

section 1 Genetics

Before You Read

Think of a parent and a child that you know. On the lines below, list four ways the child looks like the parent.

What You'll Learn

- how traits are inherited
- Mendel's role in the history of genetics
- how to use a Punnett square
- the difference between genotype and phenotype


Read to Learn

Inheriting Traits

Do you look more like one parent or grandparent? Do you have your father's eyes? Eye color, nose shape, and many other physical features are traits. Traits also include things that cannot be seen, such as your blood type. An organism is a collection of traits, all inherited from its parents.

Heredity (huh REH duh tee) is the passing of traits from parent to offspring, or children.

What is genetics?

Usually, genes on chromosomes control an organism's shape and function. The different forms of a trait that a gene may have are called **alleles** (uh LEELZ). When a pair of chromosomes separates during meiosis (mi OH sus), alleles for each trait also separate into different sex cells. As a result, every sex cell has one allele for each trait, as shown in the figure on the next page. The allele in one sex cell may control one form of the trait, such as dimples. The allele in another sex cell may control a different form of the trait, such as no dimples. The study of how traits are inherited through the interactions of alleles is called **genetics** (juh NE tihks). 

Study Coach

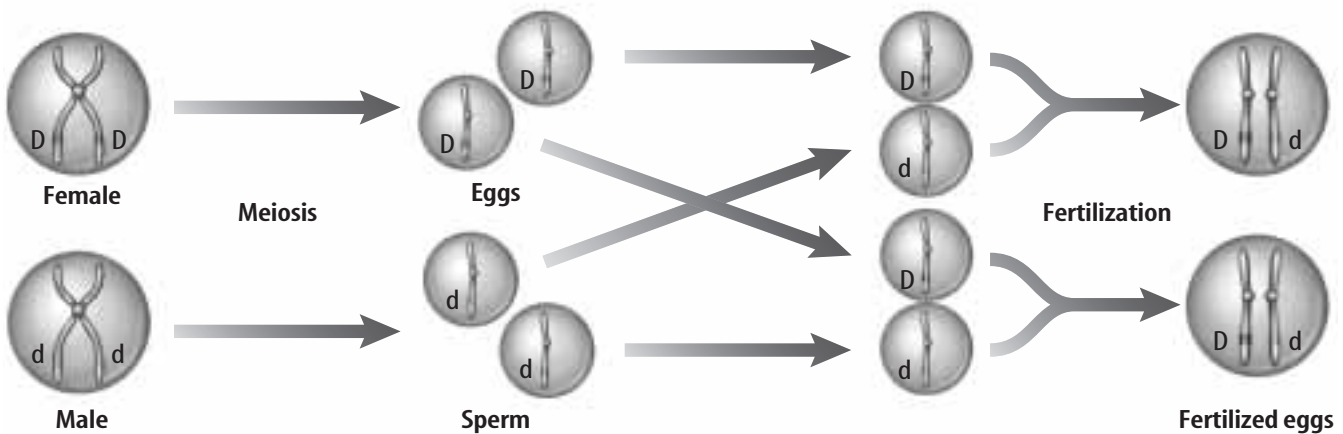
Create a Vocabulary Quiz

Write a question about each vocabulary word or term in the section. Exchange quizzes with another student. Together discuss the answers to the quizzes.

Reading Check

1. **Define** the word genetics.

Chromosomes Separate During Meiosis



A The alleles that control a trait are located on each duplicated chromosome.

B During meiosis, duplicated chromosomes separate.

C During fertilization, each parent donates one chromosome. This results in two alleles for the trait in the new individual formed.

Picture This

2. Identify Circle the sex cells on the diagram.

Think it Over

3. Analyze When Mendel studied traits, how did his methods differ from those of other scientists?

Mendel—The Father of Genetics

Did you know that an experiment with pea plants helped scientists understand why your eyes are the color they are? Gregor Mendel was an Austrian monk who studied mathematics and science. His job at the monastery where he lived was gardening. His interest in plants began as a boy in his father's orchards. He learned to predict the possible types of flowers and fruits that would result from crossbreeding plants.

In 1856, Mendel began experimenting with garden peas. He wanted to know the connection between the color of a pea flower and the type of seed the plant produced. Before Mendel, scientists relied on observation and description. They often studied many traits at one time. This made it hard to develop good hypotheses about how traits are inherited. Mendel used scientific methods in his study. Mendel was the first person to trace one trait through many generations. He was the first person to record the study of how traits pass from one generation to another. He was also the first person to use the mathematics of probability to explain heredity.

In 1900, three plant scientists repeated Mendel's experiments and reached the same conclusions as Mendel. For this reason, Mendel is known as the father of genetics.

Genetics in a Garden















When Mendel studied a trait, he crossed two plants with different forms of the trait. He found that the new plants all looked like one of the two parents. Mendel called each new plant a **hybrid** (HI brud) because it received different genetic information, or different alleles, for a trait from each parent.

What is a purebred?

Garden peas are easy to breed for pure traits. An organism that always produces the same traits, generation after generation, is called a purebred. For example, plants can be purebred for the trait of tall height. The table below shows the pea plant traits that Mendel studied.

Picture This

4. Identify How many traits did Mendel study?

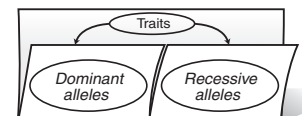
Traits Compared by Mendel							
Traits	Shape of Seeds	Color of Seeds	Color of Pods	Shape of Pods	Plant Height	Position of Flowers	Flower Color
Dominant Trait	 Round	 Yellow	 Green	 Full	 Tall	 At leaf junctions	 Purple
Recessive Trait	 Wrinkled	 Green	 Yellow	 Flat, constricted	 Short	 At tips of branches	 White

What are dominant and recessive factors?

In nature, insects carry pollen as they move from plant to plant. The pollination by insects is random. In his experiments, Mendel pollinated the plants by hand to control the results. He used pollen from the flowers of purebred tall plants to pollinate the flowers of purebred short plants. This process is called cross-pollination. He found that tall plants crossed with short plants produced seeds that produced all tall plants. Mendel called the tall form the **dominant** (DAH muh nunt) factor because it dominated, or covered up, the short form. He called the short form the **recessive** (rih SE sihv) factor because this form seemed to disappear. Today, these factors are called dominant alleles and recessive alleles.

FOLDABLES™

A Describe Make a two-tab Foldable, as shown below. Write notes under the tabs to describe dominant and recessive alleles.



Reading Check

5. **Identify** How is a dominant allele shown in a Punnett square?


Think it Over

6. **Contrast** What is the difference between a homozygous organism and a heterozygous organism?

What is probability?

A branch of mathematics that helps you predict the chance that something will happen is called probability. For example, there are two sides to a coin. If you toss the coin in the air, the probability that one side of the coin will land facing up is one out of two, or 50 percent. Mendel used probabilities in his study of genetics. His predictions were very accurate because he studied large numbers of plants over a long period of time. He studied almost 30,000 pea plants over a period of eight years. This increased Mendel's chances of seeing a repeatable pattern. Valid scientific conclusions need to be based on results that can be repeated.

What is a Punnett square?

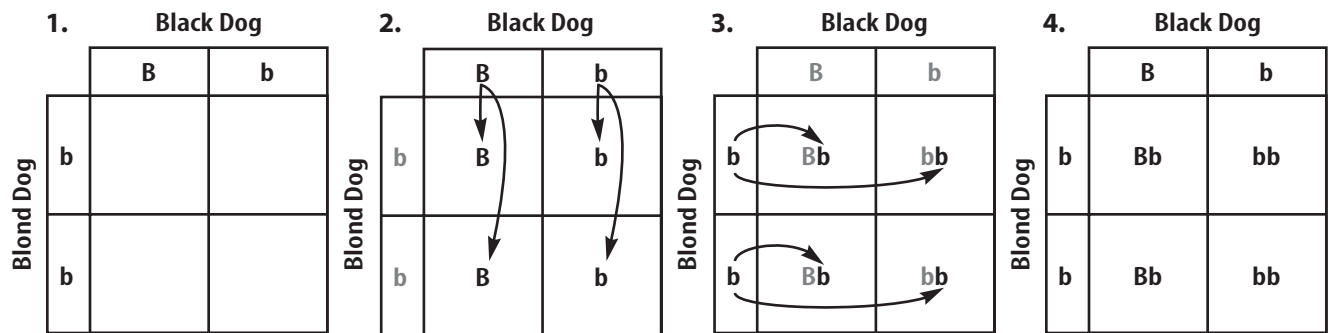
Scientists use a tool called a Punnett (PUH nut) square to predict results in genetics. A **Punnett square** is used to predict the number of times certain traits will occur. In a Punnett square, letters stand for dominant and recessive alleles. An uppercase letter stands for a dominant allele, and a lowercase letter stands for a recessive allele. The letters are a form of code. They show the **genotype** (JEE nuh tipe), or genetic makeup, of an organism. The way an organism looks and behaves as a result of its genotype is its **phenotype** (FEE nuh tipe). If you have brown hair, the phenotype for your hair color is brown. 

How do alleles determine traits?

Most cells in your body have two alleles for every trait. An organism with two alleles that are the same is called **homozygous** (hoh muh ZI gus). In his experiments, Mendel would have written *TT* (homozygous for the tall-dominant trait) or *tt* (homozygous for the short-recessive trait). An organism that has two different alleles for a trait is called **heterozygous** (he tuh roh ZI gus). Mendel would have written *Tt* for plant hybrids that were heterozygous for height.

How do you make a Punnett square?

The letters representing the two alleles from one parent are written in the top row of the Punnett square. The letters representing the two alleles from the other parent are written down the left column. Each square in the grid is then filled in with one allele from each parent. The combinations of letters in the completed Punnett square are the genotypes of the possible offspring those parents could produce.



How do you use a Punnett square?

You want to know the possible offspring of two dogs. One dog carries heterozygous black-fur traits (Bb). The other dog carries homogeneous blond-fur traits (bb). How do you complete the Punnett square to find the results? Follow the steps in the figure above.

1. Write the letters representing the alleles from the black dog (Bb) in the top row. Write the letters from the blond dog (bb) in the left column.
2. Write the letter in each column (B or b) in the two squares for that column.
3. Add the letter for each row (b or b) to the squares. You then have two letters in each square.
4. The squares show the possible genotypes of the offspring.

An offspring with a Bb genotype will have black fur, and an offspring with a bb genotype will have blond fur. In this case, there is one chance in two, or a 50 percent chance, that the offspring will have black fur.

What are the main principles of heredity?

Mendel spent many years repeating his experiments and observing the results. He analyzed the results and reached several conclusions. Mendel's principles of heredity are summarized in the table below.

Mendel's Principles of Heredity
Traits are controlled by alleles on chromosomes.
An allele's effect is dominant or recessive.
When a pair of chromosomes separates during meiosis, the different alleles for a trait move into separate sex cells.

Picture This

- 7. Identify** In step 4, shade the two squares that would result in an offspring with blond fur.

Think it Over

- 8. Explain** What controls traits?

● After You Read

Mini Glossary

alleles (uh LEELZ): the different forms of a trait that a gene may have

dominant (DAH muh nunt): factor that dominates, or covers up, another factor

genetics (juh NE tihks): the study of how traits are inherited through the interactions of alleles

genotype (JEE nuh tipe): genetic makeup of an organism

heredity (huh REH duh tee): passing of traits from parent to offspring

heterozygous (he tuh roh ZI gus): an organism that has two different alleles for a trait

homozygous (hoh muh ZI gus): an organism with two alleles that are the same for a trait

hybrid (HI brud): a plant that receives different genetic information for a trait from each parent

phenotype (FEE nuh tipe): the way an organism looks and behaves as a result of its genotype

Punnett (PUH nut) square: a tool used to predict the number of times certain traits will occur

recessive (rih SE sihv): factor that disappears if a dominant trait is present

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between a dominant allele and a recessive allele.

2. Complete the Punnett square below to show the probability of an offspring having the DD , Dd , and the dd genotypes.

	D	d
D		
d		

3. How can taking a quiz that another student wrote help you prepare for a test?



Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about genetics.

section 2 Genetics Since Mendel

Before You Read

At dog and cat shows, an animal's owner may be asked to show its pedigree. What do you think a pedigree shows?

What You'll Learn

- how traits are inherited by incomplete dominance
- the difference between multiple alleles and polygenic inheritance
- how sex-linked traits are passed to offspring

Read to Learn

Incomplete Dominance

A scientist crossed purebred red four-o'clock plants with purebred white four-o'clock plants. He thought the new plants would have all red flowers, but they were pink. Neither allele for flower color was dominant. Next, he crossed the pink-flowered plants with each other. The new plants had red, white, and pink flowers.

He discovered that when the allele for red flowers and the allele for white flowers combined, the result included red flowers, white flowers, and an intermediate, or in-between, phenotype—pink flowers. When the offspring of two homozygous parents show an intermediate phenotype, this inheritance is called **incomplete dominance**.

What are multiple alleles?

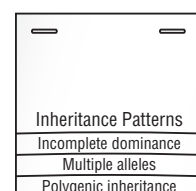
A trait that is controlled by more than two alleles is said to be controlled by multiple alleles. A trait controlled by multiple alleles will produce more than three phenotypes of that trait.

Mark the Text

Build Vocabulary Skim the section, circling any words you do not know. After you read the section, review the circled words. Write any words you cannot define on a separate sheet of paper and look up the definitions.

FOLDABLES™

B Explain Make a layered-look Foldable, as shown below. Write notes under the flaps to explain inheritance patterns.




Reading Check

1. **Identify** What are the six different blood type genotypes?

Think it Over

2. **Draw Conclusions**
What environmental factors might affect the size of leaves on a tree?

What traits are controlled by multiple alleles?

Blood type in humans is an example of a trait controlled by multiple alleles. The alleles for blood type produce six genotypes but only four phenotypes. The alleles for blood type 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, his or her phenotype is AB. A person with phenotype A blood has the genotype AA or AO. Someone with the phenotype B blood has the genotype BB or BO. A person with phenotype O blood has the genotype OO. 

Polygenic Inheritance

Eye color is an example of a trait that is produced by a combination of many genes, or polygenic (pah lih JEH nihk) inheritance. **Polygenic inheritance** occurs when a group of gene pairs acts together to produce a trait. Polygenic inheritance results in a wide variety of phenotypes. Examine the eye colors of your classmates. You will likely notice many different shades. For example, you may notice several shades of brown, several shades of green, and so on.

How does the environment affect your genes?

Your environment plays a role in how some of your genes are expressed. Genes can be influenced by an organism's internal or external environment. For example, most male birds are more brightly colored than females. Chemicals in their bodies determine whether or not the gene for brightly colored feathers is expressed.

Your environment plays a role in whether your genes are expressed at all. For example, some people have genes that make them at risk for developing skin cancer. Whether or not they get cancer might depend on external environmental factors. If people who are at risk for skin cancer limit their time in the sun and take care of their skin, they may never develop skin cancer.


Human Genes and Mutations

Sometimes genes change. Also, sometimes errors occur in the DNA when it is being copied during cell division. These changes and errors are called mutations. Many mutations are harmful. Some mutations are helpful or have no effect on an organism. Certain chemicals, X rays, and radioactive materials can cause mutations.

What are chromosome disorders?

Problems can happen if the incorrect number of chromosomes is inherited. Mistakes in the process of meiosis can result in an organism with more or fewer chromosomes than normal. Down syndrome is a disorder in which the person has one more chromosome than normal.


Recessive Genetic Disorders

Many human genetic disorders are caused by recessive genes. Such genetic disorders occur when both parents have a recessive allele responsible for the disorder. Because the parents are heterozygous, they do not show any symptoms of the disorder. However, if each parent passes a recessive allele to the child, the child inherits two recessive alleles and will have the disorder. Cystic fibrosis is a homozygous recessive disorder. It is the most common genetic disorder that can lead to death among Caucasian Americans. People with cystic fibrosis produce thicker mucus than normal. The thick mucus builds up in the lungs and makes it hard to breathe. 

Gender Determination

Each egg produced by a female normally contains one X chromosome. Males produce sperm that normally have either one X or one Y chromosome. When a sperm with an X chromosome fertilizes an egg, the offspring is a female, XX. When a sperm with a Y chromosome fertilizes an egg, the offspring is a male, XY. Sometimes chromosomes do not separate during meiosis. When this happens, a person can inherit an unusual number of sex chromosomes.

Sex-Linked Disorders

A sex-linked gene is an allele on a sex chromosome. Some conditions that result from inheriting sex-linked genes are called sex-linked disorders. Red-green colorblindness in humans is a sex-linked disorder because the related genes are on the X chromosome. People with this disorder have difficulty seeing the difference between green and red, and sometimes yellow. A female is color-blind when each of her X chromosomes has the recessive allele. A male has only one X chromosome. If his X chromosome has the recessive allele, he will be color-blind. 

Reading Check

- 3. Explain** How is cystic fibrosis inherited?

Reading Check

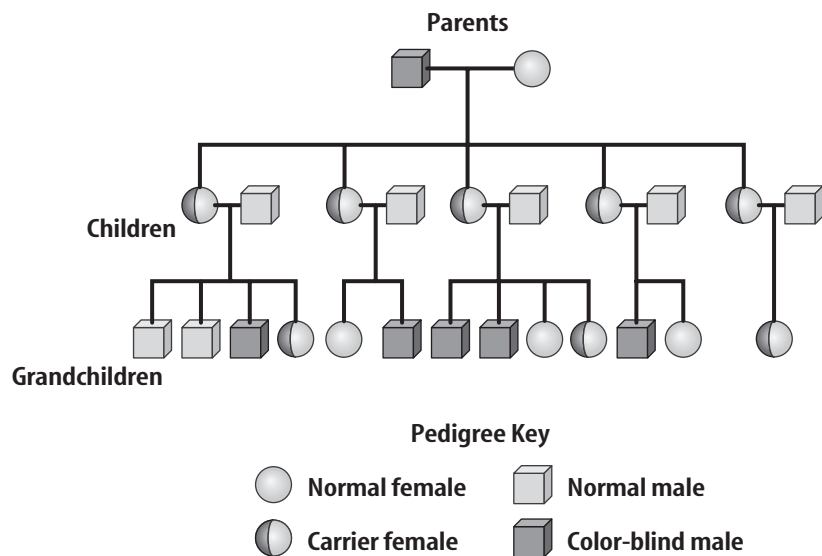
- 4. Identify** What is one sex-linked disorder?

Pedigrees Trace Traits

You can trace a trait through a family using a pedigree like the one shown below. Males are represented by squares. Females are represented by circles. A completely filled square or circle shows that the person has the trait. A half-colored square or circle shows that the person carries an allele for the trait, but does not have the trait. The pedigree in the figure below shows how the trait for color blindness is carried through a family. In this pedigree, the grandfather was color blind. He married a woman who did not carry the color-blind allele.

Picture This

5. **Infer** In the pedigree, why are there no color-blind women in this family?



How can pedigrees be helpful?

A pedigree can be used by a geneticist to trace a trait in members of a family over several generations. The pedigree allows the geneticist to determine the trait's pattern of inheritance. The geneticist can identify if the trait is recessive, dominant, sex-linked, or follows some other pattern. Geneticists use this information to predict the probability that a baby will be born with a specific trait.

Pedigrees also are used to breed animals and plants for desirable traits. Livestock and plant crops are food sources for humans. Using pedigrees, these organisms can be bred to increase their yield and nutritional content.

Think it Over

6. **Draw Conclusions**

Why do you think pedigrees are important for animals bred for show, such as dogs?

● After You Read

Mini Glossary

incomplete dominance: the offspring of two homozygous parents show an intermediate phenotype

polygenic (pah lih JEH nihk) inheritance: a group of gene pairs act together to produce a trait

sex-linked gene: an allele inherited on a sex chromosome

1. Review the terms and their definitions in the Mini Glossary. Choose one term and use it to explain one way that traits can be inherited.

2. Choose one of the question headings in the Read to Learn section. Write the question in the space below. Then write your answer to that question on the lines that follow.

Write your question here.

3. List the words that you circled in the Read to Learn section. Select one of those words and write its definition below.



section ③ Biotechnology

What You'll Learn

- the importance of advances in genetics
- the steps in making genetically engineered organisms

● Before You Read

Describe on the lines below what you have heard or read about recent advances in medical research.



Identify Main Points

Highlight the main idea in each paragraph. Underline the details that support the main idea.

● Read to Learn

Why is genetics important?

New developments in genetic research are happening all the time. The principles of heredity are being used to change the world.

Genetic Engineering

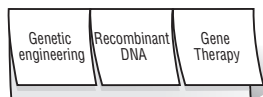
Genetic engineering is the use of biological and chemical methods to change the arrangement of DNA that makes up a gene. One use for genetic engineering is to produce large amounts of different medicines. Genes also can be inserted into cells to change how those cells perform their normal functions. Genetic engineering researchers are also looking for new ways to improve crop production and quality.

How is recombinant DNA made?


Making recombinant DNA is one method of genetic engineering. Recombinant DNA is made by inserting a useful section of DNA from one organism into a bacterium. This process is used to make large amounts of insulin, which is used to treat diabetes. Other uses include the production of a growth hormone to treat dwarfism and chemicals used to treat cancer.

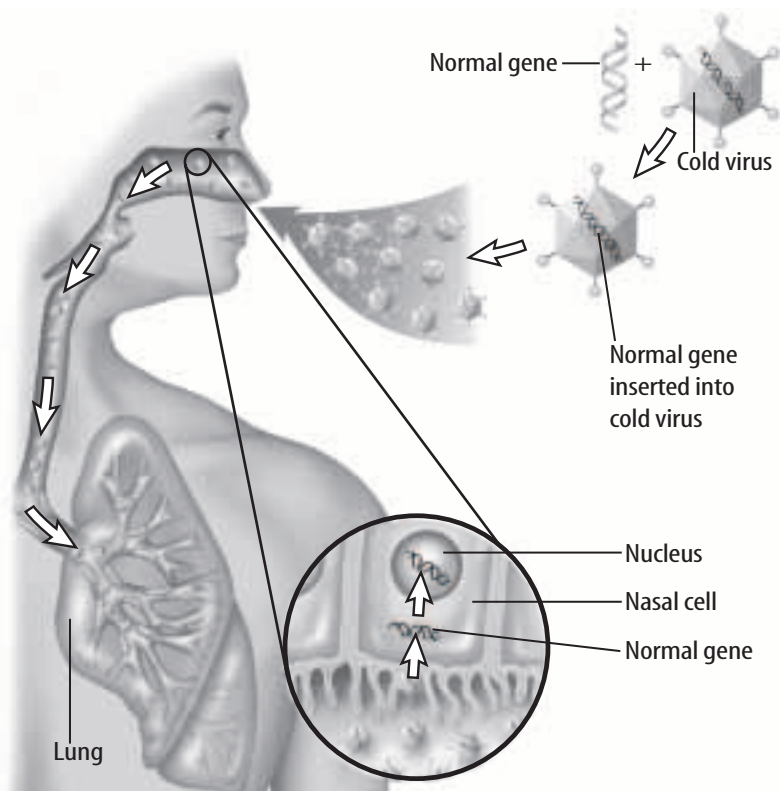


Describe Make a three-tab book, as shown below. Use the Foldable to describe genetic engineering, recombinant DNA, and gene therapy.



How does gene transfer work?

Another application of genetic-engineering is gene transfer. A goal of this experimental procedure is to replace abnormal genetic material with normal genetic material. First, normal DNA or RNA is placed in a virus. Then the virus delivers the normal DNA or RNA to target cells, as shown in the figure below. Gene transfer, also known as gene therapy, might help correct genetic disorders such as cystic fibrosis. It also is being studied as a possible treatment for cancer, heart disease, and certain infectious diseases. 



Reading Check

1. **Identify** What is replaced in gene therapy?

Picture This

2. **Explain** Use the figure to explain to a partner how gene therapy works.

How are plants genetically engineered?

Before people knew about genotypes, they selected plants with the most desired traits to breed for the next generation. This process is called selective breeding. Today people also use genetic engineering to improve crop plants. One method is to find the genes that produce desired traits in one plant and then insert those genes into a different plant. Scientists recently made genetically engineered tomatoes with a gene that allows them to be picked green. As these tomatoes are being sent to stores, they continue to ripen. You can then buy ripe, firm tomatoes in the store. The long-term effects of eating genetically engineered plants are not known.

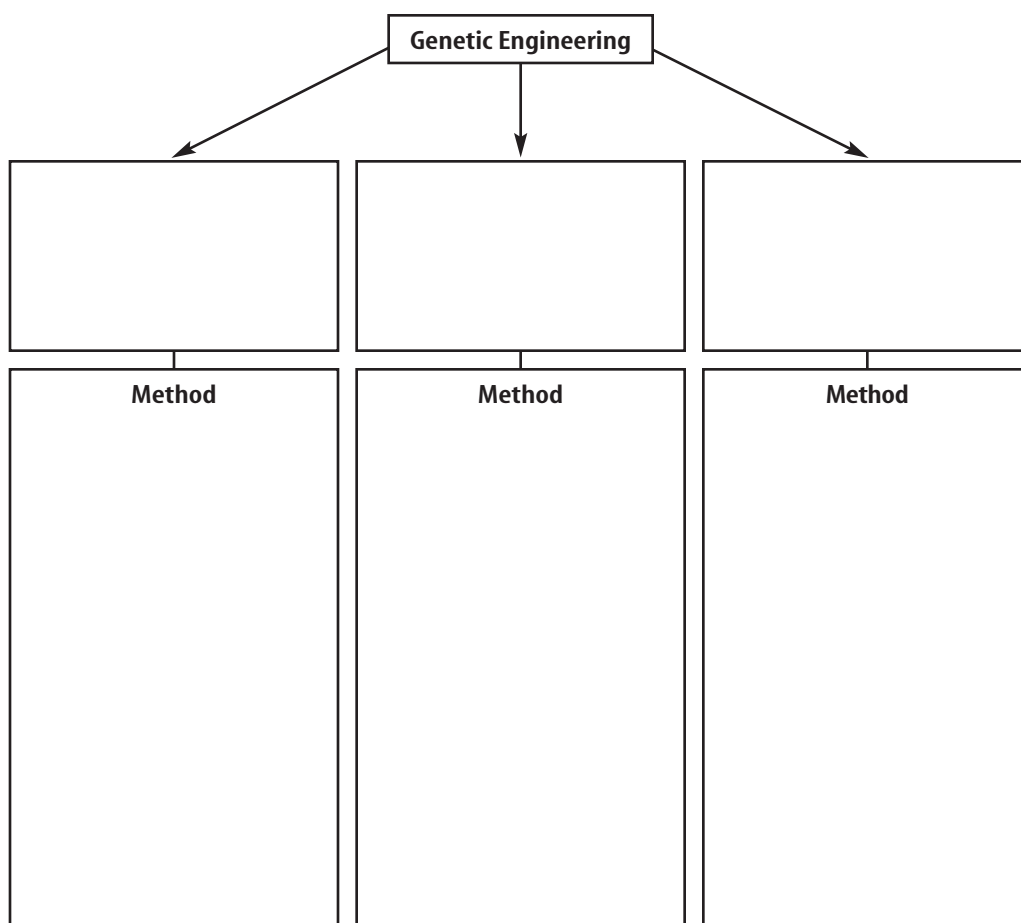
● After You Read

Mini Glossary

genetic engineering: biological and chemical methods to change the arrangement of DNA that makes up a gene

1. Review the term and its definition in the Mini Glossary. Write a sentence that explains how genetic engineering can improve crop plants.

2. Complete the concept web below to show three kinds of genetic engineering and the methods used to carry them out.



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