Big Idea

Plants reproduce either sexually or asexually, and hormones help regulate their growth, development, and response to their environment.

22.1 Plant Life Cycles

22.2 Reproduction in Flowering Plants

22.3 Seed Dispersal and Germination

22.4 Asexual Reproduction

22.5 Plant Hormones and Responses

Online Biology

ONLINE Labs
- QuickLab A Closer Look at Flowers
- Seed Germination
- S.T.E.M. Lab Seed Dispersal Prototype
- Investigating Plant Hormones
- Fruit Dissection
- Cotyledon Removal in Peanut Seeds

- Plant Propagation and Asexual Reproduction
- Monocot and Dicot Seed Structure
- Virtual Lab Exploring Plant Responses
- Video Lab Cultivation Techniques
How does a mothlike appearance help this plant?

Some pollinators are attracted to flowers that mimic insects. This orchid belongs to a genus commonly called “moth orchids.” Moths may be drawn to this flower and be dusted with pollen grains. The pollen then has a free ride to the next flower on the moth’s route. When pollen comes into contact with the female parts of another flower, the reproductive cycle begins.

**USING LANGUAGE**

**Describing Space** Understanding plant processes involves understanding what’s happening inside the plant. When you read about transport within the plant, look for words such as up and down that indicate where things are moving. This kind of language is called *spatial language* because it describes how things are moving through space.

**YOUR TURN**

Use spatial language to describe the following processes.

1. A train follows a path over the mountains.
2. Nutrients are transported through a plant.
All plants alternate between two phases in their life cycles.

MAIN IDEAS
- Plant life cycles alternate between producing spores and gametes.
- Life cycle phases look different among various plant groups.

**VOCABULARY**
- alternation of generations
- sporophyte
- gametophyte

**Connect to Your World**
The moth orchid flower mimics the shape of its pollinators, which are attracted to what they think is a potential mate. Pollination is a part of sexual reproduction in seed plants. But how do seedless plants, such as moss, reproduce? And what are the common features of all plant life cycles?

**MAIN IDEA**
Plant life cycles alternate between producing spores and gametes.

Recall that animals produce gametes—sperm and eggs—through meiosis. When a sperm fertilizes an egg, a new diploid organism is produced. Plants also produce gametes, but their reproductive cycle includes a few extra steps. Plants complete their life cycle by alternating between two phases. Together, these phases allow plants to reproduce sexually and disperse to new areas. One phase involves a diploid plant body that produces spores. Remember, diploid cells have two copies of each chromosome ($2n$). The other phase involves a haploid plant body that produces gametes. Haploid cells have one copy of each chromosome ($1n$).

This type of life cycle, which alternates between diploid and haploid phases, is called **alternation of generations**.

As shown in **Figure 1.1**, the diploid phase of a plant life cycle begins with a fertilized egg, called a zygote. A zygote divides by mitosis and grows into a mature **sporophyte** (SPAWR-uh-FYT), or spore-producing plant. A mature sporophyte has specialized cells that divide by meiosis to produce haploid spores. Recall that cell division by meiosis reduces the number of chromosomes in a cell by one-half.

A spore marks the beginning of the haploid phase of the plant life cycle. A spore divides by mitosis and grows into a mature **gametophyte** (guh-MEE-tuh-FYT), or gamete-producing plant. Specialized parts of a mature gametophyte produce gametes—sperm and eggs—through mitosis. When a sperm meets an egg, fertilization takes place, and the cycle continues with a new sporophyte.

**Analyze** Why must gametophyte cells divide by mitosis?
**MAIN IDEA**

Life cycle phases look different among various plant groups.

Different plant groups each have their own version of alternation of generations. The sporophyte and gametophyte generations look different for nonvascular plants, seedless vascular plants, and seed plants.

**Life Cycle of Nonvascular Plants: Moss**

Nonvascular plants are the only plants in which the gametophyte phase is dominant. In other words, the green, carpetlike plants that you might recognize as moss are gametophytes. If you look very closely, sometimes you can see the moss sporophytes. Moss sporophytes are stalklike structures that grow up from the gametophyte. As you can see in FIGURE 1.2, the moss sporophyte looks like a brown stem topped with a tiny cup called a capsule.

The capsule at the tip of the moss sporophyte contains spore-producing sacs called sporangia. When the spores are mature, the capsule opens and releases them. Spores allow seedless plants to disperse to new areas. If a spore lands in a favorable spot for growing, it can grow into a gametophyte.

A moss gametophyte produces gametes in special reproductive structures. Each male structure produces hundreds of sperm with whiplike flagella, and each female structure produces a single egg. When water is present, sperm swim toward an egg. Once a sperm fertilizes an egg, the sporophyte phase begins once again.

**FIGURE 1.2 MOSS LIFE CYCLE**

The gametophyte of mosses is the carpetlike plant that may be familiar to you. The sporophyte grows up from the gametophyte. A tiny cup called a capsule forms at the tip of each moss sporophyte. Spores form inside the capsule. When the spores are mature, the capsule opens and releases them. Spores can grow into new gametophytes when the environmental conditions are favorable.

**VOCABULARY**

The suffix –phyte comes from the Greek word phuton, meaning “plant.”

**CONNECT TO LIFE CYCLES**

Refer to Appendix B for a detailed view of the moss life cycle.
Life Cycle of Seedless Vascular Plants: Ferns

The sporophyte is the dominant phase for all vascular plants, including seedless vascular plants such as ferns. This means that the plants you recognize as ferns are sporophytes. If you look at the underside of a fern leaf, called a frond, you might see sori. Sori are clusters of sporangia, which are spore-producing sacs. As shown in Figure 1.3, sori look like brown dots on the fern frond. Spores are released from the sporangia when they are mature. If a spore lands in a favorable spot for growing, it can develop into a gametophyte.

A fern gametophyte is often called a prothallus. As you can see in Figure 1.3, a prothallus is a plant body about the size of your little fingernail. It anchors itself to the soil with tiny threadlike structures called rhizoids. The prothallus contains special reproductive structures that produce sperm and eggs.

When freestanding water is present, male structures release sperm. Sperm then swim toward an egg. When a sperm fertilizes an egg, a zygote forms on the prothallus. Remember that the zygote is the beginning of the sporophyte generation. The zygote grows above the prothallus, which eventually rots away. The mature sporophyte is the familiar fern plant. Newly forming fronds are called fiddleheads, and they slowly uncurl as they grow. Eventually, the sporophyte will produce spores on the underside of each frond, and the cycle begins again.

Life Cycle of Seed Plants: Conifers

The sporophyte is the familiar form for all seed plants. Unlike most seedless plants, seed plants produce two types of spores that develop into male and female gametophytes. Another difference between most seedless plants and seed plants is that the gametophytes of seed plants are microscopic.

A pine tree is a typical conifer sporophyte. If you look closely at a branch of a pine tree, you may notice two different types of cones. This is because cone-bearing plants have male and female cones. Female cones are usually larger and more scaly than male cones. They live and grow for several years. Each scale of a female pinecone has two ovules that produce spores. One spore in each ovule can develop into a microscopic female gametophyte, and the rest will die. Male spores are produced inside male cones, which live only for a few weeks. Male spores develop into pollen grains, which are the very tiny male gametophytes of seed plants.

As shown in Figure 1.4, male cones release clouds of pollen in the spring. When a pollen grain lands on a female cone, it sticks. Pollination occurs in a cone-bearing plant when a pollen grain reaches the small opening of an ovule. After pollination, eggs are produced inside the ovule and a pollen tube begins to grow from the pollen grain toward an egg. In pine species, it takes a year for the pollen tube to reach the egg, which is just millimeters away.
Two sperm also develop inside the pollen grain during this time. Eventually, these sperm travel down the pollen tube toward the egg. The sperm of seed plants do not have flagella, because they do not need to swim through water to reach an egg. One sperm may fertilize an egg, forming a zygote, which will develop into an embryo. Meanwhile, the ovule develops into a protective pine seed. Each scale of a female pinecone can be home to two developing pine seeds. Once the seeds are mature, the scales open up and release them. The life cycle then begins again with a new sporophyte—a pine tree seedling.

Contrast  What is the difference between how seedless plants and seed plants disperse to new areas?  TEKS 10B

22.1 Formative Assessment

REVIEWING MAIN IDEAS
1. What is the main difference between the two types of plant bodies involved in the alternation of generations?
2. What is the main difference between the gametophytes of nonvascular plants and those of seed plants?

CRITICAL THINKING
3. Apply  Why do seedless plants require freestanding water for sexual reproduction, while seed plants do not?  TEKS 10B
4. Infer  The scales of female pinecones produce a sticky substance. Describe the function this might serve.  TEKS 10B

CONNECT TO GENETICS
5. Draw a diagram to show how cellular division through meiosis results in the haploid spores of plants.  TEKS 6G
Reproduction in Flowering Plants

**KEY CONCEPT** Reproduction of flowering plants takes place within flowers.

**MAIN IDEAS**
- Flowers contain reproductive organs protected by specialized leaves.
- Flowering plants can be pollinated by wind or animals.
- Fertilization takes place within the flower.

**Connect to Your World**

When planning a garden, you might choose plants with sweet-smelling flowers that will add splashes of color to the space. But did you know that these same qualities can attract and guide animal pollinators? So don’t be surprised if you and the insects in your garden have a similar taste in flowers.

**MAIN IDEA**

**TEKS 10B**

**Flowers contain reproductive organs protected by specialized leaves.**

Look at a bouquet of flowers in various stages of bloom, and you will likely notice that different flower parts are arranged in layers. The outermost layer of a flower is made up of sepals. **Sepals** are modified leaves that protect the developing flower. They are often green but can also be brightly colored. The layer just inside the sepals is made up of **petals,** which are also modified leaves. Their bright colors often help attract animal pollinators. Monocot flowers, such as lilies, have sepals and petals that look the same. These structures are often called tepals. Flowering plants that are not pollinated by animals usually have very small sepals and petals, or they have none at all.

Some species have flowers with only male or only female structures, but the flowers of most species have both. A typical monocot flower is illustrated in **FIGURE 2.1.** A **stamen** is the male structure of a flower. Each stamen has a stalk called a filament that supports an anther. Anthers produce pollen grains, the male gametophytes. The innermost layer of a flower is made up of the female structure, called a **carpel.** Most flowers have several carpels fused together, forming a structure called a pistil. Each carpel is made of three parts. The tip, called the stigma, is often covered with a sticky substance that holds pollen grains when they land there. The style is a tube that leads from the stigma to the **ovary,** which is found at the base of a flower.

**Compare** What parts of conifers have functions similar to stamens?
Flowering plants can be pollinated by wind or animals.

When a pollen grain reaches the stigma of the same plant species, that flower has been pollinated. Pollination is a necessary step of sexual reproduction in flowering plants. You can often tell how a flowering plant is pollinated by looking at its flowers. Wind-pollinated species usually have small or inconspicuous flowers and produce large amounts of pollen. A lot of energy is required to produce so much pollen.

Many flowering plants are pollinated when insects, birds, or other animals visit flowers to collect pollen or nectar as a food source. In the process of feeding, an animal is dusted with pollen grains, as shown in Figure 2.2. As the animal searches for food in another flower, pollen from the first flower may brush against the stigma of the second flower. Because animal pollinators transfer pollen in this reliable way, pollination by an animal is more efficient than wind pollination. Animal pollinators are important factors in the success and diversity of flowering plants.

Infer Why is pollination more reliable by animals than by wind?

A Closer Look at Flowers

Dissect a flower to discover how its various structures aid in reproduction.

**PROBLEM** How do the parts of a flower aid in reproduction?

**PROCEDURE**

1. Locate the outermost layer of flower parts. These are the sepals. Draw and label the sepals to begin your flower diagram. Carefully remove the sepals.
2. Petals form the next layer of flower parts. Draw and label the petals in your drawing. Carefully remove each petal.
3. Now the stamens, the male flower parts, should be exposed. Add the stamens to your drawing and label them. Label an anther and a filament in your drawing. Remove the stamens.
4. The female flower part remains. Most flowers have several carpels fused together, forming a structure called a pistil. Add the carpel or pistil to your drawing. Label the carpel or pistil, stigma, style, and ovary.

**MATERIALS**

- flower
- colored pencils
- tweezers
- magnifying glass

**ANALYZE AND CONCLUDE**

1. **Identify** Write the function of the following structures next to their labels in your drawing: sepal, petal, anther, filament, stigma, style, ovary.
2. **Infer** Do flowers usually contain more stamens or carpels? Why do you think this is?
3. **Infer** What does the position of the anthers relative to the position of the stigmas suggest about how this flower is pollinated?
Fertilization takes place within the flower.

In flowering plants, as in all vascular plants, the sporophyte is the dominant phase. The parts of a flower that you have just learned about are all part of the sporophyte, while the gametophytes of flowering plants are tiny and enclosed within flower parts. **Figure 2.3** illustrates the life cycle of flowering plants.

**Production of Male Gametophytes**
Recall that anthers produce pollen grains, which are the male gametophytes of seed plants. Cells within the anthers divide by meiosis to produce four male spores. Each spore divides again, by mitosis, producing two haploid cells. These two cells, together with a thick wall that protects them, form a single pollen grain. Wind-pollinated plants have light, fine pollen grains that can be carried far by the wind. Pollen from wind-pollinated plants, such as ragweed, is the source of some outdoor allergies.

**Production of Female Gametophytes**
One female gametophyte can form in each ovule of a flower’s ovary. One cell in the ovule divides by meiosis to produce four female spores. In most flowering plants, three of these spores die. The nucleus of the last spore grows, dividing by mitosis three times, resulting in one spore with eight nuclei. Membranes grow between the nuclei to form seven cells. Together, these seven cells make up the female gametophyte, which is sometimes called an embryo sac. One large, central cell has two haploid nuclei, called polar nuclei. One of the other cells develops into an egg.

**Double Fertilization**
After pollination, one cell in the pollen grain grows into a pollen tube. This tube extends down the style toward the ovule. The other cell in the pollen grain divides by mitosis, producing two sperm. Both sperm travel down the pollen tube. One sperm fertilizes the egg. The other sperm combines with the polar nuclei in the embryo sac. This cell now has a triploid (3n) nucleus. It will become the _endosperm_, a food supply for the developing plant embryo. The process in which one sperm fertilizes an egg and the other forms a triploid cell is called **double fertilization**. Double fertilization happens only in flowering plants and gives them an advantage over cone-bearing plants. Cone-bearing plants produce a food supply for each egg before fertilization. However, if the egg of a flowering plant is not fertilized, the plant does not waste energy making an unneeded food supply.

**Summarize** What is the function of each sperm during double fertilization?
A tomato plant is a typical flowering plant. If the flower is pollinated and fertilization occurs, ovules will develop into seeds, and the surrounding ovary will develop into fruit.

**Male and female gametophytes** Tomato flowers have both male and female structures. Pollen grains, the male gametophytes, are produced in anthers. The flower’s ovary contains many ovules, which can each contain a female gametophyte.

**Pollination** A bee may transfer pollen grains from one flower’s anther to another flower’s stigma. One cell of a pollen grain divides to form two sperm. The other cell forms a pollen tube, down which the sperm travel.

**Seeds and fruit** Many seeds develop inside the ovary of each tomato flower. While the seeds develop, the ovary tissue matures into the juicy flesh of a tomato. A few seeds may find their way into the soil to grow into new tomato plants.

**Double fertilization** One sperm fertilizes the egg, which develops into an embryo. The other sperm unites with the polar nuclei to form the endosperm. The outer layer of the ovule becomes a protective seed coat.

Just before the stigma of a tomato plant becomes receptive to pollen, the style grows so that the stigma is higher than the anthers. What does this suggest about the way in which tomato plants are pollinated?

**Critical Viewing**
**Seeds and Fruit**

At fertilization, the next sporophyte generation begins. The ovule becomes a seed, which contains an embryo and a nutritive endosperm enclosed by a protective seed coat. Using the nutrients provided by the endosperm, the embryo develops one or two cotyledons, or seed leaves. Recall that monocots have one cotyledon and dicots have two cotyledons. Cotyledons sometimes provide nourishment for the new plant before it can begin producing its own food through photosynthesis.

While the seed develops, the surrounding ovary grows into a fruit. The development of a pumpkin fruit is shown in **Figure 2.4**. Remember, a fruit is the mature ovary of a flowering plant. You have probably eaten many fruits, such as apples, watermelons, and cherries. Many foods that you think of as vegetables, grains, nuts, or beans are also technically fruits. Sweet peppers, tomatoes, and cucumbers are fruits that contain many seeds. The shells of peanuts are also fruit, while the two peanut “halves” inside the shell are cotyledons.

Flowering plants that produce many seeds within one ovary have larger fruit. Pumpkin plants produce some of the largest fruits on record. If you have ever carved a pumpkin, you have actually removed the fleshy part of the mature ovary that surrounds hundreds of pumpkin seeds. As you will learn in the next section, a fruit aids in the dispersal of seeds to new areas. A seed has the ability to grow into a mature flowering plant.

**Contrast** What is the major difference between seeds of flowering plants and seeds of cone-bearing plants?

---

**22.2 Formative Assessment**

**REVIEWING MAIN IDEAS**

1. What are the functions of the four basic parts found in most flowers?  
   **TEKS** 10B
2. How does pollination occur in flowering plants?  
   **TEKS** 10B
3. What is double fertilization?  
   **TEKS** 10B

**CRITICAL THINKING**

4. Infer Why do wind-pollinated plant species generally produce more pollen than animal-pollinated species?
5. Analyze In flowering plants, which cells divide by meiosis to produce male and female spores?  
   **TEKS** 6G
6. Would brightly colored flowers and sweet, juicy fruits have been as beneficial to the earliest land plants as they are to modern flowering plants? Explain.

---

**SELF-CHECK Online**

Go Online  
HMDSScience.com
Seed Dispersal and Germination

**KEY CONCEPT** Seeds disperse and begin to grow when conditions are favorable.

- Animals, wind, and water can spread seeds.
- Seeds begin to grow when environmental conditions are favorable.

**MAIN IDEAS**

- Animals, wind, and water can spread seeds.

**Connect to Your World**

It’s lunchtime. How about a burrito stuffed with seeds and fruit? This burrito may not sound too appetizing—that is, unless you know that white rice and beans are seeds and tomatoes are fruits. Although burritos are cooked, many seeds and fruits we eat are not. Animals eat seeds and fruits for their nutritional benefits, and plants benefit by getting their seeds dispersed.

**Animals, wind, and water can spread seeds.**

You have learned that cone-bearing plants do not bear fruit, and their seeds are often spread by wind and gravity. The function of fruit in flowering plants is to help disperse seeds. Seed dispersal is important because a plant that grows right next to its parent may compete with it for space, sunlight, water, and nutrients. As shown in Figure 3.1, fruits come in a variety of different shapes and sizes, each of which is adapted to spread seeds to new areas.

Fleshy fruits, such as apples and berries, attract animals with their fragrant, nutritious offerings. When an animal eats the fruit, it digests the flesh. But the seeds, covered with a tough protective coat, pass through. Eventually, the animal eliminates the seeds from its digestive tract, along with a supply of fecal fertilizer that serves as a sprouting ground for the seedling. Some plants have fruits that can hitchhike a ride with an animal that is passing by. Burrs, for example, can cling to a passing animal and fall off later in a new area.

Seeds dispersed by wind often have fruits that act like parachutes or wings. Each clump of cotton from a cottonwood tree is actually a fruit with a seed attached. Some plants that grow near water produce fruits that float. Coconuts can travel thousands of miles across oceans and arrive on different islands.

**Analyze** Why is it important for a fruit to ripen when its seeds are mature?
Seeds begin to grow when environmental conditions are favorable.

After a parent plant releases seeds, it may be days, months, or years until the seeds begin to grow into new plants. In fact, scientists recently found a 2000-year-old seed from a now-extinct species of date palm tree in Israel. After they placed it in the conditions the tree needs to grow, the seed sprouted. How can the living embryo inside a seed last years without food or water?

Dormancy
For 2000 years, the embryo inside the date palm seed was in a state of dormancy. When a seed is dormant, the embryo has stopped growing. For some plant species, proper temperature, moisture, oxygen, and light levels are enough to end dormancy.

Other plant species have seeds that stay dormant even during good growing conditions. For example, strawberry seeds remain dormant until their seed coats are weakened in the digestive tract of an animal. This way, the seeds are not only carried far from the parent plant but they are also deposited with their own batch of fertilizer. Other seeds have waterproof seed coats that can be cracked only by winter ice. Then, in the spring, the embryo can begin to grow with less chance of freezing than if it had begun to grow in the fall.

Seed dormancy allows the next generation of plants to grow under favorable conditions. Inside the seed coat, an embryo can withstand extremes that would kill a young seedling. Gardeners contend with seed dormancy all the time. When a gardener turns over soil before planting, fresh air and sunlight can cause the buried seeds of unexpected plants to come out of dormancy.
Germination

Many types of seeds begin to grow when there are certain changes in temperature, moisture, or light levels. During germination, the embryo breaks out of the seed coat and begins to grow into a seedling, as shown in FIGURE 3.2. Germination begins when the embryo starts to take up water. Water causes the seed to swell and crack the seed coat. As the embryo grows, the embryonic root, called a radicle, breaks through the cracks. Water also activates enzymes inside the seed. Recall that enzymes are proteins that need specific conditions to speed up chemical reactions. These enzymes help break down material in the endosperm into sugars, which are moved to the growing embryo.

As the embryo continues to grow, a young shoot called the plumule eventually breaks through the surface of the soil. In most monocots, the cotyledon stays underground while the shoot grows upward. Some species of dicots have cotyledons that stay below ground, but the cotyledons of other dicots emerge above ground with the growing shoot. When leaves emerge from the shoot, they begin to make food through photosynthesis. Once photosynthesis begins, the young plant is called a seedling.

Sequence Which emerges first from a seed, a root or a shoot?

FIGURE 3.2 The embryonic root emerges from the seed. As the root continues to emerge, root hairs can be seen. The embryonic shoot and the cotyledons are revealed. The young plant is completely free of its seed coat.

Germination

22.3 Formative Assessment

REVIEWING MAIN IDEAS

1. What are three ways that seeds of flowering plants can be dispersed? 
   **TEKS** 10B

2. Why is it an advantage that most seeds go through a stage of dormancy before germination?

CRITICAL THINKING

3. Analyze How are enzymes involved in the process of germination? 
   **TEKS** 10B

4. Infer What is the adaptive advantage when water uptake causes a seed coat to crack?

CONNECT TO

ENZYMES

Recall from the chapter Chemistry of Life that enzymes are catalysts for chemical reactions in living things. Enzymes allow chemical reactions to take place under controlled conditions.

CONNECT TO

ADAPTATIONS

5. Some tropical plant species have fruit with air cavities that allow them to float. How might natural selection have led to this adaptation? 
   **TEKS** 1E
G O Online!

Went’s Experiment
Learn how Frits Went demonstrated that a chemical found in plant-shoot tips influences the direction of growth of the shoot.

Exploring Plant Responses
Explore how plants can react to light, gravity, and touch.

Green Growth

Plant Responses
Test for plant responses to different stimuli in this interactive investigation.
Fancy Plants!

Plants in Space
We often take for granted that shoots grow up and roots grow down. But what happens when you take a plant into space? How does this question affect space exploration?

Genetically Modified Foods—Do Potential Problems Outweigh Benefits? Catch the latest headlines about plants, including stories about genetically modified foods.
Asexual Reproduction

**KEY CONCEPT** Plants can produce genetic clones of themselves through asexual reproduction.

**MAIN IDEAS**
- Plants can reproduce asexually with stems, leaves, or roots.
- Humans can produce plants with desirable traits using vegetative structures.

**Connect to Your World**
Have you ever noticed that some plants, such as grasses and irises, grow in clumps? If you try to pull up a single iris, you’ll likely find that it is connected to others by underground stems. These clumps are often made up of clones, or genetically identical copies, of one individual parent plant.

**MAIN IDEA**
Plants can reproduce asexually with stems, leaves, or roots.

A combination of sexual and asexual reproduction helps plants populate a variety of environments. Sexual reproduction gives rise to genetic diversity, which allows a population to adapt to changing conditions. Asexual reproduction allows a well-adapted plant to make many copies of itself. Most plants have a way of cloning themselves through asexual reproduction.

Plants that can grow a new individual from a fragment of a stem, leaf, or root are reproducing by **regeneration**. For example, the prickly pear cactus shown in **FIGURE 4.1** has a jointed stem that looks like teardrop-shaped pads stuck together. If one of these “pads” falls off, it can take root and a new plant will grow.

**Vegetative reproduction** is a type of asexual reproduction in which stems, leaves, or roots attached to the parent plant produce new individuals. One stunning example of vegetative reproduction is a forest of aspen trees in Utah so large it would cover almost 100 football fields. The forest is actually 47,000 trunks growing from the roots of one parent plant.

Many plants have structures that are specifically adapted for vegetative reproduction.

- **Stolons** Some plants send out stems that grow horizontally along the ground. These stems are called runners, or stolons. At certain points on a stolon, roots and leaves are produced, and a new plant can grow. Strawberries reproduce almost exclusively in this way.

- **Rhizomes** Other plants, such as irises, can reproduce using horizontal underground stems called rhizomes. New plants grow from buds in the rhizome’s joints, even if separated from the parent plant.
• **Tubers** A potato is actually a tuber, an underground stem modified for storage. The “eyes” of a potato are buds that can sprout new plants, as shown in **FIGURE 4.2**.

• **Bulbs** Tulips, daffodils, and onion plants can all reproduce asexually with bulbs. Bulbs are underground stems surrounded by modified leaves adapted for storage and covered with a protective, papery skin. In favorable conditions, bulbs can divide to produce new plants.

**Analyze** What distinguishes regeneration from vegetative reproduction?

### MAIN IDEA

**Humans can produce plants with desirable traits using vegetative structures.**

Plant growers use a process called vegetative propagation to grow plants with desirable qualities, such as having no seeds or tolerance to frost. Vegetative propagation takes advantage of a plant’s ability to grow new individuals from fragments of a parent plant. For example, most apples and oranges that we eat come from propagated branches rather than trees grown from seeds.

Vegetative propagation can be achieved by a few common methods. Many houseplants, including African violets, are reproduced using cuttings from stems or leaves. If the cutting is buried in soil or placed in water, it will produce new roots, as shown in **FIGURE 4.3**. Cuttings are an easy way for horticulturists to produce new houseplants for sale to nurseries.

Fruit and nut tree growers usually use trees that have been produced by grafting, or joining vegetative structures from two or more plants. Grafting involves making an incision in the bark of one tree and attaching to it either a branch or a bud from another tree. Growers can graft a bud from a tree that produces the desired fruit or nut onto the trunk of a tree that has other desired qualities, such as disease resistance.

**Analyze** What is a benefit of producing houseplants through asexual reproduction?

### 22.4 Formative Assessment

**REVIEWING MAIN IDEAS**

1. How can a combination of sexual and asexual reproduction be beneficial for plant populations? [TEKS 10B]
2. How are plants’ abilities to reproduce asexually useful to humans?

**CRITICAL THINKING**

3. **Compare and Contrast** What are the differences and similarities between stolons and rhizomes?
4. **Infer** What is a benefit of using propagated branches to grow fruits?

**CONNECT TO GENETICS**

5. How does the genotype of an offspring produced through asexual reproduction compare with the parent plant’s genotype?
Main Idea: Plant hormones guide plant growth and development.

Main Ideas:
- Plant hormones regulate plant functions.
- Plants can respond to light, touch, gravity, and seasonal changes.

Connect to Your World:
If you have houseplants, you’ve seen how they grow toward the sunlight streaming through the nearest window. But without eyes, how do plants know where the light is? Plant hormones are involved in this process, which is only one of many ways that plants can respond to their environment.

Main Idea: Plant hormones regulate plant functions.

A **hormone** is a chemical messenger produced in one part of an organism that stimulates or suppresses the activity of cells in another part. In humans and other animals, hormones control functions vital to survival and reproduction. Hormones direct and regulate many of the same functions in plants. However, most plant hormones are very different chemicals from those in animals.

Some plant hormones are released in response to normal changes in the environment where the plant grows. Other hormones are released because of internal changes, as part of a plant's life cycle. Hormones have an influence when they move from the cells that secrete them to the cells for which they are targeted. Target cells have receptors that recognize the hormone. Most plant cells have receptors for many different hormones. When a hormone meets the right receptor, it triggers a response. Plant hormones are divided into several different groups based on their functions and chemical properties.

**Gibberellins**

Gibberellins (jihb-uh-REHL-ihnz) are plant hormones that produce dramatic increases in size. They are involved in ending seed dormancy, starting germination, and promoting the rapid growth of young seedlings. Gibberellins are also responsible for the large size of many fruits and the rapid upward growth of some flower stalks. For example, the agave shown in **FIGURE 5.1** can send a flowering stalk up to 12 meters (40 feet) tall in a few weeks. Grape growers often spray their vines with a gibberellin solution, which makes the fruits grow larger and elongates the stems in the bunches, making room for more grapes.
**Ethylene**
Put an apple in an airtight container for a day, and it will get soft and start to look rotten. The apple is being ripened abnormally fast by its own production of *ethylene* (ETH-uh-leen), a plant hormone that causes ripening and is naturally produced by fruits. Commercial growers can use ethylene to their advantage. Fruits such as apples that are shipped long distances must be kept in rooms where the ethylene is filtered out, or they may become overripe during the journey. Some fruits, such as the tomatoes in **FIGURE 5.2**, are picked before they are ripe. Once they reach their destination, they are exposed to ethylene gas, which makes them turn a ripe-tomato red. They may not taste so ripe, though, because this artificial ripening process does not bring out the same sugars that a vine-ripened tomato has.

**Cytokinins**
*Cytokinins* (sy-tuh-KY-nihnz) are plant hormones that stimulate cytokinesis, which is the final stage of cell division. They are produced in growing roots and developing seeds and fruits. They are also involved in the growth of side branches. This sideways growth is called lateral growth. Commercial florists make use of another property of cytokinins—they slow the aging process of some plant organs. For example, leaves dipped in a cytokinin solution stay green much longer than normal.

**Auxins**
*Auxins* (AWK-sihnz) are plant hormones involved in the lengthening of plant cells produced in the apical meristem, or growing tip. Auxins stimulate growth of the primary stem, preventing growth of new branches. Gardeners can use this property of auxins to control branching patterns by cutting off the tip of a growing stem. With no growing tip, there is less auxin in the stem, and side branches are encouraged to grow. Conversely, high concentrations of auxins can prevent plant growth altogether, particularly in the roots. For this reason, auxins are a common ingredient in herbicides, chemicals used to kill unwanted plants.

The lengthening of cells triggered by auxins also controls some forms of *tropism*, the movement of a plant in response to an environmental stimulus. For example, if a stimulus such as light hits one side of a stem, auxins will build up in the cells on the shaded side of the stem. These cells then elongate, or grow longer, causing the stem to bend toward the light. As you will soon learn, auxins have different effects in the cells of different plant organs.

**Apply** If you started your own plant nursery, what are two ways in which you could use different plant hormones to your advantage?
Plants can respond to light, touch, gravity, and seasonal changes.

If you’ve ever touched a hot pan in the kitchen, you likely responded by pulling your hand away quickly. And if you’ve ever been outside on a very hot summer day, you may have responded by moving to a shady spot. While plants cannot uproot themselves and change locations, they have other ways of responding to their environment.

**Phototropism**

When light hits a plant stem, it causes auxins to build up on the shaded side. Remember that in a stem, auxins cause cell elongation. As described earlier, cell lengthening on the shaded side of a stem causes the stem to bend toward the light. This tendency of a plant to grow toward light is called phototropism. If you grow a plant in a space with a light source, that plant will lean toward the light through the process of phototropism, as shown in FIGURE 5.3. Let’s say you turn that plant around so that it’s pointing away from the light. If you come back in a few days, you will likely find the plant growing in the direction of the light again.

**Thigmotropism**

Many plants also have a response to touch, called thigmotropism. This quality is apparent in climbing plants and vines. Tendrils emerge from the leaf base of these plants and grow in coils around anything they touch. In these curling “fingers,” contact with an object triggers the same pattern of cell growth that is found with other tropisms. Plants are sensitive to many kinds of touchlike stimuli. For example, a plant regularly exposed to winds on a hillside will grow as if it is being pushed in the direction of the wind. Repeatedly touching a young plant can even stunt its growth.

**Gravitropism**

When a seed germinates underground, the root grows downward into the soil, and the shoot grows upward toward the soil surface. This up-and-down growth of a plant is called gravitropism, because the plant is responding to Earth’s gravitational pull. Downward growth is positive gravitropism because the growth is in the direction that gravity pulls. Upward growth is negative gravitropism because it is growth against the force of gravity.

Auxins play a part in gravitropism, which is more complex than phototropism. Root growth is stimulated by low levels of auxin, but is slowed down by high levels of auxin. Auxins build up on the lower side of horizontally growing roots so that the upper side grows faster and the root grows downward. At the same time, high levels of auxin, which stimulate shoot growth, build up in the lower side of the stem. This buildup causes the stem to grow upward.
Rapid Responses
Some plants have very rapid responses that do not involve growth. These rapid responses are often adaptations that help protect plants from predators. For example, the mimosa, or sensitive plant, quickly folds its leaves together a few seconds after being touched. A few plants are quick enough to capture insects for a meal. The Venus flytrap shown in Figure 5.4 can close its leaves on an unsuspecting insect in less than a second. Scientists recently discovered that when the leaves are touched, water rushes to the cells at their bases, changing their curvature and snapping the trap shut.

Photoperiodism
What triggers a shrub to flower or a tree to drop its leaves? Plants take signals from the changing lengths of day and night throughout the year, in a response called **photoperiodism**. Some plants keep very accurate clocks when it comes to the amount of daylight or darkness in a 24-hour period. In fact, some plants that flower while the days are short, such as poinsettias, will not bloom if there is one extra minute of light in the evening.

Shorter days and longer nights during the fall help trigger the leaves of many deciduous trees to change color. This response is part of the preparation for winter, when these trees enter a stage of dormancy. Winter dormancy in plants is functionally similar to the hibernation of many animals during the winter months. With less rainfall and less direct sunlight, it is more energy-efficient for these plants to shut down and rely on reserved sugars than it is for them to photosynthesize. Leaves therefore begin to die in the fall. Chlorophyll, the pigment that gives leaves their green color, breaks down. Once the chlorophyll is gone, the remaining leaf pigments become visible and new pigments are produced. Water and nutrients are drawn out of the leaves for the rest of the tree to use during the winter, and the leaves eventually fall off of the tree.

Apply What stimulus causes each of the following tropisms: phototropism, gravitropism, thigmotropism? TEKS 10B

---

22.5 Formative Assessment

**REVIEWING MAIN IDEAS**

1. Describe two plant **hormones** that regulate plant growth and development.
2. Name and describe five ways in which plants can respond to their environment. TEKS 10B

**CRITICAL THINKING**

3. Apply A vine grows sideways, twisting along a railing. What type of **tropism** is this plant exhibiting? TEKS 10B
4. Apply If you want full, bushy plants, which part of the plant would you trim to control **auxin** production in your favor?

**ADAPTATIONS**

5. Many trees in temperate climates lose their leaves before the long, cold winter. How is this ability an adaptation for these trees?
22 Summary

KEY CONCEPTS

22.1 Plant Life Cycles
All plants alternate between two phases in their life cycles. This type of life cycle is called alternation of generations, and it involves a diploid (2n) and a haploid (1n) phase. The diploid phase, called the sporophyte, produces haploid spores through meiosis. A spore develops into a gametophyte, which is also haploid. The gametophyte produces gametes—sperm and eggs—by mitosis. A fertilized egg can develop into a new sporophyte. Sporophyte and gametophyte phases look different among nonvascular, seedless vascular, and seed plants.

22.2 Reproduction in Flowering Plants
Reproduction of flowering plants takes place within flowers. Flowers consist of reproductive organs that are surrounded by specialized leaves called sepals and petals. Brightly colored petals can attract animal pollinators. A flower is pollinated when a pollen grain reaches the tip of the female reproductive structure. One cell in the pollen grain grows into a pollen tube, and the other cell divides to form two sperm. In a process called double fertilization, one sperm fertilizes an egg, produced in the flower’s ovary, while the other helps produce the endosperm, which will nourish the developing embryo.

22.3 Seed Dispersal and Germination
Seeds disperse and begin to grow when conditions are favorable. The function of fruit in flowering plants is to help disperse seeds. Many seeds go through a stage of dormancy, or nongrowth, while environmental conditions do not support growth. Germination is the process by which the embryo breaks out of the seed coat and begins to grow into a seedling.

22.4 Asexual Reproduction
Plants can produce genetic clones of themselves through asexual reproduction. Some plants can grow a new individual from a fragment of a stem, a leaf, or a root in a process called regeneration. Vegetative reproduction involves new individuals growing from a stem, a leaf, or a root attached to the parent plant. Humans can produce plants with desirable traits by propagating plants asexually.

22.5 Plant Hormones and Responses
Plant hormones guide plant growth and development. Four major groups of plant hormones are gibberellins, ethylene, cytokinins, and auxins. Auxins are involved in the lengthening of plant cells that control several forms of tropism, including responses to light and gravity. Some types of plants can also respond to touch and seasonal changes in the lengths of day and night.

READING TOOLBOX

Concept Map Summarize what you know about plant responses using a concept map.

Cycle Diagram Draw a cycle diagram to show the alternation of generations in flowering plants. Include sketches of the sporophyte and gametophyte, using labels specific to flowering plants.
Reviewing Vocabulary

Label Diagrams
In your science notebook, write the vocabulary term that matches each item that is pointed out below.

1. sepal
2. petal
3. stamen
4. carpel

Reviewing MAIN IDEAS

14. What types of cellular division are involved in the alternation of generations? **TEKS** 6G, 10B

15. What is a major difference between the gametophyte generations of moss and pine trees?

16. How can brightly colored petals aid in the reproduction of flowering plants? **TEKS** 10B

17. What characteristic might be a clue that a flower is wind-pollinated? Explain your answer.

18. Name the two structures in the female gametophyte that are fertilized in the process of double fertilization.

19. How does seed dispersal aid in the survival of plant offspring?

20. People may enjoy a spring season with relatively little rain. How might this type of spring weather affect seeds that were dispersed during the previous fall?

21. Discuss the role of enzymes in the development of an embryo during germination.

22. How can the ability to produce both sexually and asexually allow plant species to populate a variety of environments? **TEKS** 10B

23. Why is plant propagation an efficient way for people to produce new plants?

24. A well-known disease of rice plants causes rice seedlings to grow to several times their normal size and then die. Which of the major plant hormones is likely involved in this disease? Explain your answer.

25. Name four types of stimuli to which plants are capable of responding. **TEKS** 10B
Critical Thinking

26. **Compare and Contrast** What are some differences and similarities between the life cycle of a seedless plant and that of a seed plant, such as a conifer? [TEKS 10B]

27. **Infer** Female pine cones have scales that open, close, and then open again. These three phases correspond with three specific events in the conifer reproductive cycle. What three events might trigger these phases in female cones? [TEKS 10B]

28. **Predict** Most people cook potatoes soon after they buy them at the store. What will happen to a potato that is left sitting on the kitchen counter for a few weeks? Explain your answer.

29. **Infer** A homeowner is planting a new garden and buys some plant seeds. The plant shop owner offers to sell her regular seeds or specially treated seeds that will germinate faster. How may these special seeds have been treated?

30. **Analyze** A kiwi fruit was purchased at the store, but it was not ripe enough to eat. It was placed in a sealed container along with an apple. Several days later, the kiwi was ripe. Explain how this likely happened.

31. **Analyze** Four-o’clock flowers bloom late in the day, as their name suggests. The flowers stay open all night and close the following morning. What type of response is the flower demonstrating? Explain your answer. [TEKS 10B]

Interpreting Visuals

Use this cartoon to answer the next two questions.

“*I’ll say he’s busy. He has hundreds of frequent flower miles.*”

source: www.CartoonStock.com

32. **Apply** Name the service that these bees have performed for the flowering plants.

33. **Summarize** Describe how this process occurs as bees fly from flower to flower. [TEKS 10B]

Analyzing Data Analyze an Experimental Design

Students are testing the effect of light on the germination of millet seeds. The setup for their experiment is shown in the table below. The students observe and track seed development for one week. Use the data to answer the next four questions.

<table>
<thead>
<tr>
<th>MILLET SEED EXPERIMENT SETUP</th>
<th>Tray A</th>
<th>Tray B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeds</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Water</td>
<td>25 mL per day</td>
<td>25 mL per day</td>
</tr>
<tr>
<td>Location</td>
<td>on a shelf beneath a grow light</td>
<td>on a shelf in a dark refrigerator</td>
</tr>
</tbody>
</table>

34. **Analyze** What are the dependent and independent variables in this experiment?

35. **Analyze** What is the control in this experiment?

36. **Evaluate** Which part of the experimental design is flawed?

37. **Experimental Design** What changes would you make to the experimental design to collect valid results?

Making Connections

38. **Write a Blog** Imagine that you are a seed that is about to come out of dormancy. Write a blog describing your experiences as you germinate. Be sure to include the following terms: dormancy, germinate, seed coat, radicle, plumule, cotyledons, and seedling. [TEKS 10B]

39. **Analyze** Look at the moth orchid shown in the chapter opener. Does this photograph show the gametophyte or sporophyte generation? Explain your answer.
MULTIPLE CHOICE

A strawberry farmer divides a large field into three sections: the first bordering a grove of trees, the second in the middle, and the third bordering an interstate. Each section is treated with a different insecticide to determine effectiveness. Which of the following is not a design flaw of the experiment?

A. No part of the field was used as a control.
B. Fumes from the interstate might kill pests in the third section.
C. The trees might harbor animals that eat pests in the first section.
D. The same type of strawberries were grown in each section.

Scientists are developing a molecule that will slow down the rate of fruit ripening to a few days. Based on the preceding graph, which molecule are they most likely to choose?

A. A
B. B
C. C
D. D

Suppose that scientists are studying the activity of enzymes that are involved in ending seed dormancy. Which statement is best supported by their data?

A. The enzyme is ineffective below 0°C.
B. Temperature does not affect enzyme activity.
C. Enzyme activity peaks at around 5°C.
D. The enzyme is most active in warm weather.

According to one hypothesis, auxins may cause a change in pH that results in the cell wall becoming more flexible. Then, the cell lengthens due to pressure from an organelle. Which organelle is most likely exerting this pressure?

A. vacuole
B. ribosome
C. nucleus
D. chloroplast

Think about the properties and functions of each organelle listed as a possible answer. Which of these is most likely to expand in size?
Genetically Modified Foods—Do Potential Problems Outweigh Benefits?

There is a food fight going on, and you may need to choose a side. Genetically modified (GM) foods have been on the market since the early 1990s. Today, most foods in the United States have GM ingredients. But the wide availability of GM food raises concerns about its effects on our health and on the environment. Should we continue to use GM foods?
New Technology, Old Idea

GM plants have genes that have been artificially introduced into the plant’s genome. This technology gives plants a new characteristic, such as a new color or different flavor. To date, most genetically engineered foods have been bred for disease resistance. GM crops on the market include wheat, rice, corn, soybeans, potatoes, tomatoes, and cantaloupes.

Genetic engineering is a fairly new process, but plants have been modified through careful selection and cross-breeding for thousands of years. In fact, many experts argue that genetic engineering of crops is just a faster and more precise method of selective breeding.

The Green Revolution

In the 1960s, scientist Norman Borlaug and a team of researchers used cross-breeding techniques to develop a new strain of wheat. The new strain produced two to three times as much wheat as traditional varieties, and resisted many types of insects and diseases. Widely planted, these new varieties changed Mexico from an importer of wheat to an exporter within 20 years. Borlaug and his team began shipping the new strain of wheat to India and Pakistan. Both countries quickly doubled their wheat production. This scientific advance, led by Borlaug, became known as the Green Revolution and drastically improved crop yields worldwide. For his work, Borlaug received the Nobel Prize in 1970. Borlaug supported the genetic engineering of crops and viewed it as the next wave of the Green Revolution.

Benefits of GM Crops

GM crops have the potential to improve nutrition worldwide. For example, researchers have developed a GM variety of rice, called “golden rice,” that is high in vitamin A. Half of the world’s population relies on rice as the main part of their diet. Non-modified rice lacks vitamin A, however, and vitamin A deficiency in humans can cause blindness and sometimes death. Golden rice could prevent millions of deaths of young children in developing countries every year.

Gene Gun

Genetic engineers use various ways to insert new genes into host cells. For plant cells, which have thick cell walls, one of the best ways to put foreign DNA into the cell is to actually shoot it through the plant tissue using a gene gun.

1. A researcher coats gold or tungsten particles with DNA and places them on the end of a microscopic plastic bullet.
2. The plastic bullet is placed in the gene gun and directed toward the target plant tissue.
3. A burst of helium propels the bullet to the end of the gun. The gold particles containing the DNA are released, while the bullet remains in the gun.
4. Particles enter the cytoplasm of some of the cells in the target tissue. DNA is released from the gold particles and moves into the plant cell’s nucleus, where it ultimately combines with the cell’s DNA.
Potential Hidden Costs of GM Crops

Opponents of genetically modified foods argue that it is impossible to predict exactly how the new crops—sometimes called “Frankenfoods”—will affect ecosystems. Two major concerns are herbicide-resistant weeds and pesticide-resistant pests, which create new ecological problems.

When herbicide-resistance genes are inserted into crop plants, the weeds are easily killed by herbicides while the crops remain unaffected. But pollen from plants can be carried by the wind for long distances, and seeds from GM crops could be accidentally dispersed outside their intended locations, causing the rise of “superweeds.” In the 1990s, several companies produced crops that were resistant to the herbicide Roundup. However, many weeds, such as pigweed, soon evolved resistance to Roundup. Pigweed can grow as much as three inches per day. It chokes out farm machinery and smothers crops.

GM plants with the bacterial gene Bt produce an insecticidal toxin that is harmless to people. However, insects that evolve resistance will reproduce, increasing the population of pesticide-resistant pests.

Unanswered Questions

Genetically modified crops are no longer considered new, but some questions about them remain. Many of the most important research questions concern the long-term effects of GM crops on human health and the environment. Specific questions include:

- How will vitamin levels in genetically modified crops differ from those in their traditional relatives?
- What adverse effects might GM crops, such as those engineered to produce medicines, have on wildlife?

Other promising uses of genetic engineering include growing fruits and vegetables that produce vaccines in their tissues. Carrying important vaccines in food might eventually make shipment, storage, and administration of medicine easier worldwide.

GM crops benefit farmers because they take less time, water, and land to grow. Some GM plants can grow in poor soils or withstand drought, cold temperature, and insect damage. These crops lessen the need for pesticide, herbicide, or fertilizer. Consumers benefit from GM produce that stays fresh longer.

Read More >> at HMDScience.com

Research Engineer in Action

**DR. TONG-JEN FU**

**TITLE** Research Engineer, Food and Drug Administration

**EDUCATION** Ph.D., Chemical Engineering, Pennsylvania State University

Dr. Tong-Jen Fu is a research engineer with the U.S. Food and Drug Administration (FDA), where she evaluates the methods currently used by scientists to determine the allergic potential of GM foods. She and other researchers are trying to understand exactly what makes substances in food cause allergic reactions.

One of the concerns of GM food is its potential to increase allergies in humans. Many proteins can potentially be an allergen—that is, cause an allergic reaction in some people. Since genetic engineering introduces new proteins into crops, concerns have been raised that unexpected allergies may arise. GM foods could trigger allergies by including proteins already known to cause a reaction, or by introducing completely new allergy-causing proteins—such as those from bacteria—into the food supply.

Researchers use extensive safety tests to determine whether a genetically modified food is likely to cause an allergic reaction. If any of these tests has a positive reaction, the GM food is not likely to be commercially produced. These tests include checking the amino acid sequences of introduced proteins against those of known allergens and testing whether the introduced proteins are resistant to digestion.

Read More >> at HMDScience.com

Read More >> at HMDScience.com