₂O.



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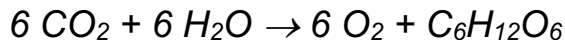
Photosynthesis



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The chemical formula for photosynthesis is:



Since most people don't speak "Chemicalese," we can write this as:

6 molecules of water plus 6 molecules of carbon dioxide

(In the presence of sunlight and chlorophyll)

Produce 1 molecule of sugar plus 6 molecules of oxygen.

This is a simplified explanation of photosynthesis. It is a much more complex process that starts with the production of a hormone, ATP (adenosine triphosphate). ATP is a molecule that provides the energy for combining CO₂ and H₂O to make glucose, the 6-carbon sugar in the above formula. Glucose is a mobile form of sugar. It can be transported all through the plant by way of the phloem and used for energy. It also serves as a building block to make polysaccharides, other monosaccharides, fats, amino acids, nucleotides, and all the carbon-based molecules the plant requires.

The chemical reactions that are directly dependent on sunlight (making ATP and glucose) are called "light reactions." Those that do not require sunlight but use photosynthate for energy are called "dark reactions." (Recent research has shown that some dark reactions are indirectly stimulated by sunlight, but these terms are still used with that understanding.)

TRANSPORT OF GLUCOSE

The "source and sink" concept is used to describe the way a plant makes and distributes the glucose. The "source" is the leaves in most plants. Glucose is made in the chloroplast and transported into the phloem. The phloem then transports the glucose to other areas of the plant for storage and later conversion.



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The glucose is then stored in the vacuoles in the plants' cells. (Plants may also store sugar in tubers, fruit and other structures.) These storage spaces are called "sinks." Once all the sinks are filled, a hormone is released as a chemical signal for the plant to start making the other chemical compounds that are needed for food and growth.

This whole cycle starts early in the morning as part of the plant's endogenous rhythm. This is similar to the internal mechanism that wakes us up each morning at the same time. It's commonly called our "body clock." This can be upset by "jet lag" or traveling across time zones too fast for our bodies to adjust to the change in sun time. It can also be upset by changing our sleeping and waking times suddenly. Plants' endogenous rhythms also are upset by rapid changes in sun time.

Plants' endogenous rhythms are set to start their cycles before daylight. They prepare for photosynthesis in the predawn hours by shutting down all other activity in the leaf cells that contain chloroplasts. They are prepared for the first rays of sun at dawn to begin photosynthesis. After this, they rely on feedback from the other cells to tell them when to change processes.

The endogenous rhythm of plants was discovered by placing plants in a completely dark room and monitoring their cycles. All the plants changed cycles in the early morning in anticipation of light. They continued this way for 3 to 4 days before their rhythms became erratic. Interestingly, this is about the same amount of time it takes for human endogenous rhythms to become disrupted by total darkness.



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PLANT HORMONES

A hormone is any chemical produced in one part of a body, transported to another, causing a response. Hormones act as control chemicals in multi-cellular organisms.

Plant hormones function as general growth stimulators or inhibitors. Unlike animal hormones, plant hormones are not produced in definite organs and do not have specific target tissues. Plant hormones interact with one another in complex ways to produce the mature, growing plant.

Five major classes of plant hormones have been extensively studied and are reasonably well understood. However, others exist which we see the effects of but have not been isolated. The five we do know of are auxin, cytokinin, gibberellin, abscisic acid and ethylene.

Auxin causes several responses in plants. Among these are bending toward a light source (phototropism), downward root growth in response to gravity (geotropism), flower formation, fruit set and root growth.

Gibberellins stimulate cell division and elongation, break seed dormancy, and speed germination.

Unlike other hormones, cytokinins are found in both plants and animals. In plants they stimulate cell division, growth of lateral buds and the formation of chloroplasts.

Ethylene is unique in that it is found only in the gaseous form. It induces ripening, causes leaves to droop and drop (abscission), and promotes maturation and death. Plants often increase ethylene production in response to stress, and ethylene is found in high concentrations within cells at the end of a plant's life. The increased ethylene in leaf tissue in the fall is part of the reason leaves fall off trees.



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Abscisic acid (ABA) is a general plant-growth inhibitor. It induces dormancy and prevents seeds from germinating. It also causes abscission of leaves, fruits, and flowers. ABA also functions to regulate transpiration by causing the stomata to close. High concentrations of ABA are present in guard cells during periods of drought stress and probably play a role in stomatal closure under these conditions.

PLANT NUTRIENT UPTAKE

Plants absorb nutrients through two structures: roots and leaves. The leaves absorb carbon dioxide and the roots absorb all the other nutrients. Carbon dioxide is the basic building block for all organic compounds produced by plants. This is absorbed from the air through the stomatal openings in the leaves.

Each stoma (singular for stomata) has two guard cells, one on each side of the opening. These act to open and close the stoma in response to signals from the plant. The guard cells swell to close the stoma and shrink to open it. The stomata are opened before sunrise to prepare the plant for water absorption through the transpiration stream and to be able to absorb carbon dioxide from the atmosphere. The stomata close during the evening or if the plant comes under stress from drought or high winds.

Since all the carbon a plant uses for energy and growth is absorbed through the stomata, it is advantageous for the plant to have sufficient water available near the roots to avoid the closing of the stomata. Water is absorbed by plants through fine structures on roots called root hairs. They do this through the process called osmosis. Once the water enters the roots it moves through the root cells primarily by this same process. This absorption of water is important because it is also the pathway for plant uptake of soluble salts like nitrates.



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Plants absorb mineral nutrients through their roots by two processes. The first, as noted above, is through the absorption of water containing soluble nutrients. The second is by direct absorption of ions from the soil. This is an energy demanding process. Roots must have photosynthate (ATP and sugar) present in the root and oxygen available around the root for ion absorption.

Plants can also absorb large, complex molecules such as hormones and vitamins directly from the soil. This is done through open spaces in the covering of the root structures that are filled with proteins. These openings let in specific molecules at specific sites.

SUMMARY

Water moves from roots to leaves through the xylem vascular tissue, powered by the energy of the sun. As a molecule of water is evaporated from the leaf, it pulls the next molecule up to take its place because of cohesion of the water molecules. Conditions that speed up the evaporation of water, such as wind, light, warm temperatures, and low humidity will speed up transpiration.

Plants make their food in the chloroplasts of the plant's cells by changing water and carbon dioxide into glucose and oxygen with the power of the sun and the pigment chlorophyll. The glucose made in photosynthesis moves through the phloem vascular tissue from the "source", into the leaves toward the "sink" of the vacuoles in plant cells or other storage structures.

Plant hormones function as general growth stimulators or inhibitors. The five major classes of plant hormones are auxins, gibberellins, cytokinins, ethylene and abscisic acid.

Carbon dioxide is absorbed by diffusion through the stomata of the leaves. Water and nutrients move into the root hairs by osmosis. Plants have special abilities to absorb ions, hormones and vitamins from the soil.



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PLANT FAMILIES

Plants are identified and grouped by like characteristics. Scientists give each organism a Latin name for species and genera. Each organism is then put in a family. These family members will have many characteristics alike which means they are attractive to the same insects and pests. Often there will be common names for the organisms, as well as scientific names, but sometimes two different organisms may be called the same common name.

Knowing the families of the farm's crops is essential for crop rotations and good planning. To avoid build up of specific pests and diseases, crop families should be rotated. Growing all the crops of a given family in one block helps to plan rotations. Crops should be rotated so the same family will not be grown in the same soil for several years. Some recommend that the best rotation is 8 years, but shorter rotations can also work.

Agricultural Crop Families

<i>Chenopodiaceae</i>	<i>Cucurbit</i>	<i>Brassica</i>	<i>Legume</i>	<i>Apiaceae</i>
Chard	Cucumber	Broccoli	Beans	Parsley
Spinach	Squash	Cabbage	Peas	Celery
	Pumpkin	Kale	Soybeans	Parsnip
	Cantaloupe	Radish	Peanuts	Dill
	Gourds	Cauliflower		
	Watermelon	Turnips		
		Arugula		
		Collards		
		Mustard		



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Agricultural Crop Families

Solanaceae

Tomatoes
Potatoes
Peppers
Eggplant

Poaceae

Corn
Popcorn

Liliaceae

Onion
Garlic
Shallots
Leeks

Asteraceae

Lettuce

Hibiscus

Okra
Cotton

Convolvulaceae

Sweet potato

PLANT LIFE/SOIL LIFE RELATIONSHIPS

As our knowledge of plant and soil life has expanded, their relationships have become more evident. These relationships are as complex and varied as the life itself. Discoveries have also been made recently about how plants can manipulate their environment for their own benefit.

Objectives:

1. Describe the 3 types of symbiotic relationships.
2. Explain the legume-rhizobia relationship and the myccorhizal relationship.



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PLANT/SOIL RELATIONSHIPS

All life forms interact with other life forms. Most of the interactions between species involve food. Their interactions can be competing for the same food supply, eating or avoiding being eaten. These interactions are usually brief and one species winds up as food for the other.

But there are many cases where two species live in close association over long periods of time. Such associations are called symbiotic or “living together.” In symbiosis, at least one member of the partnership benefits from the relationship. The other member may be injured or fed upon, relatively unaffected, or may also benefit.

An example of a symbiotic relationship where one species is injured is parasitism. This is a relationship where one species feeds on the other, making it weaker. A relationship where one species benefits from the interaction and the other is unaffected is called commensalism. A relationship where both species benefit is called mutualism. The term “symbiosis” has been commonly used as a synonym for mutualism. Examples of how plants form mutual relationships with other species are provided by rhizobial bacteria and mycorrhizal fungi.

Legumes have the ability to form a mutual relationship with rhizobial bacteria. In this relationship the bacteria live in nodules in the plant’s roots. The plant feeds the bacteria sugars and carbohydrates it makes. The bacteria in turn convert non-usable forms of nitrogen into nitrates that the plant can use.

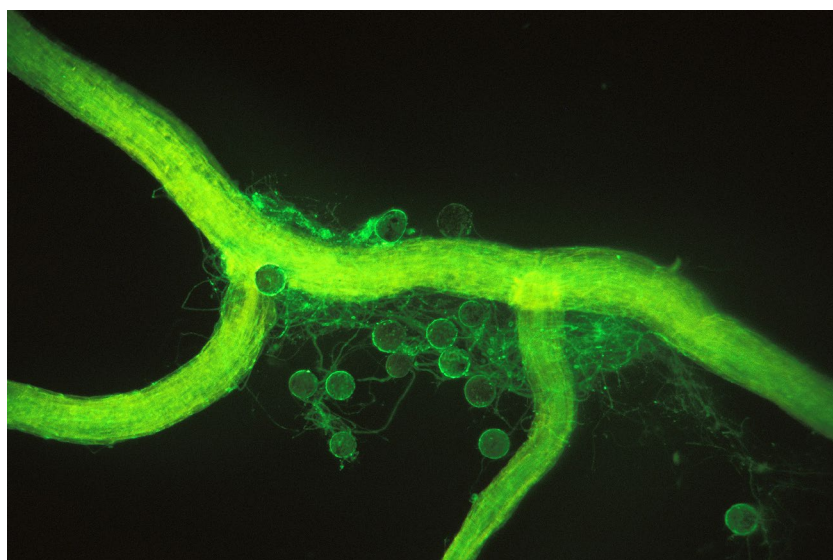


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Most plants, including those grown as food and fiber crops, form mutualistic relationships with mycorrhizal fungi. The fungi grow their fibers into the root structures of the plants. They grow through large volumes of the soil and provide the plant with water and minerals they absorb. The plants feed these fungi sugars and carbohydrates in return.



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MANIPULATION BY PLANTS

Recent research into plant and soil life relationships has shown that plants can manipulate their environment to their benefit. An example of this is the mutual relationship between legumes and rhizobial bacteria. Until recently it was thought that the bacteria “infested” the roots of the legume and that the plants accommodated them by growing nodules. However, research has shown that when a root of a legume encounters rhizobial bacteria in the soil, it grows nodules around the bacteria, “capturing” them. In soil where sufficient nitrate is present for the plants, legumes will stop feeding the bacteria and the colonies will go dormant.

We have also learned that plants encourage large colonies of beneficial bacteria around their roots by exuding photosynthate out of their roots and into the soil. These bacteria cycle nutrients in close proximity to the plant’s roots, making them easily obtainable for the plant. They also encourage bacteria that protect the plant from fungal attack in this way. (See Unit 1.2, Section III.) *Check this reference.*

SUMMARY

Symbiotic relationships are close relationships between two living organisms over a long period of time. These relationships are either mutually beneficial or beneficial to one and either neutral or detrimental to the other. Mutualism, commensalism and parasitism are the words used to describe these relationships. The legume-rhizobia relationship is mutual because the legume gets nitrogen released by the rhizobia and the bacteria gets sugars produced by the plant. Mycorrhizal fungi also feed on the sugars from the plant and provide the plant with water and nutrients. The relationships between plants and soil are complex and we are discovering more each day how the plant manipulates the soil organisms for its own good.



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UNIT SUMMARY

The roots, stems, leaves, flowers and fruits of plants are connected by the vascular tissue through which the sugars, water, and other nutrients flow. Energy from the sun powers both the movement of water up the stem of a plant and the production of glucose in photosynthesis. The sugars move through the plant along a concentration gradient from “source” to “sink”.

Plant hormones function as general growth stimulators or inhibitors. Plants may have close associations with other organisms called symbiotic relationships. Mycorrhizae and legume-rhizobia relationships are beneficial to the plant by making nutrients more available.



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CULTIVATION

Cultivation differs from tillage in both its purpose and depth. The first purpose of cultivation is to manage the soil surface for optimal gas exchange and water absorption. This is done by breaking up any crusting of the soil caused by rainfall or irrigation. Decrusting of the soil surface should be done just deep enough to break the crust apart. Pulverizing the crust isn't necessary.

The second purpose of cultivation is to control weeds. This is done because weeds can usually out-compete crops for water and nutrients. Cultivation for weed control should be done at the minimal depth necessary to disturb the weed roots in order to kill them. This will avoid disturbing the crops' roots, destroying the soil structure, and bringing new weed seeds to the surface to sprout.

The same implements can be used for both these purposes. There are a large number of implements available for use with tractors, so the choice of which ones to use will depend on the crop, the farming methods (row or beds), and soil type. In a situation where a number of different kinds of crops are grown, a "tool bar" can be used. This is a piece of equipment that has a number of square bars on which cultivation implements can be mounted. It allows for fast and easy change of row spacing and numbers of implements. Good sources of information for what will work best in your situation are Extension agents and other farmers growing the same crops.

The third purpose of cultivation is the killing and incorporation of cover crops. This can be done with any tillage equipment that will kill the cover crop and incorporate most of the plant material. One of the best implements for this is the rototiller. A rototiller can cut the growing crown of plants from the roots, killing them. The action also breaks the outer covering of the plant material and incorporates it into the soil. This sets up conditions for rapid break down by the soil life. Spading machines with square spades also work well, if set at a shallow depth.



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IV. PLANT TAXONOMY

V. PLANT LIFE/ SOIL LIFE RELATIONSHIPS

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VI. UNIT SUMMARY

INTRODUCTION

While good soil management is essential to healthy plants, an understanding of the basic anatomy and physiology of plants is also important. Many management decisions are based on the knowledge of the way plants obtain water, carbon dioxide, oxygen, and mineral nutrients they need to live. Knowledge of the action of plant hormones and symbiotic relationships will inform crop management decisions. Better crops are achieved through enhancing the conditions that are conducive to plant growth and reproduction.



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PLANT ANATOMY

Objectives

1. Identify the basic structures of plants.
2. List the 3 tissue types of plants and the general functions of each.
3. Name the substances that flow through the xylem and those that flow through the phloem.
4. List 4 ways plant and animal cells differ.

PLANT STRUCTURES

The basic plant structures in flowering plants that produce fruit and vegetables are roots, stems, leaves, flowers, fruits and seeds. The leaf, stem, and root are vegetative, or non-fruiting, structures concerned with the growth, nutrition, and development of a plant. In general, roots grow through the soil and absorb water and nutrients. The stems provide support for the plant and move nutrients from the roots to the other parts of the plant. The leaves produce food by converting light energy to sugar.

Roots, stems, and leaves are called organs because each is composed of one or more tissues. Tissues are groups of similar cells organized to carry out one or more specific functions. Plants have only three tissue types: dermal, ground and vascular. (Flowers, fruits, and seeds are concerned with reproduction and are composed of one or more different organs.)

From Oregon State University Extension

Dermal tissue covers the outer surface of herbaceous, or non-woody, plants. The outer layer of cells is called the epidermis. The epidermis consists of a single layer of living cells that are closely packed, which functions to protect the underlying tissues. Stomata, openings formed by guard cells, are found in the epidermis. The epidermal walls are thickened and covered with a thin waterproof layer called the cuticle. The cuticle prevents the desiccation of inner tissues and thus prevents water loss.

The stomata allow gaseous exchange for the processes of respiration and photosynthesis. These are pores, usually located on the underside of leaves, for the collection of carbon dioxide from the atmosphere. They also function as an opening



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through which water that has been vaporized inside the plant can be released. This acts as a cooling mechanism for the plant. The stomata have guard cells which open and close the pore.

Ground tissue is composed of small, thick-walled cells on the inside of the epidermis. These layers of cells are followed by larger thin-walled cells with intercellular air spaces. The first layer of these small, thick-walled cells strengthens the stem. The second layer stores synthesized organic food produced by the plant such as starch. Intercellular air spaces allow the exchange of gases between cells.

The vascular bundles are found scattered throughout the ground tissue. These are tube-like structures through which the fluids move inside the plant. The vascular bundles occurring nearer the outside of the stem are smaller and are closer to one another. Vascular bundles are composed of two different types of tubes: xylem and phloem.

Xylem vessels are relatively large and found within an irregular intercellular air space. Water and dissolved ions from the root system are transported to all other parts of the plant through the xylem. The xylem is a one-way transport system from the roots to other parts of the plant. Xylem tissue is composed of dead cells joined together to form long empty tubes. The ends of these cell walls are either full of holes, or are absent completely, allowing for flow. Before dying, the cells form thick cell walls containing lignin. Lignin is a woody substance that makes the xylem vessels very strong so that they don't collapse under pressure. They also help to give stems strength.

Phloem is composed of smaller, thin-walled cells. Synthesized organic food such as carbohydrate is transported from the leaves to all other parts of the plant through the phloem. Phloem is a two-way system that can transport food and nutrients to and from each structure. Phloem tissue is composed of sieve tube cells, which form long columns with holes in their end walls called sieve plates.

These cells are alive, but they lose their nuclei and other organelles, and their cytoplasm is reduced to strands around the edge of the cells. These strands pass through the holes in the sieve plates, forming continuous filaments. The center of these tubes is empty. Each sieve tube cell is associated with one or more companion cells, normal cells with nuclei and organelles. These companion cells are connected to the sieve tube cells. They provide the phloem cells with proteins, adenosine triphosphate (ATP) and other nutrients. Additional information about ATP is provided in the section below on Photosynthesis.



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PLANT CELLS

Plant cells differ from animal cells in some significant ways. Plant cells have a thick, impermeable cell wall and animals have only a thin, permeable membrane. Animal cells absorb and give off gases and nutrients directly through their cell membranes. Plant cells transfer gases and nutrients between adjacent cells through small perforations that connect each cell with all those adjacent to it.

Another difference is that plant cells contain chloroplasts and vacuoles. Chloroplasts are the structures within plant cells where light energy is used to make the hormone used in sugar production. These are usually contained in the leaf cells and give them their green color.

Vacuoles are empty spaces within the plant cells. They have their own membrane within the cell that is separate from the cell membrane. One of the functions of vacuoles is to store some of the sugar and carbohydrates the plant produces and uses for food.

SUMMARY

Roots, stems, leaves, flowers and fruits are the basic plant structures. Roots, stems, and leaves are made up of dermal, vascular, and ground tissue. Dermal tissue provides the outside covering of the structure. Vascular tissue makes up the structures that carry water and nutrients in the plant. Ground tissue make up the bulk of the plant. Xylem carries water and minerals from the roots, while phloem carries the sugars from the leaves

Plant and animal cells differ in that animal cells do not have a cell wall and so transfer of gases between cells is different. Plant cells contain chloroplasts and vacuoles, whereas animal cells do not.

PLANT PHYSIOLOGY

Objectives:

1. Describe how water moves from roots to stems to leaves.
2. Identify 3 factors which will effect transpiration.
3. Define photosynthesis and state the location of the process.
4. State the formula, in words, for photosynthesis.
5. Name the plant structure which is the “source” of glucose and the structure which is the “sink”.



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6. Define endogenous rhythm.
7. Name 5 classes of plant hormones and the general effect they have on plants.
8. Describe how carbon dioxide, minerals, and water are each absorbed by plants.

TRANSPORT OF WATER AND NUTRIENTS

Plants don't have a circulatory system like animals but they do have a complicated system for transporting water and nutrients. This transportation system starts in the roots. Roots absorb water and dissolved salts, ions and other nutrients. These enter the xylem in the root tissue, creating a slight upward pressure called root pressure.

Root pressure is from water moving through root cells by osmosis, the diffusion of water through cell membranes. This movement of water through root cell membranes is only enough force to move the water and nutrients a few centimeters up the stem, so another force is responsible for most of the transportation.

Since the xylem tubes are made up of dead cells, no osmosis can occur within them. The driving force for the movement is transpiration, or evaporation of water from the leaves through the stomata. This creates low pressure in the leaves causing water to be sucked up the stem to replace the lost water. Because of water's unique property of cohesion, it can be "pulled up" through the stem and leaves in an unbroken stream. This is called the transpiration stream. (See unit 2, "Soil Water Management" for an explanation of the properties of water.)

As the water and nutrients pass into the leaves, they diffuse from the xylem into leaf veins. These veins transport the water and nutrients to the leaf cells where they are absorbed by through the same processes that the root cells used to absorb them into the plant to begin with. The water that is turned into vapor by the heat energy from the sun moves out of the plant through the stomata. This heat from the sun is the source of energy for all water movement in plants.

Far more water passes through a plant by way of the transpiration stream than is used. Only 1% of the water absorbed is used by the plant cells for photosynthesis and retained in the plant. The remaining 99% evaporates from the leaves and is lost to the atmosphere. In the evening, most plants continue to absorb water, usually more than they transpire. This causes a build-up of water in the plant tissues.

There are a number of factors that affect the rate of transpiration in a plant. These are light, temperature, humidity and air movement. The stomata of a leaf react to light. They open when light strikes the leaf and close in darkness, causing the plant to lose water during the day.



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The air temperature and radiant heat from the sun heating a plant's tissues also affects the rate of transpiration. As the air temperature increases and the plant's tissues are heated by radiant energy, water within the leaves turns to vapor faster and exits the plant through the stomata. This "pulls up" water from the roots at a faster rate, increasing the flow of water through the plant. If the plant gets overheated, it will wilt as a self-protective measure. Plants will wilt under these conditions even with sufficient water available in the soil.

Humidity of the atmospheric air also affects the rate of transpiration. Humidity is the amount of water vapor that atmospheric air can hold at a given temperature. When the humidity is high, there is less potential for the water vapor to diffuse into the air because it is already close to saturation. In low humidity conditions, a plant will lose more water vapor because there is a greater potential for the air to absorb it.

Air movement, or wind, is a major factor in water vapor loss from plants, increasing the rate of transpiration. Plants must keep the cells just inside the stomata moist so they can absorb the carbon dioxide necessary for photosynthesis. To do this, the leaves are slightly concave on the underside. This traps some of the water vapor escaping the plant through its stomata, forming what is called a "boundary layer" of near 100% humidity. A boundary layer is only a few millimeters thick or less. This high humidity boundary layer closely matches the humidity of the cells in the leaf and slows the plants' transpiration.

When the wind blows, the boundary layer is reduced or blown away. In conditions of no wind there will be a thicker boundary layer and slower transpiration. With increasing wind, the layer will get thinner and transpiration will be more rapid. At high wind speeds, the stomata usually close to prevent the rapid water loss from the plant.

PHOTOSYNTHESIS

Photosynthesis is the process by which plants make their own food. This process starts in the chloroplasts. These structures are contained within the plant's cells. A single cell may contain as many as 50 chloroplasts. The chloroplasts contain chlorophyll, a magnesium based molecule. This molecule has the unique ability to both absorb light energy and react with CO₂ and H₂O.

The chemical formula for photosynthesis is:



Since most people don't speak "Chemicalese," we can write this as:

6 molecules of water plus 6 molecules of carbon dioxide

(In the presence of sunlight and chlorophyll)

Produce 1 molecule of sugar plus 6 molecules of oxygen.



This is a simplified explanation of photosynthesis. It is a much more complex process that starts with the production of a hormone, ATP (adenosine triphosphate). ATP is a molecule that provides the energy for combining CO₂ and H₂O to make glucose, the 6-carbon sugar in the above formula. Glucose is a mobile form of sugar. It can be transported all through the plant by way of the phloem and used for energy. It also serves as a building block to make polysaccharides, other monosaccharides, fats, amino acids, nucleotides, and all the carbon-based molecules the plant requires.

The chemical reactions that are directly dependent on sunlight (making ATP and glucose) are called “light reactions.” Those that do not require sunlight but use photosynthate for energy are called “dark reactions.” (Recent research has shown that some dark reactions are indirectly stimulated by sunlight, but these terms are still used with that understanding.)

TRANSPORT OF GLUCOSE

The “source and sink” concept is used to describe the way a plant makes and distributes the glucose. The “source” is the leaves in most plants. Glucose is made in the chloroplast and transported into the phloem. The phloem then transports the glucose to other areas of the plant for storage and later conversion.

The glucose is then stored in the vacuoles in the plants’ cells. (Plants may also store sugar in tubers, fruit and other structures.) These storage spaces are called “sinks.” Once all the sinks are filled, a hormone is released as a chemical signal for the plant to start making the other chemical compounds that are needed for food and growth.

This whole cycle starts early in the morning as part of the plant’s endogenous rhythm. This is similar to the internal mechanism that wakes us up each morning at the same time. It’s commonly called our “body clock.” This can be upset by “jet lag” or traveling across time zones too fast for our bodies to adjust to the change in sun time. It can also be upset by changing our sleeping and waking times suddenly. Plants’ endogenous rhythms also are upset by rapid changes in sun time.

Plants’ endogenous rhythms are set to start their cycles before daylight. They prepare for photosynthesis in the predawn hours by shutting down all other activity in the leaf cells that contain chloroplasts. They are prepared for the first rays of sun at dawn to begin photosynthesis. After this, they rely on feedback from the other cells to tell them when to change processes.

The endogenous rhythm of plants was discovered by placing plants in a completely dark room and monitoring their cycles. All the plants changed cycles in the early morning in anticipation of light. They continued this way for 3 to 4 days before their rhythms became



erratic. Interestingly, this is about the same amount of time it takes for human endogenous rhythms to become disrupted by total darkness.

PLANT HORMONES

A hormone is any chemical produced in one part of a body, transported to another, causing a response. Hormones act as control chemicals in multi-cellular organisms.

Plant hormones function as general growth stimulators or inhibitors. Unlike animal hormones, plant hormones are not produced in definite organs and do not have specific target tissues. Plant hormones interact with one another in complex ways to produce the mature, growing plant.

Five major classes of plant hormones have been extensively studied and are reasonably well understood. However, others exist which we see the effects of but have not been isolated. The five we do know of are auxin, cytokinin, gibberellin, abscisic acid and ethylene.

Auxin causes several responses in plants. Among these are bending toward a light source (phototropism), downward root growth in response to gravity (geotropism), flower formation, fruit set and root growth.

Gibberellins stimulate cell division and elongation, break seed dormancy, and speed germination.

Unlike other hormones, cytokinins are found in both plants and animals. In plants they stimulate cell division, growth of lateral buds and the formation of chloroplasts.

Ethylene is unique in that it is found only in the gaseous form. It induces ripening, causes leaves to droop and drop (abscission), and promotes maturation and death. Plants often increase ethylene production in response to stress, and ethylene is found in high concentrations within cells at the end of a plant's life. The increased ethylene in leaf tissue in the fall is part of the reason leaves fall off trees.

Abscisic acid (ABA) is a general plant-growth inhibitor. It induces dormancy and prevents seeds from germinating. It also causes abscission of leaves, fruits, and flowers. ABA also functions to regulate transpiration by causing the stomata to close. High concentrations of ABA are present in guard cells during periods of drought stress and probably play a role in stomatal closure under these conditions.

PLANT NUTRIENT UPTAKE

Plants absorb nutrients through two structures: roots and leaves. The leaves absorb carbon dioxide and the roots absorb all the other nutrients. Carbon dioxide is the basic building block for all organic compounds produced by plants. This is absorbed from the air through the stomatal openings in the leaves.

Each stoma (singular for stomata) has two guard cells, one on each side of the opening. These



act to open and close the stoma in response to signals from the plant. The guard cells swell to close the stoma and shrink to open it. The stomata are opened before sunrise to prepare the plant for water absorption through the transpiration stream and to be able to absorb carbon dioxide from the atmosphere. The stomata close during the evening or if the plant comes under stress from drought or high winds.

Since all the carbon a plant uses for energy and growth is absorbed through the stomata, it is advantageous for the plant to have sufficient water available near the roots to avoid the closing of the stomata. Water is absorbed by plants through fine structures on roots called root hairs. They do this through the process called osmosis. Once the water enters the roots it moves through the root cells primarily by this same process. This absorption of water is important because it is also the pathway for plant uptake of soluble salts like nitrates.

Plants absorb mineral nutrients through their roots by two processes. The first, as noted above, is through the absorption of water containing soluble nutrients. The second is by direct absorption of ions from the soil. This is an energy demanding process. Roots must have photosynthate (ATP and sugar) present in the root and oxygen available around the root for ion absorption.

Plants can also absorb large, complex molecules such as hormones and vitamins directly from the soil. This is done through open spaces in the covering of the root structures that are filled with proteins. These openings let in specific molecules at specific sites.

SUMMARY

Water moves from roots to leaves through the xylem vascular tissue, powered by the energy of the sun. As a molecule of water is evaporated from the leaf, it pulls the next molecule up to take its place because of cohesion of the water molecules. Conditions that speed up the evaporation of water, such as wind, light, warm temperatures, and low humidity will speed up transpiration.

Plants make their food in the chloroplasts of the plant's cells by changing water and carbon dioxide into glucose and oxygen with the power of the sun and the pigment chlorophyll. The glucose made in photosynthesis moves through the phloem vascular tissue from the "source", into the leaves toward the "sink" of the vacuoles in plant cells or other storage structures.

Plant hormones function as general growth stimulators or inhibitors. The five major classes of plant hormones are auxins, gibberellins, cytokinins, ethylene and abscisic acid.

Carbon dioxide is absorbed by diffusion through the stomata of the leaves. Water and nutrients move into the root hairs by osmosis. Plants have special abilities to absorb ions, hormones and vitamins from the soil.



PLANT FAMILIES

Plants are identified and grouped by like characteristics. Scientists give each organism a Latin name for species and genera. Each organism is then put in a family. These family members will have many characteristics alike which means they are attractive to the same insects and pests. Often there will be common names for the organisms, as well as scientific names, but sometimes two different organisms may be called the same common name.

Knowing the families of the farm's crops is essential for crop rotations and good planning. To avoid build up of specific pests and diseases, crop families should be rotated. Growing all the crops of a given family in one block helps to plan rotations. Crops should be rotated so the same family will not be grown in the same soil for several years. Some recommend that the best rotation is 8 years, but shorter rotations can also work.

Agricultural Crop Families

<i>Chenopodiaceae</i>	<i>Cucurbit</i>	<i>Brassica</i>	<i>Legume</i>	<i>Apiaceae</i>
Chard	Cucumber	Broccoli	Beans	Parsley
Spinach	Squash	Cabbage	Peas	Celery
	Pumpkin	Kale	Soybeans	Parsnip
	Cantaloupe	Radish	Peanuts	Dill
	Gourds	Cauliflower		
	Watermelon	Turnips		
		Arugula		
		Collards		
		Mustard		
<i>Solanaceae</i>	<i>Poaceae</i>	<i>Liliaceae</i>	<i>Asteraceae</i>	<i>Hibiscus</i>
Tomatoes	Corn	Onion	Lettuce	Okra
Potatoes	Popcorn	Garlic		Cotton
Peppers		Shallots		
Eggplant		Leeks		
<i>Convolvulaceae</i>				
Sweet potato				



PLANT LIFE/SOIL LIFE RELATIONSHIPS

As our knowledge of plant and soil life has expanded, their relationships have become more evident. These relationships are as complex and varied as the life itself. Discoveries have also been made recently about how plants can manipulate their environment for their own benefit.

Objectives:

1. Describe the 3 types of symbiotic relationships.
2. Explain the legume-rhizobia relationship and the mycorrhizal relationship.

PLANT/SOIL RELATIONSHIPS

All life forms interact with other life forms. Most of the interactions between species involve food. Their interactions can be competing for the same food supply, eating or avoiding being eaten. These interactions are usually brief and one species winds up as food for the other.

But there are many cases where two species live in close association over long periods of time. Such associations are called symbiotic or “living together.” In symbiosis, at least one member of the partnership benefits from the relationship. The other member may be injured or fed upon, relatively unaffected, or may also benefit.

An example of a symbiotic relationship where one species is injured is parasitism. This is a relationship where one species feeds on the other, making it weaker. A relationship where one species benefits from the interaction and the other is unaffected is called commensalism. A relationship where both species benefit is called mutualism. The term “symbiosis” has been commonly used as a synonym for mutualism. Examples of how plants form mutual relationships with other species are provided by rhizobial bacteria and mycorrhizal fungi.

Legumes have the ability to form a mutual relationship with rhizobial bacteria. In this relationship the bacteria live in nodules in the plant’s roots. The plant feeds the bacteria sugars and carbohydrates it makes. The bacteria in turn convert non-usable forms of nitrogen into nitrates that the plant can use.

Most plants, including those grown as food and fiber crops, form mutualistic relationships with mycorrhizal fungi. The fungi grow their fibers into the root structures of the plants. They grow through large volumes of the soil and provide the plant with water and minerals they absorb. The plants feed these fungi sugars and carbohydrates in return.



MANIPULATION BY PLANTS

Recent research into plant and soil life relationships has shown that plants can manipulate their environment to their benefit. An example of this is the mutual relationship between legumes and rhizobial bacteria. Until recently it was thought that the bacteria “infested” the roots of the legume and that the plants accommodated them by growing nodules. However, research has shown that when a root of a legume encounters rhizobial bacteria in the soil, it grows nodules around the bacteria, “capturing” them. In soil where sufficient nitrate is present for the plants, legumes will stop feeding the bacteria and the colonies will go dormant.

We have also learned that plants encourage large colonies of beneficial bacteria around their roots by exuding photosynthate out of their roots and into the soil. These bacteria cycle nutrients in close proximity to the plant’s roots, making them easily obtainable for the plant. They also encourage bacteria that protect the plant from fungal attack in this way. (See Unit 1.2, Section III.) Check this reference.

SUMMARY

Symbiotic relationships are close relationships between two living organisms over a long period of time. These relationships are either mutually beneficial or beneficial to one and either neutral or detrimental to the other. Mutualism, commensalism and parasitism are the words used to describe these relationships. The legume-rhizobia relationship is mutual because the legume gets nitrogen released by the rhizobia and the bacteria gets sugars produced by the plant. Mycorrhizal fungi also feed on the sugars from the plant and provide the plant with water and nutrients. The relationships between plants and soil are complex and we are discovering more each day how the plant manipulates the soil organisms for its own good.

UNIT SUMMARY

The roots, stems, leaves, flowers and fruits of plants are connected by the vascular tissue through which the sugars, water, and other nutrients flow. Energy from the sun powers both the movement of water up the stem of a plant and the production of glucose in photosynthesis. The sugars move through the plant along a concentration gradient from “source” to “sink”.

Plant hormones function as general growth stimulators or inhibitors. Plants may have close associations with other organisms called symbiotic relationships. Myccorhizae and legume-rhizobia relationships are beneficial to the plant by making nutrients more available.



Appendix

Riverview Farms Focus Questions

1. How did the Swancy's get started in organic farming?
2. What basic abilities are required to be successful?
3. What does Wes see as the advantage of being a farmer?
4. How does Riverview market their produce?
5. How do they use the computer?
6. What are their future plans for the farm?

