TOPIC
1.2

How is hereditary information passed from one generation to the next?

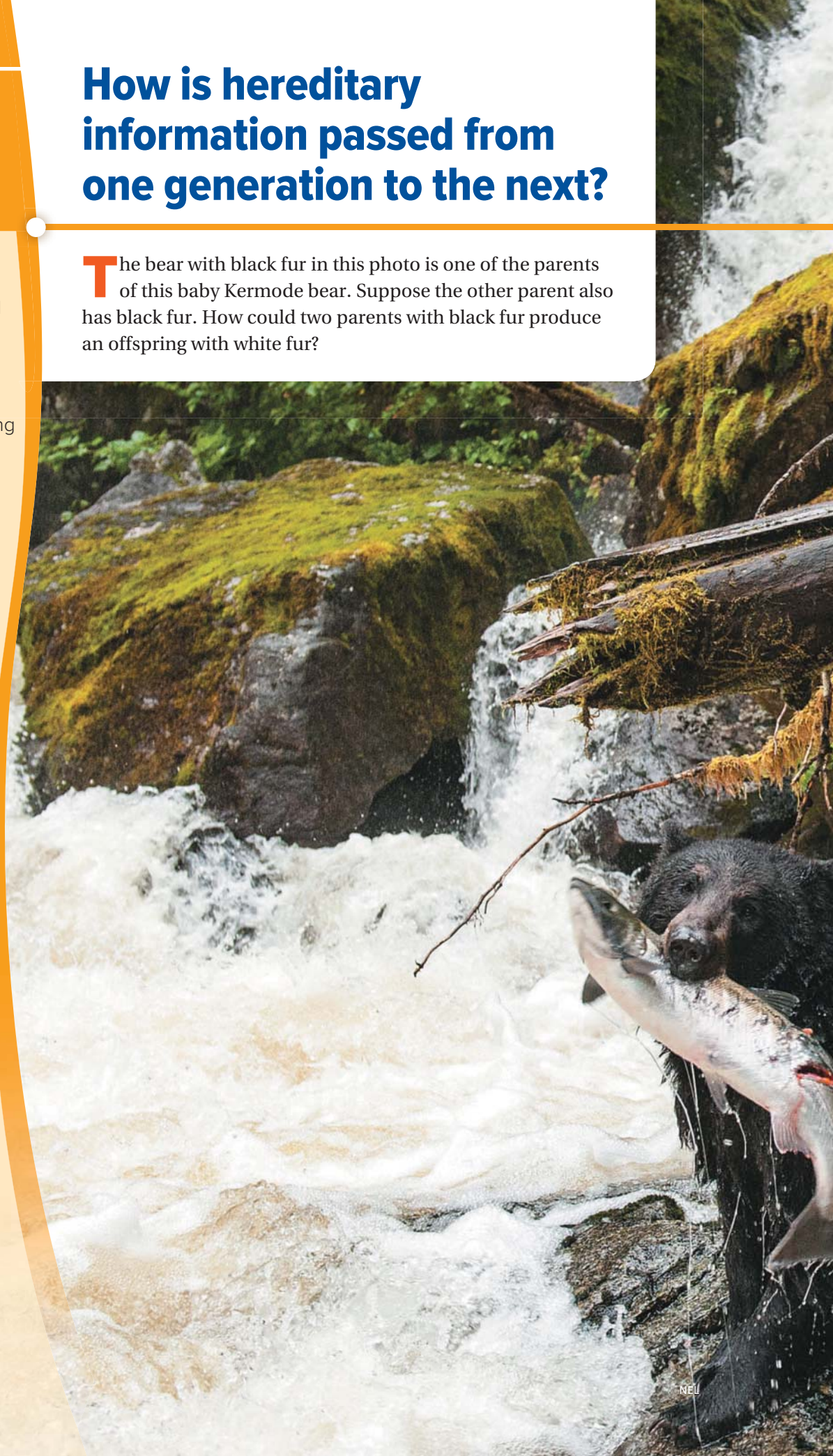
The bear with black fur in this photo is one of the parents of this baby Kermode bear. Suppose the other parent also has black fur. How could two parents with black fur produce an offspring with white fur?

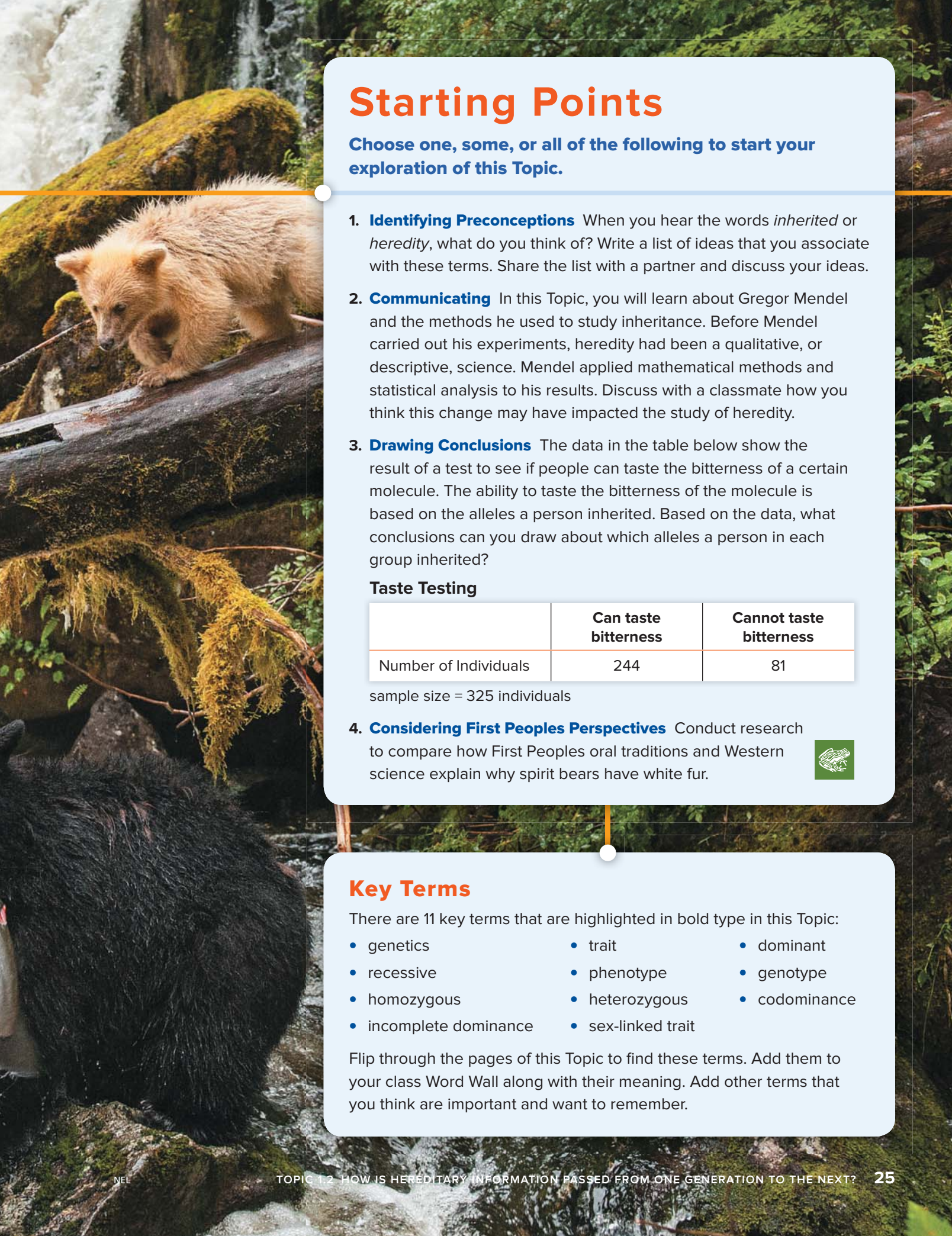
Key Concepts

- Genes pass on inherited traits from parent to offspring.
- Punnett squares show the probability of offspring inheriting specific traits.
- Both alleles are expressed in codominance.
- In incomplete dominance, alleles are neither dominant nor recessive.
- Some inherited traits are due to alleles on the sex chromosomes.

Curricular Competencies

- Plan, select, and use appropriate methods to collect reliable data.
- Analyze cause-and-effect relationships.
- Evaluate your methods and experimental conditions
- Describe ways to improve investigation methods and data quality.





Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** When you hear the words *inherited* or *heredity*, what do you think of? Write a list of ideas that you associate with these terms. Share the list with a partner and discuss your ideas.

2. **Communicating** In this Topic, you will learn about Gregor Mendel and the methods he used to study inheritance. Before Mendel carried out his experiments, heredity had been a qualitative, or descriptive, science. Mendel applied mathematical methods and statistical analysis to his results. Discuss with a classmate how you think this change may have impacted the study of heredity.

3. **Drawing Conclusions** The data in the table below show the result of a test to see if people can taste the bitterness of a certain molecule. The ability to taste the bitterness of the molecule is based on the alleles a person inherited. Based on the data, what conclusions can you draw about which alleles a person in each group inherited?

Taste Testing

	Can taste bitterness	Cannot taste bitterness
Number of Individuals	244	81

sample size = 325 individuals

4. **Considering First Peoples Perspectives** Conduct research to compare how First Peoples oral traditions and Western science explain why spirit bears have white fur.

Key Terms

There are 11 key terms that are highlighted in bold type in this Topic:

- genetics
- trait
- dominant
- recessive
- phenotype
- genotype
- homozygous
- heterozygous
- codominance
- incomplete dominance
- sex-linked trait

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Genes pass on inherited traits from parent to offspring.

Activity

DNA and Sexual Reproduction

Use your prior knowledge of meiosis and fertilization to model how an offspring gets half of its DNA from a genetic female and half of its DNA from a genetic male. Share your models with other groups. As a class, discuss how this concept is related to the traits an organism inherits.

genetics a field of biology that studies heredity, or the passing of traits from parents to offspring

trait an inherited characteristic, such as eye colour or hair colour

Genetics is a field of biology that studies heredity, which is the passing of **traits** from parents to offspring. People have been doing genetics experiments for thousands of years. These early experiments involved growing and raising food crops such as wheat and corn, livestock such as cows, and companion animals such as horses and dogs.

First Modern Experiments in Genetics

An Austrian monk, Gregor Mendel, made the first discoveries about how traits are passed from one generation to the next. In the 1860s, he experimented with pea plants. Pea plants reproduce by sexual reproduction, but they usually self-pollinate. Self-pollination occurs when a male gamete within a flower combines with a female gamete in the same flower. Cross-pollination occurs when a male gamete from one flower combines with a female gamete from flower of a different plant. Mendel discovered that he could transfer a male gamete from the flower of one pea plant to the female reproductive organ in a flower of another pea plant. By deliberately cross-pollinating plants, he could control which plants, with certain traits, were producing offspring.

Mendel kept careful records of the traits in the pea plants that he bred. He analyzed the results of his experiments and formed hypotheses about how the traits were inherited. By working in this methodical, controlled way, Mendel founded the modern science of genetics.

Mendel's Experiments

Mendel started his studies with pea plants that had purple flowers and pea plants that had white flowers. He knew that when purple-flowered plants self-fertilized, they produced new plants (offspring) with only purple flowers. He also knew that when white-flowered plants self-fertilized, they produced offspring with only white flowers. Plants that reproduce with these kinds of reliable, predictable results are called *true-breeding* plants. True-breeding plants consistently produce offspring with only one form of a trait.

Figure 1.10 outlines the procedure that Mendel developed and followed in his experiments with true-breeding plants and flower colour. The numbered steps in the text below correspond to the numbered parts of the diagram.

1. Mendel bred true-breeding purple-flowered plants with true-breeding white-flowered plants.
2. All the offspring from this cross are called first generation plants, or F_1. Mendel observed that all the first generation plants had purple flowers. He wanted to know what happened to the white-flower trait that disappeared. So he allowed the first generation plants to self-fertilize.
3. In the second generation plants, or F_2, Mendel observed that the white-flower trait reappeared in some of the offspring. Each time Mendel repeated the experiment and counted the plants in the second generation, there was always a ratio of approximately three purple-flowered plants to one white-flowered plant—a ratio of about 3:1.

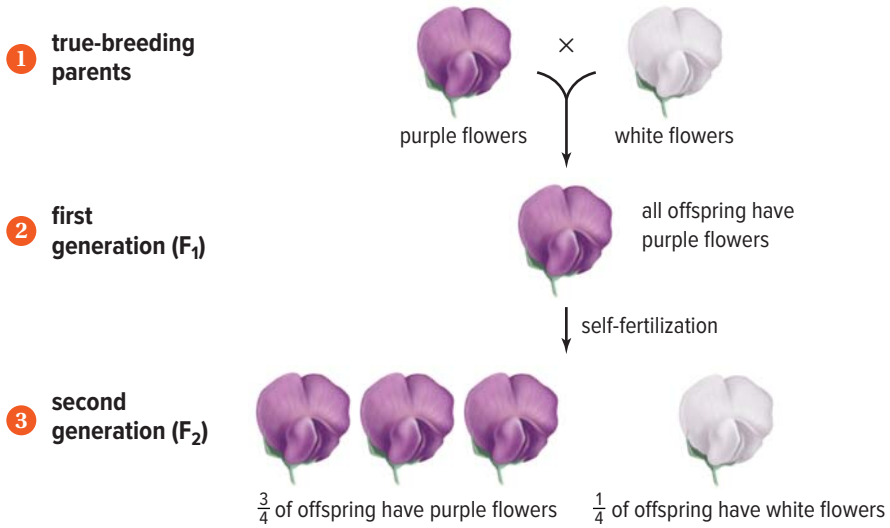


Figure 1.10 These are the results of Mendel's cross involving true-breeding pea plants with purple flowers and true-breeding pea plants with white flowers. **Analyzing: Why are all the F_1 flowers purple?**

Mendel observed the same results when he studied other traits in true-breeding pea plants, such as seed colour, seed shape, and stem length. In each case, one trait disappeared in F_1 plants, and then re-appeared in the F_2 plants. To explain his observations, Mendel proposed the following:

- Each plant had two factors that act as sets of instructions for each trait.
- Each parent donates one of these factors to the offspring.
- One factor or trait may dominate over the other if it is present.

It might seem obvious that offspring will be similar to their parents, but the reasons for this are complex. For example, do you have straight hair or curly hair? What colour are your eyes? These are traits you have because of genes you inherited from your biological parents. However, your biological parents may have a different set of traits than you do. How can that happen? Scientists have been trying to answer this question for hundreds of years. A complete answer is still not known. However, due to the work of Mendel and later scientists, many of the basic principles of heredity are understood.

Homologous Chromosomes and Gametes

Look again at **Figure 1.5** (on page 15) to remind yourself about homologous chromosomes. Also recall that chromosomes may carry different versions of the same gene: alleles. During meiosis, the pairs of homologous chromosomes are separated so that each gamete receives one member of each pair. Therefore, allele pairs that are on homologous chromosomes are also separated, and each gamete carries only one allele of each pair.

When male and female gametes meet during fertilization, the genetic material combines. A diploid cell forms and the homologous chromosomes—and the associated alleles—are again paired up. The offspring inherits one set of chromosomes and its alleles from the biological mother, and the other set of chromosomes and its alleles from the biological father. Together, these two sets of chromosomes form a set of homologous chromosomes.

The Law of Segregation

The *law of segregation* describes the genetic basis for how characteristics are inherited. It states that alleles for each inherited trait separate, or segregate, from each other during gamete formation. Each gamete carries one allele for each characteristic. When fertilization takes place, each gamete contributes its allele for a characteristic. The two "factors" that Mendel referred to in his conclusions are what we now call alleles.

Dominant and Recessive Alleles

As you now know, Mendel observed that one trait could dominate over the other. For example, Mendel found that purple flowers were dominant over white flowers. Today, we know this occurs because alleles can be **dominant** or **recessive**. The presence or absence of each type of allele determines which trait is observed. If an individual has two, or even only one dominant allele, then the trait associated with it is the dominant trait, and that is what is observed. The trait that is associated with the recessive allele is observed only if an individual carries two recessive alleles.

dominant the allele or trait that is expressed, regardless of the identity of the other allele for the characteristic

recessive the allele or trait that is expressed only when two alleles are present; the expression of the allele or trait that is "hidden" or suppressed if the dominant allele is present

Geneticists have devised a system to represent alleles so that they can be tracked from one generation to the next. The dominant allele is represented with an upper-case letter. The recessive allele is represented with the lower-case version of the same letter used for the dominant allele. The example below applies this system to Mendel's studies of flower colour in pea plants:

- The dominant allele is for purple flower colour and can be indicated by *B*.
- The recessive allele is for white flower colour and can be indicated by *b*.
- The pairs of alleles for flower colour in plants with purple flowers can be either *BB* or *Bb*.
- The pair of alleles for flower colour in plants with white flowers can only be *bb*.

Figure 1.11 summarizes how the law of segregation and dominant and recessive alleles apply to the inheritance and expression of a trait. Although flower colour is used in the example, this summary applies to all characteristics that are determined by one gene. Since the time of Mendel's work, research has shown that the law of segregation applies to all organisms that reproduce sexually, including humans.

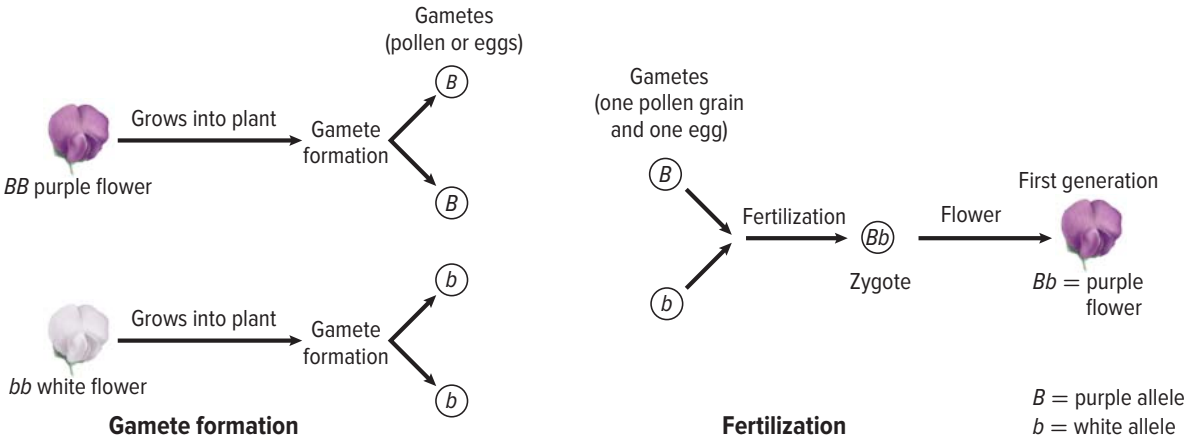


Figure 1.11 These are the results of Mendel's cross involving true-breeding pea plants with purple flowers and pea plants with white flowers.

Genotypes and Phenotypes

You know that the physical appearance of an organism does not necessarily indicate the alleles it has for a characteristic. Pea plants with purple flowers could have two dominant alleles (*BB*) or a dominant allele and a recessive allele (*Bb*) for flower colour. Therefore, scientists distinguish between an organism's physical traits and its genetic make-up. **Phenotype** is the physical expression of an organism's trait, such as purple flower colour. An organism's **genotype** is the specific combination of alleles it has for a trait. If an organism has two identical alleles, it is said to be **homozygous**. If both alleles are dominant, then the organism is *homozygous dominant*. If both alleles are recessive, the organism is *homozygous recessive*. If an organism has two different alleles for a trait, it is **heterozygous**. **Figure 1.12** shows the three possible genotypes for a trait that is determined by two alleles of a gene.

phenotype the physical description of an organism's trait

genotype the specific combination of alleles an organism has for a trait

homozygous an organism with two of the same alleles for a particular trait

heterozygous an organism with two different alleles for a particular trait

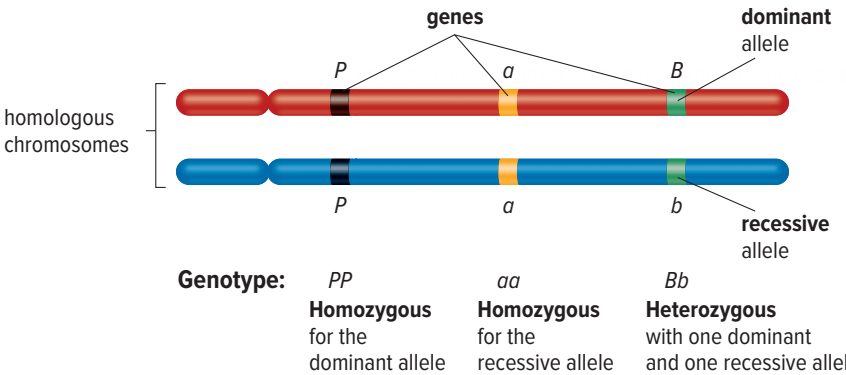


Figure 1.12 Three different genes on homologous chromosomes are indicated. Each example shows one of the three possible combinations (genotypes) of dominant and recessive alleles.

Activity

Dominant or Recessive Trait?

Do you think that broccoli and other leafy green vegetables taste bitter, while the person next to you loves broccoli as a side dish? This could be explained by your genes. In this activity, you will compile data to determine whether a particular gene is dominant or recessive for the trait of tasting the bitterness of a certain chemical.

1. Your teacher will provide you with a strip of paper that contains a chemical called phenylthiocarbamide (PTC).
2. Place the paper on the tip of your tongue and record whether it tastes bitter to you or not.
3. Combine your class data in a table like the one shown below.

Data Table

Number of People for Whom the PTC Was Bitter	
Number of People for Whom the PTC Was Not Bitter	
Total Number of People	
Percent of People for Whom the PTC Was Bitter	
Percent of People for Whom the PTC Was Not Bitter	

4. Calculate the percent of people with or without the trait. Do your results confirm that a trait is dominant or recessive according to the table? Why or why not?
5. Freckles show a dominant inheritance pattern. Do a survey in your class of how many people have freckles and how many do not. Calculate the percent of people with or without the trait. Do your results confirm that a trait is dominant? Research why your results may not confirm this.

Extending the Connections

Not Always as Simple as It Seems

In the past, scientists thought that certain traits in humans, such as the shape of a person's hairline, were controlled by a single gene. Scientists now know that the expression of a trait is often due to more than one gene. Examples include human eye colour and hair colour. How have scientists' views about applying Mendelian genetics to human traits changed, and why?

Before you leave this page . . .

1. Write a definition for genetics in your own words.
2. Seed shape in pea plants can either be round or wrinkled. The allele for round shape is indicated by *R*. Is round seed shape dominant or recessive?
3. The allele for freckles is indicated by *F*. What is the genotype of a person who is heterozygous for freckles?

CONCEPT 2

Punnett squares show the probability of offspring inheriting specific traits.

Activity

What Do You Know about Probability?

Probability is the chance that a given event will occur. If you flip a coin ten times, what is the probability that it will land on heads each time? Discuss your ideas with a partner, then test them. How might the heads-or-tails result of a coin flip be similar to alleles on homologous chromosomes?

A genetic cross is any type of deliberate breeding between a genetic male and a genetic female to produce offspring that carry the genetic material of each parent. When the parents differ in one particular trait that is being studied, the cross is called a *monohybrid cross*. A hybrid is an offspring of parents that have different traits. Often, scientists represent simple genetic crosses using the abbreviated form shown in **Figure 1.13**.

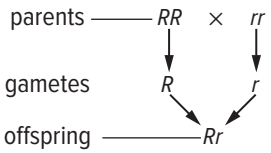


Figure 1.13 A monohybrid cross between a homozygous dominant individual and a homozygous recessive individual. Each parent contributes one type of allele to the offspring. The symbol "×" represents the word *cross*.

Punnett Squares

A *Punnett square* is another way to represent the inheritance of traits in monohybrid crosses. This model is a simple grid that shows the possible genotypes of offspring based on the genotypes of the parents. The Punnett square shown in **Figure 1.14** represents a monohybrid cross to study the inheritance of hair colour in horses. The allele for black hair (*B*) is dominant to the allele for red hair (*b*). The cross shown is between a black-haired female with the genotype *Bb* and a red-haired male with the genotype *bb*. The female gametes can contribute either a *B* allele or a *b* allele. The male gamete can contribute only the *b* allele, since its genotype is *bb*. All possible genotypes of the offspring are shown in the grid. In this case, offspring will have either a *Bb* genotype or a *bb* genotype.

A Punnett square can also indicate how often genotypes are predicted to appear in the offspring. Since the *Bb* genotype appears in two of the four squares, it is predicted that two quarters—or one half—of the offspring will have that genotype. The same frequency is predicted for offspring with the genotype *bb*. In this case, the frequency of the phenotypes in offspring, called the *phenotypic ratio*, is predicted to be the same as the genotypes. Half are predicted to have black hair and half are predicted to have red hair. The steps for how to use a Punnett square to analyze monohybrid crosses are outlined in **Figure 1.15**.

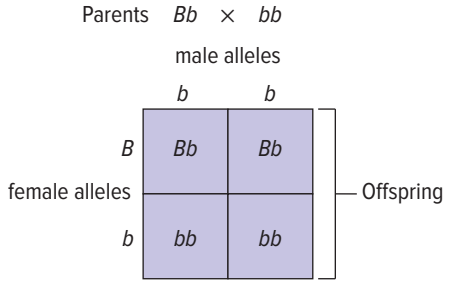
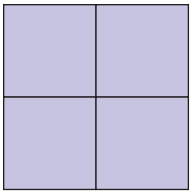
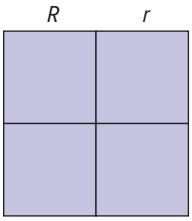


Figure 1.14 In this cross, the female horse can contribute either a *B* allele or a *b* allele to offspring. The male horse can contribute only the *b* allele. The genotypes of the offspring are all possible combinations of alleles that can occur when the gametes combine at fertilization.

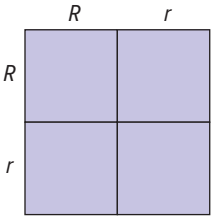
Figure 1.15 Steps for drawing and using a Punnett square.



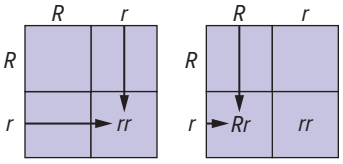
Step 1: Draw a box and divide it into four squares.



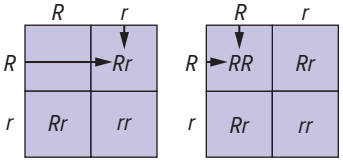
Step 2: Above the top squares, write the genotype of one parent. Place the letter for one allele above each square. Each of these represents the alleles present in that parent's gametes. The example on the left is for a parent that contributes the *R* and *r* alleles.



Step 3: Beside the squares on the left side of the grid, write the genotype of the other parent. Place the letter for one allele beside each square. Each of these represents the alleles present in that parent's gametes. The example here is for a parent that contributes the *R* and *r* alleles.



Step 4: In each square of the grid, write the symbols for the alleles above it and beside it. Each two-letter pair is the genotype of an offspring that would result from fertilization of gametes with the alleles listed above and beside the square.



Step 5: Determine the number of different genotypes and express each as a ratio and/or a fraction. This represents the expected ratio of offspring with that genotype for that cross.

Ratio: 1*RR*:2*Rr*:1*rr*

Fraction: $\frac{1}{4}RR$: $\frac{1}{2}Rr$: $\frac{1}{4}rr$

Activity

Working with Punnett Squares

Draw a Punnett square that represents a monohybrid cross between a female with genotype *Rr* and a male with genotype *RR*. What fraction of offspring is predicted to have the dominant trait?

Before you leave this page . . .

1. A monohybrid cross produces half the offspring with one genotype and half the offspring with another genotype. Express this in the form of a ratio.
2. What do the alleles that are written along the top and beside a Punnett square represent?

CONCEPT 3

Both alleles are expressed in codominance.

Activity

What Happens If Both Alleles Are Equally Expressed?

You have read that some patterns of inheritance result in phenotypes in which the dominant or recessive allele is expressed. However, that does not always happen. Some patterns of inheritance result in phenotypes that are created when both alleles for a trait are equally expressed. In horses, the alleles for chestnut coloured hair and white coloured hair are expressed equally. Suppose a horse inherits one allele for chestnut coloured hair and one allele for white coloured hair. If you looked closely at the individual hairs, what do you think you would see? What colour do you think this horse will be?

In **codominance**, both alleles are fully expressed. A roan animal is an excellent, visible example of codominance. A roan animal is a heterozygote in which both the base colour and white are fully expressed. For example, the coat of the bull in **Figure 1.16** has a mixture of red hairs and white hairs. One allele is expressed in the white hairs, and the other allele is expressed in the red hairs. Codominant alleles are represented using one capital letter for the gene, with different superscript letters for each allele. For example, the roan would be H^RH^W.

codominance the condition in which both alleles for a trait are equally expressed in a heterozygote; both alleles are dominant

Figure 1.16 A roan bull (H^RH^W) is the product of a mating between a red cow (H^RH^R) and a white bull (H^WH^W). The red and white hairs may be present in patches, as shown here, or they may be completely intermingled.

Sickle Cell Anemia—Another Example of Codominance

Sickle cell anemia is one of the most thoroughly studied genetic disorders. It is caused by a specific form of the gene that directs the synthesis of hemoglobin. Hemoglobin is a protein in red blood cells that carries oxygen in the blood. The hemoglobin molecule that is made in people who have the sickle cell allele leads to a C-shaped (or sickled) red blood cell. These misshaped red blood cells, like the one shown in **Figure 1.17**, do not transport oxygen effectively because they cannot pass through small blood vessels. This leads to blockages and tissue damage.

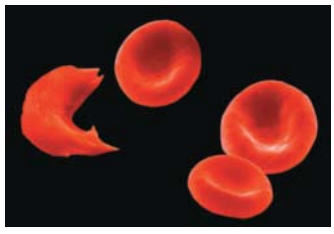


Figure 1.17 Normal red blood cells are flat and disk-shaped. Sickle-shaped cells are elongated and "C" shaped.

Sickle Cell Anemia and Malaria

The allele for normal hemoglobin is represented as Hb^A, and the allele for sickle cell hemoglobin is represented as Hb^S. As shown in **Figure 1.18**, individuals who are homozygous (Hb^SHb^S) have sickle cell anemia. Individuals who are heterozygous (Hb^AHb^S) have some normal and some sickled red blood cells. These people are said to have the sickle cell trait, but they rarely experience any symptoms. In fact, having the sickle cell trait can be an advantage, because these heterozygotes are resistant to malaria. Malaria is a life-threatening disease caused by a parasite that is transmitted to humans through mosquito bites. The parasite infects the liver and eventually the red blood cells. The sickling of red blood cells is thought to prevent the parasites from infecting the cells. Resistance to malaria is beneficial in certain parts of Africa, where deadly epidemics can occur.

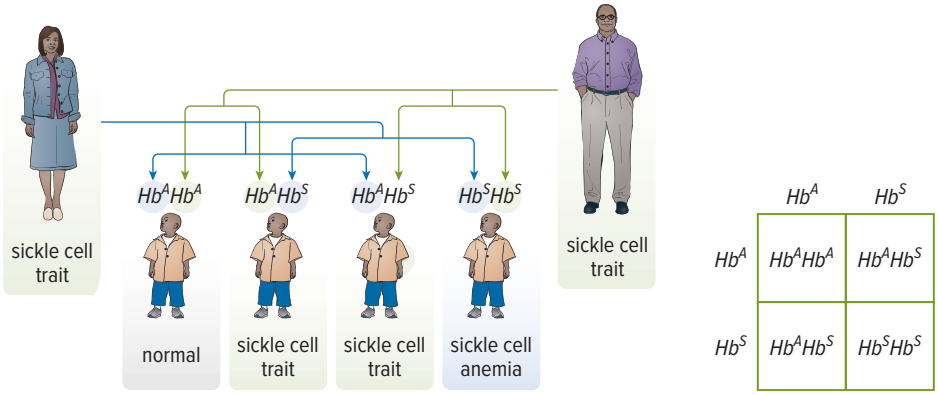


Figure 1.18 When a man and a woman are both heterozygous for the sickle cell gene, there is a one in four chance that they will have a child with sickle cell anemia.

Activity

Human Blood Groups

Do you know what blood type you are? In humans, a single gene determines a person's ABO blood type. The gene is designated *I*, and it has three common alleles: I^A, I^B, and *i*. The different combinations of the three alleles produce four phenotypes, which are commonly called blood types. These four blood types are:

- A (I^AI^A homozygotes or I^Ai heterozygotes)
- B (I^BI^B homozygotes or I^Bi heterozygotes)
- AB (I^AI^B heterozygotes)
- O (*ii* homozygotes)

Of the three alleles that determine blood type, one (*i*) is recessive to the other two, and the other two (I^A and I^B) are codominant.

Make a table with nine cells to show how different combinations of the three *I* alleles result in four different blood types. At the top of the table show the possible alleles from a genetic female as I^A or I^B or *i*. Along the left side of the table show the possible alleles from a genetic male as I^A or I^B or *i*. Fill in your table, and make a key to identify the different blood types that can result.

Before you leave this page . . .

1. What is codominance? Give three examples of codominance.
2. Hypothesize why the frequency of the sickle cell allele is much higher in Africa than in other areas of the world.

CONCEPT 4

In incomplete dominance, alleles are neither dominant nor recessive.

A condition in which neither of the two alleles for the same gene can completely conceal the presence of the other is called **incomplete dominance**. In incomplete dominance, a heterozygote shows a phenotype that is between a dominant phenotype and a recessive phenotype.

An example of incomplete dominance is the flower colour of the four o'clock plant. As you can see in **Figure 1.19**, a cross between a true-breeding red-flowered plant and a true-breeding white-flowered plant produces offspring with pink flowers in the F_1 generation. If the F_1 plants are allowed to self-fertilize, the F_2 generation will include offspring with all three phenotypes—red, pink, and white. The Punnett square in **Figure 1.19** predicts that all three phenotypes will be observed in the F_2 generation in a ratio of 1:2:1 (red:pink:white). Experiments show that is exactly what happens.

incomplete dominance a condition in which neither allele for a gene completely conceals the presence of the other; it results in intermediate expression of a trait

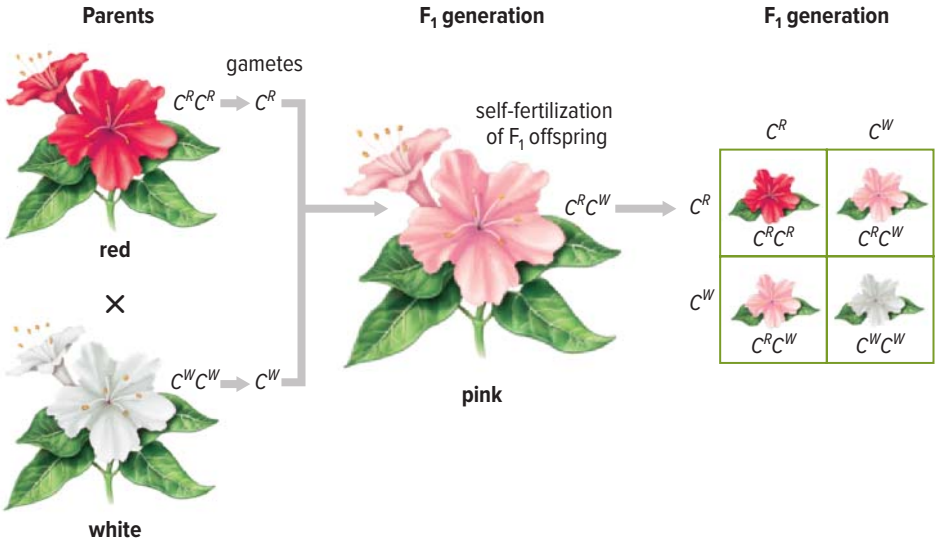


Figure 1.19 When red (C^RC^R) flowers and white (C^WC^W) flowers of the four o'clock are crossed, the resulting offspring have an intermediate phenotype, pink flowers (C^RC^W). In the F_2 generation, all three phenotypes are observed.

One way to represent alleles in incomplete dominance is to use superscripts, as you saw with codominance. For example, with four o'clocks, both alleles affect the colour of the flower, *C*. The two alleles are represented as superscripts, R for red (C^R), and W for white (C^W). Lower-case letters are used only to represent a recessive allele.

Before you leave this page . . .

1. What is the difference between incomplete dominance and codominance?
2. A plant that produces white flowers is crossed with a plant that produces purple flowers.

   Describe the phenotype of the offspring if the inheritance pattern for flower colour is
   a) incomplete dominance
   b) codominance

CONCEPT 5

Some inherited traits are due to alleles on the sex chromosomes.

Activity

Colour Perception

Some people's perception of colour differs from other people. One form of colour vision deficiency involves difficulty distinguishing between the colours red and green. Your teacher may provide a red-green colour vision deficiency test or data from such a test. Based on the data, what conclusions about the pattern of inheritance for red-green colour vision deficiency can you make?

sex-linked trait a trait controlled by genes on sex chromosomes

Traits controlled by genes located on the sex chromosomes are called **sex-linked traits**. Traits controlled by genes on the X chromosome are called *X-linked traits*. Because genetic males have only one X chromosome, they are affected by recessive X-linked traits more often than are genetic females. Females are less likely to express a recessive X-linked trait, because the other X chromosome may mask the effect of the trait.

Red-Green Colour Vision Deficiency

The trait for red-green colour vision deficiency is a recessive X-linked trait. Figures 1.20A and 1.20B show how a person with red-green colour vision deficiency might view colours compared to a person who does not.

Use the Punnett square in Figure 1.20C to study colour vision deficiency further. The mother is a *carrier* for the trait, because she has the recessive allele on one of her X chromosomes. The father is not colour vision deficient, because he does not have the recessive allele. Notice that the only offspring that can have red-green colour vision deficiency is a male child. As a result of it being an X-linked trait, red-green colour vision deficiency is very rare in females.

Figure 1.20 As an X-linked trait, colour vision deficiency occurs more often in males than in females. A A person who is not colour vision deficient can see all colours. B People with red-green colour vision deficiency view red and green as shades of grey. C The Punnett square shows how the sex-linked trait is inherited.

C

	X^B	Y
X^B	X^BX^B	X^BY
X^b	X^BX^b	X^bY

X^B = Normal
X^b = Red-green colour vision deficiency
Y = Y chromosome

Before you leave this page . . .

1. What are sex-linked traits?
2. Use vocabulary terms to describe the genotype of a male who is red-green colour vision deficient.

AT ISSUE Hemophilia

What's the Issue?

One way to examine how a trait is inherited in different generations is to use a pedigree. A *pedigree* is a type of flowchart that uses symbols to show patterns of relationships and traits in a family over many generations. The well-studied pedigree shown below represents the family of Queen Victoria of England, who lived from 1819–1901. Her son Leopold died of hemophilia. *Hemophilia* is a recessive X-linked disorder. Blood does not clot properly in people with hemophilia. As a result, they may bleed to death if they are cut or injured.

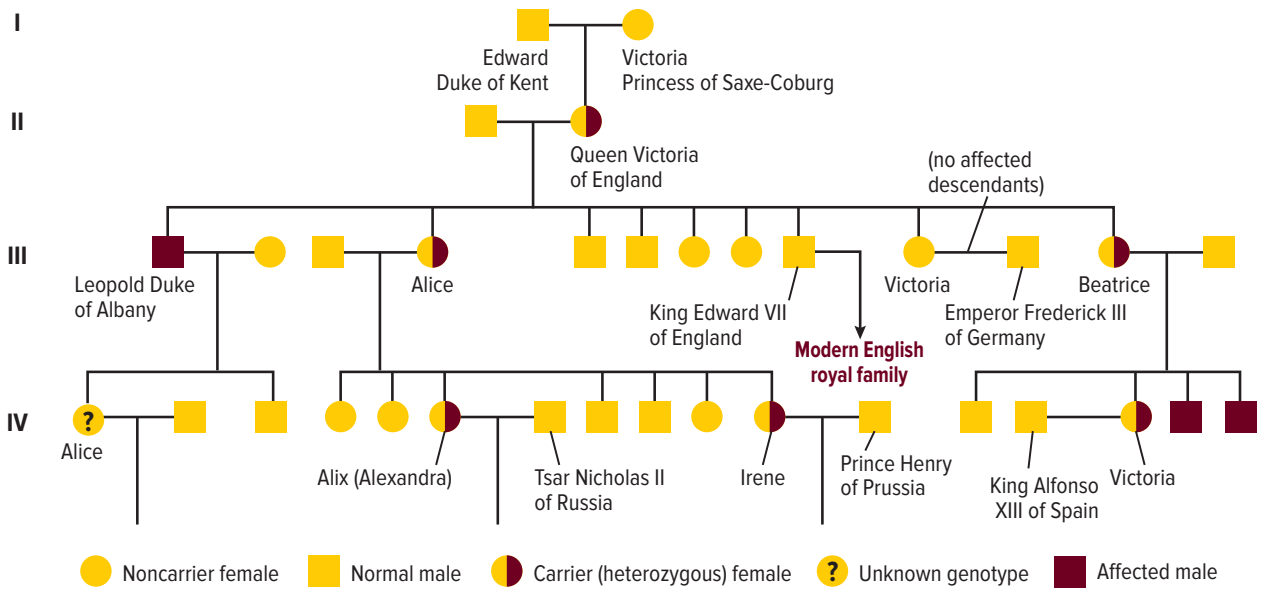
Use the pedigree to determine whether Alice—the daughter of Leopold, Duke of Albany—had hemophilia, was a carrier, or did not have the illness. Genetic females are carriers of a recessive sex-linked disorder if they inherit the allele for the disorder on one X chromosome.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Use a Punnett square to determine whether Alice (the daughter of Leopold, Duke of Albany) had hemophilia, was a carrier, or did not have the illness. (Hint: What is Alice's genotype?)
2. If Alice had a son with hemophilia, would that change or confirm your decision? Explain why. (Assume the father did not have hemophilia.)

Queen Victoria's Pedigree



BE Inspired

Make a Difference

Dr. Nadine Caron

Dr. Nadine Caron is a surgeon, public health researcher, and teacher in Prince George. "I love being a physician and surgeon, meeting people in the hospital and clinic," says Caron. "It's such an honour to hear their stories, not just about their health, but to get a glimpse of the lives they lead."

Dr. Caron also works to improve healthcare for northern and Indigenous Canadians through the Silent Genomes Project. "The 'silent' refers to the relative and significant absence of Indigenous Canadians in the area of genomics," says Caron. "Genomics is revolutionizing healthcare and we're looking at how Indigenous Canadians can be at the table…on their own terms."

Dr. Caron dreamt of being a basketball player after high school, then became the first female First Nations general surgeon in Canada. "Learning is a lifelong endeavour," says Caron. "Find your passion and be open to it; be the curious one, and apply yourself."

Apply and Innovate

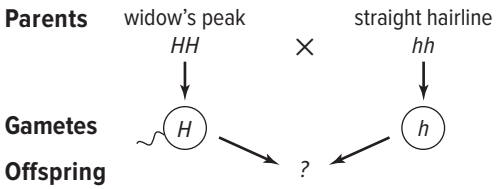
1. One application of genomics requires comparison of DNA sequences in a genome of interest (e.g. a patient with a genetic disease) to a background population of healthy patients. Dr. Caron likens this to a "spellcheck program on a computer." Explain this analogy, outlining its strengths and limitations. Devise another analogy, and explain why you think it is effective.
2. Dr. Caron began with basketball and eventually became a surgeon. What are your interests and passions now? Where do you think they might lead you? In what unexpected directions could you imagine they might lead you instead?

Check Your Understanding of Topic 1.2

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Explain how Mendel used selective breeding to learn more about heredity. C
2. In terms of experimental design, why was it important that Mendel used true-breeding plants to explore patterns of inheritance? PA
3. Explain the differences between the following sets of terms and give an example of each term: PA C
   a) dominant and recessive
   b) genotype and phenotype
   c) homozygous and heterozygous
4. The diagram below represents the genotypes of two parents and one gamete from each parent. AI C



   a) What is the genotype of the offspring?
   b) What is the phenotype of the offspring? Explain your reasoning.
5. Suppose that two siblings both have attached earlobes, and their parents have unattached earlobes. Unattached earlobes are represented as E, and attached earlobes are represented by e. What are the genotypes of the parents? Explain your reasoning. AI C
6. Copy the Punnett square into your notebook. The ability of a person to roll his or her tongue is dominant (T), and the inability is recessive (t). Fill in the blank genotypes and describe the phenotypes for each. AI C

	T	t
t	Tt	
t	Tt	

7. In pigeons, the checker pattern of feathers (F) is dominant to the non-checker pattern (f). Suppose a checkered pigeon with the genotype Ff mates with a non-checkered pigeon. Draw a Punnett square to predict the genotypes of their offspring. QP
8. A white-flowered plant is crossed with a red-flowered plant. What is the likely mode of inheritance if the offspring produced are PA
   a) plants with pink flowers?
   b) plants with red flowers?
9. How does sex-linked inheritance occur? C

Connecting Ideas

10. The Punnett square shows the genotype of the female parent and the genotypes of the offspring. AI

	?	?
X^b	X^bX^b	X^bY
X^b	X^bX^b	X^bY

X^B = Normal
X^b = Red-green colour vision deficiency
Y = Y chromosome
   a) What is the genotype of the male parent?
   b) What is the phenotype of the male parent?

Making New Connections

11. Sometimes breeders of plants and animals need to know if a plant or animal that has a dominant phenotype has a genotype that is homozygous dominant or heterozygous. One way to determine this is by doing a test cross. A test cross involves
   - mating the individual of unknown genotype with an individual who is homozygous recessive for the trait
   - analyzing the phenotypes of the offspring.

   Explain how this helps breeders identify the unknown genotype. Use a Punnett square to work through possible crosses. AI C

INVESTIGATION
1-B

STRUCTURED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing Data
- Evaluating
- Communicating

What You Need

- three coins
- game boards

Understanding Probability

Probability is the chance that a given event will occur. You can use an understanding of probability to predict the occurrence of certain traits. In this investigation, you will play a probability game, and then analyze the results.

Question

How can probability be used to predict outcome ratios or percentages?

Procedure

1. Obtain a game board from your teacher.
2. Decide which of you will represent "heads" and which will represent "tails." Use one of the coins with heads side up and the other with tails side up as game pieces (tokens).
3. Start the game with both token coins at the centre line on the game board. Each "turn" will be determined by a flip of the third coin. If the coin lands heads side up, the "heads" player moves one square toward the "heads" finish line. If it lands tails side up, the "tails" player moves one square toward the "tails" finish line. The first player to reach the finish line wins the game.
4. Record the results of each coin flip in a data table. Share the results of your game with the rest of your class.
5. Record the class data for the number of "heads" winners and the number of "tails" winners.

Analyze and Interpret

1. Do you think the game was fair? Explain why or why not.
2. Calculate how many times "heads" came up during your game. Express this outcome as a percentage and as a ratio.
3. Use the class outcome data to calculate how many times "heads" or "tails" won the game. Express this relationship as a percentage and as a ratio.
4. Did the outcome percentage and ratio from your game match that of the outcome data for the class? Why or why not?

Conclude and Communicate

5. What aspects of this game are similar to events occurring during meiosis? What aspects are different? Evaluate the effectiveness of flipping a coin to model the inheritance of traits.

INVESTIGATION
1-C

GUIDED INQUIRY

Corn Genetics

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing Data
- Evaluating
- Communicating

What You Need

- ear of corn representing the F_2 generation

When you look at an ear of corn, each one of the kernels is actually a separate offspring resulting from the union of an egg and a pollen grain, with its own unique genetics. In this investigation, you will examine the pattern of inheritance of one trait in corn: kernel colour. The allele for purple kernels is dominant to the allele for yellow kernels. By counting the number of purple and yellow kernels produced in the F_2 generation, you can verify the pattern of inheritance for kernel colour.

Question

What is the predicted phenotypic ratio for kernel colour in the F_2 generation?

Procedure

1. Design a table to record the number of purple and yellow kernels in the ear of corn.
2. Count the number of purple and yellow kernels, and record the results in the table.

Analyze and Interpret

1. Determine the ratio of purple to yellow kernels in the ear of corn.

Conclude and Communicate

2. How does the actual ratio of purple to yellow kernels compare to the theoretical ratio?
3. Is the actual ratio close enough to the theoretical ratio to confirm that the allele for purple kernel colour is dominant to the allele for yellow kernel colour? Explain any differences.

Evaluate and Apply

4. What improvement could you make to the procedure to increase your confidence in the results?
5. Corn, also known as maize, has been used to investigate genetic processes for more than 75 years. Barbara McClintock is a scientist whose studies of corn have made significant contributions to genetics. Do research to find out about and report on her work.

Performing a Monohybrid Cross

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing Data
- Evaluating
- Communicating

Safety

- Be sure to pick up all materials after the lab. Beads left on the floor could cause someone to slip and fall.

What You Need

- silver and white paper clips, pipe cleaners, beads, or other materials to represent different alleles (any two colours can be used)

A monohybrid cross is performed by breeding two individuals that differ in a particular trait under study. Gregor Mendel never used this term to describe his work, but he did perform monohybrid crosses when he fertilized homozygous dominant purple-flowered pea plants with homozygous recessive white-flowered pea plants. Mendel performed the same type of cross for several other traits in the pea plant. In this lab, you will repeat Mendel's monohybrid cross experiment using a model system, and then analyze your results.

Question

How can you model a monohybrid cross to replicate Mendel's results?

Procedure

1. The homozygous dominant parent is represented by two silver paper clips. The homozygous recessive parent is represented by two white paper clips. Working with a partner, decide who will take the role of each parent.
2. Use a table like the one below to record your results. The table should show the number of times a cross results in each of the possible combinations: two silver paper clips, two white paper clips, or one silver and one white paper clip. Leave space for data from your true-breeding crosses (which result in the F_1 generation) and your F_1 crosses (which result in the F_2 generation). Also leave space to include class results for both the true-breeding and F_1 crosses.

Results of Crosses

	2 Silver	2 White	1 Silver/1 White
F_1			
F_2			
F_1–Class			
F_2–Class			

3. One partner at a time, use this process to perform a cross.
   a) Cup your two paper clips between your palms, shake them, and then close each fist separately around only one paper clip (without looking at the clips or allowing your partner to see them). Keep your fists closed.
   b) Have your partner choose either your left or right hand.

c) Place the paper clip from that hand on the table.

d) Repeat this process for your partner's paper clips.

4. Record the outcome of each cross in the F_1 row of your table. Repeat the process nine more times, for a total of ten crosses.

5. Now perform a cross between your first generation "offspring." Each partner will start with the same combination of paper clips that resulted from the tenth cross in your first set of crosses.

6. Repeat steps 3 and 4. This time, record the results of each cross in the F_2 row of your table.

7. When you have collected data for 20 crosses in total (10 true-breeding crosses and 10 F_1 crosses), share your results with the class.

8. Record the class results in your table.

Analyze and Interpret

1. What did each paper clip represent in this model? What did each combination of two paper clips represent?

2. What was the purpose of repeating each set of crosses 9 times?

Conclude and Communicate

3. Calculate the genotypic and phenotypic ratios for the true-breeding crosses and the F_1 crosses for your own data, and then for the class data.

   a) How do each of these ratios compare to the expected ratios? (Hint: Recall the ratios for a comparable F_1 cross shown on page 27.)

   b) If the class results were closer to the expected ratios, why do you think this occurred?

4. The table below shows the results of some of Mendel's monohybrid crosses.

   a) Calculate the phenotypic ratio that resulted from each F_1 cross. Are all of the ratios exactly 3:1? Why or why not?

   b) Notice the number of offspring in the F_2 generation. How do you think using so many plants helped Mendel get results that were close to a 3:1 ratio?

   c) Reflect on your ability to model Mendel's monohybrid crosses effectively. What changes to the procedure you would recommend to improve the intent and results of this lab?

Mendel's Monohybrid Crosses

Trait	Homozygous Dominant Form	Homozygous Recessive Form	F_1 Offspring (from cross between true-breeding plants)	F_2 Offspring (from cross between F_1 plants)
Flower colour	purple	white	all purple	705 purple 224 white
Seed colour	yellow	green	all yellow	6022 yellow 2001 green
Seed shape	round	wrinkled	all round	5474 round 1850 wrinkled
Pod colour	green	yellow	all green	428 green 152 yellow
Stem length	tall	short	all tall	787 tall 277 short