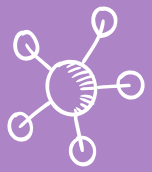
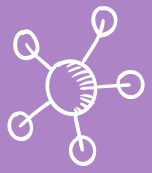


BIOMOLECULES

LIPIDS



Learning Outcomes

1(e)(ii) Describe the **structure** and **properties** of **glycerol** and **fatty acids** (in lipids).

1(f)(ii) Describe the **formation** and **breakage** of an **ester bond**.

1(g) Describe the **structures** and **properties** of **triglyceride** and **phospholipid** and explain how these are related to their **roles** in living organisms.

Introduction: Lipids

- made up mainly of **C**, **H** and **O**

e.g. phospholipid

- may contain others such as phosphorus
- proportion of oxygen much lower compared to hydrogen (e.g. $C_{57}H_{110}O_6$)
- Lipid is a general term that includes:
  - Triglycerides
  - Phospholipids
  - Glycolipids
  - Steroids and sterols
  - Waxes

General Properties of Lipids

- Insoluble in water, i.e. lipids are **hydrophobic**
- Soluble in organic solvents
- Less dense than water

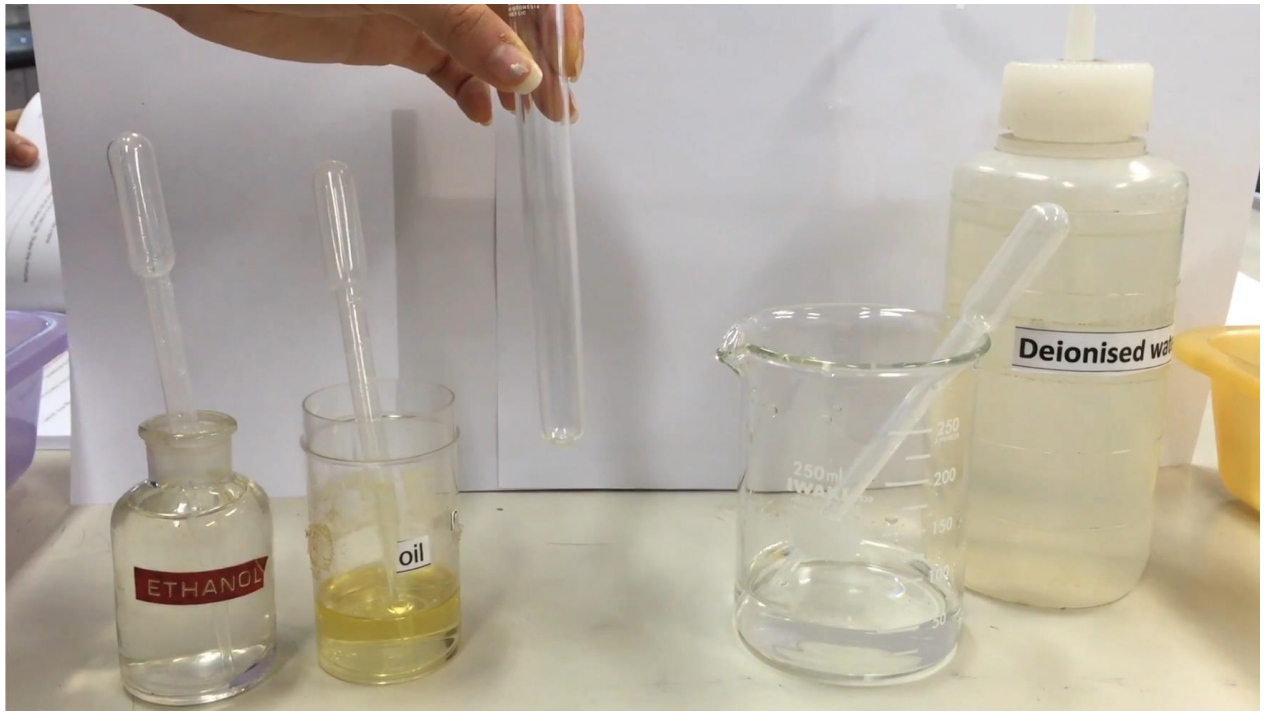
e.g. of organic solvents:
- Ethanol
- Ether
- Trichloromethane (chloroform)

TEST FOR LIPIDS

- *Ethanol-Emulsion test*:
  1 Add an **equal** volume of ethanol to 2cm^3 of test solution in a test-tube. Shake vigorously.
  2 Add 2cm^3 of water.

TEST FOR LIPIDS

- *Observation:*
  - In the presence of lipids, a homogeneous (clear) solution is formed with ethanol and a cloudy white emulsion is formed upon the addition of water.
  - Hence, a positive test of lipids is indicated by the formation of a cloudy white emulsion upon addition of water.



TEST FOR LIPIDS

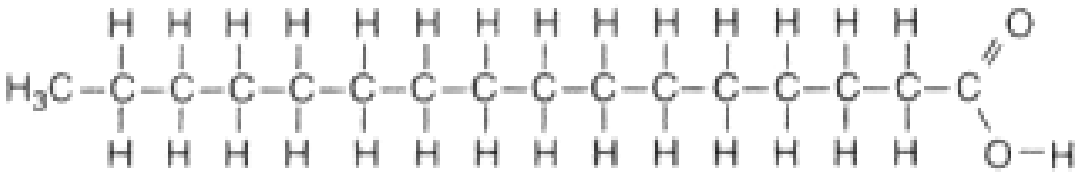
- In the absence of lipids, a homogenous (clear) solution is formed with ethanol and the test solution remains homogenous when water is added.

Basis of test:

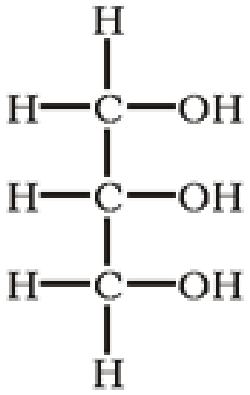
- Lipids are immiscible in water.
- Adding water to a solution of the lipid in alcohol results in the emulsion of tiny droplets in the water which reflect light and give a white, opalescent appearance.

Triglycerides have 2 components

Fatty acids



Glycerol



Learning Outcomes

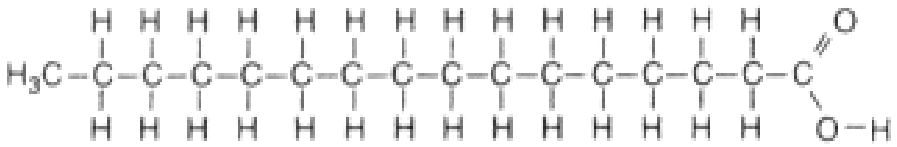
1(e)(ii) Describe the **structure** and **properties** of **glycerol** and **fatty acids** (in lipids).

1(f)(ii) Describe the **formation** and **breakage** of an **ester bond**.

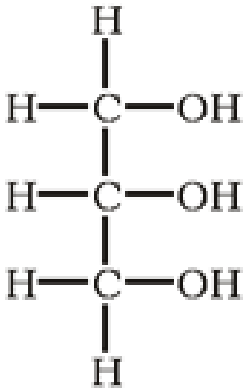
1(g) Describe the **structures** and **properties** of **triglyceride** and **phospholipid** and explain how these are related to their **roles** in living organisms.

Triglycerides have 2 components

Fatty acids



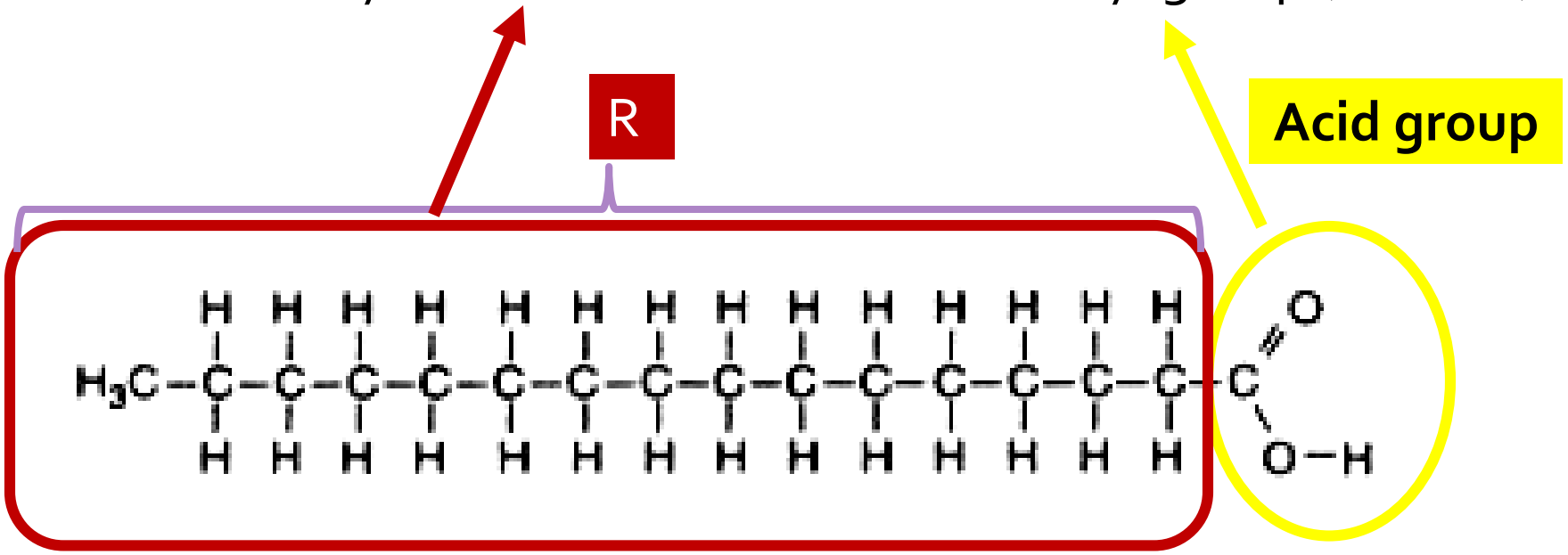
Glycerol



Fatty acids

Structure:

- consists of a hydrocarbon chain and a carboxyl group (-COOH).

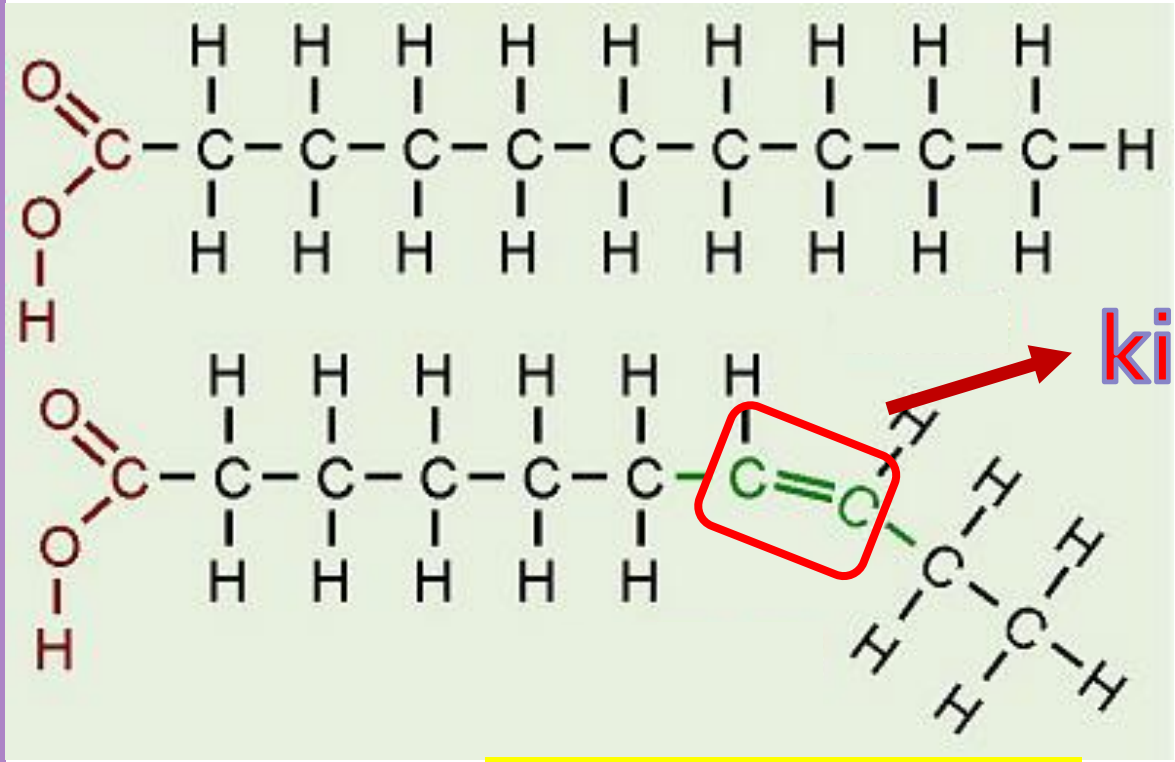


- General formula = **R**COOH

R is hydrocarbon chain

Fatty acids

Classification:



Saturated

kink

Unsaturated

Presence of **C=C** in hydrocarbon chain of unsaturated fatty acids

Fatty acids

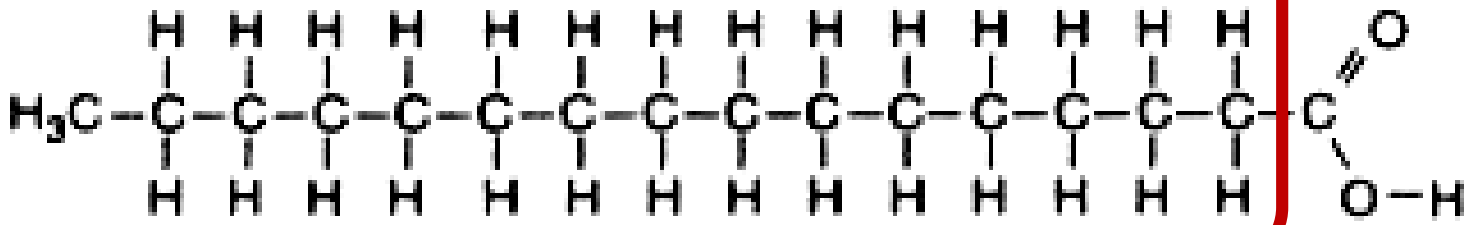
Properties:

NOT soluble in water

soluble in organic solvents

Non-polar

R is hydrocarbon chain



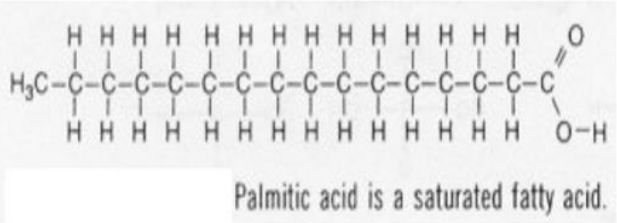
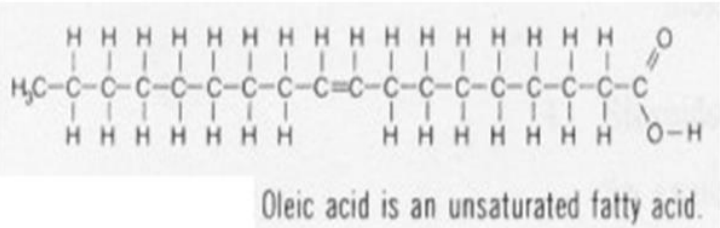
- General formula = **R**COOH
- C— H bonds in hydrocarbon chains of fatty acids are nonpolar
- => lipids are hydrophobic

What makes a sample soluble in water?

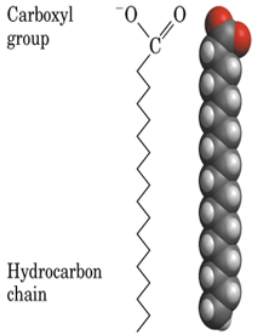
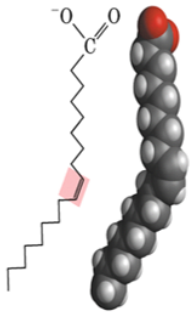
- The sample is soluble in water if:
  - The sample can form hydrogen bonds with water
  - The sample can ionize in water (i.e. form ions)

Note that there are exceptions, but you don't need to know them for biology

Fatty acids – Saturated Vs Unsaturated

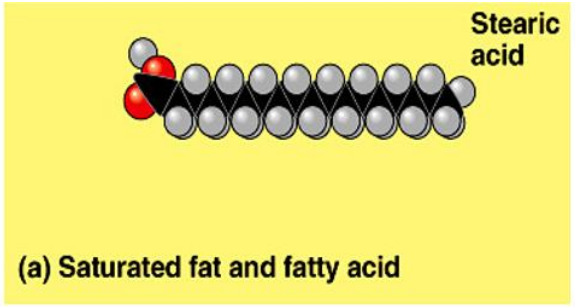
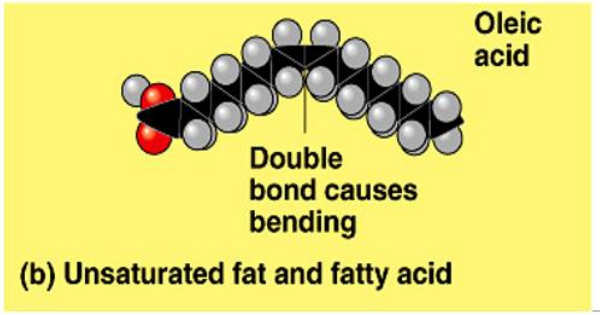
Feature of hydrocarbon chain	Saturated fatty acids	Unsaturated fatty acids
Number of H atoms	• Maximum possible number of hydrogen atoms	• Fewer hydrogen atoms
Number of C=C bond	• None → E.g. palmitic acid has 16 carbon atoms but no C=C.  Palmitic acid is a saturated fatty acid.	• At least one → E.g. oleic acid has 18 carbon atoms and contains one C=C.  Oleic acid is an unsaturated fatty acid.

Fatty acids – Saturated Vs Unsaturated

Feature of hydrocarbon chain	Saturated fatty acids	Unsaturated fatty acids
Presence of kinks	• None 	• The double bond causes a kink in the hydrocarbon chain wherever a double bond occurs. 

1 C=C: **Mono**unsaturated fatty acids
>1 C=C: **Poly**unsaturated fatty acids

Fatty acids – Saturated Vs Unsaturated

Feature of hydrocarbon chain	Saturated fatty acids	Unsaturated fatty acids
Packing	• Lacking double bonds, their flexibility allows the fat molecules to pack together tightly. → At room temperature, the molecules of a saturated fat are <u>closely packed</u> together, forming a <u>solid</u>.	• With double bonds causing kinks in their fatty acid chains, the fat molecules *cannot* pack together tightly. → At room temperature, the molecules of an unsaturated fat are <u>not closely packed</u> enough to solidify, forming <u>liquids</u>, hence they are called <u>oils</u>. E.g. olive oil and cod liver oil.
		

Fatty acids – Saturated Vs Unsaturated

Feature of hydrocarbon chain	Saturated fatty acids	Unsaturated fatty acids
E.g.	Most animal fats (such as those in butter and lard)	Most plant and fish fats

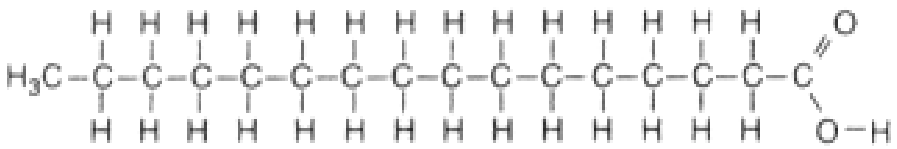
Tutorial 2: Lipids STQ 1(a)

Describe how a saturated fatty acid differs in structure from an unsaturated fatty acid. [2]

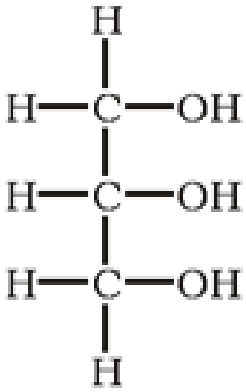
1. Absence of a C=C double bond in the hydrocarbon chain of fatty acid in saturated fatty acid but presence of a C=C double bond (in the hydrocarbon chain of fatty acid) in unsaturated fatty acid.
2. Saturated fatty acid has more hydrogen / is saturated with hydrogen while unsaturated fatty acid has less hydrogen

Triglycerides have 2 components

Fatty acids



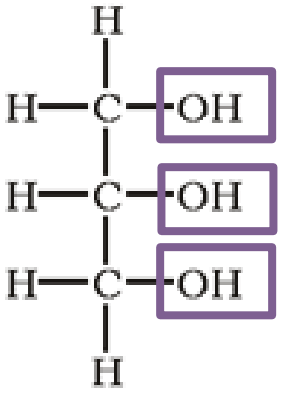
Glycerol



Glycerol

Structure:

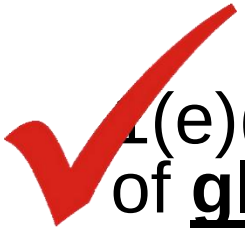
- General formula = $C_3H_8O_3$.
- Glycerol is an alcohol with **3 carbons**, each bearing a hydroxyl group.



Properties:

- Soluble in water
- Is –OH group polar or non-polar?
  - Polar!
  - Therefore, glycerol is hydrophilic

Learning Outcomes



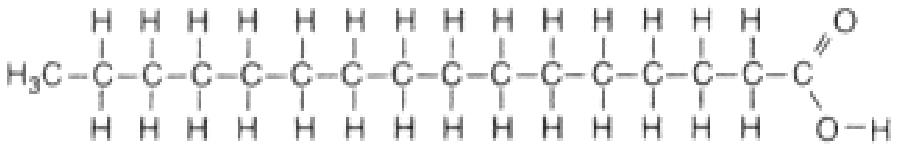
1(e)(ii) Describe the **structure** and **properties** of **glycerol** and **fatty acids** (in lipids).

1(f)(ii) Describe the **formation** and **breakage** of an **ester bond**.

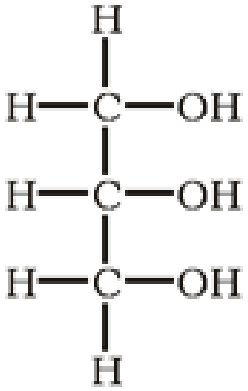
1(g) Describe the **structures** and **properties** of **triglyceride** and **phospholipid** and explain how these are related to their **roles** in living organisms.

Triglycerides have 2 components

Fatty acids



Glycerol



How do fatty acids and glycerol come together to form triglycerides?

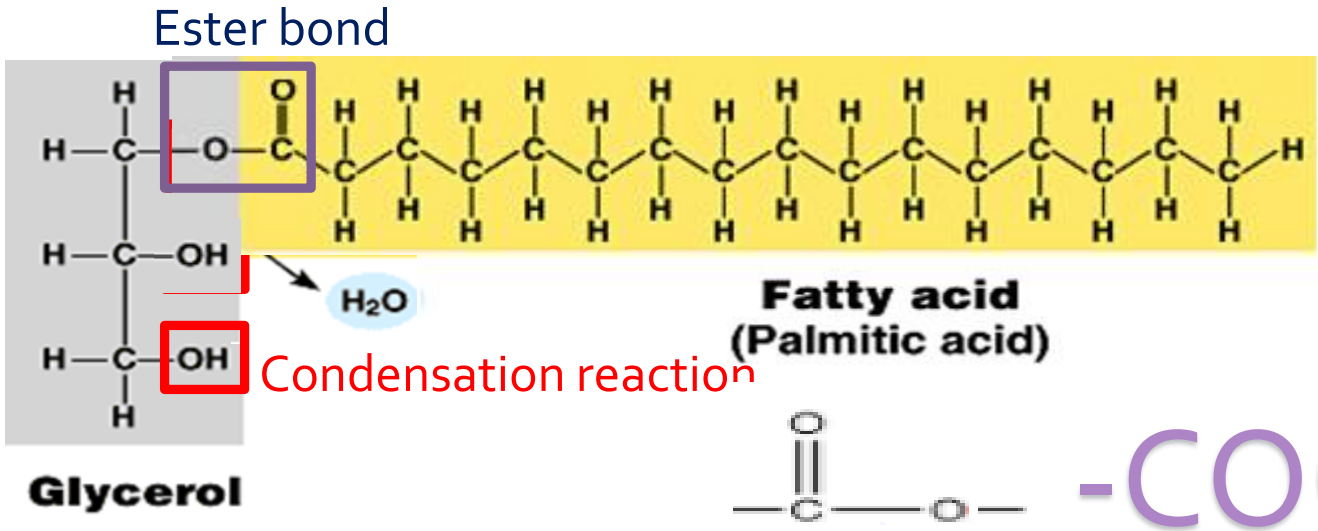
Formation of ester bond!

Formation of ester bond

- **Condensation reaction**

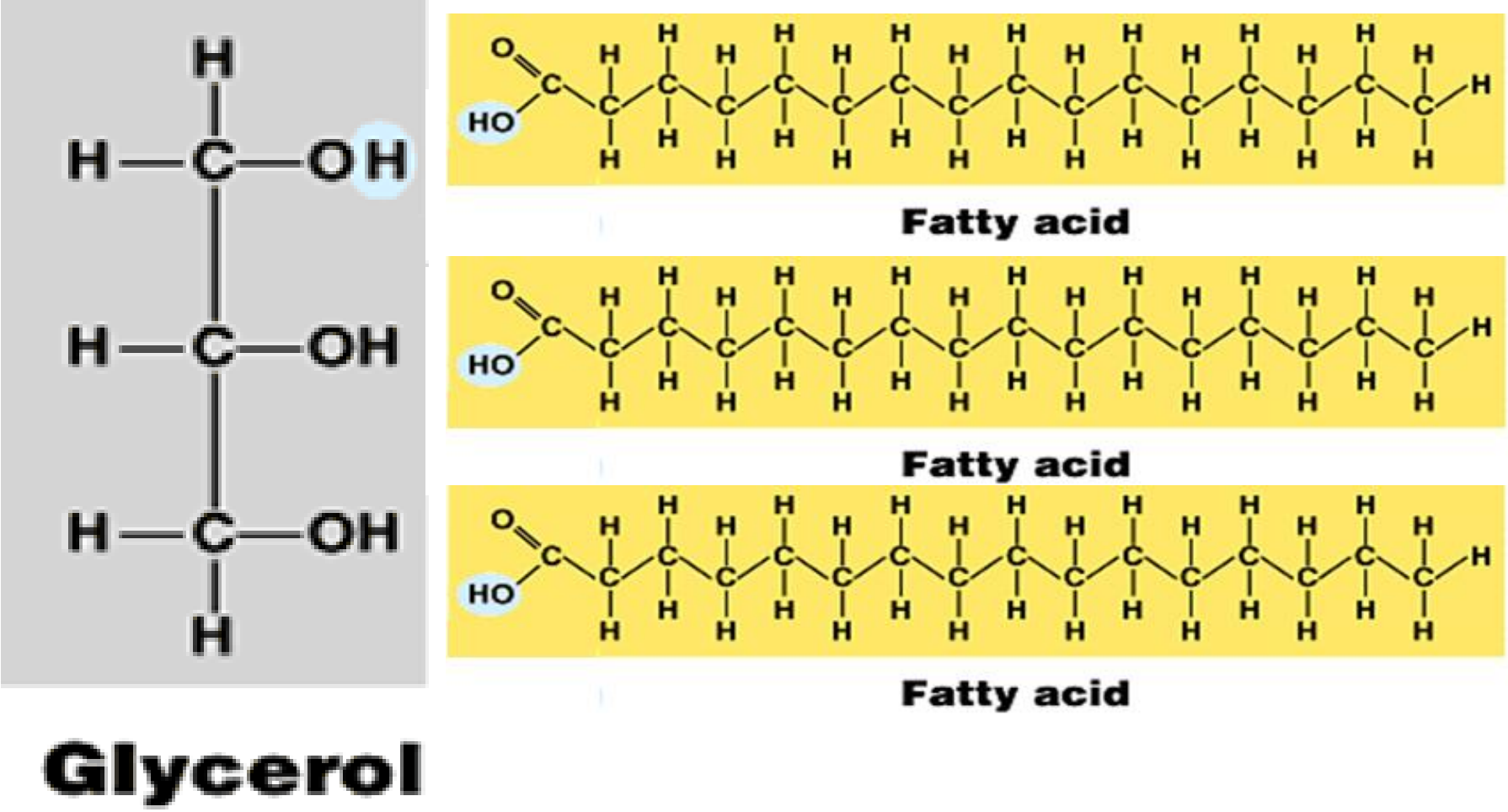
  Between a fatty acid and glycerol

  - each hydroxyl group (-OH) in the glycerol molecule
  - reacts with the carboxyl group (-COOH) of a fatty acid;



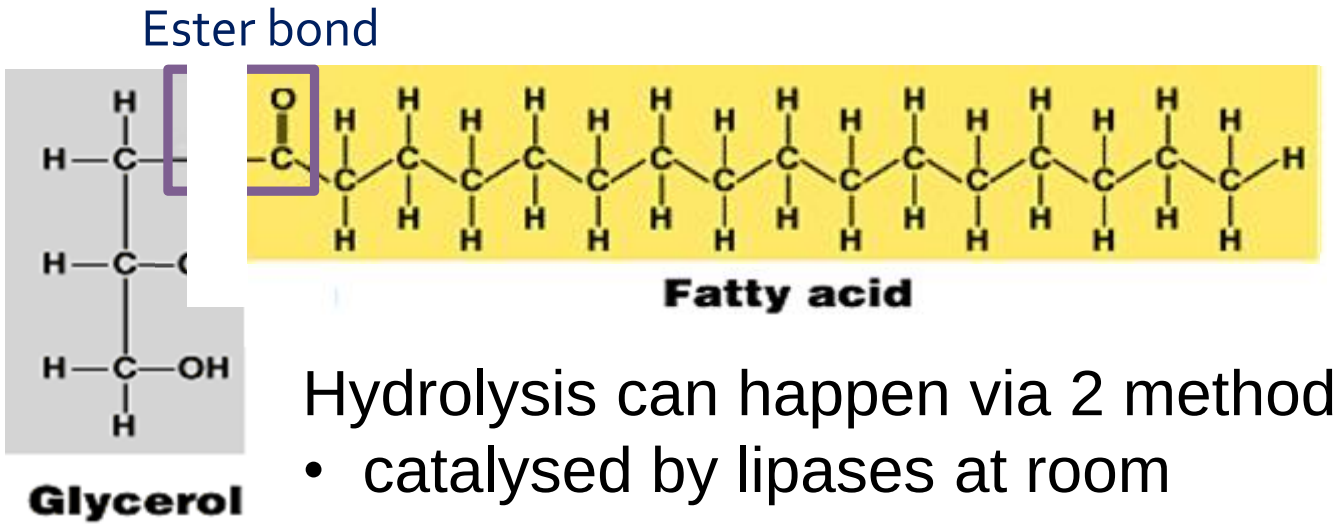
1 condensation rxn= Formation of 1 ester bond

How many H_2O molecules formed in the formation of 1 triglyceride?



Breakage of ester bond

Hydrolysis reaction: Addition of 1 water molecule across an ester bond

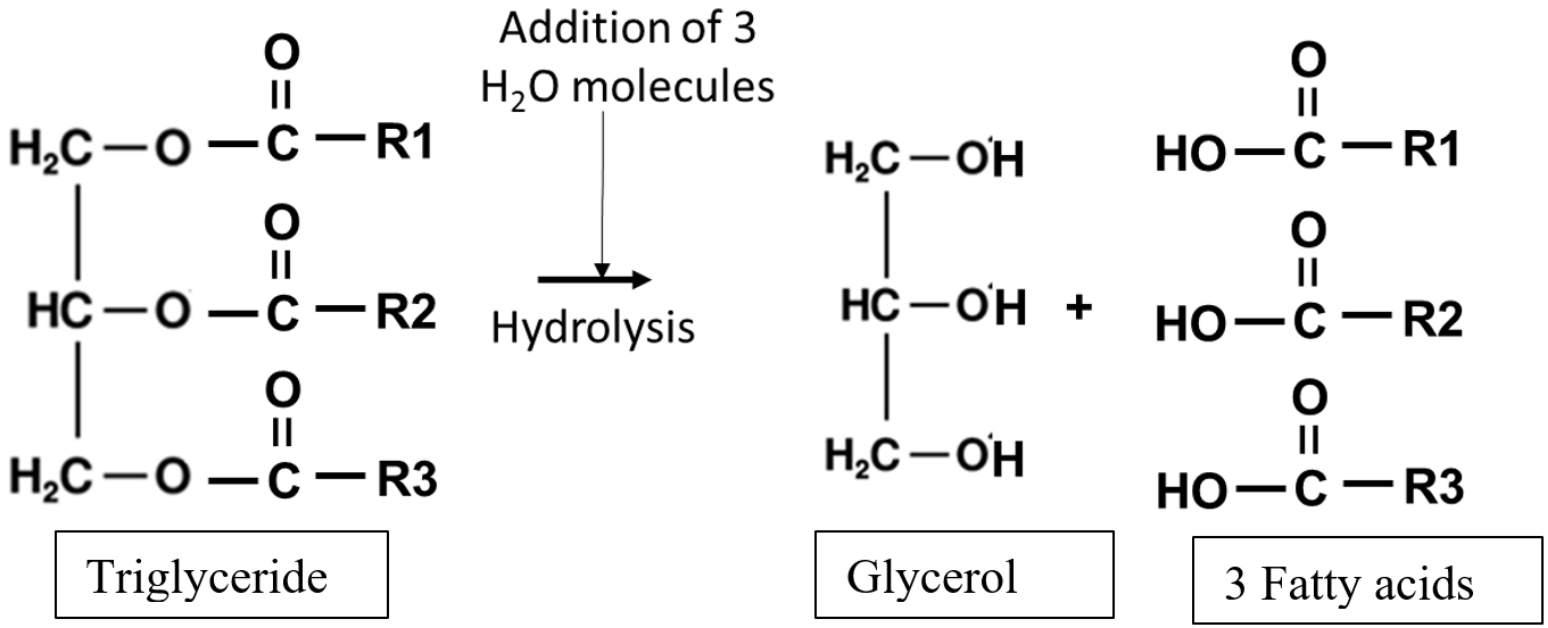


Hydrolysis can happen via 2 methods:

- catalysed by lipases at room temperature
- at high temperature in the presence of acid and water

Tutorial 2: Lipids STQ 1(d)

Draw an annotated diagram to show the hydrolysis of a triglyceride.



Learning Outcomes

1(e)(ii) Describe the **structure** and **properties** of **glycerol** and **fatty acids** (in lipids).

1(f)(ii) Describe the **formation** and **breakage** of an **ester bond**.

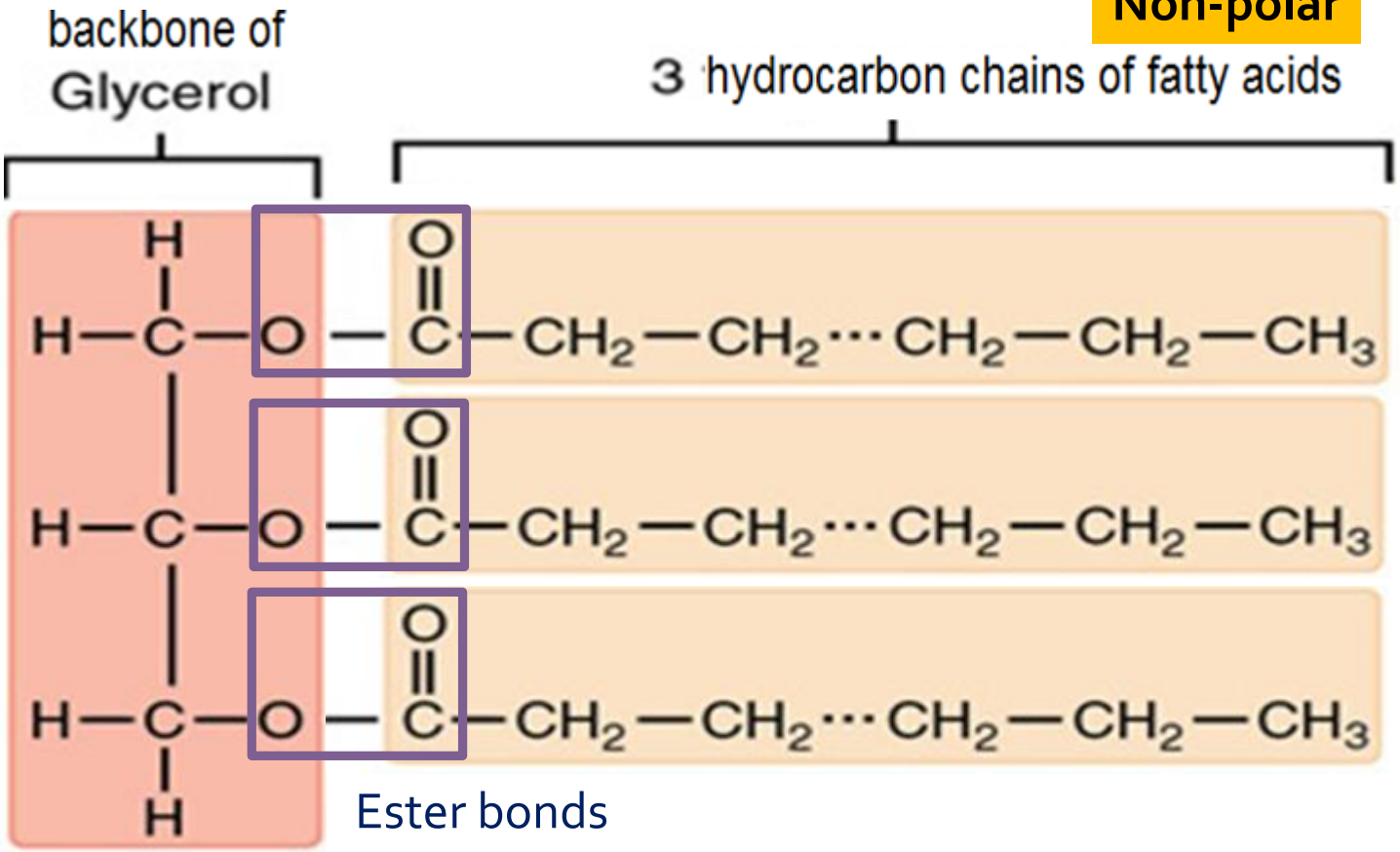
1(g) Describe the **structures** and **properties** of **triglyceride** and **phospholipid** and explain how these are related to their **roles** in living organisms.

Triglycerides

Structure:

Hydrophobic

Non-polar



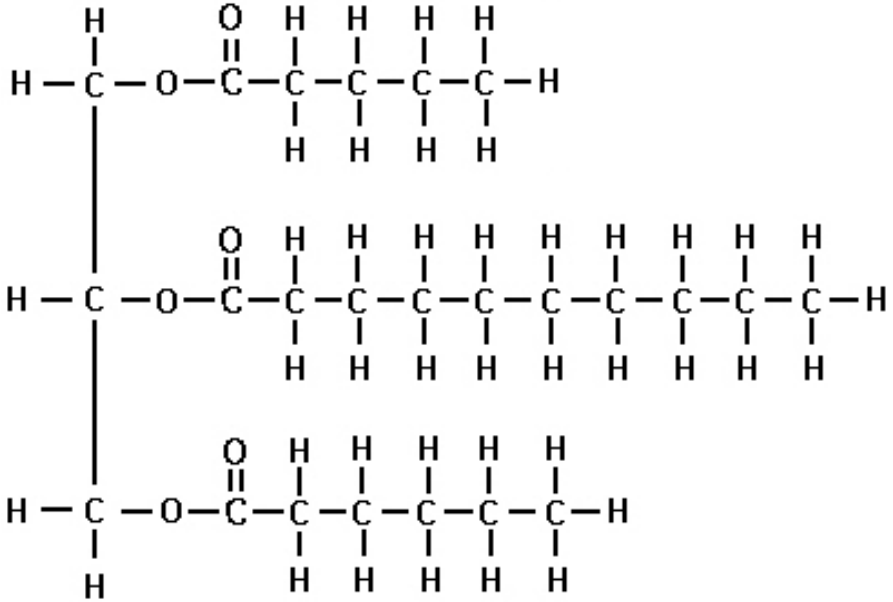
no. of carbon atoms can differ

Presence of C=C can differ

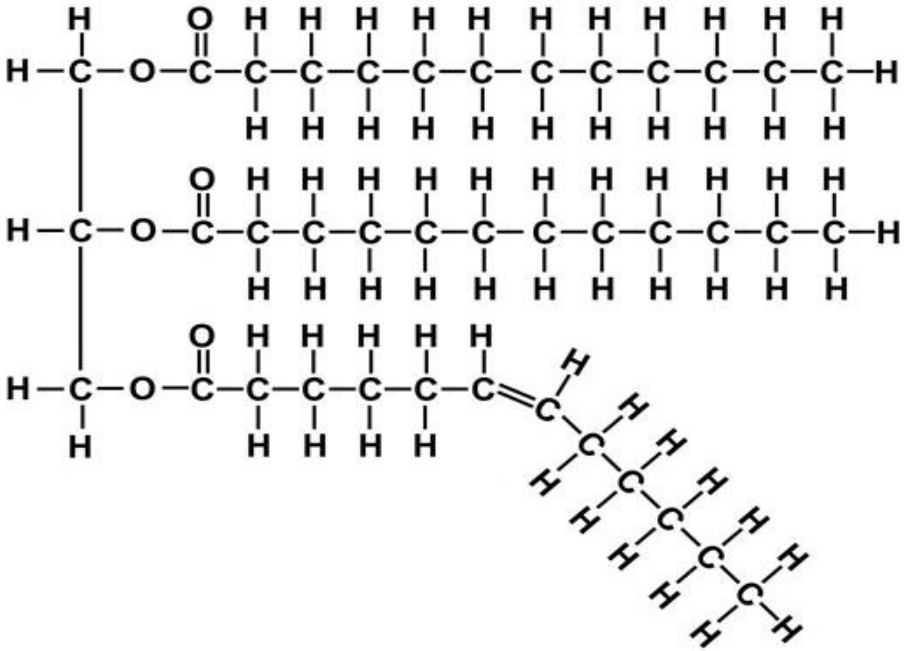
Triglycerides

Structure:

no. of carbon atoms can differ



Presence of C=C can differ



Triglycerides

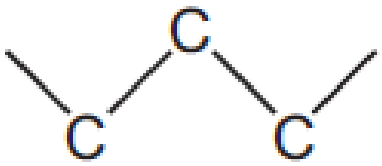
Structure:

- Triglycerides form lipid aggregates in an aqueous environment due to its hydrophobicity

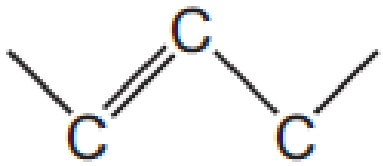
Tutorial 2: Lipids (MCQ 1)

The diagrams show some of the type of bonds in fatty acids.

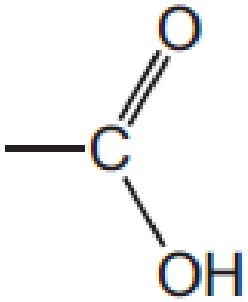
1



2



3



Which row shows the bonds found in each type of molecule?

	unsaturated fatty acid	saturated fatty acid
A	1, 2 and 3	1 and 3 only
B	1, 2 and 3	2 and 3 only
C	1 and 3 only	1, 2 and 3
D	2 and 3 only	1, 2 and 3

Extra MCQ

Which combination describes a triglyceride?

	hydrophilic	soluble in alcohol
A	√	√
B	x	x
C	√	x
D	x	√

Extra MCQ

Which statements about a triglyceride molecule are correct?

1. It always contains unsaturated hydrocarbon tails.
2. It is formed using ester bonds.
3. It does not form hydrogen bonds.
4. It contains a hydrophilic glycerol head.

A	1, 2 and 3
B	2, 3 and 4
C	1 and 4 only
D	2 and 3 only

Triglycerides - functions

1. Energy source

2. Metabolic water

3. Thermal insulation

4. Buoyancy for aquatic animals

Triglycerides - functions

- ***Structure:***
  Triglycerides have larger number of hydrogen atoms to oxygen atoms

Compared to carbohydrate

- ***Property:***
  Yields a greater amount of energy than carbohydrates per gram when oxidized during aerobic respiration ;
- ***Function:***

Locomotion

Seed dispersal

1. Energy source	**2. Metabolic water**	**3. Thermal insulation**	**4. Buoyancy for aquatic animals**

Triglycerides - functions

- ***Structure:***
  Triglycerides have 3 hydrocarbon chains of fatty acids
- ***Property:***
  Non-polar and insoluble in water / hydrophobic

No great effect on water potential of cells

Prevented from diffusing out of cells

- ***Function:***
  Stored as an energy source in large amounts

1. Energy source | **2. Metabolic water** | **3. Thermal insulation** | **4. Buoyancy for aquatic animals**

Triglycerides - functions

- ***Property:***

  Oxidised only after carbohydrates are depleted

- ***Function:***

  Important in hibernating animals which requires enough energy to be stored to last the entire winter

1. Energy source
2. Metabolic water
3. Thermal insulation
4. Buoyancy for aquatic animals

Triglycerides - functions

- ***Property:***
  Releases water when oxidised during aerobic respiration

- ***Function:***
  Water produced from oxidation of food is called metabolic water
- Important to desert animals

1. Energy source | **2. Metabolic water** | **3. Thermal insulation** | **4. Buoyancy for aquatic animals**

Triglycerides - functions

- ***Property:***
  Prevents excessive loss of heat

- ***Function:***
  Subcutaneous fats serve as heat insulator

Triglycerides - functions

- ***Property:***
  Less dense than water

- ***Function:***
  Provide aquatic mammals with buoyancy

1. Energy source
2. Metabolic water
3. Thermal insulation
4. Buoyancy for aquatic animals

Tutorial 2: Lipids MCQ 2

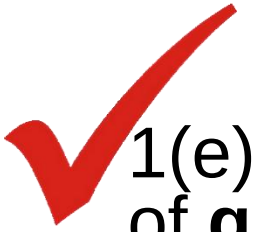
The table shows some differences between glucose and a triglyceride. Which difference explains the fact that glucose is soluble in water, while the triglyceride is insoluble in water?

Difference	Glucose	Triglyceride
A	Contains polar groups	Does not contains polar groups
B	Does not contains double bonds	contains double bonds
C	Higher ratio of carbon: hydrogen	Lower ratio of carbon: hydrogen
D	Occurs in a ring form	Does not occurs in a ring form

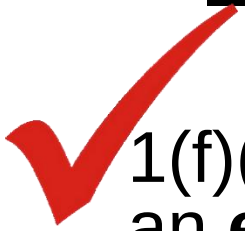
Video: fats

https://youtu.be/QhUrc4BnPgg

Learning Outcomes



1(e)(ii) Describe the **structure** and **properties** of **glycerol** and **fatty acids** (in lipids).



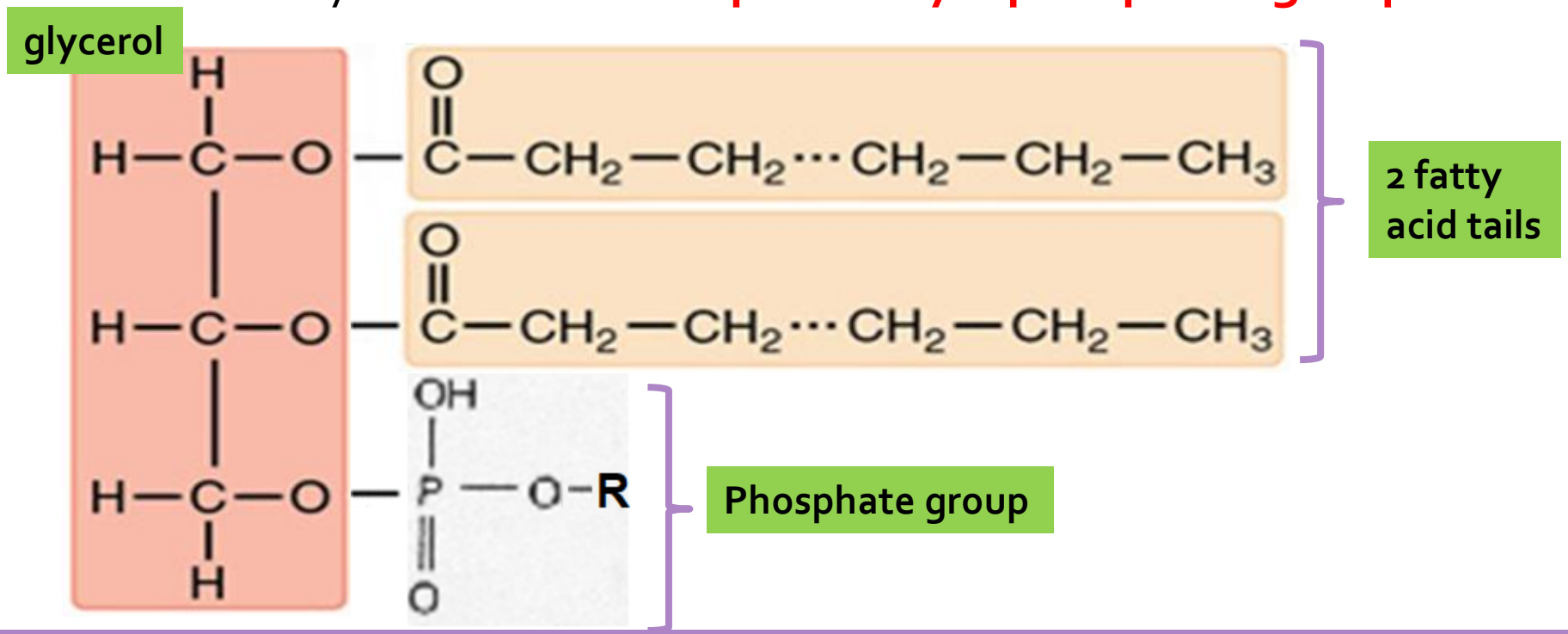
1(f)(ii) Describe the **formation** and **breakage** of an **ester bond**.

1(g) Describe the **structures** and **properties** of **triglyceride** and **phospholipid** and explain how these are related to their **roles** in living organisms.

Phospholipids

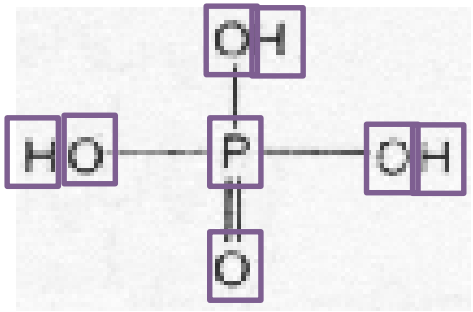
Structure:

- Lipids with <u>phosphate group</u>
- Similar to triglycerides
  - consist of a glycerol 'backbone'
  - Two fatty acid 'tails'
  - third fatty acid has been **replaced by a phosphate group 'head'**



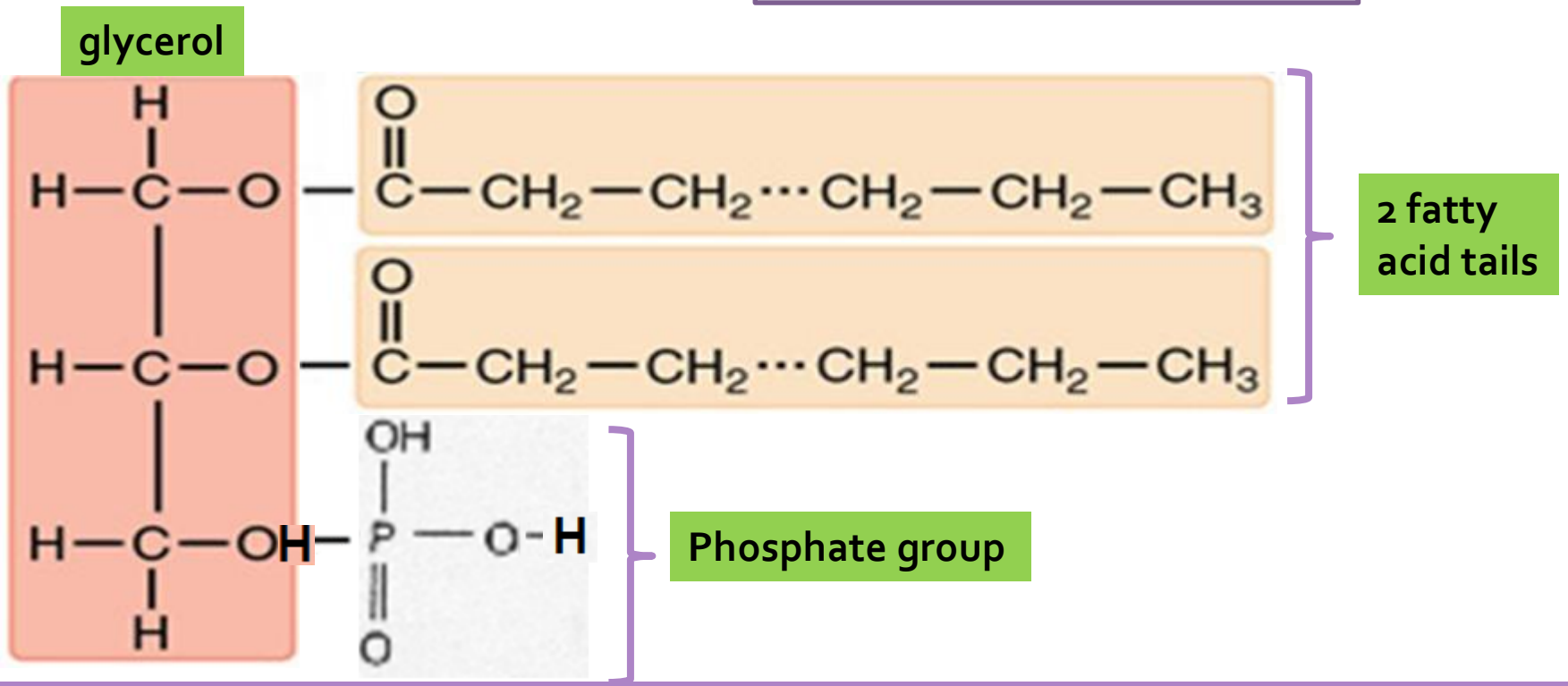
Phospholipids

Structure:



Simplest phospholipid is <u>phosphatidic acid</u>

- consist of a glycerol 'backbone'
- Two fatty acid 'tails'
- phosphate group comes from phosphoric acid (H_3PO_4)

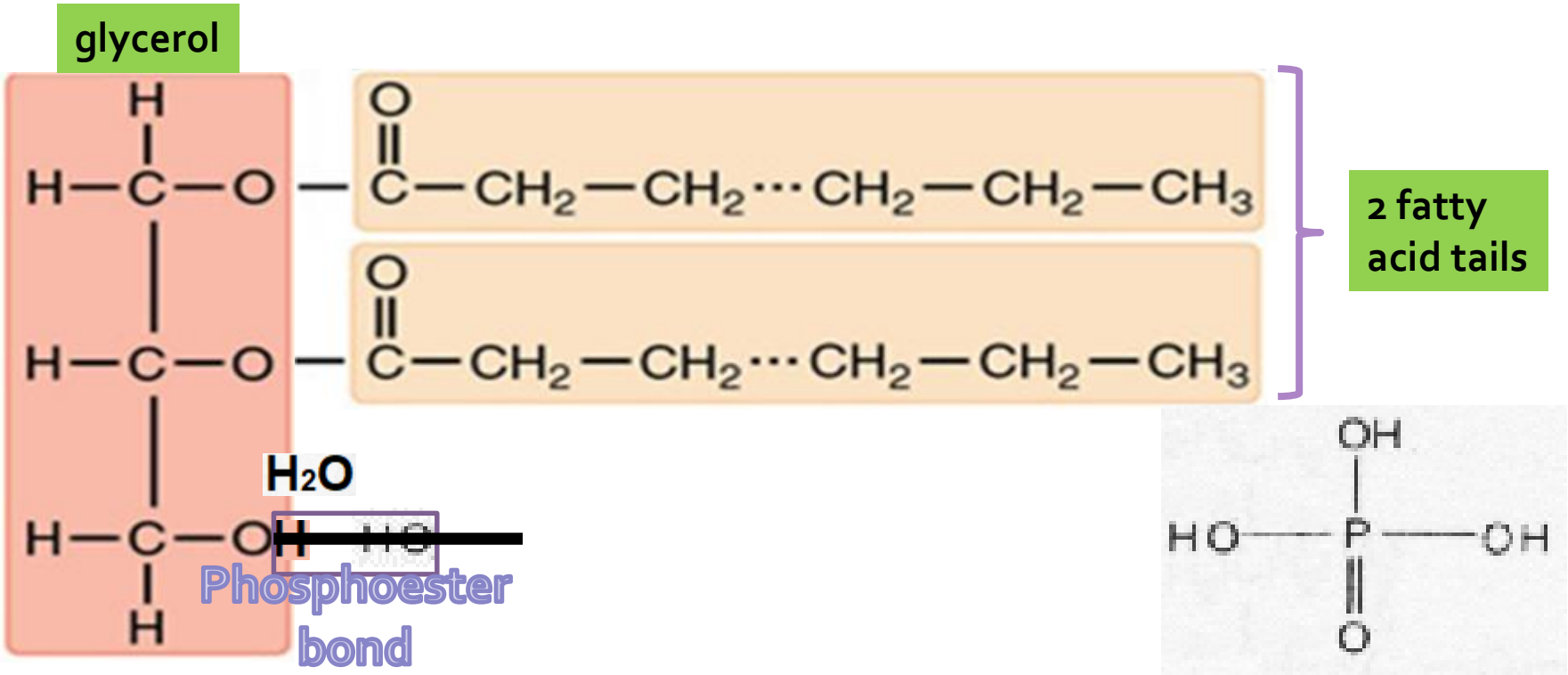


Phospholipids

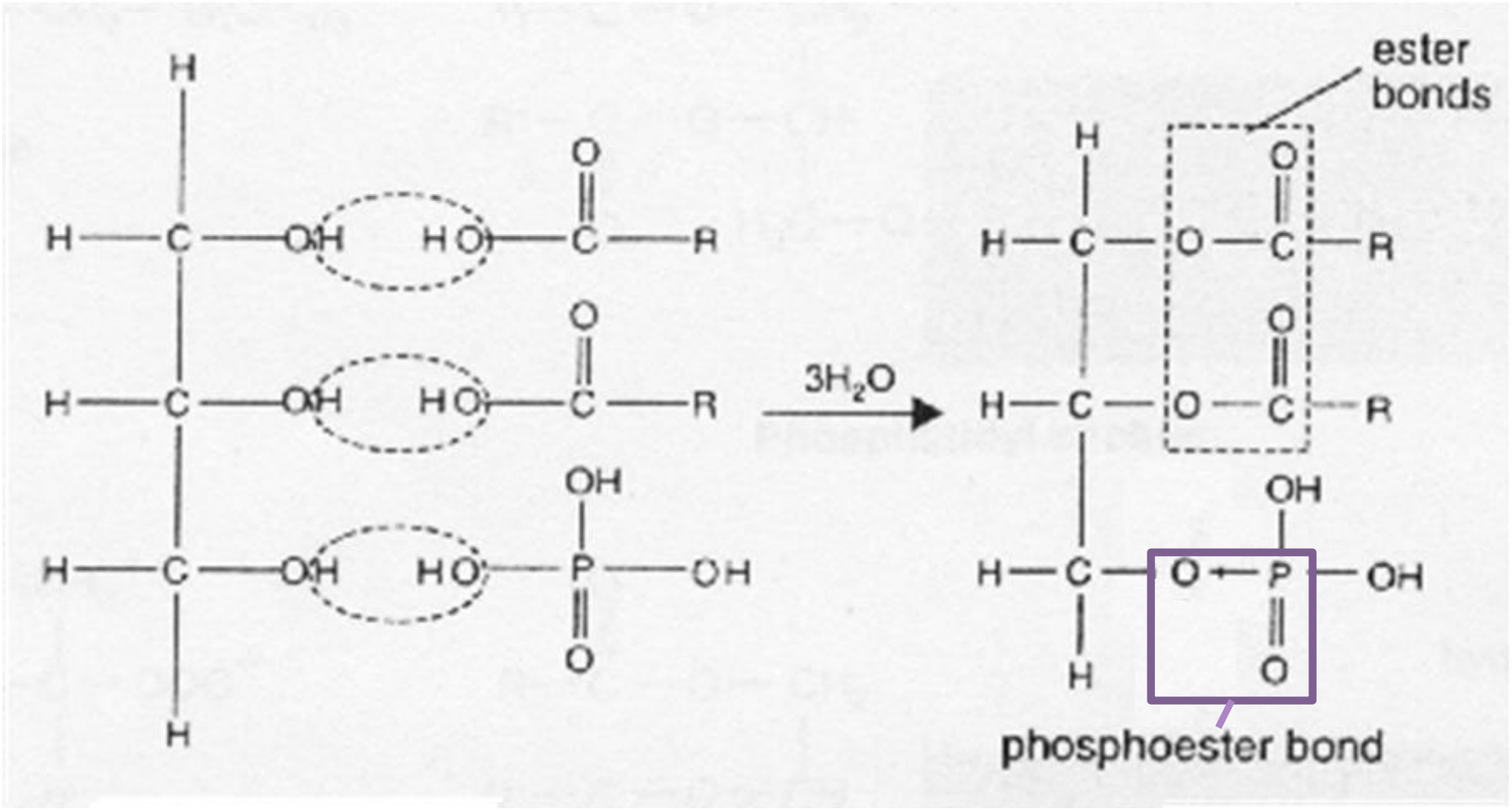
Structure:

Simplest phospholipid is <u>phosphatidic acid</u>

- consist of a glycerol 'backbone'
- Two fatty acid 'tails'
- phosphate group comes from phosphoric acid (H_3PO_4)



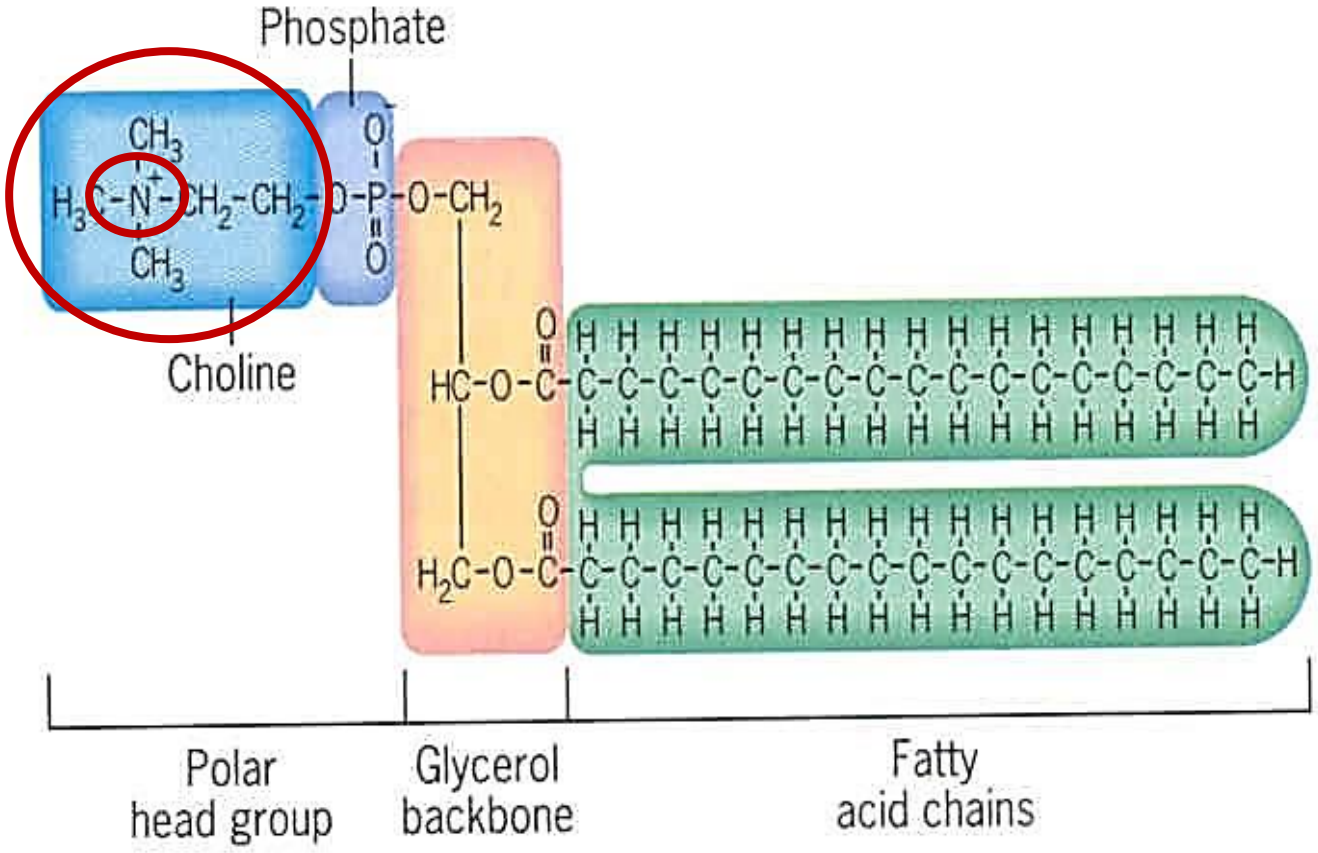
Please correct this in Lecture Book



Phospholipids

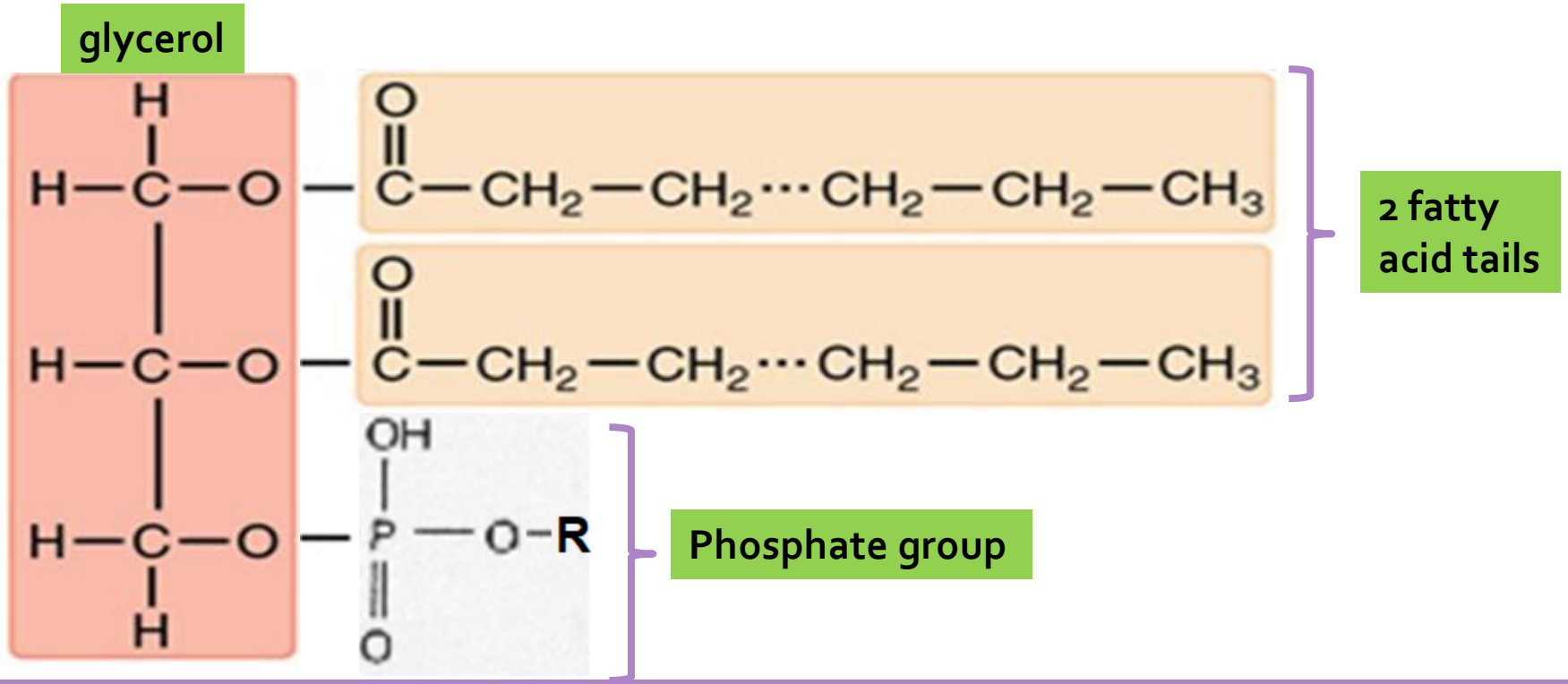
Structure:

- Other groups may be attached to phosphate group
  - e.g. nitrogen-containing choline is found commonly in phosphatidylcholines



Structure

- Synthesized from condensation reactions resulting in 2 fatty acids and 1 phosphate group **covalently bonded** to 1 glycerol molecule
- 2 ester linkages and 1 phosphoester bond result from 3 condensation reactions;
- Phospholipids may vary in structure due to
  - the nature of hydrocarbon tails in fatty acid residues (number of carbon atoms and presence/absence of double bonds)
  - molecules attached to the phosphate group e.g. nitrogen-containing choline



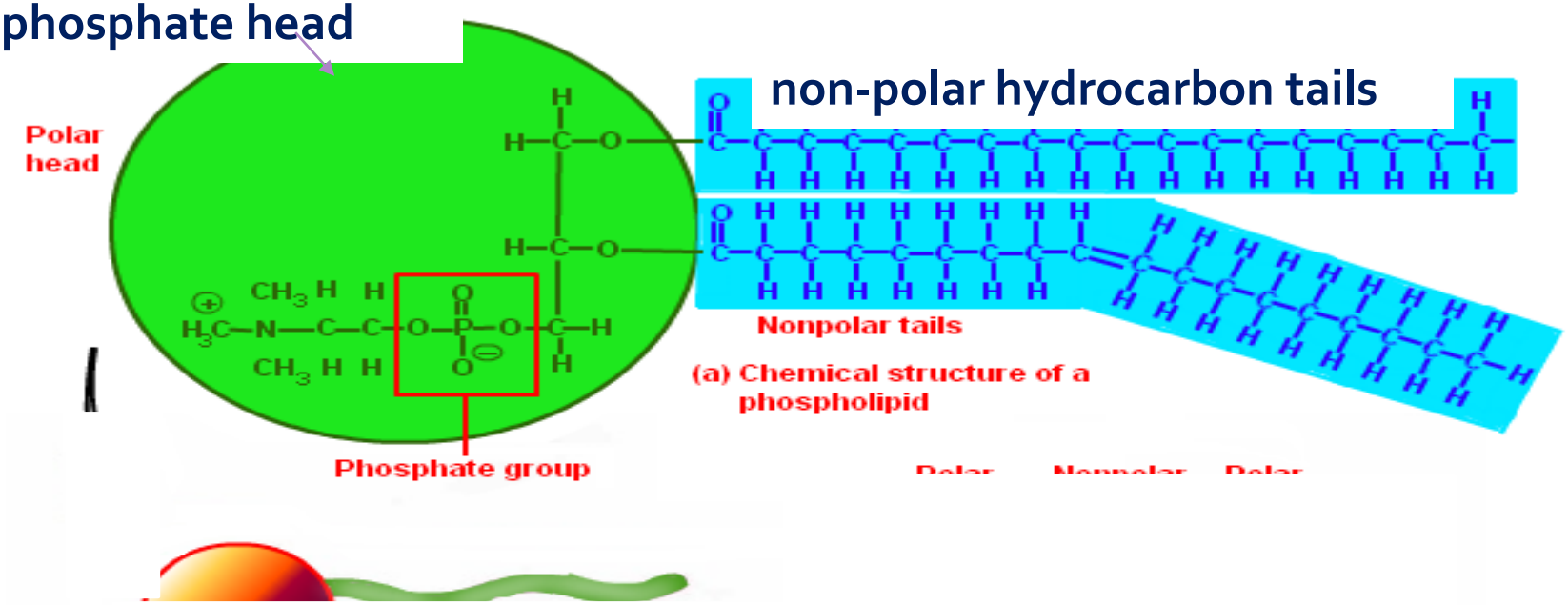
Properties and Functions ***of phospholipids***

(A) **Component of cell membrane** *(also in Lecture topic "Membrane" which will be taught later)*

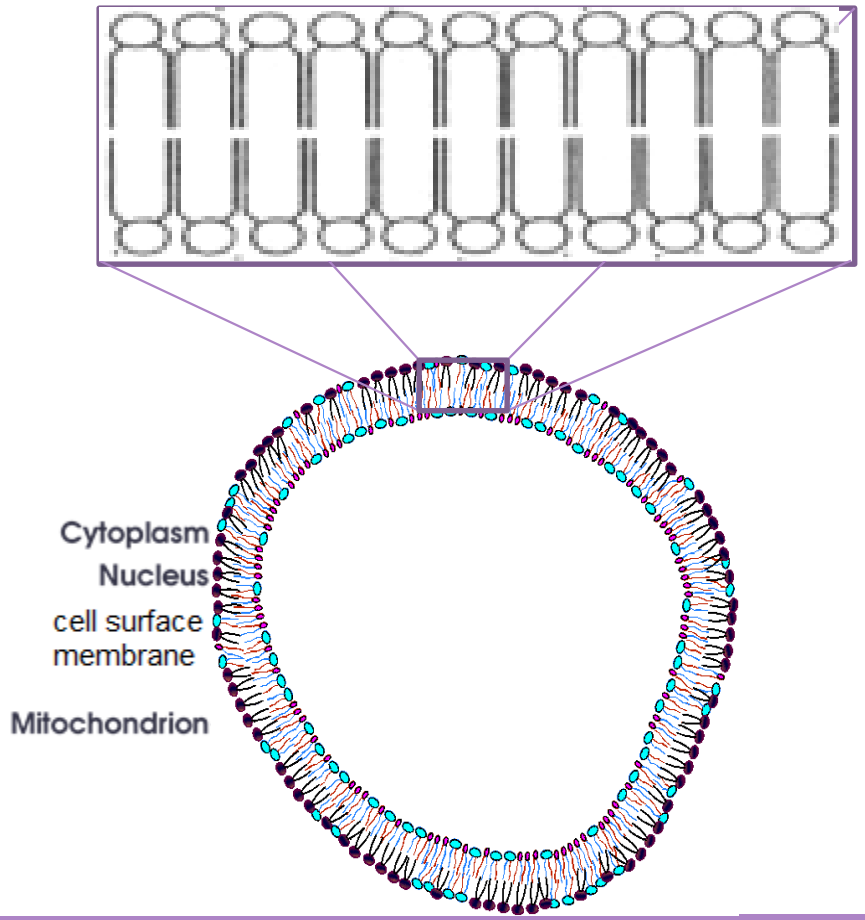
1 ***Structure****:* Consist of a hydrophilic polar phosphate head and hydrophobic non-polar fatty acid tails;

Property: Amphipathic[2].

Hydrophilic polar phosphate head

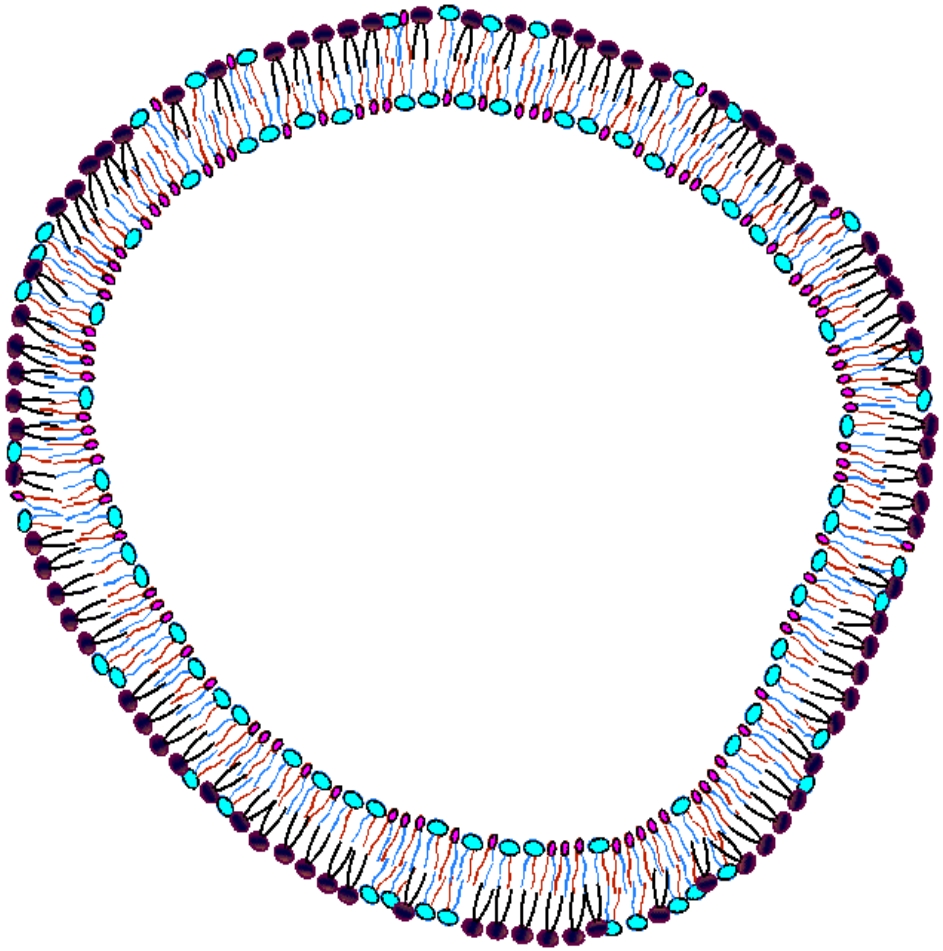


The cell membrane is made up of a double layer of phospholipid molecules, each molecule lying with its hydrophilic polar phosphate head in contact with the aqueous medium of the cytoplasm and the external environment, and its hydrophobic non-polar fatty acid tails pointing toward the interior of the bilayer, away from the water. This arrangement is called a phospholipid bilayer.

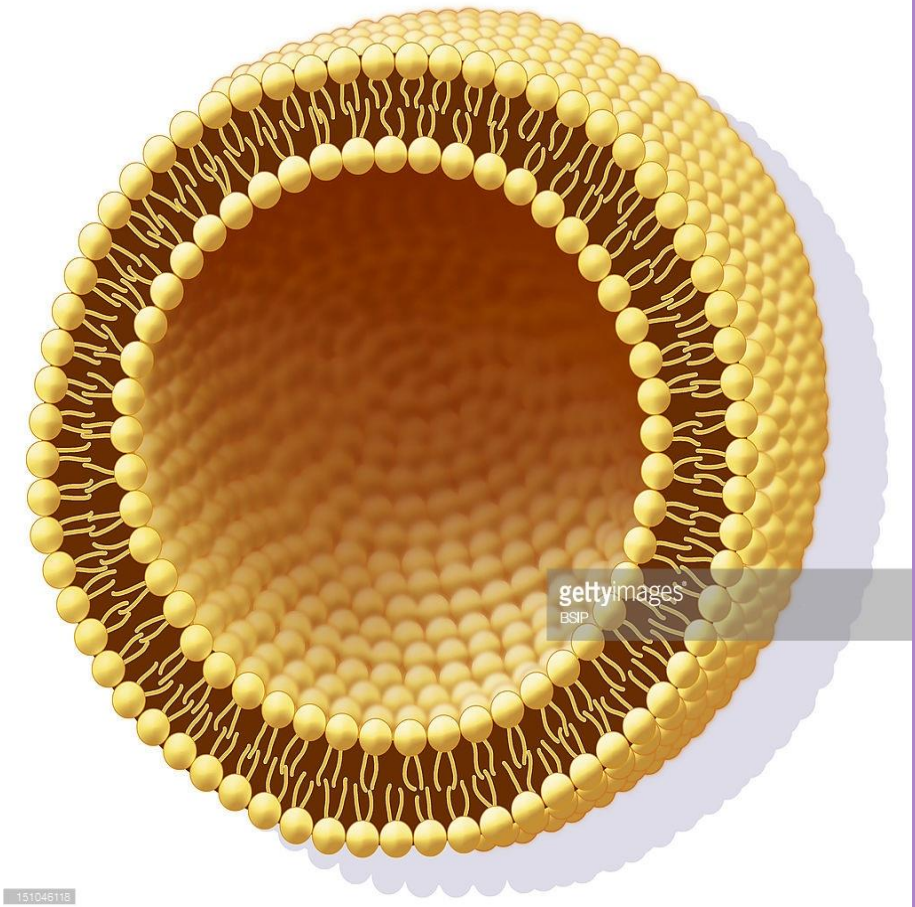


Cell membrane

Two dimensional (2D) representation



3D representation



Functions of Phospholipids

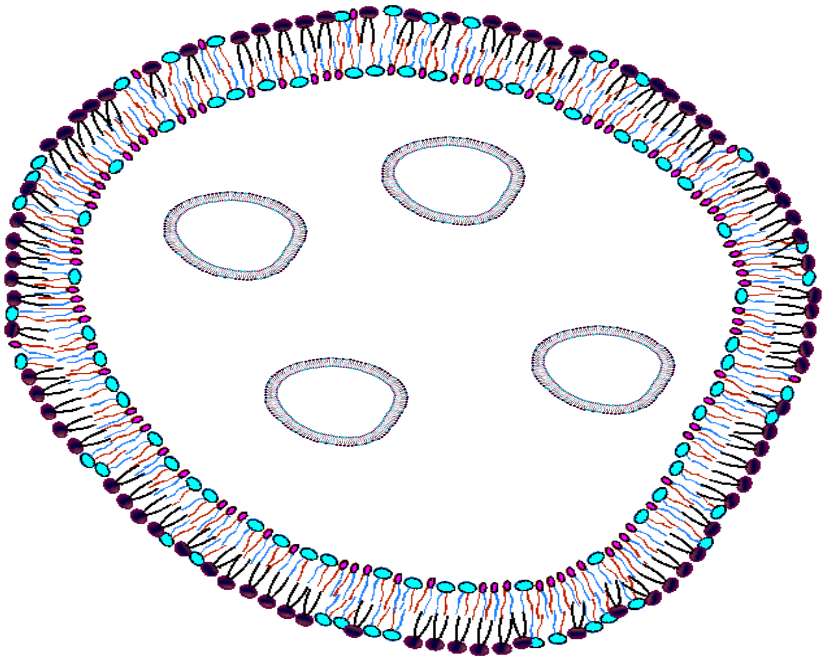
(A) Component of cell membrane

(B) Transport of fats between gut and liver

Functions of Phospholipids

(A) Component of cell membrane

- Phospholipid bilayer forms **boundary** between contents of cell and its aqueous external environment, and prevents ionic and polar molecules from entering cell (selective permeability).



- Enables separate compartments to be formed within cell (**compartmentalization**) for specific biochemical pathways to occur.

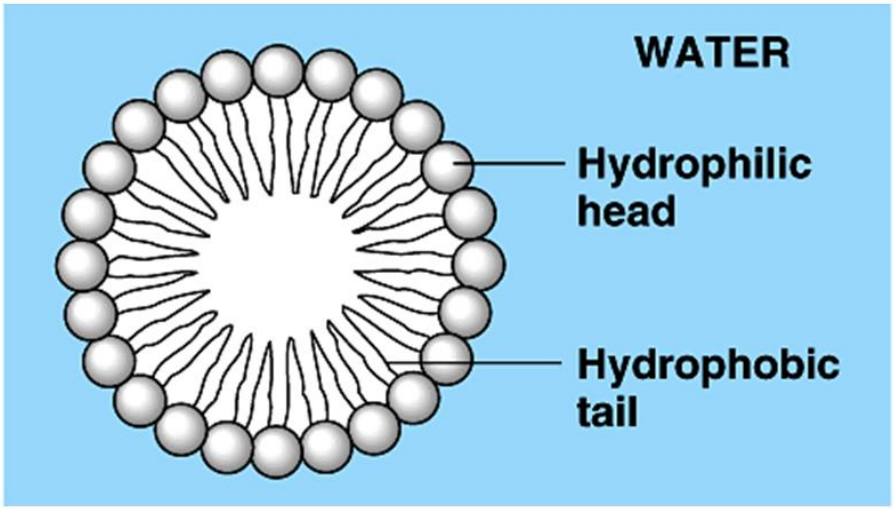
Functions of Phospholipids

(B) Transport of fats between gut and liver

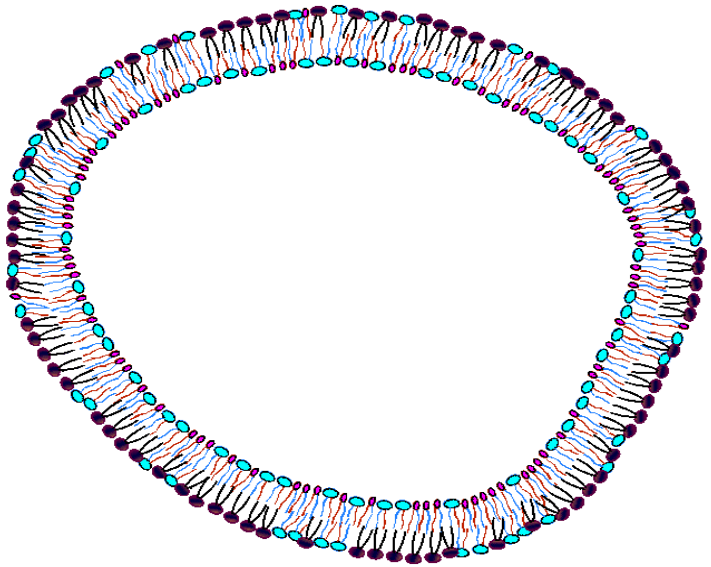
Structure: Polar phosphate head faces aqueous solution (e.g. water) since they are hydrophilic, while nonpolar hydrocarbon chain of fatty acids are inside and away from water since they are hydrophobic. ***describes how micelles are formed***

Property: When phospholipids are added to water, they self-assemble into aggregates called micelles that shield their hydrophobic tails away from water.

Function: Micelles help in the transport of fat between the gut and the liver.



Micelle

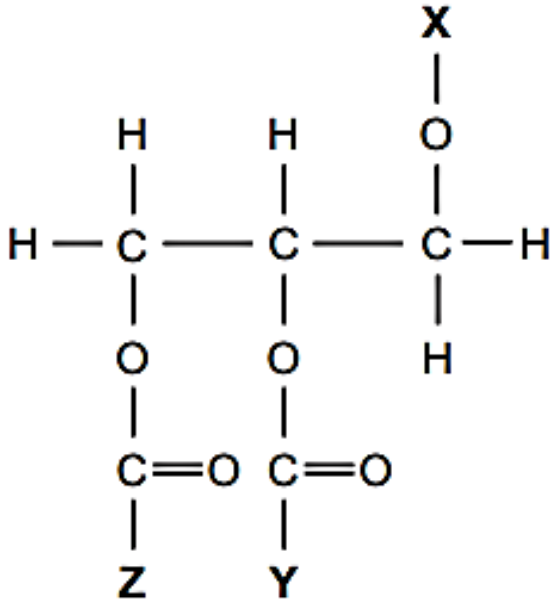


Membrane

Extra MCQ

- The diagram shows a phospholipid molecule.

What are **X**, **Y**, and **Z**?



	X	Y	Z
A	hydrocarbon chain	hydrocarbon chain	phosphate-containing group
B	hydrocarbon chain	glycerol	phosphate-containing group
C	phosphate-containing group	hydrocarbon chain	hydrocarbon chain
D	phosphate-containing group	glycerol	hydrocarbon chain

Learning Outcomes

1(e)(ii) Describe the **structure** and **properties** of **glycerol** and **fatty acids** (in lipids).

1(f)(ii) Describe the **formation** and **breakage** of an **ester bond**.

1(g) Describe the **structures** and **properties** of **triglyceride** and **phospholipid** and explain how these are related to their **roles** in living organisms.

Learning Objectives - **Membranes**

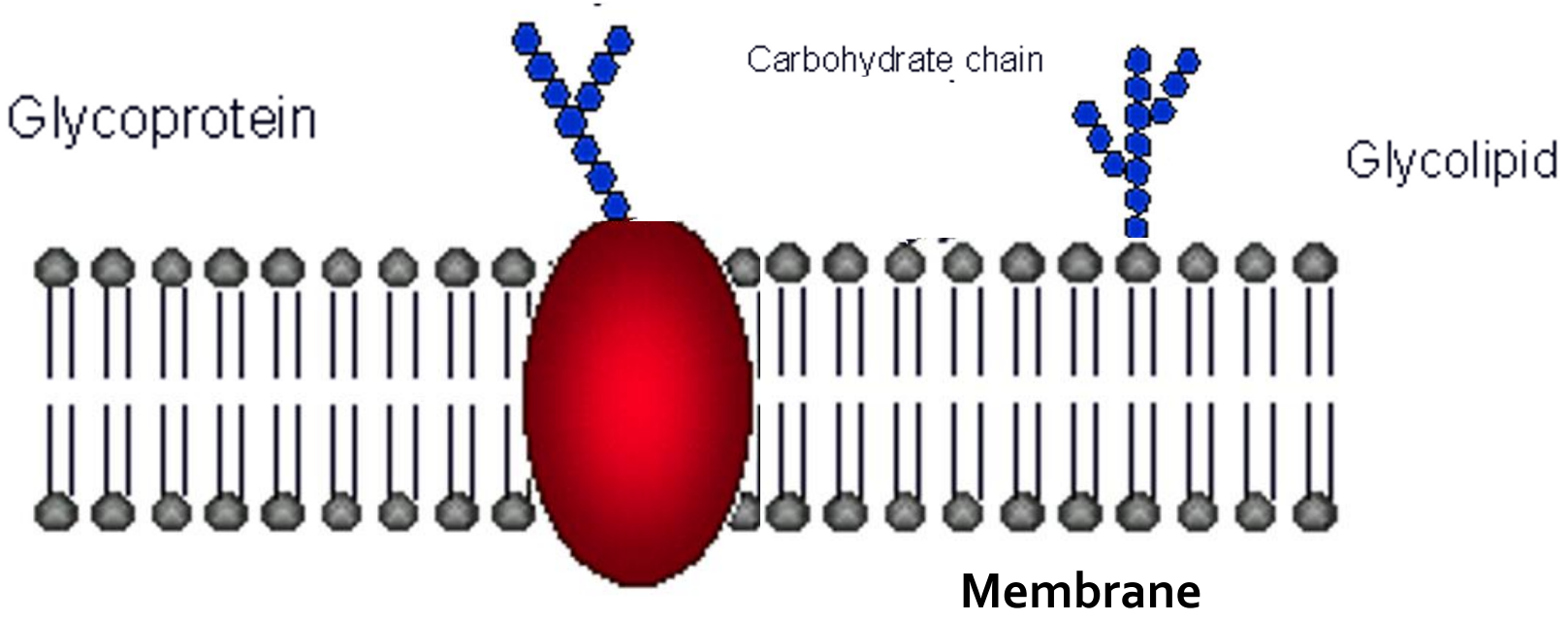
1(h) explain the fluid mosaic model and the **roles** of the constituent biomolecules (including phospholipids, proteins, **glycolipids**, glycoproteins and cholesterol) **in cell membranes**

Glycolipids

Glycolipid

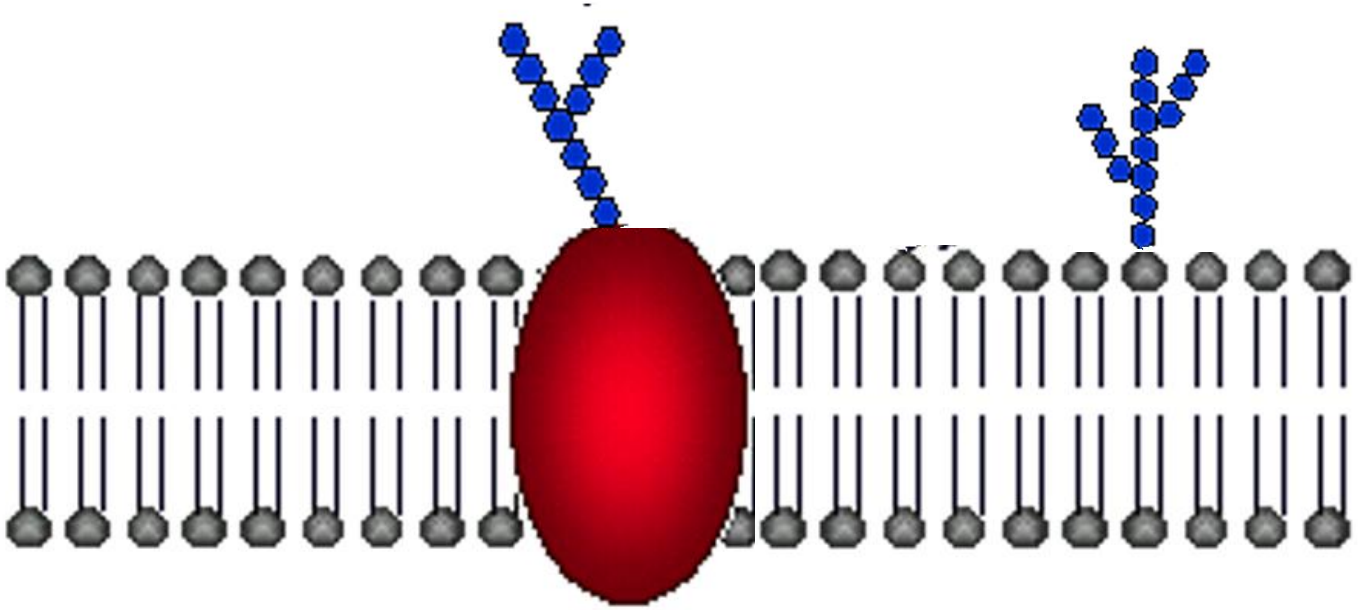
- carbohydrate chain
- ➢ covalently attached to the lipid

in the cell surface membrane via a glycosidic bond

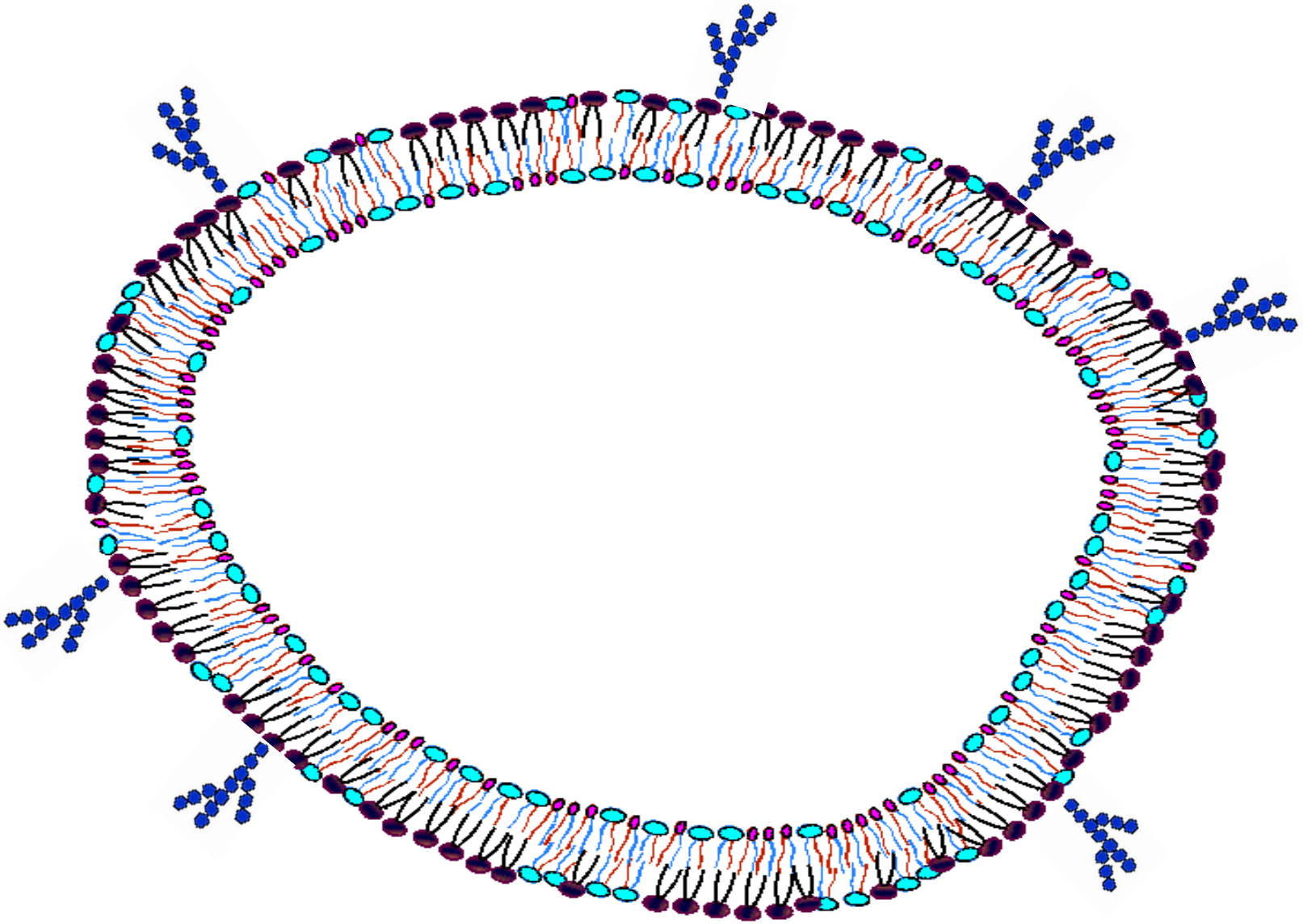


Glycolipids

The carbohydrates are found on the outer surface of all eukaryotic cell membranes

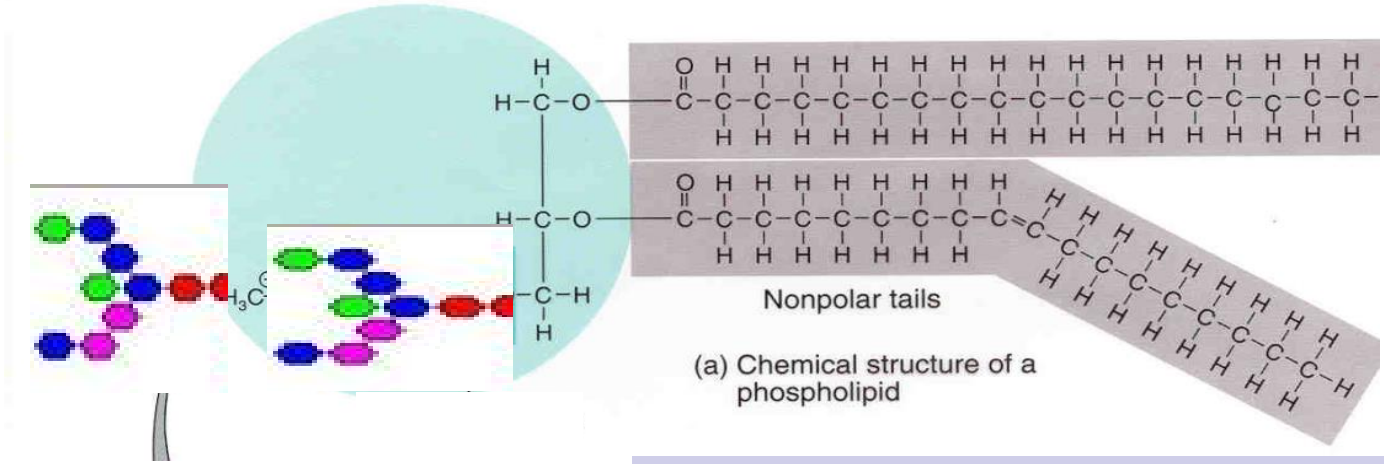


Cell



Glycolipids

- carbohydrate chain associated with lipids



Is the carbohydrate attached to the phosphate group?

The carbohydrate **replaces** the phosphate group.

Glycolipids

Functions:

- Act as recognition sites (for cell-cell recognition; e.g. ABO system)

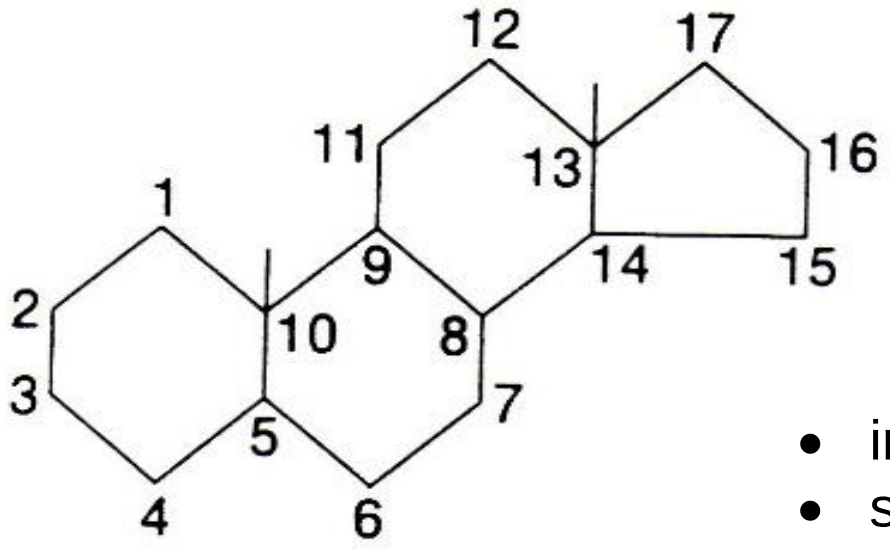
- Act as binding sites (for cell-cell adhesion, to form tissues)

STEROIDS

Steroids

Structure:

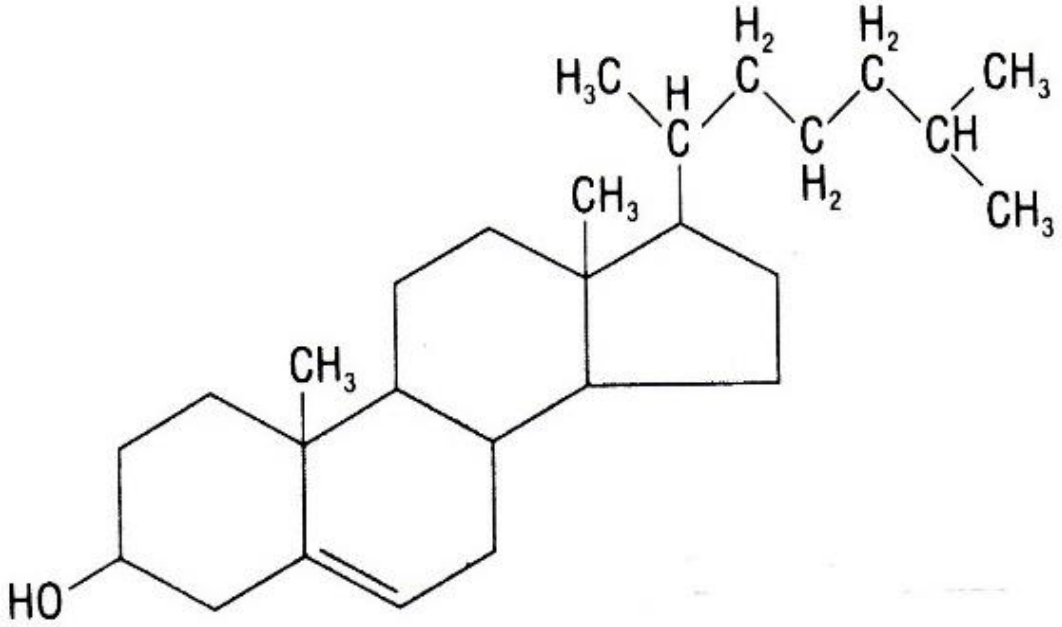
- characterized by a carbon skeleton consisting of **4 fused rings**.



- insoluble in water
- soluble in organic solvents

Steroids

Eg. cholesterol



Steroids (e.g. cholesterol)

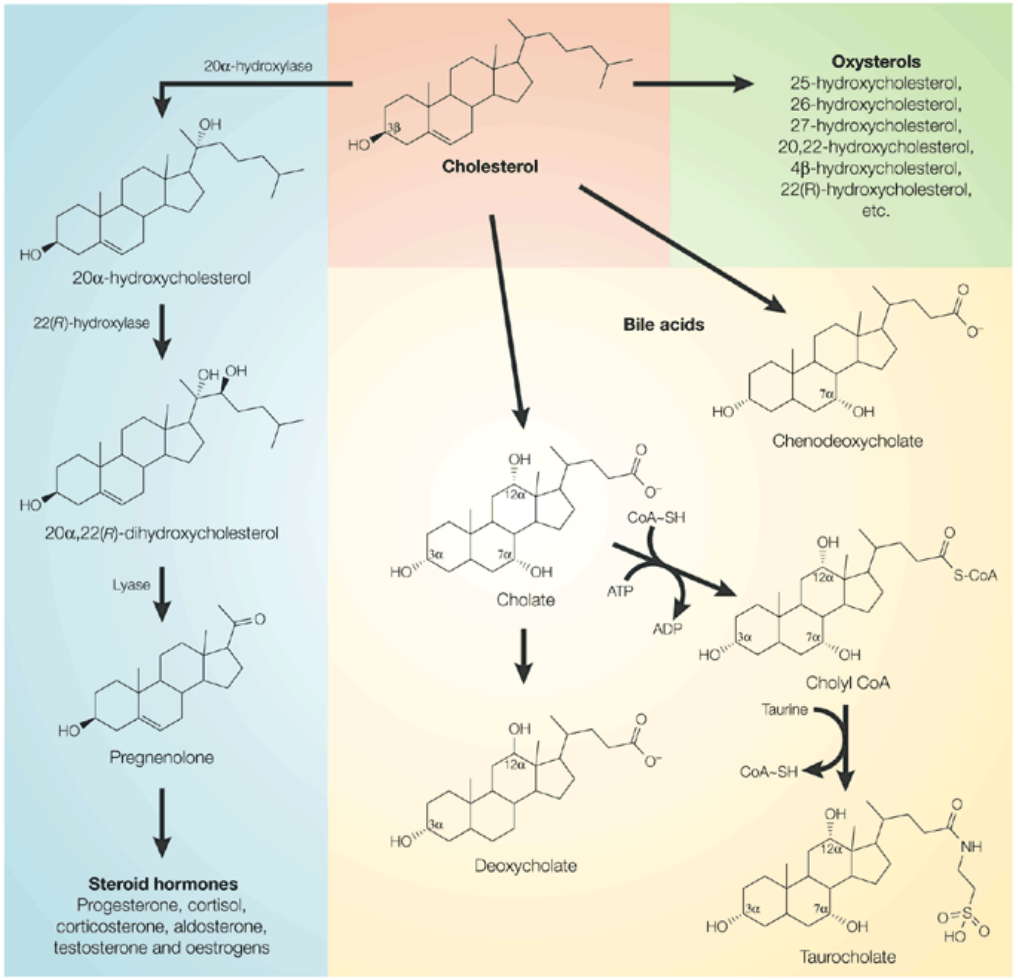
Functions:

Intermediate in a pathway that synthesises a product

1. Precursor of many steroid hormones
2. Synthesis of vitamin D
3. Synthesis of bile salts
4. Fluidity of cell membrane

Precursor of many steroid hormones

- Cholesterol is used in the synthesis of steroid hormones E.g. testosterone, oestrogen and progesterone.



Steroids (e.g. cholesterol)

Functions:

1. Precursor of many steroid hormones
2. Synthesis of vitamin D — For bone and teeth growth
3. Synthesis of bile salts
4. Fluidity of cell membrane

Steroids (e.g. cholesterol)

Functions:

1. Precursor of many steroid hormones
2. Synthesis of vitamin D
3. Synthesis of bile salts
4. Fluidity of cell membrane

To emulsify fats in the small intestines

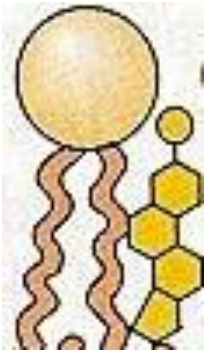
Steroids (e.g. cholesterol)

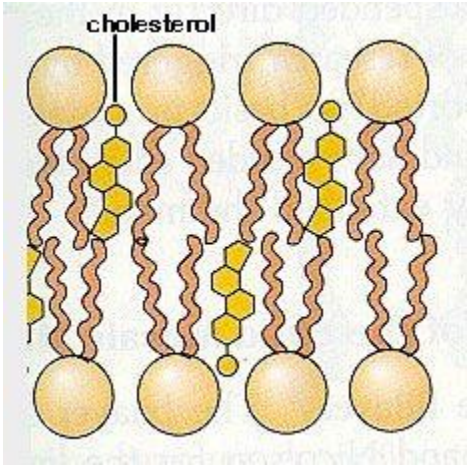
Functions:

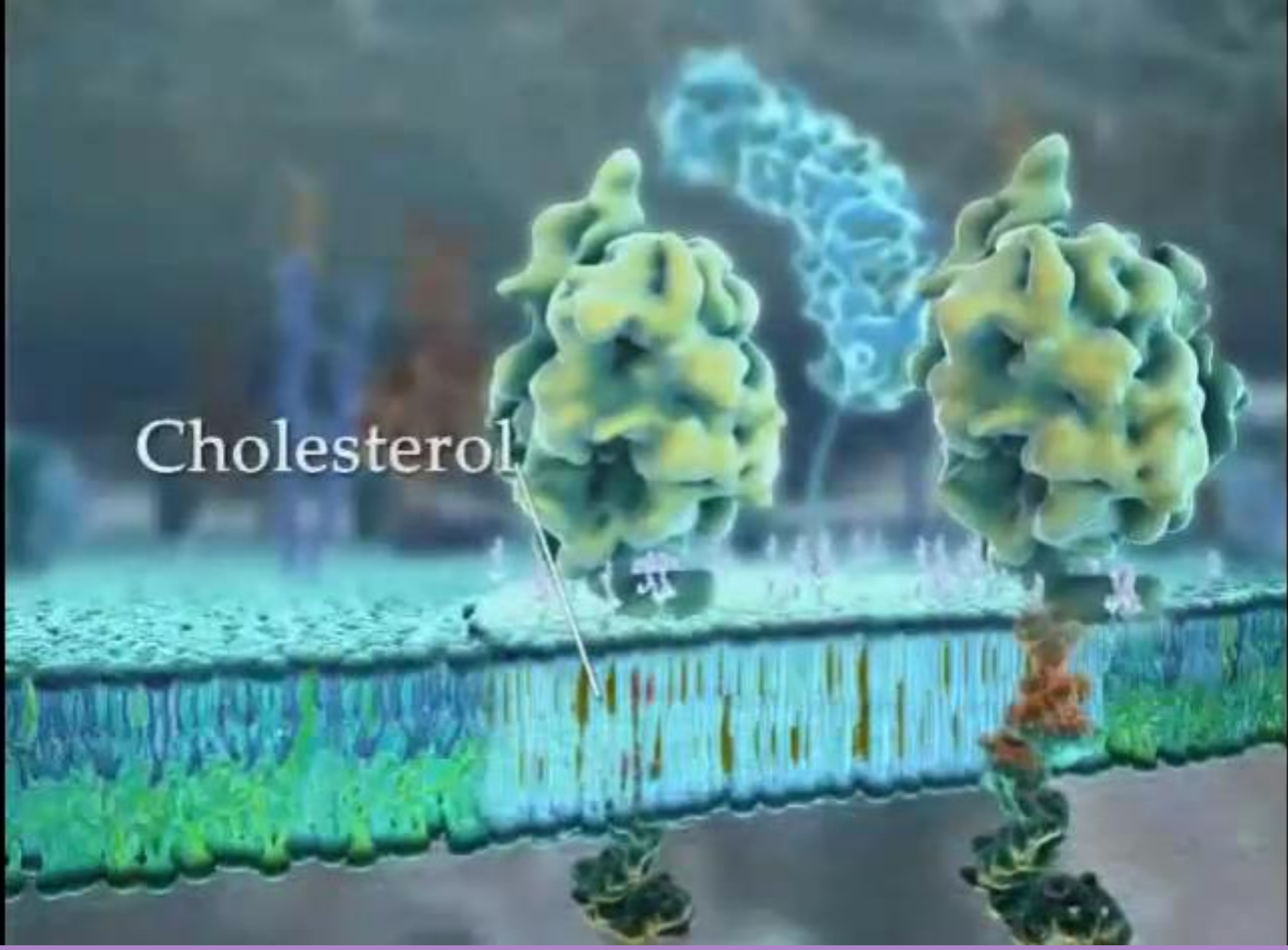
1. Precursor of many steroid hormones
2. Synthesis of vitamin D
3. Synthesis of bile salts
4. Fluidity of cell membrane

Cholesterol **regulates** membrane fluidity:

- By disrupting the close & orderly packing of phospholipids in cell membranes
- At **warm temperatures** (37 °C), cholesterol makes membrane less fluid by reducing movement of phospholipids
- At **colder temperatures**, cholesterol hinders the close packing of phospholipid molecules, and therefore membrane remains fluid






Cholesterol