Ministry of Health of Ukraine
Ukrainian Medical Stomatological Academy

It is approved
on meeting of department of
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Methodical instructions
for students' self-preparation work at preparation for a practical lesson
at home and at the classroom

Subject matter	**Medical and biological physics**
The unit	1. Fundamentals of higher mathematics and biological physics
Theme of lecture:	**Structure and functions of biological membrans. Active and passive transport. Study of biomembrane permeability.**
Year	1
Faculty	Medical
Speciality	Medicine

Poltava - 2020

The topic significance:

The biophysics of membranes is the major section of a cell biophysics. The living cell is the elementary open system, relatively independent in relation to a surrounding medium, communication with which is carried out through a biological membrane. On biological membranes the major quantity of the vital processes proceeds.

Treatment is in most cases linked to activity on membranes functioning. For example, the permeability of biological membranes determines velocity of introduction of medical preparations into a living tissue: it influences on treatment efficiency, besides activity of many medical preparations is guided on change of membranes permeability for some substances or change of other properties of membranes. Infringement of membranous processes is the cause of much pathology. Physical and chemical factors, pathological processes influence membranes.

Specific targets:

To familiarize with methods of physical examinations of biological membranes and application of their results in medicine .

To study structure and functions of biological membranes, the mechanism of passive and active transport .

To acquire concepts: passive transport; hydrostatical pressure; a filtration; osmotic pressure; an osmosis; an electro osmosis; the abnormal osmosis; a simple diffusion; the facilitated diffusion; a concentration gradient; a diffusion constant; a permeability; the active transport; the pump; uniport; antiport; symport; an exocytosis; an endocytosis; a phagocytosis; pinocytosis; .

To know: structure of lipids, proteins, carbohydrates; a constitution of biological membranes; physical and dynamic properties of membranes; Fick equation .

To seize a procedure of examination of a transmittivity of cellular membranes .

To be able: to carry out weighing with the help torsion balance; to solve the practical problems .

Basic knowledge, experience, skills necessary for studying the topic in connection with other subjects**:**

Disciplines	**Obtainable skills**
Previous (providing disciplines) physics, chemistry, biology	To explain ideas and appearances: mass, pressure, concentration gradient, diffusion, osmosis, membranes properties. Ideas of endocytosis, pinocytosis, phagocytosis, exocytosis. To know main formulas.
Subsequent disciplines: Normal physiology	To define such concepts: passive transport; hydrostatical pressure; a filtration; osmotic pressure; an osmosis; an electroosmosis; the abnormal osmosis; simple diffusion; the facilitated diffusion; the active transport; pumps; uniport; antiport; symport; exocytosis; endocytosis; phagocytosis; pinocytosys. To know description of ideas: membranes permeability, membranes functions, influences of different substances on membrane states and permeability. To define: a concentration gradient; a diffusion coefficient; permeability. To write down: Fick equation. To know main formulas of electrokinetic appearances. To use torsion balance.

Materials for the before-class self-preparation work:

List of main term, parameters, characteristics, which student have to learn at preparation to class:

Term	Definition
Passive transport	Passive transport is such that descends due to gradients of concentration, pressure or an electrochemical gradient
Active transport	Active transport of substances involves cell energy input.
Concentration gradient	The concentration gradient is a vector value, which is a function of the values of particular derivatives of concentration with respect to coordinates; the faster the concentration changes with coordinate change, the bigger is the modulus of the concentration gradient
Filtration	The filtration is a fluid stream through a membrane which is carried out owing to a difference of hydrostatical pressures.
Diffusion	The diffusion is a motion of molecules of solute from area with the greater concentration into area of its smaller concentration.
Osmosis	Osmosis is a motion of a solvent from area smaller concentration of dissolved material in area of its greater concentration.
Electrodiffusion	Electrodiffusion is diffusion of charged particles, namely, ions in conditions when and concentration gradient, and electic field field potential gradient are.
Ion pumps	Ion pumps transfer ions in one direction through biomembrane due to energy spend.

Theoretical questions to class:

1. Specify the basic structural components of membranes.
2. How mechanical strength of membranes is provided?
3. What components are parts of membranous phospholipids?
4. List dynamic characteristics of a membrane as liquid crystal.
5. Types of proteins in biological membranes.

6. What is a thickness of a cellular membrane?
7. What is caused passive transport of a fluid through a membrane?
8. What is caused resulting stream of ions at their passive transport through a membrane?
9. What features Fick equations?
10. Specify different properties of the facilitated diffusion.
11. What equation describes passive transport of substances through a membrane?
12. What equation describes active transport of substances through a membrane?
13. Term ions which are transferred aside magnifications of concentration with the help of the active transport (pumps).
14. On what the permeability of membranes for neutral small molecules depends?
15. Where it is localized the Ca++ membranous pump?
16. Specify K+-Na+-pump functions.
17. Where the proton pumps is localized?
18. Due to that the proton pump carries out transport of hydrions (hydrogen ions = protons)?
19. Specify general characteristics of the active transport and the facilitated diffusion.
20. Specify substances for which transport through a membrane is carried out with the help of the facilitated diffusion.
21. How transport of major molecules is carried out?

Practice work executed at class:

Instruction.

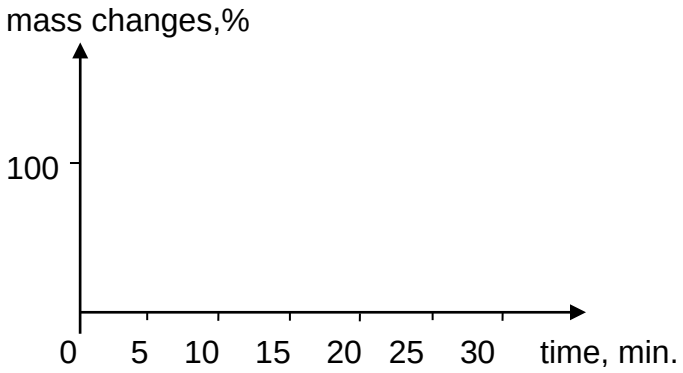
№	**Task**	**Sequence of performance**	Note, warnings
	Equipment	The torsion balance (scales; weights), pincette, wire hooks are necessary for carrying out of operation to you. We also use solutions NaCl of various concentrations, for example, hypotonic and hypertonic. Also you will utilize pieces of a living tissue, for example, small slices of a potato.	
1	Prepare the torsion balance to work.	1. Set horizontal of balance base with use of base adjusting screws by mechanic's level. 2. Set balance indicator to zero of scale. 3. Release balance stop. 4. Set equilibrium of lever with adjusting screw [clipping screw] on the back side of balance body.	Accuracy! Don't strike and shake the balance!
2	Carry out experi-ments.	1. For the convenience we use wire hooks, each of which is necessary for weighing. Then stick hook in a slice of a potato. 2. Before carrying out of experiment each slice of a potato is weighed together with a hook on torsion weights. 1. Before each weighing is checked zero set of torsion weights. Note a weight of a potato disregarding of weight of a hook (a weight of a potato minus weight of a hook) into the table. 3. Then one slice we put in hypertonic solution, second slice we put in a hypotonic solution. 4. Repeat weighing each 5 minutes within one half-	Before each weighing it is necessary to free slices from excess liquid. Use absorbent paper with care, don't press slices, and only touch paper to slice from all sides.

		hour (or up to the stopping of mass change). Each slice before weighing is dried out by a filter paper with care to eliminate a solution from a surface of a slice. The slice is hanged up for a hook to a pan (scale) of torsion weights. Then slice is weighed. 5. Note the results (the potato slice weight minus weight of the hook) into the table.	
3	Process measurement results	1. Calculate relative mass change (in percentage terms to initial mass). 2. Plot graphs of mass changes (in %) against time of allocation in solutions in one coordinate space. 3. Analyze and explain received results. Made conclusions (deductions): a) What type of transport was observed during experiment? b) What is cause of observed changes direction?	Note the results in % into the table. Use uniform scales on graph axes. Write conclusions.

Table for results

Time, min	Potato slice mass			
	In hypotonic NaCl solutions		In hypertonic solutions NaCl	
	mg	%	mg	%
0		100		100
5				
10				
15				
...				

Graph dependence time – mass changes by the sample:



The contents of the topic:

The basic building blocks of a membrane are phospholipids and proteins.

Phospholipids have polar hydrophilic "head" and two not polar hydrophobic tails. Basis of a membrane is bilayer of lipids in which not polar "tails" of molecules of both layers are inverted to each other, and hydrophilic "heads" – to environmental water medium.

Proteins, depending on their arrangement are peripheric, integrated or semisubmerged, and depending on functions are divided on structural, transport, enzymatic (fermental), receptor.

According to the liquid-mosaic model, proteins do not cover the surface of the lipid bilayer completely, but as if float therein. The character of arrangement with and relation to lipids classifies membrane proteins into peripheral and integral proteins. Peripheral proteins

are arranged on the outer or inner surface of the lipid layer and interact with the heads of phospholipids. Molecules of integral proteins have large hydrophobia sections. These sections are embedded within the lipid layer. Some integral proteins permeate the entire membrane. Integral proteins are connected with the membrane by hydrophobic interactions.

Over a certain temperature range, the phospholipid structures combine the properties of liquids and crystals. As liquids, they possess fluidity, but as crystals, they maintain order in the arrangement and orientation of molecules. Therefore, phospholipid systems can possess liquid-crystal properties. At a temperature drop below a certain critical value, a transition of phospholipids from the liquid-crystalline state to gel occurs. At the temperature, which is common for the cell, the phospholipid bilayer is in the liquid-crystal state.

Except for phospholipides and proteins, the important builders of membranes are cholesterol, glycolipides, glycoproteins.

Cell membranes has the thickness of 7 to 10 nm.

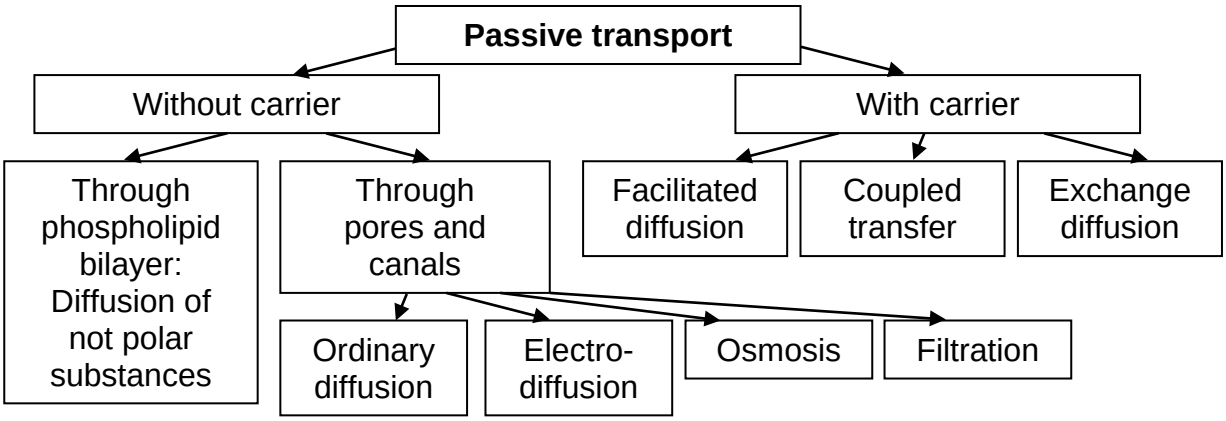
Biological membranes carry out a lot of functions: structural; protective; transport; fermental; electrogenic; adhesive; receptor; antigenic.

Besides the surface membrane, which separates the cell content from the environment, the cell also has internal membranes, which surround such intracellular structures as the mitochondria, the nucleus, the endoplasm reticulum, the Golgi apparatus, lysosomes, vacuoles, and others.

Mechanisms of transport of substances through a membrane are divided into two types: passive and active transport.

Passive transport of substances. It is named so because it does not demand cell energy input for transport of substances across the membrane.

Passive transport is such that descends due to gradients of concentration, pressure or an electrochemical gradient. To passive transport refer to: a filtration, diffusion, osmosis, an electroosmosis, the abnormal osmosis, the facilitated diffusion (uniport), exchange diffusion (antiport) and conjunct transport (symport).



The filtration is a fluid stream through a membrane which is carried out owing to a difference of hydrostatical pressures.

The diffusion is a motion of molecules of solute from area with the greater concentration into area of its smaller concentration. Charged particles (ions) can inpour through ion channels which transmittivity changes as a function of requirements.

The spatial distribution of the substance can be characterized by such a quantity as the ***concentration gradient.*** The concentration gradient is a vector value, which is a function of the values of particular derivatives of concentration with respect to coordinates; the faster the concentration changes with coordinate change, the bigger is the modulus of the concentration gradient. The direction of the concentration gradient vector coincides with the direction of the fastest growth of concentration.

Direct diffusion across the phospholipid bilayer. The number of substances, which are capable of diffusing directly across the phospholipid bilayer, is very limited. These are some gases (oxygen and carbon dioxide) and non-electrolytes, which are soluble in

lipids. Most substances that are transported across the membrane cannot diffuse across the phospholipid layer. This is clear because the cell cannot control diffusion across phospholipids, and it must maintain exact control of influx and efflux of substances to/from the cell to ensure stability of the inner content, and sustain balance of the most complex biochemical processes therein.

Diffusion through pores*.* Diffusion of most substances across the membrane is effected through specialized membrane formations known as pores or channels. They are formed from integral proteins. Diffusion of water, some simple organic compounds and ions occurs through the pores.

Electrodiffusion is diffusion of charged particles, namely, ions. The phenomenon of electrodiffusion involves not only availability of an ions concentration gradient in the medium, but also the presence of an electric field potential gradient.

The ***osmosis*** is a motion of a solvent from area smaller concentration of dissolved material in area of its greater concentration. The difference of pressures between solutions from both sides of the membrane, necessary for the arrest of osmosis, is termed as osmotic pressure.

The ***electroosmosis*** is a motion of molecules of a solvent in an electric field, if molecules of a solvent are charged, or owing to an osmosis which accompanies with a motion of the dissolved charged particles.

The ***facilitated diffusion*** is carried out by a protein-carrier.

Joint transport descends then when two substances simultaneously in one direction on a lapse rate of concentrations of one of participating substances (second are transported can be transferred in that case against a lapse rate of concentrations).

The ***exchange diffusion*** is observed, if the protein-carrier is capable in one direction to transfer one substance, and in opposite direction – another. These processes interdependent, and transport descends according to a gradient of concentrations of one of participating substances.

2. ***Active transport of substances****.* This kind of transport involves cell energy input. In most cases, special molecules-carriers participate in effecting active transport.

The active transport of substances descends due to energy of metabolic processes. The energy sources are macroergic phosphates, such as ATP. The active transport is divided on coupled and uncoupled.

Active transport of substances is often related to the action of so-called ***ion pumps****:* the sodium-potassium pump of plasma membranes, the calcium pump of sarcoplasmic reticulum membranes, and the proton pump of mitochondria and chloroplasts. Active transport includes transfer of different substances, for example, sugars, across the membranes of intestine epithelium cells.

Examples of not uncoupled active transport are calcium and proton pumps.

During the coupled active transport substances of two kinds are transferred in opposite directions at one cycle of an enzyme. The example is a sodium-potassium pump.

The sodium-potassium pump effects transport across the plasma membrane of sodium ions out of the cell and of potassium ions into the cell.

Three sodium ions and two potassium ions are usually transported during one pump action cycle, though under artificial conditions this relation can be another one.

Sodium and potassium ions are transported across the membrane by the complex integral protein-carrier that hydrolyzes ATP, whose energy activates the Na^+-K^+ pump. This protein (enzyme) is known as the transporting ATPase or Na^+-K^+ ATPase. Ion transport is caused by conformational changes in the protein-carrier.

The special types of transport through a membrane are endo- and exocytosis.

Endocytosis is divided into two kinds: a phagocytosis (englobement of solid particles) and pinocytosis.

Self-control material:

B. Test tasks to be done :

1. The liquid-mosaic model of a biological membrane includes:
   1) A peptide layer, polysaccharides and the surface lipids;
   2) lipid monolayer, microfilaments and cholesterol;
   3) lipid bilayer, proteins, microfilaments;
   4) lipid bilayer, proteins, cholesterol;
   5) lipid bilayer.
2. The non-electrolytes diffusion equation is:
   1) $J_m=D(dc/dx)$;
   2) $J_m=D(dc/dt)$;
   3) $J_m=-D(dc/dx)$;
   4) $J_m=-D(dc/dt)$.
1. Transport of substances at the facilitated diffusion in comparison with a simple diffusion descends:
   1) In an opposite direction;
   2) Faster;
   3) More slowly;
   4) With the same velocity
2. Thickness of a biological membrane makes approximately:
   1) 0,01 nm;
   2) 0,1 nm;
   3) 10 nm;
   4) 100nm;
   5) 1 mkm.
3. The liposome is...
   1) Single-layered lipid structure;
   2) Two-layer lipid structure;
   3) An organella of a cell;
   4) A peptide structure;
   5) Model of the bilayer membrane.
4. The lateral diffusion terms diffusion:
   1) Molecules from one lipid layer in another;
   2) Molecules through a biological membrane;
   3) Molecules in a membrane in limits of one stratum;
   4) Albuminous molecules from one lipid stratum in another;
   5) Ions through the bilayer membrane.
7. Transition of a molecule from one lipid layer in another is termed:
   1) "flip-flop" transition;
   2) The facilitated diffusion;
   3) The active transport;
   4) a lateral diffusion;
   5) Passive transport.
8. Lipids in a composition of biological membranes are:
   1) In a solid amorphous state;
   2) In a firm crystalline state;
   3) In a liquid amorphous state;
   4) In a liquid crystal state;
   5) The correct answer is not present.
9. Na^+-K^+-pump transports:
   6) in a cell 2 ions Na^+, out the cell 3 ions K^+;
   7) in a cell 2 ions K^+ , out the cell 3 ions Na^+;
   8) in a cell 3 ions K^+ , out the cell 2 ions Na^+;

9) in a cell 3 ions Na^+, out the cell 2 ions K^+;

10) in a cell 3 ions Na^+ , out the cell 3 ions K^+.

Task 1. Transition of solvent molecules from a solution of low concentration in a solution of high concentration is carried out through the semipermeable membrane. What is the reason of this process?

Task 3. Cellulose has arrived with Golgi complex vesicle to a surface of a cell and was released outside as a result of merging a vesicle membrane with a plasma membrane. What it for process?

Literature recommended

Main sources.

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Methodical elaboration have prepared by senior lecturer, PhD Biol.Sc. Korovina L.D.