BIOCHEMISTRY OF MEMBRANES

Associate professor
A.A. Maslovskaya

STRUCTURE AND COMPOSITION OF MEMBRANES

Major components of membranes are **lipids**, **proteins** and small amount of **carbohydrates**.

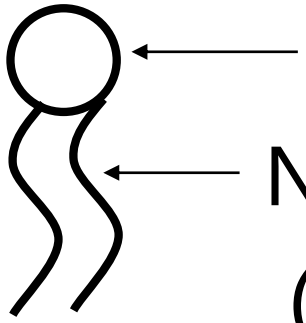
Carbohydrates in the membrane combine with lipids or proteins to form **glycolipids** and **glycoproteins,** respectively

MEMBRANE LIPIDS

1) **Phospholipids.** This is the major class of the membrane lipids.

Representatives: phosphatidylcholine, phosphatidylethanolamine, phosphatidyl-serine, phosphatidylinositol, acetalphosphatides, cardiolipins.

Phosphilipids have polar head and non-polar tail (composed of two fatty acids).



Hydrophilic (polar) head

Non-polar (hydropobic) tail

(two fatty acids)

2) Sphingophospholipids (sphingomyelin).

3**) Cholesterol**

4) **Glycolipids** (cerebrosides, gangliosides and sulphatides). They have carbohydrate chains oriented towards the extracellular side of the membrane.

In membranes, all the lipids have hydrophilic & hydrophobic parts and form a **bilayer**, with the polar heads oriented towards the extracellular side and cytoplasmic side, *i.e. towards the aqueous environment.* Hydrophobic tails oriented towards each other.

Triacylglycerols (fats) **are not** a constituent of membranes.

MEMBRANE PROTEINS

1) **Integral** proteins are firmly and deeply embedded (sunk, anchored, plunged) in the lipid bilayers.

2) **Peripheral** proteins are situated on the surfaces of the bilayer.

Some proteins of a membrane contain oligosaccharide chains oriented towards the extracellular space.

Types of membrane proteins

1) structural proteins (components of the membrane);

2) transport proteins (they transfer substrates and ions across the membrane);

3) enzymes (catalyze biochemical reactions);

4) receptors

5) tissue-specific **antigens**.

STRUCTURE OF MEMBRANE

The model of the membrane is called the **fluid mosaic model**. This model is compared with icebergs floating in a sea (the icebergs are proteins, the sea is phospholipids).

PROPERTIES OF MEMBRANES

1) **Self-assembly**.
2) **Selective permeability**. Membranes are impermeable to many molecules. Certain molecules can freely pass through the membrane. For some other molecules there are specific channels in membranes.
3) **Asymmetry**.
4) **Viscosity** (as sun-flower oil).

5) Mobility. Lipids and proteins can easily move within one layer and this is called **lateral diffusion**.

6) Fluidity. It is increased

due to the ↑of body t°, or

due to the ↑of unsaturated FA or cholesterol in the membrane.

The increase of fluidity leads to the increase of permeability.

FUNCTIONS OF MEMBRANES

1) Separation

- the cell content – from the external environment,
- one cell – from another,
- different parts of the cell.

2) Barrier function – maintenance of **different concentration of substances on the both sides of the membrane**.

3) The plasma membrane provides **cell-to-cell interactions.**

4) Receptor function. Receptor can recognize and bind substances, e.g. hormones, lipoproteins.

5) Catalytic function. Some membrane proteins are enzymes.

6) Transport of molecules. Membranes contain channels and pumps that provide selective transport of ions and substrates.

TRANSPORT MECHANISMS

Classification on the **number of molecules** moved and the **direction of movement**:

- **Uniport** - one type of molecules moves across membrane. E.g. calcium pump.
- **Symport** – two types of molecules move simultaneously at the same direction. E.g. Na+-glucose transporters and Na+-amino acid transporters.
- **Antiport** - two types of molecules move in opposite directions, e.g. Na+ in and K+ out, i.e. sodium pump.

Types of transport mechanisms

1) **passive transport**: simple diffusion and facilitated diffusion;
2) **active transport**: primary and secondary active transport;
3) **transport of macromolecules** across plasma membrane: exocytosis and endocytosis.

Passive transport (diffusion)

– molecules are transported across the membrane **down their concentration gradient and this process does not require energy**.

Two types of passive transport

Simple diffusion does not require transfer proteins (e.g. transport of H_2O, CO_2, O_2).

Facilitated diffusion requires transfer proteins which are called **transporters, permeases, translocases or carrier proteins**. These carrier proteins are regulated by hormones.

E.g. **insulin** activates the glucose transporter into skeletal muscle cells and adipocytes.

Glucocorticoids increase transport of AA into the Liver cells. **Growth hormone** increases transport of AA into all cells.

Active transport

– molecules are transported across the membrane **against their concentration gradient.** This process requires energy.

- Primary active transport uses ATP.

  E.g. Na^+, K^+-ATPase, or sodium pump, Ca^{++}-ATPase, or calcium pump, H^+-ATPase.
- Secondary active transport uses energy of membrane potential ***produced by primary active transport (e.g****.* amino acids and sugars).

Endocytosis

This is transfer of extracellular **macromolecules** into the cell. First, invagination of membrane takes place, then the matter is surrounded by the membrane so that **endocytic vesicle** is formed and then it is engulfed. This process requires energy (**ATP),** calcium ions, microfilaments and microtubules.

Two types of endocytosis:

- **Pinocytosis – “**drinking by the cell”. The cell takes up fluid and fluid contents.
- **Phagocytosis –** “eating by the cell”. It is the engulfment of large particles such as bacteria, viruses, products of the cells destruction. Phagocytosis occurs only in specialized cells, such as **macrophages** and **granulocytes.**

Exocytosis

This is the release of **macromolecules** from the cell to the exterior. The **secretory vesicles** with the substance move towards the plasma membrane and fuse with it. E.g. in such a way enzymes (trypsinogen), hormones (insulin) and neurotranmitters (acetyl choline) are released from the appropriate cells.

INTRODUCTION INTO METABOLISM

Metabolism is all the **enzymatic reactions and physical processes** in the body.

Metabolism includes three steps:

1) the uptake of substances from the outside (nutrition, respiration);

2) conversion of substances in the body, i.e. all chemical reactions occurring in the cell;

3) excretion of end products from the body.

Functions of metabolism:

- 1) **synthesis** of molecules that are required for the cell structure and functioning;
- 2) **cleavage** of molecules to end products and their removal from the body;
- 3) production and utilization of **energy**.

Two sides of metabolism:

Anabolism is synthesis of complex molecules from simpler components. This process requires energy.

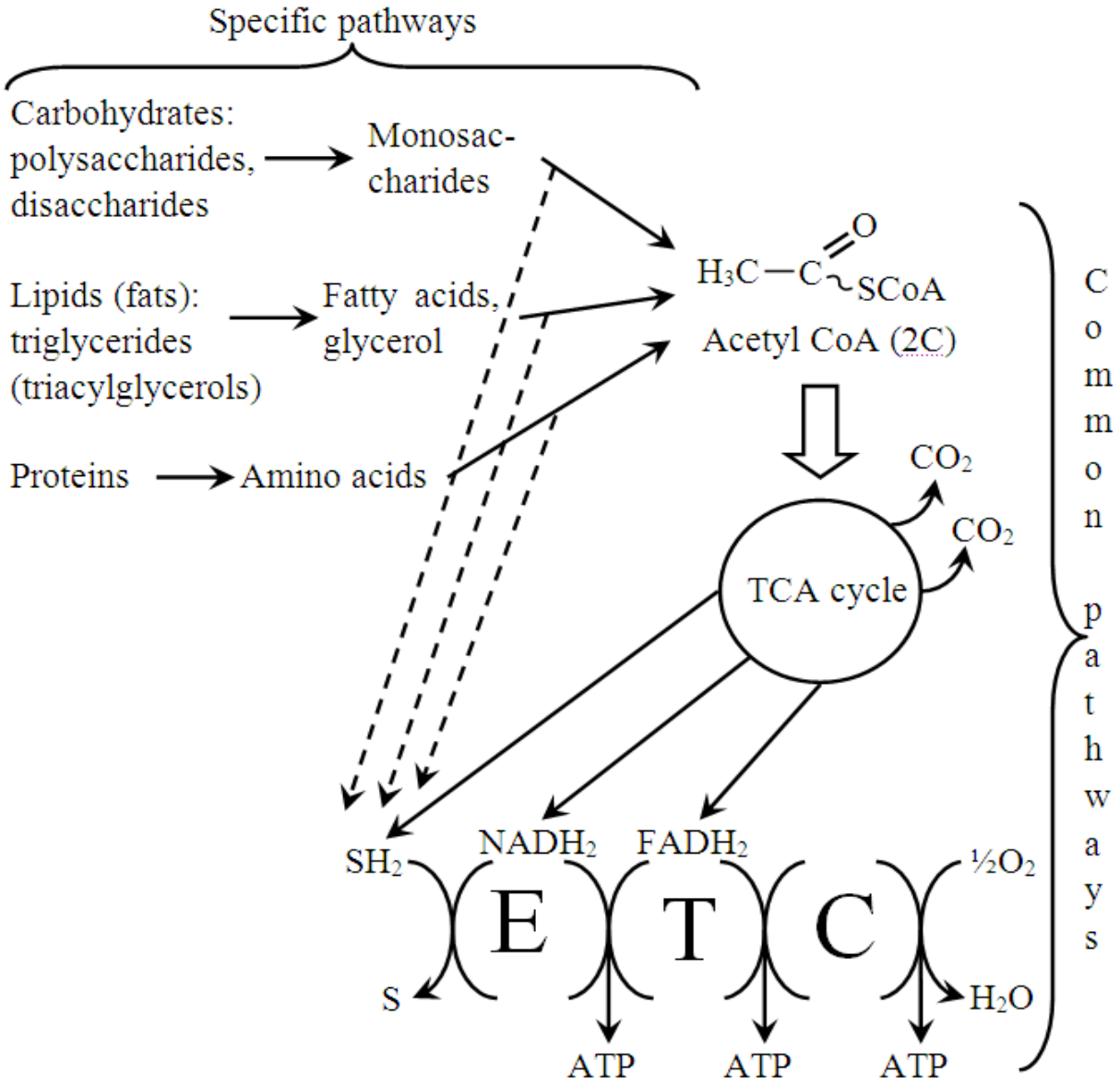
Catabolism is degradation of complex molecules to simpler components. In this process, energy is released. The catabolic and anabolic pathways are closely interrelated. Energy produced in catabolic processes is used for anabolic reactions.

MAJOR END PRODUCTS OF CATABOLISM

Body substances	End products
Carbohydrates	CO_2, H_2O
Lipids	CO_2, H_2O
Proteins (amino acids)	CO_2, H_2O, NH_3, **urea**, creatinine, indican
Nucleic acids	CO_2, H_2O, NH_3, **uric acid**

SPECIFIC AND COMMON PATHWAYS OF CATABOLISM

Specific pathways of catabolism. Carbohydrates, lipids, and proteins of the human body or from the food are degraded in the body to smaller molecules which are then converted to acetyl CoA.


Specific pathways
Carbohydrates: polysaccharides, disaccharides
Monosac-charides
Lipids (fats): triglycerides (triacylglycerols)
Fatty acids, glycerol
Proteins
Amino acids
H3C—C(=O)~SCoA
Acetyl CoA (2C)
CO2
CO2
TCA cycle
SH2
NADH2
FADH2
½O2
E
T
C
S
H2O
ATP
ATP
ATP
Common pathways

Common pathways of catabolism.

Acetyl CoA is utilized in the TCA cycle to form CO_2, reduced substrates (SH_2) and reduced coenzymes ($NADH_2$ and $FADH_2$). These reduced components are getting oxidized in the ETC to produce ATP.

EXPERIMENTAL STUDY OF METABOLISM

Levels of study

1) **The whole organism.**
2) **Isolated organ.**
3) **Organ slices**.
4) **Cell culture**.

5) **Homogenates of tissues** (tissues may be ground to a homogenous state, i.e. may be undergone homogenization – destruction of cell membranes).

6) Separated subcellular fractions.

7) **Purified enzymes**.

Methods of study

1) Colorimetry
2) Spectrophotometry
3) Centrifugation
4) Chromatography
5) Electrophoresis
6) Determination of the enzymatic activity
7) Isotope methods

The use of isotope tracers

There are radioactive isotopes such as ^{3}H (tritium), ^{32}P, ^{14}C, ^{35}S, ^{131}I (iodine), etc. They may be included into some molecule so that a **labeled compound** is formed. This labeled compound may be injected into the experimental organism. The use of radioisotope tracers helps to understand the distribution and metabolic conversions of the labeled substance in the body.