Section 3

The Cell and Inheritance

CALIFORNIA Standards Focus

S 7.2.b
Previously, students learned that an individual's genetic material is a combination of alleles from each parent. Now, they will see how these alleles are passed from parent to offspring.

Objectives

After this lesson, students will be able to

5.3.1 Describe the role chromosomes play in inheritance.

5.3.2 Identify the events that occur during meiosis.

5.3.3 Explain the relationship between chromosomes and genes.

Preteach

Build Background Knowledge L1

Relating Genetics and the Cell Cycle

Have students recall what they know about cells and cell structure. Challenge them to predict the location of Mendel's hereditary factors, or genes, within the cell. You might wish to record students' predictions on the board and have the class evaluate them as you study the section.

Teach Academic Words L2

Before teaching this section, preteach the high-use words using the TE strategy on page T47.

focused (FOH kusd) *v.* page 170, paragraph 2
Concentrate attention or effort. *This marking period, Vivian focused her effort on the subject in which she needed the most improvement.*

Section 3

The Cell and Inheritance

CALIFORNIA Standards Focus

S 7.2.b Students know sexual reproduction produces offspring that inherit half their genes from each parent.

- What role do chromosomes play in inheritance?
- What events occur during meiosis?
- What is the relationship between chromosomes and genes?

Key Term

- sexual reproduction
- diploid
- meiosis

Lab zone Standards Warm-Up

Which Chromosome Is Which?

Mendel did not know about chromosomes or their role in genetics. Today we know that genes are located on chromosomes.

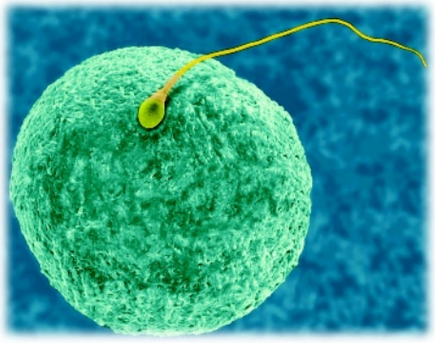
1. Label two craft sticks with the letter *A*. The craft sticks represent a pair of chromosomes in the female parent. Turn the sticks face down on a piece of paper.
2. Label two more craft sticks with the letter *a*. These represent a pair of chromosomes in the male parent. Turn the sticks face down on another piece of paper.
3. Turn over one craft stick "chromosome" from each piece of paper. Move both sticks to a third piece of paper. These represent a pair of chromosomes in the offspring. Note the allele combination that the offspring received.

Think It Over
Making Models Use this model to explain how chromosomes are involved in the inheritance of alleles.

Mendel's work showed that genes exist. But scientists in the early twentieth century did not know what structures in cells contained genes. The search for the answer to this puzzle is something like a mystery story. The story could be called "The Clue in the Grasshopper's Cells."

In 1903, Walter Sutton, an American geneticist, was studying the cells of grasshoppers. He wanted to understand how sex cells (sperm and egg) form. Sutton focused on the movement of chromosomes during the formation of sex cells. Sex cells form during sexual reproduction. In **sexual reproduction,** genetic material from two parents combines to produce a new organism, which differs from both parents. Sutton hypothesized that chromosomes were the key to understanding how offspring have traits similar to those of their parents.

Sperm ▼



Egg ▶

FIGURE 11
Sex Cells
The large egg is a female sex cell, and the smaller sperm is a male sex cell.

Lab zone Standards Warm-Up S 7.2.b

Skills Focus Making models L2

Materials 4 craft sticks, 3 pieces of paper, marking pen

Time 10 minutes

Tips Make sure each offspring receives only one allele from each parent.

Expected Outcome Students will realize that parents contribute only one of their two chromosomes to the offspring. The idea is to get students thinking about genes being carried on chromosomes.

Think It Over Genes are located on chromosomes, which must divide and separate so that the offspring get only one chromosome, or one allele, from each parent.

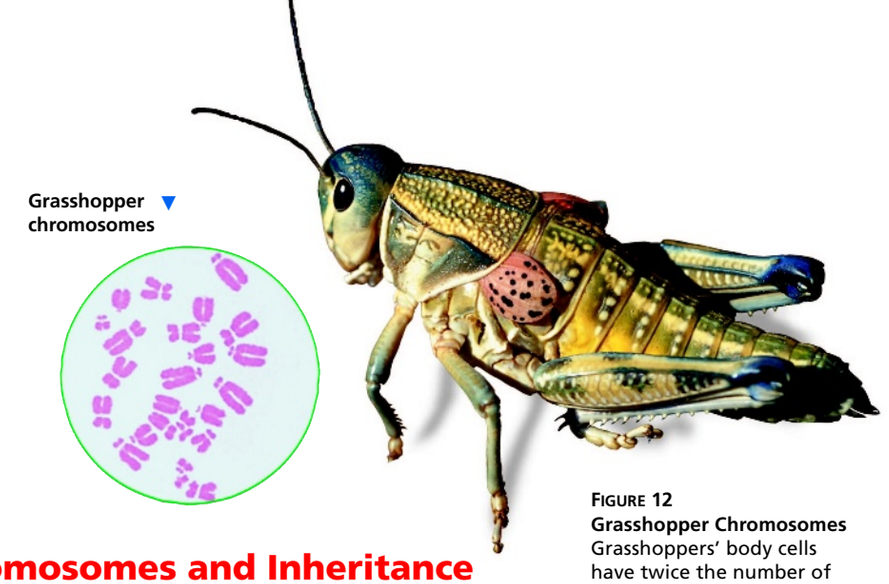


FIGURE 12
Grasshopper Chromosomes Grasshoppers' body cells have twice the number of chromosomes as their sex cells. **Applying Concepts** *What is the function of chromosomes?*

Chromosomes and Inheritance

Sutton needed evidence to support his hypothesis that chromosomes were important in the inheritance of traits. He found that evidence in grasshoppers' cells. The body cells of a grasshopper have 24 chromosomes. To his surprise, Sutton found that the grasshopper's sex cells have only 12 chromosomes. In other words, a grasshopper's sex cells have exactly half the number of chromosomes found in its body cells.

Chromosome Pairs Sutton observed what happened when a sperm cell and an egg cell joined during fertilization. The fertilized egg that formed was diploid. A **diploid** cell contains two sets of chromosomes, one set from each parent. The fertilized grasshopper egg had 24 chromosomes, or 12 pairs. One chromosome in each pair came from each parent. As result, the grasshopper offspring had exactly the same number of chromosomes in its cells as did each of its parents.

Genes on Chromosomes Recall that alleles are different forms of a gene. From the results of Mendel's work, Sutton knew that alleles exist in pairs in an organism. One allele in a pair comes from the organism's female parent and the other allele comes from the male parent. Sutton realized that paired alleles were carried on paired chromosomes. Sutton's idea came to be known as the chromosome theory of inheritance. **According to the chromosome theory of inheritance, genes are carried from parents to their offspring on chromosomes.**

Reading Checkpoint **What is the relationship between alleles and chromosomes?**

Instruct

Chromosomes and Inheritance

Teach Key Concepts L2

The Role of Chromosomes

Focus Review the definition and location of chromosomes.

Teach Ask: **What did Sutton observe about the relative numbers of chromosomes in the body cells and sex cells of grasshoppers?** *(The sex cells have half the number of chromosomes as body cells.)* **How many chromosomes does the fertilized egg receive from each parent?** *(The number that is present in each sex cell)* **How are genes passed from parent to offspring?** *(Sex cells contain half of each parent's chromosomes, which include the parent's genes. When the sex cells from each parent join during fertilization, the offspring receives a full set of genes.)* **What is the chromosomal theory of inheritance?** *(Genes are carried from parents to their offspring on chromosomes.)*

Apply Ask: **If human body cells each have 46 chromosomes, how many chromosomes do human sex cells have?** *(23)*

Independent Practice

Teaching Resources

Reading/Notetaking Guides L2

- 5.3 Guided Reading/Study Worksheets

Student Edition in MP3 Format

Universal Access

Advanced Readers L3
Drawing Conclusions Ask students how meiosis affects the number of chromosomes in sex cells. *(It reduces the number to half.)* Then challenge students to predict what would happen in the cells of offspring if sex cells did not have half the number of chromsomes. *(The number of chromosomes would double with each new generation.)*

Special Needs L1
Visualizing Chromosomes Show a picture of a cell and point out the chromosomes. Diagram two cells, each with one pair of chromosomes. Work backward to show how one chromosome came from the mother and one from the father. Point out the location of a gene. Show how it can have two alleles.

Monitor Progress L2

Drawing Have students draw a diagram of a grasshopper body cell and sex cell and show the number of chromosomes in each of these cells.

Answers

Figure 12 Chromosomes carry genes from parents to offspring.

Reading Checkpoint Paired alleles are carried on paired chromosomes.

Meiosis

Go Online SCILINKS NSTA
For: Links on meiosis
Visit: www.SciLinks.org
Web Code: scn-0333
Download a worksheet to guide students' review of meiosis.

Help Students Read

L2

Use Prior Knowledge Students absorb new material more quickly when they can relate it to previously learned concepts. Before they read about meiosis, have them write a paragraph explaining the steps in mitosis. As they read about meiosis, have them compare and contrast mitosis with meiosis, using what they have written.

Teach Key Concepts

L2

Events in Meiosis

Focus Remind students that sex cells have half the number of chromosomes as body cells.

Teach Refer students to Figure 13. Point out that before meiosis occurs, every chromosome is copied, so the cell has four copies of each chromosome. Ask: **What happens during Meiosis I?** *(The chromosome pairs separate into two different cells.)* **What happens during Meiosis II?** *(The centromeres split and the chromosome copies separate.)* **How many sex cells are produced at the end of the meiosis?** *(Four)* **How do the sex cells differ from the parent cell?** *(The sex cells have half the number of chromosomes of the parent cell.)*

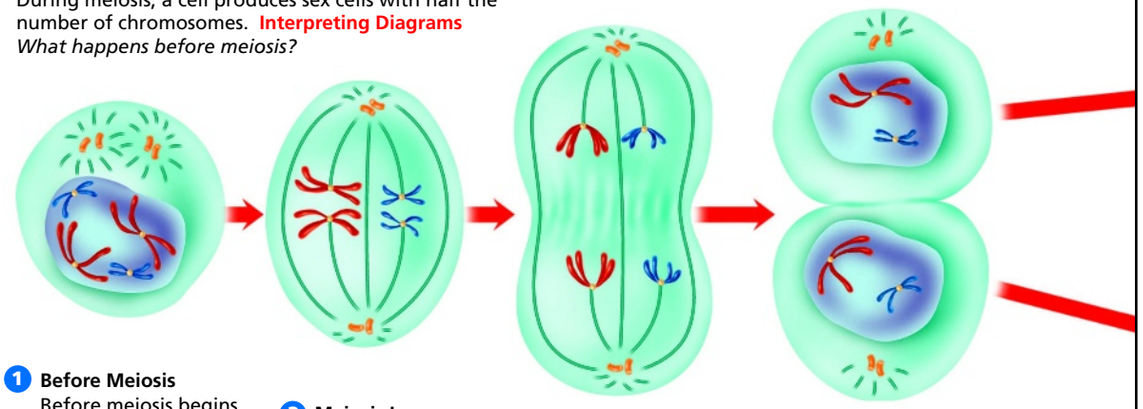
Apply Ask: **How is meiosis similar to mitosis?** *(Chromosomes are copied and line up to move to opposite sides of the cell. The cell divides.)* **Different?** *(In meiosis, the body cell divides twice, producing 4 sex cells that have half the number of chromosomes of the original body cell. Mitosis produces only 2 body cells, each with the same number of chromosomes as the parent cell.)*

Teaching Resources

Color Transparencies

- Transparency LS39

FIGURE 13
Meiosis
During meiosis, a cell produces sex cells with half the number of chromosomes. **Interpreting Diagrams** *What happens before meiosis?*



1 Before Meiosis Before meiosis begins, every chromosome in the parent cell is copied. Centromeres hold the two chromatids together.

2 Meiosis I
A The chromosome pairs line up in the center of the cell.
B The pairs separate and move to opposite ends of the cell.
C Two cells form, each with half the number of chromosomes. Each chromosome still has two chromatids.

Meiosis

How do sex cells end up with half the number of chromosomes as body cells? To answer this question, you need to understand the events that occur during meiosis. **Meiosis** (my OH sis) is the process by which the number of chromosomes is reduced by half to form sex cells—sperm and eggs.

What Happens During Meiosis You can trace the events of meiosis in Figure 13. In this example, each parent cell has four chromosomes arranged in two pairs. **During meiosis, the chromosome pairs separate and are distributed to two different cells. The resulting sex cells have only half as many chromosomes as the other cells in the organism.** The sex cells end up with only two chromosomes each—half the number found in the parent cell. Each sex cell has one chromosome from each original pair.

When sex cells combine to form an organism, each sex cell contributes half the normal number of chromosomes. Thus, the offspring gets the normal number of chromosomes—half from each parent.

Go Online SCILINKS NSTA
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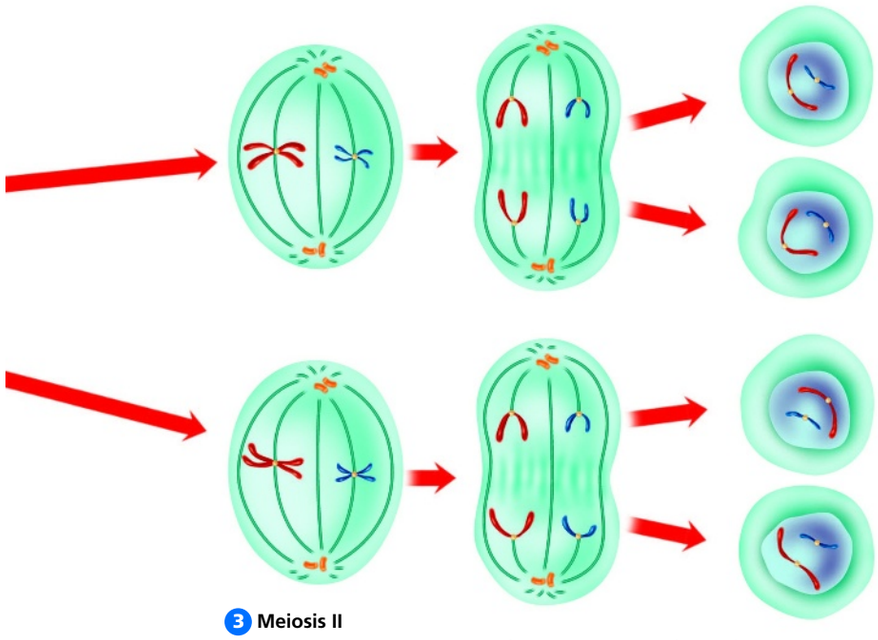


3 Meiosis II

A The chromosomes with their two chromatids move to the center of the cell.

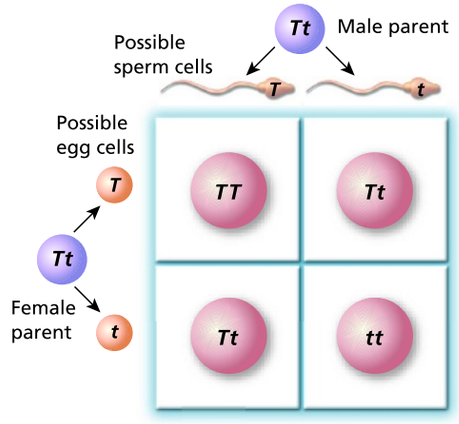
B The centromeres split, and the chromatids separate. Single chromosomes move to opposite ends of the cell.

4 End of Meiosis
Four sex cells have been produced. Each cell has only half the number of chromosomes that the parent cell had at the beginning of meiosis. Each cell has only one chromosome from each original pair.

Meiosis and Punnett Squares A Punnett square is actually a way to show the events that occur at meiosis. When the chromosome pairs separate and go into two different sex cells, so do the alleles carried on each chromosome. One allele from each pair goes to each sex cell.

In Figure 14, you can see how the Punnett square accounts for the separation of alleles during meiosis. As shown across the top of the Punnett square, half of the sperm cells from the male parent will receive the chromosome with the *T* allele. The other half of the sperm cells will receive the chromosome with the *t* allele. In this example, the same is true for the egg cells from the female parent, as shown down the left side of the Punnett square. Depending on which sperm cell combines with which egg cell, one of the allele combinations shown in the boxes will result.

FIGURE 14
Meiosis Punnett Square
Suppose both parents are heterozygous for the trait of stem height. The Punnett square shows the possible allele combinations after fertilization.



Lab zone Build Inquiry S 7.2.d

Modeling Chromosomes During Meiosis L1

Materials 8 pipe cleaners (4 of one color and 4 of another), 4 beads

Time 15 minutes

Focus Review the steps in meiosis.

Teach Challenge students to model the steps in meiosis using the pipe cleaners to represent two chromosomes in a cell. Students use pipe cleaners of the same color to represent chromosome pairs, with different chromosome pairs having different colors. Monitor students to make sure they double each chromosome before meiosis begins by adding another pipe cleaner of the same color to each pipe cleaner chromosome. Students can use beads to hold the chromosome copies together or twist the pipe cleaners together at one point. Make sure students separate the chromosome pairs during Meiosis I and the chromosome copies during Meiosis II.

Apply Ask: **How many chromosomes did you start with?** *(Two)* **How many chromosomes did each new cell have?** *(One)* **If an organism's cells had 12 pairs of chromosomes, how many chromosomes do the cells of that organism have?** *(24)* **How many chromosomes do the sex cells of that organism have?** *(12)* Emphasize that the sex cells have one chromosome from each pair, and not just a randomly selected half of the original set of chromosomes.

Universal Access

English Learners/Beginning Comprehension: Link to Visual L1

Pair beginners with more advanced English learners. Have the pairs of students go over each step in Figure 13, with the more advanced student helping the beginner understand what goes on in each step. The beginner can make sketches and take notes in his or her first language.

English Learners/Intermediate Comprehension: Link to Visual L2

Have students prepare two-column written explanations of each step in meiosis as shown in Figure 13. The first column should explain each step in the student's first language. The second column should have a corresponding explanation in English. The student can make a copy of this two-column explanation to share with a beginner.

Monitor Progress L2

Writing Have students write an outline of meiosis in which each major step is a main heading in the outline.

Answer

Figure 13 Every chromosome in the cell is copied.

A Lineup of Genes

Teach Key Concepts L2

Chromosomes and Genes

Focus Refer students to Figure 15.

Teach Ask: **How are chromosomes and genes related?** *(Chromosomes are made up of many genes joined together.)*

Apply Have students show two ways to make a chromosome pair heterozygous for all genes.

Monitor Progress L2

Answer

Figure 15 Homozygous: C, e, F, G, I; Heterozygous: A, B, D, H

Assess

S 7.2.b

Target Reading Skill

Take Notes Check students' notes for accuracy before assigning the questions.

Reviewing Key Concepts

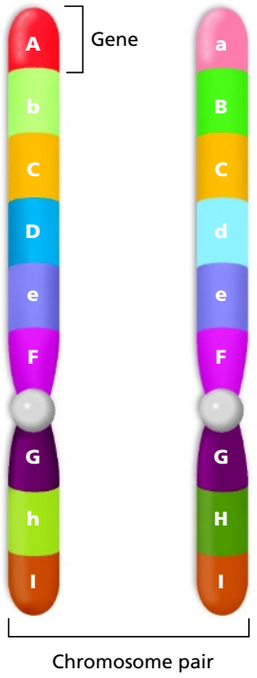
1. a. Body cells have twice the number of chromosomes (24) as sex cells (12). **b.** The fertilized egg gets 24 chromosomes. **c.** Just as the offspring get one allele from each parent for every gene, the offspring get half their chromosomes from one parent and half from the other parent.

2. a. The process by which the number of chromosomes is reduced by half to form sex cells **b.** Meiosis I: The duplicate chromosomes divide into two cells, each with half the number of chromosomes. Meiosis II: The two cells divide once more, producing sex cells that have half as many chromosomes as the body cells. **c.** In meiosis I, the members of each chromosome pair separate and end up in different cells.

3. a. They are joined together like beads on a string. **b.** They are lined up in the same order on both chromosomes.

Remediation L1

Have students sketch the stages of meiosis on separate pieces of paper, then exchange with a partner. Each student should then put the sketches in order.



A Lineup of Genes

Each human body cell contains 23 chromosome pairs, or 46 chromosomes. **Chromosomes are made up of many genes joined together like beads on a string.** Plant and animal chromosomes contain many thousands of genes. Although you have only 23 pairs of chromosomes, your body cells each contain about 35,000 genes. Each gene controls a trait.

In Figure 15, one chromosome in the pair came from the female parent. The other chromosome came from the male parent. There are usually two copies of every gene. The genes are lined up in the same order on both chromosomes. However, the alleles for some of the genes might be different. For example, the organism has the *A* allele on one chromosome and the *a* allele on the other. As you can see, this organism is heterozygous for some traits and homozygous for others.

FIGURE 15
Genes on Chromosomes
The chromosomes in a pair may have different alleles for some genes and the same alleles for others. **Classifying** *For which genes is this organism homozygous? For which genes is it heterozygous?*

Section 3 Assessment

S 7.2.b, E-LA: Reading 7.2.0, Writing 7.2.0

Target Reading Skill **Take Notes** Use your notes to help answer the questions below.

Reviewing Key Concepts

1. **a.** **Comparing and Contrasting** According to Sutton's observations, how does the number of chromosomes in a grasshopper's body cells compare to the number in its sex cells?
   b. **Describing** Describe what happens to the number of chromosomes when two grasshopper sex cells join in fertilization.
   c. **Explaining** How do Sutton's observations about chromosome number support the chromosome theory of inheritance?
2. **a.** **Defining** What is meiosis?
   b. **Interpreting Diagrams** Briefly describe meiosis I and meiosis II. Refer to Figure 13.
   c. **Sequencing** Use the events of meiosis to explain why a sex cell normally does not receive both chromosomes from a pair.
3. **a.** **Describing** How are genes arranged on a chromosome?
   b. **Comparing and Contrasting** How does the order of genes in one member of a chromosome pair compare to the order of genes on the other chromosome?

Writing in Science

Newspaper Interview You are a newspaper reporter in the early 1900s. You want to interview Walter Sutton about his work with chromosomes. Write three questions you would like to ask Sutton. Then, for each question, write answers that Sutton might have given.

Lab zone Standards Investigation

Keep Students on Track

Students will determine the traits inherited from each parent for six offspring by using a coin toss. They will write a genotype for each trait on each parent's back. Then they will construct a paper pet for each offspring, showing the traits that each one has inherited.

Writing in Science

E-LA: Writing 7.2.0

Writing Mode Expository

4 Includes complete description and is written in the format of an interview with the scientist

3 Includes all criteria, but questions are low-level comprehension type

2 Includes only two questions

1 Includes inaccurate information