Wenatchee Public Schools

Optional Emergency Education Resources

Biology

2.1 Mendel's Laws

Learning Objectives

- Define heredity.
- Explain the relationship between homologous chromosomes, alleles and the locus.
- Distinguish genotype from phenotype.
- Define heterozygote and homozygote.

Do you look like your parents?

You probably have some characteristics or traits in common with each of your parents. Mendel's work provided the basis to understand the passing of traits from one generation to the next.

Mendel's Laws and Genetics

You might think that Mendel's discoveries would have made a big impact on science as soon as he made them. But you would be wrong. Why? Because Mendel's work was largely ignored. Mendel was far ahead of his time and working from a remote monastery. He had no reputation among the scientific community and no previously published work.

Mendel's work, titled *Experiments in Plant Hybridization*, was published in 1866, and sent to prominent libraries in several countries, as well as 133 natural science associations. Mendel himself even sent carefully marked experiment kits to Karl von Nageli, the leading botanist of the day. The result - it was almost completely ignored. Von Nageli instead sent hawkweed seeds to Mendel, which he thought was a better plant for studying heredity. Unfortunately hawkweed reproduces asexually, resulting in genetically identical clones of the parent.

Charles Darwin published his landmark book on evolution in 1869, not long after Mendel had discovered his laws. Unfortunately, Darwin knew nothing of Mendel's discoveries and didn't understand heredity. This made his arguments about evolution less convincing to many people. This example demonstrates the importance for scientists to communicate the results of their investigations.

Rediscovering Mendel's Work

Mendel's work was virtually unknown until 1900. In that year, three different European scientists — named Hugo De Vries, Carl Correns, and Erich Von Tschermak-Seysenegg — independently arrived at Mendel's laws. All three had done experiments similar to Mendel's. They came to the same conclusions that he had drawn almost half a century earlier. Only then was Mendel's actual work rediscovered.

As scientists learned more about **heredity** - the passing of traits from parents to offspring - over the next few decades, they were able to describe Mendel's ideas about inheritance in terms of genes. In this way, the field of genetics was born.

Genetics of Inheritance

Today, we know that characteristics of organisms are controlled by genes on chromosomes (see the **Figure** 2.1). The position of a gene on a chromosome is called its **locus**. In sexually reproducing organisms, each individual has two copies of the same gene, as there are two versions of the same chromosome (**homologous chromosomes**). One copy comes from each parent. The gene for a characteristic may have different versions, but the different versions are always at the same locus. The different versions are called **alleles**. For example, in pea plants, there is a purple-flower allele (*B*) and a white-flower allele (*b*). Different alleles account for much of the variation in the characteristics of organisms.

During meiosis, homologous chromosomes separate and go to different gametes. Thus, the two alleles for each gene also go to different gametes. At the same time, different chromosomes assort independently. As a result, alleles for different genes assort independently as well. In these ways, alleles are shuffled and recombined in each parent's gametes.

Genotype and Phenotype

When gametes unite during fertilization, the resulting zygote inherits two alleles for each gene. One allele comes from each parent. The alleles an individual inherits make up the individual's **genotype**. The two alleles may be the same or different. As shown in the **Table** 2.1, an organism with two alleles of the same type (*BB* or *bb*) is called a **homozygote**. An organism with two different alleles (*Bb*) is called a **heterozygote**. This results in three possible genotypes.

TABLE 2.1: Genetics of Flower Color in Pea Plants

Alleles	Genotypes	Phenotypes
	BB (homozygote)	purple flowers
B (purple)	*Bb* (heterozygote)	purple flowers
b (white)	*bb* (homozygote)	white flowers

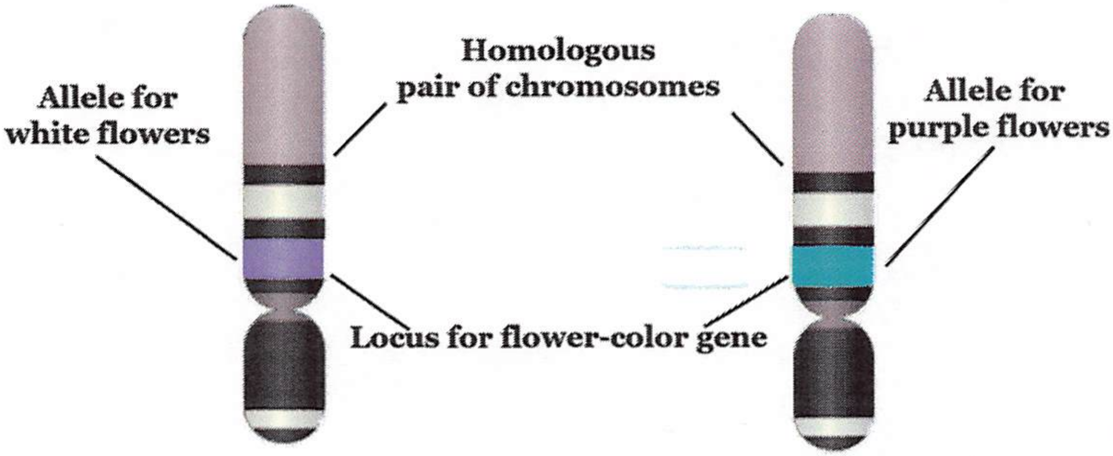

FIGURE 2.1

Chromosome, Gene, Locus, and Allele. This diagram shows how the concepts of chromosome, gene, locus, and allele are related. What is the different between a gene and a locus? Between a gene and an allele?

The expression of an organism's genotype produces its **phenotype**. The phenotype refers to the organism's characteristics, such as purple or white flowers. As you can see from the **Table** 2.1, different genotypes may produce the same phenotype. For example, *BB* and *Bb* genotypes both produce plants with purple flowers. Why does this happen? In a *Bb* heterozygote, only the *B* allele is expressed, so the *b* allele doesn't influence the phenotype. In general, when only one of two alleles is expressed in the phenotype, the expressed allele is called the **dominant** allele. The allele that isn't expressed is called the **recessive** allele.

How Mendel Worked Backward to Get Ahead

Mendel used hundreds or even thousands of pea plants in each experiment he did. Therefore, his results were very close to those you would expect based on the rules of probability (see "Probability" concept). For example, in one of his first experiments with flower color, there were 929 plants in the F2 generation. Of these, 705 (76 percent) had purple flowers and 224 (24 percent) had white flowers. Thus, Mendel's results were very close to the 75 percent purple and 25 percent white you would expect by the laws of probability for this type of cross.

Of course, Mendel had only phenotypes to work with. He knew nothing about genes and genotypes. Instead, he had to work backward from phenotypes and their percents in offspring to understand inheritance. From the results of his first set of experiments, Mendel realized that there must be two factors controlling each of the characteristics he studied, with one of the factors being dominant to the other. He also realized that the two factors separate and go to different gametes and later recombine in the offspring. This is an example of Mendel's good luck. All of the characteristics he studied happened to be inherited in this way.

Mendel also was lucky when he did his second set of experiments. He happened to pick characteristics that are inherited independently of one another. We now know that these characteristics are controlled by genes on nonhomologous chromosomes. What if Mendel had studied characteristics controlled by genes on homologous chromosomes? Would they be inherited together? If so, how do you think this would have affected Mendel's conclusions? Would he have been able to develop his second law of inheritance?

Summary

- Mendel's work was rediscovered in 1900. Soon after that, genes and alleles were discovered. This allowed Mendel's laws to be stated in terms of the inheritance of alleles.
- The gene for a characteristic may have different versions. These different versions of a gene are known as alleles.
- Alleles for different genes assort independently during meiosis.
- The alleles an individual inherits make up the individual's genotype. The individual may be homozygous (two of the same alleles) or heterozygous (two different alleles).
- The expression of an organism's genotype produces its phenotype.
- When only one of two alleles is expressed, the expressed allele is the dominant allele, and the allele that isn't expressed is the recessive allele.
- Mendel used the percentage of phenotypes in offspring to understand how characteristics are inherited.

Review

1. If Darwin knew of Mendel's work, how might it have influenced his theory of evolution? Do you think this would have affected how well Darwin's work was accepted?
2. Explain Mendel's laws in genetic terms, that is, in terms of chromosomes, genes, and alleles.
3. Explain the relationship between genotype and phenotype. How can one phenotype result from more than one genotype?

2.2 Probability

Learning Objectives

- Explain how probability is related to inheritance.
- Describe the relationship of probability to gamete formation and fertilization.

What are the odds of landing on 25 again?

Not as high as inheriting an allele from a parent. Probability plays a big role in determining the chance of inheriting an allele from a parent. It is similar to tossing a coin. What's the chance of the coin landing on heads?

Probability

Assume you are a plant breeder trying to develop a new variety of plant that is more useful to humans. You plan to cross-pollinate an insect-resistant plant with a plant that grows rapidly. Your goal is to produce a variety of plant that is both insect resistant and fast growing. What percentage of the offspring would you expect to have both characteristics? Mendel's laws can be used to find out. However, to understand how Mendel's laws can be used in this way, you first need to know about probability.

Probability is the likelihood, or chance, that a certain event will occur. The easiest way to understand probability is with coin tosses (see the **Figure** 2.2). When you toss a coin, the chance of a head turning up is 50 percent. This is because a coin has only two sides, so there is an equal chance of a head or tail turning up on any given toss.

If you toss a coin twice, you might expect to get one head and one tail. But each time you toss the coin, the chance of a head is still 50 percent. Therefore, it's quite likely that you will get two or even several heads (or tails) in a row. What if you tossed a coin ten times? You would probably get more or less than the expected five heads. For example, you might get seven heads (70 percent) and three tails (30 percent). The more times you toss the coin, however, the

FIGURE 2.2
Tossing a Coin. Competitions often begin with the toss of a coin. Why is this a fair way to decide who goes first? If you choose heads, what is the chance that the toss will go your way?

closer you will get to 50 percent heads. For example, if you tossed a coin 1000 times, you might get 510 heads and 490 tails.

Probability and Inheritance

The same rules of probability in coin tossing apply to the main events that determine the **genotypes** of offspring. These events are the formation of gametes during **meiosis** and the union of **gametes** during fertilization.

Probability and Gamete Formation

How is gamete formation like tossing a coin? Consider Mendel's purple-flowered pea plants again. Assume that a plant is heterozygous for the flower-color allele, so it has the genotype *Bb* (see the **Figure** 2.3). During meiosis, homologous chromosomes, and the alleles they carry, segregate and go to different gametes. Therefore, when the *Bb* pea plant forms gametes, the *B* and *b* alleles segregate and go to different gametes. As a result, half the gametes produced by the *Bb* parent will have the *B* allele and half will have the *b* allele. Based on the rules of probability, any given gamete of this parent has a 50 percent chance of having the *B* allele and a 50 percent chance of having the *b* allele.

Probability and Fertilization

Which of these gametes joins in fertilization with the gamete of another parent plant? This is a matter of chance, like tossing a coin. Thus, we can assume that either type of gamete—one with the *B* allele or one with the *b* allele—has an equal chance of uniting with any of the gametes produced by the other parent. Now assume that the other parent is also *Bb*. If gametes of two *Bb* parents unite, what is the chance of the offspring having one of each allele like the parents (*Bb*)? What is the chance of them having a different combination of alleles than the parents (either *BB* or *bb*)? To answer these questions, geneticists use a simple tool called a Punnett square, which is the focus of the next concept.

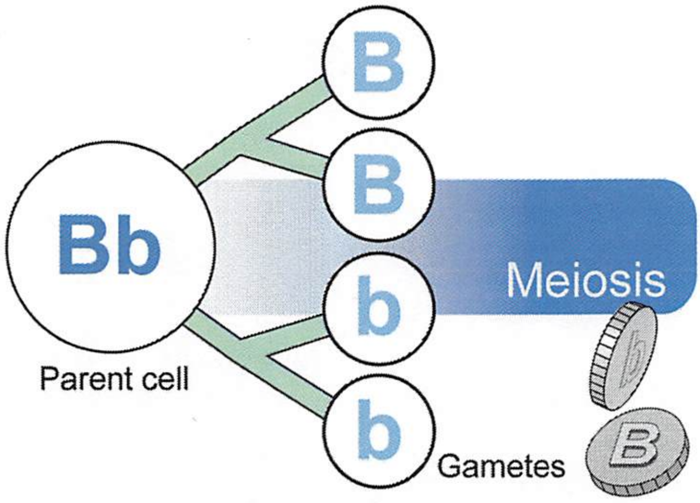

FIGURE 2.3
Formation of gametes by meiosis. Paired alleles always separate and go to different gametes during meiosis.

Summary

- Probability is the chance that a certain event will occur. For example, the probability of a head turning up on any given coin toss is 50 percent.
- Probability can be used to predict the chance of gametes and offspring having certain alleles.

Review

1. Define probability. Apply the term to a coin toss.
2. How is gamete formation like tossing a coin?
3. With a BB homozygote, what is the chance of a gamete having the B allele? The b allele?