Miller/Harley: Zoology 9e
Instructor's Manual

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Lecture Outline

Cells are the fundamental unit of life.

Prokaryotes are single-celled organisms; prokaryote DNA is not membrane bound and prokaryotic cells lack membrane bound organelles with the cytosol of the cell.

Eukaryotes may be single-celled or multicellular; eukaryotic DNA is enclosed in a nuclear membrane; specialized sub-cellular structures called organelles are present.
The plasma membrane is a selective membrane that forms the boundary of the cell.
The cytoplasm is a semi-fluid substance (cytosol) in which the organelles are suspended. The nucleus contains the chromatin (Uncoiled DNA and the proteins associated with it) surrounded by the nucleoplasm.

Cell size is constrained by the surface area to volume ratio. Smaller cells have a higher surface area to volume ratio than do larger cells. When the surface area to volume ratio is too low, diffusion cannot supply oxygen to the center of the cell, so large cells are precluded.

Membranes surround the cell and various organelles.

The fluid-mosaic model of membrane structure was developed by Singer and Nicolson. According to the model, the membrane has a bilayer of proteins and phospholipids, with some molecules moving around within it. The membrane phospholipids have hydrophilic heads facing the outer membrane surface and hydrophobic tails oriented towards the interior of the membrane. Cholesterol is an important component of membranes and increases the stability of the membrane. Peripheral proteins are attached to the inner or outer face of the membrane, whereas intrinsic proteins span the membrane. Intrinsic proteins may be attached to carbohydrates or lipids, or form channels in the membrane. Proteins with attached carbohydrates on the outer surface of the cell are known as the glycocalyx, and may be important in cell-to-cell recognition

Membranes may prevent, or facilitate, the movement of molecules across the boundary they create. Diffusion is the movement of molecules from areas of higher to lower concentration; it requires no cell energy. Facilitated diffusion occurs when carrier proteins transport molecules across the membrane or via protein channels in the membrane. Large molecules, or lipid-insoluble molecules, may pass through these channels. No additional energy is required in facilitated diffusion.

Osmosis is the diffusion of water through a selectively permeable membrane. Specialized water channels in the cell membrane are called aquaporins. Aquaporins may be water specific or also allow other small hydrophilic molecules across. The direction of diffusing water in osmosis (into, or out of, the cell) depends on the relative difference in the concentration of solutes inside and outside the cell. The concentration of solutes in a solution is also known as tonicity whenever referring to a cell. Isotonic solutions outside the cell have the same concentration of solutes as the cell does, so there is no net movement of water. Hypertonic solutions outside the cell have a higher concentration of solutes than the cell does, so water moves out of the cell. Hypotonic solutions have a lower concentration of solutes than the cell does, so water moves into the cell.

Filtration is the movement of protein-free plasma across capillary walls due to a pressure gradient created by a pumping heart.

Active transport occurs when carrier proteins transport molecules from an area of lower concentration to an area of higher concentration (movement against a gradient); cellular energy, an input of ATP, is required. The sodium-potassium pump and the calcium pump are examples of active transport that are critical for life. Active transport mechanisms help to create electrical potentials across the plasma membranes of cells and play a vital role in nerve impulse conduction and muscle contraction. The carrier proteins that allow for active transport are called uniporters, symporters, and antiporters. Uniporters just allow one type of molecule or ion across at any given moment. Symporters allow for movement of two molecules or ions in the same direction. Antiporters allow for movement of two molecules or ions in opposite directions.

Endocytosis is the process by which a cell inputs material by enveloping it. Pinocytosis is the uptake of fluid droplets, whereas phagocytosis is the uptake of solid particles. Receptor-mediated endocytosis involves receptors often located within coated pits on the plasma membrane and is specific to particular substances, such as cholesterol. Endocytosis results in loss of cell membrane.

Exocytosis is the process by which the cell expels large amounts of materials contained within transport vesicles. Exocytosis adds to the cell membrane as the vesicle rejoins the membrane.

<u>Cell components have specialized functions:</u>

The cytoplasm consists of the fluid cytosol, the organelles and other structures. Ribosomes are the site of protein synthesis; they may be free or attached to the ER. The cytomembrane system consists of organelles (the Golgi apparatus, the ER, vacuoles and vesicles) that function to modify, package and distribute proteins and lipids.

The endoplasmic reticulum (ER) is a set of interconnected membranes that may bear ribosomes (rough ER) or lack ribosomes (smooth ER). Rough ER functions in production and modification of proteins. Smooth ER is involved in production of some lipids, detoxification of various molecules, and is specialized for calcium storage in muscle cells.

The Golgi apparatus is associated with the ER, and receives vesicles from it. The Golgi apparatus modifies, marks and sorts proteins in vesicles. The Golgi apparatus also forms the lysosomes.
Lysosomes contain enzymes that are used to break down materials that the cell has taken in via endocytosis. Additionally, lysosomes may be used to recycle older organelles within some cells.
Microbodies are membrane-enclosed vesicles that perform enzymatic reactions that are best kept isolated from the rest of the cell. Peroxisomes are an example of a microbody. They isolate and break up chemicals that might be harmful to the body (ie. hydrogen peroxide).
Mitochondria are the sites of aerobic respiration in a cell, resulting in the production of ATP. They have a double membrane structure.
Vacuoles are involved in cellular maintenance as well as storage of materials; they are constantly being destroyed and replaced.
The nucleus contains the DNA. Chromatin is DNA that is spread out; the form it takes when the cell is not dividing. During cell division, the chromatin condenses around proteins making the chromosomes visible under the light microscope. DNA is the template from which RNA is made; RNA leaves the nucleus to direct protein synthesis within the cell. The nucleus is surrounded by a double membrane. The nuclear membrane or envelope is porous to RNA, but not to DNA. The nucleus contains the nucleolus, a pre-assembly point for ribosomes.
Vaults transport molecules made in the nucleus to various places within the cell; they are octagonal barrel-shaped cytoplasmic ribonucleoproteins that dock at nuclear pores to pick up the molecules and then they move through the cytoplasm.

The cytoskeleton is a flexible cellular framework that supports organelles and allows for cellular movement. It is composed of interconnecting microtubules and microfilaments. Microtubules are hollow cylinders composed of tubulin; they aid in movement of cellular components.

Both cilia and flagella have the same structure of microtubules in a 9 + 2 pattern. Cilia are short and numerous; flagella are much longer and occur in smaller numbers. The basal body lies at the junction of a cilium or flagellum and the cell proper. Cilia have also been shown to act as signal-receiving “antennae”, helping the cell to perpetually monitor the extracellular environment.

The microtubule-organizing center contains two centrioles and is involved in cell division and formation of the cytoskeleton.

Intermediate filaments are chemically heterogeneous; they help support cell shape.

Microfilaments are solid rod-like structures composed of actin; they aid in the contraction of muscle cells, as well as movement of pseudopodia.

Tissues are specialized groups of cells adapted for a particular function:

Epithelial tissue covers or lines structures, and is bounded by a basement membrane. Epithelia function in absorption, transport, excretion, protection and sensory reception. Epithelia are classified by the cell shape, and by the presence or absence of layers.

Connective tissues support and bind other tissues. Connective tissue cells are embedded in an extracellular matrix, typically with numerous fibers. Loose and fibrous connective tissues have many fibers.

Adipose tissue is characterized by cells swollen with lipids.

Cartilage and bone tissue is characterized by a relatively solid matrix.

Blood is characterized by a fluid matrix.

Muscle tissue belongs to three types: skeletal, smooth, and cardiac muscle.

Nervous tissue is composed of neurons, conducting nervous impulses, and glial cells, which support the neurons.

Organs are functional units composed of different types of tissues.
Two examples are eyespots and reproductive organs.

Organ systems are groups of organs with a particular function.
The reproductive system and the circulatory system, are two examples of organ systems.

Teaching Suggestions

It will not be easy to teach this chapter if students perceive the material as a series of isolated factoids, so an organizing scheme is essential. One organizing scheme would be the flow of genetic information in the cell needed for the production of a particular protein. The students could first identify the components of the cell involved in information storage and retrieval, and then find the cell components involved in protein synthesis and transport. It is also helpful for them to visualize the 3-D structures of the organelles, for example describing the Golgi apparatus as a stack of pita breads.

Another approach to this material is to discuss the function of individual organelles. For example, smooth ER functions in detoxification of alcohol and other drugs and is particularly abundant in cells of the liver. With increased intake of alcohol or other drugs, the amount of ER increases, and it therefore takes more of the drug to reach the same level of effect. The formation of extra smooth ER may reduce the effectiveness of medicinal drugs over time as well. The smooth ER also produces steroid hormones, and would therefore be particularly abundant in the endocrine cells of the testes and ovaries.

Lysosomes are important in renewing the organelles and organic molecules of the cell. Liver cells recycle approximately 50% of their macromolecules every week via lysosomal action. In an active cell, the mitochondria are replaced every 10 days.

The inappropriate action of lysosomes is implicated in the disorders Tay Sachs and rheumatoid arthritis. In Tay Sachs, the lysosomes of neurons lack an enzyme required to

break down lipids, and the lysosomes swell and break open, ultimately killing the cell. Children with this disease die at a few years of age. In rheumatoid arthritis, an autoimmune disease, lysosomes in white blood cells in the synovial membranes of the joints leak enzymes into the joint cavity. The enzymes erode the joint cartilage, causing inflammation.

Diffusion and osmosis are tough subjects for students to master. Spend ample time covering the subjects, including the concepts of isotonic, hypertonic, and hypotonic solutions, and how cells respond to immersion in each solution. Give students examples of diffusion that they can relate to, such as the diffusion of odorous molecules of aftershave from the person sitting next to them. These two references may help:

> Vogel, S. "Dealing honestly with diffusion." *American Biology Teacher*. October 1994. 56 (7):405–407.
>
> Odom, Arthur Louis. "Secondary and college biology students' misconceptions about diffusion and osmosis." *American Biology Teacher*. October 1995. 57 (7): 409–415.

This may be the first chance you have to point out the singular and plural forms of various scientific terms such as nucleolus/nucleoli and mitochondrion/mitochondria. This should help alleviate student confusion when they see both forms of the word in the future.

Lecture Enrichment

Discuss the nature of prokaryotic cells as compared to eukaryotic cells, pointing out the differences in how the genetic material is packaged and which organelles are absent in prokaryotes (e.g., no mitochondria in prokaryotes). If the first cells were anaerobic prokaryotes lacking a membrane-bound nucleus and mitochondria, how did eukaryotic cells evolve? Lynn Margulis' theory of endosymbiosis between various prokaryotes to form the first eukaryote was initially highly controversial, but it has now been widely accepted. This theory explains two oddities that the students may have noticed during their reading—the presence of double membranes around both the eukaryotic nucleus and a mitochondrion. You might point out that a chloroplast is also surrounded by a double membrane, suggesting a similar endosymbiotic origin for this organelle. The original reference is:

Margulis, L. "Archaeal-eubacterial mergers in the origin of the Eukarya." Proceedings of the National Academy of Sciences, USA 1996. 93: 1071–1076.