2 Cells, Tissues, Organs, and Organ Systems

Lecture Outline

Cells are the fundamental unit of life.
Prokaryotes are single celled organisms, and the DNA in a prokaryote is not membrane bound.
Eukaryotes have DNA enclosed in a nuclear membrane, and organelles that are specialized subcellular structures.
The plasma membrane is a selective membrane that forms the boundary of the cell.
The cytoplasm contains a semifluid (cytosol) in which the organelles are suspended.
The nucleus contains the chromosomes surrounded by the nucleoplasm.
Cells are typically small because of the constraints of surface area to volume as the cell enlarges

Membranes surround the cell and various organelles
The fluid-mosaic model of membrane structure was developed by Singer and Nicolson, and describes the membrane as a bilayer of proteins and phospholipids, and molecules may move around within the membrane.
The phospholipids have hydrophilic heads which face the outer surface of the membrane and hydrophobic tails oriented towards the interior of the membrane.
Cholesterol is an important component of membranes and adds to the stability of the membrane.
Peripheral proteins are attached to the inner or outer face of the membrane, and intrinsic proteins span the membrane and may be attached to carbohydrates or lipids, or the proteins may 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 facilitate, as well as prevent, movement of molecules across it
Diffusion is the movement of molecules from areas of higher to lower concentration. Facilitated diffusion occurs via protein channels in the membrane.
Large molecules, or lipid insoluble molecules may pass through these channels. No energy output by the cell is required.
Osmosis is the diffusion of water through a selectively permeable membrane. Isotonic solutions have the same concentration of solutes as the cell.
Hypertonic solutions have a higher concentration of solutes; hence water moves out of the cell.
Hypotonic solutions have a lower concentration of solutes; hence water moves into the cell

Filtration is based on water pressure, and small molecules move through a semi-permeable membrane.
On the other hand, active transport requires an input of ATP, and moves molecules from an area of lower to higher concentration.

The sodium-potassium pump and the calcium pump are critical for life.

Endocytosis is a mechanism by which the cell moves in large amounts of materials by enveloping them.

Pinocytosis is the uptake of fluid droplets, whereas phagocytosis is the uptake of solid particles.

Receptor-mediated endocytosis involves receptors on the plasma membrane and is specific to particular substances, such as cholesterol.

Exocytosis is the process by which the cell expels large amounts of materials.

Endocytosis results in loss of cell membrane; exocytosis adds to the cell membrane

Cell components have specialized functions

The cytomembrane system is composed of the fluid cytosol, and the organelles suspended in it

Ribosomes may be free or attached to the ER and are the site of protein synthesis

The endoplasmic reticulum 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

Mitochondria have a double membrane structure, which are the sites of aerobic respiration in a cell, resulting in the production of ATP

The cytoskeleton supports organelles and allows for cellular movement

Microtubules are composed of tubulin and aid in movement of cellular components

Intermediate filaments help support the shape of the cell

Microfilaments are composed of actin, and aid in the contraction of muscle cells, as well as movement of pseudopodia

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

At the junction of the cilium or flagellum and the cell proper is the basal body

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

Other organelles are involved in cellular homeostasis

Vacuoles are involved in cellular maintenance as well as storage of materials, and are constantly being destroyed and replaced

The nucleus contains the DNA

The nuclear membrane or envelope is porous, which allows RNA to leave the nucleus

Chromatin is DNA that is spread out; the form it takes when the cell is not dividing

Chromosomes become visible under the light microscope during cell division, as the chromatin condenses around proteins

The nucleolus contains proteins and RNA

Tissues are specialized groups of cell adapted for a particular function
Epithelial tissue covers or lines structures
Epithelia function in absorption, transport, excretion, protection and sensory reception
Epithelia are bounded by a basement membrane
Epithelia are classified by the cell shape, and 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 may be classified as skeletal, smooth and cardiac muscle
Nervous tissue is composed of neurons, which conduct nervous impulses, and glial cells, which support the neurons

Organs are functional units composed of different types of tissues

Organ systems are functional groupings of organized organs, specialized for a particular function

Research and Discussion Topics

• Discuss several characteristics of mitochondria and chloroplasts that lend evidence to the endosymbiotic hypothesis. This theory may explain the origin of these organelles. How does this differ from the membrane invagination hypothesis (Autogenous model)?

• Research medical conditions such as Tay Sachs or rheumatoid arthritis are caused by malfunctioning cellular organelles. What causes these conditions, and how are they treated? Cystic fibrosis is due to a defect in a membrane pump of the cell membrane. Discuss the causes and treatment of this disease.

• Describe the action of the lysosome in various "unique" situations, such as the disappearance of the tail of a tadpole during metamorphosis, or the part it plays in the endometrial cells of the uterus during the menstrual cycle.

Teaching Suggestions

• Students often have a hard time relating to organelles, but if we discuss a particular disease or condition relating to an organelle, it has more meaning. Tolerance to drugs, including alcohol, results in the increase in the amount of smooth ER in cells, particularly the liver.

• New names for old organelles. The Golgi is now commonly called the Golgi apparatus or complex, although many of us learned it as the Golgi body. Further, many of us first learned about the Golgi and visualized it as looking like a stack of pancakes; many current texts say that it looks more like a stack of pita breads. The lysosome used to be the "garbage man" of the cell, but in an environmentally conscious world, we can more appropriately call it the "recycling center" of the cell.

• This may be the first chance you have to point out the plural forms of various scientific terms. Be sure to point out the dichotomy of nucleolus / nucleoli, mitochondrion / mitochondria. This should help alleviate student confusion when they see both forms of the word, in this chapter and henceforth.

• This is the first opportunity to explain a bit about the photomicrographs that they will see in their text during the rest of the course. Distinguish between light and electron micrographs. Point out that specimens in electron micrographs are all dead, and that if depicted in color, it has been colorized.

• Diffusion and osmosis are tough subjects for students to master. Be certain to spend ample time covering the subjects, including the concepts of isotonic, hypertonic, hypotonic, and the consequences of each solution to animal cells. 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 (or perhaps less pleasant odors!).

Lecture Enrichment

• Cyto-"stuff"

Students often have a difficulty distinguishing between cytoplasm, cytosol and organelles. I use the example of cytoplasm as the cell "soup," in which the organelles float in the "broth" of the cytosol.

• History

Robert Hooke looked at cork (bark) under the microscope in 1665 and called the structures he saw "cells," meaning "little rooms," like those little rooms in the jail. Knowledge of cells progressed rather slowly until the electron microscope was developed about 40 years ago, which allowed a deeper understanding of the ultrastructure of the cell.

• Smooth ER

The 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. This may also reduce the effectiveness of some useful drugs when a person is treated for a medical condition. The smooth ER also produces steroid hormones, and would therefore be particularly abundant in the endocrine cells of the testes and ovaries.

• Lysosomes

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.

Lysosomes are implicated in the disorders Tay Sachs and rheumatoid arthritis by inappropriate action of the lysosomes. 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. RA (rheumatoid arthritis), which is an autoimmune disease, affects approximately 1% of the population. In this condition, lysosomes in white blood cells in the synovial membranes of the joints leak enzymes into the joint cavity that erodes the cartilage and causes inflammation. RA is a different condition than osteoarthritis (OA), which is just what most of us get when we get old and have creaky joints.

Suggested Readings

Keister, E. " A bug in the system." *Discover*. February 1991. 70-76. A discussion of the function of the mitochondrion, and how a few genetic defects in the mitochondrial genes leads to human diseases.

Story, R.D. "Textbook errors and misconceptions in biology: Cell structure." *American Biology Teacher*. August 1990. 52 (4): 213-217.

McLaughlin, E., J. Giannini and K. Fishbeck. "Color-coded organelles." *American Biology Teacher*. October 1994. 56 (7): 420-423. A description of the isolation of vacuoles from red beets and observation under the microscope. Osmosis and ion diffusion across the membrane is demonstrated.

Vogel, S. "Dealing honestly with diffusion." *American Biology Teacher*. October 1994. 56 (7): 405- 000. Interesting facts about diffusion, hints on teaching the subject.

Odom, Arthur Louis. "Secondary and college biology students' misconceptions about diffusion and osmosis. *American Biology Teacher*. October 1995. 57 (7): 409-415. An interesting analysis of students' lack of understanding of diffusion and osmosis.