193 total

KEY

8 The Cellular Basis of Reproduction and Inheritance

In laboratories all over the world, biologists are studying cell division to try to understand why cells divide, what determines when they divide, what happens during cell division, and why some cells divide and others do not. The process of cell division is fundamental to inheritance, reproduction, growth, and development. Much of the inquiry into cell division is basic research; but this research has immense practical importance because understanding cell division will enable us to understand cancer, birth defects, heredity, and inherited diseases. This chapter concerns the connections among cell division, reproduction, and inheritance.

Organizing Your Knowledge

Exercise 1 (Introduction – Module 8.3)

18

Review the concepts introduced in these modules by filling in the blanks.

"Like begets [1] LIKE." This old saying means offspring look like their parents. Technically, only offspring produced by [2] ASEXUAL reproduction look exactly like their parents, because they inherit all their [3] DNA from a single parent. For example, when an amoeba divides, its [4] DNA is duplicated, and identical sets of [5] CHROMOSOMES (the structures that contain most of the amoeba's DNA) are allocated to opposite sides of the cell. The parent amoeba splits, and the two daughter amoebas that are formed are genetically [6] IDENTICAL to each other and to the [7] MOTHER cell.

Prokaryotes also reproduce asexually, via a type of cell division called [8] BINARY FISSION. Most genes in a prokaryote are carried on a single [9] CIRCULAR DNA molecule, which is much [10] SMALLER and [11] SIMPLER in structure than the multiple chromosomes of eukaryotes. The prokaryote replicates its DNA and attaches the copies to different points on the plasma [12] MEMBRANE. As the cell grows, the chromosomes become separated. Finally, the plasma membrane and cell [13] WALL grow inward, separating the chromosomes and dividing the cell in two. Like the reproduction of an amoeba, binary fission produces daughter cells identical to the parent cell. Parent and offspring share identical [14] GENOMES, or sets of genetic information.

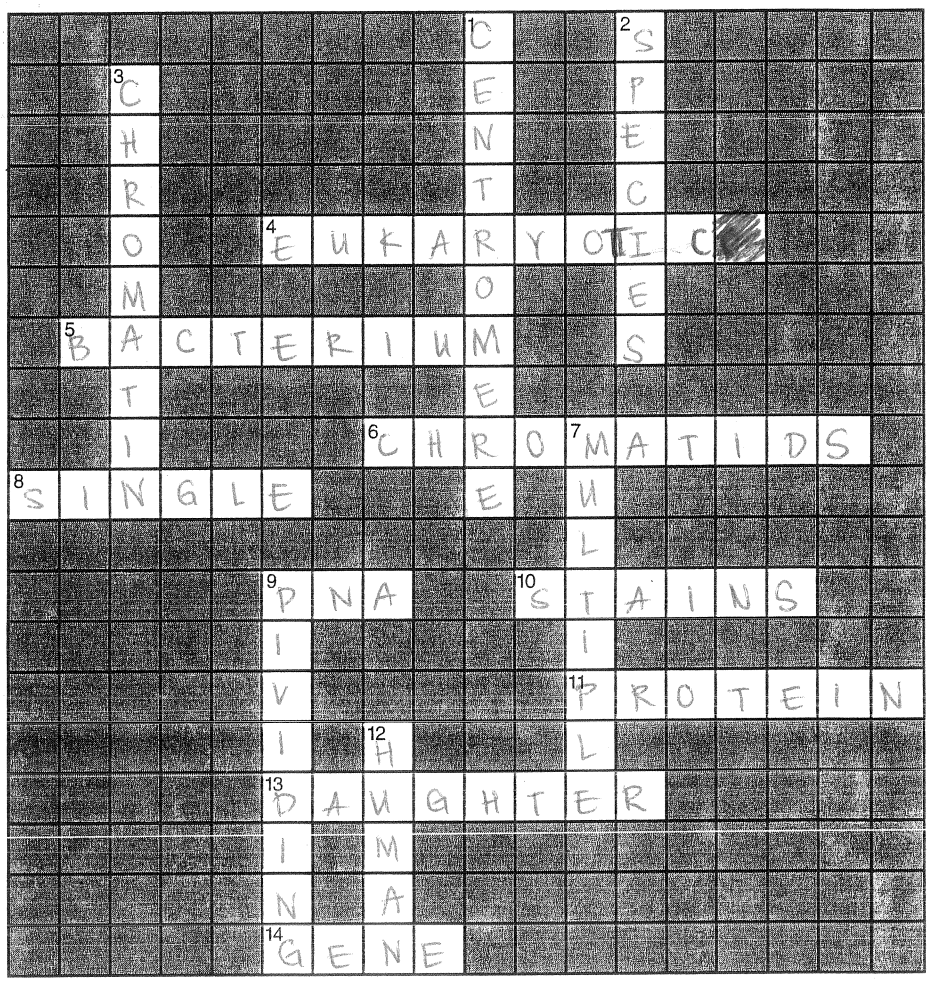
The offspring produced by sexual reproduction resemble their parents, but they are not identical to their parents or to each other. Sexual reproduction begins with the production of an [15] EGG and a [16] SPERM, specialized cells that join to produce an offspring. The egg and sperm fuse, and the [17] FERTILIZED egg inherits a unique combination of genes from both parents. Through repeated cell divisions, the fertilized egg develops into an organism with a unique combination of traits—for example, a cat with long, gray fur or a human with blue eyes and freckles. Thus, sexual reproduction produces [18] VARIATION among offspring. Through sexual reproduction "like begets like," but not exactly.

Exercise 2 (Module 8.4)

Read these modules, and then test your knowledge of chromosomes by completing the crossword puzzle.

Across

4. ____ cells have more chromosomes and genes than bacteria do.
5. A typical ____ has about 3000 genes.
6. Chromosome duplication produces two sister ____.
8. A prokaryote has a ____ simple chromosome.
9. A chromosome contains one long ____ molecule.
10. Chromosomes are named for their affinity to ____ used in microscopy.
11. Eukaryotic chromosomes involve more ____ molecules than those of bacteria.
13. When a chromosome divides, one sister chromatid goes to each ____ cell.
14. Proteins help determine chromosome shape and control ____ activity.



→ 4 ACROSS : EUKARYOTIC

Down

1. Sister chromatids are joined at the ____.
2. The number of chromosomes in a eukaryotic cell depends on the ____.
3. When a cell is not dividing, chromosomes form long, thin fibers called ____.
7. Genes in eukaryotic cells are grouped into ____ chromosomes.
9. Chromosomes are clearly visible only when a cell is ____.
12. ____ cells carry about 100,000 genes in 46 chromosomes.

Exercise 4 (Module 8.6)

8B–C *Before you do the following written exercises, check out the CD-ROM animation of mitosis and cytokinesis (8B). Then watch the video of cell division on the CD-ROM (8C).*

Summarize mitotic cell division. Briefly describe the appearance and activities of each of these cell parts during interphase and the four stages of mitosis. Include a simple sketch for each phase.

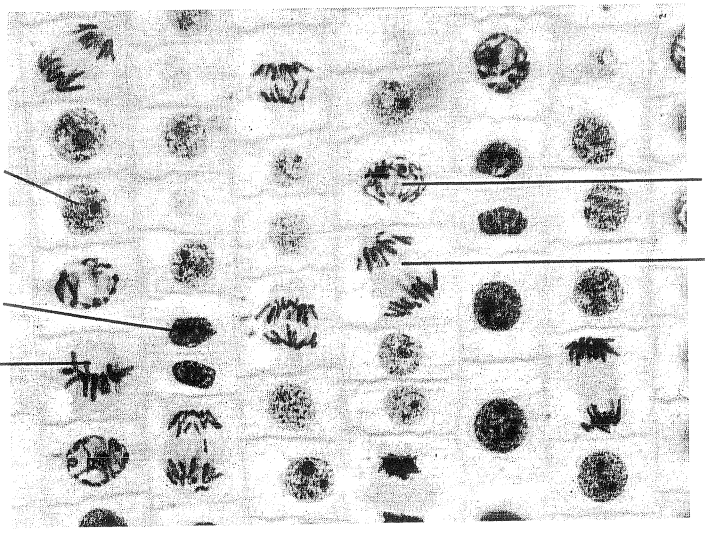
25

	Interphase	*Prophase*	*Metaphase*	*Anaphase*	*Telophase*
Nucleus and nuclear envelope	MEMBRANE - BOUNDED	ENVELOPE BREAKS DOWN	NONE	NONE	DAUGHTER NUCLEI and ENVELOPES FORM
Mitotic spindle	none	SPINDLE FORMS FROM MICROTUBULES	FULLY FORMED; SOME FIBERS ATTACHED TO CHROMOSOMES	FIBERS MOVE CHROMOSOMES TO POLES	BREAKS DOWN.
Chromosomes	DUPLICATED BUT DISPERSED AS CHROMATIN	CHROMATIN COILS TO FORM SHORTER, THICKER PAIRS OF CHROMATIDS JOINED AT CENTROMERES	LINE UP ON METAPHASE PLATE	SISTER CHROMATIDS SEPARATE	CHROMOSOMES UNCOIL TO FORM CHROMATIN
Cell size and shape	ROUNDED, DOUBLES IN VOLUME.	ROUNDED	ROUNDED	SPINDLE ELONGATES CELL	ELONGATION CONTINUES CYTOKINESIS SPLITS CELL INTO 2 SMALLER ROUNDED CELLS
Sketch	SEE MODULE 8.6 in TEXT.				

Exercise 5 (Module 8.6)

5

This is a photograph of cells in an onion root tip, an area of rapid cell division. In which stage of mitosis (or interphase) is each of the numbered cells?



1. interphase
2. telophase
3. metaphase
4. prophase
5. anaphase

Exercise 6 (Module 8.6)

Match the word or phrase on the right with the correct role in mitosis in an animal cell on the left.

5

A. Where spindle microtubules attach to chromosomes
B. Move chromosomes
C. Pulled apart by spindle microtubules
D. Material around centrioles from which mitotic spindle grows
E. Chromosomes come to rest here during metaphase

E 1. Metaphase plate
A 2. Kinetochores
C 3. Sister chromatids
B 4. Spindle microtubules
D 5. Centrosome

Exercise 7 (Module 8.7)

5

Read this module and then write a statement containing exactly 30 words (no more, no less!) comparing cytokinesis in plant and animal cells. (Writing *exactly* 30 words will force you to think about the processes and choose your words carefully. It's fun to try it.)

In animals, microfilaments produce a cleavage furrow that pinches the cell apart, while in plants, vesicles align in a cell plate, where a cell wall grows to split the cell.

Exercise 8 (Modules 8.8 – 8.11)

29

Review the functions of cell division and the factors that control it by filling in the blanks below.

Mitotic cell division has several important functions. Some animals rely on cell division for [1] asexual reproduction. *Hydra*, for example, produces buds that detach from the parent and take up life on their own. Cell division is also responsible for [2] growth, as seen in human embryos and plant roots. In an adult human, some cells, such as most [3] muscle and [4] nerve cells, cease to divide. Others, such as cells of the [5] liver, divide only if the organ is damaged. Some cells, such as those on the surface of the [6] skin and the lining of the [7] digestive tract, are constantly being abraded and lost. These cells are [8] replaced by cell division. In each of these cases, the new cells have exactly the same [9] numbers and [10] types of chromosomes as the parent cells, because of the way duplicated chromosomes divide in the process of [11] mitosis.

Growth, cell replacement, and reproduction require control of the rate and timing of cell division. Much has been learned by studying cells grown in laboratory [12] cultures. Cells growing in a laboratory dish will divide only when in contact with a solid [13] surface. In the body, this [14] anchorage dependence may keep normal cells from dividing if separated from their normal surroundings. Cells will multiply only until they touch one another, a phenomenon known as [15] density-dependent inhibition. Apparently, cells rely on proteins called [16] growth factors for division, and will stop dividing when cells are crowded and these substances are depleted.

It appears that growth factors influence cell division by acting on the cell-cycle [17] control system, a set of proteins that triggers and coordinates events in the cell cycle. The system automatically [18] stops cell division at several major checkpoints unless the "brakes" are overridden by go-ahead signals. There are checkpoints in the G_2 and M phases of the cell cycle, but the most important checkpoint for many cells is the [19] G_1 checkpoint. If a cell receives a go-ahead signal, in the form of a growth factor, at the G_1 checkpoint, the cell will proceed into the

20 S phase of the cell cycle, replicate its DNA, and eventually divide. (A growth factor probably acts on a cell by attaching to a 21 receptor protein in the cell membrane. This protein in turn generates a signal that acts on the cell-cycle control system within the cell.) In the absence of a go-ahead signal, a cell will cease dividing. Many of our cells that can no longer divide—22 nerve or muscle cells, for example—are stopped at the G_1 checkpoint.

Sometimes cells escape these control mechanisms, divide uncontrollably, and invade other body tissues. These 23 cancer cells can kill the organism. In cell culture, they can grow without being attached to a solid surface, are unaffected by density-dependent inhibition, and are less affected than normal cells by growth factors and 24 inhibiting signals. Cancer cells can go on dividing indefinitely (unlike normal cells, which can divide in culture for only about 25 50 generations). Cancer treatments, such as 26 radiation and 27 chemotherapy, slow cancer by interfering with 28 cell division. The anticancer drugs vinblastin and taxol prevent cell division by disrupting the 29 microtubles of the mitotic spindle.

Exercise 9 (Modules 8.12 – 8.13)

Compare asexual and sexual life cycles on the CD-ROM.

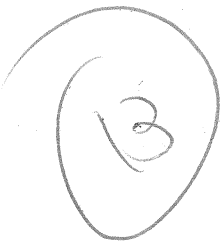
Describe the relationship between the terms or items in each of the following pairs.

1. Sex chromosomes and autosomes — Non-sex chromosomes
   XX & XY
   gametes
2. The two chromosomes of a homologous pair — carry genes for same traits at same place or locus; one from ♂ & one from ♀ parent
3. The two sister chromatids of a single chromosome
   exactly identical
   created by DNA replication
4. A diploid cell and a haploid cell
   2 homologous sets of chromosomes
   1 set
5. A somatic cell and a gamete — eggs & sperm
   body cells
6. An egg and a zygote — diploid
   haploid
7. Fertilization and meiosis — creates haploid gametes
   haploid cells fuse
8. Mitosis and meiosis → produces different gametes
   produces identical cells
9. X and Y chromosomes
   sex chromosomes
   XY = ♂ XY = ♀

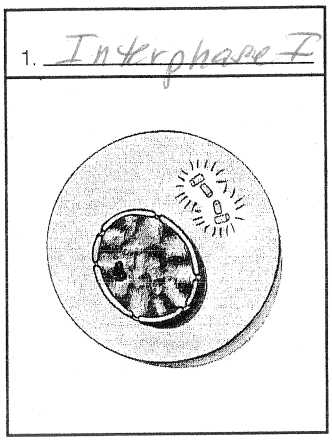
Exercise 10 (Module 8.14)

8E *The animation of meiosis on the CD-ROM will help you understand this process.*

Review meiosis by drawing in the chromosomes to complete this sequence of diagrams. Some have been done for you. Label **meiosis I, meiosis II,** the **phases** of meiosis I and II, a pair of **homologous chromosomes,** two **sister chromatids,** and an example of **crossing over.** To make you think carefully about meiosis, the diploid number is 6 in this example. (It is 4 in Module 8.14.)

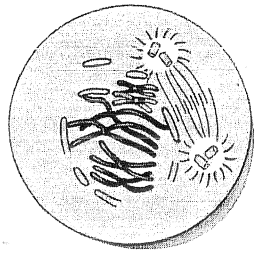


1. Interphase I

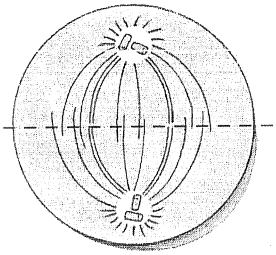


10. Meiosis I

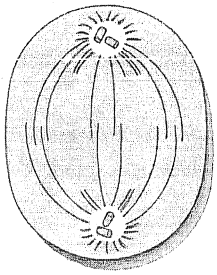
2. prophase I



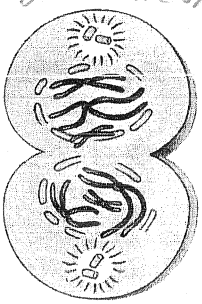
3. metaphase I



4. anaphase I

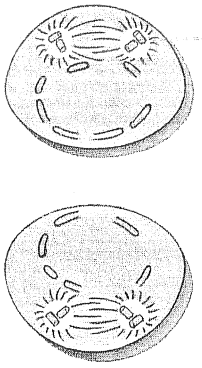


5. telophase I and cytokinesis

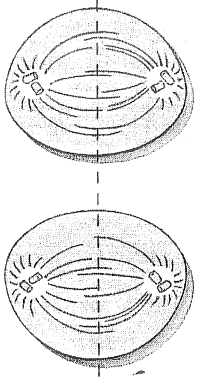


11. Meiosis II

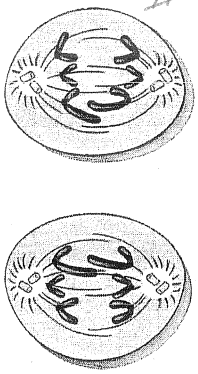
6. prophase II



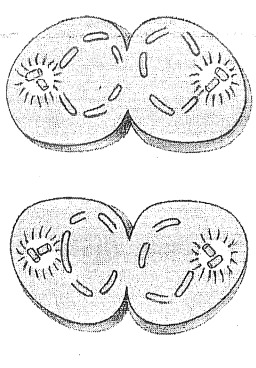
7. metaphase II



8. anaphase II



9. telophase II and cytokinesis



Exercise 11 (Module 8.15)

Compare mitosis and meiosis by completing this chart.

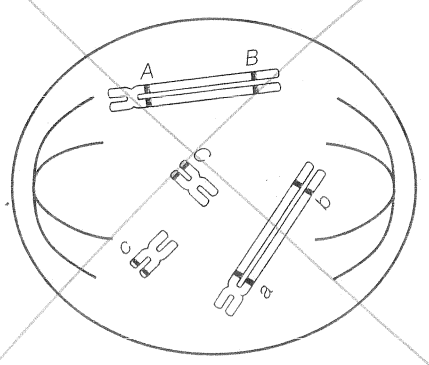
Mitosis	*Meiosis*
1. produces daughter cells identical to parent cell	Produces haploid daughter cells unlike parent cell
Involves one cell division	2. Involves 2 cell divisions
Produces two daughter cells	3. Produces 4 daughter cells
4. Sister chromatids of each chromosome separate	Homologous chromosomes pair and then separate
Individual chromosomes line up at metaphase plate	5. Homologous pairs line up
No crossing over occurs	6. Crossing over occurs
7. Provides for asexual repro, growth + repair	Needed for sexual reproduction

Exercise 12 (Modules 8.16 – 8.18)

8F

Why don't brothers and sisters look more alike or more like their parents? Several processes that are part of sexual reproduction assure variation among offspring. See how these processes contribute to genetic variation on the CD-ROM.

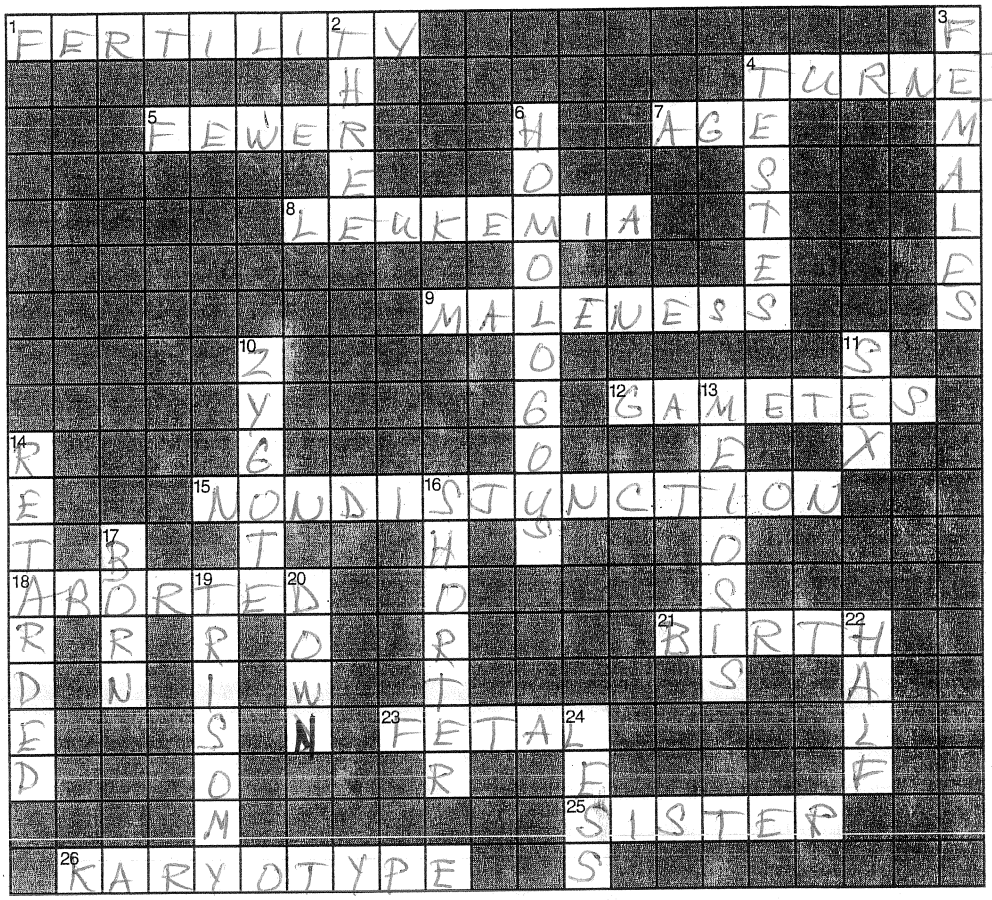
These modules discuss how orientation of chromosomes, random fertilization, and crossing over can lead to varied offspring. The diagram below shows the two homologous pairs of chromosomes in a cell with a diploid number of 4. Three different genes are also shown. On separate paper, complete the sketches described in questions 1 through 3.



1. Show how two different orientations of the chromosomes during metaphase I of meiosis could lead to the four different combinations of genes in gametes (assuming crossing over does not occur). (You don't need to show meiosis step by step—just the outcome.)
2. Show how crossing over could recombine genes on the larger pair of chromosomes, producing different gametes.
3. How many different combinations of genes in gametes are possible if these two processes happen simultaneously? Try to sketch all of them.

Exercise 13 (Modules 8.19 – 8.22)

These modules discuss human abnormalities resulting from extra or missing chromosomes. Review them by completing this crossword puzzle.



Across

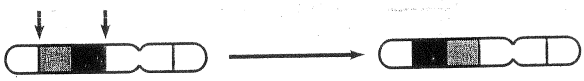
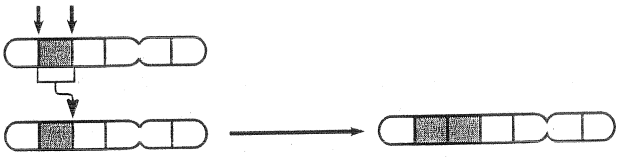
1. *XXX* females have limited ____ but are otherwise normal.
4. A woman with only one *X* chromosome is said to have ____ syndrome.
5. The *Y* chromosome carries ____ genes than the *X* chromosome.
7. The incidence of Down syndrome increases with the ____ of the mother.
8. Down syndrome individuals are prone to ____ and Alzheimer's disease.
9. A single *Y* chromosome is enough to produce "____."
12. Nondisjunction results in extra or missing chromosomes in ____.
15. ____ is when members of a pair of chromosomes fail to separate during meiosis.
18. Most human offspring with abnormal numbers of chromosomes are spontaneously ____.
21. Down syndrome is the most serious common ____ defect in the U.S.
23. Pregnant women over 35 years of age are candidates for ____ testing.
25. In meiosis II, ____ chromatids may fail to separate.
26. A ____ is a photographic inventory of an individual's chromosomes.

Down

2. A person with Down syndrome has ____ number-21 chromosomes.
3. ____ who are lacking an *X* chromosome are designated XO.
4. *XXY* or *XXYY* males have small ____ and feminine body contours.
6. In meiosis I, a pair of ____ chromosomes may fail to separate.
10. If a sperm fertilizes an egg with an extra chromosome, the ____ will have an extra chromosome.
11. Nondisjunction can alter the number of ____ chromosomes, as well as autosomes.
13. Chromosomal defects usually result from errors in ____.
14. Individuals with Down syndrome are usually mentally ____.
16. People with Down syndrome live ____-than-normal life spans.
17. Meiosis begins in a woman's ovaries before she is ____ and is completed years later.
19. An extra chromosome 21 is called ____ 21.
20. A person with an extra number-21 chromosome has ____ syndrome.
22. ____ of the eggs of a Down syndrome woman will have an extra chromosome.
24. An unusual number of sex chromosomes has ____ effect than an unusual number of autosomes.

Exercise 14 (Module 8.23)

Chromosomes sometimes break, their parts can become scrambled, and abnormalities can result. Match each of the diagrams of chromosome alterations with its name and a description of its effects.

Diagram	*Name*	*Effects*
1. 	C	X
2. 	D	W
3. 	B	Z
4. 	A	Y

Names: A. Deletion
B. Duplication
C. Inversion
D. Translocation

Effects: W. May cause chronic myelogenous leukemia in somatic cells
X. Least likely to have serious effects, because genes are still present in normal numbers
Y. Likely to have the most serious effects, as in *cri du chat* syndrome
Z. A chromosome fragment breaks off and joins a homologous chromosome

Testing Your Knowledge

Multiple Choice

1. There are a number of differences between fission of a bacterium and human cell division. Which of the following is *not* one of them?
   a. A bacterium has only one chromosome.
   b. Duplicated bacterial chromosomes attach to the plasma membrane.
   c. Bacteria are smaller and simpler than human cells.
   d. Bacteria have to duplicate their DNA before dividing.
   e. Human chromosomes are larger and more complex.

2. You would be unlikely to see which of the following human cells dividing?
   a. nerve cell
   b. skin cell
   c. cancer cell
   d. cell from an embryo
   e. intestinal lining cell

3. Which of the following correctly matches a phase of the cell cycle with its description?
   a. M—duplication of DNA
   b. S—immediately precedes cell division
   c. G_2—cell division
   d. G_1—immediately follows cell division
   e. All of the above are correctly matched.

4. Which of the following is *not* true of human somatic cells?
   a. They arise by mitotic cell division.
   b. They are haploid.
   c. They are body cells other than eggs and sperm.
   d. They are larger and more complex than bacterial cells.
   e. They contain 46 chromosomes.

5. In telophase of mitosis, the mitotic spindle breaks down and nuclear membranes form. This is essentially the opposite of what happens in
   a. prophase.
   b. interphase.
   c. metaphase.
   d. S phase.
   e. anaphase.

6. Sister chromatids
   a. cross over during prophase I of meiosis.
   b. separate during the first meiotic division.
   c. are produced during S phase between cell divisions.
   d. cross over during prophase II of meiosis.
   e. are also called homologous chromosomes.

7. Which of the following is *not* a function of mitotic cell division in animals?
   a. asexual reproduction
   b. growth
   c. repair of damaged organs
   d. production of gametes
   e. cell replacement

8. Meiosis
   a. is responsible for body growth and repair.
   b. halves the number of chromosomes in cells.
   c. is the process by which the body produces diploid cells.
   d. follows mitosis and splits the cytoplasm in two.
   e. is important in asexual reproduction.

9. Crossing over is
   a. important in genetic recombination.
   b. what makes a cell become cancerous.
   c. a key process that occurs during mitosis.
   d. an important mechanism of chromosome repair.
   e. what prevents cells from multiplying indefinitely in cell culture.

10. Human _____ are diploid, and human _____ are haploid.
    a. sex chromosomes . . . autosomes
    b. autosomes . . . sex chromosomes
    c. somatic cells . . . gametes
    d. gametes . . . somatic cells
    e. chromosomes . . . chromatids

11. Which of the following does *not* lead to genetic variability?
    a. random fertilization
    b. crossing over during meiosis
    c. division of chromosomes during anaphase of mitosis
    d. orientation of chromosomes during metaphase I of meiosis
    e. mutation

12. Most cells will divide if they receive the proper signal at a checkpoint in the ____ phase of the cell cycle.
    a. M
    b. G_1
    c. S
    d. G_2
    e. cytokinesis

13. Geneticists suspect that the extra chromosome seen in Down syndrome usually comes from the egg, rather than the sperm, because
    a. eggs are produced so rapidly that there is more chance for error.
    b. Down syndrome is due to a dominant gene in women, a recessive gene in men.
    c. most women inherit Down syndrome from their mothers.
    d. eggs are produced in much larger numbers than sperm.
    e. meiosis takes longer in the ovary, increasing the likelihood of error.

14. Which of the following chromosomal alterations would you expect to have the most drastic consequences?
    a. inversion
    b. duplication
    c. translocation
    d. deletion
    e. a and b are equally the most serious

15. Disorders involving unusual numbers of sex chromosomes show that "maleness" is caused by the
    a. presence of an *X* chromosome.
    b. presence of an *Y* chromosome.
    c. absence of an *X* chromosome.
    d. absence of an *Y* chromosome.
    e. absence of an *X* chromosome and presence of a *Y* chromosome.

Essay

1. Explain why, strictly speaking, the phrase "like begets like" applies only to asexual reproduction.
2. Briefly describe mitosis and cytokinesis and state their functions.
3. Describe how cancer cells differ from normal body cells.
4. Compare mitosis and meiosis. What are their functions? Which produces haploid cells? Diploid cells? What kinds of cells undergo mitosis and meiosis? What kinds of cells are produced by each? How many cells are produced?
5. How might the genes on the sister chromatids of a certain chromosome compare with each other and with the genes on the sister chromatids of the homologous chromosome?
6. Describe three aspects of sexual reproduction that lead to the production of varied offspring.
7. Explain how an error in meiosis can cause a baby to be born with an extra or missing chromosome.
8. About one in 700 babies born in the United States possesses an extra chromosome 21, resulting in Down syndrome. Why are few individuals seen who have extra copies of other chromosomes?

Applying Your Knowledge

Multiple Choice

1. In certain fungi and algae, cells undergo mitosis repeatedly without subsequently undergoing cytokinesis. What would result from this?
    a. a decrease in chromosome number
    b. inability to duplicate DNA
    c. division of the organism into many cells, most lacking nuclei
    d. large cells containing many nuclei
    e. a rapid rate of sexual reproduction
2. A human bone marrow cell, in prophase of mitosis, contains 46 chromosomes. How many chromatids does it contain altogether?
    a. 46
    b. 92
    c. 23
    d. 23 or 46, depending on when during prophase you look
    e. 46 or 92, depending on when during prophase you look
3. Which of the following is the most significant difference between mitosis and meiosis?
    a. Chromosomes are duplicated before mitosis.
    b. Meiosis is not followed by cytokinesis.
    c. Homologous pairs of chromosomes are split up in meiosis.
    d. A spindle formed of microtubules moves the chromosomes in mitosis.
    e. Crossing over occurs in mitosis.
4. If there are 22 chromosomes in the nucleus of a toad skin cell, a toad egg would contain ____ chromosomes.
    a. 22
    b. 44
    c. 11
    d. 33
    e. 88

5. Which of the following carry the same genetic information?
   a. sister chromatids
   b. X and Y chromosomes
   c. all autosomes
   d. homologous chromosomes
   e. all haploid cells

6. A cell biologist carefully measured the quantity of DNA in grasshopper cells growing in cell culture. Cells examined during the G_2 phase of the cell cycle contained 200 units of DNA. What would be the amount of DNA in one of the grasshopper daughter cells seen in telophase of mitosis?
   a. 50 units
   b. 100 units
   c. between 50 and 100 units
   d. 200 units
   e. 400 units

7. What would be the quantity of DNA in one of the grasshopper cells produced by telophase II of meiosis?
   a. 50 units
   b. 100 units
   c. between 50 and 100 units
   d. 200 units
   e. 400 units

8. The two chromosomes of a homologous pair
   a. carry identical genetic information at corresponding locations.
   b. carry information for the same characteristics at different locations.
   c. carry identical genetic information at different locations.
   d. carry information for the same characteristics at corresponding locations.
   e. Any of the above is possible.

9. A picture of a dividing pigeon cell taken through a microscope shows that the cell contains 7 chromosomes, each consisting of 2 chromatids. This picture must have been taken during
   a. metaphase of mitosis.
   b. prophase I of meiosis.
   c. telophase II of meiosis.
   d. prophase II of meiosis.
   e. telophase of mitosis.

10. A culture of mouse cells is treated with a chemical that interferes with the activity of microfilaments. Which of the following will probably be affected the most?
    a. mitosis
    b. chromosome duplication
    c. pairing of homologous chromosomes
    d. cytokinesis
    e. joining of sister chromatids at the centromere

11. A zoologist examined an intestine cell from a crayfish and counted 200 chromosomes, each consisting of 2 chromatids, at prophase I of mitosis. What would he expect to see in each of the four cells at telophase II of meiosis if he looked in the crayfish ovary?
    a. 50 chromosomes, each consisting of 2 chromatids
    b. 50 chromosomes, each consisting of 1 chromatid
    c. 100 chromosomes, each consisting of 2 chromatids
    d. 100 chromosomes, each consisting of 1 chromatid
    e. 200 chromosomes, each consisting of 1 chromatid

12. One chromosome of a homologous pair carries the genes *J* and *K*. The other chromosome of the pair carries the genes *j* and *k* at corresponding loci. Crossing over results in exchange of chromosome segments and production of gametes with new combinations of genes. A "recombinant"-type gamete resulting from this crossover might contain
    a. genes *J* and *K*.
    b. genes *j* and *K*.
    c. genes *J* and *j*.
    d. genes *j* and *k*.
    e. genes *K* and *k*.

13. Humans have 23 pairs of chromosomes, while our closest relatives, chimpanzees, have 24. Chromosome studies indicate that at some point early in human evolution, two chromosomes simultaneously broke into a large portion and a small portion. The large parts combined to form a large chromosome, and the small parts combined to form a much smaller chromosome, which was subsequently lost. This important chromosomal change could best be described as
    a. nondisjunction followed by deletion.
    b. translocation followed by deletion.
    c. duplication followed by deletion.
    d. translocation followed by inversion.
    e. nondisjunction followed by inversion.

14. A karyotype would be least likely to show which of the following?
    a. an extra chromosome
    b. part of a chromosome duplicated
    c. a missing chromosome
    d. part of a chromosome turned around
    e. a translocation

Essay

1. Recall how chemotherapy slows the growth of cancerous tumors. Common side effects of chemotherapy are hair loss, nausea, and loss of appetite. Why do you think that chemotherapy has its strongest side effects on the skin and lining of the digestive tract?

2. Most of the grasshopper cells examined by the cell biologist in multiple choice questions 6 and 7 above contained either 100 or 200 units of DNA. Some of the interphase cells, however, contained between 100 and 200 units. Explain what was happening in these cells.

3. A slide of dividing cells in an onion root tip (Figure 8.11A in the text) is a "snapshot" in time. Each cell is stopped at the particular point in its cell cycle when the slide was made. A biology student examined such a slide under a microscope. Out of 100 cells she caught in the act of dividing, 52 were in prophase, 8 in metaphase, 11 in anaphase, and 29 in telophase. Assuming that the cells are growing and dividing independently, what do these data tell you about the phases of mitosis in onion cells?

4. A white blood cell from a female golden retriever was found to contain a total of 78 chromosomes. How many different kinds (sizes and shapes) of chromosomes would you expect to find in the cell? Why?

5. The somatic cells of a mosquito contain three pairs of chromosomes—two large ones, two medium-sized ones, and two small ones. One large chromosome bears the *A* gene; its homologue bears the *a* gene. One medium-sized chromosome bears the *B* gene; its homologue bears the *b* gene. One small chromosome bears the C gene; its homologue bears the *c* gene. Sketch cells at metaphase I of meiosis in the ovary of the mosquito, showing the different alignments of chromosomes that are possible. Then show how these lead to different combinations of genes in the gametes. How many different combinations are possible in the eggs? In the sperm of a male mosquito with the same genes, how many different gene combinations are possible? If the male and female mate and her eggs are fertilized with his sperm, how many different combinations are possible in the zygotes?

6. One chromosome of a homologous pair carries genes *Q* and *R*. Its homologue carries genes *q* and *r*. Show how crossing over during meiosis could produce gametes with new combinations of genes. What combinations of genes occur in parental-type gametes? In recombinant-type gametes?

7. Which of the following abnormalities in sex chromosomes would result in a predominantly male phenotype? A predominantly female phenotype? Explain why. *XXXX, XXY, XYYY, X, XXYY*

Extending Your Knowledge

1. What are some features that you (and your siblings, if you have any) appear to have inherited from your parents? Why don't you look exactly like your parents (or siblings)?

2. Do you know the warning signs of cancer? Cancer is more common in older people, but even college students in their teens and twenties are not immune to its deadly effects. Next time you see a Cancer Society brochure or advertisement, it would be a good idea to read it.