1st Lecture
General Introduction to Physiology
Cell Physiology: General Functions, Cell Membrane Transport

General Introduction to Physiology[1]

Physiology definition: is the scientific study of functions and mechanisms in living systems. It is a branch of biology that focuses on how organisms, organ systems, individual organs, cells, and biomolecules carry out chemical and physical functions in living organisms.

Scope: Physiology examines life processes at various levels, from molecular and cellular to organ systems and whole organisms. It seeks to understand how different parts of living things work together to maintain life.

Integration: A central theme in physiology is the integration of different systems and processes within an organism. Physiologists study how various parts of the body communicate and cooperate to maintain homeostasis.

Experimental Approach: Physiology is an experimental science that uses a range of techniques to investigate biological processes. This includes everything from molecular biology methods to whole-organism studies.

Major Areas of Study: Physiology encompasses several specialized fields, including:

- Human physiology
- Animal physiology
- Plant physiology
- Cell physiology
- Comparative physiology

Each of these areas focuses on different aspects of life processes in various organisms.

Importance of Physiology: Physiology plays a crucial role in:

1. Understanding normal body functions
2. Identifying what goes wrong in disease

3. Developing new treatments and health guidelines

4. Advancing our knowledge of how living things adapt to their environments.

Foundations of Physiology: Physiology draws on several key disciplines:

- Anatomy
- Biochemistry
- Biophysics
- Genetics
- Evolutionary biology

[1]Citations:

[1] https://www.physoc.org/explore-physiology/what-is-physiology/

[2] https://en.wikipedia.org/wiki/Physiology

Cell Physiology: General Functions[2]

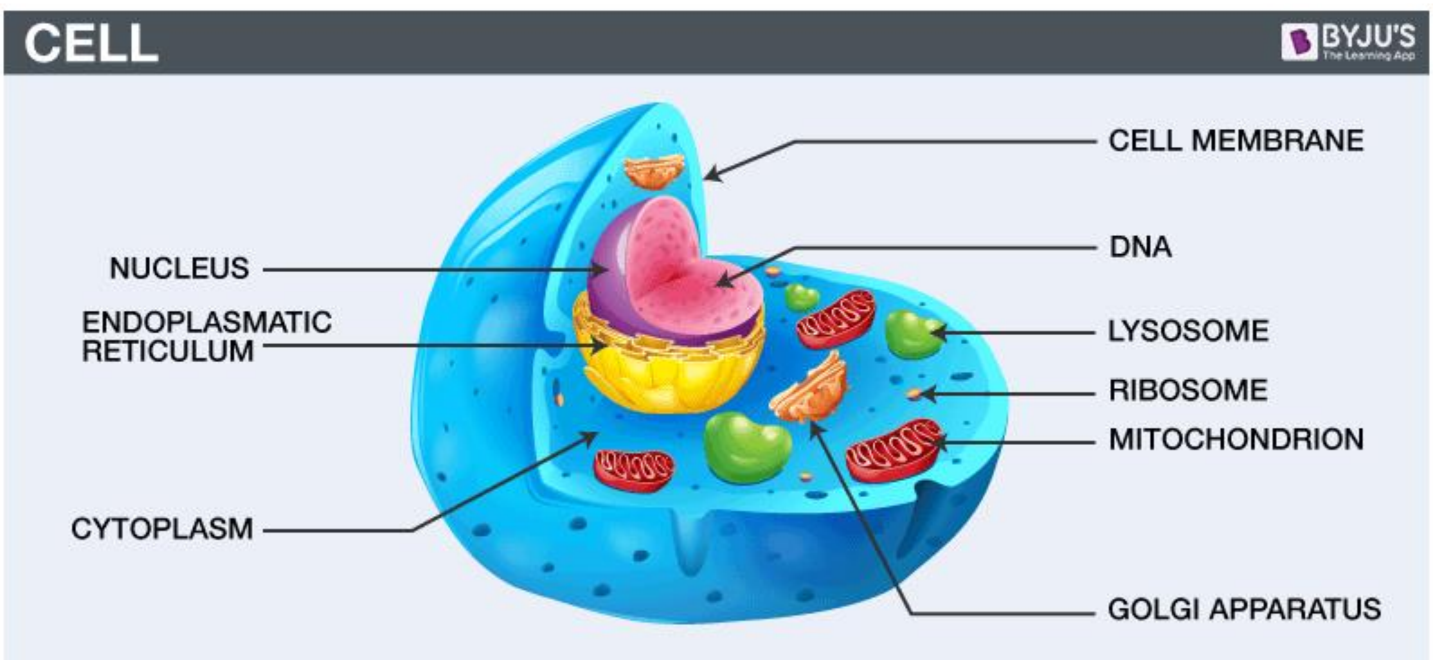

Fig.1-Cells are the fundamental unit of life. They range in size from 0.0001 mm to nearly 150 mm.

A cell is defined as the smallest, basic unit of life that is responsible for all of life's processes."
Cells are the structural, functional, and biological units of all living beings. A cell can replicate itself independently. Hence, they are known as the building blocks of life**.**

Each cell contains a fluid called the cytoplasm, which is enclosed by a membrane. Also present in the cytoplasm are several biomolecules like proteins, nucleic acids and lipids. Moreover, cellular structures called cell organelles are suspended in the cytoplasm.

General Functions

A cell performs major functions essential for the growth and development of an organism. Important functions of cell are as follows:

-Provides Support and Structure

All the organisms are made up of cells. They form the structural basis of all the organisms. The cell wall and the cell membrane are the main components that function to provide support and structure to the organism. For eg., the skin is made up of a large number of cells. Xylem present in the vascular plants is made of cells that provide structural support to the plants.

-Facilitate Growth Mitosis

In the process of mitosis, the parent cell divides into the daughter cells. Thus, the cells multiply and facilitate the growth in an organism.

-Allows Transport of substance

Various nutrients are imported by the cells to carry out various chemical processes going on inside the cells. The waste produced by the chemical processes is eliminated from the cells by active and passive transport. Small molecules such as oxygen, carbon dioxide, and ethanol diffuse across the cell membrane along the concentration gradient. This is known as passive transport. The larger molecules diffuse across the cell membrane through active transport where the cells require a lot of energy to transport the substances.

-Energy Production

Cells require energy to carry out various chemical processes. This energy is produced by the cells through a process called respiration in animals.

-Aids in reproduction

A cell aids in reproduction through the processes called mitosis and meiosis. Mitosis is termed as the asexual reproduction where the parent cell divides to form daughter cells. Meiosis causes the daughter cells to be genetically different from the parent cells.

Cell Organelles and their Functions
Nucleolus
The nucleolus is the site of ribosome synthesis. Also, it is involved in controlling cellular activities and cellular reproduction.
Nuclear membrane
The nuclear membrane protects the nucleus by forming a boundary between the nucleus and other cell organelles.
Chromosomes
Chromosomes play a crucial role in determining the sex of an individual. Each human cells contain 23 pairs of chromosomes.
Endoplasmic reticulum
The endoplasmic reticulum is involved in the transportation of substances throughout the cell. It plays a primary role in the metabolism of carbohydrates, synthesis of lipids, steroids and proteins.

Golgi Bodies	Golgi bodies are called the cell’s post office as it is involved in the transportation of materials within the cell.
Ribosome	Ribosomes are the protein synthesizers of the cell.
Mitochondria	The mitochondrion is called “the powerhouse of the cell.” It is called so because it produces ATP – the cell’s energy currency.
Lysosomes	Lysosomes protect the cell by engulfing the foreign bodies entering the cell and help in cell renewal. Therefore, they are known as the cell’s suicide bags.
Chloroplast	Chloroplasts are the primary organelles for photosynthesis. It contains the pigment called chlorophyll.
Vacuoles	Vacuoles store food, water, and other waste materials in the cell.

[2]Citation:

https://byjus.com/biology/cells/

Cell Membrane Transport[3]

The principal components of a plasma membrane are lipids, proteins, and carbohydrates. The lipids include phospholipids and cholesterol Proteins either float in the bilayer or are attached to one side or the other of it. Carbohydrate chains are attached to the proteins and lipids on the outside surface of the membrane. The proportions of proteins, lipids, and carbohydrates in the plasma membrane vary with cell type, but for a typical human cell, protein accounts for about 50 percent of the composition by mass, lipids account for about 40 percent of the composition by mass, with the remaining 10 percent of the composition by mass being carbohydrates.

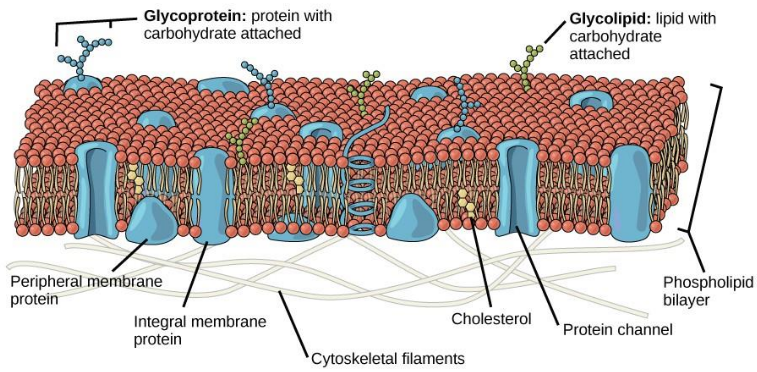

Fig.2 Cell membrane

Passive transport

The most direct forms of membrane transport are passive. **Passive transport** is a naturally occurring phenomenon and does not require the cell to exert any of its energy to accomplish the movement. In passive transport, substances move from an area of higher concentration to an area of lower concentration. A physical space in which there is a range of concentrations of a single substance is said to have a **concentration gradient**.

Diffusion

Diffusion is a passive process of transport. A single substance tends to move from an area of high concentration to an area of low concentration until the concentration is equal across a space. You are familiar with diffusion of substances through the air. For example, think about someone opening a bottle of ammonia in a room filled with people. The ammonia gas is at its highest concentration in the bottle; its lowest concentration is at the edges of the room. The ammonia vapor will diffuse, or spread away, from the bottle, and gradually, more and more people will smell the ammonia as it spreads. Materials move within the cell's cytosol by diffusion, and certain materials move through the plasma membrane by diffusion. Diffusion expends no energy. On the contrary, concentration gradients are a form of potential energy, dissipated as the gradient is eliminated.

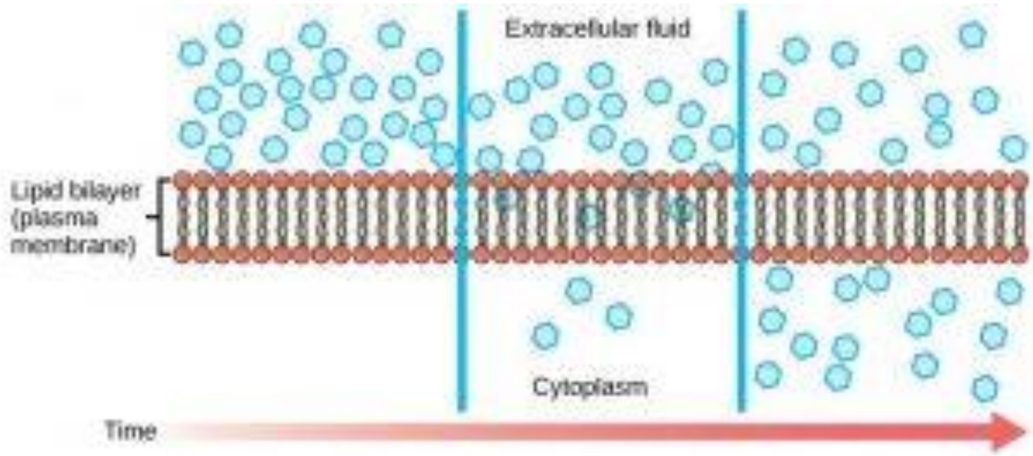

Fig.3 Diffusion through a permeable membrane moves a substance from an area of high concentration down its concentration gradient. (Credit: modification of work by Mariana Ruiz Villareal)

Each separate substance in a medium, such as the extracellular fluid, has its own concentration gradient, independent of the concentration gradients of other materials. In addition, each substance will diffuse according to that gradient. Within a system, there will be different rates of diffusion of the different substances in the medium.

Facilitated diffusion

In **facilitated diffusion**, materials diffuse across the plasma membrane with the help of membrane proteins. A concentration gradient exists that would allow these materials to diffuse into the cell without expending cellular energy. However, these materials are ions or polar molecules that are repelled by the hydrophobic parts of the cell membrane. Facilitated diffusion proteins shield these materials from the repulsive force of the membrane, allowing them to diffuse into the cell. These proteins are called **transport proteins** and can be channels or carrier proteins.

Channels

Channel proteins are transmembrane proteins that fold in such as way as to form a channel or pore through the membrane. Each channel is specific for one particular substance. Channel proteins have hydrophilic domains exposed to the intracellular and extracellular fluids. In addition, they have a hydrophilic channel through their core that provides a hydrated opening through the membrane layers. Passage through the channel allows polar compounds to avoid the nonpolar central layer of the plasma membrane that would otherwise slow or prevent their entry into the cell. **Aquaporins** are channel proteins that allow water to pass through the membrane at a very high rate.

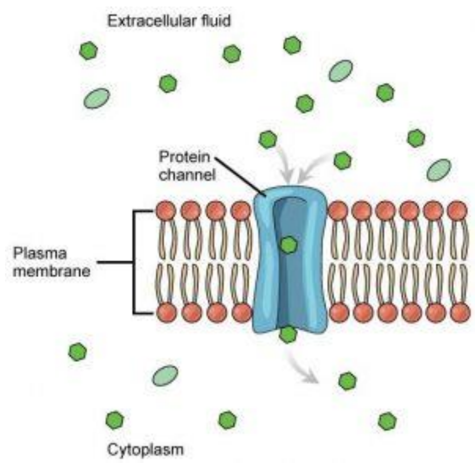

Fig.4 Facilitated transport moves substances down their concentration gradients. They may cross the plasma membrane with the aid of channel proteins. (Credit: modification of work by Mariana Ruiz Villareal)

Some channel proteins are always open but many are “gated,” meaning that they can be opened and closed. If a channel is ligand-gated, the attachment of a particular molecule to the channel protein may cause it to open. Other channels are voltage-gated, requiring a change in voltage across the membrane to open them. Cells involved in the transmission of electrical impulses, such as nerve and muscle cells, have voltage-gated ion channels in their membranes.

Carrier protein

Another type of transmembrane transporter protein is a **carrier protein**. Like channels, carrier proteins are usually specific for particular molecules. A carrier protein binds a substance and, in doing so, triggers a change of its own shape, moving the bound molecule across the membrane. Carrier proteins are used to transport molecules that are too large to pass through channels, such as amino acids and glucose.

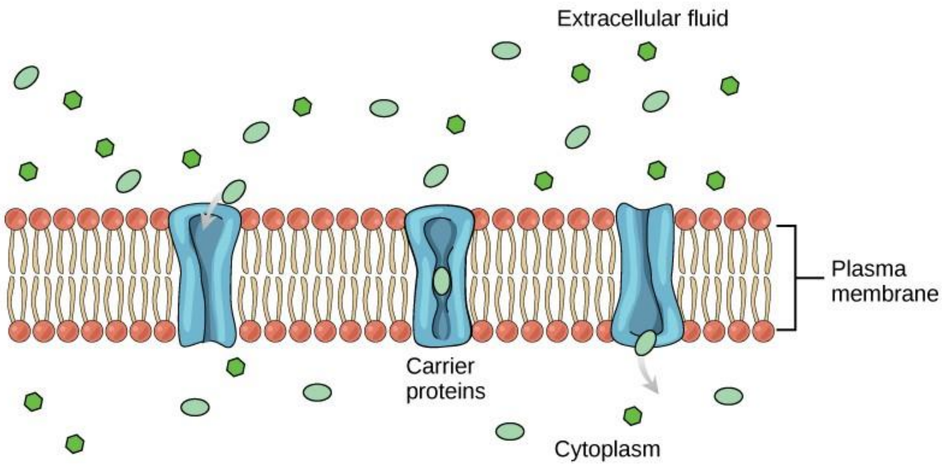

Fig.5 Some substances are able to move down their concentration gradient across the plasma membrane with the aid of carrier proteins. Carrier proteins change shape as they move molecules across the membrane. (Credit: modification of work by Mariana Ruiz Villareal)

There are a finite number of each type of carrier proteins in any membrane. This can cause problems in transporting enough of the material for the cell to function properly. When all of the proteins are bound to their ligands, they are saturated and the rate of transport is at its maximum. Increasing the concentration gradient at this point will not result in an increased rate of transport.

Osmosis

Osmosis is the diffusion of water across a semipermeable membrane. Since it is diffusion, it depends on the concentration gradient, or the amount of water on each side of the membrane. The amount of water in a solute is inversely proportional to the concentration of solutes. In other words, the higher the concentration of water, the lower the concentration of solutes, and vice versa. Water can move readily across most membranes, due in part to the presence of aquaporins; however, the membrane limits the diffusion of solutes in the water.

Mechanism of action

Osmosis is a special case of diffusion. Water, like other substances, moves from an area of high concentration to one of low concentration. An obvious question is what makes water move at all? Imagine a beaker with a semipermeable membrane separating the two sides or halves. On both sides of the membrane the water level is the same, but there are different concentrations of a dissolved substance, or **solute**, that cannot cross the membrane (otherwise the concentrations on each side would be balanced by the solute crossing the membrane). If the volume of the solution on both sides of the membrane is the same, but the concentrations of solute are different, then there are different amounts of water, the solvent, on either side of the membrane.

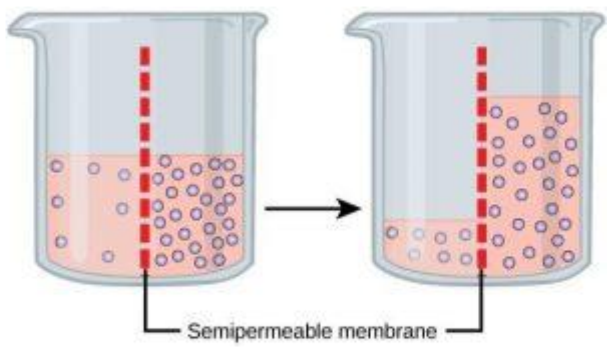

Fig.6 In osmosis, water always moves from an area of higher water concentration to one of lower concentration. In the diagram shown, the solute cannot pass through the selectively permeable membrane, but the water can.

Active transport

Active transport mechanisms require the use of the cell’s energy, usually in the form of adenosine triphosphate (ATP). If a substance must move into the cell against its concentration gradient—that is, if the concentration of the substance inside the cell is greater than its concentration in the extracellular fluid (and vice versa)—the cell must use energy to move the substance. Some active transport mechanisms move small-molecular weight materials, such as ions, through the membrane. Other mechanisms transport much larger molecules.

To move substances against a concentration or electrochemical gradient, the cell must use energy, usually in the form of ATP. Active transport proteins, called **pumps**, work against electrochemical gradients. Small substances constantly pass through plasma membranes. Active transport maintains concentrations of ions and other substances needed by living cells in the face of these passive movements. Much of a cell's supply of metabolic energy may be spent maintaining these processes.

The specific proteins that facilitate active transport are called **transporters**. There are three types of transporters. A **uniporter** carries one specific ion or molecule. A **symporter** carries two different ions or molecules, both in the same direction. An **antiporter** carries two different ions or molecules in different directions. All of these transporters can transport small, uncharged organic molecules such as glucose.

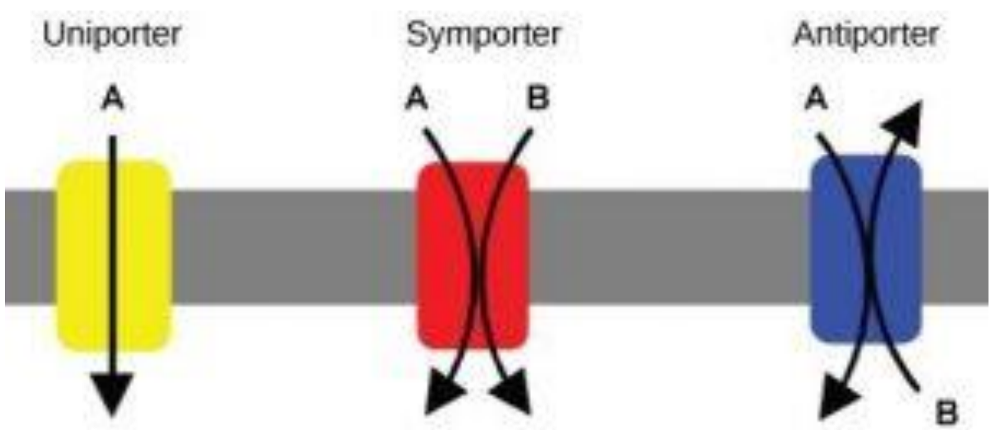

Fig.7 A uniporter carries one molecule or ion. A symporter carries two different molecules or ions, both in the same direction. An antiporter also carries two different molecules or ions, but in different directions. (credit: modification of work by "Lupask"/Wikimedia Commons)

Two mechanisms exist for the transport of small-molecular weight material and small molecules. **Primary active transport** is directly dependent on ATP. **Secondary active transport** does not directly require ATP, because it uses electrochemical gradients established by primary active transport for fuel. Primary active transport must occur first to in order to allow secondary active transport to occur. Although it does not use ATP, secondary active transport is still considered active because it requires energy.

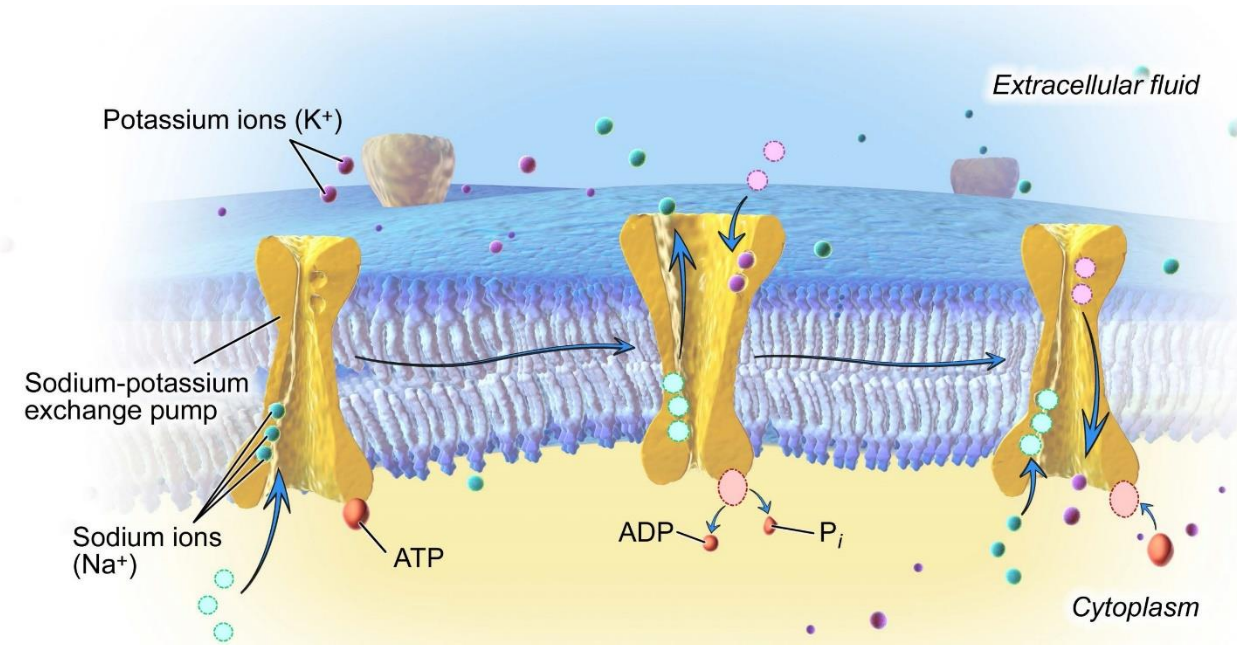

Fig.8 Primary active transport moves ions across a membrane, creating an electrochemical gradient (electrogenic transport). (Credit: Blausen.com staff. "Blausen gallery 2014". Wikiversity Journal of Medicine.)

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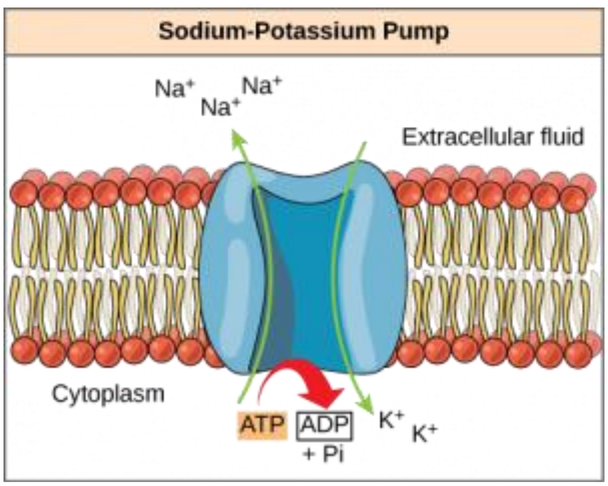

Fig.9 The sodium-potassium pump is an example of energy coupling. The energy derived from exergonic ATP hydrolysis is used to pump sodium and potassium ions across the cell membrane

Bulk Transport

In addition to moving small ions and molecules through the membrane, cells also need to remove and take in larger molecules and particles. Some cells are even capable of engulfing entire unicellular microorganisms. You might have correctly hypothesized that the uptake and release of large particles by the cell requires energy. A large particle, however, cannot pass through the membrane, even with energy supplied by the cell.

Endocytosis

Endocytosis is a type of active transport that moves particles, such as large molecules, parts of cells, and even whole cells, into a cell. There are different variations of endocytosis, but all share a common characteristic: The plasma membrane of the cell invaginates, forming a pocket around the target particle. The pocket pinches off, resulting in the particle being contained in a newly created intracellular vesicle formed from the plasma membrane. The three types of endocytosis are phagocytosis, pinocytosis, and receptor-mediated endocytosis.

Phagocytosis

Phagocytosis ("cell eating") is the process by which large particles, such as other cells or relatively large particles, are taken in by a cell. For example, when microorganisms invade the human body, a type of white blood cell called a neutrophil will "eat" the invaders through phagocytosis, surrounding and engulfing the microorganism, which is then destroyed by lysosomes inside the neutrophil.

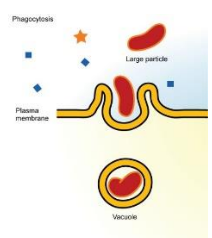

Fig.10 In phagocytosis, the cell membrane surrounds the particle and engulfs it. (Credit: Mariana Ruiz Villareal)

pinocytosis

Through **pinocytosis** ("cell drinking"), cells take in molecules, including water, which the cell needs from the extracellular fluid. Pinocytosis results in a much smaller vesicle than does phagocytosis, and the vesicle does not need to merge with a lysosome.

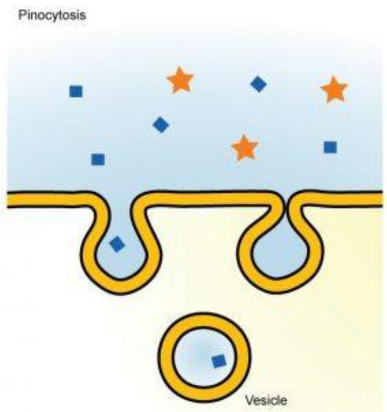

Fig.11 In pinocytosis, the cell membrane invaginates, surrounds a small volume of fluid, and pinches off. (Credit: Mariana Ruiz Villareal)

The reverse process of moving material into a cell is the process of **exocytosis**. The purpose of exocytosis is to expel material from the cell into the extracellular fluid. Waste material is enveloped in vesicle, which fuses with the interior of the plasma membrane, expelling the waste material into the extracellular space. Cells also use exocytosis to secrete proteins such as hormones, neurotransmitters, or parts of the extracellular matrix.

Exocytosis

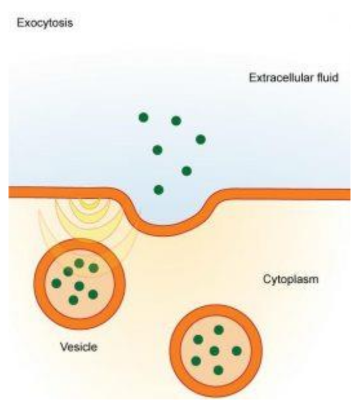

Fig.12 In exocytosis, vesicles containing substances fuse with the plasma membrane. The contents are then released to the exterior of the cell. (Credit: modification of work by Mariana Ruiz Villareal)

[3] Citation

https://rwu.pressbooks.pub/bio103/chapter/membrane-transport/pp 267- 275