Chapter 11: The Continuity of Life: Cellular Reproduction

OVERVIEW

In this chapter, you will learn about mitosis and meiosis. The authors begin with a brief discussion of the cell cycle in prokaryotes, then discuss mitosis, a basic type of eukaryotic cell division. They describe the structure of eukaryotic chromosomes and review the typical chromosome numbers in body cells and sex cells. You will read about the eukaryotic cell cycle as well as interphase, mitosis, and cytokinesis. Then, the authors contrast asexual and sexual reproduction, and focus on meiosis. They describe the stages of meiosis I and meiosis II as they relate to the production of sex cells. They compare meiosis I and II, as well as mitosis and meiosis. This chapter concludes with descriptions of the three basic types of life cycles among eukaryotic organisms. Female rattlesnakes can sometimes give birth to male offspring without having mated with a male rattlesnake at all. How can this happen?

1) What Are the Functions of Cellular Reproduction?

Cellular reproduction enables a parent cell to accurately distribute both genes and cell components to its daughter cells in a process called **cell division**: binary fission in prokaryotic cells, and mitosis and meiosis in eukaryotic cells. **Binary fission** ("splitting in two") is the cell division process in prokaryotes, producing two cells which are genetically identical. First, the cell replicates its DNA double helix, a closed circular structure with about 4000 genes. The two identical double helices attach to the plasma membrane at nearby, separate points. The plasma membrane expands, pushing the double helices apart. The plasma membrane around the middle of the cell grows inward between the two DNA attachment sites until the cell is split into two daughter cells. After binary fission, each daughter cell contains one DNA double helix and about half of the original cell's cytoplasm. Under ideal conditions, the common intestinal bacterium *Escherichia coli* (*E. coli*) can complete binary fission in about 20 minutes.

Mitotic cell division allows development, growth, maintenance, and repair of body tissues in eukaryotes. Mitotic cell division involves a process of nuclear divisions called mitosis followed by a single cell division, producing two genetically identical daughter cells. In conjunction with the differential expression of genes in different cells, mitotic cell division allows a fertilized egg to produce cells needed in a new-born organism, and allows the organism to grow into an adult. It also allows an organism to maintain its tissues, many of which may require frequent replacement of cells. It allows for repair or even regeneration of cells following injury or surgery. For instance, your liver has the ability to regenerate.

Mitotic cell division forms the basis of **asexual reproduction** in eukaryotes, in which offspring are formed from a single parent without the uniting of male and female gametes. This is routine for many unicellular organisms and some multicellular organisms as well. For instance, in *Hydra*, a small replica of the parent grows by mitotic cell division, and this bud separates from its parent to live independently. The bud is genetically identical to the parent; they are called **clones**. Asexual reproduction is not responsible for the baby rattlesnake described above. Many plants and fungi reproduce both asexually and sexually. Some organisms produce sex cells by mitotic cell division. Mitosis also gave rise to the nucleus used to produce Dolly, the cloned sheep.

Sexual reproduction in eukaryotes produces offspring with a mixture of genetic material from two parents. This is possible by a process called **meiotic cell division**. In mammals, it occurs only in the ovaries and testes. Meiotic cell division involves a nuclear division called meiosis, and cellular divisions to

produce daughter cells that can become specialized **gametes** (egg and sperm) that carry half of the genetic material of the parent. The cells produced by meiosis are not identical to each other or to the original cell.

2) How Is DNA in Eukaryotic Cells Organized into Chromosomes?

Cell division enables accurate passage of chromosomes from one generation to the next. Eukaryotic cellular DNA is packaged in **chromosomes** (darkly staining nuclear rods of condensed protein and DNA). Every species has a particular number of chromosomes, and consequently, a specific number of DNA double helices. Human body cells have 46 chromosomes, the largest of which (chromosome 1) contains about 3,000 genes and one of the smallest of which (chromosome 22) contains about 600 genes.

The eukaryotic chromosome consists of a linear DNA double helix bound to proteins, including histones that organize and compact the DNA so that it can fit into the nucleus. The total length of DNA in a single cell is about 6 feet long (about 2 meters), while the nucleus is a million times smaller. The degree of DNA compaction, or **condensation**, varies with the stage of the cell cycle. During cell growth, the DNA is maximally dispersed and active, and individual chromosomes are too thin to be visible in light microscopes. During cell division, chromosomes are condensed and shortened for easier transport, and proteins fold up the DNA into compact structures that can be seen under the microscope. At the time it condenses, the chromosomal DNA has already replicated, forming two double helices attached to each other at the **centromere** ("middle body") region. Each double helical chromosome of the attached pair is called a sister **chromatid**. Thus, the DNA replication has produced a **duplicated chromosome** with two identical sister chromatids. During mitotic cell division, the two sister chromatids separate and each chromatid becomes an independent chromosome.

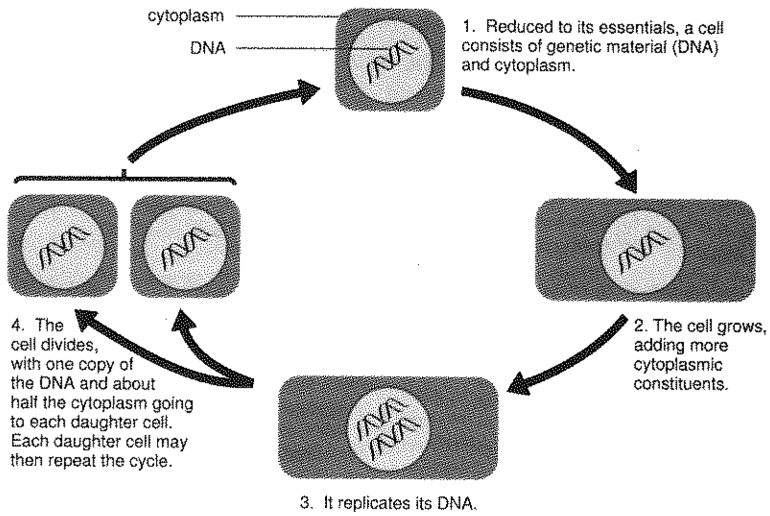
Eukaryotic chromosomes usually occur in homologous pairs with similar genetic information. An entire set of stained chromosomes from a single nonreproductive cell (the **karyotype**) shows pairs of chromosomes. Typically, the members of each pair are of the same length and have the same staining pattern, and carry the same genes arranged in the same order. Chromosomes containing the same genes are called homologous chromosomes or **homologues** ("to say the same thing"). Cells with pairs of homologues are called **diploid** ("times two"). A human skin cell, for instance, has 46 chromosomes, organized into 23 pairs of homologues. One pair is the **sex chromosomes**, two X chromosomes (XX) in females and an X and Y chromosome (XY) in males. Most body cells are diploid. During sexual reproduction, cells in the ovaries and testes undergo meiotic cell division to produce gametes (eggs or sperm) with only 23 chromosomes, one of each type. Such cells are called **haploid**. Fusion of two haploid cells produces a diploid cell. The number of different types of chromosomes in a species is the haploid number and is designated n. Diploid cells are $2n$. In humans, n=23 (in gametes) and $2n$=46 (in body cells). In male mammals, one pair of chromosomes, the X and Y, have very different sizes and staining patterns, but behave like homologues during cell division.

3) What Are the Events of the Eukaryotic Cell Cycle?

The eukaryotic **cell cycle** has two phases: interphase and mitotic cell division. Acquiring nutrients, growth, replication of DNA, and most cell functions occur during **interphase**, the relatively long time period between cell divisions. Interphase contains three subphases. During the G_1 phase (gap or growth phase 1), the cell acquires nutrients, performs specialized functions, and grows. The cell is sensitive to internal and external signals that help the cell decide whether to divide. Active cells no longer dividing (heart, brain, and eye cells, for instance) enter the G_0 phase. Alternately, cells enter the S phase (DNA synthesis phase), during which DNA and chromosome replication occurs. Next, cells enter the G_2 phase (gap or growth phase 2), during which cells make molecules required for cell division. Progression through the cell cycle is carefully regulated. At key times called "checkpoints," molecular signals ensure that the cell has completed all necessary processes before entering the next step. One such checkpoint occurs at the end of G_1.

Mitotic cell division consists of nuclear division (mitosis) and cytoplasmic division (cytokinesis).

Mitosis produces two nuclei, each containing a copy of every chromosome present in the original nucleus. In most cells, the cytoplasm divides following mitosis to form two daughter cells each with a nucleus and about half the cytoplasm, a process called **cytokinesis**. The two cells produced by mitotic cell division are essentially identical to each other cytoplasmically, and genetically identical to each other and to the parent cell. Some cells undergo mitosis without cytokinesis, producing single cells with many nuclei. All your different types of body cells (brain and liver, for example) are genetically identical but undergo **differentiation**, the process whereby cells assume specialized functions because they *use* different genes as they develop.



4) What Are the Phases of Mitosis?

Mitosis has four phases, based on the appearance and behavior of the chromosomes, within a continuous process: prophase, metaphase, anaphase, and telophase.

During **prophase** ("the stage before"), the duplicated chromosomes condense, **spindle microtubules** form, and the chromosomes are captured by the spindle. Also, the nucleolus disappears and the nuclear membrane disintegrates. The spindle microtubules assemble, originating in animal cells from a region containing a pair of **centrioles**. The centrioles replicate and each pair migrates to opposite sides of the nucleus forming the "poles." From the poles, spindle microtubules radiate towards the plasma membrane and towards the nucleus, forming a basket around the nucleus. Some of the spindle microtubules attach to the chromatids at protein-containing structures called **kinetochores**. One kinetochore of each duplicated chromosome is tethered to one spindle pole and the other kinetochore is tethered to the other spindle pole.

During **metaphase** ("the middle stage"), chromosomes become aligned along the equator of the cell through the interactions of the spindle fibers and the kinetochores. During **anaphase** ("the moving away stage"), sister chromatids separate from each other and the protein "motors" in the kinetochores pull the chromosomes to opposite poles along the spindle microtubules. The unattached spindle microtubules lengthen to push the poles of the cell apart. Because the sister chromatids are identical copies of the original chromosomes, both clusters of chromosomes moving to opposite ends of the cell contain one copy of every chromosome in the original cell. During **telophase** (the "end stage"), nuclear envelopes form around each group of chromosomes, the chromosomes revert to their extended form, and nucleoli reappear.

5) What Are the Events of Cytokinesis?

In most cells, cytokinesis occurs during telophase, enclosing each daughter nucleus into a separate cell. In animal cells, microfilaments attached to the plasma membrane around the equator contract and constrict the equator region, pinching the cell in two. In plant cells, the Golgi complex buds off carbohydrate-filled

vesicles along the equator. The vesicles fuse, forming the **cell plate** that expands to fuse with the plasma membrane, eventually forming a new cell wall. Cytokinesis is followed by G_1 of interphase.

6) What Are Some Advantages of Sexual Reproduction?

Mitosis can only produce clones, genetically identical offspring. The reshuffling of genes among individuals to create genetically unique offspring results from **sexual reproduction**. DNA mutations are the ultimate source of genetic variability and the raw material for evolution. Mutations form **alleles,** alternate forms of a gene that confer variability on individuals (black, brown or blonde hair, for instance). Reshuffling genes may combine different alleles in beneficial ways through sexual reproduction. For instance, if a parent with good camouflage ("Coloration" gene) mated with a parent with motionless behavior ("Freeze" gene) when predators are nearby, some offspring with good behavior and camouflage (both the "Coloration" and "Freeze" genes) may result.

Meiotic cell division produces haploid cells that can merge to combine genetic material from two parents. The first eukaryotic cells probably were haploid. Then, two haploid cells fused, resulting in a diploid cell with two copies of each chromosome. Then, this type of cell evolved a variation of mitotic cell division, called meiotic cell division, to produce haploid gametes.

7) What Are the Events of Meiosis?

Meiosis is the production of haploid nuclei with unpaired chromosomes from diploid parent nuclei. In meiotic cell division (meiosis followed by cytokinesis), each new daughter cell receives one member from each pair of homologous chromosomes. Meiosis separates homologous chromosomes in a diploid nucleus, producing haploid daughter nuclei. In meiotic cell division, the cell undergoes one round of DNA replication followed by two nuclear divisions known as meiosis I and meiosis II. During meiosis, the following events occur: (1) Chromosomes replicate before meiosis begins; (2) During meiosis I, duplicated homologous chromosomes separate, one duplicated homologue moving into each of the two daughter cells (a $2n$ cell produces a pair of n cells); (3) In meiosis II, sister chromatids in each daughter cell separate and cytokinesis may occur to produce four haploid cells; each with one set of unduplicated chromosomes (each n cell with duplicated chromosomes becomes a pair of n cells with unduplicated chromosomes).

Meiosis I separates homologous chromosomes into two daughter nuclei. During *prophase* I, homologous chromosomes pair up and exchange DNA, a process called **crossing over**, involving the formation of **chiasmata** (singular is **chiasma**, regions of exchange), and resulting in **genetic recombination** (formation of new combinations of different alleles on a chromosome). During *metaphase* I, paired homologous chromosomes move to the equator of the spindle. Different pairs of chromosomes align themselves randomly at the equator, allowing independent assortment to occur. During *anaphase* I, homologous chromosomes separate, with one duplicated chromosome of each pair moving to opposite poles. During *telophase* I, two haploid clusters of duplicated chromosomes are formed.

Meiosis II is very similar to mitosis; it separates sister chromatids into four daughter nuclei. You should note that there is *no* duplication of the chromosomes between meiosis I and meiosis II. During *prophase* II, the spindle microtubules re-form and the duplicated chromosomes attach to spindle microtubules as they did in mitosis. During *metaphase* II, the duplicated chromosomes line up at cell's equator. During *anaphase* II, the centromeres holding the sister chromatids together split, and spindle microtubules pull each chromatid (unduplicated daughter chromosome) to opposite poles. *Telophase* II and cytokinesis complete meiosis II; the nuclear envelopes re-form, the chromosomes unwind, and the cytoplasm divides.

The life cycles of almost all eukaryotic organisms on Earth have a common overall pattern, usually including meiosis and mitosis. First, two haploid cells fuse, endowing the resulting diploid cell with new gene combinations. Second, at some point in the life cycle, meiosis occurs, producing haploid cells. Third, at some point, mitosis of either haploid or diploid cells, or both, results in the growth of multicellular bodies and/or asexual reproduction.

8) How Do Meiosis and Sexual Reproduction Produce Genetic Variability?

Shuffling of homologues creates new combinations of chromosomes. During metaphase of the first meiotic division, random alignment of homologous chromosomes at the equator creates new combinations of chromosomes. Crossing over creates chromosomes with novel combinations of genes. Fusion of gametes adds further genetic variability to the offspring. In humans there are 2^{23} or about 8 million different types of gametes based on random alignment of homologous chromosomes at metaphase I. Fusion of gametes from two people makes 8 million x 8 million (64 trillion) possible genetically different children. Crossing over increases this number substantially.

Case study revisited. Females in many species of reptiles and birds can produce offspring without mating with males. When meiosis II is not properly completed in females, the result is two cells that have identical copies of each type of chromosome. The resulting egg can sometimes develop into a viable, diploid embryo in a process called parthenogenesis ("virgin birth"). One breed of turkey produces some 40% of its offspring by parthenogenesis.

KEY TERMS AND CONCEPTS

Fill-In: From the following list of key terms, fill in the blanks below.

asexual	crossing over	genetic recombination	meiosis
binary fission	cytokinesis	homologous	mitosis
chiasmata	gametes	interphase	sexual
chromosomes			

1. Eukaryotic cellular DNA is packaged in ___________________ (darkly staining nuclear rods of condensed protein and DNA).

2. Cell division in bacteria is called ___________________, and can occur in 30 minutes or less.

3. Eukaryotic chromosomes usually occur in ___________________ pairs with similar sizes, staining patterns, and genetic information in nonreproductive diploid cells ($2n$).

4. At some point in the life cycle of sexually reproducing organisms, ___________________ produces haploid cells (n) called ___________________ (sperm and egg), with one copy of each type of chromosome.

5. Growth, replication of chromosomes, and most cell functions occur during ___________________, the period between cell divisions.

6. Mitotic cell division consists of nuclear division or ___________________ and cytoplasmic division called ___________________.

7. ___________________ reproduction (formation of genetically identical offspring without fusion of eggs and sperm) occurs in simple organisms and plants. However, the reshuffling of genes among individuals to create genetically unique offspring results from ___________________ reproduction.

8. ___________________ separates homologous chromosomes in a diploid nucleus, producing haploid daughter nuclei.

9. Meiosis I separates homologous chromosomes into two daughter nuclei. During prophase I, homologous chromosomes pair up and exchange DNA through ____________________ and the formation of ____________________ (regions of exchange), resulting in ______________________ (formation of new combinations of different alleles on a chromosome).

Key Terms and Definitions

allele (al-ēl´): one of several alternative forms of a particular gene.

anaphase (an´-a-fāz): in mitosis, the stage in which the sister chromatids of each chromosome separate from one another and are moved to opposite poles of the cell; in meiosis I, the stage in which homologous chromosomes, consisting of two sister chromatids, are separated; in meiosis II, the stage in which the sister chromatids of each chromosome separate from one another and are moved to opposite poles of the cell.

asexual reproduction: reproduction that does not involve the fusion of haploid sex cells. The parent body may divide and new parts regenerate, or a new, smaller individual may form as an attachment to the parent, to drop off when complete.

binary fission: the process by which a single bacterium divides in half, producing two identical offspring.

cell cycle: the sequence of events in the life of a cell, from one division to the next.

cell division: splitting of one cell into two; the process of cellular reproduction.

cell plate: in plant cell division, a series of vesicles that fuse to form the new plasma membranes and cell wall separating the daughter cells.

centriole (sen´-trē-ōl): in animal cells, a short, barrel-shaped ring consisting of nine microtubule triplets; a microtubule-containing structure at the base of each cilium and flagellum; gives rise to the microtubules of cilia and flagella and is involved in spindle formation during cell division.

centromere (sen´-trō-mēr): the region of a replicated chromosome at which the sister chromatids are held together until they separate during cell division.

chiasma (kī-as´-muh; pl., chiasmata): a point at which a chromatid of one chromosome crosses with a chromatid of the homologous chromosome during prophase I of meiosis; the site of exchange of chromosomal material between chromosomes.

chromatid (krō´-ma-tid): one of the two identical strands of DNA and protein that forms a replicated chromosome. The two sister chromatids are joined at the centromere.

chromosome (krō´-mō-sōm): a single DNA double helix together with proteins that help to organize the DNA.

clone: offspring that are produced by mitosis and are therefore genetically identical to each other.

cloning: the process of producing many identical copies of a gene; also the production of many genetically identical copies of an organism.

condensation: compaction of eukaryotic chromosomes into discrete units in preparation for mitosis or meiosis.

crossing over: the exchange of corresponding segments of the chromatids of two homologous chromosomes during meiosis.

cytokinesis (sī-tō-ki-nē´-sis): the division of the cytoplasm and organelles into two daughter cells during cell division; normally occurs during telophase of mitosis.

differentiation: the process whereby relatively unspecialized cells, especially of embryos, become specialized into particular tissue types.

diploid (dip´-loid): referring to a cell with pairs of homologous chromosomes.

duplicated chromosome: a eukaryotic chromosome following DNA replication; consists of two sister chromatids joined at the centromeres.

gamete (gam´-ēt): a haploid sex cell formed in sexually reproducing organisms.

haploid (hap´-loid): referring to a cell that has only one member of each pair of homologous chromosomes.

homologue (hō-´mō-log): a chromosome that is similar in appearance and genetic information to another chromosome with which it pairs during meiosis; also called *homologous chromosome*.

interphase: the stage of the cell cycle between cell divisions; the stage in which chromosomes are replicated and other cell functions occur, such as growth, movement, and acquisition of nutrients.

karyotype: a preparation showing the number, sizes, and shapes of all chromosomes within a cell and, therefore, within the individual or species from which the cell was obtained.

kinetochore (ki-net´-ō-kor): a protein structure that forms at the centromere regions of chromosomes; attaches the chromosomes to the spindle.

meiosis (mī-ō´-sis): a type of cell division, used by eukaryotic organisms, in which a diploid cell divides twice to produce four haploid cells.

meiotic cell division: meiosis followed by cytokinesis.

metaphase (met´-a-fāz): the stage of mitosis in which the chromosomes, attached to spindle fibers at kinetochores, are lined up along the equator of the cell.

mitosis (mī-tō´-sis): a type of nuclear division, used by eukaryotic cells, in which one copy of each chromosome (already duplicated during interphase before mitosis) moves into each of two daughter nuclei; the daughter nuclei are therefore genetically identical to each other.

mitotic cell division: mitosis followed by cytokinesis.

prophase (prō´-fāz): the first stage of mitosis, in which the chromosomes first become visible in the light microscope as thickened, condensed threads and the spindle begins to form; as the spindle is completed, the nuclear envelope breaks apart, and the spindle fibers invade the nuclear region and attach to the kinetochores of the chromosomes. Also, the first stage of meiosis: In meiosis I, the homologous chromosomes pair up and exchange parts at chiasmata; in meiosis II, the spindle reforms and chromosomes attach to the microtubules.

recombination: the formation of new combinations of the different alleles of each gene on a chromosome; the result of crossing over.

sex chromosomes: the pair of chromosomes that usually determines the sex of an organism; for example, the X and Y chromosomes in mammals.

sexual reproduction: a form of reproduction in which genetic material from two parent organisms is combined in the offspring; normally, two haploid gametes fuse to form a diploid zygote.

spindle microtubules: microtubules organized in a spindle shape that separate chromosomes during mitosis or meiosis.

telophase (tēl´-ō-fāz): in mitosis, the final stage, in which a nuclear envelope reforms around each new daughter nucleus, the spindle fibers disappear, and the chromosomes relax from their condensed form; in meiosis I, the stage during which the spindle fibers disappear and the chromosomes normally relax from their condensed form; in meiosis II, the stage during which chromosomes relax into their extended state, nuclear envelopes reform, and cytokinesis occurs.

THINKING THROUGH THE CONCEPTS

True or False: Determine if the statement given is true or false. If it is false, change the underlined word(s) so that the statement reads true.

10. _____ Asexually produced organisms are similar but not identical to their parents.
11. _____ Prokaryotes have many chromosomes per cell.
12. _____ The body cells of a human are haploid.
13. _____ DNA replication occurs during the G_2 portion of interphase.
14. _____ Cell plates form during metaphase of the cell cycle.
15. _____ Diploid cells produce haploid cells by the process of meiosis.
16. _____ Crossing over occurs during meiosis II.
17. _____ Sister chromatids become daughter chromosomes during anaphase I of meiosis.
18. _____ Meiosis II resembles mitosis.
19. _____ DNA replicates between meiosis I and meiosis II.
20. _____ Reduction of chromosome number occurs during meiosis I.

Identify: Determine whether the following statements refer to **mitosis**, **meiosis**, **both**, or **neither**.

21. _______________ production of haploid cells from haploid cells
22. _______________ the mechanism by which eukaryotic unicellular organisms reproduce
23. _______________ produces genetically variable cells
24. _______________ produces sperm and egg cells in animals
25. _______________ allows multicellular organisms to grow
26. _______________ cells divide twice
27. _______________ ensures that each body cell gets a complete set of genes
28. _______________ can produce haploid cells
29. _______________ chromosomes replicate once
30. _______________ produces genetically identical cells
31. _______________ production of haploid cells from diploid ones
32. _______________ occurs in the human body
33. _______________ maintains the same number of chromosomes
34. _______________ doubles the number of chromosomes
35. _______________ reduces the number of chromosomes by half

Matching: Interphase

36. _____ phase in cells that will no longer divide
37. _____ period after DNA synthesis occurs
38. _____ period before DNA synthesis occurs
39. _____ period of DNA replication or synthesis
40. _____ period of most cell growth and metabolic activity

Choices:

a. S phase
b. G_0 phase
c. G_1 phase
d. G_2 phase

Identify: Determine whether the following statements refer to **prophase**, **metaphase**, **anaphase**, or **telophase** of mitosis.

41. _______________ Independent chromosomes have reached the opposite spindle poles.
42. _______________ Duplicated chromosomes migrate to the cell's equator.
43. _______________ Replicated chromosomes coil up and condense.
44. _______________ The centromeres divide.
45. _______________ Independent chromosomes move to the poles.
46. _______________ The spindle breaks down.
47. _______________ The nuclear envelope disintegrates.
48. _______________ Sister chromatids become independent chromosomes.
49. _______________ The spindle forms.
50. _______________ Cytokinesis begins.

Matching: Meiosis.

51. _____ Individual chromosomes migrate to the equator.
52. _____ Chiasmata form.
53. _____ Homologous chromosomes move towards opposite poles.
54. _____ Centromeres divide.
55. _____ Homologous chromosomes pair up.
56. _____ Independent chromosomes migrate towards opposite poles.
57. _____ Homologous pairs of chromosomes are together at the equator.
58. _____ Crossing over occurs.

Choices:

a. prophase I
b. metaphase I
c. anaphase I
d. telophase I
e. prophase II
f. metaphase II
g. anaphase II
h. telophase II

Multiple Choice: Pick the most correct choice for each question.

59. The genetic material in bacteria consists of
    a. several circular DNA molecules
    b. one circular RNA molecule
    c. many rod-like DNA molecules with protein
    d. one circular DNA molecule
    e. DNA in mitochondria

60. The daughter cells of binary fission are
    a. structurally identical
    b. chromosomally different
    c. genetically identical
    d. structurally similar and genetically identical
    e. not genetically the same as the parent cell

61. Cell reproduction in prokaryotic cells differs from eukaryotic cells in that
    a. prokaryotic cells reproduce asexually but eukaryotic cells do not.
    b. each prokaryotic cell has a circular chromosome but the chromosomes of eukaryotic cells are linear.
    c. prokaryotic cells lack nuclei and do not replicate their DNA before dividing but eukaryotic cells have nuclei and replicate their DNA before dividing.
    d. prokaryotic chromosomes have DNA and protein but eukaryotic chromosomes are made of only DNA.
    e. they do not differ significantly.

62. A diploid cell contains six chromosomes. After meiosis I, each of the cells contains
    a. three maternal and three paternal chromosomes each time
    b. mixture of maternal and paternal chromosomes totaling three
    c. six maternal or six paternal chromosomes each time
    d. a mixture of maternal and paternal chromosomes totaling six
    e. three pairs of chromosomes

63. A region of attachment for two sister chromatids is the
    a. centriole
    b. centromere
    c. equator
    d. microtubule
    e. spindle fiber

64. Which of the following does not occur during prophase?
    a. the nuclear membrane disintegrates
    b. nucleoli break up
    c. the spindle apparatus forms
    d. the chromosomes condense
    e. DNA replicates

65. In sexually reproducing organisms, the source of chromosomes in the offspring is
    a. almost all from one parent, usually the father
    b. almost all from one parent, usually the mother
    c. half from the father and half from the mother
    d. a random mixing of chromosomes from both parents

66. Meiosis results in the production of
    a. diploid cells with unpaired chromosomes
    b. diploid cells with paired chromosomes
    c. haploid cells with unpaired chromosomes
    d. haploid cells with paired chromosomes
    e. none of the above choices is correct

67. Which occurs in meiosis I but not in meiosis II?
    a. diploid daughter cells are produced
    b. chromosomes without chromatids line up at the equator
    c. centromeres divide
    d. pairing of homologous chromosomes occurs
    e. the spindle apparatus forms

68. The process of females giving birth to offspring without the genetic contribution of males is called
   a. sexual reproduction
   b. alternation of generations
   c. typical asexual reproduction
   d. mitosis
   e. parthenogenesis

69. When snakes give birth to offspring without a genetic contribution from a male, the offspring are usually
   a. females
   b. males
   c. either sex
   d. intersex
   e. stillborn

APPLYING THE CONCEPTS

These practice questions are intended to sharpen your ability to apply critical thinking and analysis to biological concepts covered in this chapter.

70. Suppose you are working in a lab that grows various types of human body cells in petri dishes, a technique known as "cell culturing." While you are looking at one particular cell culture under the microscope, you decide to count up the numbers of cells you see in the various phases of the mitotic cell cycle. You count 45 cells in anaphase, 34 cells in prophase, 23 cells in telophase, 11 cells in metaphase, and 1008 cells in interphase. Could you use these numbers to determine the relative amounts of time this cell type spends in each phase of the mitotic cell cycle? Explain.

71. Suppose that the cloning process used to make the ewe named Dolly becomes widely used to clone human beings. What do you suppose the effect of widespread cloning might be on human populations?

72. Why do you think that many treatments for cancer cause the loss of hair and severe nausea brought on by loss of the gastrointestinal lining?

73. There are three elements involved in sexual reproduction that lead to the production of genetically diverse offspring. What are those three elements?

74. Why is there so much scientific interest in trying to understand the mechanisms controlling the process of mitosis and cell differentiation?

75. What are some characteristics shared by chromosomes which are considered to be homologous, and what makes a cell diploid or haploid?

76. If a diploid cell has 100 units of DNA at the G_1 stage of interphase before meiosis begins, how much DNA would a cell have during the following stages of meiosis: prophase I, prophase II, and sperm cell?

Use the Case Study and the Web sites for this chapter to answer the following questions.

77. Give the sex chromosomes for males and females in each of the following organisms: humans, fruit flies, honey bees, and birds.

humans ______________ fruit flies ______________

birds ______________ honey bees ______________

78. There are no male *C. uniparens* (whiptail lizards). How does this species reproduce? What are the hypothesized origins of the species?

79. How is the automictic parthenogenesis observed in turkeys and the occasional rattlesnake different from that of the parthenogenic whiptails? (Hint: check the chromosome numbers.) Why are all the offspring male?