1. Which of the following statements is FALSE?
   A) Errors in chromosome separation are rarely a problem for an organism.
   B) Errors in chromosome separation can result in a miscarriage.
   C) Errors in chromosome separation can result in cancer.
   D) Errors in chromosome separation can result in a child with severe handicaps.
   E) Errors in chromosome separation can cause numerous problems for an organism.

2. Which of the following pairs are BOTH prokaryotes?
   A) Eubacteria and higher plants
   B) Archaea and eubacteria
   C) Higher animals and archaea
   D) Viruses and higher animals
   E) Humans and eubacteria

3. Which statement is TRUE based on our current understanding?
   A) Eubacteria are not closely related to either archaea or eukaryotes.
   B) Archaea are more closely related to eukaryotes than they are to eubacteria.
   C) Eukaryotes are more closely related to eubacteria than they are to archaea.
   D) Viruses are more closely related to prokaryotes than they are to eukaryotes.
   E) Eubacteria, archaea, and eukaryotes are all equally related.

4. Which of the following statements is FALSE?
   A) Generally, chromosomes of prokaryotes are circular.
   B) Prokaryotes usually have a single molecule of DNA.
   C) Generally, chromosomes of eukaryotes are circular**.**
   D) Eukaryotes usually have multiple chromosomes.
   E) Eukaryote chromosomes are usually linear.

5. In eukaryotes, chromosomes do NOT contain:
   A) ribosomes.
   B) chromatin.
   C) proteins.
   D) histones.
   E) DNA.

6. Prokaryotic chromosomes do NOT have telomeres because they:
   A) do not go through mitosis.
   B) do not go through DNA replication.
   C) are in the cytoplasm.
   D) are circular.
   E) have no centromeres.

7. In prokaryotes, replication usually begins at a specific place on the chromosome called the:
   A) binary fission site.
   B) origin of replication.
   C) origin of mitosis.
   D) anchoring site.
   E) kinetochore.

8. The highly organized internal scaffolding of the nucleus is called the:
   A) histone complex.
   B) spindle microtubules.
   C) nuclear cohesion.
   D) nuclear matrix.
   E) nuclear envelope.

9. The attachment point on the chromosome for spindle microtubules is the:
   A) telomere.
   B) centromere.
   C) origin of replication.
   D) sister chromatid.
   E) allele.

10. The process of splitting the cytoplasm, which separates one cell into two, is termed:
   A) cytokinesis.
   B) mitosis.
   C) anaphase.
   D) diakinesis.
   E) fusion.

11. In order to be functional, a eukaryotic chromosome requires all of the following EXCEPT:
    A) a centromere.
    B) origins of replication.
    C) a plasmid.
    D) telomeres.
    E) A centromere and origins of replication are both correct.

12. Diploid cells are cells with _____ chromosomes.
    A) a single set of
    B) circular
    C) two sets of
    D) many sets of
    E) three sets of

13. If a healthy cell passes the G_1/S checkpoint:
    A) it will enter the G_0 stage of the cell cycle.
    B) DNA will be replicated.
    C) it will not divide.
    D) it will proceed immediately to cytokinesis.
    E) it will die.

14. Which of the following does NOT occur during the G_2 phase of the cell cycle?
    A) The G_2/M checkpoint is reached.
    B) DNA replication and error checking is completed.
    C) The cell completes preparation for mitosis.
    D) The cell divides.
    E) None of above answers is correct.

15. Which of the following occurs during prometaphase?
    A) The chromosomes align in a single plane.
    B) DNA is replicated.
    C) Microtubules attach to the kinetochores.
    D) Mitotic spindles form.
    E) The two sister chromatids separate.

16. During anaphase of mitosis, which of the following occurs?
    A) Sister chromatids separate from each other.
    B) Homologous chromosomes separate from each other.
    C) The spindle-assembly checkpoint insures that each chromosome is properly aligned.
    D) The condensed chromosomes relax.
    E) Spindle microtubules anchor to kinetochores.

17. Pea plants have seven different pairs of chromosomes. A chromosome with a centromere at the very end is called :
    A) submetacentric.
    B) metacentric.
    C) acrocentric.
    D) acentric.
    E) telocentric.

18. A dividing eukaryotic cell is treated with a drug that inhibits the activity of the spindle-attachment checkpoint. At which cell cycle stage would you predict that the cell would be blocked?
    A) G_1
    B) S
    C) G_2
    D) Mitosis (metaphase)
    E) Mitosis (telophase)

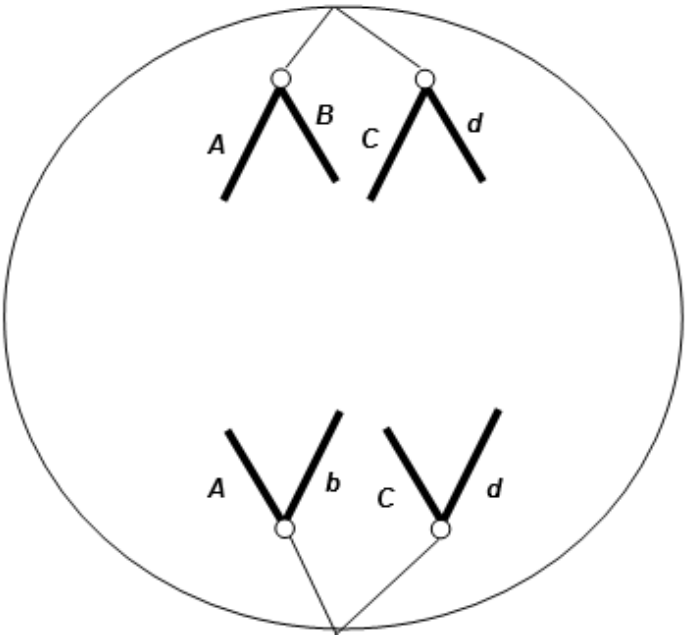
19. Pea plants have seven different pairs of chromosomes. The nucleus of a megaspore in a pea ovary would contain how many chromosomes?
    A) 3 ½
    B) 7
    C) 14
    D) 21
    E) 30

20. Pea plants have seven different pairs of chromosomes. A nucleus in the pea endosperm contains how many chromosomes?
    A) 3 ½
    B) 7
    C) 14
    D) 21
    E) 30

21. What process is unique to plants?
    A) Meiosis
    B) Double fertilization
    C) Crossing over
    D) Haploid gametes
    E) Spermatogenesis

22. Suppose that a diploid cell contains eight chromosomes ($2n = 8$). How many different combinations in the gametes are possible?
    A) 2
    B) 4
    C) 8
    D) 16
    E) 64

23. The figure shows chromosomal separation taking place. The letters stand for genes; capital and lowercase stand for different alleles. The diploid chromosome number in this organism is four. What process is shown?



    A) Anaphase of mitosis
    B) Telophase of meiosis I
    C) Anaphase of meiosis I
    D) Telophase of mitosis
    E) Anaphase of meiosis II

24. In a flowering plant, the male part of the flower (the stamen) produces haploid microspores that divide by _____ to produce sperm.
    A) mitosis
    B) meiosis
    C) gametogenesis
    D) spermatogenesis
    E) fertilization

25. A pollen grain that lands on a stigma grows a pollen tube to deliver _____ (how many?) sperm to the ovary. Fusion of a sperm with an egg produces a _____ *n* cell, called a _____.
    A) one; 1; zygote
    B) two; 1; megasporocyte
    C) two; 2; zygote
    D) one; 2; microsporocyte
    E) one; 2; megasporocyte

26. To provide food for the developing embryo, a tissue called endosperm is produced through double fertilization. Endosperm has a ploidy of:
    A) 1*n*.
    B) 2*n*.
    C) 3*n*.
    D) 4*n*.
    E) 5*n*.

27. What might be the result if breakdown of the shugoshin protein were premature?
    A) The cohesion protein would hold the chromosome arms together longer.
    B) The separation of homologous chromosomes would occur prematurely.
    C) The separation of sister chromatids would occur prematurely.
    D) Spindle fibers wouldn't form.
    E) Sister chromatids would never separate.

28. A diploid somatic cell from a rat has a total of 42 chromosomes ($2n = 42$). As in humans, sex chromosomes determine sex: XX in females and XY in males. What is the total number of telomeres in a rat cell in G_2?
    A) 21
    B) 42
    C) 84
    D) 126
    E) 168

29. A diploid somatic cell from a rat has a total of 42 chromosomes ($2n = 42$). As in humans, sex chromosomes determine sex: XX in females and XY in males. What is the total number of chromosomes present in the cell during metaphase I of meiosis?
    A) 21
    B) 42
    C) 84
    D) 126
    E) 168

30. A diploid somatic cell from a rat has a total of 42 chromosomes ($2n = 42$). As in humans, sex chromosomes determine sex: XX in females and XY in males. What is the total number of chromosomes in a polar body cell from a rat?
    A) 21
    B) 40
    C) 41
    D) 42
    E) 84

31. A dog has a diploid chromosome number of 78. How many separate DNA molecules should be present at metaphase of mitosis?
    A) 39
    B) 78
    C) 156
    D) 4
    E) None of the answers is correct.

32. The complex of DNA and histone proteins that makes up the eukaryote chromosome is called:
    A) cohesion.
    B) chromatin.
    C) microtubules.
    D) centromere.
    E) None of the answers is correct.

33. Which of the following statements is TRUE concerning the DNA of bacterial cells?
    A) It is complexed with histone proteins.
    B) It contains a single telomere.
    C) It has a centromere with a kinetochore.
    D) It is surrounded by a nuclear envelope.
    E) It is usually circular.

34. In humans how many chromosomes will be seen in a polar body derived from a primary oocyte?
    A) 23
    B) 46
    C) 92
    D) 12
    E) None of the answers is correct.

35. In the flowering plants, diploid cells in the stamen undergo meiosis and directly produce four haploid:
    A) sperm.
    B) eggs.
    C) microspores.
    D) polar nuclei.
    E) tube nuclei.

36. What evidence is there that viruses evolved after, not before, cells?

37. Why is mitosis important within the cell cycle?

38. Explain why mitosis does not produce genetic variation and how meiosis leads to the production of tremendous genetic variation.

39. Microscopy to look at a cell's chromosomes is often done when the cell is in mitotic metaphase. For example, karyotypes that extract chromosomes from a single cell and photograph them to look for abnormalities are done on metaphase, rather than interphase, cells. Why?

40. List and briefly describe three major cell cycle checkpoints. For each checkpoint, predict the consequences if the checkpoint failed to work properly.

41. Describe what is happening to chromosomes during prophase I of meiosis.

42. Describe the difference between the centromere and kinetochore.

43. Describe the difference between G_1 and G_2 of the cell cycle.

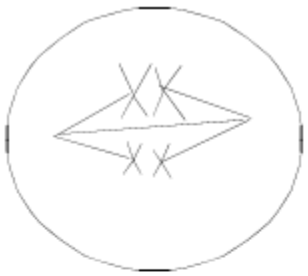
44. In tissue from the intestinal epithelium of a frog, the following proportions of cells were found at each stage of the cell cycle.

Stage	**Proportion of Cells**
Interphase	0.90
Prophase	0.04
Prometaphase	0.02
Metaphase	0.01
Anaphase	0.02
Telophase	0.01

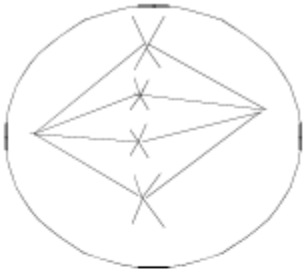
If the entire cell cycle in frog epithelium cells requires 20 hours for completion, what is the average duration of each stage?

45. The cells illustrated below belong to a species with a diploid chromosome number of four. Which stage of mitosis or meiosis is each cell in?

a.



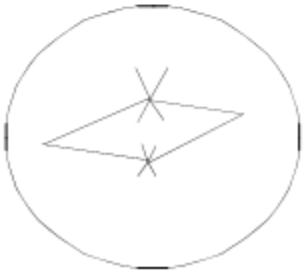
b.



c.

d.

e.



46. Match the phase(s) below (1–7) with the CORRECT statement (a–d).

    1. Meiosis I prophase
    2. Meiosis I anaphase
    3. Meiosis II prophase
    4. Meiosis II anaphase
    5. Mitosis prophase
    6. Mitosis anaphase

    a. Chromosomes are in unseparated, sister-chromatid form, at the end of the phase(s) _____.
    b. Sister chromatids separate during _____.
    c. Chromosomes are randomly partitioned during _____, contributing to genetic diversity.
    d. Crossing over (genetic recombination) occurs in _____.

47. During prophase I of meiosis, crossing over is indicated by what microscopically visible structure?

48. What is one feature of meiosis that produces genetic variability in gametes? In two or three sentences, explain how this feature causes genetic uniqueness.

49. List two differences and two similarities between mitosis and meiosis.

50. Describe the difference between homologous chromosomes and sister chromatids.

51. Describe the difference between meiosis I and meiosis II.

52. Describe the difference between the sporophyte and gametophyte.

53. What events during sexual reproduction are significant in contributing to genetic diversity?

54. (a) Compare and contrast spermatogenesis and oogenesis in animals. For each process, be sure to include information about division of the nucleus, allocation of chromosomes to the various products, and division of the cytoplasm. (b) Why is the difference in cytoplasmic division between spermatogenesis and oogenesis important to reproduction, considering the different roles of sperm and egg in reproduction?

55. (a) Describe the changing role of cohesin during the mitotic cell cycle. (b) Explain the importance of regulation of cohesin activity to normal cell division.

56. What is the type of chromosome where the centromere is located in the middle of the chromosome producing arms of equal length?
    A) Metacentric
    B) Telocentric
    C) Submetacentric
    D) Acrocentric
    E) Prokaryotic

57. Assume that a species has a diploid chromosome number of 20. How many double-stranded DNA molecules would you expect to see at prophase of mitosis in this species?
    A) 5
    B) 10
    C) 20
    D) 40
    E) 80

58. What are some of the main differences between prokaryotic and eukaryotic cells?

59. In which stage of the cell cycle does most DNA replication occur in eukaryotes?
    A) G_1
    B) G_2
    C) S
    D) Prophase of mitosis
    E) G_0

60. In a higher animal, how many secondary oocytes could be produced from 20 primary oocytes?
    A) 5
    B) 10
    C) 20
    D) 40
    E) 80

61. Which of the following is a key difference in the life cycles of higher animals and higher plants (angiosperms)?
    A) Gametes are produced by animals, but plants produce diploid spores that act as gametes and undergo fertilization.
    B) In animals the zygote is produced by the fusion of haploid sperm and eggs, but in plants the zygote is produce by fusion of a haploid sperm and a diploid egg producing a 3N cell.
    C) In animals there is a double fertilization, while in plants only one fertilization event occurs.
    D) In animals the immediate products of meiosis are gametes, while in plants the immediate products are haploid spores.
    E) Animals have a multicellular gametophyte, while plants produce single cell gametes.

62. What is a major function of telomeres?
    A) To serve as attachment points for the kinetochore protein complex
    B) To stabilize the ends of chromosomes
    C) To attach to the spindle fibers during mitosis
    D) To keep chromosomes circular
    E) To act as origins of DNA replication

63. Which of the following statements about meiosis is FALSE?
    A) Homologous chromosomes separate from each other during anaphase I.
    B) Sister chromatids separate from each other during anaphase II.
    C) Crossing over takes place during prophase I.
    D) DNA replication occurs between the first and second divisions.
    E) The chromosome number is reduced by one-half at the end of the first division.

64. In the life cycle of a higher plant (angiosperm), the female part of the flower undergoes meiosis and directly produces:
    A) four functional microspores.
    B) one functional microspore.
    C) one functional egg.
    D) the endosperm.
    E) one functional megaspore.

65. Compare the haploid portion of the life cycle of a higher animal with the haploid portion of the life cycle of a higher plant (angiosperm).

66. What is the special class of proteins that is associated with the DNA of eukaryotic chromosomes and forms a complex called chromatin?
    A) Cohesins
    B) Histones
    C) Cytokins
    D) Nuclear binding proteins
    E) Centromeres

67. Which of the following events occurs during meiosis I but not during meiosis II?
    A) Separation of sister chromatids
    B) The cytoplasm divides
    C) Individual chromosomes line up on the metaphase plate
    D) Chromosomes condense
    E) The two chromosomes of each homologous pair separate

68. A cell has a diploid or 2N chromosome number of 24 in its somatic cells. How many chromatids would you expect to see in G_2?
    A) 12
    B) 24
    C) 48
    D) 6
    E) 96

69. In animals, what is a diploid cell which can directly initiate meiosis I and produce two haploid cells?
    A) Microspore mother cell
    B) Secondary oocyte
    C) Secondary spermatocyte
    D) Primary spermatocyte
    E) First polar body

70. The normal function of shugoshin during meiosis involves:
    A) attaching spindle fibers to the kinetochores.
    B) holding homologous chromosomes together until they separate at anaphase I.
    C) keeping cohesin from being broken down in the centromere regions.
    D) holding sister chromatids together until they separate at anaphase I.
    E) allowing crossing over to only occur at specific chromosomal regions.

71. Viruses consist of a:
    A) histone molecule associated with a circular chromosome.
    B) nucleic acid surrounded by a protein coat.
    C) DNA genome associated with small RNAs.
    D) small prokaryotic cell associated with plasmids.
    E) telocentric chromosome surrounded by cohesin.

72. Three primary oocytes can lead to _____ eggs while three secondary spermatocytes can lead to _____ sperm.
    A) 12; 9
    B) 3; 3
    C) 3; 6
    D) 6; 12
    E) 6; 6

Answer Key

1. A
2. B
3. B
4. C
5. A
6. D
7. B
8. D
9. B
10. A
11. C
12. C
13. B
14. D
15. C
16. A
17. E
18. D
19. B
20. D
21. B
22. D
23. E
24. A
25. C
26. C
27. C
28. E
29. B
30. A
31. C
32. B
33. E
34. A
35. C
36. Viruses can reproduce only within host cells. Thus, they must have evolved after cells.
37. A single cell and all its genetic information is duplicated. Each cell contains a full complement of chromosomes.
38. Mitosis produces cells that are genetically identical to the parent cell. Meiosis includes two distinct processes that contribute to the generation of genetic variation: crossing over shuffles alleles on the same chromosome into new combinations, whereas the random distribution of maternal and paternal chromosomes shuffles alleles on different chromosomes into new combinations.
39. In metaphase, chromosomes are condensed and are more easily visualized.

40. (1) The G_1/S checkpoint holds the cell in G_1 until the cell has all of the enzymes necessary for replication of DNA. If the checkpoint failed, the cell would proceed into S without the necessary enzymes, causing the DNA not to be replicated properly or completely. This might cause the cell cycle to halt at the G_2/M checkpoint. Alternatively, the cell might divide without the genetic material having been replicated, causing the daughter cells to receive incomplete genetic information. (Both predictions are reasonable based on information in the chapter.)
(2) The G_2/M checkpoint is passed only if the cell's DNA is undamaged. If it fails to work properly, division would proceed in the presence of damaged DNA, possibly leading to mutations in the daughter cells and/or death of the daughter cells.
(3) The spindle-assembly checkpoint is during metaphase, and it ensures that each chromosome is aligned at the metaphase plate and attached to spindle fibers from opposite poles. This checkpoint depends on tension at the kinetochores of each chromosome. If the checkpoint fails, anaphase will occur even when the chromosomes are not aligned properly, allowing daughter cells to be produced with extra and/or missing chromosomes.
41. —Chromosomes contract and become visible.
—Chromosomes continue to condense and homologous chromosomes pair up and begin synapsis.
—Chromosomes become shorter and thicker, synaptonemal complex develops between homologous chromosomes.
—Centromeres of paired chromosomes move apart; the two homologs remain attached at each chiasma.
—Finally, the chiasmata move toward the ends of the chromosomes
42. A centromere is the physical location on a chromosome where the kinetochore and spindle microtubules attach. The kinetochore is composed of proteins that assemble on the centromere to provide a site for the spindle microtubules to attach.
43. G_1 occurs before S phase and G_2 occurs after S phase. During G_1, cells grow in size, chromosomes are composed of a single chromatid. During G_1, cells pass a critical checkpoint (the G_1/S checkpoint) after which they are committed to undergoing cell division. During G_2, the chromosomes are composed of two chromatids. There is another checkpoint during G_2 that ensures cells are prepared for mitosis. Cells typically spend more time in G_1 than in G_2.
44. Interphase = $0.9 \times 20 = 18$ hours; prophase = $0.04 \times 20 = 0.8$ hours; Prometaphase = $0.02 \times 20 = 0.4$ hours; metaphase = $0.01 \times 20 = 0.2$ hours; anaphase = $0.02 \times 20 = 0.4$ hours; telophase = $0.01 \times 20 = 0.2$ hours
45. a. Meiosis I metaphase
b. Mitosis metaphase
c. Mitosis anaphase
d. Meiosis I anaphase
e. Meiosis II metaphase
46. a. 1, 2, 3, 5
b. 4, 6
c. 2
d. 1
47. Chiasmata (chiasma) or the synaptonemal complex

48. (1) Independent assortment. In meiosis I—metaphase and anaphase—nonhomologous chromosomes distribute randomly. Alignment and separation of one pair of homologous chromosomes is independent of how a different pair separates. Different gametes have different chromosomes and can have different alleles for the same genes, so the gametes normally have different combinations of alleles.

    (2) Crossing over. In meiosis I—prophase—portions of homologous chromosomes exchange (changing combinations of alleles of genes on a single chromosome) so not even sister chromatids are identical after crossing over. Each gamete has only one copy of each homolog, and each homolog now has a unique combination of alleles.

49. *Differences:*

    (1) Mitosis occurs in somatic (nonsex) cells; meiosis occurs in sex cells to produce gametes or haploid cells that will eventually produce gametes.

    (2) Meiosis involves chromosome pairing (of homologous chromosomes); mitosis does not.

    (3) Mitosis produces nonsex cells; meiosis directly produces gametes or cells that will eventually produce gametes.

    (4) Mitosis produces cells of the same ploidy; meiosis produces haploid cells from diploid cells.

    (5) Meiosis has two consecutive divisions; mitosis has one.

    (6) Mitosis produces two daughter cells; meiosis produces four daughter cells.

    (7) Mitosis produces identical daughter cells; meiosis produces four different daughter cells.

    Similarities:

    (1) Both involve the separation of replicated chromosomes during cell division.

    (2) Both are processes to ensure that daughter cells in cell division receive a complete set of chromosomes.

    (3) DNA replication must occur first.

    (4) Cytokinesis usually occurs at the end of each.

50. Homologous chromosomes can have different alleles. Sister chromatids are duplicates and (except for errors in replication) are identical in sequence before crossing over takes place.

51. Homologs pair and segregate in meiosis I. Sister chromatids are paired and segregate in meiosis II. Crossing over occurs in meiosis I but not in meiosis II.

52. The sporophyte is the diploid phase of a plant life cycle. The gametophyte is the haploid stage.

53. (1) Crossing over changes allele combinations on chromosomes, so, after meiosis I, even sister chromatids are not genetically identical.

    (2) Independent assortment of nonhomologous chromosomes ensures each gamete has a different combination of alleles for genes on nonhomologs.

    (3) Two genetically unique gametes from each parent combine during fertilization to form a novel, genetically unique individual.

54. (a) Division of the nucleus and allocation of the chromosomes to the products are essentially the same in both processes. Starting with a 2*n* germ cell, nuclear division is by meiosis I and II, and each product of meiosis contains one set of chromosomes (1*n*). The major difference is that division of the cytoplasm during meiosis I and II is equal in

spermatogenesis and unequal in oogenesis. During oogenesis, meiosis I produces a large secondary oocyte with lots of cytoplasm and a polar body with very little cytoplasm. Meiosis II in the secondary oocyte produces a large ovum with lots of cytoplasm and a small second polar body. Therefore, only one large, functional egg is produced per primary oocyte, whereas four, small, functional sperm are normally produced per primary spermatocyte.

(b) The small size and other features of sperm structure suit them well to delivery of the haploid nucleus to the egg. The large amount of cytoplasm in the egg suits it well to nourishing development of the embryo after fertilization.

55. (a) Cohesin keeps sister chromatids together after DNA replication during S phase through metaphase of mitosis. The breakdown of cohesin allows the sister chromatids to separate from each other during anaphase.

    (b) Cohesin must be active beginning in S phase through metaphase in order to keep the sister chromatids together so that they can be properly aligned at the metaphase plate to ensure equal division of the genetic information to the two daughter cells. Cohesin must be inactivated or broken down in order to allow the sister chromatids to separate during anaphase so that each daughter cell will get one copy of the genes on each chromosome.
56. A
57. D
58. Eukaryotic cells have their genetic material enclosed in a nucleus with a nuclear membrane or envelope. In prokaryotes, the genetic material is not separated from the other cellular components, and there is no true nucleus. The DNA of eukaryotes is intimately associated with special proteins called histones. Eubacteria have no histones and the histones of the archaea have a different association with DNA than is found in eukaryotes. Eukaryotes have multiple linear chromosomes, while prokaryotes generally have a single circular chromosome (although there are exceptions).
59. C
60. C
61. D
62. B
63. D
64. E
65. The only haploid portions in the animal life cycle are the single-celled eggs and sperm that arise directly from meiosis. The gametes do not undergo further divisions and are involved in fertilization to produce the diploid zygote.

    In contrast, plants have multicellular haploid generations or gametophytes. The female portion of the flower contains megaspore mother cells that undergo meiosis and produce haploid megaspores. Functional megaspores (one per meiosis) undergo mitotic divisions and produce a multicellular structure, the embryo sac, the female gametophyte. One of the cells of the embryo sac is the egg. The male portion of the flower produces microspore mother cells that undergo meiosis and produce four functional haploid microspores that can undergo mitotic divisions to produce the male gametophyte, the pollen grain. The pollen grain produces a tube that usually contains two functional sperm.

66. B
67. E
68. C
69. D
70. C
71. B
72. C