Chapter 9

Heredity

The fruits, vegetables, and grains you eat are grown on farms all over the world. Tomato seeds produce tomatoes, which in turn produce more seeds to grow more tomatoes. Each new crop of tomatoes carries *genes* for characteristics that were inherited from the previous crop's seeds. Some scientists are trying to manipulate the information contained in the seeds to produce different tomatoes. They have even tried inserting a gene from a winter flounder (a type of fish) into a tomato so that the tomato is cold-resistant! Why would this be beneficial? This chapter will help you understand how traits in plants and animals are inherited from one generation to the next.

Key Questions

1. ***What is "genetics" and who was Gregor Mendel?***

2. ***How are traits passed from one generation to the next?***

3. ***How can you predict the traits of the next generation?***

9.1 Traits

Tyler has free earlobes like his father. His mother has attached earlobes. Why does Tyler have earlobes like his father? In this section you will learn about traits and how they are passed on to offspring. Look at your earlobes. Are they free or attached? (Figure 9.1). The type of earlobes you have is a trait that you inherited from your parents. A **trait** is a characteristic that an organism can pass on to its offspring.

Studying traits

Breeds and traits Did you know there are over 150 dog breeds, but they are all the same species (*Canis familiaris*)? A pug looks completely different than a black lab, yet they both came from the same ancestors. For thousands of years, dog breeders have selected certain traits to produce dog breeds for different purposes. People knew how to breed in order to obtain certain traits long before scientists knew about DNA, chromosomes, or meiosis.

Genetics is the study of heredity An organism's **heredity** is the set of traits it receives from its parents. **Genetics** is the study of heredity. Ancient dog breeders thought that the traits inherited by a dog were a blend of those from the mother and father. For example, a large dog crossed with a small dog in many cases would produce a medium-sized dog—a blend of both parents. It turns out that heredity is not that simple. A monk named Gregor Mendel was one of the first to find that out.

Figure 9.1: *The type of earlobes you have is a trait you inherited from your parents.*

VOCABULARY

trait - a characteristic that an organism can pass on to its offspring.

heredity - a set of traits an organism receives from its parents.

genetics - the study of heredity.

The priest and the pea

Who was Gregor Mendel?

Gregor Mendel (1822 to 1884) was an Austrian monk. He is often called the "father of genetics." Through many years of experiments in breeding pea plants, Mendel arrived at some important conclusions about inheritance. However, nobody in his lifetime (including Mendel) realized the importance of his work. It was ignored by scientists until the early 1900s. Eventually Mendel's ideas led to the science of genetics.


Gregor Mendel

Disappearing traits

Mendel worked in a garden at the monastery where he lived. Through his work, he became interested in the traits of plants and how those traits were passed on to offspring. For example, he noticed that a trait that appeared in the parent generation of plants did not show up in their offspring (the first generation), but in the second generation, the trait showed up again (Figure 9.2)! Mendel wanted to find out why. So, he decided to study inheritance in peas. Peas were a good choice because they grow quickly and are easy to breed.

Peas and pollination

Peas are flowering plants. They have male and female parts on the same plant. Flowering plants reproduce by *pollination*. During pollination, pollen containing sperm from the male part of the plant is carried to the female part of the plant called the *ovule*. Fertilization occurs when a sperm from the pollen travels to an egg in the ovule. In a pea plant, pollen can fertilize eggs on the same plant (self-pollination). Or, the pollen can be carried by the wind or an animal to another plant. Figure 9.3 shows how pollination can occur.

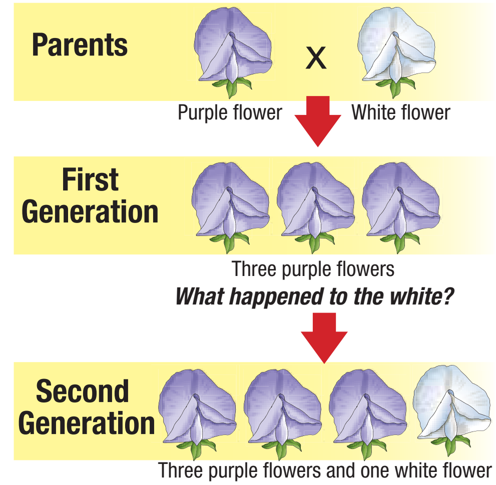


Figure 9.2: *Why do traits disappear and then reappear?*

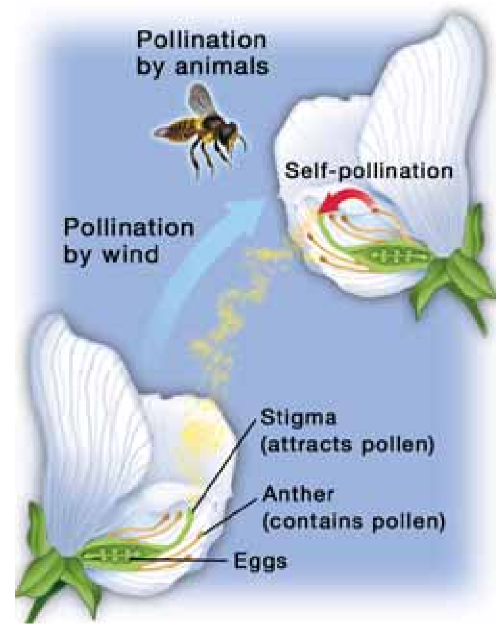


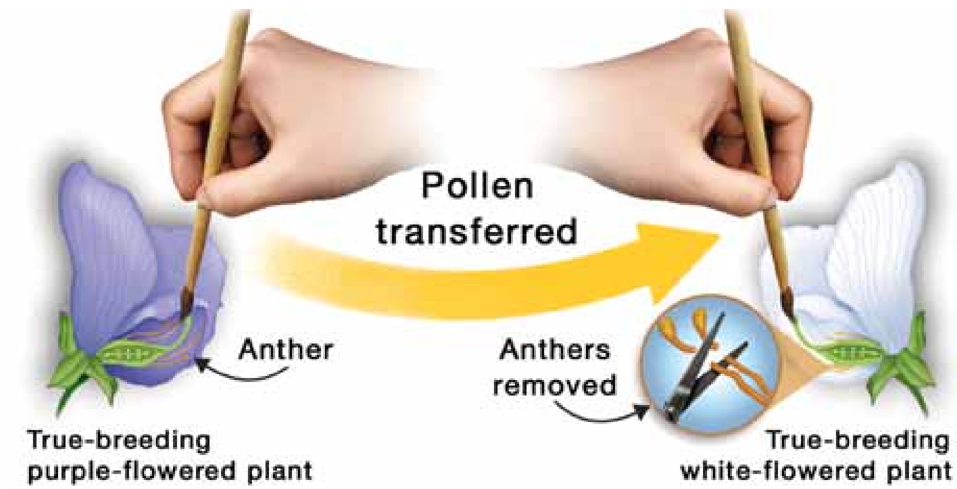
Figure 9.3: *Flowering plants reproduce by pollination.*

Mendel's experiment

Pea plant traits Mendel studied pea plants and identified several traits that had only two forms. For example, he observed that peas produced plants with either purple flowers or white flowers. Figure 9.4 shows four of the traits Mendel studied and their two forms.

True-breeding plants For his experiments, Mendel was careful to start out with true-breeding plants. When a **true-breeding plant** self-pollinates, it will always produce offspring with the same form of the trait as the parent plant. For example, a true-breeding plant with purple flowers will only produce plants with purple flowers.

Mendel's procedure for his experiments Mendel wanted to find out what would happen if he crossed two plants with different forms of a trait. He used a method called cross-pollination. In **cross-pollination**, the parts that contain pollen (anthers) are removed from one plant so it cannot self-pollinate. Next, the pollen from the other plant is used to fertilize the plant without pollen. The example below shows how Mendel crossed a purple-flowered plant with a white-flowered plant.



Four Pea Traits

TRAIT	FORM 1	FORM 2
Flower color	Purple	White
Seed shape	Smooth	Wrinkled
Seed color	Yellow	Green
Pod color	Green	Yellow

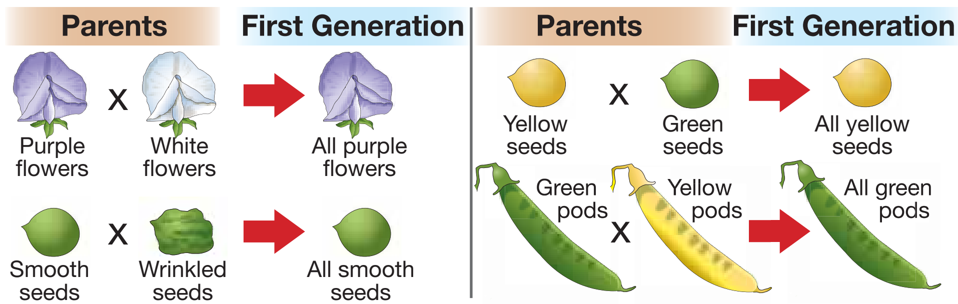
Figure 9.4: *Four of the traits Mendel studied in pea plants.*

VOCABULARY

true-breeding plant - a plant that will always produce offspring with the same form of a trait when it self-pollinates.

cross-pollination - when the pollen from one plant is used to fertilize another plant.

The first generation When Mendel crossed true-breeding, purple-flowered plants with true-breeding, white-flowered plants, the first generation produced all purple-flowered plants. Mendel got similar results for the other traits he studied. In each case, one form of the trait always showed up in the first generation and the other form of the trait always seemed to disappear.



The second generation Next, Mendel allowed the first generation of plants to self-pollinate. When the purple-flowered plants of the first generation self-pollinated, white flowers showed up again in the second generation! Figure 9.5 shows Mendel's crosses with peas for the flower-color trait.

Calculating ratios Mendel counted the plants in the second generation. He found 705 plants with purple flowers and 224 plants with white flowers. He calculated the ratio of purple-flowered plants to white-flowered plants. A *ratio* is a way to compare two numbers. Here's how to calculate the ratio of purple flowers to white flowers:

ratio symbol

1. Write as a fraction

3. Write as a ratio, rounded to the nearest whole number

$$705 \text{ purple} : 224 \text{ white} = \frac{705}{224} = \frac{(705 \div 224)}{(224 \div 224)} = \frac{3.15}{1} = 3{:}1$$

2. Divide top and bottom by the smallest number

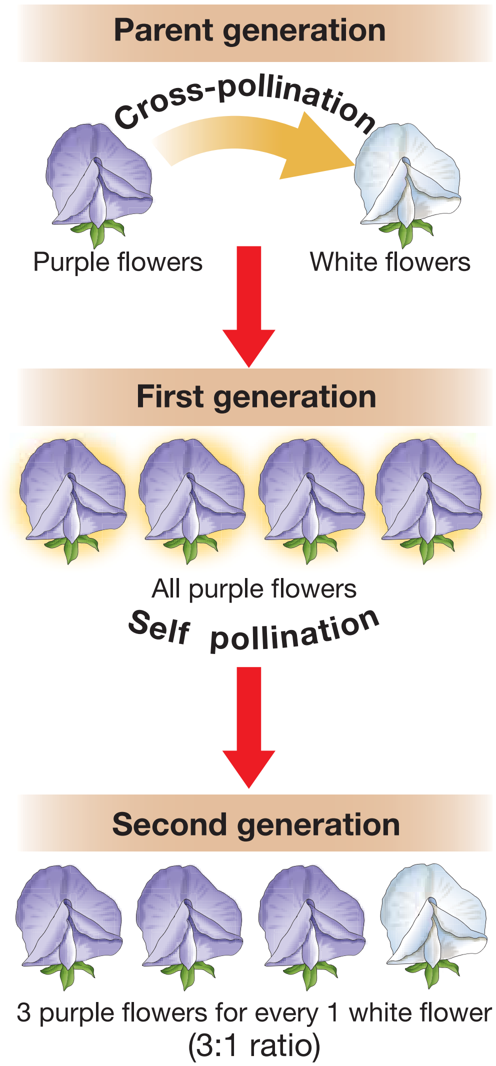


Figure 9.5: *Mendel's experiment.*

Mendel's conclusions

Second generation results Mendel got similar results for the second generation of all the traits he studied. The data from four of the traits he studied is shown in Table 9.1. For practice, calculate the ratio for the last three traits.

Table 9.1: The second generation from Mendel's peas

Trait	Form 1	Form 2	Ratio
Flower color	purple 705	white 224	**3:1**
Seed shape	round 5,474	wrinkled 1,850	**?**
Seed color	yellow 6,002	green 2,001	**?**
Pod color	green 428	yellow 152	**?**

Genes From the results, Mendel proved that all traits do not blend. For instance, purple flowers mixed with white flowers did not produce pink flowers. Mendel concluded that traits like flower color must be determined by individual *units*. Today, we call those units genes. A **gene** is a unit that determines traits.

Dominant and recessive alleles Mendel concluded that for each trait he studied, a pea plant must contain *two forms* of the same gene. Different forms of the same gene are called **alleles**. The **dominant allele** is the form of a gene that, when present, covers up the appearance of the recessive allele. The **recessive allele** is the form of a gene that is hidden when the dominant allele is present. The gene for flower color in peas has a dominant allele that causes purple flowers and a recessive allele that causes white flowers (Figure 9.6).

Alleles are different forms of the same gene. Organisms have at least two alleles for each gene—one from each parent.

VOCABULARY

gene - a unit that determines traits.

alleles - different forms of a gene.

dominant allele - the form of a gene that, when present, covers up the appearance of the recessive allele.

recessive allele - the form of a gene that is hidden when the dominant allele is present.

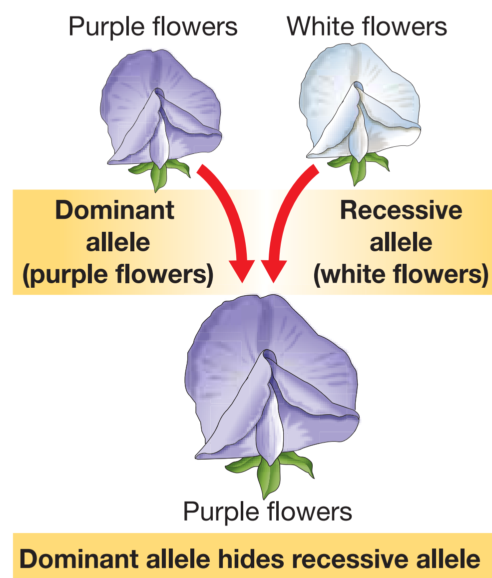


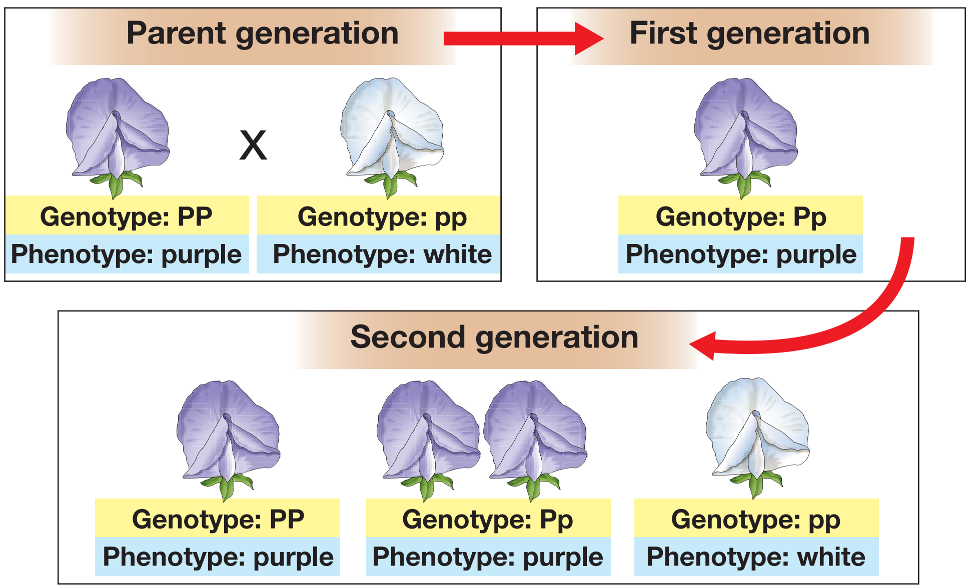
Figure 9.6: *Flower color in peas is determined by two alleles of the gene—one from each parent.*

Phenotype and genotype

An organism's **phenotype** is the form of a trait that it displays. For flower color, a pea plant can display a phenotype of purple or white flowers. An organism's **genotype** is the alleles of a gene it contains. Based on his data, Mendel concluded that a phenotype can be determined by more than one genotype.

Symbols for genes

Mendel used upper and lower case letters to symbolize the alleles of a gene. For flower color, he used upper case ***P*** for purple (the dominant allele) and lower case ***p*** for white (the recessive allele). A pea plant with purple flowers could have a genotype of either ***PP*** or ***Pp***. A pea plant with white flowers could only have a genotype of ***pp***. As long as at least one dominant allele is present, the plant will always have a phenotype of purple flowers. Figure 9.7 shows the genotypes and phenotypes of four pea plant traits. The graphic below shows the alleles present in each generation of pea plants from Mendel's experiment.



VOCABULARY

phenotype - the form of a trait that an organism displays.

genotype - the alleles of a gene an organism contains.

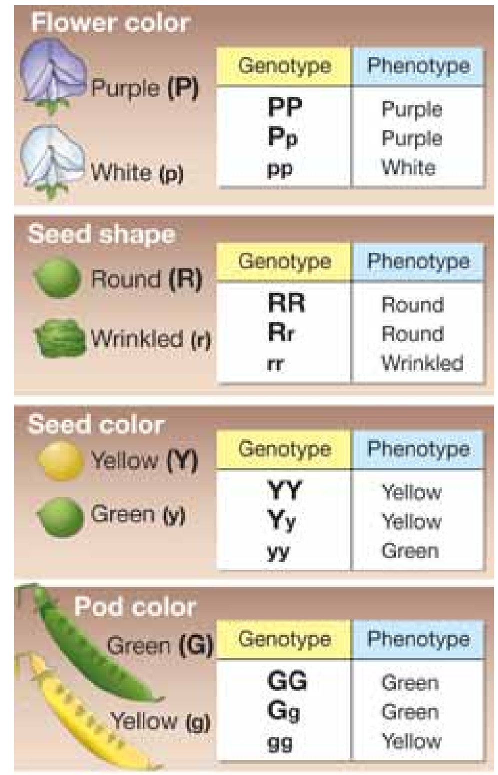


Figure 9.7: *The genotypes and phenotypes of four of the traits Mendel studied in pea plants.*

9.1 Section Review

1. Give two reasons why Mendel chose pea plants for his experiments with traits.
2. Name two ways pollination can occur.
3. What is a true-breeding plant? Why did Mendel start out his experiments with true-breeding plants?
4. What happened when Mendel crossed a true-breeding, green-seeded plant with a true-breeding, yellow-seeded plant?
5. What is the best way to determine the phenotype of a bird's feathers?
   a. analyze the bird's genes
   b. look at the bird's feathers
   c. look at the bird's offspring
   d. look at the bird's parents
6. Which statement best describes how to write the genotype for a trait?
   a. A capital letter represents the dominant allele and a different capital letter represents the recessive allele.
   b. A capital letter represents the dominant allele and a different lowercase letter represents the recessive allele.
   c. A capital letter represents the dominant allele and the lower case of that letter represents the recessive allele.
7. Write all of the possible genotypes for each pea plant:
   a. A plant with purple flowers.
   b. A plant with round seeds.
   c. A plant with green seeds.
   d. A plant with yellow pods.

SOLVE IT!

Calculating ratios

Calculate the ratio of the following pairs of numbers. Give your answers as whole-number ratios.

1. 500:250
2. 2020:1599
3. 675:1280
4. 25:499
5. 1327:1327

CHALLENGE

Free earlobes are determined by a dominant allele. Attached earlobes are determined by a recessive allele. Tyler has free earlobes. His father has free earlobes but his mother has attached earlobes. What is Tyler's genotype?

9.2 Predicting Heredity

When Mendel published his work in the 1800s, he did not use the word "gene" to describe his units of heredity. He also wasn't sure where his units might be found or how to identify them. His work went unnoticed for almost thirty years. In 1902, American scientist Walter Sutton (1877 to 1916) examined the nuclei of grasshopper cells under a microscope. He observed that chromosomes occurred in homologous pairs that separated during meiosis. A year later, Sutton found that chromosomes contained *genes*. He had discovered Mendel's units of heredity! In this section you will learn how Mendel's work is used to predict the heredity of offspring.

How traits are passed on to offspring

Genes and alleles

Mendel developed the basic laws of how traits are passed on to offspring (Figure 9.8). He did not know about genes, chromosomes, DNA, or meiosis. The laws stated below combine the work of Mendel and Sutton.

1. **Individual units called genes determine an organism's traits.**
2. **A gene is a segment of DNA, located on the chromosomes, that carries hereditary instructions from parent to offspring.**
3. **For each gene, an organism typically receives one allele from each parent.**
4. **If an organism inherits different alleles for a trait, one allele may be dominant over the other.**
5. **The alleles of a gene separate from each other when sex cells are formed during meiosis.**

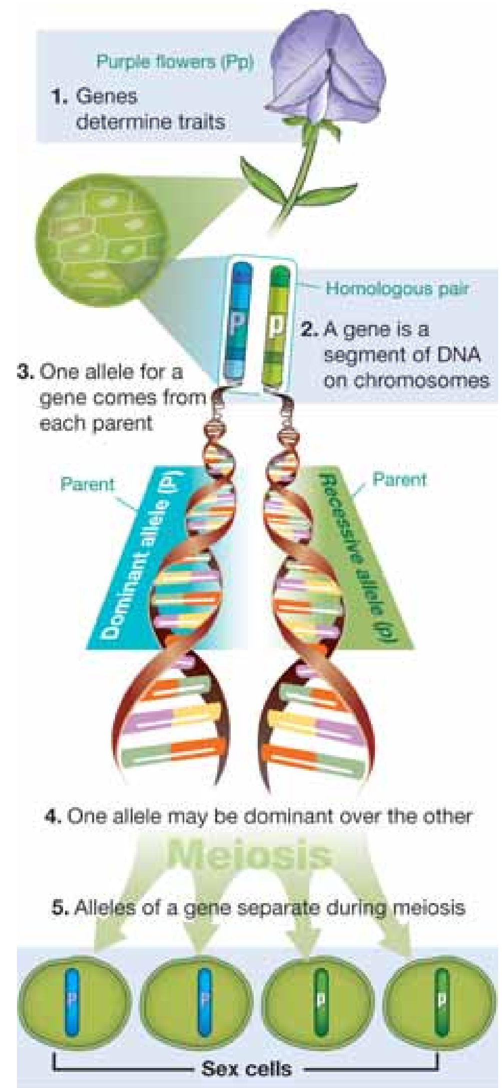


Figure 9.8: *The principles of how traits are passed on to offspring.*

Alleles and meiosis

Alleles of a gene separate during meiosis

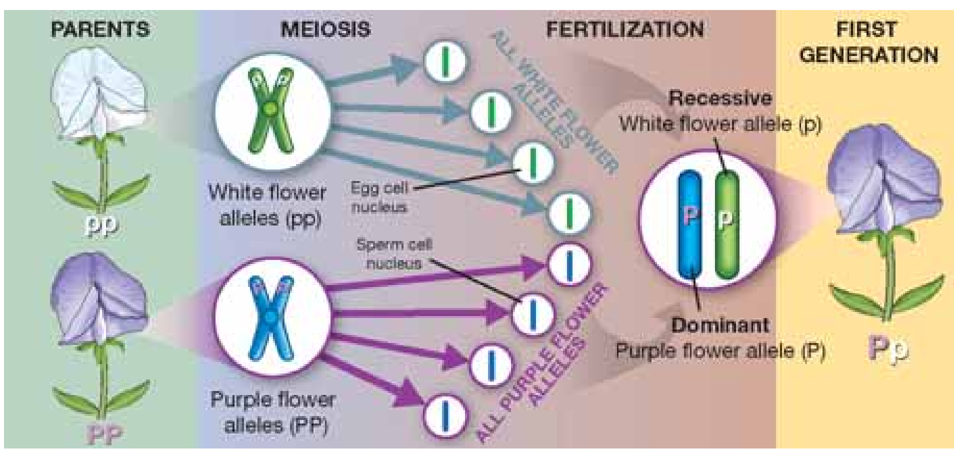
In the last chapter, you read that homologous pairs of chromosomes separate during meiosis. Since alleles of a gene are found in corresponding locations on homologous pairs of chromosomes, they also separate during meiosis.

How do alleles separate?

To illustrate how alleles separate, let's follow the alleles for the flower color trait in a pea plant with the genotype ***Pp***. The plant in our example has a dominant allele (***P***) and a recessive allele (***p***). What is the phenotype of the plant? You are correct if you said purple! Figure 9.9 shows what happens to the alleles during meiosis. To keep it simple, only one pair of chromosomes is shown. A real pea plant has 14 chromosomes (7 pairs).

Fertilization

When fertilization occurs, offspring inherit one homologous chromosome in a pair from each parent. As a result, one allele for a gene also comes from each parent. When Mendel crossed pure-breeding, purple-flowered plants with pure-breeding, white-flowered plants, the first generation offspring were purple with the genotype ***Pp***. The diagram below traces the alleles from parent to offspring.



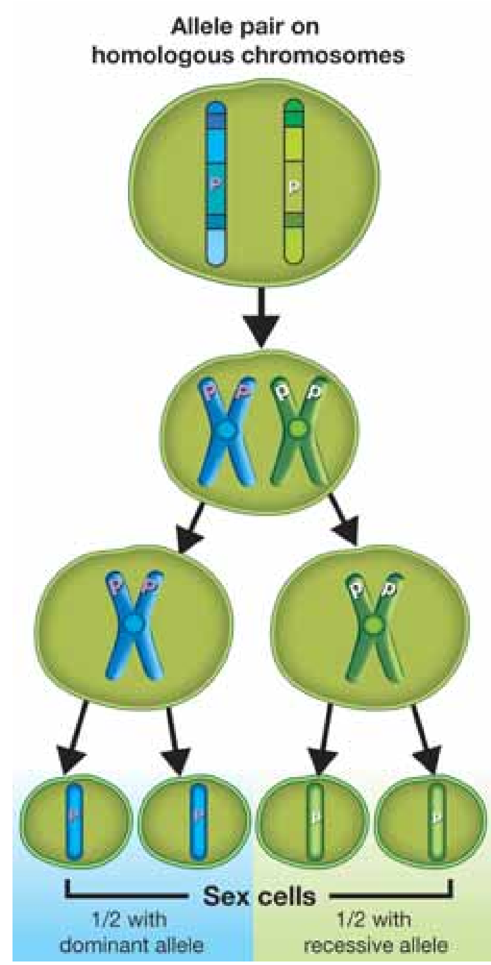


Figure 9.9: *Alleles of a gene are found in corresponding locations on homologous pairs of chromosomes.*

Predicting genotype and phenotype

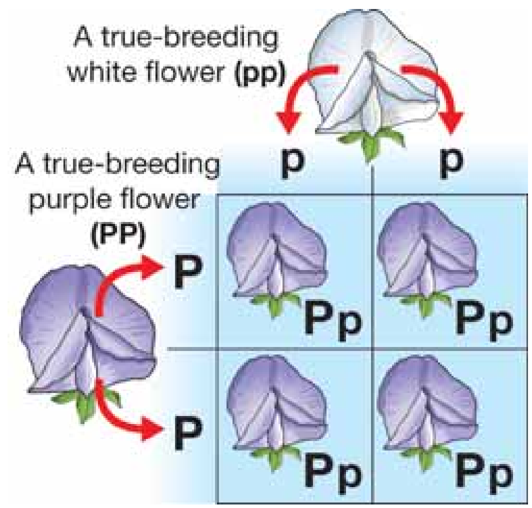
Punnett squares

You can predict the genotypes and phenotypes of offspring if you know the genotypes of the parents. A **punnett square** shows all of the possible combinations of alleles from the parents. Figure 9.10 shows how a punnett square is made.

You can predict the possible genotypes and phenotypes of offspring if you know the genotypes of the parents.

A punnett square of Mendel's first cross

You can use a punnett square to show Mendel's first cross. He crossed a true-breeding, purple-flowered plant with a true-breeding, white-flowered plant. Since the purple-flowered plant is true-breeding, it has two dominant alleles. The genotype of the purple-flowered plant is ***PP***. Since white flowers are recessive, the only possible genotype for a white-flowered plant is ***pp***.



Analyzing the punnett square

As you can see, all of the offspring in Mendel's first cross had a genotype of ***Pp***. That's why all of the plants in the first generation had purple flowers. Using a punnett square, you can predict the possible genotypes and phenotypes of the offspring. In the example above, the only possible genotype is ***Pp*** and the only possible phenotype is purple flowers.

VOCABULARY

punnett square - shows all of the possible combinations of alleles from the parents.

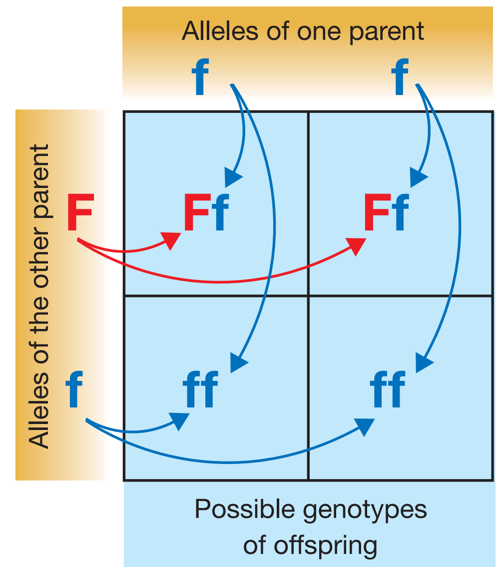


Figure 9.10: *The parts of a punnett square.*

SOLVE IT!

In the punnett square shown in Figure 9.10, F = free earlobes and f = attached earlobes. What is the genotype and phenotype of each parent? What are the possible genotypes and phenotypes of their children?

Punnett squares and probability

A punnett square of Mendel's second cross

When Mendel let the ***Pp*** plants self-pollinate, white flowers showed up in the second generation. Figure 9.11 shows a punnett square of the cross. Recall that when Mendel counted the plants, he found a 3:1 ratio of purple to white flowers. There are three possible genotypes from the cross. Of the three, ***PP***, and ***Pp*** are purple because they have the dominant allele. Only one of the three (***pp***) is white. From looking at Figure 9.11, can you see why there is a 3:1 ratio of purple-flowered to white-flowered plants?

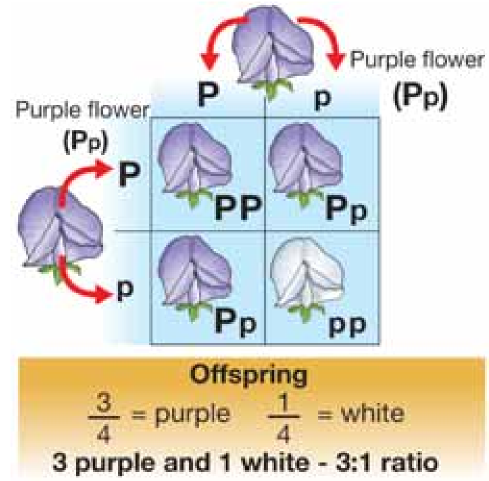


Figure 9.11: *A cross between pea plants of the first generation. The plants have a dominant and recessive allele. Can you see why white flowers showed up in the second generation?*

Probability

When you flip a coin, there is a 50 percent chance you'll get heads and a 50 percent chance you'll get tails. The way the coin lands is completely random. Like flipping a coin, the chance of inheriting a certain genotype and phenotype is random. **Probability** is the mathematical chance that an event will occur.

Punnett squares and probability

Probability can be expressed as a fraction or a percentage. A punnett square represents all of the *possible* genotypes of offspring. In Figure 9.11, 1 out of the 4 squares is ***pp***. The probability of offspring having ***pp*** is therefore 1/4. To convert this to a percentage, take the numerator of the fraction divided by the denominator and multiply by 100:

$$\frac{1}{4} \times 100 = 25\%$$

There is a 25 percent chance of offspring having the ***pp*** genotype. What is the probability of offspring having purple flowers? ***PP***, and ***Pp*** have purple flowers. That's 3 out of the 4 squares. The probability is:

$$\frac{3}{4} \times 100 = 75\%$$

VOCABULARY

probability - the mathematical chance that an event will occur.

9.2 Section Review

1. Explain the relationship between each pair of terms:
    a. gene and chromosome
    b. gene and DNA
    c. gene and allele
    d. allele and meiosis
2. The table below summarizes four traits in humans. Use the information to answer questions a through d.

Trait	Dominant allele	Recessive allele
earlobes	free (***F***)	attached (***f***)
chin	cleft (***C***)	no cleft (***c***)
thumb	straight (***S***)	hitch hiker's (***s***)

    a. What is the phenotype of a person with a genotype of ***Cc***?
    b. What are the possible genotypes of a person with a straight thumb?
    c. A man with a genotype of ***FF*** marries a woman with a genotype of ***ff***. What are the possible genotypes and phenotypes of their offspring?
    d. A woman with a genotype of ***Cc*** marries a man with a genotype of ***Cc***. What is the probability that their offspring will have a chin with no cleft?
3. Use the punnett square in Figure 9.12 to answer the following questions:
    a. What are the genotypes and phenotypes of the parents?
    b. What is the probability that their offspring will have free earlobes? Attached earlobes?

SOLVE IT!

Use Figure 9.11 on the previous page to calculate the probability that an offspring will have one dominant allele and one recessive allele.

	F	f
f	Ff	ff
f	Ff	ff

Figure 9.12: *Use this punnett square to answer question 3.*

9.3 Other Patterns of Inheritance

Perhaps it was luck for Mendel (and science) that he happened to use pea plants to discover the principles of heredity. Peas happen to have a number of traits that are determined by just two alleles. Also, for the traits he studied, one allele happened to be dominant and the other recessive. Mendel discovered an important pattern of inheritance and his laws are the foundation of genetics. Since plant and animals have *thousands* of genes, some have patterns of inheritance that are different from the ones Mendel discovered. In this section, you will learn about some of those patterns.

Male or female?

Sex chromosomes

Mendel worked with peas that had female and male parts on the same plant. Many organisms, like humans, have separate female and male individuals. In humans, sex is determined by the last pair of chromosomes, called sex chromosomes (Figure 9.13). **Sex chromosomes** carry genes that determine whether an individual is female or male.

Male and female genotypes

The female chromosome is symbolized with an ***X*** and the male with a ***Y***. A female has two ***X*** chromosomes in her body cells. Her genotype is ***XX***. A male has an ***X*** and a ***Y*** chromosome in his body cells. His genotype is ***XY***. During meiosis, the sex chromosome pairs separate. Females produce eggs with an ***X*** chromosome. Males produce sperm with an ***X*** or a ***Y*** chromosome. Figure 9.14 shows a punnett square that crosses a male and a female. What are the chances of having a boy or a girl?

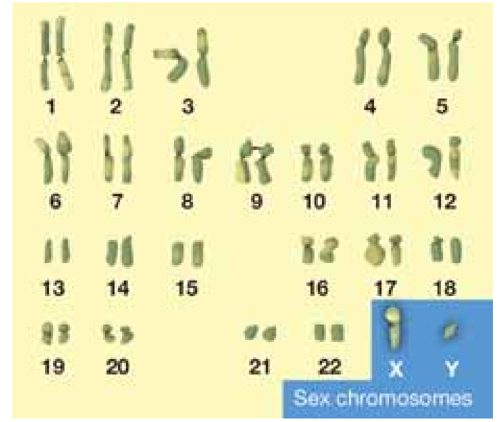


Figure 9.13: *In humans, sex is determined by the last pair of chromosomes. What is the sex of this person?*

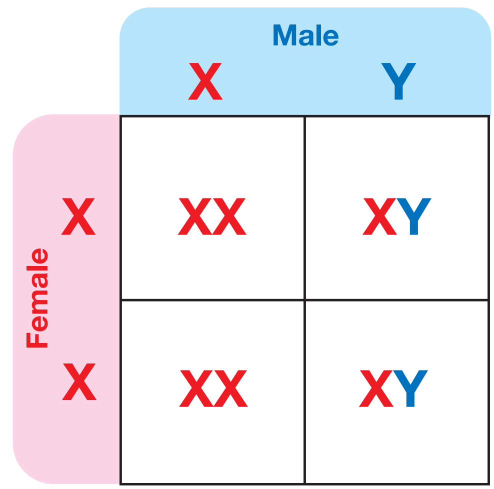


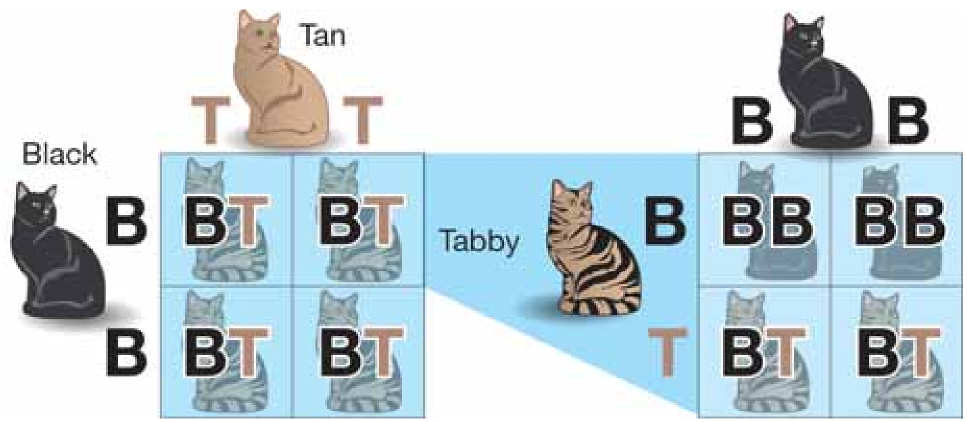
Figure 9.14: *A cross between a male and a female.*

Incomplete dominance and codominance

Pink flowers from red and white! Sometimes one allele isn't completely dominant over the other. If you cross a true-breeding, red-flowered snapdragon (***RR***) with a true-breeding, white-flowered snapdragon (***WW***), you may expect the first generation to have all red flowers. In snapdragons, this does not happen. The first generation has *pink* flowers (Figure 9.15)! When you cross two pink-flowered snapdragons (***RW***), the second generation of plants will have 25% red flowers, 50% pink flowers, and 25% white flowers.

Incomplete dominance Flower color in snapdragons is an example of incomplete dominance. In **incomplete dominance**, the phenotypes of the two alleles blend—just like mixing paints. Notice that in Figure 9.15, we use ***R*** for the red allele and ***W*** for white allele instead of upper and lower cases of the same letter.

Codominance In **codominance**, an organism that has both alleles of a gene displays *both* phenotypes at the same time. For example, a cross between a black cat (***BB***) and a tan cat (***TT***) results in a tabby cat (black and tan mixed together). Suppose a tabby cat (***BT***) crossed with a black cat (***BB***). What is the probability that one of their kittens would have tabby fur?



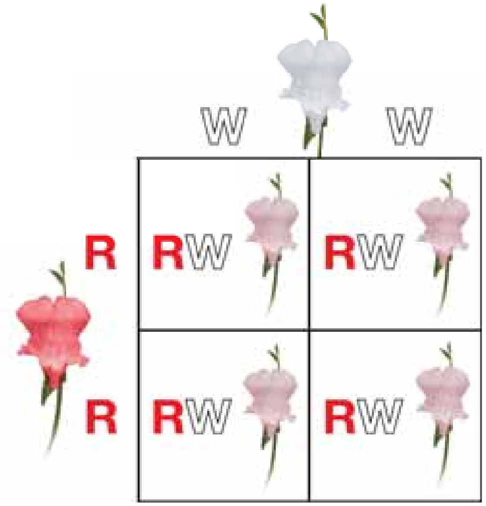


Figure 9.15: *A cross between red-flowered snapdragons and white-flowered snapdragons produces pink-flowered snapdragons. The second generation has red, pink, and white flowers.*

VOCABULARY

incomplete dominance - when the phenotype of the two alleles blend.

codominance - when an organism that has both alleles of a gene displays both phenotypes at the same time.

Other patterns of inheritance and environmental factors

Multiple alleles

So far you have learned about genes that have just two alleles. *Multiple alleles* are also common in organisms. In humans for example, *three* alleles determine blood type (***A***, ***B***, and ***O***). Each person can have only two of the alleles at one time, but there are three alleles in the human population. If a person inherits a B allele from one parent and a O allele from the other parent, she will have type B blood. The diagram (right) shows the possible genotypes and phenotypes for human blood type.

Parent Alleles	A	B	O
A	AA (Type A)	AB (Type AB)	AO (Type A)
B	AB (Type AB)	BB (Type B)	BO (Type B)
O	AO (Type A)	BO (Type B)	OO (Type O)

Polygenic traits

Inherited traits that are determined by more than one gene are called **polygenic traits**. Have you ever seen parakeets in a pet store? Feather color in parakeets is determined by two genes. One gene controls yellow color and the other controls blue color. Figure 9.16 shows the possible genotypes and phenotypes. In humans, eye color and skin color are polygenic traits. The range in skin colors of humans is determined by no less than four genes!

Environmental factors

Genes aren't the only influence on the traits of an organism. Environmental factors may also influence traits. For instance, in some turtle species, sex is determined by temperature. During the development of the embryo, higher temperature favors the production of males. Human height is determined by genes. But if a person does not get the proper nutrients, he or she may not reach his or her potential height.

VOCABULARY

polygenic traits - traits that are determined by more than one gene.

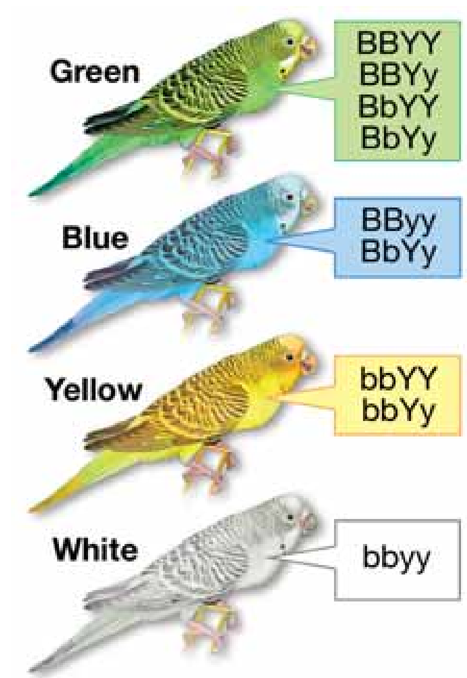


Figure 9.16: *Feather color in parakeets is determined by two genes.*

MY JOURNAL

Can you think of other environmental influences on your traits? Make a list of as many influences as you can think of.

9.3 Section Review

1. True or false: A single gene determines the sex (male or female) of a human.
2. Explain why the probability of a human giving birth to a male baby is always 50%.
3. What is incomplete dominance? Give one example.
4. How is codominance different than incomplete dominance? Give one example of codominance.
5. Figure 9.17 shows a cross between a tabby cat and a tan cat. What is the probability of offspring with black fur? Tabby fur? Tan fur?
6. Blood type is determined by three alleles, A, B, and O. Use the punnett square below to answer questions a through c.

	A	O
B	AB	BO
O	AO	OO

   a. What is the probability of an offspring with type A blood?
   b. What is the probability of an offspring with type O blood?
   c. What are the genotypes and phenotypes of the parents?

	T	T
B	BT	BT
T	TT	TT

Figure 9.17: *Use the diagram above to answer question 5.*

CHALLENGE

1. A red snapdragon is crossed with a pink snapdragon. Make a punnett square of the cross. List the possible genotypes and phenotypes of the offspring.
2. A person with type AB blood marries a person with type O blood. Make a punnett square of the cross. List the possible genotypes and phenotypes of their offspring.

HEALTH CONNECTION

An Inherited Blood Disease

Sickle cell anemia is an inherited blood disease that affects more than 70,000 Americans. The disease causes severe joint pain and weakness and often leads to an early death. The disease has been present in Africa for hundreds of years. Would you believe that some members of families that carry the sickle cell trait can actually benefit? Read on to find out how.

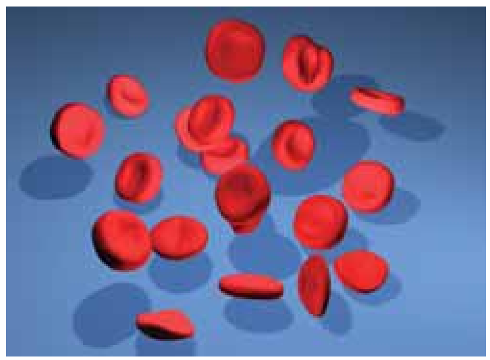
Comparing red blood cells

Sickle cell describes the shape of red blood cells in people who have the disease. The other part of the name, *anemia*, means there are too few red blood cells. In turn, this can mean that too little oxygen is being carried through the body. Red blood cells carry oxygen from the lungs to the tissues in our bodies.

Normally, red blood cells are round. They look like disks (top, right). With sickle cell anemia the red blood cells are sickle-shaped (bottom, right). A sickle is a tool shaped like the letter C.

Normal red blood cells flow easily through small blood vessels. Sickle-shaped red blood cells clog small blood vessels.

Normal red blood cells live about 120 days. Sickle-shaped red blood cells live only 10 to 20 days. This causes a constant shortage of red blood cells, a condition known as anemia.



Genes: the good and the bad

Sickle cell anemia affects populations in Africa, India, the Mediterranean area, and South America. It is most common in Africa and in people with African ancestors. About 1 in every 500 African Americans has the disease.

Some diseases are inherited just like your physical traits. Sickle cell anemia is one such inherited disease.

Everyone carries a gene that is responsible making hemoglobin. Hemoglobin is a protein in red blood cells that carries oxygen. People with sickle cell anemia have two *mutated* alleles of that gene. They produce abnormal hemoglobin. This causes the sickle-shaped cells and lowers their ability to carry oxygen to other cells. You'll learn about mutations in Chapter 10.

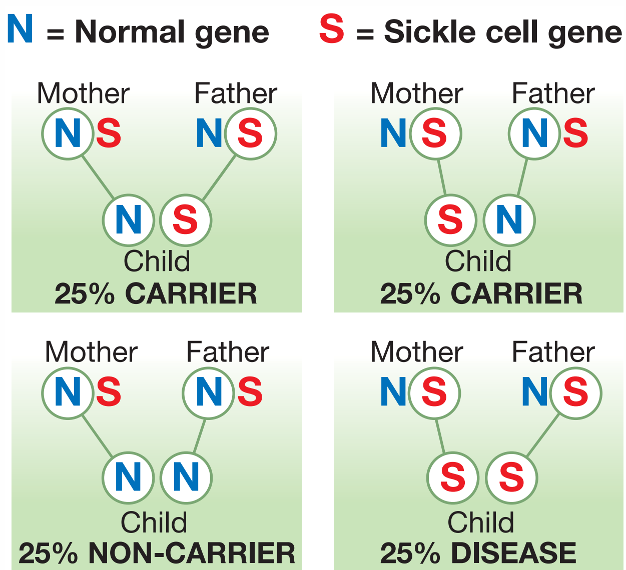
The dominant allele of the hemoglobin gene causes normal hemoglobin. The recessive allele of the gene causes sickle cell anemia. People who have sickle cell anemia have two recessive alleles for the disease. This means that one recessive allele came from each parent.

Some people have both the dominant allele and the recessive allele. These people are called *carriers*. About 8 in every 100 have the recessive allele for sickle cell anemia. Carriers may have normal lives. But the child of two carriers may have the disease.

The genetic chances

If both parents are carriers of the sickle cell trait, they each have one normal allele and one sickle cell allele. Each parent contributes one gene to the child. What are the chances of a child getting sickle cell anemia?

- There is a 50 percent chance that the child will end up with one sickle cell allele. In this case, the child has the sickle cell trait and is a carrier.
- There is a 25 percent chance that the child will get one sickle cell allele from each parent. This child will have sickle cell anemia.
- There is a 25 percent chance that the child will get no sickle cell alleles.



The malaria connection

The sickle cell allele has not disappeared because it helps some people. People with the trait are much more resistant to malaria than people without the trait.

Malaria is caused by a single-celled parasite. Mosquitoes carry the parasite from person to person, spreading the deadly disease. Malaria has killed millions of people throughout the world. The majority of the victims are children.

While non-existent in the United States, malaria is a risk in other places. The disease is still common in Africa. Sickle cell anemia carriers are more common there also. In some parts of Africa as much as 40 percent of the population has the sickle cell trait.

Why do carriers of the sickle cell trait resist malaria? The parasite causes normal red blood cells to become sickle shaped. Somehow the sickle cell carrier's body produces a resistance to the disease. Carriers of the sickle cell trait are partially protected from malaria. The trait does not provide an absolute protection, but these individuals are more likely to survive the malaria illness. The exact reason why sickle cell traits act as a resistance to malaria is still unknown.

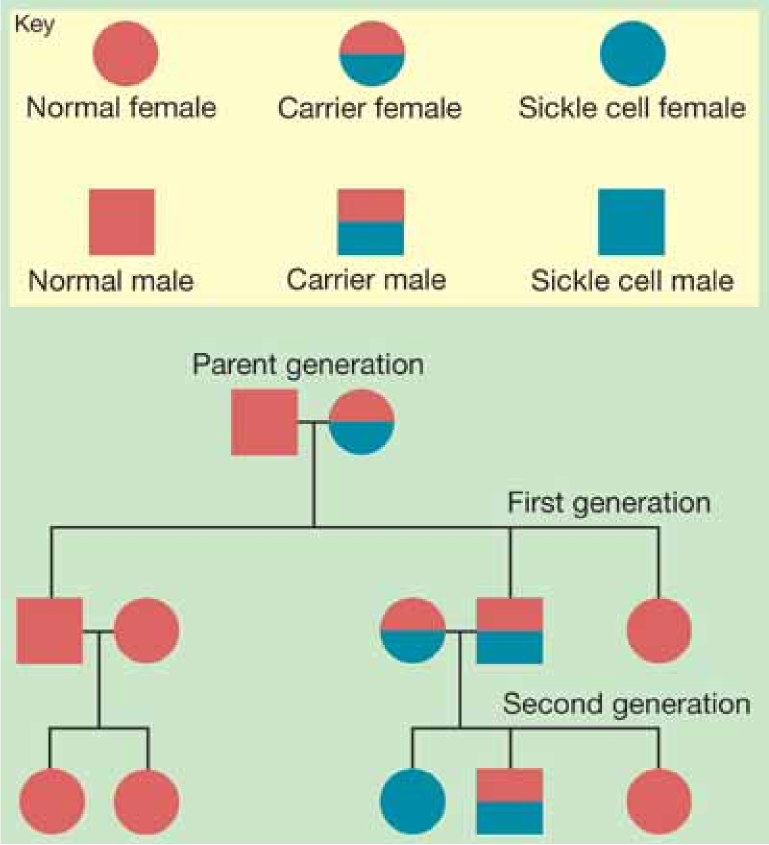
Even though sickle cell anemia is harmful to people with the disease, the trait persists in places where malaria is common. This is an example of *natural selection*. People with the sickle cell trait have an advantage where malaria thrives.

Questions:

1. How can you get sickle cell anemia?
2. If you mother and father are both sickle cell carriers, what are the chances that you will not have the trait?
3. How does sickle cell anemia affect the red blood cells?
4. Why are people with the sickle cell trait able to resist malaria?

CHAPTER ACTIVITY Making a Pedigree

A **pedigree**, or family tree, is a diagram that shows the generations of a family. A pedigree is often used to trace one or more traits from generation to generation. Pedigrees are often used to predict the chances of offspring having a genetic disorder like sickle cell anemia. The diagram below shows a pedigree of a family that carries the sickle cell trait. The mother is a carrier and the father does not carry the allele. In the first generation, one of their sons is a carrier who marries another carrier. One of their daughters has sickle cell anemia, one son is a carrier, and another daughter does not carry the allele. Use the pedigree below as a model for this activity.



What you will do

For the activity, you will need pencils and a ruler. Make a pedigree for the family described below.

1. A woman who is a carrier of sickle cell marries a man who does not carry sickle cell. Start by drawing the parents.
2. The parents have two girls and two boys. One of the boys and one of the girls each carries the sickle cell allele. The other two children are not carriers. Add the first-generation children to your chart.
3. One of the first-generation boys who carries the sickle cell allele marries a woman who also carries the allele. They have two children, one boy with sickle cell, and a girl who is not a carrier. Add their children (the second generation) to your chart.
4. A first generation girl who does not carry the sickle cell allele marries a man who also is not a carrier. They have two girls and a boy. Add their children to your chart.

Applying your knowledge

a. What are the genotypes of the original parents (the parent generation)? Use ***S*** for the normal allele and ***s*** for the sickle cell allele. Add their genotypes to your chart.

b. Add the genotypes of the first and second generation children to your chart.

c. In step four, you were not give the phenotypes of the children. Why wasn't it necessary for you to be given the phenotypes?

d. Cystic fibrosis is a genetic disorder in which the body produces abnormally thick mucus in the lungs and intestines. It is carried on a recessive allele. Make up a fictional family that has the cystic fibrosis allele. Start with the parent generation and trace the family through two generations. Create names for the family members. Make your chart on a poster board. Be creative!

Chapter 9 Assessment

Vocabulary

Select the correct term to complete t

alleles	cross-pollination	dominant allele
heredity	incomplete dominance	polygenic traits
recessive allele	sex chromosomes	true-breeding
codominance	phenotype	trait
genotype	punnett square	genetics
gene		probability

Section 9.1

1. A(n) _____ is always expressed if it is present in an organism.
2. A unit that determines traits is a(n) _____.
3. Gregor Mendel is often called the "father of _____."
4. The organism's _____ can't be seen because it is the actual alleles of a gene that the organism contains.
5. A(n) _____ is only expressed in an organism if no dominant allele is present.
6. Flower color is an example of a _____ in pea plants.
7. Mendel used all _____ in his experiments.
8. A set of traits that an organism receives from its parents is called _____.
9. The organism's _____ for a given trait can be seen because it is the form that the organism displays.
10. _____ occurs when animals or the wind carry pollen from one flowering plant to another.
11. Organisms have at least two _____ for each gene - one from each parent.

Section 9.2

12. The mathematical chance that an event will occur is called _____.
13. If the genotypes of the parents are known, a(n) _____ can be used to show the possible genotypes and phenotypes of the offspring.

Section 9.3

14. Eye color and skin color in humans are examples of _____.
15. _____ is when the phenotypes of two alleles blend together.
16. The human blood type AB is an example of _____ - when an organism shows the phenotypes of two different alleles at the same time.

Concepts

Section 9.1

1. List three examples of traits from the chapter.
2. Explain the process of pollination in flowering plants.
3. Why did Mendel remove the anthers from the pea plants when performing cross pollination in his experiments?
4. Which of these traits did not show up in Mendel's first generation at all?
   a. purple flowers
   b. yellow seeds
   c. wrinkled seeds
   d. green pods

5. From Mendel's work, choose which of each pair is the dominant form of the gene.
    a. white flowers or purple flowers
    b. smooth seeds or wrinkled seeds
    c. green seeds or yellow seeds
    d. yellow pods or green pods
6. Summarize what Mendel concluded from his pea plant experiments.
7. Label these examples as one of the following heredity terms: trait, dominant allele, recessive allele, genotypes, or phenotypes.
    a. ***R*** for smooth
    b. seed shape
    c. either smooth or wrinkled
    d. ***r*** for wrinkled
    e. ***RR***, ***Rr***, or ***rr***
8. Explain how you can have the same phenotype, but a different genotype for a given trait. Given an example to support your answer.

Section 9.2

9. Explain how Walter Sutton's work built on Gregor Mendel's work.
10. Which of these is part of the basic laws of how traits are passed onto offspring?
    a. an organism usually receives one allele for each gene from each parent
    b. a gene is a piece of DNA found on a chromosome that carries information from parent to offspring
    c. when organisms receive different alleles for one trait, one form may be dominant to the other
    d. all of the above
11. How does meiosis ensure that an organism receives only one allele from each parent for each trait?
12. What is the tool that scientists use to predict the possible genotypes and phenotypes of offspring?
13. If black fur color is dominant to white fur color in guinea pigs, explain how two parents with black fur could possibly have a white offspring.
14. From your understanding of probability, explain why it was important that Gregor Mendel used thousands of pea plants in his experiments? Would Mendel have found the same results if he had used only twenty plants? Explain.

Section 9.3

15. Who determines the sex of the baby in humans, the mother or the father? Explain.
16. What is the difference between incomplete dominance and codominance? Give an example of each in your explanation.
17. If a black chicken is crossed with a white chicken in a certain species, the offspring are black and white chickens. These chickens are an example of which pattern of inheritance?
    a. polygenic inheritance
    b. multiple alleles
    c. codominance
    d. incomplete dominance
18. In another species of chickens, a cross between a black chicken and a white chicken produces blue chickens. These chickens are an example of which pattern of inheritance?
    a. polygenic inheritance
    b. multiple alleles
    c. codominance
    d. incomplete dominance

19. Describe how Mendel's pea plant experiments are not an example of multiple alleles.
20. Explain why it makes sense that there are no less than four genes that control human skin color.
21. Give one example of how environmental factors can influence traits.

Math and Writing Skills

Section 9.1

1. Write a letter as if you were Gregor Mendel explaining your work with pea plants to a friend. Be sure to include how you actually carry out your experiments as well as what you have discovered through your work.
2. Write an obituary for Gregor Mendel. Include the important facts of Mendel's life including the years he was alive, where he lived, what his job was, and why his work was important.
3. Dr. X is a geneticist that studies fruit flies. She crossed long winged fruit flies with a short winged fruit flies. She found that 776 fruit flies had long wings and 260 had short wings.
    a. What was the ratio of long winged fruit flies to short winged fruit flies?
    b. Which is the dominant allele - long or short wings?
4. Farmer Davidson sells rabbits in the springtime. For the last few years, the solid colored rabbits have been way more popular than spotted rabbits. Unfortunately for Farmer Davidson, spotted fur color is dominant to solid fur color in rabbits. Suppose Farmer Davidson's rabbits have 200 offspring. 50 of the offspring are solid color. About how many offspring with spotted fur will Farmer Davidson have to sell?

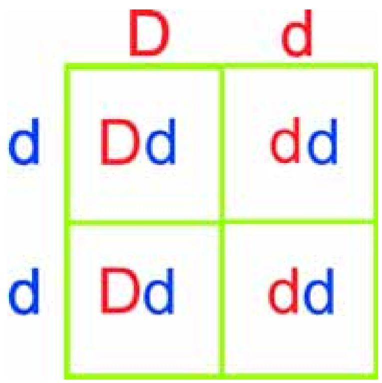
Section 9.2

5. Write a dialogue that might have happened if Gregor Mendel and Walter Sutton had met one another.
6. What advancements in science and technology do you think allowed Walter Sutton to add onto the work of Gregor Mendel?
7. In the punnett square below, ***F*** = free earlobes and ***f*** = attached earlobes. Use the punnett square to answer the questions below.

	F	f
f	Ff	ff
f	Ff	ff

    a. What are the genotypes of the parents?
    b. Suppose the parents had 12 children. What are the chances that one of their children will have free earlobes?
    c. Predict how many of their children have attached earlobes.
    d. 7 out of their 12 children have attached earlobes. Does this agree with your prediction? Explain how the numbers could be different.

8. Dark fur (D) is dominant to light fur (d) in dogs. Use the punnett square to answer these questions:



a. What are the genotypes and phenotypes of the parents?
b. What is the most likely ratio of dark fur to light fur dogs in the offspring?
c. What is the probability that the offspring will have dark fur? light fur?
d. Explain why this cross could never produce a DD offspring.

Section 9.3

9. Mrs. Allen is about to have another baby. She already has three daughters. What is the probability that her fourth child will also be a girl?

10. If you flipped a coin and it landed on heads five times in a row, what is the probability that the sixth coin toss to land on heads?

11. Use masking tape to mark both sides of a coin - one side G for the dominant allele and the other side g for the recessive allele. Toss the coin twenty times and record the tosses. Create a table to display your results.

Chapter Project

Punnett squares on the Internet

You can construct a punnett square to predict the possible genotypes and phenotypes of offspring when you know the parents' genotypes. There are many excellent websites with interactive tutorials on how punnett squares work. Simply go to a search engine and type in the key words "punnett square."

For this project, search for a website that contains a helpful punnett square tutorial and practice using the punnett square. When you have found the website and practiced with it, write a one-page paper about your experience. Write about your experience in your own words, and include the following information in your paper:

1. Full address of website
2. What person or group is the author of the punnett square tutorial?
3. When was this website last updated?
4. What did you like about this tutorial?
5. Copy down at least three punnett squares you constructed.
6. What unique features did this tutorial have?
7. What would you change about the tutorial to improve it?