“CELL MEMBRANES: THE BOUNDARIES OF LIFE”

TEACHER’S GUIDE

I. INTRODUCTION

“Cell Membranes: The Boundaries of Life” is part of the exciting six part Biochemistry Basics series. The Basics of Cell Biology series in turn is part of the 30 part Basics of Biology series which also includes the following six part series; Basics of Biodiversity, Basics of Cell Biology, Basics of Genetics, and Basics of Anatomy. The programs in the Biochemistry Basics series are designed to cover most of the topics taught in a high school biochemistry course.

“Cell Membranes: The Boundaries of Life” begins by examining cell wall structure and the major functions of cellular membranes before introducing the fluid mosaic model of the phospholipid bilayer, and transport, recognition, and receptor proteins. The concepts of simple and facilitated diffusion, passive and active transport, and osmosis are illustrated. Endocytosis and exocytosis, the role of contractile and central vacuoles, and how desmosomes and tight junctions tie cells together and how plasmodesmata and gap junctions facilitate communication are explained.

“Cell Membranes: The Boundaries of Life” contains a student study guide, a multiple-choice test and a crossword puzzle that are stored as PDF files on the DVD. For information on other programs in the series or if you have questions or comments call 1-800-325-1956 or email us at info@greatpacificmedia.com.

II. STUDENT OBJECTIVES

After watching “Cell Membranes: The Boundaries of Life” students will be able to:

* Discuss the fluid mosaic model of cellular membranes.

* Describe the structure and composition of cell membranes.

* Explain the role of cholesterol in cell membranes.

* Explain the role of transport proteins, receptor proteins and recognition proteins.

* Describe the difference between simple and facilitated diffusion.

* Describe osmosis and osmotic pressure.

* Explain the difference between isotonic, hypertonic and hypotonic solutions.

* Explain how protein pumps work and why they are important.

* Describe endocytosis and exocytosis.

III. VIEWING THE VIDEO
It is best that students view the program in its entirety first, without interruption. Then, as time allows, go back to the sections that correspond with your lesson plan for discussion. You may also want to pass out the study question worksheet that is provided with this teacher's guide for the students to fill in as they watch the program.

IV. PRESENTATION OF THE PROGRAM

The suggestions listed below will help you prepare a useful lesson plan to accompany the presentation of the program.

Teacher's Preparation

1. Preview the program and familiarize yourself with this Teacher's Guide. Review the vocabulary list, script narration, and discussion questions, as well as the student study question worksheet and crossword puzzle included with this program.

2. For your convenience, major sections of the program are divided by intertitles. Each intertitle introduces the upcoming section and will provide you with a natural place to pause for discussion. Note where these intertitles appear throughout the program and plan your lesson accordingly.

Student's Preparation

1. Discuss the topics presented in the program with students before showing them the video. This will help you discover what your students already know about the subject as well as create student interest about the topic.

2. Also introduce the vocabulary words on the board or overhead projector. Discuss any of the words with which your students are not familiar. The crossword puzzle can also be used to familiarize your students with terms introduced in the program that may be new to them.

V. VOCABULARY WORDS

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<th>phospholipids bilayer</th>
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VI. SUGGESTED DISCUSSION QUESTIONS

1. Why are cell walls in plants stiffer than other cell membranes?
2. Why are cell walls able to be both porous and strong?
3. Why does the phospholipid bilayer have both hydrophilic and hydrophobic parts?
4. What is the function of cholesterol in the cell membrane?
5. Name the three types of proteins embedded in cell membranes.
6. How do the channel proteins and carrier proteins work?
7. Why are receptor proteins called molecular triggers?
8. Why are recognition proteins important?
9. Name the three types of passive transport and describe their differences.
10. Describe osmotic pressure and turgor pressure.
11. Describe isotonic, hypertonic and hypotonic solutions.
12. Name the types of active transport and describe their differences.

VII. NARRATION FOR "CELLULAR MEMBRANES: THE BOUNDARIES OF LIFE"

Cells are the smallest units of life. There are single cell organisms and multi-celled organisms like ourselves, made up of trillions of cells. There are all sorts of cells in our bodies and in the bodies of other animals. Cells with long tail like flagella, like sperm, and cells that branch out to other cells in all sorts of directions, like nerve cells. There are single celled organisms like paramecium that have well defined shapes and others like amoebas that are constantly changing shapes.

But all these cells share the fact that within them lie the complex molecules of life. Cells can be combined to form huge living organisms such as elephants and giraffes. But the basic biochemical processes of life can only be organized at the cellular level. The biochemical organization of every cell has to be protected from conditions in the external environment that would change or destroy that organization and in the process, destroy life.

Amazingly, that protection, in most living organisms, is provided by a two layer line of molecules about 1/10,000ths the thickness of a sheet of paper. That layer or line of molecules which is referred to as either the cell or plasma membrane is all that stands between the living and non-living worlds.

The boundary between the living and non-living world is so fine because while powerful forces in the non-living environment, like waves crashing down on ocean tide pools, the burning heat of the desert sun, and the frigid cold of winter snows constantly threaten to destroy life, the living world is nevertheless totally dependent on the non-living world for its' survival. From the light energy of the sun, the nutrients in soil and sea water, gases in the atmosphere like oxygen and carbon dioxide, and freshwater from winter run-off.

So while the workings of cells have to be protected from forces in the environment that would disturb the organization of life, they also need to allow controlled access to the resources of the environment on which every living organism depends. Cell membranes not only have to provide for the protection of a cell and the controlled exchange of materials between the external environment and a cell, they also have to facilitate processes such as: communication between cells as is critical for the nerve cells of humans and other animals; provide each cell in an organism with identifying markers so that they aren't attacked by the organisms defensive antibodies as invading foreign cells; and allow the cells of single celled organisms like amoeba and to a lesser extent of multicellular organisms to take on a variety of shapes in order to carry out a variety of activities including capturing prey and alluding predators.

Cell Walls
While in animals, the cell membrane is exposed directly to the external environment in the cells of certain protists, most bacteria and fungi, and all plants the cellular membrane is covered with stiff non-living coatings called cell walls. In plant cells the cell walls are composed of a cellulose and other polysaccharides. While in fungal cells, the walls are made up of a modified polysaccharide called chitin. Bacterial cell walls also have a chitin like framework to which amino acids and other molecules are bound.

Mushrooms and plants have cell walls because unlike animals they do not have either an external or internal skeletal structure to provide support and must therefore rely on rigid cell walls in order to stand erect. Cell walls are produced by the cells they surround. In plants, vessels filled with a sticky polysaccharide such as pectin line up across the middle of dividing cells, eventually fusing together to form a new plasma membrane that separates the new daughter cells from one another.

The pectin glues the two daughter cells together and forms what is referred to as the middle lamella. Each daughter cell secretes cellulose through its cellular membrane underneath the middle lamella to form the primary cell wall. Many plants then secrete additional cellulose molecules beneath the primary wall to form a thick secondary cell wall. In some plant cells the secondary cell wall may become thicker than the rest of the cell. The cells that form tree trunks and branches have these very thick cell walls, thus these cells are composed almost entirely of cellulose. Without these strong and thick cellulose walls, trees would be incapable of supporting their large loads.

Cell walls, in addition to being strong, are also porous to allow the passage of small molecules such as minerals, amino acids, and sugars to the cell membrane. Just as in animals, however, it is the cell membrane in plants that actually controls the passage of materials between the cell and it's external environment.

**Cell Membranes: Structure- The Phospholipid Bilayer**

The current model of the cell membrane is called the fluid mosaic model, which was developed in 1972 by S.J. Singer and G.L. Nicholson. It is referred to as the fluid mosaic model because it portrays cell membranes as consisting of a viscous, fluid bilayer of phospholipids upon which a mosaic of protein tiles slide sluggishly about causing the membrane to slowly, but constantly change. The phospholipids that form the bilayer are made up of two parts, a hydrophilic or "water loving" head, which dissolves in water and a hydrophobic or “water fearing”, tail which is insoluble in water. All living cells are surrounded by water whether it is an amoeba that spends its life in a pond or the cells of animals which are bathed by extracellular fluids, like blood plasma, that are composed in large part of water. Likewise, the cytoplasm of cells are composed of a variety of substances dissolved in water. Thus the cell membrane separates a largely watery external environment from a largely watery cytoplasm. Under these conditions, phospholipids spontaneously arrange themselves in a double layer referred to as the phospholipid bilayer. The water soluble or hydrophilic heads face the cytoplasm or the extracellular fluid while the insoluble or hydrophobic tails hide inside the bilayer. Since individual phospholipid molecules are not bound to one another, this double layer is quite fluid allowing individual molecules to move about easily.

The majority of water soluble molecules such as salt, amino acids, and sugars cannot pass through the hydrophobic fatty acid tails of the phospholipid bilayer. Thus the phospholipid bilayer isolates the cell cytoplasm from these types of molecules in the external environment. The phospholipid bilayer of the cell membranes of animals often contains cholesterol. Cholesterol effects membrane structure and function in number of ways. It makes the bilayer stronger but less fluid and even less permeable to water soluble
substances such as ions, and monosaccharides as a result of binding some phospholipids together.

The flexible, almost fluid nature of the bilayer created by phospholipids and cholesterol is very important to membrane function. This is apparent as we look at the incredible flexibility of an amoeba’s cellular membrane. Flexibility is also important in animals and humans. For example, running or lifting weights creates large changes in the shape of the cell membrane of muscle cells. If the cellular membranes of our muscles were stiff and inflexible, they would probably break open when we ran, lifted weights, or engaged in any strenuous activity.

**Cell Membranes: Structure-Membrane Proteins**

A number of different types of proteins are embedded within or attached to the surface of the phospholipid bilayer of cell membranes. Some of these proteins are held into the phospholipid bilayer by chemical reactions between the amino acids of which they are composed and the tails of the phospholipids. These proteins float around within the phospholipid bilayer. Other proteins embedded in the cellular membrane are anchored in place by a network of protein strands connected to the cell’s cytoskeleton. Attachments like these, between membrane proteins and the cell’s cytoskeleton, produce the characteristic shapes of different animal cells, such as the dimpled disc shape of red blood cells and the elaborate branching of nerve cells.

Three basic types of proteins are found embedded in cellular membranes: **transport proteins, receptor proteins,** and **recognition proteins.**

**Cell Membranes: Structure-Membrane Proteins-Transport Proteins**

Transport proteins regulate the flow of most water soluble molecules through the cellular membrane. There are two basic types of transport proteins: channel proteins and carrier proteins. Channel proteins form channels or pores that allow water soluble molecules to penetrate the membrane. Cellular membrane usually have a large assortment of protein channels. Each protein channel is lined with certain specific amino acids and is of a certain diameter so as to allow only certain molecules, usually ions, to pass through. Nerve cells, for example, have separate channels for sodium ions, potassium ions, and calcium ions. These channels also often have gates at one end which open or close in response to electrical or chemical signals.

Carrier proteins have binding sites much like the active sites on enzymes that attach to specific molecules on one side of the membrane and then carry the molecule across the cellular membrane by changing shape or other means. The crossing of the cellular membrane in this manner may or may not require the use of energy provided by the cell.

**Cell Membranes: Structure-Membrane Proteins- Receptor Proteins**

Receptor proteins are molecular triggers that set off cellular responses when specific molecules in the extracellular fluid such as hormones and nutrients bind to them. The cellular membrane of most cells have dozens of receptor proteins. Some receptor proteins, when activated by appropriate molecules, set off elaborate sequences of cellular changes such as increased metabolic rate, cell divisions, movement toward a source of nutrients, secretion of hormones, or even cellular suicide.

Other receptor proteins act as the gatekeeper for channel proteins. The activation of the receptor protein
opening the channel protein allowing ions to flow through the channel. It is these types of receptors that are activated when nerve cells in your brain communicate with one another.

**Cell Membranes: Structure-Membrane Proteins-Recognition Proteins**

Recognition proteins and glycoproteins serve as identification tags and attachments sites for other molecules. Glycoproteins are proteins that have carbohydrate groups attached. These carbohydrate groups can be used by other cells to identify the cell. For example, the cells of your immune system recognize salmonella bacterium as a foreign invader and target for destruction because they have no identification tags that are recognized by your immune system. On the other hand, these same immune cells ignore the trillion of cells of your own body because of the identifying glycoproteins on their surface.

Recognition proteins can also be used for other purposes by the body. For example, during our early development, the path the growing nerve cells take from our spinal cord down to the muscles in our feet is guided by attachments between recognition proteins on the nerve cells and the tissues it traverses on the way to the muscles in the foot they will control.

As you've seen, proteins in the cellular membrane play important role in communications between cells, identifying cells and the moving and exchanging of substances between the external environment and the cytoplasm. But in order to fully understand the movement of ions and molecules through cellular membranes we must understand the movement of ions and molecules in fluids.

**Diffusion and the Random Movement of Molecules**

The individual ions and molecules in a fluid, including extracellular fluids like blood and intracellular fluids like those of the cytoplasm, are in constant random motion bouncing off one another in every direction. Ironically, this random motion of molecules in a fluid leads to a very nonrandom event. The movement of molecules from areas of high concentration to low concentration which results, if the process is allowed to go on to it's natural conclusion, in the equal distribution of molecules throughout the fluid. This process is called diffusion. We can see the process of diffusion occurring in these time lapse photographs of dye diffusing in water. Any water soluble substance placed in water, whether chlorine and sodium ions from dissolved salt or the sugar fructose, slowly spreads from areas of high concentration to areas of low concentration as a result of diffusion, with a result like that of the dye.

**Diffusion Across Cell Membranes: Passive Transport**

Diffusion can also occur through cell membranes. However, cell membranes are selectively permeable. This means that some substances can diffuse through a cell membrane while others cannot. The flow of ions or molecules through a cell membrane as a result of diffusion is referred to as passive transport. It is referred to as passive transport as it requires no energy from the cell in order to carry a substance across the membrane. In the process of passive transport, the membrane acts as a filter. Phospholipids and protein channels control which molecules can cross the membrane and may influence the rate and timing of the movement of ions and molecules across the membrane, but they do not influence the direction of movement. Substances continue to move only from areas of high concentration to areas of low concentration.

Let's now look at three types of passive transport that occur as a result of diffusion: simple diffusion,
facilitated diffusion and osmosis.

Diffusion Across Cell Membranes: Passive Transport-Simple Diffusion

Simple diffusion is the process by which gases such as oxygen and carbon dioxide dissolved in water and phospholipid soluble molecules such as ethyl alcohol and vitamin A diffuse across the phospholipid bilayer. This is referred as simple diffusion because these substances can cross anywhere along the phospholipid bilayer, while most other types of diffusion such as facilitated diffusion, that we will look at in a moment, require a substance to cross the membrane through a protein channel or with the help of a carrier protein. Generally, the rate of simple diffusion of a substance across a membrane is a function of the relative concentration of the substance on either side of the membrane, the size of the substances molecules, and on the substances lipid solubility.

Diffusion Across Cell Membranes: Passive Transport-Facilitated Diffusion

In the process of facilitated diffusion, either channel proteins or carrier proteins facilitate the crossing of a cellular membrane by water soluble substances such as sodium, potassium, and calcium ions, amino acids, and monosaccharides which cannot typically diffuse through the phospholipid bilayer. As we saw earlier, each type of channel protein is typically lined with specific amino acids and has a unique diameter in order to allow only certain ions or other substances to pass. Channel proteins also often have gates which open and close in response to electrical or chemical signals.

Carrier proteins, as we saw earlier, attach specific molecules in the cytoplasm or extracellular fluid. The attachment triggers changes in the shape of the carrier protein that allows the molecule to pass through the protein and thus cross the plasma membrane. Some carrier proteins don't use cellular energy and only allow ions and molecules through the membrane that would normally pass through it as a result of diffusion. However, as we will see later, there are carrier proteins that use cellular energy to carry substances against the flow created by diffusion.

Diffusion Across Cell Membranes: Passive Transport-Osmosis and Osmotic Pressure

Water molecules, like other molecules, move by diffusion from areas of high concentration to areas of low concentration. However, the diffusion of water across semi-permeable membrane has such dramatic consequences, for living organisms, that it is been given its own special name, osmosis.

We can see the process of osmosis taking place if we place a bag-shaped, semi-permeable membrane, filled with a sugar-water solution with a high concentration of sugar, into a container of distilled water. The selectively-permeable membrane of the bag allows water molecules to pass through it but will not allow the larger sugar molecules or water molecules attached to sugar molecules to pass through it. Obviously, because of the high concentration of dissolved sugar molecules within the bag, the concentration of water in the bag is lower than it is in the container of distilled water. As a result the water molecules in the container diffuse into the bag as they go from an area of higher concentration to lower concentration. As of result the bag swells up as more water molecules enter the bag than leave it. The sugar cannot escape at all so that the concentration of water inside the bag is always lower than the concentration of water in the container. Water continues to enter the bag until it bursts. The bursting of the bag is the result of what is referred to as osmotic pressure.
We can also reverse the experiment and place a semi-permeable bag filled with water in a container with heavy concentration of sugar water. In this case, the bag actually shrinks and shrivels up as water leaves it to go into the sugar water solution. The bursting of the membrane in the first instance and the shriveling of the membrane in the second, reflects what would happen to cell membranes in similar circumstances. Since all cells contain an appreciable amounts of dissolved salts, proteins, sugars and so on in their cytoplasm, the flow of water across the cell membrane depends on the concentration of water in the liquid that bathes the cells.

**Diffusion Across Cell Membranes: Osmosis- Isotonic, Hypertonic, and Hypotonic Solutions**

The extracellular fluid of animals is usually **isotonic** which means that it has the same concentration of water and dissolved particles as the cytoplasm of the cell. As a result there is no net tendency for water to either enter or leave the cells. It is important to note that the types of dissolved particles are rarely the same in the extracellular fluid as those in the cell cytoplasm but the total concentration of all particles in either solution is equal.

If we take red blood cells out of the body and immerse them into salt solutions of various concentrations, the effects of different concentrations of *free* water molecules inside and outside the cell membrane would become dramatically apparent. If the salt solution has a higher concentration of dissolved substances than the cell cytoplasm (that is the solution has a lower water concentration) water will leave the cell by osmosis resulting in the blood cell shriveling up the same way as the semi-permeable membrane that we saw earlier. The shriveling continues until the concentrations of water inside and outside the cell membrane become equal. Solutions that cause water to leave cells by osmosis are called **hypertonic**.

If blood cells are placed in a solution that has little or no salt, water enters the blood cells causing them to swell. If the solution has little enough salt the cells will burst. Solutions that cause water to enter cells via osmosis are referred to as **hypotonic**. The osmotic flow of water across cellular membranes is crucial to the function of many biological systems such as the absorption of water by plant roots and our intestines, as well as, the reabsorption of water and minerals in our kidneys.

As you can imagine, osmosis can be of particular problem to organisms such as freshwater protists that are constantly surrounded by high concentrations of free water molecules. Since freshwater is hypotonic relative to the cytoplasmic fluids of protozoans, water constantly enters their cells via osmosis. Increasing water volume might soon burst the fragile cell membrane of a protozoan. In order to deal with their environment, freshwater protozoans such as paramecium often contain complex **contractile vacuoles** composed of collecting ducts, a central reservoir, and a tube leading to a pore in the cell membrane. Excess water drains into the collecting ducts and funnels into the central reservoir. When the reservoir is full it contracts squirting water up the exit tube and out through the pore in the cell membrane.

Plants cells also contain vacuoles, but they are quite different in function from the contractile vacuoles of protozoans. These are called **central vacuoles**. Often up to three quarters or more of the volume of a plant cell is occupied by the central vacuole. Central vacuoles have several functions. They provide a dumping site for hazardous waste within the plant cell that cannot be excreted. Some plant cells store extremely poisonous substances in their vacuoles such as sulfuric acid, which deter animals from consuming them. Central vacuoles may also store sugars and amino acids not immediately needed by the cell. Blue and purple pigments stored in the central vacuoles of flower cells are responsible for the color of many flowers. The dissolved substances in central vacuoles makes them hypertonic relative to the cells cytoplasm. Water therefore enters the central
vacuole via osmosis making it swell. As the pressure of the water within the central vacuole, called **turgor pressure**, builds up, the vacuole pushes against the cytoplasm and cell wall with considerable force. As the cell walls of plants are usually somewhat flexible, the overall shape and rigidity of a cell depends on the turgor pressure within it.

Turgor pressure thus provides support for the non-woody parts of plants. Failure to water your houseplant can result in the central vacuoles of cells losing water and their cytoplasm and central vacuole shrinking away from the cell walls causing the cell walls to go limp and the plant as a whole to droop as a result of the cells losing turgor pressure. However, if the plant is watered, the turgor pressure is slowly restored and the plant rebounds back to normal.

**Active Transport Across Cell Membranes: An Overview**

There are cases when cells have to obtain materials such as scarce nutrients that may be less concentrated in the extracellular fluid than in the cells cytoplasm. Diffusion would cause the cells to lose not gain these needed nutrients and other materials. In brain cells, sodium and calcium ions must be maintained at lower concentrations inside the cell than in the extracellular fluid surrounding them. As a result when these ions diffuse into the brain cells, they must be pumped out against the natural flow created by their relative concentrations. There are cells that have occasion to acquire or expel materials such as whole bacteria or large proteins that are too large to diffuse across cell membranes regardless of their relative concentrations on either side of the cellular membrane. In order to deal with these conditions cells have evolved two types of processes that use cellular energy to move materials into and out of the cell, **active transport** and the related processes of **endocytosis** and **exocytosis**.

**Active Transport Across Cell Membranes: Protein Pumps**

In active transport, special membrane transport proteins use cellular energy to move individual molecules across the cellular membrane. Active transport proteins span across the membrane and have two active sites. One active site, which may be inside or outside the face of the cell membrane, recognizes a particular molecule say sugar and binds it. The second site, always inside the membrane, binds to an energy carrying molecule such as ATP. ATP donates energy to the protein allowing it to change shape and move the sugar molecule across the membrane. Active proteins are often called pumps, in an analogy to water pumps, because they use their energy to move molecules "uphill" sort of speak, against concentration flows. Such active transport pumps are critical in enabling plants to take up minerals, your intestines also to absorb minerals, for maintaining the right balance of ions inside and outside of nerve cells, and enabling cells in the gills of marine fish to pump salts out to the much more saline ocean water.

**Active Transport Across Cell Membranes: Endocytosis**

Other processes by which materials can be brought into or taken out through the cell membrane are endo and exocytosis. Endocytosis is a especially useful for carrying in particularly large proteins or entire microorganisms such as bacteria or protists. There are three types of endocytosis: **pinocytosis**, **receptor mediated endocytosis**, and **phagocytosis**.

In pinocytosis a small section of cell membrane dimples inward and buds off into the cytoplasm forming a tiny vessel containing materials in proportion to their concentration in the extracellular fluid. The
vessel eventually opens and lets the former extracellular fluid flow into the cytoplasm.

Receptor mediated endocytosis is a more specific process than pinocytosis. As we saw earlier, most cell membranes contain many different types of receptor proteins on their outer surface. Each type of receptor protein has a binding site for particular nutrient molecules. Often receptor proteins of a particular type move through the lipid bilayer and accumulate in depressions in the plasma membrane called coated pits. If the right nutrient molecule contacts a receptor protein in one of these coated pits, it attaches to the receptor proteins binding site. Once a number of these receptor proteins have attached nutrients, the coated pit deepens into a U shaped pocket that eventually pinches off into the cytoplasm as a coated vessel. The receptor proteins, captured nutrients and a bit of the extracellular fluid move into the cell in the coated vessel. Once in the cytoplasm the vessel opens and the receptor proteins release the captured nutrient molecules to the cytoplasm. The vessel and the receptor proteins rejoin and become part of the cell membrane again. Cholesterol molecules are brought into cells via receptor mediated endocytosis.

Phagocytosis is used by cells in order to pick large particles including whole microorganisms. The classic example of this is an amoeba surrounding a paramecium with long extensions of its cellular membrane called pseudo podia. The pseudo podia surround the paramecium, the ends fuse and the prey is carried into the cytoplasm of the amoeba for digestion. The resulting vessel is referred to as a food vacuole. The food vacuole fuses with ribosomes whose enzymes digest the prey. The white blood cells of our own body use phagocytosis and inner cellular digestion to engulf and destroy bacteria that invade the body.

Active Transport Across Cell Membranes: Exocytosis

Exocytosis is the reverse of endocytosis. It is often used by cells to dispose of unwanted materials such as the waste products of digestion, or to secrete materials such as hormones into the extra-cellular fluid. During exocytosis, a vesicle created by the Golgi apparatus moves to the cell surface where the membrane of the vesicle fuses with the cell membrane. The vesicle then opens and its contents diffuse out to the extra-cellular environment.

Conclusion

As exocytosis and the various forms of endocytosis suggest cellular membranes are incredibly complex, fluid structures that are critical to the survival of each and every cell. These thin phospholipid bilayers littered with various receptor, recognition, and transport proteins quite literally form a boundary between the living and non-living worlds. The role cellular membranes play in controlling the flow of ions, molecules and other materials in and out of cells is a fundamental prerequisite for all life from single-celled paramecium swimming in a prairie pond to elephants on the African savannah. How these molecular envelopes and the life contained in them came to be remains one of the life's greatest mysteries, a mystery that is being slowly unraveled by the work of scientists throughout the world.