

Name \_\_\_\_\_ Period \_\_\_\_\_

## Chapter 13: Meiosis and Sexual Life Cycles

### *Concept 13.1 Offspring acquire genes from parents by inheriting chromosomes*

1. Let's begin with a review of several terms that you may already know. Define:

**gene:** A discrete unit of hereditary information consisting of a specific nucleotide sequence in DNA (or RNA, in some viruses)

**locus:** A specific place along the length of a chromosome where a given gene is located

**gamete:** A haploid reproductive cell, such as an egg or sperm. Gametes unite during sexual reproduction to produce a diploid zygote.

**male gamete:** Sperm

**female gamete:** Eggs

**asexual reproduction:** The generation of offspring from a single parent that occurs without the fusion of gametes (by budding, division of a single cell, or division of the entire organism into two or more parts). In most cases, the offspring are genetically identical to the parent.

**sexual reproduction:** A type of reproduction in which two parents give rise to offspring that have unique combinations of genes inherited from both parents via the gametes

2. How many chromosomes are in human cells? What *is* a chromosome?

There are 46 chromosomes in human somatic cells. A *chromosome* is a cellular structure carrying genetic material, found in the nucleus of eukaryotic cells. Each chromosome consists of one very long DNA molecule and associated proteins.

3. Which type of reproduction will result in genetically identical offspring?

Asexual reproduction

### *Concept 13.2 Fertilization and meiosis alternate in sexual life cycles*

4. What is a *somatic cell*? Give examples of two human somatic cell types.

A somatic cell is any cell in a multicellular organism except a sperm or egg or their precursors.

Examples may vary but could include bone cells, skin cells, blood cells, etc.

5. How does a somatic cell compare to a gamete in terms of chromosome number?

Unlike somatic cells, gametes contain a single set of chromosomes. Such cells are called haploid cells, and each has a haploid number of chromosomes ( $n$ ). For humans, the haploid number is 23.

	Description	# in Human Cells
Sex chromosome	A chromosome responsible for determining the sex of an individual	1
Autosome	A chromosome that is not directly involved in determining sex; not a sex chromosome	22

7. What is a *karyotype*? How is it prepared?

When images of the chromosomes are arranged in pairs, starting with the longest chromosomes, the resulting ordered display is called a karyotype. Karyotypes are prepared from isolated somatic cells, which are treated with a drug to stimulate mitosis and then grown in culture for several days. Cells arrested in metaphase, when chromosomes are most highly condensed, are stained and then viewed with a microscope equipped with a digital camera. A photograph of the chromosomes is displayed on a computer monitor, and the images of the chromosomes are arranged into pairs according to their appearance.

8. What are three things that can be determined from a karyotype? (Study the Research Method, Figure 13.3, in your text carefully for this information.)

Size of the chromosome, position of the centromere, and pattern of the stained bands

9. Explain what is meant by *homologous chromosomes*.

A pair of chromosomes of the same length, centromere position, and staining pattern

10. Cells that have only one of each homologous pair are said to be *haploid*, a condition that is represented by  $n$ . Cells that have two of each homologous pair are said to be *diploid* or  $2n$ . For each of the following, is the cell haploid or diploid?

**liver cell** diploid

**gamete** haploid

**egg cell** haploid

**zygote** diploid

**skin cell** diploid

**sperm** haploid

**somatic cell** diploid

**sex cell** haploid

11. The muscle cells of a dog have 78 chromosomes. Fill in the correct chromosome number in a bone cell 78, sperm 39, haploid cell 39, somatic cell 78, and zygote 78.

12. In the cell at right, the chromosomes are shaded in two colors to represent the parent of origin. On this sketch, label the following:

See page 251 of your text for the labeled figure.

- a. sister chromatids
  - b. homologous chromosomes
  - c. centromere
  - d. replicated chromosome
  - e. maternal chromosomes
13. How many chromosomes does the cell above have? 6

How many homologous pairs? 3

How many chromatids? 12 Is this cell haploid or diploid? Diploid

14. Where are the *gametes* of an animal produced? Be specific as to male and female gametes.

The only cells of the human body not produced by mitosis are the gametes, which develop from specialized cells called germ cells in the gonads—ovaries in females and testes in males.

15. By what process are gametes produced? Meiosis
16. What is another term for a fertilized egg? Zygote What is the chromosome number of the fertilized egg? (Answer this in general terms, haploid,  $n$ , or diploid,  $2n$ ). Diploid,  $2n$
17. What is the purpose of *meiosis*?

Meiosis is a modified type of cell division in sexually reproducing organisms consisting of two rounds of cell division but only one round of DNA replication. It results in cells with half the number of chromosome sets as the original cell, producing gametes, and introducing genetic variability.

18. Study Figure 13.6 in your text. You will see that plants have a life cycle that involves spores, which form as a result of meiosis, so these spores are haploid. Notice also that *both* haploid and diploid cells can divide by mitosis. However, meiosis always begins with cells that are diploid, and as a result of meiosis, daughter cells are formed that are always haploid. These cells can be gametes (in animals) or spores (in plants).
19. Your study of plants this year will include knowing that they exhibit *alternation of generations*. What does this mean?

A life cycle in which there is both a multicellular diploid form; characteristic of plants and some algae

What are the two generations?

Sporophyte and gametophyte

Which is haploid, and which is diploid?

Sporophyte is diploid, and gametophyte is haploid

Use this information to label the moss life cycle here.

See page 252 in your text for the labeled figure.

**Concept 13.3 Meiosis reduces the number of chromosome sets from diploid to haploid**

20. What are *alleles*? Give an example.

Alleles are any of the alternative versions of a gene that may produce distinguishable phenotypic effects. A possible example is the allele for freckles.

21. In meiosis, the DNA is replicated during interphase, followed by two divisions. The first division is meiosis I. Study the events of *prophase I* as they are significant. Explain each of these events:

**synapsis:** The pairing and physical connection of duplicated homologous chromosomes during prophase I of meiosis

**crossing over:** The reciprocal exchange of genetic material between nonsister chromatids during prophase I of meiosis

**chiasmata:** The X-shaped, microscopically visible region where crossing over has occurred earlier in prophase I between homologous nonsister chromatids. Chiasmata become visible after synapsis ends, with the two homologs remaining associated due to sister chromatid cohesion.

22. The figure at the right shows metaphase I. How is the arrangement of chromosomes different from metaphase of mitosis?

During mitosis, individual chromosomes line up at the metaphase plate. During meiosis, pairs of homologous chromosomes line up at the metaphase plate.

23. There are two divisions in meiosis. What will separate in the first division in meiosis I?

In meiosis I, homologous chromosomes separate.

24. Now study the chromosomes in *anaphase I* and *telophase I* carefully. How many chromosomes are in each cell at the end of the first meiotic division? 3

Are the resultant daughter cells haploid, or diploid? Haploid

From this figure, you should see that chromosome number is reduced in meiosis I and that the daughter cells at the end of meiosis I are haploid. Did you answer correctly above? Remember this!

See pages 254-255 in your text for the labeled figure.

25. During meiosis I, homologous chromosomes separate. What separates during meiosis II?

Sister chromatids separate during meiosis II.

26. To check that you have the big picture, here are some quick review questions.

- What happens to chromosome number in meiosis? They are reduced by half.
- During which division is the chromosome number reduced? Meiosis I
- What is the purpose of meiosis? To reduce the number of sets of chromosomes from two to one in gametes
- How many times does the cell divide in meiosis? 2
- How many times do the chromosomes duplicate? None
- How many daughter cells are formed? 4
- What is the chromosome number?  $n$
- What are *homologs* (*homologous chromosomes*)? A pair of chromosomes of the same length, centromere position, and staining pattern that possess genes for the same characters at corresponding loci
- What occurs in *synapsis*? The pairing and physical connection of duplicated homologous chromosomes during prophase I of meiosis
- What is *crossing over*? The reciprocal exchange of genetic material between nonsister chromatids during prophase I of meiosis

27. Use Figure 13.9 in your text to compare mitosis and meiosis. Add these labels: *parent cell*, *mitosis*, *meiosis*, *synapsis*, *homologous chromosomes*, *replicated chromosomes*, *sister chromatids*, *daughter cells*, *meiosis I*, *meiosis II*, and *crossing over*.

See page 256 in your text for the labeled figure.

28. Students often get confused about the differences between mitosis and meiosis. To help with this, work through the following chart:

	Mitosis	Meiosis
Role in the animal body	Enables multicellular adult to arise from zygote; produces cells for growth, repair, and, in some species, asexual reproduction	Produces gametes; reduces number of chromosomes by half and introduces genetic variability among the gametes
Number of DNA replications	1	1; occurs during interphase before meiosis I begins

Number of divisions	1	2
Number of daughter cells	2	4
Chromosome number of daughter cells	2n	n

29. Synapsis and crossing over are unique to meiosis. During what specific phase do these occur?

### Prophase I

30. Explain the physical events of crossing over. You may wish to make a sketch of the event. Include these terms: *synaptonemal complex*, *chiasmata*, *homologs*, *sister chromatids*.

Crossing over, a genetic rearrangement between nonsister chromatids involving the exchange of corresponding segments of DNA molecules, begins during pairing and synaptonemal complex formation, and is completed while homologs are in synapsis. A chiasma exists at the point where a crossover has occurred.

### Concept 13.4 Genetic variation produced in sexual life cycles contributes to evolution

31. An important idea for you to understand is that new alleles arise by changes in the DNA or mutation, but genetic diversity occurs when the deck that is dealt is simply reshuffled. So, there are three ways that sexually reproducing organisms “shuffle the deck.” They are listed below. Explain what occurs in each, and *how this increases diversity*.

**independent assortment of chromosomes:** At metaphase I, the homologous pairs, each consisting of one maternal and one paternal chromosome, are situated at the metaphase plate. Each pair may orient with either its maternal or paternal homolog closer to a given pole—its orientation is as random as the flip of a coin. Thus, there is a 50% chance that a particular daughter cell of meiosis I will get the maternal chromosome of a certain homologous pair and a 50% chance that it will get the paternal chromosome. Because each pair of homologous chromosomes is positioned independently of the other pairs at metaphase I, the first meiotic division results in each pair sorting its maternal and paternal homologs into daughter cells independently of every other pair. This is called independent assortment. Each daughter cell represents one outcome of all possible combinations of maternal and paternal chromosomes.

**crossing over:** Crossing over begins very early in prophase I as homologous chromosomes pair loosely along their lengths. Each gene on one homolog is aligned precisely with the corresponding gene on the other homolog. In a single crossover event, the DNA of two nonsister chromatids—one maternal and one paternal chromatid of a homologous pair—is broken by specific proteins at precisely corresponding points, and the two segments beyond the crossover point are each joined to the other chromatid. Thus, a paternal chromatid is joined to a piece of maternal chromatid beyond the crossover point, and vice versa. In this way, crossing over produces chromosomes with new combinations of maternal and paternal alleles.

**random fertilization:** The random nature of fertilization adds to the genetic variation arising from meiosis. In humans, each male and female gamete represents one of about 8.4 million possible chromosome combinations due to independent assortment. The fusion of a male gamete with a female gamete during fertilization will produce a zygote with any of about 70 trillion diploid

combinations.

32. Here is a fun exercise to drive this point home. Pull out your calculator, and try your hand at this: When you were conceived, what were the odds that of the many possibilities, your parents would come up with *you*?

a. The number of different gametes that can be formed because of independent assortment is

$$2n, \text{ where } n = \text{the number of homologous pairs}$$

Therefore, since humans have 46 chromosomes or 23 homologous pairs, what is the number of possible gametes that can be formed due to independent assortment of chromosomes?

b. Now, this is the number of unique gametes your mom could have made. Your father could have made the same number. To see the effect of random fertilization, multiply the number of gametes one parent could make by the number of unique gametes the other parent could make.

Your answer should be in the *trillions*, and all of this is *without* crossing over. See how special you are?

### *Test Your Understanding Answers*

Now you should be ready to test your knowledge. Place your answers here:

1. a 2. d 3. b 4. a 5. d 6. c 7. d

Follow the directions for Self-Quiz question 8, DRAW IT, by labeling the appropriate structures with these terms, drawing lines or brackets as needed: *chromosome* (label as replicated or unreplicated), *centromere*, *kinetochore*, *sister chromatids*, *nonsister chromatids*, *homologous pair*, *homologs*, *chiasma*, *sister chromatid*, *cohesion*.

See page A-12 (Appendix) in your text for the labeled figure.