Chapter 5
The Working Cell

PowerPoint Lectures for

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MEMBRANE STRUCTURE AND FUNCTION
5.1 Membranes are a fluid mosaic of phospholipids and proteins

- **Membranes** are composed of **phospholipids** and **proteins**
  
  Many phospholipids are made from **unsaturated fatty acids** that have **kinks in their tails**
  
  - Membranes are commonly described as **a fluid mosaic**
  
  - This means that the surface appears **mosaic** because of the **proteins** embedded in the phospholipids and **fluid** because the **proteins** can drift about in the phospholipids
  
  - This is aided by **cholesterol** wedged into the bilayer to help stabilize the membrane at warm and also at lower temperature. **keep it liquid**

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Phospholipid bilayer (cross section)  The fluid mosaic model for membranes
5.1 Membranes are a fluid mosaic of phospholipids and proteins

Many membrane proteins function as enzymes, others in signal transduction, while others are important in transport.

- Because membranes allow some substances to cross or be transported more easily than others, they exhibit selectively permeability.
  - Nonpolar molecules (carbon dioxide and oxygen) cross easily.
  - Polar molecules (glucose and other sugars) do not cross easily.
**Enzymes** are proteins that have catalytic functions to maintenance and activity of life.
Concentration gradient

Transport

from a region of higher to lower concentration

High Concentration

Actice transport

Low Concentration

Water

Diagram of a section of a membrane sac
Diffusion is a process in which particles spread out evenly in an available space.

- Particles move from an area of more concentrated particles to an area where they are less concentrated.
- This means that particles diffuse down their concentration gradient.
- Eventually, the particles reach equilibrium where the concentration of particles is the same throughout.
5.3 Passive transport is diffusion across a membrane with no energy investment

- Diffusion across a cell membrane does not require energy, so it is called passive transport.

  - The concentration gradient itself represents potential energy for diffusion.
Passive transport of one type of molecule
Two different Substances

Membrane

Equilibrium

Passive transport of two types of molecules
5.4 Osmosis is the diffusion of water across a membrane

- It is crucial for cells that water moves across their membrane
  - Water moves across membranes in response to solute concentration inside and outside of the cell by a process called osmosis
  - Osmosis will move water across a membrane down its concentration gradient until the concentration of solute is equal on both sides of the membrane
Osmosis, the diffusion of water across a membrane.

Selectively permeable membrane

Lower concentration of solute

Higher concentration of solute

Equal concentration of solute

Solute molecule

H₂O

Net flow of water

Solute molecule with cluster of water molecules

Water Molecule
5.5 Water balance between cells and their surroundings is crucial to organisms

- **Tonicity** is a term that describes the ability of a solution to cause a cell to gain or lose water.

- Tonicity is dependent on the concentration of a nonpenetrating solute on both sides of the membrane.

  - **Isotonic** indicates that the concentration of a solute is the same on both sides.

  - **Hypertonic** indicates that the concentration of solute is higher outside the cell.

  - **Hypotonic** indicates a higher concentration of solute inside the cell.
Many organisms are able to maintain water balance within their cells by a process called osmoregulation.

- This process prevents excessive uptake or excessive loss of water.
- Plant, prokaryotic, and fungal cells have different issues with osmoregulation because of their cell walls.
Many organisms are able to maintain water balance within their cells by a process called osmoregulation.

- **Isotonic solution**: Water moves in and out of the cell (A) Normal
- **Hypotonic solution**: Water enters the cell (B) Lysed (C) Shriveled
- **Hypertonic solution**: Water leaves the cell (D) Flaccid

Animal cell

Plant cell

Plasma Membrane

(F) Shriveled (plasmolyzed)

How animal and plant cells behave in different solutions.
Many substances that are necessary for viability of the cell do not freely diffuse across the membrane because of their polarity.

- They require the help of specific transport proteins.

- These proteins assist in facilitated diffusion, (type of passive transport that does not require energy) including sugar, amino acids and ions. Water transported through specific transport protein called aquaporin.
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Some proteins function by becoming a hydrophilic tunnel for passage

- Other proteins bind their passenger, change shape, and release their passenger on the other side

- In both of these situations, the protein is specific for the substrate,
These proteins assist in facilitated diffusion, a type of passive transport that does not require energy.
5.8 Cells expend energy in the active transport of a solute against its concentration gradient

- **Cells have a mechanism** for moving a solute against its concentration gradient
  - It requires the expenditure of energy in the form of ATP
  - The mechanism alters the shape of the membrane protein through phosphorylation using ATP
5.8 Cells expend energy in the active transport of a solute against its concentration gradient.
A cell uses two mechanisms for moving large molecules across membranes:

- **Exocytosis** is used to export bulky molecules, such as proteins or polysaccharides.

- **Endocytosis** is used to import substances useful to the livelihood of the cell.

In both cases, material to be transported is packaged within a **vesicle** that fuses with the membrane.
ENERGY AND THE CELL
Cells are small units, a chemical factory, housing thousands of chemical reactions.

- The result of reactions is maintenance of the cell, manufacture of cellular parts, and replication.
5.10 Cells transform energy as they perform work

- **Energy** is the capacity to do work and cause change
  
  - Work is accomplished when an object is moved against an opposing force, such as friction

- There are **two kinds of energy**
  
  - **Kinetic energy** is the energy of motion
  
  - **Potential energy** is energy that an object possesses as a result of its location
Kinetic energy, the energy of motion

Potential energy, stored energy as a result of location or structure

Potential energy being converted to kinetic energy
5.12 Chemical reactions either release or store energy

- A living organism produces thousands of endergonic and exergonic chemical reactions
  - All of these combined is called **metabolism**
  - **A metabolic pathway** is a series of chemical reactions that either **break down a complex molecule** or **build up a complex molecule**
5.12 Chemical reactions either release or store energy

- A cell does three main types of cellular work
  - Chemical work — driving endergonic reactions
  - Transport work — pumping substances across membranes
  - Mechanical work — beating of cilia
- To accomplish work, a cell must manage its energy resources, and it does so by energy coupling—the use of exergonic processes to drive an endergonic one
A cell does three main types of cellular work
5.13 ATP shuttles chemical energy and drives cellular work

- **ATP**, adenosine triphosphate, is the energy currency of cells.
  
  - ATP is the immediate source of energy that powers most forms of cellular work.
  
  - It is composed of **adenine** (a nitrogenous base), **ribose** (a five-carbon sugar), and **three phosphate groups**.
5.13 ATP shuttles chemical energy and drives cellular work
الطاقة الكيميائية اللازمة للخلية للفيام مهماتها

Hydrolysis of ATP releases energy by transferring its third phosphate from ATP to some other molecule

– The transfer is called phosphorylation

– In the process, ATP energizes molecules
The structure and hydrolysis of ATP. The reaction of ATP and water yields ADP, a phosphate group, and energy.
Energy from exergonic reactions

Phosphorylation

ADP + P

Hydrolysis

Energy for endergonic reactions

The ATP cycle
HOW ENZYMES FUNCTION
5.14 Enzymes speed up the cell’s chemical reactions by lowering energy barriers

- The cell uses **catalysis** to drive (speed up) biological reactions
  
  - Catalysis is accomplished by **enzymes**, which are **proteins** that function as biological catalysts

  - Each enzyme has a particular target molecule called the **substrate**
5.15 A specific enzyme catalyzes each cellular reaction

- **Enzymes** have unique three-dimensional shapes
  
  - **The shape** is critical to their role as biological catalysts
  
  - As a result of its shape, *the enzyme has an active site where the enzyme interacts with the enzyme’s substrate*
  
  - Consequently, *the substrate’s chemistry is altered to form the product of the enzyme reaction*
1. Enzyme available with empty active site

Active site

2. Substrate binds to enzyme with induced fit

Substrate (sucrose)

3. Substrate is converted to products

Glucose  Fructose

H₂O

4. Products are released

The catalytic cycle of an enzyme
5.15 A specific enzyme catalyzes each cellular reaction

For **optimum activity**, enzymes require certain environmental conditions

1- **Temperature** is very important, and optimally, human enzymes function best at 37ºC, close to normal body temperature

- High temperature will **denature human enzymes**

2- Enzymes also require **optimal PH** near neutrality for best results
Some enzymes require nonprotein helpers

- **Cofactors** are inorganic, such as zinc, iron, or copper

- **Coenzymes** are organic molecules and are often vitamins
Inhibitors are chemicals that inhibit an enzyme’s activity.

One group inhibits because they compete for the enzyme’s active site and thus block substrates from entering the active site.

- These are called competitive inhibitors.
Other inhibitors do not act directly with the active site

- These bind somewhere else and change the shape of the enzyme so that the substrate will no longer fit the active site
- These are called noncompetitive inhibitors
Substrate → Enzyme → Active site

Normal binding of substrate

How inhibitors interfere with substrate binding

Competitive Inhibitor

Noncompetitive Inhibitor

Enzyme inhibition
Enzyme inhibitors are important in regulating cell metabolism

- Often the product of a metabolic pathway can serve as an inhibitor of one enzyme in the pathway, a mechanism called feedback inhibition

- The more product formed, the greater the inhibition, and in this way, regulation of the pathway is accomplished
Diffusion
Requires no energy
Passive transport
Higher solute concentration
Facilitated diffusion
Osmosis
Higher water concentration
Requires energy
Active transport
Lower solute concentration
Higher solute concentration
Lower water concentration
Solute
Water
ATP