

As You Read

What You'll Learn

- **Explain** how traits are inherited by incomplete dominance.
- **Compare** multiple alleles and polygenic inheritance, and give examples of each.
- **Describe** two human genetic disorders and how they are inherited.
- **Explain** how sex-linked traits are passed to offspring.

Vocabulary

incomplete dominance
polygenic inheritance
sex-linked gene

Why It's Important

Most of your inherited traits involve more complex patterns of inheritance than Mendel discovered.

Incomplete Dominance

Not even in science do things remain the same. After Mendel's work was rediscovered in 1900, scientists repeated his experiments. For some plants, such as peas, Mendel's results proved true. However, when different plants were crossed, the results were sometimes different. One scientist crossed purebred red four-o'clock plants with purebred white four-o'clock plants. He expected to get all red flowers, but they were pink. Neither allele for flower color seemed dominant. Had the colors become blended like paint colors? He crossed the pink-flowered plants with each other, and red, pink, and white flowers were produced. The red and white alleles had not become blended. Instead, when the allele for white flowers and the allele for red flowers combined, the result was an intermediate phenotype—a pink flower. When the offspring of two homozygous parents show an intermediate phenotype, this inheritance is called **incomplete dominance**. Other examples of incomplete dominance include the feather color of some chicken breeds and the coat color of some horse breeds, as shown in **Figure 5**.

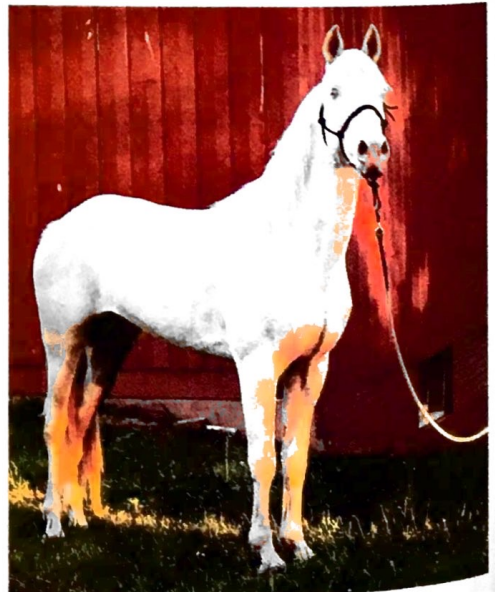
Figure 5

When **A** a chestnut horse is bred with **B** a cremello horse, all offspring will be **C** palomino. The Punnett square shown in **D** can be used to predict this result. *How does the color of the palomino horse in **C** show that the coat color of horses may be inherited by incomplete dominance?*

A



B




Multiple Alleles Mendel studied traits in peas that were controlled by just two alleles. However, many traits are controlled by more than two alleles. A trait that is controlled by more than two alleles is said to be controlled by multiple alleles. Traits controlled by multiple alleles produce more than three phenotypes of that trait.

Imagine that only three types of coins are made—nickels, dimes, and quarters. If every person can have only two coins, six different combinations are possible. In this problem, the coins represent alleles of a trait. The sum of each two-coin combination represents the phenotype. Can you name the six different phenotypes possible with two coins?

Blood type in humans is an example of multiple alleles that produce only four phenotypes. The alleles for blood types are called A, B, and O. The O allele is recessive to both the A and B alleles. When a person inherits one A allele and one B allele for blood type, both are expressed—phenotype AB. A person with phenotype A blood has the genetic makeup, or genotype—AA or AO. Someone with phenotype B blood has the genotype BB or BO. Finally, a person with phenotype O blood has the genotype OO.

Reading Check What are the six different blood type genotypes?



SCIENCE Online 

Research Visit the Glencoe Science Web site at science.glencoe.com for information on the importance of blood types in blood transfusions. In your Science Journal, draw a chart showing which blood types can be used safely during transfusions.

D

| | | Chestnut horse (CC) | |
|-----------------------|----|---------------------|-----|
| | | C | C |
| Cremello horse (C'C') | C' | CC' | CC' |
| | C' | CC' | CC' |

Genotypes: All CC'
Phenotypes: All palomino horses

Mini LAB

Interpreting Polygenic Inheritance

Procedure

1. Measure the hand spans of your classmates.
2. Using a **ruler**, measure from the tip of the thumb to the tip of the little finger when the hand is stretched out. Read the measurement to the nearest centimeter.
3. Record the name and hand-span measurement of each person in a data table.

Analysis

1. What range of hand spans did you find?
2. Are hand spans inherited as a simple Mendelian pattern or as a polygenic or incomplete dominance pattern? Explain.

Polygenic Inheritance

Eye color is an example of a trait that is produced by a combination of many genes. **Polygenic** (pahl ih JEHN ihk) **inheritance** occurs when a group of gene pairs acts together to produce a trait. The effects of many alleles produces a wide variety of phenotypes. For this reason, it may be hard to classify all the different shades of eye color.

Your height and the color of your eyes and skin are just some of the many human traits controlled by polygenic inheritance. It is estimated that three to six gene pairs control your skin color. Even more gene pairs might control the color of your hair and eyes. The environment also plays an important role in the expression of traits controlled by polygenic inheritance. Polygenic inheritance is common and includes such traits as grain color in wheat and milk production in cows. Egg production in chickens is also a polygenic trait.

Impact of the Environment Your environment plays a role in how some of your genes are expressed or whether they are expressed at all, as shown in **Figure 6**. Environmental influences can be internal or external. For example, most male birds are more brightly colored than females. Chemicals in their bodies determine whether the gene for brightly colored feathers is expressed.

Although genes determine many of your traits, you might be able to influence their expression by the decisions you make. Some people have genes that make them at risk for developing certain cancers. Whether they get cancer might depend on external environmental factors. For instance, if some people at risk for skin cancer limit their exposure to the Sun and take care of their skin, they might never develop cancer.

Reading Check

What environmental factors might affect the size of leaves on a tree?

Figure 6

Himalayan rabbits have alleles for dark-colored fur. However, this allele is able to express itself only at lower temperatures. Only the areas located farthest from the rabbit's main body heat (ears, nose, feet, tail) have dark-colored fur.



Human Genes and Mutations

Sometimes a gene undergoes a change that results in a trait that is expressed differently. Occasionally errors occur in the DNA when it is copied inside of a cell. Such changes and errors are called mutations. Not all mutations are harmful. They might be helpful or have no effect on an organism.

Certain chemicals are known to produce mutations in plants or animals, including humans. X rays and radioactive substances are other causes of some mutations. Mutations are changes in genes.

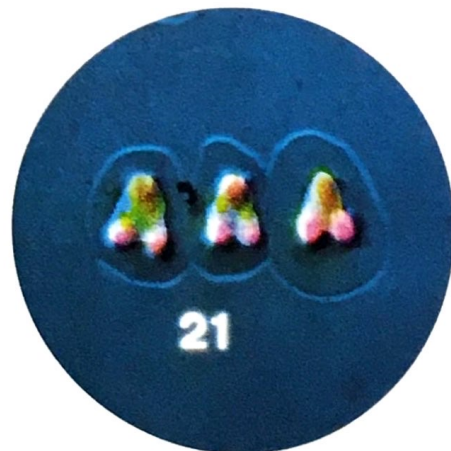
Chromosome Disorders In addition to individual mutations, problems can occur if the incorrect number of chromosomes is inherited. Every organism has a specific number of chromosomes. However, mistakes in the process of meiosis can result in a new organism with more or fewer chromosomes than normal. A change in the total number of human chromosomes is usually fatal to the unborn embryo or fetus, or the baby may die soon after birth.

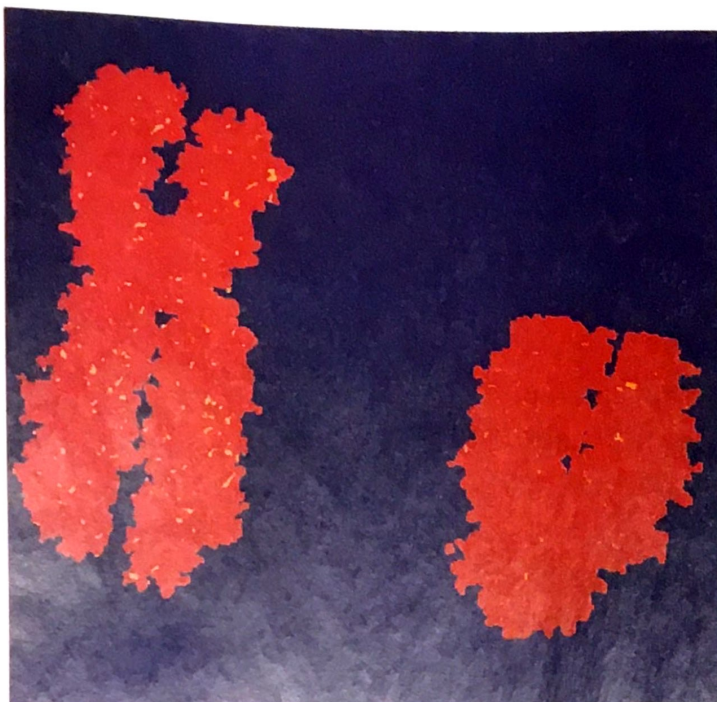
Look at the human chromosomes in **Figure 7**. If three copies of chromosome 21 are produced in the fertilized human egg, Down's syndrome results. Individuals with Down's syndrome can be short, exhibit learning disabilities, and have heart problems. Such individuals can lead normal lives if they have no severe health complications.



Figure 7

Humans usually have 23 pairs of chromosomes. Notice that three copies of chromosome 21 are present in this photo, rather than the usual two chromosomes. This change in chromosome number results in Down's syndrome. Chris Burke, a well-known actor, has this syndrome.





Magnification: 10,000×

Figure 8

Sex in many organisms is determined by X and Y chromosomes.

How do the X (left) and Y (right) chromosomes differ from one another in shape and size?



Chemistry INTEGRATION

People with PKU, a recessive disorder, cannot produce the enzyme needed for the breakdown of a substance found in some artificially sweetened drinks. Soft-drink cans must be labeled to ensure that individuals with this disorder do not unknowingly consume the substance. Explain in your Science Journal how a person can be born with PKU if neither parent has this recessive disorder.

Recessive Genetic Disorders

Many human genetic disorders, such as cystic fibrosis, are caused by recessive genes. Some recessive genes are the result of a mutation within the gene. Many of these alleles are rare. Such genetic disorders occur when both parents have a recessive allele responsible for this disorder. Because the parents are heterozygous, they don't show any symptoms. However, if each parent passes the recessive allele to the child, the child inherits both recessive alleles and will have a recessive genetic disorder.



Reading Check

How is cystic fibrosis inherited?

Cystic fibrosis is a homozygous recessive disorder. It is the most common genetic disorder that can lead to death among Caucasian Americans. In most people, a thin fluid is produced that lubricates the lungs and intestinal tract. People with cystic fibrosis produce thick mucus instead of this thin fluid. The thick mucus builds up in the lungs and makes it hard to breathe. This buildup often results in repeated bacterial respiratory infections. The thick mucus also reduces or prevents the flow of substances necessary for digesting food. Physical therapy, special diets, and new drug therapies have increased the life spans of patients with cystic fibrosis.

Sex Determination

What determines the sex of an individual? Much information on sex inheritance came from studies of fruit flies. Fruit flies have only four pairs of chromosomes. Because the chromosomes are large and few in number, they are easy to study. Scientists identified one pair that contains genes that determine the sex of the organism. They labeled the pair XX in females and XY in males. Geneticists use these labels when studying organisms, including humans. You can see human X and Y chromosomes in **Figure 8**.

Each egg produced by a female normally contains one X chromosome. Males produce sperm that normally have either an X or a Y chromosome. When a sperm with an X chromosome fertilizes an egg, the offspring is a female, XX. A male offspring, XY, is the result of a Y-containing sperm fertilizing an egg. What pair of sex chromosomes is in each of your cells? Sometimes chromosomes do not separate during meiosis. When this occurs, an individual can inherit an abnormal number of sex chromosomes.

Sex-Linked Disorders

Some inherited conditions are linked with the X and Y chromosomes. An allele inherited on a sex chromosome is called a **sex-linked gene**. Color blindness is a sex-linked disorder in which people cannot distinguish between certain colors, particularly red and green. This trait is a recessive allele on the X chromosome. Because males have only one X chromosome, a male with this allele on his X chromosome is color-blind. However, a color-blind female occurs only when both of her X chromosomes have the allele for this trait.

The allele for the distinct patches of three different colors found in calico cats is recessive and carried on the X chromosome. As shown in **Figure 9**, calico cats have inherited two X chromosomes with this recessive allele—one from both parents.

Female carrier of calico gene (X^cX)

| | | |
|-------|----------|--------|
| | X^c | X |
| X^c | X^cX^c | XX^c |
| Y | X^cY | XY |

Male carrier of calico gene (X^cY)

Genotypes: X^cX^c , X^cX , X^cY , XY
Phenotypes: One calico female, one carrier female, one carrier male, one normal male



Figure 9
 Calico cat fur is a homozygous recessive sex-linked trait. Female cats that are heterozygous are not calico but are only carriers. Two recessive alleles must be present for this allele to be expressed. *Why aren't all the females calico?*

Pedigrees Trace Traits

How can you trace a trait through a family? A pedigree is a visual tool for following a trait through generations of a family. Males are represented by squares and females by circles. A completely filled circle or square shows that the trait is seen in that person. Half-colored circles or squares indicate carriers. A carrier is heterozygous for the trait and it is not seen. People represented by empty circles or squares do not have the trait and are not carriers. The pedigree in **Figure 10** shows how the trait for color blindness is carried through a family.

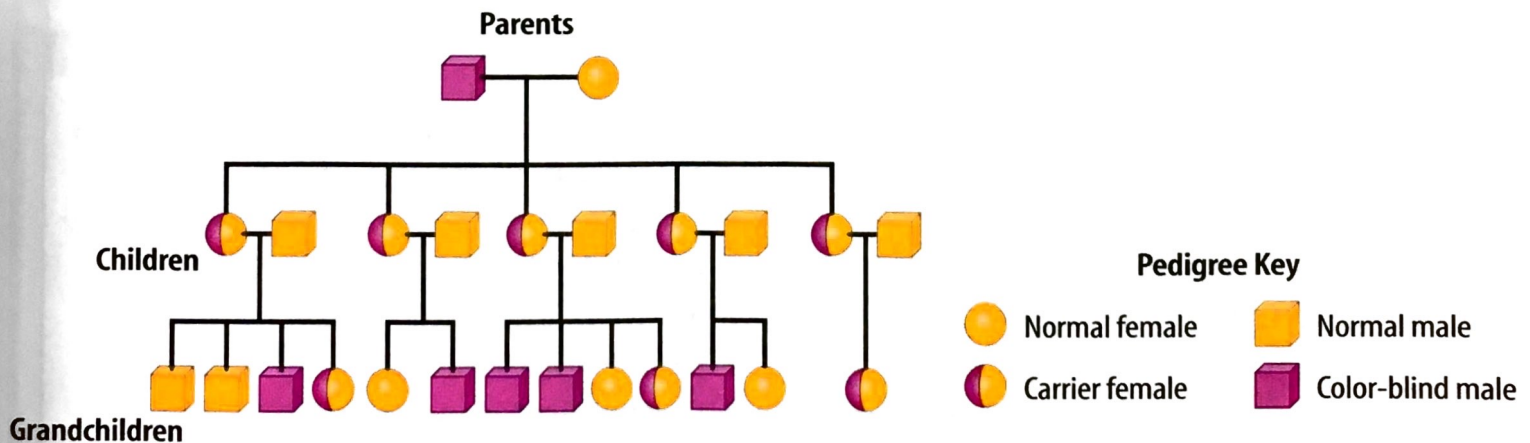


Figure 10
 The symbols in this pedigree's key mean the same thing on all pedigree charts. The grandfather in this family was color-blind and married to a woman who was not a carrier of the color-blind allele. *Why are no women in this family color-blind?*



B



Figure 11

A variety of traits are considered when breeding dogs. **A** Black Labrador retrievers often are bred to be sporting dogs.

B Shih tzus are usually companion or show dogs.

Using Pedigrees A pedigree is a useful tool for a geneticist. Sometimes a geneticist needs to understand who has had a trait in a family over several generations to determine its pattern of inheritance. A geneticist determines if a trait is recessive, dominant, sex-linked, or has some other pattern of inheritance. When geneticists understand how a trait is inherited, they can predict the probability that a baby will be born with a specific trait.



Reading Check

Why is a pedigree a useful tool for a geneticist?

Pedigrees also are important in breeding animals or plants. Because livestock and plant crops are used as sources of food, these organisms are bred to increase their yield and nutritional content. Breeders of pets and show animals, like the dogs pictured in **Figure 11**, also examine pedigrees carefully for possible desirable physical and ability traits. Issues concerning health also are considered when researching pedigrees.

Section

2

Assessment

1. Compare inheritance by multiple alleles and polygenic inheritance.
2. Explain why a trait inherited by incomplete dominance, such as the color of Appaloosa horses, is not a blend of two alleles.
3. Describe two genetic disorders and discuss how they are inherited.
4. Using a Punnett square, explain why males are affected more often than females by sex-linked genetic disorders.
5. **Think Critically** Calico male cats are rare. Explain how such a cat can exist.

Skill Builder Activities

6. **Predicting** A man with blood type B marries a woman with blood type A. Their first child has blood type O. Predict what other blood types are possible for their future children. Explain your answer using a Punnett square. **For more help, refer to the Science Skill Handbook.**
7. **Communicating** In your Science Journal, write an essay that explains why the offspring of two parents may or may not show much resemblance to either parent. **For more help, refer to the Science Skill Handbook.**