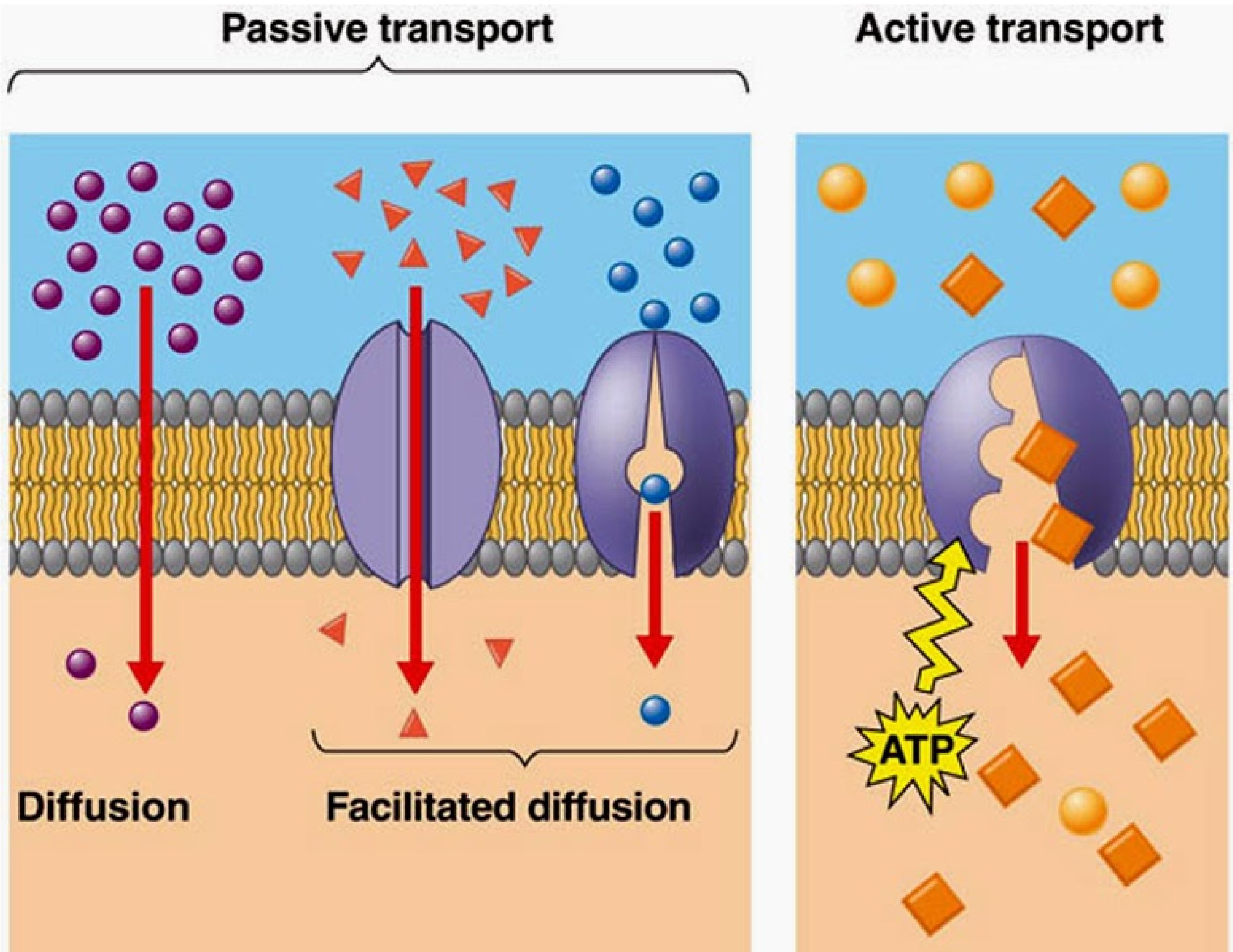
Unit 3 Transport Across Cell Membrane

In order for a cell to survive it must be able to selectively permit certain substances it requires in and out of its cell walls. In this section you will explore the various transport mechanisms a cells use to fuel itself. As a result of your exploration you will compare the various transport mechanisms.

It's also time for a lab: The Potato Lab. If you can do this experiment, do so. You will get a lot more out of it if you can perform it in real life. If you are not able to perform the experiment, the data required to complete the lab is provided. You will interpret the experimental data to identify the various types of solutions the potatoes are soaking in. The lab reinforces the notion of how a cell (or in this case a potato) can be affected by a solution.



http://biology4alevel.blogspot.com/2014/09/25-passive-and-active-transport-across.html

Cell Membrane Structure

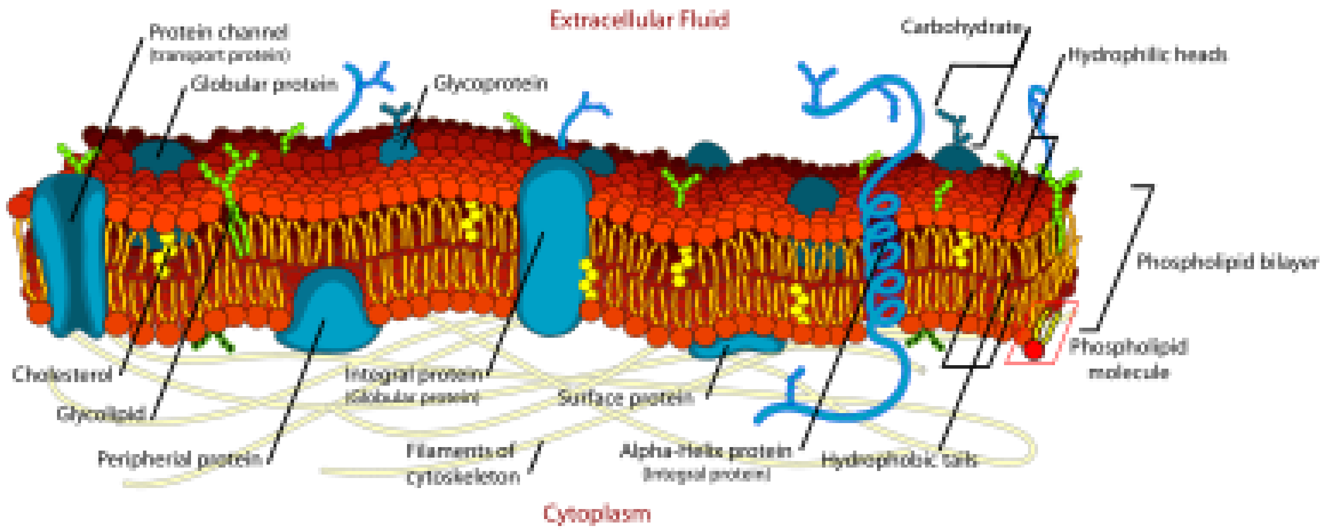
The cell membrane, or plasma membrane, forms a boundary around the cell that regulates the movement of molecules into and out of the cell, maintaining a constant internal environment. The cell membrane is composed of a lipid bilayer that has protein molecules embedded throughout.

In this lesson you will learn about the structure and function of the cell's plasma membrane, use your knowledge of organic molecules to explain the structure and function of the fluid-mosaic membrane, and understand why the membrane is described as selectively permeable.

Plasma Membrane Structure and Function

The cell membrane is composed of double layer of phospholipids that form a screen. Small molecules, such as water, carbon dioxide, oxygen, and glucose, and easily pass through this screen. Large molecules, such as proteins and starch, are too large to move through the membrane. Because some molecules can pass through the membrane and others cannot, the membrane is said to be selectively permeable.

Protein molecules are randomly distributed throughout the plasma membrane. The membrane's phospholipid bilayer has a fluid consistency, similar to oil, and lipid molecules have freedom to move. The proteins embedded just outside or within the bilayer create a mosaic pattern, and scientists have come up with the fluid-mosaic model to explain the function of cell membranes.



https://en.wikipedia.org/wiki/Fluid_mosaic_model

The following table highlights a few of the biological molecules associated with cell membranes and their roles.

Phospholipids	Phospholipids are the main constituent of the plasma membrane. The hydrophilic (water-loving) heads of the molecule face the outside and inside of the cell. The hydrophobic (water-fearing) tails face each other in the inner part of the membrane. Phospholipids that have attached carbohydrate (sugar) chains are called glycolipids.
Cholesterol	This lipid, with its four-fused-rings structure, and related steroids are found in the plasma membrane. They stiffen and control the fluidity of the membrane.
Proteins	Proteins in the membrane serve many different functions, depending on their structure and location. Proteins may be peripheral (on the inside surface of the membrane, held in place by the cytoskeleton) or may be integral (embedded in the membrane but can move laterally back and forth). Proteins that have attached carbohydrate (sugar) chains are called glycoproteins. Proteins can act as channels, through which a particular molecule or ion can move freely across the membrane, or as carriers that selectively combine with an ion or substance to help to move across the membrane. Receptors proteins have a specific shape that allows a certain molecule, such as a hormone, to bind to it. This may cause the protein to change shape and create a cellular response. Enzymatic proteins catalyze (speed up) specific metabolic reactions. Cell recognition proteins are composed of carbohydrates chains that give individual cells a unique fingerprint that facilitates adhesion between cells, cell-to-cell recognition, and reception of signal molecules. Cells with foreign fingerprints are attacked by the blood cells responsible for immunity.
Carbohydrates	Carbohydrate chains are attached to membrane lipids and proteins on cell's outer surface. These glycolipids and glycoproteins give each cell and unique fingerprint, allowing cells to adhere to one another, to receive signals from various molecules, and to recognize other cells. Cells in the body can recognize other cells that belong there. Sometimes transplanted organs and incompatible blood types are rejected the body because the donor's cells may have different sugar chains that are attacked by the recipient's immune system.

Passive Transport

The plasma membrane is selectively permeable because some substances can move freely across it while others cannot. There are two ways for molecules to pass through a plasma membrane – one is active, the other is passive. Passive transport requires no chemical energy from the cell. Instead, this process involves facilitated diffusion. Active transport is discussed in the next lesson.

In this lesson you will compare and contrast the processes of diffusion, by which small molecules move from areas of high concentration to low concentration, facilitated transport, which requires no energy, and osmosis, the movement of water molecules from areas of high concentration to low concentration. You will also learn about the factors that affect the rate of diffusion across a cell membrane, and you will be able to predict the effects of hypertonic (more solute), isotonic (equal amounts of solute), and hypotonic (less solute) environments on animal cells.

VIDEO: Cell Transport by Amoeba Sisters

LINK: https://youtu.be/Ptmlvtei8hw

VIDEO: Transport in Cells: Diffusion and Osmosis | Biology for All | FuseSchool by FuseSchool - Global Education

LINK: https://youtu.be/PRi6uHDKeW4

Passive Transport

Passive transport is the movement of biochemical and other molecular substances across membranes. This process does not involve chemical energy. Passive transport depends on the permeability of the cell membrane, which in turn is dependent on the organization and characteristics of the membrane lipids and proteins. The three main kinds of passive transport through the membrane are diffusion, facilitated transport, and osmosis.

Diffusion

Diffusion is the movement of molecules from an area where the molecule is in high concentration (more solute) to an area of lower concentration (less solute).

For example, imagine a spray of perfume is released into a closed room. The area where the perfume was originally sprayed is the area of high concentration. Since the perfume molecules are in constant random motion, they bump into each other, causing some molecules to be pushed out of the original mass. The molecules gradually spread from the area of high concentration and can be sensed by someone standing across the room in an area of low perfume concentration. Eventually the perfume molecules become evenly mixed with other gases in the air so that each area of the room has the same number of perfume molecules.

These molecules follow their concentration gradient. The process of diffusion in a cell allows the cell to obtain nutrients and dispose of carbon dioxide without using energy. Simple diffusion only works for very small, uncharged molecules such as O_2, CO_2, and H_2O.

VIDEO: Cell - Diffusion - CBSE 9 by Don't Memorise

LINK: https://youtu.be/71MSBEwMGDA

Facilitated Diffusion

Facilitated diffusion/transport is the movement of molecule from an area of high concentration to an area of lower concentration, with the aid of a protein chancel or carrier. This process is required for larger molecules or charged ion (ex. Amino acids, glucose, Na+, and K+). This explains molecules such as glucose and amino acids cross plasma membrane, even though they are not lipid soluble. Cell membranes have proteins specific to each molecule.

VIDEO: How Facilitated Diffusion Works by AHMED ALDANAF

LINK: https://youtu.be/IX-kLh34KcQ

The rate of diffusion is determined by several factors, including the number of molecules inside the cell (mol), the permeability of a particular molecule, the surface area of the cell membrane, the width of the cell membrane, and the concentration of the diffusing molecule (mol/cm^3).

Other factors include:

A. Size – smaller molecules can slip by the polar heads of the phospholipids but larger molecules can not
B. Shape – carrier proteins are specific for certain molecules, for example, glucose carrier proteins can move up to 100 glucose molecules per second
C. Concentration – the greater the concentration gradient between the outside and the inside fo the cell, the greater rate of diffusion
D. Charge (+/-) – ions and molecules that have a charge cannot pass though the membrane; the mechanisms required for this will be discussed in the next lesson
E. Lipid solubility – molecules such as steroid hormones (testosterone and estrogen) are considered lipid soluble and can move through the lipid bilayer
F. Temperature – the rate of diffusion increases as the temperature increases because the particles are moving faster (kinetic molecular theory)

Osmosis

Osmosis is the diffusion of water through a semi-permeable membrane. Water moves from an area of high water molecule and low solute concentration to an area of low water molecule and high solute concentration. Osmotic pressure is the force that moves the water in either direction.

VIDEO: Osmosis and Water Potential (Updated) by Amoeba Sisters

LINK: https://youtu.be/L-osEc07vMs

The Effects of Hypertonic, Isotonic, and Hypotonic Environments on Animal Cells

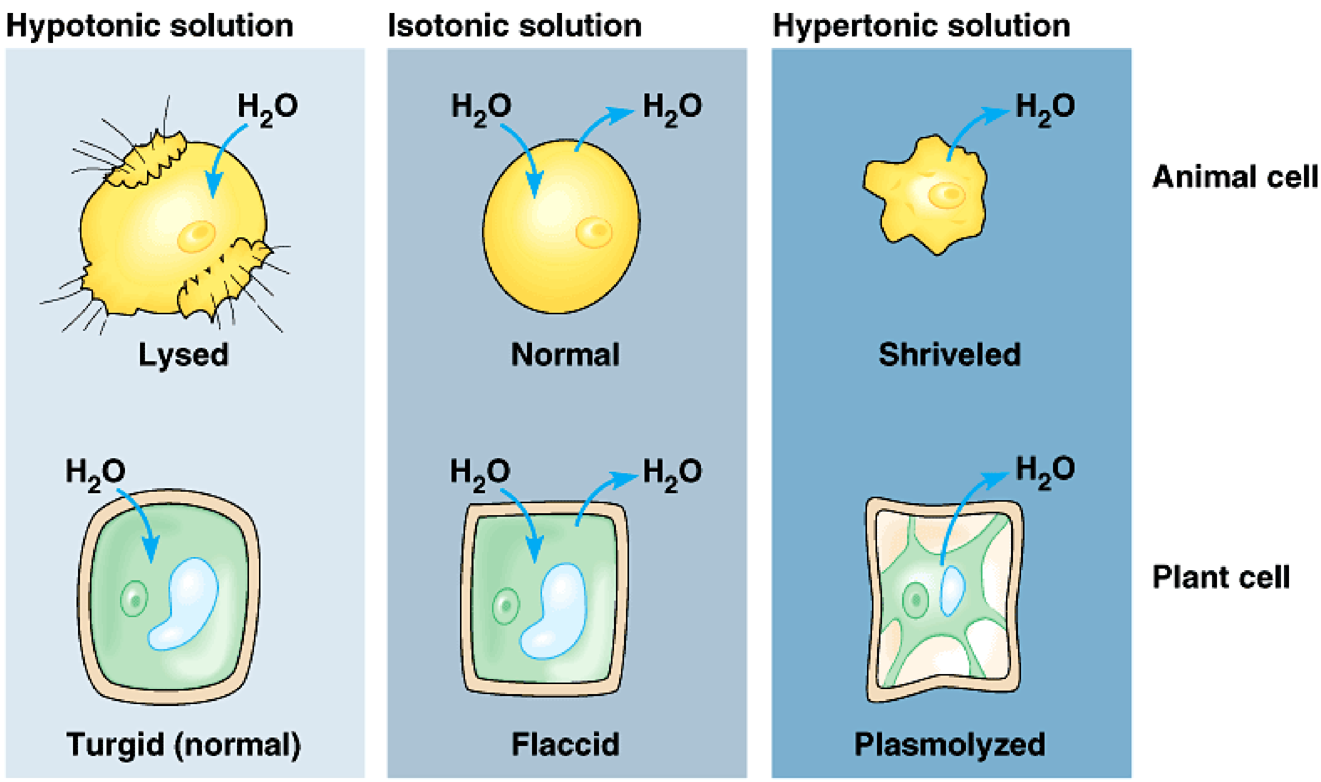
Cells are very much affected by osmosis. The type of solution surrounding a cell determines the direction of water flow, either into or out of the cell.

A solution contains a solute, usually a solid (ex. NaCl), and a solvent, usually a liquid (ex. Water).

Cells are found in three types of environments – isotonic solutions, hypotonic solutions, and hypertonic solutions.

VIDEO: Hypertonic, Hypotonic and Isotonic Solutions! by BOGObiology

LINK: https://youtu.be/rMa9MzP19zI



https://biowithvanessa.wordpress.com/2013/03/01/hypotonic-hypertonic-isotonic-differences/

Isotonic Solutions

Isotonic solutions have the same concentration of solute and water, both inside and outside the cell. Iso means "the same as" and tonicity refer to the strength of the solution. In this case the fluid outside of the cell and the cytoplasm inside the cell would both be 1% solute and 99% water. Because the concentrations are equal, there is no net gain or loss of water. Although water will still move into and out of the cell, there is no net movement of water or change in cell volume. The cell remains the same size.

Hypotonic Solutions – Water Enters Cell

Hypotonic solutions cause cells to swell or even burst due to the intake of water. The prefix hypo means "less than" and refers to a solution with less solute and more water than inside the cell. For example, the fluid outside the cell has 0% solute and 100% water (ex. Distilled water), while the cell has 1% solute and 99% water. This causes osmotic pressure to build up outside the cell and push water into the cell. Lysis, the build-up of pressure in the cell, can cause it to burst.

When a plant cell is placed in a similar solution, the swelling creates turgor pressure. The plant cell will not burst, however, because the plasma membrane pushes against the rigid cell wall.

Hypertonic Solution – Water Exits the Cell

When animal cells are placed in a hypertonic solution, the cells shrink or shrivel up due to the movement of water out of the cell. The prefix hyper means "more than" and refers to a solution with more solute and water than inside the cell. For example, the fluid outside the cell has 5% solute and 95% water, while the cell has 1% solute and 99% water. If a cell is placed in this type of solution, water will move from the area of high concentration and move outside of the cell.

Active Transport

In the previous lesson you learned how a cell's selectively permeable membrane allows certain molecules move across it without using chemical energy. However, transport into and out of the cell is not always so simple. Sometimes ions or molecules must move through the plasma membrane and accumulate either inside or outside a cell, and that requires chemical energy. Did you know it's estimated that nearly 40% of a cell's energy supply is used for active transport of a solute across the cell's membrane against the concentration gradient?

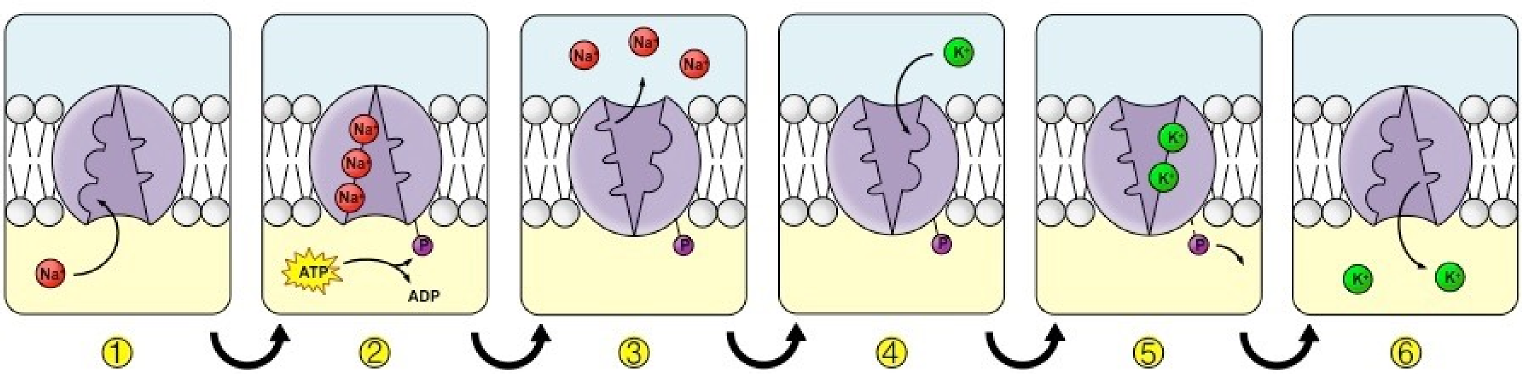
In this lesson you will learn about the process of active transport and how molecules move into a cell (endocytosis) and out of a cell (exocytosis) against concentration gradients.

Active Transport

During active transport, ions and molecules moving across a cell's plasma membrane accumulate inside or outside the cell. To accomplish this, cells require carrier proteins and energy (ATP molecules). Energy is needed for the carrier to change its shape and transport the molecule to the other side of the membrane. Proteins involved in active transport are called pumps because they are used to pump the substance across concentration gradients.

An example of a pump that is active in all animal cells is that sodium-potassium pump. This pump is associated with nerve and muscle cells, and it is responsible for moving sodium ions (Na+) to the outside of the cell and potassium ions (K+) into the cell. The carrier is able to change its shape after the attachment and detachment of a phosphate group, allowing it to combine alternately with sodium and potassium ions. This process requires energy.

Sodium-Potassium Pump

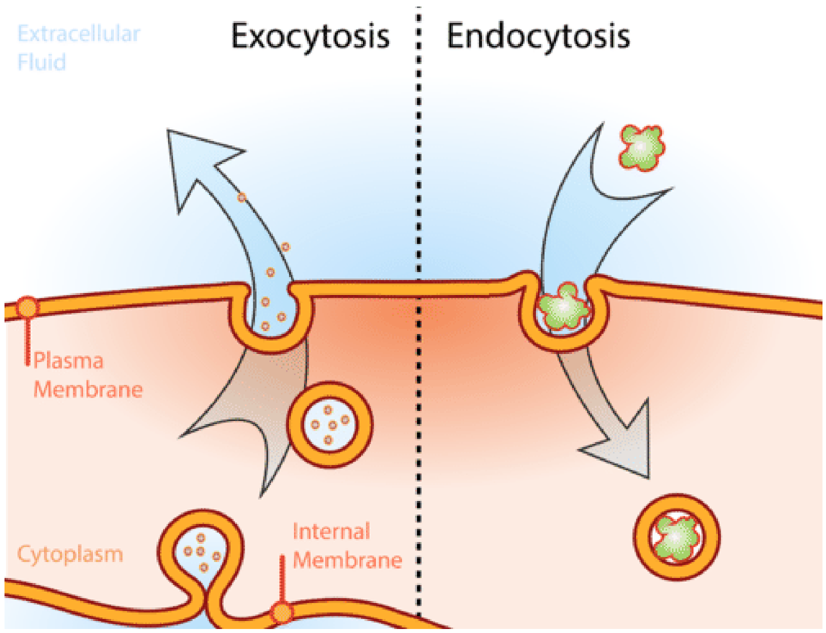


https://ib.bioninja.com.au/standard-level/topic-1-cell-biology/14-membrane-transport/active-transport.html

Some large macromolecules, such as polypeptides, polysaccharides, or polynucleotides, are too large to be transported across the plasma membrane by carrier proteins. A vesicle engulfs these large molecules and transports them in or out of the cell. Endocytosis (entering the cell) and exocytosis (exiting the cell) are the two methods of active transport that allows macromolecules to move through the plasma membrane. Basically, they are swallowed up and spit out by the plasma membrane itself.

Exocytosis

Exocytosis involves the movement of materials out of the cytoplasm. This process also requires ATP energy to create a vesicle or vacuole (large vesicle) that will migrate to the membrane's inner surface and fuse with the cell membrane. Energy is needed to alter the membrane shape and allow the vesicle to merge with the cell membrane and force its contents to the outside of the cell. This process is basically the opposite of endocytosis. The cells of glands that produce enzyme proteins or steroids use this method to export molecules for use in other areas of the body.



https://www.ck12.org/biology/Exocytosis-and-Endocytosis/lesson/Exocytosis-and-Endocytosis-BIO/

Endocytosis

Endocytosis requires the use of a cell's ATP energy to alter the shape of the membrane surface (called invagination) to allow large molecules into the cell. This process allows the material outside the cell to be engulfed by the entire membrane – like sticking your finger into a balloon. When the macromolecule is completely surrounded, the membrane pinches together forming an intracellular vesicle inside the cytoplasm of the cell.

There are two main types of endocytosis:

1. Endocytosis of large particles is called phagocytosis. Many unicellular organisms, such as an amoeba, use this process to obtain food. In the human body, various white blood cells engulf debris such as bacteria and worn out red blood cells through the process of phagocytosis.
2. Endocytosis of liquid and very small particles is called pinocytosis. It's by this process that the villi of the small intestine are able to absorb small nutrient particles. This process can be referred to as "sipping." The cells that line the kidney tubules and the intestinal wall, blood cells, and plant root cells also use pinocytosis.

Comparison of Transport Mechanisms

In the previous lessons you learned how cells are able to transfer molecules and nutrients into and out of the cell through the selectively permeable membrane.

In summary, there are two basic categories of transport through the membrane. Passive transport does not require chemical energy. Molecules move along a concentration gradient, from areas of higher concentration to areas of lower concentration. This method of transport includes diffusion (the movement of molecules), facilitated diffusion (the movement of a molecule with the help of a protein channel or carrier), and osmosis (the diffusion of water through a semi-permeable membrane).

The second category of transport requires energy from the cell because the movement of molecules goes against the concentration gradient. This method is called active transport.

In the guided practice you will construct a table to compare the various transport methods. You will compare and contrast the direction of movement, the conditions under which each occurs, and examples of each type of transport.

Cell Size: Surface Area to Volume Ratio

Did you ever wonder why cells are so small? There is, in fact, a limit to how big a cell can grow.

In this lesson you will learn the factors that limit a cell's size and understand the relationship and significance of the surface area of a cell's membrane to its volume.

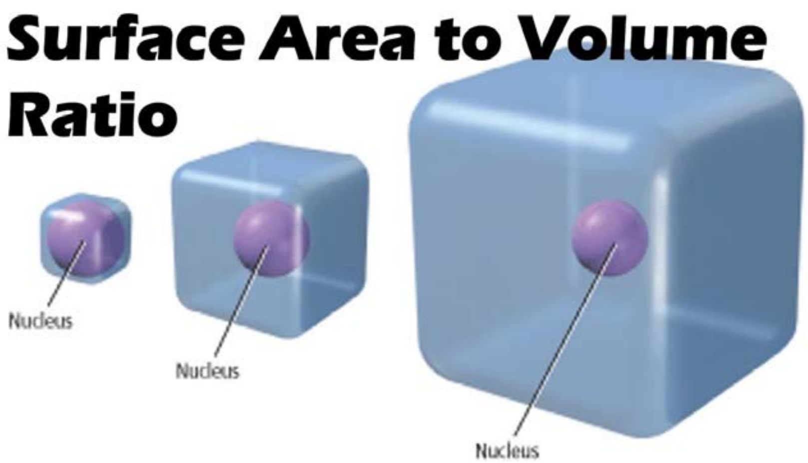
Cell Size and Surface-Area-to-Volume Ratio

To understand why cells are so small, consider the surface-area-to-volume ratio of a cell. Surface area affects a cell's ability to move things in and out, many of which are transported by diffusion.

Small cells are very effective at moving materials across the membrane because they have a greater surface area compared to volume. Therefore, small cells can effectively meet their metabolic needs.

Larger cells are less effective at moving materials across the membrane because there have a lesser surface-area-to-volume ratio than smaller cells. Therefore, larger cells are not able to function at their optimal level of efficiency.

As a cell increases in size, the proportionate amount of surface area to volume decreases. To see this, compare these two cells:



https://www.youtube.com/watch?v=CYaADg5NfEw

Calculating Surface-Area-to-Volume Ratios

If a cell is shaped like a sphere or a ball:

A. The surface area of a cell can be calculated by the following equation:

Surface area = $4\pi r^2$

B. The volume of the cell can be calculated by the following equation:

Volume = $\frac{4}{3}\pi r^3$

The following table demonstrates how the surface-area-to-volume ratio changes as a cell becomes larger and its radius increases.

Radius of Cell (m)	Surface are of cell SA = $4\pi r^2$	Volume of Cell V = $\frac{4}{3}\pi r^3$	Surface Area/Volume Ratio (SA/V)	Cell's Efficiency
1	12.56	4.19	3.0	Most efficient
2	50.24	33.49	1.5	Moderate efficiency
3	113.04	113.04	1.0	Poor efficiency

Nutrients enter a cell and wastes exit a cell at its surface; therefore, the amount of surface affects the ability to get material in and out of the cell.

In summary, a greater surface-area-to-volume ratio makes a cell more efficient. Because small cells have the greatest surface-area-to-volume ratios, they are the most efficient at transporting molecules across their cell membranes. Larger cells have a lower surface-area-to-volume which makes diffusion of materials into and out of the cell less efficient.

Some cells, such as intestinal cells and red blood cells, have unique shapes that help them overcome this problem. Intestinal cells on villi (columnar epithelial cells), have thousands of microvilli that act as brushes. Having thousands of microvilli greatly increases the surface area, which allows for greater diffusion of nutrients. The biconcave shape of red blood cells increases their surface-area-to-volume ratio, which increases the diffusion of gas across the membranes.

https://www.openaccessgovernment.org/red-blood-cells-physics/56337/