chapter 15

Agricultural Biotechnologies

Sections

What You'll Learn

- **List** highlights in the evolution of farming.
- **Explain** how animals are traditionally bred.
- **Discuss** methods used in plant and animal maintenance.
- **Discuss** genetic engineering in agriculture.
- **Describe** the cloning process.
- **Identify** the roles of the USDA, FDA, and EPA in approving new agricultural technologies.
- **Discuss** biosynthesis and pharming.
- **Explain** the purpose of bioremediation.
- **Describe** different kinds of artificial ecosystems.

Explore the Photo

Mechanical Farm Hand One driver runs this harvester that picks and separates cotton for cotton bales. *What other things might advanced machines do to be more efficient?*

Launch the TECHNOLOGY LAB

Construct a Hydroponic System

At the end of this chapter, you will be asked to build and operate a hydroponic system used to grow plants. Get a head start by using this checklist to prepare for the Technology Lab.

PROJECT CHECKLIST

- ✓ Go to the Internet and do a search using the keywords *hydroponic systems*. Find an example of a simple system.
- ✓ Your teacher will provide many of the materials needed for the lab, but you can begin to collect markers, water, and a pH testing kit.
- ✓ Ask your teacher to review safety procedures to follow before doing this lab.

Andy Sacks/Getty Images

section 15.1

Farming Technologies

Reading Guide

Before You Read **Connect** Have you heard the word *hybrid*? What might it mean?

Content Vocabulary

- hybrid
- irrigation
- fertilizer
- monoculture farming
- dehydrate

Academic Vocabulary

You will see these words in your reading and on your tests. Find their meanings at the back of this book

- monitor
- income

Graphic Organizer

Draw the section diagram. Use it to organize and write down information as you read.

Outcomes of Farming

	Fertilizers	Antibiotics
Positive		Promotes Growth
Negative		

Go to **glencoe.com** to this book's OLC for a downloadable graphic organizer and more.

TECHNOLOGY STANDARDS

STL 7 Influence on History

STL 13 Impact of Products & Systems

STL 15 Agricultural & Related Biotechnologies

ACADEMIC STANDARDS

Science

NSES Content Standard F Science and technology in society

Mathematics

NCTM Problem Solving Solve problems that arise in mathematics and in other contexts.

STL *National Standards for Technological Literacy*

NCTM *National Council of Teachers of Mathematics*

NCTE *National Council of Teachers of English*

NSES *National Science Education Standards*

NCSS *National Council for the Social Studies*

Agriculture's Biotechnology Roots

Why is agriculture classified as a biotechnology?

Agriculture is the science of cultivating the land to produce crops and raise livestock. As a biotechnology, it uses knowledge of biology to increase crop yields and improve livestock health. It also uses industrial processing to convert living organisms into processed foods, textile fibers, fuels, and medicine.

New agricultural biotechnologies use genetic engineering to modify species. These new animals and plants become healthier foods. They also become living chemical factories that produce medicines, plastics, and fuels, and can digest oil spills.

As You Read

Predict How has farming changed since ancient times?

The Evolution of Farming

What tools and equipment did the first farmers use?

Cave dwellers obtained food by hunting and gathering. They traveled with the seasons and followed animal migrations. Eventually they began to domesticate animals and plant crops. They worked the soil with sticks and primitive tools. Then, around 3000 B.C.E., people developed the plow, which enabled them to work larger areas of land more efficiently.

The Industrial Revolution produced a real revolution in agriculture. After 1750, people began to leave the countryside to work in factories in the cities. With fewer workers available, farmers began to rely on machinery to help them prepare the soil, plant, and harvest crops.

The tractor was introduced to farming at the beginning of the 20th century. Now, at the start of the 21st century, it is undergoing important changes. It is becoming part of the Information Age. Some tractor models are equipped with robotic control systems. Guidance information comes from the Global Positioning System (GPS). GPS is a series of satellites orbiting the earth that tell the farmer where the tractor is located. Computers also help **monitor** crop quality and make planting the next crop more efficient.

Russ Munn/AGStock USA, SuperStock, Inc./SuperStock

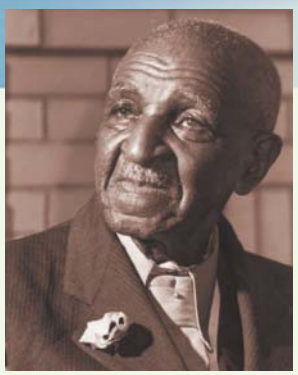
Low-Tech Plows Early plows were usually guided by a farmer who walked behind the animals that pulled the plow through the soil. *Why is the plow considered to be such a critical farming invention?*

Reading Check

Name What was the name of the era when people began to work in factories?

Soil Mapping The GPS system, combined with a computer on board the tractor, allows the farmer to map each field to determine how much fertilizer and pesticide each area will need before planting. *How will this knowledge save the farmer time and money?*

Tech Stars



George Washington Carver

Agricultural Chemist

George Washington Carver was born into slavery on a Missouri farm in 1864. After the Civil War, when slavery was abolished, Carver pursued an education in horticulture. He eventually earned his master's degree. His research focused on developing byproducts from plants such as peanuts, soybeans, pecans, and sweet potatoes. He also researched improved soil conditions for agricultural purposes.

Among Carver's many contributions were recipes and improvements to hundreds of byproducts. These included cereals, oils, dyes, ink, instant coffee, shaving cream, carpeting, synthetic marble, and food substitutes. He owned three U.S. patents.

His Epitaph The words that are inscribed on his memorial say, "He could have added fortune to fame, but caring for neither, he found happiness and honor in being helpful to the world."

English Language Arts/Writing Write an article for your school newspaper discussing at least five items that you use on a daily basis that are byproducts from plants.

Go to **glencoe.com** to this book's OLC to learn about young innovators in technology.

Breeding Plants and Animals

How are plants and animals traditionally bred?

The first farmers probably saved seeds from wild plants and planted them. Over time, seeds from crops with desirable characteristics, such as hardiness or tastiness, were prized. Eventually certain plants were crossed with other plants to improve crop quality. Pollen from one plant was transferred to the flowers of another plant. When it worked, the seeds produced plants with the desired characteristics.

The first livestock were found in the wild and raised for human needs. Herders learned to select the best mates for breeding bigger, healthier, and easier to control animals. When animals of two different species or varieties are bred, the resulting animal is called a hybrid.

These breeding processes, though controlled by humans, are actually natural processes. The animals themselves have not been altered. More advanced breeding technologies are discussed in Section 15.2.

Reading Check **Identify** How did some plants crossbreed with other plants?

Frank Lukasseck/age fotostock, Bryan Mullennix/age fotostock RF

Plant and Animal Maintenance

What is necessary to maintain plants and animals?

After seeds have been planted and animals have been purchased or bred, they must be cared for, or maintained. They need water and food, and conditions have to be right for their growth. They must also be kept free of disease.

Irrigation

Without water, rich farm soil quickly dries out and destroys the crops. Famines have been caused by too little rainfall. Too much water causes flooding, which can also destroy crops.

To offset dry spells, modern farms use **irrigation** systems to pump and sprinkle water where it is needed. To offset wet spells, the land on these farms is graded so that excess rainwater will flow away from the crops into canals and ponds.

Fertilizing

When a plant grows, it takes nutrients out of the soil. If you plant the same crop on the same plot of land repeatedly, crop yields will decrease. So, before the development of modern agriculture, farmers learned to rotate their crops. They might plant corn one year in a field and soybeans in that same field the next year. Some fields were left unplanted.

Then, in 1912, Fritz Haber, a German chemist, developed a process for making nitrogen fertilizer. **Fertilizer** is a chemical compound that restores nutrients to the soil. Mixing fertilizer that contains nitrogen, phosphorus, and potassium into the soil makes it possible to grow plentiful crops year after year without rotating them in the same fields.

A Mule is Not a Donkey A mule is a cross between a horse and a donkey. It is a hybrid animal. *Before off-road vehicles were invented, why did people prefer to ride mules instead of horses as pack animals in hot, mountainous terrain?*

Water When Needed This tractor irrigation system is mobile. A farmer can quickly set it up to provide watering where needed. *When would an underground sprinkler system that pipes water to certain locations be more practical?*

Ethics in Action

Organic Foods

More and more people are concerned about the food they eat. They want groceries that do not contain antibiotics, pesticides, or GMOs, which are genetically modified organisms. So, many consumers are turning to fresh food grown by organic farmers.

Going Organic Organic farmers let animals roam freely. They use natural feed and no antibiotics. Instead of using synthetic fertilizers, they use manure. By bringing back traditional techniques like crop rotation, farmers do not have to use pesticides.

English Language Arts/Writing

Good Business Pretend you and a partner are selling apples. Your partner wants to say they are "organic," even though they are not completely organic. By doing this, you can sell them at a higher price.

1. Think about what you would say to your partner and why.
2. Write a short role play for you and your partner.
3. Present your role play to the class.

Fertilizers have made monoculture farming cost effective. **Monoculture** is a farming practice that involves growing only one crop or one plant species on many acres of farmland.

Pros and Cons of Fertilizing

Fertilizer has caused some unexpected negative results. It has produced big crops of weeds. Runoff of fertilizer into lakes and oceans has affected wildlife and increased the growth of algae. On a monoculture farm, pests or disease can quickly spread through the single crop and completely destroy it, which negatively affects the farmer's income.

Use of Antibiotics

To keep costs low, many farm animals are raised in crowded conditions where diseases can spread very quickly. To prevent disease and promote animal growth, farmers started to give healthy animals antibiotics.

This technology, too, had negative outcomes. By giving antibiotics to healthy animals, small numbers of mutated pathogens that were antibiotic-resistant survived and multiplied. Now antibiotic-resistant pathogens cause diseases that can no longer be cured by using older, less expensive, antibiotics.

The overuse of antibiotics by the general population, plus ingesting antibiotics when eating meat and poultry, helped create diseases that are resistant to antibiotics. Also, antibiotics in animal waste have entered the soil and waterways.

Reading Check **List** What are three important processes for growing plants?

From Farm to Consumer

What processes are used during harvesting?

At harvest time, large machines go into the fields and pick cotton, corn, beans, and other crops. Waste, such as stalks, is separated out, and the rest is sent to a market or a factory for processing. Livestock, such as hogs and cattle, are shipped to processing plants where they are butchered for meat.

Cold Processing

Today most food is processed in very cold warehouses or factories to keep it fresh. Many food products are shipped in refrigerated trucks and stored in refrigerated cases at supermarkets. Freezing is also used for some food products.

Dehydration

Some foods, such as rice and other grains, must be kept very dry to maintain freshness. Other foods are **dehydrated**, which means the water they normally contain is removed. For example, raisins are dried grapes.

section 15.1 assessment

After You Read — Self-Check

1. Define a hybrid.
2. Explain irrigation.
3. Name at least three methods for preserving foods.

Think

4. Discuss how tractors have become part of the Information Age.

Practice Academic Skills

English Language Arts/Writing

5. Write a short report about the possible solution to the overuse of antibiotics in meat-producing animals. Discuss how farmers might continue to keep their animals disease-free and also promote growth.

STEM — Mathematics

6. Jennifer wanted to plant a vegetable garden. She made 4 rows of plants. In the first row, she planted 8 cucumbers. In the second row, she planted 12 carrot plants. She planted 5 eggplants in the third row and 3 tomato plants in the last row. If the seeds for each plant were sold in packs of 20, how many extra seeds would she have?

Math Concept **Choosing Operations** Some problems can be solved in more than one way. Think about the operations you will use to solve the problem and the order in which you will use them.

1. First, use multiplication to find out how many seeds Jennifer had in all. Then add up the number of seeds she used and subtract the sum from the total.
2. Another way to solve this problem is to subtract the number of each type of seed planted from 20, and then add up the extras.

For help, go to **glencoe.com** to this book's OLC and find the Math Handbook.

section 15.2

New Breeding Technologies

Reading Guide

Before You Read **Preview** What do you know about cloning?

Content Vocabulary

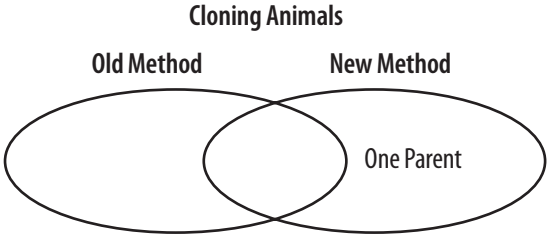
- gene
- DNA
- transgenic organism
- cloning

Academic Vocabulary

- principle
- convince

Graphic Organizer

Draw the section diagram. Use it to organize and write down information as you read.



Go to **glencoe.com** to this book's OLC for a downloadable graphic organizer and more.

TECHNOLOGY STANDARDS

STL 6 Role of Society

STL 14 Medical Technologies

STL 15 Agricultural & Related Biotechnologies

ACADEMIC STANDARDS

Science

NSES Content Standard F Science and technology in society

NSES Content Standard C Reproduction and heredity

STL *National Standards for Technological Literacy*

NCTM *National Council of Teachers of Mathematics*

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Genetics

What happens when one plant is crossbred with a different plant?

In 1865, the Austrian monk Gregor Mendel discovered the basic principles of genetics by crossbreeding pea plants. He discovered that each plant had hereditary elements that are now called genes. Genes contain all the information needed to reproduce an organism. Genes are small sections of DNA (deoxyribonucleic acid), which are the molecules that contain the genetic information that determines inherited characteristics.

In the past, farmers crossbred the best of breed to produce the most favorable characteristics. Today genetic engineering and cloning are used to create new organisms. Many people question these processes and need to be convinced of their safety.

As You Read

Identify How is genetic engineering used today?

Genetic Engineering

How does genetic engineering relate to agriculture?

In the 1990s, researchers learned how to directly alter and recombine the genetic material in DNA to produce desired characteristics or remove undesirable ones. For example, a **transgenic organism** occurs when genes from one organism of a different species are transplanted into another.

GM Food Approval

It was very difficult to get the first genetically modified (GM) food, a tomato, approved. The Federal Drug Administration (FDA) regulates food additives. The U.S. Department of Agriculture (USDA) oversees food safety and agricultural research. The Environmental Protection Agency (EPA) is charged with protecting the environment. Before the "Flavr Savr" tomato could go on sale, these organizations had to sign off on its safety. Today approval of genetically modified species is mostly in the hands of the USDA.

To be approved, the offspring of the altered plants or animals must first be raised in a laboratory to see if the new characteristics show up and can be passed on. Tests are done to learn if the altered plant or animal could be dangerous to the environment. Other tests determine if food produced from these plants or animals is safe for human consumption.

Advantages of GM Crops

Improving plants genetically has produced crops that need less water, can grow in salty soil, are immune to certain diseases, can kill pests, can grow and ripen faster, and can stay fresh longer after harvesting. Also, improving livestock genetically has produced animals that can grow faster, are immune to certain diseases, and are larger and leaner than other livestock. Their meat tastes better and stays fresh longer.

Growth of GM Crops

A USDA biotech report indicated that, in 2007, a majority of different crops grown in the United States germinated from genetically engineered crops:

- 82 percent of corn crops
- 89 percent of soybean crops
- 86 percent of cotton crops

The current estimate is that 75 percent of all processed foods eaten in the United States contains GM ingredients. Although researchers claim these foods are safe for humans to eat, many people have doubts.

Academic Connections
Social Studies

What Came First?
Throughout history, the "how" of technology often came before the "why" of science. For thousands of years, people used special "seeds" to make bread rise. Scientists later discovered that the seeds were actually yeast, a type of fungus.

Apply Obtain a packet of yeast used to make bread. Sprinkle it into a bowl of lukewarm water and add a pinch of sugar. Observe what happens over the next 20 minutes. Explain why the result you observe might occur.

Genetic Control Since 1997, many crops have been genetically modified. *In what way is each one considered superior to its non-modified species?*

SuperStock Royalty Free

Disadvantages of GM Crops

Many people fear that the pollen or seeds from altered plants could escape into the wild and affect other plants. For example, could the genes of a plant that is resistant to weed killer find their way into the weeds themselves? If so, the weeds might then be unstoppable. To prevent this, some seed companies have developed a "terminator" gene. This type of gene prevents a plant from reproducing. Its seeds will not grow. Any genetic changes would die with it. However, this situation might be even more dangerous. If the terminator gene escapes into the wild, all affected plants would die out in one generation.

Other Applications

You should not assume that genetic modification only modifies plants and animals for human consumption. In July of 2007, a research project, sponsored by the U.S. Defense Advanced Research Project Agency (DARPA), developed a biosensor that contains a genetically engineered yeast that has the ability to sniff out explosives. The researchers infused the specific rat genes for identifying odors into the yeast's DNA. They combined the special-function genes from the yeast and the genes from the rat to create a new organism biosensor that could smell and identify dangerous chemical odors.

Reading Check

Recall What are some possible advantages and disadvantages of genetic engineering?

Cloning

What is cloning?

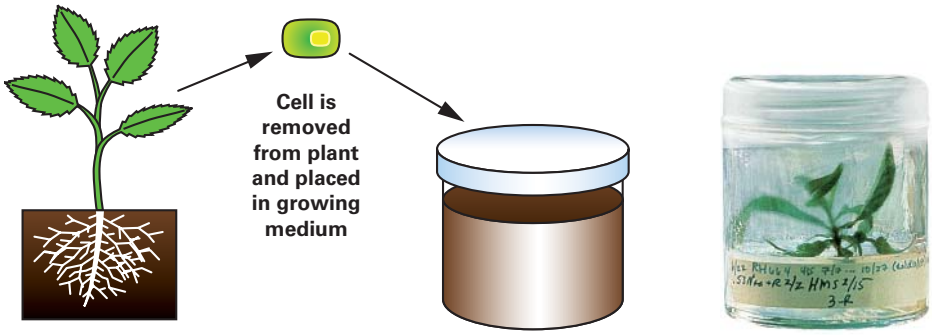
Cloning is a process that produces an identical copy of a plant or animal. Some clones, such as identical twins, are natural. A single cell divides in the mother's womb and produces two identical people. The older method of animal cloning uses a medical procedure to cause the egg in a pregnant animal to split. This produces identical twins by mimicking the natural accident that causes twins.

Cloning of some species of plants has been common for a very long time. For example, a plant cutting is placed in soil; it takes root, and a new plant grows. See **Figure 15.1**.

Reading Check **Explain** How does cloning take place?

In 1996, a sheep named "Dolly" was cloned in a new way. This method creates a clone of an adult animal. The single parent and baby have identical DNA, even though their birthdays are years apart. A cell is taken from the animal to be cloned and placed in a weak nutrient culture where it will grow. The lack of all the needed nutrients causes the cell to stop dividing and switch off its active genes. Then an unfertilized egg cell is taken from a female animal, and its nucleus is removed. Although its genes are gone, the egg cell still has all the other things needed to produce a baby. The nucleus from the first cell is removed and fused into the egg cell with a spark of electricity. Another spark "wakes up" the sleeping genes in the nucleus, and the cell begins to divide. After a few days, the embryo is placed in the womb of another female animal and allowed to develop.

Figure 15.1 **Cloning Plants**



Two of a Kind In plant cloning, one piece of a plant or even one cell from the plant is used to grow a new plant. *What makes these two separate plants clones?*

The First Cloned Sheep Many animals have been cloned since Dolly was cloned in 1997. *Do you think it is all right to clone any living creature? Why or why not?*

Genetic engineering and cloning can be combined. A new genetically engineered cow cannot catch mad cow disease because the natural cow protein that gets infected with this disease has been eliminated. Altered cows and bulls with the genetic change were cloned into a herd of safe cows. Cows bred from this herd would remain immune to the disease because the protein needed for the disease no longer exists. Could this procedure be used to clone animals back into existence after they have become extinct? A Texas A&M University project, Noah's Ark, is freezing tissue of endangered animals in the hope that some day clones of them can be created.

section 15.2 assessment

After You Read Self-Check

1. Define a transgenic animal or plant.
2. Explain a clone.
3. Describe a terminator gene.

Think

4. The U.S. Department of Agriculture must approve new technologies that affect the foods we eat. Write a paragraph discussing the pros and cons of this mandate.

Practice Academic Skills

English Language Arts/Writing

5. The McIntosh apple is a cloned species. Do research on the Internet and/or at the library to find out the location of the parent tree and when the apple was first cloned. How many copies have been made, and where is it grown? Also, find out what other fruits have been cloned. Write a report on your findings.

STEM Mathematics

6. A field of soybeans is long and narrow. It measures 145 yards by 76 feet. What is the area of the field in square feet?

Math Concept Measurement Conversion Converting measurements involves multiplication or division.

1. Determine which measurement needs to be converted.
2. To solve this problem, remember that there are three feet in a yard.

For help, go to **glencoe.com** to this book's OLC and find the Math Handbook.

section 15.3

Other Agricultural Technologies

Reading Guide

Before You Read **Preview** What is aquaculture?

Content Vocabulary

- biosynthesis
- pharming
- bioremediation
- artificial ecosystem
- hydroponics
- aquaculture
- agroforestry

Academic Vocabulary

- source
- adequate

Graphic Organizer

Draw the section diagram. Use it to organize and write down information as you read.

Artificial Ecosystems

1. Hydroponics	2. Aquaculture	3. Agroforestry
		Fast-Growing

Go to **glencoe.com** to this book's OLC for a downloadable graphic organizer and more.

TECHNOLOGY STANDARDS

STL 5 Environmental Effects

STL 7 Influence on History

STL 15 Agricultural & Related Biotechnologies

ACADEMIC STANDARDS

Social Studies

NCSS Content Standard 8 Science, technology, and society

Science

NSES Content Standard C Population and ecosystems

STL *National Standards for Technological Literacy*

NCTM *National Council of Teachers of Mathematics*

NCTE *National Council of Teachers of English*

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Biosynthesis

Could a living organism produce a piece of fabric?

Biosynthesis is the making of chemicals by using biological processes. Technologists are working to develop genetically altered living organisms that will produce chemicals that were once produced in factories. For example, one microbe can manufacture polyester used to make clothing. Another can produce silk. A British company has developed biopolymers, which are plastics produced from living organisms.

Reading Check **Recall** What is biosynthesis?

As You Read **Compare** What is the difference between *farming* and *pharming*?

EcoTech

Pest-Free Naturally

Traditional pesticides can be as harmful to humans or pets as they are to the pests that they eliminate. Nontoxic alternatives to pesticides include natural repellants, such as herbs or soap, and predators like ladybugs.

Try This To get rid of pests, try using liquid dish soap, garlic, or household products such as borax. They can often eliminate or repel insects without harming people, pets, and your environment.

Pharming

How can biosynthesis create medicines?

Some crops, animals, and microbes have been genetically modified to produce medicines. This process is called **pharming** (*pharmaceutical* and *farming*). Plants, animals, and microbes become bio-factories that convert food and water into medicine.

Certain transgenic animals, such as cows, are able to produce compounds in their milk that are active against diabetes, arthritis, hemophilia, emphysema, and gastrointestinal infections. A tobacco plant can produce vaccines and human growth hormones. Other transgenic organisms produce human blood components and anti-tooth decay compounds.

Reading Check **Recall** What are bio-factories?

Bioremediation

What is bioremediation?

Bioremediation is the use of bacteria and other organisms to clean up contaminated land and water. Ordinary microbes work in landfills (dump sites) to break down garbage. Petroleum waste can be biodegradable by mixing it with soil, nutrients, and microbes. Engineered microbes clean up oil spills by eating the oil. Today other microbes remove dangerous materials from toxic (poisonous) wastes.

A Way to Go! Gasohol is a combination of gasoline and alcohol made from corn and crop waste that can substitute for plain gasoline. *Why has gasohol affected the price of food?*

Biofuels

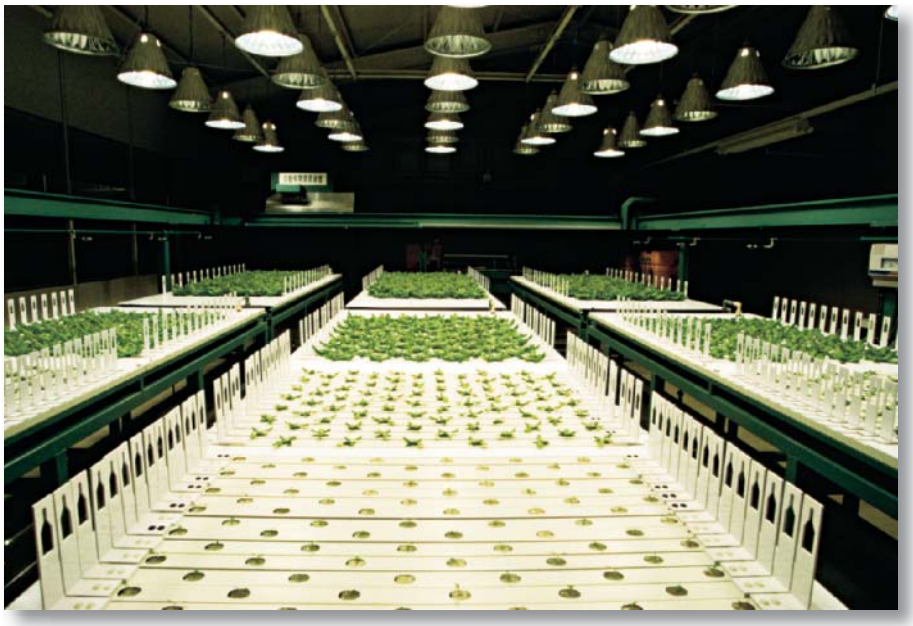
What kinds of fuels can agriculture produce?

Biofuels are fuels made from agricultural products. Biofuels are a **source** of renewable energy. Materials such as corn, crop wastes, and lumber wastes can all be used to manufacture fuel alcohol. When this alcohol is mixed with gasoline, it is sold as "gasohol."

Plant and animal wastes can be mixed with bacteria to produce methane gas, which is similar to natural gas and propane fuel. Methane gas can also power vehicles. Some farms sell their waste products to power plants that can recycle the wastes to produce electricity.

Reading Check **Connect** What biofuels could run a car?

SuperStock, Inc./SuperStock



Water Culture Sprouts grow as the conveyor moves in this hydroponic hot house. *How are these plants watered?*

Artificial Ecosystems

Why are artificial ecosystems developed?

An **artificial ecosystem** is a human-made, controlled environment that is built to support humans, plants, or animals. Some artificial ecosystems include hydroponic farms, aquacultures, and agroforests. They copy some aspects of the natural environment. Astronauts in space live in an artificial ecosystem that supports their need for air, food, and water.

Reading Check **Name** What are examples of some artificial ecosystems?

Hydroponics

Only about 6 percent of the earth's surface is **adequate** for traditional farming in soil. With **hydroponics**, plants are grown in nutrient solutions without soil.

Some hydroponic farms plant their seedlings on a long, wide, slow-moving conveyor system. The system moves at the same speed as the plants grow. When the plants reach the end of the conveyor system, they are ready for harvest.

Hydroponics re-circulates water and fertilizer. This means the fertilizer that is used is not released into the environment to pollute lakes and streams. Insects cannot reach the plants easily. Weather conditions are not important, so crops can grow in any climate. All these factors make some people think hydroponics could be used to help relieve world hunger.

Imagine This...

Breathing Easy

NASA has created an artificial ecosystem on the International Space Station. It is also working on systems that could sustain life during space journeys to distant planets. One engineer spent 15 days sealed in a chamber, breathing oxygen produced by wheat plants. All air, food, water, and waste would be recycled for journeys that take many years. *Write a paragraph on how air, food, water, and waste could be recycled on board a spacecraft.*

Go to **glencoe.com** to this book's OLC for answers and to learn more about artificial ecosystems.

Aquaculture

When fish, shellfish, or plants that naturally grow in water are grown in artificial water ecosystems, the process is called **aquaculture**. Aquaculture farms can be a totally enclosed indoor environment or a pen in a lake, pond, river, or ocean. Predators that would destroy or consume the plants or fish cannot enter these enclosures protected by nets.

Bruce Forster/Getty Images

From Seed to Paper
Paper-mill reforestation programs use very fast-growing tree saplings to grow enough new trees to replace harvested trees. *If using computers results in a paperless society, do you think reforestation will still be needed?*

Agroforestry

Agroforestry is turning forests into controlled environments dedicated to the replacement of trees. Under natural conditions, trees grow very slowly. When clear cutting is done, even if the entire forest is replanted with seedlings, it will be many years before the forest will return to its former state.

Hybridization and genetic engineering help to create fast-growing softwood and hardwood trees. New trees are quickly planted to rebuild the stock for future cutting seasons. Biotechnologists have developed a fast-growing tree species for papermaking.

section 15.3 assessment

After You Read Self-Check

1. Define bioremediation.
2. Identify products produced from pharming.
3. Name three kinds of artificial ecosystems.

Think

4. Discuss the advantages of biofuels versus fossil fuels.

Practice Academic Skills

English Language Arts/Writing

5. Write a radio commercial for a new biofuel. Choose a current biofuel being used today. Describe the advantages of using it. Also think of a catchy new name for the fuel.

STEM Science

6. Research cloning technology. Write a few paragraphs explaining the process of cloning and what achievements have been made in cloning. Discuss the ethical issues related to types of cloning. Include your opinion of cloning and what types of cloning, if any, should be allowed.

Exploring Careers in Technology

Sonia Barker

NATURALIST

Q: *What got you interested in being a naturalist?*
A: I didn't even know what a naturalist was until I was a junior in college. The director of the arboretum at my college gave a special course on being a naturalist. I was studying research biology at the time. Being a naturalist appealed to me because it didn't deal with just one tiny part of science—you get to learn about all of it.

Q: *What do you do?*
A: I work as a resident naturalist at an elementary school. My first responsibility is to take care of the animals. I feed them and clean their cages. Then the students come down to my area, which is called "The Inquiry Zone." We start each class with a focus point. That could be an animal or an artifact that I bring from the Bell Museum of Natural History, my employer, who partnered with the school to make this job possible.

Q: *What do you like most about your job?*
A: I feel that even if I teach the same class 100 times, it's new every time, especially with younger kids. They have a fascination that catches me every time. Now that the kids know me, they bring things to my office. It could be something they found in their yard or maybe a bug that bit them. We get out books and discover what it is. They come and find out more, and it's great one-on-one time.

English Language Arts/Writing

Your Environment Find a familiar plant in your yard at home or in a nearby park. Find out the name of it. Do research on the Internet or at the library and write a report. Find out this information:

1. Does this plant grow naturally in your part of the country?
2. If not, where did it come from? If so, where else does it grow?
3. Can this plant be used for anything besides decoration?

Go to **glencoe.com** to this book's OLC to learn more about this career.

Real-World Skills
Communication, research, organization

Academics and Education
Biology, chemistry, natural history

Career Outlook
Growth faster than average for the next ten years
Source: *Occupational Outlook Handbook*

Digital Vision/Getty Images

chapter 15 Review and Assessment

Chapter Summary

Section 15.1 Agriculture is a biotechnology because it is related to living things. It applies the principles of biology to create commercial products and processes. During the Industrial Revolution, people left the countryside to work in factories in the cities. Farmers began to rely on machinery. Breeding animals is part of agriculture. Plants and animals must be cared for, or maintained. Many farmers give animals antibiotics to protect them from disease.

Section 15.2 Gregor Mendel discovered the basic principles of genetics by careful breeding of pea plants. In the past, improving a species of plant or animal was a slow process. Today improvement is more rapid with genetic engineering and cloning. In some cases, genes from one organism are transplanted into another. The result is a transgenic plant or animal. Cloning is a process that produces an identical copy of a plant or animal.

Section 15.3 Some crops, animals, and microbes have been genetically modified to produce drugs. This process is called "pharming." Bioremediation is the use of bacteria and other organisms to clean up contaminated land and water. Biofuels are made from agricultural products, which can be a source of renewable energy. Artificial ecosystems include hydroponic, aquaculture, and agroforestry farms.

Review Content Vocabulary and Academic Vocabulary

1. On a sheet of paper, use each of these terms and words in a written sentence.

Content Vocabulary

- hybrid
- irrigation
- fertilizer
- monoculture farming
- dehydrate
- gene
- DNA
- transgenic organism
- cloning
- biosynthesis
- pharming
- bioremediation
- artificial ecosystem
- hydroponics
- aquaculture
- agroforestry

Academic Vocabulary

- monitor
- income
- principle
- convince
- source
- adequate

Review Key Concepts

2. **List** three highlights in the history of farming.
3. **Explain** how animals are traditionally bred.
4. **Discuss** methods of plant and animal maintenance.
5. **Give an example** of genetic engineering in agriculture.
6. **Define** cloning.
7. **Identify** the role of the USDA, FDA, and EPA with agricultural technologies.
8. **Describe** biosynthesis.
9. **Explain** the process of bioremediation.
10. **Identify** different types of artificial ecosystems.

Andy Sacks/Getty Images

Real-World Skills

11. Organic Foods Go to your grocery store and look at organic foods. Compare the foods labeled "organic" with similar foods not labeled "organic." Write a few paragraphs describing what you find, including the price and appearance.

STEM Technology Skill

12. Farming Technology The tools used in farming and gardening are constantly changing. Some are simple, and others are very complex.

a. Research some of the different tools used in the agriculture industry.

b. Make a model of one of the tools. Use available materials or sketch the tool. Change the design if you think it will improve the tool.

Academic Skills

Social Studies

13. Many people in the world suffer from hunger and even famine. Research and find areas of the world that suffer from famine. Write a few paragraphs describing the reasons for famine and ways to eliminate it.

STEM Mathematics

14. A farmer is changing fertilizer. The old fertilizer cost $140.80 for a 55-gallon drum. The new fertilizer costs $86.70 for a 30-gallon drum. Which fertilizer costs less per gallon and by how much?

Math Concept Multi-Step Problems Some problems require two steps. Take notes to organize information given. Write out what you are solving for to determine which step to take first.

TSA WINNING EVENTS

Agricultural and Biological Scientists

Situation You are part of a research team which includes scientists, technologists, and ethicists who will investigate an agricultural or biotechnology discovery or innovation.

Activity Working in a team, brainstorm contemporary agricultural or biotechnology discoveries and innovations. Choose one topic. Conduct research, prepare a report, develop drawings, and build a model of your topic. Then give a formal presentation.

Evaluation The team's work will be evaluated by the following criteria:

- Report—well researched, well written
- Drawings—complete, accurate
- Display and model—complete, attractive
- Presentation—well organized, informative

Go to **glencoe.com** to this book's OLC for information about TSA events.

Standardized Test Practice

Directions Choose the letter of the best answer. Write the letter on a separate piece of paper.

1. What is the volume of a box that is 13.2 inches wide, 10.5 inches tall, and 24.4 inches deep?

A 3,351.84 cubic inches

B 4,800.1 cubic inches

C 48.1 cubic inches

D 3,381.84 cubic inches

2. Bioremediation involves genetically modifying plants and animals to produce medicine.

T

F

Test-Taking Tip Answer the simple questions first to help build up your confidence for answering the harder questions.

chapter 15

TECHNOLOGY LAB

Construct a Hydroponic System

Hydroponics is a good method of farming for regions where rainfall is scarce, soil is poor, insects are difficult to control, or farmland is limited. To grow plants, you need seeds or young plants, water, sunlight, air, nutrients, and a way to hold the plants in place. In hydroponic greenhouses, plants grow faster, take up less space, and produce larger crops. Water and nutrients are recycled.

Tools and Materials

- ✓ One 6-inch diameter plastic pipe, 2 feet long
- ✓ Two ¼-inch-thick plastic pieces, 6½-inches square
- ✓ One 4-foot length of ⅜-inch flexible plastic tubing
- ✓ Two adaptors with rubber washers and nuts to fit tubing
- ✓ Two ⅝-inch clamps
- ✓ 32-ounce plastic pails
- ✓ Drill set
- ✓ Electric drill
- ✓ 2¼-inch hole saw
- ✓ Marking pen
- ✓ Drill press
- ✓ All-purpose plastic cement
- ✓ Hot glue gun
- ✓ Hot glue
- ✓ Chlorine-free water
- ✓ pH testing kit
- ✓ Baking soda
- ✓ Vinegar
- ✓ Sterilized sand
- ✓ Fine plastic screening
- ✓ Plant food
- ✓ Four small potted plants
- ✓ Wood blocks
- ✓ 18″ × 10″ × ¾″ plywood

Set Your Goal

You will build and operate a hydroponic system used to grow plants.

Know the Criteria and Constraints

In this lab, you will:

1. Keep a daily record of solution mixtures and any experiments.
2. Monitor your system daily for water and to check for leaks.

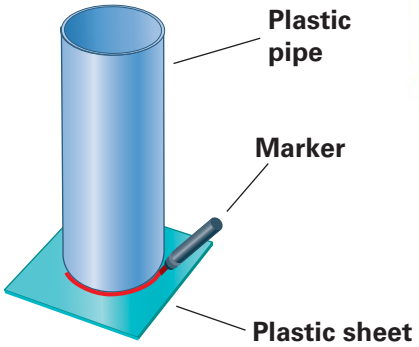
Design Your Project

Follow these steps to design your project and complete this lab.

1. **Build Your Hydroponic System**
   - Stand the pipe (the planter) on end in the center of the plastic square. Draw a circle using the pipe as a template.
   - Mark the locations for the tubing adaptor on the plastic square and on the pail. Drill holes in both places.
   - Insert one tubing adaptor in the holes in the plastic square and the pail.
   - Place rubber washers on both sides of the adaptor to prevent water leaks. Tighten the nuts to hold in place.
   - On the inside of this plastic square, place a circle of hot glue around the tubing adaptor. Place a piece of screen on it.

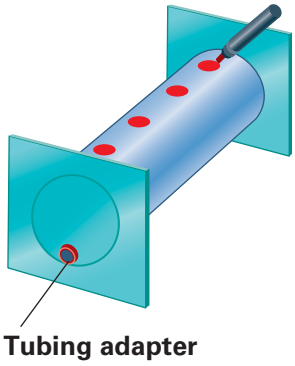
Ben Weaver/Getty Images

- Place the pipe on plywood to keep it raised. Use stop blocks to keep it from rolling.
- Coat both pipe ends with plastic glue. Attach one plastic square to each end, making sure that the bottom edges rest flat on the table.
- Hold or clamp the parts together as the glue sets.
- Carefully set the project aside to dry.
- After glue is dry, mark spots for plant holes on pipe.
- Drill holes in the pipe using the hole saw in the drill press.
- Clamp tubing to the planter and pail.
- Fill the planter with water to check for leaks.
- Partially fill the planter with sand.



2. Add plants to planter

- Remove plants from containers and wash away soil.
- Carefully place your plants into the planter, filling in sand.
- Test the pH of the water you set aside. It should read 6 or 7 for best growth. Add a few drops of baking soda if pH is low or a few drops of vinegar if pH is high. Retest.

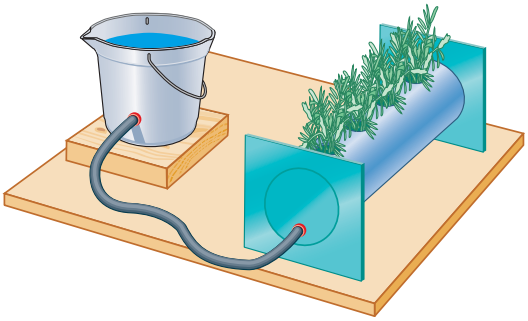


3. Care for the Plants

- Mix plant food with water according to instructions. Place the pail higher than the planter so the mixture will fill the planter.
- Lower the pail so the extra solution drains.

4. Follow-Up

- Check plants daily and keep the sand moist. Add water to the pail to replace evaporated water. Keep a record.



Evaluate Your Results

After you complete the lab, answer these questions on a separate piece of paper.

1. Which nutrient mixtures were most effective for plant growth?
2. If you repeated this activity, what would you do differently and why?

Academic Skills Required to Complete Lab

Tasks	English Language Arts	Math	Science	Social Studies
Build hydroponic system.	✓	✓	✓	
Test pH of water and adjust.		✓	✓	
Learn to care for plants.	✓		✓	
Keep track of water needed daily.		✓	✓	
Perform experiments on plants.	✓	✓	✓	

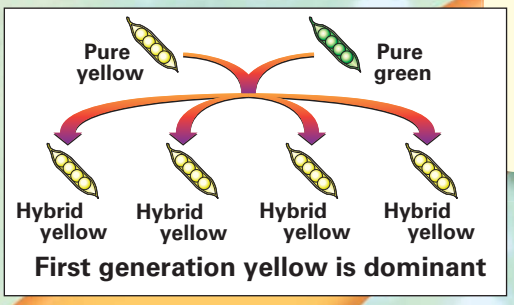
Technology Time Machine

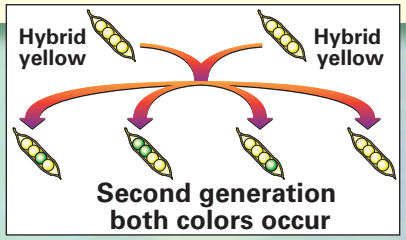
Understanding Genetics

Play the Game This time machine will travel to the past to show you that genetics is the science of heredity. It can explain how specific traits are passed on from generation to generation. To operate the time machine, you must know the secret code word. To discover the code, read the clues, and then answer the questions.

Clue 1

1857 The field of genetics began with an Austrian monk named Gregor Mendel. He studied what happened when plants with one set of characteristics were crossed with plants with another set of characteristics. He theorized that cells from the parent plants contained certain elements that influenced heredity. Today these elements are called "genes."





Clue 2

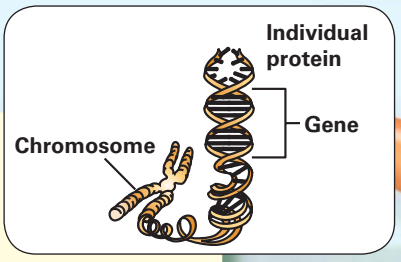
1907 Thomas Hunt Morgan used fruit flies for his gene experiments because they are simple creatures that reproduce quickly. His research confirmed that each gene is responsible for a particular characteristic.

Clue 3

1920s Researchers developed corn plants that increased crop yields by pollinating them for desired characteristics.

Index Stock Imagery/Jupiter Images, Stan Waxman/Getty Images

Clue 4



1953 Genetic researchers worked out the structure of DNA (deoxyribonucleic acid). Within each gene, DNA is a long chain of four molecules twisted into a coil that looks like a double helix. DNA molecules carry the genetic information.

Clue 5

1995 The bacterium *Haemophilus influenzae* was the first free-living organism whose DNA was successfully analyzed. In the United States, the Human Genome Project is an effort to analyze human DNA.

Clue 6

2000s Genetic codes may have been formed more than 3 billion years ago. Some researchers believe humans can be traced back to an original parent they have nicknamed "Eve."

Crack the Code

On a piece of paper, write the answers to these questions:

1. What type of molecule carries genetic information?
2. What did Gregor Mendel theorize cells from parent plants could do?
3. Who hopes to discover secrets in the genetic code?
4. What is the nickname of a possible original parent?
5. Where was Gregor Mendel from?
6. Morgan used fruit files because they were _____.
7. What did Morgan and Mendel do to make their discoveries?

Now write down the first letter of each answer. Put them together to discover the secret code word!

Hint Pathogens are organisms that cause this in living beings.

Lester V. Bergman/Corbis

unit 4 Thematic Project

Discovering Careers in Biotechnology

Meeting Human Needs In Unit 4, you learned how biotechnology has improved our way of life. You also read about careers in biotechnologies, including medical, industrial, agricultural, and marine.

The Colors of Biotechnology

Red—Medical biotechnology offers careers in fields as varied as pharmaceuticals, genetic testing, gene therapy, and X-ray technology.

White—In industrial biotechnology, chemists design organisms to produce useful chemicals. Lab technicians use enzymes to destroy hazardous chemicals.

Green—Agricultural biotechnology touches all aspects of food production. Farmers grow crops, and chemists genetically engineer plants.

Blue—Marine and aquatic applications of biotechnology include restoring and preserving endangered marine species and aquaculture, also known as fish farming.

This Project In this project, you will research a career in biotechnology that you think would be interesting.

Your Project

- Choose a "color of biotechnology".
- Research career possibilities in that field.
- Choose and complete one task:
  1. Create a checklist of educational requirements for this career.
  2. Design a fictional day-in-the-life blog entry.
  3. Develop a fictional résumé.
- Write a report about what you learned.
- Create a presentation.
- Present your findings to the class.

Big Cheese Photo/Jupiter Images

Tools and Materials

- ✓ Computer
- ✓ Internet access
- ✓ Trade magazines
- ✓ Word-processing software
- ✓ Presentation software
- ✓ Posterboard
- ✓ Colored markers

The Academic Skills You'll Use

- Communicate effectively.
- Speak clearly and concisely.
- Use correct spelling and grammar when taking notes or writing presentations.
- Think about what it takes to be a biotechnologist.

English Language Arts

NCTE 4 Use written language to communicate effectively.

NCTE 12 Use language to accomplish individual purposes.

Science

NSES Content Standard E Science and Technology: Understandings about Science and Technology

Step 1 Choose Your Topic

You can choose any career in the biotechnology field. Examples might include:

- Biopharmaceutical engineer
- Bioinformatics scientist
- Farmer
- Marine biotechnician

Tip! *Choose a job that interests you!*

Step 2 Do Your Research

Research your project. Your fact-finding may include several activities. Answer these questions:

- What does someone with that job do during a day?
- What college courses are required?
- What do companies' online job postings say they require in a biotechnologist?
- What do old and new articles in libraries and online sites say about your topic?

Tip! *Remember to list all your resources!*

Step 3 Explore Your Community

Find someone in your community who knows something about your topic. Ask him or her in person or on the phone how his or her job connects to your career. Does biotechnology make the job easier? Is biotechnology controversial? Why or why not?

Tip! *Thank the person afterward!*

Step 4 Create Your Project

Your project should include:

- 1 research project (checklist, blog, or résumé)
- 1 report
- 1 presentation

Project Checklist

	Objectives for Your Project
Visual	✓ Make a poster or slide presentation to illustrate your project.
Presentation	✓ Make a presentation to your class and discuss what you have learned.
	✓ Turn in research and names from your interview to your teacher.

Step 5 Evaluate Your Presentation

In your report and/or presentation, did you remember to:

- List your sources?
- Explain ideas using clear examples?
- Show thorough evidence?
- Practice before presenting?
- Write clearly?

GLOBAL TECHNOLOGY

Health Tourism

There are jobs for people who work in medical biotechnology all over the world. Tourists visit Thailand to see ancient temples and pristine beaches. But its state-of-the-art medical science and reputation as "The Land of Smiles" make it popular for health tourism. Patients from Asia, Europe, and North America travel there for vacations—and less expensive treatment.

Critical Thinking *What patients should probably not take part in health tourism?*

Thai

hello	sa-wat dee
goodbye	sa-wat dee!
How are you?	Sabai dee rue?
thank you	khorb koon
You're welcome	Mai ben rai

Go to **glencoe.com** to the book's OLC to learn more and to find resources from **The Discovery Channel.**