BIO 311C
Spring 2010

Exam 2:
Next Friday, Mar. 12, in this classroom

The last 20 minutes of Wednesday's lecture will be devoted to answering questions regarding the subject matter to be covered on Exam 2.

Lecture 19 – Monday 8 Mar.

Mechanisms of Transport Across Biological Membranes

1. Non-specific transport of small nonpolar molecules

2. Specific transport of individual molecules
   - A. Water
   - B. Facilitated diffusion
     - i. permease-mediated
     - ii. ionophore-mediated
   - C. Active transport
     - i. permease-mediated
     - ii. electron-transport mediated

3. Bulk transport
   - A. Endocytosis
   - B. Exocytosis

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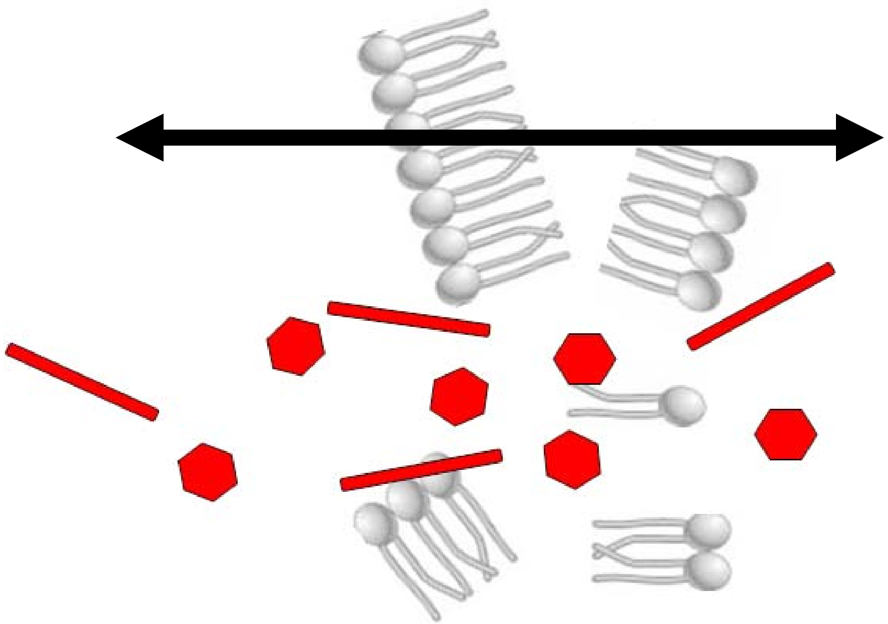
Small nonpolar molecules such as short-chain hydrocarbons easily pass through biological membranes, but often disrupt and may even dissolve the membrane as they pass through.



Fortunately, we seldom come into contact with these kinds of molecules. The keratin surface on skin provides temporary protection from membrane exposure to small nonpolar molecules.

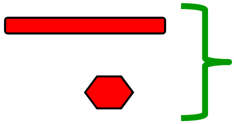


illustration of small nonpolar molecules such as those which occur in gasoline

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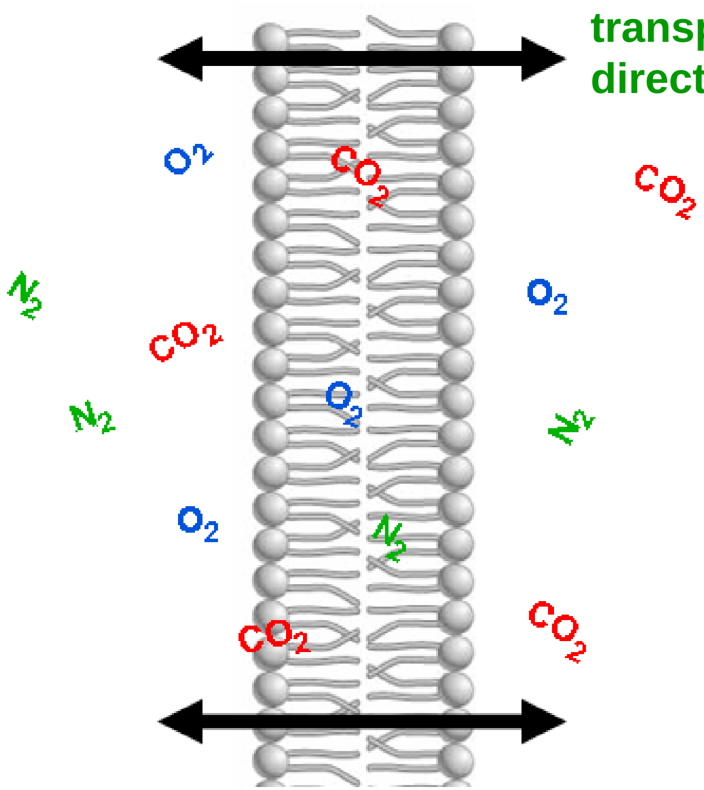
Review

Gasses such as O_2, CO_2 and N_2 require no special mechanism to pass through biological membranes because they are very small and are quite nonpolar.



transport rapidly across the membrane in both directions without altering the membrane

Both O_2 (molecular oxygen) and CO_2 (carbon dioxide) must be transported across cellular membranes rapidly for efficient respiration and photosynthesis. N_2 (dinitrogen gas) is completely inert in most kinds of cells and has very little influence on cellular activities.

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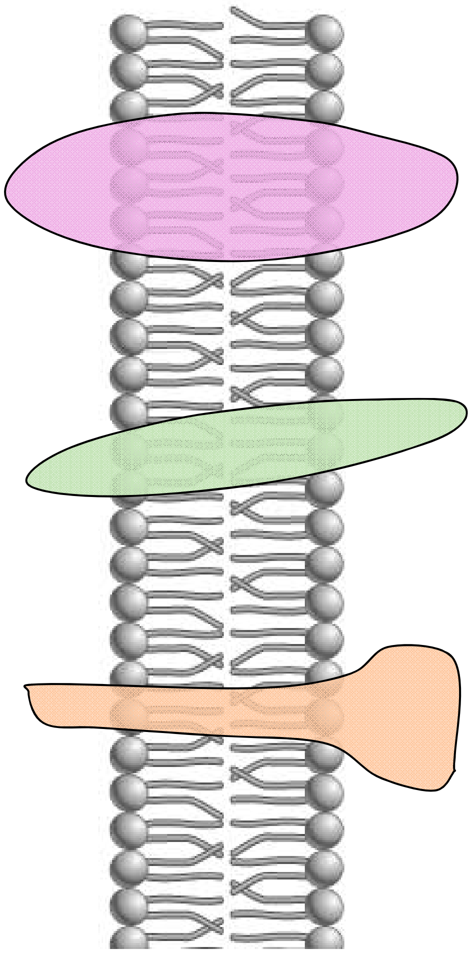
Transmembrane proteins with transport-enabling functions greatly expand the range of chemical substances that pass through biological membranes



Each different transport-enabling protein allows transport across the membrane of only one or a very few kinds of chemical substances.

Highly specific transport-enabling transmembrane proteins are called permeases.

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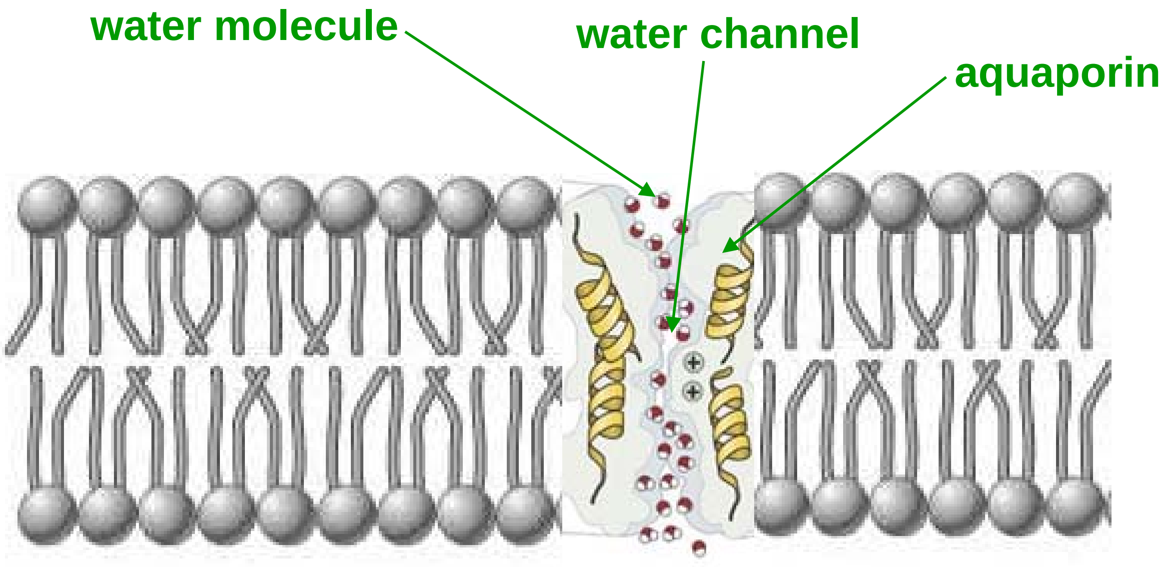
Biological membranes contain many copies of a permease called <u>aquaporin</u>, which facilitates very rapid movement of water across the membrane.



Water moves freely in either directions through the aquaporin channel.

Aquaporin is highly selective for water, not allowing other kinds of molecules to move through its channels.

Because of the abundance of aquaporins in biological membranes, water is capable of moving much faster than any other kind of polar molecule across biological membranes.

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Definitions:

Osmosis (in aqueous solutions):

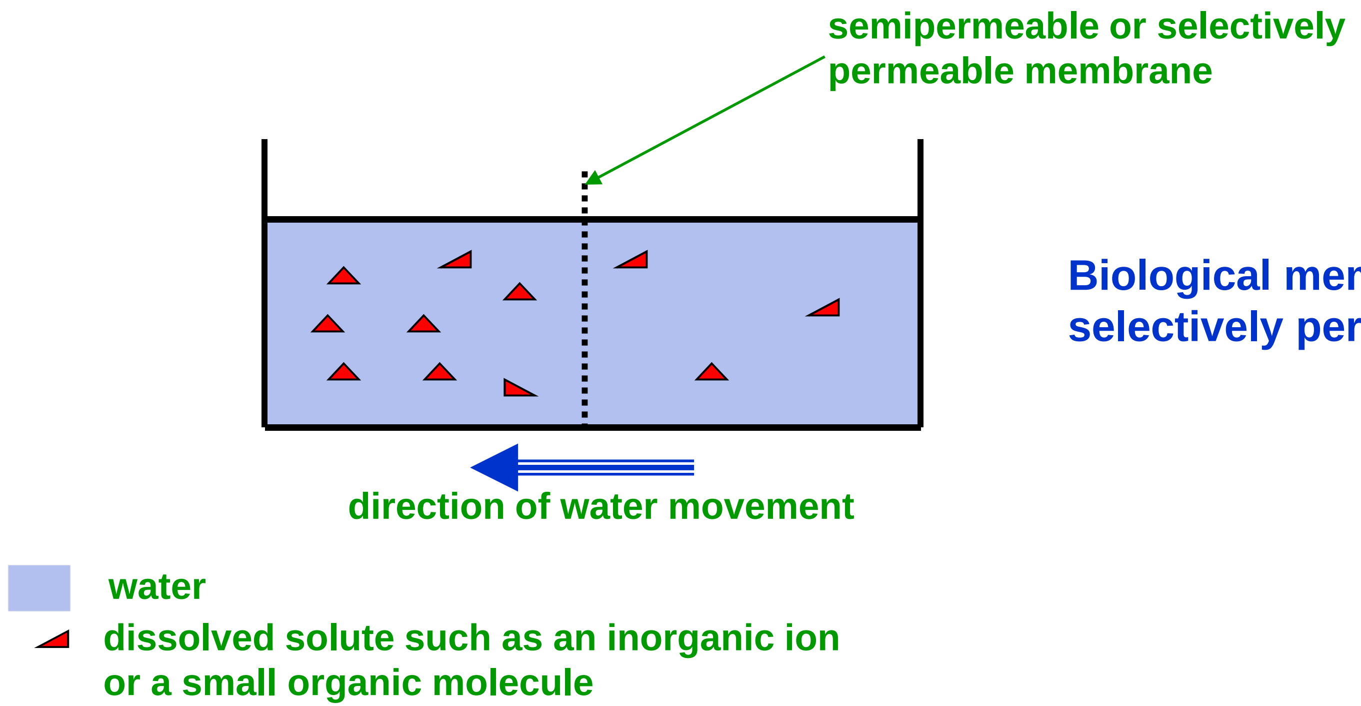
The movement of water across a semipermeable membrane from a compartment with a lower concentration of dissolved solute to a compartment of higher concentration of dissolved solute.

Semipermeable membrane:

A membrane that lets water pass through rapidly but prevents dissolved solutes from passing through.

Selectively permeable membrane:

A membrane that lets water pass through much more rapidly than it allows solutes to pass through.



Biological membranes are selectively permeable.

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Definitions:

<u>Hypotonic solution</u> (with respect to another solution):

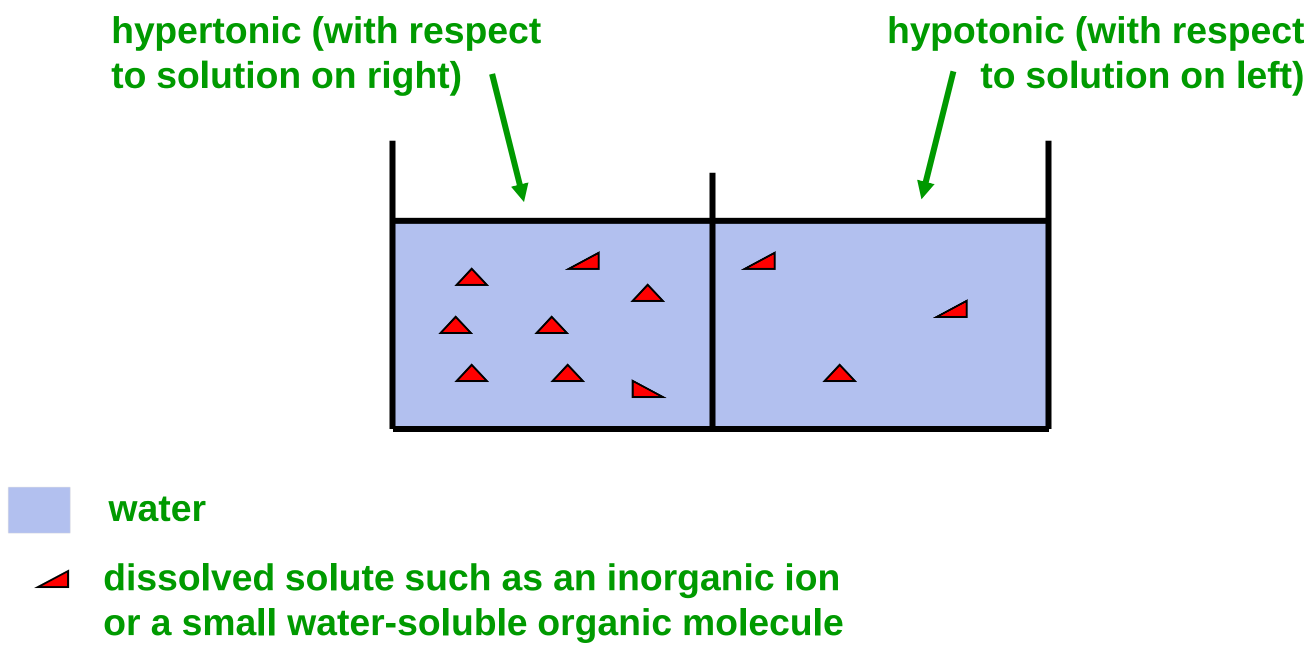
A solution that has a lower concentration of dissolved solute than the solution to which it is compared.

<u>Hypertonic solution</u> (with respect to another solution):

A solution that has a higher concentration of dissolved solute than the solution to which it is compared.

<u>Isotonic solution</u> (with respect to another solution):

A solution that has the same concentration of dissolved solute as the solution to which it is compared.



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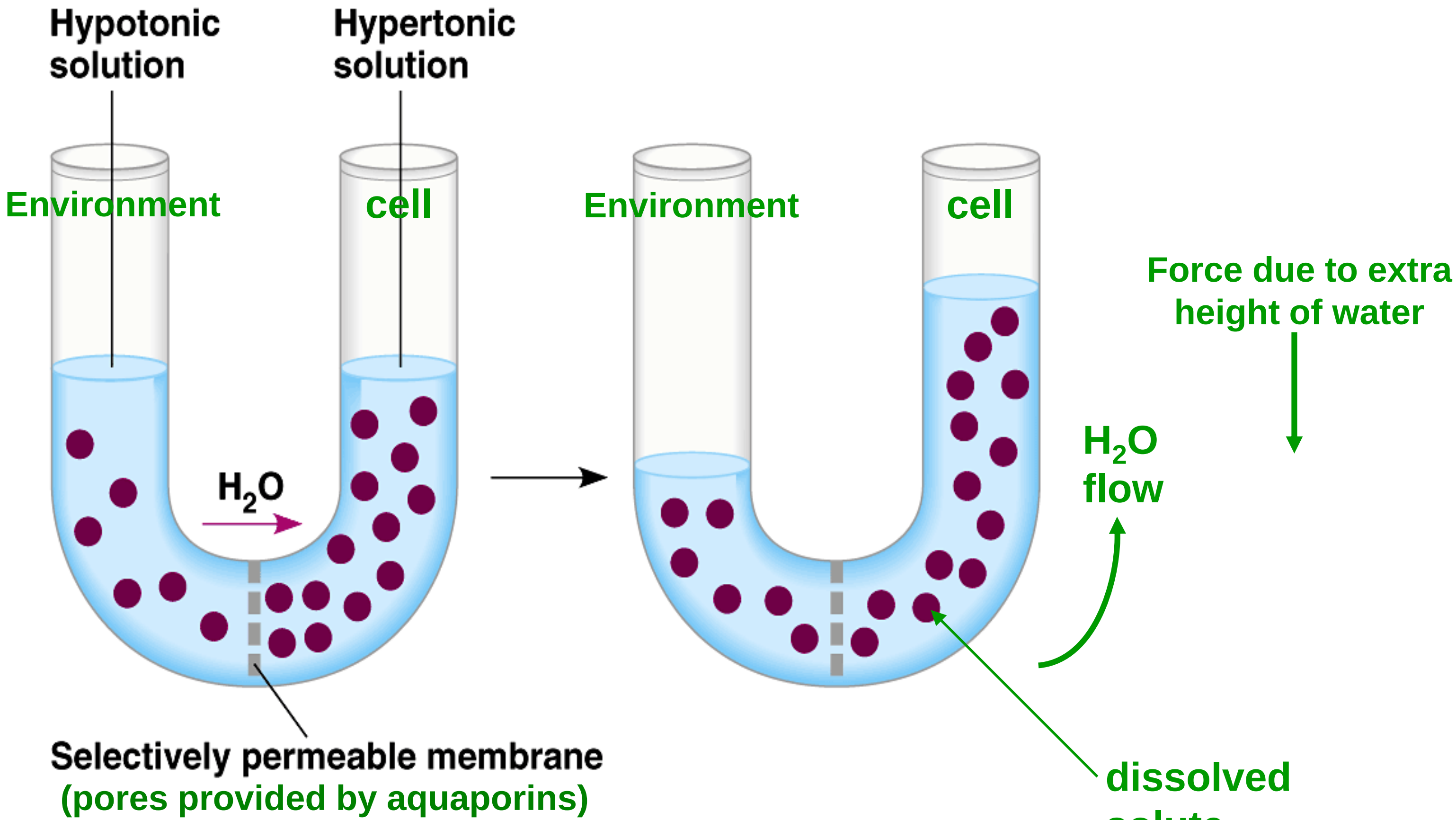
Demonstration of Osmosis in a U-tube;
A Model of Osmosis Across a Biological Membrane

See textbook Fig. 7.12, p. 133



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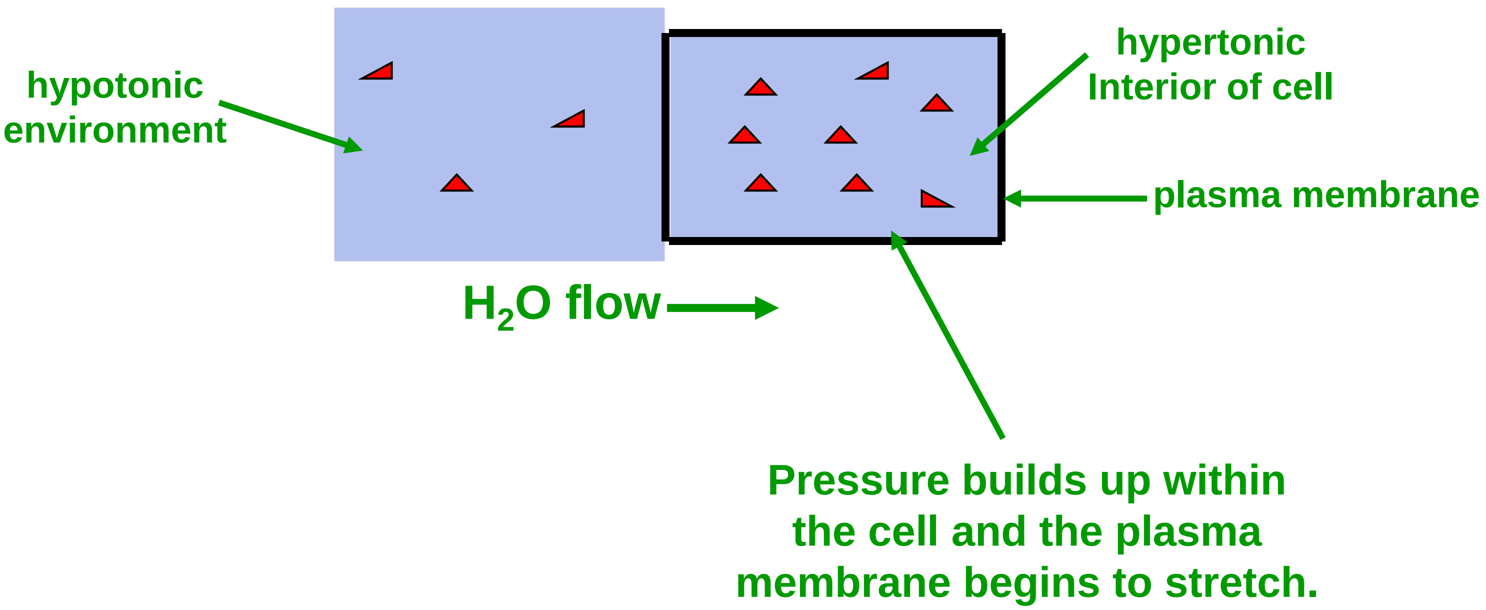
Model of a Cell in a Hypotonic Environment



water

dissolved solute such as an inorganic ion
or a small water-soluble organic molecule

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Both sides of biological membranes are surrounded by aqueous solution.

Living organisms that live in the ocean are exposed externally to solution approximately isotonic with respect to the interior of cells. Living organisms elsewhere are nearly always surrounded by hypotonic solution.

Question: How do non-marine organisms prevent osmosis from swelling up and bursting their cells?

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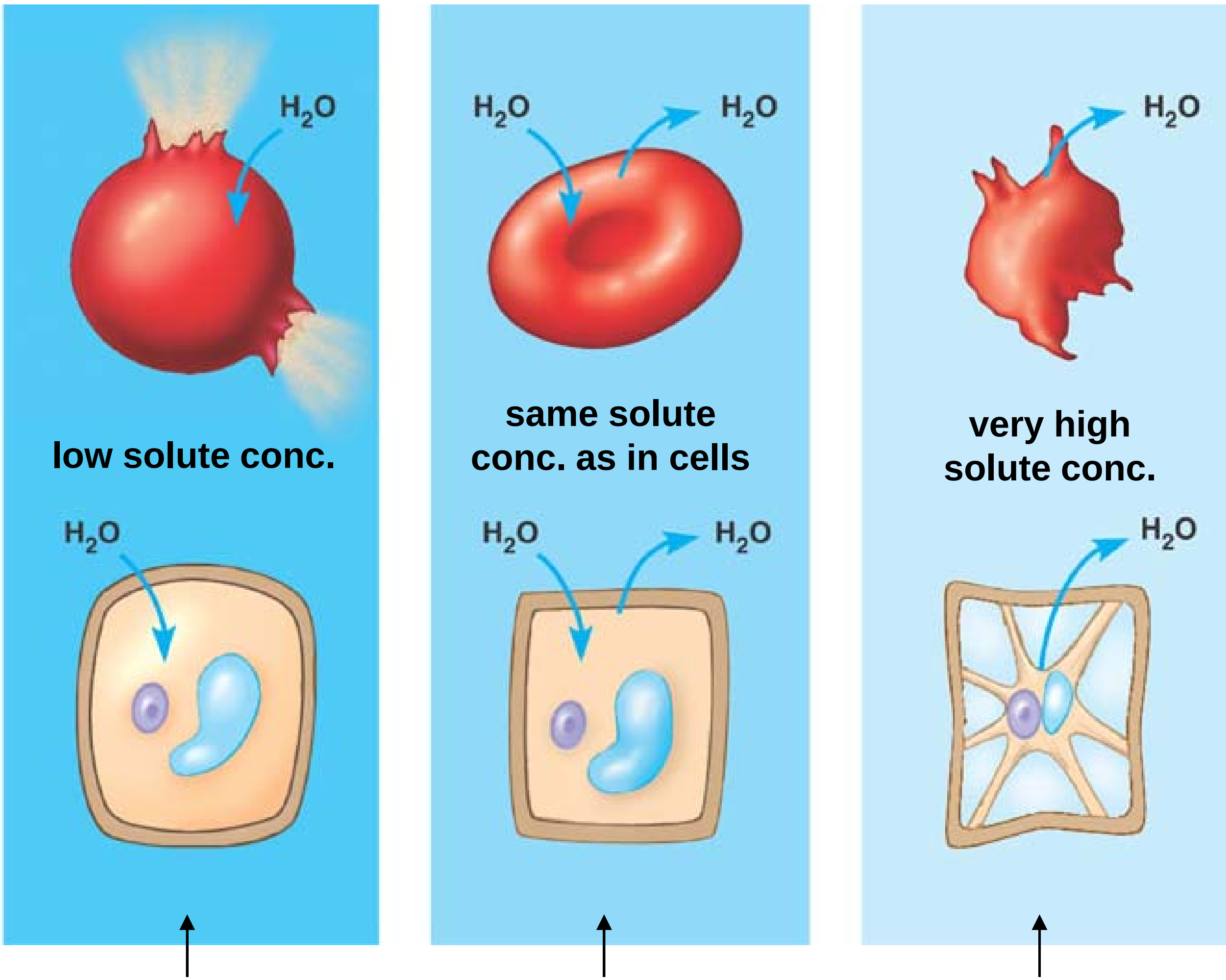
Effects of Environmental Solutions of Various Concentrations on Animal and Plant Cells

From textbook Fig. 7.13, p. 133



Hypotonic soln.

Typical environment of cells in organisms that don't live in the ocean

Isotonic soln.

Environment of cells of organisms that live in the ocean

Hypertonic soln.

Not a typical environment of cells

Animal cells are not surrounded by a rigid cell wall and do not survive exposure to a hypotonic solution unless they have an adaptive mechanism.

Plant cells and most prokaryotic cells are surrounded by a rigid cell wall that prevents the cell from swelling and bursting in a hypotonic solution.

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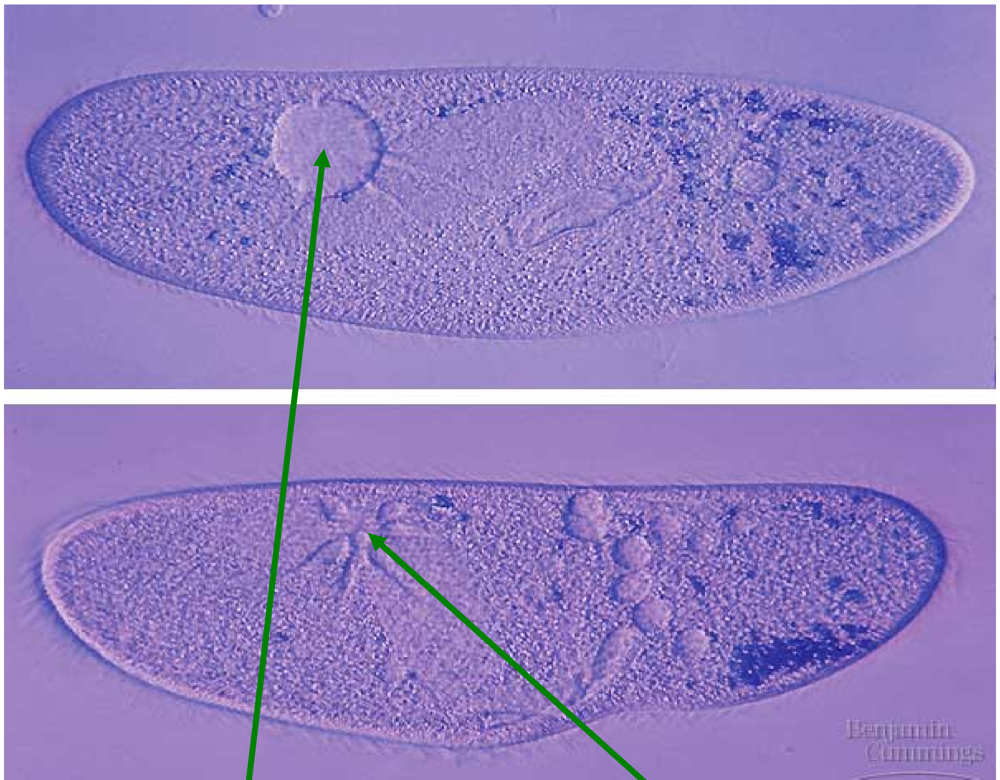
Contractile vacuoles

The *Paramecium* shown here is a unicellular organism that lives in bodies of fresh water (not salt water).

Textbook Fig. 7. 14, p. 134



Filling or full contractile vacuole

Nearly empty contractile vacuole

Cells of many small eukaryotes contain specialized organelles called contractile vacuoles. These organisms use energy of ATP hydrolysis to continuously pump the accumulating intracellular water into the contractile vacuole, and then expel it when the contractile vacuole becomes full.

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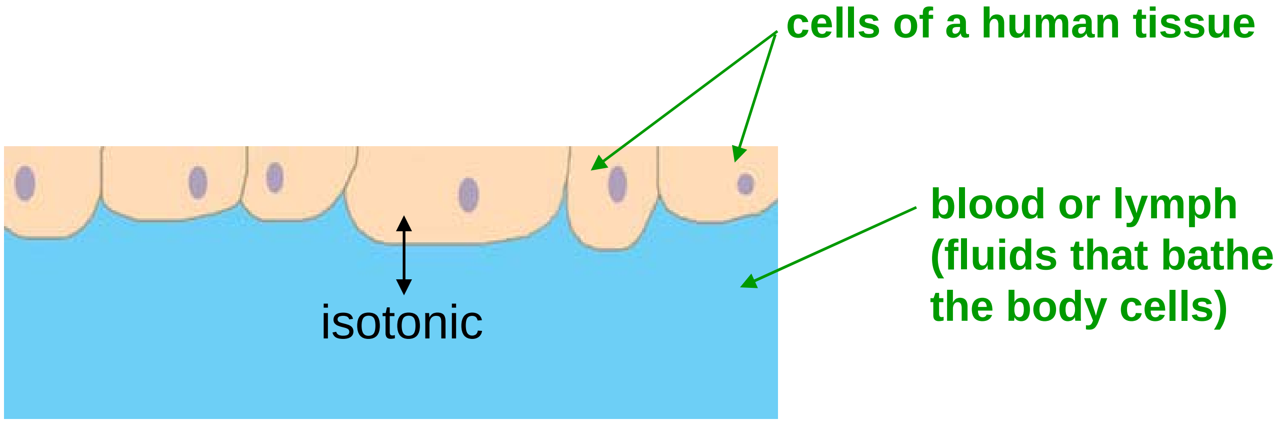
The cells of large animals such as humans are bathed in fluid that is nearly isotonic with respect to the interior of the cells.



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Ionophores are doughnut-shaped organic molecules with a nonpolar exterior surface and a hole lined with polar R-groups. The hole is just the right size to fit a specific inorganic ion.

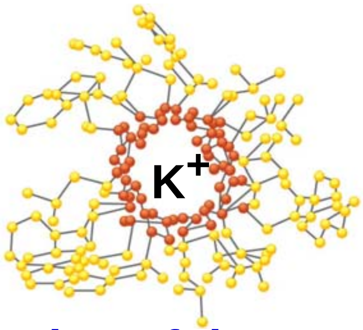

illustration of the structure of a potassium ionophore enclosing a potassium ion

Different kinds of ionophore are specific for different inorganic ions.

Ionophores are potent toxins that slide into biological membranes. They carry inorganic ions back and forth across the membrane, thereby making the concentration of the ion the same on both sides of the membrane.

Most ionophores are oligopeptides whose outward-projecting R-groups are hydrophobic and whose inward projecting R-groups are hydrophylic.

Their N-terminal and C-terminal ends are attached together in a peptide bond, and therefore are called cyclic oligopeptides.

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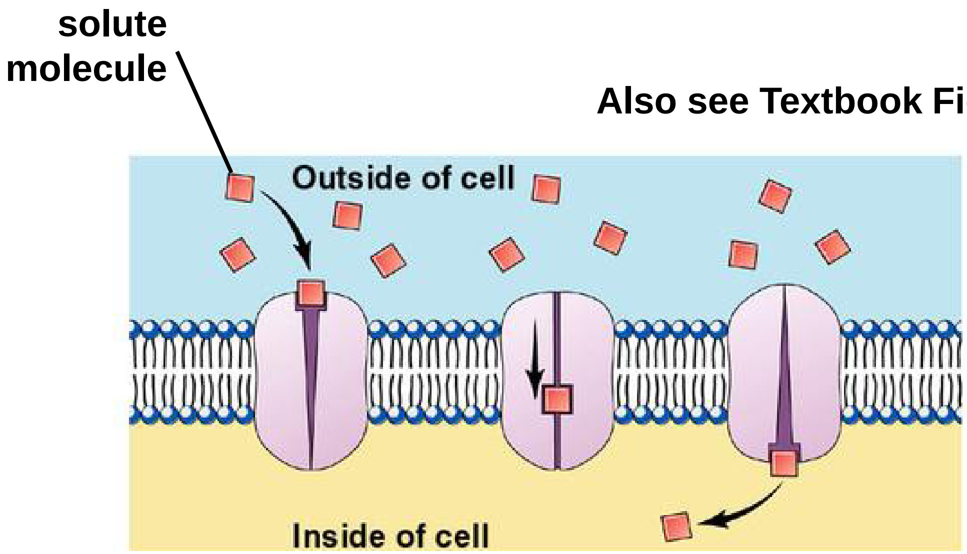
Facilitated diffusion is a term that is applied to any process that allows a specific kind of molecule or ion to pass through a biological membrane, one at a time, without the cell expending any energy.

Also see Textbook Figure 7.15. p. 135



This picture illustrates the transport of a specific solute across the plasma membrane.

A different transmembrane protein is used for each different kind of molecule or ion that is transported across the membrane.

Facilitated diffusion allows the transported molecule or ion to move either direction through the membrane. Thus, net direction of solute flow is always to the solution on side of the membrane with the lowest concentration of the transported molecule or ion (in this example from the outside to the inside of the cell.

Transmembrane proteins that participate in facilitated diffusion are examples of permeases.

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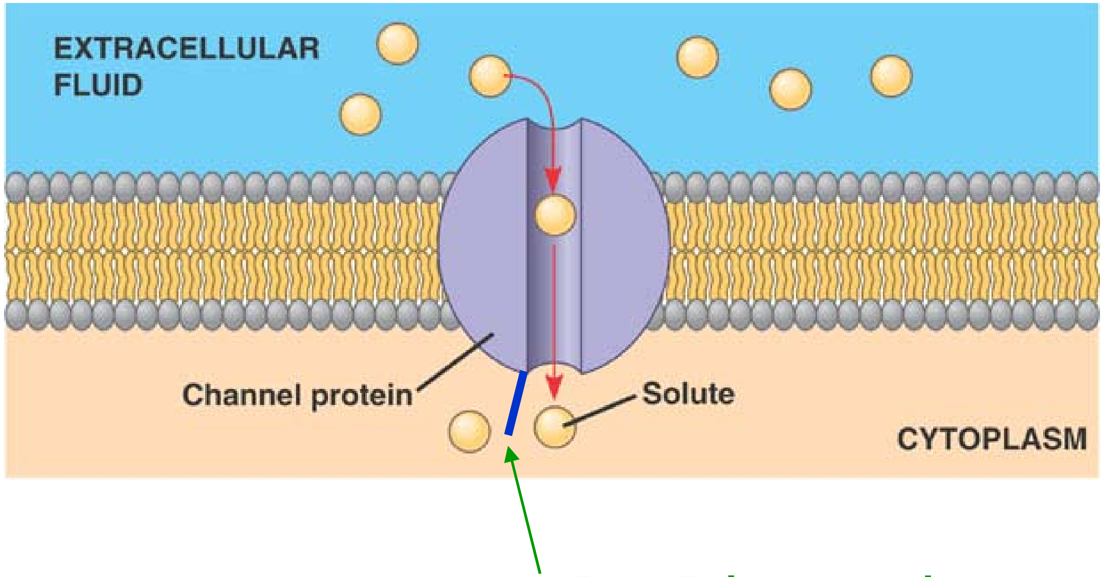
Some transmembrane proteins that allow transport of a molecule or an ion by facilitated diffusion simply have a channel through the protein that is the right size and shape to allow only one chemical species to move through the membrane.

Also see Textbook Figure 7.15. p. 135



a "gate" that may close to prevent passage of the solute through the channel

Most channel proteins are protected by a “gate” that the cell may close in order to prevent an excessive amount of the molecule or ion from moving across the membrane. These permeases are called gated channels.

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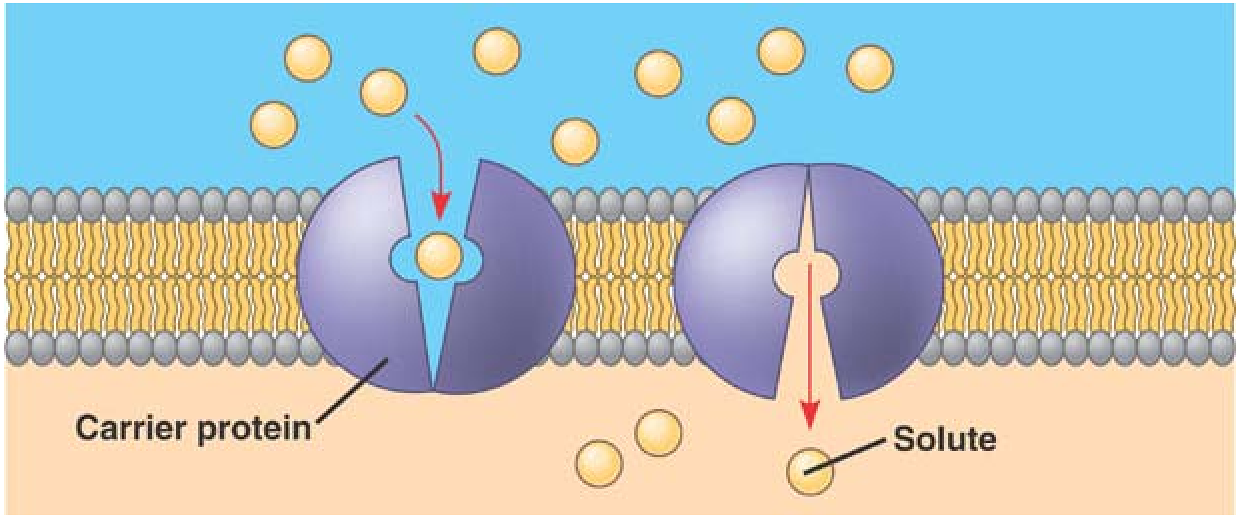
Some transmembrane proteins that allow movement of a molecule or ion by facilitated diffusion change shape after the molecule to be transported first becomes bound to a specific domain on the protein. The new shape exposes the molecule or ion to the other surface of the membrane, where it may then be released. These shape-changing proteins are called <u>carrier</u> <u>proteins</u>.

Also see textbook Fig. 7.15b, p. 135



Many carrier proteins are gated much like channels, so the cell can control when the molecule or ion is allowed to move through the membrane.

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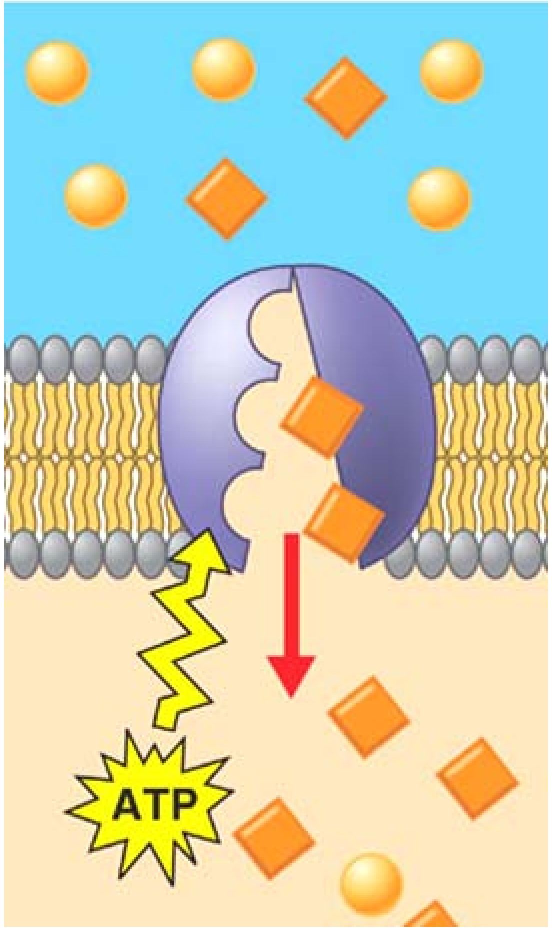
Active transport is a term that is applied to any process that expends cellular energy while transporting a specific kind of molecule across a biological membrane, one at a time.

From Fig. 7.17, p. 136



Transport is in one direction only, regardless of the direction of the concentration gradient. Active transport permeases often concentrate solutes against the concentration gradient, which is why energy must be expended.

A different transmembrane protein (permease) is used for each different solute molecule or ion that is transported across the membrane.

Many active transport proteins use energy that is made available in the form of ATP hydrolysis, but active transport may utilize other forms of cellular energy.

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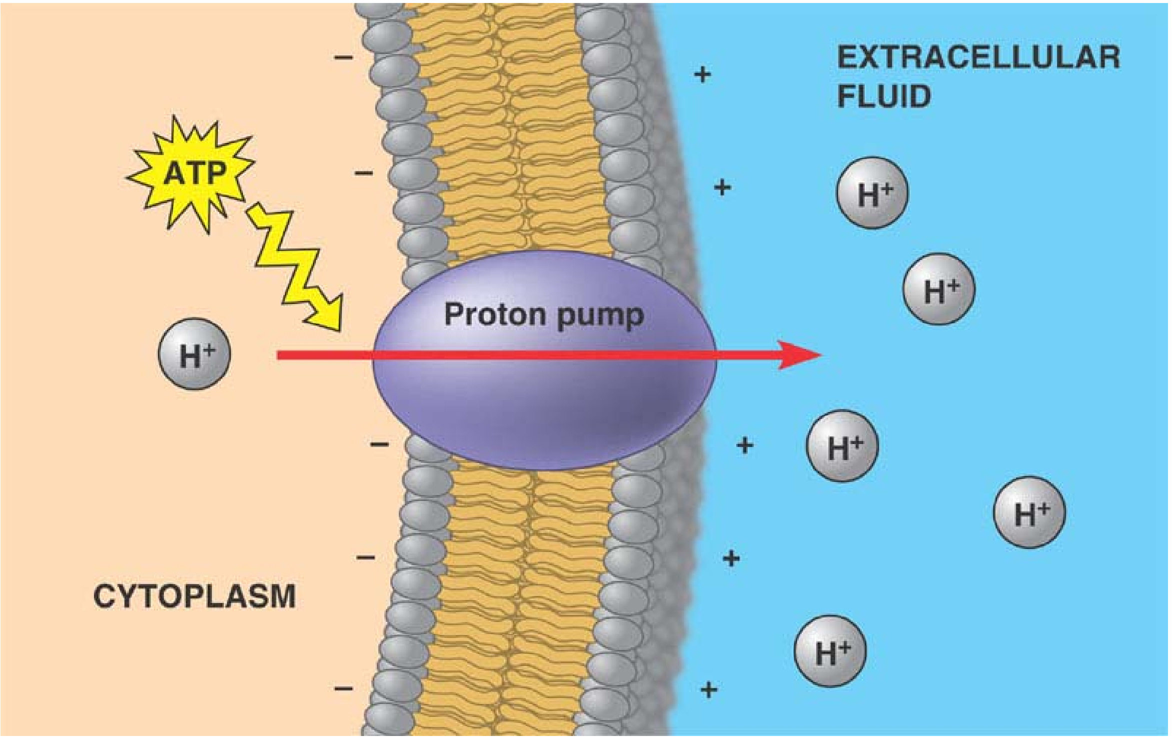
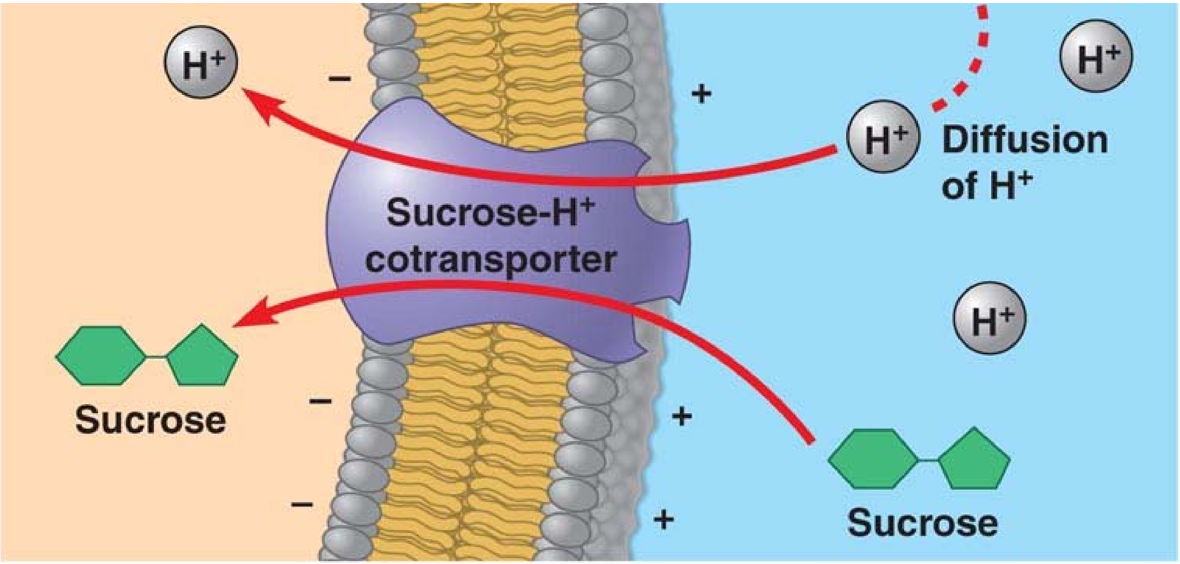
An ATP-driven Electrogenic Pump

Textbook Fig. 7.18, p. 137



An electrogenic pump uses a transmembrane protein to transports ions (in this case protons) from one side of the membrane to the other, generating a much higher (often 100 times higher) concentration of protons on one side of the membrane than the other. This causes a difference in pH (often by more than 2 pH units) and a difference in electrical charge across the membrane, which is a form of stored energy called a <u>protonmotive</u> <u>force</u> (pmf). *

Use of a Proton Gradient Across a Membrane as an Energy Source to Drive the Transport of Sucrose Across the Membrane



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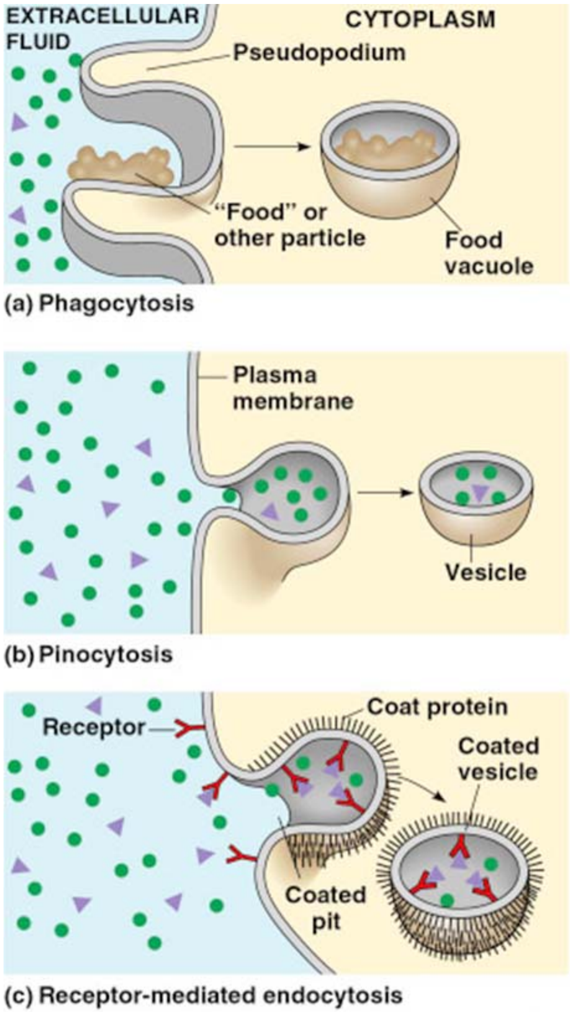
Bulk transport into animal cells occurs in a process called endocytosis. Several different mechanisms of endocytosis are shown.

Also see textbook Fig.7.20, p. 139



Phagocytosis is a mechanism of ingestion of solid particulate matter into the cell.

Pinocytosis is a mechanism of ingestion of a volume of the extracellular fluid into the cell.

Receptor-mediated endocytosis is a mechanism of ingestion whereby binding of a specific molecule or ion in the extracellular fluid to a "receptor" domain on the exterior surface of a transmembrane protein triggers endocytosis.

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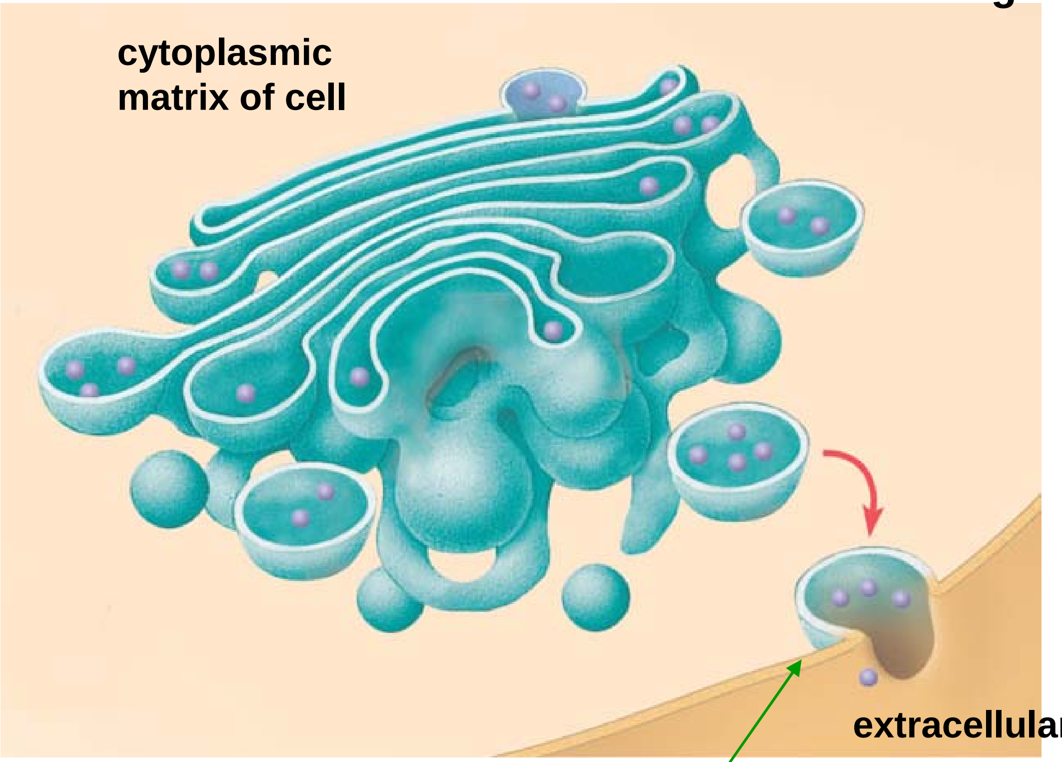
Exocytosis

Excretion or Secretion Substances from the Cell

From textbook Fig. 6.16, p. 109



<u>secretion</u>: export from the cell of substances intended for use elsewhere in the body.

<u>excretion</u>: export from the cell of waste products.

Vesicles derived from golgi membranes fuse with the plasma membrane, releasing into the external environment substances that were in the lumen of the vesicle.

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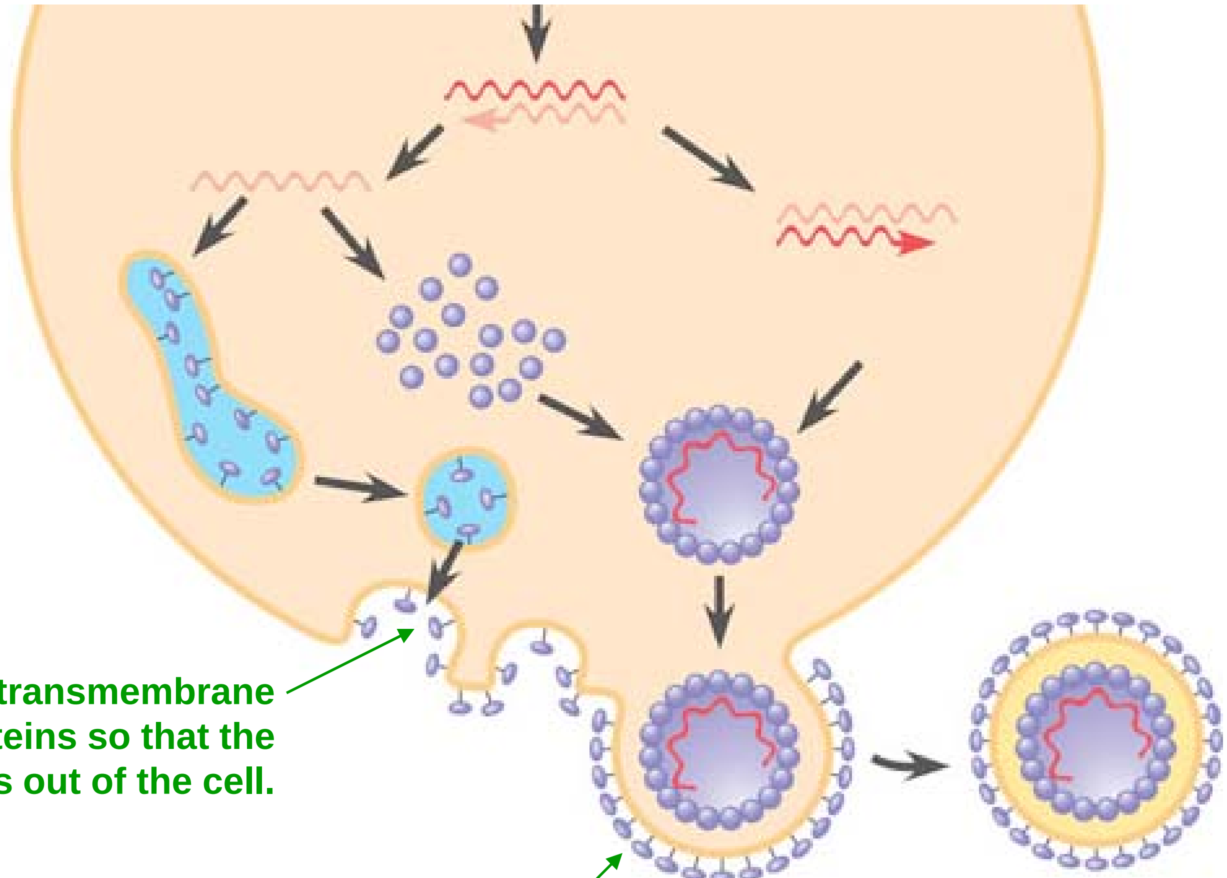
Exocytosis
A budding Virus

From textbook Fig. 19.4, p. 384



Insertion of virus transmembrane glycoproteins so that the carbohydrate projects out of the cell.

Export of virus, surrounded by a piece of the plasma membrane that contains virus glycoproteins

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