Chapter 13: Meiosis and Sexual Life Cycles

1. Define the following terms.

A gene is a hereditary unit of coded information consisting of a specific nucleotide sequence in DNA (or RNA, in some viruses). The locus is a specific place along the length of a chromosome where a given gene is located. A gamete is a haploid reproductive cell; male gametes (sperm) and female gametes (eggs) unite during sexual reproduction to produce a diploid zygote. Asexual reproduction is the generation of offspring from a single parent that occurs without the fusion of gametes, i.e. by budding, division of a single cell, or division of the entire organism. In sexual reproduction, two parents give rise to offspring that have unique combinations of genes inherited from both parents through the fusion of 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 generally results in clones, genetically identical offspring.

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

Somatic cells are all body cells except the reproductive cells, including blood cells and skin cells.

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 (rather than diploid) cells, and each has a haploid number of chromosomes (n).

6. Distinguish between sex chromosomes and autosomes. How many of each are found in human cells?

	Explanation	*# in human cells*
Sex chromosome	X and Y chromosomes; responsible for determining individual's sex	1
Autosome	not a sex chromosome	22

7. What is a karyotype? How is it prepared? What are three things that can be determined from a karyotype?

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 densely condensed, are stained, 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 in pairs according to their appearance. The size of the chromosomes, the position of the centromeres, and the pattern of the stained bands can be determined from a karyotype.

8. Explain what is meant by homologous chromosomes.

Homologous chromosomes are a pair of chromosomes of the same length, centromere position, and staining pattern.

9. 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.

Haploid cells include gametes (eggs, sperm), and sex cells. Diploid cells include liver cells, skin cells, somatic cells, and zygotes.

10. The muscle cells of a dog have 78 chromosomes.

There are 78 chromosomes in a bone cell, 39 in a sperm cell, 39 in a haploid cell, 78 in a somatic cell, and 78 in a zygote.

12. Describe the cell sketched in #11.

This diploid cell has 6 chromosomes, 3 homologous pairs, and 12 chromatids.

13. Where are the gametes of an animal produced?

Gametes, the only cells of the human body not produced by mitosis, develop from specialized cells called germ cells in the gonads (ovaries in females produce eggs; testes in males produce sperm).

14. By what process are gametes produced?

Gametes are produced through meiosis.

15. What is another term for a fertilized egg? What is the chromosome number of the fertilized egg?

Zygotes are diploid cells with 2*n* chromosomes.

16. What is the purpose of meiosis?

Meiosis is a type of cell division in sexually reproducing organisms consisting of two rounds of cell division but only one round of DNA replication, resulting in daughter cells with half the number of chromosome sets as the mother cell. Meiosis produces gametes and enhances genetic variability.

17. Meiosis always begins with cells that…

are diploid, and as a result of meiosis, daughter cells are formed that are always haploid.

18. Explain alternation of generations.

Alternation of generations is a life cycle of plants and some algae involving both diploid (sporophyte) and haploid (gametophyte) stages that are multicellular.

19. What are alleles? Give an example.

Alleles are any of the alternative versions of a gene that may produce distinguishable phenotypic effects, such as freckles.

20. Explain the events of prophase I.

Synapsis is the pairing and physical connection of duplicated homologous chromosomes. Crossing over is the reciprocal exchange of genetic material between nonsister chromatids. A chiasma is an 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 through sister chromatid cohesion.

21. How is the arrangement of chromosomes in metaphase 1 different from the 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.

22. There will be two divisions in meiosis.

Homologous chromosomes separate in the first division of meiosis I. Sister chromatids separate during meiosis II.

23. Study the chromosomes in anaphase I and telophase I carefully.

Three chromosomes remain in each cell at the end of the first meiotic division. The resultant daughter cells are haploid.

26. Explain the meiotic process.

In the meiosis I stage of meiosis, the number of chromosomes are reduced by half. Meiosis reduces the number of sets of chromosomes from two to one in gametes. The cell divides twice in meiosis, the chromosomes do not duplicate

themselves, and 4 daughter cells formed. The chromosome number is *n*. Homologs (homologous chromosomes) are a pair of chromosomes of the same length, centromere position, and staining pattern that possess genes for the same characters at corresponding loci. In synapsis, duplicated homologous chromosomes are paired and physically connected during prophase I. Crossing over is the reciprocal exchange of genetic material between nonsister chromatids during prophase I.

28. Compare and contrast mitosis and meiosis.

	Mitosis	*Meiosis*
Role in the animal body	enables multicellular adult to arise from zygote; produces cells for growth, repair, and asexual reproduction	produces gametes; reduces number of chromosomes by half; introduces genetic variability among gametes
Number of DNA replications	1	1 (during interphase)
Number of divisions	1	2
Number of daughter cells	2	4
Chromosome number of daughter cells	2*n*	*n*

29. Synapsis and crossing over are unique to meiosis.

These occur during prophase I.

30. Explain the physical events of crossing over.

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 forms at the point where a crossover has occurred.

31. Explain what occurs in each way that sexually reproducing organisms diversify the gene pool.

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 itself with either its maternal or paternal homolog closer to a given pole. 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.

During crossing over, 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.

The random nature of fertilization adds to the genetic variation arising from meiosis. 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. 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?

The number of possible combinations of maternal and paternal chromosomes in the resulting gametes is 2^{23}, or about 8.4 million.