

# ***Visualizing Cell Processes***

A Series of Five Programs  
produced by BioMEDIA ASSOCIATES

## Content Guide for Program 2 **Cell Movement and Transport**

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Each of the five programs in this series consists of a set of short, narrated, full-motion modules 1-3 minutes long. Each module conveys an essential process or concept of cellular biology. The modules are organized around national standards for teaching biology.

### **1. Structure and Behavior of the Plasma Membrane**

The plasma membrane can be described as a fluid film in which lipid molecules form two layers. The lipids within a layer trade places thousands of times each second in a frantic molecular dance. The lipid layers are held in place by their interaction with water. The "head" of each lipid is "hydrophilic" (water loving), and the carbon chain tails are "hydrophobic" (water hating). Thus, in any watery medium, lipids orient with heads out and tails in, forming a bilayer. The fluidity of biological membranes helps explain their extraordinary ability to fuse and self-seal.

### **2. Osmosis**

Water, like all molecules in a fluid state, tends to move from regions of greater concentration to regions of lesser concentration. Because of their small size and favorable electronic charge, water molecules can zip through the rapidly shifting lipids that make up biological membranes. However, larger molecules and ions (charged particles) cannot easily pass through the membrane. Thus the plasma membrane is said to be a "selectively permeable membrane."

At one time biology teachers explained osmosis in just these terms. One could predict the net flow of water in or out of a cell if one knew the solute concentrations on each side of a membrane. The net movement of water was always toward the side with the greater concentration of solutes, or to put it more directly in terms of the principle of diffusion, water moves (across the membrane) from its (water's) greater concentration to its lesser concentration. This observation is true, but the explanation fails to explain how solutes actually affect water molecules—the ultimate cause of osmotic phenomena.

Here's the current view: A cell's interior is a soup of organic molecules and ions that interferes with the free movement of water molecules, slowing them, and in effect, lowering their energy. If the cell is surrounded by water (molecules moving freely unaffected by solutes) then these higher energy water molecules will stream through the membrane and into the cell causing it to swell until the solute (and water) concentrations are equal on both sides of the membrane. Red blood cells show the effects of solute concentration most dramatically. Inside the blood cells the solute concentration is the equivalent of a .9% salt solution. Immersed in plasma (also .9% solutes), the

RBCs have the normal biconcave shape. Immerse them in .7% solute and water rushes in until the inside becomes diluted to a .7% solute concentration. At this point water molecules moving in and water molecules moving out are in equilibrium, however the extra water the cell now contains turns it from a biconcave disc into a balloon. Continue lowering the outside concentration (increasing the water molecules energy to drive through the membrane) and the blood cells will at some point fill until they experience osmotic rupture. Had you increased the solute concentration outside the results would be quite different. Bathing the cells in 1.5% solute solution and they will shrivel into spiky little balls—a process known as crenation.

The physical process of osmosis effects all cells. Drink ocean water (3.5% solutes) and your body will loose water into the intestine, causing your body to dehydrate and your blood cells to crenate. At the opposite extreme a protist living in a pure mountain lake must constantly expend energy getting rid of water that constantly enters by osmosis.

### **3. Transport Proteins**

The plasma membrane allows small molecules such as water, oxygen and carbon dioxide to pass through. Larger molecules, like sugars are transported through the membrane by two kinds of methods:

Passive Transport: Embedded in the membrane are protein molecules that form channels allowing certain kinds of molecules to pass in and out of cells. These transfers require no expenditure of energy by the cell.

Active Transport: Also in the membrane are proteins that bind to particular kinds of molecules transferring them through the membrane, a process that requires the expenditure of ATP.

### **Endocytosis**

(Includes phagocytosis, pinocytosis, and receptor-mediated endocytosis)

**4. Phagocytosis** An early step in the evolution of eukaryotic cells involved the ability to engulf other cells. Engulfment provide a new food source for life, created a food chain ecology, and led to the formation of symbiotic partnerships in which the symbionts eventually become organelles such as mitochondria and chloroplasts.

Protists such as *Amoeba* and *Paramecium* engulf prey organisms by phagocytosis. This form of engulfment internalizes the plasma membrane during the formation of a "food vacuole." Inside the food vacuole (also called a secondary lysosome) the food is digested under an onslaught of acids and enzymes delivered by primary lysosomes (see next module).

A feeding protist (or a phagocytic white blood cell) may internalize as much as 40% of its plasma membrane per hour. However, this membrane is not wasted. Following digestion the vacuole membrane is shunted back to the outside, rejoining the cell's outer envelope.

The champions of phagocytosis are large protists that inhabit the gut of termites. These symbionts engulf whole wood chips swallowed by their host.

**5. Pinocytosis** (cell drinking) is a similar process whereby the cell surface forms small inpockets that take in fluids.

**6. Receptor mediated endocytosis** allows cells to chemically recognize special molecules in their environment (often hormones carried by the blood stream). Receptors on the plasma membrane fish for their target molecules and as they become loaded, the receptors coalesce and are engulfed. Delivered to the cell's interior, the receptors release their target molecules. Receptors and the engulfment membrane then return to the cell's surface.

### **7. Golgi Function,**

Protists, certain kinds of white blood cells, and other phagocytic cells incorporate their food into membranous pouches called food vacuoles (secondary lysosomes).

### **8. Lysosomes and Hydrolytic Digestion**

When digestion is required the Golgi complex sorts and pinches off membranous sacks filled with digestive enzymes called "primary lysosomes."

The video program demonstrates the use of neutral red stain to show lysosomes and the acidity of food vacuoles in Paramecium. The stain shows acidic regions of the cell pH 4 and lower in bright red. Clearly, lysosomes not only contain digestive enzymes, they produce hydrogen ions as well, creating an acidic environment that optimizes the action of digestive enzymes.

Primary lysosomes merge with the vacuole membrane dumping in their acids and digestive enzymes. The food vacuole now becomes 'the cell's stomach'. As digestion proceeds, nutrients are pumped out creating a stockpile of molecules for cell use and export.

Lysosomes function as the digestive system for phagocytic cells. But in all cells, lysosomes break down cell organelles that wear out, allowing their materials to be recycled.

### **9. Microtubules**

Movement is a distinguishing quality of life. At the cell level one kind of movement is produced by microtubules, threadlike protein tubes that move materials throughout the cell's interior.

Microtubules are composed of a globular protein called "tubulin." In one form of cell transport another motor protein, kinesin, adds a conveyor belt function. Hydrolyzing A.T.P. for energy, kinesin moves along the tracks of tubulin transporting vesicles loaded with cell products.

Tubulin proteins are easily disassembled and reassembled creating new microtubules where needed.

A good place to see the breakdown and reassembly of microtubules is in heliozoans, spiny relatives of amoebas. The spines are made up of bundles of microtubules that break down during prey capture but quickly re-form when undisturbed. Chromosome movements during mitosis and meiosis are produced by microtubules. The ciliary beat is produced by microtubules and associated proteins.

## 10. Cilia

Cilia are short, hair-like bundles of microtubules with many uses. They move protists through the water and set up feeding currents. The gliding locomotion of flatworms is produced by cilia. The larva of many kinds of marine invertebrates are propelled by cilia. Many kinds of small filter feeders use cilia to bring in food. In animal bodies, cilia move material along passageways such as trachea and oviducts.

A cilium has two central microtubules surrounded by nine double ones. The outer microtubules are coupled with proteins that use energy from A.T.P. to flex, pulling down on an adjacent microtubule. The clawing action causes the cilium to bend, the mechanism behind the ciliary power stroke. The same process produces the bends and twists seen in the longer whips known as flagella.

Here are some of the best places to observe cilia with a student microscope:

- the hind gut and caudal gills of oligochaete worms—
- the gut of many kinds of rotifers—
- an isolate patch of clam gill—
- the feeding tentacles of bryozoans—
- and of course in common ciliated protists such as *Vorticella*, *Colpidium* and *Paramecium*. In *Stentor*, *Euplotes* and many others, cilia are fused together forming tendril-like structures called cirri.

## 11. Actin and Myosin Motor Proteins

The very long cylindrical cells of the pond alga *Nitella* show cytoplasmic streaming. The rapid circulation of the cytoplasm is produced by threads of the protein actin working in combination with myosin.

Actin is composed of a chain of globular proteins that interact with myosin proteins. Using energy from A.T.P. the myosin heads walk along the actin filament dragging the cytoplasmic particles along.

Actin and myosin motor proteins make up muscles. In muscle tissue, the myosin molecules form bundles. Surrounding the myosin are cylinders of actin threads. With energy from A.T.P., the myosin heads walk in concert to produce a contraction. The cylinders lie in banks forming larger arrays that work together to produce the synchronized contractions of a muscle fiber.

An excellent example of the cytoplasmic streaming, produced by actin/myosin proteins, is seen in *Tradescantia*, a common houseplant with small white flowers that produce a fluff of stamen hairs. These hairs are actually strings of large cells that contain fluid vacuoles through which pass streams of flowing cytoplasm, easily studied using the high power objective of a student microscope. Tip: To see the streaming most clearly, and the organelles being carried along, use oblique lighting creating by slipping a card over half of the microscope illuminator. Small adjustments will create stunningly clear images of the stamen filament cells, particularly at the dark-bright interface produced by the edge of the card.

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