# PEER-LED TEAM LEARNING
# INTRODUCTORY BIOLOGY

# MODULE 3: CELL STRUCTURE AND FUNCTION

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## I. Introduction

*"The cell is as fundamental to biology as the atom is to chemistry…..Everything an organism does is fundamentally occurring at the cellular level." Neil Campbell, Biology, 4th Edition, Benjamin-Cummings, New York.*

The cell is the simplest organization of molecules that show the properties of life. Cells are either **prokaryotic** or **eukaryotic**; these two basic types differ fundamentally in structure. Unlike eukaryotic cells, prokaryotic cells do not contain a system of internal membranes. For example, they lack well-defined nuclei (yet still contain DNA) and don't have other comparable membrane-bound organelles. A **plasma membrane** serves to separate a cell from its surroundings. The membrane is composed of amphipathic phospholipids and proteins. It is selectively permeable to the solutes that it allows to pass. All cell membranes are asymmetrical phospholipid bilayers with embedded proteins; each monolayer differs in lipid and protein composition.

Cells are highly diverse in their sizes and structures—often related to specializations in function. In some simpler living things, a single cell is the entire organism performing all the life functions. In multicellular organisms, cells tend to be more specialized—each doing one or a few of the life functions, but depending on different cells to do the rest. In our bodies, for example, muscle cells produce movement and nerve cells (neurons) are communication specialists.

In this module your goal is to understand the important structural components of cells and how these subunit work together in carrying out life processes. Prepare for your workshop by reading in your textbook (ex., Audesirk, et al. 6th edition, Chapter 5; Campbell, 4th edition, Chapter 7), and completing the Pre-Workshop Activities below. Show your work in these pages.

## . II. Pre-Workshop Activities

1. **Activity 1.** Work on the three Chapter 7 activities on the CD Rom which accompanies your text to review the structures and functions of the components of prokaryotic, animal and plant cells.

2. **Activity 2**. In defining each of the following give information about structure, location, function, and connections to other terms in the list.

| | | |
|---|---|---|
| organelle | nucleus | fractionation |
| prokaryotic cell | chromatin | centrifugation |
| eukaryotic cell | nucleolus | homogenization |
| cytosol | ribosomes | microscopy |
| cytoplasm | endoplasmic reticulum | desmosomes |
| Golgi body | gap junctions | cytoskeleton |
| lysosomes | plasmodesmata | plasma membrane |
| extracellular matrix | lumen | mitochondria |
| membrane proteins | tight junctions | chloroplasts |

3. **Activity 3.** Match the following cell components with their characteristic structure and function.

| Cell Component | Structural Feature | Function |
|---|---|---|
| ER | rRNA and protein | Storage of water |
| Vacuoles | Cis and trans faces | Hydrolysis of macromolecules |
| Lysosomes | Three sets of membranes | Modification of ER products |
| Nucleus | Rough and smooth portions | Membrane synthesis |
| Cytoskeleton | Phospholipids and proteins | Photosynthesis |
| Chloroplasts | Low internal pH | Fatty acid oxidation |
| Golgi Body | Capable of occupying large volume | Provides support and shape |
| Mitochondria | Encased by an perforated envelope | Selectively permeable to the extracellular environment |
| Peroxisomes | Can be studded with ribosomes | The home of the chromosomes |
| Plasma membrane | Compartment of oxidases | Cellular respiration |

4. **<u>Activity 4.</u>** Label the two cells in Figures 3.1 and 3.2 using the terms at the top of the figure.

**Animal Cell -** Use the following terms:
1. Centrioles; 2. Flagellum; 3. Plasma Membrane; 4. Rough endoplasmic reticulum; 5. Golgi apparatus; 6. Ribosomes; 7. Nucleus; 8. Chromatin; 9. Nucleolus; 10. Nuclear envelope; 11. Smooth endoplasmic reticulum; 12. Lysosome; 13. Peroxisome; 14. Microtubules; 15. Microfilaments; 16. Mitochondrion

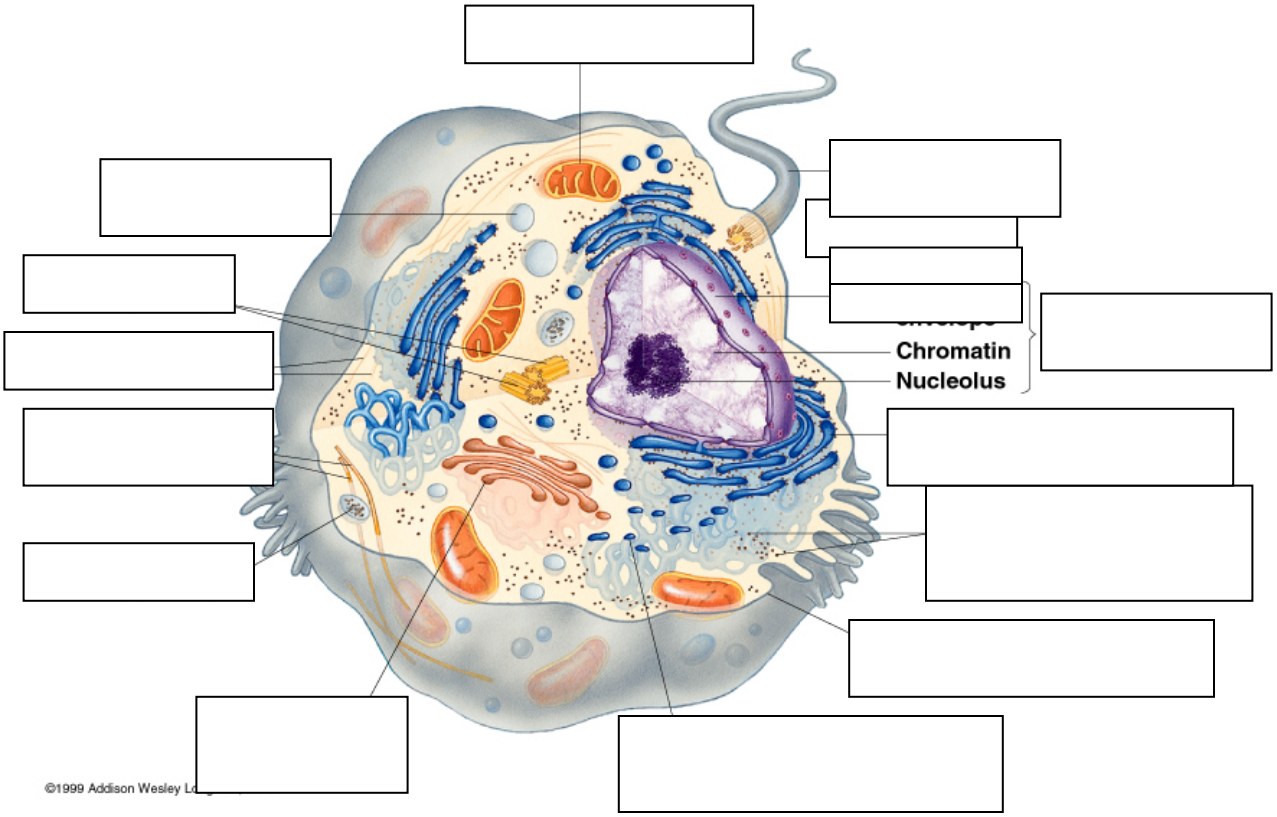
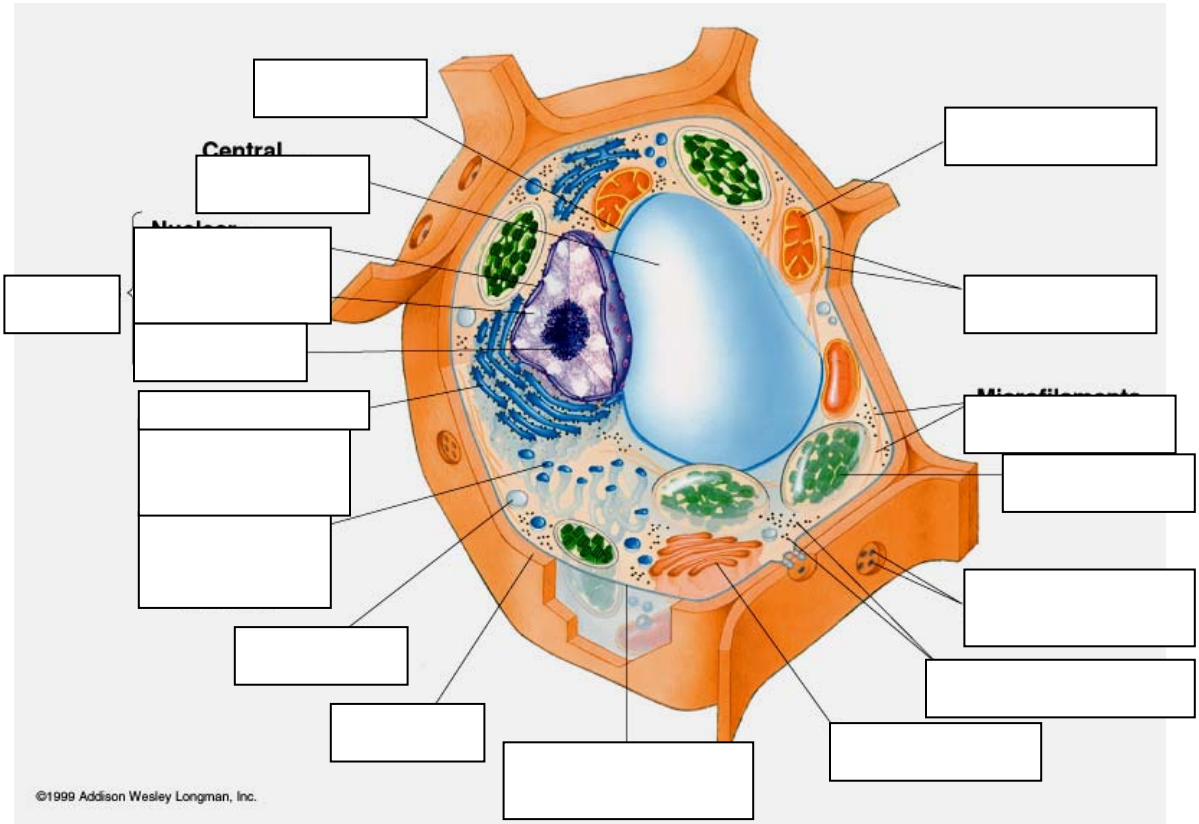


**Figure 3.2. Plant Cell:** Use the following terms:
1. Golgi apparatus; 2. Peroxisome; 3. Central Vacuole; 4. Cell Wall; 5. Mitochondrion; 6. Chloroplast; 7. Plasmodesmata; 8. Tonoplast; 9. Nucleolus; 10. Rough Endoplasmic Reticulum; 11. Smooth Endoplasmic Reticulum; 12. Nuclear Envelope; 13. Chromatin; 14. Nucleus; 15. Microtubules; 16. Microfilaments; 17. Ribosomes; 18. Plasma Membrane




## III. Workshop Activities

**<u>Activity 1. Jeopardy.</u>** 1) Methods for Studying Cells, 2) Cell Structure, 3) Cell Function, 4) Cell Surfaces and Junctions

In this section you will be playing Jeopardy. As instructed by the peer leader, sit in a semicircle around the board. The peer leader will write the 4 categories (as listed above in the title to part I) and your names on the board. The peer leader will think of a number (e.g., between 1-10) and you will guess the number. The student that comes closest to the peer leader's number gets to select a category first. The peer leader will read one of the "questions" (see below) in that category. The first person to stand up (or raise their hand - whichever or whatever is directed by the peer leader), can try to "answer the question". In Jeopardy, the "question" is actually a statement and the "answer" is to be phrased as a question. If a wrong "answer" is provided, another student will be given a chance to answer (selected based on criterion chosen by the peer leader). Once a student has given the correct "answer", 10 pts will be awarded (the peer leader should keep track on the board and may decide to subtract points for a wrong answer) and that student selects the next category.

You are highly encouraged to prepare, outside of workshop, a set of note cards for self-study with the "questions" on one side and the "answers" on the other.

**Category 1: <u>Methods for Studying Cells</u>**

1. In microscopy, this is how much larger an object appears compared to its actual size.

2. In microscopy, this is the minimum distance between two points that can still be distinguished as two points.

3. In this type of microscope, visible light is passed through a specimen and then through glass lenses.

4. In this type of microscope, a beam of electrons is passed through a specimen and electromagnets focus and magnify the image.

5. This is when cells are disrupted and various components are separated.

6. This instrument is utilized to pellet larger cellular components, leaving smaller cellular components in the supernatant fraction.

In this type of microscope, an electron beam scans the surface of the sample, which is coated with a thin film of gold.

**Category 2: <u>Cell Structure</u>**

1. This is the chromosome-containing organelle of an eukaryotic cell.

2. This is a membrane-enclosed sac taking up most of the interior of a plant cell.

3. This is an organelle found in plants that absorbs sunlight and uses it to drive synthesis of organic compounds.

4. This is an extensive membranous network in eukaryotic cells that is composed of ribosome-studded and ribosome-free regions.

5. This organelle serves as the site of cellular respiration.

6. This organelle is essentially a membrane-enclosed bag of hydrolytic enzymes.

7. This organelle consists of stacks of flat membranous sacs that modify, store, and route products of the endoplasmic reticulum.

8. This organelle contains enzymes that transfer hydrogen from various substrates to oxygen, producing and then degrading hydrogen peroxide.

**Category 3: Cell Function**

1. This is how DNA exists when the cell is not dividing. It is made up of DNA plus proteins.

2. These are used as guide tubes for movement of materials, for separation of chromosomes during cell division, and for maintaining the shape of cells by assuming a compression-resisting role.

3. These are used in muscle contraction, cell motility, and for resisting pulling forces in the maintenance of cell shape.

4. These help maintain the shape of the cell by bearing tension (resisting pulling forces) and are made up of a diverse family of proteins.

5. This is made up of a phospholipid bilayer and is the outer boundary of an animal cell.

6. This organelle functions as the site of protein synthesis.

7. This is a short cellular appendage specialized for locomotion.

8. This is where metabolism of carbohydrates and detoxification of drugs occur.

**Category 4: <u>Cell Surfaces and Junctions</u>**

1. This is formed when plasma membranes of neighboring cells in a layer are fused, forming a barrier that prevents leakage of extracellular fluid across the layer.

2. In plants, these structures allow movement of cytoplasm from one cell to another.

3. Plant cells have a plasma membrane, which is then surrounded by this.

4. A young plant cell first secretes a relatively thin and flexible wall that is called this.

5. This is a thin layer, rich in sticky polysaccharides (or pectins), between primary walls of adjacent plant cells.

6. These connections provide cytoplasmic channels between adjacent animal cells.

7. These junctions fasten animal cells together like rivets.

**<u>Activity 2: Review of Organelle Structure and Function</u>**

Find a partner or partners as instructed by the peer leader and get an overhead transparency film(s) and colored markers. Your will be assigned a cell type or cellular component(s) from the following list for the activity described below.

| | |
|---|---|
| Nucleus | Ribosomes |
| Rough Endoplasmic Reticulum | Smooth Endoplasmic Reticulum |
| Golgi Body | Lysosomes |
| Vacuoles | Peroxisomes |
| Mitochondria | Chloroplasts |
| Cytoplasm | Cytoskeleton |
| Plasma membrane | Cell wall |
| Intercellular junctions | Prokaryotic cell |
| Animal Cell | Plant Cell |

1. Draw the cell or cellular component on the overhead. Be as detailed as possible. You may use resources to get additional information.

2. Below the drawing describe the functions associated with the cell part, or the special features of the cell. Relate the structures or special features to function. For instance, why does a nuclear envelope have nuclear pores? Why is the inner membrane of a mitochondrion so extensively folded?
3. Decide how you and your partner will present the drawing and information to the rest of the group.
4. When you are called upon to present your drawing and description, take no longer than 2-3 minutes.
5. At the end of your presentation, invite the rest of the group to ask questions, add information or suggest correction/ improvements. It is a task for the entire group to make the best diagram and description possible for each item.
Five to seven minutes are allowed for this task.

## Activity 3. Analogies to Cellular Organization and Interplay of Organelles

The organization cells and the processes that support life lend themselves to familiar analogies such as a house, a factory, a college, or a city. All of these are complex organizations in which there are many components that must work together to enable the whole to function. In this activity your task is to develop and explain cellular structure and function by comparison to an analogue.
1. Divide the workshop into groups of 3-4 students.

2. Decide in your group what type of analogue you might most successfully compare to a cell. Use a eukaryotic animal or plant cell for comparison. Focus on the following cell parts: Nucleus, Ribosomes, RER, SER, Golgi Body, Lysosomes, Vacuoles, Peroxisomes, Mitochondria, Chloroplasts, Cytoplasm, Cytoskeleton, Plasma membrane, Cell wall, Intercellular junctions,
Central vacuole, Extracellular matrix, Centrioles, Flagella or Villi.

3. Your group may use the blackboard, newsprint and magic markers (assorted colors, preferably), or other material that is provided for making designing your comparison.

4. Draw the organization you selected (city, factory, etc.) and identify all of the *functional analogs* to parts of a cell, and explain your reasoning. For instance, if you choose the city government to be analogous to a nucleus, you have to explain why (What does it do? How does it interact with other parts?). You are encouraged to be creative. You have about 20 minutes to complete this task.

5. The peer leader chooses the order in which groups present. Each member of the group will present part of the analogy, showing the drawing, identifying the comparison and explaining it. Group members may assist the presenter, if necessary to help clarify or answer questions.

6. During the presentations, the peer leader will fill in a large table (either on overhead or on a black board), with the following column headings: Nucleus, Ribosomes, RER, SER, Golgi Body, Lysosomes, Vacuoles, Peroxisomes, Mitochondria, Chloroplasts, Cytoplasm, Cytoskeleton, Plasma membrane, Cell wall, Intercellular junctions,
Central vacuole, Extracellular matrix, Centrioles, Flagella or Villi.

7. Following the last presentation, the students reflect on the TA's table that has included all analogies put forth by the students and vote on the best analogy for each cellular component.

## Activity 4. Endosymbiosis, Secretion and Signal Transduction

### A. Endosymbiosis

Lynn Margulis (U. Massachusetts) has pioneered the theory of *endosymbiosis*. Endosymbiosis refers to the process of a cell (aka host cell) engulfing a smaller cell (aka endosymbiont). The two cells subsequently enter into a symbiotic relationship in which both cells have become dependent on each other. The theory further states that eukaryotic cells were once anaerobic cells that engulfed cells with aerobic capacity. These endosymbionts have evolved into our mitochondria. Much evidence supports this theory, for instance

mitochondria resemble bacteria in the way they are organized and the mechanism by which they replicate. Mitochondria contain their own genome and gene expression systems.

The theory of serial endosymbiosis states that cells already housing an endosymbiont can further take up an additional endosymbiotic cell. The origin of the chloroplast presumably reflects such a series of events. Presumably, a eukaryotic cell (containing mitochondria) engulfed a smaller autotrophic cell. This second endosymbiont evolved into a chloroplast (retaining its photosynthetic capacity).

1. Divide the workshop into small groups (two to four people each). Each group receives three pieces of play-doh or modeling clay of different colors.
2. Reconstruct the events behind endosymbiosis and serial endosymbiosis using cells with play-doh or modeling clay membranes. Make a series of steps to show the processes. You have 15 minutes to perform this activity
3. Answer the following questions:
    a. What is the origin of the mitochondrial inner membrane?
    b. What is the origin of the mitochondrial outer membrane?
    c. What is the origin of the chloroplast inner membrane?
    d. What is the origin of the chloroplast outer membrane?
    e. Would you expect homologies between mitochondrial/ chloroplast genomes and prokaryotic genomes?

4. After this activity, the peer leader will select students to reconstructs endosymbiosis and serial endosymbiosis using an overhead transparency or the black board using three colors of markers or chalk (analogous to the three colors of play-doh or modeling clay) to review the processes.

**B. Secretion**

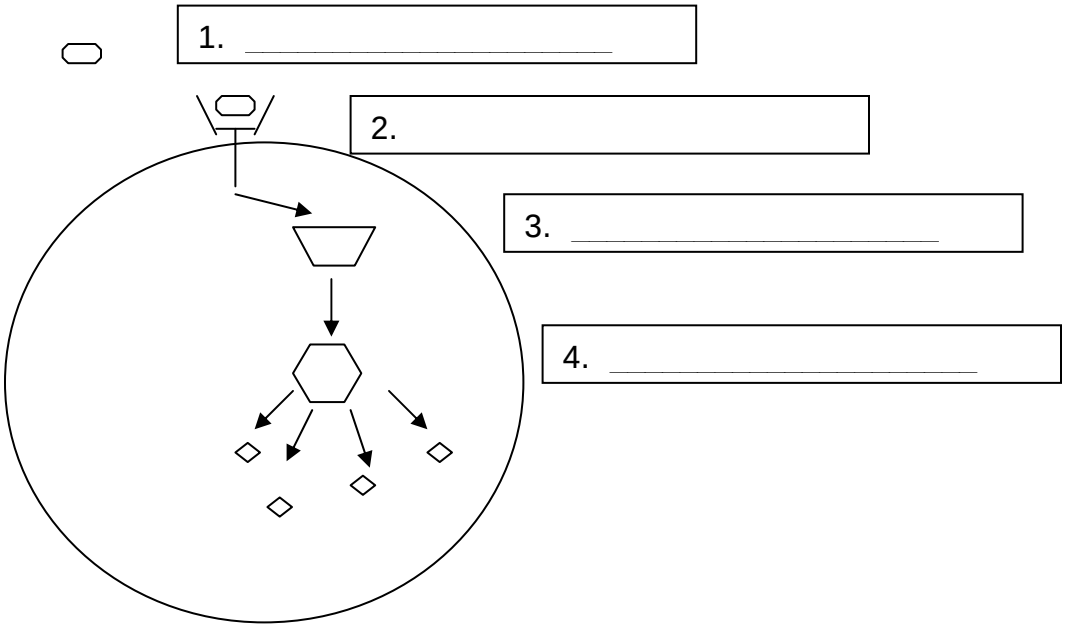
Secretory proteins are synthesized on ribosomes attached to the RER. During synthesis, they are translocated into the ER lumen by translocator proteins in the ER membrane. In the ER, the proteins are chemically modified and sent to the Golgi body via transport vesicles. The transport vesicles fuse onto the cis face of the Golgi body and the contents are released into the Golgi lumen. In the Golgi body, the proteins are further modified and sorted into transport vesicles that pinch off the trans face of the Golgi Body. The transport vesicles carrying secretory proteins are targeted to the plasma membrane. At the plasma membrane, the transport vesicles fuse and empty their contents to the outside of the cell.

1. Use the same groups as the prior investigation or rearrange them as directed by your leader.
2. Reconstruct the pathway of transport vesicles from the ER to the plasma membrane using:
    a. play-doh or modeling clay, or
    b. a flow chart or concept map, or
    c. by acting out the process
3. Present your finished product to the group with an explanation of your reasoning in its design.
4. Answer questions and discuss suggestions on how your product could be improved.

**C. Signal Transduction**

Signals that never physically enter the cell can, nevertheless, affect intracellular events. The term signal transduction refers to the series of events that occur between exposure of a cell to a signal and a response from within the cell. The first step in a generalized signal transduction pathway is the interaction between an *extracellular signal* and its specific *cell-surface receptor*. The cell-surface receptor next undergoes a conformation (shape) change and activates an intracellular protein. This second protein is called a *relay protein*. The relay protein (once activated by the cell-surface receptor) proceeds to activate an *effector protein*. The effector protein is typically an *enzyme* that causes the synthesis or release of a *secondary messenger*. The secondary messenger continues the pathway by binding to other *target proteins*, and activating them. Some of these target proteins are factors that can turn select *genes* on. These activated genes encode additional *proteins* that elicit a response within the cell.

1. In your small group use Figure 3.3 that shows a generalized signal transduction pathway as described above.
2. Identify each pathway component, focusing on the italicized terms in the description above:
3. For each arrow write a brief description of what is happening in the transition from one step to another.
4. Each group will be asked to comment on one or more steps in the process.




**IV. Additional Resources. Cell biology web sites for further information**

http://www.vlib.org/Science/Cell_Biology/general_cell_biology.shtml
The WWW Virtual Library: Cell Biology:
Contains links to a huge list of website that relate to Cell Biology.

http://www.vlib.org/Science/Cell_Biology/signal_transduction.shtml
The WWW Virtual Library: Cell Biology:
This link is helpful if you are interested in learning more about Signal Transduction.

http://www.cellsalive.com/
Cells Alive Website: Has animal cell and plant cell diagrams.

http://on.to/cellbiology
The Dictionary of Cell and Molecular Biology 3rd Edition.

http://personal.tmlp.com/Jimr57/index.htm
The Virtual Cell. Click on the Virtual Textbook. Chapter 3 = Cell Biology.

http://encarta.msn.com/find/Concise.asp?ti=042EA000
Encarta Encyclopedia.

http://www.ma.ultranet.com/~jkimball/BiologyPages/A/AnimalCells.html
Animal Cells. At the bottom of this website is an external link to ITG Technologies web site. Under the Exhibits link, click on Galleries. This is a web atlas of cellular structures using light and confocal microscopy.

http://www.life.uiuc.edu/plantbio/cell/
Virtual Cell.

http://esg-www.mit.edu:8001/esgbio/
The MIT Biology Hypertext book. The Cell Biology chapter covers parts of the cell, membrane structure, as well as receptor signaling cascades. There are Practice Problems here too.

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