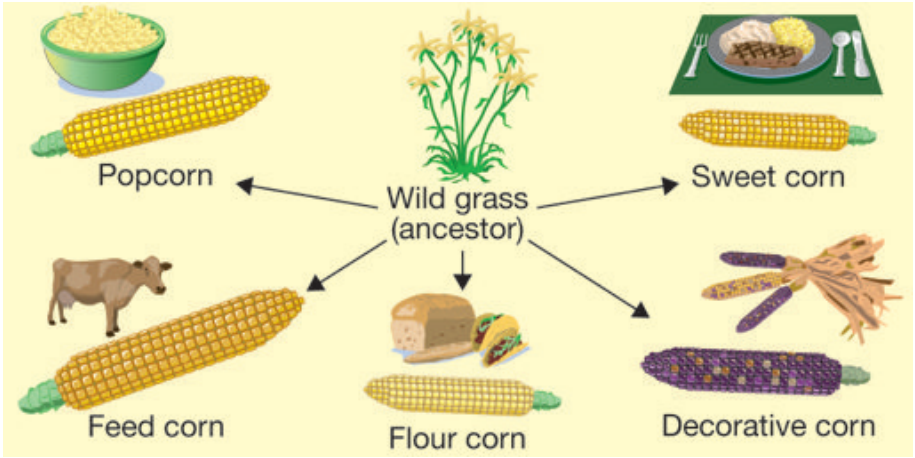
12.2 DNA and Technology

Over a period of thousands of years, Native Americans transformed a type of wild grass into *maize*—better known as corn. Maize was developed from a wild grass originally growing in Central America 7,000 years ago. The seeds of that grass looked very different from today's kernels of corn. By collecting and growing the plants best suited for eating, Native Americans encouraged the formation of larger kernels on cobs (Figure 12.6).

Selective breeding

Selecting desirable traits

Native Americans used selective breeding to produce maize. **Selective breeding** is the process of selecting organisms with desired traits to serve as parents for the next generation. Native Americans began by selecting seeds of wild grass that were the best for eating. They grew those seeds and then selected the best seeds from that generation. By repeating this process over many generations of plants, they developed a variety of maize that produced the most food per plant. Today we have many varieties of corn. All are descendents of those early plants.



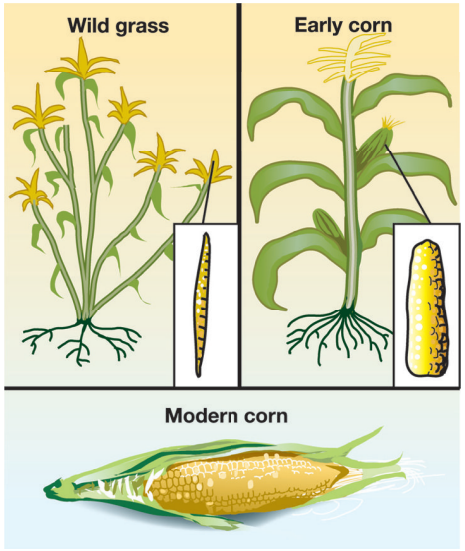


Figure 12.6: *Native Americans transformed a wild grass into maize.*

VOCABULARY

selective breeding - the process of selecting organisms with desired traits to serve as parents for the next generation.

Genetic engineering

What is genetic engineering?

Since the discovery of DNA, scientists have found new methods of producing organisms with desired traits. One of those methods is called genetic engineering. **Genetic engineering** is the process of transferring genes from one organism into the DNA of another organism. Walk down the produce aisle at your grocery store and you'll find some products of genetic engineering. Supersweet corn and cold-resistant tomatoes are examples.

Genetically engineered bacteria

Another example of genetic engineering is the production of insulin to treat people with diabetes. *Insulin* is a protein that regulates carbohydrates in the blood. People with diabetes can't produce enough insulin. Scientists insert a human gene for insulin into the circular DNA of bacteria (called a *plasmid*). The transformed bacteria are tricked into producing insulin. When the transformed bacterial cells divide, their offspring carry the gene for insulin (Figure 12.7). Because bacteria reproduce rapidly, large amounts of insulin can be produced in a short amount of time.

Treatments for genetic disorders

Scientists routinely insert genes into the plasmids of bacteria, which are prokaryotes. Eukaryotic cells are more complex and usually do not contain plasmids. Therefore it is more difficult to use genetic engineering in eukaryotic cells. One method is to inject new DNA into a cell with a tiny needle. Sometimes the cell accepts the DNA. Other times it destroys the DNA. In one case, scientists were able to insert a cold-water fish gene into a tomato plant, making the plant more cold-resistant.

Important questions

Genetic engineering raises many ethical questions. For example, should we genetically engineer humans to be taller and stronger? Are genetically engineered foods bad for you? Learning genetics can help you make informed decisions about genetic engineering.

VOCABULARY

genetic engineering - the process of transferring genes from one organism into the DNA of another organism.

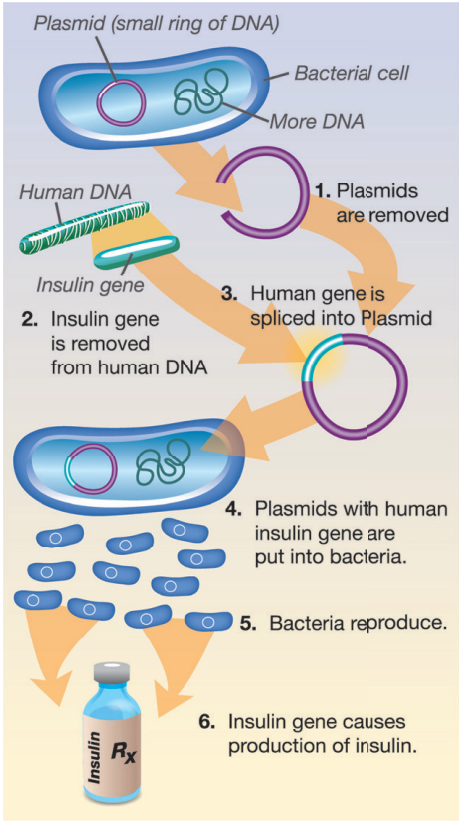


Figure 12.7: *How genetic engineering is used to make insulin.*

DNA fingerprinting

DNA is unique from person to person

The DNA of all organisms contains the same four bases: **A**, **G**, **T**, and **C**. However, the base sequence varies for all organisms. There are also variations in the base sequence within the same species of organisms. The base sequence in your DNA is different from that of every other person on Earth—unless you have an identical twin. **Human DNA is unique from person to person, but the same from cell to cell.**

What is DNA fingerprinting?

As scientists have learned more about DNA, they have found a way to use it to identify individuals. A technique called **DNA fingerprinting** produces an image of patterns made by a person's DNA. Using an enzyme, scientists "cut" DNA strands in specific places. The DNA fragments are injected into a gel and an electric current is applied. As the fragments migrate across the gel, they create patterns. Those patterns (DNA fingerprints) are related to the base sequences along the DNA strand.

Each person has a unique fingerprint

Like normal fingerprints, the patterns produced by DNA are unique to each individual person. Therefore, DNA fingerprints can be used to identify suspects in a crime. They can also be used to identify relationships among children and their parents, or among siblings (brothers and sisters). The DNA fingerprints of parents and their offspring show similarities but are not identical.

Using DNA fingerprints to solve a crime

Suppose a serious crime has been committed. There are seven suspects. How can police prove which suspect actually committed the crime? Since blood was found at the crime scene, DNA fingerprints can be produced. Blood is drawn from the six suspects and DNA fingerprints are produced. By comparing the DNA fingerprints of the suspects to the blood from the crime scene, police quickly determine who committed the crime (Figure 12.8).

VOCABULARY

DNA fingerprinting - the process of producing an image of patterns from someone's DNA.

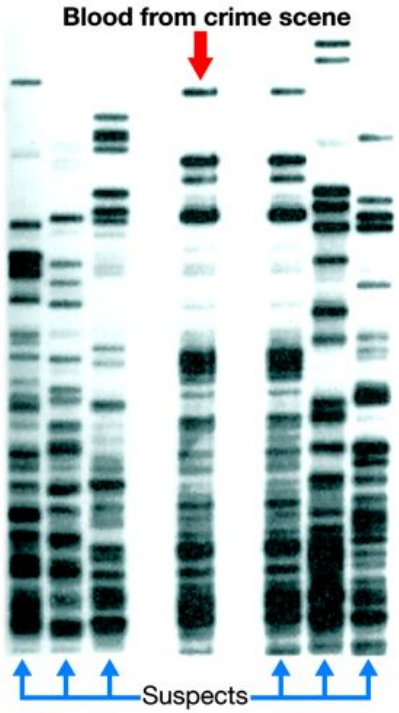


Figure 12.8: *The DNA fingerprints in the middle are from the crime scene. Which one of the suspects committed the crime?*

The human genome

What is a genome?

Scientists use DNA technology to study the human genome. A **genome** is the total amount of hereditary material in a single cell of an organism. If you think of a *genome* as a set of books, each *chromosome* is a book from the set. Each *gene* is a paragraph from the book and each *base* is a letter from the paragraph (Figure 12.9). The *Human Genome Project* is a study of the human genome. One of the goals of the project was to map the base sequence of the entire human genome.

Using DNA technology to trace human origins

Scientists also use DNA technology to trace the origins of humans. In the past, scientists could only analyze the bones and skulls of our human ancestors. Now they have tools to determine the base sequences of their DNA. Most of the ancient DNA scientists can recover is broken into fragments. Recently though, scientists have developed a way to make copies of those fragments, making them easier to analyze. They have also found a way to recover DNA from preserved bones and teeth.

Mitochondrial DNA

Not all of your genome is found in the nuclei of your cells. **Mitochondrial DNA** is DNA that is found in the mitochondria of a cell. Human mitochondrial DNA consists of about 16,000 base pairs contained in 5–10 rings. Unlike nuclear DNA, which is equally inherited from both the father and mother, mitochondrial DNA is inherited only from the mother. That's because all of our mitochondria are descended from those in our mother's egg cell. Mitochondria in the sperm cell are destroyed during fertilization.

The origin of humans

Mitochondrial DNA is often used to study human origins. Since it is inherited only from the mother, mitochondrial DNA allows scientists to trace human origins along a direct ancestral line. Recent evidence suggests that modern humans descended from Africa about 100,000 years ago.

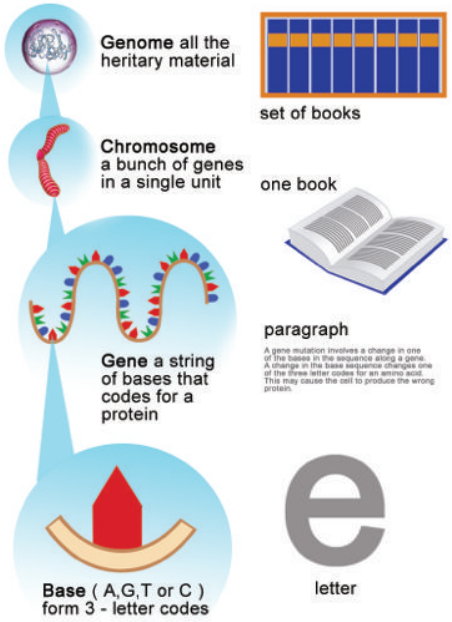


Figure 12.9: *One of the goals of the human genome is to map the base sequence of the entire human genome.*

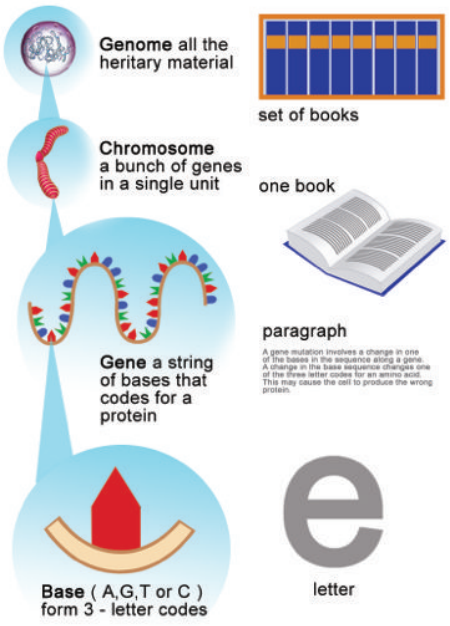
VOCABULARY

genome - the total amount of hereditary material in a single cell of an organism.

mitochondrial DNA - DNA that is found in the mitochondria of a cell.

12.2 Section Review

1. What is selective breeding? Name three instances where people use selective breeding.
2. What is genetic engineering? How is it similar to selective breeding? How is it different?
3. List the steps to genetic engineering and explain what happens in each step.
4. Figure 12.10 shows DNA fingerprints of four suspects. DNA fingerprints from blood collected at the crime scene are shown in the middle column. Which suspect committed the crime? Explain your reasoning.
5. What is a genome? Where is an organism's genome found?
6. STUDY SKILLS: The graphic to the right is an analogy. An analogy shows the similarities between two things that are otherwise different. Think of another analogy for DNA that compares it to something else.
7. What is mitochondrial DNA? Why is mitochondrial DNA used to study human origins?



MY JOURNAL

There is much debate on the topic of genetic engineering. What are the potential advantages and disadvantages of genetic engineering?

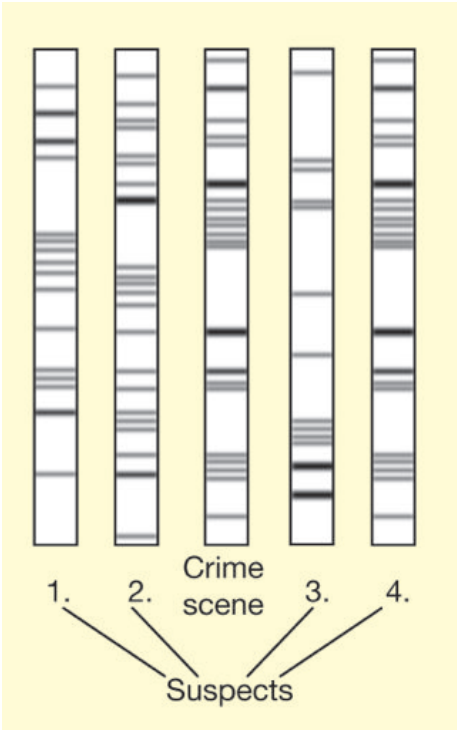


Figure 12.10: *Use the image above to answer question 4.*

TECHNOLOGY CONNECTION

Cracking the Code

Have you ever tried to break a code? Suppose that 2-21-19 is code for a common word. The coded word is used in a sentence. "We took the 2-21-19 to school this morning." Using the clue in the sentence, the code is easy to crack. The word is bus. Each letter equals the number of its order in the alphabet.

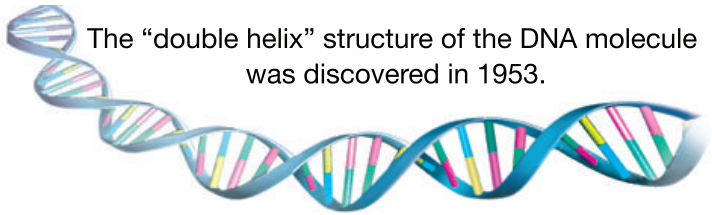
Sometimes breaking a code can add to human knowledge. One example is Egyptian hieroglyphics. This ancient Egyptian writing is very complex. For a long time, its meaning was unknown. The system of writing was a key to understanding the people of ancient Egypt. Yet no one could translate the system for hundreds of years.

Then in 1799, the Rosetta Stone was discovered. It was a stone tablet. It had the same words written in three languages. One of the languages was Greek. Another was the system of writing used by the ancient Egyptians and helped to break the code.

The human genome

Scientists are now breaking the most important code in human history. This code is the human genome. The human genome is the complete set of DNA in a human being. DNA is a chemical compound. It carries all of the instructions an organism needs to develop and function.

The DNA molecule is made of two connected, twisted strands. The shape of the molecule is called a double helix. The two strands connect at many points. Each point is a pair of connected base chemicals. DNA can be described as two spiral ladders running together. The pairs of base chemicals make the "rungs" in the ladders.



The "double helix" structure of the DNA molecule was discovered in 1953.

The human genome contains more than 3 billion of these base pairs. DNA is "packaged" in compact units called chromosomes. Every human has a total of 46 chromosomes. We get 23 from each parent. Each chromosome has between 50 million and 300 million base pairs.

Chromosomes contain genes. Some contain many more genes than others. Genes are specific sequences of base pairs. These sequences are coded instructions. The instructions tell cells to make proteins. Organisms make proteins in order to develop and function. Scientists estimate that the human genome contains between 20,000 and 25,000 genes.

The Human Genome Project

To find the genes and break the code, we need to know the exact order of their base pairs. This is called "sequencing." In 1990, scientists began a project to sequence the human genome. It was called the Human Genome Project. The goals of the project were to:

- Find the sequences of the 3 billion base pairs in the human genome.
- Identify all the genes of the human genome.
- Make the information available to other scientists.
- Address ethical and social issues that surrounded the project.

Scientists all around the world added their efforts to the task. In 2003, the Human Genome Project announced that the sequencing of the human genome was completed. This was a major step in cracking the code of human DNA. But the code is still not broken.

Scientists had long known that DNA was a code. In 1953, Watson and Crick identified the structure of DNA. They recognized a pattern in the double helix and new it was a code. This is like recognizing that the letters in a code are grouped in words. But the meanings of the words are still unknown.

Likewise, sequencing the human genome does not crack the code of DNA. Finding the sequence is like recognizing that the words in the code are grouped in sentences and paragraphs. But the meanings of the sentences and paragraphs are still not completely known.

The final step will be to find out which genes have instructions for building which proteins. This is knowing what genes do. This is like understanding the meanings of sentences and paragraphs in the code. The process is underway. However, the function of most human genes is still unknown.

The future

Breaking the code of human genes may even help us understand some of the basic mysteries of life. Eventually, scientists will understand the function of each individual gene in the human genome. Why is this so important? It will lead to a better understanding of genetic diseases, and treatments for these diseases. It should also help scientists discover ways to prevent diseases in humans.

Questions:

1. How did the Rosetta stone help to crack a code?
2. What is the human genome?
3. How many base pairs are there in the human genome? How many chromosomes are there in the human genome? How many genes are there in the human genome?
4. What is the final step in cracking the code of the human genome?

CHAPTER ACTIVITY Gene Drama

In this activity, your class will perform a skit to show how genes work.

What you will do

1. Each person will wear a sign that identifies his or her role in the skit. The blocks in the table below show what to write on each of 24 different signs. Colors refer to suggested choices of colored paper.

Original DNA segment	Complementary DNA Segment	Messenger RNA Segment	Transfer RNA Segment	Amino Acid	Misc.
Red	Blue	Orange	Green	Purple	Yellow
C	G	G	CCA	proline	ribosome
C	G	G	CGA	arginine	narrator
A	T	U			
C	G	G			
G	C	C			
A	T	U			

2. Make signs as directed by your teacher.
3. Divide your classroom into two areas. Identify one area as the "nucleus" and the other as the "cytoplasm."
4. Act out the skit! The narrator reads the steps while members of the class act it out. Perform the skit several times, switching roles each time.

Narrator	Action	Location
1. Our story begins with a segment of a DNA strand. Ours has 6 bases, but actual DNA can be made up of millions of bases!	Original DNA strand bases stand in order, shoulder-to-shoulder, from Left to Right CCACGA	Nucleus
2. DNA is double-stranded. The DNA bases pair up in specific combinations.	Complementary DNA bases join hands with original DNA bases to create correct pairings: GGTGCT	Nucleus
3. A copy of the DNA code has to be made before it can be used to build a protein. First, the double DNA strand "unzips."	DNA base pairs drop hands and move apart, but strands remain shoulder-to-shoulder	Nucleus
4. Next, messenger RNA bases pair up with the original DNA strand segment and then detach from the DNA strand. The DNA base pairs re-join to form the double strand of DNA.	Perform the action.	Nucleus
5. The messenger RNA leaves the nucleus and meets up with the ribosome in the cytoplasm.	Perform the action.	Cytoplasm
6. The messenger RNA base sequence is a code that tells the cell which protein to make. Amino acids are the building blocks of proteins. Each amino acid is paired with a transfer RNA.	CCA should have both hands placed on shoulders of proline. CGA should have both hands placed on shoulders of arginine. They move around in the cytoplasm, not far from the ribosome.	Cytoplasm
7. The ribosome binds the correct transfer molecule code to the messenger strand.	Perform the action.	Cytoplasm
8. The amino acids bond together in the start of a long chain that will become a protein. The transfer molecule leaves the amino acids.	Amino acids link arms at the elbows and the transfer molecules leave.	Cytoplasm
9. Our story ends with the amino acid chain. We have started a protein with two amino acids. In an actual cell, the amino acid chain that becomes the protein can contain 100 to 10,000 amino acids or more!	Take a bow!	Cytoplasm

Applying your knowledge

a. Blueprints are directions that a builder needs to construct a house. What part of the protein synthesis process could be referred to as a blueprint? Explain your answer.
b. Create a table that compares the process of making proteins to the process of making cookies.

Chapter 12 Assessment

Vocabulary

Select the correct term to complete the sentences.

base sequence	DNA replication	genetic engineering
genome	mutation	selective breeding
DNA fingerprinting	genetic disorder	protein synthesis
mitochondrial DNA		

Section 12.1

1. Sickle cell anemia, a blood disorder, is caused by a _____.
2. During _____, the cell reads the three letter codes of the DNA to build proteins from amino acids.
3. _____ ensures that each daughter cell has an exact copy of the genetic information of the parent cell.
4. Cystic fibrosis is an example of a _____.
5. The _____ provides the code that directs the cell to make specific proteins.

Section 12.2

6. _____ can be used to identify suspects in a crime.
7. Cold-resistant tomatoes, super sweetcorn, and maize are all the results of _____.
8. Scientists use _____ to study human origins because it is only inherited from the mother.
9. Insulin for people with diabetes is produced by _____.
10. A _____ is the total amount of hereditary material in a single cell of an organism.

Concepts

Section 12.1

1. Of the four nitrogen base pairs, cytosine always pairs with:
   a. adenine
   b. guanine
   c. thymine
   d. cytosine
2. Draw and label a DNA molecule with these terms: sugar, phosphate, A, T, C, and G.
3. Write out the bases that pair with the base sequence shown below.

4. When does DNA replication occur?
5. Put these steps of DNA replication in the correct order from beginning to end.
   a. Two daughter molecules have been produced - each of one original strand and one new strand.
   b. The double helix partially unwinds.
   c. A new strand is put together along each original strand using pieces made from molecules in the cytoplasm.
   d. The base pairs separate.
6. Which body cells have no nuclear DNA?
7. Proteins are made of smaller molecules called _____.

8. Fill in this chart to compare DNA and RNA.

	DNA	RNA
# of strands		
Letter names of bases		
Where found?		

9. If the base sequence of the DNA is GTCAGGATC, what would be the corresponding base sequence of the messenger RNA?
10. Predict what might happen if the three letter "stop code" was missing from a DNA sequence.
11. The type of protein made in the ribosomes depends on which of the following? You may choose more than one answer.
    a. The base sequence of the gene
    b. The sequence of the amino acids
    c. The number of codons in the gene
    d. The number of messenger RNA molecules present
12. If a mutation takes place in a human skin cell, will that mutation be passed on to the person's offspring? Explain your answer.
13. What is an amniocentesis? Explain how it works.

Section 12.2

14. Explain how selective breeding and/or genetic engineering might be used to solve these problems:
    a. low apple production from trees
    b. lack of human hormone
    c. poor fur quality of alpacas
    d. corn crops destroyed by disease
15. What kind of cells are most commonly used in genetic engineering? Why?
16. How is DNA like a fingerprint?
17. Who has DNA fingerprints that are similar to your DNA fingerprints?
18. What is one possible benefit of the Human Genome Project?
19. What is mitochondrial DNA? Why do you inherit your mitochondrial DNA only from your mother?

Math and Writing Skills

Section 12.1

1. Describe the accomplishments of Franklin, Watson, and Crick that added to the understanding of DNA structure.
2. Suppose adenine makes up 23% of an organism's nitrogen bases. What percent of that organism's nitrogen bases would be guanine? Explain your answer.
3. The four nitrogen base pairs combine in sets to create three-letter codes used in the creation of proteins. How many possible three-letter codes are there? (HINT: bases can be repeated in a three letter code and the order of the bases is important.)
4. Imagine that you are DNA writing a thank you letter to RNA. Explain how critical RNA is to your work in a cell.
5. Write a dialogue that might occur between messenger RNA and transfer RNA working together in a cell.
6. Why is more known about harmful mutations than beneficial ones?

Section 12.2

7. Pretend that you are a farmer explaining to your daughter how you use selective breeding to get the best quality animals and crops that you possibly can.
8. Cloning technology is one result of DNA research. Think about whether you believe human cloning should be allowed. Write a paragraph supporting your opinion.
9. Create an analogy to explain how bases, genes, chromosomes, and genomes fit together. Explain your analogy.
10. If 16,000 base pairs of human mitochondrial DNA are contained in 5 - 10 rings, what is the maximum number of base pairs that each ring could be? What is the minimum number of base pairs that each ring must be?

Chapter Project—Genetic Disorder Brochure

A genetic disorder is an abnormal condition that an organism inherits from its parents. Genetic disorders are not contagious, and a parent with a genetic disorder does not always pass it to offspring. Some genetic disorders appear at birth, and others do not show up until later in life.

For this project you will choose a particular genetic disorder and create a tri-fold brochure that could be displayed in the waiting room of a doctor's office. Make your brochure creative and informative so people will want to read it. You need to list four sources of information on the very back of your brochure. Only two of the sources can be websites.

Things to include in your brochure:

1. Name of disorder
2. Sketch of chromosome with location of disorder gene clearly marked and labeled
3. Symptoms of disorder
4. Complications associated with disorder
5. How the disorder is detected
6. Treatment
7. Two other interesting, unique facts about this disease
8. Places to go for more information (4 sources; only 2 websites)

Choose one of these genetic disorders (if you are interested in one that isn't on the list, check first with your teacher).

Alzheimer's disease

Cystic Fibrosis

Down's Syndrome

Hemophilia

Marfan Syndrome

Muscular Dystrophy

Sickle Cell Anemia

Huntington Disease

Phenylketonuria (PKU)

Diabetes

Familial hypercholesterolemia