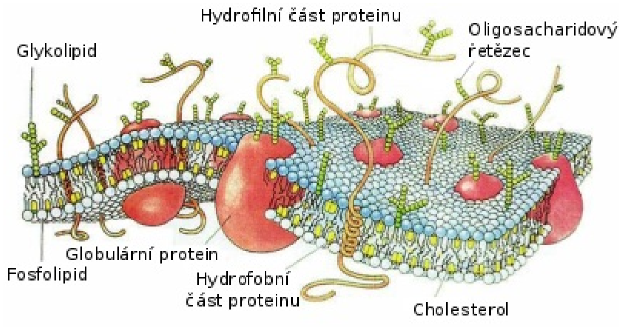
Biological Membrane

Biological membrane (biomembrane, cell membrane) occurs **on the surface of cells** and forms a semipermeable barrier between two compartments (cell contents and extracellular environment). It also occurs **on the surface of membrane organelles** in the cell, such as mitochondria, Golgi apparatus or the endoplasmic reticulum. It performs many important functions, such as the transport of substances, receives information from its surroundings and also serves for mutual recognition and communication between cells.

Structure

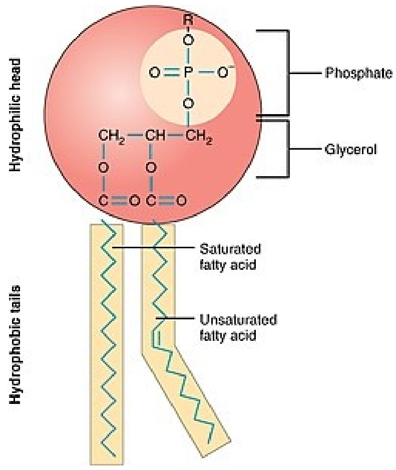
The basic building block of biological membranes is the **lipid bilayer**. **Membrane proteins** are built into it, which give the membrane its specific functions and properties. Carbohydrates acting as signalling molecules can be found on the outer surface of the membranes. cholesterol molecules are also found in mammalian membranes. A biological membrane is about 5nm thick.



Biological Membrane

Lipids

Lipids are substances of biological origin (chemically, they are esters of alcohols and higher fatty acids). Biological membranes mainly contain **lipids with two hydrocarbon aliphatic chains**, which usually also contain other substances (e.g. a residue of phosphoric acid or a saccharide). It is these molecules that cause the so-called [[amphiphatic (amphilic) character molecules|amphiphilic] character of lipids. While the molecule of alcohol and the two carbon chains attached to it are hydrophobic, phosphoric acid forms the hydrophilic part. This fact leads to the formation of ordered structures (micelles, liposomes, lipid bilayer), which orient the lipids with their polar heads towards water and their hydrophobic tails towards the inside, thereby protecting them from contact with water. The described behavior is based on electrostatic interactions and the formation of hydrogen bridges.



Structure of membrane lipid. Red – hydrophilic head, yellow – 2 MK forming the hydrophobic part of the molecule

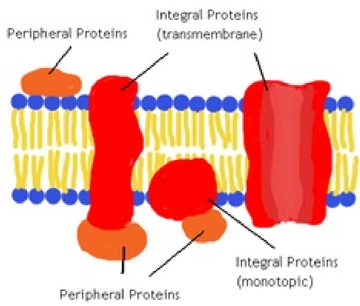
There are many lipids in the human body, but they can be divided into two basic groups: **glycerolphospholipids** and **sphingolipids**. If it is a lipid with a phosphate head, we are generally talking about **Phosoholipids**.

For more information see Lipids.

Proteins

Only a few substances can pass freely through the lipid bilayer, the others must be transported through the membrane **with the help of proteins**. Proteins thus create specific properties of cell membranes and are also specifically distributed.

Proteins perform a number of tasks in membranes. In addition to the mentioned **transfer of ions**, **metabolites** and **nutrients**, proteins can also **anchor the membrane** to macromolecules inside or outside the cell. Many proteins also function as **receptors**, whose task is to recognize chemical signals in the environment. This task is very important for **cell-to-cell communication**. Proteins exhibiting enzymatic activity catalyze specific reactions. Special fibrous proteins then form the cell cortex, which creates a submembrane network attached to the surface of the membrane. It supports and strengthens cell membranes and **helps maintain the shape of the cells**.



Proteins in biological membrane

Integral proteins are tightly bound to the membrane by hydrophobic forces. It is very difficult to separate them from the membrane, they reach between the lipid chains. Integral proteins, like phospholipids, are amphiphilic, the parts exposed to water are hydrophilic and the parts classified as lipids are hydrophobic (non-polar). If such a protein passes through the entire lipid bilayer, we are talking about **penetrating/transmembrane proteins**, if they pass only part of the membrane, they are **non-penetrating proteins**.

Peripheral proteins attach to the surface of the membrane using electrostatic forces or by forming hydorgen bonds. They associate with integral proteins and are relatively easy to separate from the membrane.

For more information see Proteins.

Carbohydrates

The surface of the biological membrane of eukaryotic cells are often supplemented with carbohydrate moleules. These can join lipid and protein molecules (so-called. glycoproteins are formed). All carbohydrates are found only on the outside of the membrane, where they form a coat called **glycocalyx**. This serves as protection against damage and gives the cell a slimy surface (oligosaccharides and polysaccharides are able to absorb water). This is mainly used by moving cells, such as blood cells. Carbohydrates also serve as **recognition signs for cells**, as they can form very diverse formations.

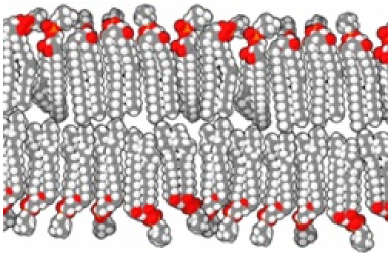
For more information see Carbohydrates.

Membrane fluidity

In 1972, SJ Singer and GL Nicolson created a model of the structure of the biological membrane, the so-called **liquid (fluid) mosaic model**, which includes the knowledge that the lipid bilayer is a two-dimensional liquid in which the individual components are not rigidly bound in one place, but can move here in different ways (although not completely freely) move. **The degree of fluidity of the membrane** expresses how easily the lipid molecules move in the plane of the double layer. It depends on the representation of individual components and must be kept within certain limits. The degree of fluidity at a given temperature **depends on the phospholipids**, and also **on the nature of the hydrocarbon chains**. The more tightly and regularly a chain can pack, the more more viscous and less fluid the bilayer will be. The arrangement of hydrocarbon chains is mainly influenced by two of their properties – **length and saturation**. Shorter chains reduce the effort of the hydrocarbon ends to interact with each other and therefore increase the fluidity of the bilayer. Each double bond creates a tiny irregularity that makes it difficult to attach one chain to another. Lipid bilayers with a higher content of double bonds are more fluid. In animal cells, membrane fluidity is reduced by **the presence of cholesterol**, which fills the gaps between adjacent phospholipid molecules in the membrane. The double layer is strengthened by cholesterol, its fluidity and permeability are reduced. This fact is used, for example, by bacteria and yeast, which must adapt to changing temperature conditions. In their cells, chain lengths and composition are constantly changing to maintain membrane fluidity. Biomembrane fluidity is important to the cell for many reasons. It allows membrane proteins **to interact** and **rapidly diffuse** in the plane of the membrane, which is important for example in cell signalling. It allows membrane lipids and proteins **to move** from the place where they were incorporated after their synthesis to other places in the cell. It allows the membranes **to fuse** (merge) and mix with their molecules. It also ensures **the equal distribution of membrane molecules** between daughter cells during their cell division.

Mobility of membrane components

Although the lipid bilayer maintains an organized structure, its individual molecular components carry out random movements (Brownian movement) in it, characteristic of a liquid state.



Movements of lipids in the membrane

Phospholipid molecules have been shown to constantly perform rapid rotational and **translational movements** in the bilayer. The Frequency of these movements is of the order of μs^{-1} and the position of two neighbouring molecules is exchanged about 10^7x per second. Proteins differ greatly in their mobility in the biomembrane. Some of them move constantly like lipids, others, creating channels in the membrane, stand still.

Thus, membrane components perform several different modes of movement. **Rotation** of entire molecules in the membrane surface, **lateral movement** in the membrane and **flipping of** molecules from one lipid layer to another layer are possible.

The rotational motion (i.e. rotational diffusion) is described using the rotational diffusion coefficient as

$$D_R = \frac{k_B T}{4\pi r^2 h\eta} ,$$

where k_B is the Boltzmann constant, r is the radius of the rotating molecule, h is its height, and η is the viscosity of the surrounding medium.

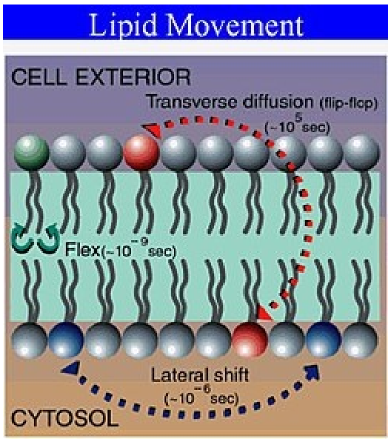
Another movement that takes place in the membrane is **lateral diffusion** - the so-called „floating" through the sheet of the membrane. In a membrane forming a two-dimensional liquid, the structural lipid molecules move freely in their own layer in any direction in the plane of the membrane. The derivation of the lateral diffusion coefficient D_L is based on Einstein's equation for Brownian motion and has the form

$$D_L = \frac{vd^2}{4},$$

where d is the average distance between molecules in the membrane and v is the frequency of molecule jumps. The distance x, that the membrane molecule travels in time t, can be determined using Einstein's equation for two-dimensional system where

$$x = 2(D_L t^{\frac{1}{2}}).$$

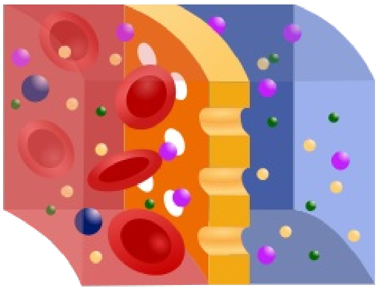
The last, relatively rare type are **flipping movements** (flip-flop, transverse diffusion). They are almost never found in proteins. Another important property of biomembranes is structural and functional asymmetry. It manifests itself both in the distribution of proteins and in the different composition of the inner and outer lipid layers. The distribution of different types of polar lipids in both membranes is arranged in such a way that the frequency of flip-flop movements is reduced as much as possible. Specific, ATP-dependent enzymes, called **flippases**, exist to flip lipids during their insertion into biomembranes.



Movement of lipids in the membrane: rotation (green), lateral movement (blue), flip-flop (red)

Membrane permeability

The transfer **of non-polar (lipophilic) low-molecular** compounds (hydrogen, steroids, O_2, N_2, H_2, CO_2) takes place through **free diffusion**, which is governed by I. By Fick's Law. These compounds usually penetrate through a small pore that can form for a short time in the membrane (e.g. due to intense movement of lipids). Small polar molecules such as water, urea or ethanol can also use the free places that arise during the chaotic and fast movement of long chains to cross the membrane. It is impermeable to **hydrophilic substances** these substances can pass through the membrane only through different channels **transporters or channels**, e.g. water passes through channels called aquaporins.


Semipermeable membrane (yellow) during hemodialysis

Cooperativeness and flexibility

Another important feature of the structure of biological membranes is **cooperativity**. It results from the repetitive application of non-covalent bonds. It has three important consequences: bilayers show a natural tendency to **expand**, **close** and **solidify** (openings in the bilayer are energetically disadvantageous).

Flexibility refers to the ability of the membranes to bend (form folds). This is another important property, it determines the lower limit of 25 nm for the size of vesicles that can form from the membrane.

Passive electrical properties of membranes

Membranes and direct current

If we were to connect a biological membrane to a circuit with direct current, it will show the properties of a resistor (it will have resistance) like most substances. The actual resistance of the membranes will depend on many factors, e.g. the composition of the membrane or the temperature. Specific electrical conductivity is different for membranes, for extracellular and intracellular space. For membranes, the specific electrical conductivity can range around 10^{-6}-10^{-8} s/m, for cytoplasm and intercellular space it is 0,2 – 1,0 s/m. If the current passes through the membrane, it also depolarizes the membrane and increases its permeability.

Because of the high resistance of biological membranes, direct current is transmitted in the organism mainly through the intercellular fluid.

Membranes and alternating current

Since the membrane is composed of two layers (plates) of phospholipids with a space (insulator) between them, it shows the characteristics of a capacitor when connected to an alternating current circuit. The membrane starts to form elektric field, it is able to accumulate electric energy and has its own capacitance.

Therefore, if we use low frequencies for alternating current impedance of the membranes will be higher than when using higher frequencies.

Links

Related Articles

- Cell membrane

- Active transport
- Passive transport
- Biological membrane and transport of substances through the biological membrane

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