CHAPTER 2

The Cell

Introduction

Powerful instruments such as electron microscopes reveal more detail of the inner workings of cells than ever before. Therefore, new texts can offer increasing amounts of cytological information, which can be overwhelming to students. You, the instructor, must decide what amount is appropriate for teaching gross anatomy. In a basic gross anatomy course, there is not enough time to go into great detail, but a basic knowledge of cytology is helpful in understanding anatomy, particularly regarding function of tissues and organs. Your challenge is to simplify, summarize, and offer analogies in this somewhat abstract subject area. If students have time and interest, they can always do further study on their own.

Chapter Learning Outcomes

1. Identify and explain the functions of the plasmalemma, cytoplasm, and nonmembranous and membranous organelles.
2. Explain how cells can be interconnected to maintain structural stability in body tissues.
3. Summarize the life cycle of a cell and how cells divide by the process of mitosis.

Teaching Strategies

1. Lecture Ideas

a. Figure 2.3 and Spotlight Figure 2.4 in the text are excellent figures to introduce membrane structure, membrane permeability, and passive and active membrane transport processes. Use Figure 2.3 to explain how membrane structure determines permeability characteristics, and Spotlight Figure 2.4 to explain diffusion, osmosis, facilitated diffusion, active transport, endocytosis, and exocytosis. Then, while still referring to the Spotlight Figure, use the examples of each process that are given in the text (and any others you may think of) to help students understand how these processes occur naturally within the body.

2. Lab Ideas

a. A simple and beneficial lab activity involves taking a swab of cheek cells, preparing an unstained slide and then a stained slide (methylene blue is a good all-purpose nuclear stain), and finally, viewing these slides through a compound light microscope if one is available. In doing so, students learn about the following:

- *Slide preparation.*
- *Organelles.* Ask students the following questions: What organelles are visible with a compound light microscope using first unstained material and then stained material? What organelles are not visible when following this same sequence of steps? What advantages are there to staining a cell, or parts of a cell?
- *The benefit of staining procedures.* This will be particularly helpful later on when students are learning about epidermal strata and white blood cells, which are identified by their ability to bind stains (eosinophils, basophils, neutrophils). This activity will drive home the necessity of using some type of contrast enhancement technique (e.g., staining with methylene blue) to see cellular detail.
- *The limitations of light micrography.* If you don't have access to electron microscopes, then direct students to look at photos in the textbook (e.g., Figure 2.5b, 2.6a, 2.7a, 2.9a, 2.9c, or 2.11) or search online for electron micrographs ("SEM and TEM pictures").

3. Analogies

a. By comparing the cell to a "town" or "city," students can visualize the cell diagram as a map and each organelle as a location providing a needed service to the community. Try the following comparisons:

- **Plasmalemma or cell membrane or plasma membrane.** This is the perimeter fence around this town or city. It functions as a container providing shape and a semipermeable barrier for the cell contents. It is a security system and only allows those substances that it recognizes or that have a key (a specialized molecule or molecular group attached to it) to enter the cell. Essentially, it is a city-wide security system. As with any security system, some substances enter and exit more easily than others. Those that are preapproved and have a valid ID require little or no effort and move through by *passive transport*, such as water, lipids, some food molecules, some hormones, and some drugs. Other substances require more work, time, effort, and assistance, and need energy to be expended to get in or out. These substances require *active transport*, which can be as simple as providing a key or as complex as requiring an escort, which obviously takes more energy. Examples include the transport of sugars such as glucose (which needs the hormone insulin to trigger the signal transduction pathway controlling blood sugar concentrations), large proteins, and many minerals and other molecules with electrochemical charges on them.

Membrane-bound organelles include the nucleus, endoplasmic reticulum, Golgi apparatus, and mitochondria. All of these organelles are linked directly or indirectly through continuous membranes or the movement of vesicles. Nonmembranous organelles include ribosomes, centrioles, and the cytoskeleton. Try the following comparisons:

- **Mitochondria:** Power suppliers, generators, or batteries of the cell; the fuel for these generators is sugar, which they convert into chemical energy in the form of ATP, which is then exchanged and converted among the various structures of the cell like currency. Cells that are working a lot have more mitochondria and can produce more mitochondria based on demand. Examples are muscles, brain cells, liver tissues, and sperm.

- **Nucleus:** Town or city hall where all important records and information to operate the city are kept. This information is in the form of DNA, as *chromatin* (opened up and exposed for copying) when the city is in operation, and as condensed *chromosomes* (packed up or filed) when information is to be stored or moved, as when cells divide and separate.
- **Endoplasmic reticulum:** A transportation grid or system like a railroad or canal system. Along some of the sides or banks are industrial sites (*fixed ribosomes*) where proteins are manufactured. This is the rougher part of town—the *rough ER*. As distance from the nucleus increases, fewer ribosomes are attached and the *smooth ER* predominates (like the suburbs).
- **Golgi bodies or Golgi apparatus:** The UPS Store®. Located at the outskirts of the ER (derived from ER), the Golgi apparatus packages manufactured proteins for shipping or storage. The packages are known as *vesicles*. The substances might be enzymes to assist with cell functions, such as lysis or digestion; structural proteins, such as mucin to produce mucus; or hormones; and so on. Also, they might package wastes to export from the cell. (Refer the students to Spotlight Figure 2.13 for a visual representation of normal Golgi function.)
- **Ribosomes:** Like workers on an assembly line, ribosomes assemble proteins according to the instructions from the nucleus. They may be *fixed* on ER or *free* in the cytosol.
- **Centrioles:** The cowboys of the cell, called into action only to move the DNA in chromosomes in preparation for cell division (mitosis and meiosis). Like cowboys, they lasso each set of chromosomes and separate them so a new cell membrane can form to corral each set of chromosomes. Centrioles are housed in the *centrosome* (like a bunkhouse) when not in operation. Both are centrally located near the nucleus.
- **Cytoskeleton:** Infrastructure of the cell, made up of a variety of fibrous proteins, such as *actin*, which can contract, and *tubulin*, which can move rhythmically. The cytoskeleton provides shape, helps to circulate materials, and even forms extensions of *cytosol/cytoplasm* that reach outside the cell as *cilia, flagella*, and *pseudopodia*. Think of the cytoskeletal proteins as being as varied in structure and function as the information and transportation grids of the town, or perhaps the structural components of the walls in your home.
- **Cytosol and cytoplasm:** The *cytoplasm* (*cyto:* cell; *sol:* solution or mixture; *plasm:* something molded or formed) can be thought of as everything inside the city limits; this includes the *cytosol,* a gel-like substance in which organelles and structures are suspended, plus the organelles themselves.

4. Demonstrations

a. Concentration gradients, diffusion/osmosis, and equilibrium are important concepts for discussion. (Refer students to Spotlight Figure 2.4 for a good starting point of this discussion.) To demonstrate diffusion, spray a strong room spray or perfume at the front of the lecture hall or lab and ask students to raise their hands the first time they smell it. Or ask students if they have ever smelled a skunk and how close they think one has to be in order to smell the skunk. The initial spray sets up the gradient: Ask students to think of a grade or incline on a highway that a truck coasts down—it takes

little or no energy. A high concentration of molecules in one place is like the top of the hill or grade, and a low concentration is like the bottom of the grade. The molecules of spray are all close together at first, and once released they will move and bump into one another until they can spread out and reach equilibrium. Once equilibrium is reached, the odor dissipates. *Diffusion* is this movement of substances from areas of higher concentration to lower concentration. Cell membranes create barriers because they are selective about which molecules can enter and when they can enter cells. If a molecule can't pass through the cell membrane, water will sometimes move across the membrane to dilute the substance in question. *Osmosis* is the diffusion of water. If more energy or escorts are needed—or if the truck is to be pushed uphill against the gradient from low to high concentration—then extra energy or active transport is needed. Examples of active transport include *endo-* and *exocytosis*.

5. Common Student Misconceptions/Problems

a. *Cilia, flagella*, *villi, and microvilli* are often confused by students. *Cilia* are found in respiratory and reproductive systems and are extensions of microtubules from the cytoskeleton. They are able to move rhythmically and sweep materials across cell surfaces. *Flagella* are similar but longer and allow movement of cells; sperm are the only human cells with flagella. The tiny multicellular folds in the walls of the small intestine are an example of *villi*. Microvilli are microscopic extensions of a cell's membrane. Together, villi and microvilli increase the surface area for greater absorption.

b. Students often confuse *mitosis* and *meiosis*. *Mitosis* has a *t*—it results in only *t*wo daughter cells, and cells divide in *t*wo. Meiosis is the process that produces gametes, with each sex cell containing one-half the genetic material needed to create a new organism. It is helpful to postpone going over the details of meiosis until you study reproduction. This helps students separate mitosis and meiosis in their minds. Some good questions to ask at this point to assist students in understanding the importance of mitosis include the following:

Under what circumstances are new cells needed? Possible answers include

- for repair of damaged or destroyed cells as with broken bones or burns,
- for growth, and
- for replacement of worn-out cells, like red blood cells and skin cells.

What would prevent cells from being able to divide? Possible answers include

- lack of proper nutrients/materials to make cells;
- highly specialized cells (e.g., skeletal muscle or neurons) that have lost the organelles necessary to undergo mitosis; and
- damage to cells by things like UV radiation, drugs, or radiation.

What happens if mitosis does not stop when it should? Possible answers are

- Normal cells experience "contact inhibition" with neighboring cells, which should halt mitotic activity, but some cells stop responding to this. Cancer is an uncontrolled mitosis that progresses at a rapid rate. This results in cells abnormal in structure and function, the formation of tumors, and possibly seeding of new areas of cancer through metastasis.

6. Vocabulary Aids

a. Reticulum: An important term to have students add to their glossaries to study, it means "network" or "mesh" and will pop up again in the histology chapter and later in the chapters on the skeleton, the brain, and the digestive system.

b. Eponym: "Golgi bodies" is an example of an *eponym* or "tombstone" name (same root word as *epitaph*—the words engraved on a tombstone). Eponyms are terms that have been traditionally named after their discoverers, who are usually long dead. Modern anatomical nomenclature has replaced most of these with more descriptive names to assist students with recognition of structures. For example, *fallopian tubes* or *oviducts* are more accurately named *uterine tubes*, but the term *fallopian tubes* is still quite commonly used. It is valuable to at least familiarize students with some of these eponyms in case the health professionals they work with use these less modern names. Eponyms can also be used for fun bonus questions for quizzes, exams, and lab exercises. Refer students to the appendix in their textbooks.

c. Vesicles: Small vessels. Now is a good time to introduce some Latin grammar. When a term has an extensive ending added to it like this one (*icles*), it is usually a diminutive. In other words, the longer the suffix on the root word, the smaller the structure usually is. Some examples include

vessel versus *vesicle*,

tube versus *tubulin*, and

organ versus *organelle*.

d. Centrosome: Literally, "central body." *Soma* is a good term to learn: It means "body" and gets added onto many terms in anatomy and other biological sciences (e.g., chromo*some*, lyso*some*, *soma* of neurons, etc.).

e. Endocytosis/Exocytosis: *Endo* means "inside"; *exo* means "outside." *Endocytosis* might occur as *pino*cytosis—literally drinking or taking in of a "liquid" by cell membrane folding in and pinching off into vesicles; or *phago*cytosis—literally eating or taking in "solid" matter. *Exocytosis* would be the dumping of secretions or wastes from vesicles at the plasma membrane.

f. Important prefixes to know at this point also include **intra-, extra-,** and **inter**cellular. *Intra* means "within" as in intramural sports, which are between teams *within* the same campus (e.g., one dorm against another). *Intra*cellular means within a single cell. **Extra**cellular refers to anything *outside* the cell. *Inter* means "between" as in *interstate* highways running between two different states. A pertinent example would be *interphase* in meiosis and mitosis, the time in *between* cell divisions. Essentially the lifetime of the cell, interphase is the time during which the cell is actively working or growing. Once the end of interphase is chemically or physically triggered (how this occurs is not yet known), **prophase** begins. *Pro* means "before" or "early" (similar to the preface of a book), and chromosomes are just becoming visible. **Metaphase** is the middle phase when the chromosomes line up in the middle of the cell. **Anaphase** is when the chromosomes move *a*way from one another. (Notice that both begin with the letter A.) **Telophase** is when *t*wo separate sets of chromosomes become apparent and the cytoplasm begins to cleave in two.