What Did Mendel Learn About Heredity?

Mendel knew from his pea plant experiments that there must be two sets of instructions for each characteristic. All of the first-generation plants showed the dominant trait. However, they could give the recessive trait to their offspring. Instructions for an inherited trait are called genes. Offspring have two sets of genes—one from each parent.

The two sets of genes that parents give to offspring are never exactly the same. The same gene might have more than one version. The different versions of a gene are called alleles.

Alleles may be dominant or recessive. A trait for an organism is usually identified with two letters, one for each allele. Dominant alleles are given capital letters (A). Recessive alleles are given lowercase letters (a). If a dominant allele is present, it will hide a recessive allele. An organism can have a recessive trait only if it gets a recessive allele for that trait from both parents.

PHENOTYPE

An organism’s genes affect its traits. The appearance of an organism, or how it looks, is called its phenotype. The phenotypes for flower color in Mendel’s pea plants were purple and white. The figure below shows one example of a human phenotype.

Albinism is an inherited disorder that affects a person’s phenotype in many ways.
GENOTYPE

A **genotype** is the combination of alleles that an organism gets from its parents. A plant with two dominant or two recessive alleles (\(PP, pp\)) is **homozygous**. Homo means “the same.” A plant with one dominant allele and one recessive allele (\(Pp\)) is **heterozygous**. Hetero means “different.” The allele for purple flowers (\(P\)) in pea plants is dominant. The plant will have purple flowers even if it has only one \(P\) allele.

PUNNETT SQUARES

A Punnett square is used to predict the possible genotypes of offspring from certain parents. It can be used to show the alleles for any trait. In a Punnett square, the alleles for one parent are written along the top of the square. The alleles for the other parent are written along the side of the square. The possible genotypes of offspring are found by combining the letters at the top and side of each square.

![Punnett Square Diagram]

The figure shows a Punnett square for a cross of two true-breeding plants. One has purple flowers and the other has white flowers. The alleles for a true-breeding purple-flowered plant are written as \(PP\). The alleles for a true-breeding white flowered plant are written as \(pp\). Offspring get one of their two alleles from each parent. All of the offspring from this cross will have the same genotype: \(Pp\). Because they have a dominant allele, all of the offspring will have purple flowers.
MORE EVIDENCE FOR INHERITANCE

In his second experiments, Mendel let the first-generation plants self-pollinate. He did this by covering the flowers of the plant. This way, no pollen from another plant could fertilize its eggs. The Punnett square below shows a cross of a plant that has the genotype $Pp$.

A self-pollinating purple flower

This Punnett square shows the possible results from the cross $Pp \times Pp$.

Notice that one square shows the genotype $Pp$ and another shows $pP$. These are exactly the same genotype. They both have one $p$ allele and one $P$ allele. The combinations $PP$, $Pp$, and $pP$ have the same phenotype—purple flowers. This is because they all have at least one dominant allele, $P$.

Only one combination, $pp$, produces plants that have white flowers. The ratio of dominant phenotypes to recessive phenotypes is 3:1. This means that three out of four offspring from that cross will have purple flowers. This is the same ratio Mendel found.

What Is the Chance That Offspring Will Receive a Certain Allele?

Each parent has two alleles for each gene. When an individual reproduces, it passes one of its two alleles to its offspring. When a parent has two different alleles for a gene, such as $Pp$, offspring may receive either of the alleles. Both alleles have an equal chance to be passed from the parent to the offspring.

Think of a coin toss. When you toss the coin, there is a 50% chance you will get heads, and a 50% chance you will get tails. The chance of the offspring receiving one allele or another from a parent is as random as a coin toss.
PROBABILITY

The mathematical chance that something will happen is known as **probability**. Probability is usually written as a fraction or percentage. If you toss a coin, the probability of tossing tails is 1/2, or 50%. In other words, you will get tails half of the time.

What is the probability that you will toss two heads in a row? To find out, multiply the probability of tossing the first head (1/2) by the probability of tossing the second head (1/2). The probability of tossing two heads in a row is 1/4.

**GENOTYPE PROBABILITY**

Finding the probability of certain genotypes for offspring is like predicting the results of a coin toss. To have white flowers, a pea plant must receive a *p* allele from each parent. Each offspring of a *Pp* × *Pp* cross has a 50% chance of receiving either allele from either parent. So, the probability of inheriting two *p* alleles is 1/2 × 1/2.

This equals 1/4, or 25%.

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**Math Focus**

7. Complete Complete the Punnett square to show the cross between two heterozygous parents. What percentage of the offspring are homozygous?

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**Are There Exceptions to Mendel’s Principles?**

Mendel’s experiments helped show the basic principles of how genes are passed from one generation to the next. Mendel studied sets of traits such as flower color and seed shape. The traits he studied in pea plants are easy to predict because there are only two choices for each trait. √

Traits in other organisms are often harder to predict. Some traits are affected by more than one gene. A single gene may affect more than one trait. As scientists learned more about heredity, they found exceptions to Mendel’s principles.
INCOMPLETE DOMINANCE

Sometimes, one trait isn’t completely dominant over another. These traits do not blend together, but each allele has an influence on the traits of offspring. This is called incomplete dominance. For example, the offspring of a true-breeding red snapdragon and a true-breeding white snapdragon are all pink. This is because both alleles for the gene influence color.

\[
\begin{array}{c|c|c|c}
    & \text{R}^1 & \text{R}^1 & \text{R}^1 \\
\hline
\text{R}^2 & \text{R}^1 & \text{R}^2 & \text{R}^2 \\
\end{array}
\]

The offspring of two true-breeding show incomplete dominance.

ONE GENE, MANY TRAITS

In Mendel’s studies, one gene controlled one trait. However, some genes affect more than one trait. For example, some tigers have white fur instead of orange. These white tigers also have blue eyes. This is because the gene that controls fur color also affects eye color.

MANY GENES, ONE TRAIT

Some traits, such as the color of your skin, hair, and eyes, are the result of several genes acting together. In humans, different combinations of many alleles can result in a variety of heights.

THE IMPORTANCE OF ENVIRONMENT

Genes are not the only things that can affect an organism’s traits. Traits are also affected by factors in the environment. For example, human height is affected not only by genes. Height is also influenced by nutrition. An individual who has plenty of food to eat may be taller than one who does not.

Critical Thinking

9. Infer If snapdragons showed complete dominance like pea plants, what would the offspring look like?

10. Compare How is the allele for fur color in tigers different from the allele for flower color in pea plants?

11. Identify Give an example of a single trait that is affected by more than one gene.
Section 2 Review

SECTION VOCABULARY

| **allele** | one of the alternative forms of a gene that governs a characteristic, such as hair color |
| **gene**   | one set of instructions for an inherited trait |
| **genotype** | the entire genetic makeup of an organism; also the combination of genes for one or more specific traits |
| **phenotype** | an organism’s appearance or other detectable characteristic |
| **probability** | the likelihood that a possible future event will occur in any given instance of the event |

1. **Identify Relationships** How are genes and alleles related?

2. **Explain** How is it possible for two individuals to have the same phenotype but different genotype for a trait?

3. **Punnett Square** Mendel allowed a pea plant that was heterozygous for yellow seeds (Y) to self-pollinate. Fill in the Punnett square below for this cross. What percentage of the offspring will have green (y) seeds?

   4. **Discuss** How is human height an exception to Mendel’s principles of heredity?
2. During interphase, chromosomes are copied. Mitosis begins with prophase. The chromosomes condense. During metaphase, the nuclear membrane dissolves. The chromosomes align. During anaphase, the chromatids separate and move to opposite sides of the cell. During telophase, the nuclear membrane forms. The chromosomes lengthen, and mitosis ends. During cytokinesis, the cytoplasm divides.

3. A cell makes a copy of its DNA before it divides so that each new cell will receive a copy. Each new cell will be an exact copy of the parent cell.

4. Eukaryotic cells have more chromosomes to copy than prokaryotic cells. The nuclear membrane of a eukaryotic cell also has to break down before the cell can divide.

Chapter 3 Heredity

SECTION 1 MENDEL AND HIS PEAS
1. the study of how traits are inherited
2. They grow quickly, and they have many traits that are easy to see.
3. In cross-pollination, sperm from one plant fertilize eggs of another. In self-pollination, sperm fertilize eggs of the same plant.
4. Pollen can be carried by organisms, such as insects, or by the wind.
5. Traits are the different forms of a characteristic.
6. Mendel removed the anthers from the flower of the plant with round seeds.
7. the dominant trait
8. dominant and recessive
9. Correct ratios, from top to bottom:
   3.00:1, 2.96:1, 2.82:1, 2.95:1, 3.14:1, 2.84:1
10. 3:1

Review
1. A true-breeding plant is one that will produce offspring with all its same traits when it self-pollinates.
2. Dominant; in the first generation, a recessive trait disappears.
3. True-breeding plants with white flowers were crossed to produce plants that all had purple flowers. When self-pollinated, they produced three plants with purple flowers and one with white.

SECTION 2 TRAITS AND INHERITANCE
1. a version of a gene
2. the appearance of an organism
3. one recessive allele and one dominant allele
4. Homozygous; both of its alleles are the same
5. PP, Pp, and pp
6. They all have at least one dominant allele.
7. 50% of the offspring are homozygous.

8. There are only two alleles for each trait.
9. The offspring would probably be one color. They would be the color of the dominant allele.
10. In pea plants, one gene affects flower color. The gene that controls fur color in tigers affects more than one trait.
11. Possible answers: hair color, skin color, eye color, height

Review
1. Genes carry the instructions for a trait. Alleles are the different versions of a gene.
2. If one individual is homozygous for a dominant trait, and the other individual is heterozygous for a dominant trait, the two individuals have different genotypes. However, their phenotype is the same, because they show the same trait.
3. 25% of the offspring will have green seeds.

4. Each trait that Mendel studied in peas was controlled by a single gene. Height in humans is determined by the interaction of many genes. Height can also be affected by environment.

SECTION 3 MEIOSIS
1. a pair of chromosomes that carry the same genes
2. 46