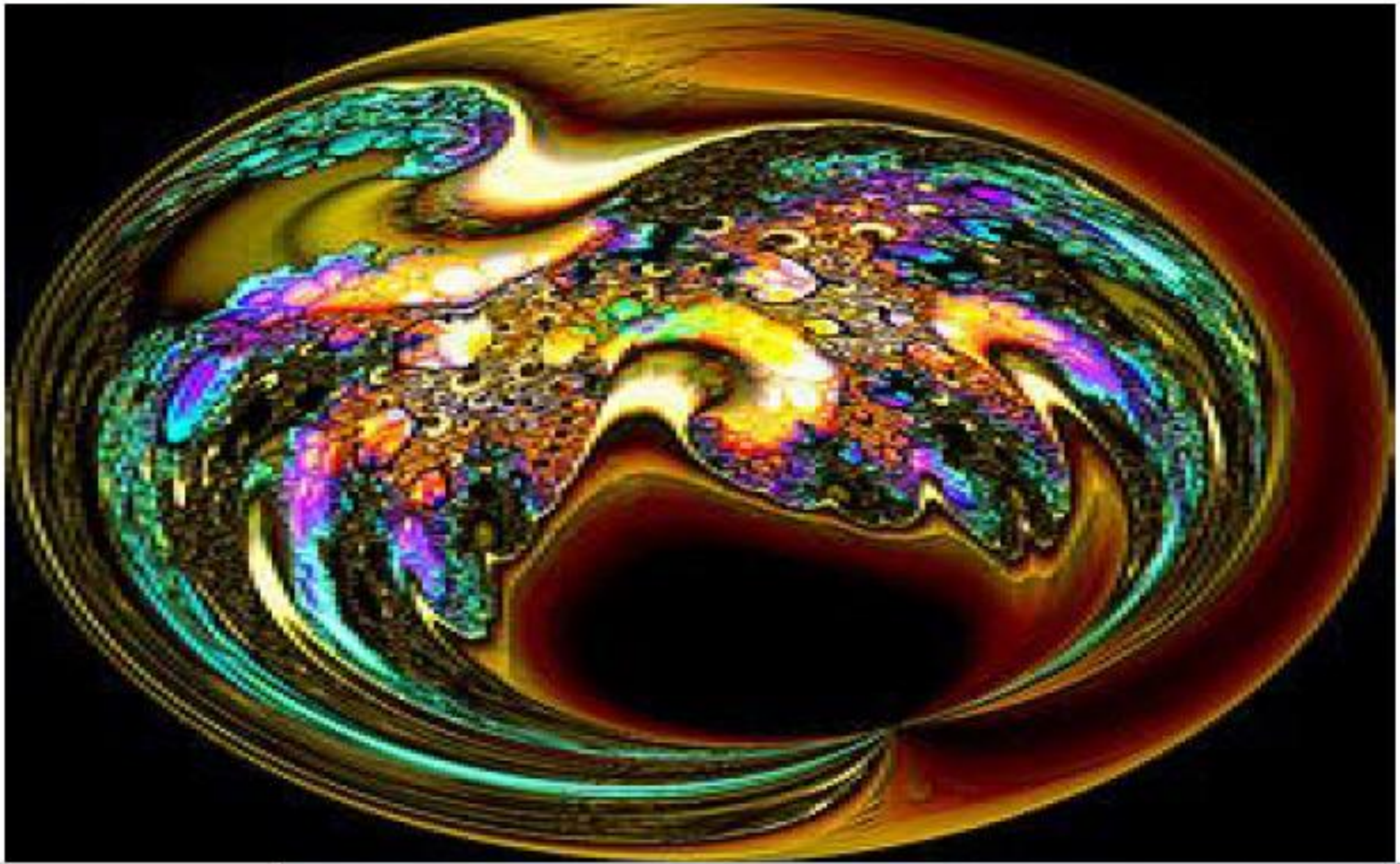
Lipids



LIPIDS

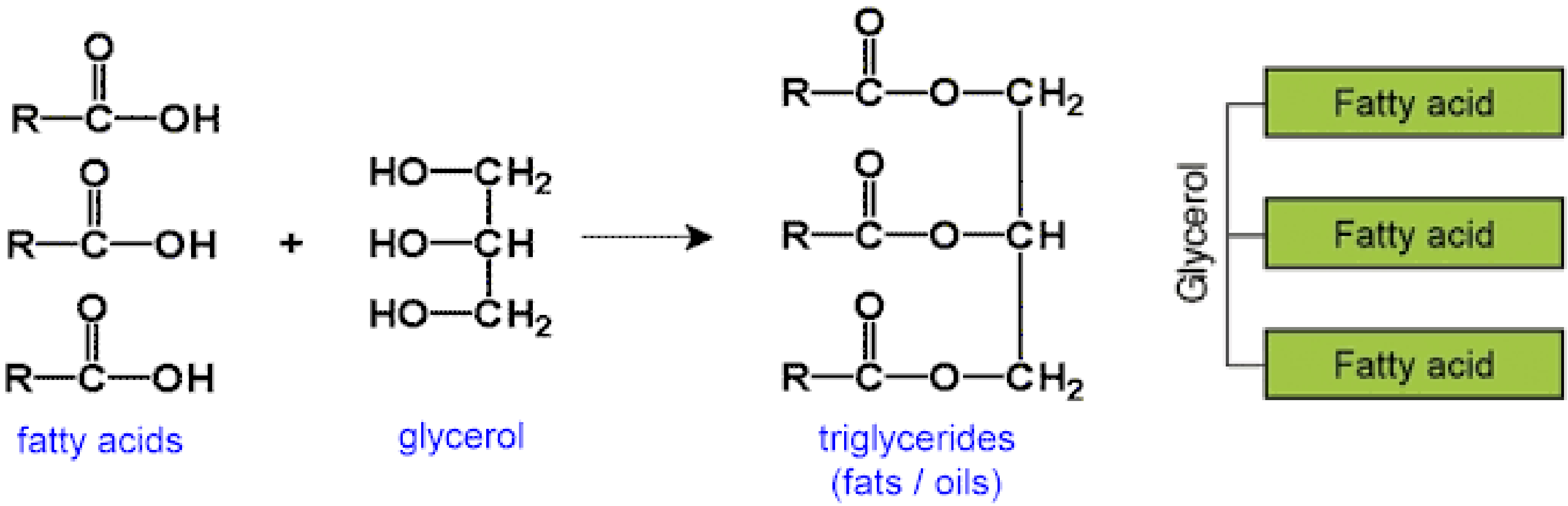
- Lipids are a diverse group of organic compounds
- Lipids contain carbon,hydrogen,oxygen,nitrogen and phosphorous
- Lipids are non-polar and hydrophobic compounds i.e insoluble in water
- They are easily soluble in organic solvents like ether, alcohol, chloroform, benzene etc
- Lipids store double the amount of energy as compared to carbohydrates and proteins because
- They contain high proportion of C-H bonds & very low oxygen as compared to carbohydrates and proteins
- Act as insulating layer e.g. waxes in exoskeleton of insects

Biomedical Importance

- Major source of energy for the body (High caloric value= 9.3 cal/g)
- Important dietary constituent, fat soluble vitamins & essential fatty acid are contained in the fat of natural food
- Fat is stored in adipose tissue
- Serve as thermal insulator in subcutaneous tissues & around certain organs
- Act as electrical insulator, allowing rapid propagation of depolarization waves along myelinated nerves
- Combination of lipid & protein (LP) serve as the means of transporting lipid in blood

LIPIDS

- Lipids are esters of **fatty acids with alcohol**



"R" group is made up of hydrocarbon chains

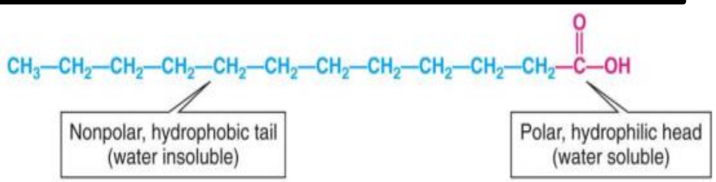
What are fatty acids and its types?

Fatty Acids

carboxylic acid group (COOH)
joined to a long tail of
carbon and hydrogen atoms

The **length** of the **hydrocarbon tail** varies, giving rise to the various fatty acids.

The tail is normally written as **R**, giving the formula **R.COOH**



Saturated fatty acid (no double bonds)

- Butyric acid: CH3-CH2-CH2-COOH
- Caprylic acid: CH3(CH2)8 COOH
- Palmitic acid:CH3(CH2)14 COOH
- Stearic acid: CH3(CH2)16 COOH

Unsaturated fatty acid

1. Monounsaturated fatty acid (single double bond)

a.) oleic acid: C18 H34 O2
b.) palmitolic acid: C16 H30 O2

2. Polyunsaturated fatty acid (more than one double bond)

a.) linolic acid: C18 H32 O2
b.) eleostearic acid: C18 H30 O2
c.) arachidonic acid: C20 H32 O2

- Properties
  - Saturated fatty acids are solid at room temperature and have a high melting point
  - Unsaturated fatty acids are liquid at room temperature and have a low melting point

PUFA & MUFA

Fatty acids types

- Two types of fatty acids
- 1. Saturated fatty acids:
- These fatty acids have no double bonds between carbon atoms
- Can't accommodate any more hydrogen atoms
- Solid at room temperature
- Stored in animals as fats. Example is Palmatic acid (16-C)
- Unsaturated fatty acids:
- They have one or more double bonds between carbon atoms.(C=C)
- Accommodate any more hydrogen atoms
- Liquid at room temperature
- Stored in plant seeds. Example is Oleic acid (18-C)

Physical properties of fatty acids

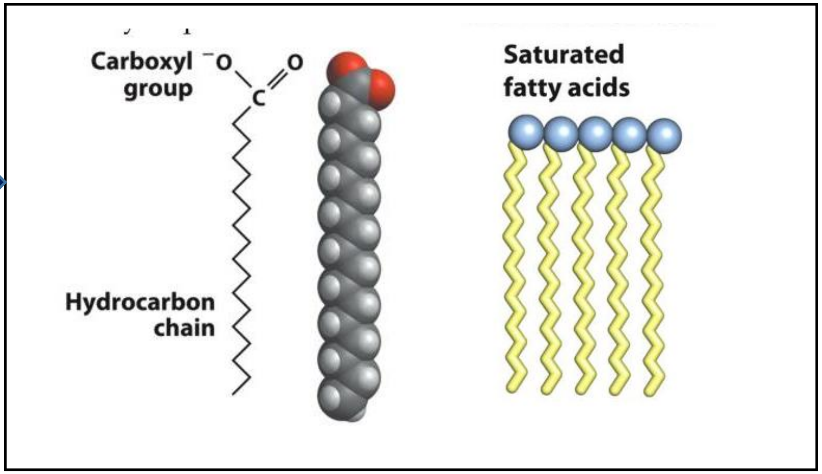
The physical properties of the fatty acids, and of compounds that contain them, are largely determined by the length and degree of unsaturation of the hydrocarbon chain.

A. The nonpolar hydrocarbon chain accounts for the poor solubility of fatty acids in water. Solubility decreases:
   - With longer fatty acyl chain
   - With fewer double bonds

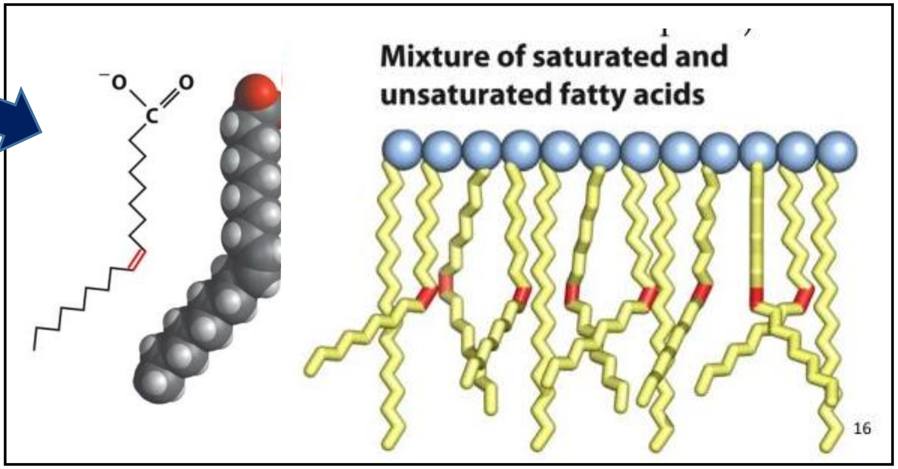
B. Melting points are also strongly influenced by:
   - The length of the hydrocarbon chain
     ↑ length, ↑ melting point
   - Degree of unsaturation
     ↑ unsaturation, ↓ melting point

Why saturated fatty acids are solid and have high melting point than unsaturated fatty acids?

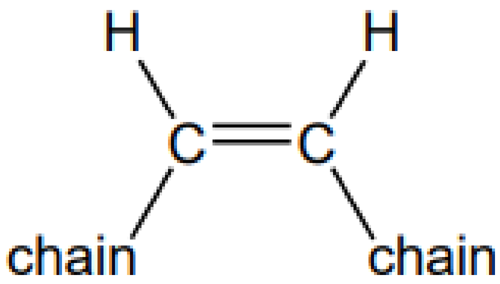
- Hydrocarbon chains of saturated fatty acids can lie parallel with strong dispersion forces between their chains; they pack into well-ordered, compact crystalline forms and melt above room temperature.



- Because of the *cis* configuration of the double bonds in unsaturated fatty acids, their hydrocarbon chains have a less ordered structure and dispersion forces between them are weaker; these triglycerides have melting points below room temperature.



- Requires less thermal energy to disrupt (lower melting point)



Some chemistry of common fatty acids

#C's	Name	Formula	MP	Common Sources
Saturated				
14	Myristic acid	$CH_3(CH_2)_{12}COOH$	54°C	Butterfat, coconut oil, nutmeg oil
16	Palmitic acid	$CH_3(CH_2)_{14}COOH$	63°C	Lard, beef fat, butterfat, cottonseed oil
18	Stearic acid	$CH_3(CH_2)_{16}COOH$	70°C	Lard, beef fat, butterfat, cottonseed oil
20	Arachidic acid	$CH_3(CH_2)_{18}COOH$	76°C	Peanut oil
Monounsaturated				
16	Palmitoleic acid	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$	-1°C	Cod liver oil, butterfat
18	Oleic acid	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	13°C	Lard, beef fat, olive oil, peanut oil
Polyunsaturated				
18	Linoleic acid	$CH_3(CH_2)_4(CH{=}CHCH_2)_2(CH_2)_6COOH$	-5°C	Cottonseed oil, soybean oil, corn oil, linseed oil
18	Linolenic acid	$CH_3CH_2(CH{=}CHCH_2)_3(CH_2)_6COOH$	-11°C	Linseed oil, corn oil
20	Arachidonic acid	$CH_3(CH_2)_4(CH{=}CHCH_2)_4(CH_2)_2COOH$	-50°C	Corn oil, linseed oil, animal tissues

What patterns do you observe?

Lipids classification

Simple lipids

They are esters of fatty acids with glycerol.

1. **True fats and oil** (alcohol is glycerol)- also called as glycerides

2. **Waxes** (alcohol is other than glycerol. Example is beeswax)

Conjugated or compound lipids or complex lipids

They are esters of fatty acids with glycerol or other alcohol and other groups

1. Glycerophospholipids

2. Sphingophospholipids

3. Sphingoglycolipids

4. Lipoproteins

Derived lipids

They are obtained on hydrolysis of simple and complex lipids

1. Cholesterol

2. Retinol

3. Steroids

4. Hormones

5. Fat soluble vitamins

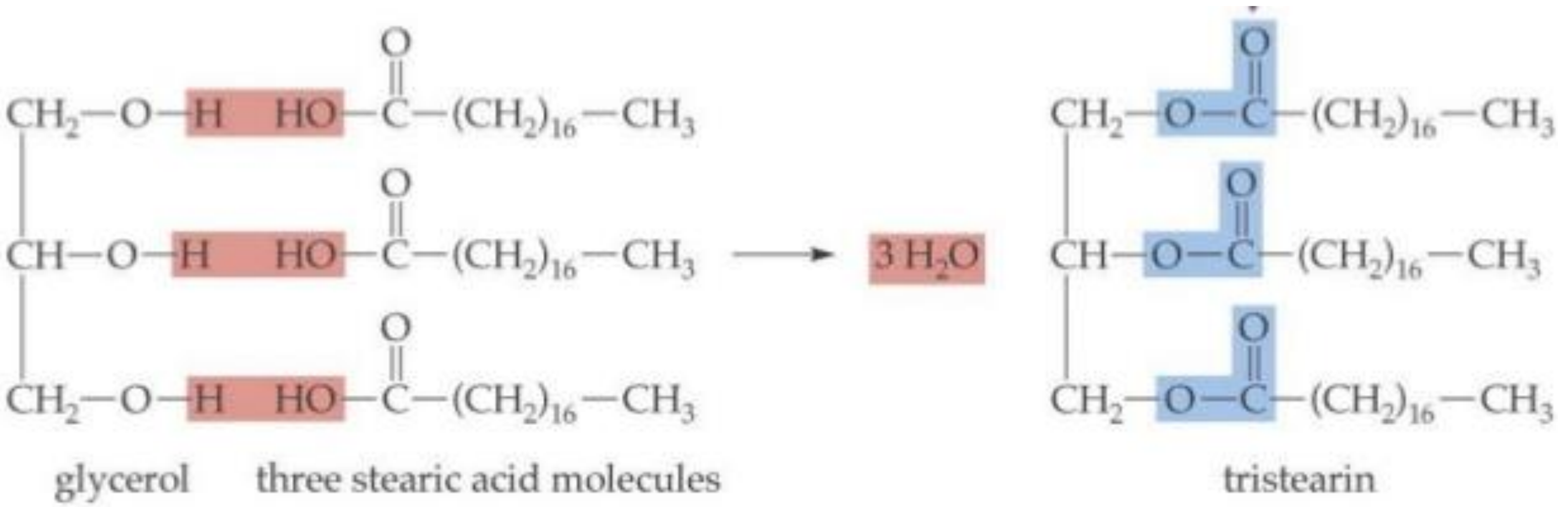
6. Ketone bodies

Simple Lipids

- Animal fats and vegetable oils are esters composed of three molecules of a fatty acid connected to a glycerol molecule, producing a structure called a **triglyceride** or a **triacylglycerol**:

Fats – also known as triglyceride or triacylglycerol

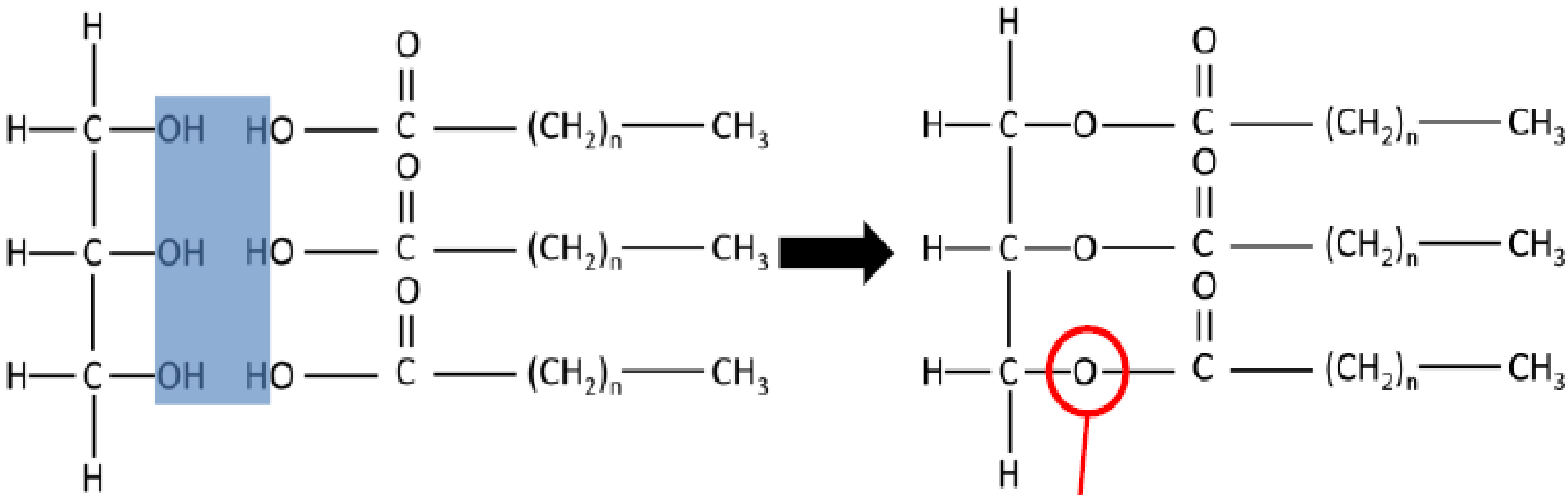
Example: Tristearin (3 molecules of stearic acid + one molecule of glycerol).



Tristearin

Triglycerides formation

Condensation reaction between glycerol and fatty acids



Glycerol

Three Fatty Acids

Triglyceride

\+ $3H_2O$

Lipids are glycerol combined with 1, 2 or 3 fatty acids, therefore **triglycerides are lipids**

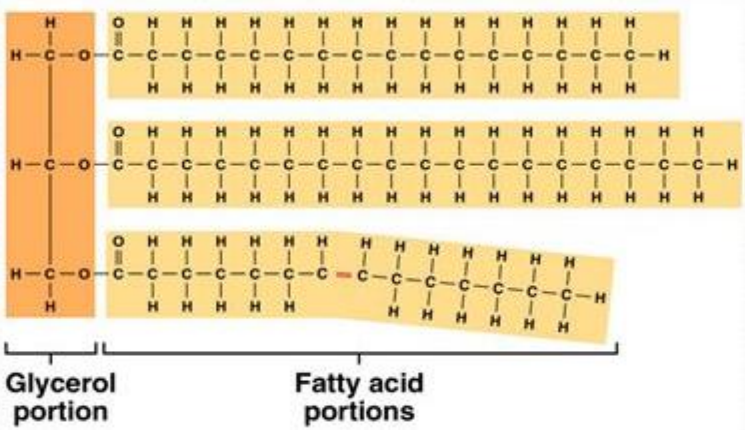
__n.b. hydrolysis__ is the reverse of this process, catalysed by lipase

Covalent bonds called ester bonds are formed between the fatty acids and glycerol molecules.

- *Oils*: Triglycerides rich in unsaturated fatty acids are generally liquid at room.
- *Fats*: Triglycerides rich in saturated fatty acids are generally semisolids or solids at room temperature.

- **Fats & Oils (triglycerides)- long term energy storage**

- Fat has twice the calories of carbohydrates.
  - fat = 9 cal/g   sugar= 4 cal/g



Health tip:

Saturated or hydrogenated fats(bad) vs. unsaturated (good)

Conjugated lipids

- **Conjugated or compound lipids or complex lipids**
- **Esters of fatty acids with either glycerol and/or other alcohol and other groups**

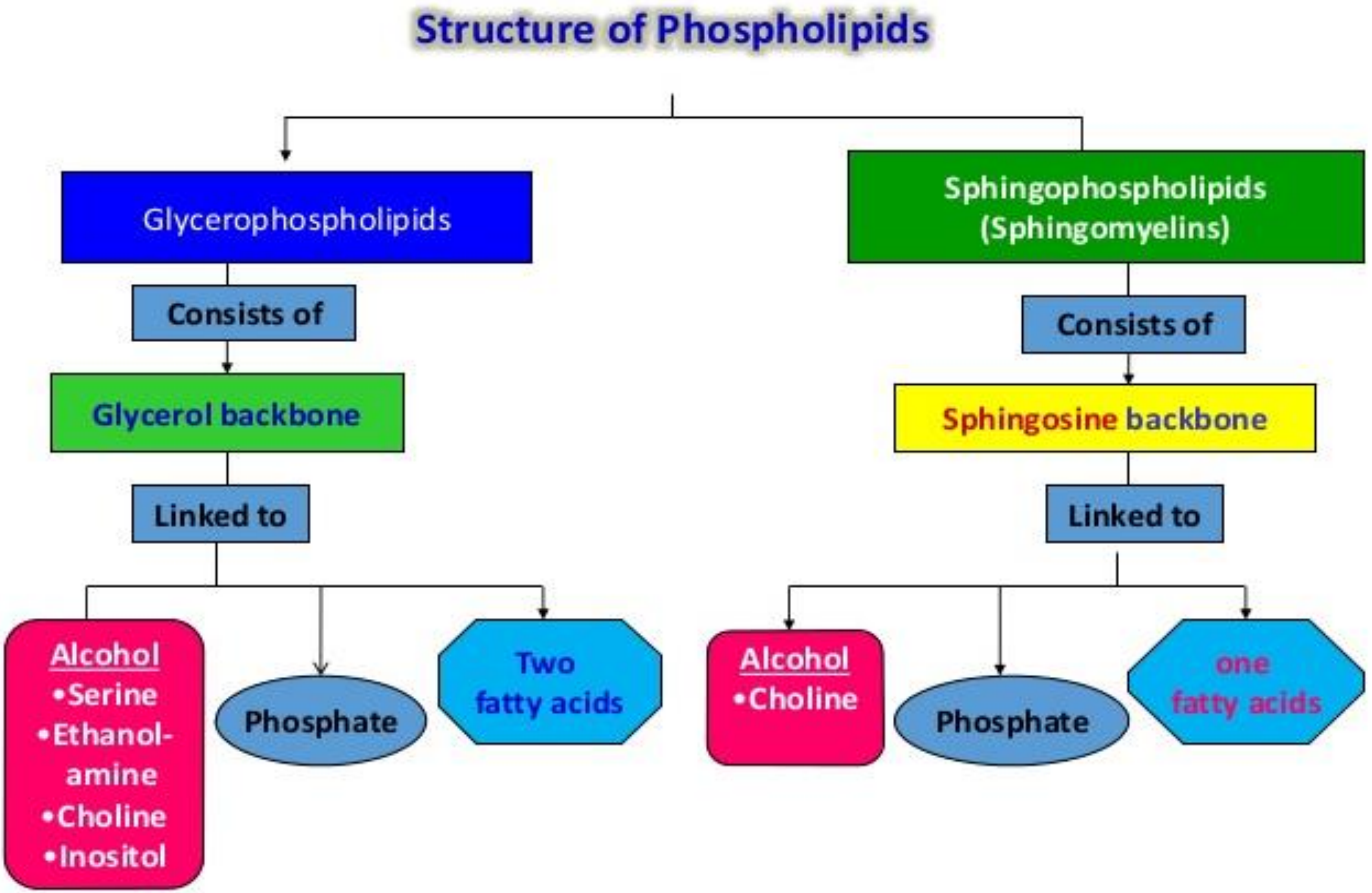
1. **Glycerophospholipids**
2. **Sphingophospholipids**
3. **Sphingoglycolipids**
4. **Lipoproteins**

Phospholipids

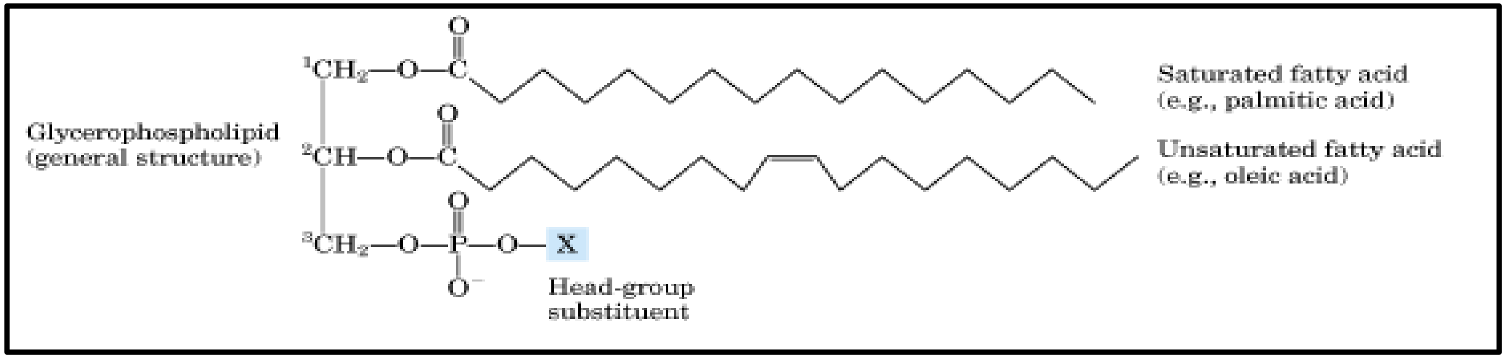
Phospholipids

- A class of lipids that are a major component of all cell membranes as they can form lipid bilayers.
- Composition: phospholipids are composed of
- i. Glycerol: one molecule
- ii. Fatty acids :Two molecules
- iii. Phosphoric acid: one molecule
- When a nitrogen containing group is attached with phosphate end of phospholipids, it is known as Phosphatidyl Choline.
- Phospholipids have two parts
- i) Head:
- Head is polar in nature, Soluble in water (Hydrophilic).
- ii) Tails:
- Tail is non-polar in nature, insoluble in water (Hydrophobic)

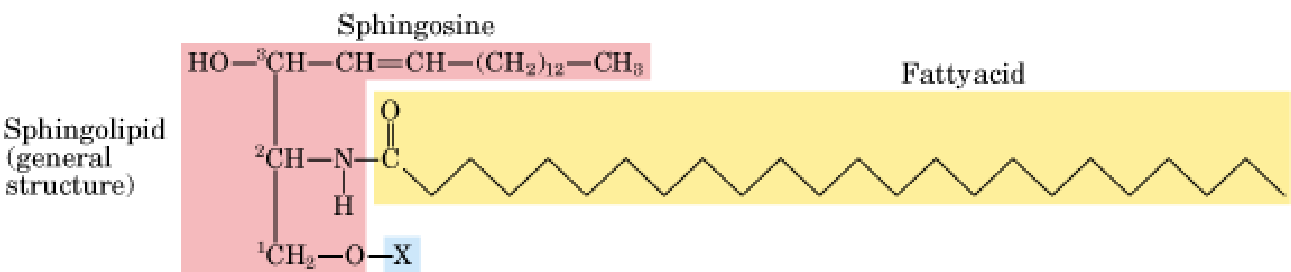
Phospholipids

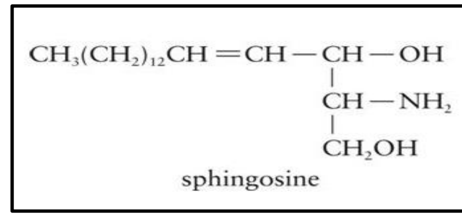


Structure of glycerophospholipid

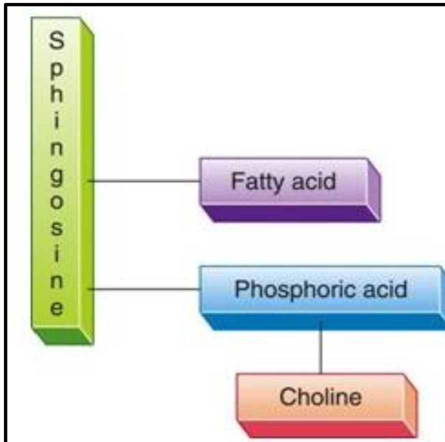


Structure of sphingophospholipid

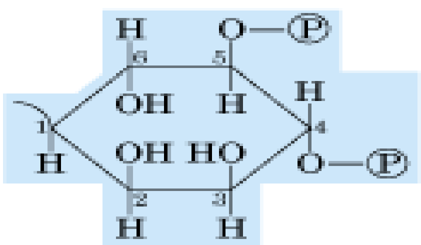
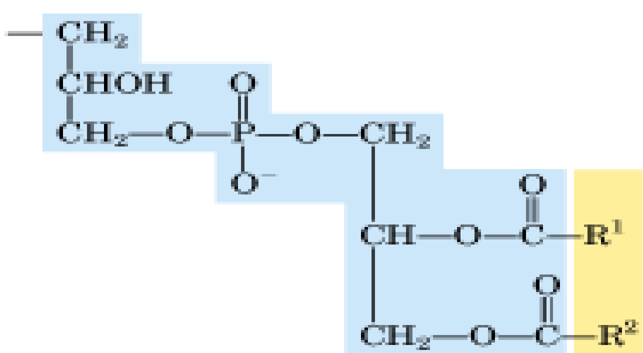




Name of sphingolipid	Name of X	Formula of X
Ceramide	—	— H
Sphingomyelin	Phosphocholine	$-\mathrm{P}(=\mathrm{O})(\mathrm{O}^-)-\mathrm{O}-\mathrm{CH_2}-\mathrm{CH_2}-\overset{+}{\mathrm{N}}(\mathrm{CH_3})_3$



Examples of glycerophospholipids

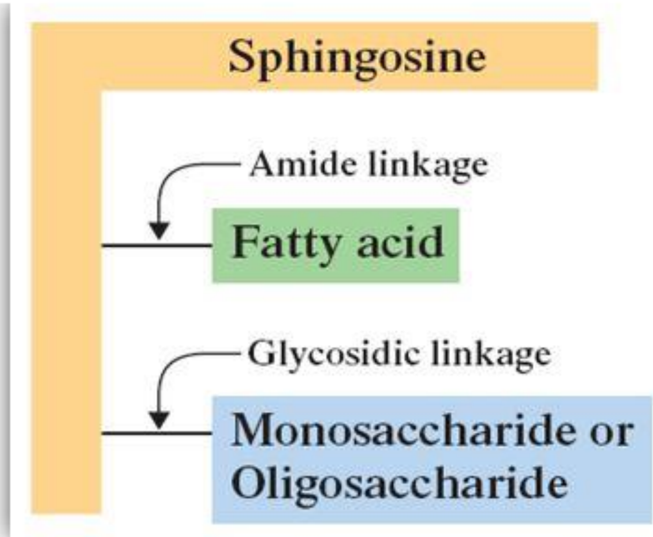
Name of glycerophospholipid	Name of X	Formula of X	Net charge (at pH 7)
Phosphatidic acid	—	$-H$	−1
Phosphatidylethanolamine	Ethanolamine	$-CH_2-CH_2-\overset{+}{N}H_3$	0
Phosphatidylcholine	Choline	$-CH_2-CH_2-\overset{+}{N}(CH_3)_3$	0
Phosphatidylserine	Serine	$-CH_2-\underset{\Large COO^-}{CH}-\overset{+}{N}H_3$	−1
Phosphatidylglycerol	Glycerol	$-CH_2-\underset{\Large OH}{CH}-CH_2-OH$	−1
Phosphatidylinositol 4,5-bisphosphate	*myo*-Inositol 4,5-bisphosphate		−4
Cardiolipin	Phosphatidyl-glycerol		−2

Sphingoglycolipids

Or Glycolipids

Cerebrosides
(Monosaccharide)

Gangliosides
(Oligosaccharide)



are carbohydrate-containing ceramide derivatives
(in the outer face of plasma membranes)

Glycosphingolipids at the cell surface are sites of recognition.

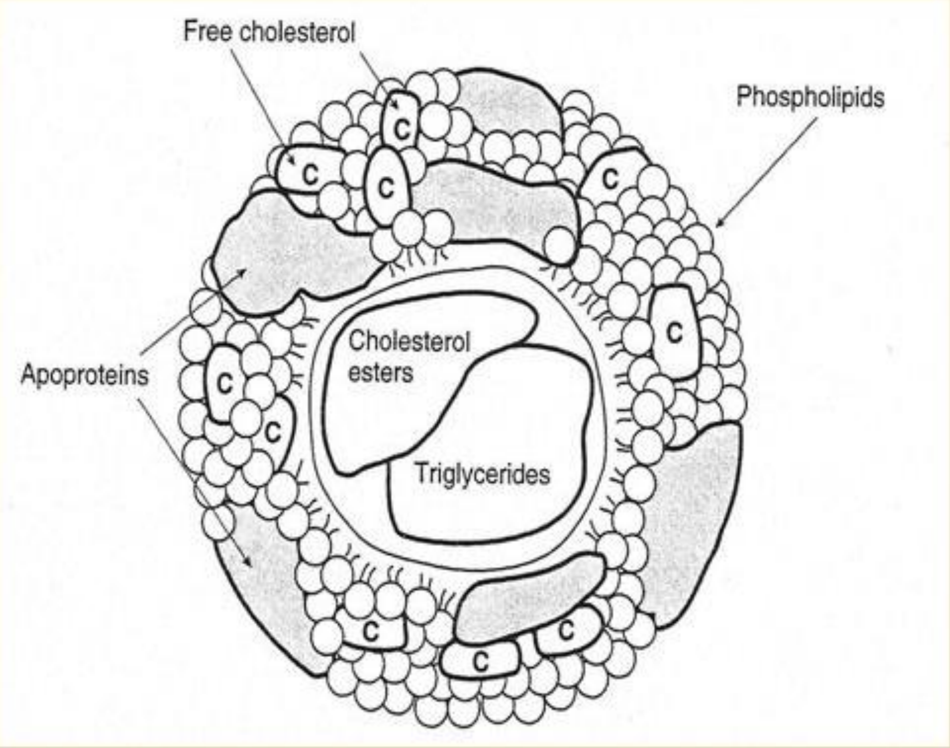
They found mainly in the myelin sheath and cell membrane of RBCs.
They act as cell membrane receptors for hormones and external stimuli.
They provide recognition properties.

Lipoproteins

All the lipids contained in plasma, including fat, phosphalipids, cholesterol, cholesterol ester and fatty acid, exist and transport in the form of lipoprotein

Structure

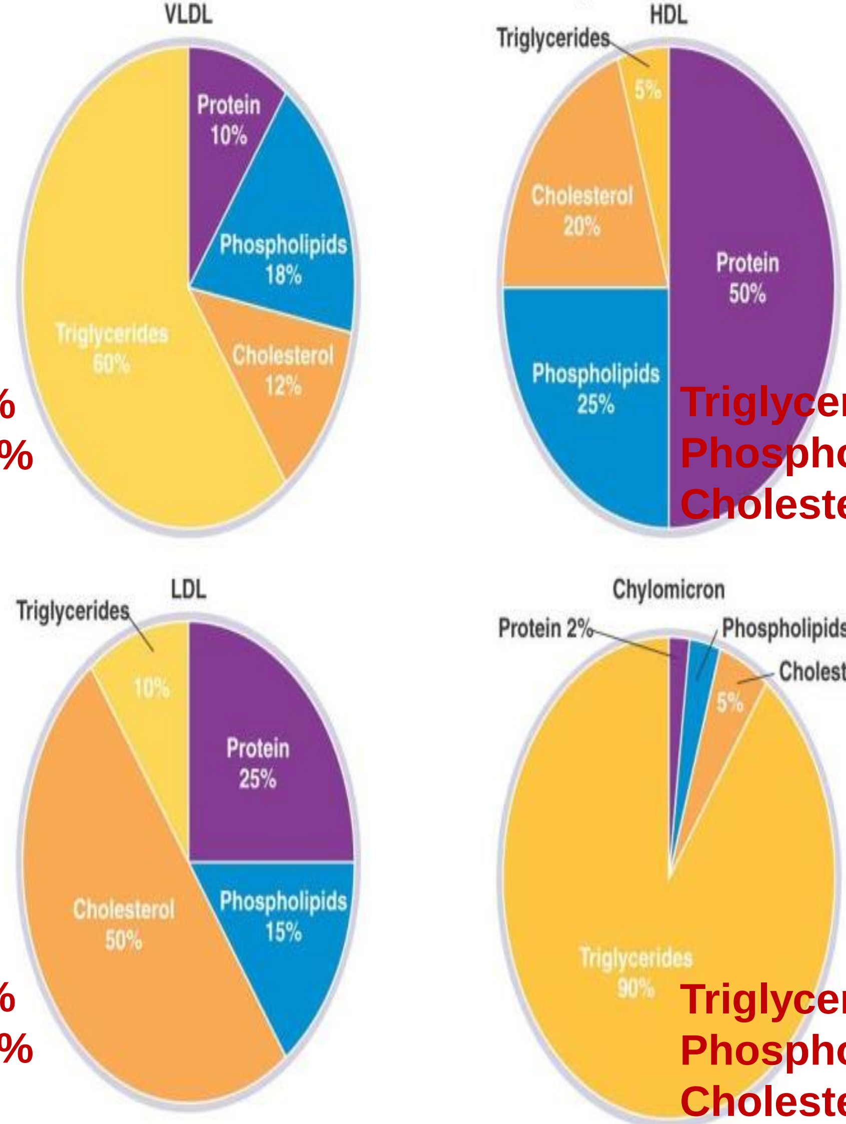
- Non-covalent assemblies of lipids and proteins
- LP core
  - Triglycerides
  - Cholesterol esters
- LP surface
  - Phospholipids
  - Proteins
  - cholesterol



Function as transport vehicles for triacylglycerols and cholesterol in the blood

The Various Types of Lipoproteins and Their Composition

- There are various types of lipoproteins:
  - They differ in lipid and protein composition, therefore they differ in: Size, density and apoprotein content



Triglycerides: 60%
Phospholipids:18%
Cholesterol: 12%

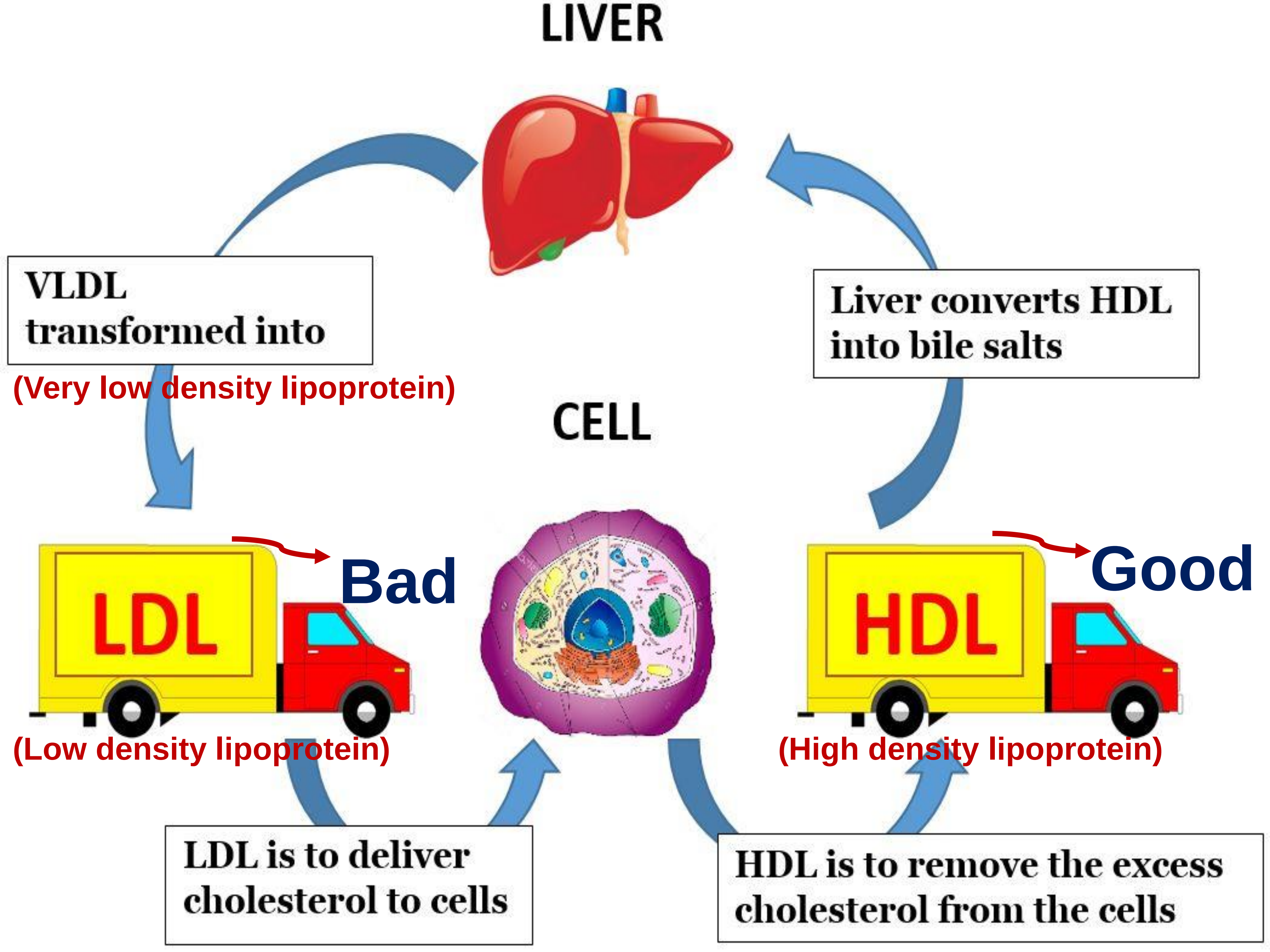
Triglycerides: 5%
Phospholipids:25%
Cholesterol: 20%

- They are:

Chylomicrons (CM)
Very low density Lipoprotein VLDL)
Low density Lipoprotein (LDL)
High density Lipoprotein (HDL)

Triglycerides: 10%
Phospholipids:15%
Cholesterol: 50%

Triglycerides: 90%
Phospholipids:3%
Cholesterol: 5%

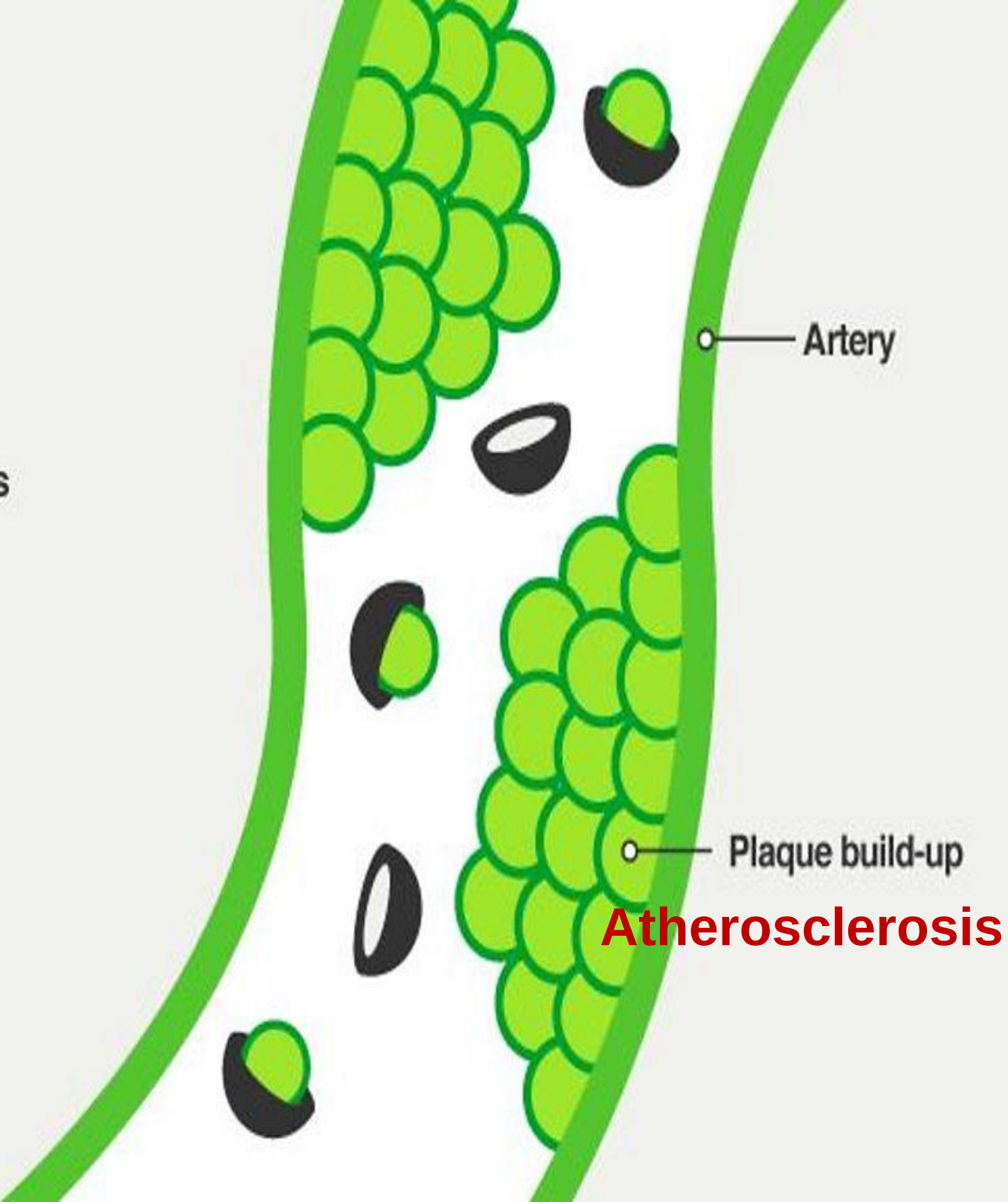

LIVER
VLDL transformed into
(Very low density lipoprotein)
Liver converts HDL into bile salts
CELL
LDL
Bad
HDL
Good
(Low density lipoprotein)
(High density lipoprotein)
LDL is to deliver cholesterol to cells
HDL is to remove the excess cholesterol from the cells

Bad cholesterol

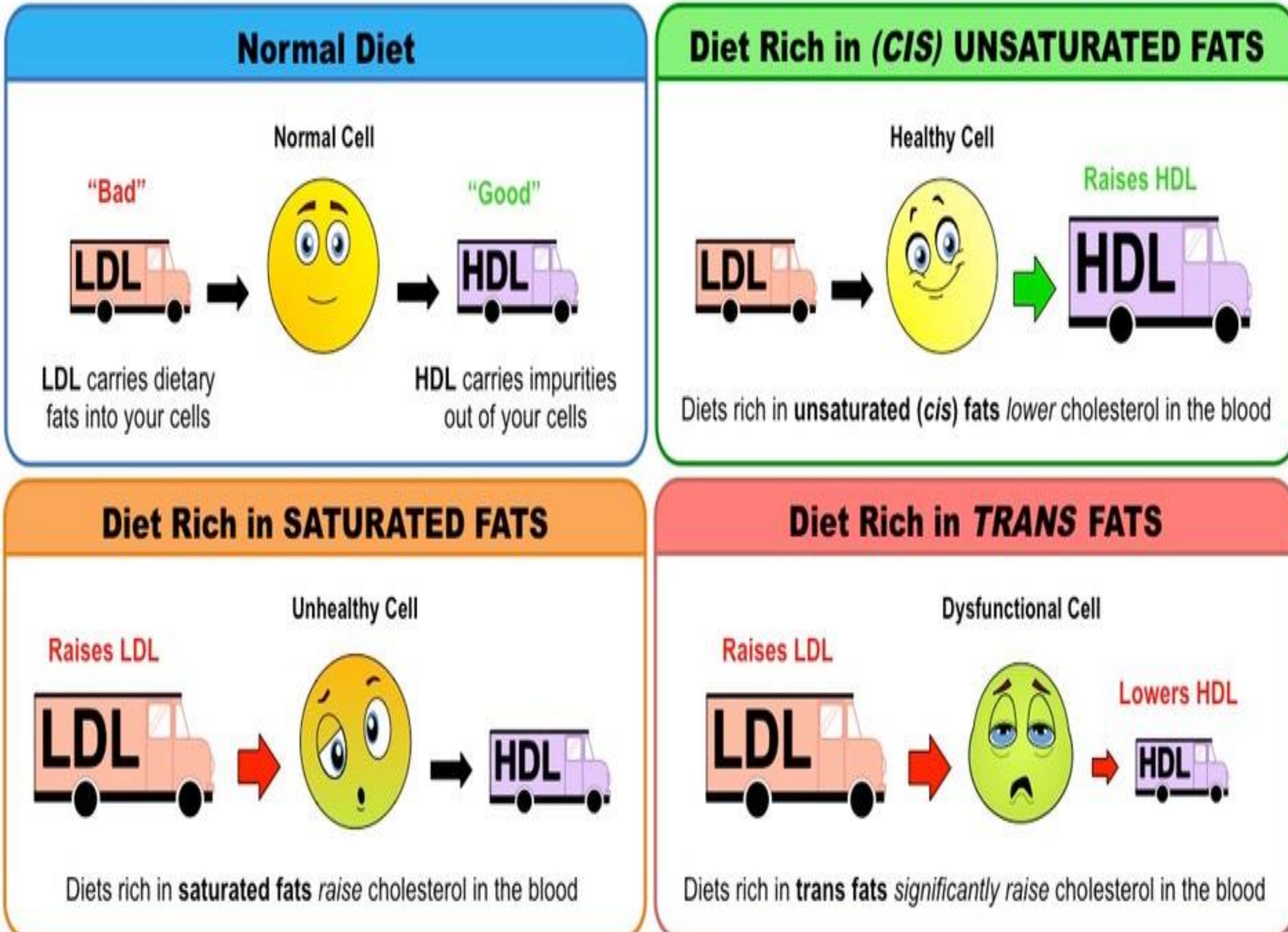
LDL (Low-density lipoproteins)
Sticks to artery walls and causes plaque build-up, narrowing arteries

Good cholesterol

HDL (High-density lipo-proteins)
Carries bad cholesterol to the liver for disposal and stops it building up in arteries



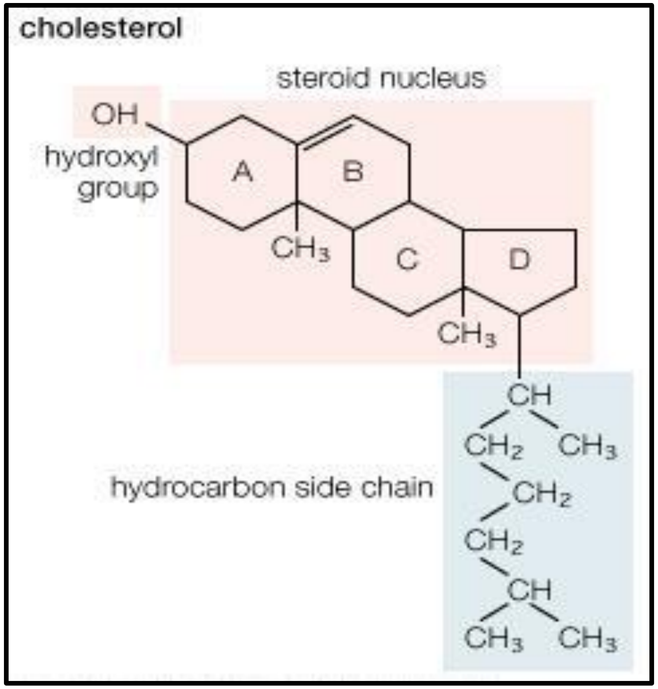
Atherosclerosis

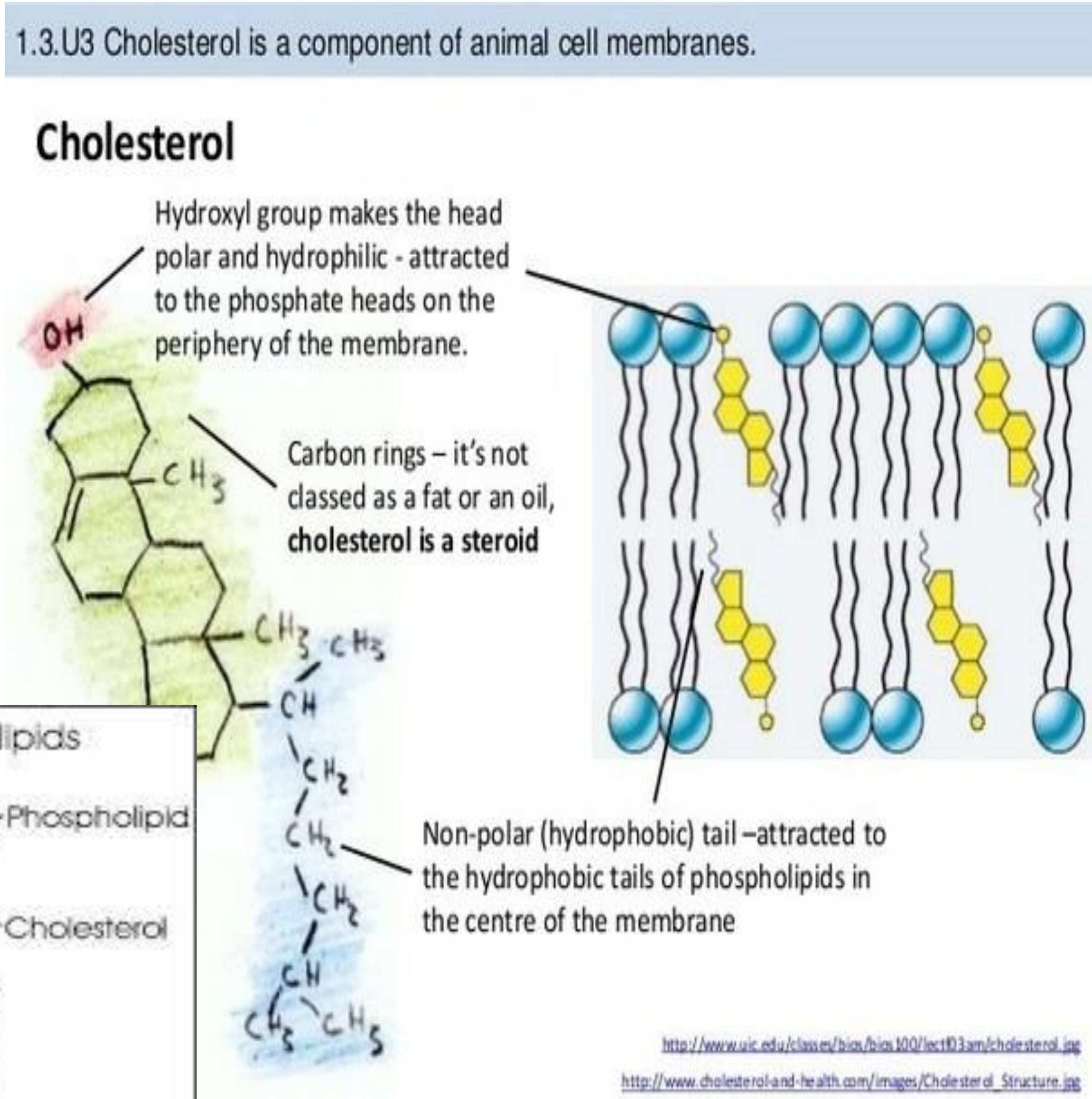

Normal Diet
Normal Cell
"Bad"
LDL
"Good"
HDL
LDL carries dietary fats into your cells
HDL carries impurities out of your cells
Diet Rich in (CIS) UNSATURATED FATS
Healthy Cell
Raises HDL
LDL
HDL
Diets rich in unsaturated (cis) fats lower cholesterol in the blood
Diet Rich in SATURATED FATS
Unhealthy Cell
Raises LDL
LDL
HDL
Diets rich in saturated fats raise cholesterol in the blood
Diet Rich in TRANS FATS
Dysfunctional Cell
Raises LDL
LDL
Lowers HDL
HDL
Diets rich in trans fats significantly raise cholesterol in the blood

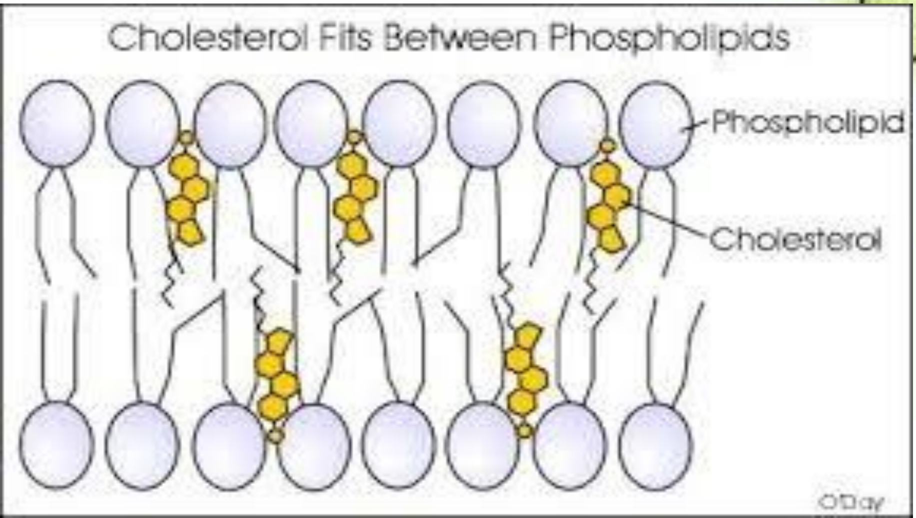
Derived lipids—Steroids

- **Steroids** are lipids characterized by a carbon skeleton consisting of four fused rings
- **Cholesterol**, an important steroid, is a component in animal cell membranes
- Although cholesterol is essential in animals, high levels in the blood may contribute to cardiovascular disease

Cholesterol –a derived lipid



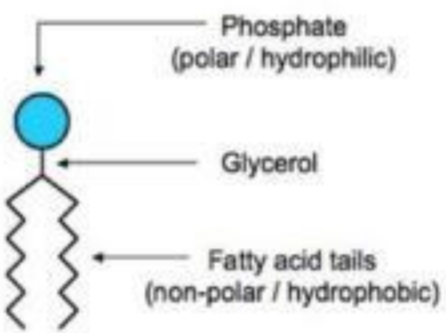




Functions of Cholesterol

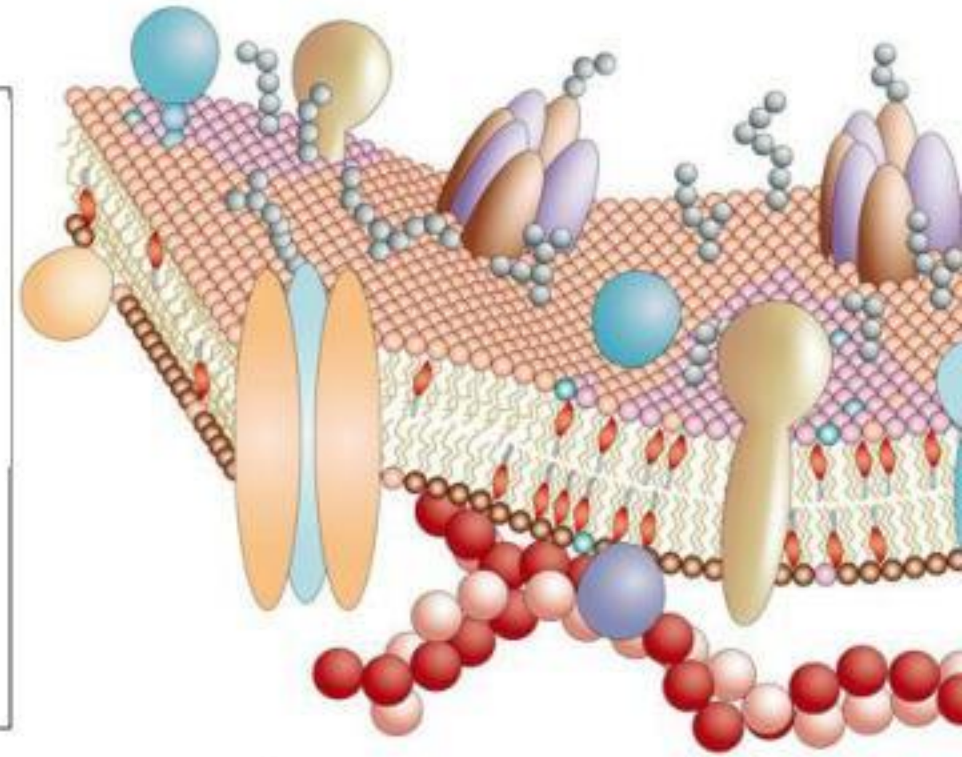
Cholesterol in mammalian membranes reduces membrane fluidity and permeability to some solutes.

Membrane fluidity



The hydrophobic hydrocarbon tails usually behave as a liquid. Hydrophilic phosphate heads act more like a solid.

Though it is difficult to determine whether the membrane is truly either a solid or liquid it can definitely be said to be fluid.



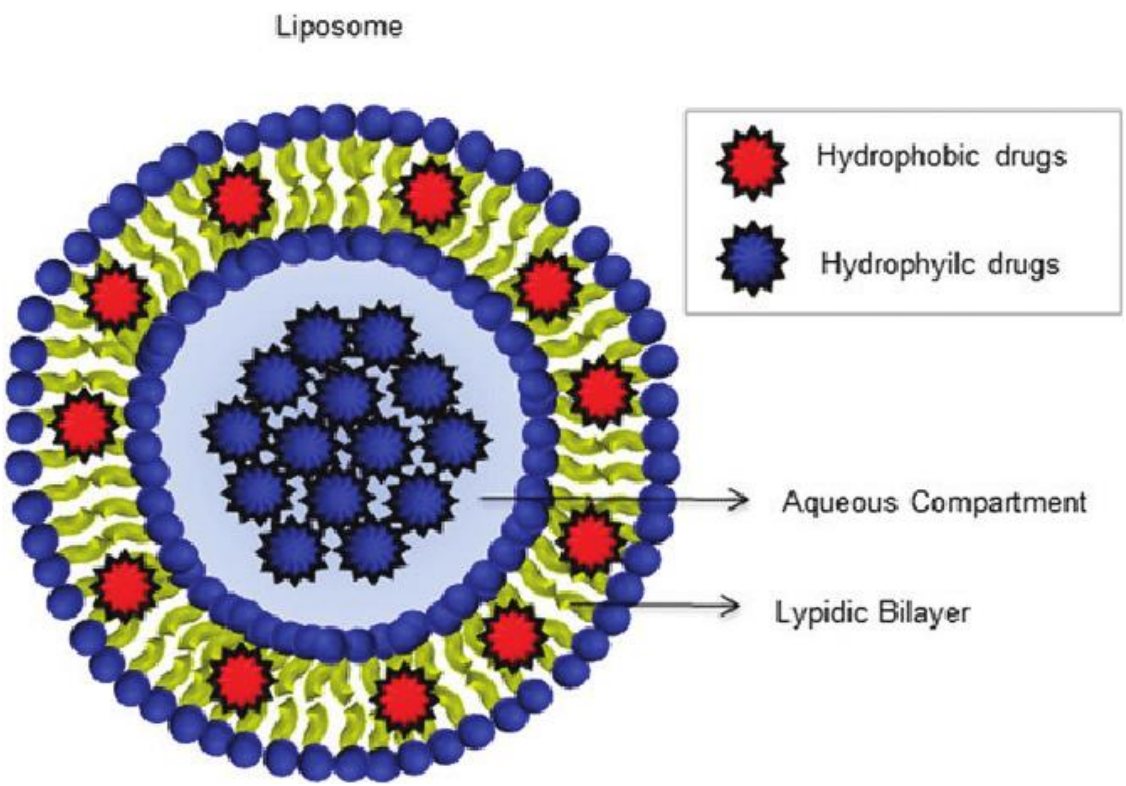
It is important to regulate the degree of fluidity:

- Membranes need to be fluid enough that the cell can move
- Membranes need to be fluid enough that the required substances can move across the membrane
- If too fluid however the membrane could not effectively restrict the movement of substances across itself

http://www.nature.com/scitable/content/ne0000/ne0000/ne0000/ne0000/14668965/U2.cp5.3_membrane_f2.jpg

Functions of lipids

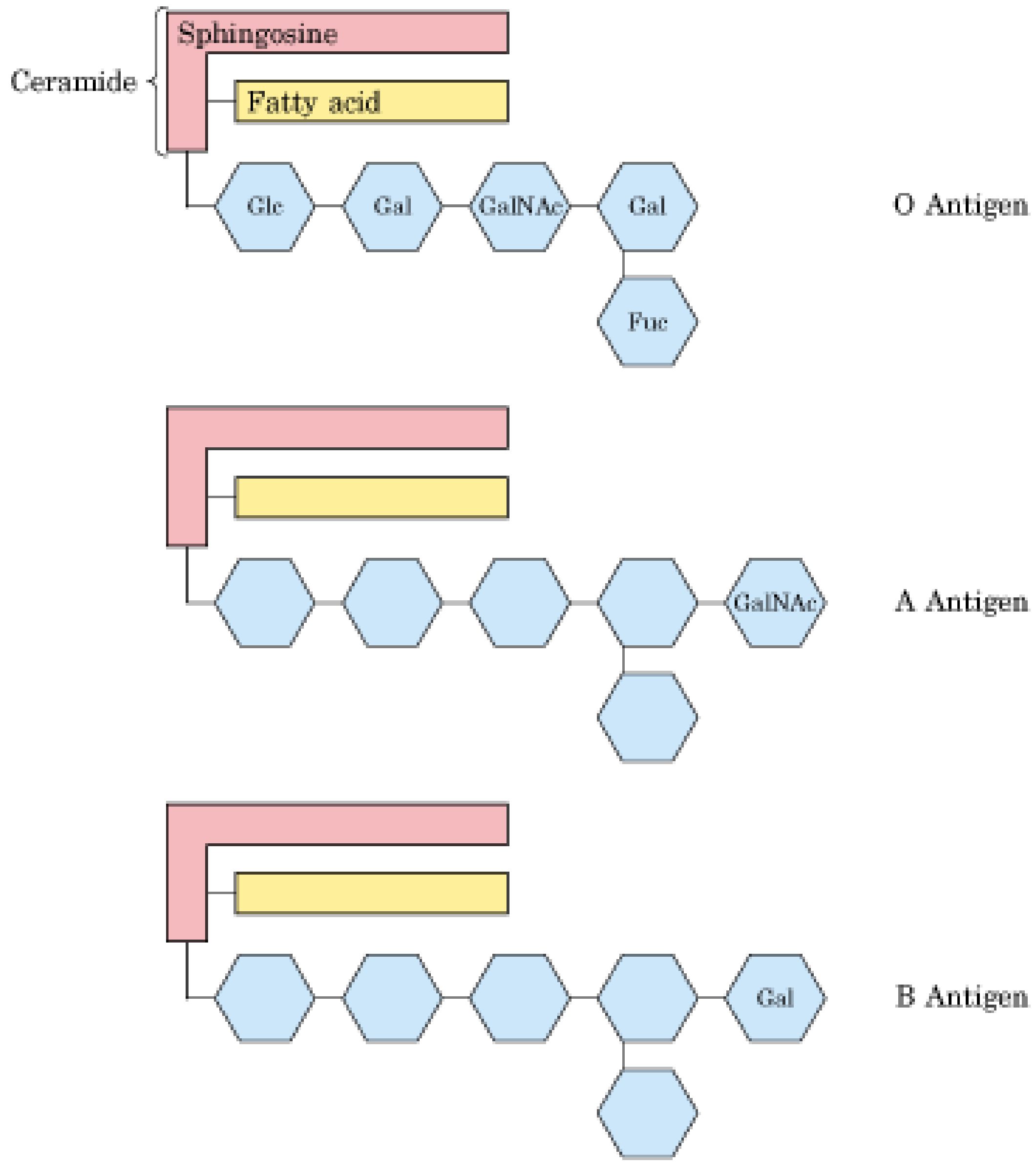
- Glycosphingolipids as blood group determinants
- Phospholipids are the major constituent of cell membrane.
- Lipids applications in drug delivery



Glycosphingolipids as blood group determinants

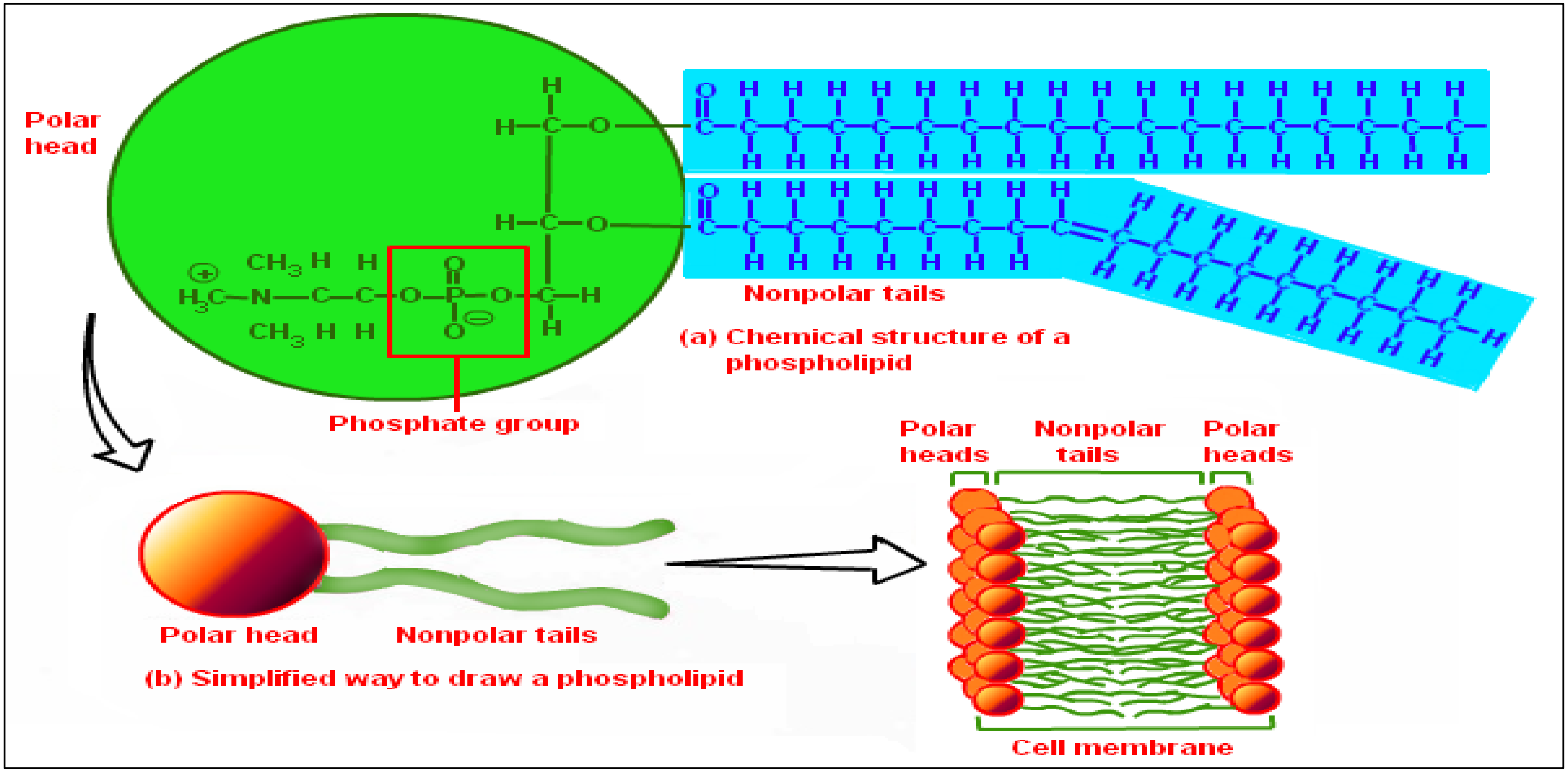
The human blood groups (O, A, B) are determined in part by the **oligosaccharide head groups** of these **glycosphingolipids.**

Glc:D-glucose
Gal:D-galactose
GalNAc:N-acetyl-D-galactosamine
Fuc:fucose

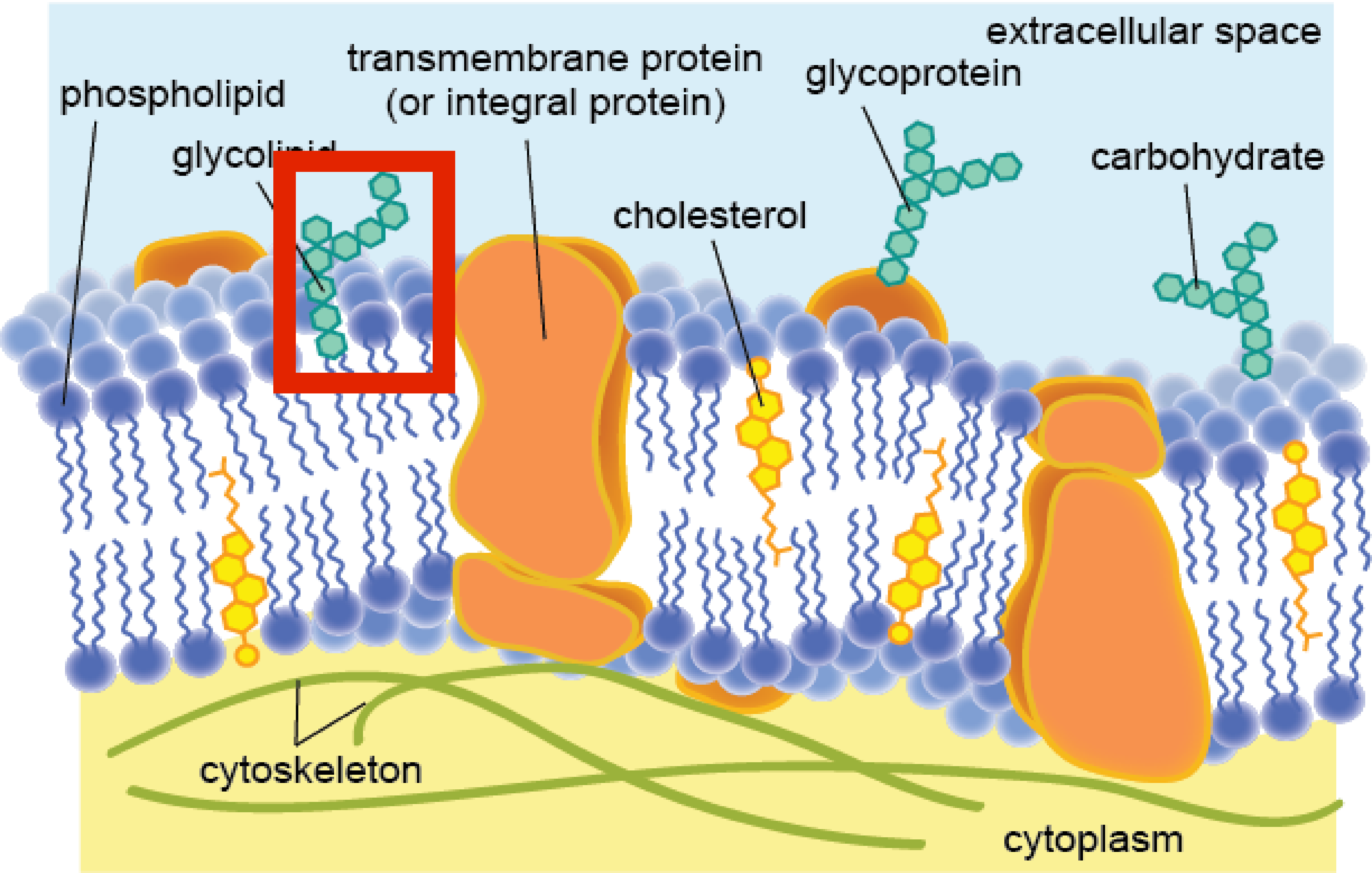


Lipids are the major constituent of cell membrane

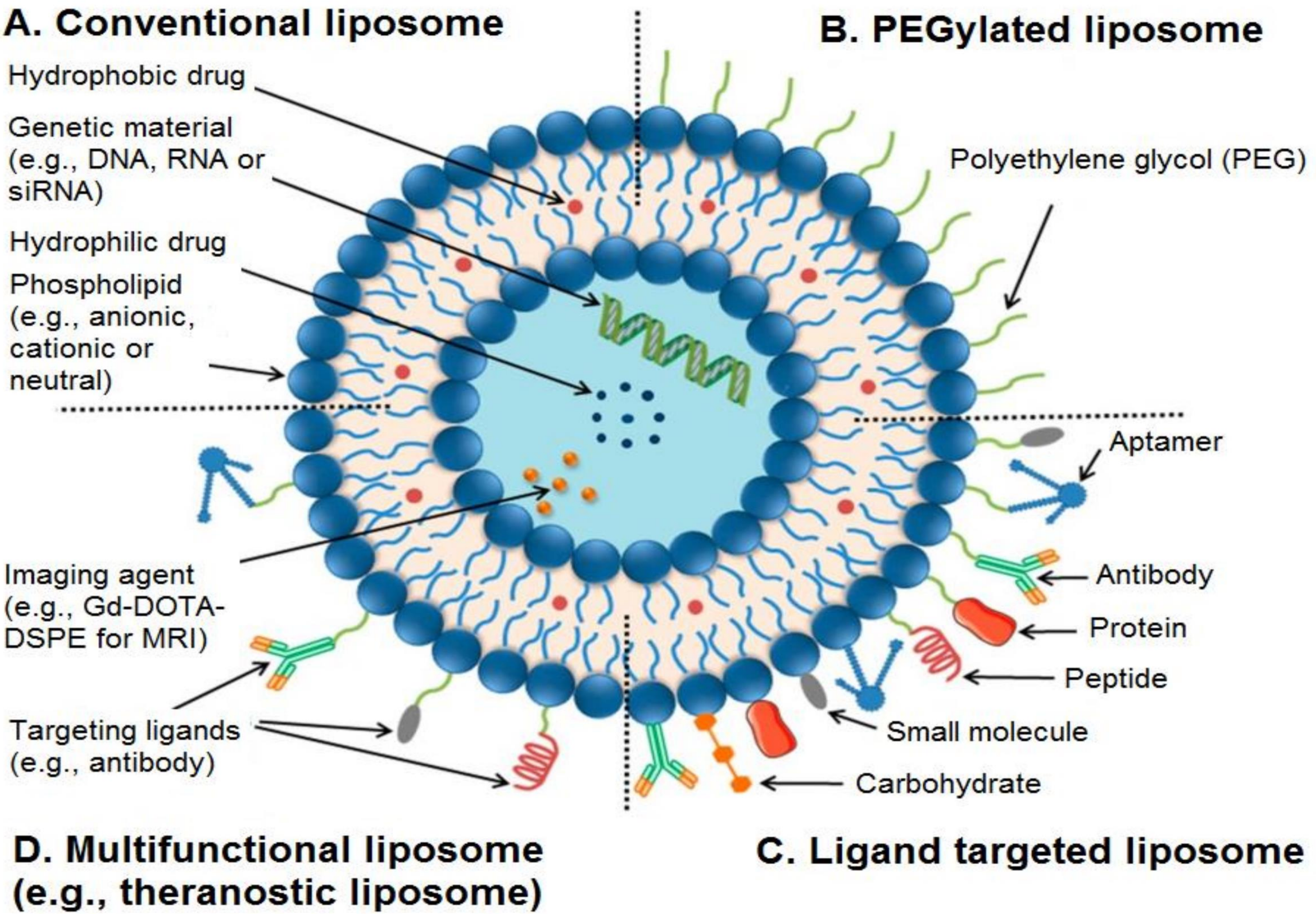
- **Plasma membrane is composed of phospholipids.**
- Phospholipids are arranged in two layers called **phospholipid bilayer**.



LIPID BILAYER STRUCTURE



Liposomes in drug/gene delivery



Sample questions

1. What is the solubility of lipids in water?

a) Soluble
b) Partially soluble
c) Insoluble
d) Partially insoluble

2. Fatty acids are amphipathic by nature.

a) True
b) False

3. Find the INCORRECT statement about the biological functions of lipids.

a) Storage form of metabolic fuel
b) Have a protective function in bacteria, plant, and insects
c) The structural component of membranes
d) Exhibit increased catalytic activity

4. The melting point of fatty acids depends upon chain length and __________

a) The shape of the fatty acids
b) The position of the double bond
c) Charge on the carbon
d) Degree of unsaturation

5. Which of the following is not a component of a phospholipid?

a) Phosphate
b) Alcohol
c) Glycerol
d) Protein

6. Which of the following phospholipid is considered as a major constituent of nervous tissue?

a) Glycerophospholipid
b) Plasmalogen
c) Inositol
d) Sphingomyelin

7. Identify the lowest density lipoprotein among the following?

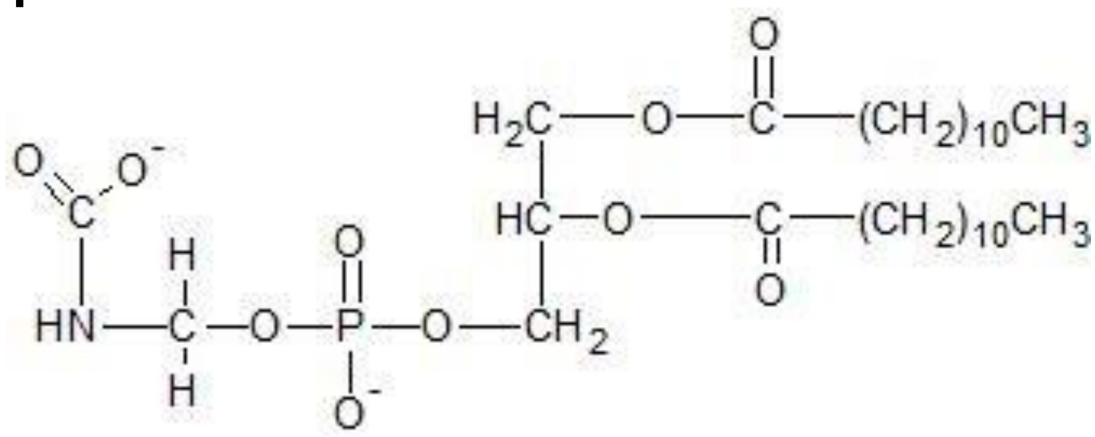
a) HDL
b) LDL
c) VLDL
d) Chylomicrons

8. The ____________ the degree of unsaturation of the fatty acids of the bilayer, the ____________ the temperature before the bilayer gels.

a) greater, lower
b) greater, more
c) lesser, higher
d) lesser, higher

Sample questions

(9). Examine the membrane lipid pictured below and answer the following questions.



I. **Is this lipid classified as a phospholipid or a glycolipid? How can you tell?**
II. **Is this lipid considered a sphingolipid or a glycerophospholipid? How can you tell?**
III. **What fatty acid chains are used in this lipid? Are they saturated or unsaturated?**
IV. **What functional group enables them to connect to the backbone?**

(10). Arrange the following fatty acids in order from lowest melting point to highest: myristic acid, arachidonic acid, linolenic acid, stearic acid, oleic acid.

A. **Myristic acid: 14 carbon saturated acid**
B. **Arachidonic acid: 20 carbon polyunsaturated acid (4 double bonds)**
C. **Linolenic acid: 18 carbon polyunsaturated acid (3 double bonds)**
D. **Stearic acid: 18 carbon saturated acid**
E. **Oleic acid: 18 carbon monounsaturated acid (1 double bond)**

(11). If a sample of a lipid contains fatty acids that are 89% saturated, would you expect this lipid to be solid at room temperature or liquid? What if the fatty acids were only 13% saturated?

(12) How can we differentiate between a glycerophospholipid and a sphingophospholipid?

(13) Steroid derivatives like cholesterol are also part of the lipid family. Name three useful by-products that cholesterol can be converted into within the body.