Name Date Class

Section 10.1

Mendel's Laws of Heredity

North Carolina Objectives **Objective 3.03** Interpret and predict patterns of inheritance: Dominant, recessive . . . Independent assortment; Punnett squares

Before You Read

Gregor Mendel was a mathematician and a monk. Mendel used his skills in math to understand why some characteristics are passed from parent to offspring and other characteristics are not. On the lines below, tell why you think having math skills is important in life.

Read to Learn

STUDY COACH

Mark the Text **Identify Concepts** Highlight each question head in this section. Then use a different color to highlight the answers to the questions.

Reading Check

1. What is the difference between self-pollination and cross-pollination?

Why Mendel Succeeded

Gregor Mendel, an Austrian monk, discovered important facts about heredity. **Heredity** is the passing on of characteristics from parents to offspring. These characteristics are called **traits.** Mendel was the first person to predict which traits would be passed from parents to offspring. The study of heredity is called **genetics.**

Mendel used garden peas for his experiments. Garden peas produce male and female sex cells called **gametes. Fertilization** occurs when the male sex cell unites, or joins, with the female sex cell. The united gametes form a new fertilized cell called a **zygote** (ZI goht). The zygote becomes part of a seed.

In garden peas, as with most flowers, the male sex cells are the grains of pollen. When pollen is transferred from the male reproductive organ to the female reproductive organ, it is called **pollination.** Garden peas are self-pollinators. That means the pollen from a flower pollinates the female sex cells within that same flower. The seeds that develop carry the traits of that plant. This was important for Mendel. When he wanted to have the gametes of different plants unite, Mendel opened the petals of a flower and removed the male reproductive organs on one plant, and dusted the female reproductive organ with the pollen from a different plant. This is cross-pollination. The seeds that develop from cross-pollination have traits of the two different plants.

Section 10.1 **Mendel's Laws of Heredity,** *continued*

How did Mendel proceed?

To get accurate results, Mendel needed to carefully control his experiment. He studied one trait at a time to control variables. He decided to study how height in pea plants is passed from parent to offspring. He used plants that were true breeding. That meant the plants always passed the same trait from parent to offspring. He took pollen from a true-breeding tall pea plant and cross-pollinated a true-breeding short pea plant.

Mendel's Monohybrid Crosses

Crossing a tall pea plant with a short pea plant produced offspring called hybrids. A **hybrid** is the offspring of parents that have different forms of a trait, such as tall and short height. The first hybrids that Mendel produced are known as monohybrid crosses. *Mono* means one. Since the parent plants that Mendel used differed from each other by only one trait—height—the offspring are called monohybrids.

Reading Check

2. What is a monohybrid?

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What were Mendel's results?

The results of Mendel's experiment were interesting. Mendel cross-pollinated a six-foot tall pea plant with a pea plant less than two feet tall. When he planted the seeds from this cross, all of the offspring grew as tall as the taller parent plant. The short trait did not appear at all.

Mendel allowed the offspring, known as the first generation, to self-pollinate. Mendel planted the seeds from the first generation. There were more than 1000 plants in the second generation. Three-fourths of the plants were as tall as the tall parent plant. One-fourth of the plants were as tall as the short parent plant. The short trait had reappeared. The ratio of tall to short plants in the second generation was three tall plants for every one short plant.

Reading Check

3. List the abbreviations for each generation and tell what they stand for.

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How do you identify the generations?

In genetics, abbreviations are used for the generations. The original parents are known as the P_1 generation. *P* stands for "parent." The offspring of the parents are called the F_1 generation. The *F* stands for "filial," which means son or daughter. When you cross two F_1 plants with each other their offspring are the F_2 generation, the second filial generation.

Section 10.1 **Mendel's Laws of Heredity,** *continued*

Mendel did similar monohybrid crosses with seven pairs of traits. He used traits such as whether a seed was wrinkled or round, yellow or green. In every case he found that one trait of a pair did not appear in the F_1 generation. Then the trait reappeared in one fourth of the F_2 plants. For example, when he crossed a plant that produced round seeds with a plant that produced wrinkled seeds, all of the offspring (F_1) had round seeds. But when the plants of the F_1 generation self-pollinated, one fourth of their offspring (F_2) had wrinkled seeds.

From these results Mendel determined that each organism has two factors that control each of its traits. Today we know that these factors are genes. Genes exist in alternative forms, such as, tall and short, round and wrinkled. The alternative forms are called **alleles** (uh LEELZ). Mendel's pea plants had two alleles for height. A plant could have two alleles for tallness, two alleles for shortness, or one allele for tallness and one allele for shortness. The organism receives or inherits one allele from the female parent and one allele from the male parent.

Reading Check

4. If a plant has a dominant allele for height and a recessive allele for height, which allele will determine the height of the plant?

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What is dominance?

But why did the offspring of a short plant crossed with a tall plant all grow into tall plants? Mendel called the observed trait **dominant** and the trait that disappeared **recessive.** A dominant allele will mask, or cover up, a recessive allele. The allele for tall plants is dominant to the allele for short plants. The plants that had a tall and short allele were tall because the tall allele is dominant and the short allele is recessive. The plants with two alleles for tallness were tall. The plants with two alleles for shortness were short. In the F_1 generation of plants each plant had one tall allele and one short allele. That is why the offspring of a tall and short plant were all tall.

When the results of crosses are written down, scientists use the same letter for different alleles of the same trait. An uppercase letter is used for the dominant allele, and a lowercase letter is used for a recessive allele. So in writing down the results of Mendel's experiment, *T* is used for the dominant allele for tallness, while *t* is used for the recessive allele for shortness. The dominant allele is always written first.

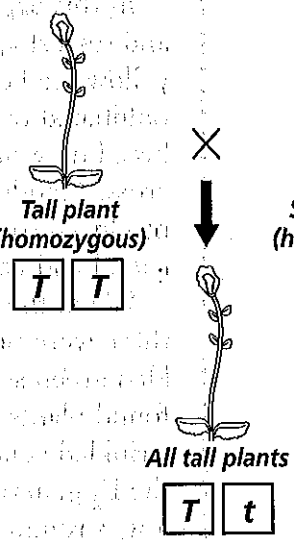
Section 10.1 Mendel's Laws of Heredity, *continued*

Mendel took the facts that he learned from his experiments to create rules or laws to explain heredity. The first of his laws is called the **law of segregation.** This law says that every organism has two alleles of each gene and when gametes are produced the alleles separate. Each gamete receives one of these alleles. During fertilization, these gametes randomly pair to produce four combinations of alleles.

Phenotypes and Genotypes

You cannot always tell by looking at an organism what genes it might pass on. Sometimes tall plants crossed with each other produce both tall and short offspring. Sometimes a short plant and a tall plant produce all tall offspring.

Two organisms can look alike but have different allele combinations. The way an organism looks and behaves is called its **phenotype** (FEE noh tipe). The phenotype of a tall plant is tall. The plant could have an allele combination of *TT* or *Tt*. The allele combination of an organism is called the **genotype** (JEE noh tipe). The genotype cannot always be determined even if you know the phenotype.



Reading Check

5. Explain the difference between phenotype and genotype.

What are homozygous and heterozygous alleles?

An organism is **homozygous** (hoh moh ZI gus) for a trait if the two alleles for the trait are the same. So a plant with two alleles for tallness (*TT*) would be homozygous for the trait of height. Remember that since tallness is dominant, a *TT* plant is homozygous dominant for height. A short plant always has two alleles for shortness (*tt*). Therefore, a short plant would be homozygous recessive for height.

What if the two alleles are not the same? An organism is **heterozygous** (heh tuh roh ZI gus) for a trait if its two alleles for the trait are different from each other. A tall plant that has one allele for tallness and another allele for shortness (*Tt*) is heterozygous for the trait of height.

Reading Check

6. Explain the difference between homozygous and heterozygous.

Mendel's Dihybrid Crosses

In Mendel's first set of experiments he used monohybrid crosses. He used plants that differed from each other in only one trait. Later, Mendel used pea plants that differed from each other in two traits. A cross involving two different traits is called a dihybrid cross. *Di* means two. Mendel wanted to know whether, in a dihybrid cross, the two traits would stay together in the next generation, or whether they would be passed on independently of each other.

In this experiment Mendel observed the traits for seed color and seed shape. He knew from previous experiments that the yellow seed color and round seed shape were dominant. He cross-pollinated true-breeding round, yellow seeds (*RRYY*) with true-breeding wrinkled, green seeds (*rryy*). This created a dihybrid cross. Mendel discovered that in the F_1 generation all the plants produced round yellow seeds. That was not surprising since round and yellow are dominant traits.

When the F_1 plants self-pollinated and produced offspring there were plants with round yellow seeds and plants with wrinkled green seeds. That was not surprising either. But Mendel also found plants producing two other seed types, round green, and wrinkled yellow. When Mendel sorted and counted the plants of the F_2 generation he found a ratio of phenotypes—9 round yellow, 3 round green, 3 wrinkled yellow, 1 wrinkled green.

What is the law of independent assortment?

To explain his results, Mendel created his second law of heredity, known as the **law of independent assortment.** This law states that genes for different traits are inherited independently of each other. In a dihybrid cross you can see both of Mendel's laws at work. The plants in the F_1 generation of the dihybrid cross had the genotype *RrYy*. When a plant with this genotype produces gametes, the alleles *R* and *r* will separate from each other. That is the law of segregation at work. The *R* and *r* alleles will also separate from the *Y* and *y* alleles. That is the law of independent assortment at work. The alleles will then recombine in four different ways. If the alleles for seed shape and color were inherited together, only two kinds of seeds would have been produced. Instead, four different kinds of seeds were produced.

Reading Check

7. What does the law of independent assortment state?

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Punnett Squares

Reginald Punnett, an English biologist, came up with a way to predict the proportions of possible genotypes in offspring. It is called a Punnett square. If you know the genotypes of the parents you can use a Punnett square to predict the possible genotypes of their offspring. For example, in Mendel's original experiment, the F_1 generation had the genotype *Tt*. That means that half the gametes for each plant would contain the *T* allele, and the other half would contain the *t* allele. A Punnett square can show the possible combinations for offspring with parents with this genotype.

A Punnett square for a single trait is two boxes tall and two boxes wide. The genotype of one parent is listed across the top. The genotype for the other parent is listed along the left side. Look at the illustration to see the possible combinations. A Punnett square can also be created for dihybrid crosses. It would be larger, four boxes tall and four boxes wide.

Punnett Square

	T	*t*
T	*TT*	*Tt*
t	*Tt*	*tt*

Probability

Punnett squares show all of the possible outcomes. Because chance is a factor in genetics, the actual results don't always match the Punnett square's probability. It is like flipping a coin. The probability is 50/50 that the coin will be heads or tails. However if you flip a coin 100 times, you cannot guarantee that 50 times it will be heads and 50 times it will be tails. It is the same in genetics. Even though a Punnett square may predict that one fourth of the offspring will have a particular genotype, in reality the amount could be higher or lower.

After You Read

Mini Glossary

allele (uh LEEL): alternative form of a gene for each trait of an organism

dominant: trait of an organism that is observed and that masks the recessive trait

fertilization: uniting of male and female gametes

gamete: male and female sex cells

genetics: study of heredity

genotype (JEE noh tipe): allele combination of an organism

heredity: passing on of characteristics from parents to offspring

heterozygous (heh tuh roh ZI gus): when there are two different alleles for a trait

homozygous (hoh moh ZI gus): when there are two identical alleles for a trait

hybrid: offspring of parents having different forms of a trait

law of independent assortment: Mendelian principle stating that genes for different traits are inherited independently of each other

law of segregation: Mendelian principle explaining that because every organism has two alleles for every gene, it can produce different types of gametes. During fertilization, these gametes randomly pair to produce four combinations of alleles.

phenotype (FEE nuh tipe): the way an organism looks and behaves

pollination: the transfer of pollen grains from male reproductive organs to female reproductive organs of plants

recessive: traits of an organism that can be masked by the dominant form of the trait

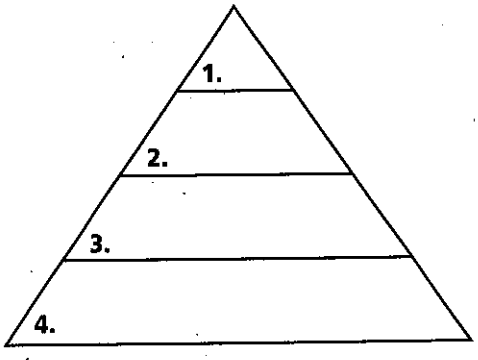
trait: characteristics that are passed from parents to offspring

zygote (ZI goht): cell formed when a male gamete unites with a female gamete

1. Review the terms and their definitions in the Mini Glossary above. Write a sentence using at least two of the terms.

2. Use the pyramid diagram to help you review what you have read. Arrange the steps Mendel used in his first experiment with pea plants. Place the letter of each step in the correct order in the pyramid.

   a. Cross-pollinate P_1 generation to grow monohybrids
   b. Observe results in F_2 generation
   c. Find true breeders for a single trait
   d. Allow F_1 generation to self-pollinate



Section 10.1 Mendel's Laws of Heredity, *continued*

3. Use the cause and effect diagram below to explain Mendel's two laws. Write the effect of each law in the correct box.

Cause	Effect
Law of Segregation	
Law of Independent Assortment	

Visit the Glencoe Science Web site at **science.glencoe.com** to find your biology book and learn more about Mendel's laws of heredity.