Preview Key Concepts

6.1 **Chromosomes and Meiosis**
Gametes have half the number of chromosomes that body cells have.

6.2 **Process of Meiosis**
During meiosis, diploid cells undergo two cell divisions that result in haploid cells.

6.3 **Mendel and Heredity**
Mendel’s research showed that traits are inherited as discrete units.

6.4 **Traits, Genes, and Alleles**
Genes encode proteins that produce a diverse range of traits.

6.5 **Traits and Probability**
The inheritance of traits follows the rules of probability.

6.6 **Meiosis and Genetic Variation**
Independent assortment and crossing over during meiosis result in genetic diversity.

Review Academic Vocabulary
Write the correct word for each definition.

<table>
<thead>
<tr>
<th>Word</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>mitosis</td>
<td>results in identical daughter cells</td>
</tr>
<tr>
<td>data</td>
<td>recorded observations</td>
</tr>
<tr>
<td>chromosome</td>
<td>long, continuous piece of DNA</td>
</tr>
<tr>
<td>experiment</td>
<td>allows scientists to test hypothesis</td>
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</table>

Preview Biology Vocabulary
To see how many key terms you already know from this chapter, choose the word that makes sense in each sentence.

<table>
<thead>
<tr>
<th>Word</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>trait</td>
<td>The shape of your ears is a(n)</td>
</tr>
<tr>
<td>gene</td>
<td>A(n) is a grid system that helps predict information about the offspring of two parent organisms.</td>
</tr>
<tr>
<td>egg</td>
<td>A(n) is a sex cell in a female organism.</td>
</tr>
<tr>
<td>Punnett square</td>
<td>A segment of DNA that codes for a protein is a(n)</td>
</tr>
</tbody>
</table>
You have body cells and gametes.

All of the different cells in your body can be divided into two groups: somatic cells and germ cells.

- **Germ cells** are the cells in your reproductive organs—the ovaries or testes—that develop into eggs or sperm.
- **Somatic cells** (soh-MAT-ihk), or body cells, are all the other cells in your body.

Somatic cells make up most of your tissues and organs. The DNA in your somatic cells will not be passed on to your children. Only the DNA in the egg or sperm cells gets passed on to offspring. Egg cells and sperm cells are called **gametes**.

Each species has a characteristic number of chromosomes per cell. For example:

- **Humans** have 23 pairs of chromosomes. In other words, there are $23 \times 2 = 46$ chromosomes in all body cells.
- **Fruit flies** have 4 pairs of chromosomes, or 8 chromosomes per cell.
- **Yeast** have 16 pairs of chromosomes, or 32 chromosomes per cell.

The organism currently known to have the most chromosomes is a fern. It has more than 1200 chromosomes. Chromosome number is not related to the size or complexity of an organism.

Do gametes come from germ cells or somatic cells?

Your cells have autosomes and sex chromosomes.

Suppose you had 23 pairs of gloves. You would have a total of $23 \times 2 = 46$ gloves. You could divide them into two sets: 23 right-hand and 23 left-hand gloves. Similarly, your body cells have 23 pairs of chromosomes, for a total of 46. These can be divided into two sets: 23 from your mother and 23 from your father. Just as you use both gloves if it is cold outside, your cells use both sets of chromosomes to function properly.

Each pair of chromosomes is called a homologous pair. Here, *homologous* means “having the same structure.” **Homologous chromosomes** are two chromosomes—one from the mother and one from the father—that are the same size and have copies of the same genes.
Although each chromosome in a homologous pair has copies of the same genes, the two copies may differ. For example, each chromosome in a pair might have a gene that influences eye color. But the gene on one chromosome of the pair may lead to brown eyes and the gene on the other chromosome may lead to green eyes.

One of your 23 pairs of chromosomes is your pair of sex chromosomes. These chromosomes control the sex of an organism. Humans, and all mammals, have two different sex chromosomes called X and Y.

- Females have two X chromosomes.
- Males have one X chromosome and one Y chromosome.

The rest of your chromosomes—the other 22 pairs—are called autosomes. These chromosomes contain genes for all of the rest of an organism’s life functions.

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**Instant Replay**
If a person’s pair of sex chromosomes is XY, is the person male or female? 

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**Body cells are diploid; gametes are haploid.**

Sexual reproduction involves two gametes—an egg and a sperm—joining together. Fertilization happens when the egg and sperm actually combine. The nucleus of the egg combines with the nucleus of the sperm to form one nucleus. This new nucleus must have the correct number of chromosomes—46 for humans. Therefore, the egg and sperm each must each have half that number of chromosomes—23 for humans.

**Diploid and Haploid Cells**

Gametes—eggs and sperm—are haploid (HAP-LOYD) cells. Haploid cells have one copy of each chromosome—again, 23 for humans. A sperm and egg join together to form a diploid (DIHP-LOYD) cell—for a total of 46 chromosomes for humans. Body cells are all diploid. Only gametes are haploid.

**Meiosis**

The germ cells in your reproductive organs form gametes through a process called meiosis. Meiosis (my-OH-sihs) is a process that divides a diploid cell into a haploid cell. In Chapter 5 you learned about mitosis, another process that divides a cell. The figure on the next page shows some of the differences between mitosis and meiosis.
Remember that mitosis results in two identical diploid cells. Mitosis is used for development, growth, and repair. In contrast, meiosis results in four haploid cells that are unique. Meiosis happens only in germ cells to make gametes. Meiosis will be presented in detail in the next section.

What is the difference between the cells that result from mitosis and the cells that result from meiosis?

6.1 Vocabulary Check

- somatic cell
- gamete
- homologous chromosome
- sex chromosome
- autosome
- sexual reproduction
- fertilization
- haploid
- diploid
- meiosis

1. when the nucleus of an egg joins the nucleus of a sperm __________
2. a body cell __________
3. an egg or sperm cell __________
4. any chromosome except a sex chromosome __________

6.1 The Big Picture

5. If a diploid cell with 8 chromosomes goes through meiosis, how many chromosomes will the resulting haploid cells have? __________
6. Circle the sex of a person with the sex chromosomes XX: male / female
Cells go through two rounds of division in meiosis.

Meiosis begins with a diploid cell that already has duplicated chromosomes. There are two rounds of cell division—meiosis I and meiosis II. The phases of meiosis are similar to the phases of mitosis. To keep the two processes separate in your mind, focus on the big picture. Mitosis results in identical diploid cells, and meiosis results in unique haploid cells.

**Homologous Chromosomes and Sister Chromatids**

Recall that homologous chromosomes are two separate chromosomes: one from your mother and one from your father. Homologous chromosomes carry the same genes in the same order. However, the copies of the genes may differ. Homologous chromosomes are not copies of each other. In contrast, recall that a duplicated chromosome is made of two sister chromatids, attached at the centromere. Sister chromatids are identical copies of each other.

**The Process of Meiosis**

Before meiosis begins, DNA has already been copied. Homologous chromosomes are separated in the first half of meiosis—meiosis I. This results in two haploid cells with duplicated chromosomes. These cells are haploid because they each have only one of every pair of homologous chromosomes. Sister chromatids are separated in the second half of meiosis—meiosis II. This results in four haploid cells with undoubled chromosomes. Like mitosis, scientists describe this process in phases. Follow the process of meiosis illustrated on the next page. The figure is simplified, showing only four chromosomes.
Meiosis I separates homologous chromosomes.

1. **Prophase I** The nuclear membrane breaks down. The duplicated chromosomes condense and homologous chromosomes begin to pair up. Notice that there are two pairs of duplicated homologous chromosomes.

2. **Metaphase I** The chromosomes line up along the middle of the cell.

3. **Anaphase I** The paired homologous chromosomes separate. Sister chromatids remain attached.

4. **Telophase I** Cytokinesis separates the cells. Each cell contains only one of each pair of chromosomes—not both. In other words, the cells are now haploid. The chromosomes are still duplicated.

Meiosis II separates sister chromatids. The overall process produces haploid cells.

5. **Prophase II** The nuclear membrane breaks down and the cells prepare to divide.

6. **Metaphase II** The chromosomes line up along the middle of the cell.

7. **Anaphase II** The sister chromatids are separated and move to opposite sides of the cell.

8. **Telophase II** The nuclear membranes form again. The result of meiosis is four haploid cells with a combination of chromosomes from both the mother and father.

Now that you’ve seen how meiosis works, let’s review two key differences between the processes of meiosis and mitosis.

- Meiosis has two cell divisions. Mitosis has only one cell division.
- Meiosis results in haploid cells. Mitosis results in diploid cells.

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**On the diagram above, circle the part in the process of meiosis when the cells first become haploid.**
Haploid cells develop into mature gametes.

Gametogenesis (guh-MEE-tuh-JEHN-ih-sis) is the production of gametes—eggs or sperm. Gametogenesis includes both meiosis and other changes that the haploid cells must go through. The sperm cell, the male gamete, is much smaller than the egg, the female gamete. After meiosis, a cell that develops into a sperm will form a compact shape with a long tail, or flagellum, that the cell uses to move. For egg production, only one of the cells from meiosis becomes an egg. It receives most of the cytoplasm and organelles. The other cells produced by meiosis become polar bodies, smaller cells that contain little more than DNA, and are eventually broken down.

How do mature gametes differ from the immature haploid cells?

1. Sperm and eggs are formed through the process of ______________.
2. For egg formation, one of the cells resulting from meiosis becomes an egg and the others become ____________________________.
3. What is the end result of meiosis? ____________________________
4. What are two differences between meiosis and mitosis? _____________

6.2 Vocabulary Check

Choose the correct term from the list above to complete the sentences below.

- gametogenesis
- egg
- sperm
- polar body

Mark It Up

Go back and highlight each sentence that has a vocabulary word in bold.
Mendel laid the groundwork for genetics.

Traits are characteristics* that are inherited, such as eye color, leaf shape, or tail length. Scientists recognized that traits are hereditary, or passed from one generation to the next, long before they understood how traits are passed on. Genetics is the study of biological inheritance patterns and variation in organisms.

The study of genetics started in the 1800s with an Austrian monk named Gregor Mendel. He recognized that there are separate units of inheritance—what we now call genes—that come from each parent. Mendel studied inheritance in pea plants.

Mendel's data revealed patterns of inheritance.

Three things about Mendel’s experiments helped him develop his laws of inheritance.

1. **He controlled the breeding of the pea plants he studied.**
   Pea flowers have both male and female parts. They usually self-pollinate. In other words, a plant mates with itself. As shown in the figure to the right, Mendel controlled the matings of his pea plants. He chose which plants to cross. In genetics, the mating of two organisms is called a **cross**.

2. **He used “either-or” characteristics.** Mendel studied seven different pea traits, including flower color and pea shape. All of the characteristics he studied had only two forms, so all plants either had one form or the other. For example, all of the flowers were purple or white. All of the peas were wrinkled or round.

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* **ACADEMIC VOCABULARY**

characteristic: something that is recognizable, or that distinguishes someone or something

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Mendel and Heredity

KEY CONCEPT Mendel's research showed that traits are inherited as discrete units.
He used purebred plants. If a line of plants self-pollinates for long enough, the plants become genetically uniform, or purebred. The offspring of a purebred parent inherits all of the parent organism’s characteristics—they are all the same as the parent. Because Mendel started with purebred plants, he knew that any variation in the offspring was a result of his crosses.

Results
Mendel found that when he crossed purebred plants, one of the forms of a trait was hidden in the offspring. But the form would reappear in the next generation.

MENDEL’S EXPERIMENTAL CROSS
Traits that were hidden when parental purebred flowers were crossed reappeared when the F1 generation was allowed to self-pollinate.

Mendel studied many plants and made many crosses. He found similar patterns in all of his results. In the figure above, you can see that the white flowers disappeared in the first generation of offspring. In the second generation, however, he found that about one-fourth of the plants had the form of the trait that had disappeared in the first generation. The other three-fourths of the plants had purple flowers. In other words there was a 3:1 ratio of purple-flowered:white flowered plants in the second generation.
**Conclusions**

These observations helped Mendel form his first law, called the **law of segregation**. There are two main parts of this law.

- Organisms inherit two copies of each gene, one from each parent.
- Only one copy of a gene goes into an organism’s gametes. The two copies of a gene separate—or segregate—during gamete formation.

Highlight the two parts of Mendel’s law of segregation listed above.

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**6.3 Vocabulary Check**

<table>
<thead>
<tr>
<th>trait</th>
<th>purebred</th>
</tr>
</thead>
<tbody>
<tr>
<td>genetics</td>
<td>law of segregation</td>
</tr>
<tr>
<td>cross</td>
<td></td>
</tr>
</tbody>
</table>

Choose the correct term from the list for each description.

1. the study of biological inheritance ________________
2. the mating of two organisms ________________
3. a characteristic that is inherited ________________

---

**6.3 The Big Picture**

4. The law of segregation says that gametes receive only one chromosome from each homologous pair of chromosomes. Turn back to the image on page 94 that shows the process of meiosis. In which stage of meiosis do homologous chromosomes separate?

   ________________
   ________________
   ________________

5. Give two examples of human traits that are not mentioned in the section above. ________________
   ________________
   ________________
The same gene can have many versions.

As you learned, the units of inheritance that Mendel studied are now called genes. You can think of a gene as a piece of DNA that stores instructions to make a certain protein. Each gene is located at a particular place on a chromosome called a locus. Just like a house has an address on a street, a gene has a locus on a chromosome.

Many things come in different forms. For example, bread can be wheat, white, or rye. Most genes have many forms, too. An allele (uh-LEEL) is any of the different forms of a gene. The gene for pea shape, for example, has two alleles—one for round peas and another for wrinkled peas.

Your cells, like the pea plant’s cells, have two alleles for each gene—one on each chromosome of a homologous pair. The term homozygous (HOH-moh-ZY-gus) means the two alleles of a gene are the same—for example, both alleles are for round peas. The term heterozygous (HEHT-uhr-uh-ZY-gus) means the two alleles are different—for example, one allele is for wrinkled peas and one is for round peas.

Genes influence the development of traits.

For Mendel’s peas, if a plant was heterozygous for pea shape, the pea shape would be round. This is because the allele for round peas is dominant, or expressed when two different alleles are present. A recessive allele is expressed only when there are two copies of the recessive allele. A dominant allele is not better or stronger or more common; it is simply the allele that is expressed when there are two different alleles. Mendel studied traits that had just two alleles, one that was dominant and one that was recessive. Most traits involve much more complicated patterns of inheritance.

Alleles are represented with letters—capital letters for dominant alleles and lowercase letters for recessive alleles. For example, the dominant allele for round pea shape can be
written as \( R \), for round. The recessive allele, for wrinkled pea shape, can be represented with the same letter, but lowercase—\( r \).

A **genotype** is the set of alleles an organism has for a trait. For example, a genotype could be homozygous dominant (\( RR \)), heterozygous (\( Rr \)), or homozygous recessive (\( rr \)). A **phenotype** is what the resulting trait looks like—for example, round or wrinkled. A **genome** is all of an organism’s genetic material—all of the genes on all of the chromosomes.

What is the difference between a genotype and a phenotype?

<table>
<thead>
<tr>
<th>6.4 Vocabulary Check</th>
<th>Mark It Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>gene recessive</td>
<td><strong>Go back and highlight each sentence that has a vocabulary word in bold.</strong></td>
</tr>
<tr>
<td>allele genotype</td>
<td></td>
</tr>
<tr>
<td>homozygous phenotype</td>
<td></td>
</tr>
<tr>
<td>heterozygous genome</td>
<td></td>
</tr>
<tr>
<td>dominant</td>
<td></td>
</tr>
</tbody>
</table>

1. What is the difference between a gene and an allele? ______________
   ________________________________________________________________

2. What is the difference between a dominant allele and a recessive allele? ______________
   ________________________________________________________________

3. Fill in the blanks in the chart below regarding pea shape.

<table>
<thead>
<tr>
<th>GENOTYPE</th>
<th>PHENOTYPE</th>
<th>HOMOZYGOUS OR HETEROZYGOUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>( RR )</td>
<td></td>
<td>homozygous dominant</td>
</tr>
<tr>
<td>( Rr )</td>
<td>round peas</td>
<td></td>
</tr>
<tr>
<td>( rr )</td>
<td></td>
<td>homozygous recessive</td>
</tr>
</tbody>
</table>

4. Which of the alleles in the chart above is dominant? ______________
Punnett squares illustrate genetic crosses.

A **Punnett square** is a grid* system for predicting all possible genotypes resulting from a cross. The outside edges, or axes*, of the grid represent the possible genotypes of gametes from each parent. The grid boxes show the possible genotypes of offspring from those two parents.

Let’s briefly review what you’ve learned about meiosis and segregation to examine how the Punnett square works. Both parents have two alleles for each gene. These alleles are represented on the axes of the Punnett square. During meiosis, the chromosomes—and therefore the alleles—are separated. Each gamete can receive only one of the alleles, but not both. When fertilization happens, gametes from each parent join together and form a diploid cell with two copies of each chromosome. The new cell has two alleles for each gene. This is why each box shows two alleles. One is from each parent.

**What do the letters on the axes of the Punnett square represent?**

**A monohybrid cross involves one trait.**

Thus far, we have studied crosses of one trait. **Monohybrid crosses** are crosses that examine the inheritance of only one specific trait—for example, flower color. If we know the genotypes of the parents, we can use a Punnett square to predict the genotypes of the offspring.

The Punnett squares on the next page show the results of three different crosses:

- Homozygous dominant crossed with homozygous recessive ($FF \times ff$)
- Heterozygous crossed with heterozygous ($Ff \times Ff$)
- Heterozygous crossed with homozygous recessive ($Ff \times ff$)
MONOHYBRID CROSSES

All offspring receive a dominant allele, \( F \), from one parent and a recessive allele, \( f \), from the other parent. So all offspring—100 percent—have the heterozygous genotype \( Ff \). And 100 percent of offspring have purple flowers.

From each parent, half of the offspring receive a dominant allele, \( F \), and half receive a recessive allele, \( f \). Therefore, one-fourth of the offspring have an \( FF \) genotype, one-half are \( Ff \), and one-fourth are \( ff \). In other words, the genotypic ratio is 1:2:1 of \( FF:Ff:ff \). Remember that both \( FF \) and \( Ff \) genotypes have a purple phenotype. The phenotypic ratio is 3:1 of purple:white flowers.

All of the offspring receive a recessive allele, \( f \), from the homozygous recessive parent. Half receive a dominant allele, \( F \), from the heterozygous parent, and half receive the recessive allele, \( f \). The resulting genotypic ratio is 1:1 of \( Ff:ff \). The phenotypic ratio is 1:1 of purple:white.

Suppose that we had a purple-flowered pea plant but did not know its genotype. It could be \( FF \) or \( Ff \). We could figure out its genotype by crossing the purple-flowered plant with a white-flowered plant. We know that the white-flowered plant is \( ff \), because it has the recessive phenotype. If the purple-flowered plant is \( FF \), the offspring will all be purple. If the purple-flowered plant is \( Ff \), half of the offspring will have purple flowers, and half will have white flowers. Crossing a homozygous recessive organism with an organism of unknown genotype is called a **testcross**.

**STANDARDS CHECK**

What is the phenotype of the offspring from the cross \( FF \times ff \)?
A dihybrid cross involves two traits.

So far, we have examined monohybrid crosses, or crosses that examine only one trait. Mendel also performed **dihybrid crosses**, or crosses that examine the inheritance of two different traits.

For example, Mendel crossed a purebred plant that had yellow round peas with a purebred plant that had green wrinkled peas. He wanted to see if the two traits—pea shape and color—were inherited together. The first generation of offspring all looked the same, and they were all heterozygous for both traits. The second generation of offspring is shown in the figure to the right. In addition to green wrinkled and yellow round peas, there were also green round and yellow wrinkled peas. In other words, Mendel found that pea shape and color were independent of each other—they were not inherited together. Mendel’s second law of genetics is the **law of independent assortment**, which states that alleles of different genes separate independently of one another during gamete formation, or meiosis. Different traits are inherited separately.

**DIHYBRID CROSS**

This dihybrid cross is heterozygous-heterozygous.

**Heredity patterns can be calculated with probability.**

**Probability** is the likelihood, or chance, that a particular event will happen. It predicts the average number of times something happens, not the exact number of times.

\[
\text{Probability} = \frac{\text{number of ways a specific event can occur}}{\text{number of total possible outcomes}}
\]

Suppose you flip a coin. There is a \( \frac{1}{2} \) chance it will land on heads, and a \( \frac{1}{2} \) chance that it will land on tails. Suppose you flip two coins. For each one, the chance it will land on heads is \( \frac{1}{2} \). But for both to land on heads, the chance is \( \frac{1}{2} \times \frac{1}{2} = \frac{1}{4} \).
These probabilities can be applied to meiosis, too. Suppose a germ cell has heterozygous alleles for a trait, for example, \( Ff \). A gamete has a \( \frac{1}{2} \) chance of getting an \( F \) and a \( \frac{1}{2} \) chance of getting an \( f \). If two heterozygous plants are crossed, what is the chance that the offspring will be \( FF \)? There is a \( \frac{1}{2} \) chance that the sperm will carry an \( F \) and a \( \frac{1}{2} \) chance that the egg will carry an \( F \). Therefore, there is a \( \frac{1}{2} \times \frac{1}{2} = \frac{1}{4} \) chance that the offspring will be \( FF \). Probability can be used to determine all of the possible genotypic outcomes of a cross.

If you flip two coins, what is the probability that they will both land on tails?

**6.5 Vocabulary Check**

**Punnett square**
- dihybrid cross

**Monohybrid cross**
- law of independent assortment

**Testcross**
- probability

Choose the correct term from the list for each description.

1. crossing an organism of unknown genotype with a homozygous recessive organism

2. a cross to examine one trait only

3. a cross to examine two different traits

**6.5 The Big Picture**

4. Fill in the Punnett square and list the genotype and phenotype ratios.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td>( F )</td>
</tr>
<tr>
<td>( f )</td>
<td></td>
</tr>
<tr>
<td>( Ff )</td>
<td></td>
</tr>
<tr>
<td>( f )</td>
<td></td>
</tr>
</tbody>
</table>

Genotype ratio: ________
Phenotype ratio: ________
Sexual reproduction creates unique gene combinations.

Sexual reproduction produces a lot of variety within a species. This genetic variety comes from the events of meiosis and from the fertilization of gametes, which is a random process. Recall that humans have 23 pairs of chromosomes, and that each pair assorts independently from the others. As a result, there are about 8 million different combinations of chromosomes that can be produced during meiosis of one human cell.

Suppose a human sperm cell that has one of 8 million different possible combinations fertilizes a human egg cell that has one of 8 million different possible combinations. Since any sperm cell can fertilize any egg, more than 64 trillion possible combinations can result.

For all sexually reproducing organisms, sexual reproduction results in unique combinations of the two parents’ genes. Therefore, their offspring have unique phenotypes. This variety helps some organisms of a species survive and reproduce in conditions where other organisms of the species cannot.

What are two parts of sexual reproduction that produce genetic variation?

Crossing over during meiosis increases genetic diversity.

Crossing over is a process that occurs during meiosis and also contributes to genetic variation. Crossing over is the exchange of chromosome pieces between homologous chromosomes. This happens during prophase I of meiosis I. The process is shown in the figure to the right. Crossing over can happen many times—even within the same pair of homologous chromosomes.

* ACADEMIC VOCABULARY

exchange  to give and receive, or to trade something
Recall that a single chromosome has many genes, each with its own locus, or place, on the chromosome. Two genes on the same chromosome may be close together or far apart. For example, in the figure to the right, genes A and B are close together, but they are both far apart from genes C and D. When crossing over occurs, it is likely that genes A and B will be separated from genes C and D. But it is unlikely that genes A and B will be separated from each other—or that C and D will be separated—because they are so close together. Genes located close together tend to be inherited together, which is called genetic linkage.

In the figure above, which genes are likely to be separated by crossing over?

6.6 Vocabulary Check

1. Draw a picture that shows two chromosomes crossing over.
2. Draw a picture that shows genetic linkage of two genes on a chromosome.

6.6 The Big Picture

3. How is genetic diversity beneficial to a species?

4. How does crossing over contribute to genetic diversity?
Chapter 6 Review

1. Which pair of sex chromosomes makes a person male: XX or XY?  

2. Which cells in a multicellular organism undergo meiosis?  

3. What is the final product of meiosis?  
   a. identical diploid cells  
   b. unique diploid cells  
   c. identical haploid cells  
   d. unique haploid cells  

4. In pea plants, the allele for tall stems, T, is dominant to the allele for short stems, t. Draw and fill in a Punnett square that shows the cross of a heterozygous plant, Tt, with a homozygous dominant plant, TT.  

5. List all the possible genotypes of the offspring from your Punnett square in question 4. Next to each genotype write the corresponding phenotype—short stems or tall stems.  

6. What part of meiosis is responsible for Mendel's law of segregation?  
   a. DNA condensing into tightly packaged chromosomes  
   b. homologous chromosomes crossing over  
   c. alleles assorting independently into gametes  
   d. homologous pairs of chromosomes separating into different gametes  

7. Which human cells are haploid?  

8. Explain in words or with drawings how the processes of fertilization and crossing over contribute to genetic diversity.