Unit 4

Genetics

Physical traits, such as the colors of these snapdragons, are encoded in small segments of a chromosome called genes, which are passed from one generation to the next. By studying the inheritance pattern of a trait through several generations, the probability that future offspring will express that trait can be predicted.

Unit Contents

Unit Project

BIOLOGY Online Use the Glencoe Science Web site for more project activities that are connected to this unit.
science.glencoe.com

CLICK HERE

Chapter

10 Mendel and Meiosis

What You'll Learn

- You will identify the basic concepts of genetics.
- You will examine the process of meiosis.

Why It's Important

Genetics explains why you have inherited certain traits from your parents. If you understand how meiosis occurs, you can see how these traits were passed on to you.

READING BIOLOGY

Look over the chapter, and make a list of several vocabulary words that are familiar. Review the list. For each word, think of where and how you may have heard the word used before. As you read the text, note if the words are used differently in a science context than elsewhere.

BIOLOGY Online

To find out more about genetics, visit the Glencoe Science Web site.
science.glencoe.com

CLICK HERE

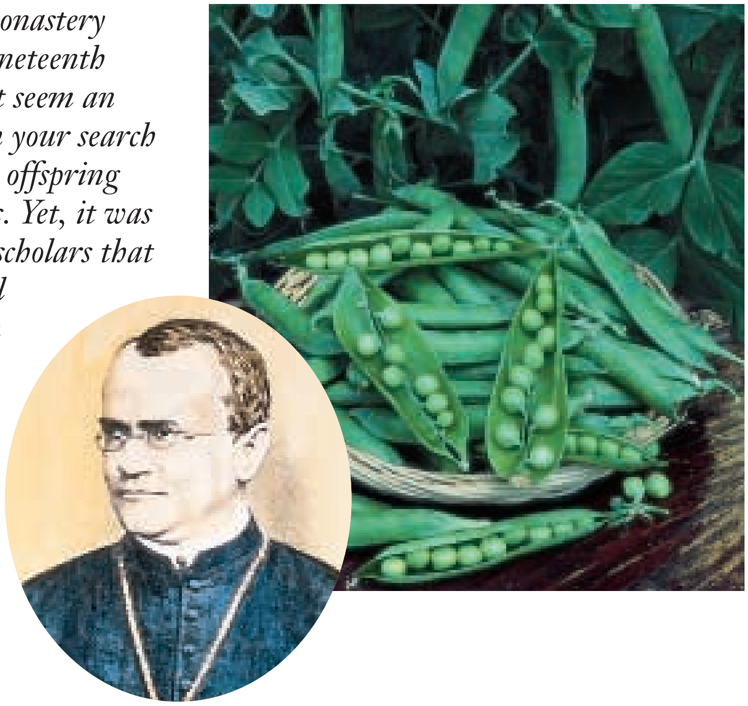
Organisms usually resemble their parents because they inherit certain characteristics from them. These characteristics, also called traits, are determined by genetic information on chromosomes such as those shown in the inset photo.

CONTENTS

Section

10.1 Mendel's Laws of Heredity

An Austrian monastery in the mid-nineteenth century might seem an unusual place to begin your search for the answer to why offspring resemble their parents. Yet, it was in this community of scholars that young Gregor Mendel began to breed garden pea plants so that he could study the inheritance of their characteristics.



Gregor Mendel and pea plants

SECTION PREVIEW

Objectives

Analyze the results obtained by Gregor Mendel in his experiments with garden peas.

Predict the possible offspring of a genetic cross by using a Punnett square.

Vocabulary

heredity
genetics
trait
gamete
pollination
fertilization
hybrid
allele
dominant
recessive
law of segregation
phenotype
genotype
homozygous
heterozygous
law of independent assortment

Why Mendel Succeeded

Gregor Mendel carried out the first important studies of **heredity,** the passing on of characteristics from parents to offspring. Although people had noticed for thousands of years that family resemblances were inherited from generation to generation, a complete explanation required the careful study of **genetics**—the branch of biology that studies heredity. Characteristics that are inherited are called **traits.** Mendel was the first person to succeed in predicting how traits would be transferred from one generation to the next. How was he able to solve this problem of heredity?

Mendel chose his subject carefully

Mendel studied many plants before deciding to use the garden pea in his experiments. Garden pea plants reproduce sexually, which means they have two distinct sex cells—male and female. Sex cells are called **gametes.**

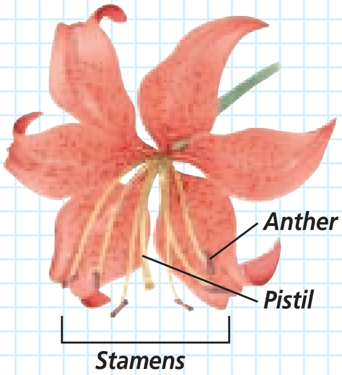
In peas, both male and female gametes are in the same flower. The male gamete is in the pollen grain, which is produced by the anther. The female gamete is in the ovule, which is located in the pistil. The transfer of the male pollen grains to the pistil of a flower is called **pollination.** The uniting of male and female gametes, in a process called **fertilization,** occurs

Word Origin

heredity
From the Latin word *hered-*, meaning "heir." Heredity describes the genetic qualities you receive from your ancestors.

MiniLab 10-1 Observing and Inferring

Looking at Pollen Pollen grains are formed within the male anthers of flowers. What is their role? Pollen contains the male gametes or sperm cells needed for fertilization. This means that pollen grains carry the hereditary units from male parent plants to female parent plants. The pollen grains that Mendel transferred from the anther of one pea plant to the pistil of another plant carried the hereditary traits that he so carefully observed in the next generation.



Procedure

1. Examine a flower. Using the diagram as a guide, locate the stamens of your flower. There are usually several stamens in each flower.
2. Remove one stamen and locate the enlarged end—the anther.
3. Add a drop of water to a microscope glass slide. Place the anther in the water. Add a coverslip. Using the eraser end of a pencil, tap the coverslip several times to squash the anther.
4. Observe under low power. Look for numerous small round structures. These are pollen grains.

Analysis

1. Provide an estimate of the number of pollen grains present in an anther.
2. Describe the appearance of a single pollen grain.
3. Explain the role of pollen grains in plant reproduction.

when the male gamete in the pollen grain meets and fuses with the female gamete in the ovule. After the ovule is fertilized, it matures into a seed.

The reproductive parts of the pea flower are tightly enclosed in petals, preventing the pollen of other flowers from entering. As a result, peas normally reproduce by self-pollination; that is, the male and female gametes come from the same plant. In many of Mendel's experiments, this is exactly what he wanted. When he needed to breed—or cross—one plant with another, Mendel opened the petals and removed the anthers from a flower, ***Figure 10.1a.*** He then dusted the pistil with pollen from the plant he wished to cross it with, ***Figure 10.1b,*** and covered the flower with a small bag to prevent pollen in the air from landing on the pistil. This process is called cross-pollination. By using this technique, Mendel could be sure of the parents in his cross. You can observe anthers and their pollen grains in the *MiniLab* on this page.

Mendel was a careful researcher

Mendel carefully controlled his experiments and the peas he used. He studied only one trait at a time to control variables, and he analyzed his data mathematically. The tall pea plants

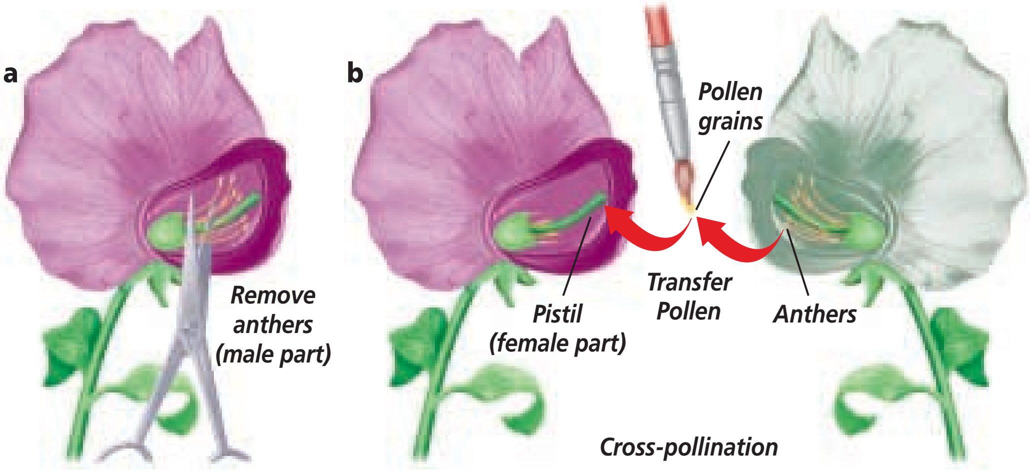


Figure 10.1
In his experiments, Mendel often had to transfer pollen from one plant to another plant with different traits. This is called making a cross.

he worked with were from populations of plants that had been tall for many generations and had always produced tall offspring. Such plants are said to be true breeding for tallness. Likewise, the short plants he worked with were true breeding for shortness.

Mendel's Monohybrid Crosses

What did Mendel do with the tall and short pea plants he so carefully selected? He crossed them to produce new plants. Mendel referred to the offspring of this cross as hybrids. A **hybrid** is the offspring of parents that have different forms of a trait, such as tall and short height. Mendel's first experiments are called monohybrid crosses because *mono* means "one" and the two parent plants differed by a single trait—height.

The first generation

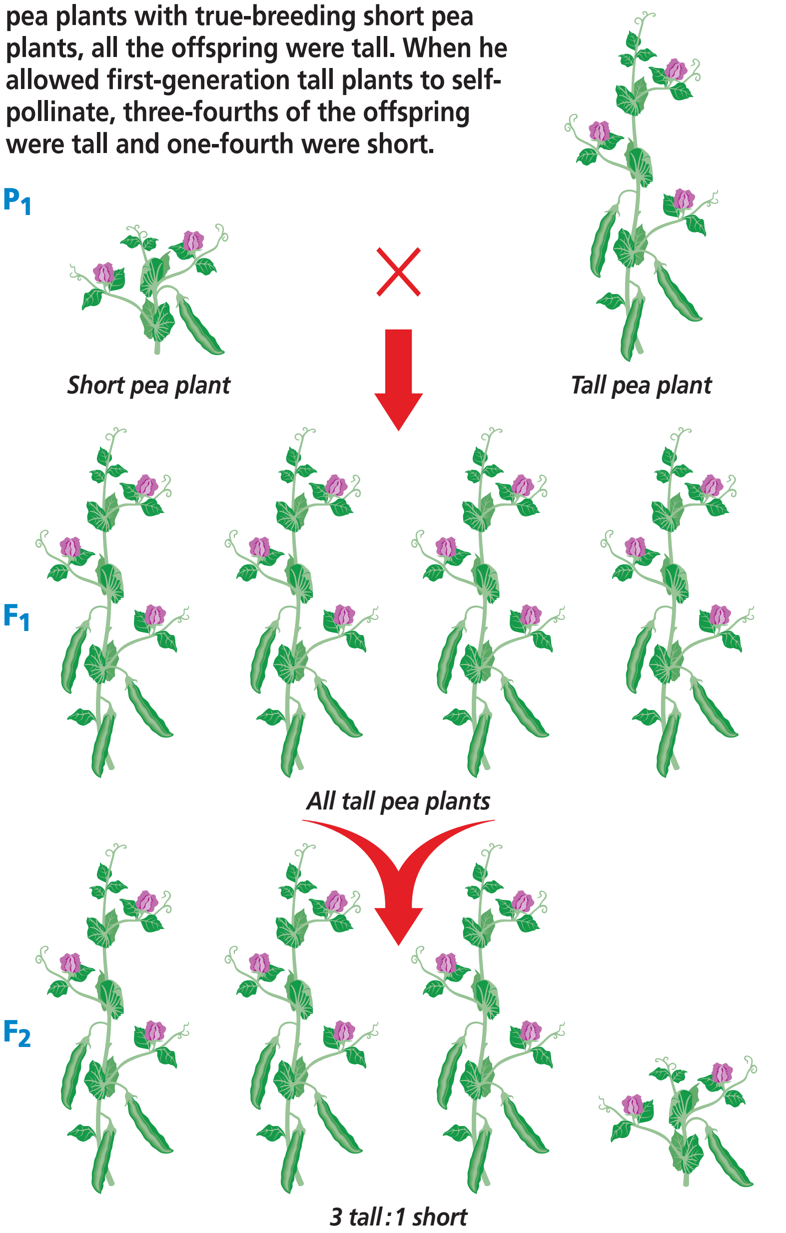
Mendel selected a six-foot-tall pea plant that came from a population of pea plants, all of which were over six feet tall. He cross-pollinated this tall pea plant with a short pea plant that was less than two feet tall and which came from a population of pea plants that were all short. When he planted the seeds from this cross, he found that all of the offspring grew to be as tall as the taller parent. In this first generation, it was as if the shorter parent had never existed!

The second generation

Next, Mendel allowed the tall plants in this first generation to self-pollinate. After the seeds formed, he planted them and counted more than 1000 plants in this second generation. Mendel found that three-fourths of the plants were as tall as the tall plants in the parent and first generations. He also found that one-fourth of the offspring were as short as the short plants in the parent generation. In other words, in the second generation, tall and short plants occurred in a ratio of approximately three tall plants to one short plant, ***Figure 10.2.*** The short trait had reappeared as if from nowhere!

The original parents, the true-breeding tall and short plants, are known as the P_1 generation. The *P* stands for "parent." The offspring of the parent plants are known as the F_1

Figure 10.2
When Mendel crossed true-breeding tall pea plants with true-breeding short pea plants, all the offspring were tall. When he allowed first-generation tall plants to self-pollinate, three-fourths of the offspring were tall and one-fourth were short.



CONTENTS

generation. The *F* stands for "filial"—son or daughter. When you cross two F_1 plants with each other, their offspring are called the F_2 generation—the second filial generation. You might find it easier to understand these terms if you look at your own family. Your parents are the P_1 generation. You are the F_1 generation, and any children you might have in the future would be the F_2 generation.

Word Origin

allele
From the Greek word *allelon*, meaning "of each other." Genes exist in alternative forms called alleles.

Mendel did similar monohybrid crosses with a total of seven pairs of traits, studying one pair of traits at a time. These pairs of traits are shown in ***Figure 10.3.*** In every case, he found that one trait of a pair seemed to disappear in the F_1 generation, only to reappear unchanged in one-fourth of the F_2 plants.

The rule of unit factors

Mendel concluded that each organism has two factors that control each of its traits. We now know that these factors are genes and that they are located on chromosomes. Genes exist in alternative forms. We call these different gene forms **alleles** (uh LEELZ). For example, each of Mendel's pea plants had two alleles of the gene that determined its height. A plant could have two alleles for tallness, two alleles for shortness, or one allele for tallness and one for shortness. An organism's two alleles are located on different copies of a chromosome—one inherited from the female parent and one from the male parent.

The rule of dominance

Remember what happened when Mendel crossed a tall P_1 plant with a short P_1 plant? The F_1 offspring were all tall. In other words, only one trait was observed. In such crosses, Mendel called the observed trait **dominant** and the trait that disappeared **recessive.** We now know that

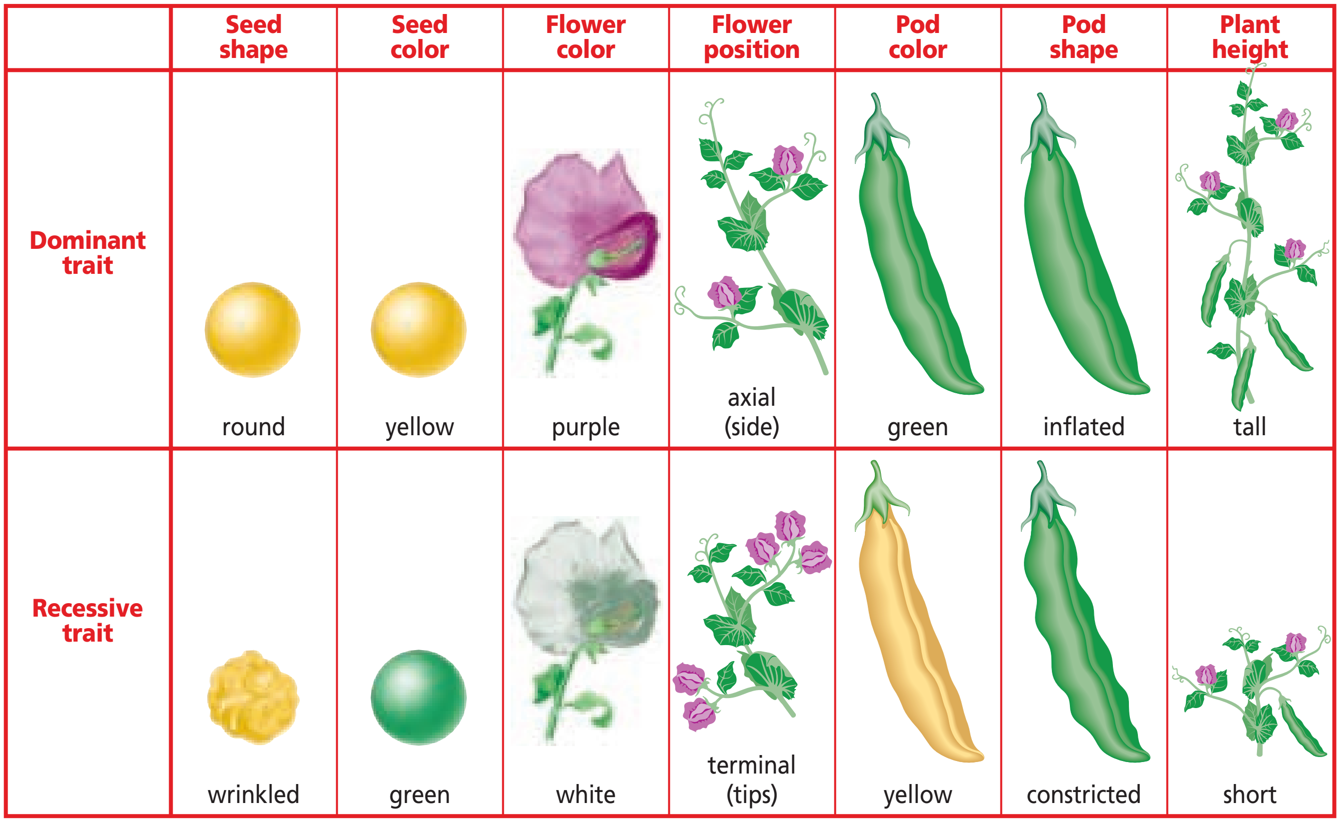


Figure 10.3
Mendel chose seven traits of peas for his experiments. Each trait had two clearly different forms; no intermediate forms were observed.

in Mendel's pea plants, the allele for tall plants is dominant to the allele for short plants. Plants that had one allele for tallness and one for shortness were tall because the allele for tallness is dominant to the allele for shortness. Expressed another way, the allele for short plants is recessive to the allele for tall plants. Pea plants that had two alleles for tallness were tall, and those that had two alleles for shortness were short. You can see in ***Figure 10.4*** how the rule of dominance explained the resulting F_1 generation.

When recording the results of crosses, it is customary to use the same letter for different alleles of the same gene. An uppercase letter is used for the dominant allele, and a lowercase letter for the recessive allele. The dominant allele is always written first. So the allele for tallness is written as *T*, and the allele for shortness as *t*, as it is in ***Figure 10.4.***

The law of segregation

Now recall the results of Mendel's cross between F_1 tall plants, when the trait of shortness reappeared. To explain this result, Mendel formulated the first of his two laws of heredity. He concluded that each tall plant in the F_1 generation carried one dominant allele for tallness and one unexpressed recessive allele for shortness. It received the allele for tallness from its tall parent and the allele for shortness from its short parent in the P_1 generation. Because each F_1 plant has two different alleles, it can produce two different types of gametes— "tall" gametes and "short" gametes. During fertilization, these gametes randomly pair to produce four combinations of alleles. This conclusion, illustrated in ***Figure 10.5*** on the next page, is called the **law of segregation.**

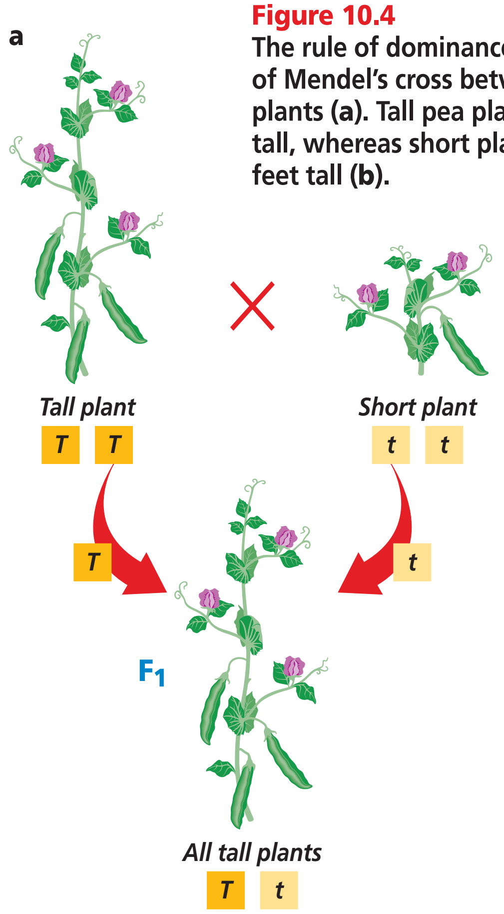
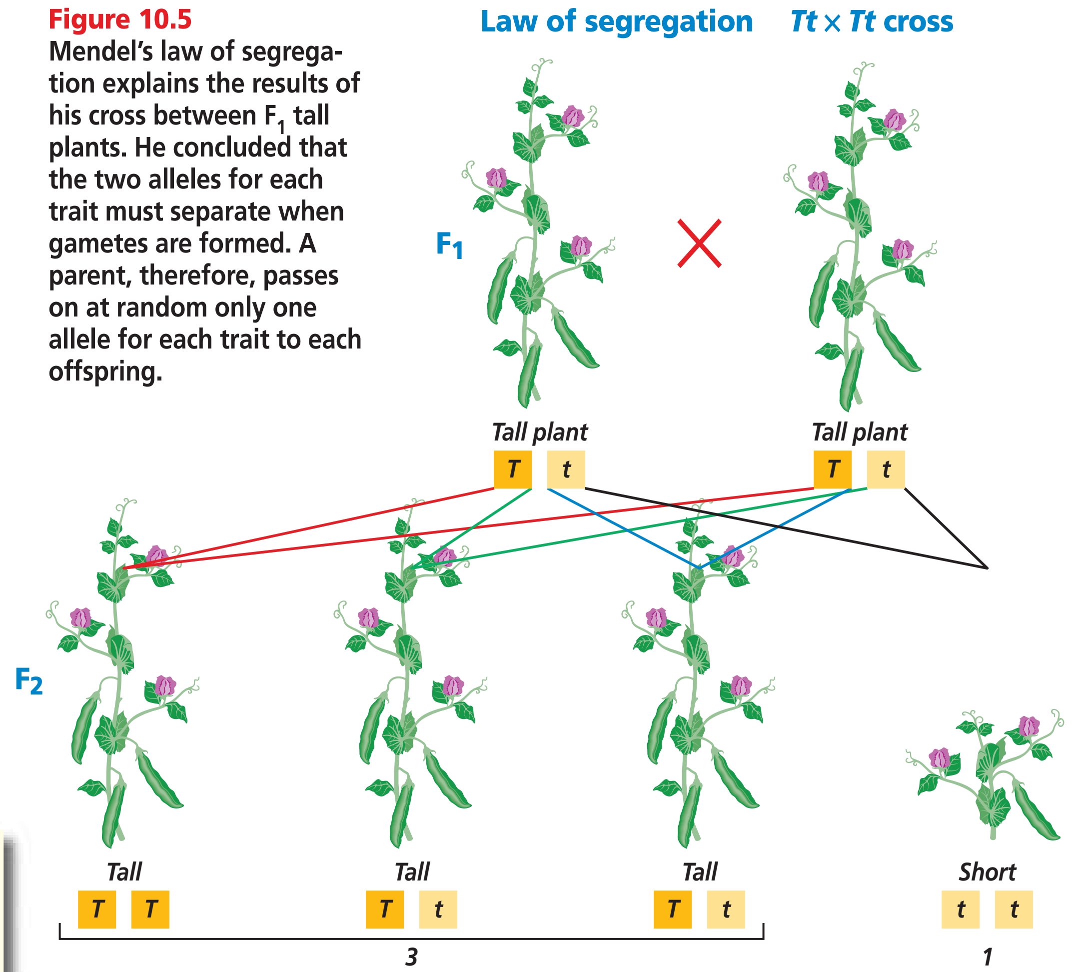


Figure 10.4
The rule of dominance explains the results of Mendel's cross between P_1 tall and short plants (a). Tall pea plants are about six feet tall, whereas short plants are less than two feet tall (b).

b

CONTENTS

Figure 10.5
Mendel's law of segregation explains the results of his cross between F_1 tall plants. He concluded that the two alleles for each trait must separate when gametes are formed. A parent, therefore, passes on at random only one allele for each trait to each offspring.



WORD Origin

phenotype
From the Greek words *phainein*, meaning "to show," and *typos*, meaning "model." The visible characteristics of an organism make up its phenotype.

genotype
From the Greek words *gen* or *geno*, meaning "race," and *typos*, meaning "model." The genetic characteristics of an organism make up its genotype.

Phenotypes and Genotypes

Mendel showed that tall plants are not all the same. Some tall plants, when crossed with each other, yielded only tall offspring. These were Mendel's original P_1 true-breeding tall plants. Other tall plants, when crossed with each other, yielded both tall and short offspring. These were the F_1 tall plants in ***Figure 10.5*** that came from a cross between a tall plant and a short plant.

Two organisms, therefore, can look alike but have different underlying gene combinations. The way an organism looks and behaves is called its **phenotype** (FEE nuh tipe). The phenotype of a tall plant is tall, whether it is *TT* or *Tt*. The gene combination an organism contains is known as its **genotype** (JEE nuh tipe). The genotype of a tall plant that has two alleles for tallness is *TT*. The genotype of a tall plant that has one allele for tallness and one allele for shortness is *Tt*.

You can see that you can't always know an organism's genotype simply by looking at its phenotype. An organism is **homozygous** (hoh muh ZI gus) for a trait if its two alleles for the trait are the same. The true-breeding tall plant that had two alleles for tallness *(TT)* would be homozygous for the trait of height. Because tallness is dominant, a *TT* individual is homozygous dominant for that trait. A short plant would always have two alleles for shortness *(tt)*. It would, therefore, always be homozygous recessive for the trait of height.

An organism is **heterozygous** (het uh roh ZI gus) for a trait if its two alleles for the trait differ from each other. Therefore, the tall plant that had one allele for tallness and one allele for shortness *(Tt)* is heterozygous for the trait of height.

Now look at ***Figure 10.5*** again. Can you identify the phenotype and genotype of each plant? Is each homozygous or heterozygous? You can practice determining genotypes and phenotypes in the *BioLab* at the end of this chapter.

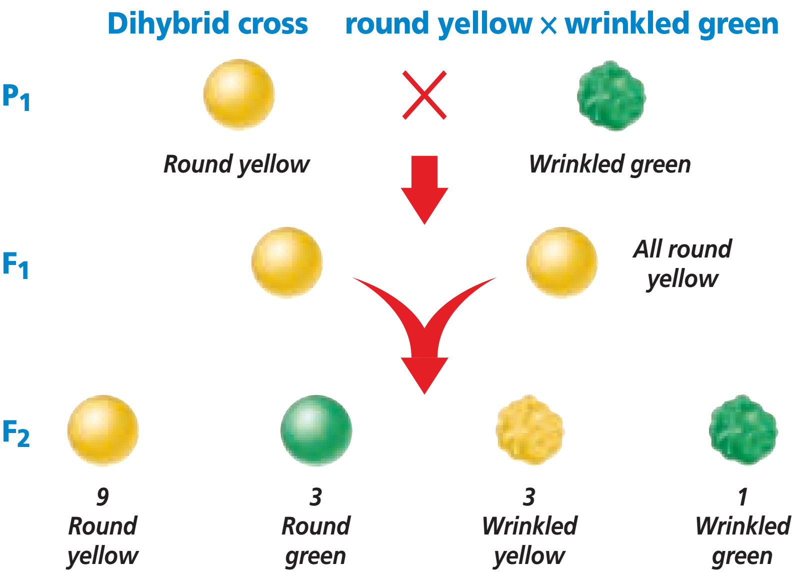
Mendel's Dihybrid Crosses

Mendel performed another set of crosses in which he used peas that differed from each other in two traits rather than only one. Such a cross involving two different traits is called a dihybrid cross because *di* means "two." In a dihybrid cross, will the two traits stay together in the next generation or will they be inherited independently of each other?

The first generation

Mendel took true-breeding pea plants that had round yellow seeds *(RRYY)* and crossed them with true-breeding pea plants that had wrinkled green seeds *(rryy)*. He already knew that when he crossed plants that produced round seeds with plants that produced wrinkled seeds, all the plants in the F_1 generation produced seeds that were round. In other words, just as tall plants were dominant to short plants, the round-seeded trait was dominant to the wrinkled-seeded trait. Similarly, when he crossed plants that produced yellow seeds with plants that produced green seeds, all the plants

Figure 10.6
When Mendel crossed true-breeding plants with round yellow seeds and true-breeding plants with wrinkled green seeds, the seeds of all the offspring were round and yellow. When the F_1 plants were allowed to self-pollinate, they produced four different kinds of plants in the F_2 generation.



in the F_1 generation produced yellow seeds—yellow was dominant. Therefore, Mendel was not surprised when he found that the F_1 plants of his dihybrid cross all had the two dominant traits of round and yellow seeds, as ***Figure 10.6*** shows.

The second generation

Mendel then let the F_1 plants pollinate themselves. As you might expect, he found some plants that produced round yellow seeds and others that produced wrinkled green seeds. But that's not all. He also found some plants with round green seeds and others with wrinkled yellow seeds. When Mendel sorted and counted the plants of the F_2 generation, he found they appeared in a definite ratio of phenotypes—9 round yellow: 3 round green: 3 wrinkled yellow: 1 wrinkled green. To explain the results of this dihybrid cross, Mendel formulated his second law.

WORD *Origin*

heterozygous
From the Greek words *heteros*, meaning "other," and *zygotos*, meaning "joined together." A trait is heterozygous when an individual has two different alleles for that trait.

The law of independent assortment

Mendel's second law states that genes for different traits—for example, seed shape and seed color—are inherited independently of each other. This conclusion is known as the **law of independent assortment.** When a pea plant with the genotype *RrYy* produces gametes, the alleles *R* and *r* will separate from each other (the law of segregation) as well as from the alleles *Y* and *y* (the law of independent assortment), and vice versa. These alleles can then recombine in four different ways. If the alleles for seed shape and color were inherited together, only two kinds of pea seeds would have been produced: round yellow and wrinkled green.

Punnett Squares

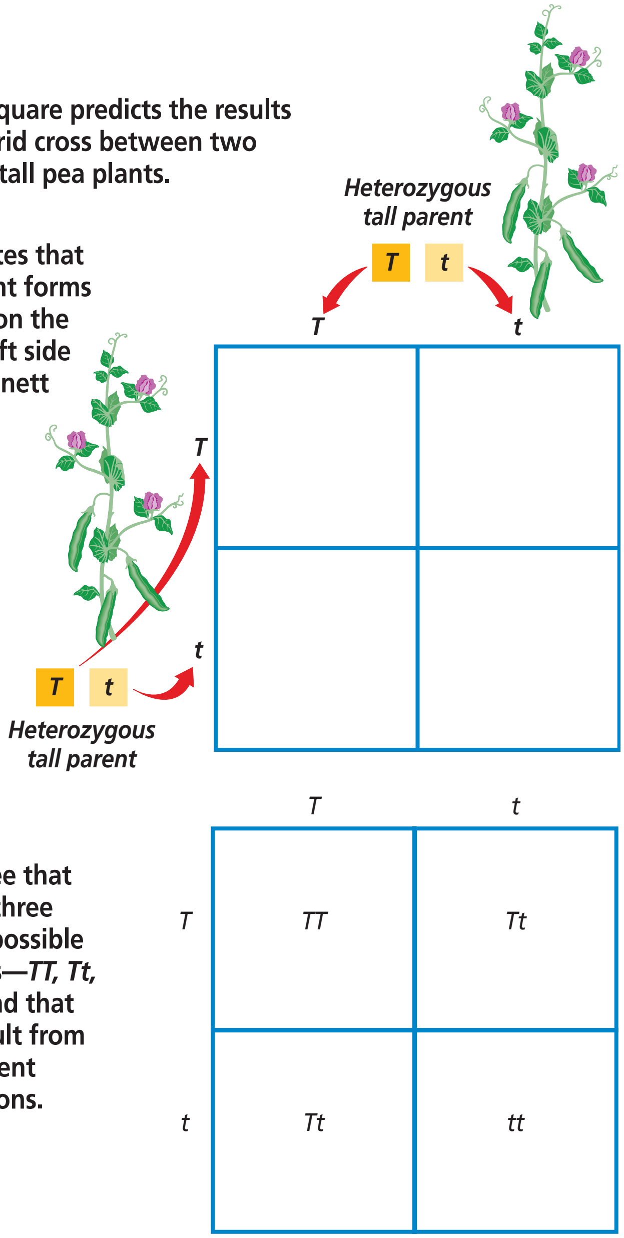
In 1905, Reginald Punnett, an English biologist, devised a shorthand way of finding the expected proportions of possible genotypes in the offspring of a cross. This method is called a Punnett square. It takes account of the fact that fertilization occurs at random, as Mendel's law of segregation states. If you know the genotypes of the parents, you can use a Punnett square to predict the possible genotypes of their offspring.

Monohybrid crosses

Consider the cross between two F_1 tall pea plants, each of which has the genotype *Tt*. Half the gametes of each parent would contain the *T* allele, and the other half would contain the *t* allele. A Punnett square for this cross is two boxes tall and two boxes wide because each parent can produce two kinds of gametes for this trait. The two kinds of gametes from one parent are listed on top of the square, and the two kinds of gametes from the other parent are listed on the left side, ***Figure 10.7A***. It doesn't matter which set of gametes is on top and which is on the side, that is, which parent contributes the *T* and which contributes the *t*. Refer to the Punnett square in ***Figure 10.7B*** to determine the possible genotypes of the offspring. Each box is filled in with the gametes above and to the left side of that box. You can see that each box then contains two alleles—one possible genotype.

After the genotypes have been determined, you can determine the

Figure 10.7
This Punnett square predicts the results of a monohybrid cross between two heterozygous tall pea plants.



A The gametes that each parent forms are listed on the top and left side of the Punnett square.

B You can see that there are three different possible genotypes—*TT, Tt,* and *tt*—and that *Tt* can result from two different combinations.

CONTENTS

phenotypes. Looking at the Punnett square for this cross in ***Figure 10.7B,*** you can see that three-fourths of the offspring are expected to be tall because they have at least one dominant allele. One-fourth are expected to be short because they lack a dominant allele. Of the tall offspring, one-third will be homozygous dominant *(TT)* and two-thirds will be heterozygous *(Tt)*. Note that whereas the genotype ratio is 1*TT*: 2*Tt*: 1*tt*, the phenotype ratio is 3 tall: 1 short. You can practice doing calculations such as Mendel did in the *Math Connection* at the end of this chapter.

Dihybrid crosses

What happens in a Punnett square when two traits are considered? Think again about Mendel's cross between pea plants with round yellow seeds and plants with wrinkled green seeds. All the F_1 plants produced seeds that were round and yellow and were heterozygous for each trait *(RrYy)*. What kind of gametes will these F_1 plants form?

Mendel explained that the traits for seed shape and seed color would be inherited independently of each other. This means that each F_1 plant will produce gametes containing the following combinations of genes with equal frequency: round yellow *(RY)*, round green *(Ry)*, wrinkled yellow *(rY)*, and wrinkled green *(ry)*. A Punnett square for a dihybrid cross will then need to be four boxes on each side for a total of 16 boxes, as ***Figure 10.8*** shows.

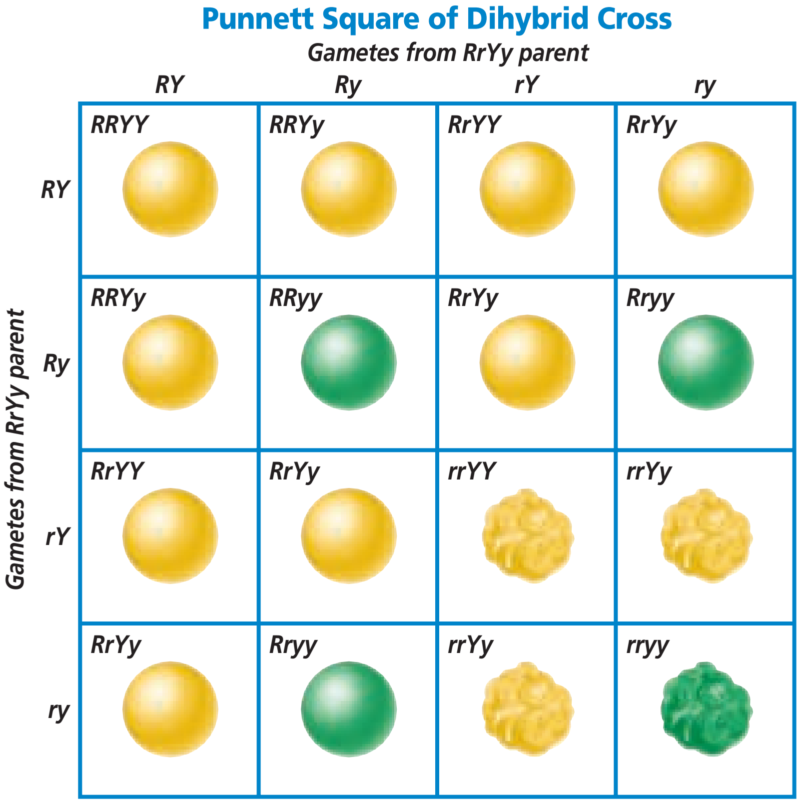
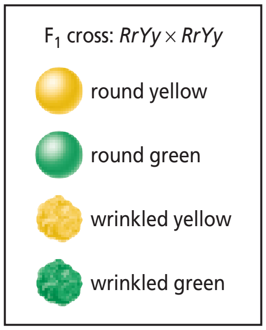


Figure 10.8
A Punnett square for a dihybrid cross between heterozygous pea plants with round yellow seeds shows clearly that the offspring fulfill Mendel's observed ratio of 9 round yellow: 3 round green: 3 wrinkled yellow: 1 wrinkled green.



Probability

Punnett squares are good for showing all the possible combinations of gametes and the likelihood that each will occur. In reality, however, you don't get the exact ratio of results shown in the square. That's because, in some ways, genetics is like flipping a coin—it follows the rules of chance.

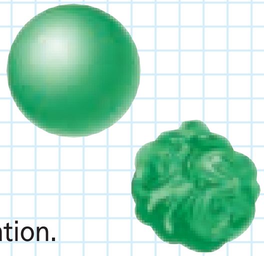
When you toss a coin, it lands either heads up or tails up. The probability or chance that an event will occur can be determined by dividing the number of desired outcomes by the total number of possible outcomes. So the probability of getting heads when you toss a coin would be one in two chances, written as 1: 2 or 1/2. A Punnett square can be used to determine the probability of getting a pea plant that produces round seeds when two plants that are heterozygous *(Rr)* are crossed. Because this Punnett

Problem-Solving Lab 10-1

Analyzing Information

How did Mendel analyze his data?

In addition to crossing tall and short pea plants, Mendel crossed plants that formed round seeds with plants that formed wrinkled seeds. He found a 3: 1 ratio of round-seeded plants to wrinkled-seeded plants in the F_2 generation.



Analysis

Mendel's actual results in the F_2 generation are shown to the right.

Mendel's results

Kind of Plants	Number of Plants
Round-seeded	5474
Wrinkled-seeded	1850

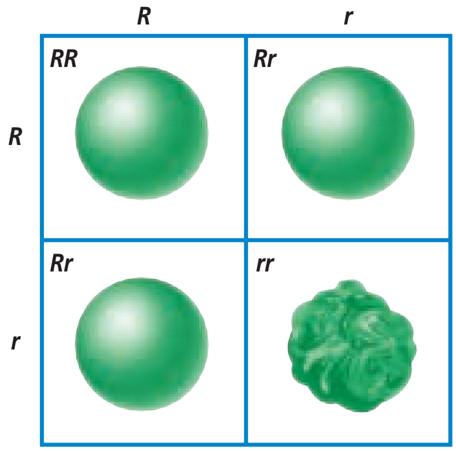
1. Calculate the actual ratio of round-seeded plants to wrinkled-seeded plants. To do this, divide the number of round-seeded plants by the number of wrinkled-seeded plants (round to the nearest hundredth). Your answer tells you how many more times round-seeded plants resulted than wrinkled-seeded plants.
2. To express your answer as a ratio, write the number from step 1 followed by a colon and the numeral *1.*

Thinking Critically

1. What was the actual ratio Mendel observed for this cross?
2. How does Mendel's observed ratio compare with the expected 3: 1 ratio?
3. Why was the actual ratio different from the expected ratio?

square shows three plants with round seeds out of four total plants, the probability is 3/4, as ***Figure 10.9*** shows. Yet, if you calculate the fraction of round-seeded plants from Mendel's actual data in the *Problem-Solving Lab* on this page, you will see that slightly less than three-fourths of the plants were round-seeded. It is important to remember that the results predicted by probability are more likely to be seen when there is a large number of offspring.

Figure 10.9
The probability that the offspring from a mating of two heterozygotes will show a dominant phenotype is 3 out of 4, or 3/4.



Section Assessment

Understanding Main Ideas

1. What structural features of pea plant flowers made them suitable for Mendel's genetic studies?
2. What are the genotypes of a homozygous and a heterozygous tall pea plant?
3. One parent is homozygous tall and the other parent is heterozygous tall. Make a Punnett square to determine what fraction of their offspring is expected to be heterozygous.
4. How many different gametes can an *RRYy* parent form? What are they?

Thinking Critically

5. In garden peas, the allele for yellow peas is dominant to the allele for green peas. Suppose you have a plant that produces yellow peas, but you don't know whether it is homozygous dominant or heterozygous. What experiment could you do to find out? Draw a Punnett square to help you.

Skill Review

6. **Observing and Inferring** The offspring of a cross between a purple-flowered plant and a white-flowered plant are 23 plants with purple flowers and 26 plants with white flowers. Use the letter *P* for purple and *p* for white. What are the genotypes of the parent plants? Explain your reasoning. For more help, refer to *Thinking Critically* in the **Skill Handbook.**

Section

10.2 Meiosis

SECTION PREVIEW

Objectives

Analyze how meiosis maintains a constant number of chromosomes within a species.

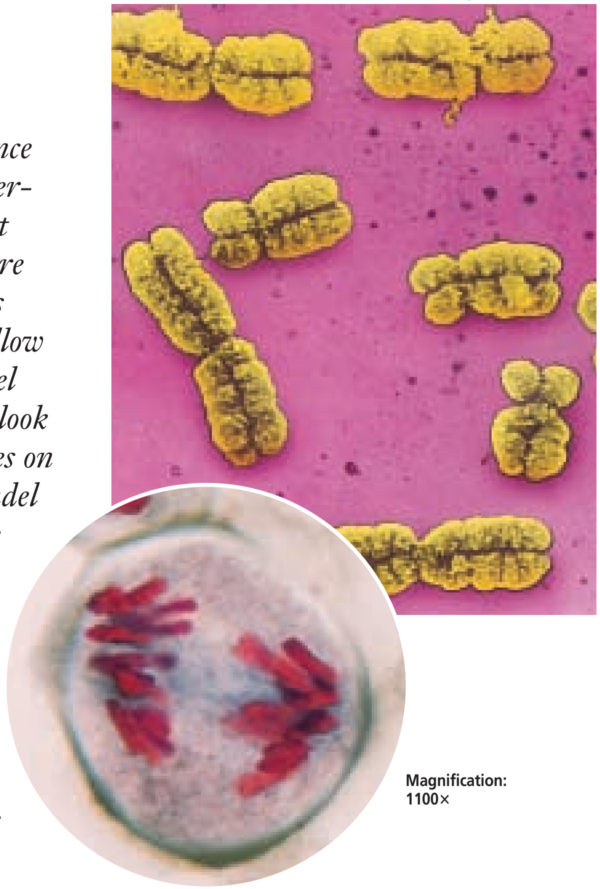
Infer how meiosis leads to variation in a species.

Relate Mendel's laws of heredity to the events of meiosis.

Vocabulary

diploid
haploid
homologous chromosome
meiosis
sperm
egg
zygote
sexual reproduction
crossing over
genetic recombination
nondisjunction

Mendel's study of inheritance was based on careful observations of pea plants, but pieces of the hereditary puzzle were still missing. Modern technologies such as high-power microscopes allow us a glimpse of things that Mendel could only imagine. You can now look inside a cell to see the chromosomes on which the traits described by Mendel are carried. You can also examine the process by which these traits are transmitted to the next generation.



Metaphase chromosomes (top) and a plant cell in early anaphase of meiosis

Genes, Chromosomes, and Numbers

Organisms have tens of thousands of genes that determine individual traits. Genes do not exist free in the nucleus of a cell; they are lined up on chromosomes. Typically, a chromosome can contain a thousand or more genes.

Diploid and haploid cells

If you examined the nucleus in a cell of one of Mendel's pea plants, you would find it had 14 chromosomes—seven pairs. In the body cells of animals and most plants, chromosomes occur in pairs. One chromosome in each pair came from the male parent, and the other came from the female parent. A cell with two of each kind of chromosome is called a **diploid** cell and is said to contain a diploid, or 2*n*, number of chromosomes. This pairing supports Mendel's conclusion that organisms have two factors—alleles—for each trait. One allele is located on each of the paired chromosomes.

Organisms produce gametes that contain one of each kind of chromosome. A cell with one of each kind of chromosome is called a **haploid** cell and is said to contain a haploid, or *n*,

Problem-Solving Lab 10-2

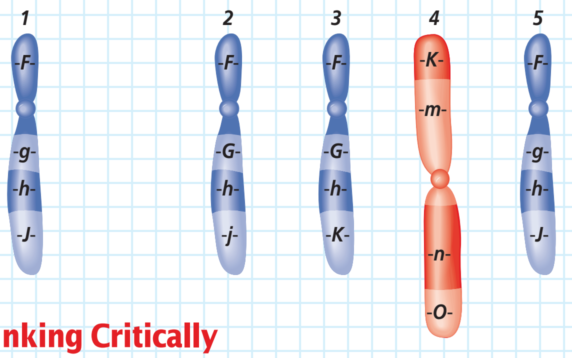
Interpreting Scientific Illustrations

Can you identify homologous chromosomes?

Homologous chromosomes are paired chromosomes having genes for the same trait located at the same place on the chromosome. The gene itself, however, may have different alleles, producing different forms of the trait.

Analysis

The diagram below shows chromosome 1 with four different genes present. These genes are represented by the letters *F, g, h,* and *J.* Possible homologous chromosomes of chromosome 1 are labeled 2-5. Examine the five chromosomes and the genes they contain to determine which of chromosomes 2-5 are homologous with chromosome 1.



Thinking Critically

1. Could chromosome 2 be homologous with chromosome 1? Explain why.
2. Could chromosome 3 be homologous with chromosome 1? Explain why.
3. Could chromosome 4 be homologous with chromosome 1? Explain why.
4. Could chromosome 5 be homologous with chromosome 1? Explain why.

number of chromosomes. This fact supports Mendel's conclusion that parent organisms give one factor, or allele, for each trait to each of their offspring.

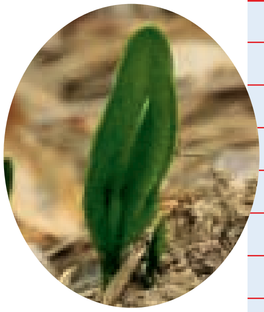
Each species of organism contains a characteristic number of chromosomes. ***Table 10.1*** shows the diploid and haploid numbers of chromosomes of some species. Note the large range of chromosome numbers. Note also that the chromosome number of a species is not related to the complexity of the organism.

Homologous chromosomes

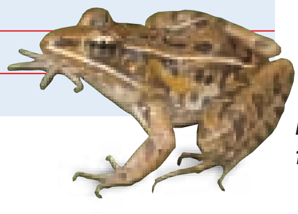
The two chromosomes of each pair in a diploid cell help determine what the individual organism looks like. These paired chromosomes are called **homologous chromosomes** (huh MAHL uh gus). Each of a pair of homologous chromosomes has genes for the same traits, such as pod shape. On homologous chromosomes, these genes are arranged in the same order, but because there are different possible alleles for the same gene, the two chromosomes in a homologous pair are not always identical to each other. Identify the homologous chromosomes in the *Problem-Solving Lab.*

Table 10.1 Chromosome Numbers of Some Common Organisms

Organism	Body Cell (2*n*)	Gamete (*n*)
Fruit fly	8	4
Garden pea	14	7
Corn	20	10
Tomato	24	12
Leopard frog	26	13
Apple	34	17
Human	46	23
Chimpanzee	48	24
Dog	78	39
Adder's tongue fern	1260	630


Adder's tongue fern


Corn


Leopard frog

CONTENTS

Let's look at the seven pairs of homologous chromosomes in Mendel's peas. These chromosome pairs are numbered 1 through 7. Each pair contains certain genes located at specific places on the chromosome. Chromosome 4 contains the genes for three of the traits that Mendel studied. Many other genes can be found on this chromosome as well.

Every pea plant has two copies of chromosome 4. It received one from each of its parents and will give one at random to each of its offspring. Remember, however, that the two copies of chromosome 4 in a pea plant may not necessarily have identical alleles. Each can have one of the different alleles possible for each gene. The homologous chromosomes diagrammed in ***Figure 10.10*** show both alleles for each of three traits. Thus, the plant represented by these chromosomes is heterozygous for each of the traits.

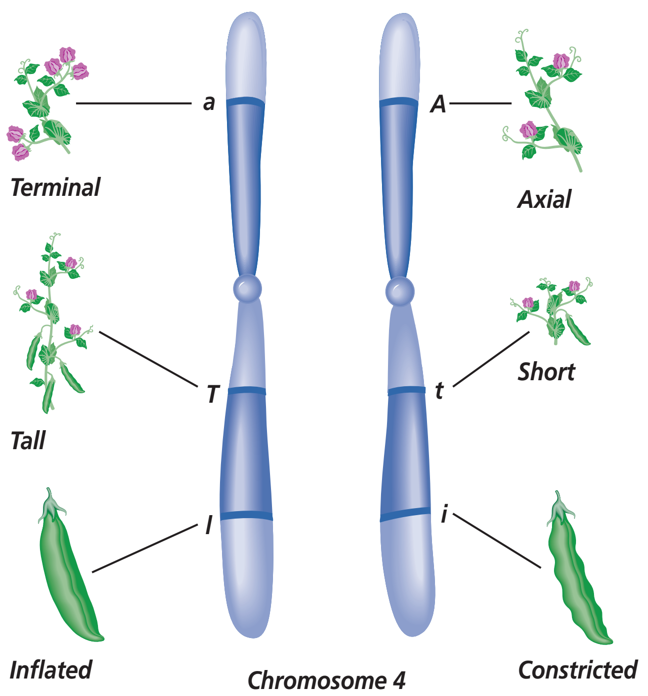


Figure 10.10
Each chromosome 4 in garden peas contains genes for flower position, height, and pod shape. Flower position can be either axial (flowers located along the stems) or terminal (flowers clustered at the top of the plant). Plant height can be either tall or short. Pod shape can be either inflated or constricted.

Why meiosis?

When cells divide by mitosis, the new cells have exactly the same number and kind of chromosomes as the original cells. Imagine if mitosis were the only means of cell division. Each pea plant parent, which has 14 chromosomes, would produce gametes that contained a complete set of 14 chromosomes. That means that each offspring formed by fertilization of gametes would have twice the number of chromosomes as each of its parents. The F_1 pea plants would have cell nuclei with 28 chromosomes, and the F_2 plants would have cell nuclei with 56 chromosomes. The nuclei would certainly be crowded! What do you think these plants might look like?

Clearly, there must be another form of cell division that allows offspring to have the same number of chromosomes as their parents. This kind of cell division, which produces gametes containing half the number of chromosomes as a parent's body cell, is called **meiosis** (mi OH sus). Meiosis occurs in the specialized body cells of each parent that produce gametes.

Meiosis consists of two separate divisions, known as meiosis I and meiosis II. Meiosis I begins with one diploid ($2n$) cell. By the end of meiosis II, there are four haploid (n) cells. These haploid cells are called sex cells—gametes. Male gametes are called **sperm.** Female gametes are called **eggs.** When a sperm fertilizes an egg, the resulting cell, called a **zygote** (ZI goht), once again has the diploid number of chromosomes.

WORD *Origin*

meiosis
From the Greek word *meioun*, meaning "to diminish." Meiosis is cell division that results in a gamete containing half the number of chromosomes of its parent.

The zygote then can develop by mitosis into a multicellular organism. The pattern of reproduction that involves the production and subsequent fusion of haploid sex cells is called **sexual reproduction.** This reproductive pattern is illustrated in ***Figure 10.11.***

The Phases of Meiosis

During meiosis, a spindle forms and the cytoplasm divides in the same ways they do during mitosis. However, what happens to the chromosomes in meiosis is very different. ***Figure 10.12*** illustrates interphase and the phases of meiosis. Examine the diagram and photo of each phase as you read about it.

Interphase

Recall from Chapter 8 that, during interphase, the cell replicates its chromosomes. During interphase that precedes meiosis I, the cell also replicates its chromosomes. After replication, each chromosome consists of two identical sister chromatids, held together by a centromere.

Prophase I

A cell entering prophase I behaves in a similar way to one entering prophase of mitosis. The chromosomes coil up and a spindle forms. Then, in a step unique to meiosis, each pair of homologous chromosomes comes together, matched gene by gene, to form a four-part structure called a tetrad. A tetrad consists of two homologous chromosomes, each made up of two sister chromatids. The chromatids in a tetrad pair tightly. In fact, they pair so tightly that nonsister chromatids from homologous chromosomes sometimes actually exchange genetic material in a process known as **crossing over.** Crossing over can occur at any location on a chromosome, and it can occur at several locations at the same time. It is estimated that during prophase I of meiosis in humans, there is an average of two to three crossovers for each pair of homologous chromosomes.

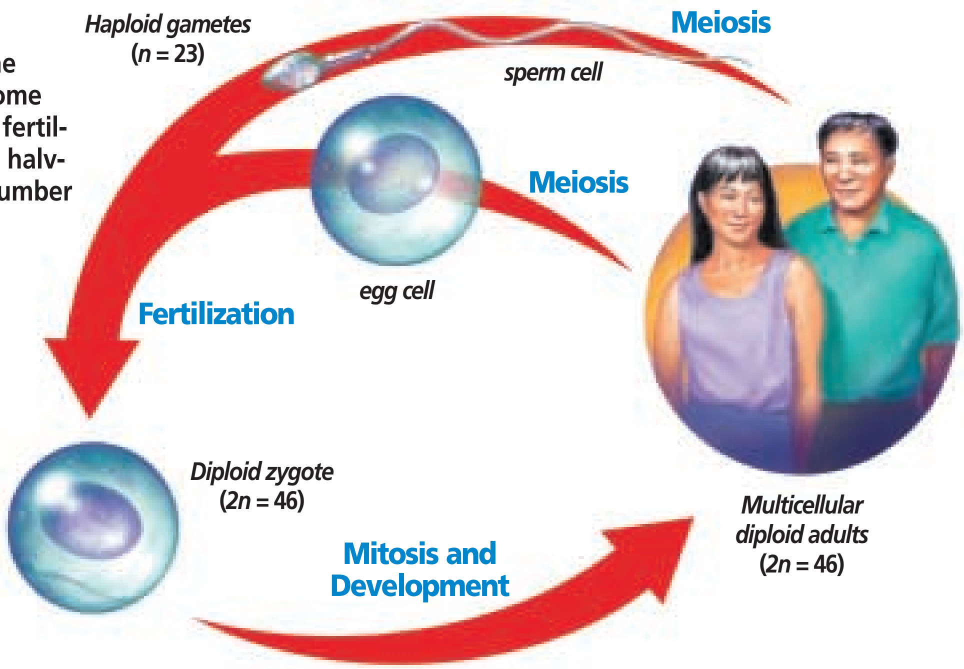
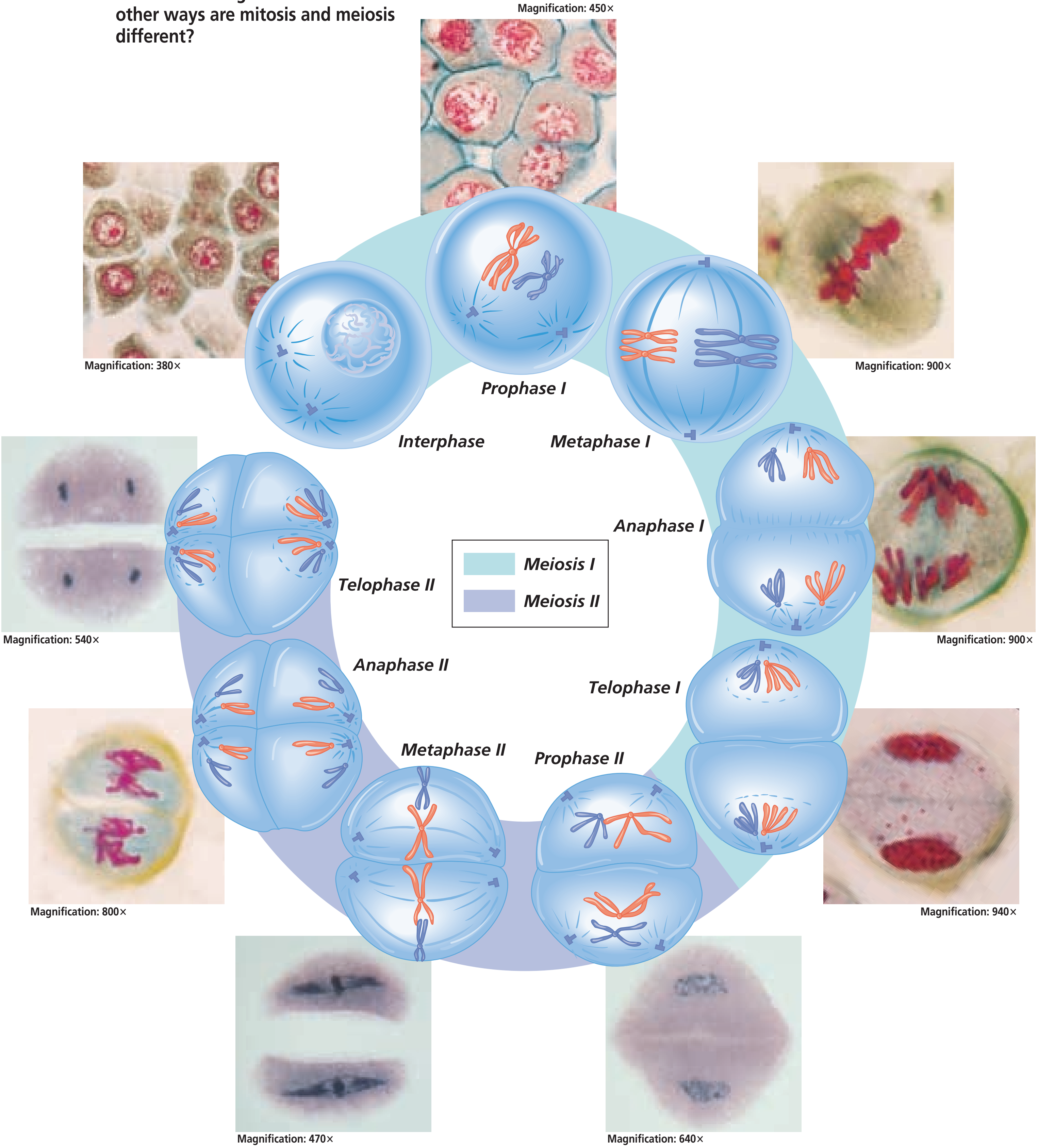


Figure 10.11
In sexual reproduction, the doubling of the chromosome number that results from fertilization is balanced by the halving of the chromosome number that results from meiosis.

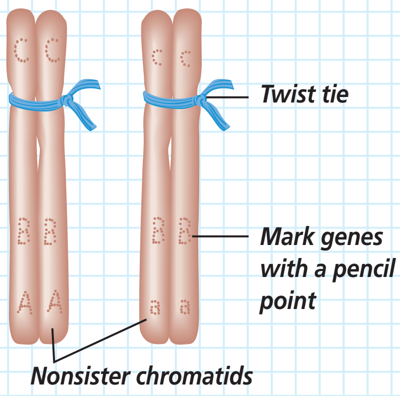
Figure 10.12
Follow the diagrams showing interphase and meiosis as you read about each phase. Compare these diagrams with those of mitosis in Chapter 8. Note that after telophase II, meiosis is finished and gametes form. In what other ways are mitosis and meiosis different?



MiniLab 10-2 Formulating Models

Modeling Crossing Over

Crossing over occurs during meiosis and involves only the nonsister chromatids that are present during tetrad formation. The process is responsible for the appearance of new combinations of alleles in gamete cells.



Procedure

1. Copy the data table.
2. Roll out four long strands of clay at least 10 cm long to represent two chromosomes, each with two chromatids.
3. Use the figure above as a guide in joining and labeling these model chromatids. Although there are four chromatids, assume that they started out as a single pair of homologous chromosomes prior to replication. The figure shows tetrad formation during prophase I of meiosis.
4. First, assume that no crossing over takes place. Model the appearance of the four gamete cells that will result at the end of meiosis. Record your model's appearance by drawing the gametes' chromosomes and their genes in your data table.
5. Next, repeat steps 2-4. This time, however, assume that crossing over occurs between genes B and C.

Data Table

No crossing over	Crossing over
Appearance of gamete cells	Appearance of gamete cells

Analysis

1. Predict and diagram the appearance of the chromosomes prior to replication.
2. Define crossing over and explain when it occurs.
3. Compare any differences in the appearance of genes on chromosomes in gamete cells when crossing over occurs and when it does not occur.
4. Crossing over has been compared to "shuffling the deck" in cards. Explain what this means.
5. What would be accomplished if crossing over occurred between sister chromatids? Explain your answer.

This exchange of genetic material is diagrammed as an X-shaped configuration in ***Figure 10.13b.*** Crossing over results in new combinations of alleles on a chromosome, as shown in ***Figure 10.13c.*** You can practice modeling crossing over in the *MiniLab* at the left.

Metaphase I

As prophase I ends, the centromere of each chromosome becomes attached to a spindle fiber. The spindle fibers pull the tetrads into the middle, or equator, of the spindle. This is an important step unique to meiosis. Note that homologous chromosomes are lined up side by side as tetrads. In mitosis, on the other hand, homologous chromosomes line up on the equator independently of each other.

Anaphase I

Anaphase I begins as homologous chromosomes, each with its two chromatids, separate and move to opposite ends of the cell. This occurs because the centromeres holding the sister chromatids together do not split as they do during anaphase in mitosis. This critical step ensures that each new cell will receive only one chromosome from each homologous pair.

Telophase I

Events occur in the reverse order from the events of prophase I. The spindle is broken down, the chromosomes uncoil, and the cytoplasm divides to yield two new cells. Each cell has only half the genetic information of the original cell because it has only one chromosome from each homologous pair. However, another cell division is needed because each chromosome is still doubled, consisting of two sister chromatids.

The phases of meiosis II

The newly formed cells in some organisms undergo a short interphase in which the chromosomes do not replicate. In other organisms, however, the cells go from late anaphase of meiosis I directly to metaphase of meiosis II, skipping telophase I, interphase, and prophase II.

The second division in meiosis consists of prophase II, metaphase II, anaphase II, and telophase II. During prophase II, a spindle forms in each of the two new cells and the spindle fibers attach to the chromosomes. The chromosomes, still made up of sister chromatids, are pulled to the center of the cell and line up randomly at the equator during metaphase II, just as they do in mitosis. Anaphase II begins as the centromere of each chromosome splits, allowing the sister chromatids to separate and move to opposite poles. Finally, nuclei re-form, the spindles break down, and the cytoplasm divides during telophase II. The events of meiosis II are identical to those you studied for mitosis.

At the end of meiosis II, four haploid sex cells have been formed from one original diploid cell. Each haploid cell contains one chromosome from each homologous pair. These haploid cells will become gametes, transmitting the genes they contain to offspring.

Meiosis Provides for Genetic Variation

Cells that are formed by mitosis are identical to each other and to the parent cell. Meiosis, however, provides a mechanism for shuffling the chromosomes and the genetic information they carry. By shuffling the chromosomes, genetic variation is produced.

Genetic recombination

How many different kinds of sperm can a pea plant produce? Each cell undergoing meiosis has seven pairs of chromosomes. Because each of the seven pairs of chromosomes can line up at the cell's equator in two different ways, 128 different kinds of sperm are possible ($2^7 = 128$).

Word Origin

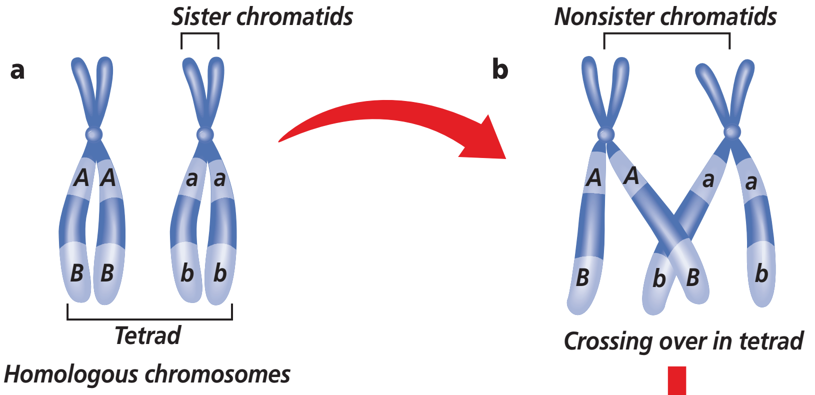
pro-
From the Greek word *pro*, meaning "before."

meta-
From the Greek word *meta*, meaning "after."

ana-
From the Greek word *ana*, meaning "away, onward."

telo-
From the Greek *telos*, meaning "end."

The four phases of cell division are prophase, metaphase, anaphase, and telophase.



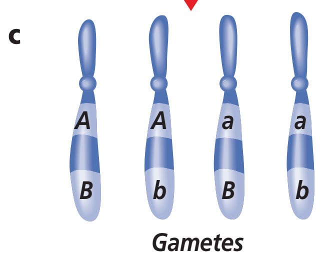


Figure 10.13
Late in prophase I, the homologous chromosomes come together to form tetrads (a). Arms of nonsister chromatids wind around each other (b), and genetic material may be exchanged (c).

In the same way, any pea plant can form 128 different eggs. Because any egg can be fertilized by any sperm, the number of different possible offspring is 16 384 (128 × 128). ***Figure 10.14a*** shows a simple example of how genetic recombination occurs. You can see that the gene combinations in the gametes vary depending on how each pair of homologous chromosomes lines up during metaphase I, a random process.

These numbers increase greatly as the number of chromosomes in the species increases. In humans, $n = 23$, so the number of different kinds of eggs or sperm a person can produce is more than 8 million (2^{23}). When fertilization occurs, $2^{23} \times 2^{23}$, or 70 trillion, different zygotes are possible! It's no wonder that each individual is unique.

In addition, crossing over can occur anywhere at random on a chromosome. Typically, two or three crossovers per chromosome occur during meiosis. This means that an almost endless number of different possible chromosomes can be produced by crossing over, providing additional variation to that already produced by the random assortment of chromosomes. This reassortment of chromosomes and the genetic information they carry, either by crossing over or by independent segregation of homologous chromosomes, is called **genetic recombination.** It is a major source of variation among organisms. Variation is important to a species because it is the raw material that forms the basis for evolution. How does crossing over increase genetic variability? To answer this question, read the *Inside Story* on the next page.

Meiosis explains Mendel's results

Meiosis provides the physical basis for explaining Mendel's results. The segregation of chromosomes in anaphase I of meiosis explains Mendel's observation that each parent gives one allele for each trait at random to each offspring, regardless of whether the allele is expressed. The segregation of chromosomes at random during anaphase I explains Mendel's observation that factors, or genes, for different traits are inherited independently of each other. Today, Mendel's laws of heredity form the foundation of modern genetics.

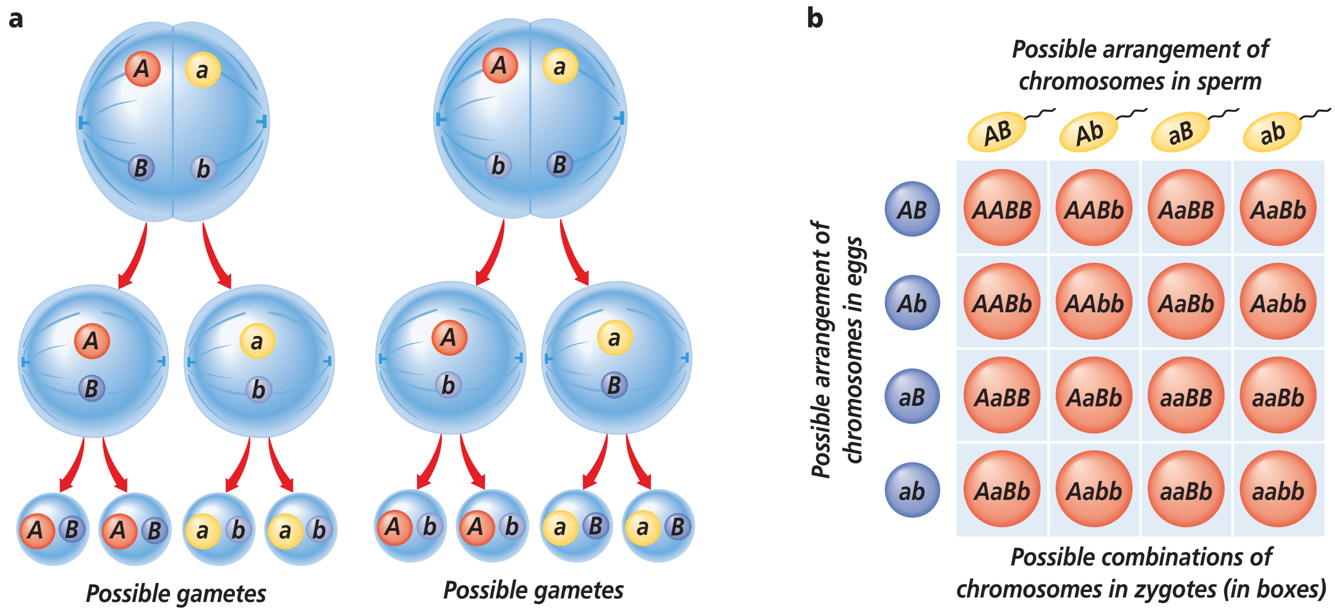


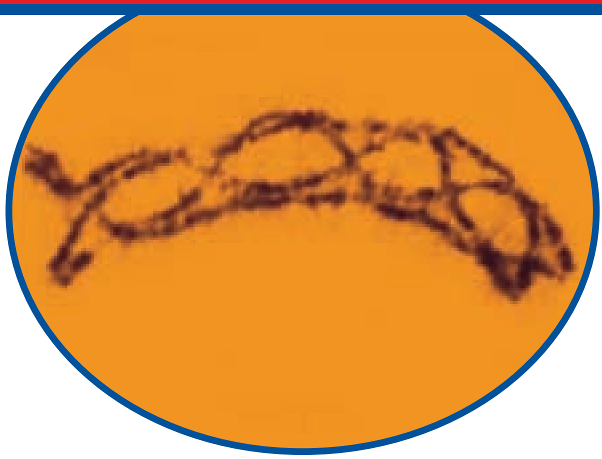
Figure 10.14
If a cell has two pairs of chromosomes (*n* = 2), four kinds of gametes (2^2) are possible, depending on how the homologous chromosomes line up at the equator during meiosis I (a). This event is a matter of chance. When zygotes are formed by the union of these gametes, 4 × 4 or 16 possible combinations may occur (b).

INSIDE STORY

Genetic Recombination

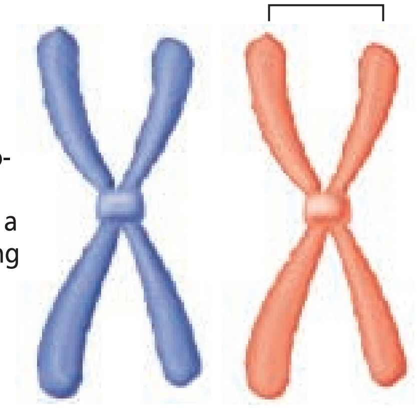
One source of genetic recombination is a process known as crossing over, the exchange of genetic material by nonsister chromatids during meiosis.

Critical Thinking *How can the frequency of crossing over be used to map the location of genes on chromosomes?*



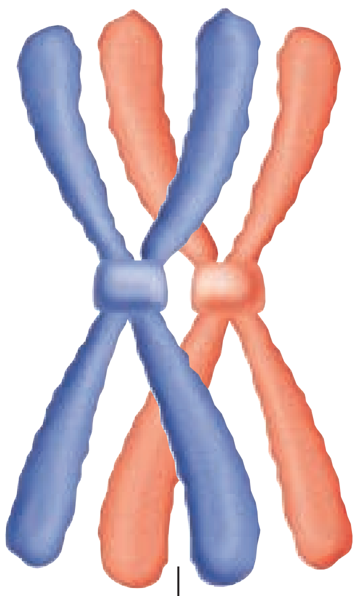
The X-shaped regions are called chiasmata.

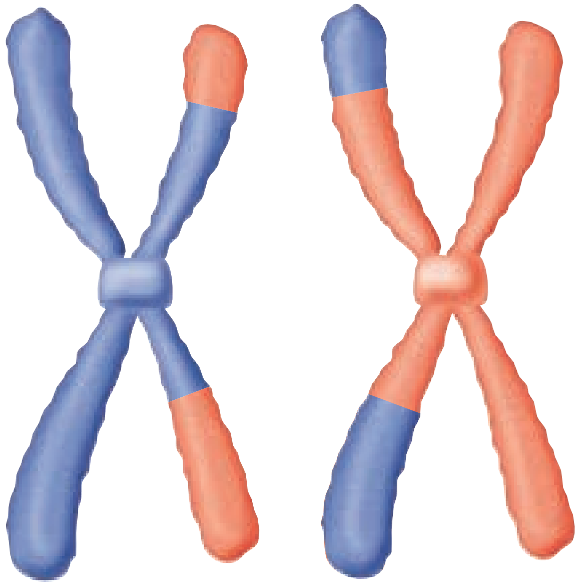
1 Tetrads During late prophase I, homologous chromosomes come together to form a tetrad. This pairing of homologous chromosomes is called synapsis.



4 Mapping Geneticists have used the frequency of crossing over to map the relative location of alleles on chromosomes. Alleles that are further apart on the chromosomes are more likely to have chiasmata between them than alleles that are close together.

2 Chiasmata The pairing of homologous chromosomes during synapsis is precise—they line up with each other allele by allele. The nonsister chromatids twist around each other, forming X-shaped regions called chiasmata (ki az MAH tuh). The two nonsister chromatids break and exchange genetic material.





3 New allele combinations Crossing over causes a shuffling of allele combinations, just as shuffling a deck of cards produces new combinations of cards dealt in a hand. Rather than the alleles from each parent staying together on their homologous chromosome, new combinations of alleles can form. Thus, variability is increased.

Mistakes in Meiosis

Although the events of meiosis usually proceed accurately, sometimes an accident occurs and chromosomes fail to separate correctly. The failure of homologous chromosomes to separate properly during meiosis is called **nondisjunction.** Recall that during meiosis I, one chromosome from each homologous pair moves to each pole of the cell. Occasionally, both chromosomes of a homologous pair move to the same pole of the cell.

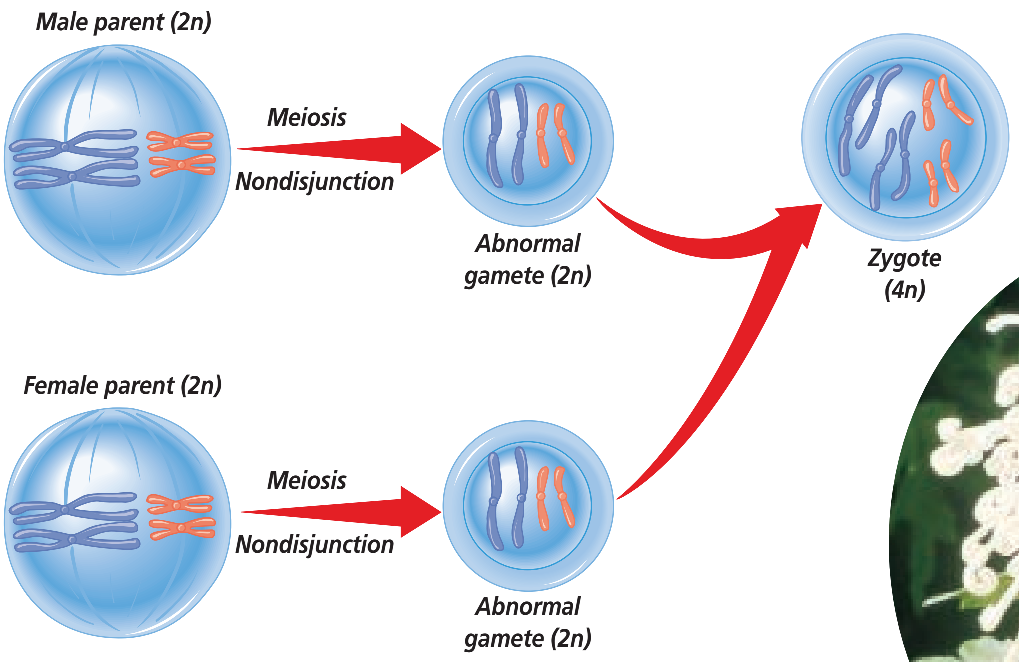
Trisomy, monosomy, and triploidy

In one form of nondisjunction, two kinds of gametes result. One has an extra chromosome, and the other is missing a chromosome. The effects of nondisjunction are often seen after gametes fuse. For example, when a gamete with an extra chromosome is fertilized by a normal gamete, the zygote will have an extra chromosome. This condition is called trisomy (TRI soh mee). In humans, if a gamete with an extra chromosome number 21 is fertilized by a normal gamete, the resulting zygote has 47 chromosomes instead of 46. This zygote will develop into a baby with Down syndrome.

Although organisms with extra chromosomes often survive, organisms lacking one or more chromosomes usually do not. When a gamete with a missing chromosome fuses with a normal gamete during fertilization, the resulting zygote lacks a chromosome. This condition is called monosomy. In humans, most zygotes with monosomy do not survive. If a zygote with monosomy does survive, the resulting organism usually does not. An example of monosomy that is not lethal is Turner syndrome, in which human females have only a single X chromosome instead of two.

Another form of nondisjunction involves a total lack of separation of homologous chromosomes. When this happens, a gamete inherits a complete diploid set of chromosomes, as shown in ***Figure 10.15.*** When a gamete with an extra set of chromosomes is fertilized by a normal haploid gamete, the offspring has three sets of chromosomes and is triploid. The fusion of two gametes, each with an extra set of chromosomes, produces offspring with four

Figure 10.15
Follow the steps to see how a tetraploid plant such as this chrysanthemum is produced.



CONTENTS

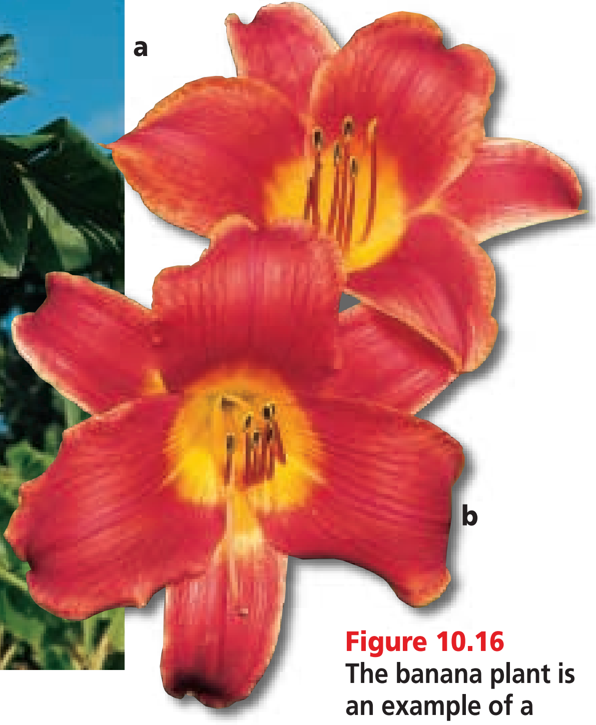


Figure 10.16
The banana plant is an example of a triploid plant (a). This day lily is a tetraploid plant (b).

sets of chromosomes—a tetraploid. This can be seen in ***Figure 10.15***

Organisms with more than the usual number of chromosome sets are called polyploids. Polyploidy is rare in animals and almost always causes death of the zygote. However, polyploidy frequently occurs in plants. Often, the flowers and fruits of these plants are larger than normal, and the plants are healthier. Many polyploid plants, such as the sterile banana plant and the day lily shown in ***Figure 10.16***, are of great commercial value.

Meiosis is a complex process, and the results of an error occurring are sometimes unfortunate. However, mistakes in meiosis can be beneficial, such as those that have occurred in agriculture. Tetraploid ($4n$) wheat, triploid ($3n$) apples, and polyploid chrysanthemums all are available commercially. You can see that a thorough understanding of meiosis and genetics would be very helpful to plant breeders. In fact, plant breeders have learned to artificially produce polyploid plants using chemicals that cause nondisjunction.

Section Assessment

Understanding Main Ideas

1. How are the cells at the end of meiosis different from the cells at the beginning of meiosis? Use the terms *chromosome number, haploid,* and *diploid* in your answer.
2. What is the role of meiosis in maintaining a constant number of chromosomes in a species?
3. Why are there so many varied phenotypes within a species such as humans?
4. If the diploid number of a plant is 10, how many chromosomes would you expect to find in its triploid offspring?

Thinking Critically

5. How do the events of meiosis explain Mendel's law of independent assortment?

Skill Review

6. **Interpreting Scientific Illustrations** Compare ***Figures 10.12*** and ***8.12.*** Explain why crossing over between nonsister chromatids of homologous chromosomes cannot occur during mitosis. For more help, refer to *Thinking Critically* in the **Skill Handbook.**

INTERNET

BioLab

How can phenotypes and genotypes of plants be determined?

It's difficult to predict the traits of plants if all that you see is their seeds. But if these seeds are planted and allowed to grow, certain traits will appear. By observing these traits, you might be able to determine the possible phenotypes and genotypes of the parent plants that produced these seeds. In this lab, you will determine the genotypes of plants that grow from two groups of tobacco seeds. Each group of seeds came from different parents. Plants will be either green or albino (white) in color. Use the following genotypes for this cross. CC = *green,* Cc = *green, and* cc = *albino*

PREPARATION

Problem

Can the phenotypes and genotypes of the parent plants that produced two groups of seeds be determined from the phenotypes of the plants grown from the seeds?

Hypotheses

Have your group agree on a hypothesis to be tested that will answer the problem question. Record your hypothesis.

Objectives

In this BioLab, you will:

- **Analyze** the results of growing two groups of seeds.
- **Draw conclusions** about phenotypes and genotypes based on those results.
- **Use the Internet** to collect and compare data from other students.

Possible Materials

potting soil
small flowerpots or seedling flats
two groups of tobacco seeds
hand lens
light source
thermometer
plant-watering bottle

Safety Precautions

Always wash your hands after handling plant materials. Always wear goggles in the lab.

Skill Handbook

Use the **Skill Handbook** if you need additional help with this lab.

Plan the Experiment

1. Examine the materials provided by your teacher. As a group, make a list of the possible ways you might test your hypothesis.
2. Agree on one way that your group could investigate your hypothesis.
3. Design an experiment that will allow you to collect quantitative data. For example, how many plants do you think you will need to examine?
4. Prepare a numbered list of directions. Include a list of materials and the quantities you will need.
5. Make a data table for recording your observations.

Check the Plan

1. Carefully determine what data you are going to collect. How many seeds do you think you will need? How long will you carry out the experiment?
2. What variables, if any, will have to be controlled? (Hint: Think about the growing conditions for the plants.)
3. ***Make sure your teacher has approved your experimental plan before you proceed.***
4. Carry out your experiment. Make any needed observations, such as the numbers of green and albino plants in each group, and complete your data table.
5. Go to the Glencoe Science Web Site at the address shown below to **post your data.**

Analyze and Conclude

1. **Thinking Critically** Why was it necessary to grow plants from the seeds in order to determine the phenotypes of the plants that formed the seeds?
2. **Drawing Conclusions** Using the information in the introduction, describe how the gene for green color (*C*) is inherited.
3. **Making Inferences** For the group of seeds that yielded all green plants, are you able to determine exactly the genotypes of the parents that formed these seeds? Can you determine the genotype of each plant observed? Explain.
4. **Making Inferences** For the group of seeds that yielded some green and some albino plants, are you able to determine exactly the genotypes of the plants that formed these seeds? Can you determine the genotype of each plant observed? Explain.
5. **Using the Internet** Compare your experimental design with that of other students. Were your results similar? What might account for the differences?

Sharing Your Data

BIOLOGY Online Find this BioLab on the Glencoe Science Web site at **science.glencoe.com.** Briefly describe your experimental design. Post your results in the table provided.

CLICK HERE

Math Connection

A Solution from Ratios

Gregor Mendel was an Austrian monk who experimented with garden peas. In 1866, he published the results of eight years of experiments. His work was ignored until 1900, when it was rediscovered.

Mendel had three qualities that led to his discovery of the laws of heredity. First, he was curious, impelled to find out why things happened. Second, he was a keen observer. Third, he was a skilled mathematician. Mendel was the first biologist who relied heavily on statistics for solutions to how traits are inherited.

Darwin missed his chance

About the same time that Mendel was carrying out his experiments with pea plants, Charles Darwin was gathering data on snapdragon flowers. When Darwin crossed plants that had normal-shaped flowers with plants that had odd-shaped flowers, all the offspring had normal-shaped flowers. He thought the two traits had blended. When he allowed the F_1 plants to self-pollinate, his results were 88 plants with normal-shaped flowers and 37 plants with odd-shaped flowers. Darwin was puzzled by the results and did not continue his studies with these plants. Lacking Mendel's statistical skills, Darwin failed to see the significance of the ratio of normal-shaped flowers to odd-shaped flowers in the F_2 generation. What was this ratio? Was this ratio similar to Mendel's ratio of dominant to recessive traits in pea plants?

Finding the ratios for four other traits

Figure 10.3 on page 262 shows seven traits that Mendel studied in pea plants. You have already looked at Mendel's data for plant height and seed shape. Now use the data for seed color, flower position, pod color, and pod shape to find the ratios of dominant to recessive for these traits in the F_2 generation.

Draw ***Table B*** in your notebook or journal. Calculate the ratios for the data in Table A and complete Table B by following these steps:

- Step 1 Divide the larger number by the smaller number.
- Step 2 Round to the nearest hundredth.
- Step 3 To express your answer as a ratio, write the number from step 2 followed by a colon and the number *1*.

Table A Mendel's Results

Seed Color	Flower Position	Pod Color	Pod Shape
Yellow 6022	Lateral 651	Green 428	Inflated 882
Green 2001	Terminal 207	Yellow 152	Constricted 299

Table B Calculating Ratios for Mendel's Results

	Seed Color	Flower Position	Pod Color	Pod Shape
Calculation	$\frac{6022}{2001} = 3.00$			
Ratio	3:1 yellow:green			

Connection to Biology

Why were ratios so important in understanding how dominant and recessive traits are inherited?

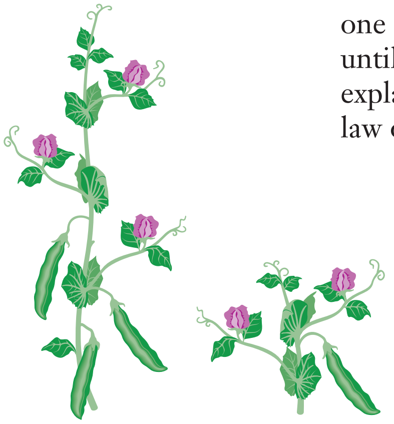
BIOLOGY Online To find out more about Mendel's work, visit the Glencoe Science Web site.
science.glencoe.com

CLICK HERE

Chapter 10 Assessment

Summary

Section 10.1
Mendel's Laws of Heredity



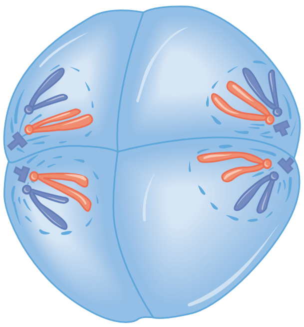
Main Ideas

- Genes are located on chromosomes and exist in alternative forms called alleles. A dominant allele can mask the expression of a recessive allele.
- When Mendel crossed pea plants differing in one trait, one form of the trait disappeared until the second generation of offspring. To explain his results, Mendel formulated the law of segregation.
- Mendel formulated the law of independent assortment to explain that two traits are inherited independently.
- Events in genetics are governed by the laws of probability.

Vocabulary

allele (p. 262)
dominant (p. 262)
fertilization (p. 259)
gamete (p. 259)
genetics (p. 259)
genotype (p. 264)
heredity (p. 259)
heterozygous (p. 265)
homozygous (p. 264)
hybrid (p. 261)
law of independent assortment (p. 266)
law of segregation (p. 263)
phenotype (p. 264)
pollination (p. 259)
recessive (p. 262)
trait (p. 259)

Section 10.2
Meiosis



Main Ideas

- In meiosis, one diploid ($2n$) cell produces four haploid (n) cells, providing a way for offspring to have the same number of chromosomes as their parents.
- Mendel's results can be explained by the distribution of chromosomes during meiosis.
- Random assortment and crossing over during meiosis provide for genetic variation among the members of a species.
- Mistakes in meiosis may result from nondisjunction, the failure of chromosomes to separate properly during cell division.

Vocabulary

crossing over (p. 272)
diploid (p. 269)
egg (p. 271)
genetic recombination (p. 276)
haploid (p. 269)
homologous chromosome (p. 270)
meiosis (p. 271)
nondisjunction (p. 278)
sexual reproduction (p. 272)
sperm (p. 271)
zygote (p. 271)

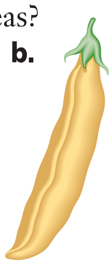
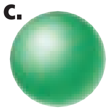
Understanding Main Ideas

1. An organism that is true breeding for a trait is said to be ________.
   a. homozygous **c.** a monohybrid
   b. heterozygous **d.** a dihybrid
2. At the end of meiosis, how many haploid cells have been formed from the original cell?
   a. one **c.** three
   b. two **d.** four
3. When Mendel transferred pollen from one pea plant to another, he was ________ the plants.
   a. self-pollinating **c.** self-fertilizing
   b. cross-pollinating **d.** cross-fertilizing
4. A short pea plant is ________.
   a. homozygous recessive
   b. homozygous dominant
   c. heterozygous
   d. a dihybrid

Chapter 10 Assessment

5. Which of these shows a dominant trait in garden peas?

a.

b.

c.

d


6. During what phase of meiosis do sister chromatids separate?
a. prophase I
b. telophase I
c. anaphase II
d. telophase II

7. During what phase of meiosis do homologous chromosomes cross over?
a. prophase I
b. anaphase I
c. telophase I
d. telophase II

8. Recessive traits appear only when an organism is ________.
a. mature
b. different from its parents
c. heterozygous
d. homozygous

9. Mendel's use of peas was a good choice for genetic study because ________.
a. they produce many offspring
b. they are easy to grow
c. they can be self-pollinated
d. all of the above

10. A dihybrid cross between two heterozygous parents produces a phenotypic ratio of ________.
a. 3: 1
b. 1: 2: 1
c. 9: 3: 3: 1
d. 1: 6: 9

11. If two heterozygous organisms for a single dominant trait mate, the ratio of their offspring should be about ________.

THE PRINCETON REVIEW

Test-Taking Tip

Use the Buddy System
Study in a group. A small gathering of people works well because it allows you to draw from a broader base of skills and expertise. Keep it small and keep on target.

12. A trait that is hidden in the heterozygous condition is said to be a ________ trait.

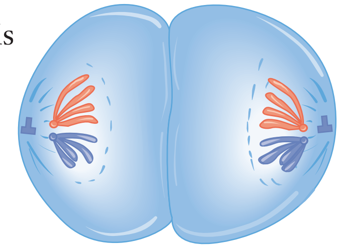
13. An organism that has two different alleles for a trait is called ________.

14. The process that results in Down syndrome is called ________.

15. If a species normally has 46 chromosomes, the cells it produces by meiosis will each have ________ chromosomes.

16. Metaphase I of meiosis occurs when ________ line up next to each other at the cell's equator.

17. The stage of meiosis shown here is ________.



18. In the first generation of Mendel's experiments with a single trait, the ________ trait disappeared, only to reappear in the next generation.

19. A cell that has successfully completed meiosis has a chromosome number called ________.

20. Meiosis results in the direct production of ________.

Applying Main Ideas

21. Why do you think Mendel's results are also valid for humans?

22. On the average, each human has about six recessive alleles that would be lethal if expressed. Why do you think that human cultures have laws against marriage between close relatives?

23. Assume that a couple has four children who are all boys. What are the chances that their next child will also be a boy? Explain your answer.

24. How does separation of homologous chromosomes during anaphase I of meiosis increase variation among offspring?

CONTENTS

25. Relating to the methods of science, why do you think it was important for Mendel to study only one trait at a time during his experiments?

Thinking Critically

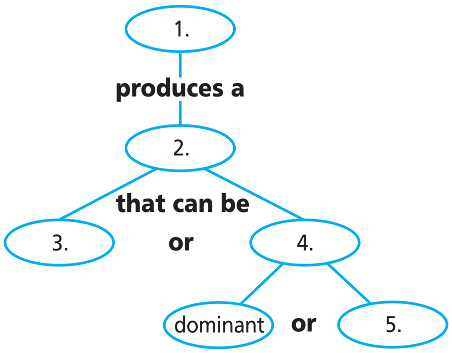
26. Observing and Inferring Why is it possible to have a family of six girls and no boys, but extremely unlikely that there will be a public school with 500 girls and no boys?

27. Comparing and Contrasting Compare metaphase of mitosis with metaphase I of meiosis.

28. Recognizing Cause and Effect Why is it sometimes impossible to determine the genotype of an organism that has a dominant phenotype?

29. Observing and Inferring While examining a cell in prophase I of meiosis, you observe a pair of homologous chromosomes pairing tightly. What is the significance of the places at which the chromosomes are joined?

30. Concept Mapping Complete the concept map by using the following vocabulary terms: recessive, zygote, homozygous, fertilization, heterozygous.



CD-ROM

For additional review, use the assessment options for this chapter found on the ***Biology: The Dynamics of Life Interactive CD-ROM*** and on the Glencoe Science Web site.
science.glencoe.com

Assessing Knowledge & Skills

In fruit flies, the allele for long wings is dominant to the allele for short wings.

	W	*w*
?	*Ww*	*ww*
?	*Ww*	*ww*

Interpreting Data Study the Punnett square and answer the following questions.

1. What term is given to the parent fly whose genotype is shown?
a. heterozygous
b. homozygous
c. recessive
d. haploid

2. What is the phenotype of each parent?
a. both dominant
b. both recessive
c. one dominant and one recessive
d. unable to tell

3. What is the genotype of each parent?
a. *WW—Ww*
b. *Ww—ww*
c. *Ww—Ww*
d. *WW—WW*

4. What are the phenotypes of the offspring?
a. all long wings
b. all short wings
c. mostly long wings
d. half short and half long

5. Interpreting Data Suppose the fruit fly parents in the Punnett square above were both heterozygous for an eye color trait in which *R* is red and *r* is white. What genotypes appear in the offspring? What fraction of the offspring will have short wings and white eyes?