

Inside the Living Cell

Study Guide for Instructors and Students
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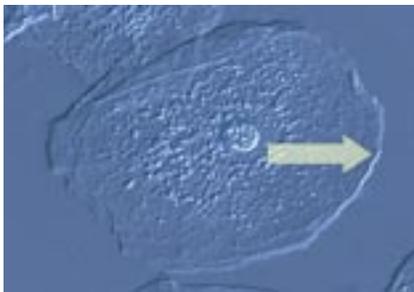
The Outer Envelope

THE CELL MEMBRANE

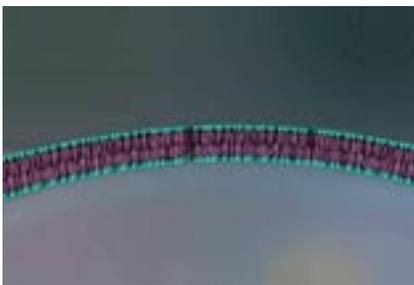
A soap bubble is an amazing thing. If you are lucky enough to occasionally wash the dishes, study the bubbles closely. They do tricks.

A soap bubble may be just a few layers of molecules, fat molecules, otherwise known as phospholipids -- the same kind of molecules that surround every cell in your body.

Take a cheek swab and smear it on a microscope slide with a drop of saliva. Then look for cheek cells.



This photograph of a cheek cell clearly shows the cell nucleus surrounded by the cytoplasm where most of the chemistry of life occurs. Surrounding the cell is the cell membrane, the skin that holds it all in place. The cell membrane, like a soap bubble, is made up of two layers of phospholipid molecules.



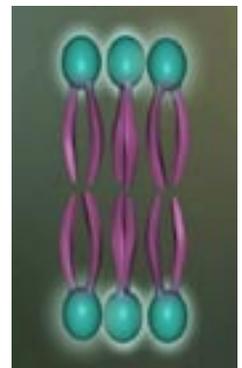
If you could see the cell membrane on the molecular level you would see the phospholipid molecules moving constantly, shifting around, trading places thousands of times a second.

A lipid molecule has a head end and a pair of tails, which are actually long chains of carbon atoms.

Two things keep the phospholipids organized in sheets: the heads are electrically attracted to each other; they are also attracted to water. And while the phospholipid heads are attracted to water, the carbon chain tails are repelled by H₂O.

Therefore phospholipids have no choice but to form a double layer, with the water-loving heads out, and the water-hating carbon tails pointing in, away from the water.

Because cell membranes are essentially fluids, they can fuse and seal themselves, just like soap bubbles.

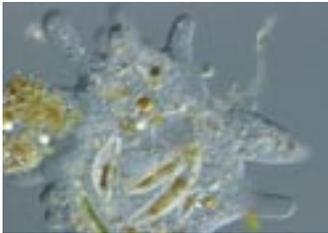


MEMBRANE BEHAVIOR and CELL WALLS

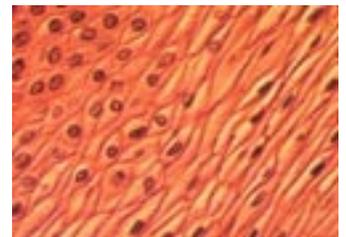


The best organisms for observing membranes in action are protozoans. Ponds are full of these independently-living single celled organisms.

The self-sealing ability of membrane phospholipids is important during cell division. When cells pull apart, they must quickly reseal the break.



To observe the most extreme membrane behavior there is no protozoan better than an amoeba. Only a sheet of constantly shifting lipid molecules can be modified so rapidly, allowing the cell to take on so many different shapes.



Most animal cells are tightly packed in tissues, so that their cell membranes are in close contact.



The same is true of plants, but with one additional structure. Plant cells surround their outer membrane with a tough cell wall. These cell walls are what give plants their rigidity.

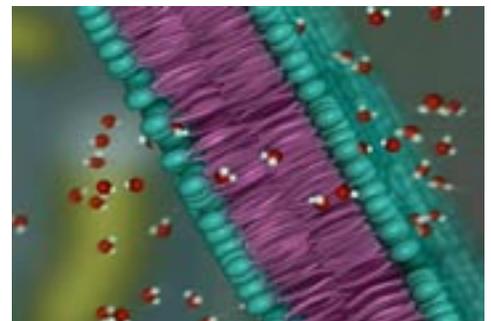


Leaf skeletons and wood are simply the cell walls that remain after the juicier cell parts have decomposed.

OSMOSIS

The cell membrane presents a barrier to large molecules, including harmful chemicals that may occur in its environment.

One substance moves easily through the shifting lipids -- molecules of water. Temporary gaps between the rapidly moving phospholipids make the membrane permeable to water molecules. However, the gaps are too small for larger molecules to get through. Therefore, the cell membrane is said to be selectively permeable membrane.

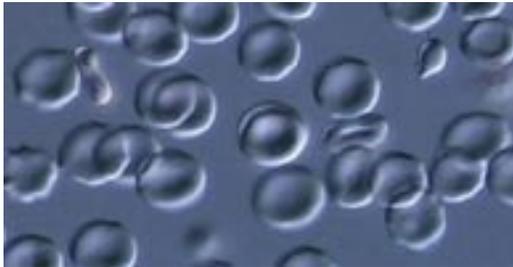
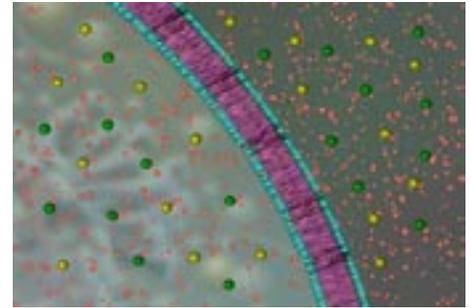


Being surrounded by a selectively permeable membrane has consequences. If more water enters the cell than leaves, the cell swells up. If more water leaves than enters, the cell shrinks. This movement of water through a selectively permeable membrane is known by one of the big words of biology -- osmosis.

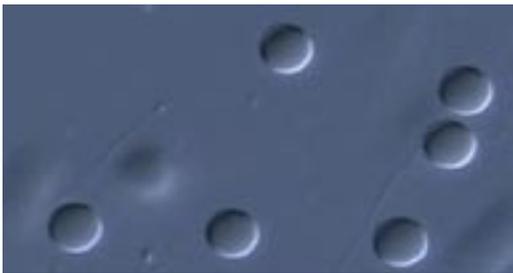
OSMOSIS -- continued

There is, of course, water on both sides of the cell membrane, so it is other molecules, dissolved in the water that cause a cell to shrink, grow, or stay the same. These dissolved substances are called solutes.

Whether more water enters or leaves a cell can be predicted by knowing the concentration of solutes inside and outside of the cell.



Red blood cells contain about one percent solutes and 99% water. The blood plasma in which they are bathed also contains about 1% solutes. Under these balanced conditions inflow and outflow, due to osmosis, is equal, and the red blood cells retain their donut-with-the-hole-filled-in shape.



If we flood the blood cells with distilled water -- water in which all solutes have been removed -- what do you think will happen? Try it.

As you probably guessed, the cells blow up as water rushes in. But why?



It's because the solute molecules inside have a tendency to trap water molecules, holding them, or at least slowing them down. Therefore water molecules inside the cell can't collide as often with the water molecules that are zipping in through the membrane. Thus more come in than go out and the cell swells up. Under these extreme conditions some blood cells rupture leaving empty membrane ghosts. But can the opposite effect occur?

Sea water contains a lot of solutes, 3.5 percent by weight. This is the picture when normal shaped red blood cells are flooded with sea water. So, if you are lost at sea, and dying of thirst, you better hope for rain, because there may be water, water, everywhere, but nary a drop fit to drink.

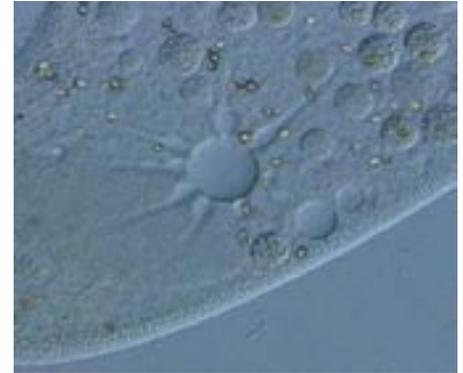
Our kidneys keep the concentration of solutes in blood plasma just right most of the time, so our cells stay in shape.

But a freshwater lake contains a very low percentage of solute molecules, and this creates a problem for single cells living there.

If osmosis were the only factor at work, the inflow of water would balloon them up until their internal solutes reached the same concentration as the water around them.

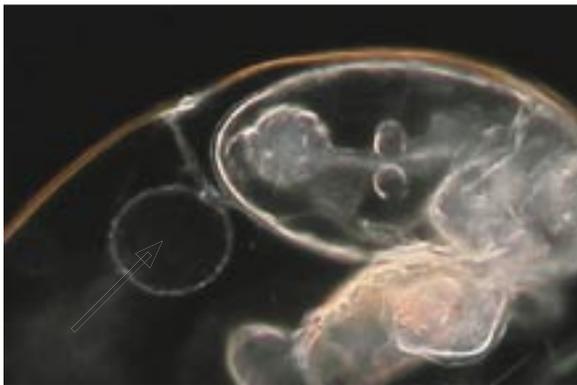
OSMOSIS -- continued

If you collect some Paramecia from a lake, and observe one for a minute or so, you will see a star-shaped organelle pumping water out of the cell. This “contractile vacuole” is getting rid of the excess water entering by osmosis.



Rotifers, microscopic water animals, uses a primitive kind of kidney to expel excess water.

The water is collected in a bladder and emptied back into the pond.

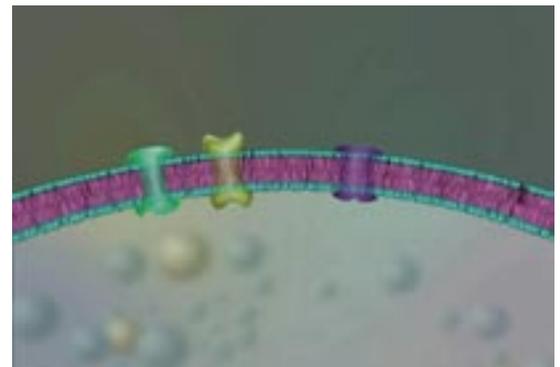


So osmosis explains how water enters plant roots, why people dehydrate if they drink sea water, and why body cells normally maintain their shapes.

TRANSPORT PROTEINS

Getting water in and out of body cells is one thing, but cells also need to take in nutrients. The problem is nutrients molecules are too big to diffuse through the phospholipid layers. They get in with the help of large protein molecules embedded in the membrane. Actually the cell membrane is a rather bumpy surface due to these embedded proteins.

Some proteins form tunnels, allowing molecules that are in greater concentrations outside the cell to diffuse in through the tunnels. This type of transfer, called Facilitated Diffusion, requires no energy output by the cell.



TRANSPORT PROTEINS -- continued

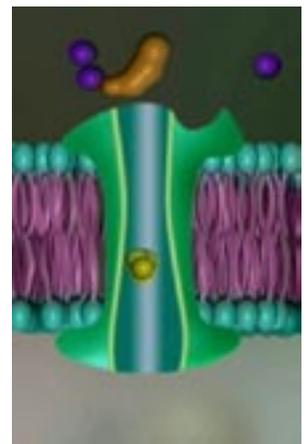
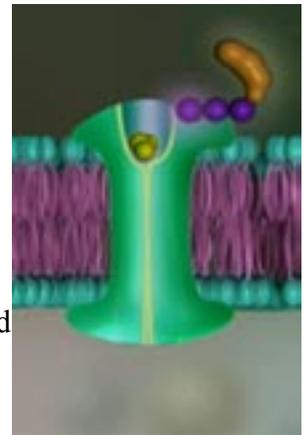
Facilitated diffusion can be a relatively slow process. By expending some energy, cells can pump large molecules through their membranes very rapidly through a process called, appropriately, Active Transport.

Imbedded in the cellular membrane, special membrane proteins act as gates that open and close, using energy donated by ATP, the cell's energy carrier molecule.

Active transport allows cells to concentrate molecules that are scarce outside the cell. Once inside, the selectively permeable membrane prevents them from escaping.

Active transport explains how nutrients that are in very low concentration in the blood, can be harvested by hungry body cells.

Active transport is a major part of cell business. It may consume as much as 50% of a cell's ATP at any given time.



ENDOCYTOSIS

Osmosis, Facilitated Diffusion and Active Transport are all ways of getting molecules in and out of cells. But cells can also take larger bites through various kinds of endocytosis, the wholesale engulfment of items by in-pocketing of the cell membrane.



Engulfing large solid items is called phagocytosis, a kind of eating at which amoebas excel. Gradually, the amoeba's outer membrane closes around the prey until it is trapped in a food vacuole. As digestive enzymes are pumped in the prey begins to digest. Our own white blood cells perform exactly the same kind of phagocytosis, gobbling up invading bacteria.



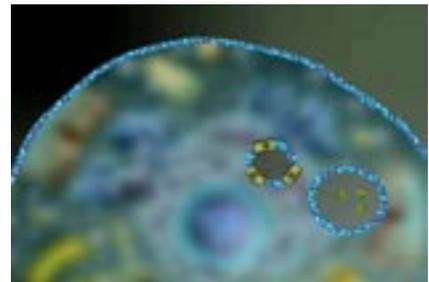
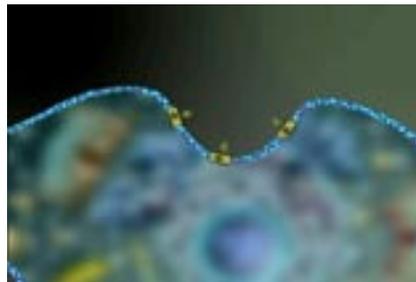
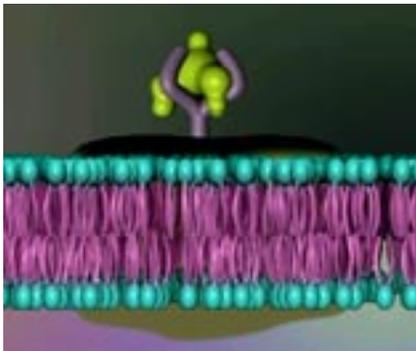
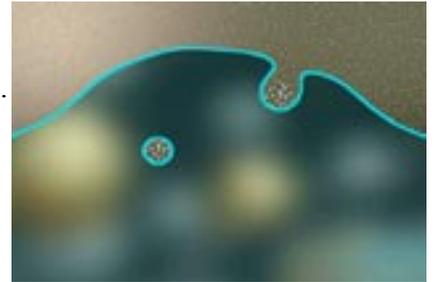
Ponds are filled with bacteria that break down dead organic material. Bacteria attract paramecia and other bacteria feeders that engulf the bacteria in food vacuoles.

As you can see, phagocytosis is a process of converting outer membrane into inner membrane. The membrane in-pockets to form the vacuole -- which pinches off -- and goes circulating around the cell while its cargo of bacteria undergo digestion.

ENDOCYTOSIS -- continued

As much as 40% of the outer membrane is converted into food vacuoles during intensive feeding. So, where does the replacement membrane come from? Following digestion and absorption of the nutrients, the bacteria cell walls are expelled and the vacuole phospholipids are reunited with the cell membrane. This “defecate and recycle” strategy is one way protozoans conserve valuable phospholipids.

Cells can also take in nutrient fluids, such as the digested soup found in an animal’s intestine. Here we are looking into the intestine of a small earthworm. Cells lining the intestine wall pick up the nutrient fluid in tiny pockets called pinocytotic vesicles. This kind of drinking is called pinocytosis. Once inside, the nutrients pass into the blood vessels, and off they go to nourish cells in all parts of the body, just as they do in humans. But, blood carries more than food and oxygen.



Hormones are carried from the glands where they are produced to cells in other body regions, signaling them into action. But how do these target cells recognize the appropriate hormone? Cells that are targets for hormones carry special proteins on their plasma membrane, proteins that fit the hormone molecule like a lock and key. Once the hormone docks with its receptor protein, the protein migrates to an intake site, where the plasma membrane in-pockets carrying both the receptors and hormones into the cell. The hormones are released from the membrane to do their job, and just as in phagocytosis and pinocytosis, the membrane patch is returned and merges back into the cell’s outer membrane along with its receptor molecules.

Yet another feature of a cell’s outer membrane is its ability to carry out electrical activity. The electrical energy is generated by special membrane proteins that pump charged particles – ions -- across the membrane. More charges on one side than the other set up a traveling electrical imbalance that can send a nerve impulse -- or flex a muscle.

So the outer envelope is a vital cell organelle. It’s double lipid layer allows water to pass, but not larger molecules. Thus osmosis occurs. Membrane proteins transport larger molecules into the cell by facilitated diffusion and through active transport. And it can also engulf, drink, fish for hormones, and generate electric impulses. And if that’s not impressive enough, consider that this incredibly thin envelope, just two molecular layers thick, is all that separates the highly organized cell interior from the chaotic outer world.

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