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Name:_____ Class:_____ Date:_____

Chapter 02: Chromosomes and Cellular Reproduction

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.

ANSWER: a

2. Which of the following are NOT prokaryotes?
   a. eubacteria
   b. archaea
   c. viruses
   d. ancient bacteria

ANSWER: c

3. Which of the following statements is TRUE?
   a. Eubacteria are prokaryotes while the archaea are eukaryotes.
   b. Archaea are more closely related to eukaryotes than to eubacteria.
   c. Eukaryotes are more closely related to eubacteria than to archaea.
   d. Viruses are more closely related to prokaryotes than to eukaryotes.
   e. Eubacteria, archaea, and eukaryotes are all equally related.

ANSWER: b

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.

ANSWER: c

5. In eukaryotes, chromosomes do NOT contain
   a. ribosomes.
   b. chromatin.
   c. proteins.
   d. histones.
   e. DNA.

ANSWER: a

6. Why are viruses considered to be neither prokaryotic nor eukaryotic?

ANSWER: Viruses do not possess the structure of a cell. Viruses are actually simple structures composed of an

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outer protein coat surrounding nucleic acid.

Viruses cannot reproduce outside of their host cells, suggesting that viruses evolved after cells were present and not before.

7. 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.

ANSWER: d

8. 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.

ANSWER: b

9. 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.

ANSWER: d

10. The attachment point on the chromosome for spindle microtubules is the
   a. telomere.
   b. centromere.
   c. origin of replication.
   d. sister chromatid.
   e. allele.

ANSWER: b

11. The process of splitting the cytoplasm, which separates one cell into two, is termed
   a. cytokinesis.
   b. mitosis.
   c. anaphase.

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d. diakinesis.
e. fusion.

ANSWER: a

12. 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.

ANSWER: c

13. 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

ANSWER: c

14. 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.

ANSWER: b

15. 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 are completed.
c. The cell completes preparation for mitosis.
d. The cell divides.
e. All of these occur during the G_2 phase of the cell cycle.

ANSWER: d

16. 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.

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e. The two sister chromatids separate.

ANSWER: c

17. Chromosome movement during anaphase is a result of
   a. disassembly of tubulin molecules by molecular motor proteins.
   b. kinetochore shortening causing chromosomes to pull apart.
   c. metaphasal plate splitting resulting in chromosomal disassembly.
   d. the cohesion protein attaching to the centromeres of sister chromatids.
   e. cilia movement inside the cellular structure.

ANSWER: a

18. A chromosome with a centromere at the very end is called
   a. submetacentric.
   b. metacentric.
   c. acrocentric.
   d. acentric.
   e. telocentric.

ANSWER: e

19. A dividing eukaryotic cell is treated with a drug that inhibits the molecular motors associated with kinetochores. At which cell cycle stage would it stop?
   a. G_1
   b. S
   c. G_2
   d. M (metaphase)
   e. M (telophase)

ANSWER: d

20. 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?
   a. 18 hours for interphase, 0.4 hour for prophase, 0.2 hour for prometaphase, 0.2 hour for metaphase,

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0.2 hour for anaphase, 0.4 hour for telophase

b. 1.8 hours for interphase, 0.8 hour for prophase, 0.2 hour for prometaphase, 0.2 hour for metaphase, 0.2 hour for anaphase, 0.8 hour for telophase

c. 18 hours for interphase, 0.8 hour for prophase, 0.4 hour for prometaphase, 0.2 hour for metaphase, 0.4 hour for anaphase, 0.2 hour for telophase

d. 9 hours for interphase, 0.8 hour for prophase, 0.2 hour for prometaphase, 0.2 hour for metaphase, 0.6 hour for anaphase, 0.4 hour for telophase

e. 18 hours for interphase, 0.8 hour for prophase, 0.6 hour for prometaphase, 0.2 hour for metaphase, 0.2 hour for anaphase, 0.8 hour for telophase

ANSWER: c

21. The centromere divides a chromosome into two sections or "arms." A chromosome is found to have two arms of equal lengths. Such a chromosome can be BEST described as

a. telocentric.

b. circular.

c. acrocentric.

d. metacentric.

e. homologous.

ANSWER: d

22. Somatic cancer cells often are unstable and divide inappropriately (divide when they should not be dividing). In addition, such cells often contain losses of some chromosomes and extra copies of other chromosomes. Defects in which of the following may be partially responsible for the aberrant behavior of cancer cells? (Select all that apply.)

a. spindle-assembly checkpoint

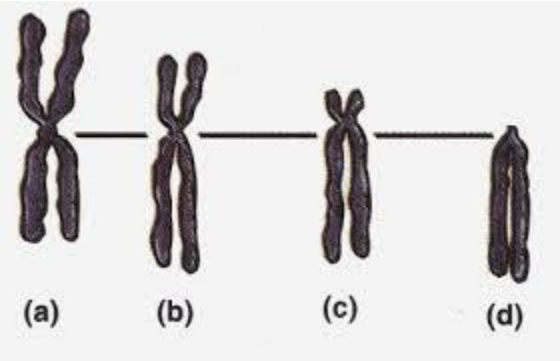
b. G_1/S checkpoint

c. homologous chromosome pairing

d. crossing over

ANSWER: a, b

23. Which chromosome in the following figure is MOST likely to be described as acrocentric?



a. (a)

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b. (b)

c. (c)

d. (d)

e. Chromosomes (a) and (b) are both acrocentric.

ANSWER: c

24. Why is mitosis important within the cell cycle?

ANSWER: Mitosis is important because it results in two daughter cells that have identical nuclear chromosome complements so the daughter cells are genetically identical to each other and genetically identical to the parent cell from which they arose. The process of mitosis makes new cells and replaces cells that are worn out or damaged.

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

ANSWER: 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 pairs of homologous chromosomes, one member of each pair coming from the mother and the other from the father, shuffles alleles on different chromosomes into new combinations.

26. Microscopy to look at a cell's chromosomes is often performed when the cell is in mitotic metaphase. For example, karyotyping (extracting chromosomes from a single cell and photographing them to look for abnormalities) is performed on metaphase, rather than interphase, cells. Why?

ANSWER: In metaphase, chromosomes are condensed and are more easily visualized.

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

ANSWER: (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.

28. Describe what is happening to chromosomes during the five substages of prophase I.

ANSWER: Leptotene—chromosomes contract and become visible

Zygotene—chromosomes continue to condense and homologous chromosomes pair up and begin

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synapsis
Pachytene—chromosomes become shorter and thicker; synaptonemal complex develops between homologous chromosomes
Diplotene—centromeres of paired chromosomes move apart; the two homologs remain attached at each chiasma
Diakinesis—centromeres move apart

29. Describe the difference between the centromere and kinetochore.

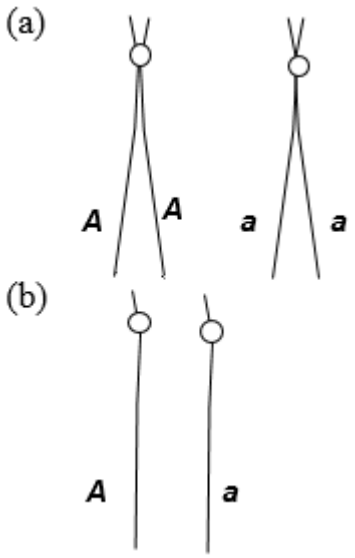
ANSWER: A centromere is the physical location (DNA sequence) on a chromosome where the kinetochore and spindle microtubules attach. The kinetochore is composed of proteins that assemble on the centromere to provide a site for the spindle microtubules to attach.

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

ANSWER: 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.

31. (a) Draw a pair of acrocentric homologous chromosomes as they would appear in G_2. Indicate centromeres with a small circle, and place the alleles *A* and *a* on each of the chromatids. (b) Draw the same chromosomes as they would appear in G_1. Place the alleles *A* and *a* on each of the chromatids.

ANSWER:



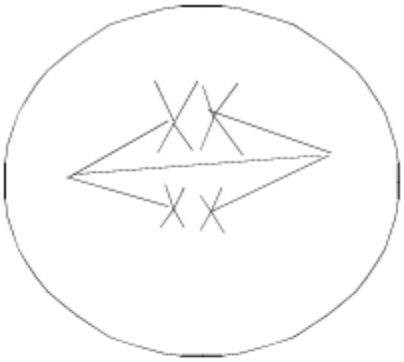
32. The cells illustrated here belong to a species with a diploid chromosome number of four. Each of the following cells is in which stage of mitosis or meiosis?

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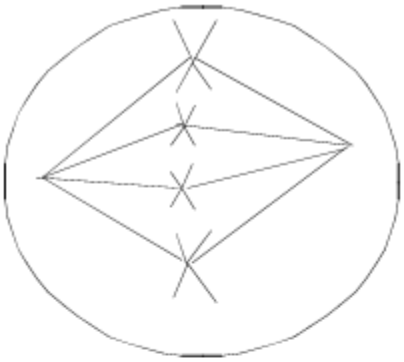
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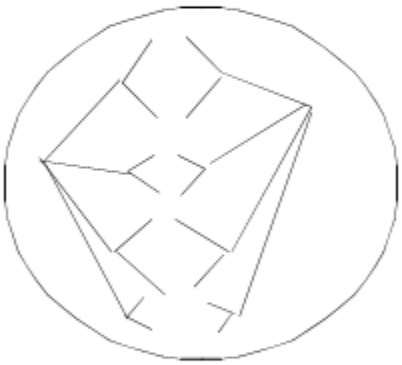
a.



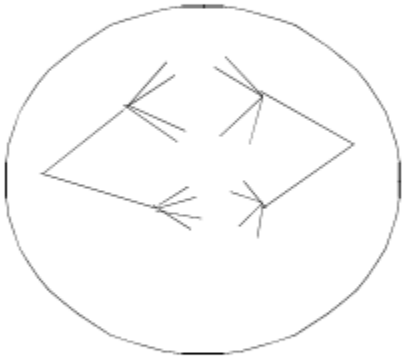
b.



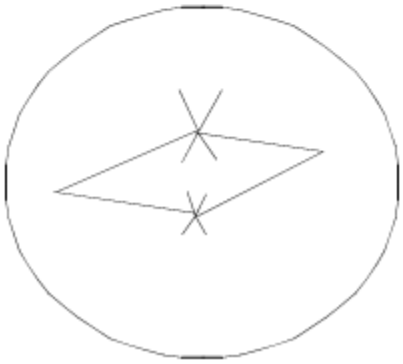
c.



d.



e.



ANSWER: a. meiosis I metaphase
b. mitosis metaphase
c. mitosis anaphase
d. meiosis I anaphase
e. meiosis II metaphase

33. Using the following choices, indicate the CORRECT phase(s) in parts a–e.
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 phase(s) _____.

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b. Chromosomes condense during _____.
c. Sister chromatids separate during _____.
d. Chromosomes are randomly partitioned during _____, contributing to genetic diversity.
e. Crossing over (genetic recombination) occurs in _____.

ANSWER: a. 1, 2, 3, 5
b. 1, 3, 5
c. 4, 6
d. 2
e. 1

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

ANSWER: Differences:
(1) Mitosis occurs in somatic (nonsex) cells; meiosis occurs in sex cells to produce gametes.
(2) Meiosis involves chromosome pairing (of homologous chromosomes); mitosis does not.
(3) Mitosis produces nonsex cells; meiosis produces gametes directly or indirectly.
(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.

35. The cells of a mature pea plant have 14 chromosomes. In a pea plant ovary, how many chromosomes would the nucleus of a megaspore contain?

a. 3 1/2
b. 7
c. 14
d. 21
e. 30

ANSWER: b

36. The cells of a mature pea plant have 14 chromosomes. How many chromosomes does a nucleus in the pea endosperm contain?

a. 3 1/2
b. 7
c. 14
d. 21
e. 30

ANSWER: d

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37. Which of the following processes is unique to plants?
    a. meiosis
    b. double fertilization
    c. crossing over
    d. haploid gametes
    e. spermatogenesis

ANSWER: b

38. 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

ANSWER: d

39. In a flowering plant, the male part of the flower (the stamen) produces haploid microspores that divide by _____ to eventually produce sperm.
    a. mitosis
    b. meiosis
    c. gametogenesis
    d. spermatogenesis
    e. fertilization

ANSWER: a

40. In a typical flowering plant, 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. 1; 1; zygote.
    b. 2; 1; megasporocyte.
    c. 2; 2; zygote.
    d. 1; 2; microsporocyte.
    e. 1; 2; megasporocyte.

ANSWER: c

41. 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*.

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e. 5*n*.

ANSWER: c

42. What might be the result if the 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 would not form.
e. Sister chromatids would never separate.

ANSWER: c

43. 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

ANSWER: e

44. 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

ANSWER: b

45. 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

ANSWER: a

46. A geneticist observes 10 pairs of homologous chromosomes at metaphase I of meiosis in a newly discovered species of flowering plant. How many chromosomes should be found in a microsporocyte?

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a. 20
b. 10
c. 5
d. 40
e. 2

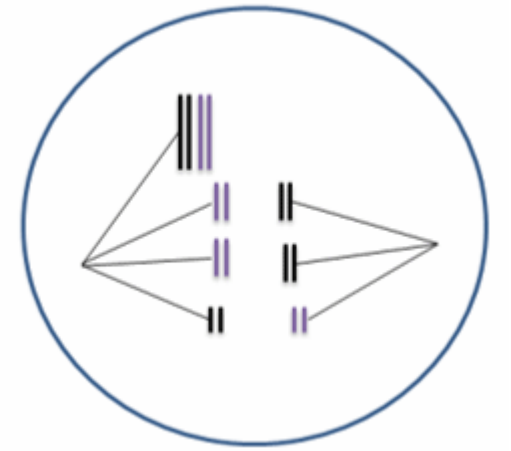
ANSWER: a

47. Assume that cells that are about to undergo meiosis are treated with a chemical that blocks crossing over but does not affect the cells in any other way, and four viable cells are produced by the two divisions of meiosis. What will be the consequence of such a treatment?

a. The four products of meiosis will be genetically identical.
b. The four products of meiosis will all be genetically unique.
c. All the chromosomes of two of the products of meiosis will have chromosomes that are paternal in origin, but the other two products will have chromosomes that are of both paternal and maternal origins.
d. All the chromosomes of two of the products of meiosis will have chromosomes that are maternal in origin, but the other two products will have chromosomes that are of both paternal and maternal origins.
e. Two of the products will be genetically identical but genetically different from the other two products, which will also be genetically identical.

ANSWER: e

48. A "mistake" is happening during meiosis I in the following figure. Assume the second meiotic division is normal. How many chromosomes would be expected in the four cellular products of this meiotic event?



a. All four cells would have four chromosomes.
b. All four cells would have three chromosomes.
c. Two cells would have three chromosomes, and two cells would have five chromosomes.
d. Two cells would have six chromosome, and two cells would have 10 chromosomes.
e. One cell would have three chromosomes, one cell would have five chromosomes, and two cells

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would have four chromosomes.

ANSWER: c

49. Humans have 23 pairs of chromosomes. Rarely, an egg is produced with 46 chromosomes instead of 23. How might such an egg have originated?

a. When the first polar body divides in meiosis II, all the chromatids go to one daughter cell.
b. When the secondary oocyte divides in meiosis II, all the chromatids go to one daughter cell.
c. When the second polar body divides in meiosis II, all the chromatids go to one daughter cell.
d. When the primary oocyte divides in meiosis I, all the chromosomes go to the first polar body.
e. When the secondary oocyte divides in meiosis I, all the chromatids go to the second polar body.

ANSWER: b

50. Assume that the diploid or 2*n* number of chromosomes is 18 for a certain species of animal. How many DNA molecules will be found in metaphase II for this species?

a. 9
b. 18
c. 36
d. 72
e. 24

ANSWER: b

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

ANSWER: Chiasmata (chiasma) or the synaptonemal complex

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

ANSWER: a. 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 that have different chromosomes can have different alleles for the same genes, so the gametes normally have different combinations of alleles.
b. 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.

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

ANSWER: Homologous chromosomes can have different alleles. Sister chromatids are duplicates and (except for errors in replication) are identical in sequence.

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

ANSWER: 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.

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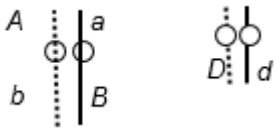
55. Describe the difference between the sporophyte and gametophyte.

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

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

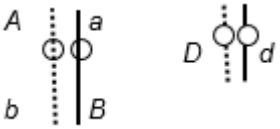
ANSWER: (1) Crossing over changes allele combinations on chromosomes, so, after meiosis I, even sister chromatids are not genetically identical.
(2) Independent assortment of nonhomologous chromosomes ensures each gamete has a different combination of alleles for genes on nonhomologs.
(3) Two genetically unique gametes from each parent combine during fertilization to form a novel, genetically unique individual.

57. Write all possible genotypes of each of the cells resulting from mitosis and meiosis of a cell of the genotype shown below.



ANSWER: Mitosis: *A*/*a B*/*b D*/*d* or *ABD*/*abd* (diploid and heterozygous at all three loci)
Meiosis: *ABd*, *aBd*, *AbD*, *abD*, *Abd*, *aBD*, *ABD*, *abd* (haploid at all three loci)

58. A diploid, eukaryotic cell in interphase has these two pairs of homologous chromosomes with the indicated arrangement of alleles:



Draw the chromosomes at the end of (a) prophase of mitosis and (b) prophase I (of meiosis I) with the most likely crossing-over events. Indicate placement of alleles on the chromosomes.

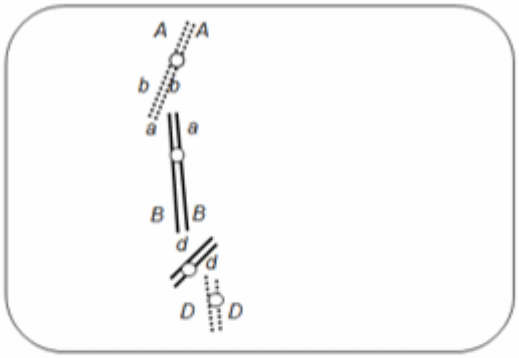
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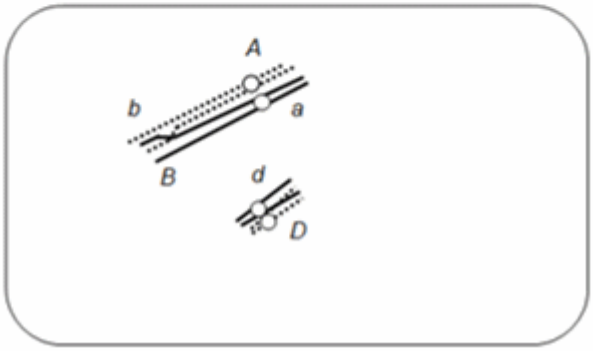
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ANSWER:

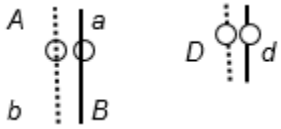
(a)



(b)



59. A diploid, eukaryotic cell in interphase has these two pairs of homologous chromosomes with the indicated arrangement of alleles:



Draw the chromosomes at the end of telophase of (a) mitosis and (b) meiosis II. Indicate placement of alleles on the chromosomes.

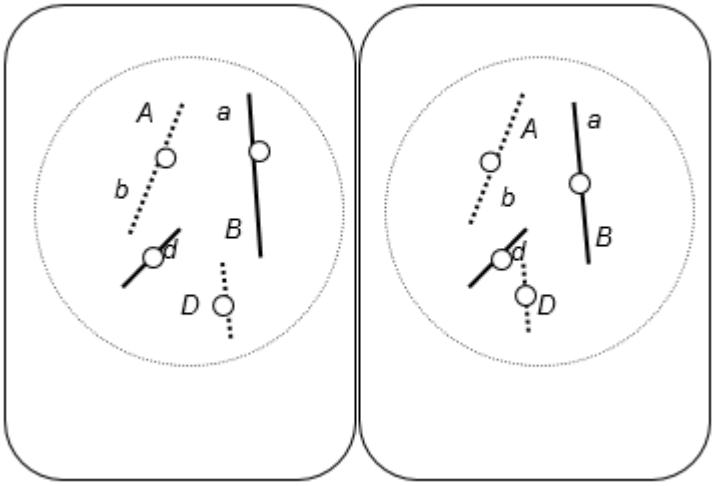
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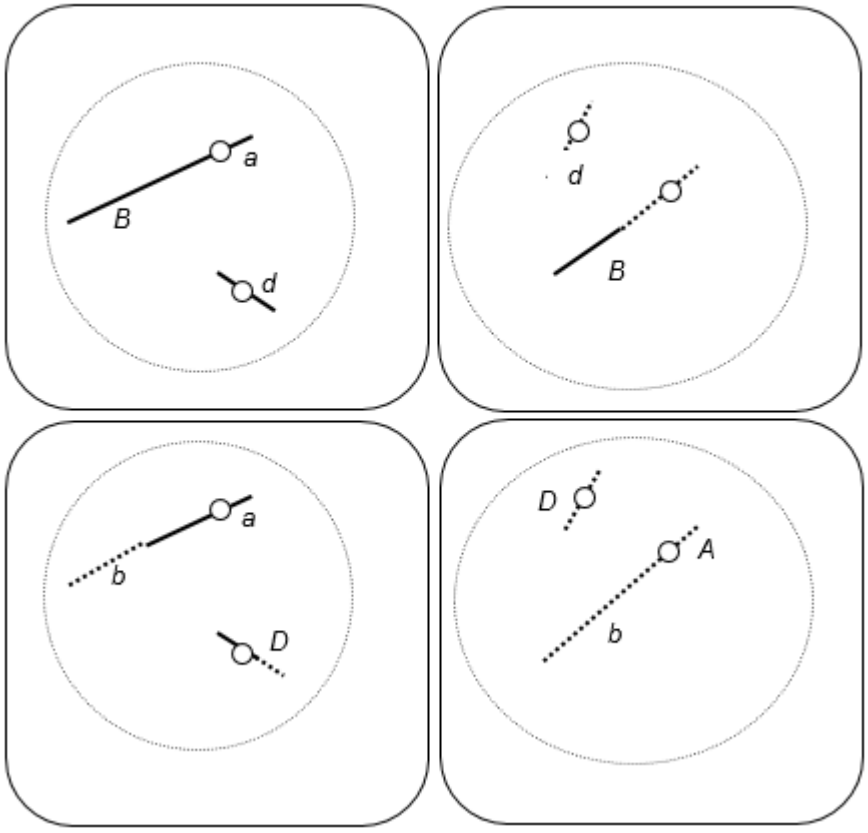
Chapter 02: Chromosomes and Cellular Reproduction

ANSWER:

(a)



(b) [One possibility]



60. (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 eggs in reproduction?

ANSWER: (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

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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.

61. (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.

ANSWER: (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.

62. Which of the following statements is TRUE?

a. Archaea resemble eukaryotes in cell structure.
b. Evolutionarily, it is clear archaea are mostly closely related to bacteria.
c. The evolutionary relationships among bacteria, archaea, and bacteria are well understood.
d. While cell structure between archaea and bacteria is similar, certain genetic processes such as transcription are more similar between archaea and eukaryotes.
e. While cell structure between archaea and eukaryotes is similar, certain genetic processes such as transcription are more similar between archaea and bacteria.

ANSWER: d

63. *B. subtilis* is a type of bacterium. Under certain growth conditions, *smc* null mutants (i.e., completely lacking *smc* function) can develop with abnormal nucleoids and some have increased DNA content.* Based on your knowledge of SMC function, explain why these phenotypes might arise.

*Reference:
Britton R. A., Lin D. C., Grossman A. D. (1998) Characterization of a prokaryotic SMC protein involved in chromosome partitioning. Genes Dev. **12**:1254–1259.

ANSWER: Answers should provide an overview and not be detailed. As described in Section 1.2, SMC (structural maintenance of chromosome) proteins encircle DNA during binary fission of prokaryotic cells to keep them untangled. So, SMC proteins are required for binary fission and chromosome segregation. Thus, *smc* null mutations will lead to defects associated with proper chromosome segregation, such as improper nucleoids and some cells having excess DNA content because excess DNA was segregated to one daughter cell.

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Chapter 02: Chromosomes and Cellular Reproduction

64. Why is meiosis I also called reductional division? (Select all that apply.)
    a. The resulting cells are smaller than the original cell.
    b. The resulting cells have half the chromosome content of the original cell.
    c. The resulting cells have a quarter of the chromosome content of the original cell.
    d. The ploidy number is reduced by a factor of 2.
    e. Individual cell DNA content goes from 2n to 1n.

ANSWER: b, d, e

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