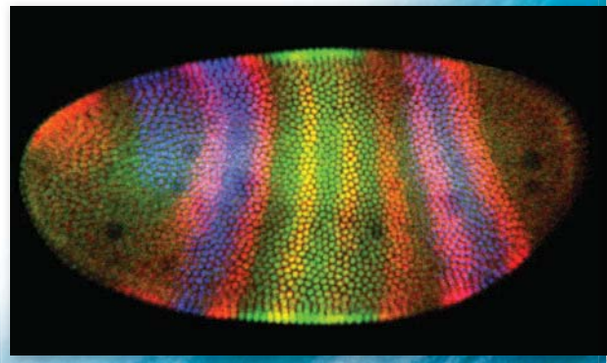
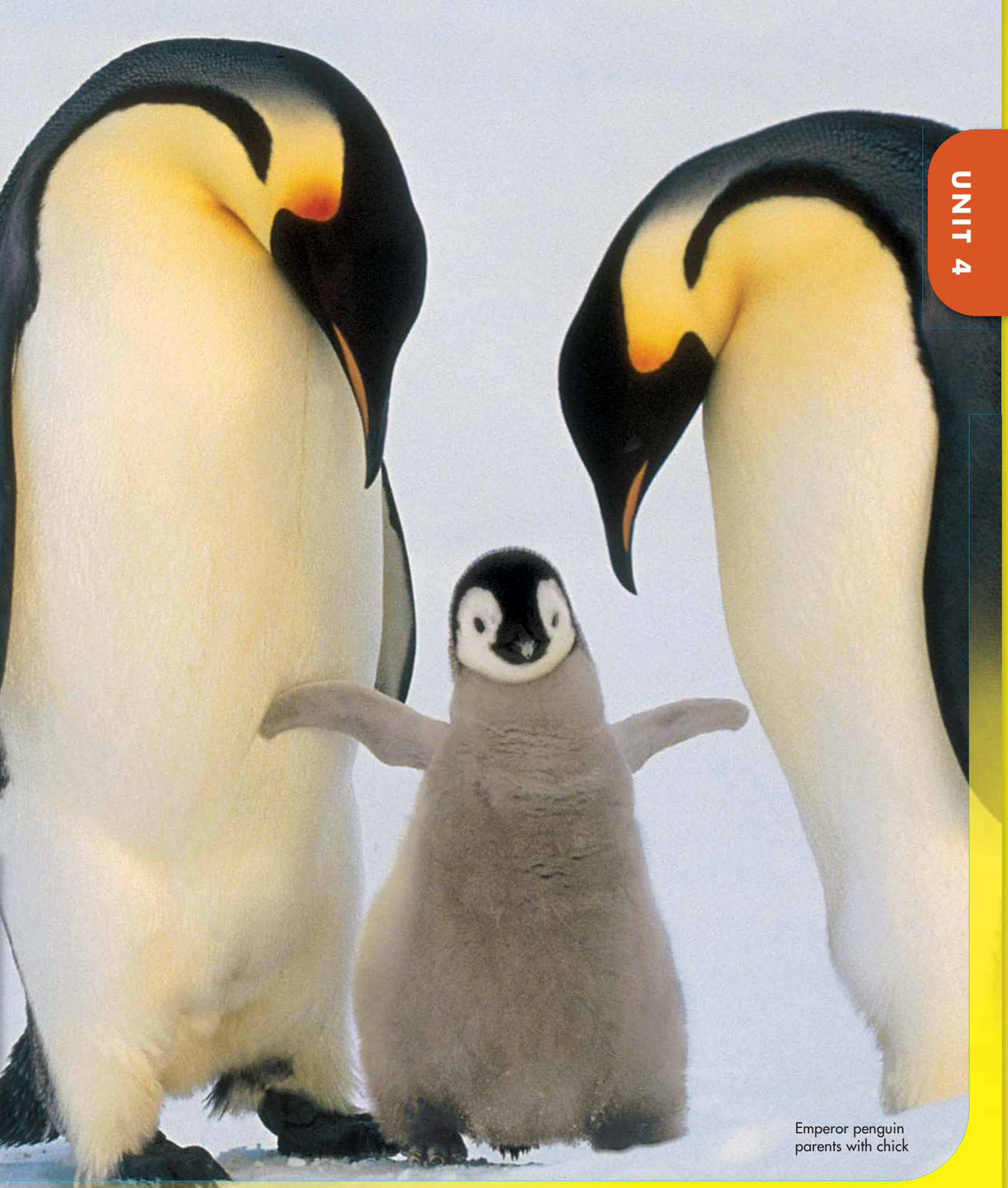
UNIT 4 Heredity

Eggs of the red-eyed tree frog stuck to the underside of a leaf



Fruit fly embryo, marked to show pattern of genes being expressed



Emperor penguin parents with chick

DISCOVERIES IN SCIENCE

Heredity and Genetics

1865

Gregor Mendel publishes the results of his studies of genetic inheritance in pea plants. Although his work is not widely known until much later, Mendel is remembered as the founder of the science of genetics.

Gregor Mendel

1879

After staining cells with Perkins dye and viewing them under a microscope, Walter Fleming identifies chromatin in cells. Soon after, he observes and describes all stages of mitosis, using terms such as *metaphase, anaphase and telophase.*

1905

Nettie Maria Stephens describes how human gender is determined by the X and Y chromosomes.

Nettie Stevens

1909

The Elements of Heredity, by Wilhelm Johannsen, a Danish biologist, is revised and translated into German. In the book, Johannsen develops many of the concepts of modern genetics, particularly phenotype and genotype. This book becomes a founding text of genetics.

1913

Alfred Henry Sturtevant, an undergraduate student at Columbia University, determines the relative location of genes on a fruit fly chromosome. He publishes a genetic map showing the order of genes and their relative distance from each other.

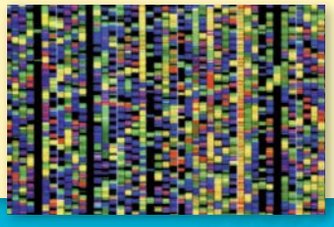
1915

Thomas Hunt publishes the book *Mechanism of Mendelian Heredity,* which explains the phenomenon of sex-linked traits observed in fruit flies.

***Drosophila melanogaster* (fruit fly)**

1989

Francis Collins and Lap-Chee Tsui identify a mutant version of a gene on chromosome 7 that causes cystic fibrosis. Discovery of the gene leads to the development of tests that can determine whether potential parents are carriers of the gene.

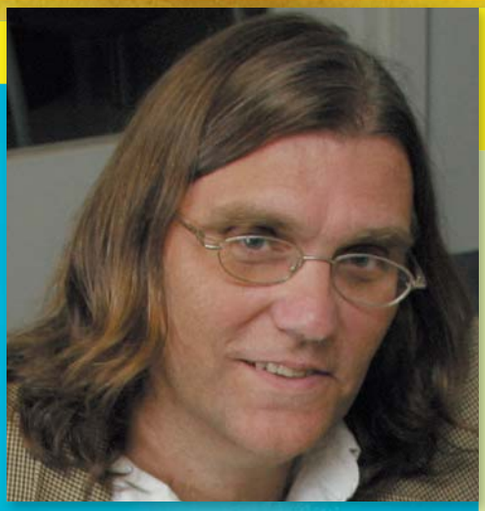


Genetic sequences on a computer screen

2003

The Human Genome Project is completed. Research teams around the world collaborated to identify all genes and decode the sequence of all DNA in human cells.

Albino peacock



BIOLOGY CAREER

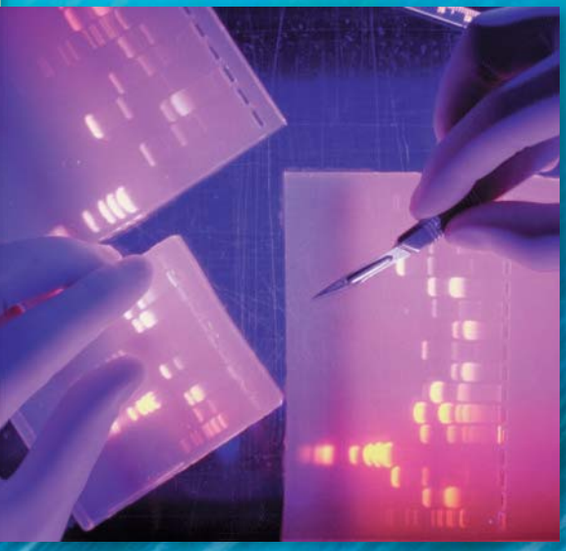
Genetics Researcher

Rob Desalle

Rob DeSalle is a curator in the Division of Invertebrate Zoology at the American Museum of Natural History in New York City. His current research focuses on molecular evolution in a variety of organisms, including pathogenic bacteria and insects.

DeSalle studies molecular evolution through comparative genomics, which is the study of similarities and differences between the genomes of various species or strains within species. Comparing the genomes of species can help determine how the species are related.

DeSalle also helped found the Conservation Genetics Program at the American Museum of Natural History. This program uses the tools of molecular genetics to help protect wildlife around the world. For example, DeSalle helped develop a genetic test to determine if caviar sold in the United States was illegally harvested from endangered species of sturgeon in the Caspian Sea.



Genetic analysis by gel electrophoresis

UNIT 4

Chapter Planner 15

Gene Technologies and Human Applications

		Standards	Teach Key Ideas
CHAPTER OPENER, pp. 342–343	15 min.	*National Science Education Standards*	
SECTION 1 The Human Genome, pp. 345–349 › Secrets of the Human Genome › Applications of Human Genetics › Ongoing Work	90 min.	LSEvol 3, UCP2, SI2, ST2, SPSP1, SPSP5, SPSP6, HNS1	**Bellringer Transparency** **Visual Concepts** Vaccine • Genetically Engineered Vaccines • DNA Fingerprint • Making a DNA Fingerprint
SECTION 2 Gene Technologies in Our Lives, pp. 350–354 › Manipulating Genes › Manipulating Bodies and Development › Ethical and Social Issues	45 min.	LSCell 3, LSCell 4, LSCell 6, UCP4, SI1, SI2, ST1, ST2, SPSP1, SPSP5, SPSP6, HNS1, HNS3	**Bellringer Transparency** **Transparencies** C34 Genetic Engineering • C38 Making a Genetically Engineered Vaccine **Visual Concepts** Genetic Engineering • Cloning
SECTION 3 Gene Technologies in Detail, pp. 355–365 › Basic Tools for Genetic Manipulation › Major Gene Technology Processes › Exploring Genomes	45 min.	LSCell 1, LSCell 2, LSGene 1, UCP5, SI1, SI2, ST1, ST2, HNS3	**Bellringer Transparency** **Transparencies** C32 Restriction Enzymes Cut DNA • C33 Gel Electrophoresis • C35 Genetically Engineered Medicine **Visual Concepts** Gel Electrophoresis • Polymerase Chain Reaction • Cloning Vectors and Plasmids • Using Plasmids to Produce Insulin

See also PowerPoint® Resources

Chapter Review and Assessment Resources

- SE Super Summary, p. 366
- SE Chapter Review, p. 367
- SE Standardized Test Prep, p. 369
- Review Resources
- Chapter Tests A and B
- Holt Online Assessment

CHAPTER FastTrack

To shorten instruction due to time limitations, eliminate the Skills Practice Lab.

Basic Learners

- TE Cloned Animals, p. 352
- TE Models of Blotting Processes, p. 358
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide* ■
- Note-taking Workbook*
- Special Needs Activities and Modified Tests*

Advanced Learners

- TE Cystic Fibrosis, p. 347
- TE Genetically Modified Tomatoes, p. 351
- TE Computational Biology, p. 361
- Critical Thinking Worksheets*
- Concept Mapping Worksheets*
- Science Skills Worksheets*
- Lab Datasheets, Level C*

Key

SE Student Edition
TE Teacher's Edition

Chapter Resource File
Workbook
Transparency

CD or CD-ROM
* Datasheet or blackline master available

■ Also available in Spanish

All resources listed below are also available on the Teacher's One-Stop Planner.

Why It Matters	Hands-On	Skills Development	Assessment
Build student motivation with resources about high-interest applications.	SE **Inquiry Lab** Code Comparison, p. 343*■	TE **Reading Toolbox** Assessing Prior Knowledge, p. 342 SE **Reading Toolbox,** p. 344	
TE **Demonstration** DNA Fingerprints, p. 345 TE **The Human Genome Project,** p. 345 TE **Genetically Engineered Vaccines,** p. 346 TE **Genetically Engineered Insulin,** p. 347 TE **Future Decision-Makers,** p. 348 SE **Cleanup Microbes,** p. 349	SE **Quick Lab** Forensic DNA Fingerprints, p. 347*■ SE **Skills Practice Lab** DNA Fingerprint Analysis, p. 364*■ **Exploration Lab** DNA Fingerprinting*	TE **Math Skills** Unique DNA, p. 345 TE **Reading Toolbox** Using Words, p. 346 SE **Reading Toolbox,** Word Parts, p. 347 TE **Reading Toolbox** Word Parts, p. 347 TE **Reading Toolbox** Visual Literacy, p. 349	SE **Section Review** TE **Formative Assessment** **Spanish Assessment***■ **Section Quiz**■
TE **Key Discoveries,** p. 350 TE **Demonstration** Better Produce, p. 350 TE **Flavor Savor™ Tomato,** p. 351 TE **Success of Cloning,** p. 352 TE **Stem Cell Research,** p. 353	**Skills Practice Lab** Transforming Bacteria with a Firefly Gene*	SE **Reading Toolbox** Analogies, p. 353 TE **Reading Toolbox** Analogies, p. 353	SE **Section Review** TE **Formative Assessment** **Spanish Assessment***■ **Section Quiz**■
TE **Naming Restriction Enzymes,** p. 355 TE **Molecular Scissors,** p. 360 TE **Demonstration** Recombinant DNA, p. 360	SE **Quick Lab** Gel Electrophoresis Model, p. 356*■	TE **Science Skills** DNA Electric Charge, p. 356 TE **Math Skills** DNA Replication, p. 357 SE **Reading Toolbox** Learning Steps, p. 361 TE **Reading Toolbox** Learning Steps, p. 361	SE **Section Review** TE **Formative Assessment** **Spanish Assessment***■ **Section Quiz**■
	See also Lab Generator		**See also Holt Online Assessment Resources**

Resources for Differentiated Instruction

English Learners

TE Identifying DNA Differences, p. 356
TE Sequencing, p. 359
TE Mapping, p. 362
Directed Reading Worksheets*
Active Reading Worksheets*
Lab Manuals, Level A*
Study Guide*■
Note-taking Workbook*
Multilingual Glossary

Struggling Readers

TE Types of Stem Cells, p. 353
TE Outlining, p. 357
Directed Reading Worksheets*
Active Reading Worksheets*
Lab Manuals, Level A*
Study Guide*
Note-taking Workbook*
Special Needs Activities and Modified Tests*

Special Education Students

TE Identifying Separation Patterns, p. 356
TE Modeling Processes, p. 360
Directed Reading Worksheets*
Active Reading Worksheets*
Lab Manuals, Level A*
Study Guide*■
Note-taking Workbook*
Special Needs Activities and Modified Tests*

Alternative Assessment

TE Implications of Genomics and Gene Technologies, p. 346
Science Skills Worksheets*
Section Quizzes*■
Chapter Tests A, B, and C*■

Chapter 15

Overview

The purpose of this chapter is to explain modern advancements and applications of genetics, such as the Human Genome Project. The chapter also explains how genes are manipulated and discusses the ethical issues that arise from gene technologies.

READING TOOLBOX

Assessing Prior Knowledge Students should be familiar with the following:
- components of a DNA nucleotide
- genes and gene expression
- somatic and germ cells

Visual Literacy After students look at the picture and read the captions, ask what scientists needed to know to make this pig turn green. (understanding of gene expression, how to insert a gene from one organism into another, understanding of light and fluorescence) Ask why scientists would put a gene like the one for fluorescence into another organism. (to study how genes are expressed)

Chapter 15

Preview

Why It Matters

Gene technologies aid the study of basic biology. They have many other applications, such as producing food and treating disease.

Gene Technologies and Human Applications

Chapter Correlations

National Science Education Standards

LSCell 1 Cells have particular structures that underlie their functions.

LSCell 2 Most cell functions involve chemical reaction.

LSCell 3 Cells store and use information to guide their functions.

LSCell 4 Cell functions are regulated.

LSCell 6 Cells can differentiate and form complete multicellular organisms.

LSGene 1 In all organisms, the instructions for specifying the characteristics of the organisms are carried in DNA.

LSEvol 3 Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms as well as for the striking molecular similarities observed among the diverse species of living organisms.

UCP2 Evidence, models, and explanation

UCP4 Evolution and equilibrium

UCP5 Form and function

SI1 Abilities necessary to do scientific inquiry

SI2 Understandings about scientific inquiry

ST1 Abilities of technological design

ST2 Understandings about science and technology

SPSP1 Personal and community health

SPSP5 Natural and human-induced hazards

SPSP6 Science and technology in local, national, and global challenges

HNS1 Science as a human endeavor

HNS3 Historical perspectives

The green-glowing gene was inserted into cloned pig cells by scientists using modern gene technologies. This gene is often used as a "marker" in genetic experiments because it is easy to see if the gene is present in an organism.

InquiryLab

15 min

Code Comparison

All humans have very similar DNA, with slight individual variations. The differences that are easiest to observe are among DNA stretches that have many short, repeating base sequences, as shown below. Different people have different numbers of repeats.

GATATATAGACTACTACTACTA

AGATATAGACTACTACTGACTT

GATATAGACTACTACTACTAGC

Procedure

1. Copy and then examine the three DNA sequences shown here.
2. Mark the portions of the code that include repeating bases.

Analysis

1. **Identify** what the four letters in the code sequences represent.
2. **State** how many kinds of repeating sequences you find.
3. **Identify** the basic repeating unit(s) among all segments.
4. **Explain** how each person can have a unique genetic code, even though some people may share an identical pattern of repeating base sequences.

InquiryLab

Teacher's Notes Have students revisit this lab when they get to the parts of the chapter on DNA fingerprinting and polymorphisms. Repeating DNA patterns similar to these are called *tandem repeats*; repeats of the same few nucleotides are called *short tandem repeats* (STRs). Since STRs have been identified in similar places in every person's genome, DNA fingerprinting has begun to depend on the analysis of STRs. Students should highlight each repeating sequence on each segment. There are at least two tandem repeats per segment.

Answers to Analysis

1. Each letter represents a DNA nucleotide: adenine, thymine, guanine, and cytosine.
2. At least three.
3. TA, TAC, and ACT
4. It is unlikely that two people will share the same tandem repeats.

Key Resources

Interactive Tutor

READING TOOLBOX

Using Words

1. *Electrophoresis* is the use of electricity to carry something.
2. A *microarray* is a very small, orderly arrangement of something.

Using Language

protein or amino acid chain

Using Graphic Organizers

Paper strips might include the following:

- Use a restriction enzyme to cut a gene of interest.
- Use the same enzyme to cut a bacterial plasmid.
- Splice the DNA into the bacterial plasmid using ligase enzyme.
- Reinsert plasmid into bacterial cell.
- Allow bacteria to reproduce. "Harvest" the gene product.

READING TOOLBOX

These reading tools can help you learn the material in this chapter. For more information on how to use these and other tools, see **Appendix: Reading and Study Skills.**

Using Words

Word Parts You can tell a lot about a word by taking it apart and examining its parts, such as the prefix and root.

Your Turn Use the information in the table to define the following terms:

1. *electrophoresis*
2. *microarray*

Word Parts

Word Part	Meaning
electro-	using electricity
phore	to carry
micro-	very small
array	orderly arrangement

Using Language

Analogies Analogies compare words with similar relationships. You can write analogies with words or with colons. For example, the analogy "up is related to down in the same way that top is related to bottom" can be written "up : down :: top : bottom." To answer an analogy problem, you must figure out how the words are related. In this example, up is above down, and top is above bottom.

Your Turn Use information found in prior chapters to complete the following analogy:

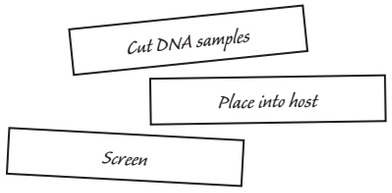
transcription : RNA :: translation : ___.

Using Graphic Organizers

Pattern Puzzles You can use pattern puzzles to help you remember sequential information. Exchanging puzzles with a classmate can help you study.

Your Turn Make a pattern puzzle for the steps of a recombinant gene cloning process, as shown in this chapter.

1. Write the steps of the process on a sheet of notebook paper, one step per line. Do not number the steps.
2. Cut the paper so that there is one step per strip of paper.
3. Shuffle the paper strips so that they are out of sequence.
4. Try to place the strips in their proper sequence.
5. Check your sequence by consulting your textbook, class notes, or a classmate.



Section 1

The Human Genome

Key Ideas	Key Terms	Why It Matters
❯ Why is the Human Genome Project so important? ❯ How do genomics and gene technologies affect our lives? ❯ What questions about the human genome remain to be studied?	genomics microarray DNA fingerprint	Many diseases may someday be cured by genetic technologies.

In 2000, headlines announced that scientists had deciphered the "book of life" by listing almost the entire sequence of bases in human DNA. This major feat was only the beginning of a new era.

Secrets of the Human Genome

The term *genome* refers to all of the genetic material in an organism, population, or species. **Genomics** is the study of entire genomes, especially by using technology to compare genes within and between species. A major part of genomics is to *sequence* genomes, or to identify every DNA base pair that makes up each genome. Only recently has it been possible to sequence the human genome.

The *Human Genome Project* (HGP) was an international cooperative effort to sequence the human genome. More than 20 laboratories in six countries worked together to sequence the 2.9 billion DNA base pairs that make up the human genome. ❯ **The sequencing of the human genome has advanced the study of human biology yet created new questions.**

Surprising Findings The major draft of the human genome sequence was completed and reported in 2003. Scientists were surprised and excited by findings such as these:

- **Humans have few genes.** Scientists expected to find 120,000 genes but found only about 25,000.
- **Most human DNA is noncoding.** Less than 2% of human DNA seems to code for proteins. The rest is either introns or is not yet fully explained.
- **Many human genes are identical to those of other species.** Much of what we learn about mice and flies can be used to understand ourselves.
- **All humans are genetically close.** If the DNA of any two people is compared, 99.9% is identical.

❯ **Reading Check** ***How big is the human genome? (See the Appendix for answers to Reading Checks.)***

genomics (juh NOH miks) the study of entire genomes, especially by using technology to compare genes within and between species

Figure 1 Despite differences in appearance, the DNA of any two humans is 99.9% similar.

Key Resources

Visual Concepts
Vaccine
Genetically Engineered Vaccines
DNA Fingerprint
Making a DNA Fingerprint

Why It Matters

The Human Genome Project Tell students that the HGP was launched in 1990. Its goal was to determine the entire nucleotide sequence of the human genome. Completion of the initial sequencing was announced in June 2000, and in April 2003 complete sequencing was announced. In May 2006, *Nature* announced complete sequencing of the last chromosome. Despite these announcements, the project will not be finished for years. Areas such as the centromere and telomere regions have highly repetitive sequences that are problematic.

Section 1

❯ Focus

This section explains how information from the Human Genome Project is being used today. It also discusses its future applications and considerations for gene technology.

Bellringer

Use the Bellringer transparency to prepare students for this section.

❯ Teach

Demonstration

DNA Fingerprints Have students use an inkpad and white paper to take their own fingerprints. Then, have small groups of students compare their prints. Ask students what they observe about the prints. (Each person's prints are unique.) Explain that just as everyone has different fingerprints, each person also has a unique pattern of DNA sequences, called a DNA fingerprint. LS Interpersonal

Math Skills

Unique DNA Given the information from the HGP findings, have students calculate the amount of an individual's DNA that is unique. (0.01% of 2.9 billion bases = 2,900,000,000 × 0.0001 = 290,000 bases) LS Logical

Teach, *continued*

Teaching Key Ideas

Genetic Engineering The term *genetic engineering* may have a negative connotation to some people. Address this issue by asking students why they think that some people have negative ideas about gene technology. (Sample answers: Movies show "mad" scientists making monsters by genetic engineering; uninformed people have made incorrect statements in the press.) LS Interpersonal

READING TOOLBOX

Using Words Ask students to name a vaccine they have received. (Sample answers: polio, hepatitis B, mumps, flu) Explain that a traditional vaccine is made from dead or weakened forms of the organism. Tell students that the word *vaccine* comes from the Latin word *vacca,* which means "cow," because the first vaccine (to treat smallpox) was made from cowpox. LS Verbal

Answers to Caption Questions

Figure 2: signs of genetic disorders or cancer

microarray (MIE kroh uh RAY) a device that contains a micro-scale, orderly arrangement of biomolecules; used to rapidly test for the presence of a range of similar substances, such as specific DNA sequences

DNA fingerprint a pattern of DNA characteristics that is unique, or nearly so, to an individual organism

Applications of Human Genetics

Studying the human genome opens new doors to understanding our bodies. In addition, we have new ways to apply this knowledge. *Gene technologies* allow us to find genes, copy them, turn them on or off, and even move them between organisms. ❯ **Genomics and gene technologies have many applications in human healthcare and society.**

A major part of gene technologies is *genetic engineering,* which usually refers to the transfer of genes from one organism to another. For example, the human gene for insulin has been inserted into bacteria. Insulin is lacking in people with some forms of diabetes. So, the engineered bacteria are used to produce insulin to treat diabetes.

Diagnosing and Preventing Disease The first challenge to fighting disease is simply to diagnose, or identify, the problem. Modern gene technologies can help. For example, a **microarray,** shown in **Figure 2,** shows which genes are being actively transcribed in a sample from a cell. Some patterns of gene activity can be recognized as signs of genetic disorders or cancer.

Although most genetic disorders cannot be cured, they may be avoided in the future. For example, a person with a family history of genetic disorders may wish to undergo genetic counseling before becoming a parent. *Genetic counseling* informs people about the risk of genetic problems that could affect them or their offspring.

Many viral diseases are best prevented by vaccination. However, vaccines can be dangerous because they are made from disease-causing agents. Vaccines made through genetic engineering may limit such dangers by being more carefully designed. Various vaccines are now produced through genetic engineering. Some of these vaccines prevent diseases that were not preventable before.

❯ **Reading Check** ***When might a person seek genetic counseling?***

Figure 2 A microarray contains an assortment of gene sequences, each set in a dot. The colors indicate whether a sample of genetic material has bound to the sequence at that dot. Thus, a pattern of gene expression can be seen. ❯ **What conditions could be detected this way?**

Why It Matters

Genetically Engineered Vaccines Inform students that the FDA approved the vaccine for Hepatitis B for human use in 1981. This virus is 100 times more contagious than HIV, infecting over 200,000 people a year in the United States alone. The actual viral DNA is not used to produce the vaccine; instead, surface antigens on the virus' protein coat are the source of the vaccine. The future of recombinant vaccines depends on the cost of research-to-market and the effectiveness of such vaccines, which are less immunogenic than their conventional counterparts.

Differentiated Instruction

Alternative Assessment

Implications of Genomics and Gene Technologies Ask students to choose a topic under the passage Applications of Human Genetics. Have them write a two- to three-paragraph essay that describes the implications of a specific application to society. Essays should give reasons why understanding these implications is important. LS Verbal/Interpersonal

Data

QuickLab

15 min

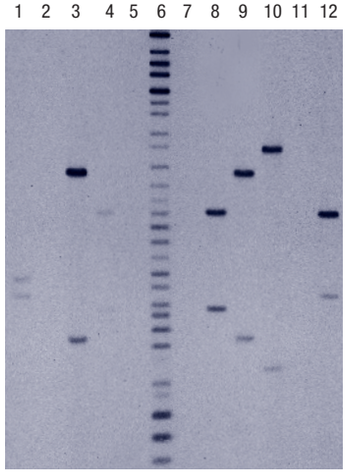
Forensic DNA Fingerprints

DNA "fingerprinting" is useful in forensics because it can be performed on a sample of DNA from body tissues such as hair or blood. Samples can be compared to find genetically identical or closely related people. Identical segments of DNA will form identical patterns of bands in the columns of a DNA fingerprint, as shown here.

Analysis

1. **Identify** the number of individuals whose DNA samples are being analyzed in this DNA fingerprint.
2. CRITICAL THINKING **Interpreting Graphics** Identify the suspect sample that matches the sample from the crime scene.
3. CRITICAL THINKING **Analyzing Methods** Column 6 shows an array of DNA segments sorted by increasing length. Propose a purpose for these columns in this method.

1 Control
3 Sample from crime scene
4 Victim
6 Standard size marker
8 Suspect A
9 Suspect B
10 Suspect C
12 Suspect D



Treating Disease Many genetic disorders occur when a specific protein, such as insulin, is missing or malformed because a gene has been mutated. So, the disorder can often be treated by supplying the needed protein. Many drug companies are now genetically engineering organisms to produce specific proteins for human use.

Another possible treatment for genetic disorders is to insert a functional "replacement" gene into a person's cells by using a genetically engineered virus. This technique is called *gene therapy*. However, gene therapy has had limited success because the human body has many protections against the invasion and genetic change that viruses cause.

The use of genomics to produce drugs is called *pharmacogenomics*. Currently, most drugs are made to combat diseases in a broad way. The drugs are generally effective for many people but not tailored to individuals. Soon, drugs could be custom-made for individuals based on a personal genetic profile. Such a profile could be produced by technologies that rapidly sequence a person's DNA.

Identifying Individuals Each person (other than identical twins) has some parts of the DNA sequence that are unique. So, samples of DNA can be compared to determine if the samples came from the same person or from people related by ancestry. These samples of DNA are cut, sorted, and "tagged" to produce a pattern of banding called a **DNA fingerprint.** DNA fingerprints are now used regularly to confirm the identity of criminals, family members, or dead bodies.

› **Reading Check** *Why is insulin used to treat genetic diabetes?*

READING TOOLBOX

Word Parts The prefix *pharma-* means "medicine" or "drug." Use this information to analyze the meaning of the term *pharmacogenomics*.

Differentiated Instruction

Advanced Learners/GATE

Cystic Fibrosis Cystic fibrosis (CF) is a life-threatening genetic disease that affects about 30,000 people in the United States. In addition, more than 10 million people are genetic carriers of the disease. In people with CF, a defective gene causes the body's secretory cells to produce a faulty protein that leads to abnormally thick, sticky mucus that clogs the lungs. Have students investigate how gene therapy is being used to treat cystic fibrosis. Tell them to include how the genetically engineered virus is delivered. Ask students to report their findings in a visual display, such as a poster or bulletin board. LS **Visual**

QuickLab

Teacher's Notes Use a transparency of the DNA fingerprint to show how to match the horizontal bands. Have students use a ruler to align the bands.

Answers to Analysis

1. Probably five: Victim, Suspect A, Suspect B, Suspect C, and Suspect D. It is possible that the sample from the crime scene is from a sixth person.
2. Suspect B
3. Sample answer: to compare to the other results; to serve as a "control" of sorts.

Why It Matters

Genetically Engineered Insulin The first genetically engineered product used to treat a human disease was insulin. Prior to the drug's FDA approval in 1982, diabetics had to rely on cow or pig insulin to manage their disease. Ask students what advantage genetically engineered insulin might have. (eliminate adverse reactions due to incompatibility) LS **Logical**

READING TOOLBOX

Word Parts Ask students to break down the word into its three parts. (*pharma-*, *co-*, *genomics*) Ask what *co-* means. If students have difficulty, provide an example, such as *cooperate*. (to work together, so *co-* means "with" or "together.") Have students put the word parts together in a definition. (medicines made with the technology of studying genomes) LS **Verbal**

Teach, *continued*

Why It Matters

Future Decision-Makers Point out that as knowledge about the human genome increases, students will be faced with increasingly complex social, medical, and ethical issues. In order to be informed decision-makers, they will need to know the facts about gene technologies.

Close

Formative Assessment

Which is *not* an application of gene technologies?

A. producing insulin (Incorrect. The human gene for insulin has been inserted into bacteria.)

B. diagnosing diseases and disorders (Incorrect. Patterns of gene activity can indicate signs of certain disorders or cancer.)

C. eliminating ethical issues (Correct! As a result of gene technologies, many ethical questions arise.)

D. better drugs (Incorrect. Custom-made drugs may be possible by knowing a person's DNA.)

Figure 3 The human genome contains as much information as 180 phone books from different major cities.

SCILINKS
www.scilinks.org
Topic: Human Genome Project
Code: HX80770

ACADEMIC VOCABULARY
implication something involved or resulting from

Ongoing Work

Making a list of all of the bases in the human genome was only a first step. Understanding this "book of life" will take much more work. First, a huge amount of information is involved, as **Figure 3** shows. Second, although we know how to read the "letters" of this "book," we do not understand most of its meaning. We have compiled a long list of genes, but we do not know what many of the genes actually do. **› Many important questions about the human genome remain to be investigated or decided.** These questions include the following:

- **How do our genes interact?** To understand how genes interact, scientists are looking closely at the processes of gene expression. For example, they study how the protein that results from one gene may regulate the expression of other genes.
- **How unique are we?** Scientists are increasingly comparing our genome to those of other organisms to find out how small differences in genomes result in different species. Genome projects for many other species have been completed or are under way.
- **Can genetics help us live longer?** Gene technologies and genomics are thus leading to increased knowledge of how we could live longer, healthier lives. We are just beginning to find genetic clues about complex conditions such as asthma, obesity, schizophrenia, cancer, and aging. These conditions are affected by complex interactions between many genes as well as our environment. For many disorders, we are not likely to find a single cause, much less a simple cure.
- **How should we deal with ethical issues?** With so much information about human DNA being recorded, many questions arise that cannot be answered by scientific lab work. For example, Who should get the information? Who owns it? Should it be used to make decisions about individuals? Scientists and governments expect these issues to arise. In the United States, a portion of the federal funds for the HGP are dedicated to a special program of the HGP called *Ethical Legal and Social Implications* (ELSI).

› Reading Check ***Why is asthma difficult to cure?***

Section 1 Review

› KEY IDEAS

1. **Describe** the major findings of the Human Genome Project.
2. **Identify** some applications of genomics and genetic engineering that benefit humans.
3. **List** remaining questions about the human genome.

CRITICAL THINKING

4. **Proposing Explanations** Propose some possible explanations for the large volume of noncoding DNA in the human genome.
5. **Applying Logic** Scientists say that knowing the sequence of nucleotides in the human genome is only the first step in understanding the genome. What are some possible next steps?

WRITING FOR SCIENCE

6. **Genetics on Trial** When were gene technologies first used as evidence in criminal cases? Research the early history of this field, and summarize your findings in a news-style oral report.

Answers to Section Review

1. Humans have fewer genes than predicted, most human DNA is noncoding, many human genes are identical to those of other species, all humans are genetically similar.
2. Applications of genomics and genetic engineering include diagnosing, preventing, and treating disease; and identifying individuals.
3. How do genes interact? Will we be able to live longer? How are we related to other species? How should we deal with ethical issues?
4. Sample answer: Noncoding intron segments of DNA may be genes once useful to other organisms or needed to control transcription.
5. Sample answer: determining which nucleotides make up genes and how they become expressed
6. The first use of DNA for a criminal case was in the 1980s, by Professor Alec Jeffries of the University of Leicester in England.

Why It Matters

Cleanup Microbes

BIOTECHNOLOGY

Using microbes for environmental cleanup is called *bioremediation*. For example, oil-devouring microbes are used to help clean up oil spills. Increasingly, genetically modified organisms (GMOs) are being engineered for use in bioremediation.

Oil Spills

Spills of fuel oil can be devastating to environments because the oil is toxic, floats on water, and soaks into soils. Fortunately, scientists have found that some marine bacteria are capable of using oil as food. Some of the first genetically modified (GM) microbes were derived from such bacteria. In fact, the first organism to be patented was an oil-eating, genetically engineered bacterium.

Radioactive Waste

Nuclear waste is another bioremediation challenge with which GM microbes may help. Water near nuclear waste dumps may become polluted with radioactive substances. Again, bacteria naturally exist that can break down most of these substances, but those bacteria cannot survive high levels of radiation. So, scientists have turned to another kind of bacteria that can withstand 3,000 times the normal radiation levels. They hope to engineer a solution by transferring genes between these species.

An impossible job? Cleaning oil and dangerous chemical spills out of sand or soil can be nearly impossible for humans, even with tools. However, this cleanup is simple work for a microbe.

An Enormous Mess Oil spills at sea are dangerous to wildlife, dangerous to the people involved in fighting them, and difficult to contain.

Quick Project Find out the date that the first patent for a GMO was awarded in the United States. Also find out the name of the scientist to whom it was awarded.

Answer to Quick Project

The question of awarding patents on genetically modified organisms arose when a microbiologist Ananda Chakrabarty filed for a patent on a bacterium capable of digesting the components of crude oil. His patent request was controversial because it would be the first patent on a living organism. The case was eventually brought before the U.S. Supreme Court, which ruled in 1980 that human-engineered organisms are patentable under federal law. The first patent for gene cloning was awarded to Herb Boyer and Stanley Cohen in 1980.

Why It Matters

Teacher's Notes While bacteria that can digest oil were used to clean up the *Exxon Valdez* oil spill, those bacteria were not genetically modified. Genetically modified bacteria have the potential to be used for bioremediation purposes, but their use is heavily regulated and controversial because of the possibility that they could "escape" into the environment and cause unforeseen problems.

READING TOOLBOX

Visual Literacy Before students read the text, have them study the pictures. Ask them how an oil spill might harm an ecosystem. (kill organisms living there and disrupt the food web) Then, ask how they would clean up an oil spill. (Accept any reasonable answers.)

LS Logical/Visual

Section 2

Gene Technologies in Our Lives

Key Ideas	Key Terms	Why It Matters
For what purposes are genes and proteins manipulated? How are cloning and stem cell research related? What ethical issues arise with the uses of gene technologies?	genetic engineering recombinant DNA clone stem cell	Gene technologies have many applications in modern life, but ethical issues exist for each of these applications.

Focus

This section focuses on applications of gene technologies and the ethical and social issues associated with them.

Bellringer

Use the Bellringer transparency to prepare students for this section.

Teach

Demonstration

Better Produce Provide student groups with different fruits or vegetables. Have them list ways that they would like to improve their item. Tell them to consider not only how it tastes, but also how it is grown, picked, transported, and sold. What properties would make the fruit or vegetable better able to withstand these processes? Then, tell students that genetic engineering has already improved produce. Point out that students most likely have already eaten genetically altered crops because many crops raised in the United States—including more than 80 percent of the soy and 40 percent of the corn—are genetically altered.

LS Logical

Recall that a gene has a DNA sequence that is translated into the sequence of amino acids in a protein. In a sense, proteins are the "actors" in biology, and genes are the "directors." To understand how genes work, scientists have studied both the instructions in the genes and the actions of the proteins. Meanwhile, some have tried to modify the instructions to change the actions that result.

Manipulating Genes

Gene technologies include a wide range of procedures that analyze, decode, or manipulate genes from organisms. **Gene technologies are now widely applied to study organisms in new ways, to alter organisms for human use, and to improve human lives.** Gene technologies have rapidly changed over the past two decades, yet the basic applications are not so new. Human beings have been influencing the lives and genes of organisms for thousands of years. The first farmers and herders did so when they selected plants and animals to breed. But today, we have more specific knowledge, molecular tools, and the ability to move genes between organisms.

Figure 4 These fish "glow" because scientists have copied a gene from a naturally "glowing" jellyfish and inserted it into the fishes' genomes.

Genetic Engineering The application of science for specific purposes is often referred to as *engineering*. **Genetic engineering** is the deliberate alteration of the genetic material of an organism. The process often involves inserting copies of a gene from one organism into another. DNA that has been recombined by genetic engineering is called **recombinant DNA.** Organisms with recombinant genes may be called *recombinant, transgenic,* or *genetically modified.* In everyday use, they are often referred to as *genetically modified organisms* (GMOs). An example of a GMO is shown in **Figure 4.**

Many applications of gene technologies have become part of our everyday lives, from food to healthcare. In some ways, we are starting to depend on gene technologies, just as we depend on electricity and telephones. As with other technologies, gene technologies raise new social and ethical issues.

Reading Check ***What is a GMO?***

Key Resources

Transparencies
C34 Genetic Engineering
C38 Making a Genetically Engineered Vaccine

Visual Concepts
Genetic Engineering
Cloning

Why It Matters

Key Discoveries Tell students that genetic engineering relies on two important discoveries. In 1952, Joshua Lederberg identified and named the plasmid, a ring of DNA found in some bacteria. In 1970, Hamilton Smith discovered restriction enzymes in bacteria that act as molecular "scissors" to cut pieces of invading viral DNA. Because DNA is universal, the bacteria could be used to cut DNA from any source. In 1972, relying on both of these discoveries, Paul Berg successfully assembled the first recombinant DNA molecule—a plasmid with an external source of DNA that was incorporated into the plasmid genome.

Everyday Applications Genetic engineering was first applied to bacteria, viruses, and plants and is now applied to many life-forms. Today, GMOs are widely used in agriculture, medicine, industry, and basic research. Following are examples of the many uses of GMOs.

- **Food Crops** Most corn and soybean products sold in grocery stores in the United States are made from GMOs. In many cases, the crops have a gene added from the bacterium *Bacillus thuringiensis* (*Bt*). The gene produces an insecticide and thus benefits the crop grower. Many food crops are engineered to be easier to grow or to be more nutritious.
- **Livestock** New breeds of livestock are being engineered to grow faster or to have more muscle or less fat. Some are made to produce milk with specific proteins. Some GMOs are sold as unusual pets.
- **Medical Treatment** As you have learned, many genetic disorders, such as hemophilia and diabetes, result from a missing or abnormal protein. If the normal human gene for needed protein has been identified, the gene can be spliced into bacterial cells. Then, the recombinant bacteria will rapidly produce the human protein in large quantities. People with hemophilia and diabetes are being treated with proteins produced in this way.
- **Basic Research Tools** A variety of GMOs have been made just for laboratory research. Some plants and animals have been engineered with genes from other organisms that "glow." Often, this engineering is done so that researchers can study another, less obvious gene. In this case, the two foreign genes are spliced into the GMO at the same time. The "glow" gene then serves as a "marker" of the presence of the second gene being studied.

Manipulating Cell Interactions Gene technologies involve more than just inserting genes. Cells and bodies are affected by when and where each gene is expressed. So, gene technologies are also used to control the expression of genes or to redirect the products.

The study of how proteins interact within cells is called *proteomics* (PROH tee OHM iks). As you have learned, these interactions are very complex. Gene technologies can be used to manipulate the production of specific proteins at specific times and in specific cells, tissues, organs, or individuals. This manipulation can be done for medical treatment or simply for research.

One way to study the actions of genes in cells is to work with living tissues. To do so, scientists can remove living cells from an organism and grow them in a laboratory as tissue culture, as **Figure 5** shows. Then, the cells can be studied closely and experimentally controlled.

› **Reading Check** ***What is the* Bt *gene used for?***

genetic engineering a technology in which the genome of a living cell is modified for medical or industrial use

recombinant DNA (ree KAHM buh nuhnt) DNA molecules that are artificially created by combining DNA from different sources

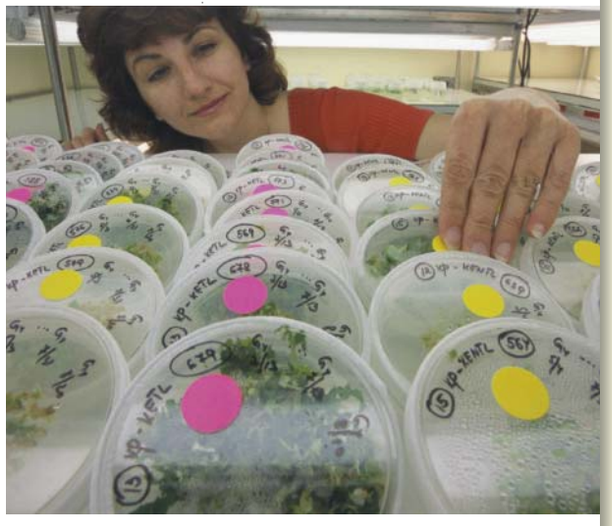


Figure 5 Tissue culture is often used to study living cells. › **What can we learn about genes from tissue culture?**

Teaching Key Ideas

Food Crops Some food crops, such as corn and soybeans, have been altered genetically to be resistant to glycophosate, a popular weed killer. The weed killer will thus kill most plants besides the engineered crops, so crop yields may increase. Other plants have been altered to be resistant to insects. This application is important because a large percentage of the world's food supply is lost to pests. Pesticides have traditionally been used, but although effective, they have disadvantages. Ask students what some disadvantages of pesticides might be. (Over time the pests become resistant to the pesticide; other organisms might be harmed by the pesticide.) LS Verbal

Answers to Caption Questions

Figure 5: We can learn when and where genes are expressed in different cells, and learn how each cells' environment affects gene expression.

Differentiated Instruction

Advanced Learners/GATE

Genetically Modified Tomatoes Have students investigate why the tomato was chosen as the first GM food to be sold, how it was altered, and its advantages. LS Verbal

Why It Matters

Flavr Savr™ Tomato Explain to students that not all genetically modified crops have met with marketing success. The Flavr Savr™ tomato was the first genetically modified food approved by the FDA for market in 1994, but it was not very popular. The public was apprehensive about eating a genetically modified plant. The product was also very expensive in order to offset the expense of research and development. In 1997, the tomato was pulled from the marketplace.

Teach, *continued*

Teaching Key Ideas

Multicellular Cloning Explain to students that in mammals the egg cell cytoplasm generally directs the "program" for development, which is normally triggered by fertilization. During SCNT, an unfertilized haploid egg nucleus is replaced by a diploid, somatic cell nucleus. Environmental conditions are then controlled to trigger development of an embryo.

Teaching Key Ideas

Cloning and Age Make sure students note the difference in the muzzle of the donor of the somatic cell and the surrogate mother in **Figure 6.** Ask what the muzzle of Dolly would look like. (white like the donor) Point out that as Dolly grew older, her chromosomes began showing signs of premature aging. Ask students to speculate on Dolly's "chromosomal" age at birth. (Her chromosomes were the age of the donor!) LS Logical

clone an organism, cell, or piece of genetic material that is genetically identical to one that was preexisting; to make a genetic duplicate

stem cell a cell that can divide repeatedly and can differentiate into specialized cell types

SCILINKS
www.scilinks.org
Topic: Cloning
Code: HX80303

Manipulating Bodies and Development

Biologists still have much to learn about the development of multicellular organisms. To do so, they must study cells in the process of multiplying and differentiating into the many types of cells found in a body. **Cloning and stem cell techniques are used in research on animal development and have potential for treating certain diseases.**

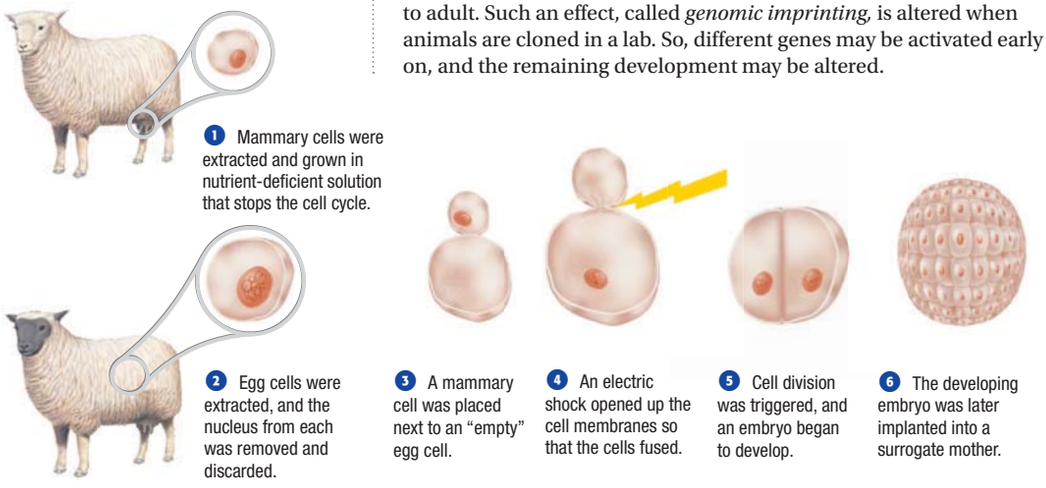
Cloning A **clone** is an organism or piece of genetic material that is genetically identical to one that was preexisting. Making a clone in a lab is called *cloning,* but the process does occur in nature. Organisms clone themselves whenever they reproduce asexually. Single-celled organisms clone themselves by simple division. Multicellular organisms may clone themselves by budding off parts, as some plants and fungi do, or by self-fertilization, as many plants and some animals do.

Very few large animals can clone themselves. Also, animals have complex processes of fertilization and embryo development. So, scientists are still experimenting with cloning animals. The first such experiments made clones from eggs or embryos. Then, a clone was made from an adult mammal, as **Figure 6** shows. The clone was made using a process called *somatic-cell nuclear transfer* (SCNT). In this process, the nucleus of an egg cell is replaced with the nucleus of an adult cell. Then, the egg begins to develop into an embryo.

Problems with Cloning Although scientists have successfully cloned many kinds of animals, only a few of the cloned offspring have survived for long. In some cases, the fetuses have grown beyond normal size. Many have failed to develop normally with age. Because of such problems and because of ethical issues, efforts to clone humans are illegal in most countries.

Genomic Imprinting Some problems with cloning may be related to the ways that eggs and sperm normally develop. Chemicals in the reproductive system turn "on" or "off" certain genes in the developing gametes. These genes later affect development from embryo to adult. Such an effect, called *genomic imprinting,* is altered when animals are cloned in a lab. So, different genes may be activated early on, and the remaining development may be altered.

Figure 6 Dolly, a cloned sheep, was born in 1997. Dolly was the first successful clone produced from the nucleus of an adult somatic cell.



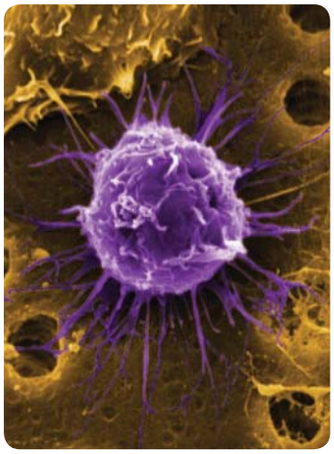
Why It Matters

Success of Cloning Point out to students that the success rate of SCNT is very low. There were 246 failures before cloning Dolly. Not only does embryonic development depend on genomic imprinting, there are many other factors that come into play after implantation into the uterus. These points should be underscored so that students recognize that the possibility of human cloning is very remote.

Differentiated Instruction

Basic Learners

Cloned Animals Have students research which have been cloned, when, and where. Ask students to present their findings in the form of a poster, with photos if possible. LS Verbal



1 An adult stem cell can be removed from a specific tissue, such as bone marrow.

2 The cell can be grown in tissue culture to produce more cells of a specific tissue type.

3 The cells can be re-implanted into a patient whose tissues are lacking or damaged.

Figure 7 Adult stem cells can be removed and used to grow more cells of specific tissue types. This kind of therapy can replace tissue that is damaged or deficient due to disease or other medical treatment. **How do adult stem cells differ from embryonic stem cells?**

Using Stem Cells A stem cell is a cell that can continuously divide and differentiate into various tissues. Some stem cells have more potential to differentiate than others. *Totipotent* cells can give rise to any cell or tissue type, *pluripotent* cells can give rise to all types except germ cells, and *multipotent* cells can give rise to just a few other cell types. The state of the cell depends on the stage of development of the body and the tissue of which the cell is part.

Adults' bodies have some multipotent cells, such as bone marrow cells, that give rise to various blood cells. These cells can be removed, frozen or cultured, and used for medical treatments, as **Figure 7** shows. The cells of new embryos have more potential uses. These cells are totipotent at first and pluripotent during development.

Issues with Stem Cell Research The first major source of human embryos for stem cell research was fertility clinics. Such clinics help people have children, often by uniting people's gametes and culturing embryos in a lab. Many extra embryos are stored in a frozen state in clinics. In some cases, the parents have given scientists permission to use the embryos for research. But such uses of human embryos pose ethical problems. In the United States, there have been strong debates about the use of federal funds for this kind of research.

Stem Cells from SCNT A newer source of embryonic stem cells is through cloning using SCNT. Some people believe that using this kind of stem cell for medical research and treatment should be ethically acceptable. One reason is that an embryo made through SCNT does not have true parents. Another reason is that the cells of the embryo are separated early in its development, so there is no chance of the embryo developing further.

Reading Check *What are the two main types of stem cells?*

READING TOOLBOX

Analogies Use the information in this section to help you write an analogy that relates adult stem cells to embryonic stem cells. Try to use the terms *pluripotent* and *multipotent* in your analogy.

Differentiated Instruction

Struggling Readers

Types of Stem Cells Have students make a three-column chart with these column headings: *Cell Type, Definition, Where Found.* Have them fill in the chart with information about totipotent cells, pluripotent cells, and multipotent cells. LS Verbal

Why It Matters

Stem Cell Research Tell students that the use of embryonic stem cells in research remains controversial, partly because it is a complex and rapidly advancing field. Meanwhile, laws regarding such research differ between different states in the U.S. and between the U.S. and other countries. Debate in the U.S. has centered on limiting the practices of laboratories that receive any form of federal funding. Research in this area has continued with funding from private, state, and foreign sources. LS Verbal

Teaching Key Ideas

Embryonic and Adult Stem Cells Ask students which stem cell has more potential: an adult bone marrow cell or a cell from a very young embryo. (embryo cell) Why? (Embryonic stem cells can give rise to all kinds of cells; adult bone marrow stem cells can give rise only to various blood cells.) Ask why adult stem cells are being used even though they have less potential. (lack of availability of embryos, ethical considerations) LS Logical

READING TOOLBOX

Analogies First, have students review the definitions of *pluripotent* and *multipotent*. Then, ask them which term applies to embryonic stem cells and which term to adult stem cells. Finally, ask students to write the analogy. (multipotent: adult stem cells :: pluripotent: embryonic stem cells) LS Verbal

Answers to Caption Questions

Figure 7: Adult stem cells have less potential to differentiate; they are multipotent, whereas embryonic stem cells are either totipotent or pluripotent.

Close

Formative Assessment

The process of changing the DNA of an organism is called _____.

A. proteomics (Incorrect. Proteomics is the study of how proteins interact within cells.)

B. genomic imprinting (Incorrect. Genomic imprinting is an effect on the genes of a developing embryo.)

C. genetic engineering (Correct! Genetic engineering is deliberately changing the genetic material of an organism.)

D. recombinant DNA (Incorrect. Recombinant DNA is a result of changing DNA.)

Figure 8 This corn has been genetically modified to carry the *Bt* gene, which causes the corn plant to produce an insect-killing chemical. As with any use of pesticides, this practice presents risks. An additional danger is that the gene may be transferred to other plants.

Ethical and Social Issues

Ethical issues involve differing values and perspectives. For example, the use of GMOs is prohibited or tightly controlled by laws in some countries. In others, GMOs are widely used, and GM foods are sold with few restrictions. **› Ethical issues can be raised for every use of gene technologies.**

Safety One danger of GMOs is that they can "escape" and have unforeseen effects. For example, the *Bt* toxin gene from GM corn crops, such as those in **Figure 8,** has been transferred to other plants. In addition, the toxic corn pollen seems to be harming populations of the monarch butterfly. Ecologists worry that we do not know enough to safely manipulate genes on a large scale.

Human Rights Being able to predict disease before it happens is a major achievement of modern medicine. Today, the DNA of individuals can be tested to find the risk of genetic disorders. But what should we do with this information? Many decisions could be influenced by such genetic information, such as whom to marry or what to eat. Who should have this information? Who should make these decisions? How can future probabilities be weighed against current human needs and rights? There are no easy answers to these ethical questions, but the questions need to be considered carefully.

Property Laws Gene technologies have also created new issues for old laws, especially those related to intellectual property and patents. Intellectual property (IP) is the ownership of the ideas or plans that a person creates. A patent is a specific set of rights that allows an inventor to control and profit from the uses of his or her idea. In the 1980s, the first patent for a GMO was awarded to a scientist who had engineered an oil-eating bacterium. Before this event, living organisms were considered a part of nature and, as such, were not patentable. Now, specific DNA sequences can be patented.

› Reading Check ***What issues does the use of genetic testing raise?***

ACADEMIC VOCABULARY

ethical conforming to moral standards

Section 2 Review

› KEY IDEAS

1. **Identify** applications of manipulating genes and proteins.
2. **Relate** stem cell research to the potential use of cloning.
3. **Describe** a specific ethical issue related to a gene technology.

CRITICAL THINKING

4. **Inferring Relationships** How can manipulating gene expression help advance the study of proteomics?
5. **Evaluating Risks** Given the difficulties that researchers have had with raising cloned animals, do you think it is safe to grow tissues or organs from cloned embryonic stem cells for the purpose of transplanting? Explain.

ALTERNATIVE ASSESSMENT

6. **Debate** Suppose that genetic analysis could predict a person's ability in sports, math, or music. Should genetic screening be used to determine the course selections and team assignments of every student in school? Prepare and conduct a formal debate on the subject.

Answers to Section Review

1. genetic engineering to produce new crops, livestock and medical treatments, and as a research tool to study the roles of proteins
2. Cloning can produce organisms that are genetically identical to preexisting individuals; stem cells can be used to grow new tissues.
3. Sample answer: GM crops may have unforeseen, harmful effects on the environment.
4. Manipulating gene expression changes protein production. Therefore, researchers can determine the proteins that specific genes code for.
5. Sample answer: No, because there may be abnormalities in the organs of cloned animals that would make them unsuitable for transplantation, as well as posing a risk to the recipient. Accept all reasonable answers.
6. Sample arguments: pros: Students might be more successful in courses for which they had an aptitude; cons: students would limit their exposure to other areas, which might make them less "well-rounded."

Section 3

Gene Technologies in Detail

Key Ideas	Key Terms	Why It Matters
❯ What are the basic tools of genetic manipulation? ❯ How are these tools used in the major processes of modern gene technologies? ❯ How do scientists study entire genomes?	restriction enzyme DNA polymorphisms electrophoresis polymerase chain reaction (PCR) DNA sequencing bioinformatics genome mapping genetic library	Humans now have the ability to identify and manipulate genes in many organisms.

How do you find a needle in a haystack? This phrase is often used to speak of a nearly impossible task. But if the haystack is a genome and the needle is a gene, the task is now possible!

Basic Tools for Genetic Manipulation

Molecular biologists spent many years developing tools and methods to manipulate genetic material. The methods continue to be used and adapted for a wide range of applications, but the basic tools are similar. ❯ **The basic tools of DNA manipulation rely on the chemical nature of genetic material and are adapted from natural processes discovered in cells.** These tools include restriction enzymes, polymorphisms, gel electrophoresis, denaturation, and hybridization. For example, the first GMOs were made by using plasmids and enzymes that are naturally present in some bacterial cells.

Restriction Enzymes Among the first tools used to manipulate DNA were enzymes that are made by bacteria as a defense. The enzymes serve to slice up any invading DNA sequences or genes from other organisms. These **restriction enzymes** recognize a specific sequence of DNA, called a *restriction site*. The enzymes will cut DNA strands at all such sites, as **Figure 9** shows.

restriction enzyme an enzyme that cuts double-stranded DNA into fragments by recognizing specific nucleotide sequences and cutting the DNA at those sequences

These enzymes are useful in two ways. First, different enzymes recognize different sequences, so the enzymes can be used to cut up a DNA sample in specific ways. Second, the cuts of most restriction enzymes create sticky ends. A *sticky end* has a few bases on one strand that are unpaired but complementary to unpaired bases on other sticky ends. So, sticky ends will easily bind to one another.

❯ **Reading Check** ***Which basic genetic tools were used to make the first GMOs?***

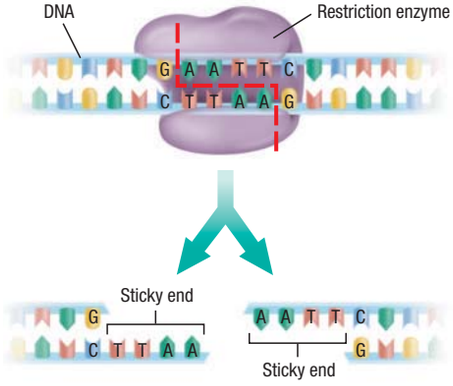


Figure 9 Restriction enzymes recognize and cut DNA at specific sequences. Usually, complementary ("sticky") ends are created. ❯ **In what ways are restriction enzymes useful?**

Why It Matters

Naming Restriction Enzymes Tell students that each specific type of restriction enzyme is named for the species of bacteria from which it was isolated: For example *EcoRI,* the restriction enzyme shown in the student book, comes from *E. coli.* The first three letters come from genus and species; the fourth letter, *R,* represents the strain, and the Roman numerals represent the order of discovery. Point out that there are thousands of types of restriction enzymes, and each recognizes a different DNA sequence.

Key Resources

Transparencies
- C32 Restriction Enzymes Cut DNA
- C33 Gel Electrophoresis
- C35 Genetically Engineered Medicine

Visual Concepts
- Gel Electrophoresis
- Polymerase Chain Reaction
- Cloning Vectors and Plasmids
- Using Plasmids to Produce Insulin

Section 3

❯ Focus

This section identifies basic tools used for genetic manipulation and explains the processes of modern gene technologies.

Bellringer

Use the Bellringer transparency to prepare students for this section.

❯ Teach

Teaching Key Ideas

Restriction Enzymes Point out that restriction enzymes work by identifying a specific sequence of nucleotide bases that are palindromes—words, phrases, numbers, or other sequences of units that read the same in either direction. Write the palindrome "Madam I'm Adam" on the board. Point out that when read from right to left and adjusting the spacing and punctuation, the letters state the same message as when read from left to right. Have students look at **Figure 9** and notice that the bases on the upper strand are read in reverse of the sequence on the lower strand. LS Visual

Answers to Caption Questions

Figure 9: They can be used to find specific sites on DNA or to cut it so that pieces can be spliced together.

Teach, *continued*

QuickLab

Teacher's Notes Use beads of three different sizes and colors. The large beads should be big enough so that the smallest beads can flow through the spaces between them.

Materials
- beads, 3 sizes
- plastic cup, 500 mL
- unbreakable plastic jar, 1 qt or larger

Answers to Analysis

1. The smallest beads flowed faster.
2. In gel electrophoresis, small bits of DNA are pulled (by electrical force instead of gravity) through a matrix of other molecules.
3. They were slowed less by the larger beads (the matrix).

Science Skills

DNA Electric Charge Tell students that the phosphate functional group of a nucleotide has a negative charge, making the overall charge on a DNA molecule negative. When an electric current is applied to a gel containing DNA fragments, the DNA moves through the gel in response to its attraction to the positive electrode. LS Logical

Answers to Caption Questions

Figure 10: The semisolid property of the gel slows down large molecules as they are pulled through it by an electric field.

Hands-On

QuickLab

15 min

Gel Electrophoresis Model

You can use beads to model how DNA fragments are separated in a gel during electrophoresis.

Procedure

1. Fill a large jar with the largest of three sets of beads (each set should be a different size and different color). The filled jar represents a gel.
2. Mix the smaller sets of beads in a plastic cup, and then pour them slowly on top of the "gel." The smaller beads represent DNA fragments.
3. Observe the flow of the beads through the "gel." Lightly agitate the jar if the beads do not flow easily.

Analysis

1. **Identify** which beads flowed through faster.
2. **Relate** this model to how electrophoresis works.
3. CRITICAL THINKING **Using Models** Why did the beads identified in item 1 pass through the "gel" more quickly?

ACADEMIC VOCABULARY

slight very small or barely detectable

Polymorphisms Differences between the DNA sequences of individuals are called **DNA polymorphisms.** These differences may be slight but can be compared and analyzed for several purposes, as you will learn. Differences of just one nucleotide are called *single nucleotide polymorphisms* (SNPs). SNPs result from point mutations and are usually unique to individuals or populations. At a broader level, each species has a unique pattern of restriction sites. When different DNA samples are cut with the same restriction enzyme, the segments that result will have different lengths. These differences are called *restriction fragment length polymorphisms* (RFLPs).

Gel Electrophoresis DNA carries an electric charge, so an electric current can be used to push or pull DNA fragments. This process is called **electrophoresis.** Often, the DNA fragments are forced though a *gel,* a semisolid that allows molecules to move slowly through it. When a current is applied, shorter fragments will move faster through the gel than longer fragments will. The result is a lane of fragments sorted by size, as shown in **Figure 10.** If the fragments separate clearly, each lane is called a *ladder*. If the fragments have overlapping sizes and do not separate clearly, each lane is called a *smear*.

There are many types of electrophoresis. Different kinds of gels are used to sort different sizes of DNA fragments, and other methods are used to sort RNA or proteins. Newer methods use tiny tubes of gel to sort tiny samples that can then be "read" by a machine and analyzed by a computer.

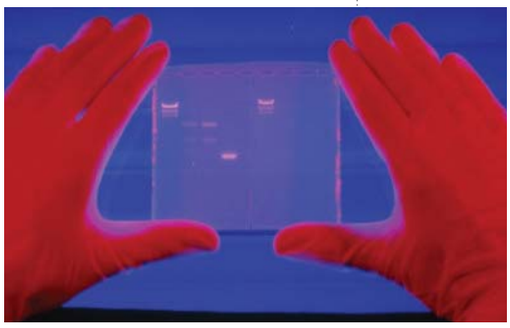


Figure 10 Gel electrophoresis separates samples of molecules, such as DNA or proteins, into bands that are ordered by size. **What is the role of the gel?**

Reading Check ***What property of a gel does gel electrophoresis depend upon?***

Differentiated Instruction

English Learners

Identifying DNA Differences Have students make drawings to illustrate SNPs and RFLPs. Tell them to label their drawing with these terms: *SNP, RFLP, nucleotide, DNA segment.* LS Visual

Special Education Students

Identifying Separation Patterns Have students work in mixed groups. Provide a sheet of paper with strips marked with DNA bases that include GAATTC restriction sites at irregular intervals. Have students cut the strips and tape them into one long segment. Using scissors, have the students cut at the restriction sites. Have students position the segments from largest to smallest in a line to represent how the segments would sort by size during electrophoresis. LS Kinesthetic

Denaturation Recall that DNA in cells is usually double stranded, twisted, and often associated with proteins. Some conditions, such as heat or strong chemicals, can cause DNA to denature, or untwist and split into single strands. Scientists can easily denature and renature DNA and use the single strands for further manipulations.

Hybridization When single-stranded segments of DNA or RNA are mixed together under the right conditions, complementary segments will bind together, or hybridize. Genetic tools that take advantage of this natural process include the following:

- **Primers** *Primers* are short, single strands of DNA that will hybridize with a specific sequence. For this use, the sequence is one that will be recognized by an enzyme, such as DNA polymerase. Thus, primers can be used to initiate replication of single strands of DNA.
- **Probes** When DNA samples are sorted in a gel, probes are used to "tag" and find specific sequences. Probes are much like primers but carry radioactive or fluorescent materials that can be detected.
- **cDNA** Complementary DNA (cDNA) is DNA that has been made to match mRNA from cells. Recall that this mRNA is the result of transcription and has exons removed. So, making cDNA is a shortcut to getting just the expressed DNA of complete genes.

Major Gene Technology Processes

The major methods for working with genes use some combination of the basic tools and mechanisms of cellular machinery. These methods include PCR, blotting, DNA sequencing, and gene recombination.

Polymerase Chain Reaction (PCR) The **polymerase chain reaction (PCR)** process is widely used to clone DNA sequences for further study or manipulation. PCR imitates the normal process of DNA replication in cells. So, using PCR is as simple as combining the right components in a test tube and then controlling the temperature, as **Figure 11** shows. The process is called a *chain reaction* because it is repeated over and over.

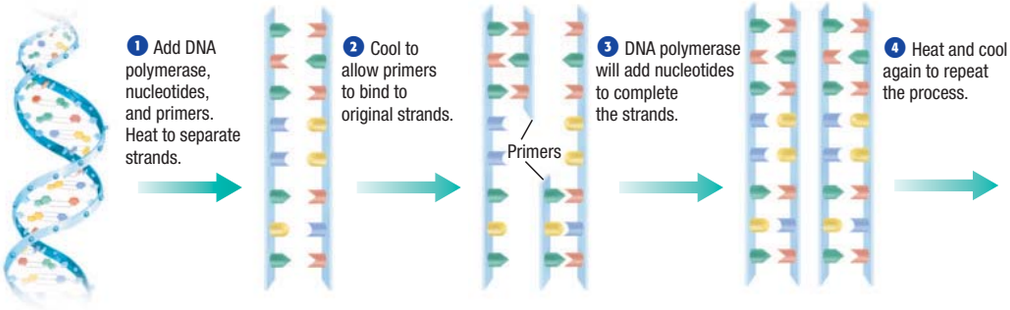
DNA polymorphisms
(PAHL ee MAWR FIZ uhmz) variations in DNA sequences; used as a basis for comparing genomes

electrophoresis (ee LEK troh fuh REE sis) the process by which electrically charged particles suspended in a liquid move through the liquid because of the influence of an electric field

polymerase chain reaction
(puh LIM uhr ays) a technique that is used to make many copies of selected segments of DNA (abbreviation, PCR)

Figure 11 PCR rapidly produces many copies of a DNA sample. The process can make 1 billion copies of a DNA sample within a few hours!

Polymerase Chain Reaction (PCR)



Differentiated Instruction

Struggling Readers

Outlining Students are introduced to several new terms and processes in this lesson. To help them summarize and organize the information, assign pairs of students to outline the lesson. Tell them to use these two major heads in their outlines: *Basic Gene Technology Tools* and *Major Gene Technology Processes.* LS Verbal

Teaching Key Ideas

PCR Tell students that PCR is a very common technique used to amplify minute amounts of DNA, such as the DNA from a single hair found at a crime scene. PCR is used in research as well. In PCR, billions of copies of DNA are made in a few hours. It is a quicker and more selective process than recombinant cloning. Ask students to identify the processes and components that are needed for the PCR process. (Processes: denaturation of DNA from heat to expose the nucleotide bases, use of primers to initiate replication; Components: DNA nucleotides, primers, and DNA polymerase)
LS Verbal

Math Skills

DNA Replication Tell students that in PCR, DNA replicates about every five minutes. Have students calculate the number of DNA copies that would be generated after one hour of PCR. (60 min/5 min/cycle = 12 cycles; 2^{12} or 4,096 copies.)
LS Logical

Teach, *continued*

Teaching Key Ideas

Southern Blot Process Refer students to **Figure 12,** and ask what the Roman numerals represent. (DNA from different individuals) Ask how the fragments in step 2 were generated. (restriction digest followed by gel electrophoresis) Point out that these fragments are of different sizes, with the smallest fragments closest to the positive pole. Ask why there are fewer bands in step 4 than in step 2. (Only those segments of interest were supplied with radioactive probes to match.) How does this process relate to an RFLP? (RFLPs are what create the differences in fragment size between different individuals.) LS Visual

Answers to Caption Questions

Figure 12: restriction enzymes, gel electrophoresis, and hybridization (probes)

SCILINKS
www.scilinks.org
Topic: Gene Technologies
Code: HX80539

Blotting Processes and Applications Several gene technologies use a combination of restriction enzymes, gel electrophoresis, and hybridization with probes. The goal is to find or compare sequences of DNA or RNA. Many include a blotting step in which sorted segments are preserved by transferring from the gel to another surface or grid (such as a sheet of special paper). Then, probes are used to reveal the location of specific sequences.

Southern Blot The Southern blot process, shown in **Figure 12,** is used specifically for DNA, and especially for DNA fingerprints. The process may vary by using either different restriction enzymes on one DNA sample or different DNA samples with the same enzyme.

Fingerprints and Bar Codes DNA polymorphisms can be used to identify individuals or species. When restriction fragments are sorted through a Southern blot process, each person's DNA will have a unique pattern of banding called a *DNA fingerprint*. Similarly, a *DNA bar code* can be made to help identify species.

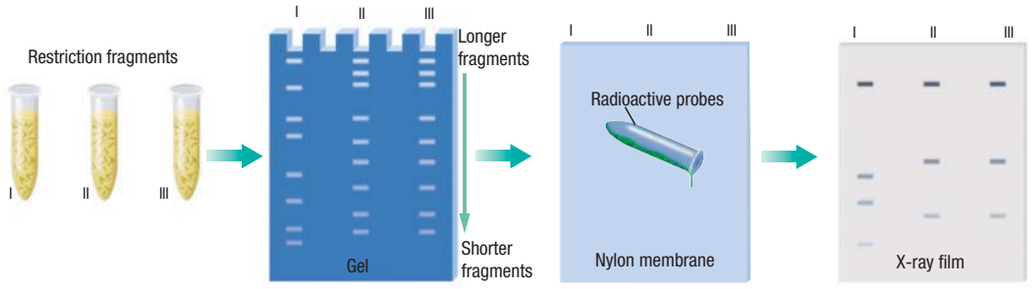
Northern Blot The Northern blot process differs from Southern blot in that the sample fragments are mRNA instead of DNA. Recall that mRNA in cells comes from genes being transcribed. So, Northern blot can be used to tell which genes in a cell are "turned on" (being expressed) or to tell the size of the expressed parts of a gene (after exons are removed).

Microarrays A *microarray* is a device that enables thousands of tiny Northern blots to be done at once. Microarrays can be used to show patterns of gene expression. For example, a cancer cell will have certain genes turned on or off. The pattern of gene activity seen in a microarray can help identify specific kinds of cancer.

Reading Check *What does "blotting" refer to?*

Figure 12 In this example, a DNA sample is analyzed by using the Southern blot process. **Which basic genetic tools are used as part of this process?**

Southern Blot Process



1 The Southern blot process begins with a sample of DNA. The DNA is cut into fragments using restriction enzymes. A unique enzyme may be used to create several batches of sample DNA.

2 The DNA fragments are sorted by gel electrophoresis. One lane in the gel is used for each batch. Then, a chemical splits all fragments into single-stranded form.

3 The DNA strands are transferred (blotted) onto a piece of nylon paper. A solution containing probes is applied to the nylon paper. The probes bind to specific sites on the single strands.

4 The exposure of photographic or X-ray film to the nylon paper reveals the location of those sample strands that hybridized with the probe. Each person's DNA will make a unique pattern.

Differentiated Instruction

Basic Learners

Models of Blotting Processes Have students research and prepare models to explain any of the blotting processes explained in the text. LS Visual

go.hrw.com
interact online
Keyword: HX8GTCF13

Chain Termination Sequencing

1 Copy The unknown DNA sequence is copied, denatured, and incubated with specific genetic molecules.

2 Terminate New copies of the original sequence begin to form, but some are terminated randomly by tagged nucleotides.

3 Sort The resulting strands are denatured and sorted in a gel. The color-coded bands in the gel will match the orginal sequence.

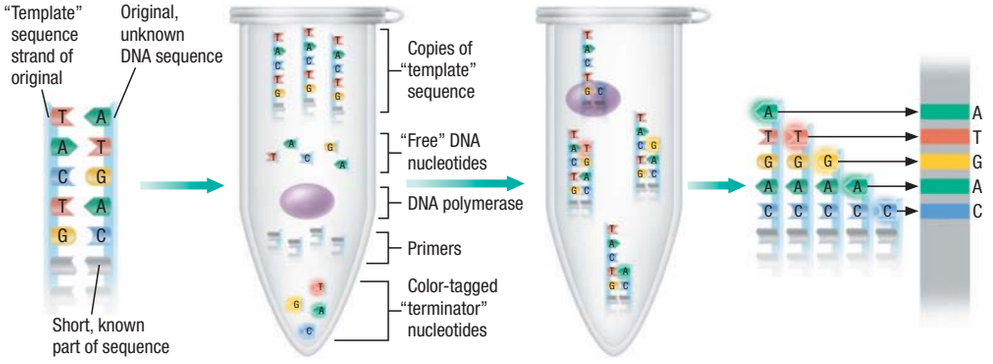


Figure 13 Chain termination sequencing modifies DNA replication processes in order to deduce a DNA sequence. **Why is this method so important?**

DNA Sequencing Among the great achievements of modern biology are DNA sequencing methods. **DNA sequencing** is the process of determining the exact order of every nucleotide in a gene. The major modern method is *chain termination sequencing*, as shown in **Figure 13.** This method has been improved over time.

Step 1 Start Copying a Template The gene (DNA segment) of interest is copied (using PCR) and split into single strands. The copies are placed in solution with primers, DNA polymerase, and an assortment of bases. The primers will bond to the "template" strand, and then DNA polymerase will begin to add bases to the "copy" strand, as in normal DNA replication.

Step 2 Randomly Terminate the Copies Some of the bases act as "terminator" bases. When one of these bases is placed in one of the growing copy strands, copying will stop on that strand. Thus, an assortment of randomly "cut-off" sequence copies is produced.

Step 3 Sort the Copies by Size At this point, the sequence of bases can be deduced by sorting the segments by size. When sequencing was first developed, scientists would use four batches of radioactively tagged "terminators" (one for each base type). Then, they would perform electrophoresis in four lanes, side by side, which would reveal the relative order of each end-base. Today, scientists use color-coded fluorescent tags (one color for each base type) and run a single batch through a tiny tube of gel. A machine with a laser can detect the wavelengths of the tags and thus "read" the sequence.

Reading Check *When are primers used in DNA sequencing?*

DNA sequencing (SEE kwuhns ing)
the process of determining the order of every nucleotide in a gene or genetic fragment

Differentiated Instruction

English Learners

Sequencing Have pairs of students make drawings on separate index cards to represent each step in chain termination sequencing. Then, ask partners to use the drawing to explain to each other the steps in the process. LS Visual

Teaching Key Ideas

DNA Sequencing Ask students what chain termination sequencing is used for. (sequencing DNA, including the human genome) How is the process like DNA fingerprinting? (Gel electrophoresis is used to separate fragments.) How does it differ from DNA fingerprinting? (Each band on the gel contains pieces that have been tagged to identify only one specific nucleotide base.) How are the bands analyzed? (They are read from the bottom of the gel to the top; since the same piece of DNA was used to generate all of the bands, each band represents the position of one of the bases of the original sequence.) LS Visual, Logical

Answers to Caption Questions

Figure 13: This method is now widely used to rapidly sequence genomes.

go.hrw.com
interact online

Students can interact with "Chain Termination Sequencing" by going to go.hrw.com and typing in the keyword HX8GTCF13.

Teach, *continued*

Demonstration

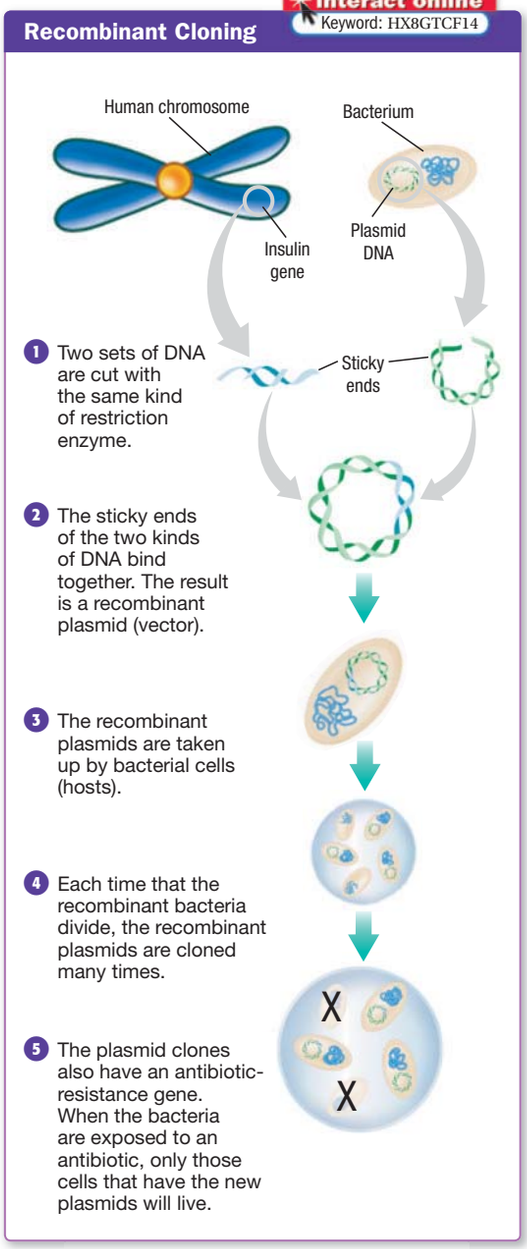
Recombinant DNA Take a piece of yarn tied to form a ring (representing a plasmid) out of a plastic bag (representing a bacterial cell). Use a longer piece of yarn of a different color to represent human DNA (hDNA) containing a gene of interest. Using scissors smeared with a bit of glue to represent a specific restriction enzyme, make a single cut through the plasmid. Make two cuts through the hDNA to remove a "gene." Remind students that the cuts made by the scissors produced the *same* sticky ends on both pieces of yarn. Using fingertips as ligase, glue the ends of the hDNA piece to the plasmid. Ask what the plasmid represents. (a vector) Ask why the new circle of yarn represents recombinant DNA. (The plasmid now contains foreign DNA.) Ask what is the next step in recombination. (The plasmid is placed into a host cell.) Place the connected yarn into a plastic bag. Tell students that at this point, the plasmid would begin replicating the hDNA gene with its own DNA. LS Visual

go.hrw.com
interact online

Students can interact with "Recombinant Cloning" by going to go.hrw.com and typing in the keyword HX8GTCF14.

Figure 14 The earliest gene cloning and recombination methods used the steps shown here. The first GMOs were produced in this way.

go.hrw.com
interact online
Keyword: HX8GTCF14



Gene Recombination and Cloning The first attempts at gene recombination and cloning were done by inserting a gene into an organism that replicates easily, as shown in **Figure 14.** Other methods may use similar steps.

Step 1 Cut DNA Samples Two sets of DNA are cut by the same kind of restriction enzyme so that all fragments have matching sticky ends. One set of DNA is from an organism containing a specific gene (in this case, the human insulin gene). The other DNA is part of a vector, such as a virus or a bacterial plasmid, that can carry or move DNA between cells. The vector will be replicated when placed in a host, such as a bacterial cell.

Step 2 Splice Pieces Together The DNA fragments from the first organism are combined with the fragments from the vector. Then, an enzyme called *DNA ligase* is added to help bond the sticky ends of all the fragments together.

Step 3 Place into Host At this point, some plasmids are recombinant with human DNA. When the plasmids are placed in a culture of bacteria, some cells take up the plasmids. The cells are allowed to replicate normally.

Step 4 Replicate Gene Each time that a bacterial cell divides, its plasmids are copied many times. In a few generations, the cells make millions of clones of the recombinant plasmids.

Step 5 Screen for Gene At this point, only some of the bacterial cells contain the recombinant plasmids. These cells must be identified in some way. One clever solution is to use vectors that contain another gene that is easy to detect. In this example, the original plasmids contained a gene that makes bacteria resistant to an antibiotic chemical. When the bacteria from step 4 are exposed to that chemical, only the cells that have taken up the vectors will survive.

These steps are just the beginning of genetic-engineering applications. Before PCR, this process of recombination was the main way to clone genes for further research. Another use is simply to produce a protein, such as insulin, from a cloned gene. As you have learned, recombinant organisms are created for many applications, from agriculture to medicine.

Reading Check *What is a vector?*

Why It Matters

Molecular Scissors Molecular biologists have determined the structure of more than 3,000 restriction enzymes. Imagine their surprise when one of them actually turned out to resemble a pair of scissors! The enzyme, BglII, recognizes and cleaves the DNA sequence AGACTC. Using X-ray crystallography, scientists found that the enzyme's two subunits swing away from each other in a scissorlike motion. The sliding of the BglII subunits past each other results in cutting of the DNA. After cutting, the enzyme resets itself to an open position. Other restriction enzymes, such as BamHI, grip DNA like a pair of tongs.

Differentiated Instruction

Special Education Students

Modeling Processes After students have observed you model recombinant cloning, provide them with assorted materials so that they can model other processes discussed in this section. Pair or group students with different abilities together and challenge them to ensure that all group members can demonstrate the model in action. LS Kinesthetic/Visual

Exploring Genomes

Until recently, the human genome was largely "unexplored." But now, specific genes are being identified and their locations "mapped." These first steps lead to understanding how each gene works. Like geographic maps, maps of genetic data can have different levels of detail or scale. For example, one can view a map of an entire nation or "zoom in" to view a particular state, city, neighborhood, or street. In a similar way, **› one can explore and map a genome at many levels, including species, individual, chromosome, gene, or nucleotide.**

Managing Genomic Data Your school library has a system for organizing and keeping track of books, as **Figure 15** shows. Similarly, scientists need systems for managing the vast amounts of data in a genome. Today, they use information technologies. The application of information technologies in biology is **bioinformatics.** **› Genomic bioinformatics starts with the mapping and assembly of the many parts of each genome.** The major stages of this work include the following:

- **Mapping and Assembly** Many genes have been "mapped" to reveal their location relative to other genes. In addition, large collections of sequences are being pieced together like a puzzle.
- **Organized Storage** Genomic information is stored in a logical system or database. This way, the information can be sorted and searched, and new information can be added easily.
- **Annotation** Each gene or sequence is named and categorized according to its location, structure, or function in each genome.
- **Analysis** The ultimate goal of genomics is to understand the exact function of each gene or sequence. This analysis includes studying the complex interactions among genes and proteins.

› Reading Check ***What are the first steps of studying genomes?***

bioinformatics the application of information technologies in biology, especially in genetics

READING TOOLBOX

Learning Steps If you have not yet completed your pattern puzzle for **Figure 14,** do so now. Then, close your book, scramble the pieces, and see if you can put them in order.

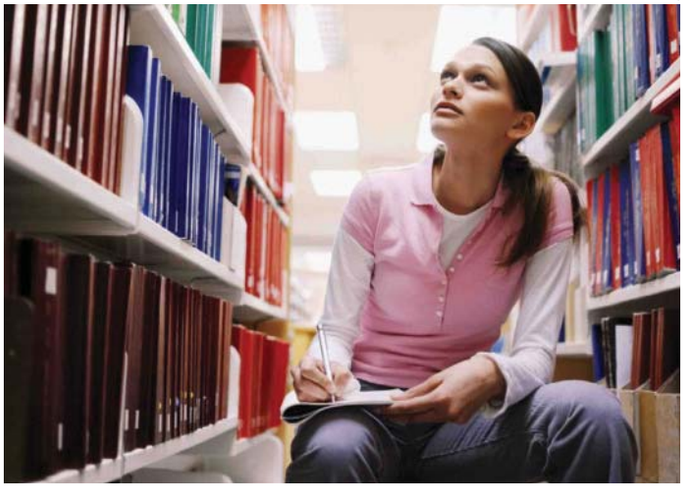


Figure 15 Like a library full of books, genomic data must be organized in order to be useful. **› What other actions are needed to manage genomic data?**

Differentiated Instruction

Advanced Learners/GATE

Computational Biology Perhaps one of the most important tasks in bioinformatics involves computational biology, the analysis of DNA sequence information. Have students research this branch of science and report on how DNA sequences are used to model protein structure. LS **Logical**

Teaching Key Ideas

Human Genome Library To help students understand that the application of information from the Human Genome Project has just begun, use the analogy of a book. In this book, there are only four letters—A, T, C, and G—arranged in any order. Most of the book is a just a series of letters; on a few pages letters make "words." (analogous to the amino acids that make up a gene) Most words have not been organized into sentences with meaning. (analogous to gene expression that has not been determined) LS **Visual**

READING TOOLBOX

Learning Steps Student pattern-puzzle steps should be in order. (Cut DNA Samples; Splice Pieces Together; Place into Host; Replicate Gene; Screen for Gene) LS **Logical**

Answers to Caption Questions

Figure 15: mapping, annotation, and analysis

Teaching Key ideas

Linkage vs. Physical Mapping Direct students' attention to **Figure 16.** First, ask students to look at the linkage map. Ask what the map shows. (the relative order of genes along a chromosome) Point out that the map identifies the position of the gene, but not its composition. Ask why *Black body* is closer to *Purple eyes* than to *Shriveled wings* on the map. (There is a smaller percent of crossing over in the former, meaning the genes for these two traits are closer together along a chromosome.) Next, have students look at the physical chromosome map. Tell students that because of the prevalence of sex-linked disorders associated with the X chromosome, it became the first human chromosome to be mapped. Ask what this map measures. (physical distance between genes on the chromosome) Point out that relatively little recombination may occur between two genes on the same chromosome, even though they may be very far apart physically with many thousands of base pairs separating them. LS Visual

Answers to Caption Questions

Figure 16: Sex-linked genes are relatively easy to trace through family histories.

genome mapping the process of determining the relative position of genes in a genome

genetic library a collection of genetic sequence clones that represent all of the genes in a given genome

Mapping Methods

Genome mapping is the process of determining the relative position of all of the genes on chromosomes in an organism's genome. To make a city map from scratch, you might start with landmarks that are easy to find and recognize. Similarly, genome mapping methods use *genetic markers,* or traits that can be easily detected, to trace the movement and location of genes. Examples are shown in **Figure 16.** Any detectable physical, behavioral, or chemical trait can be used as a marker. As the next step in making a map, you might try to determine the location of each thing relative to other things. Similarly, genome mapping uses several methods.

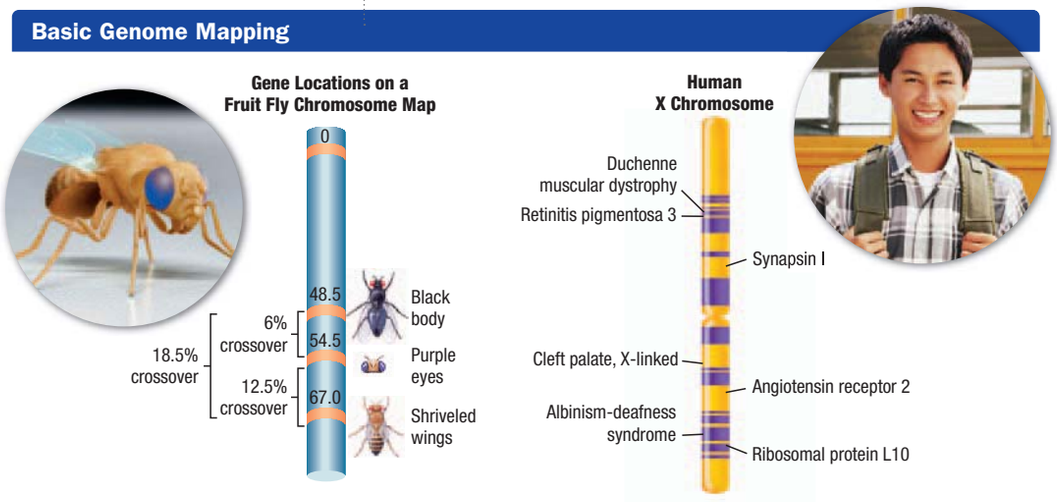
Linkage Mapping Linkage mapping methods identify the relative order of genes along a chromosome. Recall that the closer together that two genes are, the less frequently they will be separated during chromosome crossover. So, closely linked genes are more often associated, or found together, in the same individual. By comparing how often genes are associated, scientists can deduce their location relative to one another, as **Figure 16** shows.

Physical Mapping Physical mapping methods determine the exact number of base pairs between specific genes. These methods manipulate DNA to deduce exactly how close together genes are.

Human Chromosome Mapping Early attempts to map human genes used historical family records. By studying the patterns of inheritance of specific traits, scientists could infer which genes tend to be inherited together. This method was especially useful for initial mapping of the X chromosome. Such maps have since been filled in with data from physical mapping, as **Figure 16** shows.

Figure 16 Each of these maps shows the relative positions of genes on chromosomes. The physical map is more specific than the linkage map. **Why was the X chromosome mapped more easily than other chromosomes?**

Basic Genome Mapping



Linkage Map This map shows the frequencies of crossover of specific genes in the *Drosophila* genome.

Physical Chromosome Map This map shows the locations of some genes on the human X chromosome.

Differentiated Instruction

English Learners

Mapping Students may be confused by the term *mapping* as it is used in this lesson. Show students a geographical map and ask what it shows. (where things such as cities, mountain, lakes, and roads are located) Tell students **Figure 16** also shows where things are located, but the things that are mapped are not mountains, cities or the like. Ask what is being mapped. (genes) Where are the genes found? (on chromosomes) LS Verbal

Genome Sequence Assembly As they zoom in on the map of genes, scientists want to record all of the nucleotide sequences in a genome. The process of deducing and recording the exact order of every base and gene in a genome is called *sequence assembly*. The process involves collecting, sorting, and comparing large samples of genetic material.

Genetic Libraries To study an entire genome, scientists break up the genome into small fragments and clone all of the fragments. A collection of clones that represent all of the genes in a given genome is called a **genetic library.** Two kinds of genetic libraries are made. A *genomic library* is made by cloning all of the DNA in a cell. A genomic library includes all functional genes as well as all noncoding DNA. An *expressed sequence tag* (EST) *library* starts with the mRNA that results from transcription. The mRNA is used to make cDNA segments, which are then cloned to make the library.

Using the Libraries Once the clones are assembled, they can be sequenced, sorted, and organized. Early methods involved sorting through libraries one gene at a time by repeated probing and deduction. More recently, a method called *shotgun sequencing* was developed. In this method, an entire genome is cut up randomly into segments of varying size. All resulting segments are cloned and sequenced. Then, by looking for overlapping parts, researchers put together the entire sequence like a puzzle. The resulting genome sequence is stored as data and can be searched for specific genes or sequences of any size.

Automated Sequencing Robotic devices are now used to sequence a genome in a fraction of the time that it took to complete such a project only decades ago. Automated sequencing devices can quickly "read" many tiny sequence gels at one time. In such a device, a laser beam scans each gel tube, and detectors identify each of the four kinds of tags. Finally, a computer compiles the data into a string of letters, as **Figure 17** shows.

› **Reading Check** *What are the two kinds of genetic libraries?*

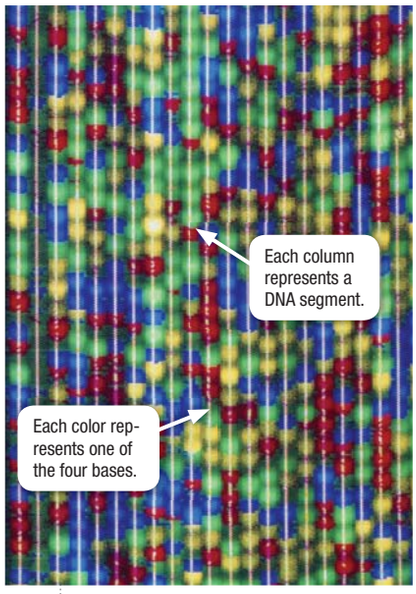


Figure 17 This computer screen shows the output of an automated sequencing device. The device "reads" DNA sequences by detecting color-coded, "tagged" bases in tiny gel-electrophoresis tubes. › **What advantages do computers provide?**

Section 3 Review

› KEY IDEAS

1. **Identify** the basic tools of genetic manipulation.
2. **Outline** any one of the major processes of modern gene technologies.
3. **Identify** the major stages of the work of genomics, in terms of bioinformatics.

CRITICAL THINKING

4. **Relating Concepts** Differentiate between SNPs and RFLPs.
5. **Predicting Outcomes** If samples of nerve cells and bone cells from the same person were run through the same type of microarray, would the results differ? Explain.
6. **Analyzing Information** Why is *expressed sequence tag library* a fitting name for a collection of clones made from mRNA?

METHODS OF SCIENCE

7. **Choosing Appropriate Tools** Suppose that you are a genetic scientist who has been asked to help stop the illegal killing of some tropical bird species. These birds are being killed so that their feathers can be sold for fashionable hat decorations. Propose some ways that you could use gene technologies to help protect these birds.

Teaching Key Ideas

Automated Sequencing Ask students to compare **Figure 17** to **Figure 13.** Ask the following questions: How are sequences of nucleotide bases shown? (by a series of colored bands or dots in a column) About how many bases are shown in Figure 17? (about 700). About how many base pairs are in one person's DNA? (about 3 billion) Why isn't DNA sequencing done for every individual? (It is still time-consuming and the machines are probably expensive.) LS **Logical**

Answers to Caption Questions

Figure 17: Large amounts of data can be organized, sorted, and searched quickly; repetitive tasks can be done by robotic devices.

› Close

Formative Assessment

What is a vector?

A. a specific sequence of DNA (Incorrect. This describes any recognizable sequence, such as a restriction site.)

B. an enzyme that recognizes a specific sequence of DNA (Incorrect. This describes a restriction enzyme.)

C. a mobile form of DNA, such as a plasmid (Correct! A vector is a way for DNA to be moved between genomes.)

D. an electrophoresis lane (Incorrect. An electrophoresis lane is called a ladder or a smear.)

Answers to Section Review

1. restriction enzymes, gel electrophoresis, primers, probes, and plasmids
2. Sample answer: PCR—1) DNA denatured by heat; 2) primers bind; 3) DNA polymerase binds free nucleotides; 4) cycle repeats with products from previous cycle
3. organized storage, mapping and assembly; annotation; and analysis
4. SNPs are single base-pair variations; RFLPs are different-sized segments of DNA that contain multiple base pairs.
5. The results probably would differ, because each of these tissues expresses different genes.
6. The clones consist of DNA that is complementary to mRNA; therefore, this kind of library contains only those genes that are expressed.
7. To identify feathers from the bird species, DNA from the endangered birds could be compared to DNA from a feather. First, PCR would amplify the feather DNA. Then, restriction digest and gel electrophoresis would be used to compare samples.

Lab

Time Required

Three 30-minute lab periods

Ratings

Teacher Prep	
Concept Level	
Student Setup	
Cleanup	

Safety Caution

Review with students all safety procedures related to the use of chemicals and electricity. Consult labels and packaging for guidelines regarding the handling and disposal of chemical solutions and samples. Ensure that students use electrical equipment in a safe, dry area, that plug receptacles have ground-fault protection devices (GFCIs), and that wires are properly connected before power is applied.

Preparation

For ease of preparation, obtain a forensic DNA fingerprinting kit and simulated suspect DNA samples. A typical kit includes prepared agarose, concentrated TBE buffer, loading dye, and chemical reagents, in addition to a coupon for DNA samples, with enough materials for eight lab stations.

Prepare 2400 mL of 1X TBE buffer. (This is enough buffer to construct and run 8 gels.) Prepare 200 mL 0.8% agarose or place a bottle of prepared agarose in the water bath to melt agarose. (This is enough prepared agarose to pour eight 25 mL gels.) Determine the volume of running buffer that will be needed by each lab group in advance so that accurate volumes of buffer can be dispensed in graduated cylinders to each group. Pour TBE buffer into the electrophoresis chamber, and establish a 37 °C hot water bath.

Tips and Tricks

Make sure students keep all DNA and reagents on ice throughout the procedure unless otherwise directed, because the enzymes and DNA samples will begin to degrade at room temperature. Also remind them to avoid touching any tube openings, pipette tips, or buffers, because molecules from their skin can degrade the restriction enzymes and DNA samples.

If time permits, have students practice loading sugar-saturated food-coloring dyes into agarose wells to improve their loading technique and to reduce their risk of puncturing the wells. This could be done the day before, at which time students could also make their own agarose gels for the experiment.

Draw a large microfuge tube on the board, and show how to dispense the reagents along the inside of the tube to eliminate contamination. Also demonstrate how to gently flick a closed tube, twice on the bottom, to create a mixing vortex.

Skills Practice

Chapter 15 Lab

Objectives

- Model the forensic analysis of evidence from a crime scene.
- Use restriction enzymes, PCR, and gel electrophoresis to manipulate DNA samples.
- Compare DNA fingerprints to match identical DNA samples.

Materials

- lab apron, safety goggles, and disposable gloves
- marker, permanent, waterproof
- microcentrifuge tubes (5)
- micropipettes, sterile, disposable (25)
- DNA samples (5)
- restriction enzyme buffer
- restriction enzyme
- incubator or hot water bath
- ice, crushed
- cup, plastic-foam
- gel, agarose, precast for electrophoresis chamber
- electrophoresis chamber with power supply and wires
- running buffer
- loading dye
- bag, plastic, resealable
- DNA staining solution
- tray for staining gel
- water, distilled
- paper, white, or light table

Safety

DNA Fingerprint Analysis

Each person's DNA is unique. This fact can be used to match crime suspects to DNA samples taken from crime scenes. *DNA fingerprints* can be made by using restriction enzymes and gel electrophoresis to reveal unique patterns in each individual's DNA.

Procedure

Cut DNA with Restriction Enzyme

1. Read all procedures, and prepare to collect your data. Label each microcentrifuge tube with a code for each DNA sample provided. For example, label one tube "C" for "crime scene sample" and the remaining tubes "S1" to "S4," one for each suspect.
2. Wear a lab apron, safety goggles, and gloves during all parts of this lab.
3. **CAUTION: Never taste chemicals or allow them to contact your skin.** Using a clean pipette each time, transfer 10 µL of each DNA sample to the microcentrifuge tube that has the matching label.
4. Using a clean pipette each time, transfer 2 µL of restriction enzyme buffer to each of the tubes.
5. Using a clean pipette each time, transfer 2 µL of restriction enzyme to each of the tubes. Close all of the tubes. Gently flick the bottom of each tube to mix the DNA and reagents.
6. **CAUTION: Use caution when working with heating devices.** Transfer the tubes to the incubator or water bath set at 37 °C. Let the samples incubate for one hour.
7. Stand the tubes in crushed ice in the plastic-foam cup.
8. If you need to pause this lab at this point, store the cup at 4 °C.

Separate Fragments by Gel Electrophoresis

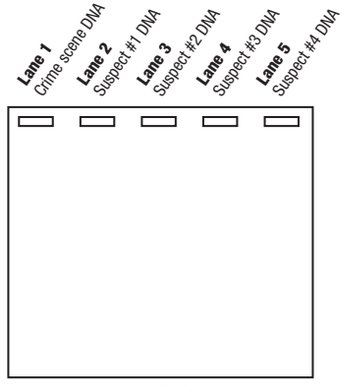
9. Place the precast gel on the level surface of the electrophoresis chamber. The wells in the gel should be closest to the black, or negative, electrode. Keep the gel level and flat at all times.
10. Fill the chamber with enough buffer to barely cover the gel. Do not pour the buffer directly onto the gel. Sketch a diagram of your gel in your lab notebook, as the sample diagram shows.
11. Using a clean pipette each time, transfer 2 µL of loading dye to each of the tubes. Gently flick the tubes to mix the contents.
12. Using a clean pipette, load the crime scene DNA into the well for Lane 1 of your gel. Be careful not to overflow or puncture the well.
13. Repeat step 12 for the remaining DNA samples and gel lanes. End with the DNA from Suspect 4. Use a clean pipette for each transfer.

14. **CAUTION: Use caution when working with electrical equipment; use only as directed by your teacher.** Make sure that everything outside the chamber is dry before proceeding. Attach the power connectors to the chamber and power supply as directed by your teacher. Set the power supply to the voltage determined by your teacher, and turn on the power supply.
15. Allow the gel to run undisturbed for the time directed by your teacher. Observe the gel periodically, and stop the process when the dye front is about 3 cm away from the end of the gel. At that point, turn off the power supply. Then, disconnect the power connectors from the power supply and chamber.
16. **CAUTION: Dispose of all waste materials as directed by your teacher.** Carefully remove the casting tray from the chamber. Pour off the running buffer according to your teacher's instructions.
17. If you need to pause this lab at this point, carefully slide the gel into a resealable bag. Add 2 mL running buffer, seal the bag, and store the bag in a refrigerator. Remember to keep the gel flat.

View Separated DNA Fragments

18. Gently slide the gel onto the staining tray. Pour enough stain into the tray to barely cover the gel. Do not pour the stain directly onto the gel. Let the gel sit for at least 30 min.
19. Carefully pour off the stain as directed by your teacher.
20. Gently pour distilled water into the tray to cover the gel. Do not pour the water directly onto the gel. After 5 min, carefully pour off the water as directed by your teacher.
21. Repeat step 20 until bands are clearly visible on the gel.
22. Gently transfer the gel to a white sheet of paper or to a light table. Sketch and describe your observations in your lab notebook.
23. Clean up your lab materials according to your teacher's instructions. Wash your hands before leaving the lab.

Loading the gel



Sample gel diagram

Analyze and Conclude

1. SCIENTIFIC METHODS **Organizing Data** Organize your data into a table. How many different fragment sizes resulted from the treatment of each DNA sample?
2. **Analyzing Data** Identify any bands of fragments that are the same size among any of the samples. Mark these bands on your sketch.
3. **Forming Conclusions** Use this evidence to determine which suspect most likely committed the crime. Explain your answer.
4. SCIENTIFIC METHODS **Evaluating Methods** Do these results provide enough evidence to convict the suspect? Explain your answer.

Extension

5. **Applying Concepts** Some bands appeared in the same position in several lanes. Propose an explanation for this result.
6. **Predicting Results** How might the results have been affected if a different restriction enzyme had been used? Explain your answer.

Have students use the inner wells to load DNA, to prevent an "eddy effect." More advanced students should load a *HindIII* standard in an outer lane, because the fragments from this digested DNA serve as a standard.

Follow the directions provided for your materials for time of incubation. Remove the microfuge tubes and freeze them overnight. Remove them from freezer 30 minutes before class. If time permits for the students to monitor the electrophoresis process, make sure they understand that the band they see migrating is the loading dye, which is used as a marker.

Stain gels for thirty minutes; destain overnight.

For analysis, use a piece of transparency film over the white paper if no light box is available.

Answers to Analyze and Conclude

1. Sample data table:

DNA Sample	Number of Fragments
Standard (if used)	6
Crime scene	9
Suspect 1	8
Suspect 2	7
Suspect 3	9
Suspect 4	9

2. Check that students have marked their sketches as directed. Several of the samples will have some matching bands formed by fragments of the same size (thus, in the same horizontal position).
3. Sample answer: Suspect 3 most likely committed the crime. The bands in suspect 3's lane were identical to the bands formed by DNA from the crime scene.
4. No, because this is a single line of evidence and may be the result of a coincidence

Answers to Extensions

5. There is low variability in these regions of human DNA.
6. A different restriction enzyme would produce different-sized fragments, but since it would be used for both the crime scene DNA and suspects' DNA, there would still be bands that match.

Key Resources

- Holt Lab Generator
- Lab Datasheet (Levels A, B, C)
- Holt Science Biology Video Labs
- Virtual Investigations

Chapter 15

SUPER SUMMARY

Have students connect the major concepts in this chapter through a Super Summary. Visit **go.hrw.com** and type in the key word **HX8GTCS** to access.

Reteaching Key Ideas

Human Genome Project Have students describe the HGP and give applications for the information provided by this project. Make sure they understand the scope of the project. Ask them to identify some concerns raised and how these are being addressed. LS Logical

Cloning and Stem Cells Ask students to explain the difference between cloning and stem cell culture techniques and to identify the purpose and the ethical issues of each technique. Have students provide other examples of how gene technologies are being used with plants. LS Verbal

Recombinant Products Ask students to explain how to make a recombinant product, such as insulin. Make sure students understand the use of PCR, Southern blotting, and gene sequencing. LS Verbal

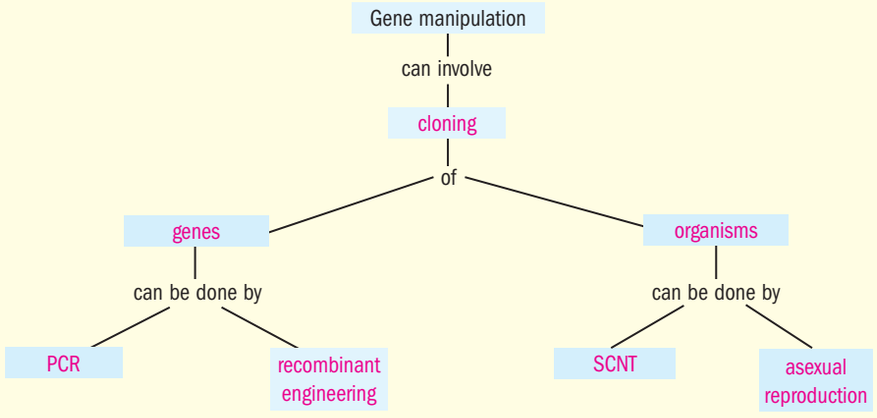
Chapter 15 Summary

go.hrw.com
SUPER SUMMARY
Keyword: HX8GTCS

Key Ideas	Key Terms
1 The Human Genome › The sequencing of the human genome has advanced the study of human biology yet created new questions › Genomics and gene technologies have many applications in human healthcare and society. › Many important questions about the human genome remain to be investigated or decided. 	**genomics** (345) **microarray** (346) **DNA fingerprint** (347)
2 Gene Technologies in Our Lives › Today, gene technologies are widely applied to study organisms in new ways, to alter organisms for human use, and to improve human lives. › Cloning and stem cell techniques are used in research on animal development and have potential for treating certain diseases. › Ethical issues can be raised for every use of gene technologies. 	**genetic engineering** (350) **recombinant DNA** (350) **clone** (352) **stem cell** (353)
3 Gene Technologies in Detail › The basic tools of DNA manipulation rely on the chemical nature of genetic material and are adapted from natural processes discovered in cells. These tools include restriction enzymes, polymorphisms, gel electrophoresis, denaturation, and hybridization. › The major methods for working with genes use some combination of the basic tools of cellular machinery. These methods include PCR, blotting, DNA sequencing, and gene recombination. › One can explore and map a genome at many levels, including species, individual, chromosome, gene, or nucleotide. Genomic bioinformatics starts with the mapping and assembly of the many parts of each genome. 	**restriction enzyme** (355) **DNA polymorphisms** (356) **electrophoresis** (356) **polymerase chain reaction (PCR)** (357) **DNA sequencing** (359) **bioinformatics** (361) **genome mapping** (362) **genetic library** (363)

Answer to Concept Map

The following is one possible answer to Chapter Review question 2.



Chapter 15 Review

READING TOOLBOX

1. **Analogies** Complete the following analogy:

   genetic disorder : protein :: diabetes : ___

2. **Concept Map** Construct a concept map that differentiates the major processes of gene manipulation. Try to use the following terms: *cloning, genes, organisms, PCR, recombinant, engineering, SCNT,* and *asexual reproduction*.

Using Key Terms

3. Use the following terms in the same sentence: *restriction enzyme, DNA polymorphisms,* and *DNA fingerprint.*

Complete each of the following sentences by choosing the correct word from the word bank.

Genomics
Bioinformatics
Electrophoresis

4. ___ is the use of computers with biological data.
5. ___ is the separation of molecules using electricity.
6. ___ is the study of entire genomes.

Understanding Key Ideas

7. One of the surprising discoveries of the Human Genome Project was that
   - **a.** the human genome consists of only about 25,000 genes.
   - **b.** about 99% of the human genome codes for proteins.
   - **c.** each gene encodes only a single protein.
   - **d.** DNA is found in the nucleus of cells.

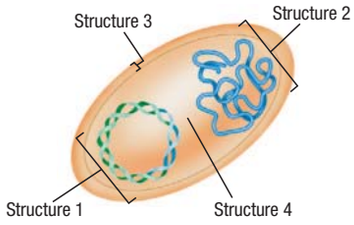
8. A DNA microarray is an important tool because it
   - **a.** can cure cancer.
   - **b.** identifies an individual.
   - **c.** makes tumor cells glow green.
   - **d.** shows which genes are active in a cell.

9. An organism that has been given a new gene through genetic engineering can be called any of the following *except*
   - **a.** transgenic.
   - **b.** sequenced.
   - **c.** recombinant.
   - **d.** genetically modified.

10. The Southern blot process is used to analyze
    - **a.** RNA.
    - **b.** DNA.
    - **c.** mRNA.
    - **d.** protein.

11. What do linkage mapping methods identify?
    - **a.** only genes that are inherited together
    - **b.** the exact nucleotide sequence of a chromosome
    - **c.** the relative position of genes along a chromosome
    - **d.** the exact number of base pairs between specific genes

This diagram shows a cell with recombinant DNA. Use the diagram to answer the following questions.



12. Which part of this cell is recombinant DNA?
    - **a.** structure 1
    - **b.** structure 2
    - **c.** structure 3
    - **d.** structure 4

13. The most appropriate term to describe this cell is
    - **a.** *somatic.*
    - **b.** *totipotent.*
    - **c.** *transgenic.*
    - **d.** *nongenetic.*

Explaining Key Ideas

14. **Identify** an application of gene technologies in human health care.
15. **Describe** how cloning can be used to produce embryonic stem cells.
16. **Identify** a risk associated with growing genetically modified cereal crops on farms.
17. **Describe** how a scientist could use gene recombination and cloning to produce a human protein.
18. **Compare** genomic libraries to EST libraries.

Assignment Guide

Section	Questions
1	1, 4, 7, 8, 14, 21
2	2, 9, 13, 15, 16, 22, 26, 28
3	2, 3, 5, 6, 10, 11, 12, 17, 18, 19, 20, 23, 24, 25, 27, 29

Review

Reading Toolbox

1. insulin
2. See previous page for answer to concept map.

Using Key Terms

3. *Restriction enzymes* can be used to make a *DNA fingerprint*, which will reveal *DNA polymorphisms* among individuals.
4. Bioinformatics
5. Electrophoresis
6. Genomics

Understanding Key Ideas

7. a 8. d 9. b 10. b
11. c 12. a 13. c

Explaining Key Ideas

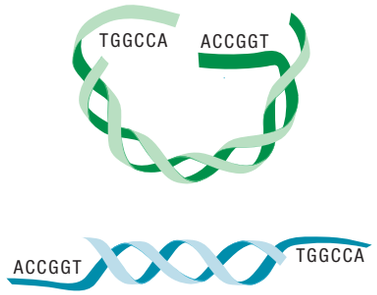
14. Answers might include insulin production, genetic counseling, vaccines, or gene therapy.
15. The nucleus of a somatic cell can be placed in an enucleated egg cell; when it divides, the new cells are clones of the somatic cells.
16. Genes from a modified crop may spread to a wild species and become part of a genome for which it was not intended.
17. First, the scientist would isolate the gene that codes for the human protein, splice it into plasmids, and induce bacteria to take up the plasmids. Then, the scientist would place the bacteria in culture medium to allow the cells to divide. Next, the scientist would screen for bacteria that have the gene and culture more of these. As the gene is expressed in the bacteria, the protein will be produced and can be harvested from the culture.
18. A genomic library contains all the DNA in the genome of a particular organism; an EST library contains only the expressed genes in an organism's genome.

Using Science Graphics

19. c 20. b

Using Science Graphics

This diagram shows two pieces of DNA that originated in two different organisms. Use the diagram to answer the following questions.



19. The single-stranded segments that stick out at the end of each DNA piece are called *sticky ends* because the strands form pairs that are
- **a.** identical.
- **b.** denatured.
- **c.** complementary.
- **d.** double stranded.

20. From the diagram, you can tell that each of these DNA segments has been
- **a.** taken up by a bacterium.
- **b.** cut by a restriction enzyme.
- **c.** denatured by a polymerase enzyme.
- **d.** recombined to make a genetically modified organism.

Critical Thinking

21. Forming Reasoned Opinions A student says that the Human Genome Project is a purely scientific pursuit and that there is no need to worry about ethical questions because science can answer any question. Do you agree with this statement? Explain.

22. Evaluating Complex Issues In the United States, government regulations require researchers to contain experimental GMOs inside a laboratory and to ensure that the organism cannot survive outside the lab. Why do you think that these strict regulations are in place?

23. Relating Concepts Scientists often use PCR before performing other DNA manipulation processes, such as Southern blot or sequencing. Why?

24. Making Inferences Should communication be an important aspect of bioinformatics? Explain.

Methods of Science

25. Critiquing Procedures The earlier method of DNA sequencing used four separate batches of radioactively tagged nucleotides. These nucleotides were added to four separate batches of the same DNA fragments, each of which were run through the termination and sorting steps. The newer method uses one mixture of four fluorescent, color-coded nucleotides mixed together and run in one batch. In what ways is the newer process more efficient?

Writing for Science

26. Script Your geneticist friend has just e-mailed you with exciting news: She has produced the first crop of glow-in-the-dark cotton! She has asked you to help think of ways to sell the cotton or to make new products from it. Help out your friend by writing a script for a television commercial that will help sell the cotton or products made from it.

Technology Skills

27. Visual Communication Create a slide show, cartoon, or animation that illustrates what happens in the PCR cycle. Present your project to your class, or display it on the internet.

Alternative Assessment

28. Veggie Invention Would people eat more broccoli if it were pink? Would they eat butter-flavored corn on the cob or orange-flavored spinach? Invent an idea for a new fruit or vegetable that could encourage people to eat more fruits and vegetables. Create an advertisement for your new item, and present it to your class. Be sure to consider the potential benefits of the new item and any negative reactions that people might have to it.

Math Skills

29. Rates Suppose a scientist wants to search for a specific gene from a complete genome sequence. Looking at printed sequences, a trained scientist can search through about 1,000 bases per minute. At this rate, estimate the amount of time it would take to search for a 1000-base-pair gene in the *Drosophila* genome, which contains 80,000,000 base pairs.

Critical Thinking

21. Sample answer: I disagree. The HGP raises many ethical questions that cannot be answered by science, such as the emotional aspects of what make us human.

22. The regulations are prompted by concerns that GMOs might cause disease or harm the environment. By limiting their survival outside the lab, scientists are preventing the organisms from possibly harming people or other organisms and interfering in food chains.

23. Often the amount of DNA available for analysis is so limited that PCR is needed to amplify it for analysis.

24. Sample answer: Yes, information needs to be shared with the research community and the public in order to promote understanding and facilitate progress.

Methods of Science

25. Being able to use four color-coded fluorescent tags side-by-side allows researchers to read the entire sequence of a piece of DNA at once.

Writing for Science

26. Sample ad: "Want to be the 'light' of the party? Wear a Glo-Clo™ T-shirt and be prepared for 'enlightening' conversation.

Technology Skills

27. Student products should show the thermal cycling steps: denaturing and exposing bases, adding primers, and adding nucleotides with DNA polymerase. Each new cycle needs to start with the previous end products.

Alternative Assessment

28. Student products should show novel modifications of existing fruits and vegetables, propose potential benefits, and address dangers or concerns.

Math Skills

29. 1000 bp × 60 min/h × 8 h/day = 480,000 bp/day. To examine an 80,000,000 bp sequence, divide by 480,000 bp/day. It would take 166 days to examine them all!

Chapter 15 Standardized Test Prep

TEST TIP When you encounter a question that involves graphics, pay close attention to any labels.

Science Concepts

1. The international effort to deduce the sequence of all of the DNA in human cells is called the
- **A** Human DNA Fingerprint.
- **B** Human Genome Project.
- **C** Polymerase Chain Reaction.
- **D** Global Genetic Engineering Program.

2. Which of the following is a molecule that contains DNA taken from two different organisms?
- **F** cDNA
- **G** mRNA
- **H** recombinant DNA
- **J** double-stranded DNA

3. The process that produces genetically identical embryos from adult somatic cells is called
- **A** adult stem cell culturing.
- **B** embryonic stem cell culturing.
- **C** totipotent cell transfer cloning.
- **D** somatic cell nuclear transfer cloning.

4. Protein molecules that cut DNA molecules at specific places are called
- **F** primers.
- **G** sticky ends.
- **H** restriction enzymes.
- **J** polymerase enzymes.

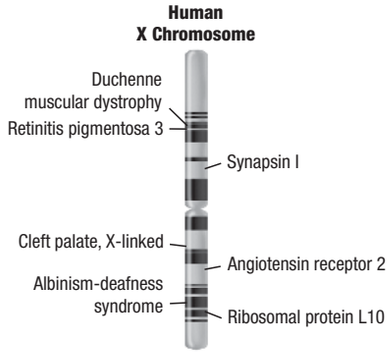
5. Complementary segments of DNA or RNA will spontaneously
- **A** hybridize.
- **B** denature.
- **C** terminate.
- **D** electrophorese.

Writing Skills

6. Extended Response It is becoming possible to identify some genetic factors that increase a person's risk of developing health problems such as asthma or cancer. Write a short essay supporting your answer to the following question: Should a health insurance company be able to use genetic analysis to assess the risks of insuring potential customers?

Using Science Graphics

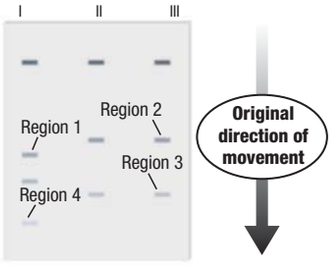
This diagram shows the approximate location on an X chomosome of genes for some human traits. Use the diagram to answer the following question(s).



7. This kind of information about genome is called a
- **F** chromosome map.
- **G** genetic fingerprint.
- **H** genomic library.
- **J** karyotype.

8. Many of these genes code for
- **A** typical traits.
- **B** sex-linked traits.
- **C** unlinked traits.
- **D** unexpressed traits.

This diagram shows the result of gel electrophoresis of DNA. The same DNA sample was run through each of the three lanes, but each lane is the result of a different kind of treatment of the DNA sample. Use the diagram to answer the following questions.



9. Which of the following regions contains longer DNA fragments than the other regions?
- **F** region 1
- **G** region 2
- **H** region 3
- **J** region 4

State Resources

For specific resources for your state, visit go.hrw.com and type in the keyword **HSHSTR**.

Test Practice with Guided Reading Development

Answers

1. B **2.** H **3.** D
4. H **5.** A
6. Student essays should be supported by facts and logical arguments. Consider peer review of essays. Sample argument: No, such information might create biases against those whose diseases are well-researched as opposed to those about which less is known. Genetic research should not be abused because this might limit future research.
7. F **8.** B **9.** G

TEST DOCTOR

Question 2 **F** is incorrect. cDNA is equivalent to the expressed DNA from one individual or species. **G** is incorrect. mRNA used for transcription is not DNA. **H** is correct! When DNA from two different organisms combine, it is called recombinant DNA. **J** is incorrect. All DNA is double-stranded by nature.

Question 4 **F** is incorrect. Primers are DNA sequences that initiate replication. **G** is incorrect. Sticky ends are open segments of DNA cut by a restriction enzyme. **H** is correct! Restriction enzymes do cut DNA at specific sites. **J** is incorrect. Enzymes that facilitate *building* molecules are called polymerases.

Question 9 **F** is incorrect. The DNA fragments moved from the top to the bottom of this diagram, and the shorter fragments moved faster. Region 1 is in between other regions, so it is neither the shortest nor longest. **G** is correct! The DNA fragments moved from the top to the bottom of this diagram, and the shorter fragments moved faster. Region 2 moved less than the other regions, so it contains the longest fragments. **H** is incorrect. The DNA fragments moved from the top to the bottom of this diagram, and the shorter fragments moved faster. Region 3 is in between other regions, so it is neither the shortest nor longest. **J** is incorrect. The DNA fragments moved from the top to the bottom of this diagram, and the shorter fragments moved farther. Region 4 moved more than the other regions, so it contains the shortest fragments.