Cell Structure and Function

Tenets of Cell Theory

1. All living things are made up of one or more cells
2. Cells are the basic living units within organisms, and the chemical reactions of life take place within cells
3. All cells arise from preexisting cells

Issues Related to Cell Size

Cell size and shape are related to cell function
There are lower and upper limits to cell size
- At a minimum, a cell must be able to house enough DNA, protein, and internal structures to survive and reproduce
- The maximum size of a cell is limited by its requirement for enough surface area to obtain enough nutrients from its environment and dispose of wastes

Although large cells have a greater surface area than small cells, they have much less surface area relative to their volume than do small cells of the same shape
Because the large cell has a much smaller surface area relative to its volume, it would have a more difficult time servicing all its cytoplasm than the smaller cells would

So, it is the ratio of cell surface to cell volume that imposes upper limits on cell size

Prokaryotic and Eukaryotic Cells

Prokaryotic Cells

Typically much smaller than eukaryotic cells (2-8 um in length); about 1/10 as big
A prokaryote ("before nucleus") cell lacks a nucleus; its DNA is coiled into a nucleoid (nucleus-like) region; no membrane surrounds this region
A plasma membrane encloses the cytoplasm of the prokaryote cell
And surrounding the plasma membrane of most prokaryotes is a rigid cell wall

Eukaryotic Cells

A eukaryote ("true nucleus") has a membrane bound nucleus
Also, eukaryote cells possess a number of cellular compartments called membranous organelles, each of which has a particular function in the cell
Organization of Cells: Common Structures and Functions

1. The Plasma Membrane

The cell's content is delineated from the world around it by a flexible sheet composed of lipid and protein called the **plasma membrane** or **cell membrane**

**The Lipid Bilayer**

The lipid is a phospholipid and each molecule has a polar "head" region and a nonpolar "tail" region. The head portion is hydrophobic ("water fearing") and the tail portion is hydrophilic ("water loving")

When such molecules are surrounded by water, they align in a characteristic 2-layered sheet with the heads pointed outward and the tails pointed inward and water excluded from the middle - **lipid bilayer**

**The Proteins**

There are proteins embedded in the lipid bilayer that form passage ways for materials. Some are embedded in the outer surface, inner surface, and some extend all the way from one side to another.

These proteins often recognize specific materials and allow them to pass through the membrane or they transport them across - **selectively permeable**

The cell membrane has often been described as a **fluid mosaic**,

Fluidity - Phospholipid molecules can freely move in the plane of the membrane. The steroid cholesterol helps maintain the fluidity of the membrane.

Mosaic - the proteins are scattered in the lipid bilayer like a tile mosaic.

The proteins in the membrane serve a variety of functions:

- attaching the membrane to the cytoskeleton
- forming junctions between adjacent cells
- many membrane proteins function as enzymes (see. Fig 5.13)
- some function as receptors for chemical messengers from other cells
- some membrane proteins help move substances across membranes
Movement of Materials across Cell Membranes

The plasma membrane exhibits *selective permeability*.
Nonpolar hydrophobic molecules are soluble in lipids and an easily pass through membranes.
Polar hydrophylic molecules are not soluble in lipids.
Whether polar molecules pass through the membrane depends on protein molecules in the phospholipid bilayer.

I. Passive Mechanisms for Transport Across Cell Membranes

A. Diffusion

The tendency of particles of any kind to spread out spontaneously from where they are more concentrated to where they are less concentrated.
Diffusion requires no work; it results from the random motion of molecules (Brownian movement) and it is driven by entropy (universal tendency to go from order to disorder).

Because a cell does not perform work when molecules diffuse across its membrane, the diffusion of a substance across a biological membrane is called **passive transport**.

B. The Diffusion of Water

The diffusion of water molecules across a selectively permeable membrane down its concentration gradient is a special case of passive transport called **osmosis**.

A solution with the higher concentration of solutes is said to be **hypertonic**.
A solution with the lower solute concentration is **hypotonic**.
A solution with solute concentrations on both sides that are equal is said to be **isotonic**.

During osmosis water moves down a concentration gradient - from where solute concentrations are low, to where solute concentrations are high.

Water Balance and Organisms - Osmosis and Living Cells

If, animals are in a hypotonic solution, which has a lower solute concentration than its cell, the cells gain water, swell, and may burst (= **lysis**).
If an animal cell is placed in a hypertonic solution, its cells will lose water and may shrivel up and die from the water loss.
C. Facilitated Diffusion of Solutes

**Facilitated Diffusion**

Many molecules move across a membrane with the help of transport proteins in the membrane because they too large to pass or are charged ions or molecules that do not interact well with lipids (Na+, Cl-)

When a protein molecule in the membrane makes it possible for a substance to move across a membrane down a concentration gradient, the process is called **facilitated diffusion**

The most common type of facilitated diffusion is via **channel proteins**

**Active Transport**

It’s the movement of substances across the membrane that requires the expenditure of energy by the cell

In active transport, membrane proteins actively pump specific solutes across the membrane *against* the solute's concentration gradient

**Exocytosis and Endocytosis**

A cell uses the process of **exocytosis**, to export bulky materials from its cytoplasm to the outside

Exocytosis is the movement of materials out of the cytoplasm of the cell via membranous vesicles

To import large molecules, the cell uses a transport process called **endocytosis**

Endocytosis is the movement of materials into the cytoplasm of the cell via membranous vesicles

**Phagocytosis**, or "cell eating" is a special kind of endocytosis
2. The Nucleus

The DNA inside the nucleus is the cell's heredity blueprint,
Most of the DNA is attached to proteins forming long fibers called chromatin
During cell division it becomes coiled structures called chromosomes

Also in the nucleus is a mass of fibers and granules called the nucleolus
The nucleolus is a combination of DNA, RNA, and proteins, and it's where ribosomes are made

Enclosing the nucleus and separating it from the rest of the cell is a nuclear envelope

3. The Cytoplasm with Its Organelles

*Organelles Related Through an Endomembrane System*

a. Endoplasmic reticulum (ER)

There are 2 kinds of ER: rough ER and smooth ER

*Rough ER*

A network of interconnected flattened sacs
The roughness is due to ribosomes which stud the membranes of the organelle

*Ribosome*

A ribosome is composed of 2 subunits: RNA and protein
They are the sites of protein synthesis

The rough ER has 2 main functions:

1. Make more membrane for itself and other organelles
2. Produce proteins that are secreted by the cell

*Smooth ER*

Smooth ER is a series of interconnected tubules that lack ribosomes
Smooth ER is continuous with rough ER
One of the most important functions of smooth ER is the synthesis of lipids, including fats and steroids
e.g., smooth ER cell in the ovaries and testes produce the sex hormones
Much of the activity of smooth ER results from enzymes embedded in its membranes.

Some enzymes in the smooth ER regulate the amount of sugar released from liver cells into the bloodstream. Others help break down drugs (e.g. antibiotics, sedatives, barbituates) and harmful toxins.

b. The Golgi Apparatus

The Golgi apparatus performs several functions in close partnership with the ER.

The Golgi apparatus receives and modifies substances that are manufactured by the ER. One side of the Golgi serves as a receiving dock, for vesicles produced by the ER. Once in the Golgi, the materials in the vesicles are modified (final assembly of carbohydrates with proteins or lipids with proteins).

The opposite side of the Golgi serves as a shipping depot. Finished products, bound in vesicles, move to the cell membrane for export. They may also move into other organelles.

c. Lysosomes

Produced by the rough ER and the Golgi. Lysosomes are membrane bound sacs that contain digestive (hydrolytic) enzymes.

Lysosomes have several types of digestive functions:

They fuse with food vacuoles taken in by the cell and breakdown the nutrients inside the vacuole.
They help destroy harmful bacteria in the cell.
Lysosomes also serve as recycling centers for the cell, by engulfing old organelles and making its molecules available for new organelles.

d. Vacuoles

*Food vacuole* - Stores food taken in by cells and later works in conjunction with the lysosomes.

*Central vacuole* (plants) - serve as a large lysosome; help plants grow in size; store vital chemicals.

*Contractile vacuole* - Found in a number of protists and play a role in osmoregulation.
Chloroplasts and Mitochondria

Chloroplasts

They are found in plants and some protists. Chloroplasts are complex structures that carry out photosynthesis, absorbing solar energy from the sun and converting it to chemical energy in sugar molecules.

Internal membranes partition the chloroplast into 3 major compartments:

1. *Intermembrane space* between the outer and inner membranes
2. The space enclosed by the inner membrane
   - It contains a fluid called stroma and a network of tubules and hollow discs formed of membranes.
3. The space inside the membranous tubules and discs
   - Notice that the discs occur as stacks each called a granum - the sites where chlorophyll actually traps solar energy.

Mitochondria

Mitochondria carry out the process of cellular respiration in which the chemical energy of foods such as sugars is converted into chemical energy of a cellular fuel molecule called ATP.

The mitochondrion is enclosed by 2 membranes:
- The mitochondrion has only 2 compartments:
  1. The inner membrane space forms one fluid filled compartment
  2. The inner membrane encloses the second compartment, containing a fluid called the mitochondrial matrix

The inner membrane is highly folded and has enzymes embedded in it that are responsible for the production of ATP.
- Each fold is called a crista (e); they greatly increase the membrane's surface area for ATP production.
**The Internal Skeleton of Cells**

For structural support, cells contain a supportive network of fine fibers that are collectively called the **cytoskeleton**

1. **Microfilaments**

Solid helical rods composed mainly of the globular protein **actin**
These filaments can help cells change shape and move by assembling (adding subunits) at one end and disassembling (losing subunits) at the other

2. **Intermediate Filaments**

They are made up of fibrous proteins and have a rope-like structure
They often help to anchor organelles

3. **Microtubules**

They are straight hollow tubes composed of globular proteins called **tubulins**
They are very easily assembled and disassembled in various parts of the cell

**Functions of Microtubules:**

They provide rigidity and shape to various parts of the cell
They also anchor organelles and act as tracts along which the organelles move
Microtubules also guide the movement of chromosomes when cells divide
They are the basis of ciliary and flagellar movement

**Ciliary and Flagellar Movement**

**Structure**

Their microtubules are arranged in a ring of 9 microtubule doublets surrounding a central pair of microtubules (9+2 arrangement)
The microtubules are covered by an extension of the plasma membrane
They are anchored to the cell by a **basal body**

The short, numerous appendages that propel protists through water are called **cilia**
Longer, less numerous appendages on other protists are called **flagella**
**Movement**

Cilia and flagella provide a locomotor mechanism for the cell by moving (bending) in a whip like fashion. Bending results from small protein arms - **dynein arms** - from one microtubule doublet attaching to a an adjacent microtubule doublet.

**The Cell Wall of Plants**

Plant cells have a non-living material that surrounds them called the **cell wall**. The cell wall is composed primarily of **cellulose** (a complex polysaccharide).

The cell wall of most plants is actually a layered structure. **Primary cell wall** - remains relatively stretchy and flexible until the cell stops growing; it is porous, allowing water, gases, etc to pass through.

**Secondary cell wall** - produced after the plant has stopped growing; rigid structure, impregnated with stiffening materials,

**Communication among Cells**

Q. **How do the cells communicate so they can function as coordinated unit?**

**Plants**

To function in a coordinated way plant cells have what are called **cell junctions**, structures that connect them to one another. There are numerous channels between adjacent cells called **plasmodesmata**. They allow the cytoplasm of one cell to be connected to the cytoplasm of an adjacent cell.

**Animals**

1. **Tight Junctions**

   These bind cells together, forming a leak proof sheet.

2. **Gap Junctions**

   These are channels that are similar in function to plasmodesmata. They allow water and other small molecules to flow between neighboring cells.