The Cell & Cellular Processes 4B

4.B investigate and explain cellular processes, including homeostasis, energy conversions, transport of molecules, and synthesis of new molecules

Cell Transport: Glossary:
Diffusion: is a movement of a molecule from a high to a low concentration.
Osmosis: is the diffusion of water.
Hypotonic: (in animal cells)- less outside than inside of the cell. (in plant cells)- water rushes in to try to dilute the salt on the inside.
Hypertonic: (in animal cells)- more stuff is in the solution than in the cell. (in plant cells)- water leaves the cells and it shrinks. The cell membrane sinks inside and the cell wall remains the same.
Isotonic: (in animal cells)- salt solution is the same on the inside and outside of the cell. (in plant cells)- there is an equal amount of water going in and out of the cell.
Homeostasis: is a process by which organisms keep internal conditions relatively stable regardless of changes in the external environment. Homeostasis is important because the processes that keep the cell alive can only take place under certain internal conditions.
Passive transport: is the movement of materials across the cell membrane without using the cell’s energy.
Diffusion: is the process by which materials spread out from areas where there are more of them to areas where there are fewer of them. It is the simplest form of passive transport.
Osmosis: is the diffusion of water across a selectively permeable membrane.
Facilitated diffusion: is a form of passive transport in which molecules are helped across the cell membrane by carrier proteins.
Active transport: is the movement of materials from an area where there are fewer of them to an area where there are more of them. It requires energy and, possibly, a carrier protein.
Endocytosis: is a process in which a cell completely surrounds a substance to move materials into the cell.
Exocytosis: is the process in which a vesicle in a cell joins

HOMEOSTASIS AND TRANSPORT
I. Cell Membranes
A. Cell membranes help organisms maintain homeostasis by controlling what substances may enter or leave cells
B. Some substances can cross the cell membrane without any input of energy by the cell
C. The movement of such substances across the membrane is known as passive transport
D. To stay alive, a cell must exchange materials such as food, water, & wastes with its environment
E. These materials must cross the cell or plasma membrane
F. Small molecules like water, oxygen & carbon dioxide can move in and out freely

G. Large molecules like proteins & carbohydrates cannot move easily across the plasma membrane
H. The Cell Membrane is semipermeable or selectively permeable only allowing certain molecules to pass through
II. Diffusion
A. Diffusion is the movement of molecules from an area of higher concentration to an area of lower concentration.

B. Small molecules can pass through the cell membrane by a process called diffusion.
C. Diffusion across a membrane is a type of passive transport because it does not require energy.
D. This difference in the concentration of molecules across a membrane is called a concentration gradient.
E. Diffusion is driven by the kinetic energy of the molecules.
F. Kinetic energy keeps molecules in constant motion causing the molecules to move randomly away from each other in a liquid or a gas.
G. The rate of diffusion depends on temperature, size of the molecules, & type of molecules diffusing.
H. Molecules diffuse faster at higher temperatures than at lower temperatures.
I. Smaller molecules diffuse faster than larger molecules.
J. Most short-distance transport of materials into & out of cells occurs by diffusion.
K. Solutions have two parts --- the solute which is being dissolved in the solvent.
L. Water serves as the main solvent in living things.
M. Diffusion always occurs down a concentration gradient (water moves from an area where it is more concentrated to an area where it is less concentrated).
N. Diffusion continues until the concentration of the molecules is the same on both sides of a membrane.
O. When a concentration gradient no longer exists, equilibrium has been reached but molecules will continue to move equally back & forth across a membrane.

III. Osmosis
A. The diffusion of water across a semipermeable membrane is called osmosis.
B. Diffusion occurs from an area of high water concentration (less solute) to an area of lower water concentration (more solute).
C. Movement of water is down its concentration gradient & doesn’t require extra energy.
D. Cytoplasm is mostly water containing dissolved solutes.
E. Concentrated solutions have many solute molecules & fewer water molecules.
F. Water moves from areas of low solute concentration to areas of high solute concentration.
G. Water molecules will cross membranes until the concentrations of water & solutes are equal on both sides of the membrane; called equilibrium.
H. At equilibrium, molecules continue to move across membranes evenly so there is no net movement.
I. Hypertonic Solution
1. Solute concentration outside the cell is higher (less water)
2. Water diffuses out of the cell until equilibrium is reached
3. Cells will shrink & die if too much water is lost
4. Plant cells become flaccid (wilt); called plasmolysis

J. Hypotonic Solution
1. Solute concentration greater inside the cell (less water)
2. Water moves into the cell until equilibrium is reached
3. Animal cells swell & burst (lyse) if they take in too much water
4. Cytolysis is the bursting of cells
5. Plant cells become turgid due to water pressing outward against cell wall
6. Turgor pressure in plant cells helps them keep their shape
7. Plant cells do best in hypotonic solutions

K. Isotonic Solutions
1. Concentration of solutes same inside & outside the cell
2. Water moves into & out of cell at an equal rate so there is no net movement of water
3. Animal cells do best in isotonic solutions

IV. How Cells Deal With Osmosis
A. The cells of animals on land are usually in isotonic environment (equilibrium)
B. Freshwater organisms live in hypotonic environments so water constantly moves into their cells
C. Unicellular freshwater organisms use energy to pump out excess water by contractile vacuoles
D. Plant cell walls prevent plant cells from bursting in hypotonic environments
E. Some marine organisms can pump out excess salt

V. Facilitated Diffusion
A. Faster than simple diffusion
B. Considered passive transport because extra energy not used
C. Occurs down a concentration gradient
D. Involves carrier proteins embedded in a cell’s membrane to help move across certain solutes such as glucose
E. Carrier molecules change shape when solute attaches to them
F. Change in carrier protein shape helps move solute across the membrane
G. Channel proteins in the cell membrane form tunnels across the membrane to move materials.

H. Channel proteins may always be open or have gates that open & close to control the movement of materials; called gated channels.

I. Gates open & close in response to concentration inside & outside the cell.

**VI. Active Transport**

A. Requires the use of ATP or energy

B. Moves materials against their concentration gradient from an area of lower to higher concentration

C. May also involve membrane proteins

D. Used to move ions such as Na⁺, Ca²⁺, and K⁺ across the cell membrane

E. Sodium-Potassium pump moves 3 Na⁺ out for every 2 K⁺ into the cell
   1. Causes a difference in charge inside and outside the cell
   2. Difference in charge is called membrane potential

F. Ion pumps help muscle & nerve cells work

G. Plants use active transport to help roots absorb nutrients from the soil (plant nutrients are more concentrated inside the root than outside)

**VII. Bulk Transport**

A. Moves large, complex molecules such as proteins across the cell membrane

B. Large molecules, food, or fluid droplets are packaged in membrane-bound sacs called vesicles

C. **Endocytosis** moves large particles into a cell
D. **Phagocytosis** is one type of endocytosis
1. Cell membrane extends out forming pseudopods (fingerlike projections) that surround the particle
2. Membrane pouch encloses the material & pinches off inside the cell making a vesicle
3. Vesicle can fuse with lysosomes (digestive organelles) or release their contents in the cytoplasm
4. Used by ameba to feed & white blood cells to kill bacteria
5. Known as "cell eating"

E. **Pinocytosis** is another type of endocytosis
1. Cell membrane surrounds fluid droplets
2. Fluids taken into membrane-bound vesicle
3. Known as "cell drinking"

F. **Exocytosis** is used to remove large products from the cell such as wastes, mucus, & cell products

G. **Proteins** made by ribosomes in a cell are packaged into transport vesicles by the Golgi Apparatus
H. Transport vesicles fuse with the cell membrane and then the proteins are secreted out of the cell (e.g. insulin
Energy Conversion

Light energy radiated from the sun in the form of waves strikes the leaf. The energy is used to run photosynthesis.

Photosynthesis in cell organelle called the chloroplast.

Carbon Dioxide (CO₂) and Water (H₂O) → Glucose (C₆H₁₂O₆) and Oxygen (O₂)

Heat given off in respiration in organelle of cell called the mitochondria.

**Photosynthesis**

\[
\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{O}_2 + \text{SUGARS}
\]

**Respiration**

\[
\text{SUGARS} + \text{O}_2 \rightarrow \text{H}_2\text{O} + \text{CO}_2
\]

**Photosynthesis**

\[
6 \text{ CO}_2 + 6 \text{ H}_2\text{O} \rightarrow C_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2
\]

**Cellular Respiration**

\[
\text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2 \rightarrow 6 \text{ CO}_2 + 6 \text{ H}_2\text{O} + \text{ATP}
\]

**Energy in ATP**
Photosynthesis

- Chloroplasts carry out photosynthesis
- Chlorophylls and other pigments involved in absorption of solar energy reside within thylakoid membranes of chloroplasts

Plants as Solar Energy Converters
A. Solar Radiation - Only 42% of solar radiation that hits the earth’s atmosphere reaches surface; most is visible light.
B. Photosynthetic Pigments - Pigments found in chlorophyll absorb various portions of visible light; absorption spectrum. Two major photosynthetic pigments are chlorophyll a and chlorophyll b.
C. Photosynthetic Reaction
1. In 1930 C. B. van Niel showed that O₂ given off by photosynthesis comes from water and not from CO₂.
2. The net equation reads:

Two Sets of Reactions in Photosynthesis
1. Light reactions cannot take place unless light is present. They are the energy-capturing reactions.
   a. Chlorophyll within thylakoid membranes absorbs solar energy and energizes electrons.
   b. Energized electrons move down the electron transport system; energy is captures and used for ATP production.
   c. Energized electrons are also taken up by NADP⁺, becoming NADPH.
2. Calvin Cycle Reactions
   a. These reactions take place in the stroma; can occur in either the light or the dark.
   b. These are synthesis reactions that use NADPH and ATP to reduce CO₂.
Light reactions:
- Are carried out by molecules in the thylakoid membranes
- Convert light energy to the chemical energy of ATP and NADPH
- Split H₂O and release O₂ to the atmosphere

Calvin cycle reactions:
- Take place in the stroma
- Use ATP and NADPH to convert CO₂ to the sugar G3P
- Return ADP, inorganic phosphate, and NADP⁺ to the light reactions

Photosynthesis:
- Light reactions convert light energy into chemical energy
- Calvin cycle uses this energy to convert CO₂ into glucose
- Glucose is then converted into sucrose for export or further breakdown into amino acids, fatty acids, and starch (storage)
**Cellular Respiration**

**Cellular respiration** is the process in which the chemical bonds of energy rich molecules (like glucose) are converted into a form of energy that cells can use. In eukaryotic (including animal and plant) cells, cellular respiration takes place in the mitochondria. **Cellular respiration takes place in the mitochondria.**

Cellular respiration is the enzymatic breakdown of glucose ($C_6H_{12}O_6$) in the presence of oxygen ($O_2$) to produce cellular energy (ATP).

$$C_6H_{12}O_6 + O_2 \rightarrow 6CO_2 + 2H_2O + 36ATP$$

**Aerobic Respiration consists of 3 Main Steps:**

1. **Glycolysis** (Anaerobic - No $O_2$ needed)
   a) splits Glucose (6 C) to make two 3-carbon molecules. 2 ATP needed to split glucose.
   b) removes energy and hydrogen from the 3-carbon molecules. This is used to make NADH (E. carrier).
   c) removes more energy to make 4 ATP. 2 ATP go to split next glucose. 2 ATP available for cell use.
   d) At end of glycolysis, 2 pyruvate molecules (3C) left.
2. Citric Acid or Krebs Cycle (Aerobic - O₂ needed)
a. occurs in the inner mitochondrial matrix
b) the acetyl group detaches from the co-enzyme A and enters the reaction cycle
c) an aerobic process; will proceed only in the presence of O₂
d. net yield of 6 NADH and 2 FADH₂
e. the oxidation of glucose to CO₂ is completed in this stage
3. Electron Transport (Aerobic - O₂ needed)
   a. consists of a series of enzymes on the inner mitochondrial membrane
   b. electrons are released from NADH and from FADH₂ and as they are passed along the series of enzymes, they give up energy which is used to fuel a process called chemiosmosis by which H⁺ ions are actively transported across the inner mitochondrial membrane into the outer mitochondrial compartment. The H⁺ ions then flow back through special pores in the membrane, a process that is thought to drive the process of ATP synthesis.
   c. net yield of 34 ATP per glucose molecule
   d. 6 H₂O are formed when the electrons unite with O₂ at the end of electron transport chain. [* Note: This is the function of oxygen in living organisms!]

<table>
<thead>
<tr>
<th>Aerobic Respiration Step</th>
<th>Location</th>
<th># of ATP Made</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1) Glycolysis</td>
<td>Cytoplasm</td>
<td>4 gross, 2 net ATP</td>
<td>Begins breakdown of Glucose. Converts glucose energy to ATP &amp; NAD.</td>
</tr>
<tr>
<td>#2) Krebs Cycle</td>
<td>Matrix</td>
<td>2 ATP</td>
<td>Finishes breakdown of Glucose. Converts glucose energy to ATP, NADH &amp; FADH₂.</td>
</tr>
<tr>
<td>#3) Electron Transport</td>
<td>Cristae</td>
<td>32 ATP</td>
<td>Converts energy in NADH &amp; FADH₂ to ATP.</td>
</tr>
</tbody>
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Fermentation

There are times, such as during heavy exercise, when your cells are without oxygen for a short period of time. When this happens an anaerobic process called fermentations follows glycolysis and provides the means to continue producing ATP until oxygen is available again.

<table>
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<tr>
<th>Lactic Acid</th>
<th>Alcoholic</th>
<th>Cellular respiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>glucose → glycolysis (pyruvic acid)</td>
<td>glucose → glycolysis (pyruvic acid)</td>
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</tr>
<tr>
<td></td>
<td>carbon dioxide + lactic acid + 2 ATP</td>
<td>carbon dioxide + alcohol + water + 36 ATP</td>
</tr>
</tbody>
</table>

Formation of new Molecules

A. Protein synthesis

B. DNA replication

(more detail found under 6.C)