chapter 11

Complex Inheritance and Human Heredity

section 2 Complex Patterns of Inheritance

Before You Read

Cats can look different from one another because of differences in their coats. On the lines below, describe differences you have seen in the coats of cats. Then read the section to learn more about complex inheritance patterns.

MAIN Idea

Complex inheritance of traits does not follow the inheritance patterns described by Mendel.

What You'll Learn

- the difference between sex-linked and sex-limited inheritance
- how environment can influence a trait

Read to Learn

Mark the Text

Highlight each question head. Then highlight the answer to the question.

Incomplete Dominance

Not all traits follow Mendel's rules. Some traits are not dominant or recessive. Sometimes, the heterozygous organism has a mixed phenotype. **Incomplete dominance** occurs when the heterozygous phenotype is an intermediate phenotype between the two homozygous phenotypes.

An example of incomplete dominance occurs in snapdragon flowers. Red-flowered snapdragons ($C^R C^R$) can be crossed with white-flowered snapdragons ($C^W C^W$) to produce offspring with pink flowers ($C^R C^W$). When heterozygous F_1 generation snapdragon plants ($C^R C^W$) self-fertilize, the offspring have a 1:2:1 ratio of red, pink, and white flowers.

Codominance

In Mendel's experiments with pea plants, heterozygous pea plants expressed only the dominant allele. **Codominance** occurs when a heterozygous organism expresses both alleles. Sickle-cell anemia is an example of codominance. People who are heterozygous for the sickle-cell trait have both normal and sickle-shaped cells.

Reading Check

1. Define What is codominance?

What happens in sickle-cell disease?

Sickle-cell disease is common in people of African descent. Sickle-cell disease affects red blood cells and their ability to transport oxygen. Changes in the protein in red blood cells cause those red blood cells to change from a normal disc shape to a sickle or *C* shape.

Reading Check

2. Describe What effect does sickle-cell disease have on red blood cells?

Sickle-cell disease is a codominant trait. People who are heterozygous for the trait make both normal and sickle-shaped cells. The normal cells compensate for the sickle-shaped cells.

How does sickle-cell disease relate to malaria?

Sickle-cell disease is found in areas of Africa where malaria occurs. Scientists have discovered that people who are heterozygous for the sickle-cell trait are resistant to malaria. Because the sickle-cell gene helps people resist malaria, they are more likely to pass the sickle-cell trait on to their offspring.

Multiple Alleles

So far you have learned about traits that result from a gene with two alleles. Some traits are controlled by a gene that has **multiple alleles**. Blood groups in humans is an example of a multiple allele trait.

How are blood types produced?

There are four blood types in people: A, AB, B, or O. The four types result from the interaction of three different alleles, as shown below. The allele I^A produces blood type A. I^B produces blood type B. The allele i is recessive and produces blood type O. Type O is the absence of AB alleles. People with one I^A and one I^B allele have blood type AB. Blood types are examples of multiple alleles and codominance.

Rh factors are also in blood. One factor is inherited from each parent. Rh factors are either positive or negative (Rh+ or Rh−); the Rh+ is dominant.

Picture This

3. Evaluate What phenotype results from a genotype of I^Bi?

Genotypes	Resulting Phenotypes
I^AI^A	Type A
I^Ai	Type A
I^BI^B	Type B
I^Bi	Type B
I^AI^B	Type AB
ii	Type O

What genes control coat color in rabbits?

The fur color of rabbits is another trait controlled by multiple alleles. In rabbits, four alleles control coat color: *C*, c^{ch}, c^{h}, and *c*. The alleles are dominant in varying degrees. The hierarchy can be written as $C > c^{ch} > c^{h} > c$.

Allele *C* is dominant to all other alleles and results in a dark gray coat color. Allele c^{ch} is dominant to c^{h}, and c^{h} is dominant to *c*. Allele *c* is recessive and results in an albino when the genotype is homozygous recessive.

Multiple alleles increase the possible number of genotypes and phenotypes. Two alleles have three possible genotypes and two possible phenotypes. Four alleles have ten possible genotypes and can have five or more phenotypes.

Epistasis

Epistasis (ih PIHS tuh sus) occurs when one allele hides the effects of another allele. Coat color in Labrador retrievers is a trait controlled by epistasis. Labrador coats vary from yellow to black. Two different genes control coat color. The dominant allele *E* determines whether the coat will have dark pigment. A dog with genotype *ee* will not have any pigment. The dominant allele *B* determines how dark the pigment will be. If the genotype is *EEbb* or *Eebb* the coat will be chocolate. If the genotype is eebb, *eeBb,* or *eeBB* the coat will be yellow because the *e* allele hides the effects of the dominant *B* allele.

Sex Determination

Each cell in your body contains 23 pairs of chromosomes. One pair, the **sex chromosomes,** determines gender. The other 22 pairs of chromosomes are called **autosomes**.

There are two types of sex chromosomes—X and Y. A person's gender is determined by the sex chromosomes present in the egg and sperm cell. Females inherit two X chromosomes. Males inherit one X and one Y chromosome.

Dosage Compensation

In humans, the X chromosome carries genes needed by males and females. The Y chromosome mainly carries genes needed to develop male characteristics. Because females have two X chromosomes and males have only one, body cells randomly turn off one of the X chromosomes. This is called dosage compensation or X-inactivation.

Think it Over

4. Evaluate What allele is dominant over c^{ch}?

a. c^{h}
b. *c*
c. *C*

Think it Over

5. Identify A person has 22 pairs of autosomes and two X chromosomes. What is the person's gender?

How is coat color determined in calico cats?

The coat color of calico cats is controlled by the random inactivation of X chromosomes. Orange patches are formed when an X chromosome carrying the allele for black coat color is turned off. Black patches are formed when an X chromosome carrying the allele for orange coat color is turned off.

What are Barr bodies?

Canadian scientist Murray Barr first observed inactivated X chromosomes, now known as Barr bodies. Barr bodies appear as dark objects in the cell nuclei of female mammals.

Think it Over

6. Draw Conclusions Why is a recessive sex-linked trait less likely to occur in females than in males?

Sex-Linked Traits

Traits controlled by genes on the X chromosome are called **sex-linked traits** or X-linked traits. Males who have only one X chromosome are affected more than females by recessive sex-linked traits. Females would not likely express a recessive sex-linked trait because one X chromosome will mask the effect of the recessive trait on the other X chromosome.

How is red-green color blindness inherited?

The trait for red-green color blindness is a recessive sex-linked trait. People who are color blind cannot see the colors red and green. About 8 percent of males in the United States are red-green color blind. Examine the Punnett square below to see how red-green color blindness is inherited.

Picture This

7. Predict Circle the genotype that represents a color-blind person.

X^B = Normal
X^b = Red-green color blind
Y = Y chromosome

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

How is hemophilia inherited?

Normally, when a person is cut, the bleeding stops quickly. Hemophilia is a recessive sex-linked disorder that slows blood clotting. Hemophilia is more common in males. Until the discovery of clotting factors in the twentieth century, most men with hemophilia died at an early age. Safe methods of treating the disorder now allow for a normal life span.

Polygenic Traits

So far you have learned about traits that are controlled by one gene with different alleles. **Polygenic traits** develop from the interaction of multiple pairs of genes. Many traits in humans are polygenic, including skin color, height, eye color, and fingerprint pattern.

Reading Check

8. List an example of a polygenic trait.

Environmental Influences

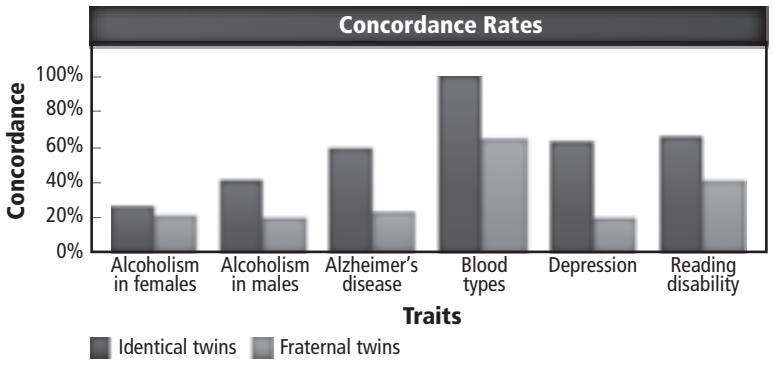
The environment influences many traits. Factors such as sunlight, temperature, and water can affect an organism's phenotype. For example, the gene that codes for the production of color pigment in Siamese cats functions only under cooler conditions. Cooler parts of the cat's body, such as the ears, nose, feet, and tail, are darker. The warmer parts of the body, where pigment production is inhibited, are lighter.

Environmental factors also include an organism's actions. Heart disease can be inherited, but diet and exercise also strongly influence the disease. An organism's actions are considered part of the environment because they do not come from genes.

Twin Studies

Scientists can learn about inheritance patterns by studying twins. Twin studies often reveal how genes and the environment affect phenotype.

Identical twins have identical genes. If a trait is inherited, both identical twins will have the trait. Scientists presume that traits that are different in identical twins are strongly influenced by the environment. The percentage of identical twins who both have the same trait is called a concordance rate, as shown in the graph below. The higher the concordance rate, the stronger the genetic influence.



Picture This

9. Evaluate Circle the trait that shows the strongest genetic influence.