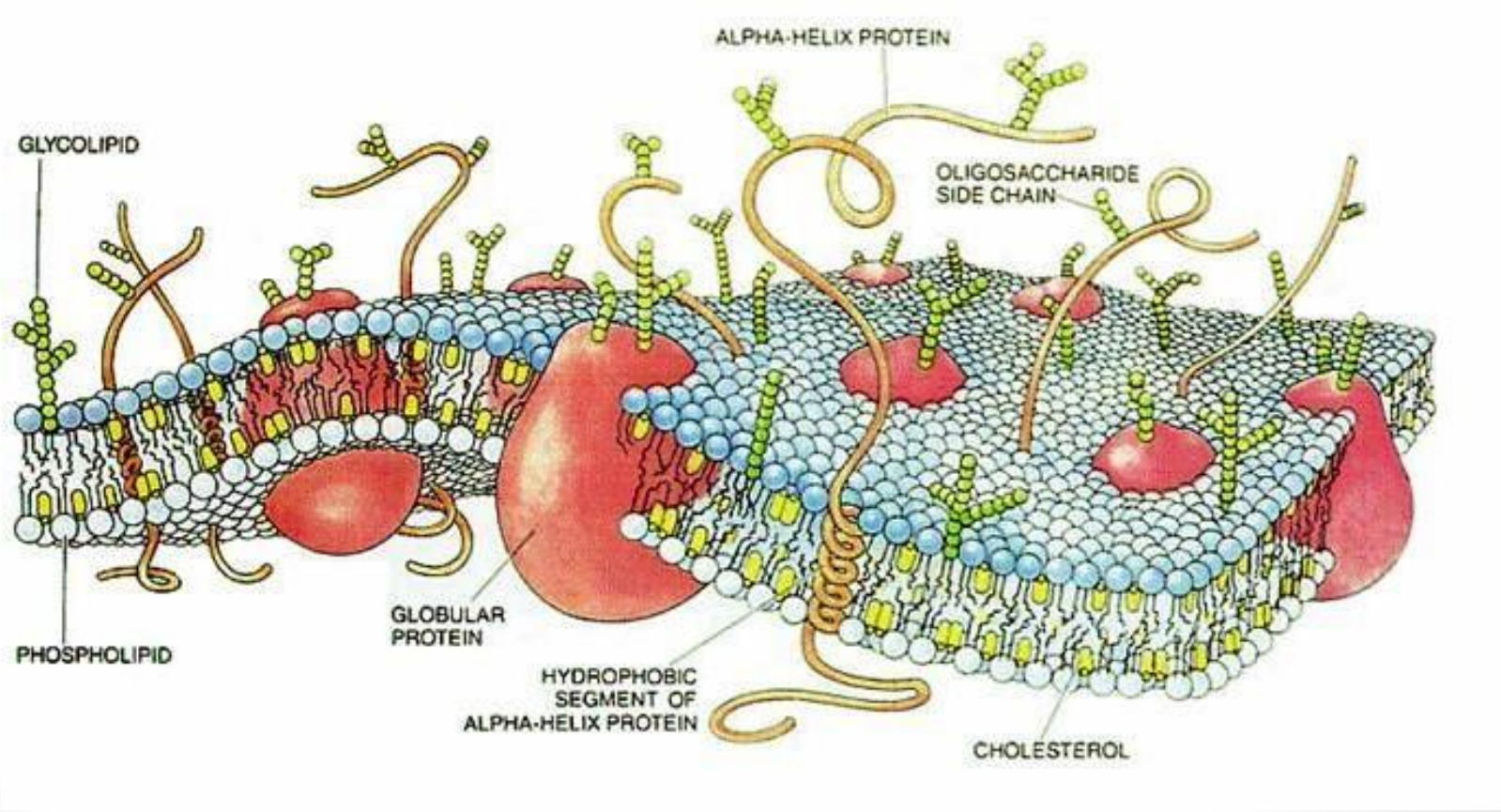
OVERVIEW OF BIOLOGICALLY ACTIVE MOLECULES

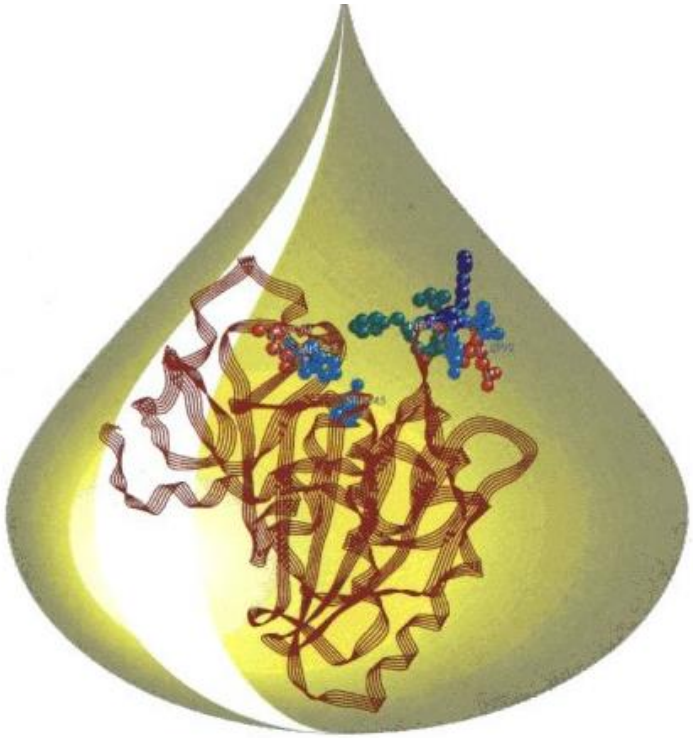
(Part 2. Lipids)

Lecturer: **Darya Rudenko**
Department of Biochemistry of "Professor V.F. Voino-Yasenetsky Krasnoyarsk State Medical University"

LIPIDS (OVERVIEW)



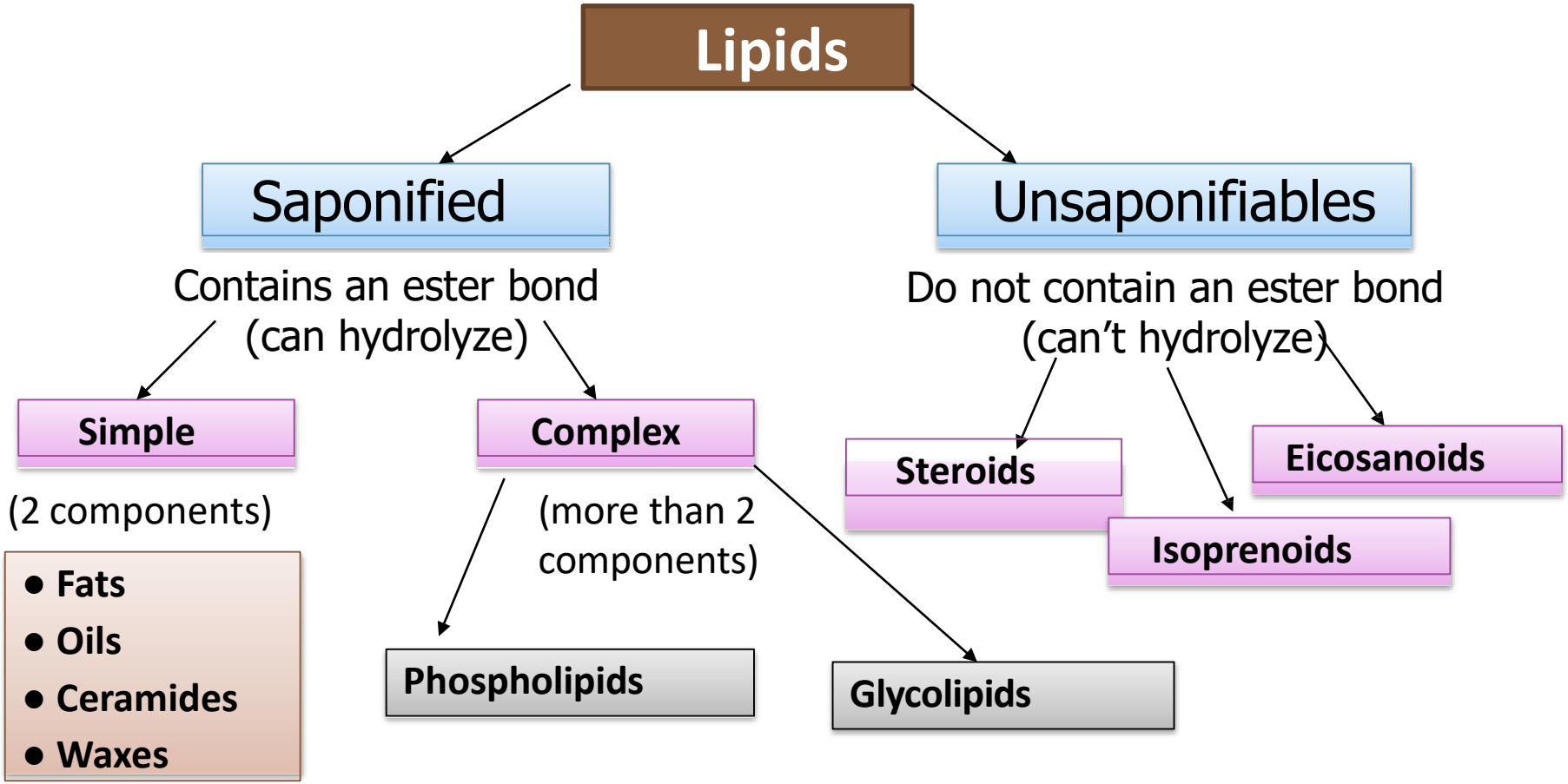
Lipids are a heterogeneous class of fat-like substances that are poorly soluble in water and readily soluble in non-polar organic solvents. Under this name, substances that are different in chemical structure and biological functions are combined.



Biological classification (by function)

Class	1. Fats	2. Lipoids	3. Biologically active substances
Function	Energy	Membrane-forming	Regulatory (vitamins and hormones)

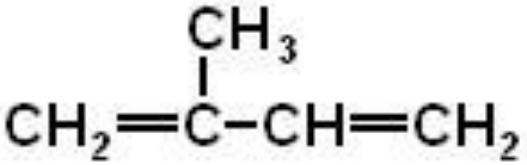
Chemical classification (composition and structure)



Unsaponifiable lipids (one component)

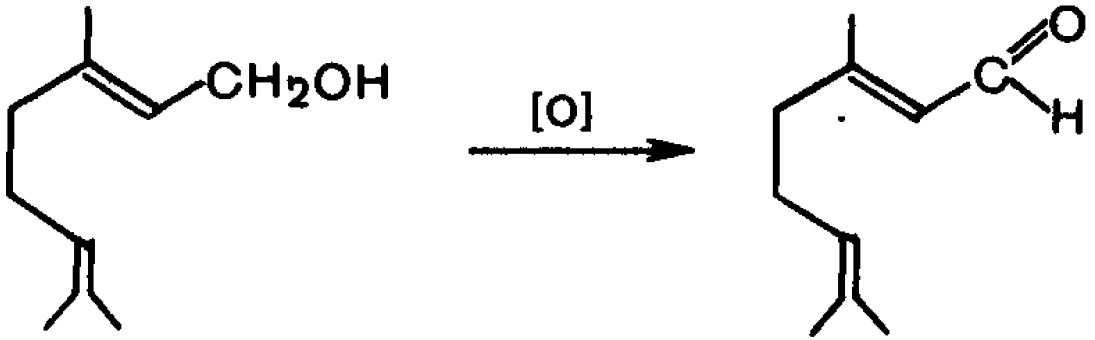
I. Isoprenoids (terpenes and terpinoids)

A number of compounds containing isoprene units are combined under this name. Oxygenated derivatives of terpenes are called **terpenoids.**



isoprene (2-methyl-butadiene-1,3)

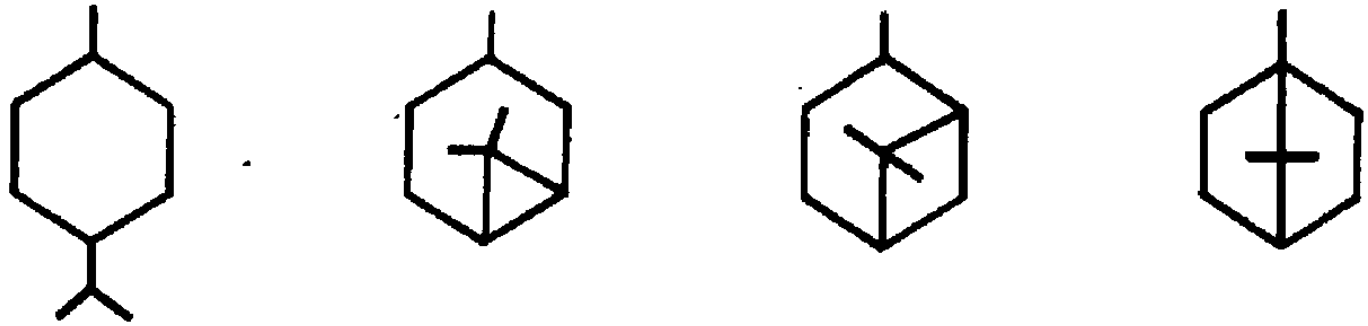
Examples of acyclic terpenes are **myrcene**, as well as the related alcohol and aldehyde, **geraniol and citral**, which function as pheromones in worker bees.



Гераниол
geraniol

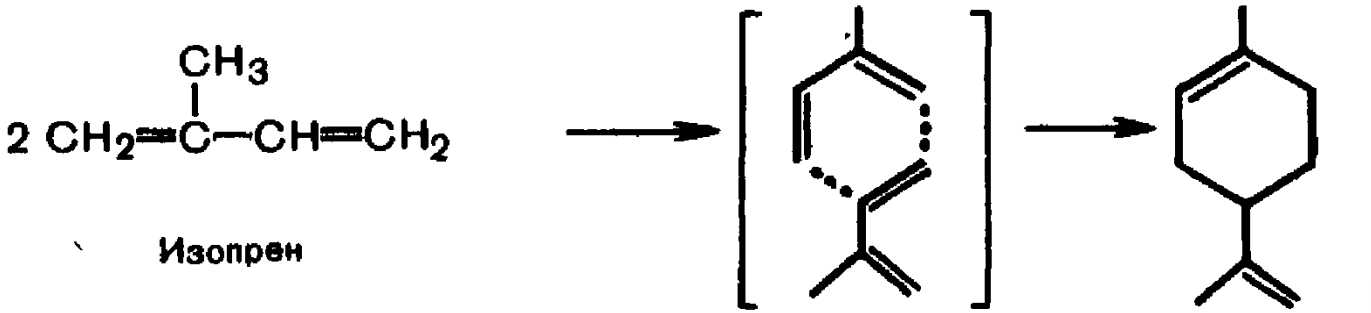
Цитраль *α*
(гераниаль)
citral

The most common are mono- and bicyclic terpenes. Many of them are either directly used in medicine, or serve as raw materials for the synthesis of many drugs.



Ментан Каран Пинан Борнан

Typical monocyclic terpenes are **limonene (dipentene)** and **menthol.**



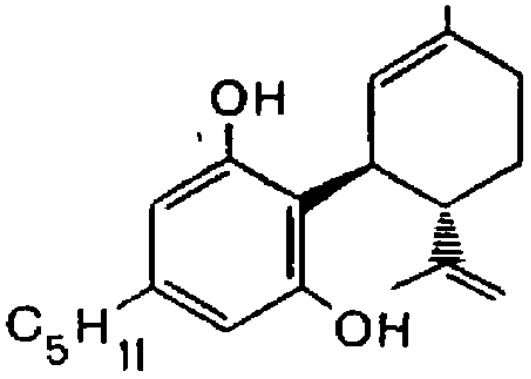
Изопрен

(±)-Дипентен

dipentene

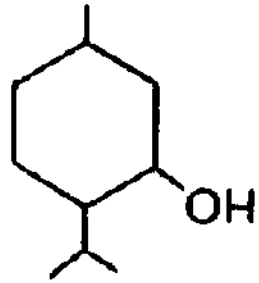
Substituted dipentenes, such as **cannabidiol**, are psychoactive substances

Menthol is part of **validol**, as well as ointments used for the runny nose



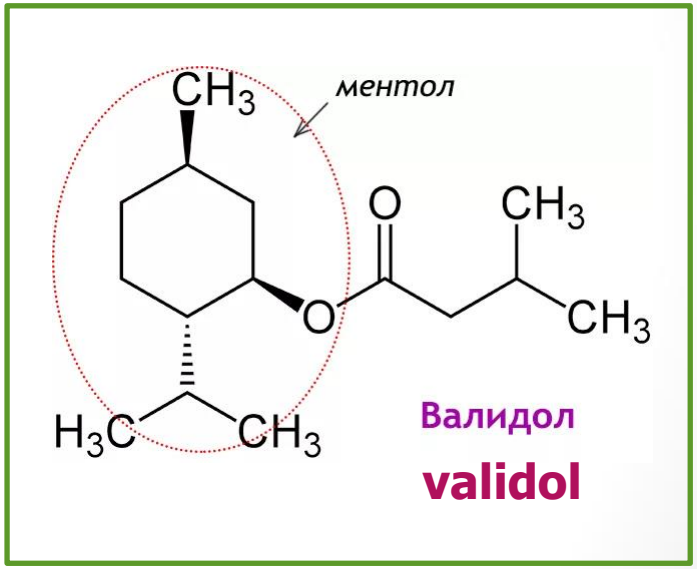
Наннабидиол

cannabidiol

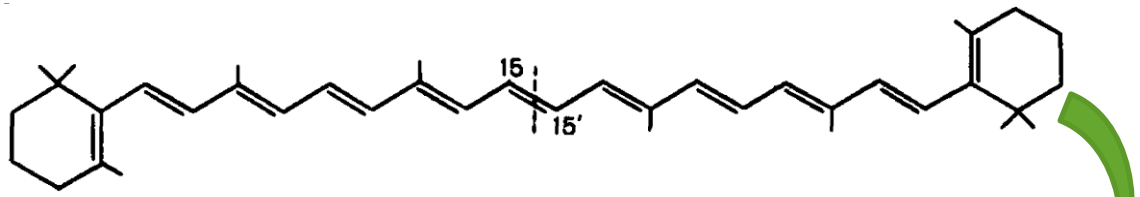


Ментол

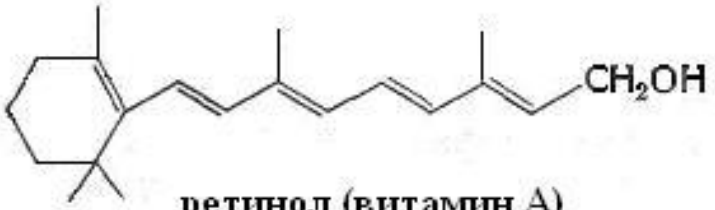
menthol



A special group of terpenes are **carotenoids** - plant pigments. Some of them are capable of performing the functions of vitamins. Their typical representatives are α-, β- and γ-carotenes, the precursors of group A vitamins (витамин А).



β-Каротин



ретинол (витамин А)

Terpenes include **vitamins of group E (tocopherols)**, **vitamins of group K**. Also, **ubiquinones (убихиноны)**, capable of sequential oxidation (reduction).

Убихиноны (кофермент Q, n=6–10)

Восстановленные убихиноны

II Eicosanoids

A very large group of biological regulator molecules. All of them are derivatives of arachidonic (eicosanoic) acid (C20:4 – арахидоновая кислота). They are highly active regulators of cellular functions.

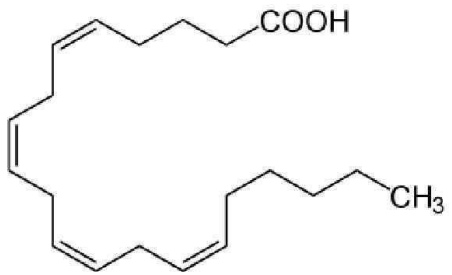
Eicosanoids include:

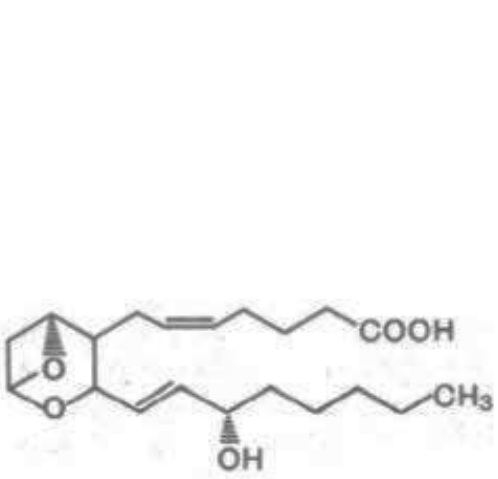
Prostaglandins (простациклин),

Thromboxanes (тромбоксаны),

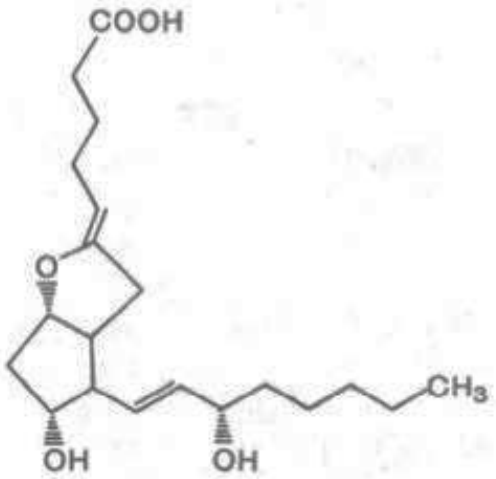
leukotrienes and a number of other substances.

Арахидоновая кислота:
$CH_3(CH_2)_4(CH{=}CHCH_2)_4(CH_2)_2COOH$





Тромбоксан A_2

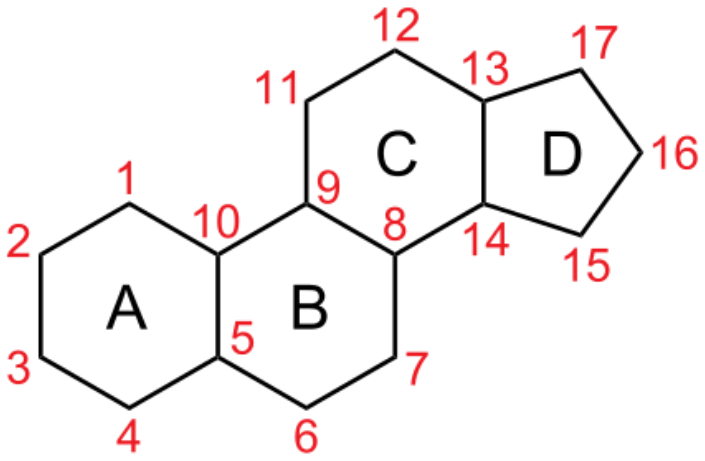


Простациклин (PGI$_2$)

III Steroids

Their structure is based on the condensed cyclic system of cyclopentaneperhydrophenanthrene (**sterane**).

Natural steroids have two methyl substituents in the ring (at C10 and C13) and a hydroxyl group at C3. A side chain (**sterols**) is attached to C17 in the ring.



стеран

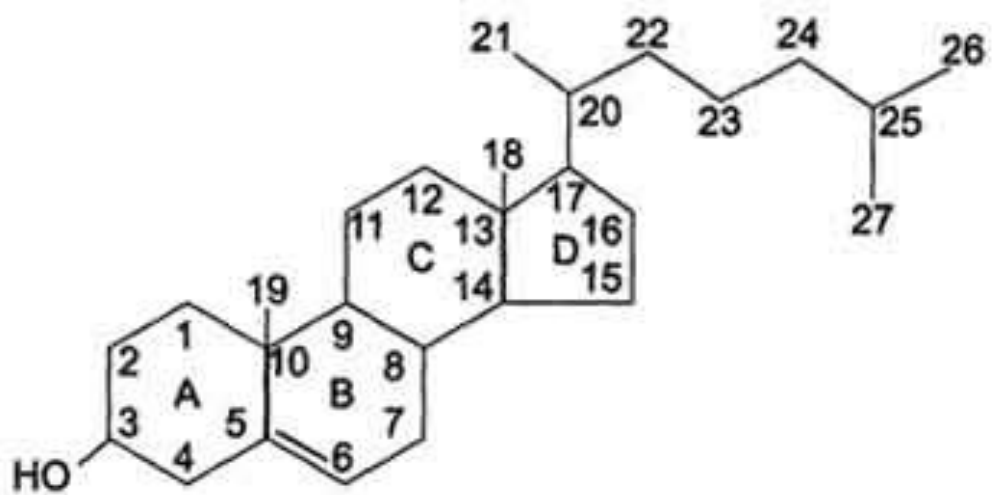
sterane

стерины

sterols

Cholesterol (холестерол) is a monohydric alcohol with one double bond (C5 = C6) and a side chain of eight carbons at the C17 of the sterol ring. According to the total number of carbon atoms in the molecule, cholesterol is called **C27-sterol.**

In the human body, a number of different steroids are synthesized from cholesterol, which are formed by shortening the side chain and oxidizing either the ring atoms or the si



Холестерол

7-дегидрохолестерин (7-dehydrocholesterol)

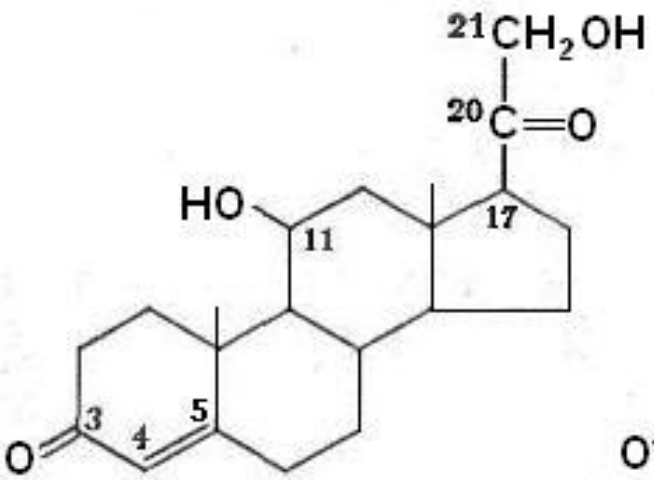
7-дегидрохолестерин

Желчные кислоты (Bile acids)

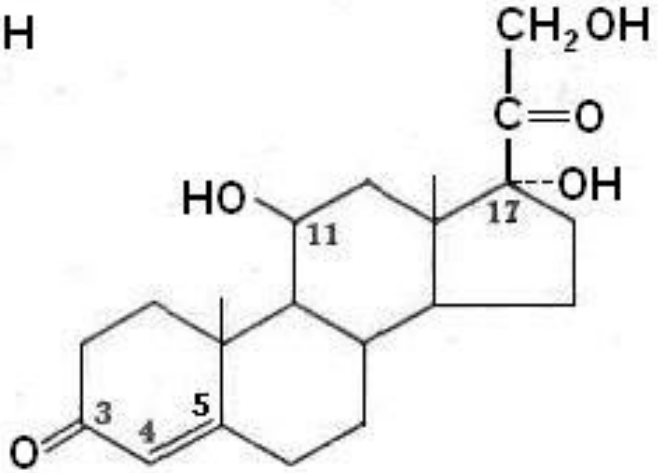
Холевая кислота

Дезоксихолевая кислота

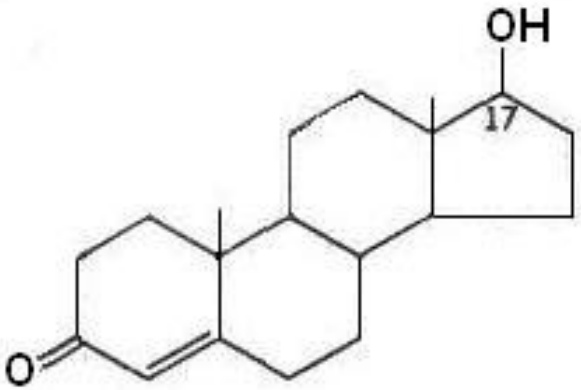
Стероидные гормоны (Steroid hormones)



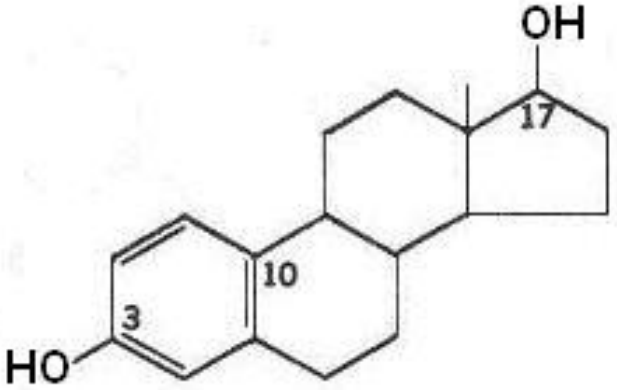
corticosterone Кортикостерон



Кортизол cortisol
(17-оксикортикостерон)



Тестостерон testosterone



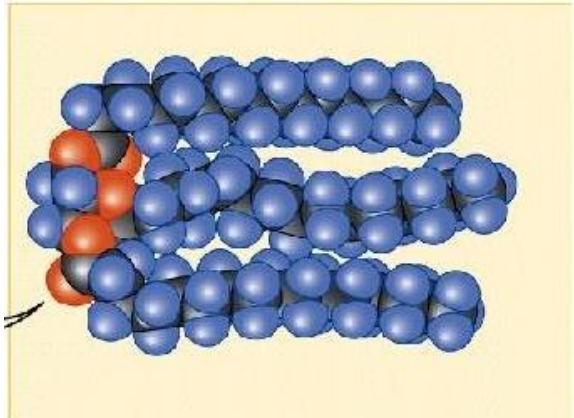
Эстрадиол estradiol

Simple saponifiable lipids (two-component)

Hydrolyzed to form two components.

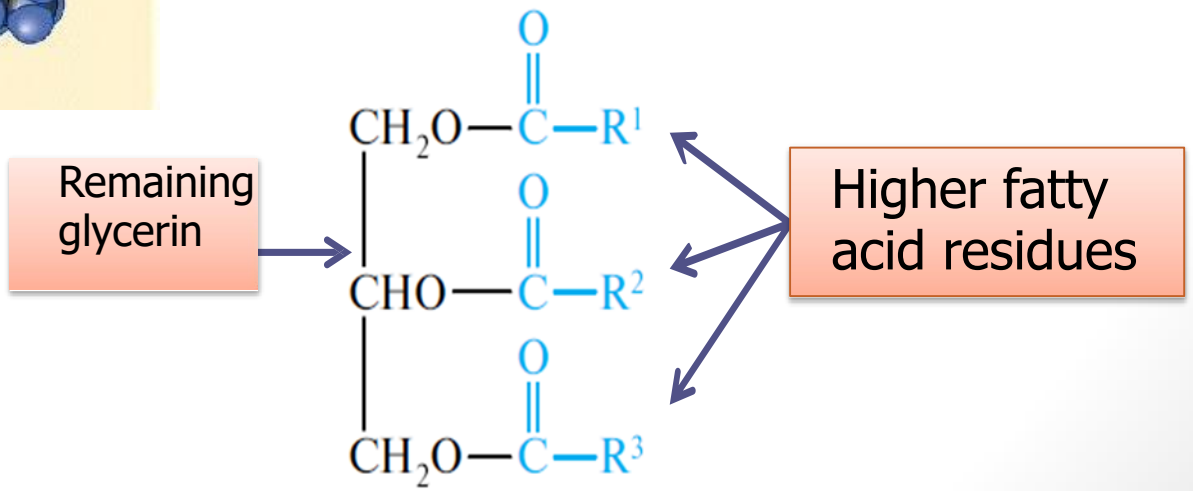
Triglycerides (triacylglycerols, fats, neutral fats).

Triglycerides are esters of the trihydric alcohol of glycerol and higher carboxylic acids.

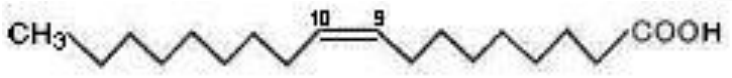
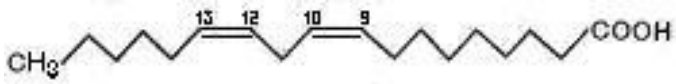
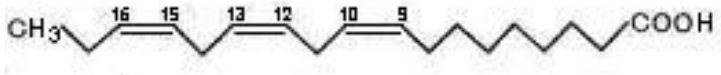
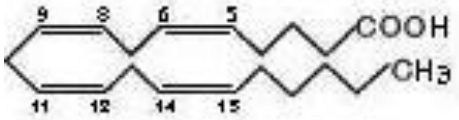


Oils - liquid triacylglycerols with a predominance of the composition of unsaturated acids (vegetable origin)

Fats - solid triacylglycerols with a predominance of saturated acids (animal origin)



Higher fatty acids

Saturated acids (all connections are single)	Unsaturated acids (contain one or more double bonds)
Capric acid: $CH_3(CH_2)_8COOH$ Lauric acid: $CH_3(CH_2)_{10}COOH$ Myristic acid: $CH_3(CH_2)_{12}COOH$ Palmitic acid: $CH_3(CH_2)_{14}COOH$ Stearic acid: $CH_3(CH_2)_{16}COOH$ Arachinic acid: $CH_3(CH_2)_{18}COOH$	Oleic acid: C(18:1), ω−9  Linoleic acid: C(18:2), ω−6  α-Linolenic acid: C(18:3), ω−3  Arachidonic acid: C(20:4), ω−6 
• Molecules are hydrophobic • High melting point • (from 31˚C to 76˚C) • At room temperature they are solid (if there are less than 10 carbon atoms in the chain, then such acids are liquid at room temperature).	• Double bonds - in cis configuration • Lower melting point (-49 ˚C to 14˚C) • At room temperature - liquid • Linoleic and linolenic acids are indispensable for humans (must be taken with food)

<u>All properties of triglycerides are determined by the composition of fatty acids in the molecule</u>

Physical properties of triglycerides:

Triglyceride molecules are completely hydrophobic (insoluble in water).

The state of aggregation at room temperature depends on the composition of fatty acids:

liquid - contain unsaturated acids (vegetable oils)

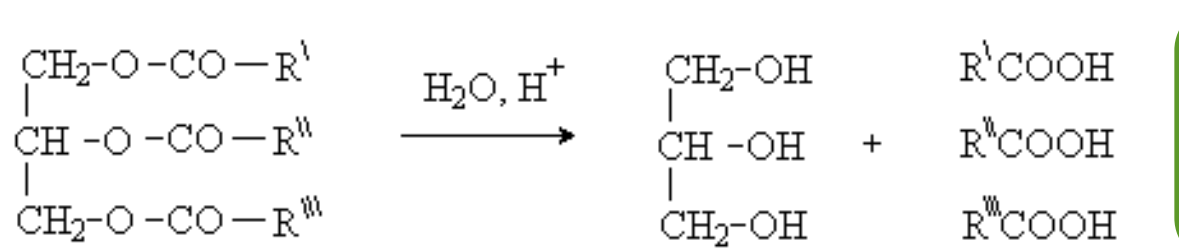
solid - contains saturated acids (animal fats)

human fat - three body temperature - liquid, but slightly different in composition and consistency depending on localization in the body.

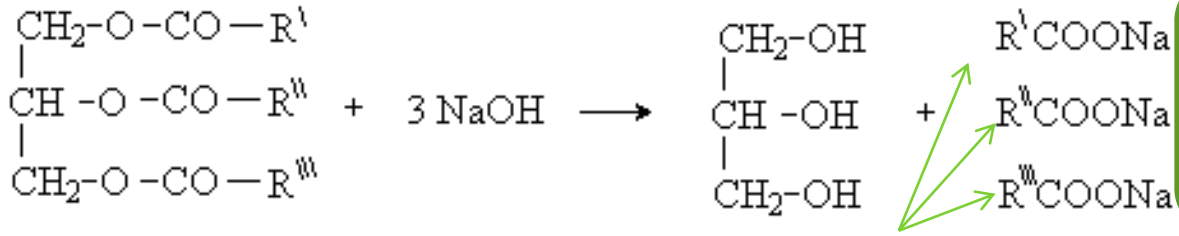
The density of fat is less than 1, so it is lighter than water and floats on its surface. Under the action of surfactants (surfactants) or detergents, fats are well emulsified. In the human intestine, under the influence of bile acids (natural detergents), a suspension of tiny droplets of fat in water is formed, which contributes to the normal digestion of dietary fats.

Chemical properties of fats

- Hydrolysis and transesterification

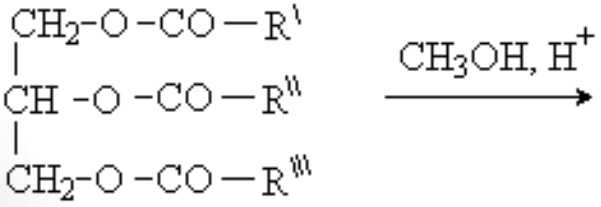


Acid hydrolysis underlies the breakdown of fat in our body



Alkaline hydrolysis is at the heart of soap production

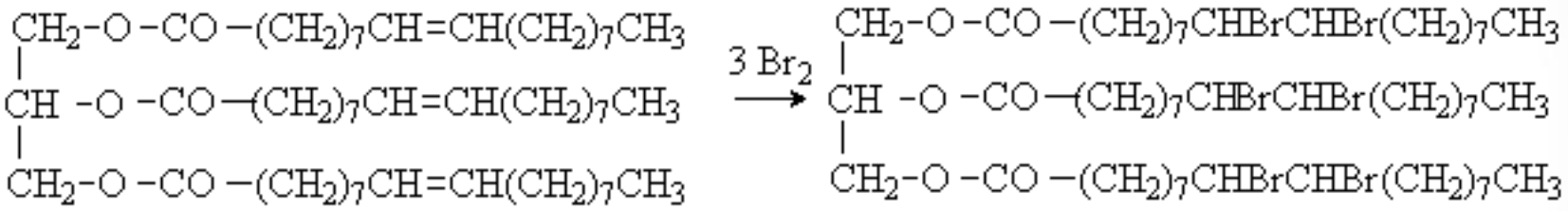
soap



It is used in the food industry to lower the melting point of fats, increase their plasticity and stability against oxidation by atmospheric oxygen.

Chemical properties of fats

Triacylglycerides containing residues of unsaturated fatty acids enter into addition reactions at the double bond.

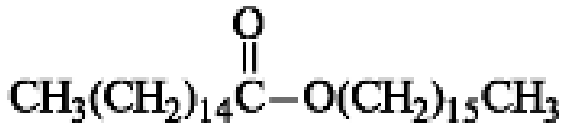


The halogen addition reaction is used to determine the content of unsaturated acid residues in fats. The quantitative characteristic of the degree of unsaturation of fats is the iodine number - the number of grams of iodine that can add to 100 g of fat.

Waxes

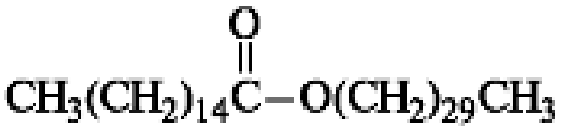
These are esters of higher fatty acids and higher monohydric alcohols.

An example is palmitic acid **cetyl ester (cetin)**, the main component of **spermacet**. Spermaceti is secreted from the fat contained in the cranial cavities of sperm whales. Another example is palmitic acid melissil ester, a component of beeswax.



цетиловый эфир пальмитиновой кислоты
(цетилпальмитат)

cetyl palmitate



мелиссиловый эфир пальмитиновой кислоты
(мелиссилпальмитат)

melissil palmitate

Complex saponifiable lipids (> 2 components)

I Phospholipids are the general name for lipids containing a phosphoric acid residue. Phospholipids are the main lipid components of cell membranes.

GlyceroPhospholipids

Includes:

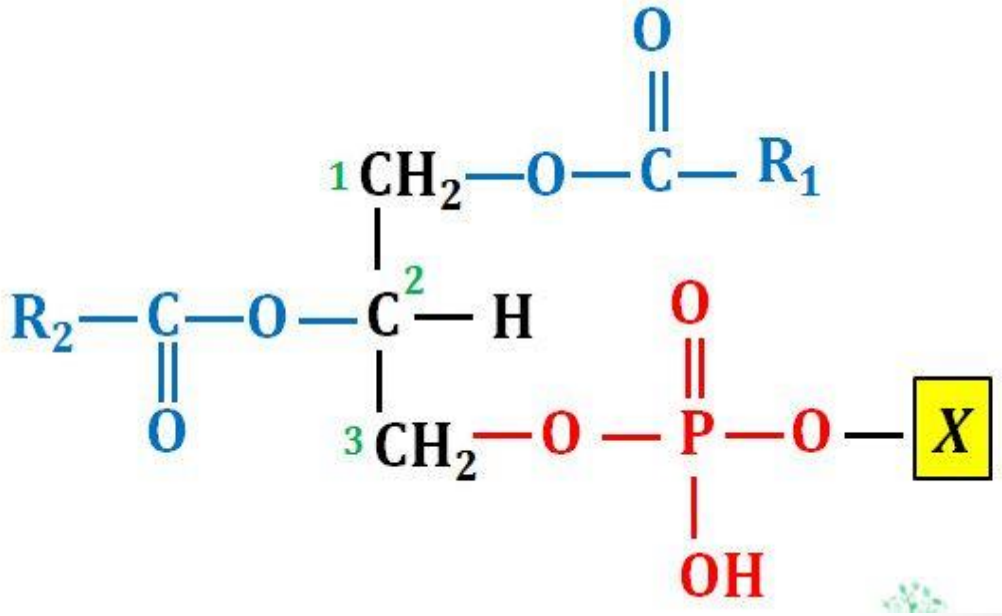
glycerol,

fatty acid,

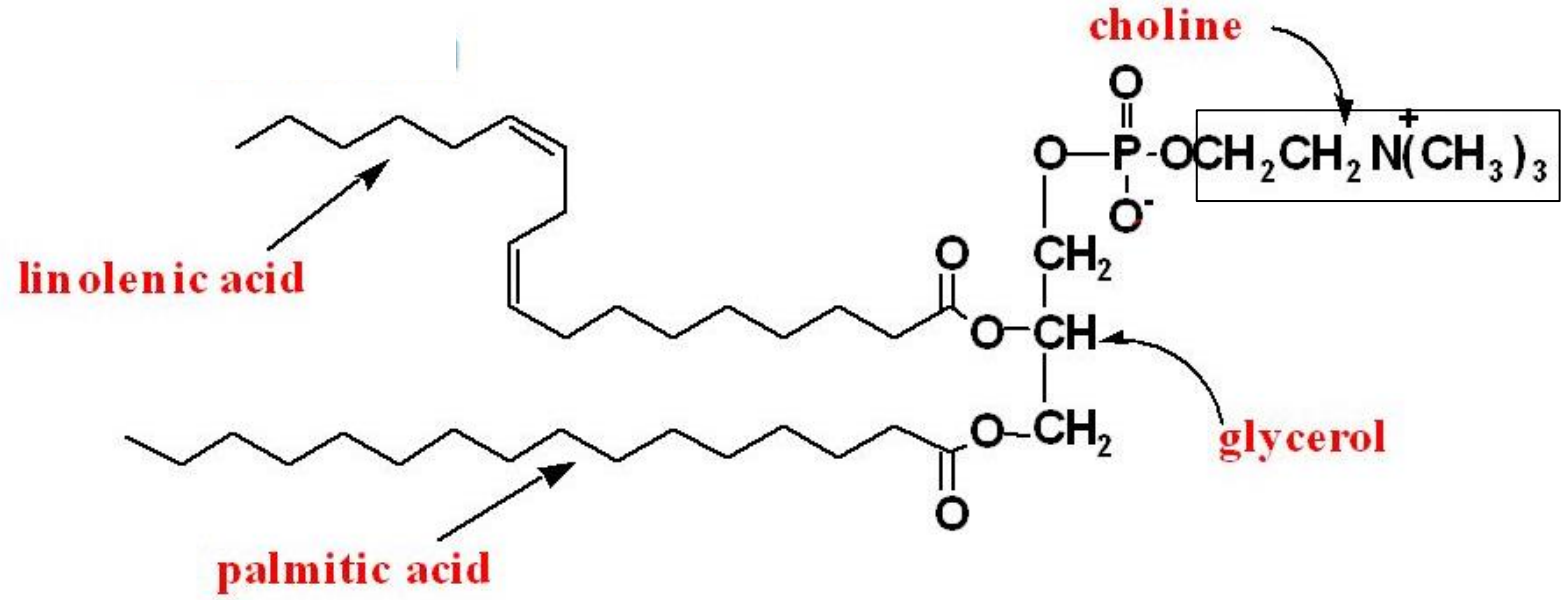
phosphoric acid,

amino alcohols

(ethanolamine or choline or the amino acid serine).



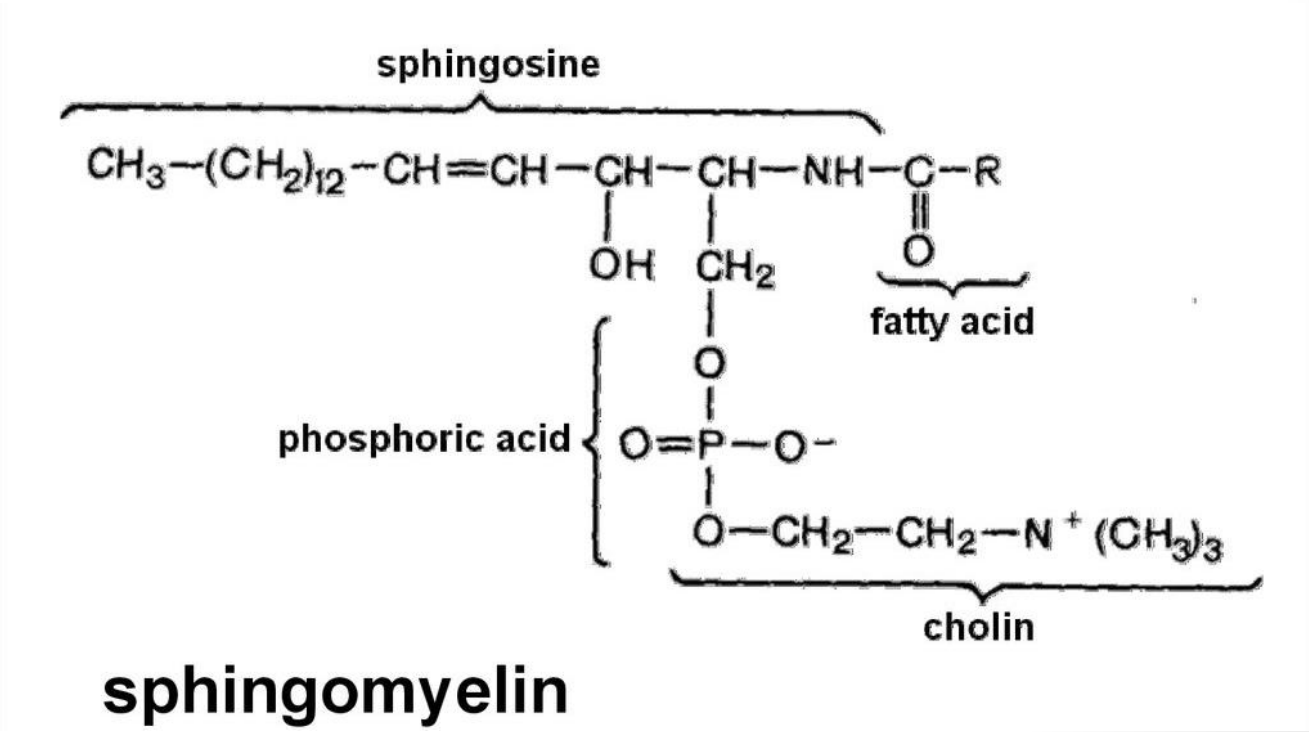
For example **Lecithin**



Lecithin is a biological cholesterol antagonist. It removes excess cholesterol in the blood from the body, helps to normalize weight (break down fat cells) and maintain vascular health.

SphingoPhospholipids

Main structural components: sphingosine, fatty acid, phosphoric acid, aminoalcohols ethanolamine or choline. *For example* **sphingomyelin. Sphingomyelin** is a type of sphingolipid found in animal cell membranes, especially in the membranous myelin sheath that surrounds some nerve cell axons.

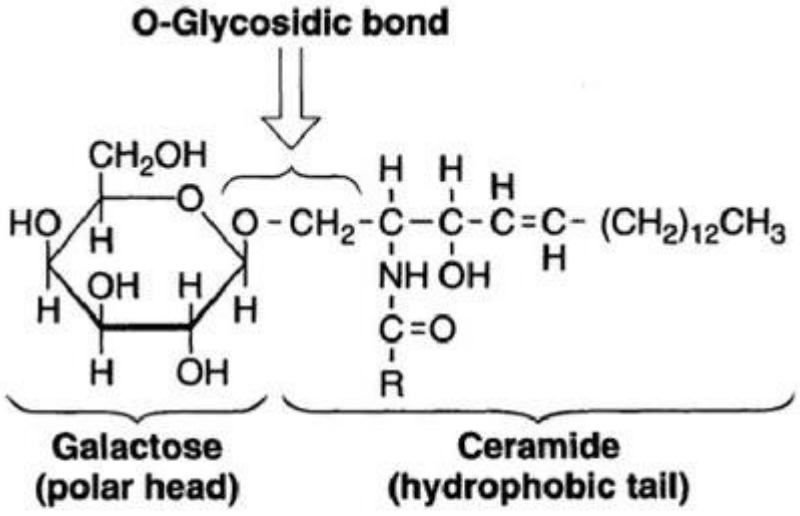


sphingomyelin

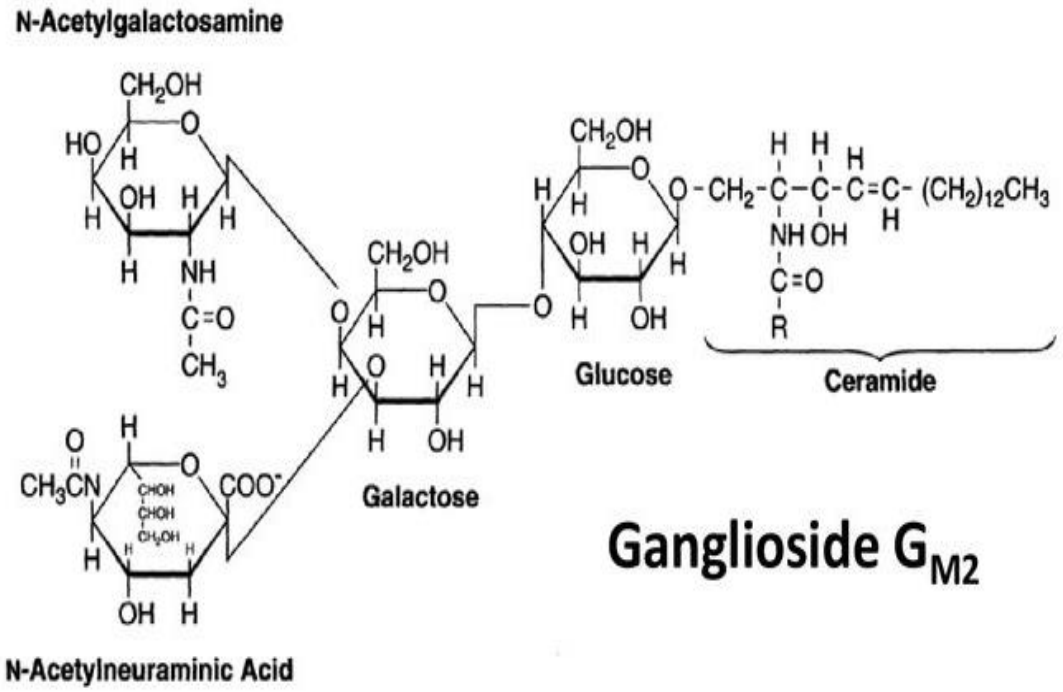
II Glycolipids

Glycolipids contain carbohydrate residues and do not contain phosphoric acid. The most important of these are glycosphingolipids.

Main structural components: sphingosine, a fatty acid, mono- or oligosaccharide.



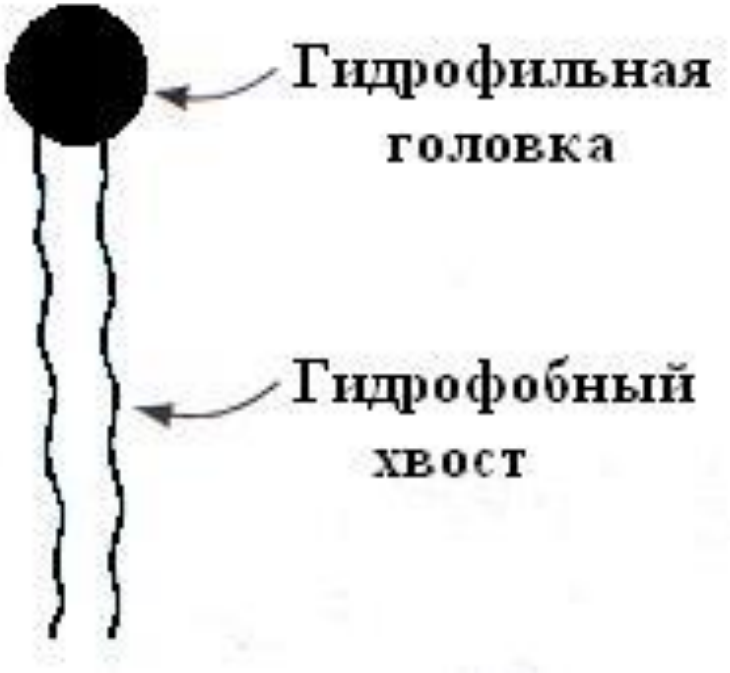
Galactocerebroside
(a glycosphingolipid)



Ganglioside G_{M2}

- Carbohydrate chains in glycolipid molecules perform a receptor function.
- They are involved in the processes of intercellular interaction, in contact inhibition of cell growth, in binding toxins and neutralizing poisons, in ensuring the immune activity of certain blood cells

- Molecules of phospholipids and glycolipids are *diphilic (amphiphilic)*. They contain a polar hydrophilic "head" (гидрофильная головка) and a non-polar hydrophobic "tail" (гидрофобный хвост).



- At physiological pH values, the hydrophilic part of the molecule is a bipolar ion.

non-polar hydrophobic "tail"

Гидрофобная часть (хвост)

Гидрофильная полярная часть (голова)

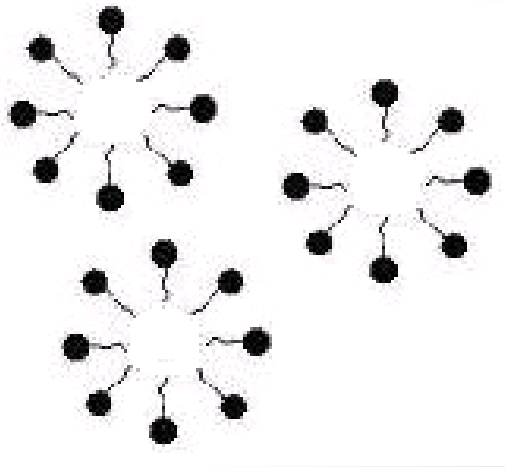
polar hydrophilic "head"

Фосфатидил этаноламин

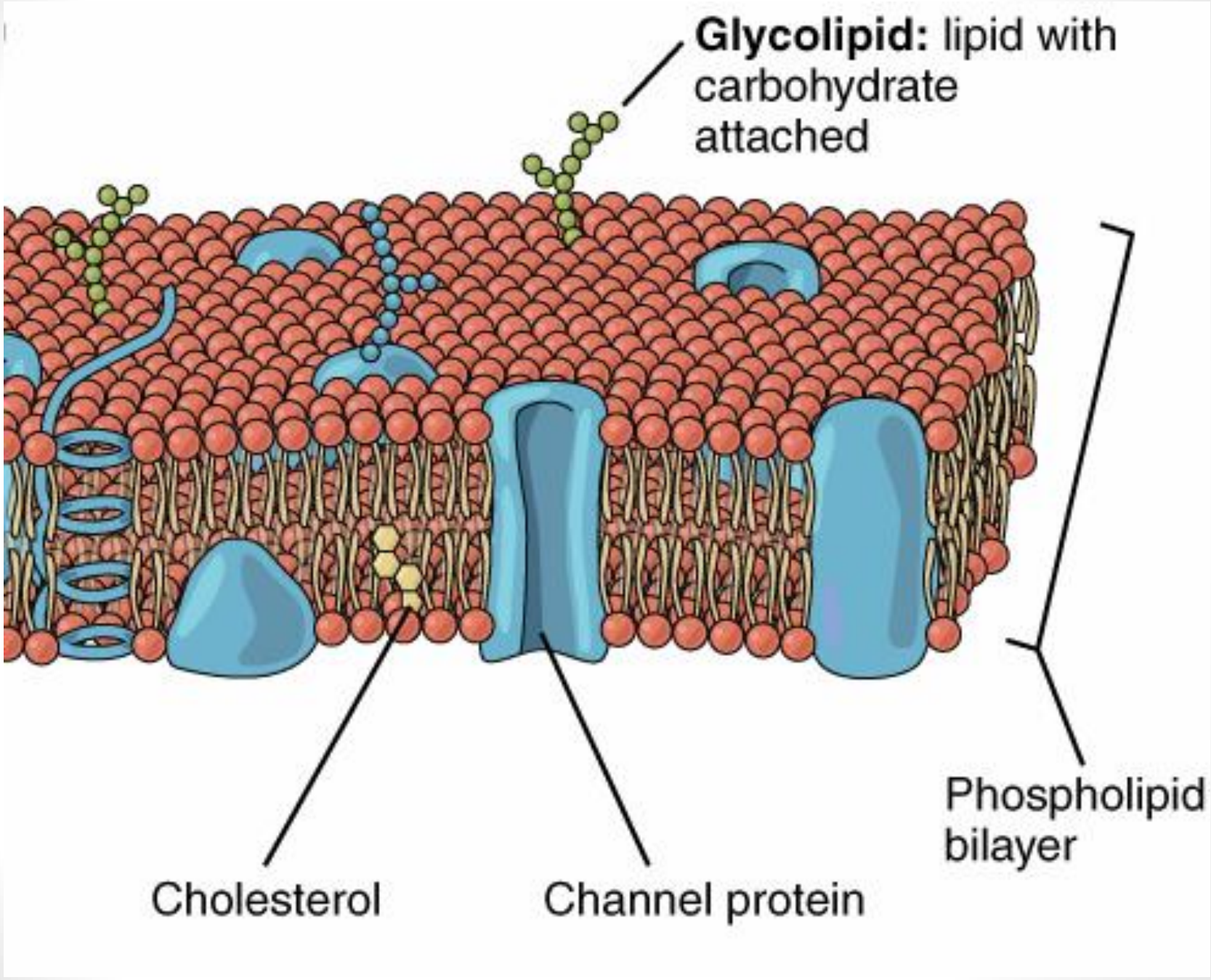
Сфингомиелин

Participation of phospholipids and glycolipids in the formation of cell membranes

- In an aqueous environment, amphiphilic molecules, at a certain concentration, easily associate with each other and form micelles, in which hydrophobic tails are located inside, and polar heads are outside (hydrophobic tails "hide" from water).
- Phospholipids form such micelles at very low concentrations. Moreover, they are more likely to form not micelles, but lipid double layers. Such layers are spontaneously formed due to hydrophobic interactions between individual phospholipid molecules (they are located "tail to tail")



- Glycerophospholipids and glycolipids are mainly involved in the formation of bilipid layer.
- The lipid bilayers formed in this way form the basis of all cell membranes.
- Bilipid cell membranes include protein molecules. The lipid: protein ratio in membranes varies from 1: 4 to 4: 1. Protein molecules can be located integrally or peripherally. The membranes are composed of complex proteins - glycoproteins.
- Lipids in membranes provide its property of impermeability to ions and many polar molecules (selective membrane permeability). Proteins, glycoproteins and glycolipids, by their carbohydrate components are responsible for the receptor properties of membranes.


Glycolipid: lipid with carbohydrate attached
Phospholipid bilayer
Cholesterol
Channel protein