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GENETIC VARIATION

Why is it that individuals within a species don't all look alike? The environment can explain some differences. For example, hydrangea plants will have flowers of pink or blue, depending on the pH of the soil in which they grow. A dog may have a shinier coat than other dogs of the same litter if it gets proper nutrition and the littermates don't. Individual variations caused by the environment are acquired traits that can't be passed on to offspring.

Other differences among individuals can be explained by meiosis. **Meiosis** is a type of cell division that results in gametes with half the number of chromosomes found in body cells. The process of meiosis is summarized in Figure 5-11.

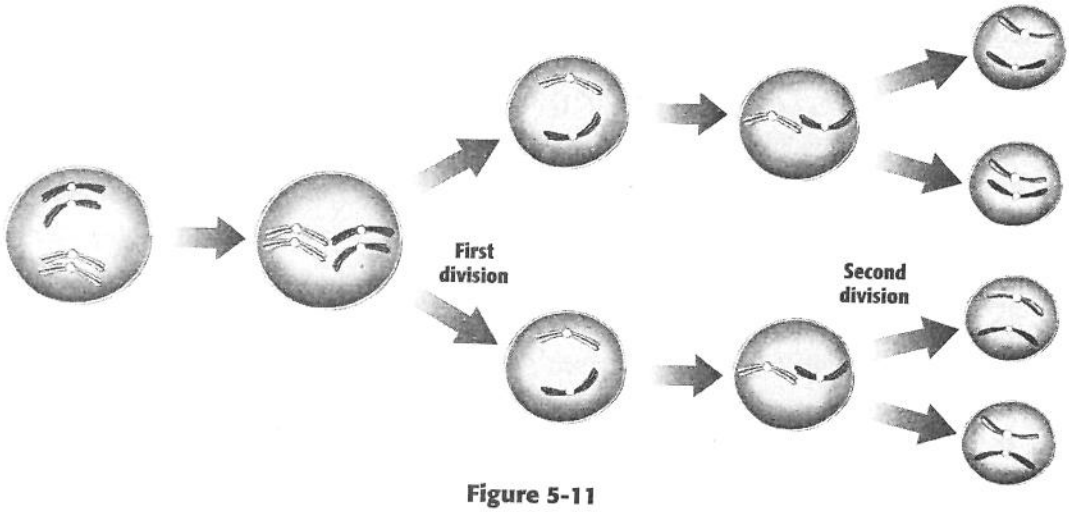


Figure 5-11

Three mechanisms of meiosis contribute to genetic variation:

- **Independent assortment.** Organisms that produce sexually have chromosome pairs; one chromosome of each pair is received from a different parent. But the chromosomes that an offspring receives from each parent are a matter of chance. Each pair of homologous chromosomes separates independently from other chromosomes in the cell. In humans, about 8 million different gene combinations are possible from a single gamete.
- **Crossing-over.** During meiosis, portions of each chromosome pair can be broken off and exchanged, which can result in mutations.
- **Random fertilization.** A new individual is formed by the random joining of two gametes.

Genetic variation is important because it increases the chances of producing individuals that can adapt to new environmental conditions that may arise. In this way, variation makes the extinction of species less likely.

Genetic variation in plants and animals

Genetic variation is easy to see all around you. Just look at the differences among any particular species—cats, for example. Look at a litter of kittens and no two look exactly alike. Fur color may vary, and even kittens of the same color will have different markings.

Breeders can use genetic variation to help produce offspring with particular traits. Dog breeders have produced many varieties of dogs by choosing certain traits and breeding only individuals that possessed the desired traits. For example, a breeder might breed a female that has a particularly long coat with a male that has a certain coat color, in the hopes that some of the offspring will have a coat of both the desired color and length. Dairy farmers use genetic variation in dairy cows to produce heifers that yield more milk.

An important genetic variation among plants is the percentage of oil content of corn plants that are grown as food crops. Breeding programs for corn select varieties that are high in oil content. The result of one such program is illustrated in Figure 5-12. As you can see, over a period of 80 generations of selecting for the high oil trait, the percentage of oil content in this population of corn increased from approximately 4.7 percent to more than 19 percent.

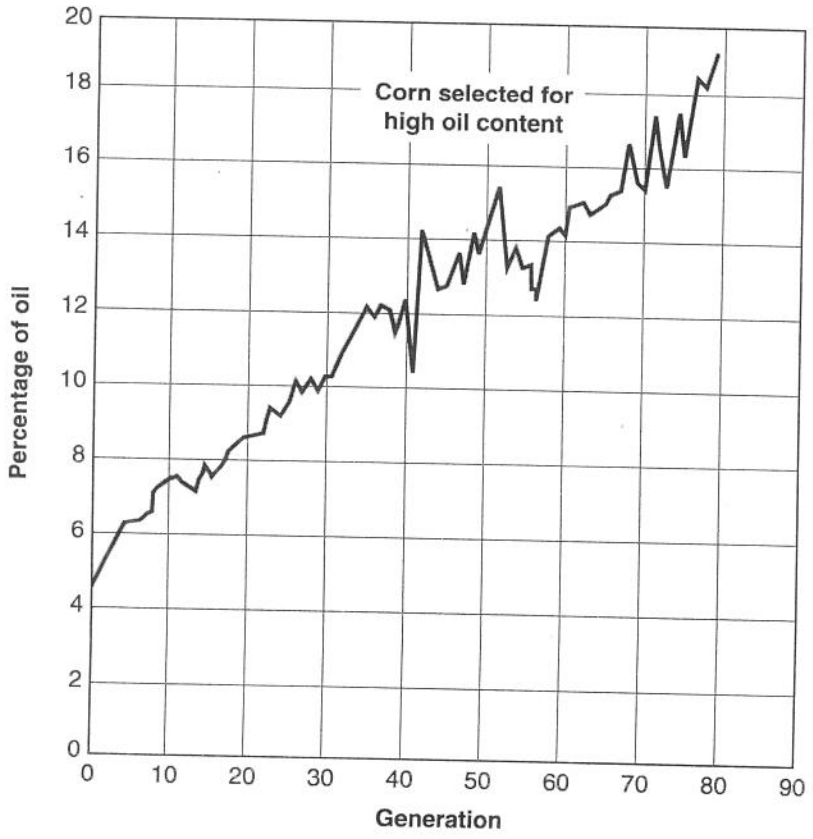


Figure 5-12

GENETIC ENGINEERING

Imagine taking the genes that control the traits of your favorite fruits and putting them into a single fruit that would have all those traits! Would the new fruit taste like a peach, have skin like a banana, and look like an apple? Although the idea may seem far-fetched, scientists are able to move genes from one organism to another in a process called **genetic engineering**. In this way, scientists can give organisms traits that they normally would not have.

For example, people with diabetes can't make insulin, an important protein that helps control the level of sugar in the blood. Scientists are able to take the human gene for the production of the protein from a healthy person and put it into a bacterium. The bacterium makes the human protein, which can be given to people with diabetes. When DNA from two different organisms is combined, the result is **recombinant DNA**.

Let's look at how scientists combine DNA from two organisms.

Step 1 Scientists take DNA from a healthy person's cells and use enzymes to cut it at specific places in the base sequence.

Step 2 The DNA fragments are then combined with DNA fragments from a second organism, often a bacterium. Another enzyme is added to help bond the two fragments.

Step 3 In a process called **gene cloning**, many copies of the gene of interest are made each time the host cell reproduces. The cell can transcribe and translate the gene to make the protein coded for in the gene.

Genetic engineering has many important uses. The process can help make plants that live longer, produce more food, and have greater resistance to disease, climate conditions, insects, or harmful chemicals. In human health, genetic engineering can be used to produce medically important proteins, such as insulin. Scientists use recombinant DNA to produce vaccines and to treat genetic disorders.

HUMAN GENOME PROJECT

In 1990 an important project began that may help scientists use gene technology to fight disease. The purposes of the **Human Genome Project** are to identify all the approximately 30,000 genes in human DNA and to determine the sequences of the 3 billion base pairs that make up human DNA. Scientists largely completed the gene-sequencing part of the project in 2000. They hope that they can use the information gained from the project to improve the diagnosis, treatment, and cures for approximately 4,000 human genetic disorders.

Name _____ Date _____ Class _____

THEORY OF HEREDITY

If you look at most children, you can see similarities to both of their parents. That's because of **heredity**—the passing of traits from parents to offspring. A trait is a characteristic of an organism—shape, color, and size, for example. Your traits include your eye and hair color, the shape of your ears and nose, even your height and weight.

For most of history, heredity was a mystery. Then in the mid-1800s, an Austrian monk, Gregor Mendel, conducted a scientific study of heredity. His study of garden peas laid the foundation for today's genetics, which can be summarized in four points.

1. For each inherited trait, an individual has two genes—one from each parent.
2. For each trait, there are alternative versions of genes, known as **alleles**. If an individual has two alleles of a particular gene that are the same, then the individual is said to be **homozygous** for that trait. If the alleles the individual has for the trait are different, the individual is said to be **heterozygous** for the trait.
3. The presence of an allele doesn't mean that the trait will be expressed in the individual. When two different alleles occur together, one may be completely expressed, while the other may have no observable effect on the organism's appearance. The expressed trait is **dominant**. The trait that isn't expressed when the dominant form of the gene is present is called **recessive**. For example, suppose a plant is heterozygous for flower color—it has two genes for flower color, one purple and the other white. If the plant's flowers are purple, we can conclude that the purple allele is dominant and the white allele is recessive.
4. When gametes are formed, the alleles for each gene in an individual separate independently of one another. Thus gametes carry only one allele for each inherited trait. When gametes unite during fertilization, each gamete contributes one allele.

Name _____ Date _____ Class _____

Using Punnett squares

When animal breeders breed their animals, they usually want very specific characteristics in the offspring. For example, a dairy farmer would want cows that produce a lot of milk. Breeders must be able to predict what traits are likely to appear and how often the traits are likely to appear when they **cross**—or breed—the animals.

One way to predict the chances that offspring will inherit an allele for a trait is to use a **Punnett square**. The Punnett square in Figure 5-13 shows the cross of flower color in pea plants. The pairs of letters outside the boxes represent the alleles of the parents. Notice each parent has two alleles. A capital *W* means that the allele is dominant; a lowercase *w* means that it is recessive. Both parents are homozygous; one has two dominant alleles, and the other has two recessive alleles.

The letters inside the boxes represent the *possible* pairs of alleles in offspring. Notice that each offspring will receive only one allele from each parent. All the offspring have purple flowers because they all receive a dominant allele for purple flowers.

But what would happen if the parents weren't homozygous? Figure 5-14 shows a cross between two heterozygous parents for the same traits. The set of alleles that an organism has makes up its **genotype**. The physical appearance of a trait makes up its **phenotype**. Notice how the phenotypes and genotypes differ among the offspring in the two crosses.

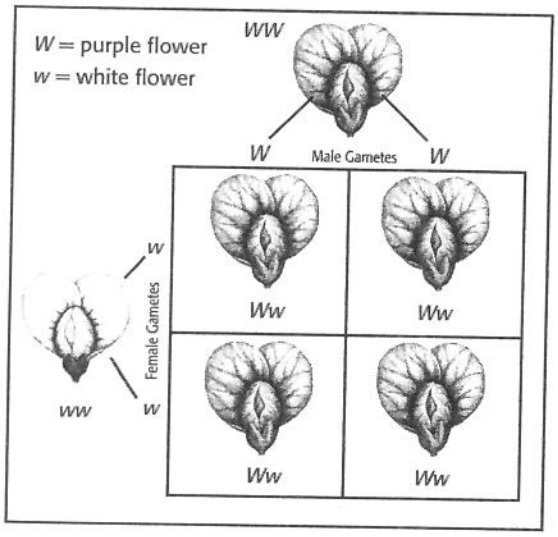


Figure 5-13

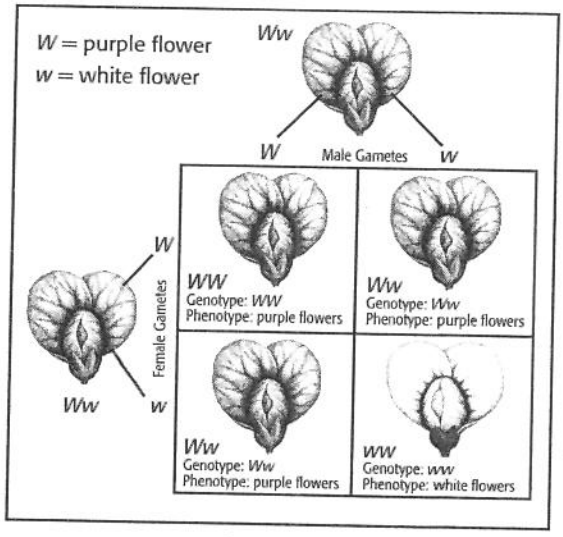


Figure 5-14

Name _____ Date _____ Class _____

Using probabilities

Probability is the likelihood that a specific event will happen. For example, suppose you toss a coin into the air. What is the probability that it will land head up? The probability is one chance in two. That's 50 percent, or $\frac{1}{2}$.

Now suppose you toss the coin twice. What is the probability that the coin will land head up twice? Because each coin flip is an independent event, the probability of the coin landing head up each time is still $\frac{1}{2}$. But the probability of flipping two heads in a row is equal to the product of both probabilities:

$$\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$$

In a similar way, you can predict the probability of an allele being present in a gamete. For example, if a parent plant has two alleles for flower color—one for purple and one for white—the plant can contribute either allele to the gamete it produces, somewhat like the flip of a coin. The probability that the gamete will carry the allele for purple flowers is $\frac{1}{2}$, or 50 percent. The probability that the gamete will carry the allele for white flowers is also $\frac{1}{2}$, or 50 percent.

To figure out the probability that offspring of a specific cross will have certain characteristics, such as being homozygous for flower color, you can work through equations like the one shown above. Or you can easily and directly predict possibilities using a Punnett square. You know that a Punnett square shows the *types*—both genotype and phenotype—of offspring that could be produced. But a Punnett square also shows the *ratio* of those expected offspring types to each other—a value that equals the probability that they will occur.

For example, the Punnett square in Figure 5-14 on the previous page shows the cross of two plants—both heterozygous for flower color. In this four-celled Punnett square, the ratio of purple-flower cells to the total number of cells is three to four (written 3:4). This means the cross has a $\frac{3}{4}$, or 75 percent, chance of producing a purple-flowering plant. Likewise, the ratio of white-flower cells to the total number of cells is 1:4. This means that the cross has a $\frac{1}{4}$, or 25 percent, chance of producing a white-flowering plant.

We can also see that there are three possible genotypes represented in the Punnett square in Figure 5-14: *WW*, *Ww*, and *ww*. The ratio of *WW* cells to the total number of cells is 1:4. Thus the cross has a $\frac{1}{4}$, or 25 percent, chance of producing a *WW* plant. The ratio of *Ww* cells to the total number of cells is 2:4; the cross has a $\frac{2}{4}$, or 50 percent, chance of producing a *Ww* plant. And finally, the ratio of *ww* cells to the total number of cells is 1:4, meaning the cross has a $\frac{1}{4}$, or 25 percent, chance of producing a *ww* plant.

Name _____ Date _____ Class _____

COMPLEX PATTERNS OF HEREDITY

You may have seen family pedigrees like the one in Figure 5-15. A **pedigree** is a family history that shows how a trait is inherited over several generations. The pedigree shows a family history of albinism, a genetic disorder in which the body is unable to produce an enzyme necessary for the production of melanin. Melanin is a pigment that gives dark color to hair, skin, and eyes.

Scientists can determine several pieces of genetic information from a pedigree, such as whether individuals are homozygous or heterozygous for a trait and if a trait is dominant or recessive. They also can determine if a particular trait is sex-linked.

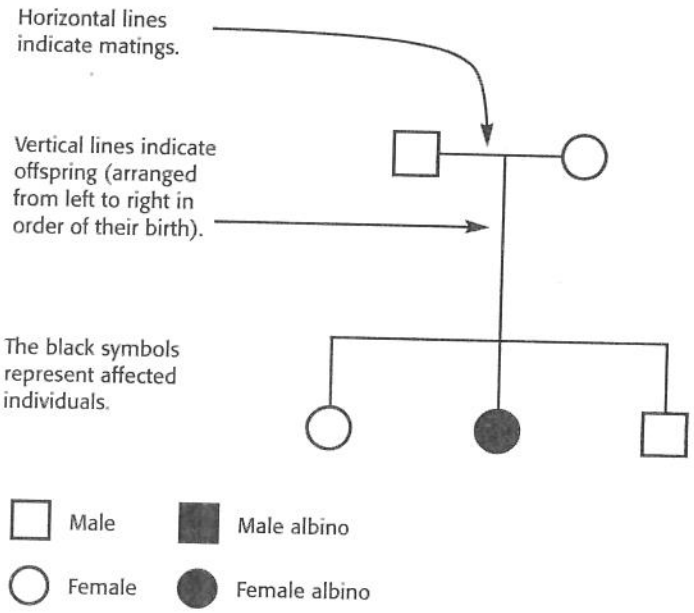


Figure 5-15

Sex-linked traits

Many traits—**autosomal** traits —appear in both sexes equally. But some traits, called **sex-linked traits**, have alleles that are located on the X chromosome. Most sex-linked traits are recessive. Because males have only one X chromosome, a male who carries a recessive allele on the X chromosome will exhibit the sex-linked trait. A female who carries a recessive allele on one X chromosome won't exhibit the trait if there is a dominant allele on her other X chromosome. She will express the condition only if she inherits two recessive alleles. Hemophilia is an example of a sex-linked trait in humans.

Name _____ Date _____ Class _____

Multiple alleles

Figuring out genetic patterns would be easy if all traits were controlled by simple dominant-recessive patterns. But most often, several genes influence a trait. Because the genes for these types of traits may be scattered along the same chromosome or they may be located on different chromosomes, determining the effect of any one gene is difficult. Many different combinations may appear in offspring. Examples of human traits that are determined by more than a single pair of alleles are eye color, hair color, skin color, height, and weight. Figure 5-16 shows another example, ABO blood groups. You can see how different combinations of three alleles, I^A, I^B, and i, result in four different blood types.

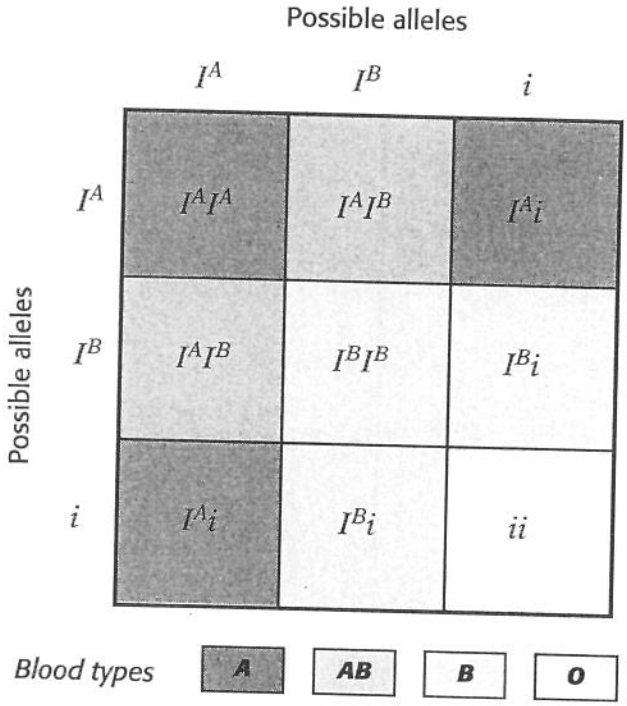


Figure 5-16

Name _____ Date _____ Class _____

TAKS OBJECTIVE

2 TAKS PRACTICE QUESTIONS

1 Where in a cell are all the traits of an organism encoded by a set of instructions?

A Cytoplasm

B DNA

C Vacuoles

D tRNA

	D	*d*
D	*DD*	*Dd*
?	*D?*	*d?*

2 The Punnett square above shows a cross between two individuals that are heterozygous for a trait. What is the missing parental allele?

F *d*

G *D*

H *Dd*

J *DD*

3 A change in which part of a gene is the result of a mutation?

A Hydrogen bonds

B Sugar molecule

C Phosphate molecule

D Base sequence

4 Which sequence of bases will pair with the base sequence CTAGGATTC in a DNA molecule?

F GATCCTAAG

G ATGTTGCCA

H CTAGGATTC

J CAATCCTAG

GO ON

Question 10

Allele	Symbol
Low-yield	H
High-yield	h
Rapidly maturing	M
Slow-growing	m
Tall	T
Short	t
Yellow kernels	Y
White kernels	y

An agricultural scientist wants to develop a variety of corn that will mature rapidly and will produce high yields. Which genotypes should the scientist cross to produce the most plants with the desired characteristics?

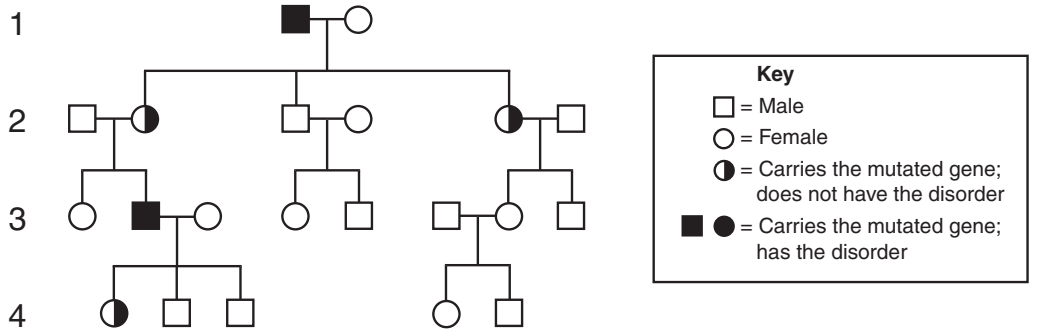
A hhmmTtyy × hhMMttyy

B HHmmttyy × hhMMttyy

C hhMmttyy × HhmmttYY

D HHmmttyy × hhMmttYy

Question 13



Duchenne muscular dystrophy is a genetic disorder. It results from a mutation in the gene that codes for a protein necessary for muscle strength. A geneticist prepared a pedigree for a family in which the disorder is present in some members. According to this information, what type of allele is responsible for Duchenne muscular dystrophy?

A Autosomal recessive

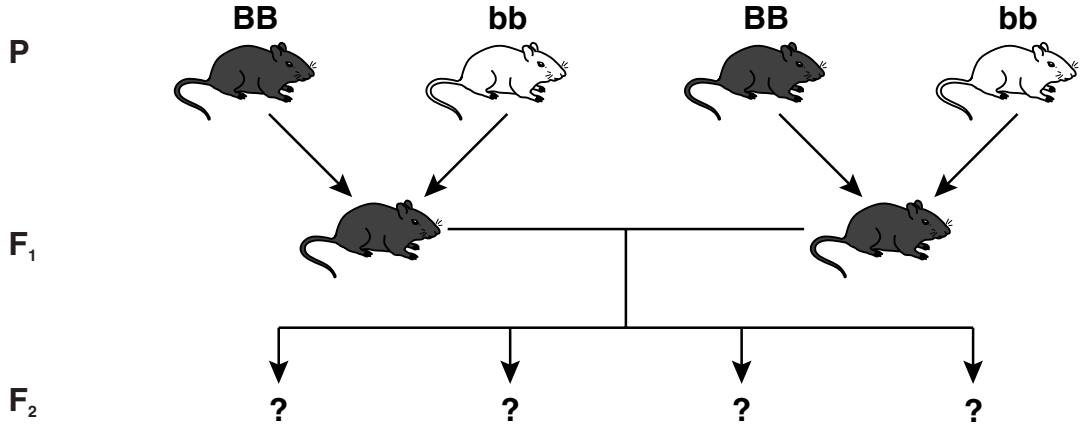
B Autosomal dominant

C Sex-linked recessive

D Sex-linked dominant

Question 14

When a black mouse that is homozygous for coat color (BB) is crossed with a white mouse that is homozygous for coat color (bb), all of the F_1 generation offspring have black coats.



What are the expected genotypes and phenotypes of coat color in the F_2 generation?

A All F_2 mice have BB genotypes and black phenotypes.

B All F_2 mice have bb genotypes and white phenotypes.

C The genotypes of the F_2 mice are 25% BB, 50% Bb, and 25% bb. The phenotypes are 75% black and 25% white.

D The genotypes of the F_2 mice are 50% BB and 50% bb. The phenotypes are 50% black and 50% white.