Chapter 6

Wednesday, April 17, 2019 8:17 PM

BIG IDEA: In meiosis, genetic material from two parent organisms results in offspring with traits that follow a pattern of inheritance.

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Section 6.1: Chromosomes and Meiosis

Sunday, May 12, 2019 7:38 PM

KEY CONCEPT: Gametes have half the number of chromosomes that body cells have.
SECTION SUMMARY: Gametes have half the number of chromosomes that body cells have. Your body has 23 pairs of homologous chromosomes, making 46 total chromosomes. Gametes have only one chromosome from each homologous pair-23 chromosomes in all.
MAIN IDEAS:

- You have body cells and gametes
- Your cells have autosomes and sex chromosomes
- Body cells are diploid; gametes are haploid

VOCAB:

- Somatic Cells: Cell that makes up all of the body tissues and organs, except gametes
- Gamete: A haploid reproductive cell that unites with another reproductive cell to form a zygote
- Homologous Chromosome: Chromosomes that have the same length, appearance, and copies of genes, although the alleles may differ
- Autosome: Any chromosome that is not a sex chromosome
- Sex Chromosome: One of the pair of chromosomes that determine the sex of an individual
- Sexual Reproduction: Reproduction in which gametes from two parents unite.
- Fertilization: The union of a male and female gamete to form a zygote
- Diploid: A cell that contains two haploid sets of chromosomes
- Haploid: Describes a cell, nucleus, or organism that has only one set of unpaired chromosomes
- Meiosis: A process in cell division during which number of chromosomes decreases to half the original number by two divisions of the nucleus, which results in the reproduction of sex cells (gametes or spores)

TEKS:

- 6A: Identify components of DNA, and describe how information for specifying the traits of an organism is carried in the DNA
- 6G: Recognize the significance of meiosis to sexual reproduction

CONNECT TO YOUR WORLD:

Perhaps you are familiar with the saying "Everything old is new again." This phrase usually indicates that a past style is again current. However, it applies equally well to you. The fusion of a single egg and sperm cell resulted in the complex creature that is you. There's never been anyone quite like you. And yet the DNA that directs your cells cane from your mother and father, and so on and so on. In this chapter, you will examine the process that went into making you who you are.

MAIN IDEA: You have body cells and gametes

You have many types of specialized cells in your body, but they can be divided into two major groups: somatic cells and germ cells. Somatic cells, also called body cells, make up most of your body tissues and organs. For example, your spleen, kidneys, and eyeballs are all made entirely of body cells. DNA in your body cells is not passed to your children. Germ cells, in contrast, are cells in your reproductive organs, the ovaries, or the testes, that develop into gametes. Gametes are sex cells-ova or eggs in the female, and spermatozoa, or sperm cells, in the male. DNA in your gametes can be passed on to your children.
Each species has a characteristic number of chromosomes per cell. This number is typically given for body cells, not for gametes. Chromosome number does not seem to be related to the complexity of an organism. For example, yeast have 32 chromosomes, which come in 16 pairs. The fruit flies commonly used in genetic experiments have 8 chromosomes, which come in 4 pairs. A fern holds the record for most chromosomes-more than 1200. Each of your body cells contains a set of 46 chromosomes, which come in 23 pairs. These cells are genetically identical to each other unless mutations have occurred. As you have learned,

cells within an organism differ from one another because different genes are expressed, not because they have different genes.

MAIN IDEA: Your cells have autosomes and sex chromosomes

Suppose you had 23 pairs of gloves. You would have a total of 46 gloves that you could divide into two sets, 23 right and 23 left. Similarly, your body cells have 23 pairs of chromosomes for a total of 46 that can be divided into two sets: 23 from your mother and 23 from your father. Just as you use both gloves when it's cold outside, your cells use both sets of chromosomes to function properly.

Together, each pair of chromosomes is referred to as a homologous pair. In this context, the word homologous means "having the same structure." Homologous chromosomes are two chromosomes—one inherited from the mother, one from the father—that have the same length and general appearance. More importantly, these chromosomes have copies of the same genes, although the two copies may differ. For example, if you have a gene that influences blood cholesterol levels on chromosome 8, you will have one copy from your mother and one copy from your father. It is possible that one of these copies is associated with high cholesterol levels, while the other is associated with low cholesterol levels. For convenience, scientists have assigned a number to each pair of homologous chromosomes, ordered from largest to smallest. As FIGURE 1.1 shows, the largest pair of chromosomes is number 1, the next largest pair is number 2, and so forth.

Collectively, chromosome pairs 1 through 22 make up your autosomes, chromosomes that contain genes for characteristics not directly related to the sex of an organism. But what about the 23rd chromosome pair?

Most sexually reproducing species also have sex chromosomes that directly control the development of sexual characteristics. Humans have two very different sex chromosomes, X and Y. How sex is determined varies by species. In all mammals, including humans, an organism's sex is determined by the XY system. An organism with two X chromosomes is female. An organism with one X and one Y chromosome is male. Sex chromosomes make up your 23rd pair of chromosomes. Although the X and Y chromosomes pair with each other, they are not homologous. The X chromosome is the larger sex chromosome and contains numerous genes, including many that are unrelated to sexual characteristics. The Y chromosome is the sex chromosome that contains genes that direct the development of the testes and other male traits. It is the smallest chromosome and carries the fewest genes.

MAIN IDEA: Body cells are diploid; gametes are haploid

Sexual reproduction involves the fusion of two gametes, resulting in offspring that are a genetic mixture of both parents. The actual fusion of an egg and a sperm cell is called fertilization. When fertilization occurs, the nuclei of the egg and sperm cell fuse to form one nucleus. This new nucleus must have the correct number of chromosomes for a healthy new organism to develop. Therefore, both the egg and the sperm cell need only half the usual number of chromosomes—one chromosome from each homologous pair.

Diploid and Haploid Cells

Body cells and gametes have different numbers of chromosomes. Your body cells are diploid. Diploid (DIHP- LOYD) means that a cell has two copies of each chromosome: one copy from the mother, and one copy from the father. Diploid cells can be represented as 2n. In humans, the diploid chromosome number is 46.

Gametes are not diploid cells; they are haploid cells, represented *asn* . Haploid (HAP- LOYD) means that a cell has only one copy of each chromo- some. Each human egg or sperm cell has 22 autosomes and 1 sex chromo- some. In the egg, the sex chromosome is always an X chromosome. In the sperm cell, the sex chromosome can be an X chromosome or a Y chromo- some. The reason for this difference will be discussed in the following sections.

Maintaining the correct number of chromosomes is important to the survival of all organisms. Typically, a change in chromosome number is harmful. However, increasing the number of sets of chromosomes can, on occasion, give rise to a new species. The fertilization of nonhaploid gametes has played an important role in plant evolution by

rapidly making new species with more than two sets of chromosomes. For example, some plants have four copies of each chromosome, a condition called tetraploidy (4n). This type of event has occurred in many groups of plants, but it is very rare in animals.

Meiosis

Germ cells in your reproductive organs undergo the process of meiosis to form gametes. Meiosis (my-OH-sihs) is a form of nuclear division that divides a diploid cell into haploid cells. This process is essential for sexual reproduction. The details of meiosis will be presented in the next section. FIGURE 1.2 highlights some differences between mitosis and meiosis in advance to help you keep these two processes clear in your mind.

You have already learned about mitosis, another form of nuclear division. Recall that mitosis is a process that occurs in body cells. It helps produce daughter cells that are genetically identical to the parent cell. In cells undergoing mitosis, DNA is copied once and divided once. Both the parent cell and the daughter cells are diploid. Mitosis is used for development, growth, and repair in all types of organisms. It is also used for reproduction in asexually reproducing eukaryotes.

In contrast, meiosis occurs in germ cells to produce gametes. This process is sometimes called a “reduction division” because it reduces a cell’s chromo- some number by half. In cells undergoing meiosis, DNA is copied once but divided twice. Meiosis makes genetically unique haploid cells from a diploid cell. These haploid cells then undergo more processing in the ovaries or testes, finally forming mature gametes.

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Section 6.2: Processes of Meiosis

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KEY CONCEPT: During meiosis, diploid cells undergo two cell divisions that result in haploid cells.

SECTION SUMMARY: During meiosis, diploid cells undergo two cell divisions that result in haploid cells. In meiosis I, homologous chromosomes pair up along the cell equator and are divided into separate cells. In meiosis II, sister chromatids are divided into separate cells, making a total of four haploid cells that are genetically unique.

MAIN IDEAS:

- Cells go through two rounds of division in meiosis
- Haploid cells develop into mature gametes

VOCAB:

- Gametogenesis: process by which gametes are produced through the combination of meiosis and other maturational changes.
- Sperm: the male gamete (sex cell)
- Egg: Female gamete
- Polar Body: one of the small cells that sperate from an oocyte during meiosis, that have little cytoplasm, and that are ultimately discarded.

TEKS:

- 6G: Recognize the significance of meiosis to sexual reproduction

CONNECT TO YOUR WORLD:

Sometimes division, such as splitting the bill at a restaurant or dividing people into teams for basketball, is difficult. Luckily, understanding how meiosis divides chromosomes between cells is not that hard. Meiosis begins with a diploid cell that has already undergone DNA replication. The cell copies the chromosomes once and divides them twice, making four haploid cells.

MAIN IDEA: Cells go through two rounds of division in meiosis

Meiosis is a form of nuclear division that creates four haploid cells from one diploid cell. This process involves two rounds of cell division—meiosis I and meiosis II. Each round of cell division has four phases, which are similar to those in mitosis. To keep the two processes distinct in your mind, focus on the big picture. Pay attention to the way meiosis reduces chromosome number and creates genetic diversity

Homologous Chromosomes and Sister Chromatids

To understand meiosis, you need to distinguish between homologous chromosomes and sister chromatids. As FIGURE 2.1 shows, homologous chromosomes are two separate chromosomes: one from your mother, one from your father. Homologous chromosomes are very similar to each other, since they have the same length and carry the same genes. But they are not copying of each other. In contrast, each half of a duplicated chromosome is called a chromatid. Together, the two chromatids are called sister chromatids. Thus, the term sister chromatids refers to the duplicated chromosomes that remain attached (by the centromere). Homologous chromosomes are divided in meiosis I. Sister chromatids are not divided until meiosis II.

Meiosis I

Before meiosis begins, DNA has already been copied. Meiosis I divides homologous chromosomes, producing two haploid cells with duplicated chromosomes. Like mitosis, scientists describe meiosis in terms of phases, illustrated in FIGURE 2.3 below. The figure is simplified, showing only four chromosomes.

- Prophase I centrosomes and centrioles move to opposite sides of the cell, and Early in meiosis, the nuclear membrane breaks down, the spindle fibers start to assemble. The duplicated chromosomes condense, and homologous chromosomes pair up. They appear to pair up

precisely, gene for gene, down their entire length. The sex chromosomes also pair with each other, and some regions of their DNA appear to line up as well.

- Metaphase I The homologous chromosome pairs are randomly lined up along the middle of the cell by spindle fibers. The result is that 23 chromosomes—some from the father, some from the mother—are lined up along each side of the cell equator. This arrangement mixes up the chromosomal combinations and helps create and maintain genetic diversity. Since human cells have 23 pairs of chromosomes, meiosis may result in 2 23 , or 8,388,608, possible combinations of chromosomes.
- Anaphase I Next, the paired homologous chromosomes separate from each other and move toward opposite sides of the cell. The sister chromatids remain together during this step and throughout meiosis I.
- Telophase I spindle fibers disassemble, and the cell undergoes cytokinesis. The end. The nuclear membrane forms again in some species, the result is two cells that each have a unique combination of 23 duplicated chromosomes coming from both parents.

Meiosis II

Meiosis II divides sister chromatids and results in undoubled chromosomes. The following description of this process applies to both of the cells produced in meiosis I. Note that DNA is not copied again between these two stages.

- Prophase II The nuclear membrane breaks down, centrosomes and centrioles move to opposite sides of the cell, and spindle fibers assemble.
- Metaphase II Spindle fibers align the 23 chromosomes at the cell equator. Each chromosome still has two sister chromatids at this stage. Anaphase II Next, the sister chromatids are pulled apart from each other and move to opposite sides of the cell.
- Telophase II Finally, nuclear membranes form around each set of chromosomes at opposite ends of the cell, the spindle fibers break apart, and the cell undergoes cytokinesis. The end result is four haploid cells with a combination of chromosomes from both the mother and father.

- Now that you've seen how meiosis works, let's review some key differences between the processes of meiosis and mitosis.
- Meiosis has two cell divisions. Mitosis has only one cell division.
- During meiosis, homologous chromosomes pair up along the cell equator. During mitosis, homologous chromosomes never pair up.
- In anaphase I of meiosis, sister chromatids remain together. In anaphase of mitosis, sister chromatids separate.
- Meiosis results in haploid cells. Mitosis results in diploid cells.

MAIN IDEA: Haploid cells develop into mature gametes

Haploid cells are the end result of meiosis. Yet these cells are incapable of fertilization until they go through more changes to form mature gametes. Gametogenesis (guh-mee-tuh-JEHN-ih-sihs) is the production of gametes. As FIGURE 2.4 shows, gametogenesis includes both meiosis and other changes that produce a mature cell. The final stages of gametogenesis differ between the sexes.

The sperm cell, the male gamete, is much smaller than the egg, the female gamete. The sperm cell's main contribution to an embryo is DNA. Yet it must swim to an egg to fertilize it, so the ability to move is critical. Sperm formation starts with a round cell and ends by making a streamlined cell that can move rapidly. During this process, significant changes occur. DNA is tightly packed and much of the cytoplasm is lost, resulting in a compact head. The sperm cell develops a whip like flagellum and connecting neck region packed with mitochondria that drive the cell. Other changes, such as the addition of new proteins to the cell membrane, also take place.

The formation of an egg is a complicated process. It begins before birth, inside the developing body of a female embryo, and is not finished until that egg is fertilized by a sperm many years later. The process includes periods of active development and long periods of inactivity.

An egg not only gives its share of DNA to an embryo, but also contributes the organelles, molecular building blocks, and other materials an embryo needs to begin life. Only one of

the four cells produced by each round of meiosis actually makes an egg. One cell—the egg—receives most of the organelles, cytoplasm, and nutrients. Many molecules are not evenly distributed throughout the egg's cytoplasm. This unequal distribution of molecules helps cells in the developing embryo to specialize. The other cells produced by meiosis become polar bodies, cells with little more than DNA that are eventually broken down. In many species, including humans, the polar body produced by meiosis I does not undergo meiosis II.

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Section 6.3: Mendel and Heredity

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KEY CONCEPT: Mendel's research showed that traits are inherited as discrete units.
SECTION SUMMARY: Mendel's research showed that traits are inherited as discrete units. His large amount of data, control over breeding, use of purebred plants, and observation of "either-or" traits allowed him to see patterns in the inheritance of traits. He concluded that organisms inherit two copies of each gene and that organisms donate only one copy of each gene in their gametes.
MAIN IDEAS:

- Mendel laid the groundwork for genetics.
- Mendel's data revealed patterns of inheritance.

VOCAB:

- Trait: one of two or more possible forms of a character; a recognizable feature or characteristic of an organism.
- Genetics: the science of heredity and of the mechanisms by which traits are passed from parents to offspring.
- Purebred: Type of organism whose ancestors are genetically uniform.
- Cross: Mating of two organisms
- Law of Segregation: Mendel's first law, stating that (1) organisms inherit two copies of genes, one from each parent, and (2) organisms donate only one copy of each gene in their gametes because the genes separate during gamete formation

TEKS:

- 3F research and describe the history of biology and contributions of scientists
- 6F predict possible outcomes of various genetic combinations such as monohybrid crosses, dihybrid crosses and non-Mendelian inheritance.

CONNECT TO YOUR WORLD: When a magician makes a coin disappear, you know that the coin has not really vanished. You simply cannot see where it is. Maybe it is up a sleeve or in a pocket. When organisms reproduce, some traits seem to disappear, too. For centuries, no one could explain why. Then a careful, observant scientist showed that behind this phenomenon were inherited units, or genes.

MAIN IDEA: Mendel laid the groundwork for genetics.

When we think of how offspring resemble or differ from their parents, we typically refer to specific traits. Traits are distinguishing characteristics that are inherited, such as eye color, leaf shape, and tail length. Scientists recognized that traits are hereditary, or passed from one generation to the next, long before they understood how traits are passed on. Genetics is the study of biological inheritance patterns and variation in organisms.

The groundwork for much of our understanding of genetics was established in the middle of the 1800s by an Austrian monk named Gregor Mendel, shown in FIGURE 3.1. Scientists of the time commonly thought that parents' traits were blended in offspring, like mixing red and white paint to get pink paint. But this idea failed to explain how certain traits remained without being "diluted." Mendel, a shrewd mathematician, bred thousands of plants, carefully counting and recording his results. From his data, Mendel correctly predicted the results of meiosis long before chromosomes were discovered. He recognized that traits are inherited as discrete units from the parental generation, like different colored marbles mixed together that can still be picked out separately. By recognizing that organisms inherit two copies of each discrete unit, what we now call genes, Mendel described how traits were passed between generations.

MAIN IDEA: Mendel's data revealed patterns of inheritance.

Mendel studied plant variation in a monastery garden. He made three key choices about his experiments that played an important role in the development of his laws of inheritance:

control over breeding, use of purebred plants, and observation of "either-or" traits that appeared in only two alternate forms.

Experimental Design

Mendel chose pea plants for his experiments because they reproduce quickly, and he could easily control how they mate. The sex organs of a plant are in its flowers, and pea flowers contain both male and female reproductive organs. In nature, the pea flower typically self-pollinates; that is, the plant mates with itself. If a line of plants has self-pollinated for long enough, that line becomes genetically uniform, or purebred. As a result, the offspring of purebred parents inherit all of the parent organisms' characteristics. Mendel was able to mate plants with specific traits by interrupting the self-pollination process. As you can see in FIGURE 3.2, he removed the male parts of flowers and fertilized the female parts with pollen that contained sperm cells from a different plant. Because he started with purebred plants, Mendel knew that any variations in offspring resulted from his experiments.

Mendel chose seven traits to follow: pea shape, pea color, pod shape, pod color, plant height, flower color, and flower position. All of these traits are simple "either-or" characteristics; they do not show intermediate features. The plant is tall or short. Its peas are wrinkled or round. What Mendel did not know was that most of the traits he had selected were controlled by genes on separate chromosomes. The selection of these particular traits played a crucial role in enabling Mendel to identify the patterns he observed

Results

In genetics, the mating of two organisms is called a cross. An example of one of Mendel's crosses is highlighted in FIGURE 3.3. In this example, he crossed a purebred white-flowered pea plant with a purebred purple-flowered pea plant. These plants are the parental, or P, generation. The resulting offspring, called the first filial—or F 1 —generation, all had purple flowers. The trait for white flowers seemed to disappear. When Mendel allowed the F 1 generation to self-fertilize, the resulting F 2 generation produced both plants with purple flowers and plants with white flowers. Therefore, the trait for white flowers had not disappeared; it had been hidden or masked.

Mendel did not cross only two plants, however; he crossed many plants. As a result, he was able to observe patterns. He noticed that each cross yielded similar ratios in the F purple flowers, and about one-fourth had white flowers. A ratio is a comparison- 2 generation: about three-fourths of the plants had son that tells how two or more things relate. This ratio can be expressed as 3:1 (read "three to one") of purple: white flowers. As you can see in FIGURE 3.4, Mendel's data show this approximately 3:1 ratio for each of his crosses.

Conclusions

From these observations, Mendel drew three important conclusions. He demonstrated that traits are inherited as discrete units, which provided an explanation for individual traits that persisted without being blended or diluted over successive generations. Mendel's two other key conclusions are collectively called the law of segregation, or Mendel's first law.

- Organisms inherit two copies of each gene, one from each parent.
- Organisms donate only one copy of each gene in their gametes. Thus, the two copies of each gene segregate, or separate, during gamete formation.

Section 5 covers Mendel's second law, the law of independent assortment.

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Section 6.4: Traits, Genes, and Alleles

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KEY CONCEPT: Genes encode proteins that produce a diverse range of traits.
SECTION SUMMARY: Genes encode proteins that produce a diverse range of traits. Every diploid organism has two alleles for each gene: one from the mother, one from the father. These two alleles may be the same (homozygous) or different (heterozygous). One allele may be dominant over another.
MAIN IDEAS:

- The same gene can have many versions.
- Genes influence the development of traits.

VOCAB:

- Gene: the most basic physical unit of heredity; a segment of nucleic acids that codes for a functional unit of RNA and/or a protein.
- Allele: one of the alternative forms of a gene that governs a characteristic, such as hair color.
- Homozygous: describes an individual that has identical alleles for a trait on both homologous chromosomes.
- Heterozygous: describes an individual that carries two different alleles of a gene.
- Genome: the complete genetic material contained in an individual or species.
- 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 that results from the organism's genotype and the environment.
- Dominant: in genetics, describes an allele that is fully expressed whenever the allele is present in an individual.
- Recessive: in genetics, describes an allele that is expressed only when no dominant allele is present in an individual.

TEKS:

- 6A: Identify components of DNA and describe how information for specifying the traits of an organism is carried in the DNA.
- 6F: Predict possible outcomes of various genetic combinations such as monohybrid crosses, dihybrid crosses and non-Mendelian inheritance.

CONNECT TO YOUR WORLD: Most things come in many forms. Bread can be wheat, white, or rye. Cars can be two-door, four-door, hatchback, or convertible. Potatoes have more varieties than can be counted on two hands. Genes, too, come in many forms.
MAIN IDEA: The same gene can have many versions

As you have learned, Mendel's discrete units of heredity are now called genes. But what are genes? You can think of a gene as a piece of DNA that provides a set of instructions to a cell to make a certain protein. This definition is not precise, but it gives you the main idea. Each gene has a locus, a specific position on a pair of homologous chromosomes. Just as a house is a physical structure and an address tells where that house is located, you can think of the locus as the "address" that tells where a gene is located on a chromosome. Most genes exist in many forms. In Mendel's experiments, the effects of these different forms were easy to see yellow or green, round or wrinkled. An allele (uh-LEEL) is any of the alternative forms of a gene that may occur at a specific locus. Your cells have two alleles for each gene, one on each of the homologous chromosomes on which the locus for that gene is found. Each VISUAL VOCAB parent gives one allele. The two alleles may be the same, or they may be different. The term homozygous (HOH-moh-ZY-guhs) describes two of the same alleles at a specific locus. For example, both might code for white flowers. The term heterozygous (HEHT-uhr-uh-ZY- guhs) describes two different alleles at a specific locus. Thus, one might code for white flowers, the other for purple flowers.

MAIN IDEA: Genes influence the development of traits

As you have learned, Mendel's discrete units of heredity are now called genes. But what are genes? You can think of a gene as a piece of DNA that provides a set of instructions to a cell to make a certain protein. This definition is not precise, but it gives you the main idea. Each gene has a locus, a specific position on a pair of homologous chromosomes. Just as a house is a physical structure and an address tells where that house is located, you can think of the locus as the "address" that tells where a gene is located on a chromosome.

Most genes exist in many forms. In Mendel's experiments, the effects of these different forms were easy to see yellow or green, round or wrinkled. An allele (uh-LEEL) is any of the alternative forms of a gene that may occur at a specific locus. Your cells have two alleles for each gene, one on each of the homologous chromosomes on which the locus for that gene is found. Each VISUAL VOCAB parent gives one allele. The two alleles may be the same, or they may be different. The term homozygous (HOH-moh-ZY-guhs) describes two of the same alleles at a specific locus. For example, both might code for white flowers. The term heterozygous (HEHT-uhr-uh-ZY- guhs) describes two different alleles at a specific locus. Thus, one might code for white flowers, the other for purple flowers.

Dominant and Recessive Alleles

If an organism is heterozygous for a trait, which allele will be expressed? That is, if a plant has one allele for purple flowers and one for white flowers, what color will the flowers be? As Mendel learned, one allele may be dominant over another allele. A dominant allele is the allele that is expressed when two different alleles or two dominant alleles are present. A recessive allele is the allele that is expressed only when two copies are present. In Mendel's experiments, the allele for purple flowers was dominant to the allele for white flowers. All F 1 plants were purple even though they had only one allele for purple flowers.

Sometimes the word dominant is misunderstood. A dominant allele is not necessarily better or stronger than a recessive allele. It does not necessarily occur most often in the population. An allele is dominant in a heterozygote simply because it is expressed, and the other allele is not.

Alleles are often represented on paper with individual letters. An organ- ism's genotype for a trait can be shown with two letters—one per allele. Uppercase letters are used for dominant alleles, and lowercase letters are used for recessive alleles. For example, the dominant allele for height in pea plants is written ast , for tall. The recessive allele for short plants is written ast.

A plant's genotype might be homozygous dominant (TT), heterozygous (Tt), or homozygous recessive (tt).

Alleles and Phenotype

Because some alleles are dominant over others, two genotypes can produce the dominant phenotype. For example, smooth pods and constricted pods in pea plants, shown in FIGURE 4.2, are phenotypes. A plant with smooth pods could have a homozygous dominant (SS) or heterozygous (Ss) genotype. In contrast, a plant with constricted, or compressed, pods could have only a homozygous recessive (ss) genotype.

What actually makes one allele dominant over another? The answer is very complicated. It depends on the nature of the protein that is, or is not, made. Let's look at a fairly simple example. Pigment gives cells color. If P directs flower cells to make pigment, the flower may look purple. If p directs the cells not to make pigment, the flower looks white. So P codes for pigment to be present, but p codes for nothing, the absence of pigment. As a result, P has to be dominant. Even if the flower has only one P allele (Pp), that one allele tells its cells to make pigment, and the flower has color. Flower pigment is only one example. Many factors make one allele dominant over another.

As you know, most plants are not simply tall or short. Most flowers are not just white or purple. Most traits occur in a range. Other factors also affect traits. A lack of sunshine or vital nutrients could stunt a plant's growth. How does genetics account for these issues? Mendel studied traits that follow simple dominant-recessive patterns of inheritance, and each trait was the result of a single gene. In general, however, inheritance is much more

complex. Most alleles are not simply dominant or recessive; some are codominant. Many traits are influenced by multiple genes. The environment also interacts with genes and affects their expression.

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Section 6.5: Traits and Probability

Sunday, May 12, 2019 7:47 PM

KEY CONCEPT: The inheritance of traits follows the rules of probability.
SECTION SUMMARY: The inheritance of traits follows the rules of probability. Punnett squares are a grid system for predicting all possible genotypes resulting from a cross. When Mendel performed two-trait crosses, he discovered that different traits appear to be inherited separately—the law of independent assortment. The patterns of inheritance that he observed can be predicted by using mathematical probabilities.
MAIN IDEAS:

- Punnett Squares illustrate genetic crosses
- A monohybrid cross involves one trait
- A dihybrid cross involves two traits
- Heredity patterns can be calculated with probability

VOCAB:

- Punnett Square: a graphic used to predict the results of a genetic cross
- Monohybrid Cross: a cross between individuals that involves one pair of contrasting traits
- Testcross: cross between an organism with an unknown genotype and an organism with a recessive phenotype
- Dihybrid Cross: a cross between individuals that have different alleles for the same gene
- Law of Independent Assortment: the law that states that genes separate independently of one another in meiosis
- Probability: the likelihood that a possible future event will occur in any given instance of the event; the mathematical ratio of the number of times one outcome of any event is likely to occur to the number of possible outcomes of the event.

TEKS:

- 3F: research and describe the history of biology and contributions of scientists.
- 6F: Predict possible outcomes of various genetic combinations such as monohybrid crosses, dihybrid crosses and non-Mendelian inheritance.
- 6G: Recognize the significance of meiosis to sexual reproduction

CONNECT TO YOUR WORLD: If you have tried juggling, you know it can be a tricky thing. Keeping three flaming torches or clubs in motion at the same time is a challenge. Trying to keep track of what organism has which genotype and which gamete gets which allele can also be a lot to juggle. Fortunately, R. C. Punnett developed a method to keep track of all of the various combinations graphically.
MAIN IDEA: Punnett Squares illustrate genetic crosses

Shortly after Mendel's experiments became widely known among scientists, a poultry geneticist named R. C. Punnett, shown in FIGURE 5.1, developed the Punnett square. A Punnett square is a grid system for predicting all possible genotypes resulting from a cross. The axes of the grid represent the possible gamete genotypes of each parent. The grid boxes show all of the possible genotypes of offspring from those two parents. Because segregation and fertilization are random events, each combination of alleles is as likely to be produced as any other. By counting the number of squares with each genetic combination, we can find the ratio of genotypes in that generation. If we also know how the genotype corresponds to the phenotype, we can find the ratio of phenotypes in that generation as well.

Let's briefly review what you've learned about meiosis and segregation to examine why the Punnett square is effective. Both parents have two alleles for each gene. These alleles are represented on the axes of the Punnett square. During meiosis, the chromosomes—and, therefore, the alleles—are separated.

Each gamete gets one of the alleles. Since each parent contributes only one allele to the

offspring, only one allele from each parent is written inside each grid box. Fertilization restores the diploid number in the resulting offspring. This is why each grid box has two alleles, one from the mother and one from the father. Since any egg has the same chance of being fertilized by any sperm cell, each possible genetic combination is equally likely to occur.

MAIN IDEA: A monohybrid cross involves one trait

Thus far, we have studied monohybrid crosses, crosses that examine the inheritance of only one specific trait. Three example crosses are used below 6F and on the next page to illustrate how Punnett squares work and to highlight the resulting ratios—for both genotype and phenotype.

Homozygous-Homozygous

Suppose you cross a pea plant that is homozygous dominant for purple flowers with a pea plant that is homozygous recessive for white flowers. To deter- mine the genotypic and phenotypic ratios of the offspring, first write each parent's genotype on one axis: FF for the purple-flowered plant, ff for the white-flowered plant. Every gamete from the purple-flowered plant contains the dominant allele, F . Every gamete from the white-flowered plant contains the recessive allele, f . Therefore, 100% of the offspring have the heterozygous genotype, Ff. And 100% of the offspring have purple flowers because they all have a copy of the dominant allele, as shown in FIGURE 5.2.

Heterozygous-Heterozygous

Next, in FIGURE 5.3, you can see a cross between two purple-flowered pea plants that are both heterozygous (Ff). From each parent, half the offspring receive a dominant allele, F, and half receive a recessive allele, f . Therefore, one-fourth of the offspring have a homozygous dominant genotype, FF ; half have a heterozygous genotype, Ff ; and one-fourth have a homozygous recessive genotype, ff. Both the FF and the Ff genotypes result in purple flowers. Only the ff genotype results in white flowers. Thus, the genotypic ratio is 1:2:1 of homozygous dominant: heterozygous: homozygous recessive. The phenotypic ratio is 3:1 of purple: white flowers.

Heterozygous-Homozygous

Finally, suppose you cross a pea plant that is heterozygous for purple flowers (Ff) with a pea plant that is homozygous recessive for white flowers (ff). As before, each parent's genotype is placed on an axis, as shown in FIGURE 5.4. From the homozygous parent with white flowers, the offspring each receive a recessive allele, f. From the heterozygous parent, half the offspring receive a dominant allele, F , and half receive a recessive allele, f. Half the offspring have a heterozygous genotype, Ff . Half have a homozygous recessive genotype, ff . Thus, half the offspring have purple flowers, and half have white flowers. The resulting genotypic ratio is 1:1 of heterozygous: homozygous recessive. The phenotypic ratio is 1:1 of purple: white.

Suppose we did not know the genotype of the purple flower in the cross above. This cross would allow us to determine that the purple flower is heterozygous, not homozygous dominant.

A testcross is a cross between an organism with an unknown genotype and an organism with the recessive phenotype. The organism with the recessive phenotype must be homozygous recessive. The offspring will show whether the organism with the unknown genotype is heterozygous, as above, or homozygous dominant.

MAIN IDEA: A dihybrid cross involves two traits

All of the crosses discussed so far have involved only a single trait. However, Mendel also conducted dihybrid crosses, crosses that examine the inheri- tance of two different traits. He wondered if both traits would always appear together or if they would be expressed independently of each other.

Mendel performed many dihybrid crosses and tested a variety of different combinations. For example, he would cross a plant with yellow round peas with a plant with green wrinkled peas. Remember that Mendel began his crosses with purebred plants. Thus, the first generation offspring (F_1) would all be heterozygous and would all look the same. In this example, the plants would all have yellow round peas. When Mendel allowed the F_1

plants to self- pollinate, he obtained the following results: 9 yellow/round, 3 yellow/wrinkled, 3 green/round, 1 green/wrinkled.

Mendel continued to find this approximately 9:3:3:1 phenotypic ratio in the F 2 generation, regardless of the combination of traits. From these results, he realized that the presence of one trait did not affect the presence of another trait. His second law of genetics, the law of independent assortment, states that allele pairs separate independently of each other during gamete formation, or meiosis. That is, different traits appear to be inherited separately.

The results of Mendel's dihybrid crosses can also be illustrated with a Punnett square, like the one in FIGURE 5.5. Drawing a Punnett square for a dihybrid cross is the same as drawing one for a monohybrid cross, except that the grid is bigger because two genes, or four alleles, are involved. For example, suppose you cross two plants with yellow, round peas that are heterozygous for both traits (YyRr). The four allele combinations possible in each gamete— YR , Yr , yR , and yr —are used to label each axis. Each grid box can be filled in using the same method as that used in the monohybrid cross. A total of nine different genotypes may result from the cross in this example. However, these nine genotypes produce only four different phenotypes. These phenotypes are yellow round, yellow wrinkled, green round, and green wrinkled, and they occur in the ratio of 9:3:3:1. Note that the 9:3:3:1 phenotypic ratio results from a cross between organisms that are heterozygous for both traits. The phenotypic ratio of the offspring will differ (from 9:3:3:1) if one or both of the parent organisms are homozygous for one or both traits.

MAIN IDEA: Heredity patterns can be calculated with probability

Probability is the likelihood that a particular event will happen. It predicts the average number of occurrences, not the exact number of occurrences.

Probability = number of ways a specific event can occur/number of total possible outcomes

Suppose you flip a coin. The number of total possible outcomes is two: heads up or tails up. The probability that it would land heads up is 1/2, or one out of two. The probability that it would land tails up is also 1/2.

Next, suppose you flip two coins. How one-coin lands does not affect how the other coin lands. To calculate the probability that two independent events will happen together, multiply the probability of each individual event. The probability that both coins will land heads up, for example, is 1/2 X 1/2 = 1/4.

These probabilities can be applied to meiosis. Suppose a germ cell under- goes meiosis in a plant that is heterozygous for purple flowers. The number of total possible outcomes is two because a gamete could get a dominant or a recessive allele. The probability that a gamete will get a dominant allele is 1/2. The probability that it will get a recessive allele is also 1/2. If two plants that are heterozygous for purple flowers fertilize each other, the probability that both egg and sperm have a dominant allele is 1/2 X 1/2 = 1/4. So, too, the probability that both have a recessive allele is 1/4. There is also a 1/4 chance that a sperm cell with a dominant allele will fertilize an egg with a recessive allele, or that a sperm cell with a recessive allele will fertilize an egg with a dominant allele. These last two combinations are basically the same. In either case, the resulting plant will be heterozygous. Thus, the probability that a pea plant will be heterozygous for this trait is the sum of the probabilities: 1/4 + 1/4 = ½.

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Section 6.6: Meiosis and Genetic Variation

Sunday, May 12, 2019 7:48 PM

KEY CONCEPT: Independent assortment and crossing over during meiosis result in genetic diversity

SECTION SUMMARY: Independent assortment and crossing over during meiosis result in genetic diversity. Independent assortment produces unique combinations of parental chromosomes. Crossing over between homologous chromosomes creates a patchwork of genes from both parents. Genetic linkage describes genes that are close together and tend to be inherited as a unit.

MAIN IDEAS:

- Sexual reproduction creates unique gene combinations
- Crossing over during meiosis increases genetic diversity

VOCAB:

- Crossing over: exchange of chromosome segments between homologous chromosomes during meiosis I.
- Genetic linkage: tendency for genes located close together on the same chromosome to be inherited together.

TEKS:

- 6F: Predict possible outcomes of various genetic combinations such as monohybrid crosses, dihybrid crosses and non-Mendelian inheritance.
- 6G: Recognize the significance of meiosis to sexual reproduction

CONNECT TO YOUR WORLD: A surprising number of people make their living as Elvis impersonators. They wear slicked-up hairdos, large sunglasses, and big white jumpsuits. They mimic his voice, his dancing, and his phrases. They copy every possible detail, but they still do not come close to being the King. Elvis, like all people, was unique, or one of a kind. This uniqueness arises more from the events of meiosis—from the tiny shuffling's of chromosomes and the crossing over of DNA segments—than from our hairstyles or our clothing.

MAIN IDEA: Sexual reproduction creates unique gene combinations

The major advantage of sexual reproduction is that it gives rise to a great deal of genetic variation within a species, as shown in FIGURE 6.1.This variation results largely from (1) the independent assortment of chromosomes during meiosis and (2) the mixing of alleles as gametes join during fertilization.

Recall that homologous chromosomes pair up randomly along the cell equator during meiosis I. In other words, it's a matter of chance which of the two chromosomes from any homologous pair ends up on a given side of the cell equator. As you've learned, human cells have 23 pairs of chromosomes, and each pair lines up independently. As a result, gametes with 223, or about 8 million, different combinations of chromosomes can be produced through meiosis from one human cell.

Now think about the fact that sexual reproduction produces offspring through the combination of gametes. In humans, for example, a sperm cell with one of 223 (about 8 million) chromosome combinations fertilizes an egg cell, which also has one out of 223 chromosome combinations. If sperm cells and eggs were combined at random, the total number of possible combinations is the product of 223X 223, or more than 70 trillion. In other words, a human couple can produce a child with one of about 70 trillion different combinations of chromosomes.

Independent assortment and fertilization play key roles in creating and maintaining genetic diversity in all sexually reproducing organisms. However, the number of possible chromosome combinations varies by species. The probability that a bald eagle or a rabbit-eared bandicoot will inherit a specific allele is determined in the same way that it is for a

pea plant.

Sexual reproduction creates unique combinations of genes. This results in organisms with unique phenotypes. The offspring of sexual reproduction have a mixture of both parents' traits. For example, rabbit-eared bandicoot off-spring all share many traits for the things that make them bandicoots, but they may also differ in many ways. Some may be colored more like the mother, others more like the father. Some may dig deeper burrows or hunt more skillfully; others may in time produce more milk for their own offspring or have more litters. Having some of these traits may allow one bandicoot to reproduce in conditions where another bandicoot could not.

MAIN IDEA: Crossing over during meiosis increases genetic diversity

It is clear that independent assortment creates a lot of variation within a species. Another process, called crossing over, occurs during meiosis and helps create even greater variation. Crossing over is the exchange of chromosome segments between homologous chromosomes during prophase I of meiosis I. At this stage, each chromosome has been duplicated, the sister chromatids are still connected to each other, and homologous chromosomes have paired with each other. When homologous chromosomes are in this position, some of the chromatids are very close to each other. Part of one chromatid from each chromosome breaks off and reattaches to the other chromosome, as shown in FIGURE 6.2. Crossing over happens any time a germ cell divides. In fact, it can occur many times within the same pair of homologous chromosomes.

Because crossing over results in new combinations of genes, it is also called recombination. The term recombination generally refers to any mixing of parental alleles, including recombination events.

Now that you know about crossing over, let's look again at some of Mendel's results and conclusions. As you know from his research, genes located on separate chromosomes assort independently. This independence is caused by the random assortment of chromosomes during meiosis. But you also know that a single chromosome can have hundreds of genes. What happens when two genes are both on the same chromosome? Will they display independent assortment as well? Or will they travel together as a unit?

The answer to these questions is, "It depends." Recall that each gene has its own locus, or place on a chromosome. As FIGURE 6.3 shows, some genes on the same chromosome are close together; others are far apart. The farther apart two genes are located, the more likely they are to be separated when crossing over happens. Thus, genes located close together tend to be inherited together, which is called genetic linkage. Linked genes will be inherited in the same predicted ratios as would a single gene. In contrast, genes that are far apart are more likely to assort independently. For example, the alleles for flower and seed color are located on the same chromosome in pea plants, but they are not near each other. Because they are so far apart, Mendel observed independent assortment for these traits.

Genetic linkage has let scientists calculate the physical distance between two genes. By exploring relationships between many genes, scientists have been able to build a linkage, or genetic, map of many species.

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