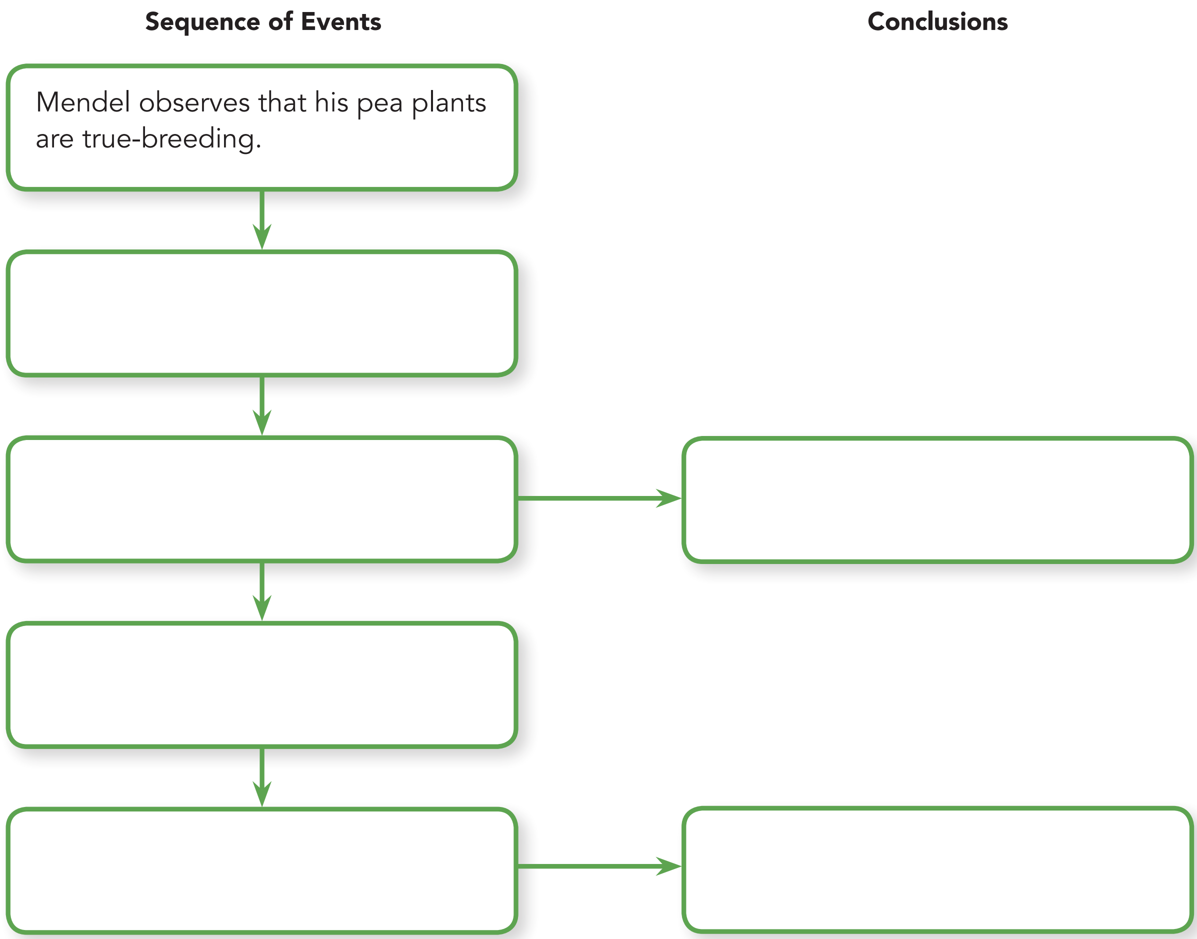
CHAPTER 12

LESSON 1

The Work of Gregor Mendel

READING TOOL **Sequence of Events** As you read your textbook, identify the sequence of events that influenced Mendel's conclusions about genetics. Pay attention to his experiments with the F_1 and F_2 generations. The first event is filled in for you.



Lesson Summary

Mendel's Experiments

KEY QUESTION *Where does an organism get its unique characteristics?*

All living organisms have characteristics that are inherited from their parent or parents. The scientific study of biological inheritance is called **genetics**. Modern genetics began with the work of Gregor Mendel in the 1800s. Mendel studied inheritance in peas, which produce hundreds of offspring.

As you read, circle the answers to each Key Question. Underline any words you do not understand.

Build Vocabulary

genetics scientific study of heredity

fertilization process of sexual reproduction in which male and female reproductive cells join to form a new cell

trait specific characteristic of an individual

hybrid offspring of crosses between parents with different traits

gene sequence of DNA that codes for a protein and thus determines a trait; factor that is passed from parent to offspring

allele one of a number of different forms of a gene

principle of dominance Mendel's second conclusion, which states that some alleles are dominant and others are recessive

segregation separation of alleles during gamete formation

gamete sex cell

Using Prior Knowledge Some cars are hybrid automobiles. Most automobiles are powered only by gasoline engines, and a few are powered by electric motors. In a hybrid automobile, there are two sources of power: a gasoline engine and an electric motor. ☑ **Give an example of a trait that Mendel studied in hybrids.**

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The Role of Fertilization During sexual reproduction, male and female reproductive cells join in a process called **fertilization** to produce a new cell. In peas, this cell develops into an embryo encased in a seed. Peas are normally self-pollinating, which means that the male and female reproductive cells come from within the same flower. Plants like this inherit all of its characteristics from its single parent. Mendel had stocks of pea plants with different specific characteristics, or **traits**. The stocks were true-breeding, meaning that when self-pollinated, the offspring had the same traits as the parents. One stock produced tall plants and another produced short plants. One produced green seeds and another produced yellow seeds. Mendel crossed his stocks of plants, causing one plant to reproduce with a plant from another stock. He did this by placing pollen from one plant on the female part of another. This process is called cross-pollination. Mendel examined seven traits of pea plants. Each trait had two different characteristics, such as green or yellow pods. The offspring of crosses between parent plants with different characteristics are called **hybrids**.

Genes and Alleles In genetic crosses, the original pair of plants are called the P, or parental, generation. Their offspring are called the F_1, or first filial, generation. In one experiment, Mendel was surprised to find that his F_1 plants had the characteristics of only one of their parents. For each cross, the characteristics of the other parent seemed to disappear from the offspring. Mendel's first conclusion from these results is that an individual's characteristics are determined by factors that are passed from one parental generation to the next. Today we call these factors **genes**. Each trait that Mendel studied was controlled by a single gene that occurred in two varieties. The different forms or varieties of a single gene are called **alleles** (uh LEELZ). For the gene for pea plant height, one allele produced tall plants and another allele produced short plants.

Dominant and Recessive Alleles Mendel's second conclusion is called the **principle of dominance**. The principle of dominance states that some alleles are dominant and some alleles are recessive. An organism that has both a dominant allele and a recessive allele for a trait will show the dominant characteristic. Mendel found that the allele for tall plants was dominant over the recessive allele for short plants, and the allele for yellow pods was dominant over the recessive allele for green pods.

Segregation

KEY QUESTION *How are different forms of a gene distributed to offspring?*

Mendel had another question: Had the recessive alleles disappeared, or were they still present in the new plants? To find out, he allowed all seven kinds of F_1 hybrids to self-pollinate. This cross of the F_1 generation produced the F_2 (second filial) generation.

The F_1 Cross When Mendel examined the F_2 plants, he found that traits produced by the recessive alleles reappeared in this generation. About one fourth of the F_2 plants showed the trait controlled by the recessive allele. Why did these traits appear to disappear in the F_1 generation and then reappear in the F_2 generation?

Explaining the F_1 Cross Mendel assumed that a dominant allele had masked the corresponding recessive allele in the F_1 generation. However, the recessive trait did appear in the F_2 generation. This indicates that at some point the allele for yellow pods had separated, or segregated, from the allele for green pods. Mendel suggested that the **segregation** of the alleles for yellow and green pods occurred during the formation of the reproductive cells, or **gametes** (GAM eetz).

The Formation of Gametes All of the F_1 plants inherited an allele (*G*) for green pods from the green parent and an allele (*g*) for yellow pods from the yellow parent. (For each trait, we use a capital letter to represent the dominant allele, and the same letter in lowercase to represent the recessive allele). Because the allele for green pods is dominant, all of the F_1 plants (*Gg*) have green pods. During gamete formation, the alleles for each gene segregate from each other, so that each gamete carries only one allele for each gene. Each F_1 plant produces two kinds of gametes, those with the green pod allele (*G*) and those with the yellow pod allele (*g*). When a gamete with the allele for yellow pods pairs with another gamete with the allele for yellow pods, the resulting F_2 plant (*gg*) has yellow pods. If one or both gametes that pair have the allele for green pods (*GG* or *Gg*), an F_2 plant with green pods is produced.

READING TOOL

Cause and Effect What happened to the yellow-pod characteristic in the F_1 cross?
☑ **Write the effect of the F_1 cross on the yellow-pod characteristic, and then write the cause.**

Effect: ______________________

____

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Cause: ______________________

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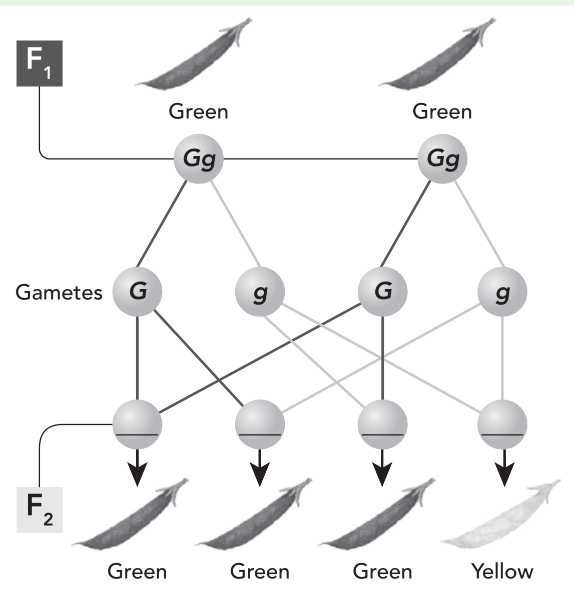
Visual Reading Tool: Segregation



A cross between yellow-pod and green-pod pea plants results in only green-pod plants in the F_1 offspring. When the F_1 offspring are crossed with themselves, the yellow pods reappear in the F_2 generation. Use the figure to answer the questions.

1. In the figure, label each individual in the F_2 generation with the alleles it inherited from the F_1 generation.
2. What color is a pod with the *gg* alleles? ______________
3. What color is a pod with the *GG* or *Gg* alleles? ______________
4. Describe in your own words how a plant with a yellow pod can have two green-pod parents.

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CHAPTER 12

LESSON 2

Applying Mendel's Principles

READING TOOL Connect to Visuals Before you read, preview **Figure 12-7**. Try to infer the purpose of this diagram. As you read, compare your inference to the text. After you read, revise your statement if needed or write a new one about the diagram's purpose. Take notes on the lines provided. Then view the Punnett square and answer the questions below regarding the genotypes and phenotypes.

Inference:

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Revision:

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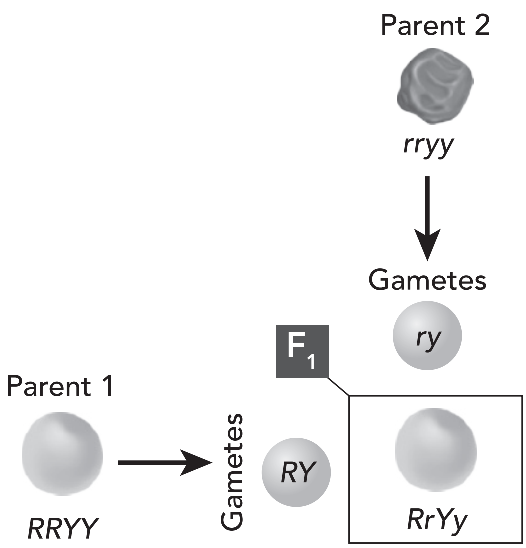

The F_1 generation are all *RrYy*.

1. What is the phenotype of parent 1? ______________________

2. What is the genotype of parent 1? ______________________

3. What is the phenotype of parent 2? ______________________

4. What is the genotype of parent 2? ______________________

5. What is the phenotype of the F_1 offspring? ______________________

6. What is the genotype of the F_1 offspring? ______________________

7. What kind of cross does this figure describe? ______________________

Lesson Summary

Probability and Heredity

KEY QUESTION *How can we use probability to predict traits?*

By analyzing his data, Mendel realized that the principles of probability could explain the results of his crosses. **Probability** is the likelihood that a particular event will occur.

Using Segregation to Predict Outcomes During gamete formation, alleles segregate randomly. Therefore, the principles of probability can predict the outcomes of genetic crosses, similar to the way probability is used to predict the outcomes of coin tosses. In Mendel's F_1 cross, each F_1 plant (*Gg*) has one green pod allele and one yellow pod allele, so $\frac{1}{2}$ of the gametes produced by the F_1 plants have yellow alleles (*g*). Because the yellow pod (*g*) allele is recessive, the only way to produce a plant with yellow pods (*gg*) is for two gametes, each carrying the *g* allele, to combine. Each gamete produced by the F_1 plants has a one in two, or $\frac{1}{2}$, chance of carrying the *g* allele. Since each plant is formed from two gametes, the probability of both gametes carrying the *g* allele is $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$. Therefore, roughly one fourth of the F_2 offspring should have yellow pods, and the remaining three fourths should have green pods. Both the *GG* and *Gg* allele combinations result in green pea pods. Organisms that have two identical alleles for a particular gene, such as *GG* or *gg*, are said to be **homozygous**. Organisms that have two different alleles for the same gene, such as *Gg*, are said to be **heterozygous**.

Probabilities Predict Averages Probabilities predict the average outcome of a large number of events. In genetics, the predicted ratios may only occur when observing a large number of offspring. An F_2 generation with only a few offspring may not match Mendel's predicted ratios, but if there are hundreds or thousands of offspring, the results should come close to the predicted ratios.

Genotype and Phenotype One of Mendel's most important insights is that every organism has a genetic makeup as well as observable physical characteristics. The physical traits are called the **phenotype**, and the genetic makeup is called the **genotype**. Mendel's F_2 plants had three different genotypes—*GG*, *Gg*, and *gg*—but only two phenotypes: green or yellow pods. The *GG* and *Gg* genotypes have the same phenotype, green pods.

As you read, circle the answers to each Key Question. Underline any words you do not understand.

BUILD Vocabulary

probability likelihood that a particular event will occur

homozygous having two identical alleles for a particular gene

heterozygous having two different alleles for a particular gene

phenotype physical characteristics of an organism

genotype genetic makeup of an organism

Using Prior Knowledge In math class, you have studied probability using coin tosses. Flipping a coin is like studying the genetics of a gene with two different alleles. Each coin flip has a probability of $\frac{1}{2}$ of landing heads up. The probability of flipping two coins and getting heads on both tosses is $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$. ☑ **If you flip a coin 50 times, about how many times would you expect to get heads?**

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Using Punnett Squares Punnett squares are one good way to predict the outcome of genetic crosses. **Punnett squares** use mathematical probability to help predict the genotype and phenotype combinations in genetic crosses. The number of possible alleles from each parent determines the number of rows and columns in the Punnett square.

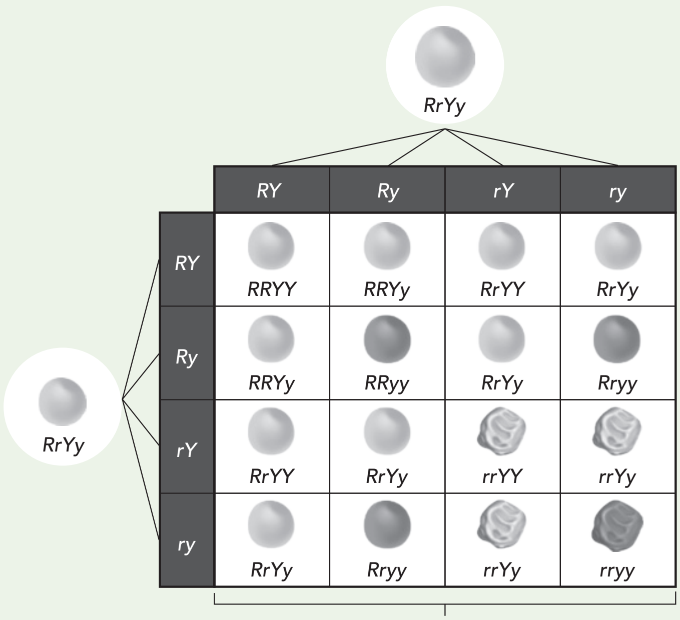
Independent Assortment

KEY QUESTION *How do alleles segregate when more than one gene is involved?*

Mendel wondered if the segregation of one pair of alleles affects another pair. For example, does the gene that determines the shape of a seed affect the gene for seed color? This type of experiment is known as a two-factor, or dihybrid, cross because it involves two different genes. Single-gene crosses are monohybrid crosses.

Visual Reading Tool: Two-Factor Cross: F_2

The Punnett square shows the results of self-crossing the F_1 generation of a cross between round yellow peas and wrinkled green peas.



F_2 Generation

1. List the different genotypes in the F_2 generation. What is the frequency of each genotype? One is filled out for you.

Genotype	Frequency
RRYY	$\frac{1}{16}$
rryy	$\frac{1}{16}$

2. List the different phenotypes in the F_2 generation. What is the frequency of each phenotype? One is filled out for you.

Phenotype	Frequency
wrinkled, green	$\frac{1}{16}$

The Two-Factor Cross: F_1 First, Mendel crossed true-breeding plants that produced only round, yellow peas with plants that produced only wrinkled, green peas.

The genotype is *RRYY* for the round, yellow peas and *rryy* for the wrinkled, green peas. All of the F_1 offspring produced round yellow peas. This shows that the alleles for yellow and round peas are dominant and the alleles for green and wrinkled peas are recessive. The genotype of the F_1 plants is *RrYy*. The F_1 plants are all heterozygous for seed shape and color.

The Two-Factor Cross: F_2 Mendel then crossed the F_1 plants to produce F_2 offspring. Each F_1 plant was formed from the fusion of a gamete with the dominant *RY* alleles with a gamete carrying the recessive *ry* alleles. Would the two dominant alleles always stay together or would they segregate independently, forming new combinations? If they segregated independently, a Punnett square shows that there will be a 9:3:3:1 ratio of round, yellow seeds to round, green seeds to wrinkled, yellow seeds to wrinkled, green seeds. In Mendel's experiment, the F_2 plants produced 556 seeds in a roughly 9:3:3:1 ratio. There were 315 round, yellow seeds, and 32 wrinkled, green seeds. However there were 209 seeds that had round, green seeds or wrinkled, yellow seeds. These were phenotypes that were not found in either parent. Therefore, the alleles for seed shape segregate independently from the alleles for seed color. Genes that segregate independently do not influence each other's inheritance. The principle of **independent assortment** states that genes for different traits can segregate independently during the formation of gametes. Independent assortment explains much of the variation observed in organisms that have the same parents.

A Summary of Mendel's Principles

KEY QUESTION *What did Mendel contribute to our understanding of genetics?*

Mendel's principles of heredity, observed through patterns of inheritance, form the basis of modern genetics. The following principles of heredity apply to many organisms, not just pea plants.

- The inheritance of biological characteristics is determined by individual units called genes.
- Where two or more forms (alleles) of the gene for a single trait exist, some alleles may be dominant and others may be recessive.
- In most sexually reproducing organisms, each adult has two copies for each gene—one from each parent. These genes segregate from each other when gametes are formed.
- Alleles for different genes usually segregate independently of each other.

BUILD Vocabulary

Punnett square diagram that can be used to predict the genotype and phenotype combinations of a genetic cross

independent assortment one of Mendel's principles that states that genes for different traits can segregate independently during the formation of gametes

Word Origins The Punnett square is named after Reginald Punnett, a British geneticist from the early 1900s. ☑ **How many squares are in a Punnett square for a one-factor cross?**

____

How many for a two-factor cross?

____

READING TOOL

Use Structure Mendel's principles of heredity are listed on this page in a bulleted list. Read the list carefully and answer the question below. ☑ **Two offspring from the same parents can have different phenotypes. How is this possible?**

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____
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CHAPTER 12

LESSON 3

Other Patterns of Inheritance

READING TOOL **Main Idea and Details** As you read your textbook, identify the five different types of nontraditional inheritance. In each box in the graphic organizer below, give an example of that main idea from the text.

Beyond Dominant and Recessive Alleles

Incomplete dominance:

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____

____

Non-Mendelian Inheritance:

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Codominance:

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Polygenic Traits:

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Multiple Alleles:

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Lesson Summary

Beyond Dominant and Recessive Alleles

As you read, circle the answers to each Key Question. Underline any words you do not understand.

KEY QUESTION *What are some exceptions to Mendel's principles?*

Incomplete Dominance Some alleles are neither completely dominant nor recessive. In the four o'clock plant (*Mirabilis jalapa*), a cross between a red-flowered (*RR*) plant and a white-flowered (*rr*) plant produces F_1 plants with pink flowers (*Rr*). This situation is called incomplete dominance. In **incomplete dominance**, the heterozygous phenotype lies somewhere between the two homozygous phenotypes.

Codominance

Codominance is when the phenotypes produced by both alleles are clearly expressed. In some chickens, the allele for black feathers is codominant with the allele for white feathers. Heterozygous chickens have a mixture of black and white feathers. Unlike the blending of red and white colors in heterozygous four o'clock flowers, the black and white colors remain separate in chickens.

Multiple Alleles

In nature, many genes have more than two alleles. Many genes exist in several different forms and are therefore said to have **multiple alleles**. A gene with more than two alleles has multiple alleles. An individual usually has two copies of each gene, but in a population there are many different alleles. A rabbit's coat color is determined by a single gene with at least four different alleles, and the four alleles display a pattern of dominance that can produce four different coat colors.

Polygenic Traits

Many traits are produced by the interaction of several genes. Traits controlled by two or more genes are said to be **polygenic traits**. Polygenic means "many genes." There may be as many as a dozen genes that are responsible for the many different shades of human eye colors.

Non-Mendelian Inheritance

Some traits follow non-Mendelian patterns of inheritance. Leaf color in *Mirabilis jalapa* is determined by the leaf color in the maternal parent. This pattern, known as maternal inheritance, would not be predicted from Mendel's principles. Maternal inheritance occurs because chloroplasts and mitochondria are inherited from the maternal gamete, or egg cell. Chloroplasts and mitochondria contain genes on small DNA molecules. Genes in the chloroplast determine leaf color in *Mirabilis*. Therefore, this trait shows maternal inheritance. Another source of non-Mendelian inheritance is genetic imprinting. In genetic imprinting, certain genes have been chemically modified in one parent in a way that prevents their expression in the next generation.

Genes and the Environment

KEY QUESTION *Does the environment have a role in how genes determine traits?*

An organism's characteristics are not only determined by the genes it inherits. Environmental conditions can affect gene expression and influence genetically determined traits. In some butterflies, the amount of pigmentation in the wing is influenced by the length of daylight during the time of year the larva hatches. Butterflies hatched when there is less daylight have more pigmentation, and therefore darker markings, than butterflies hatched when there is more daylight.

BUILD Vocabulary

incomplete dominance situation in which one allele is not completely dominant over another allele

codominance situation in which the phenotypes produced by both alleles are completely expressed

multiple alleles a gene that has more than two alleles

polygenic trait trait controlled by two or more genes

Prefixes *Poly-* is a prefix that means "many." Many roots that can use the prefix *poly-* can also use the prefix *mono-*, which means "one." ☑ **What would be a word for a trait controlled by a single gene?**

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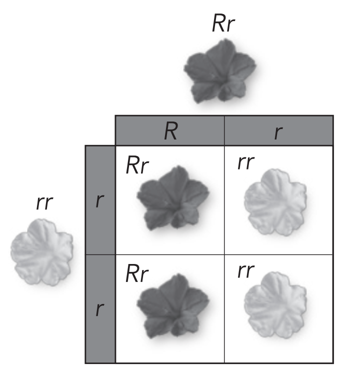
READING TOOL

Connect to Visuals In four o'clock plants, the gene for flower color is inherited by incomplete dominance. View the Punnett square below that shows the cross of a pink plant with a white plant.



☑ **What is the probability that the offspring of this cross has white flowers?**

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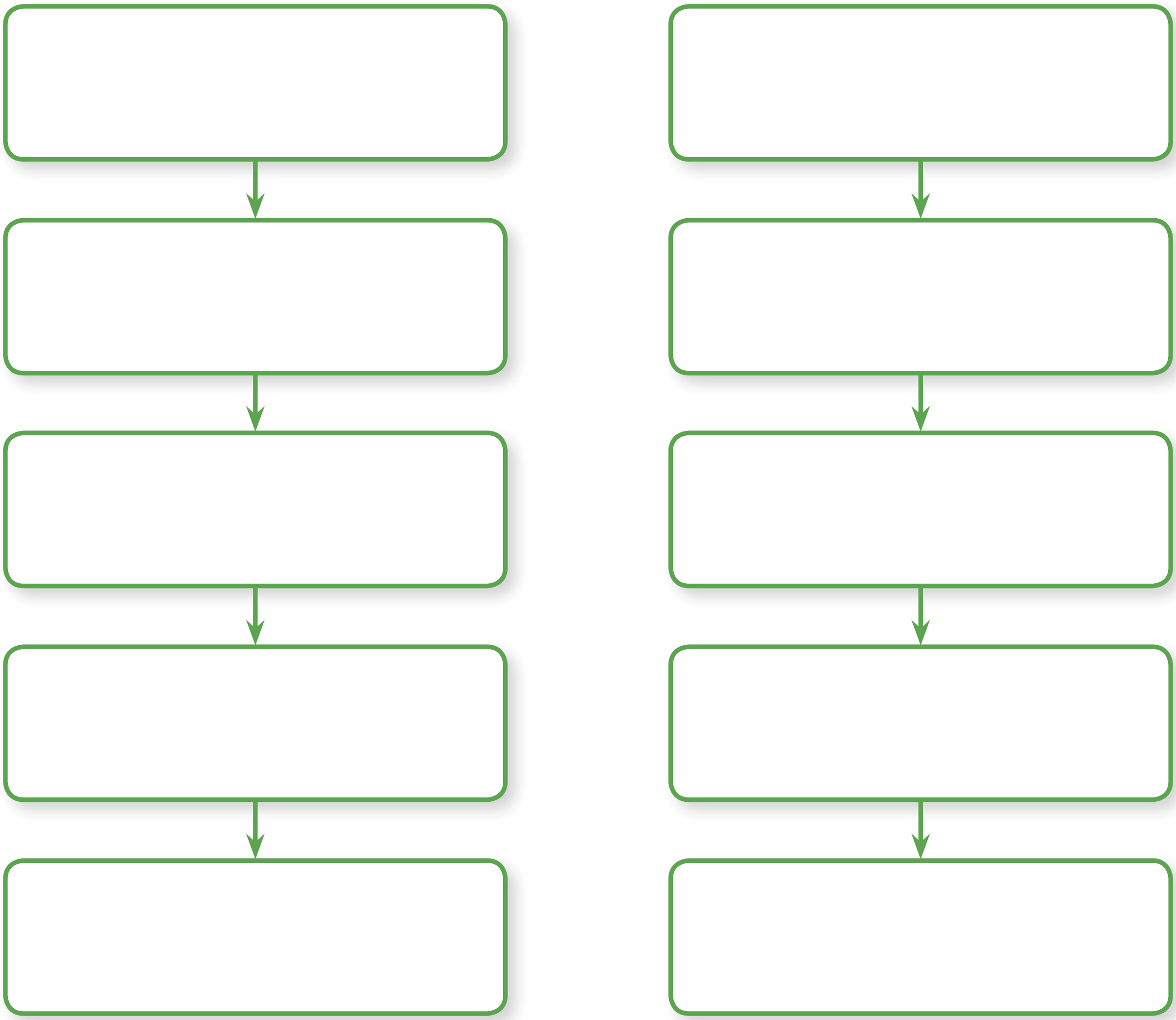
LESSON 4 Meiosis

READING TOOL **Sequence of Events** Identify the sequence of events in the process of meiosis. Take notes in the chart.

MEIOSIS I | **MEIOSIS II**



Lesson Summary

Chromosome Number

KEY QUESTION *How many sets of genes are found in most adult organisms?*

Mendel's principles require at least two events to occur. First, an organism with two parents must inherit one copy of every gene from each parent. Then, when the organism reproduces, its two sets of genes must be separated so that each gamete contains just one set of genes. Genes are located on chromosomes, strands of DNA and proteins in the cell.

Diploid Cells Each cell of the fruit fly *Drosophila melanogaster* has eight chromosomes. Four of these chromosomes come from the male parent and four from the female parent. The two sets of chromosomes are **homologous**, meaning that each chromosome from the male parent has a corresponding chromosome from the female parent. A cell with two sets of homologous chromosomes is **diploid**, meaning "double." The diploid cells of most adult organisms contain two complete sets of inherited chromosomes and two complete sets of genes. The diploid number of chromosomes can be represented by the symbol 2N. For *Drosophila*, the diploid number is 8, or $2N = 8$.

Haploid Cells Some cells, such as gametes, have a single set of chromosomes and therefore a single set of genes. Such cells are **haploid**, meaning "single." The haploid number of chromosomes is represented by N.

Phases of Meiosis

KEY QUESTION *What events occur during each phase of meiosis?*

Sexually reproducing organisms produce haploid (N) gamete cells from diploid (2N) cells in meiosis (my OH sis). **Meiosis** is a process in which the homologous chromosomes of a diploid cell are separated from each other. Meiosis involves two distinct cell divisions called meiosis I and meiosis II. Through meiosis, a single diploid cell produces four haploid cells.

Meiosis I Prior to meiosis I, the cell replicates its chromosomes during interphase. Each replicated chromosome consists of two identical chromatids joined at the center.

As you read, circle the answers to each Key Question. Underline any words you do not understand.

BUILD Vocabulary

homologous type of chromosomes in which one set comes from the male parent and one set comes from the female parent

diploid a cell that contains two sets of homologous chromosomes

haploid a cell that contains only a single set of genes

meiosis process in which the number of chromosomes per cell is cut in half through the separation of homologous chromosomes in a diploid cell

Prefixes The prefix *homo-* means "same," and, in general usage, means "same position," or "same structure." *Homologous* chromosomes are two chromosomes from different parents that have the same genes and structure. **What other word from this unit has the prefix *homo-* and means to have two copies of the same allele?**

____

BUILD Vocabulary

tetrad structure containing four chromatids that forms during meiosis

crossing-over process in which homologous chromosomes exchange portions of their chromatids during meiosis

Word Origins *Tetrad* means "four" and comes from a Greek root. You may be familiar with other words or prefixes that mean "four," such as *quartet* or *quad-*, both of which come from Latin roots. Tetrapod and quadruped mean the same thing in regards to the number of legs that an animal has.

☑ **How many feet do tetrapod/ quadrupeds have?**

____

Prophase I After interphase I, the chromosomes pair up. In prophase I of meiosis, each replicated chromosome pairs with its corresponding homologous chromosome. This pairing forms a structure with four chromatids called a **tetrad**. As the chromosomes pair, they sometimes exchange pieces of the homologous chromosomes in a process called **crossing-over**. Crossing-over produces new combinations of alleles on each chromosome.

Metaphase I and Anaphase I As prophase I ends, a spindle forms and attaches to each tetrad. During metaphase I of meiosis, paired homologous chromosomes line up across the center of the cell. Then the homologous pairs of chromosomes separate. During anaphase I, spindle fibers pull each homologous chromosome pair toward opposite ends of the cell.

Telophase I and Cytokinesis When anaphase I is complete, the separated chromosomes cluster at opposite ends of the cell. The next phase is telophase I, in which a nuclear membrane forms around each cluster of chromosomes. Cytokinesis follows, forming two new cells. Meiosis I produces two daughter cells. Since each pair of homologous chromosomes are separated, neither cell has the two complete sets of chromosomes found in a diploid cell. The two sets of chromosomes have been shuffled, so that the sets of chromosomes and alleles differ from those in the diploid cell that started meiosis I.

Meiosis II

The two cells now enter a second meiotic division called meiosis II. Neither cell replicates its chromosomes before entering meiosis II.

Prophase II As cells enter prophase II, their chromosomes—each consisting of two chromatids—become visible. The chromosomes do not pair, because the homologous pairs were already separated during meiosis I.

Metaphase II, Anaphase II, Telophase II, and Cytokinesis During metaphase of meiosis II, the chromosomes line up in the center of each cell. As the cells enter anaphase, the paired chromatids separate. The final four phases of meiosis II are similar to those in meiosis I. However, the result is four haploid cells that contain the haploid number (N) of chromosomes. The haploid cells produced by meiosis develop into the gametes for sexual reproduction. The male gametes are usually called sperm, and the female gametes are called egg cells.

Comparing Meiosis and Mitosis

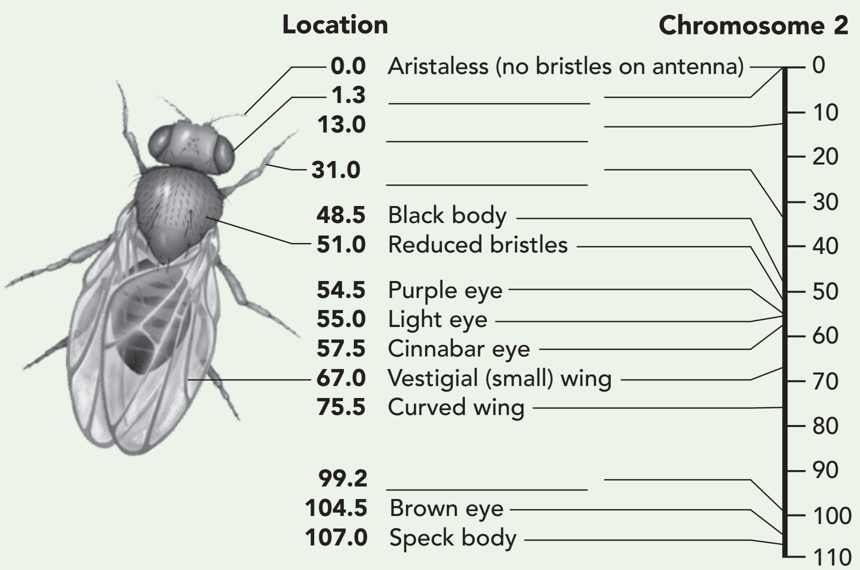
KEY QUESTION *How is meiosis different from mitosis?*

Meiosis and mitosis are very different. Mitosis can be a form of asexual reproduction. Meiosis is an early step in sexual reproduction. Mitosis and meiosis also differ in the way chromosomes are divided between daughter cells and in their number of cell divisions.

Replication and Separation of Genetic Material

A cell replicates, or copies, all of its chromosomes before entering either mitosis or meiosis. In mitosis, each daughter cell receives a complete diploid set of chromosomes. In meiosis, homologous chromosomes are separated, and each daughter cell receives only a haploid set of chromosomes. In meiosis, the two alleles for each gene are segregated and end up in different gamete cells. The sorting and recombination of genes in meiosis increases genetic variation.

Visual Reading Tool: Gene Map



This gene map shows the locations of genes on chromosome 2 of the fruit fly *Drosophila melanogaster.*

1. Write in the following genes at their listed location on the gene map.
   Arc (bent wings): 99.2 — Dumpy wing: 13.0
   Dachs (short legs): 31.0 — Star eye: 1.3
2. Which pair of genes are closer together on the chromosome—*dachs* and *dumpy wing*, or *arc* and *star eye*? ____________________
3. Which pair of genes are more likely to assort independently—*dachs* and *dumpy wing*, or *arc* and *star eye*? ____________________
4. What process can lead to genes on the same chromosome assorting independently?

   ____
5. When does the process from question 4 occur during meiosis? ____________________

READING TOOL

Compare and Contrast

Mitosis and *meiosis* are two similar biological processes with important differences. They both start with a diploid cell, but end up with very different products. ☑ **What is the final product for each process?**

Changes in Chromosome Number Mitosis does not change the chromosome number of the original cell. This is not the case for meiosis, which reduces the chromosome number by half. A diploid cell that enters mitosis with eight chromosomes will produce two diploid daughter cells, each with eight chromosomes. A diploid cell that enters meiosis with eight chromosomes will pass through two meiotic divisions to produce four haploid daughter cells, each with four chromosomes.

Number of Cell Divisions Mitosis is a single cell division. Meiosis requires two rounds of division. Mitosis results in the production of two genetically identical diploid cells, whereas meiosis produces four genetically different haploid cells.

Gene Linkage and Gene Maps

KEY QUESTION *How can two alleles from different genes be inherited together?*

Genes located on different chromosomes assort independently. What about genes on the same chromosome?

Gene Linkage Thomas Hunt Morgan's research on the *Drosophila* fruit fly showed that genes on the same chromosome are inherited together. Morgan found that many genes appeared to be "linked" together and are not independently assorted. Morgan and others observed many genes that were inherited together. They were able to group all of the fly's genes into four linkage groups. The linkage groups assorted independently from each other, but all of the genes in one group were inherited together. *Drosophila* has four linkage groups, and four pairs of chromosomes. Morgan's results led to two conclusions.

- First, each chromosome is a group of linked genes.
- Second, Mendel's principle of independent assortment holds true.

It is the chromosomes, not the individual genes, that assort independently. Alleles of different genes tend to be inherited together from one generation to the next when those genes are located on the same chromosome. Mendel missed gene linkage, because several of the genes he studied are on different chromosomes. Others are on the same chromosome, but are so far apart that they also assort independently.

Gene Mapping One of Morgan's students, Alfred Sturtevant, reasoned that the farther apart two genes were on a chromosome, the more likely it was that crossing-over would occur between them. If genes are far apart and more likely to cross-over, then they are more likely to assort independently. Sturtevant used the frequency of crossing-over between genes to determine their distances from each other. Sturtevant produced in one night a gene map showing the relative locations of each known gene on one of the *Drosophila* chromosomes.

12 Chapter Review

Review Vocabulary

Choose the letter of the best answer.

1. A diagram to predict the outcome of a genetic cross is a/an
- ◯ independent assortment.
- ◯ Punnett square.
- ◯ polygenic trait.

2. The exchange of genetic information between homologous chromosomes during meiosis is called
- ◯ segregation.
- ◯ a polygenic trait.
- ◯ crossing-over.

Match the vocabulary term to its definition.

3.	the offspring of parents with contrasting characteristics	a. hybrid
4.	structure formed by paired homologous chromosomes	b. genotype
5.	the genetic makeup of an organism	c. tetrad

Review Key Questions

Provide evidence and details to support your answers.

6. How are alleles segregated in sexually reproducing organisms?

7. In a Punnett square for a two-factor cross, is it possible for all of the offspring to be identical? Explain why or why not.

8. A parent with blood type A (genotype AO) and a parent with blood type B (genotype BO) have children with blood types A, B, and AB. What type of inheritance pattern is shown by the child with type AB blood and why?

9. How does meiosis increase genetic variation?