Keystone Biology Remediation

Homeostasis, Transport, and Bioenergetics

Homeostasis

- The regulation of metabolic processes to maintain the stable internal conditions required for survival.
  - Every organism has mechanisms that allow it to respond to changing external conditions in order to maintain a stable internal temperature, pH, and ion concentrations.

Temperature

- Cells function properly only in a narrow range of temperatures.
  - Sweating and shivering are two of the body's mechanisms for regulating internal temperatures.
  - In plants, when high temperatures and dry environmental conditions exist, guard cells reduce water loss by closing the openings in their leaves.
- In cases of exposure to extreme heat or cold, the homeostatic balance is disturbed, and cell die-off, organ damage, or even death can result.

pH Balance

- Cells rely on enzymes to perform many essential tasks.
  - Enzymes can function only in a narrow range of temperatures and pHs.
  - So, it is necessary for the pH of the blood and the cytoplasm to remain constant at about a pH of 7.4.
- If the pH rises due to illness or elevated carbon dioxide levels, the body increases the rate of respiration.
  - This removes excess carbon dioxide from the blood, and the pH balance is restored.
- Some health conditions can cause the blood pH to be outside the normal range.
  - People with emphysema have lung damage, and they can no longer expel carbon dioxide normally. As a result, blood pH is lower than normal. This causes cell die-off.

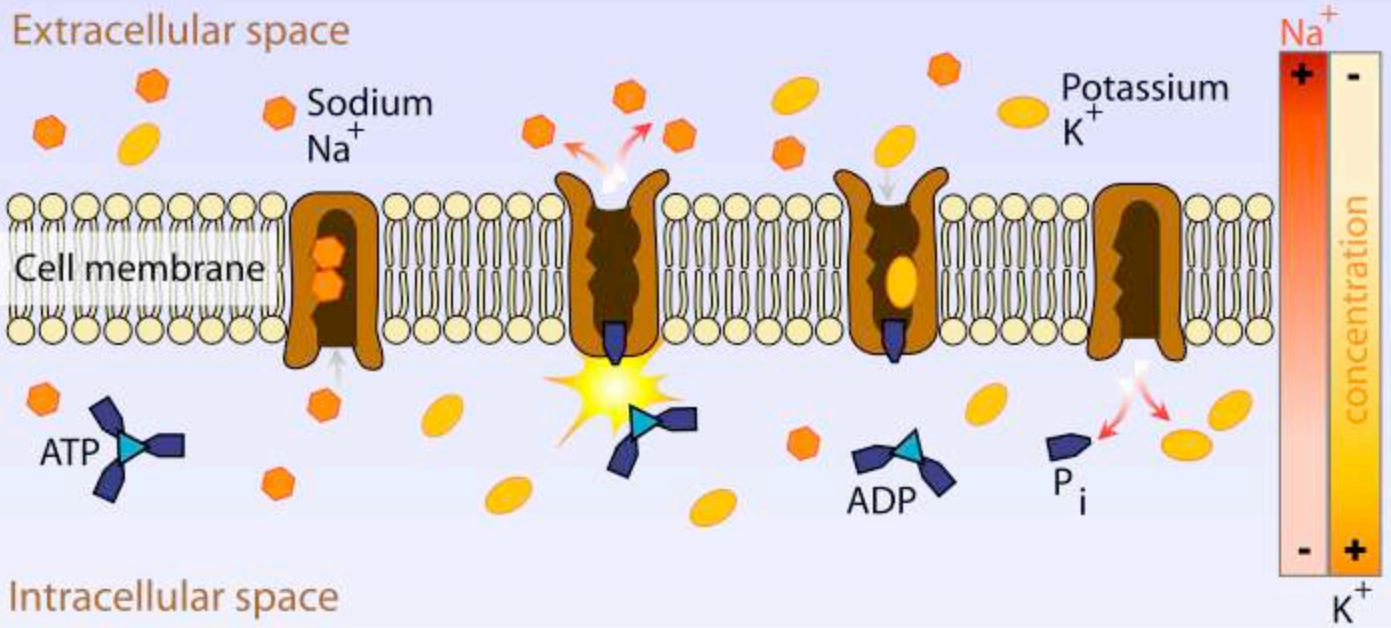
Concentration of Solutes

- ***Solute***-*The substance that is dissolved*
- A cell's membrane is key in maintaining homeostasis because the membrane allows cells to regulate the materials that are entering or leaving.
  - For example, human cells must have a lower sodium ion concentration and a higher potassium ion concentration than the blood.
  - To do this, cells have membrane pumps that move sodium out of the cell and move potassium into it.
- A steady concentration of other solutes in the blood must also be maintained.
  - When solutes become imbalanced, diseases occur.
    - Diabetes, for example, is the result of large fluctuations of blood glucose levels

Image: Sodium-potassium pump – Mariana Ruiz Villarreal – Public domain

Active transport

Sodium-potassium pump



Because the ions have a natural tendency to diffuse and reach equilibrium, the cell must use ATP to move the ions against the concentration gradient.

Organelles and Homeostasis

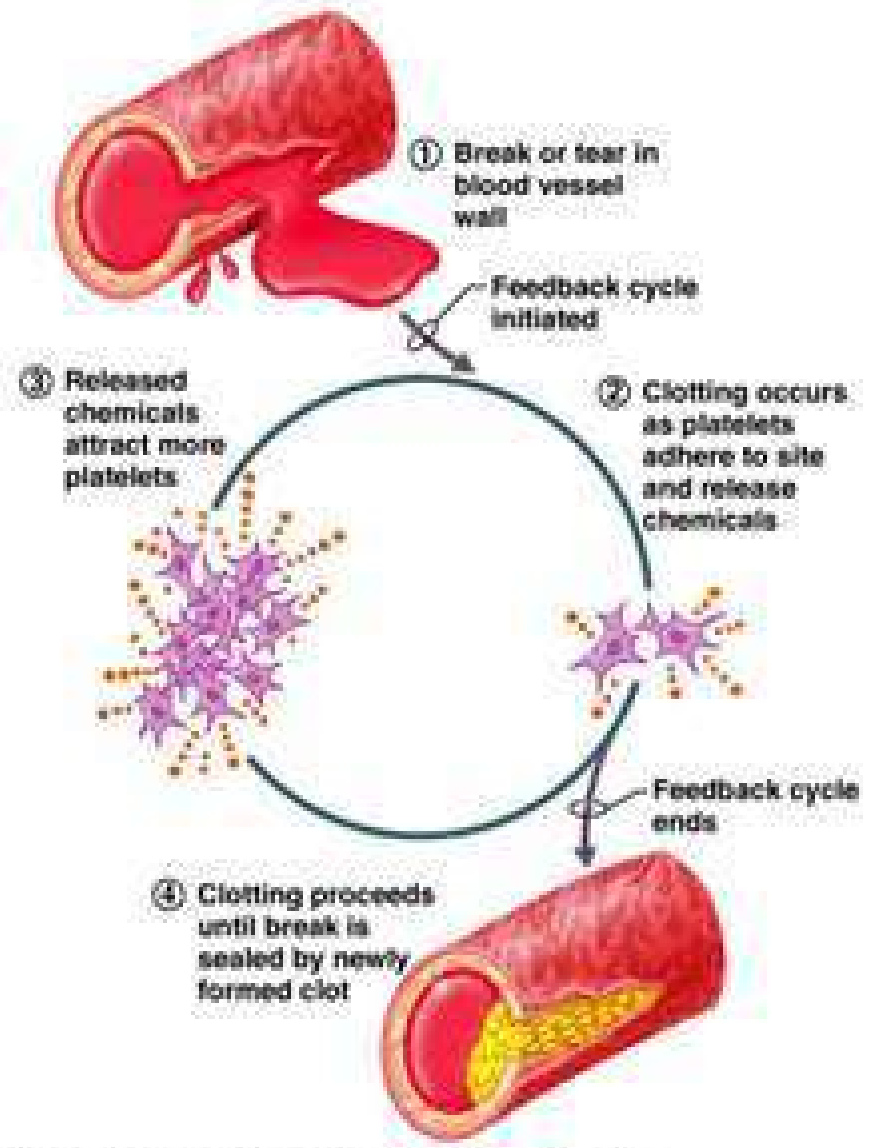
- The **Golgi apparatus** and **endoplasmic reticulum** help maintain cellular homeostasis by assisting with the transport of needed macromolecules.
- In order to maintain homeostasis, cells must be able to sort and send substances to the correct location.
- The Golgi apparatus is key in sorting and packaging macromolecules, particularly proteins.
- The endoplasmic reticulum, or ER, is the initial location of protein transport.

Maintenance of Homeostasis

- In order to keep all parts of the organism functional and working together, an organism must be able keep internal conditions constant despite external pressures.
  - Examples of processes that help organisms maintain **homeostasis**, an internal equilibrium, include thermoregulation, oxygen regulation, and maintenance of a proper water balance.
- Organisms accomplish these tasks by various feedback mechanisms.

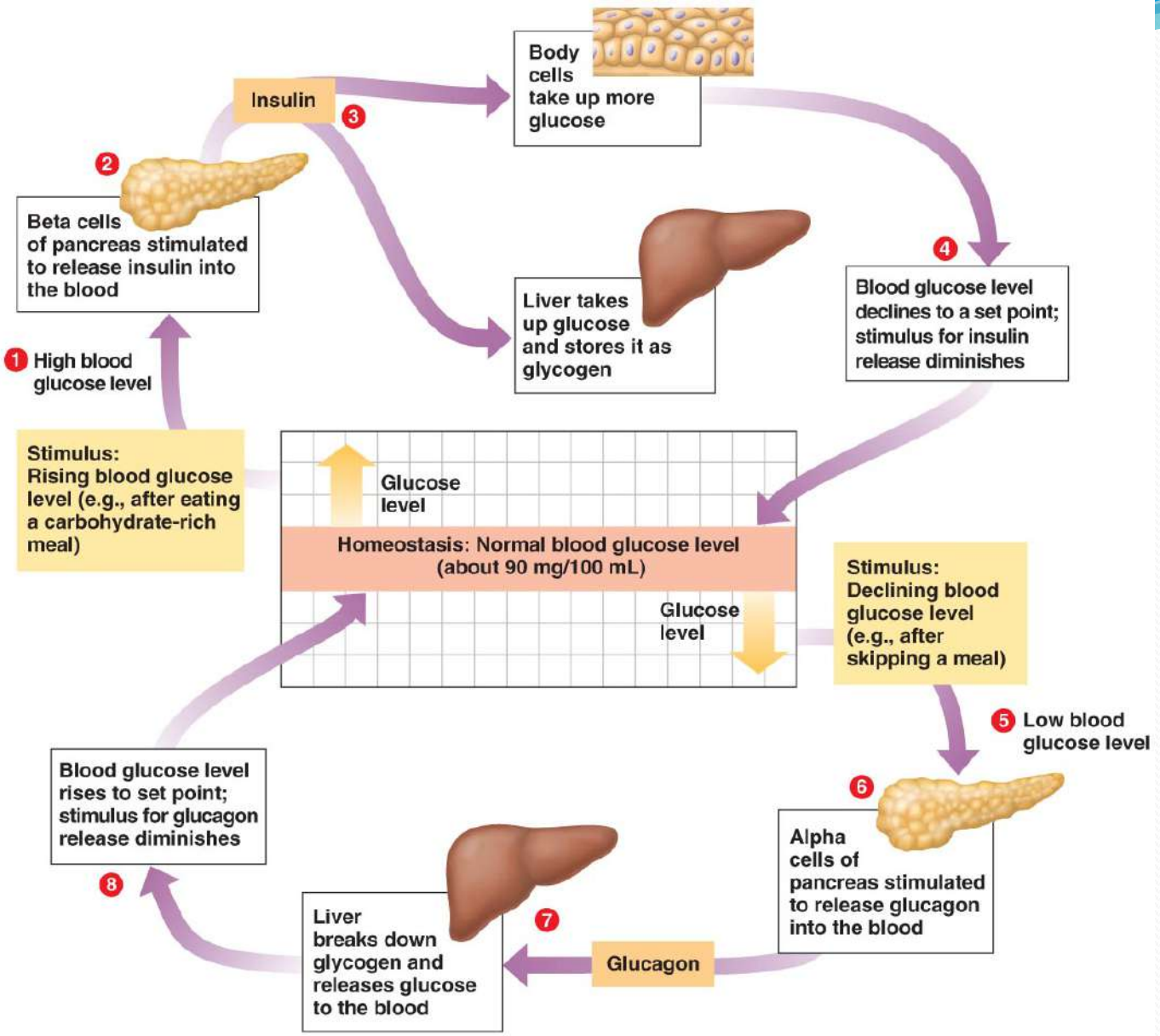
Positive Feedback Mechanism

- ***A positive feedback mechanism is an interaction that increases or amplifies the response of the system in which it is incorporated.***
  - Coagulation, or blood clotting, is an example of positive feedback.
    - Damage to a vessel wall will signal for the release of substances that trigger the activation of blood platelets. As platelets begin to accumulate around the damaged portion, they send chemical signals to activate more platelets resulting in the formation of a clot, which acts as a temporary plug until the vessel tissue can be repaired.



Negative Feedback Mechanism

- ***A negative feedback mechanism is an interaction that reduces or dampens the response of the system in which it is incorporated*.**
- Negative feedback loops are more common mechanisms in maintaining homeostasis.
- Whereas positive feedback loops reinforce changes to a system, negative feedback loops are responses in which a system works against change.
  - The insulin production model is an example.



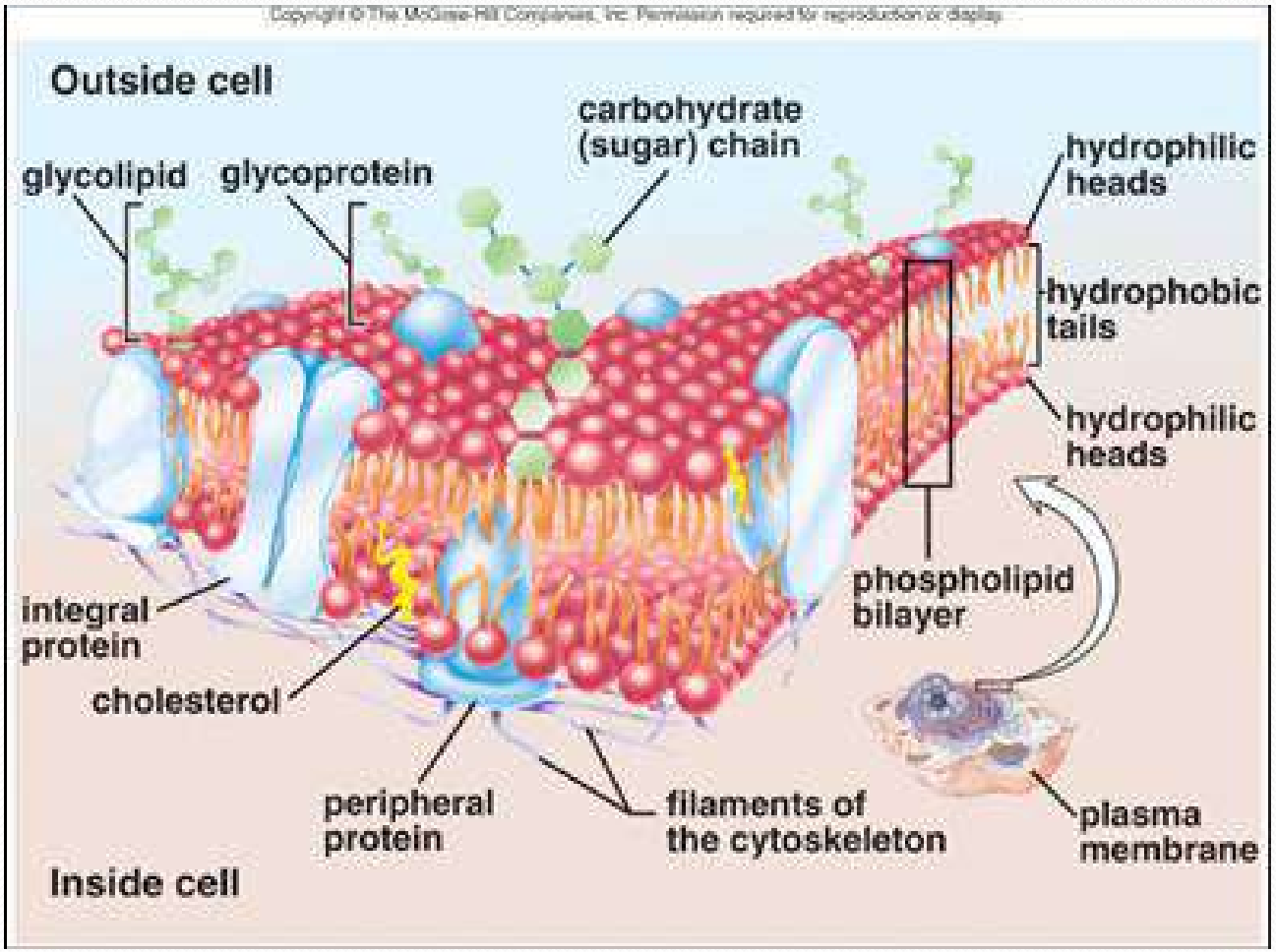
Cell Membrane

- The main purpose of the **cell membrane** is to control the movement of substances in and out of the cell. Another name for the cell membrane is the **plasma membrane**.
- Both animal and plant cells have cell membranes. In animal cells, the cell membrane separates the cell's internal environment from its external environment. In plant cells, the cell membrane is surrounded by a cell wall.

Fluid Mosaic Model

- The structure and function of a cell membrane can be described by the *fluid mosaic model*.
- According to this model, the membrane is like a mosaic because it is made up of many different parts, including different types of macromolecules, proteins, and lipids. Also, according to this model, the membrane is considered to be fluid because the proteins and lipids within the membrane can move.

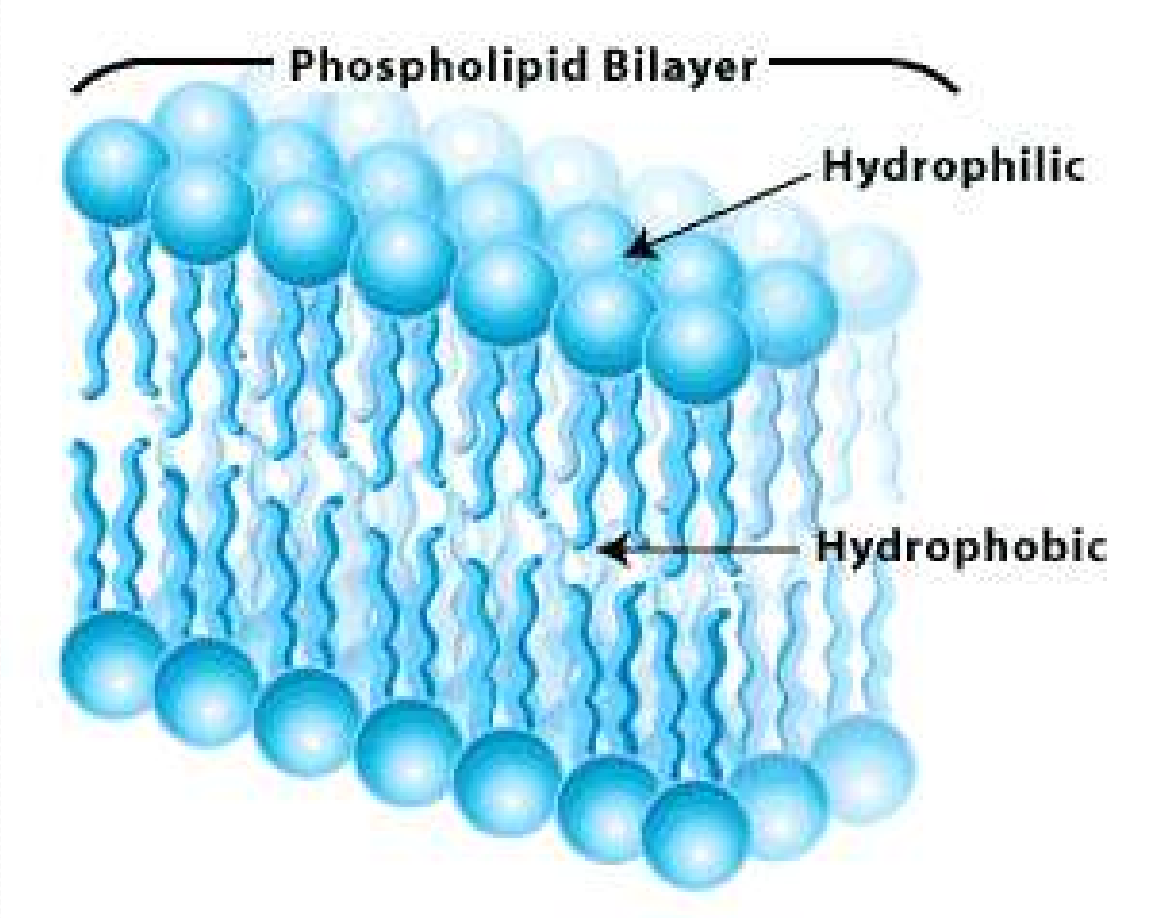
Fluid Mosaic Model



Phospholipid Bilayer

- The proteins and lipids in the cell membrane form a phospholipid bilayer. In the phospholipid bilayer, the hydrophilic ("water-loving") heads of the phospholipids face outward and the hydrophobic ("water-fearing") tails face inward.
- This arrangement allows the cell membrane to control the movement of substances in and out of the cell.
  - In fact, due to this arrangement, polar molecules are unable to go across the cell membrane unless they pass through channels, or their diffusion must be facilitated by carrier proteins.

Lipid Bilayer



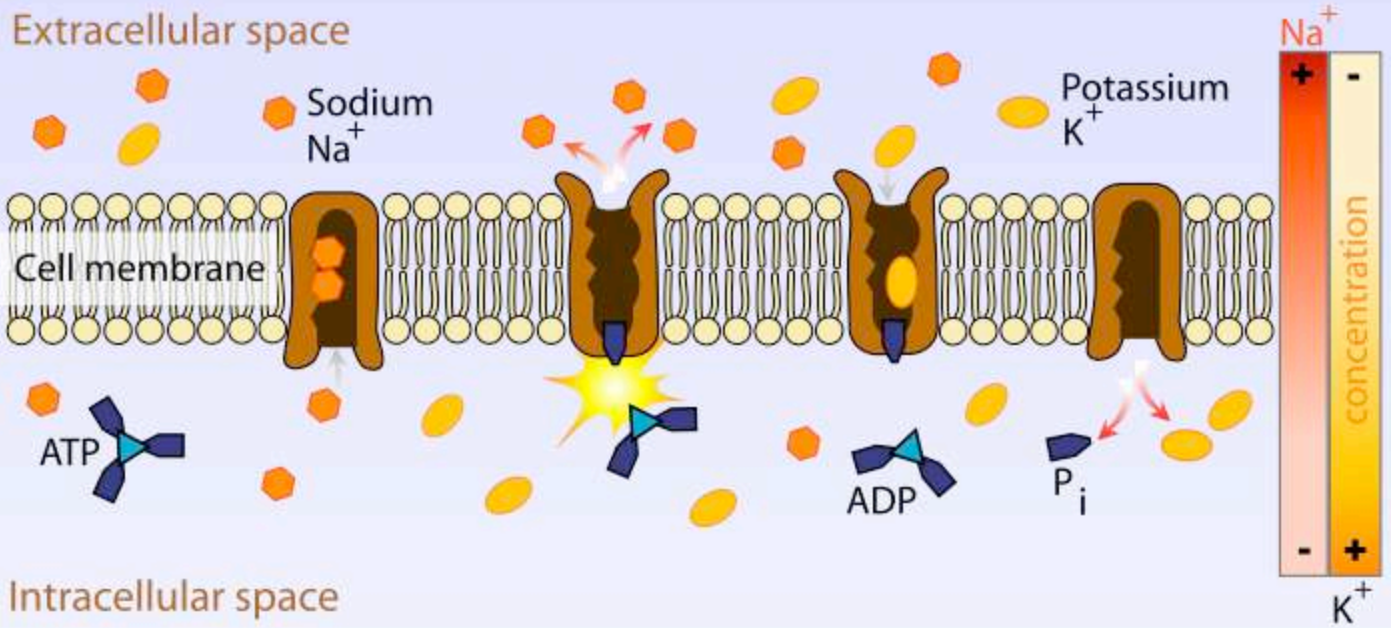
Active Transport

- Active transport involves the movement of molecules up a concentration gradient, or from an area of low concentration to an area of high concentration. Since the amount of entropy (disorder) is decreasing, it requires the input of energy (ATP). Active transport can take place with the help of membrane pumps.
- Membrane pumps are protein molecules embedded in the cell membrane that transport molecules across the cell membrane against the concentration gradient.
- The sodium-potassium pump is an example of this type of active transport. Sodium-potassium pumps are found in almost all animal cells and play a vital role in the transportation of nerve impulses.

Image: Sodium-potassium pump – Mariana Ruiz Villarreal – Public domain

Active transport

Sodium-potassium pump

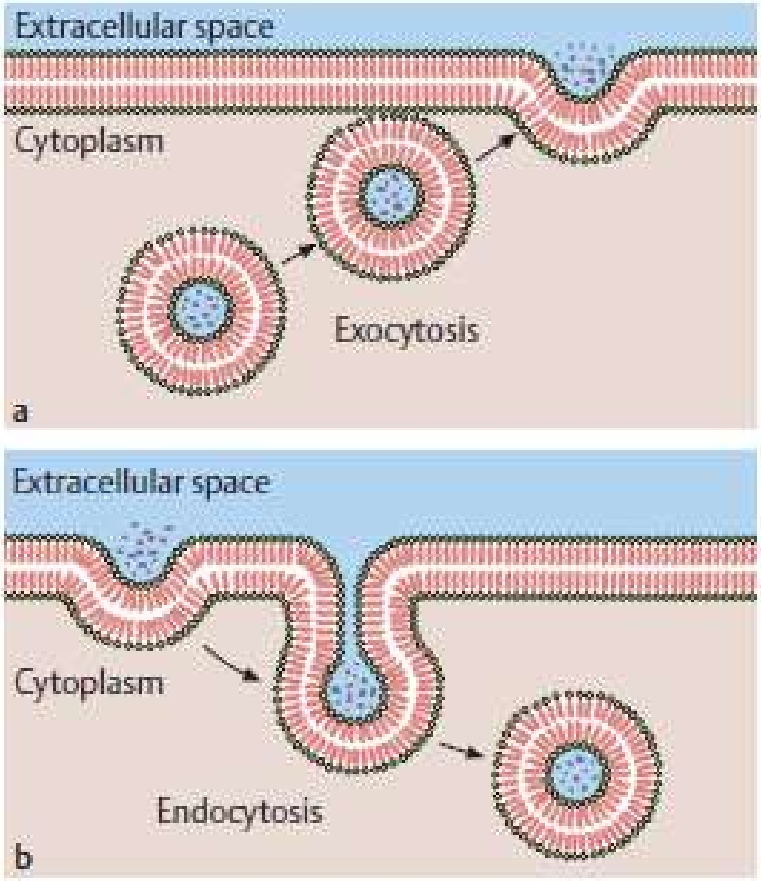


Because the ions have a natural tendency to diffuse and reach equilibrium, the cell must use ATP to move the ions against the concentration gradient.

Active Transport

- Other types of active transport include endocytosis and exocytosis. **Endocytosis** is the process in which cells bring large molecules inside by surrounding them with the cell membrane and forming vesicles. **Exocytosis** is the process in which cells package materials into vesicles using the Golgi apparatus, and expel the vesicles from the cell.

Endocytosis and Exocytosis



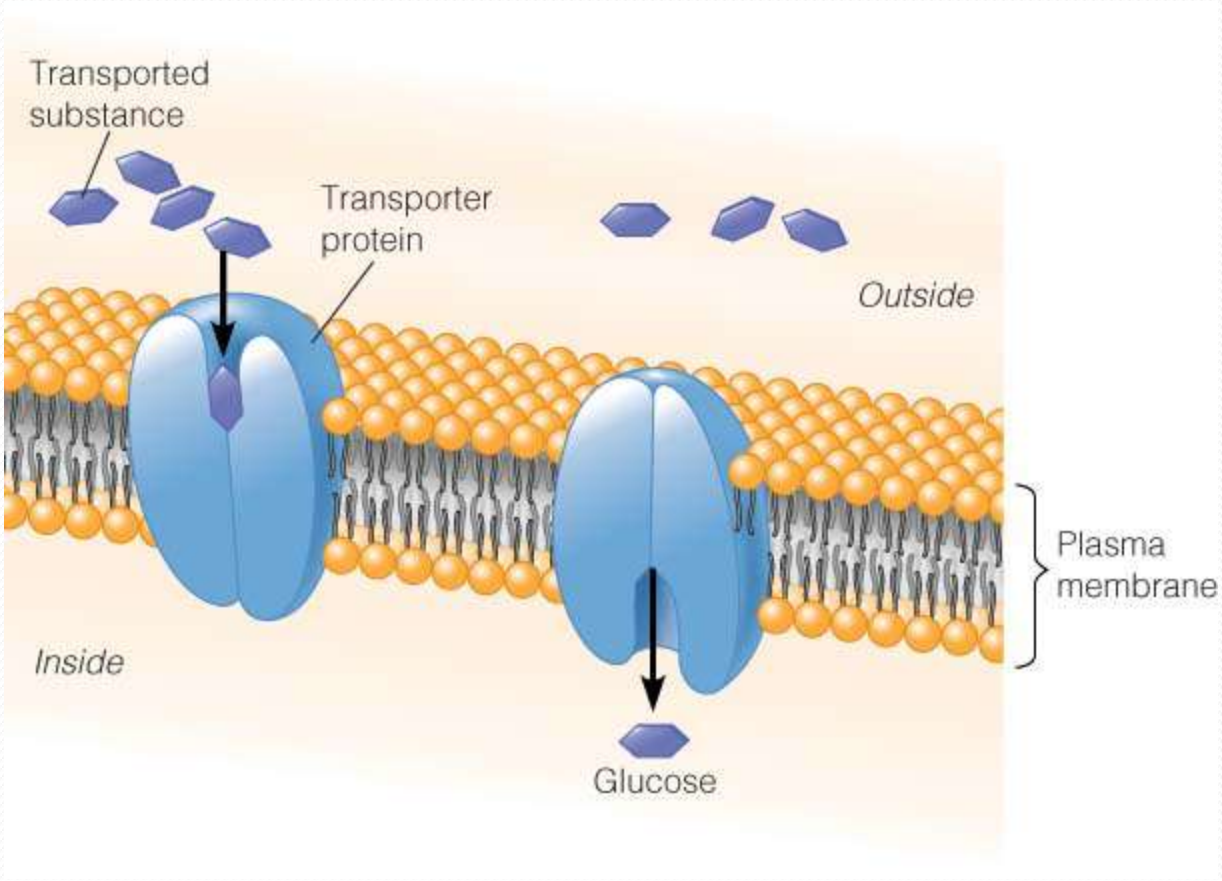
Passive Transport

- **Passive transport** involves the movement of molecules down a concentration gradient,
  - or from a high concentration to a low concentration.
  - Since the amount of entropy (disorder) is increasing, no input of metabolic energy or ATP is required.
  - There are four main types of passive transport: simple diffusion, facilitated diffusion, osmosis, and filtration.
- Simple diffusion involves the movement of material across the cell membrane from an area of high concentration to an area of low concentration.
  - Small molecules such as oxygen, ethanol, and carbon dioxide easily diffuse across membranes.
  - Some larger molecules, such as glucose, require the assistance of a carrier protein. When carrier proteins are involved, the process is called facilitated diffusion.

Facilitated Diffusion

- Facilitated diffusion is a type of diffusion that uses special transport proteins to transfer larger molecules across cell membranes.
- The carrier molecules used in facilitated diffusion are similar to those used in membrane pumps.
  - However, since molecules transported by diffusion are following a concentration gradient, energy is not needed.

Facilitated Diffusion



Osmosis

- Osmosis is a type of diffusion that specifically involves the movement of water across a semi-permeable membrane.
- A semi-permeable membrane allows only small molecules to pass through unaided.
  - Thus they are permeable to some substances, but not others.
  - The plasma or cell membrane is an example of a semi-permeable membrane. Water is able to flow into and out of cells freely, but larger molecules and ions (solutes) cannot.
  - When solute concentrations are unequal on both sides of a semi-permeable membrane, water flows from areas of lower solute concentration to areas of higher solute concentration.
  - Osmosis can also be described as the flow of water from areas of higher water concentration to areas of lower water concentration. This continues until the concentration of solutes is equivalent on both sides of the membrane, or until *equilibrium* is met.
- When equilibrium is met, water continues to flow across the membrane in both directions. However, the flow of water into the cell is equal to the flow of water outside the cell. Thus, it can be said that during equilibrium there is no *net movement* of water across the membrane.

Filtration

- Filtration involves the movement of water and solute molecules across the cell membrane due to hydrostatic pressure.
  - Hydrostatic pressure is generated by the cardiovascular system as blood is pumped through the body's blood vessels.
  - Filtration occurs when water and solute molecules are transported across the cell membrane as a result of this pressure.
- This process frequently occurs in the kidneys.

The Cell membrane

- One of the features that allows cells to perform their necessary activities is their selectively permeable cell membranes.
- These membranes are located inside the cell walls of plant cells, and they form the outer cell boundary in animal cells.
- The semi-permeability of the membrane permits cells to control what comes into the cell and what goes out. In this way, they take in nutrients and other materials and expel wastes and cell products.

Molecular Transport through Osmosis

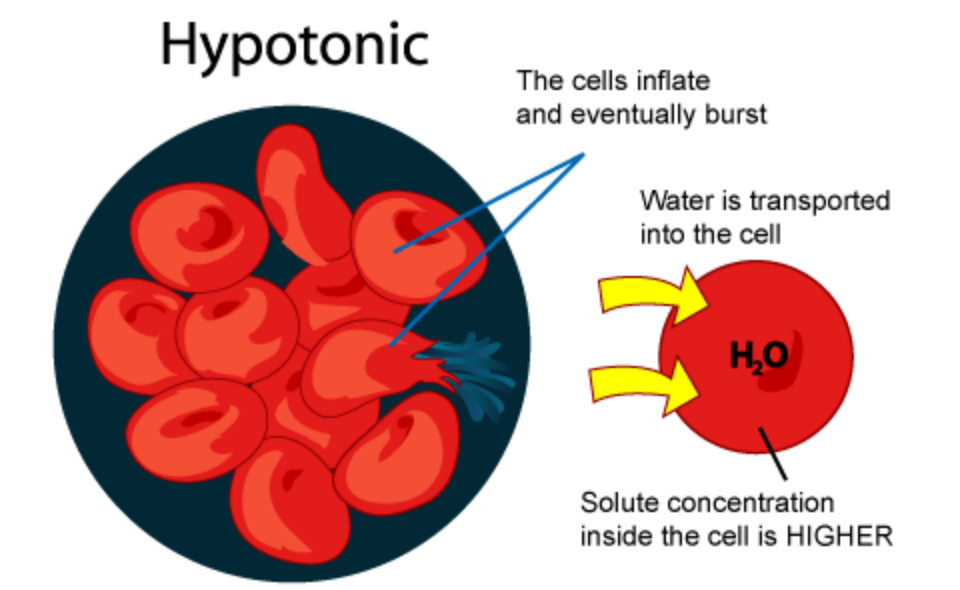
- Water is an essential component of plant and animal materials.
  - It provides a soluble environment for chemical reactions, serves as a reactant in chemical reactions, and provides hydration that maintains cell shape.
- **Osmosis** is the movement of water molecules across the cell membrane.
  - Water moves down a concentration gradient from areas of high water concentration to areas of low water concentration.
  - When salt concentrations are not the same on both sides of a semi-permeable membrane, such as cell membranes, osmosis causes water to flow from areas of lower salt concentration to areas of higher salt concentration.
  - When salt concentrations are the same in both areas, osmosis does not occur. That is, water does not flow in either direction.

Hypotonic, Isotonic and Hypertonic Solutions

- When concentrations of solute molecules, such as salt or sugar, are not the same on both sides of the cell membrane, water will move across the membrane to balance the concentration of solute.
- In the lab, osmosis can be studied using samples of red blood cells and salt solutions of different concentrations.
  - A solution that has a higher salt concentration than that inside the cell is called **hypertonic**.
  - A solution that has a lower salt concentration than that inside the cell is called **hypotonic**.
  - A solution that has the same salt concentration as that inside the cell is called **isotonic**.

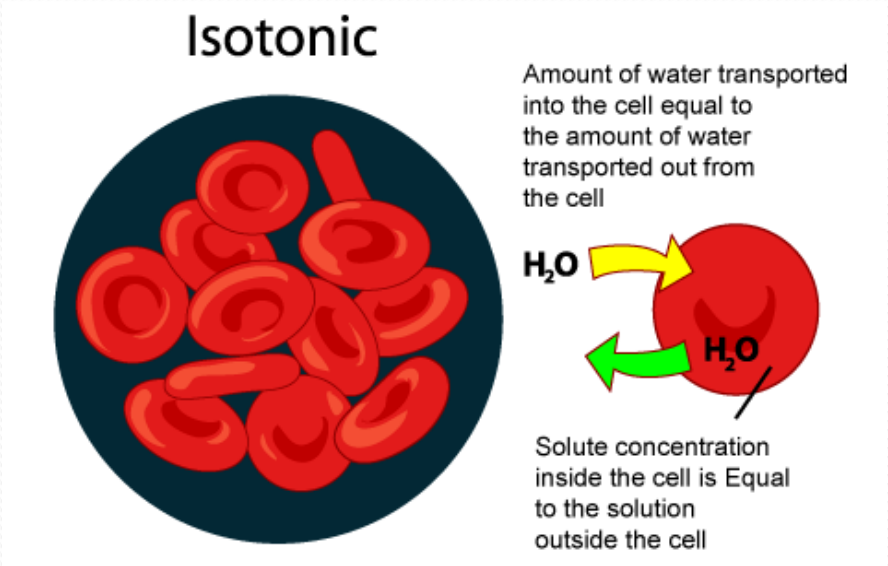
Hypotonic Solutions

- In a hypotonic solution, the salt concentration inside the cell is higher than the salt concentration outside the cell. So, water rushes into the cells and the cells can burst.



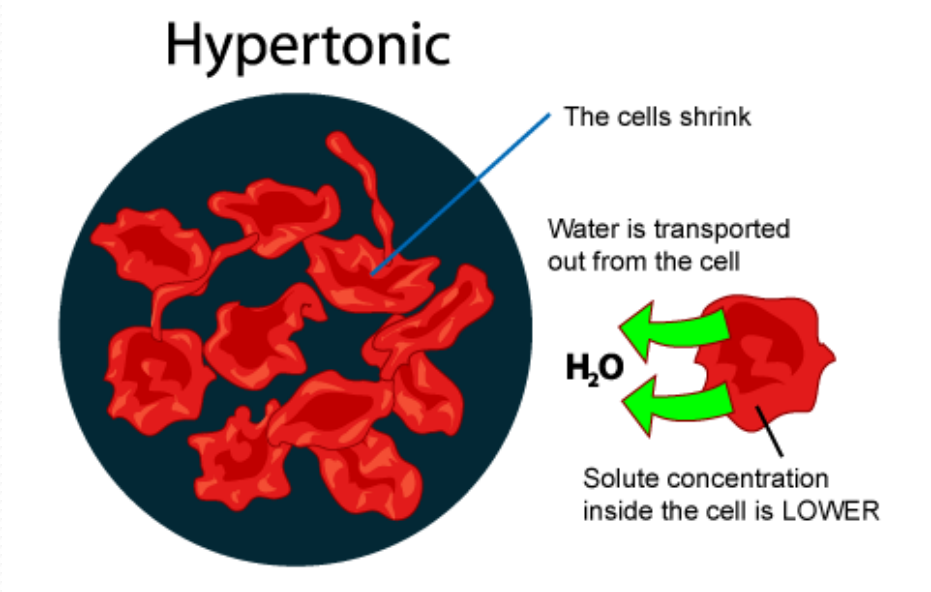
Isotonic Solutions

- In an isotonic solution, the salt concentration inside the cells is the same as the salt concentration outside the cells.
- When cells are placed in an isotonic solution, the net movement of water and salts will be zero.



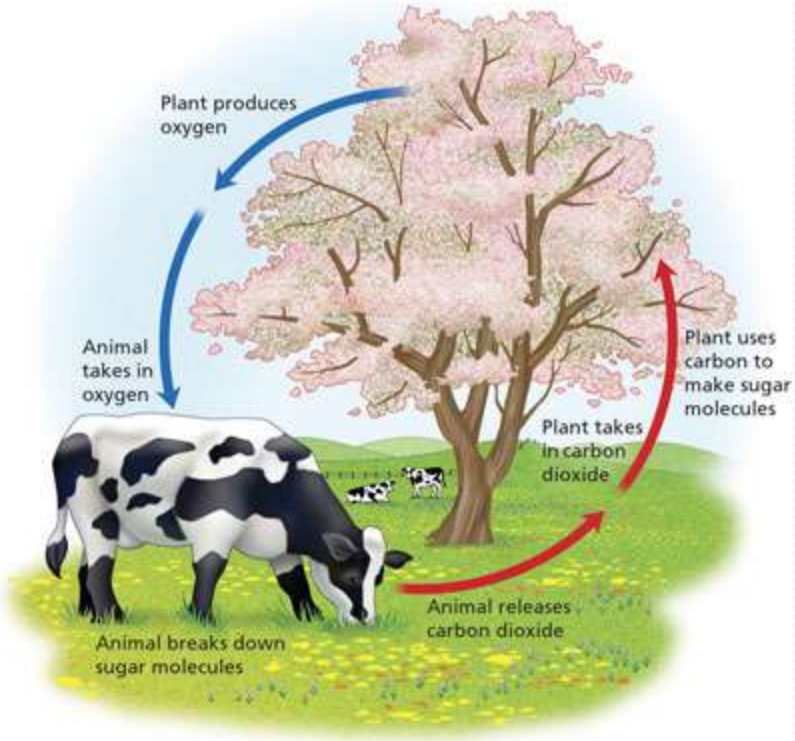
Hypertonic Solutions

- In a hypertonic solution, the salt concentration inside the cells is lower than the salt concentration outside the cells.
  - Virtually all of the water in the cells will move out of the cells into the surrounding solution, and the cells will shrivel.



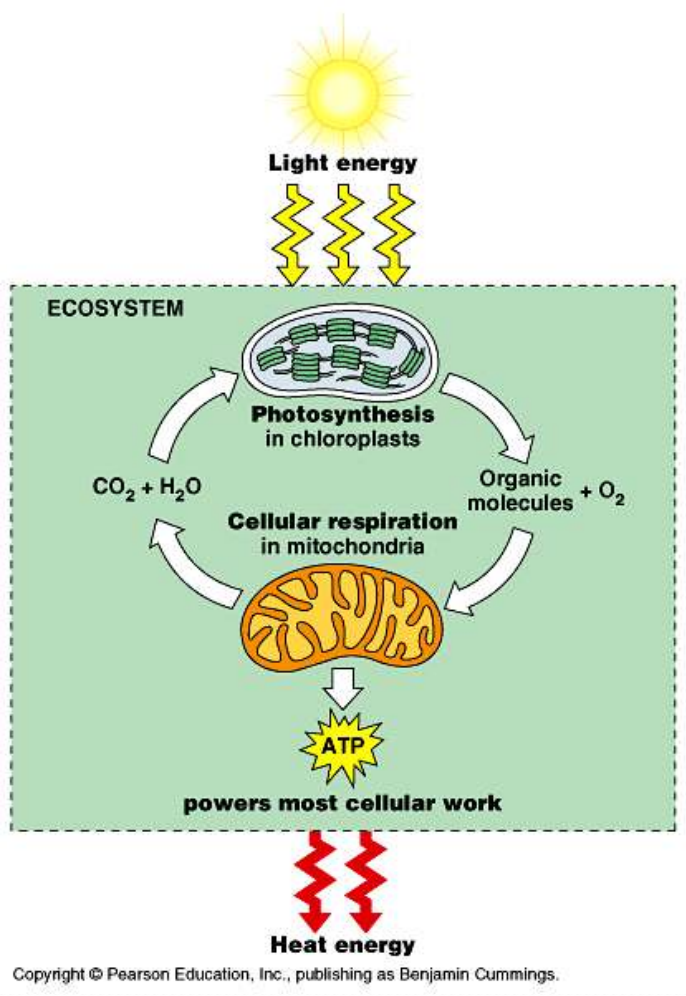
Photosynthesis and Cellular Respiration

- The processes of **photosynthesis** and **cellular respiration** are interdependent.
  - That is, each process is necessary to fuel the other.



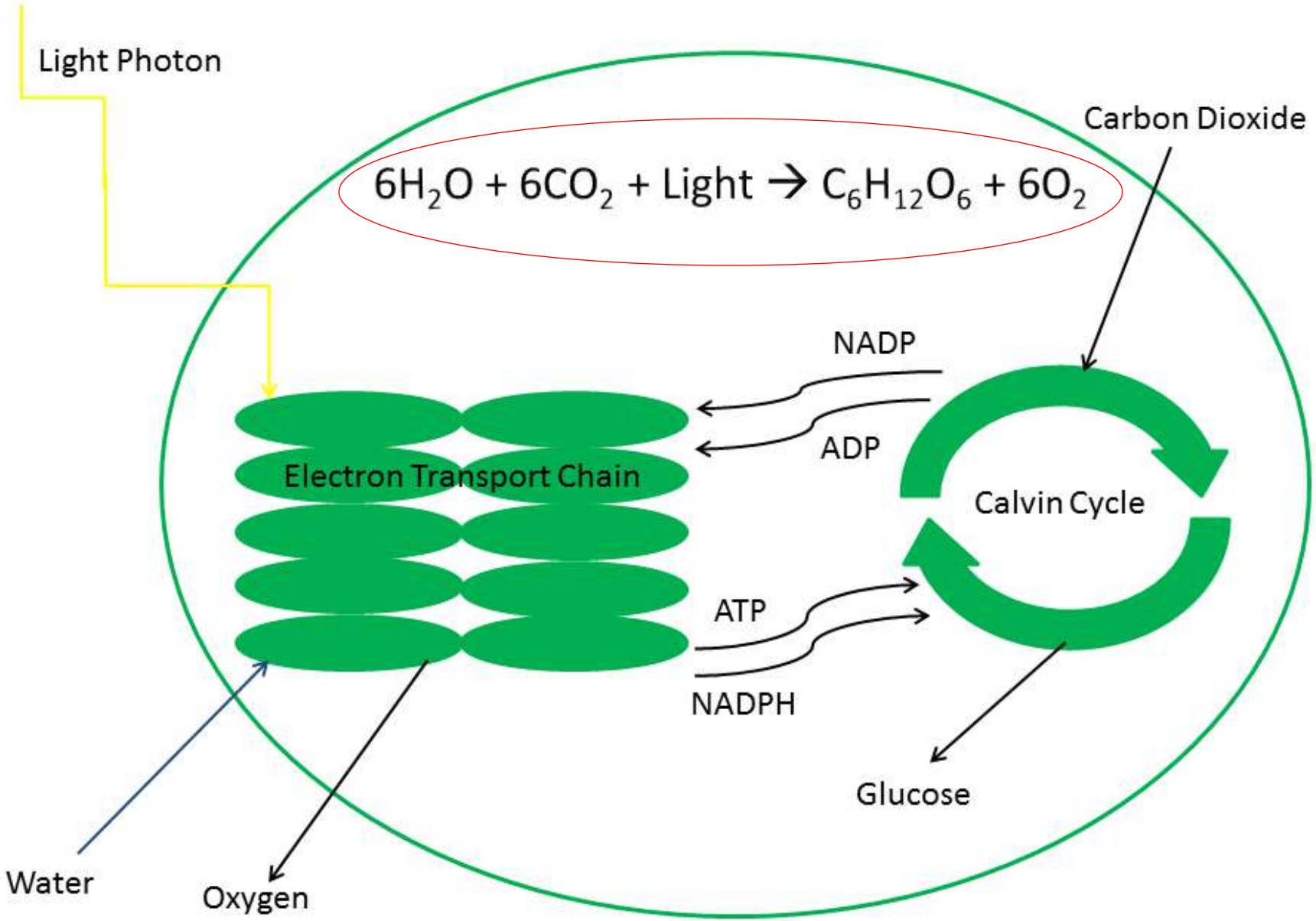
Interdependent Energy Processes

- Energy is cycled through ecosystems by the processes of photosynthesis and respiration.
- The processes of photosynthesis and cellular respiration are dependent <u>on one another.</u>



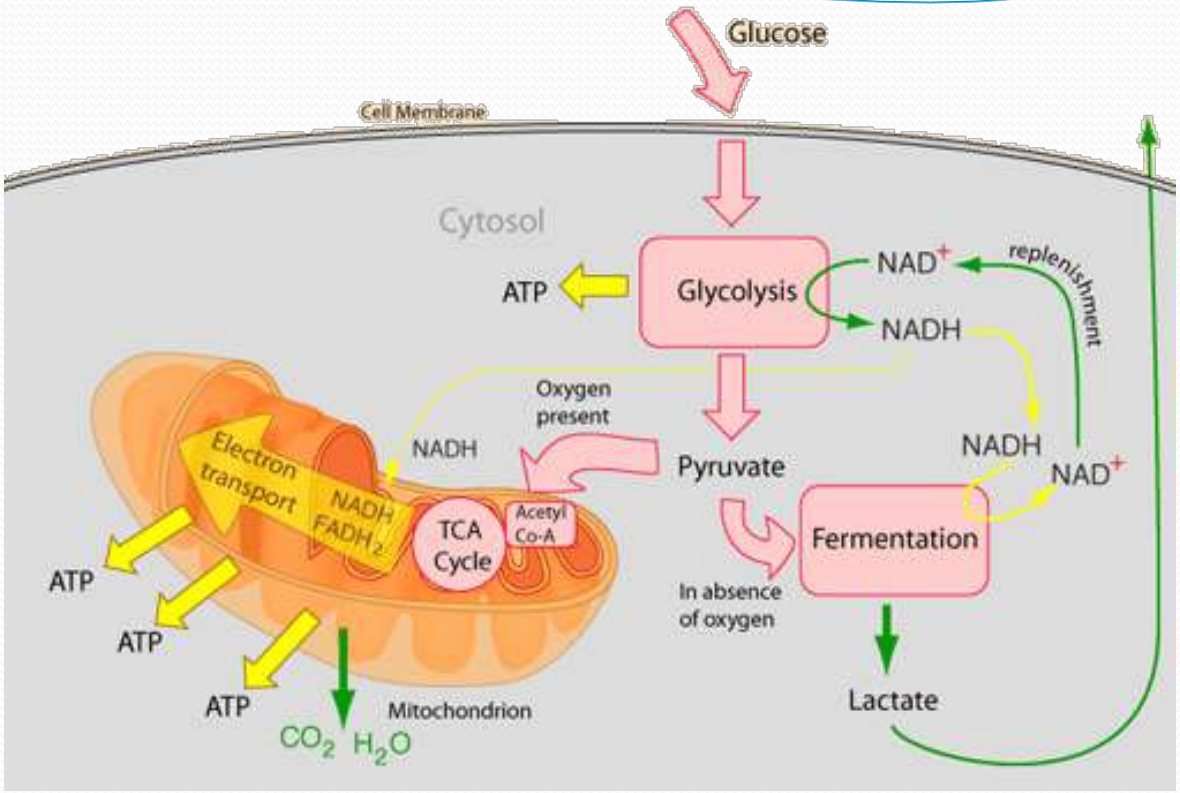
Photosynthesis

- Photosynthesis occurs within the **chloroplast** of a cell.
- Chloroplasts are cellular organelles that are shaped like flattened discs.
  - They contain stroma and stacks of thylakoids, and they are the site of photosynthesis.
    - Chloroplasts are found in the cells of plants and other eukaryotic, photosynthetic organisms.
- During photosynthesis, plants and phytoplankton capture light energy from the Sun and use it to build *sugars* (chemical energy) out of *carbon dioxide* and *water*.


Light Photon
$6H_2O + 6CO_2 + Light \rightarrow C_6H_{12}O_6 + 6O_2$
Carbon Dioxide
NADP
ADP
Electron Transport Chain
Calvin Cycle
ATP
NADPH
Glucose
Water
Oxygen

Cellular Respiration

- Cellular respiration occurs in the **mitochondrion** of a cell.
  - Mitochondria are found in both plant and animal cells.
  - These organelles are rod-shaped with cristae and highly folded inner membranes.
- Energy from the Sun is essentially stored in the chemical bonds of the sugar molecules in plants.
  - Whenever organisms, including plants, need to use the energy stored in the bonds of these molecules, cells perform **cellular respiration**.
  - During this process, cells take in *oxygen* in order to break the bonds of the plant *sugars* and produce *ATP*, *water*, and **carbon dioxide**.
- Cellular energy is stored in the in the phosphate bonds of ATP molecules.
  - Each time a phosphate group is removed from a molecule of ATP, energy is released.
  - This energy can then be used to perform cellular work.



$$36\ ADP + 36P_i \rightarrow 36\ ATP$$

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

Glucose + Oxygen → Carbon dioxide + Water

EQUATION 1. PHOTOSYNTHESIS.

$$6\,CO_2 + 6\,H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

carbon dioxide — water — chlorophyll, sunlight — sugar — oxygen

EQUATION 2. RESPIRATION.

$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O$$

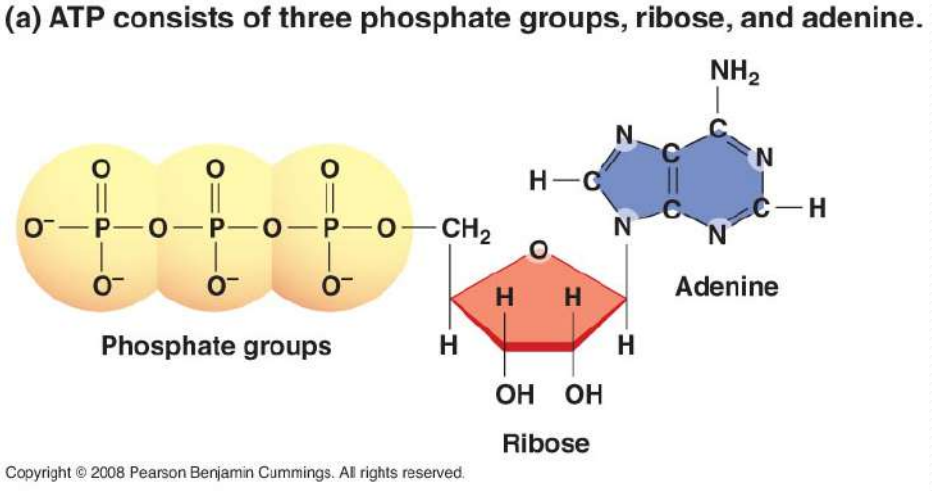
sugar — oxygen — carbon dioxide — water

Macromolecules & Cellular Energy

- Cells depend on specific types of macromolecules to store energy. These types of macromolecules include **ATP** and **lipids**

ATP

- **Adenosine triphosphate**, or *ATP*, is a macromolecule used by the body for **energy storage**.
  - ATP contains adenine, ribose, and three phosphate groups.
    - Each of the phosphate bonds stores a large quantity of energy, which is released for use when the bond is broken.



Lipids

- Lipids are macromolecules used by the body for long-term energy storage.
  - Lipids, like sugars, are composed primarily of carbon, hydrogen, and oxygen.
  - They contain high-energy bonds that can be broken by cells to release energy to do cellular work.
- Triglycerides are a type of lipid that contain one glycerol molecule and three fatty acids.