

Chromosomes and Chromosome Number

All students in your class have characteristics passed on to them by their parents. Each characteristic, such as hair color, eye color, and height, is called a trait.

The instructions for each trait are found on chromosomes. Recall that chromosomes are found in the nuclei of cells. The DNA on the chromosomes is arranged in sections that control the production of proteins. These DNA sections are called **genes**. Each chromosome has about 1500 genes. Each gene has a role in the characteristics of the cell and how the cell works. Living things have thousands of genes.

Human body cells have 46 chromosomes. Chromosomes come in pairs. You have 23 chromosomes from your father and 23 chromosomes from your mother, making 23 pairs of chromosomes.

What are homologous chromosomes?

The chromosomes that make up a pair, one from each parent, are called **homologous** (huh MAH luh gus) **chromosomes**. Homologous chromosomes are the same length and have the centromere in the same place. They also carry genes for the same traits at the same place. Look at the picture below, and see if you can spot the homologous pair.

Homologous chromosomes are similar but not identical. For example, the gene for ear shape will be located at the same place on each homologous chromosome. Although these genes code for ear shape, the gene on one chromosome might code for one ear shape. The gene on the other chromosome might code for a different ear shape.



How is chromosome number maintained in a species?

The number of chromosomes does not change from generation to generation. You have the same number of chromosomes as your parents. **Gametes** (GA meets), or sex cells with half the number of chromosomes, ensure the chromosome number stays the same.

The symbol n represents the number of chromosomes. In humans, n is equal to 23. A cell with n number of chromosomes is called a **haploid** cell. Gametes are haploid cells. ✓

The process in which one haploid gamete joins with another haploid gamete is called **fertilization**. After fertilization, the cell has $2n$ chromosomes— n chromosomes from the female parent plus n chromosomes from the male parent. A cell with $2n$ chromosomes is called a **diploid** cell. Notice that n also represents the number of chromosome pairs in an organism.

Meiosis I

Recall that most cells are formed by mitosis. During mitosis the chromosome number stays the same. Because sex cells need half the number of chromosomes, a different process of cell division is needed. Gametes are formed during a process called meiosis. **Meiosis** is a kind of cell division that reduces the number of chromosomes by half through the separation of homologous chromosomes. Meiosis takes place in the reproductive organs of plants and animals. During meiosis, there are two cell divisions. They are called meiosis I and meiosis II.

What happens during interphase I?

Just as in mitosis, a cell goes through interphase before undergoing meiosis. A cell in interphase carries out a variety of metabolic functions, copies its DNA, and makes proteins.

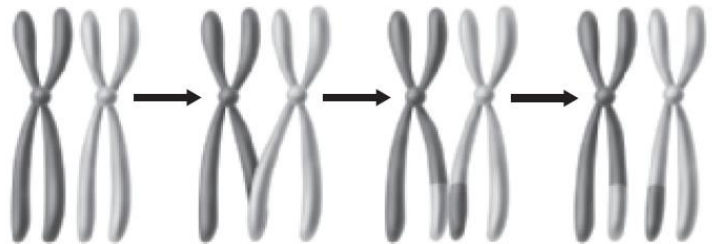
What happens during prophase I?

Meiosis I begins with prophase I. During prophase I, replicated chromosomes, consisting of two sister chromatids, condense. When that happens, the chromosomes become visible under a light microscope.

As the homologous chromosomes condense, they begin to form homologous pairs in a process called synapsis (suh NAP sus). The homologous chromosomes are held tightly together along their lengths by a protein that acts like a zipper. Prophase I continues as the chromosomes move to opposite sides of the cell.

What is crossing over?

During synapsis, the chromosomes often swap pieces of DNA. **Crossing over** occurs when a section of one chromosome changes place with a section of its homologous chromosome. This is shown in the figure below. The centrioles move to the opposite poles of the cell. Spindle fibers form and bind to the sister chromatids at the centromere.



What happens during metaphase I?

The next phase is metaphase I. During metaphase I, the pairs of homologous chromosomes line up in the center of the cell. The spindle fibers attach to the centromere of each homologous chromosome.

What happens during anaphase I?

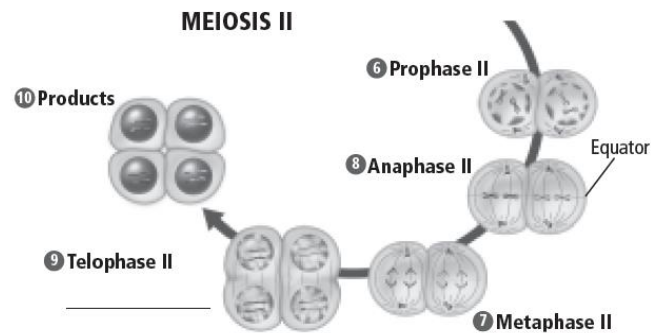
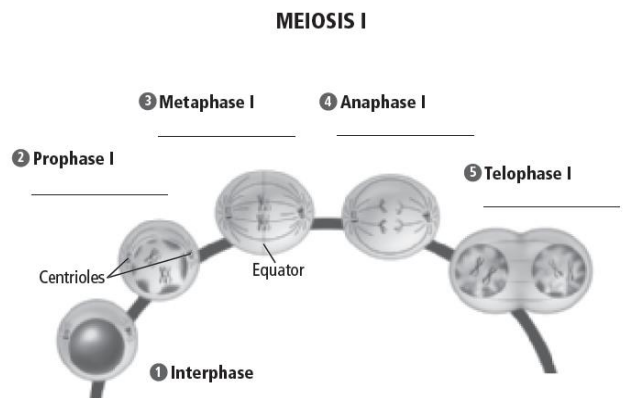
Next is anaphase I. During anaphase I, each homologous chromosome is guided by the spindle fibers toward opposite poles of the cell. When this happens, the chromosome number is reduced from $2n$ to n . Notice that the sister chromatids do not split during meiosis I. Each homologous chromosome still has two sister chromatids. ☑

What is the final stage of meiosis I?

The final stage of meiosis I is telophase I. During telophase I, the homologous chromosomes reach opposite poles of the cell. Each pole contains only one member of a pair of homologous chromosomes.

The sister chromatids might not be identical because crossing over might have occurred during synapsis in prophase I. Crossing over is one way that meiosis leads to more genetic diversity. This diversity helps explain how species can change over time.

At the end of telophase I, the cell undergoes cytokinesis, meaning it divides into two cells. The cells then might go into interphase again, but this time, the DNA is not copied during interphase. The events of meiosis I are shown below.



Meiosis II

Meiosis is now half finished. To complete meiosis, the cell must go through meiosis II. Meiosis II is similar to mitosis.

What events occur during meiosis II?

During prophase II, the spindle apparatus forms, and the chromosomes condense. During metaphase II, a haploid number of chromosomes lines up near the center of the cell by the spindle fibers. During anaphase II, the sister chromatids are pulled apart at the centromere by the spindle fibers, and the sister chromatids are pulled to the opposite poles of the cell. In telophase II, the chromosomes reach the poles, and the nuclear membrane and nuclei reform. Cytokinesis, or cell division, occurs. The result is four haploid cells, each with n number of chromosomes.

The Importance of Meiosis

The figure below shows that meiosis and mitosis have similar steps, but they are different in important ways. An important difference is that mitosis produces two identical diploid daughter cells, while meiosis produces four different haploid daughter cells.

| | Mitosis | Meiosis |
|------------------------------------|-----------------------------------|-----------------------------------------------|
| Number of cell divisions | one | two |
| Synapsis of homologous chromosomes | does not occur | occurs during prophase I |
| Products | _____ identical, diploid cells | _____ nonidentical, haploid cells |
| Type of cells produced | body cells | reproductive cells |
| Purpose | growth and repair of body tissues | production of gametes for sexual reproduction |

Word Bank

- Diploid
- Gamete
- Gene
- Haploid
- Homologous chromosomes
- Meiosis
- Fertilization
- Crossing over

Use the terms in the left margin to complete the paragraph below.

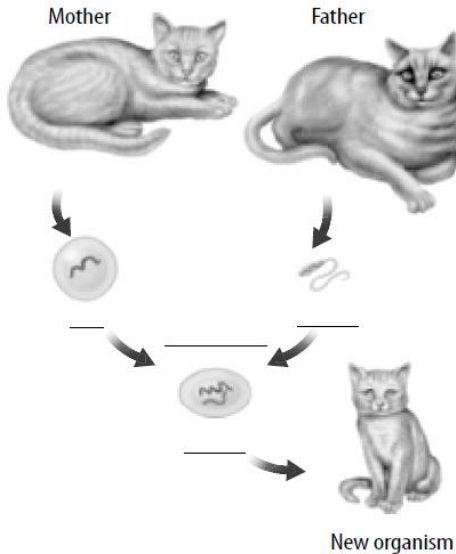
A segment of DNA on a chromosome that controls the production of a protein is called a _____. A _____ cell contains two copies of each chromosome. A sex cell, or _____, is _____, meaning it contains one copy of each chromosome. _____ are pairs of chromosomes, one from each parent.

Compare meiosis and mitosis by filling in the chart below.

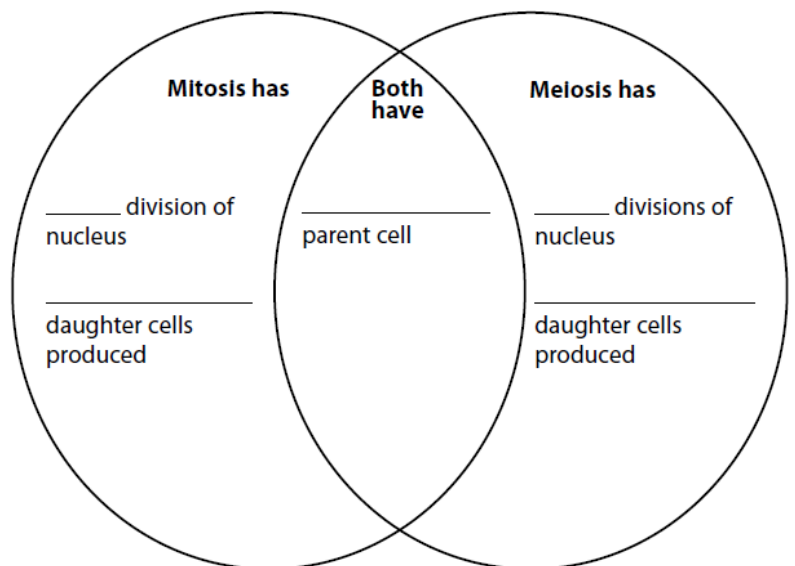
| | Mitosis | Meiosis |
|-------------------------------------|---------|---------|
| Number of DNA replications | | |
| Number of cell divisions | | |
| Number of daughter cells | | |
| Chromosome number of daughter cells | | |

Model the process of sexual reproduction. Complete the diagram using these labels:

- egg
- sperm
- fertilization
- zygote



Compare and contrast meiosis and mitosis and cell division.



Sexual Reproduction and Meiosis

Key Concept What is the order of the phases of meiosis, and what happens in each phase?

Directions: On each line, write the term from the word bank that correctly completes each sentence. Some terms may be used more than once or not at all.

diploid **haploid** **homologous chromosomes**
meiosis **mitosis** **sister chromatids**

1. In meiosis, one _____ cell divides to make four _____ cells.
2. A _____ cell has half the chromosomes of a _____ cell.
3. A _____ cell has pairs of chromosomes.
4. Pairs of chromosomes that are not identical but have genes for the same trait arranged in the same order are _____.
5. Each pair of _____ has one chromosome from the mother and one chromosome from the father.
6. In _____, the two chromosomes are always identical.
7. During _____, two divisions of the nucleus and the cytoplasm occur.
8. When a cell duplicates one chromosome, two _____ are formed.
9. During interphase of mitosis and meiosis, two _____ are formed for each chromosome.
10. A reproductive cell goes through interphase before beginning _____ I, but not before _____ II.
11. Prophase I and Prophase II are stages in _____.

Directions: Answer each question on the lines provided.

1. If a male organism has 40 chromosomes in each body cell, how many chromosomes does a female of the same species have in each body cell? _____
2. How many homologous pairs of chromosomes does the male have? _____
3. How many chromosomes would be in a sperm cell and in an egg cell? _____
4. How many chromosomes would be in an offspring? _____
5. How many pairs of homologous chromosomes would be in an offspring? _____

| Meiosis I | |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Phase | Description |
| Prophase I | <p>1. Chromosomes that are duplicated during _____ remain sister chromatids.</p> <p>2. _____ join and form pairs.</p> <p>3. The membrane surrounding the nucleus _____ apart.</p> |
| Metaphase I | <p>4. Homologous chromosome pairs align along the _____ of the cell.</p> <p>5. _____ fibers attach to each pair.</p> |
| Anaphase I | <p>6. Pairs of duplicated _____ chromosomes separate and are pulled toward opposite ends of the cell.</p> <p>7. _____ stay together.</p> |
| Telophase I | <p>8. A nuclear membrane forms around each group of chromosomes. The cytoplasm divides forming _____ daughter cells.</p> <p>9. _____ remain together.</p> |

| Meiosis II | |
|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Phase | Description |
| Prophase II | <p>10. _____ do not duplicate. _____ breaks apart.</p> |
| Metaphase II | <p>11. Sister chromatids _____ along the middle of the cell.</p> |
| Anaphase II | <p>12. Sister chromatids of each duplicated chromosome are _____ and move to _____.</p> |
| Telophase II | <p>13. A nuclear membrane forms around each set of chromatids, which are again called _____.</p> <p>14. The cytoplasm divides, and _____ cells form.</p> <p>15. Each cell has _____ the number of chromosomes as the original cell.</p> |

Label the diagrams below. Use these choices:

anaphase I
prophase I

anaphase II
prophase II

interphase
telophase I

metaphase I
telophase II

metaphase II

1. _____ 2. _____ 3. _____ 4. _____ 5. _____



6. _____ 7. _____ 8. _____ 9. _____

Complete the table by checking the correct column(s) for each description.

| Description | Mitosis | Meiosis |
|------------------------------------------------------------|---------|---------|
| 10. Involved in the production of gametes | | |
| 11. Involved in growth and repair | | |
| 12. Promotes genetic variation in organisms | | |
| 13. Consists of one nuclear division | | |
| 14. Produces daughter cells that are genetically identical | | |
| 15. Involves two sets of nuclear divisions | | |
| 16. Produces daughter cells that are not identical | | |
| 17. Involves the synapsis of homologous chromosomes | | |
| 18. Occurs during asexual reproduction | | |
| 19. Results in four haploid gametes | | |
| 20. Also called <i>reduction division</i> | | |