CHAPTER 8

The Cellular Basis of Reproduction and Inheritance

Objectives

Introduction Describe the role of cell division in asexual and sexual reproduction of a sea star.

Connections Between Cell Division and Reproduction

8.1 Compare the relationship between a parent and its offspring resulting from asexual versus sexual reproduction.
8.2 Explain the significance of Virchow's principle regarding cellular reproduction.
8.3 Explain how daughter prokaryotic chromosomes are separated from each other during binary fission.

The Eukaryotic Cell Cycle and Mitosis

8.4 Compare the structure of prokaryotic and eukaryotic chromosomes.
8.5 Describe the stages and significance of the cell cycle.
8.6 List the phases of mitosis and describe the events characteristic of each phase. Recognize the phases of mitosis from diagrams and micrographs.
8.7 Compare cytokinesis in animals and plants.
8.8–8.9 Explain how anchorage, cell density, and growth factors control the cell cycle.
8.10 Explain how cancerous cells are different from healthy cells; distinguish between benign and malignant tumors; and explain the strategies behind some common cancer treatments.
8.11 Describe the functions of mitosis.

Meiosis and Crossing Over

8.12 Explain how chromosomes are paired.
8.13 Distinguish between (a) somatic cells and gametes, (b) diploid cells and haploid cells, and (c) autosomes and sex chromosomes.
8.14 List the phases of meiosis I and meiosis II and describe the events characteristic of each phase. Recognize the phases of meiosis from diagrams or micrographs.
8.15 Describe key differences between mitosis and meiosis. Explain how the end result of meiosis differs from that of mitosis.
8.16–8.18 Explain how independent orientation, crossing over, and random fertilization contribute to genetic variation in sexually reproducing organisms.

Alterations of Chromosome Number and Structure

8.19 Explain how and why karyotyping is performed.
8.20 Describe the causes and symptoms of Down syndrome.
8.21 Define nondisjunction and explain how it can occur.
8.22 Describe the consequences of abnormal numbers of sex chromosomes.
8.23 Describe the main types of chromosomal changes. Explain why cancer is not usually inherited.

Key Terms

life cycle
sexual reproduction
genome
asexual reproduction
chromosome
cell division
binary fission
chromatin
sister chromatid
centromere
cell cycle
interphase
mitosis
cytokinesis
mitotic phase
prophase
metaphase
anaphase
telophase
mitotic spindle
centrosome
cleavage furrow
cell plate
anchorage dependence
density-dependent inhibition
growth factor
cell cycle control system
cancer cell
tumor
benign tumor
malignant tumor
metastasis
carcinoma
sarcoma
leukemia
lymphoma
somatic cell
homologous chromosome
locus
autosome
sex chromosome
diploid cell
gamete
haploid cell
fertilization
zygote
meiosis
crossing over
chiasma
genetic recombination
karyotype
trisomy 21
Down syndrome
nondisjunction
deletion
duplication
inversion
translocation

Word Roots

ana- = up, throughout, again (*anaphase:* the mitotic stage in which the chromatids of each chromosome have separated and the daughter chromosomes are moving to the poles of the cell)

auto- = self (*autosome:* the chromosomes that do not determine gender)

bi- = two (*binary fission:* a type of cell division in which a cell divides in half)

centro- = the center; **-mere** = a part (*centromere:* the narrow "waist" of a condensed chromosome)

chiasm- = marked crosswise (*chiasma:* the X-shaped microscopically visible region representing homologous chromosomes that have exchanged genetic material through crossing over during meiosis)

chroma- = colored (*chromatin:* DNA and the various associated proteins that form eukaryotic chromosomes)

cyto- = cell; **-kinet** = move (*cytokinesis:* division of the cytoplasm)

di- = two (*diploid:* cells that contain two homologous sets of chromosomes)

fertil- = fruitful (*fertilization:* process of fusion of a haploid sperm and a haploid egg cell)

gamet- = a wife or husband (*gamete:* a haploid egg or sperm cell)

gen- = produce (*genome:* a cell's endowment of DNA)

inter- = between (*interphase:* time when a cell metabolizes and performs its various functions)

haplo- = single (*haploid:* cells that contain only one chromosome of each homologous pair)

karyo- = nucleus (*karyotype:* a display of the chromosomes of a cell)

meio- = less (*meiosis:* a variation of cell division which yields daughter cells with half as many chromosomes as the parent cell)

meta- = between (*metaphase:* the mitotic stage in which the chromosomes are aligned in the middle of the cell, at the metaphase plate)

soma- = body (*somatic:* body cells with 46 chromosomes in humans)

Lecture Outline

Introduction *How to Make a Sea Star—With and Without Sex*

A. Introduce the general topics of reproduction, genetics, and inheritance, perhaps tracing the pedagogical development of the chapters in this unit.

B. A life cycle is the sequence of life forms (and the processes forming them) from one generation to the next. Depending on one's needs, a life cycle can be more or less detailed. For example, use the sea star life cycle.

1. Adult sea star (sexual reproduction) → Fertilized egg (development) → Morula (development) → Young sea star (development) → Reproductively mature, adult sea star → etc. Possible asexual reproduction by fragmentation is mentioned.
2. Sexual reproduction involves passing traits from two parents to the next generation.
3. Asexual reproduction involves passing traits from only one parent to the next generation.
4. Cell division is the basis of all of the processes (developmental or reproductive) that link the phases in a life cycle.
   NOTE: There are two conflicting events in the whole life cycle progression: How, during reproduction, are faithful copies of organisms assured? How, during development, are subtle changes to the cells of a multicellular organism introduced?

I. Connections Between Cell Division and Reproduction

Module 8.1 Like begets like, more or less.

A. This is strictly true only for organisms reproducing asexually.

B. Single-celled organisms, like amoebas, can reproduce asexually by dividing in two. Each daughter cell receives an identical copy of the parent's genes (Figure 8.1A).

C. For multicellular organisms (and many single-celled organisms), the offspring are not genetically identical to the parents, but each is a unique combination of the traits of both parents (Figure 8.1B).

D. Breeders of domestic plants and animals manipulate sexual reproduction by selecting offspring that exhibit certain desired traits. In doing so, the breeders reduce the variability of the breed's population of individuals.
   NOTE: You might want to discuss the ethics of selective breeding as well as the impact of reduced variability on a population's survivorship. For example, some species have reduced genetic variability due to being pushed to the verge of extinction by human behaviors.

E. *Preview:* Observations of the work of breeders were part of the data Charles Darwin used in developing the theory of natural selection (Module 13.4).

Module 8.2 Cells arise only from preexisting cells.

A. This principle was formulated in 1858 by German physician Rudolf Virchow.

B. Cell reproduction is called **cell division.**

C. Cell division has two major roles. It enables a fertilized egg to develop through various embryonic stages, and for an embryo to develop into an adult organism. It ensures the continuity from generation to generation; it is the basis of both asexual reproduction and sperm and egg formation in sexual reproduction.

Module 8.3 Prokaryotes reproduce by binary fission.

A. Genes of most prokaryotes are carried on a circular DNA molecule. Prokaryotic chromosomes are simpler than eukaryotic chromosomes.

B. Packaging is minimal: The DNA is complexed with a few proteins and attached to the plasma membrane at one point.

C. Most of the DNA lies non-membrane-bounded, in a region of the cell called the nucleoid.

D. **Binary fission** (Figure 8.3A). Prior to dividing, an exact copy of the chromosome is made. The attachment point divides so that the two new chromosomes are attached at separate parts of the plasma membrane. As the cell elongates and new plasma membrane is added, the attachment points of the two chromosomes move apart. Recent evidence shows that the duplicate chromosomes are actively moving away from each other (Figure 8.3B). Finally, the plasma membrane and new cell wall "pinch" through the cell, separating the two chromosomes into two new, genetically identical cells.
Preview: Fission in sea anemones is discussed in Module 27.1.

II. The Eukaryotic Cell Cycle and Mitosis

Module 8.4 The large, complex chromosomes of eukaryotes duplicate with each cell division.

A. Whereas a typical bacterium might have 3000 genes, human cells, for example, have 50,000–100,000 (recent evidence shows that there may be as few as 26,000 to 30,000 genes in humans).

B. The majority of these genes are organized into several separate, linear chromosomes that are found inside the nucleus.

C. The DNA in eukaryotic chromosomes is complexed with protein in a much more complicated manner. This organizes and allows expression of much greater numbers of genes (Chapter 11).
Review: Module 4.6.

D. During the process of cell division **chromatin** condenses and the chromosomes become visible under the light microscope (Figure 8.4).

E. In multicellular plants and animals, the body cells (somatic cells) contain twice the number of chromosomes as the sex cells. Humans have 46 chromosomes in their somatic cells and 23 chromosomes in their sex cells. Different species may have different numbers of chromosomes.

F. The DNA molecule in each chromosome is copied prior to the chromosomes' becoming visible.

G. As the chromosomes become visible, each is seen to be composed of two identical **sister chromatids,** attached at the **centromere** (Figure 8.4B).

H. It is the sister chromatids that are parceled out to the daughter cells (the chromatids are then referred to as chromosomes). Each new cell gets a complete set of identical chromosomes (Figure 8.4C).

Module 8.5 The cell cycle multiplies cells.

NOTE: The result of this process (more or less) is two daughter cells that are genetically identical to each other and to their parental cell.

A. Most cells in growing, and fully grown, organisms divide on a regular basis (once an hour, once a day), although some have stopped dividing. This process allows new cells to replace worn-out or damaged cells.

B. Such dividing cells undergo a cycle, a sequence of steps that is repeated from the time of one division to the time of the next, called the **cell cycle** (Figure 8.5).

C. **Interphase** represents 90% or more of the total cycle time and is divided into G_1, S, and G_2 subphases.

D. During G_1, the cell increases its supply of proteins and organelles and grows in size.

E. During S, DNA synthesis (replication) occurs.

F. During G_2, the cell continues to prepare for the actual division, increasing the supply of other proteins, particularly those used in the process.

G. Cell division itself is called the mitotic phase (it excludes interphase) and involves two subprocesses, mitosis (nuclear division, the M phase) and cytokinesis (cytoplasmic division). Ask your students what the result would be if mitosis occurred without cytokinesis.

H. The overall result is two daughter cells, each with identical sets of chromosomes.

I. Mitosis is very accurate. In experiments with yeast, one error occurs every 100,000 divisions.

J. *Preview:* The molecular mechanism by which DNA is copied prior to mitosis is discussed in Modules 10.4 and 10.5.

Module 8.6 Cell division is a continuum of dynamic changes.

NOTE: If possible, show a video or film clip of the process. Stress the dynamic, repeating, and continuous nature of mitosis, pointing out that biologists divide the overall process into what appear to be natural phases, to make it easier to follow.

A. Interphase: duplication of the genetic material ends when chromosomes begin to become visible (Figure 8.6).

B. **Prophase** (the first stage of mitosis): The **mitotic spindle** is forming, emerging from **centrosomes** (also known as microtubule-organizing centers [MTOCs]). Prophase ends when the chromatin has completely coiled into chromosomes; nucleoli and nuclear membrane disperse. The mitotic spindle provides a scaffold for the movement of chromosomes and attaches to chromosomes at their kinetochore.
Review: The mitotic spindle is made of microtubules (Module 4.17).

C. **Metaphase:** The spindle is fully formed; chromosomes are aligned single file with centromeres on the metaphase plate (the plane that cuts the spindle's equator).

D. **Anaphase:** Chromosomes separate from the centromere, dividing to arrive at poles.
NOTE: The concept that a single chromosome can consist of a single chromatid or two chromatids and that when two chromatids separate they are then independent chromosomes can be confusing. The way to determine the number of chromosomes a cell contains is to count the centromeres.

E. **Telophase** is the reverse of prophase: Cell elongation continues, a nuclear envelop forms around chromosomes, chromosomes uncoil, and nucleoli reappear.

F. **Cytokinesis:** the division of the cytoplasm. This usually, but not always, accompanies telophase.

Module 8.7 Cytokinesis differs for plant and animal cells.

NOTE: The cells of advanced plants do not have centrioles (Figure 8.4A).

A. In animals, a ring of microfilaments contracts around the periphery of the cell, forming a **cleavage furrow** that eventually cleaves the cytoplasm (Figure 8.7A).

B. In plants, vesicles containing cell wall material collect among the spindle microtubules, in the center of the cell, then gradually fuse, from the inside out, forming a **cell plate** that gradually develops into a new wall between the two new cells. The membranes surrounding the vesicles fuse to form the new parts of the plasma membrane (Figure 8.7B).
NOTE: For the plant, the process of cytokinesis must accommodate the cell wall.

Module 8.8 Anchorage, cell density, and chemical growth factors affect cell division.

A. To grow and develop, or replenish and repair tissues, multicellular plants and animals must control when and where cell divisions take place.

B. Most animal and plant cells will not divide unless they are in contact with a solid surface; this is known as **anchorage dependence.**

C. Laboratory studies show that cells usually stop dividing when a single layer is formed and the cells touch each other (Figure 8.8A). This **density-dependent inhibition** of cell growth is controlled by the depletion of **growth factor** proteins in masses of crowded cells (Figure 8.8B). Growth factors are proteins secreted by cells that stimulate growth of other cells in close proximity.

Module 8.9 Growth factors signal the cell cycle control system.

A. The **cell cycle control system** regulates the events of the cell cycle. Three major checkpoints exist (Figure 8.9A):
1. At G_1 of interphase
2. At G_2 of interphase
3. At the M phase

B. If, at these checkpoints, a growth factor is released, the cell cycle will continue. If a growth factor is not released, the cell cycle will stop (Figure 8.9B).

C. *Preview:* This regulation is a type of signal transduction (Modules 11.13 and 5.13).

D. Nerve and muscle cells are nondividing cells stuck at the G_1 checkpoint.

Module 8.10 Connection: Growing out of control, cancer cells produce malignant tumors.

NOTE: Cancer is a general term for many diseases in multicellular animals and plants involving uncontrolled cell division with the resultant tumor metastasizing (Figure 8.10). Breast cancer is illustrated in this figure. For females at age 90 there is a 1 in 8 lifetime risk of breast cancer—the risk of dying of cardiovascular disease is much greater.
Preview: Lifestyle and cancer are discussed in Modules 11.19 and 21.20.

A. **Cancer cells** grown in culture are not affected by the growth factors that regulate density-dependent inhibition of cell division.

B. A **malignant tumor** consists of cancerous cells. These tumors **metastasize.** This is in contrast to **benign tumors,** which do not metastasize.
NOTE: This is not to say that a benign tumor cannot cause death.
NOTE: When someone dies of cancer, they rarely die as a result of the primary tumor; it is usually the metastases that kill them.

C. Cancers are named according to the tissue or organ of origin.

D. Usually, cancer cells do not exhibit density-dependent inhibition.

E. Some cancer cells divide even in the absence of growth factors.

F. Some cancer cells actually continually synthesize factors that keep them dividing. Thus, unlike normal mammalian cells (in culture), there is no limit to the number of times cancer cells can divide.

G. Radiation and chemotherapy are two treatments for cancer. Radiation disrupts the process of cell division, and since cancer cells divide more often than most normal cells, they are more likely to be affected by radiation. Chemotherapy involves drugs that, like radiation, disrupt cell division. Some of these drugs—for example, taxol—target the mitotic spindle.

Module 8.11 Review of the function of mitosis: Growth, cell replacement, and asexual reproduction.

A. Mitosis and cytokinesis (cell division) are used to add more cells to growing tissue (Figure 8.11A).

B. Cell division is also used to replace dead or damaged tissue (Figure 8.11B).

C. Cell division can be used in asexual reproduction, producing genetically identical offspring (Figure 8.11C).

III. Meiosis and Crossing Over

Module 8.12 Chromosomes are matched in homologous pairs.

A. In diploid organisms, **somatic cells** (nonsex cells) have pairs of homologous chromosomes. **Homologous chromosomes** share shape and genetic **loci,** and carry genes controlling the same inherited characteristics (Figure 8.12).

B. Each of the homologues is inherited from a separate parent.
NOTE: The sets are combined in the first cell following fertilization and passed down together from cell to cell during growth and development by mitosis.

C. In humans, 22 pairs, found in males and females, are **autosomes.** Two other chromosomes are **sex chromosomes.**

D. In mammalian females, there are two *X* chromosomes; in male mammals, an *X* and a *Y* chromosome.

E. *Preview:* Sex chromosomes, sex determination, and sex chromosome anomalies are discussed further in Modules 8.22, 9.21, 9.22, and 9.23.

Module 8.13 Gametes have a single set of chromosomes.

A. Adult animals have somatic cells with two sets of homologues (**diploid,** $2n$).

B. Sex cells (**gametes** = eggs and sperm) have one set of homologues (**haploid,** n). These cells are produced by meiosis.

C. Sexual life cycles involve the alternation between a diploid phase and a haploid phase (Figure 8.13).

D. The fusion of haploid gametes in the process of **fertilization** results in the formation of a diploid **zygote.**

Module 8.14 Meiosis reduces the chromosome number from diploid to haploid.

A. An understanding of the cell cycle is needed for an understanding of meiosis.

B. Meiosis occurs only in diploid cells.

C. Like mitosis, meiosis is preceded by a single duplication of the chromosomes.

D. The overall result of **meiosis** is four daughter cells, each with half the number of chromosomes.

E. Again, the process is dynamic but may stop at certain phases for long periods of time.

F. The process includes two consecutive divisions (meiosis I and meiosis II).

G. The halving of the chromosome number occurs in meiosis I (Figure 8.14). The end result is two haploid cells, with each chromosome consisting of two chromatids.

H. Sister chromatids separate in meiosis II (Figure 8.14).

I. The end result is four haploid cells
Preview: Gamete formation by meiosis is discussed in Module 27.4.

Module 8.15 Review: A comparison of mitosis and meiosis.

A. The cell diagrammed has four chromosomes, two homologous pairs (Figure 8.15).

B. All the events unique to meiosis occur in meiosis I. In prophase I, homologous chromosomes pair to form a tetrad, and crossing over occurs between homologous chromatids.
NOTE: This results in the formation of unique genetic combinations (Module 8.16).

C. Meiosis II is virtually identical to mitosis (except the cells are haploid).

D. Mitosis results in two daughter cells, each with the same chromosomes as the parent cell. Mitosis can happen in diploid or haploid cells.

E. Meiosis results in four daughter cells (or, at least, nuclei), each with half the number of chromosomes as the parent cell. Meiosis happens only in diploid cells.

Module 8.16 Independent orientation of chromosomes in meiosis and random fertilization lead to varied offspring.

A. During prophase I of meiosis, each homologue pairs up with its "other." During this process *X* and *Y* chromosomes behave as a homologous pair (Figure 8.16).
NOTE: This pairing of homologues is called synapsis.

B. When they separate at anaphase I, maternally and paternally inherited homologues move to one pole or the other independently of other pairs.
Preview: This is the basis of Mendel's Laws (Modules 9.3, 9.5, and 9.7).

C. Given n chromosomes, there are 2^n ways that different combinations of the half-pairs can move to one pole.

D. In humans, there are 2^{23}combinations of combining an individual's maternally inherited and paternally inherited homologues.

E. Combining gametes into zygotes suggests that there are $2^{23} \rightarrow 2^{23}$ combinations in the zygote (but see the next two modules).
Preview: The consequences of the large amount of genetic variation generated by sexual reproduction are contrasted with the lower levels of genetic variation associated with asexual reproduction in Module 27.1.

Module 8.17 Homologous chromosomes carry different versions of genes.

A. Simplified examples: coat color and eye color in mice.

B. *C* (agouti = brown) and *c* (white) for different versions of the coat-color gene and *E* (black) and *e* (pink) for different eye-color genes (Figure 8.17A).

C. In this example, with the information up to this point, there would be two possible outcomes for the genes on the two chromosomes in a gamete (2^1) (Figure 8.17B).

Module 8.18 Crossing over further increases genetic variability.

A. **Crossing over** is the exchange of corresponding segments between two homologues (sister chromatid exchange). The site of crossing over is called a **chiasma** (Figure 8.18A).

B. This happens between chromatids within tetrads as homologues pair up during synapsis (prophase I).

C. Crossing over produces new combinations of genes **(genetic recombination)** (Figure 8.18B).

D. Because crossing over can occur several times in variable locations among thousands of genes in each tetrad, the possibilities are much greater than calculated above. Essentially, two individual parents could never produce identical offspring from two separate fertilizations.
NOTE: It is for this reason that, with the exception of identical twins (and the like), everyone is a unique genetic entity never seen before and never to be seen again (with the advent of the successful cloning of mammals, I state this with much less confidence than I once did).

E. *Preview:* The mechanisms discussed here that result in new genetic combinations, meiosis and fertilization, do not occur in bacteria. However, there are several processes in which bacteria engage that result in the production of new genetic combinations (Modules 12.1 and 12.2).

IV. Alterations of Chromosome Number and Structure

Module 8.19 A **karyotype** is a photographic inventory of an individual's chromosomes.

A. Blood samples are cultured for several days under conditions that promote cell division of white blood cells (Figure 8.19).
NOTE: Red blood cells lack nuclei and do not divide.

B. The culture is treated with a chemical that stops cell division at metaphase.

C. White blood cells are separated, stained, and squashed (to spread out the chromosomes) following the procedure.

D. The individual chromosomes in a photograph are cut out and rearranged by number.

E. From this the genetic sex of an individual can be determined and abnormalities in chromosomal structure and number can be detected (Figure 8.20A).

Module 8.20 Connection: An extra copy of chromosome 21 causes Down syndrome.

A. In most cases, human offspring that develop from zygotes with an incorrect number of chromosomes abort spontaneously.

B. **Trisomy 21** is the most common chromosome-number abnormality, occurring in about 1 out of 700 births (Figure 8.20A).

C. **Down syndrome** includes a wide variety of physical, mental, and disease-susceptibility features (Figure 8.20B).

D. The incidence of Down syndrome increases with the age of the mother (Figure 8.20C).
NOTE: The age of the father is also correlated with an increased incidence of Down syndrome.

Module 8.21 Accidents during meiosis can alter chromosome number.

A. *Review:* Meiosis (Module 8.14).

B. **Nondisjunction** is the failure of chromosome pairs to separate during either meiosis I or meiosis II (Figure 8.21A, B).

C. Fertilization of an egg resulting from nondisjunction with a normal sperm results in a zygote with an abnormal chromosome number (Figure 8.21C).

D. The explanation for the increased incidence of trisomy 21 among older women is not entirely clear but probably involves the length of time a woman's developing eggs are in meiosis. Meiosis begins in all eggs before the woman is born, and finishes as each egg matures in the monthly cycle following puberty. Eggs of older women have been "within" meiosis longer.

Module 8.22 Connection: Abnormal numbers of sex chromosomes do not usually affect survival.

A. Unusual numbers of sex chromosomes upset the genetic balance less than do unusual numbers of autosomes, perhaps because the *Y* chromosome carries fewer genes and extra *X* chromosomes are inactivated as Barr bodies in females.
Preview: X-chromosome inactivation is discussed in Module 11.7.

B. Abnormalities in sex chromosome number result in individuals with a variety of different characteristics, some more seriously affecting fertility or intelligence than others (Table 8.22).

C. The greater the number of *X* chromosomes (beyond 2), the more likely is (and the greater the severity of) mental retardation.

D. These sex chromosome abnormalities illustrate the crucial role of the *Y* chromosome in determining a person's sex. A single *Y* is enough to produce "maleness," even in combination with a number of *X*s, whereas the lack of a *Y* results in "femaleness" (Figure 8.22A and B).

Module 8.23 Connection: Alterations of chromosome structure can cause birth defects and cancer.

A. **Deletions, duplications,** and **inversions** occur within one chromosome (Figure 8.23A).

B. Inversions are less likely to produce harmful effects than deletions or duplications because all the chromosome's genes are still present.

C. Duplications, if they result in the duplication of an oncogene in somatic cells, may increase the incidence of cancer.

D. **Translocation** involves the transfer of a chromosome fragment between nonhomologous chromosomes (Figure 8.23B).

E. Translocations may or may not be harmful. One type of translocation results in Down syndrome.

F. Chromosomal changes in somatic cells may increase the risk of cancer (Figure 8.23C).
Preview: The genetic basis of cancer is discussed in more detail in Modules 11.1–11.18.

Class Activities

1. Show a video or film clip that illustrates the dynamic development of the early, few-cell to larval stages of a tadpole or echinoderm as a basis from which to start this lecture. Time-lapse movies of mitosis are also valuable for stressing the dynamic nature of this process. Be sure to describe any

change in the time frame used in the films. Ask students to watch for points at which there are natural hesitations in the flow of activity, or events that might be used to divide the process into phases. Then go over the process with figures from the text, pointing out the fact that biologists have divided up the process into what appear to be natural phases, to make it easier to follow.

2. Sets of interconnected plastic beads can be used to demonstrate the behavior of chromosomes during both the cell cycle and meiosis.
3. Give your students photographs that they can use to construct karyotypes. See if they can use these karyotypes to diagnose the sex of an individual as well as chromosomal abnormalities.

Transparency Acetates

Figure 8.3A	Binary fission of a prokaryotic cell
Figure 8.4B	Electron micrograph of a duplicated chromosome
Figure 8.4C	Chromosome duplication and distribution *(combined with Figure 8.4B)*
Figure 8.5	The eukaryotic cell cycle
Figure 8.6	Mitosis (Part 1)
Figure 8.6	Mitosis (Part 2)
Figure 8.7A	Cleavage of an animal cell
Figure 8.7B	Cell plate formation in a plant cell
Figure 8.8A	An experiment demonstrating density-dependent inhibition, using animal cells grown in culture
Figure 8.8B	An experiment demonstrating the effect of growth factors on the division of cultured animal cells
Figure 8.9A	Mechanical model for the cell cycle control system
Figure 8.9B	How a growth factor signals the cell cycle control system
Figure 8.10	Growth and metastasis of a malignant (cancerous) tumor of the breast
Figure 8.11B	Cell replacement (in skin)
Figure 8.12	A homologous pair of chromosomes
Figure 8.13	The human life cycle
Figure 8.14	Meiosis (Part 1)
Figure 8.14	Meiosis (Part 2)
Figure 8.15	Comparison of mitosis and meiosis
Figure 8.16	Results of the independent orientation of chromosomes at metaphase I
Figure 8.17A	Differing genetic information on homologous chromosomes
Figure 8.18A	Chiasmata
Figure 8.18B	How crossing over leads to genetic recombination
Figure 8.19	Preparation of a karyotype from a blood sample
Figure 8.20C	Maternal age and Down syndrome
Figure 8.21A	Nondisjunction in meiosis I
Figure 8.21B	Nondisjunction in meiosis II
Figure 8.21C	Fertilization after nondisjunction in the mother
Figure 8.22A	A man with Klinefelter syndrome (XXY)
Figure 8.22B	A woman with Turner syndrome (XO)

Table 8.22	Abnormalities of sex chromosome number in humans
Figure 8.23A	Alterations of chromosome structure involving one chromosome or a homologous pair
Figure 8.23B	Chromosomal translocation between nonhomologous chromosomes
Figure 8.23C	The translocation associated with chronic myelogenous leukemia

Media

See the beginning of this book for a complete description of all media available for instructors and students. Animations and videos are available in the Campbell Image Presentation Library. Media Activities and Thinking as a Scientist investigations are available on the student CD-ROM and web site.

Animations and Videos	File Name
Mitosis Overview Animation	08-06a-MitosisOverviewAnim.mov
Late Interphase Animation	08-06b-LateInterphaseAnim.mov
Prophase Animation	08-06c-ProphaseAnim.mov
Late Prophase Animation	08-06d-LateProphaseAnim.mov
Metaphase Animation	08-06e-MetaphaseAnim.mov
Anaphase Animation	08-06f-AnaphaseAnim.mov
Telophase Animation	08-06g-TelophaseAnim.mov
Cytokinesis Animation	08-06h-CytokinesisAnim.mov
Animal Mitosis Video	08-06-AnimalMitosisVideo-B.mov
Animal Mitosis Video	08-06-AnimalMitosisVideo-S.mov
Hydra Budding Video	08-11C-HydraBuddingVideo-B.mov
Hydra Budding Video	08-11C-HydraBuddingVideo-S.mov
Interphase I Animation	08-14a-InterphaseIAnim.mov
Prophase I Animation	08-14b-ProphaseIAnim.mov
Metaphase I Animation	08-14c-MetaphaseIAnim.mov
Anaphase I Animation	08-14d-AnaphaseIAnim.mov
Telophase I & Cytokinesis Animation	08-14e-TelophaseICytokinAnim.mov
Meiosis II & Cytokinesis Animation	08-14f-MeiosisIICytokinAnim.mov
Crossing Over Animation	08-18B-CrossingOverAnim.mov

Activities and Thinking as a Scientist	Module Number
Web/CD Activity 8A: *The Cell Cycle*	8.5
Web/CD Activity 8B: *Mitosis and Cytokinesis Animation*	8.6
Web/CD Thinking as a Scientist: *How Much Time Do Cells Spend in Each Phase of Mitosis?*	8.6
Web/CD Activity 8C: *Mitosis and Cytokinesis Video*	8.7
Web/CD Activity 8D: *Connection: Causes of Cancer*	8.10
Web/CD Activity 8E: *Asexual and Sexual Life Cycles*	8.13
Web/CD Activity 8F: *Meiosis Animation*	8.14
Web/CD Activity 8G: *Origins of Genetic Variation*	8.18
Web/CD Thinking as a Scientist: *How Is Crossing Over Measured in the Fungus* Sordaria*?*	8.18