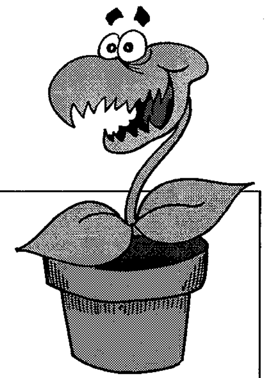
Kingdom Plantae

Section 16.1
Overview of Plants



Pre-View 16.1

- **Division** – the next largest taxon used for plants under kingdom; same as "phylum" used in other kingdoms
- **Botanists** – scientists who study plants
- **Vascular tissue** – "tubes" that move water and nutrients throughout some plants
- **Non-vascular plants** – plants that do not contain vascular tissue; examples: mosses and liverworts
- **Seedless vascular plants** – plants that contain vascular tissue but produce spores instead of seeds; example: ferns
- **Gymnosperms** – vascular plants that may produce seeds in a cone; example: pine tree
- **Angiosperms** – vascular plants that produce seeds by flowers; example: apple tree

How are plants different from the other organisms we've studied so far? Plants are classified into the Kingdom Plantae if they have all of the characteristics listed below.

Characteristics of All Plants

- They are made of more than one cell (multicellular).
- The cells are eukaryotic cells (cells with a nucleus).
- They are autotrophs (producers) because they produce their own food through photosynthesis.
- Their cells have cell walls made of cellulose.

Scientists know that over 250,000 species of plants exist on the earth today. Plants are classified using the same taxa as other organisms, but the largest group after kingdom is called a **division** instead of a phylum. There are twelve divisions of plants recognized by **botanists**, the scientists who study plants.

To make it easier to study plants, the Kingdom Plantae is usually split into two main groups: vascular plants (tracheophytes) and non-vascular plants (bryophytes). Plants are placed into one of these two groups depending on whether or not they have specialized tissues called **vascular tissues**. Vascular tissues are tubes that help move water and nutrients throughout the plant.

The vascular plants can be further divided. First, they are divided into groups according to the way they reproduce: seedless plants and seeded plants. Then the plants with seeds are divided into gymnosperms and angiosperms. Finally, the angiosperms are divided into the monocots and the dicots. Figure 16-1 on the right summarizes the way the plant kingdom is divided.

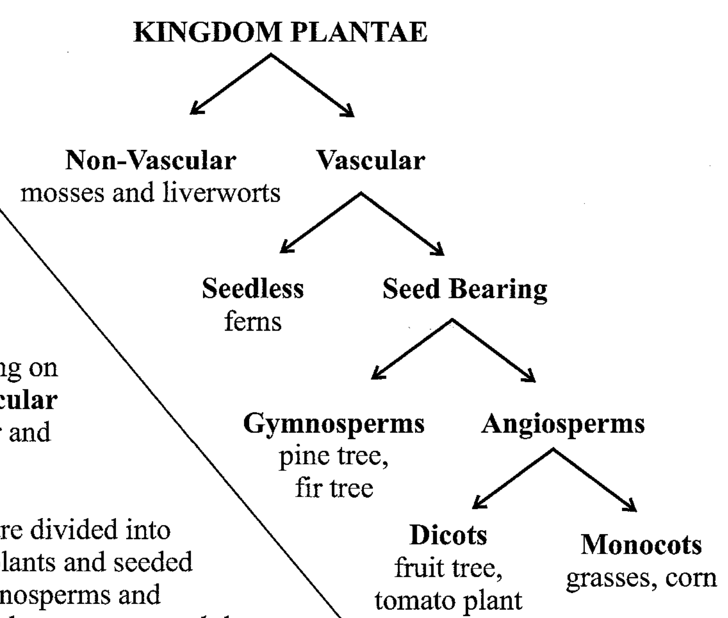


Fig. 16-1

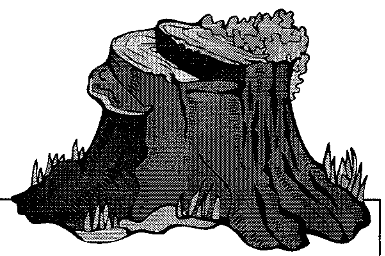
How can you tell in which group a plant belongs? The following chart may help you decide.

	Example	Vascular Tissue?	True Roots, Stems, Leaves?	Flowers?	Reproduce by Spores?	Reproduce by Seeds?
Non-Vascular Plants	mosses	no	no	no	yes	no
Seedless Vascular Plants	ferns	yes	yes	no	yes	no
Gymnosperm Vascular Plants	pine tree	yes	yes	no	no	yes, some produced in cones
Angiosperm Vascular Plants	fruit tree	yes	yes	yes	no	yes, produced by flowers

As you can see from figure 16-1 and the table above, plants have a variety of traits. Some have vascular tissue, and some don't. Some produce flowers, some produce cones, and some produce spores. We'll also see in the subsections to follow that some have large leaves, some have small leaves, and some have no leaves at all. These specialized traits allow different types of plants to live in different types of environments. We'll talk about these special characteristics later. In the subsections to follow, we'll review the basics about each plant type.

Kingdom Plantae

Section 16.2
Non-Vascular Plants (Bryophytes)



Pre-View 16.2

- **Bryophytes** – a term used to describe all non-vascular plants such as mosses, liverworts, and hornworts
- **Rhizoids** – root-like structures that anchor mosses
- **Alternation of generations** – having two stages of reproduction, a gametophyte stage with haploid (n) cells and a sporophyte stage with diploid cells (2n)

Non-vascular plants, sometimes called **bryophytes**, belong to three different divisions: **bryophyta**, **hepatophyta**, and **antheocerophyta**. These non-vascular plants have several things in common. They do not have vascular tissue, special tubelike cells, to moves water and nutrients throughout the plants. They don't have true roots, stems, or leaves either. So what makes them a plant? They still carry out photosynthesis and have all of the other characteristics of plants.

Division Bryophyta
You are probably most familiar with this division of non-vascular plants because it contains mosses. **Mosses** have thin, leaf-like structures that cause them to look feathery.

Division Hepatophyta
This division includes plants called liverworts. **Liverworts** are very small, flat plants that are usually less than two centimeters tall. They get their name because they are shaped somewhat like a human liver. The waxy coating that keeps the liverworts from drying out makes them look shiny even when they are not wet.

Division Antheocerophyta
This third division of non-vascular plants includes the hornworts. **Hornworts** look very similar to liverworts except that they produce spores in a long, thin, horn-shaped structure. Their cells are unusual because they have one large chloroplast per cell like many algae.

Structure and Function

Mosses, liverworts, and hornworts do not have true leaves. Instead they have tissues made up of cells only a few cells thick. Instead of roots, the mosses have structures called **rhizoids** that anchor them (figure 16-2). Mosses also have a stem-like structure and leaf-like structures, but since they don't have vascular tissues, these are not true stems or leaves.

Since non-vascular plants don't have vascular tissue, water and dissolved materials move through them by diffusion and osmosis. These are very slow processes that move materials from one cell to the next. Because these processes are so slow, non-vascular plants are small — usually no taller than a few centimeters. It would take too long to move water through a plant as tall as an oak tree if the water had to move completely by diffusion or by osmosis.

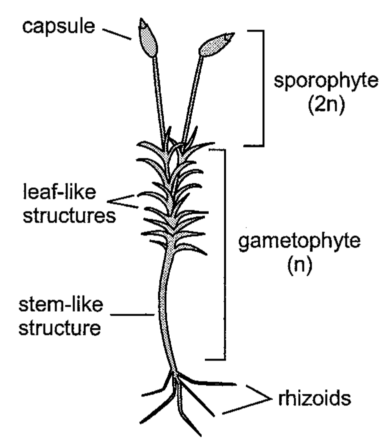


Fig. 16-2
Diagram of a Moss Plant

Reproduction and Life Cycle

Non-vascular plants can live on land, but they must live in places where there is moisture since they need moisture to reproduce. During one stage of their lives, non-vascular plants reproduce by forming sperm cells and egg cells. If the plant dries out, the sperm cells cannot travel to fertilize the egg cells.

Life Cycle of Moss

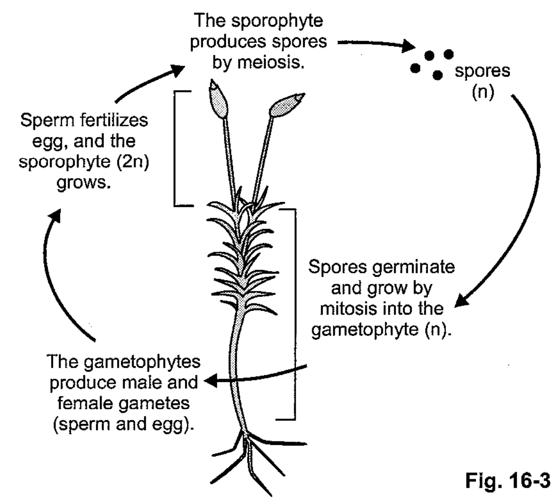


Fig. 16-3

Like all plants, the bryophytes undergo **alternation of generations**, which is made up of two stages of reproduction. See figure 16-3 for the life cycle of moss. The first stage is the **gametophyte** stage. The cells in the gametophyte stage are haploid (having half the number of chromosomes as the parent plant, n). *Note: Non-vascular plants are the only divisions of plants that have a dominant gametophyte stage.* The second stage is the **sporophyte** stage. In the sporophyte stage, diploid cells (2n) undergo meiosis to produce spores. The spores are haploid, and when they germinate, they begin the gametophyte stage once again.

Special Traits

Mosses are the best known non-vascular plants. Their small size is an important trait. It allows many types of mosses to live in environments where there is little soil or where the soil does not contain many nutrients. Many mosses can also tolerate low temperatures. They grow well in colder areas like the polar regions where they are an important food source for other organisms. They can be found in cold tundra areas above the timberline (at elevations above which no trees can grow). Mosses are resistant to most diseases and pollutants, and they are sometimes considered pest organisms by people who would prefer to grow grass rather than moss. (A **pest** is any organism that lives in an area where it is not wanted or where it does damage.)

Kingdom Plantae

Section 16.3
Seedless Vascular Plants

Pre-View 16.3

- **Tracheophyte** – a term for all vascular plants
- **Vascular tissue** – "tubes" that move water and nutrients throughout some plants
- **Xylem** – the tissues that transport water and nutrients up the plant (from the roots up the stem and to the leaves)
- **Phloem** – the tissues that carry food from the leaves to wherever it is needed
- **Rhizomes** – the thick underground stems of ferns
- **Fronds** – the leaves of ferns
- **Sporangia** – brownish spore cases found on the underside of fern fronds

Introduction to Vascular Plants

What is a vascular plant? A vascular plant, called a **tracheophyte**, is a plant that has vascular tissues. **Vascular tissues** are tubes that transport water and materials throughout the plant. There are two kinds of vascular tissue: xylem and phloem. **Xylem** is made of cells that carry water and minerals from the roots of the plant up to the stem and leaves. **Phloem** is made of cells that carry the food molecules from the leaves where they are produced to wherever the food is needed in the plant.

If anything damages the vascular tissues of a plant, the plant can die from an inadequate supply of water or nutrients. For example, a beaver can kill a tree if it eats the bark and vascular tissues underneath the bark all the way around a tree. Likewise, certain organisms, such as the fungus that causes Dutch elm disease, can kill a tree by invading the vascular tissue and causing the tubes to become clogged.

Vascular plants have a wide variety of shapes and sizes. First, let's look at vascular plants that reproduce by forming spores instead of by forming seeds.

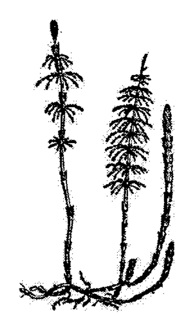
Seedless Vascular Plants

Many vascular plants do not form flowers and seeds for reproduction. Instead, they reproduce by forming spores. Most seedless vascular plants are found in warm, moist regions of the world.

Division Psilotophyta
This division of vascular plants includes whisk ferns. **Whisk ferns** are very simple plants that have no roots and no true leaves.

Division Lycophyta
This division includes club mosses. **Club mosses** have leaves that look a little like moss, but unlike bryophyte mosses, club mosses have true roots, stems, and leaves. The spores of club mosses were used to make the "flash" for photographers before flash bulbs and electronic flashes were invented.

Horsetail



Division Sphenophyta
This division includes a group of plants called **horsetails**. These plants were once used to scrub pots and pans because of the silica in their stems. The only genus in this division that is not extinct is genus *Equisetum,* and they are considered living fossils.

Ferns

Division Pterophyta

This division of seedless plants includes **ferns**, and it is the second largest division in the plant kingdom. Of all the seedless vascular plants, you are probably most familiar with ferns. They have true vascular tissues that move water and nutrients throughout the plant. These vascular tissues allow them to grow much taller than non-vascular plants. Some species of ferns can grow as tall as a telephone pole or a small tree! At least 10,000 species of ferns exist today.

Fern

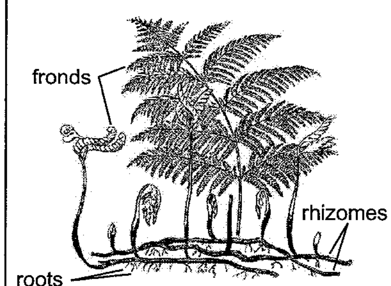


Fig. 16-4

Fern Structure and Characteristics

Ferns have true roots and leaves. They have thick underground stems called **rhizomes**. The leaves are called **fronds**. Ferns produce thousands of spores yearly. The spores are stored in brownish colored spore cases called **sporangia** found on the underside of the fronds. Fronds and roots grow from nodes on the rhizomes. See figure 16-4 for a diagram of a fern.

Ferns can live in areas where there is not much light, but they grow best where there is a lot of moisture for at least part of the year. The moisture is needed for reproduction. Today there are many types of ferns, and they can be found from the tropics to the edges of the polar regions. Some ferns can grow as tall as telephone poles and are commonly called tree ferns. The young leaves of ferns (called **fiddleheads**) are a delicacy for many types of wildlife.

Reproduction and Life Cycle

Life Cycle of Ferns

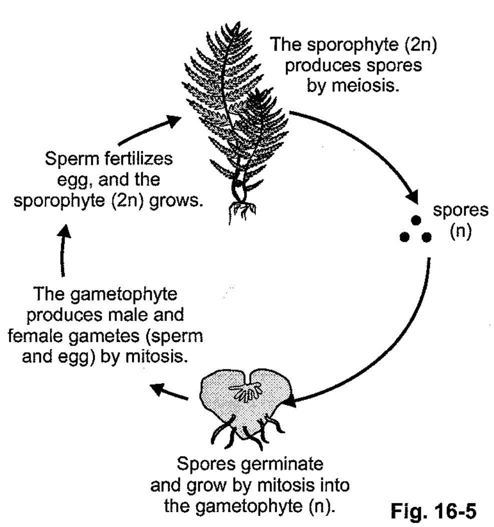


Fig. 16-5

Ferns do not form flowers or seeds for reproduction. Instead, they reproduce by forming spores — thousands of spores yearly. Ferns, like mosses, require water to reproduce.

Like all plants, ferns reproduce by an alternation of generations. The life cycle is similar to mosses, but the sporophyte is the dominant stage. (Nonvascular plants such as mosses are the only ones to have a dominant gametophyte stage.) The fern plant that you usually see is the sporophyte stage. The steps of reproduction can be seen in figure 16-5.

- The diploid sporophyte (2n) produces haploid spores (n) by meiosis.
- The spores grow into the gametophyte (n).
- The gametophyte produces gametes, sperm and egg cells, by mitosis.
- When water is present, a sperm cell can fertilize an egg cell.
- The fertilized cell then can grow into another sporophyte, and the cycle begins again.

Quick Review

- How do all plants reproduce? They all reproduce by an alternation of generations.
- What is the dominant stage in *non-vascular plants*? The gametophyte (n) stage is the dominant stage.
- What is the dominant stage in *vascular plants*? The sporophyte (2n) stage is the dominant stage.
- What is meant by *dominant stage*? The dominant stage is the stage you will most often see.
- How does a gametophyte produce gametes in ferns? The gametophyte produces gametes by mitosis.
- How does the sporophyte produce spores in ferns? The sporophyte produces spores by meiosis.

Kingdom Plantae

Section 16.4
Gymnosperms

Pre-View 16.4

- **Gymnosperm** – a vascular plant that produces seeds that are not enclosed in a fruit
- **Conifer** – a type of gymnosperm that produces seeds in cones
- **Pollen** – a gametophyte structure that carries the male gamete
- **Pollination** – the transfer of pollen from the male structure to the female structure of a plant

Vascular Seed-Producing Plants

Instead of producing spores, many vascular plants produce seeds. Using seeds instead of spores eliminates the need for water in order to reproduce. In seed plants, **pollen** that contains the male gamete can be carried by the wind to fertilize an egg.

Gymnosperms

Many vascular plants produce seeds although not all of them have flowers. The non-flowering vascular plants that produce seeds are the **gymnosperms**, which means "naked seed." Gymnosperms get this name because their seeds are not enclosed in a fruit. Some, but not all, protect their seeds in a cone. Being able to produce seeds is a major advantage to these plants since it allows the transfer of gametes without water. The structure of the seed itself also protects the plant embryo inside it.

Gymnosperms are divided into four divisions: Cycadophyta, Ginkgophyta, Gnetophyta, and Coniferophyta. A brief description of each is given below.

Division Cycadophyta
Plants in this division are called cycads. **Cycads** look similar to palm trees, but they produce separate seed and pollen cones that can be up to three feet long.

Division Ginkgophyta
Only one species from this division can be found living today — *Ginkgo biloba*. The ginkgo tree is prized for its beautiful yellow leaves in the fall, but the fruit of the ginkgo tree smells so bad that it has the nickname of "Dog Vomit Tree."

Division Gnetophyta
This division also has some strange plants. Plants in this division can be woody vines, small shrubs, or even turnip-like plants.

Division Coniferophyta
This division should be more familiar to you; it includes the conifers. **Conifers** are plants that produce seeds in cones. This division also includes the tallest trees, the redwoods.

Since conifers are the most familiar of the gymnosperms, let's take a closer look at them.

Conifer Characteristics

There are over 500 known species of conifers, including pine trees, cedars, giant redwoods, spruces, and firs. Their leaves are usually needle-like or scale-like, and many are considered to be "evergreen" since they remain green all year.

Reproduction and Life Cycle

One of the most outstanding characteristics of conifers is that they reproduce by forming seeds in cones. But like all plants, conifers and other gymnosperms reproduce by an alternation of generations. The sporophyte stage is again the dominant stage.

Think about a pine tree, a common conifer. The pine tree is the sporophyte that you see. The gametophyte stage is very small, and it is actually contained in the sporophyte tissues. Conifers, such as the pine tree, produce two kinds of cones. Small pollen cones produce pollen grains that contain the male gametes, or sperm cells. The larger seed cones contain the female gametes, or egg cells. In the spring, the pollen cones release huge amounts of pollen, the yellow dust that covers your car. Some of the pollen grains get caught on the sticky material found on the female cones. This transfer is called **pollination**. If the sperm in a pollen grain fertilizes an egg cell, an embryo grows and is encased in the seed inside the seed cone. The scales of the seed cone help to protect the seeds.

Life Cycle of Conifers

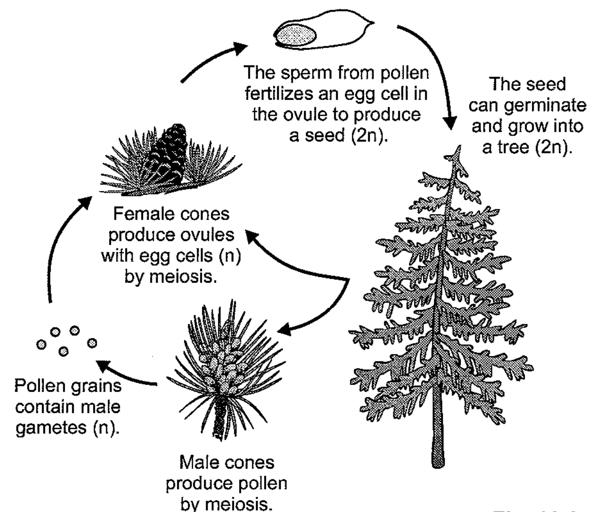


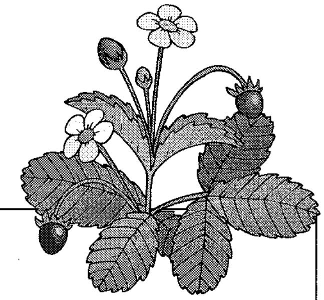
Fig. 16-6

Importance

Conifers are important in many ways. They provide timber for building materials, furniture, toothpicks, and pencils. The wood pulp is also used to make paper. The needles and resin provide oils that are used in making cleaning products, perfumes, and disinfectants. The bark and roots of many conifers have been used by Native Americans for medicine, baskets, and clothing. A recently discovered anti-cancer agent, taxol, is made from the bark of one species of conifer, the yew tree. Conifers also play a vital role in many ecosystems by providing food and habitats for wildlife.

Kingdom Plantae

Section 16.5
Angiosperms



Pre-View 16.5

- **Angiosperm** – a vascular plant that produces flowers
- **Cotyledon** – the leaf part of an embryo that is present in a seed; also called the *seed leaf*
- **Monocot** – flowering plant that has only one cotyledon per seed
- **Dicot** – flowering plant that has two cotyledons per seed
- **Pistil** – female part of the flower (also called the **carpel**)
- **Ovary** – the part of the pistil that contains the egg cells (female gametes)
- **Stamen** – male part of the flower
- **Anther** – the part of the stamen that produces pollen
- **Pollen** – small structures that contain sperm cells (male gametes)
- **Pollination** – in angiosperms, the transfer of pollen from the male anther to the female pistil
- **Fertilization** – the union of sperm and egg

The most well-known plants are the flowering plants. They are called **angiosperms** and are in the division **Anthophyta**. Although they all have flowers, the flowers are not always big and colorful. In fact, sometimes you don't even notice them because they are so inconspicuous. All of the over 240,000 species of angiosperms identified have roots, stems, and leaves, and they also produce seeds.

Flowers provide several advantages to the plants. The flowers help attract insects and animals, such as bees and hummingbirds, that help pollinate the flowers. This process of pollination is more efficient than it is in gymnosperms. The flowers also contain a part called an ovary, which develops into a fruit that protects the seed. In fact, the word angiosperm means "enclosed seed." The fruit or seeds of many angiosperms are used for food by animals.

Like gymnosperms and all plants, angiosperms also reproduce by an alternation of generations. The sporophyte stage is the dominant stage. First, let's review the two major divisions of angiosperms, monocots and dicots.

Monocots and Dicots

There are many types of angiosperms and many ways of classifying them. One main way of classifying them is into two categories: monocots and dicots. If you could look into the seeds from angiosperms, you would see that each seed has three main parts: the seed coat, the embryo or immature plant, and the stored food. The leaf part of the embryo is called a **cotyledon** or seed leaf. It often becomes the first leaf of the plant once it sprouts. In **monocots**, the seed has only one cotyledon. In **dicots,** each seed has two cotyledons. Plants like corn, grasses, and lilies are monocots. Oak trees, roses, clover, and tomatoes are dicots. These main seed parts for a typical monocot seed and a typical dicot seed are diagramed in figure 16-7.

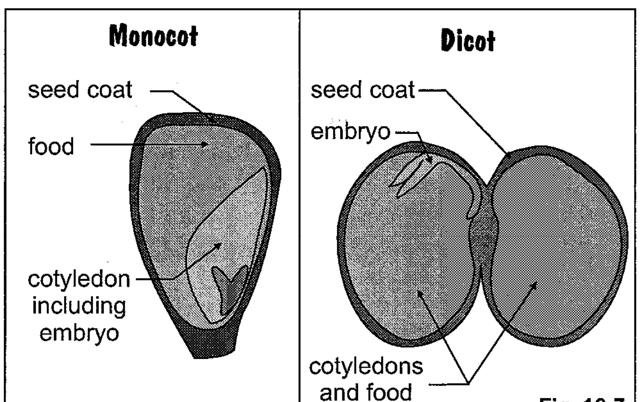
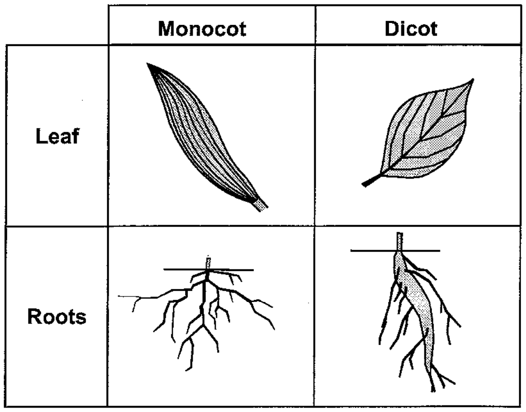


Fig. 16-7



There are also other differences between monocots and dicots. Monocots tend to have leaves with parallel veins and fibrous roots. Have you ever examined a blade of grass? Have you ever pulled up a clump of grass and noticed its roots? If so, you've seen a good example of monocot leaves and roots. Dicots tend to have leaves with branched veins and a main taproot. A maple leaf is a good example of a dicot leaf, and a carrot is an example of a dicot tap root. The table to the left shows diagrams of general monocot and dicot leaves and roots.

In addition to different leaves and roots, monocots and dicots also have differences in their stems and flowers. The table below summarizes all of these differences.

	Monocots	Dicots
seeds	one cotyledon	two cotyledons
flowers	flower parts are often in multiples of 3	flower parts are often in multiples of 4 or 5
stems	vascular bundles are scattered throughout the stem	vascular bundles are arranged in a circle
leaves	veins are parallel	veins are branched
roots	roots are usually fibrous	usually have a taproot

Flower Structure

Since all angiosperms have flowers, let's review the basic parts of a flower. A diagram of a typical flower is shown in figure 16-8.

Diagram of Main Flower Parts

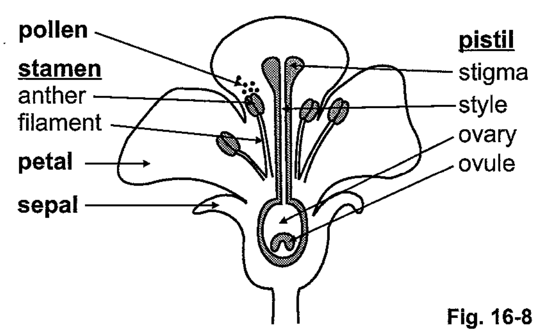


Fig. 16-8

The female part of the flower is called the **pistil** (or **carpel**). The pistil is made up of the stigma, the style, and the ovary. The **ovary** contains the ovule(s), which are the female gametes, or egg cells.

The **stamen** is the male part of the flower and is made up of anther and filament. The **anther** produces **pollen**, which contains the male gametes, or sperm cells.

The sepals and petals are not directly involved in plant reproduction, but they are still important parts of a flower. The **sepals** are the green parts that protect the flower before it blooms. The **petals** are there to look pretty but not necessarily to us. They are meant to attract insects and other animals that may help to pollinate the flower. Examples of important pollinators are honey bees, butterflies, moths, hummingbirds, and even certain types of bats. We tend to think about flowers as being showy with colorful petals. But many angiosperms have flowers that we seldom notice until the pollen they produce causes us to sneeze!

Pollination and Fertilization

In order for seeds to be produced, two things must happen: pollination and fertilization. **Pollination** is the transfer of pollen to the female part of the flower. It can occur by wind, by water, or by pollinating animals. The anthers split open and expose mature pollen grains. The pollen is then picked up by one of the pollinating agents. At the same time that the pollen has been maturing, the egg cells have been maturing also. The stigma at the top of the pistil becomes "receptive" so that pollen will stick to it. When the correct type of pollen sticks to the stigma, the pollen forms a pollen tube which travels down to the ovary of the pistil. In the ovary of the pistil, the pollen releases two sperm cells near the mature egg cell. **Fertilization** occurs when one of the sperm cells joins with the egg cell. Once fertilization occurs, a zygote is formed that will develop into the embryo found in the seed. This simple explanation of the life cycle can be seen in figure 16-9.

Life Cycle of Angiosperms

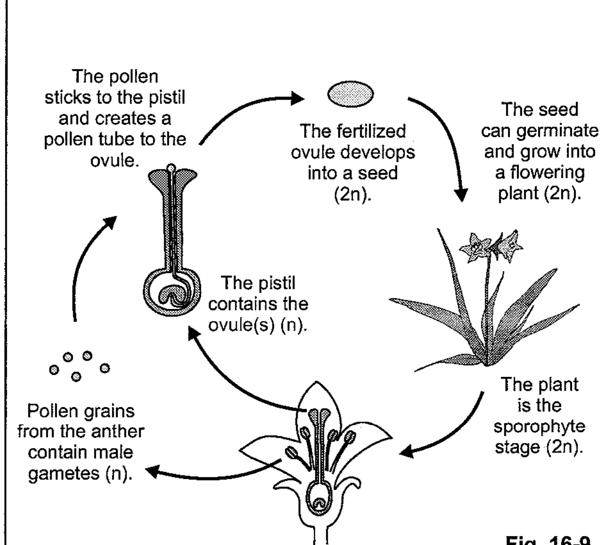
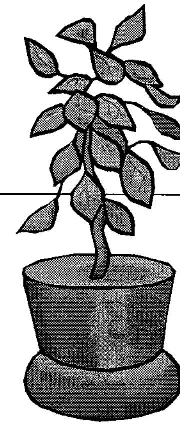


Fig. 16-9

Kingdom Plantae

Section 16.6
Plant Cells and Tissues



Pre-View 16.6

- **Meristematic tissue** – undifferentiated plant tissue that is responsible for cell division
- **Dermal tissue** – the tissue that makes up the outer surface of a leaf, stem, etc.
- **Vascular tissue** – tissue that makes up the xylem and phloem, the "tubes" that transport water and nutrients
- **Ground tissue** – tissue that makes up most of a plant
- **Transpiration** – the process of losing water through a plant's leaves
- **Cuticle** – the waxy coating on leaves
- **Mesophyll** – the middle layer of cells in a leaf that contain chloroplasts
- **Chloroplasts** – plant organelles that carry out photosynthesis
- **Stomata** – openings usually on the underside of a leaf that allow carbon dioxide to enter and oxygen and water to escape
- **Guard cells** – cells on either side of a stoma that cause the stoma to open or close
- **Pith** – part of a plant stem often used for storage
- **Cortex** – a part of a plant stem used to store sugar and proteins to be used during spring growth
- **Epidermis** – the outside layer of cells on leaves and stems
- **Cambium** – undifferentiated cells between the xylem and phloem that allow for growth
- **Xylem** – vascular tissue that transports water and minerals from the roots up the stem and to the leaves
- **Phloem** – vascular tissue that carries food molecules from the leaves to wherever it is needed

Plant Tissues

In Section 6.4 you learned that different types of cells are specialized to do specific jobs. You also saw that groups of cells that work together to perform a certain function make up a tissue. Even though you may be much more familiar with animal or human cells and tissues, plants also have their own types. Plants are made up of four types of tissues:

Meristematic tissue is undifferentiated tissue that is responsible for all cell division. In order for a plant to grow or repair itself, the cells must divide by mitosis. Meristematic tissue divides, and then it can develop into one of the other three kinds of tissues. Think of meristematic tissue as being similar to stem cells in humans. They can differentiate into specific types of cells. Meristematic tissue is usually found at the tips of growing stems or roots. It is also found inside stems in an area called the cambium. The cambium allows a plant to grow wider.

Dermal tissue in plants is like your skin. It is usually one layer of cells on the outside of roots, stems, and leaves. In roots, the dermal tissue also makes up root hairs. Since leaves have a top and a bottom, they contain dermal tissue on both sides. Dermal tissue protects the plant against its environment.

Vascular tissue make up the xylem and phloem, which transport water and nutrients. Think of vascular tissue as being similar to your blood vessels.

Ground tissue makes up most of the plant. Ground tissues are found throughout the plant in roots, stems, leaves, fruits, and flowers. Anything that isn't dermal tissue or vascular tissue is most likely ground tissue.

Now that you know a little bit about the cells and tissues that make up plants, let's review the functions of leaves, stems, and roots.

Leaves

The primary purpose of a leaf is to absorb light and carry out photosynthesis. **Photosynthesis** is a process that plants use to convert carbon dioxide and water into sugar (food) and oxygen. This process requires the leaf to take in the carbon dioxide needed and to release the oxygen produced.

Plant roots take in water, but water is also lost through the plant's leaves by a process called **transpiration**. Leaves have specific structures that allow them to control the amount of water that is lost through transpiration.

A general cross-sectional diagram of a leaf is given in figure 16-10.

Cross-Section of a Leaf

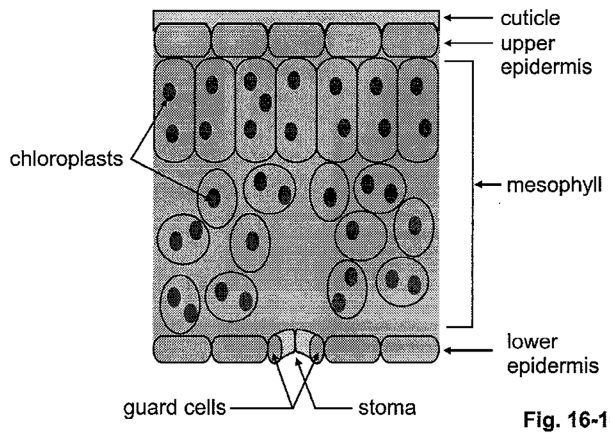


Fig. 16-10

Leaves have a waxy coating on top called the **cuticle**, which helps protect against water loss. Underneath the cuticle is a layer of epidermis cells. What type of tissue do you think make up the upper epidermis? If you said dermal tissue, you'd be correct! The epidermis is usually a single layer of cells on the outside of the leaf that offers protection. Dermal cells also make up the lower epidermis.

The inside of most leaves is packed with cells called mesophyll. **Mesophyll** is a type of ground tissue. In leaves, mesophyll cells contain many **chloroplasts**, which are the plant organelles that carry out photosynthesis. Part of the mesophyll is called spongy mesophyll because it is full of air spaces.

The air spaces between the spongy mesophyll connect to openings usually on the underside of the leaf called **stomata**. (The singular is stoma.) Stomata are like pores that let carbon dioxide and oxygen diffuse in and out of the leaf. On each side of the opening is a **guard cell**, a specialized cell that opens or closes the stoma as needed for gas exchange or for conservation of water. Usually the stomata are open long enough to allow gas exchange for photosynthesis, but then they close so the plant does not lose too much water. The guard cells open and close the stomata in response to changes in water pressure inside the cells. On hot, dry days when a plant needs to conserve water, the guard cells relax and close. On most days when the plant has enough water, water pressure pulls the stomata open to allow water to escape.

Stems

Plant stems have several important functions. Most obviously, they support the leaves and flowers. They also transport materials throughout the plant. As you can see from figure 16-11, monocot stems and dicot stems have the same types of tissues, but they are arranged differently. All four types of plant tissue can be found in the stem.

Vascular Arrangement in Stems

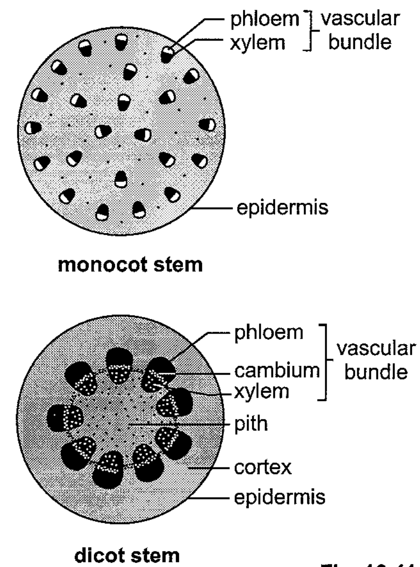


Fig. 16-11

Vascular bundles are mainly composed of xylem and phloem, types of vascular tissue. Remember that **xylem** is made of cells that carry water and minerals from the roots of the plant up to the stem and leaves, and **phloem** is made of cells that carry the food molecules from the leaves where they are produced to wherever the food is needed in the plant. The vascular tissue in monocots is scattered throughout an area called the pith, but in dicots it is arranged in a ring around the pith.

Cambium cells are undifferentiated (meristematic) cells between the xylem and phloem that allow the stem to grow thicker. Besides cambium and vascular tissue, the vascular bundles also contain ground tissue that helps to support the plant.

Pith, another type of ground tissue, is often used for storage. In dicots the pith is in the center of the stem, but in monocots it is spread throughout the stem. The **cortex**, also made of ground tissue, is a layer between the epidermis and vascular tissue. Like the pith, it is used for the storage of sugars and proteins that help plants to grow in early spring.

The **epidermis** makes up the outer layer on both monocot and dicot stems. The epidermis is made up of dermal tissue. On woody plants, the epidermis is replaced by bark.

Roots

The roots of plants take in water and nutrients, and they hold the plant in place in the ground. To allow the roots to absorb as much water and nutrients as possible, the roots are covered with tiny root hairs that increase the surface area sometimes as much as 130% more than the surface area of the stems and leaves of a plant.

The most common types of roots are fibrous and taproots. Fibrous roots branch again and again, and the roots are about equal in size. Grasses and other monocots have fibrous roots. On the other hand, some plants have one large root called a taproot with smaller secondary roots that grow off to the sides. Dicots have taproots, and a good example is a carrot.

Like stems, the roots of monocots and dicots have many of the same parts, but they are arranged differently. Look at figure 16-12. What differences do you see between these cross-sections of young roots? You should see that the structures are very similar, but the size, shape, and position of the xylem and phloem tissues are different.

Root Tissues

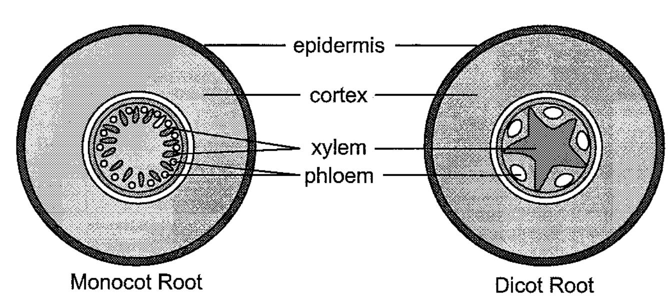
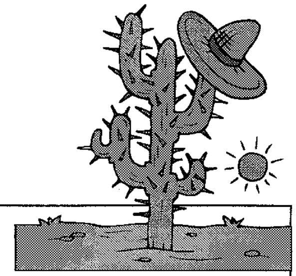


Fig. 16-12

Kingdom Plantae

Section 16.7
Plant Adaptations



Pre-View 16.7

- **Adaptations** – characteristics that help an organism to survive in its environment
- **Adventitious roots** – roots that grow in unusual places, such as on the stem of a plant
- **Prop roots** – roots that grow partially in the air and partially in the ground

Adaptations are physical, chemical, or behavioral characteristics that help an organism to survive in its environment. Let's think about plants a little more. Plants live in all different types of environments, from the hot and dry desert to the cold tundra and everywhere in between. Since most plants live out their lives in one specific place, what adaptations do they have that allow them to survive extreme temperatures, live in very dry areas, live in either salt water or fresh water, or keep them from being consumed by predators? How are they able to reproduce and spread to new areas? These adaptations can be found in their leaves, stems, seeds, flowers, fruits, and roots.

Leaf Adaptations

Leaves are specialized according to where the plant lives. The different sizes, shapes, and structures of leaves allow plants to survive in specific environments. Let's review a few basics about leaves. You should remember these points from previous sub-sections:

Leaf Review

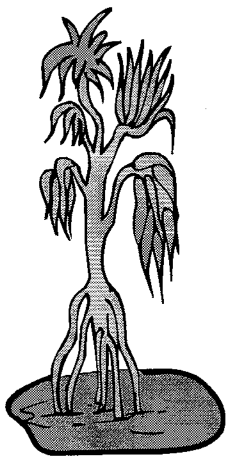
- The primary purpose of a leaf is to absorb light and carry out photosynthesis to make food for the plant.
- For photosynthesis, the leaf must be able to take in carbon dioxide and release oxygen.
- The plant loses water through its leaves during transpiration.
- The stomata allow leaves to take in carbon dioxide and release oxygen, and they control the amount of water that is lost through transpiration.

Many times, the shape and size of the leaves, the number and location of stomata, and the type of cuticle will indicate the type of climate in which a plant can grow. Most plants have stomata on the underside of the leaves where they are protected from the drying effects of wind and sun. Let's consider some specific examples.

Plants that live in habitats where water is scarce may conserve water by having smaller leaves, leaves coated with a thick waxy cuticle, fewer stomata, or stomata that are deep in the leaves. Most cacti growing in deserts have no true leaves. Chloroplasts and stomata are found on their stems, and the stomata are closed during the day and open at night when it is cooler. The spines of a cactus are modified leaves that have no chloroplasts and contain no stomata, so they reduce water loss to the plant. The spines also protect the cactus from herbivores, provide some shade to the plant, and help to channel rain water to the base of the plant.

For conifers, the thin leaves with their waxy coating are an adaptation that helps the plants to conserve water. Many conifers can live in fairly dry climates. They also tolerate colder temperatures. By keeping most of their leaves, these plants can begin photosynthesis very early in the spring when plants without leaves are still dormant. Since they don't have to produce an entire set of new leaves every year, they can grow in habitats where nutrients are not as available.

Where do you think you would find plants with really large, flat leaves? Large, flat leaves are well suited to collect sunlight in shady areas. If leaves are large, you would correctly assume that they have many stomata. This type of plant would not live in a dry environment or in direct sunlight where water loss would be great. It would most likely live in a shady, humid (or wet) environment.



Root Adaptations

Plants that live in the desert usually have very extensive root systems. They reach either deep or wide into the soil, and they have extra root hairs to quickly absorb the water after it rains.

Some plants have specialized roots due to their habitats. **Adventitious roots** grow where they are not normally found, such as the roots growing on the stem of poison ivy. Another kind of adventitious root is called a prop root. **Prop roots** are roots that are partially in the air and partially in the ground. You may have noticed prop roots growing on the lower part of corn stalks. These prop roots help to keep the stalks from getting blown over in the wind. Prop roots are most commonly found on plants that grow in swamps. For example, mangrove trees can grow in shallow water because their roots have air spaces in them to conduct oxygen to the roots that are under water.

Seed and Fruit Adaptations

The most abundant plant is the angiosperm, which reproduces using flowers. What has made them so successful and widespread? Angiosperms have several adaptations that have made them the dominant plants on earth today.

Angiosperms produce a wide variety of seeds "packaged" in a wide variety of fruits. Each type of seed or fruit is specifically adapted to help the angiosperm to disperse, multiply, and reproduce more plants.

Examples of Seed Adaptations

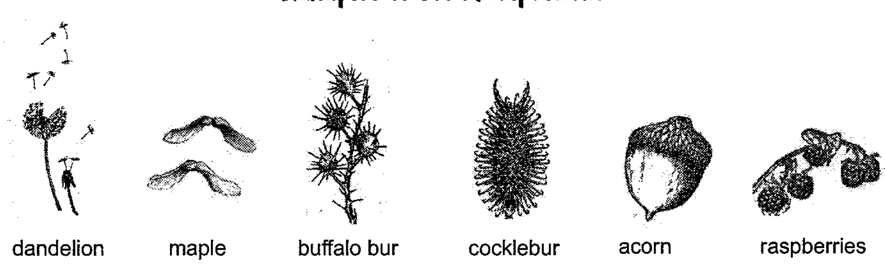
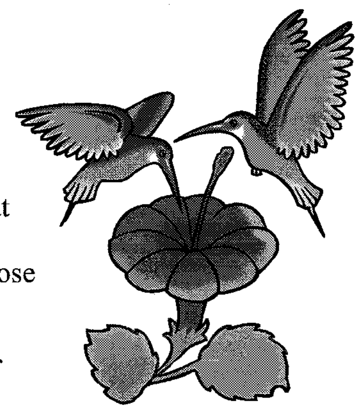


Fig. 16-13

The fruit surrounding the seed is there for a reason, and it's not always to provide nutrition for the embryo in the seed. Instead, the fruits allow dispersal of the seeds in many ways. For example, some fruits, such as blackberries, are eaten by animals. The seeds pass through the animal's digestive system without being harmed and then are eliminated in the animal's feces, usually at some distance from the parent plant. As a result, the new plant can grow where there is less competition for nutrients and water. Many seed nuts like acorns, pecans, and walnuts are important food sources for animals. Even though some of the seeds are eaten and digested, animals such as squirrels also bury some of the nuts but never retrieve them. Other seeds, such as those of maple trees, have lightweight "wings" that allow them to be carried away by the wind. Heavier fruits like coconuts can float in water. The thick shell allows the coconut to be carried in sea water for weeks to remote islands. Other seeds have a seed coat that is covered with tiny hooks, so the seeds are caught on the fur of animals and transported away from the parent plant. Some plants even have adaptations that fling mature seeds several feet away from the parent plant when the seed pod is touched even lightly. A few examples of seed adaptations can be seen in figure 16-13.



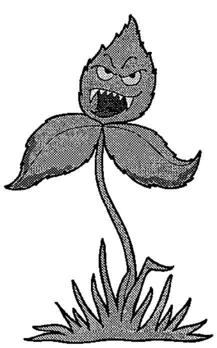
Flower Adaptations

Remember that flowers contain the gametes, or sex cells, for a plant. Also remember that many plants rely on pollinators to transfer pollen, which contains the male gametes. In order to transfer pollen, plants have flower adaptations to attract specific pollinators. Those adaptations include size and shape of the flower, the smell of the flower, the color of the flower, and the type of nectar produced by the flower. Nectar is a sugary substance produced by plants and often by the flower itself. It is used as food for different types of insects and animals. Pollinators are attracted to specific plants by these different flower adaptations. The pollinators get food, and the plant is able to transfer its pollen.

Consider a few examples: Snapdragon flowers are shaped in such a way that they open only under the specific weight of bumblebees, their primary pollinators. Bees, in general, see the colors purple and violet, so they are attracted to flowers of those colors. Moonflower plants have large white flowers with a strong, sweet scent that attract moths. Since moths are active at night, the moonflowers open in the late evening and stay open only at night. Other flowers stink like rotten meat to attract flies for pollination. Butterflies, on the other hand, have great vision but poor senses of smell. Some brightly colored flowers, especially red ones, attract butterflies as their main pollinators. Hummingbirds are also attracted to red flowers.

Chemical Adaptations

Sometimes it is a little harder to think about plants as having chemical adaptations, but many plants have secondary chemical compounds that help them to survive. These chemicals may allow plants to defend themselves, to keep from being eaten, to decrease competition, to attract pollinators, or to attract prey. Let's look at some examples of how plants use chemicals adaptations.



Skin Irritants: A well-known group of plants produce a chemical called **urushiol**, which is a skin irritant. What? You've never heard of it? Maybe you're more familiar with the common names for these plants, poison-oak and poison-ivy. They're not really a type of oak or ivy at all, but people who are allergic to urushiol are well aware that they don't want to pick the pretty green leaves of these plants!

Repellants and Deterrents: Other plants produce chemicals that repel other organisms. A common flowering plant called a chrysanthemum produces pyrethroids, which are used as insecticides. Many herbs, such as mint, basil, and citronella, produce oils that repel insects. Phenol compounds in leaves or in unripened fruit can cause a bitter taste that deters insects or animals from eating them.

Toxins: Some plants, even common ones, may contain chemicals that are quite toxic if eaten. Fruits like peaches and apricots contain cyanide, a type of poison, in their pits. Other trees, such as almond and cherry, can contain cyanide in their leaves if they become wilted. Plants like larkspur and hemlock produce alkaloids that are very toxic to many herbivores. You may have heard of Socrates who died by drinking hemlock tea. These alkaloids can also be passed on in cow's milk and cause problems for humans. Let's say a cow grazes on larkspur. The milk of that cow can then be contaminated with larkspur alkaloids. If a pregnant woman drinks the contaminated milk, it can cause birth defects in the infant.

Other Deterrents: Not all plant chemicals are meant to protect a plant from being eaten. Sometimes chemicals are used in other ways to help a plant survive. For example, many plants that live in the desert give off chemicals called phenols that keep other plants from growing too close to them. These chemicals increase a plant's chances of survival by eliminating competition for water and nutrients.