Chapter 5

Genetics

THE BIG IDEA

How are traits passed from parents to offspring?

inquiry

How did this happen?

The color of this calf is caused by a genetic trait called albinism. Albinism is the absence of body pigment. Notice that the calf's mother has brown fur.

- Why do you think the calf looks so different from its mother?
- What do you think determines the color of the offspring?
- How do you think traits are passed from generation to generation?

Get Ready to Read

What do you think?

Before you read, decide if you agree or disagree with each of these statements. As you read this chapter, see if you change your mind about any of the statements.

1. Like mixing paints, parents' traits always blend in their offspring.
2. If you look more like your mother than you look like your father, then you received more traits from your mother.
3. All inherited traits follow Mendel's patterns of inheritance.
4. Scientists have tools to predict the form of a trait an offspring might inherit.
5. New DNA is copied from existing DNA.
6. A change in the sequence of an organism's DNA always changes the organism's traits.

Lesson 1

Mendel and His Peas

Reading Guide

Key Concepts

ESSENTIAL QUESTIONS

- Why did Mendel perform cross-pollination experiments?
- What did Mendel conclude about inherited traits?
- How do dominant and recessive factors interact?

Vocabulary

heredity p. 149

genetics p. 149

dominant trait p. 155

recessive trait p. 155

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Inquiry Same Species?

Have you ever seen a black ladybug? It is less common than the orange variety you might know, but both are the same species of beetle. So why do they look different? Believe it or not, a study of pea plants helped scientists explain these differences.

What makes you unique?

Traits such as eye color have many different types, but some traits have only two types. By a show of hands, determine how many students in your class have each type of trait below.

Student Traits

Trait	Type 1	Type 2
Earlobes	 Unattached	 Attached
Thumbs	 Curved	 Straight
Interlacing fingers	 Left thumb over right thumb	 Right thumb over left thumb

Think About This

1. Why might some students have types of traits that others do not have?
2. If a person has dimples, do you think his or her offspring will have dimples? Explain.
3. **Key Concept** What do you think determines the types of traits you inherit?

Early Ideas About Heredity

Have you ever mixed two paint colors to make a new color? Long ago, people thought an organism's characteristics, or traits, mixed like colors of paint because offspring resembled both parents. This is known as blending inheritance.

Today, scientists know that **heredity** (huh REH duh tee)–*the passing of traits from parents to offspring*–is more complex. For example, you might have blue eyes but both of your parents have brown eyes. How does this happen? More than 150 years ago, Gregor Mendel, an Austrian monk, performed experiments that helped answer these questions and disprove the idea of blending inheritance. Because of his research, Mendel is known as the father of **genetics** (juh NEH tihks)–*the study of how traits are passed from parents to offspring.*

WORD ORIGIN

genetics
from Greek *genesis*, means "origin"

Mendel's Experimental Methods

During the 1850s, Mendel studied genetics by doing controlled breeding experiments with pea plants. Pea plants were ideal for genetic studies because

- they reproduce quickly. This enabled Mendel to grow many plants and collect a lot of data.
- they have easily observed traits, such as flower color and pea shape. This enabled Mendel to observe whether or not a trait was passed from one generation to the next.
- Mendel could control which pairs of plants reproduced. This enabled him to determine which traits came from which plant pairs.

Pollination in Pea Plants

To observe how a trait was inherited, Mendel controlled which plants pollinated other plants. Pollination occurs when pollen lands on the pistil of a flower. **Sperm** cells from the pollen then can fertilize **egg** cells in the pistil. Pollination in pea plants can occur in two ways. Self-pollination occurs when pollen from one plant lands on the pistil of a flower on the same plant, as shown in **Figure 1.** Cross-pollination occurs when pollen from one plant reaches the pistil of a flower on a different plant. Cross-pollination occurs naturally when wind, water, or animals such as bees carry pollen from one flower to another. Mendel allowed one group of flowers to self-pollinate. With another group, he cross-pollinated the plants himself.

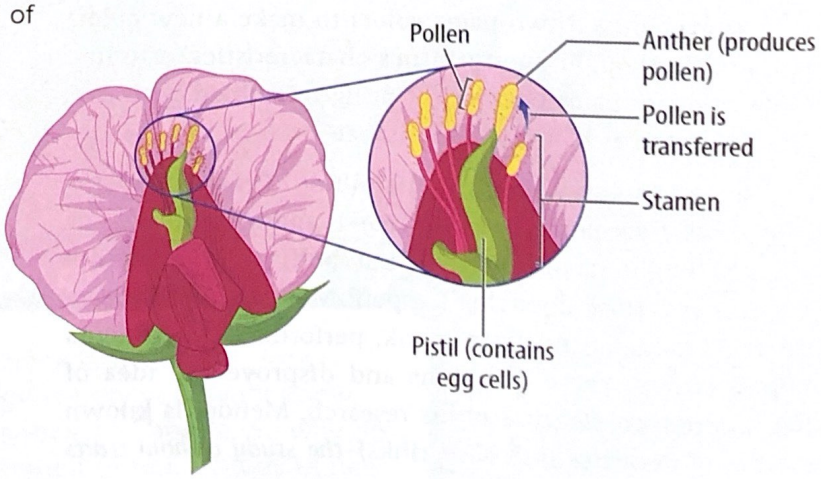
REVIEW VOCABULARY

sperm
a haploid sex cell formed in the male reproductive organs

egg
a haploid sex cell formed in the female reproductive organs

Self-Pollination

Figure 1 Self-pollination occurs when pollen from a stamen lands on a pistil of the same flower or on another flower on the same plant.



True-Breeding Plants

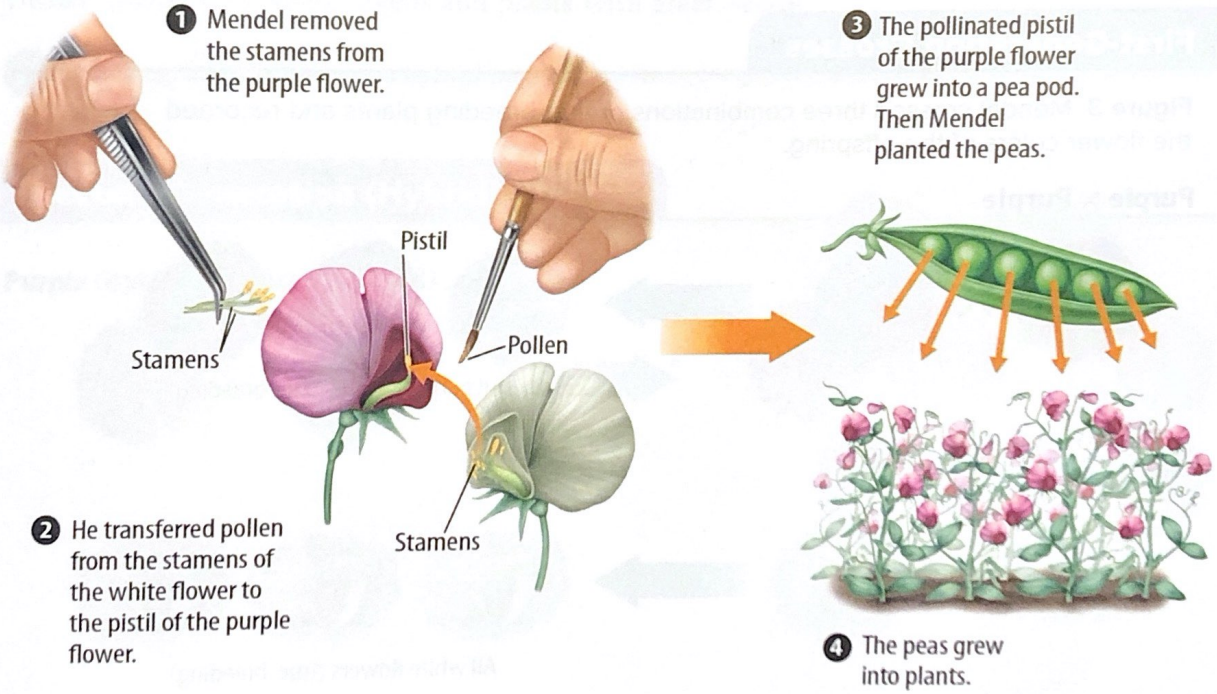
Mendel began his experiments with plants that were true-breeding for the trait he would test. When a true-breeding plant self-pollinates, it always produces offspring with traits that match the parent. For example, when a true-breeding pea plant with wrinkled seeds self-pollinates, it produces only plants with wrinkled seeds. In fact, plants with wrinkled seeds appear generation after generation.

Mendel's Cross-Pollination

By cross-pollinating plants himself, Mendel was able to select which plants pollinated other plants. Figure 2 shows an example of a manual cross between a plant with white flowers and one with purple flowers.

Figure 2 Mendel removed the stamens of one flower and pollinated that flower with pollen from a flower of a different plant. In this way, he controlled pollination.

Cross-Pollination



Mendel cross-pollinated hundreds of plants for each set of traits, such as flower color–purple or white; seed color–green or yellow; and seed shape–round or wrinkled. With each cross-pollination, Mendel recorded the traits that appeared in the offspring. By testing such a large number of plants, Mendel was able to predict which crosses would produce which traits.

Key Concept Check Why did Mendel perform cross-pollination experiments?

Mendel's Results

Once Mendel had enough true-breeding plants for a trait that he wanted to test, he cross-pollinated selected plants. His results are shown in Figure 3.

First-Generation Crosses

A cross between true-breeding plants with purple flowers produced plants with only purple flowers. A cross between true-breeding plants with white flowers produced plants with only white flowers. But something unexpected happened when Mendel crossed true-breeding plants with purple flowers and true-breeding plants with white flowers–all the offspring had purple flowers.

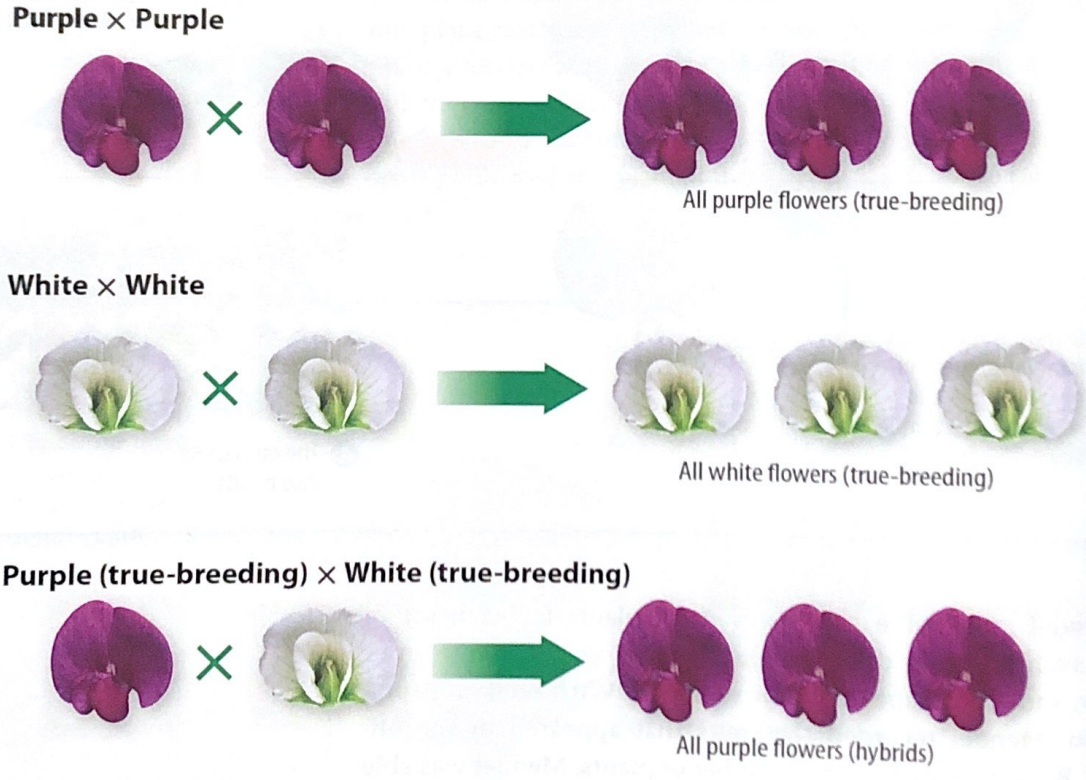
New Questions Raised

The results of the crosses between true-breeding plants with purple flowers and true-breeding plants with white flowers led to more questions for Mendel. Why did all the offspring always have purple flowers? Why were there no white flowers? Why didn't the cross produce offspring with pink flowers–a combination of the white and purple flower colors? Mendel carried out more experiments with pea plants to answer these questions.

Reading Check Predict the offspring of a cross between two true-breeding pea plants with smooth seeds.

First-Generation Crosses

Figure 3 Mendel crossed three combinations of true-breeding plants and recorded the flower colors of the offspring.



Visual Check Suppose you cross hundreds of true-breeding plants with purple flowers with hundreds of true-breeding plants with white flowers. Based on the results of this cross in the figure above, would any offspring produce white flowers? Explain.

Second-Generation (Hybrid) Crosses

The first-generation purple-flowering plants are called **hybrid** plants. This means they came from true-breeding parent plants with different forms of the same trait. Mendel wondered what would happen if he cross-pollinated two purple-flowering hybrid plants.

As shown in **Figure 4**, some of the offspring had white flowers, even though both parents had purple flowers. The results were similar each time Mendel cross-pollinated two hybrid plants. The trait that had disappeared in the first generation always reappeared in the second generation.

The same result happened when Mendel cross-pollinated pea plants for other traits. For example, he found that cross-pollinating a true-breeding yellow-seeded pea plant with a true-breeding green-seeded pea plant always produced yellow-seeded hybrids. A second-generation cross of two yellow-seeded hybrids always yielded plants with yellow seeds and plants with green seeds.

Reading Check What is a hybrid plant?

SCIENCE USE V. COMMON USE

hybrid

Science Use the offspring of two animals or plants with different forms of the same trait

Common Use having two types of components that perform the same function, such as a vehicle powered by both a gas engine and an electric motor

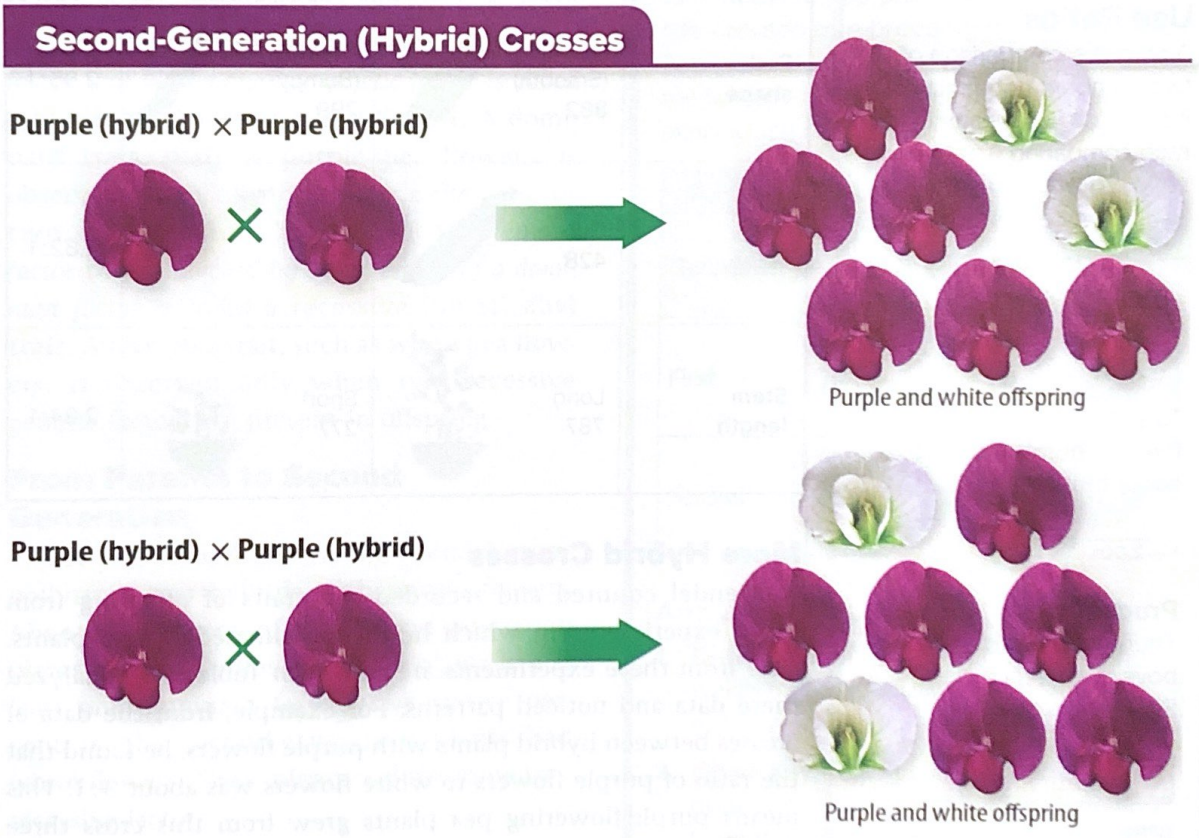
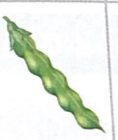


Figure 4 Mendel cross-pollinated first-generation hybrid offspring to produce second-generation offspring. In each case, the trait that had disappeared from the first generation reappeared in the second generation.

Interactive Table

Table 1 When Mendel crossed two hybrids for a given trait, the trait that had disappeared then reappeared in a ratio of about 3:1.

Table 1 Results of Hybrid Crosses

Characteristic	Trait and Number of Offspring	Trait and Number of Offspring	Ratio
Flower color	Purple 705 	White 224 	3.15:1
Flower position	Axial (Side of stem) 651 	Terminal (End of stem) 207 	3.14:1
Seed color	Yellow 6,022 	Green 2,001 	3.01:1
Seed shape	Round 5,474 	Wrinkled 1,850 	2.96:1
Pod shape	Inflated (Smooth) 882 	Constricted (Bumpy) 299 	2.95:1
Pod color	Green 428 	Yellow 152 	2.82:
Stem length	Long 787 	Short 277 	2.84

Math Skills

Use Ratios

A ratio is a comparison of two numbers or quantities by division. For example, the ratio comparing 6,022 yellow seeds to 2,001 green seeds can be written as follows:

6,022 to 2,001 or

6,022 : 2,001 or

$\frac{6,022}{2,001}$

To simplify the ratio, divide the first number by the second number.

$\frac{6,022}{2,001} = \frac{3}{1}$ or 3:1

Practice

There are 14 girls and 7 boys in a science class. Simplify the ratio.

Math Practice

Personal Tutor

More Hybrid Crosses

Mendel counted and recorded the traits of offspring many experiments in which he cross-pollinated hybrid pl Data from these experiments are shown in **Table 1.** He ana these data and noticed patterns. For example, from the d crosses between hybrid plants with purple flowers, he foun the ratio of purple flowers to white flowers was about 3:1 means purple-flowering pea plants grew from this cross times more often than white-flowering pea plants grew fr cross. He calculated similar ratios for all seven traits he te

Mendel's Conclusions

After analyzing the results of his experiments, Mendel concluded that two genetic factors control each inherited trait. He also proposed that when organisms reproduce, each reproductive cell–sperm or egg–contributes one factor for each trait.

Key Concept Check What did Mendel conclude about inherited traits?

Dominant and Recessive Traits

Recall that when Mendel cross-pollinated a true-breeding plant with purple flowers and a true-breeding plant with white flowers, the hybrid offspring had only purple flowers. Mendel hypothesized that the hybrid offspring had one genetic factor for purple flowers and one genetic factor for white flowers. But why were there no white flowers?

Mendel also hypothesized that the purple factor is the only factor seen or expressed because it blocks the white factor. *A genetic factor that blocks another genetic factor is called a* **dominant** (DAH muh nunt) **trait.** A dominant trait, such as purple pea flowers, is observed when offspring have either one or two dominant factors. *A genetic factor that is blocked by the presence of a dominant factor is called a* **recessive** (rih SE sihv) **trait.** A recessive trait, such as white pea flowers, is observed only when two recessive genetic factors are present in offspring.

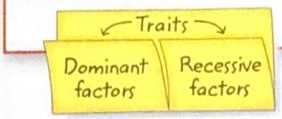
From Parents to Second Generation

For the second generation, Mendel cross-pollinated two hybrids with purple flowers. About 75 percent of the second-generation plants had purple flowers. These plants had at least one dominant factor. Twenty-five percent of the second-generation plants had white flowers. These plants had the same two recessive factors.

Key Concept Check How do dominant and recessive factors interact?

FOLDABLES

Make a vertical two-tab book and label it as shown. Use it to organize your notes on dominant and recessive factors.



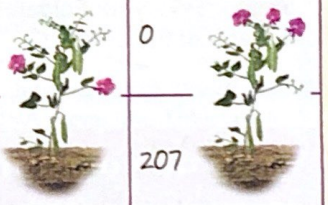
MiniLab 20 minutes

Which is the dominant trait?

Imagine you are Gregor Mendel's lab assistant studying pea plant heredity. Mendel has crossed true-breeding plants with axial flowers and true-breeding plants with terminal flowers. Use the data below to determine which trait is dominant.

Pea Flower Location Results

Generation	Axial (Number of Offspring)	Terminal (Number of Offspring)
First	794	0
Second	651	207



Analyze and Conclude

1. **Determine** which trait is dominant and which trait is recessive. Support your answer with data.
2. **Key Concept** Analyze the first-generation data. What evidence do you have that one trait is dominant over the other?

Lesson 1 Review

Online Quiz

Visual Summary

Genetics is the study of how traits are passed from parents to offspring.

Mendel studied genetics by doing cross-breeding experiments with pea plants.

Purple 705

White 224

Mendel's experiments with pea plants showed that some traits are dominant and others are recessive.

FOLDABLES

Use your lesson Foldable to review the lesson. Save your Foldable for the project at the end of the chapter.

What do you think NOW?

You first read the statements below at the beginning of the chapter.

1. Like mixing paints, parents' traits always blend in their offspring.
2. If you look more like your mother than you look like your father, then you received more traits from your mother.

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

Use Vocabulary

1. **Distinguish** between heredity and genetics.
2. **Define** the terms *dominant* and *recessive*.
3. **Use the term** *recessive* in a complete sentence.

Understand Key Concepts

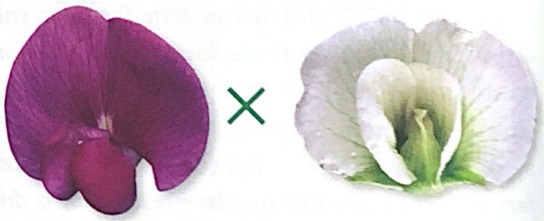
4. A recessive trait is observed when an organism has _____ recessive genetic factor(s).

   A. 0 **C.** 2
   B. 1 **D.** 3

5. **Summarize** Mendel's conclusions about how traits pass from parents to offspring.
6. **Describe** how Mendel cross-pollinated pea plants.

Interpret Graphics

7. **Suppose** the two true-breeding plants shown below were crossed.



What color would the flowers of the offspring be? Explain.

Critical Thinking

8. **Design an experiment** to test for true-breeding plants.
9. **Examine** how Mendel's conclusions disprove blending inheritance.

Math Skills

Math Practice

10. A cross between two pink camellia plants produced the following offspring: 7 plants with red flowers, 7 with white flowers, and 14 with pink flowers. What is the ratio of red to white to pink?

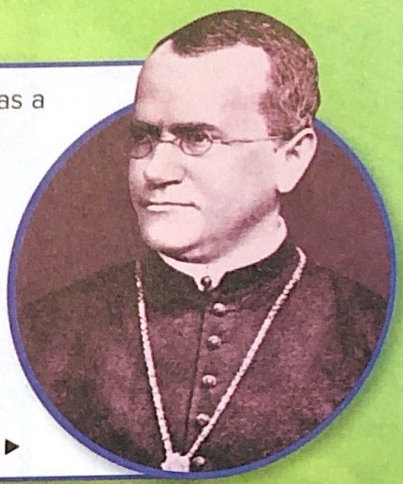
Pioneering the Science of Genetics

SCIENCE & SOCIETY

One man's curiosity leads to a branch of science.

Gregor Mendel—monk, scientist, gardener, and beekeeper—was a keen observer of the world around him. Curious about how traits pass from one generation to the next, he grew and tested almost 30,000 pea plants. Today, Mendel is called the father of genetics. After Mendel published his findings, however, his "laws of heredity" were overlooked for several decades.

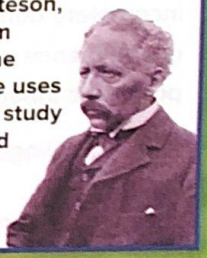
In 1900, three European scientists, working independently of one another, rediscovered Mendel's work and replicated his results. Then, other biologists quickly began to recognize the importance of Mendel's work.



Gregor Mendel ▶

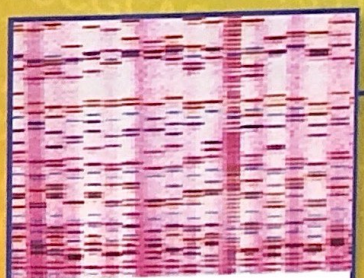
1902: American physician Walter Sutton demonstrates that Mendel's laws of inheritance can be applied to chromosomes. He concludes that chromosomes contain a cell's hereditary material on genes.

1906: William Bateson, a United Kingdom scientist, coins the term *genetics*. He uses it to describe the study of inheritance and the science of biological inheritance.



1952: American geneticists Martha Chase and Alfred Hershey prove that DNA transmits inherited traits from one generation to the next.

1953: Francis Crick and James Watson determine the structure of the DNA molecule. Their work begins the field of molecular biology and leads to important scientific and medical research in genetics.



2003: The National Human Genome Research Institute (NHGRI) completes mapping and sequencing human DNA. Researchers and scientists are now trying to discover the genetic basis for human health and disease.

It's Your Turn

RESEARCH What are some genetic diseases? Report on how genome-based research might help cure these diseases in the future.