UNIT 3

Genetics

Chapter 10
Sexual Reproduction and Genetics

BIG Idea Reproductive cells, which pass on genetic traits from the parents to the child, are produced by the process of meiosis.

Chapter 11
Complex Inheritance and Human Heredity

BIG Idea Human inheritance does not always follow Mendel's laws.

Chapter 12
Molecular Genetics

BIG Idea DNA is the genetic material that contains a code for proteins.

Chapter 13
Genetics and Biotechnology

BIG Idea Genetic technology improves human health and quality of life.

CAREERS IN BIOLOGY

Geneticist

Geneticists are scientists who study heredity, genes, and variation in organisms. Geneticists, such as the ones shown here extracting genetic material from a dinosaur egg, work to uncover the building blocks of life.

WRITING in Biology

Visit biologygmh.com to learn more about geneticists. Write an account of a geneticist's contribution to the field of medicine, agriculture, biotechnology, or criminology.

Karen Kasmauski/CORBIS

Biology Online

To read more about geneticists in action, visit biologygmh.com.

CHAPTER 10

Sexual Reproduction and Genetics

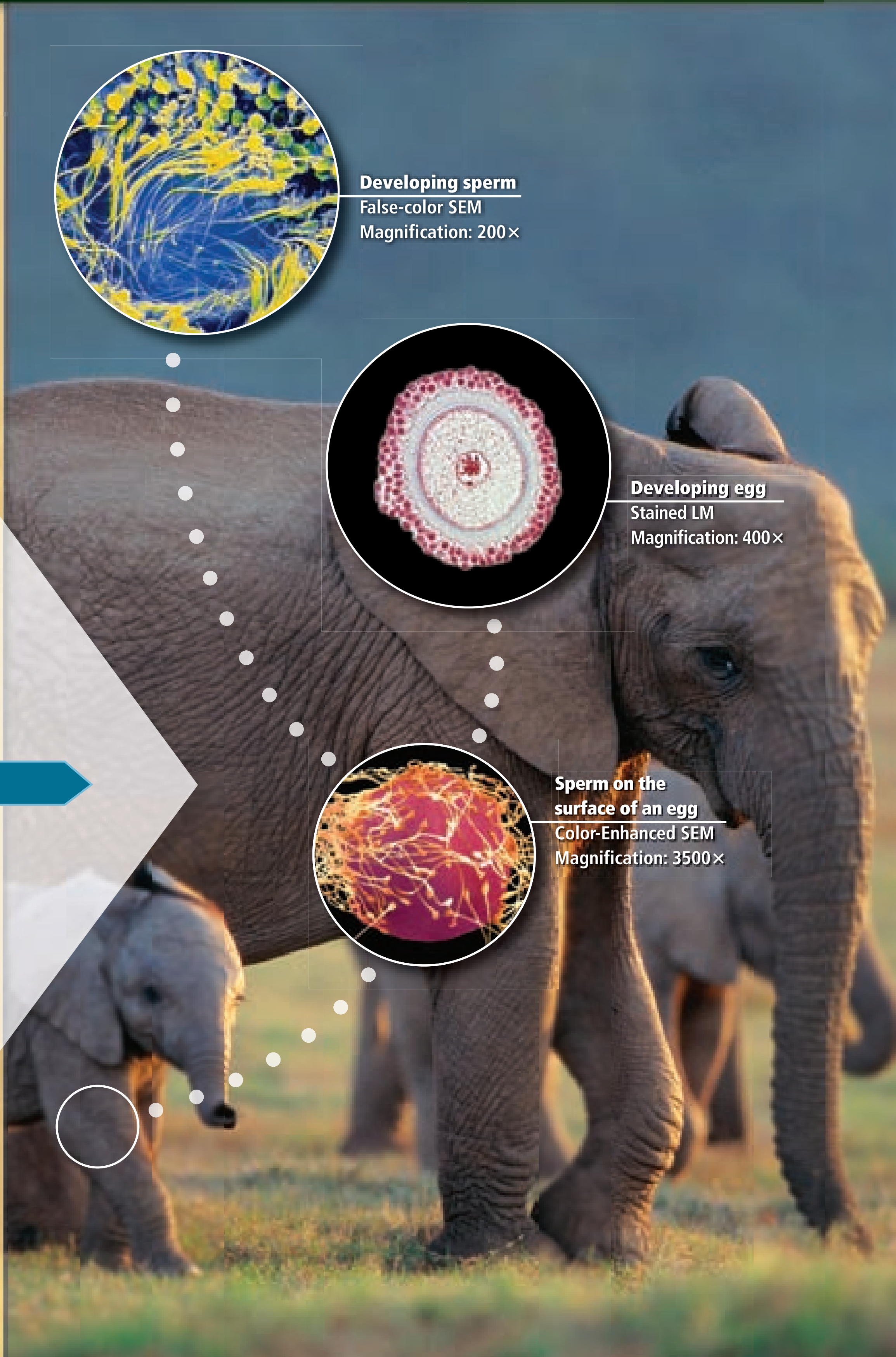
Section 1
Meiosis
MAIN Idea Meiosis produces haploid gametes.

Section 2
Mendelian Genetics
MAIN Idea Mendel explained how a dominant allele can mask the presence of a recessive allele.

Section 3
Gene Linkage and Polyploidy
MAIN Idea The crossing over of linked genes is a source of genetic variation.

BioFacts

- A female elephant gives birth after carrying her baby for 22 months.
- Baby elephants begin as a single, fertilized cell and at birth weigh about 120 kg.



LAUNCH Lab

What would happen without meiosis?

In sexual reproduction, cells from each parent fuse; offspring have the same chromosome number as the parents. Explore what would happen to the chromosome number if mitosis were the only type of cell division.

Procedure

1. Read and complete the lab safety form.
2. Construct a data table with the headings *Cycle Number, Stage,* and *Chromosome Number.*
3. Fill in your data table for Steps 4-5.
4. Model a cell with a pair of chromosomes.
5. Demonstrate mitosis.
6. Fuse one of your cells with another student's cell.
7. Repeat Steps 4-5 two more times, recording the second and the third cycles.

Analysis

1. **Summarize** How does the chromosome number in your model change with each cycle of mitosis and fusion?
2. **Infer** What must occur when cells fuse in order for chromosome number to remain constant?

Biology Online

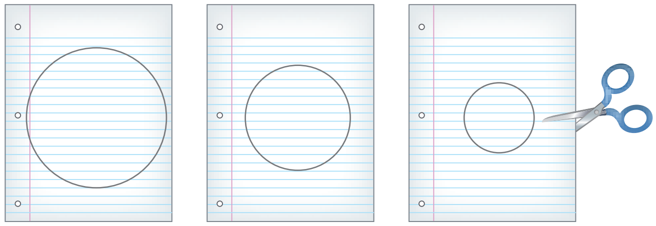
Visit biologygmh.com to:

- **study the entire chapter online**
- **explore Concepts in Motion, the Interactive Table, Microscopy Links, Virtual Labs, and links to virtual dissections**
- **access Web links for more information, projects, and activities**
- **review content online with the Interactive Tutor and take Self-Check Quizzes**

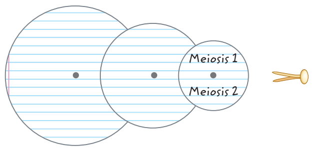
FOLDABLES™ Study Organizer

Illustrating Meiosis Make this Foldable to help you sequence, illustrate, and explain the phases of meiosis.

STEP 1 Draw and cut three circles on three separate pieces of paper.



STEP 2 Fasten the circles together using a brad so that they will rotate. Label the small circle *Meiosis 1* on the top half of the circle and *Meiosis 2* on the bottom half of the circle.



FOLDABLES Use this Foldable with Section 10.1. On the middle circle, write at equal intervals around the edge of the circle the following terms: *Prophase 1, Metaphase 1, Anaphase 1, Telophase 1, Prophase 2, Metaphase 2, Anaphase 2, Telophase 2.* On the largest circle, draw the phases of meiosis. Turn the circles so that both *Meiosis 1* and *Meiosis 2* align with appropriate phase names and illustrations.

Section 10.1

Meiosis

Objectives

- **Explain** the reduction in chromosome number that occurs during meiosis.
- **Recognize** and **summarize** the stages of meiosis.
- **Analyze** the importance of meiosis in providing genetic variation.

Review Vocabulary

chromosome: cellular structure that contains DNA

New Vocabulary

gene
homologous chromosome
gamete
haploid
fertilization
diploid
meiosis
crossing over

MAIN Idea **Meiosis produces haploid gametes.**

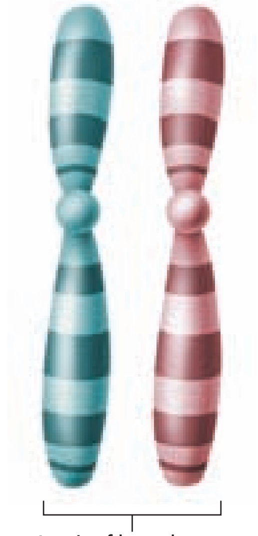
Real-World Reading Link Look around your biology class. You might notice that the students in your class do not all look the same. They might be of different heights and have different eye color, hair color, and other features. This variety of characteristics is a result of two sex cells combining during sexual reproduction.

Chromosomes and Chromosome Number

Each student in your biology class has characteristics passed on to them by their parents. Each characteristic, such as hair color, height, or eye color, is called a trait. The instructions for each trait are located on chromosomes, which are found in the nucleus of cells. The DNA on chromosomes is arranged in segments that control the production of proteins. These DNA segments are called **genes.** Each chromosome consists of hundreds of genes, each gene playing an important role in determining the characteristics and functions of the cell.

Homologous chromosomes Human body cells have 46 chromosomes. Each parent contributes 23 chromosomes, resulting in 23 pairs of chromosomes. The chromosomes that make up a pair, one chromosome from each parent, are called **homologous chromosomes.** As shown in **Figure 10.1,** homologous chromosomes in body cells have the same length and the same centromere position, and they carry genes that control the same inherited traits. For instance, the gene for earlobe type will be located at the same position on both homologous chromosomes. Although these genes each code for earlobe type, they might not code for the exact same type of earlobe.

Figure 10.1 Homologous chromosomes carry genes for any given trait at the same location. The genes that code for earlobe type might not code for the exact same type of earlobe.


A pair of homologous chromosomes

CONTENTS

Haploid and diploid cells In order to maintain the same chromosome number from generation to generation, an organism produces **gametes,** which are sex cells that have half the number of chromosomes. Although the number of chromosomes varies from one species to another, in humans each gamete contains 23 chromosomes. The symbol n can be used to represent the number of chromosomes in a gamete. A cell with n number of chromosomes is called a **haploid** cell. Haploid comes from the Greek word *haploos,* meaning *single.*

The process by which one haploid gamete combines with another haploid gamete is called **fertilization.** As a result of fertilization, the cell now will contain a total of $2n$ chromosomes—n chromosomes from the female parent plus n chromosomes from the male parent. A cell that contains $2n$ number of chromosomes is called a **diploid** cell.

Notice that n also describes the number of pairs of chromosomes in an organism. When two human gametes combine, 23 pairs of homologous chromosomes are formed.

VOCABULARY

ACADEMIC VOCABULARY

Equator:
a circle or circular band dividing the surface of a body into two usually equal and symmetrical parts.
The chromosomes line up at the equator of the cell.

Meiosis I

Gametes are formed during a process called **meiosis,** which is a type of cell division that reduces the number of chromosomes; therefore, it is referred to as a reduction division. Meiosis occurs in the reproductive structures of organisms that reproduce sexually. While mitosis maintains the chromosome number, meiosis reduces the chromosome number by half through the separation of homologous chromosomes. A cell with $2n$ number of chromosomes will have gametes with n number of chromosomes after meiosis, as illustrated in **Figure 10.2.** Meiosis involves two consecutive cell divisions called meiosis I and meiosis II.

FOLDABLES
Incorporate information from this section into your Foldable.

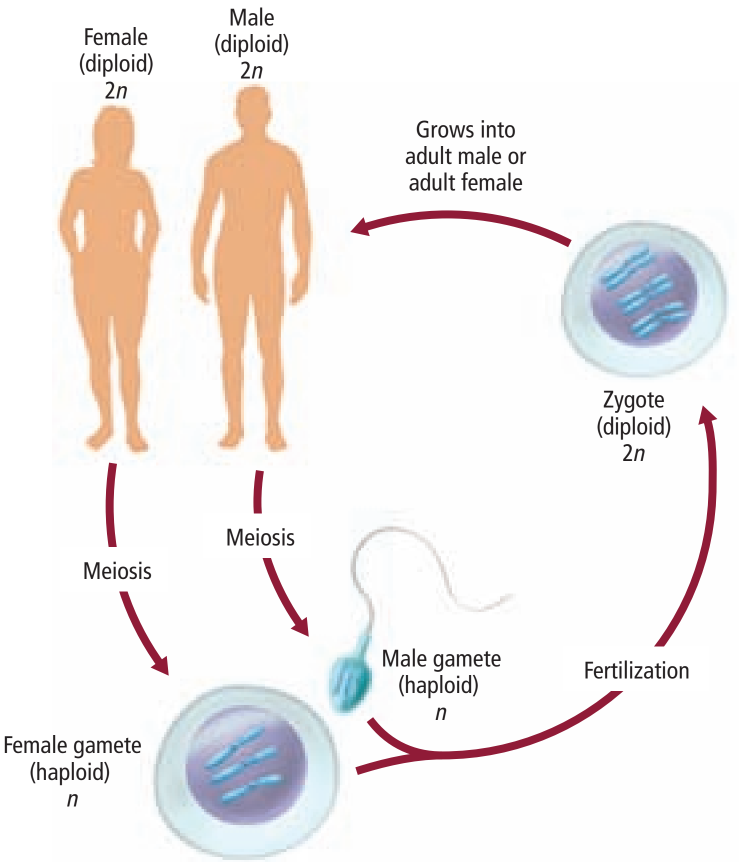
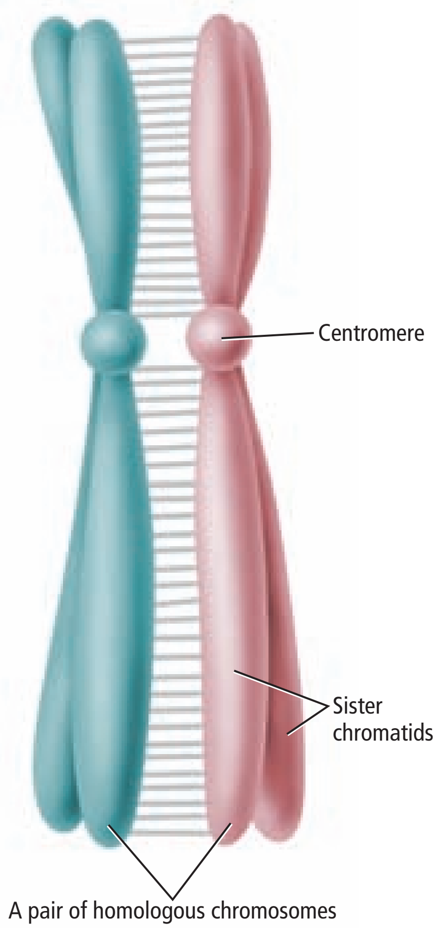


Figure 10.2 The sexual life cycle in animals involves meiosis, which produces gametes. When gametes combine in fertilization, the number of chromosomes is restored.
Describe ***What happens to the number of chromosomes during meiosis?***



■ **Figure 10.3** The homologous chromosomes are physically bound together during synapsis in prophase I.

Interphase Recall that the cell cycle includes interphase prior to mitosis. Cells that undergo meiosis also go through interphase as part of the cell cycle. Cells in interphase carry out various metabolic processes, including the replication of DNA and the synthesis of proteins.

Prophase I As a cell enters prophase I, the replicated chromosomes become visible. As in mitosis, the replicated chromosomes consist of two sister chromatids. As the homologous chromosomes condense, they begin to form pairs in a process called synapsis. The homologous chromosomes are held tightly together along their lengths, as illustrated in **Figure 10.3.** Notice that in **Figure 10.4** the purple and green chromosomes have exchanged segments. This exchange occurs during synapsis. **Crossing over** is a process during which chromosomal segments are exchanged between a pair of homologous chromosomes.

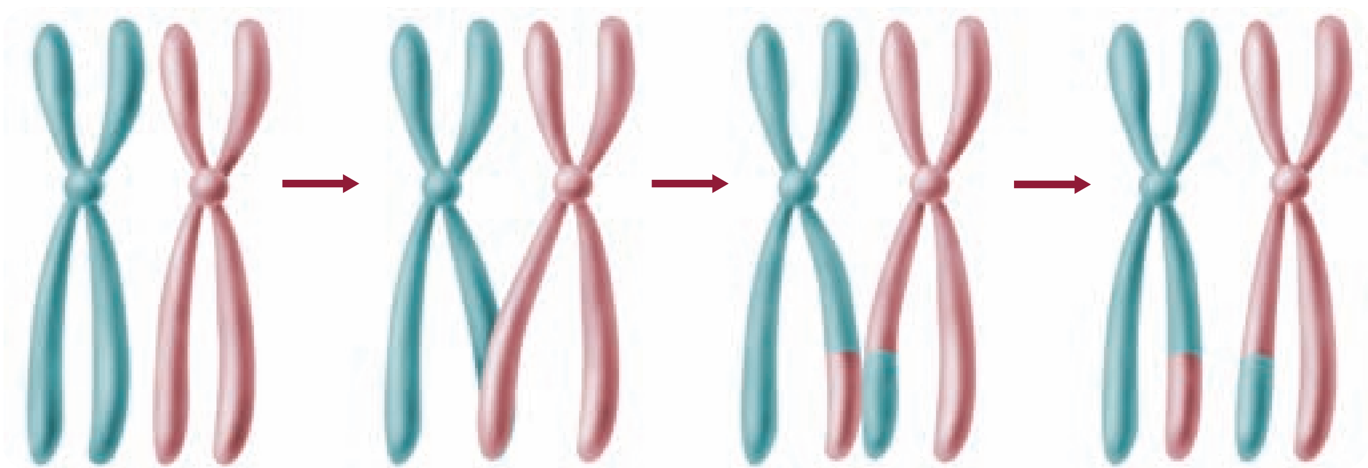
As prophase I continues, centrioles move to the cell's opposite poles. Spindle fibers form and bind to the sister chromatids at the centromere.

Metaphase I In the next phase of meiosis, the pairs of homologous chromosomes line up at the equator of the cell, as illustrated in **Figure 10.5.** In meiosis, the spindle fibers attach to the centromere of each homologous chromosome. Recall that during metaphase in mitosis, the individual chromosomes, which consist of two sister chromatids, line up at the cell's equator. During metaphase I of meiosis, the homologous chromosomes line up as pairs at the cell's equator. This is an important distinction between mitosis and meiosis.

Anaphase I During anaphase I, the homologous chromosomes separate, which is also illustrated in **Figure 10.5.** Each member of the pair is guided by spindle fibers and moves toward opposite poles of the cell. The chromosome number is reduced from $2n$ to n when the homologous chromosomes separate. Recall that in mitosis, the sister chromatids split during anaphase. During anaphase I of meiosis, however, each homologous chromosome still consists of two sister chromatids.

Telophase I The homologous chromosomes, consisting of two sister chromatids, reach the cell's opposite poles. Each pole contains only one member of the original pair of homologous chromosomes. Notice in **Figure 10.5** that each chromosome still consists of two sister chromatids joined at the centromere. The sister chromatids might not be identical because crossing over might have occurred during synapsis in prophase I.

■ **Figure 10.4** The results of crossing over are new combinations of genes.
Determine *Which chromatids exchanged genetic material?*



Visualizing Meiosis

NATIONAL GEOGRAPHIC

Figure 10.5
Follow along the stages of meiosis I and meiosis II, beginning with interphase at the left.

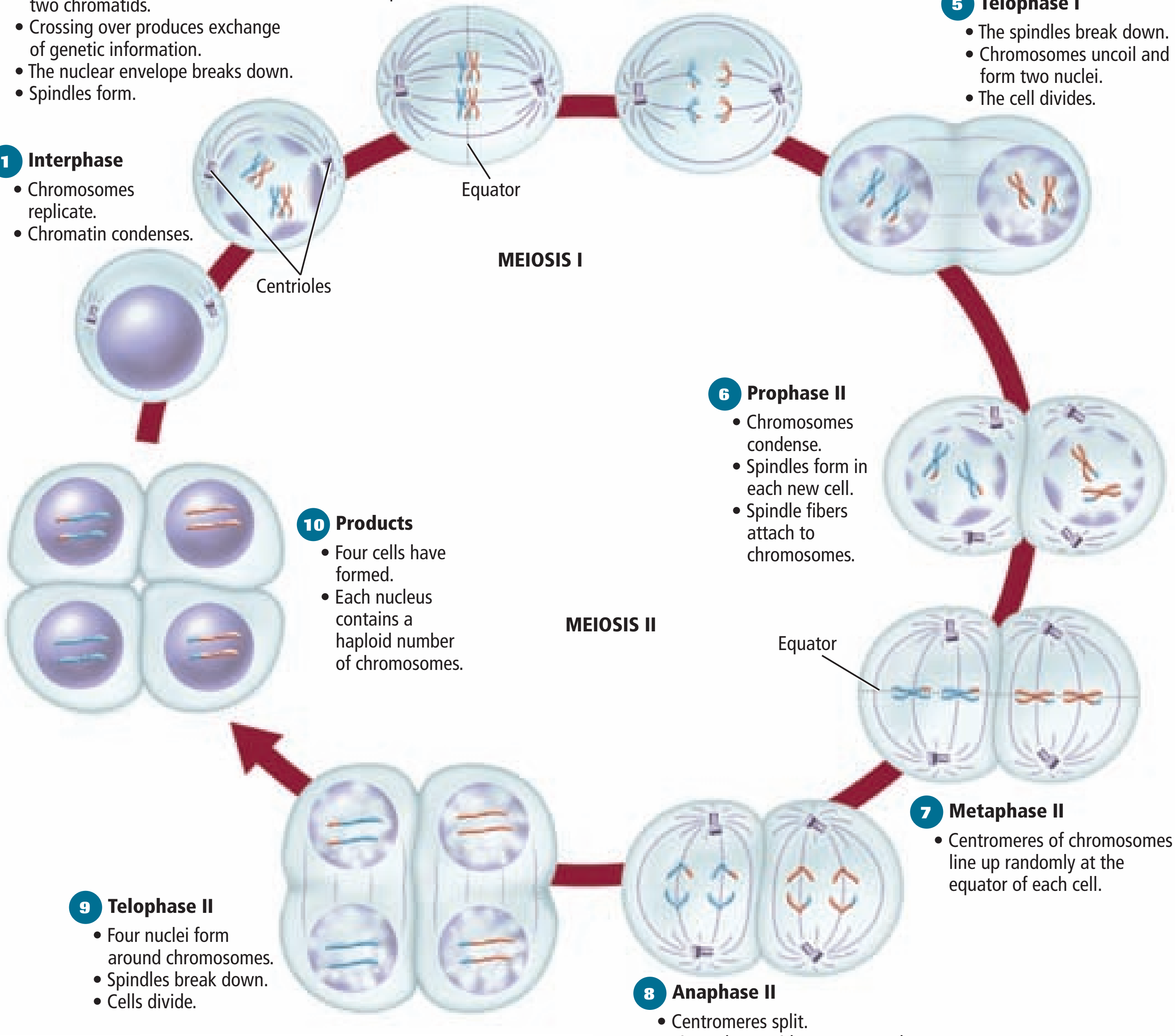
1 Interphase
- Chromosomes replicate.
- Chromatin condenses.

2 Prophase I
- Pairing of homologous chromosomes occurs, each chromosome consists of two chromatids.
- Crossing over produces exchange of genetic information.
- The nuclear envelope breaks down.
- Spindles form.

3 Metaphase I
- Chromosome centromeres attach to spindle fibers.
- Homologous chromosomes line up at the equator.

4 Anaphase I
- Homologous chromosomes separate and move to opposite poles of the cell.

5 Telophase I
- The spindles break down.
- Chromosomes uncoil and form two nuclei.
- The cell divides.



6 Prophase II
- Chromosomes condense.
- Spindles form in each new cell.
- Spindle fibers attach to chromosomes.

7 Metaphase II
- Centromeres of chromosomes line up randomly at the equator of each cell.

8 Anaphase II
- Centromeres split.
- Sister chromatids separate and move to opposite poles.

9 Telophase II
- Four nuclei form around chromosomes.
- Spindles break down.
- Cells divide.

10 Products
- Four cells have formed.
- Each nucleus contains a haploid number of chromosomes.

Concepts in Motion **Interactive Figure** To see an animation of meiosis, visit biologygmh.com.

Biology Online

CAREERS IN BIOLOGY

Medical Geneticist A medical geneticist researches how diseases are inherited, how to diagnose genetic conditions, and treatments for genetic diseases. For more information on biology careers, visit biologygmh.com.

During telophase I, cytokinesis usually occurs, forming a furrow by pinching in animal cells and by forming a cell plate in plant cells. Following cytokinesis, the cells may go into interphase again before the second set of divisions. However, the DNA is not replicated again during this interphase. In some species, the chromosomes uncoil, the nuclear membrane reappears, and nuclei re-form during telophase I.

Meiosis II

Meiosis is only halfway completed at the end of meiosis I. During prophase II, a second set of phases begins as the spindle apparatus forms and the chromosomes condense. During metaphase II, the chromosomes are positioned at the equator by the spindle fibers, as shown in **Figure 10.5.** During metaphase of mitosis, a diploid number of chromosomes line up at the equator. During metaphase II of meiosis, however, a haploid number of chromosomes line up at the equator. During anaphase II, the sister chromatids are pulled apart at the centromere by the spindle fibers, and the sister chromatids move toward the opposite poles of the cell. The chromosomes reach the poles during telophase II, and the nuclear membrane and nuclei reform. At the end of meiosis II, cytokinesis occurs, resulting in four haploid cells, each with n number of chromosomes, as illustrated in **Figure 10.5.**

LAUNCH Lab

Review Based on what you have read about meiosis, how would you now answer the analysis questions?

Reading Check **Infer** Why are the two phases of meiosis important for gamete formation?

DATA ANALYSIS LAB 10.1

Based on Real Data*

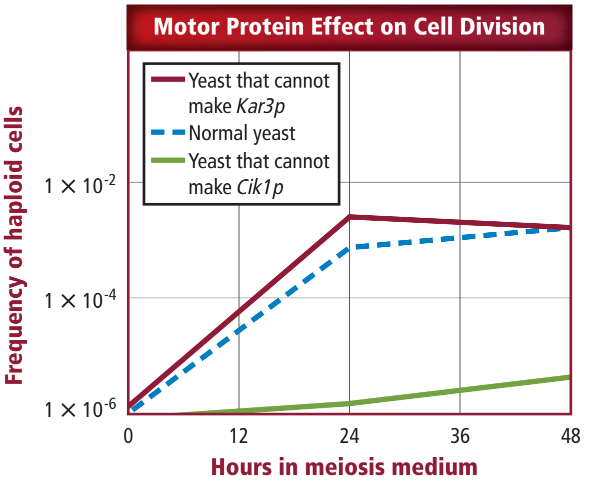
Draw Conclusions

How do motor proteins affect cell division? Many scientists think that motor proteins play an important role in the movement of chromosomes in both mitosis and meiosis. To test this hypothesis, researchers have produced yeast that cannot make the motor protein called Kar3p. They also have produced yeast that cannot make the motor protein called Cik1p, which many think moderates the function of Kar3p. The results of their experiment are shown in the graph to the right.

Think Critically

1. **Evaluate** Does Cik1p seem to be important for yeast meiosis? Explain.
2. **Assess** Does Kar3p seem to be necessary for yeast meiosis? Explain.
3. **Conclude** Do all motor proteins seem to play a vital role in meiosis? Explain.

Data and Observations



*Data obtained from: Shanks, et al. 2001. The Kar3-Interacting protein Cik1p plays a critical role in passage through meiosis I in *Saccharomyces cerevisiae*. *Genetics* 159: 939-951.

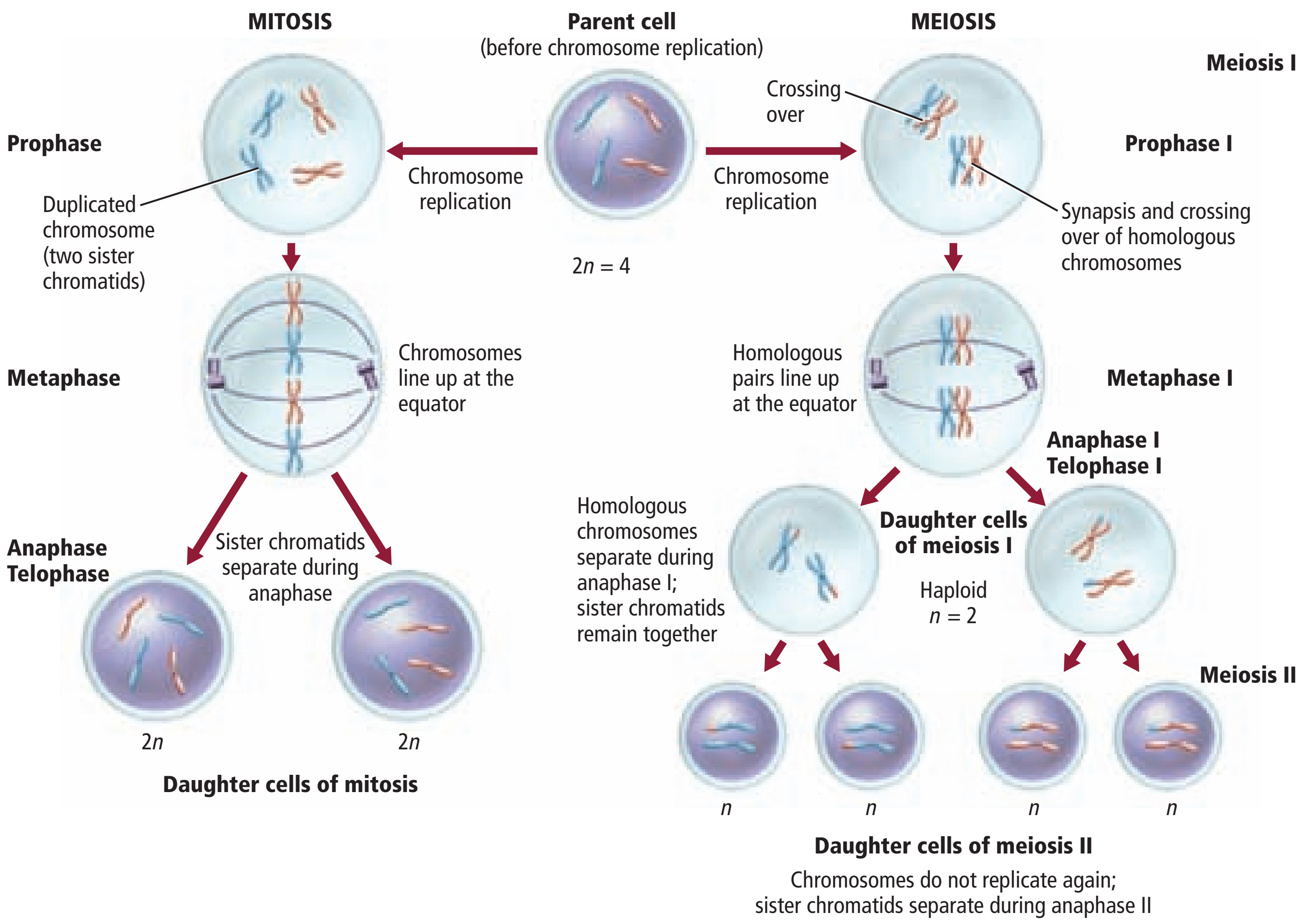
The Importance of Meiosis

Table 10.1 shows a comparison of mitosis and meiosis. Recall that mitosis consists of only one set of division phases and produces two identical diploid daughter cells. Meiosis, however, consists of two sets of divisions and produces four haploid daughter cells that are not identical. Meiosis is important because it results in genetic variation.

Table 10.1 Mitosis and Meiosis

Concepts In Motion
Interactive Table To explore more about mitosis and meiosis, visit biologygmh.com.

Mitosis	Meiosis
One division occurs during mitosis.	Two sets of divisions occur during meiosis: meiosis I and meiosis II.
DNA replication occurs during interphase.	DNA replication occurs once before meiosis I.
Synapsis of homologous chromosomes does not occur.	Synapsis of homologous chromosomes occurs during prophase I.
Two identical cells are formed per cell cycle.	Four haploid cells (n) are formed per cell cycle.
The daughter cells are genetically identical.	The daughter cells are not genetically identical because of crossing over.
Mitosis occurs only in body cells.	Meiosis occurs in reproductive cells.
Mitosis is involved in growth and repair.	Meiosis is involved in the production of gametes and providing genetic variation in organisms.



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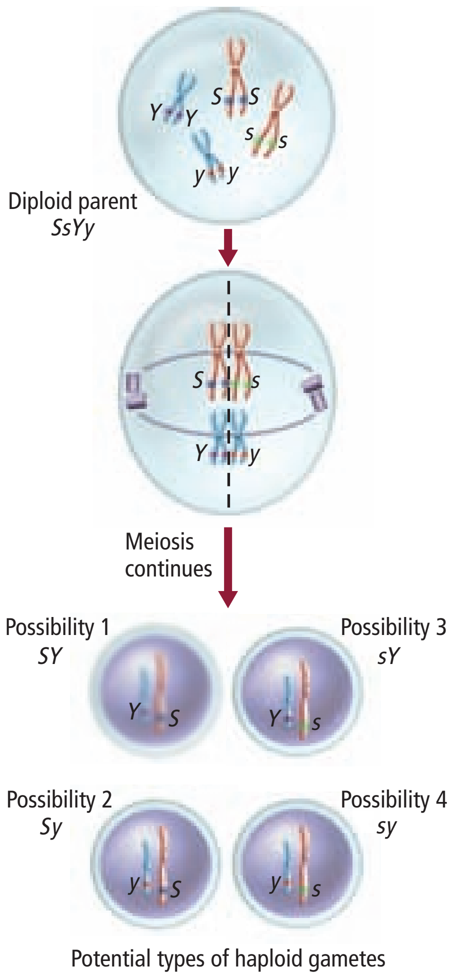


Figure 10.6 The order in which the homologous pairs line up (*Y* with *S* or *Y* with *s*) explains how a variety of sex cells can be produced.

Meiosis provides variation Recall that pairs of homologous chromosomes line up at the equator during prophase I. How the chromosomes line up at the equator is a random process that results in gametes with different combinations of chromosomes, such as the ones in **Figure 10.6.** Depending on how the chromosomes line up at the equator, four gametes with four different combinations of chromosomes can result.

Notice that the first possibility shows which chromosomes were on the same side of the equator and therefore traveled together. Different combinations of chromosomes were lined up on the same side of the equator to produce the gametes in the second possibility. Genetic variation also is produced during crossing over and during fertilization, when gametes randomly combine.

Sexual Reproduction v. Asexual Reproduction

Some organisms reproduce by asexual reproduction, while others reproduce by sexual reproduction. The life cycles of still other organisms might involve both asexual and sexual reproduction. During asexual reproduction, the organism inherits all of its chromosomes from a single parent. Therefore, the new individual is genetically identical to its parent. Bacteria reproduce asexually, whereas most protists reproduce both asexually and sexually, depending on environmental conditions. Most plants and many of the more simple animals can reproduce both asexually and sexually, compared to more advanced animals that reproduce only sexually.

Why do some species reproduce sexually while others reproduce asexually? Recent studies with fruit flies have shown that the rate of accumulation of beneficial mutations is faster when species reproduce sexually than when they reproduce asexually. In other words, when reproduction occurs sexually, the beneficial genes multiply faster over time than they do when reproduction is asexual.

Section 10.1 Assessment

Section Summary

- DNA replication takes place only once during meiosis, and it results in four haploid gametes.
- Meiosis consists of two sets of divisions.
- Meiosis produces genetic variation in gametes.

Understand Main Ideas

1. MAIN Idea **Analyze** how meiosis produces haploid gametes.
2. **Indicate** how metaphase I is different from metaphase in mitosis.
3. **Describe** how synapsis occurs.
4. **Diagram** a cell with four chromosomes going through meiosis.
5. **Assess** how meiosis contributes to genetic variation, while mitosis does not.

Think Scientifically

6. *Compare and contrast* mitosis and meiosis, using **Figure 10.5** and **Table 10.1,** by creating a Venn diagram.
7. WRITING in **Biology** Write a play or activity involving your classmates, to explain the various processes that occur during meiosis.

Biology Online **Self-Check Quiz** biologygmh.com

Section 10.2

Objectives

- **Explain** the significance of Mendel's experiments to the study of genetics.
- **Summarize** the law of segregation and law of independent assortment.
- **Predict** the possible offspring from a cross using a Punnett square.

Review Vocabulary

segregation: the separation of allelic genes that typically occurs during meiosis

New Vocabulary

genetics
allele
dominant
recessive
homozygous
heterozygous
genotype
phenotype
law of segregation
hybrid
law of independent assortment

■ **Figure 10.7** Gregor Mendel is known as the father of genetics.

Bettmann/CORBIS

Mendelian Genetics

MAIN Idea **Mendel explained how a dominant allele can mask the presence of a recessive allele.**

Real-World Reading Link There are many different breeds of dogs, such as Labrador retrievers, dachshunds, German shepherds, and poodles. You might like a certain breed of dog because of its height, coat color, and general appearance. These traits are passed from generation to generation. The work of an Austrian monk led to a greater understanding of how genetic traits are passed on to the next generation.

How Genetics Began

In 1866, Gregor Mendel, an Austrian monk and a plant breeder, published his findings on the method and the mathematics of inheritance in garden pea plants. The passing of traits to the next generation is called inheritance, or heredity. Mendel, shown in **Figure 10.7,** was successful in sorting out the mystery of inheritance because of the organism he chose for his study—the pea plant. Pea plants are easy to grow and many are true-breeding, meaning that they consistently produce offspring with only one form of a trait.

Pea plants usually reproduce by self-fertilization. A common occurrence in many flowering plants, self-fertilization occurs when a male gamete within a flower combines with a female gamete in the same flower. Mendel also discovered that pea plants could easily be cross-pollinated by hand. Mendel performed cross-pollination by transferring a male gamete from the flower of one pea plant to the female reproductive organ in a flower of another pea plant.

Connection to History Mendel rigorously followed various traits in the pea plants he bred. He analyzed the results of his experiments and formed hypotheses concerning how the traits were inherited. The study of **genetics,** which is the science of heredity, began with Mendel, who is regarded as the father of genetics.

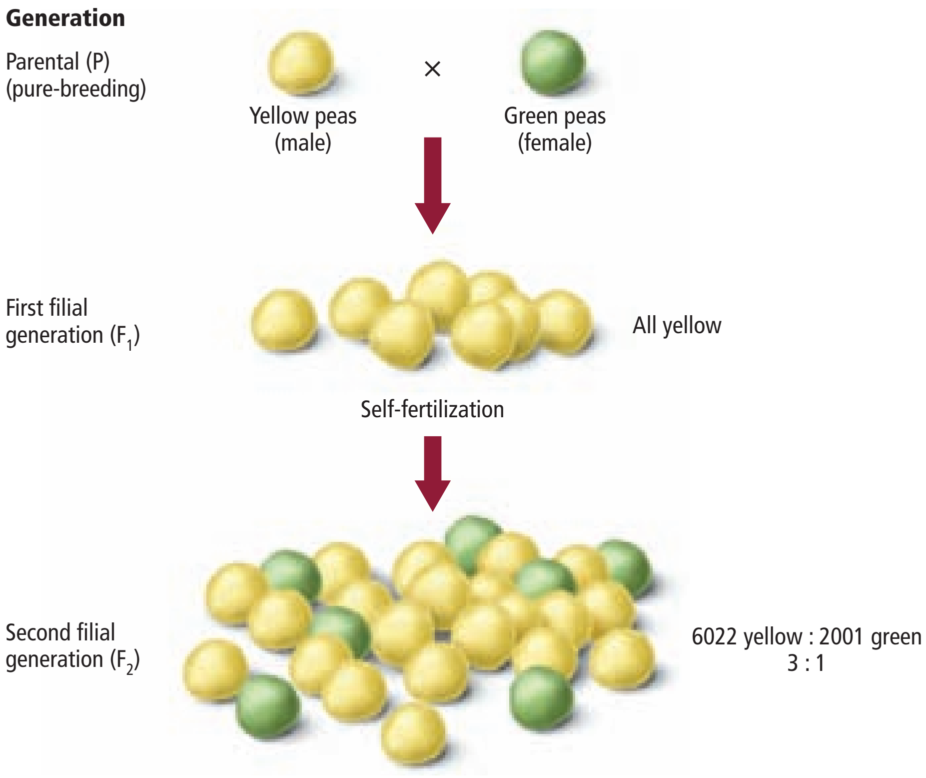
The Inheritance of Traits

Mendel noticed that certain varieties of garden pea plants produced specific forms of a trait, generation after generation. For instance, he noticed that some varieties always produced green seeds and others always produced yellow seeds. In order to understand how these traits are inherited, Mendel performed cross pollination by transferring male gametes from the flower of a true-breeding green-seed plant to the female organ of a flower from a true-breeding yellow-seed plant. To prevent self-fertilization, Mendel removed the male organs from the flower of the yellow-seed plant. Mendel called the green-seed plant and the yellow-seed plant the parent generation—also known as the P generation.

■ **Figure 10.8** The results of Mendel's cross involving true-breeding pea plants with yellow seeds and green seeds are shown here.
Explain ***why the seeds in the F_1 generation were all yellow.***

Interactive Figure To see an animation of the allele frequencies of three generations of flowers, visit biologygmh.com.

CLICK HERE



F_1 and F_2 generations When Mendel grew the seeds from the cross between the green-seed and yellow-seed plants, all of the resulting offspring had yellow seeds. The offspring of this P cross are called the first filial (F_1) generation. The green-seed trait seemed to have disappeared in the F_1 generation, and Mendel decided to investigate whether the trait was no longer present or whether it was hidden, or masked.

Mendel planted the F_1 generation of yellow seeds, allowed the plants to grow and self-fertilize, and then examined the seeds from this cross. The results of the second filial (F_2) generation—the offspring from the F_1 cross—are shown in **Figure 10.8.** Of the seeds Mendel collected, 6022 were yellow and 2001 were green, which almost is a perfect 3:1 ratio of yellow to green seeds.

Mendel studied seven different traits—seed or pea color, flower color, seed pod color, seed shape or texture, seed pod shape, stem length, and flower position—and found that the F_1 generation plants from these crosses also showed a 3:1 ratio.

Genes in pairs Mendel concluded that there must be two forms of the seed trait in the pea plants—yellow-seed and green-seed—and that each was controlled by a factor, which now is called an allele. An **allele** is defined as an alternative form of a single gene passed from generation to generation. Therefore, the gene for yellow seeds and the gene for green seeds are each different forms of a single gene.

Mendel concluded that the 3:1 ratio observed during his experiments could be explained if the alleles were paired in each of the plants. He called the form of the trait that appeared in the F_1 generation **dominant** and the form of the trait that was masked in the F_1 generation **recessive.** In the cross between yellow-seed plants and green-seed plants, the yellow seed was the dominant form of the trait and the green seed was the recessive form of the trait.

CAREERS IN BIOLOGY

Genetics Laboratory Technician
A technician in a genetics laboratory assists a researcher by conducting experiments and helping to maintain the lab. For more information on biology careers, visit biologygmh.com.

Dominance When he allowed the F_1 generation to self-fertilize, Mendel showed that the recessive allele for green seeds had not disappeared but was masked. Mendel concluded that the green-seed form of the trait did not show up in the F_1 generation because the yellow-seed form of the trait is dominant and masks the allele for the green-seed form of the trait.

Because the yellow-seed form of the trait is dominant, the allele for the yellow-seed form of the trait is represented by a capital *Y*. The allele for the green-seed form of the trait is represented by a lowercase *y* because it is recessive. An organism with two of the same alleles for a particular trait is **homozygous** (ho muh ZI gus) for that trait. Homozygous, yellow-seed plants are *YY* and green-seed plants are *yy*. An organism with two different alleles for a particular trait is **heterozygous** (heh tuh roh ZY gus) for that trait, in this case *Yy*. When alleles are present in the heterozygous state, the dominant trait will be observed.

Genotype and phenotype A yellow-seed plant could be homozygous or heterozygous for the trait form. The outward appearance of an organism does not always indicate which pair of alleles is present. The organism's allele pairs are called its **genotype.** In the case of plants with yellow seeds, their genotypes could be *YY* or *Yy*. The observable characteristic or outward expression of an allele pair is called the **phenotype.** The phenotype of pea plants with the genotype *yy* will be green seeds.

Mendel's law of segregation Mendel used homozygous yellow-seed and green-seed plants in his P cross. In **Figure 10.9,** the first drawing shows that each gamete from the yellow-seed plant contains one *Y*. Recall that the chromosome number is divided in half during meiosis. The resulting gametes contain only one of the pair of seed-color alleles.

The second drawing in **Figure 10.9** shows that each gamete from the green-seed plant contains one *y* allele. Mendel's **law of segregation** states that the two alleles for each trait separate during meiosis. During fertilization, two alleles for that trait unite.

The third drawing in **Figure 10.9** shows the alleles uniting to produce the genotype *Yy* during fertilization. All resulting F_1 generation plants will have the genotype *Yy* and will have yellow seeds because yellow is dominant to green. These heterozygous organisms are called **hybrids**.

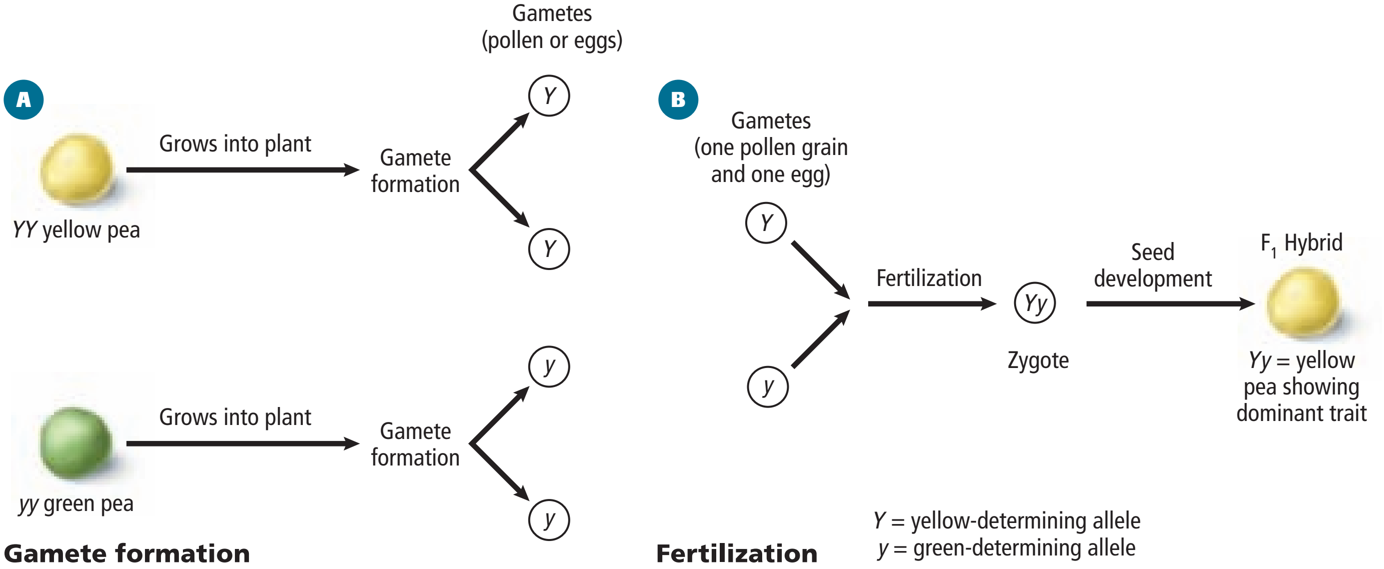
VOCABULARY

WORD ORIGIN

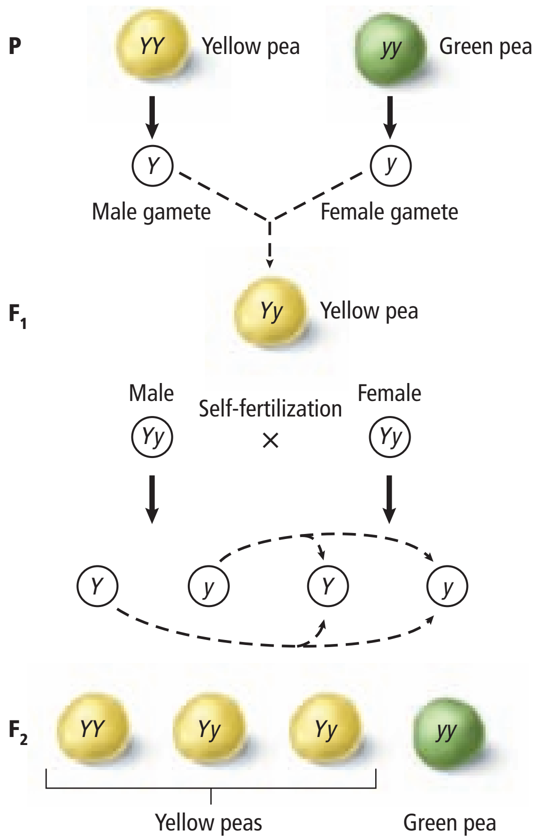
Homozygous and **Heterozygous** come from the Greek words *homos,* meaning *the same; hetero,* meaning *other* or *different;* and *zygon,* meaning *yoke.*

Study Tip

BioJournal While you are reading, find more information and further clarification on different aspects of genetics at biologygmh.com. Add the information that you find to your BioJournal.



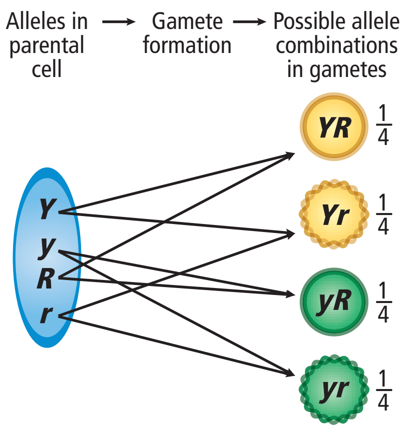
■ **Figure 10.9** During gamete formation in the *YY* or *yy* plant, the two alleles separate, resulting in *Y* or *y* in the gametes. Gametes from each parent unite during fertilization.



■ **Figure 10.10** During the F_1 generation self-fertilization, the male gametes randomly fertilize the female gametes.

■ **Figure 10.11** The law of independent assortment is demonstrated in the dihybrid cross by the equal chance that each pair of alleles (*Yy* and *Rr*) can randomly combine with each other.

Predict ***How many possible gamete types are produced?***



Monohybrid cross The diagram in **Figure 10.10** shows how Mendel continued his experiments by allowing the *Yy* plants to self-fertilize. A cross such as this one that involves hybrids for a single trait is called a monohybrid cross. The *Yy* plants produce two types of gametes—male and female—each with either the *Y* or *y* allele. The combining of these gametes is a random event. This random fertilization of male and female gametes results in the following genotypes—*YY, Yy, Yy,* or *yy,* as shown in **Figure 10.10.** Notice that the dominant *Y* allele is written first, whether it came from the male or female gamete. In Mendel's F_1 cross, there are three possible genotypes: *YY, Yy,* and *yy;* and the genotypic ratio is 1:2:1. The phenotypic ratio is 3:1—yellow seeds to green seeds.

Dihybrid cross Once Mendel established inheritance patterns of a single trait, he began to examine simultaneous inheritance of two or more traits in the same plant. In garden peas, round seeds *(R)* are dominant to wrinkled seeds *(r),* and yellow seeds *(Y)* are dominant to green seeds *(y).* If Mendel crossed homozygous yellow, round-seed pea plants with homozygous green, wrinkle-seed pea plants, the P cross could be represented by *YYRR* × *yyrr.* The F_1 generation genotype would be *YyRr*—yellow, round-seed plants. These F_1-generation plants are called dihybrids because they are heterozygous for both traits.

Law of independent assortment Mendel allowed F_1 pea plants with the genotype *YyRr* to self-fertilize in a dihybrid cross. Mendel calculated the genotypic and phenotypic ratios of the offspring in both the F_1 and F_2 generations. From these results, he developed the **law of independent assortment,** which states that a random distribution of alleles occurs during gamete formation. Genes on separate chromosomes sort independently during meiosis.

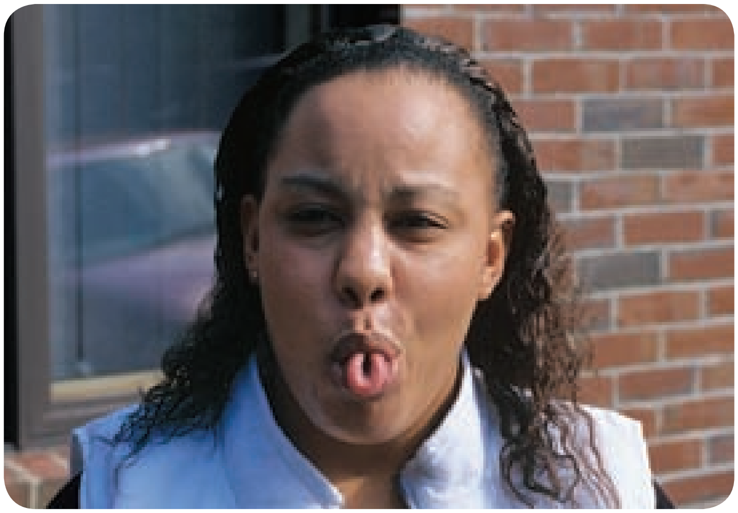
As shown in **Figure 10.11,** the random assortment of alleles results in four possible gametes: *YR, Yr, yR* or *yr,* each of which is equally likely to occur. When a plant self-fertilizes, any of the four allele combinations could be present in the male gamete, and any of the four combinations could be present in the female gamete. The results of Mendel's dihybrid cross included nine different genotypes: *YYRR, YYRr, YYrr, YyRR, YyRr, Yyrr, yyRR, yyRr,* and *yyrr.* He counted and recorded four different phenotypes: 315 yellow round, 108 green round, 101 yellow wrinkled, and 32 green wrinkled. These results represent a phenotypic ratio of approximately 9:3:3:1.

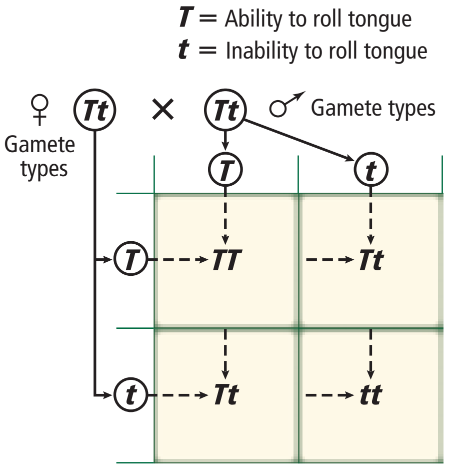
Reading Check **Evaluate** How can the random distribution of alleles result in a predictable ratio?

Punnett Squares

In the early 1900s, Dr. Reginald Punnett developed what is known as a Punnett square to predict the possible offspring of a cross between two known genotypes. Punnett squares make it easier to keep track of the possible genotypes involved in a cross.

Robert Folz/Visuals Unlimited





■ **Figure 10.12** The ability to roll one's tongue is a dominant trait. The Punnett square is a visual summary of the possible combinations of the alleles for the tongue-rolling trait.

Punnett square—monohybrid cross Can you roll your tongue like the person pictured in **Figure 10.12?** Tongue-rolling ability is a dominant trait, which can be represented by *T*. Suppose both parents can roll their tongues and are heterozygous (*Tt*) for the trait. What possible phenotypes could their children have?

Examine the Punnett square in **Figure 10.12.** The number of squares is determined by the number of different types of alleles—*T* or *t*—produced by each parent. In this case, the square is 2 squares × 2 squares because each parent produces two different types of gametes. Notice that the male gametes are written across the horizontal side and the female gametes are written on the vertical side of the Punnett square. The possible combinations of each male and female gamete are written on the inside of each corresponding square.

MiniLab 10.1

Predict Probability in Genetics

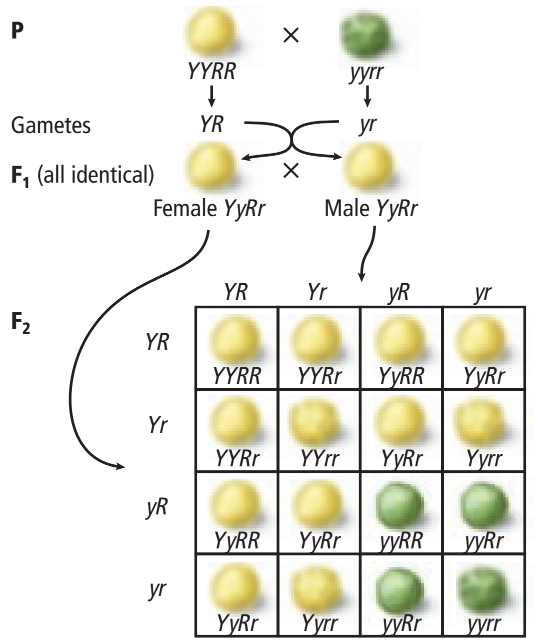
How can an offspring's traits be predicted? A Punnett square can help predict ratios of dominant traits to recessive traits in the genotype of offspring. This lab involves two parents who are both heterozygous for free earlobes (E), which is a dominant trait. The recessive trait is attached earlobes (e).

Procedure

1. Read and complete the lab safety form.
2. Determine the gamete genotype(s) for this trait that each parent contributes.
3. Draw a Punnett square that has the same number of columns and the same number of rows as the number of alleles contributed for this trait by the gametes of each parent.
4. Write the alphabetical letter for each allele from one parent just above each column, and write the alphabetical letter for each allele from the other parent just to the left of each row.
5. In the boxes within the table, write the genotype of the offspring resulting from each combination of male and female alleles.

Analysis

1. **Summarize** List the possible offspring phenotypes that could occur.
2. **Evaluate** What is the phenotypic ratio of the possible offspring? What is the genotypic ratio of the possible offspring?



Type	Genotype	Phenotype	Number	Phenotypic Ratio
Parental	Y_R_	yellow round	315	9:16
Recombinant	yyR_	green round	108	3:16
Recombinant	Y_rr	yellow wrinkled	101	3:16
Parental	yyrr	green wrinkled	32	1:16

Figure 10.13 The dihybrid Punnett square visually presents the possible combinations of the possible alleles from each parent.

How many different genotypes are found in the Punnett square? One square has *TT,* two squares have *Tt,* and one square has *tt.* Therefore, the genotypic ratio of the possible offspring is 1:2:1. The phenotypic ratio of tongue rollers to non-tongue rollers is 3:1.

Punnett square—dihybrid cross Now examine the Punnett square in **Figure 10.13.** Notice that in the P cross, only two types of alleles are produced. However, in the dihybrid cross—when the F_1 generation is crossed—four types of alleles from the male gametes and four types of alleles from the female gametes can be produced. The resulting phenotypic ratio is 9:3:3:1, yellow round to green round to yellow wrinkled to green wrinkled. Mendel's data closely matched the outcome predicted by the Punnett square.

Probability

The inheritance of genes can be compared to the probability of flipping a coin. The probability of the coin landing on heads is 1 out of 2, or 1/2. If the same coin is flipped twice, the probability of it landing on heads is 1/2 each time or 1/2 × 1/2, or 1/4 both times.

Actual data might not perfectly match the predicted ratios. You know that if you flip a coin you might not get heads 1 out of 2 times. Mendel's results were not exactly a 9:3:3:1 ratio. However, the larger the number of offspring involved in a cross, the more likely it will match the results predicted by the Punnett square.

Section 10.2 Assessment

Section Summary

- The study of genetics began with Gregor Mendel, whose experiments with garden pea plants gave insight into the inheritance of traits.
- Mendel developed the law of segregation and the law of independent assortment.
- Punnett squares help predict the offspring of a cross.

Understand Main Ideas

1. MAIN Idea **Diagram** Use a Punnett square to explain how a dominant allele masks the presence of a recessive allele.
2. **Apply** the law of segregation and the law of independent assortment by giving an example of each.
3. **Use a Punnett square** In fruit flies, red eyes (*R*) are dominant to pink eyes (*r*). What is the phenotypic ratio of a cross between a heterozygous male and a pink-eyed female?

Think Scientifically

4. *Evaluate* Why would a large number of offspring in a cross be more likely to match Punnett-square ratios than a small number would?
5. MATH in Biology What is the probability of rolling a 2 on a six-sided die? What is the probability of rolling two 2s on two six-sided die? How is probability used in the study of genetics?

Section 10.3

Objectives

- **Summarize** how the process of meiosis produces genetic recombination.
- **Explain** how gene linkage can be used to create chromosome maps.
- **Analyze** why polyploidy is important to the field of agriculture.

Review Vocabulary

protein: large, complex polymer essential to all life that provides structure for tissues and organs and helps carry out cell metabolism

New Vocabulary

genetic recombination
polyploidy

Gene Linkage and Polyploidy

MAIN Idea The crossing over of linked genes is a source of genetic variation.

Real-World Reading Link You might find many varieties of plants in a garden center that are not found in the wild. For example, you might have seen many varieties of roses that range in color from red to pink to white. Plant breeders use scientists' knowledge of genes to vary certain characteristics in an effort to make their roses unique.

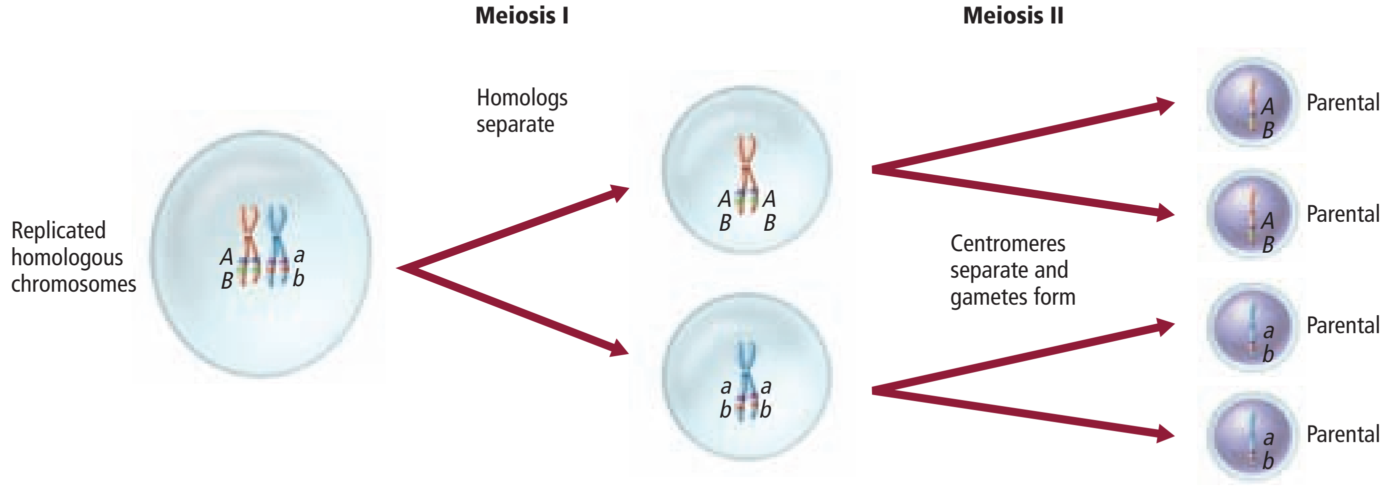
Genetic Recombination

Connection Math The new combination of genes produced by crossing over and independent assortment is called **genetic recombination.** The possible combinations of genes due to independent assortment can be calculated using the formula 2^n, where n is the number of chromosome pairs. For example, pea plants have seven pairs of chromosomes. For seven pairs of chromosomes, the possible combinations are 2^7, or 128 combinations. Because any possible male gamete can fertilize any possible female gamete, the number of possible combinations after fertilization is 16,384 (128×128). In humans, the possible number of combinations after fertilization would be $2^{23} \times 2^{23}$, or more than 70 trillion. This number does not include the amount of genetic recombination produced by crossing over.

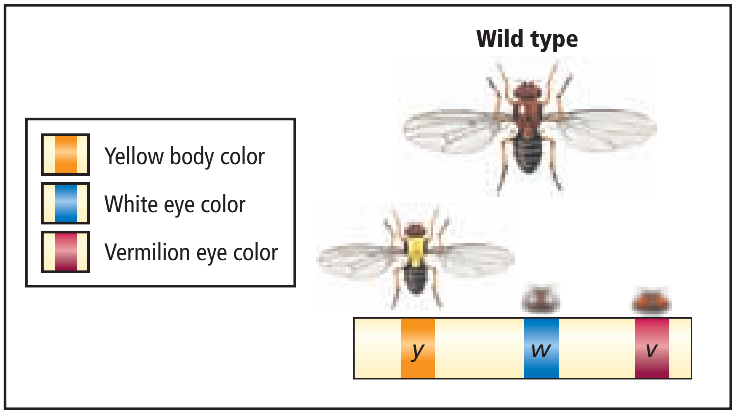
Gene Linkage

Recall that chromosomes contain multiple genes that code for proteins. Genes that are located close to each other on the same chromosome are said to be linked and usually travel together during gamete formation. Study **Figure 10.14** and observe that genes *A* and *B* are located close to each other on the same chromosome and travel together during meiosis. The linkage of genes on a chromosome results in an exception to Mendel's law of independent assortment because linked genes usually do not segregate independently.

■ **Figure 10.14** Genes that are linked together on the same chromosome usually travel together in the gamete.
Calculate *the number of possible combinations if two or three of these gametes were to combine.*



■ **Figure 10.15** This chromosome map of the X chromosome of the fruit fly *Drosophila melanogaster* was created in 1913.



Gene linkage was first studied using the fruit fly *Drosophila melanogaster*. Thousands of crosses confirmed that linked genes usually traveled together during meiosis. However, some results revealed that linked genes do not always travel together during meiosis. Scientists concluded that linked genes can separate during crossing over.

Chromosome maps Crossing over occurs more frequently between genes that are far apart than those that are close together. A drawing called a chromosome map shows the sequence of genes on a chromosome and can be created by using crossover data. The very first chromosome maps were published in 1913 using data from thousands of fruit fly crosses. Chromosome map percentages are not actual chromosome distances, but they represent relative positions of the genes. **Figure 10.15** shows the first chromosome map created using fruit fly data. Notice that the higher the crossover frequency, the farther apart the two genes are.

MiniLab 10.2

Map Chromosomes

Where are genes located on a chromosome? The distance between two genes on a chromosome is related to the crossover frequency between them. By comparing data for several gene pairs, a gene's relative location can be determined.

Procedure

1. Read and complete the lab safety form.
2. Obtain a table of the gene-pair crossover frequencies from your teacher.
3. Draw a line on a piece of paper and make marks every 1 cm. Each mark will represent a crossover frequency of 1 percent.
4. Label one mark near the middle of the line *A*. Find the crossover frequency between Genes A and B on the table, and use this data to label *B* the correct distance from A.
5. Use the crossover frequency between genes A and C and genes B and C to infer the position of gene C.
6. Repeat steps 4–5 for each gene, marking their positions on the line.

Analysis

1. **Evaluate** Is it possible to know the location of a gene on a chromosome if only one other gene is used?
2. **Consider** Why would using more crossover frequencies result in a more accurate chromosome map?

Strawberries (8*n*)

In a cross, the exchange of genes is directly related to the cross-over frequency between them. This frequency correlates with the relative distance between the two genes. One map unit between two genes is equivalent to 1 percent of the crossing over occurring between them. Genes that are further apart would have a greater frequency of crossing over.

Polyploidy

Most species have diploid cells, but some have polyploid cells. **Polyploidy** is the occurrence of one or more extra sets of all chromosomes in an organism. A triploid organism, for instance, would be designated 3*n*, which means that it has three complete sets of chromosomes. Polyploidy rarely occurs in animals but sometimes occurs in earthworms and goldfish. In humans, polyploidy is always lethal.

Roughly one in three species of known flowering plants are polyploid. Commercially grown bread wheat *(6n)*, oats *(6n)*, and sugar cane *(8n)* are polyploidy crop plants. Polyploid plants, such as the ones shown in **Figure 10.16,** often have increased vigor and size.

Coffee (4*n*)

Figure 10.16 Various commercial plants, such as strawberries and coffee, are polyploids.

Section 10.3 Assessment

Section Summary

- Genetic recombination involves both crossing over and independent assortment.
- Early chromosome maps were created based on the linkage of genes on the chromosome.
- Polyploid plants are selected by plant growers for their desirable characteristics.

Understand Main Ideas

1. MAIN Idea **Analyze** how crossing over is related to variation.
2. **Draw** Suppose genes *C* and *D* are linked on one chromosome and genes *c* and *d* are linked on another chromosome. Assuming that crossing over does not take place, sketch the daughter cells resulting from meiosis, showing the chromosomes and position of the genes.
3. **Describe** how polyploidy is used in the field of agriculture.

Think Scientifically

4. ***Construct*** a chromosome map for genes *A*, *B*, *C* and *D* using the following crossing over data: *A* to *D*=25 percent; *A* to *B*=30 percent; *C* to *D*=15 percent; *B* to *D*=5 percent; *B* to *C*=20 percent.
5. ***Evaluate*** what advantage polyploidy would give to a plant breeder.
6. *WRITING in* **Biology** Write a story describing a society with no genetic variation in humans.

In the Field

Career: Plant Geneticist

Is it better for plants to have more chromosomes?

Compare the two flowers in the photo. What differences do you notice? Both flowers were produced by a plant known as a daylily. The larger, more robust-looking flower on the left, however, is from a polyploid plant. What makes this plant so unusual? Its cells contain more than the usual two sets of chromosomes.

Plant geneticists have been fascinated by polyploids for decades. Having multiple sets of chromosomes can dramatically affect how a plant looks, performs, and appeals to consumers.

Putting Plant Genetics to Work

Plant geneticists apply scientific methods and the principles of genetics to improve the quality and production of plants. They develop species that are more resistant to diseases, pests, and drought. Some polyploid plants, such as seedless grapes, melons, and citrus fruits, are developed to meet consumer demand. Many plant geneticists also work to make crops more nutritious.

The development of new plant varieties, including polyploid species, benefits humans in many ways. In Thailand, for example, researchers have developed polyploid rice plants with a high tolerance for salt. These plants might thrive in areas where the soil is highly salty and useless agriculturally, providing income for farmers in previously economically depressed regions.

How Does Polyploidy Occur?

Plant geneticists produce polyploids by soaking the seeds or buds of certain plants in a chemical called colchicine. This chemical interferes with cell division, causing all of the chromosomes to remain in one cell as gametes are formed. During fertilization, the number of chromosomes is doubled, producing a polyploid plant. Polyploidy occurs naturally in many flowering plants. Scientists theorize that most natural polyploids resulted from mutations during cell division.

The Benefits of Being Polyploid

Having more than one set of chromosomes can provide evolutionary advantages for plants. Polyploids often are larger and stronger, have more developed root systems, and produce larger flowers and fruits. Plant geneticists seek to understand these characteristics based on heredity and variation and to utilize them to develop plants that can thrive in specific environmental conditions.

CAREERS in Biology

Imagine that a position for a plant geneticist has become available at an arboretum, and you are assigned to write the job description. Develop a list of skills and knowledge needed for this position. To explore more about plant geneticists, visit biologygmh.com.

BIOLAB

Design Your Own

HOW CAN THE PHENOTYPE OF OFFSPRING HELP DETERMINE PARENTAL GENOTYPE?

Background: **The traits of most plants have dominant and recessive alleles. Analysis of plants grown from seeds can be a good indicator of the expected genotypes of offspring as well as phenotypes and genotypes of the parent plants.**

Question: *Can the phenotypes and genotypes of parent organisms be determined from the phenotype of the offspring?*

Materials

Choose materials that would be appropriate for this lab.

two groups of plant seeds
potting soil
small flowerpots or other growing containers
watering can or bottle
small gardening trowel

Safety Precautions

Plan and Perform the Experiment

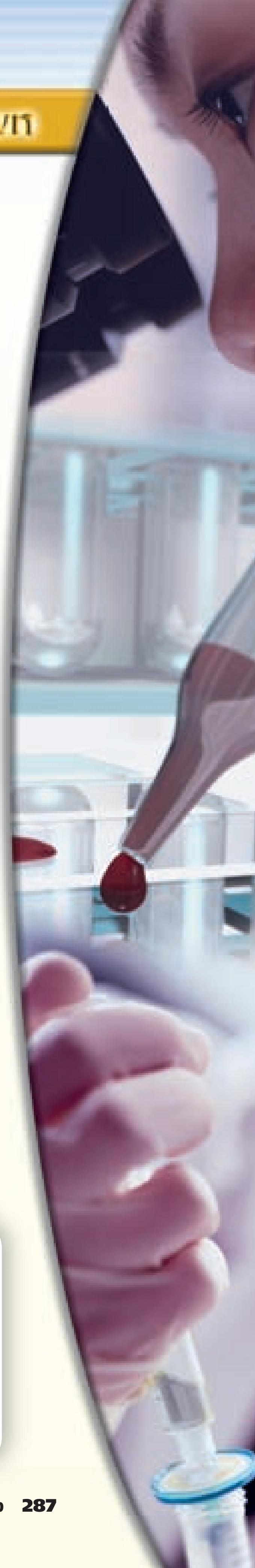
1. Read and complete the lab safety form.
2. Hypothesize whether the phenotype of offspring could be used to infer the genotypes of the parents.
3. Design an experiment to test your hypothesis.
4. Decide what data you need to collect.
5. Create a data table to record your observations.
6. Make certain your teacher has approved your experiment before you proceed.
7. Conduct your experiment.
8. **Cleanup and Disposal** Properly dispose of seeds or plants considered to be invasive species in your area. Never release invasive species into the environment.

Analyze and Conclude

1. **Collect and Organize Data** Count the number of seedlings of the different phenotypes in each group of plants. Prepare a graph of your data.
2. **Calculate** the ratio of different seedlings for each of your groups of seeds.
3. **Identify** two or more possible crosses that could have resulted in your observed ratio of seedlings.
4. **Analyze** Make a Punnett square for each cross you identified in question 3. Determine whether each possible cross could have resulted in the data you collected.
5. **Evaluate** how the combined data from the two seed groups affect the ratio of seedlings.
6. **Draw Conclusions** Based on the data from your two groups of seeds, list the genotype and phenotype of the parent plants.
7. **Error Analysis** Compare your calculated ratios to those of another student. Describe any differences. Combine your data with another group's data. Infer how increasing the number of seeds analyzed affects the outcome of the experiment.

COMMUNICATE

Poster Session Prepare a poster that describes the experiment you conducted and displays the data you collected. When posters are complete, have a poster session during which you examine each others' work and compare your results. To learn more about determining genotypes, visit BioLabs at biologygmh.com.



CHAPTER 10

Study Guide

Download quizzes, key terms, and flash cards from biologygmh.com.

FOLDABLES **Conclude** On the back of your Foldable, conclude how meiosis and genetic recombination work together and result in genetic diversity.

Vocabulary	Key Concepts
Section 10.1 Meiosis	
• crossing over (p. 271) • diploid (p. 271) • fertilization (p. 271) • gamete (p. 271) • gene (p. 270) • haploid (p. 271) • homologous chromosome (p. 270) • meiosis (p. 271)	MAIN Idea Meiosis produces haploid gametes. • DNA replication takes place only once during meiosis, and it results in four haploid gametes. • Meiosis consists of two sets of divisions. • Meiosis produces genetic variation in gametes.
Section 10.2 Mendelian Genetics	
• allele (p. 278) • dominant (p. 278) • genetics (p. 277) • genotype (p. 279) • heterozygous (p. 279) • homozygous (p. 279) • hybrid (p. 279) • law of independent assortment (p. 280) • law of segregation (p. 279) • phenotype (p. 279) • recessive (p. 278)	MAIN Idea Mendel explained how a dominant allele can mask the presence of a recessive allele. • The study of genetics began with Gregor Mendel, whose experiments with garden pea plants gave insight into the inheritance of traits. • Mendel developed the law of segregation and the law of independent assortment. • Punnett squares help predict the offspring of a cross.
Section 10.3 Gene Linkage and Polyploidy	
• genetic recombination (p. 283) • polyploidy (p. 285)	MAIN Idea The crossing over of linked genes is a source of genetic variation. • Genetic recombination involves both crossing over and independent assortment. • Early chromosome maps were created based on the linkage of genes on the chromosome. • Polyploid plants are selected by plant growers for their desirable characteristics.

Vocabulary PuzzleMaker biologygmh.com

CHAPTER 10 Assessment

Section 10.1

Vocabulary Review

Use what you know about the terms in the Study Guide to answer the following questions.

1. When two cells with *n* number of chromosomes fuse, what type of cell results?

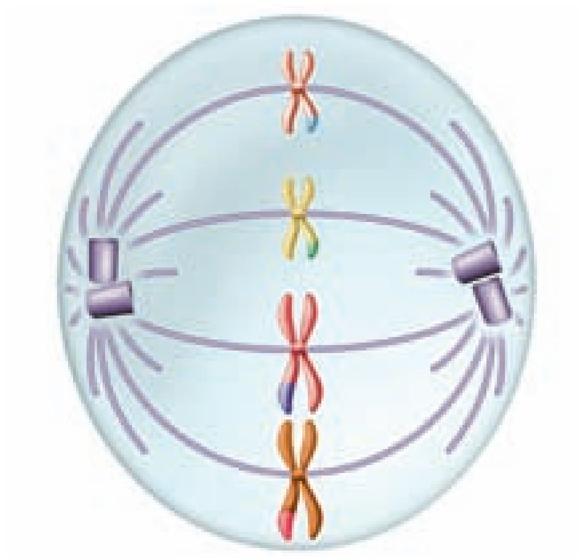
2. During which process are gametes formed?

3. What process results in an exchange of genes between homologous chromosomes?

Understand Key Concepts

4. How many chromosomes would a cell have during metaphase I of meiosis if it has 12 chromosomes during interphase?
A. 6
B. 12
C. 24
D. 36

Use the diagram below to answer questions 5 and 6.



5. Which stage of meiosis is illustrated above?
A. prophase I
B. prophase II
C. metaphase I
D. metaphase II

6. What is the next step for the chromosomes illustrated above?
A. They will experience replication.
B. They will experience fertilization.
C. Their number per cell will be halved.
D. They will divide into sister chromatids.

7. Which is not a characteristic of homologous chromosomes?
A. Homologous chromosomes have the same length.
B. Homologous chromosomes have the same centromere position.
C. Homologous chromosomes have the exact same type of allele at the same location.
D. Homologous chromosomes pair up during meiosis I.

Constructed Response

8. Short Answer Relate the terms meiosis, gametes, and fertilization in one or two sentences.

9. Open Ended Plant cells do not have centrioles. Hypothesize why plant cells might not need centrioles for mitosis or meiosis.

Think Critically

10. Analyze A horse has 64 chromosomes and a donkey has 62. Using your knowledge of meiosis, evaluate why a cross between a horse and a donkey produces a mule, which usually is sterile.

11. Hypothesize In bees, the female queen bee is diploid but male bees are haploid. The fertilized eggs develop into female bees and the unfertilized eggs develop into males. How might gamete production in male bees differ from normal meiosis?

Section 10.2

Vocabulary Review

Explain the differences between the vocabulary terms in the following sets.

12. dominant, recessive

13. genotype, phenotype

Understand Key Concepts

14. If a black guinea pig (*Bb*) were crossed with a white guinea pig (*bb*) what would be the resulting phenotypic ratio?
A. 0:1 black to white
B. 1:0 black to white
C. 1:1 black to white
D. 3:1 black to white

15. In garden peas, purple flowers (*P*) are dominant to white (*p*) flowers, and tall plants (*T*) are dominant to short plants (*t*). If a purple tall plant (*PpTt*) is crossed with a white short plant (*pptt*), what is the resulting phenotypic ratio?
- **A.** 1:1:1:1 purple tall to purple short to white tall to white short
- **B.** 3:2 purple tall to purple short
- **C.** 9:3:3:1 purple tall to purple short to white tall to white short
- **D.** all purple tall

Use the figure below to answer questions 16 and 17.

16. The unusual cat shown was crossed with a cat with noncurled ears. All the kittens born from that cross had noncurled ears. Later, when these offspring were crossed with each other, the phenotypic ratio was 3:1 noncurled to curled ears. What conclusions can be made about the inheritance of curled ears?
- **A.** Curled ears are a result of crossing over.
- **B.** It is a dominant trait.
- **C.** It is a recessive trait.
- **D.** More crosses need to be done to determine how the trait is inherited.

Constructed Response

17. Short Answer What might occur in the F_3 generation of the curly-eared cat shown above if the F_2 generation all reproduce with cats that have non-curly ears?

18. Short Answer If there are five boys and no girls born into a family, does that increase the likelihood that the sixth offspring will be a girl? Explain.

Think Critically

Use the figure below to answer question 19.

19. Predict There are two types of American rat terrier dogs—those without hair and those with hair, as shown in the figure. The presence of hair is a genetically determined trait. Some female rat terriers with hair produce only puppies with hair, whereas other females produce rat terrier puppies without hair. Explain how this can occur.

20. MATH in Biology What is the probability of a couple giving birth to five girls in a row?

Section 10.3

Vocabulary Review

Replace the underlined words with the correct vocabulary term from the Study Guide page.

21. Human growth hormone has been used in agriculture to increase the size of flowers.

22. Both meiosis and crossing over contribute to the amount of chromosomes in a particular species.

Understand Key Concepts

23. Which does not contribute to genetic variation?
- **A.** chromosome number
- **B.** crossing over
- **C.** meiosis
- **D.** random mating

24. Which concept is considered an exception to Mendel's law of independent assortment?
- **A.** crossing over
- **B.** gene linkage
- **C.** polyploidy
- **D.** law of segregation

Chapter Test biologygmh.com

Use the figure below to answer questions 25 and 26.

25. Houseflies, as shown in the photo above, have six pairs of chromosomes. If two houseflies are crossed, how many possible types of fertilized eggs could result from the random lining up of the pairs?

A. 256
B. 1024
C. 4096
D. 16,384

26. For the housefly with its six pairs of chromosomes, how many possible combinations of gametes can be produced by the random lining up of pairs in meiosis?

A. 32
B. 48
C. 64
D. 120

Constructed Response

27. Short Answer What three processes increase genetic variation?

28. Open Ended Hypothesize how a plant breeder might create a polyploid plant.

29. Short Answer How is chromosome gene linkage an exception to the law of independent assortment?

Think Critically

30. CAREERS IN BIOLOGY Horticulturists grow thousands of genetically identical plants by using cuttings. Cuttings do not involve sexual reproduction. Discuss the benefits and drawbacks of using cuttings to reproduce a certain type of plant.

31. Hypothesize Crossing over provides genetic variation, eventually changing the gene pool in a population. Yet some sexually reproducing organisms do not seem to display recombination mechanisms. Why might it be advantageous for these organisms to reduce genetic recombination?

Additional Assessment

32. WRITING in Biology In sheep, white wool is dominant and black wool is recessive. Suppose some sheep belonging to a certain flock are heterozygous for wool color. Write a plan indicating how a flock of pure-breeding white sheep could be developed.

DBQ Document-Based Questions

The paragraphs below were obtained from Mendel's publication.

Data obtained from: Mendel, Gregor. 1866. *Experiments in Plant Hybridization*. Originally translated by Bateson, William, 1901: 2.

"The hybrids of such plants must, during the flowering period, be protected from the influence of all foreign pollen, or be easily capable of such protection."

33. Mendel made the above rule for his experimental plants. Summarize why this rule was important for the success of his experiments.

Ibid: 4

"The object of the experiment was to observe these variations in the case of each pair of differentiating characters, and to deduce the law according to which they appear in successive generations. The experiment resolves itself therefore into just as many separate experiments. There are constantly differentiating characters presented in the experimental plants."

34. Describe Mendel's purpose for conducting plant breeding experiments.

Cumulative Review

35. Suggest what the consequences of biodiversity will be if globalization of species continues at its present pace. **(Chapter 5)**

36. How do prokaryotic cells differ from eukaryotic cells? **(Chapter 7)**

37. Compare and contrast the way in which plants and animals obtain energy. **(Chapter 8)**

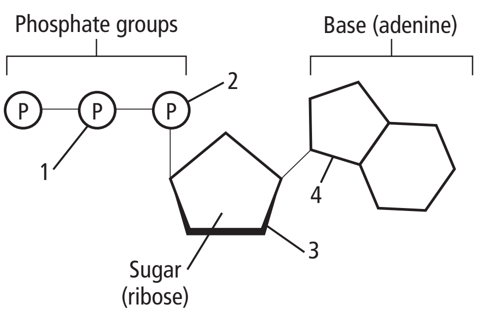
Standardized Test Practice

Cumulative

Multiple Choice

1. A population will likely enter a long-term high growth rate when many individuals are which?
   A. below the main reproductive age
   B. just above the main reproductive age
   C. at the middle of the main reproductive age
   D. at the upper end of the main reproductive age

Use the illustration below to answer question 2.



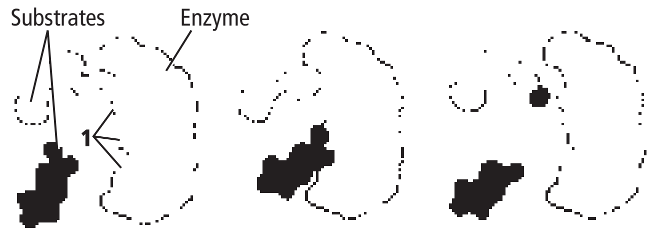
2. To release energy for use in the organism, the bond between which two groups in the ATP molecule must be broken?
   A. 1 and 2
   B. 2 and 3
   C. 2 and 4
   D. 3 and 4

3. Which process divides a cell's nucleus and nuclear material?
   A. cell cycle
   B. cytokinesis
   C. interphase
   D. mitosis

4. Which is the source of electrons in the electron transport chain stage of respiration?
   A. formation of acetyl CoA during the Krebs cycle
   B. creation of NADH and $FADH_2$ during the Krebs cycle
   C. fermentation of lactic acid
   D. breaking of bonds in glycolysis

5. Which would most likely cause lung cancer?
   A. exposure to asbestos particles
   B. exposure to fungus spores
   C. exposure to infrared radiation
   D. exposure to ultraviolet radiation

Use the illustration below to answer question 6.



6. Which is the role of "1" in the activity of the enzyme?
   A. to make a reaction happen more slowly
   B. to make more reactants available to the substrate
   C. to provide a unique spot for substrate binding
   D. to raise the activation energy for the reaction

7. What causes the movement of calcium and sodium ions in and out of cardiac cells?
   A. charged particles in the phospholipid bilayer
   B. cholesterol molecules in the phospholipid bilayer
   C. diffusion channels in the cell membrane
   D. transport proteins in the cell membrane

8. In a cell undergoing meiosis, during which stage do the sister chromatids separate from each other?
   A. anaphase I
   B. anaphase II
   C. telophase I
   D. telophase II

9. Which is the standard SI unit for mass?
   A. candela
   B. kelvin
   C. kilogram
   D. meter

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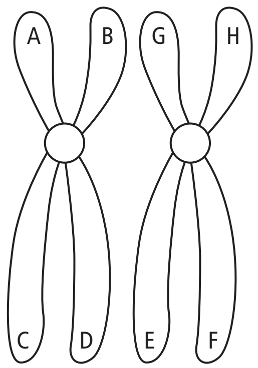
CONTENTS

Short Answer

Use the diagram below to answer questions 10 and 11.



10. The diagram above shows a pair of chromosomes with different regions on the chromosomes labeled. Explain where crossing over could occur on this pair of chromosomes.

11. When is crossing over most likely to occur?

12. Suppose the concentration of CO_2 in a greenhouse decreases. Explain how the photosynthesis process could be affected by that change. Predict the overall effect on plants.

13. How does the process of meiosis promote genetic variation in a species?

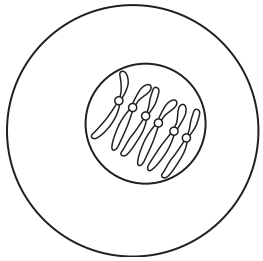
14. Describe how the chromosomes change during the S phase.

15. Hypothesize why meiosis occurs in two stages—meiosis I and meiosis II.

16. Explain how factors in the environment can cause cancer to develop.

Extended Response

Use the diagram below to answer question 17.



17. The diagram above shows the chromosomes found in the sex cells of a particular animal. Based on this diagram, describe what happens during fertilization in this species.

18. Assess what might happen if mitosis were NOT an extremely precise process.

Essay Question

Stem cells are cells that are not specialized for a particular function. Like other cells, stem cells contain all of the genetic material found in the organism. Stem cells, if given the correct signal, can become any type of specialized cell. There are two different types of stem cells. Embryonic stem cells are found in embryos, while adult stem cells are found in small quantities in mature tissues. The process of conducting research using stem cells, especially using embryonic stem cells, is controversial because of ethical concerns.

Using the information in the paragraph above, answer the following question in essay format.

19. Do you think medical researchers should be allowed to use stem cells as research material? Judge what you think are the benefits or risks of stem cell research.

NEED EXTRA HELP?

If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Review Section . . .	4.2	8.2	9.1	8.3	9.3	6.2	7.2, 7.4	10.1	1.2	10.1	10.1	8.2	10.1, 10.3	9.2	10.2	9.3	10.1	9.2	9.2