10–2 Cell Division

Guide for Reading

Key Concepts

- What are the main events of the cell cycle?
- What are the four phases of mitosis?

Vocabulary

mitosis
cytokinesis
chromatid
centromere
interphase
cell cycle
prophase
centriole
spindle
metaphase
anaphase
telophase

Reading Strategy: Outlining As you read this section, outline the major events of the cell cycle. Write a few sentences to describe the activity of chromosomes as they progress through each part of the cell cycle.

What do you think would happen if a cell were simply to split into two, without any advance preparation? Would each daughter cell have everything it needed to survive? Because each cell has only one set of genetic information, the answer is no. Every cell must first copy its genetic information before cell division begins. Each daughter cell then gets a complete copy of that information.

In most prokaryotes, the rest of the process of cell division is a simple matter of separating the contents of the cell into two parts. In eukaryotes, cell division is more complex and occurs in two main stages. The first stage, division of the cell nucleus, is called **mitosis** (my-TOH-sis). The second stage, division of the cytoplasm, is called **cytokinesis** (sy-toh-kih-NEE-sis).

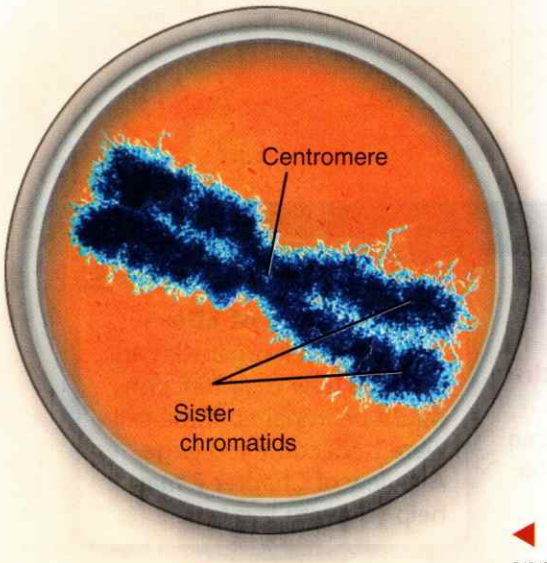
Many organisms, especially unicellular ones, reproduce by means of mitosis and cytokinesis. Reproduction by mitosis is classified as asexual, since the cells produced by mitosis are genetically identical to the parent cell. Mitosis is also the source of new cells when a multicellular organism grows and develops. In humans, for example, mitosis begins shortly after the egg is fertilized, producing the vast numbers of cells needed for the embryo to take form.

Chromosomes

In eukaryotic cells, the genetic information that is passed on from one generation of cells to the next is carried by chromosomes. Chromosomes are made up of DNA—which carries the cell's coded genetic information—and proteins. The cells of every organism have a specific number of chromosomes. The cells of fruit flies, for example, have 8 chromosomes; human cells have 46 chromosomes; and carrot cells have 18 chromosomes.

Chromosomes are not visible in most cells except during cell division. This is because the DNA and protein molecules that make up the chromosomes are spread throughout the nucleus. At the beginning of cell division, however, the chromosomes condense into compact, visible structures that can be seen through a light microscope.

Well before cell division, each chromosome is replicated, or copied. Because of this, each chromosome consists of two identical "sister" **chromatids** (KROH-muh-tidz), as shown in **Figure 10–3.** When the cell divides, the "sister" chromatids separate from each other. One chromatid goes to each of the two new cells.



(magnification: 20,000×)

◀ **Figure 10–3** This is a human chromosome shown as it appears through an electron microscope. Each chromosome has two sister chromatids attached at the centromere. **Inferring** *Why is it important that the sister chromatids are identical?*

Each pair of chromatids is attached at an area called the centromere (SEN-troh-meer). **Centromeres** are usually located near the middle of the chromatids, although some lie near the ends. A human body cell entering cell division contains 46 chromosomes, each of which consists of two chromatids.

The Cell Cycle

At one time, biologists described the life of a cell as one cell division after another separated by an "in-between" period of growth called **interphase.** We now appreciate that a great deal happens in the time between cell divisions, and use a concept known as the cell cycle to represent recurring events in the life of the cell. The **cell cycle** is the series of events that cells go through as they grow and divide. **During the cell cycle, a cell grows, prepares for division, and divides to form two daughter cells, each of which then begins the cycle again.** The cell cycle is shown in **Figure 10–4.**

The cell cycle consists of four phases. Mitosis and cytokinesis take place during the M phase. Chromosome replication, or synthesis, takes place during the S phase. When the cell copies the chromosomes, it makes a duplicate set of DNA. Between the M and S phases are G_1 and G_2. The *G* in the names of these phases stands for "gap," but the G_1 and G_2 are definitely not periods when nothing takes place. They are actually periods of intense growth and activity.

Events of the Cell Cycle

During the normal cell cycle, interphase can be quite long, whereas the process of cell division takes place quickly. Interphase is divided into three phases: G_1, S, and G_2.

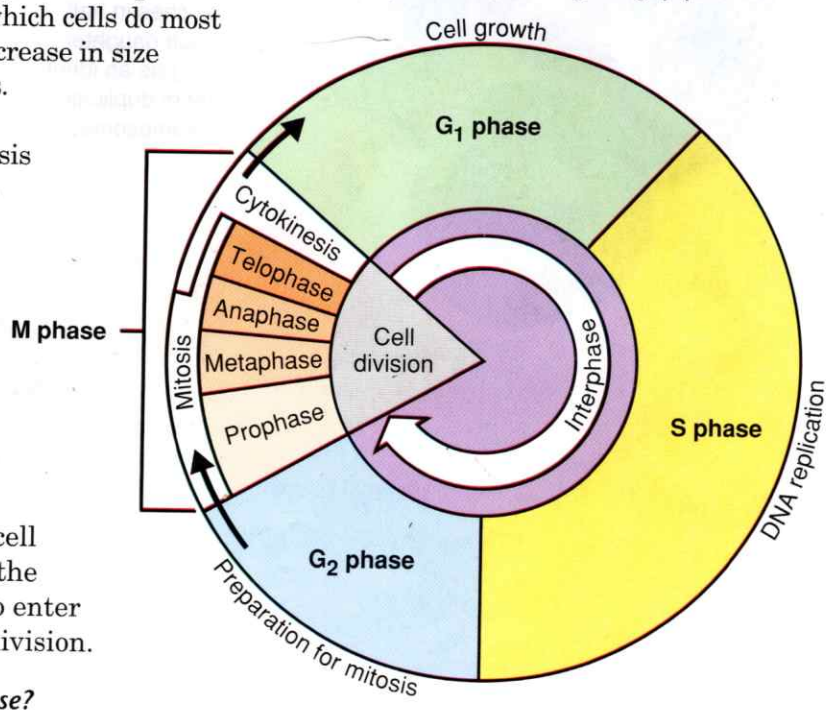
The G_1 phase is a period of activity in which cells do most of their growing. During this phase, cells increase in size and synthesize new proteins and organelles.

G_1 is followed by the S phase, in which chromosomes are replicated and the synthesis of DNA molecules takes place. Key proteins associated with the chromosomes are also synthesized during the S phase. Usually, once a cell enters the S phase and begins the replication of its chromosomes, it completes the rest of the cell cycle.

When the DNA replication is completed, the cell enters the G_2 phase. G_2 is usually the shortest of the three phases of interphase. During the G_2 phase, many of the organelles and molecules required for cell division are produced. When the events of the G_2 phase are completed, the cell is ready to enter the M phase and begin the process of cell division.

CHECKPOINT *What happens during the G_1 phase?*

Figure 10–4 **During the cell cycle, the cell grows, replicates its DNA, and divides into two daughter cells.** DNA synthesis takes place during the S phase. Cell division takes place during the M phase. G_1 and G_2 are gap phases.



Go Online NSTA SCILINKS
For: Links on cell division
Visit: www.SciLinks.org
Web Code: cbn-3102

Mitosis

Biologists divide the events of mitosis into four phases: prophase, metaphase, anaphase, and telophase. Depending on the type of cell, the four phases of mitosis may last anywhere from a few minutes to several days. As you read about each phase of mitosis, look at **Figure 10–5.**

Prophase The first and longest phase of mitosis, **prophase,** can take as much as 50 to 60 percent of the total time required to complete mitosis. During prophase, the chromosomes become visible. The **centrioles** (SEN-tree-ohlz), two tiny structures located in the cytoplasm near the nuclear envelope, separate and take up positions on opposite sides of the nucleus.

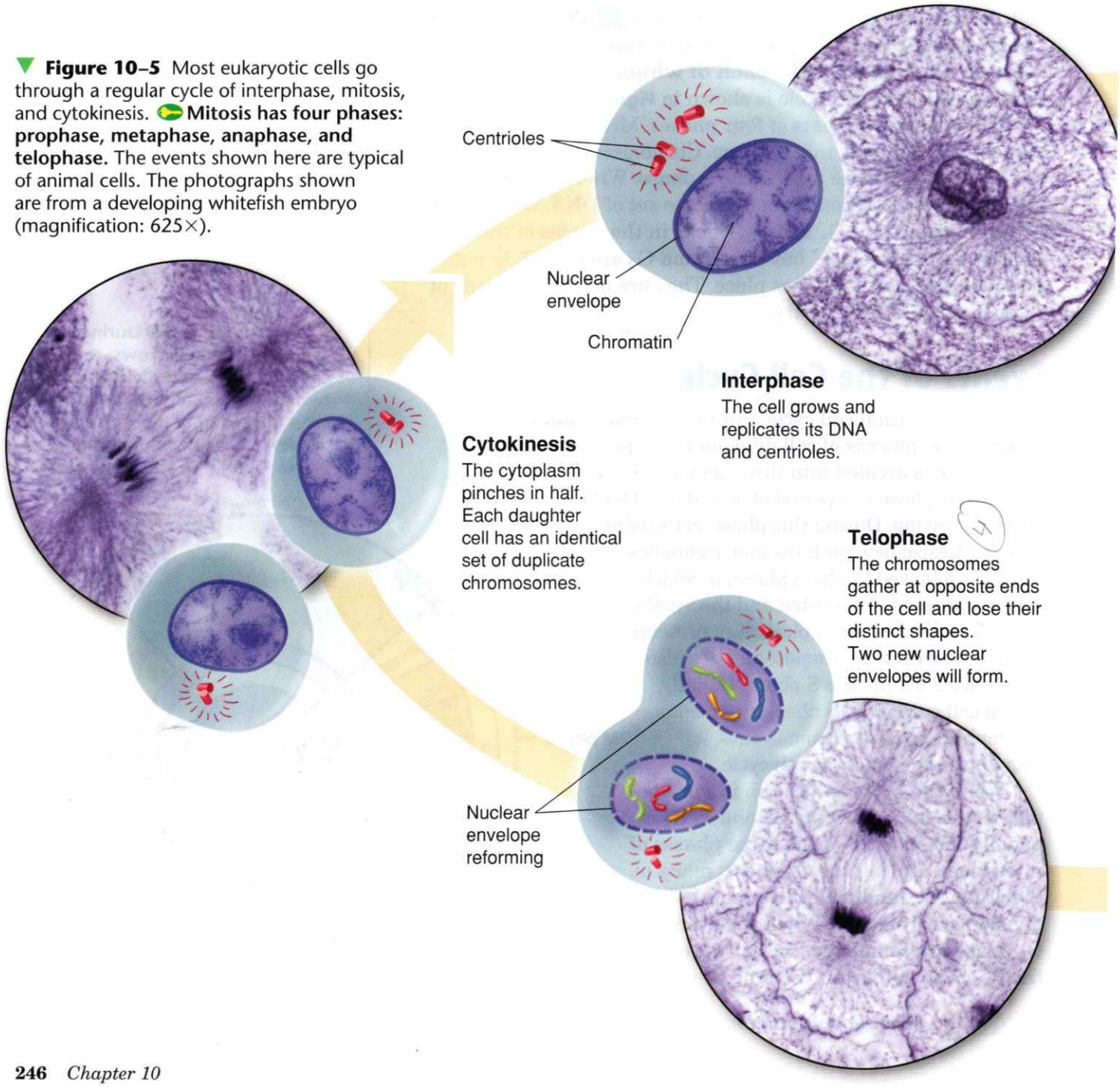


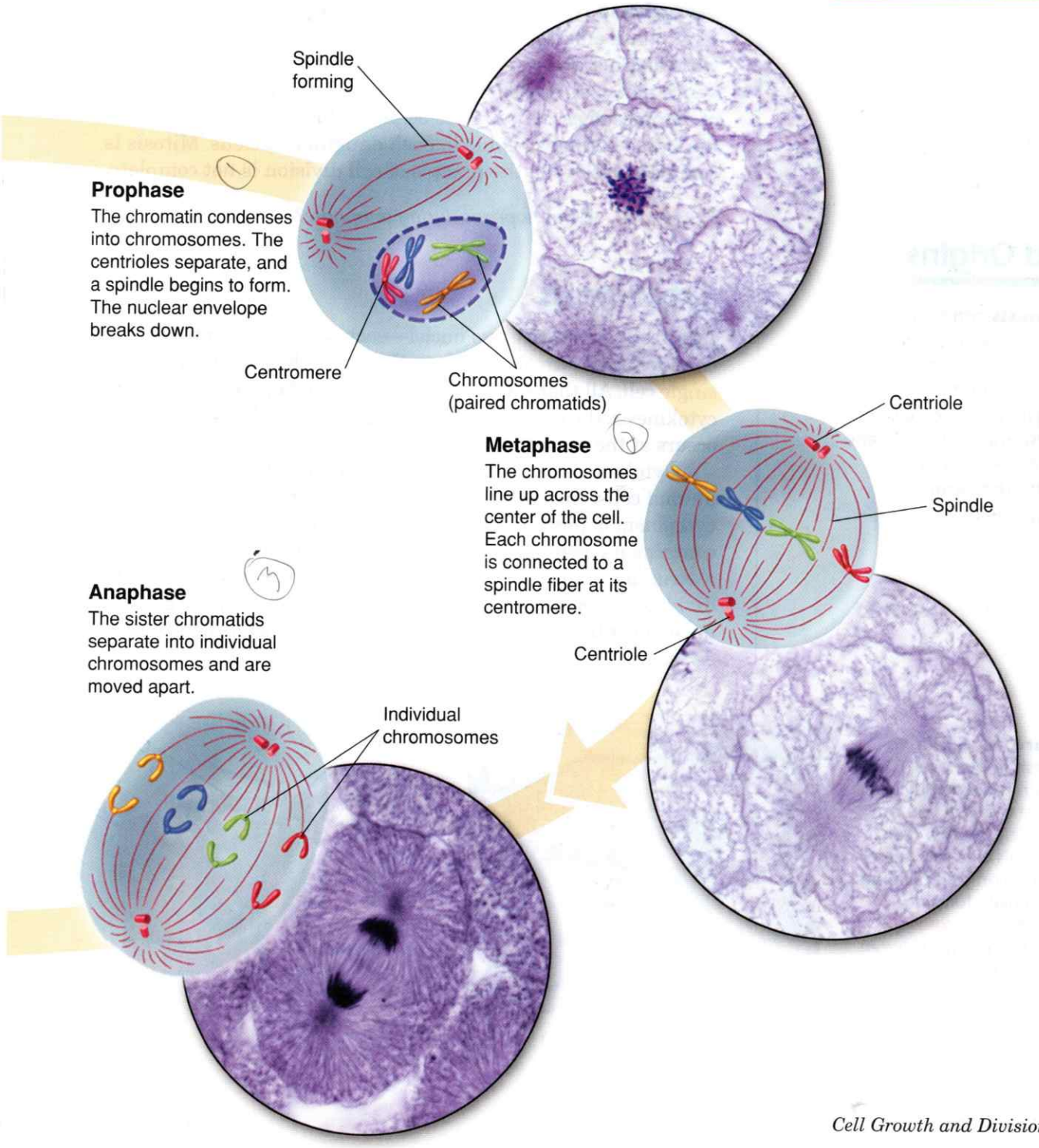
Figure 10–5 Most eukaryotic cells go through a regular cycle of interphase, mitosis, and cytokinesis. **Mitosis has four phases: prophase, metaphase, anaphase, and telophase.** The events shown here are typical of animal cells. The photographs shown are from a developing whitefish embryo (magnification: 625×).

The centrioles lie in a region called the centrosome that helps to organize the **spindle,** a fanlike microtubule structure that helps separate the chromosomes. During prophase, the condensed chromosomes become attached to fibers in the spindle at a point near the centromere of each chromatid. Interestingly, plant cells do not have centrioles, but still organize their mitotic spindles from similar regions.

Near the end of prophase, the chromosomes coil more tightly. In addition, the nucleolus disappears, and the nuclear envelope breaks down.

CHECKPOINT ***What is the function of the spindle?***

Go Online
active art
For: Cell Cycle activity
Visit: PHSchool.com
Web Code: cbp-3102



Metaphase The second phase of mitosis, **metaphase,** often lasts only a few minutes. During metaphase, the chromosomes line up across the center of the cell. Microtubules connect the centromere of each chromosome to the two poles of the spindle.

Anaphase **Anaphase** is the third phase of mitosis. During anaphase, the centromeres that join the sister chromatids split, allowing the sister chromatids to separate and become individual chromosomes. The chromosomes continue to move until they have separated into two groups near the poles of the spindle. Anaphase ends when the chromosomes stop moving.

Telophase Following anaphase is **telophase,** the fourth and final phase of mitosis. In telophase, the chromosomes, which were distinct and condensed, begin to disperse into a tangle of dense material. A nuclear envelope re-forms around each cluster of chromosomes. The spindle begins to break apart, and a nucleolus becomes visible in each daughter nucleus. Mitosis is complete. However, the process of cell division is not complete.

CHECKPOINT ***What happens during anaphase?***

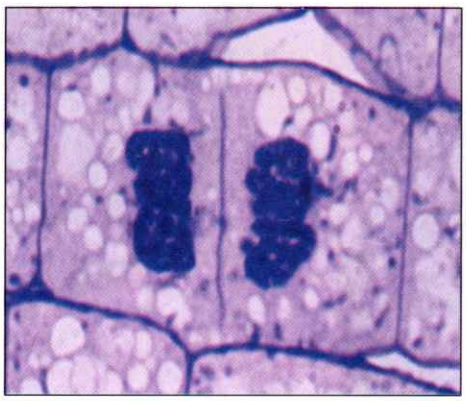
Word Origins

Cytokinesis comes from the Greek words *kytos,* meaning "hollow vessel," and *kinesis,* meaning "motion." The prefix *cyto-* refers to cells, so *cytokinesis* means movement within the cell. **What do you think the term *cytotoxic* means?**

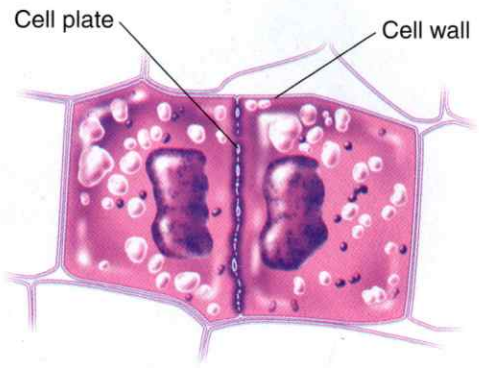
Cytokinesis

As a result of mitosis, two nuclei—each with a duplicate set of chromosomes—are formed, usually within the cytoplasm of a single cell. All that remains to complete the M phase of the cycle is cytokinesis, the division of the cytoplasm itself. Cytokinesis usually occurs at the same time as telophase.

Cytokinesis can take place in a number of ways. In most animal cells, the cell membrane is drawn inward until the cytoplasm is pinched into two nearly equal parts. Each part contains its own nucleus and cytoplasmic organelles. In plants, a structure known as the cell plate forms midway between the divided nuclei, as shown in **Figure 10–6.** The cell plate gradually develops into a separating membrane. A cell wall then begins to appear in the cell plate.



(magnification: 2200×)



▶ **Figure 10–6** During cytokinesis in plant cells, the cytoplasm is divided by a cell plate. The thin line you can see between the two dark nuclei in this electron micrograph of onion cells dividing is the cell plate forming.
Interpreting Graphics
What structure forms between the divided nuclei?