

Biochemistry

Lipids 1



2nd year Biology
Mustansiriyah University

د. زهراء سالم محسن

د. عبير حازم مصطفى

Lipids

Lipids are **are non-polar** (hydrophobic) compounds, soluble in organic solvents.

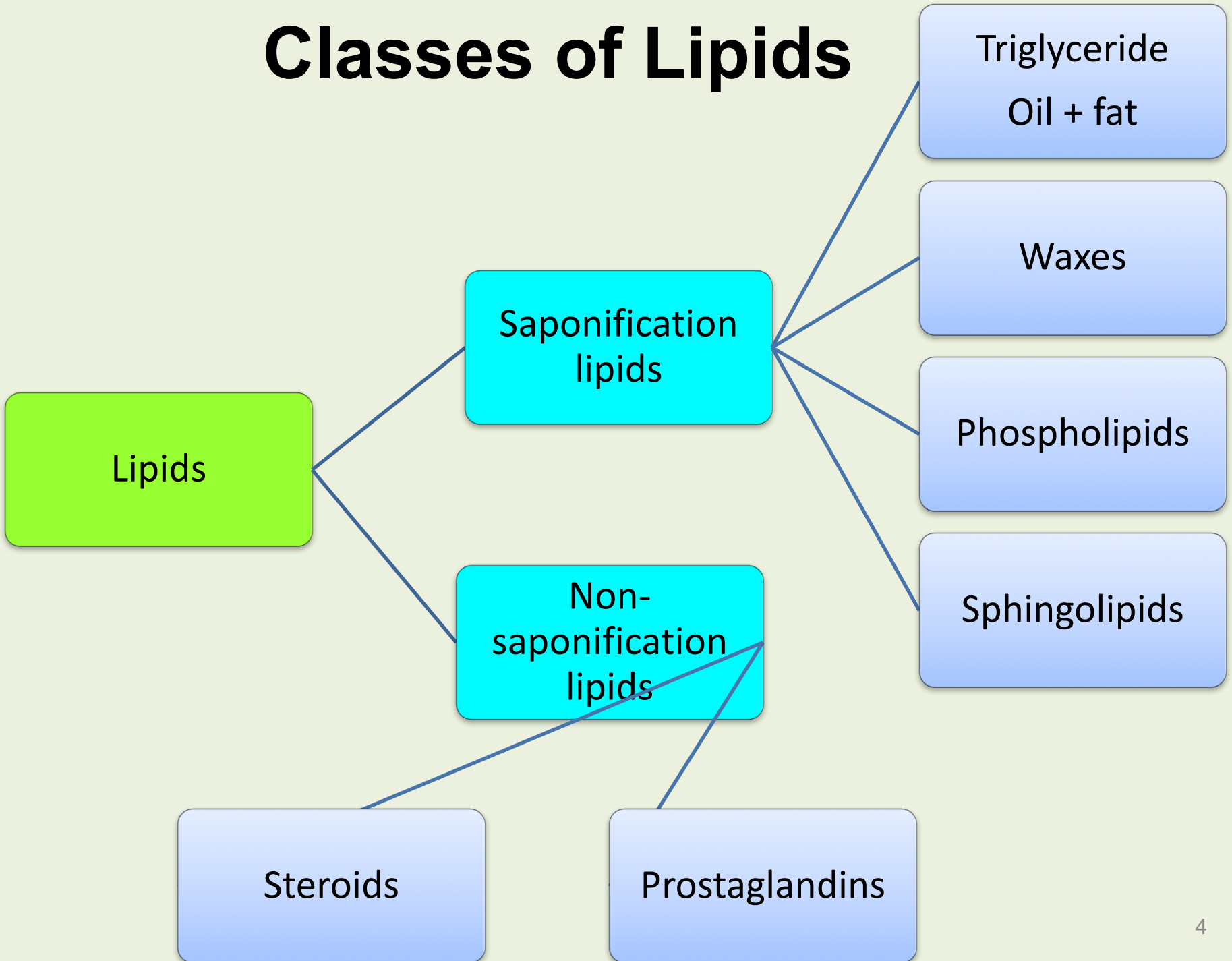
- Most membrane lipids are **amphipathic**, having a **non-polar** end and a **polar** end.
- Biomolecules that contain fatty acids or a steroid nucleus.
- Named for the Greek word *lipos*, which means “fat.”
- Extracted from cells using organic solvents.

Lipids

Lipids are consist of fatty acids (F.As) as a building block and could be grouped as:

1. Neutral fats and oils (triglycerides)
3. Phospholipid and sphingolipids
4. Waxes
5. Steroids
6. Prostaglandins
6. Fat soluble vitamins

Classes of Lipids



Lipids

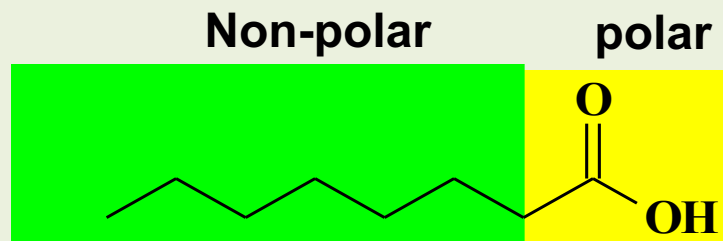
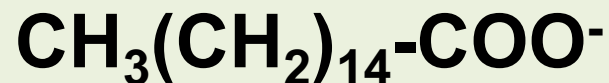
Fatty Acids (F.As)



Copyright © 2007 by Pearson Education, Inc.
Publishing as Benjamin Cummings

Fatty acids (F.As) : a hydrocarbon chain with a carboxylic acid at one end.

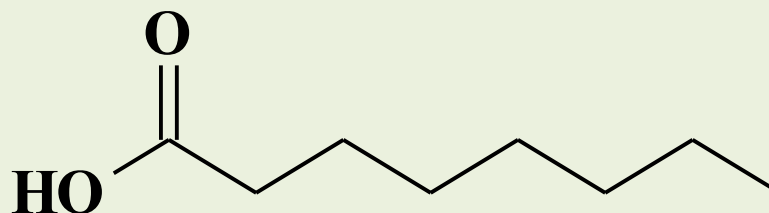
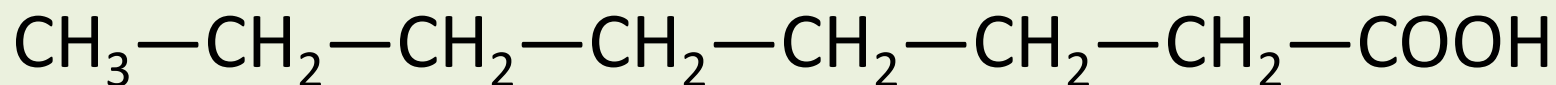
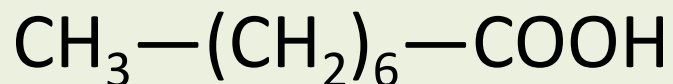
A 16-C fatty acid:



F.As Formulas

The **formulas for F.As** are written as

- Condensed formulas.
- Line-bond formulas.
- For example caprylic acid with 8 carbon atoms.



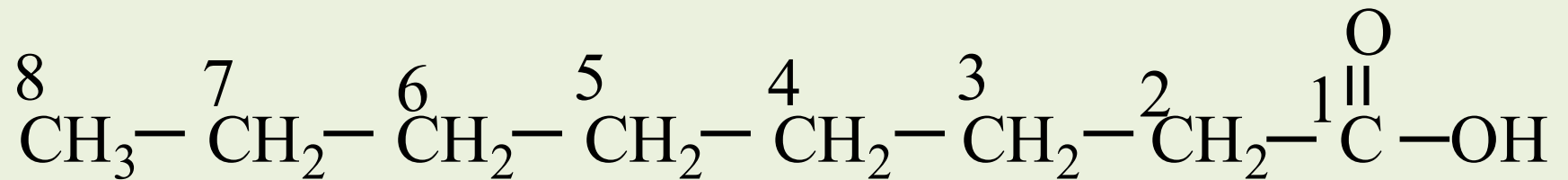
Fatty Acids

F.As

- Are long-chain carboxylic acids.
- Typically contain 12-18 carbon atoms.
- Are water insoluble .
- Can be saturated or unsaturated.

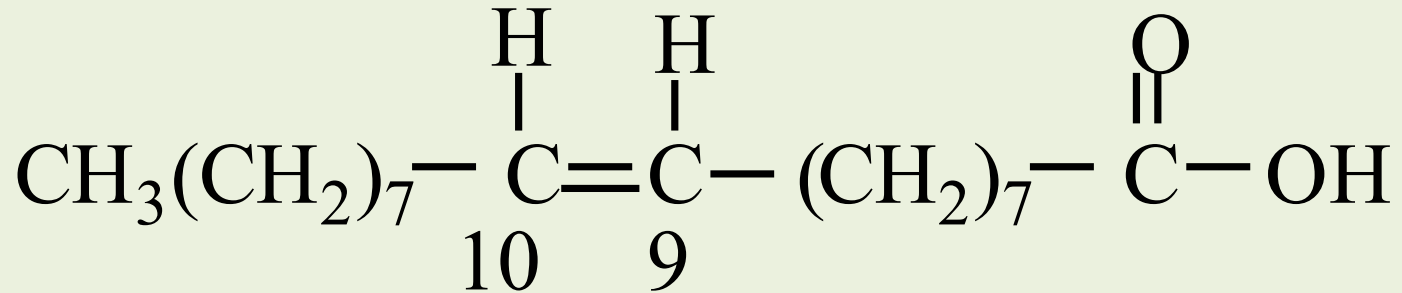


Saturated Fatty Acids

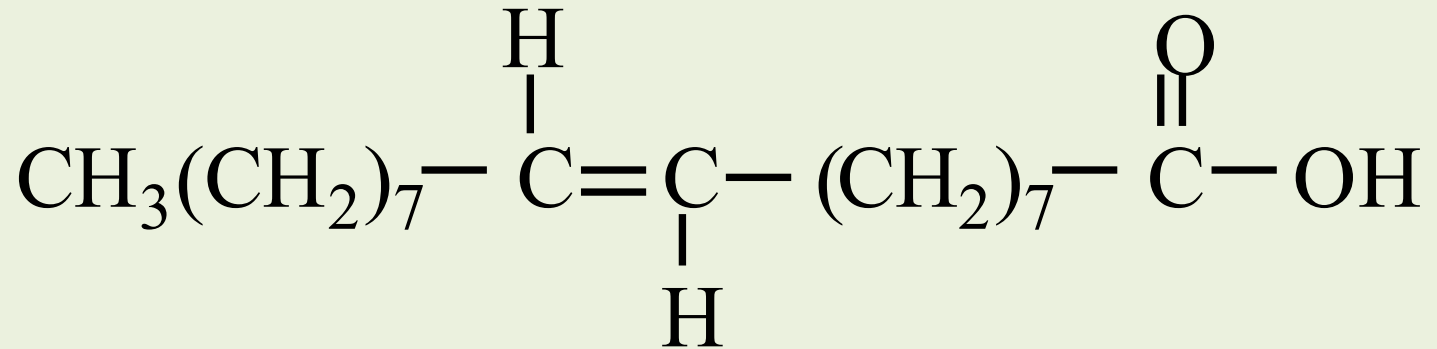


Octanoic Acid

Cis And Trans Fatty Acids



Cis 9 - Octadecenoic Acid (oleic)



Trans 9 - Octadecenoic Acid (elaidic acid)

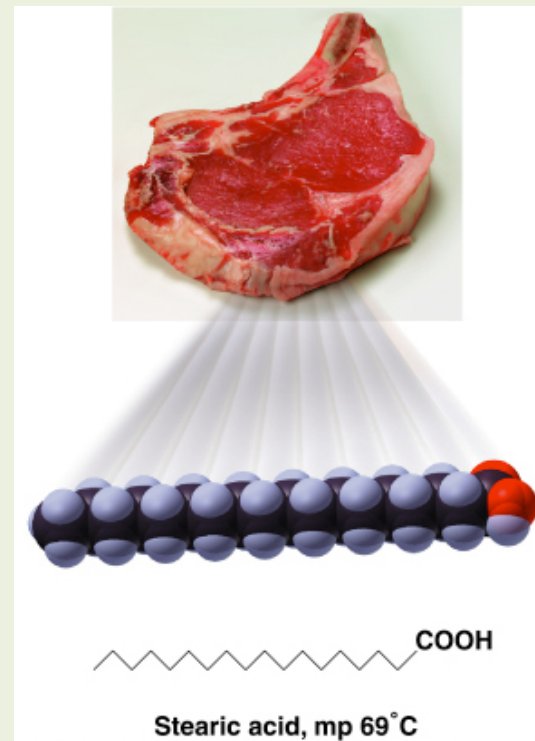
A 18-C fatty acid with one cis double bond between C atoms 9-10 may be represented as **18:1 cis Δ^9** .

A 18-C fatty acid with one trans double bond between C atoms 9-10 may be represented as **18:1 trans Δ^9** .

Saturated Fatty Acids

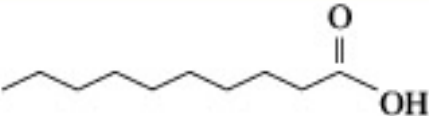
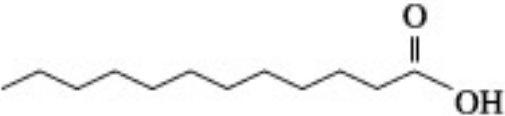
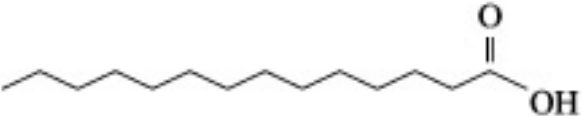
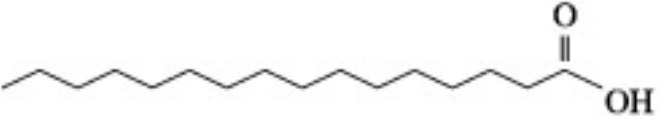
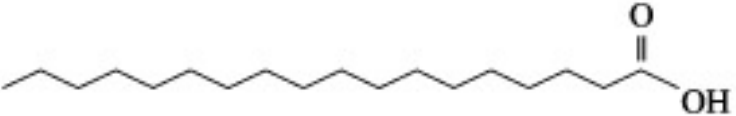
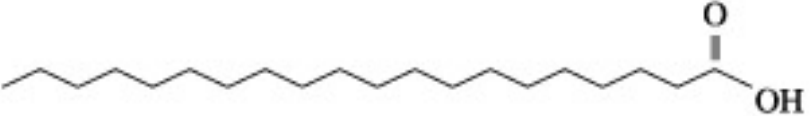
Saturated fatty acids have

- Single C–C bonds.
- Molecules that fit closely together in a regular pattern.
- Strong attractions between fatty acid chains.
- High melting points that make them solids at room temperature.



Some Saturated Fatty Acids

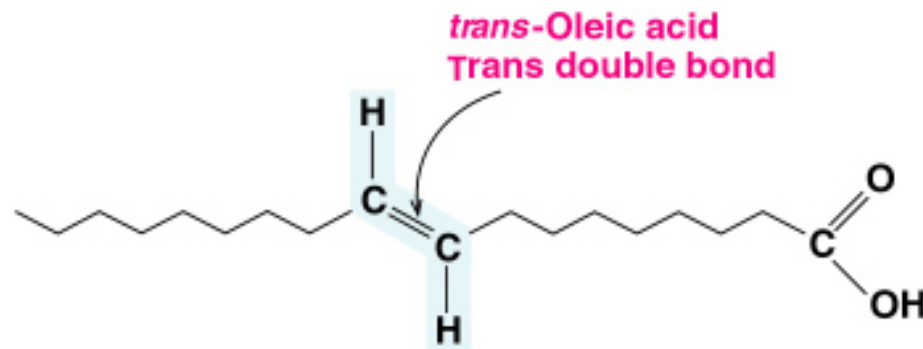
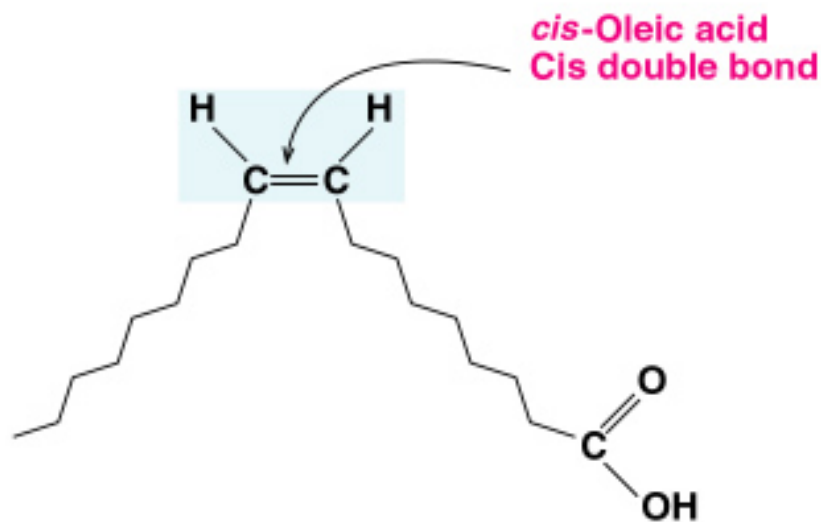
Table 18.1 Structures and Melting Points of Common Fatty Acids

Name	Carbon Atoms	Structure	Melting Point (°C)	Source
Saturated Fatty Acids				
Capric acid	10		32	Saw palmetto
Lauric acid	12		43	Coconut
Myristic acid	14		54	Nutmeg
Palmitic acid	16		62	Palm
Stearic acid	18		69	Animal fat
Arachidic acid	20		76	Peanut oil, vegetable and fish oils

Unsaturated Fatty Acids

Unsaturated fatty acids

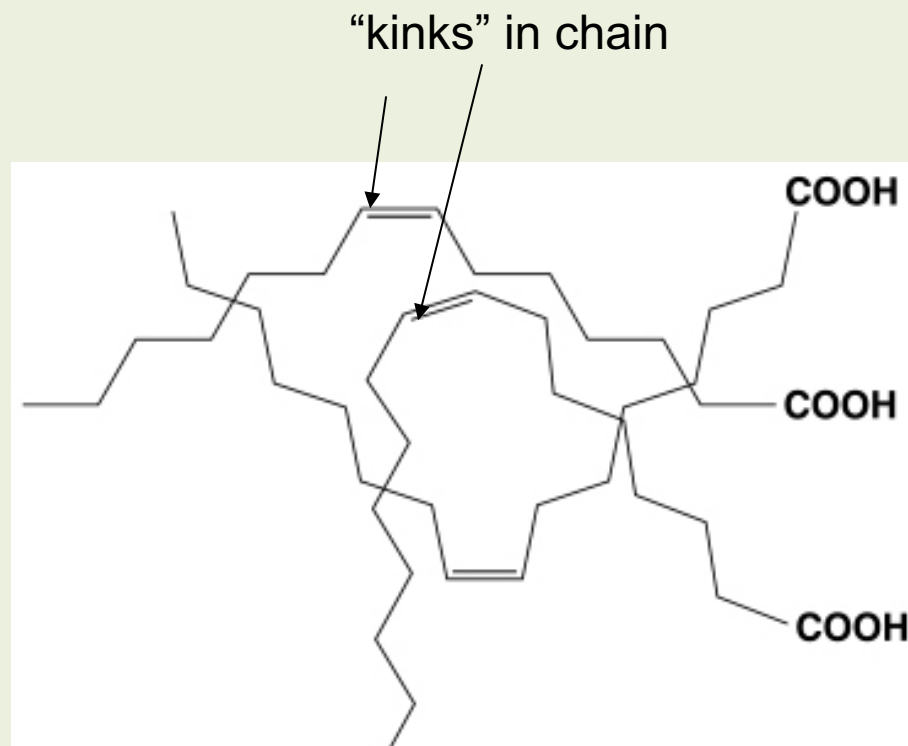
- Have one or more double C=C bond.
- Typically contain *cis* double bonds.



Properties of Unsaturated Fatty Acids

Unsaturated fatty acids

- Have “kinks” in the fatty acid chains.
- Do not pack closely.
- Have few attractions between chains.
- Have low melting points.
- Are liquids at room temperature.



Polyunsaturated Fatty Acids

Linoleic acid: Cis, cis, 9, 12 - Octadecadienoic acid

Linolenic acid: Cis, cis, cis 9, 12, 15 - Octadecatrienoic acid

Arachidonic acid: Cis, cis, cis, cis 5, 8, 11, 14 - Eicosatetraenoic acid

Linoleic Acid



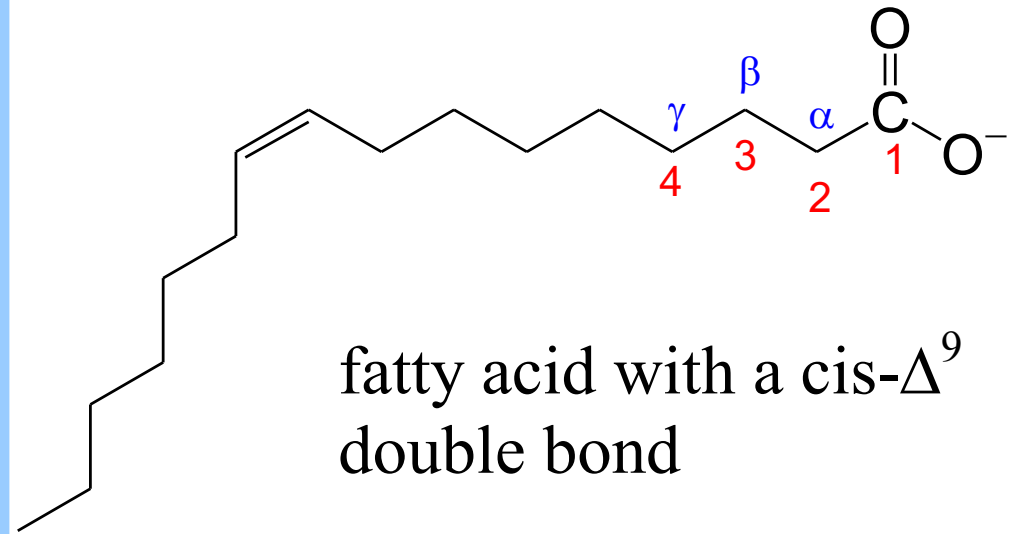
Linolenic Acid



Arachidonic Acid

Double bonds in fatty acids usually have the **cis** configuration.

Most naturally occurring fatty acids have an **even number** of carbon atoms.



Some fatty acids and their common names:

14:0 myristic acid; 16:0 palmitic acid; 18:0 stearic acid;
18:1 cis Δ^9 oleic acid

18:2 cis $\Delta^{9,12}$ linoleic acid

18:3 cis $\Delta^{9,12,15}$ α -linolenic acid

20:4 cis $\Delta^{5,8,11,14}$ arachidonic acid

Comparing Melting Points of Some Fatty Acids

Structures and Melting Points of Common Fatty Acids

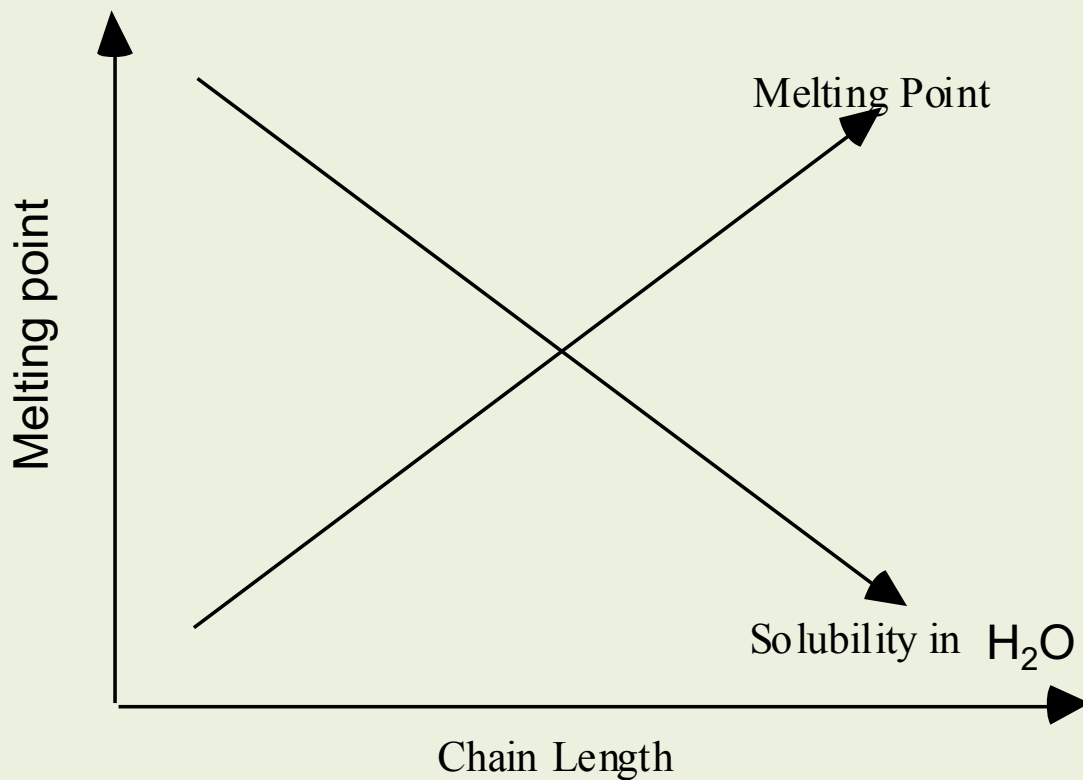
Name	Carbon Atoms	Double Bonds	Structure	Melting Point (°C)	Source
Saturated					
Lauric acid	12	0	$\text{CH}_3\text{---}(\text{CH}_2)_{10}\text{---COOH}$	43	Coconut
Myristic acid	14	0	$\text{CH}_3\text{---}(\text{CH}_2)_{12}\text{---COOH}$	54	Nutmeg
Palmitic acid	16	0	$\text{CH}_3\text{---}(\text{CH}_2)_{14}\text{---COOH}$	62	Palm
Stearic acid	18	0	$\text{CH}_3\text{---}(\text{CH}_2)_{16}\text{---COOH}$	69	Animal fat
Unsaturated					
Palmitoleic acid	16	1	$\text{CH}_3\text{---}(\text{CH}_2)_5\text{---CH=CH---}(\text{CH}_2)_7\text{---COOH}$	0	Butter
Oleic acid	18	1	$\text{CH}_3\text{---}(\text{CH}_2)_7\text{---CH=CH---}(\text{CH}_2)_7\text{---COOH}$	13	Olives, corn
Linoleic acid	18	2	$\text{CH}_3\text{---}(\text{CH}_2)_4\text{---CH=CH---CH}_2\text{---CH=CH---}(\text{CH}_2)_7\text{---COOH}$	-9	Soybean, safflower, sunflower
Linolenic acid	18	3	$\text{CH}_3\text{---CH}_2\text{---CH=CH---CH}_2\text{---CH=CH---CH}_2\text{---CH=CH---}(\text{CH}_2)_7\text{---COOH}$	-17	Corn

Copyright © 2007 by Pearson Education, Inc. Publishing as Benjamin Cummings

Effects of Double Bonds on the Melting Points

Fatty. Acids.	Melting point. P. (0C)
16:0	60
16:1	1
18:0	63
18:1	16
18:2	-5
18:3	-11
20:0	75
20:4	-50

Melting Points of Fatty Acids and Solubility in Water



Learning Check

Assign the melting points of -17°C , 13°C , and 69°C to the correct fatty acid. Explain.

stearic acid (18 C)	saturated
oleic acid (18 C)	one double bond
linoleic acid (18 C)	two double bonds

Solution

Stearic acid is saturated and would have a higher melting point than the unsaturated fatty acids. Because linoleic has two double bonds, it would have a lower mp than oleic acid, which has one double bond.

stearic acid mp 69°C saturated

oleic acid mp 13°C

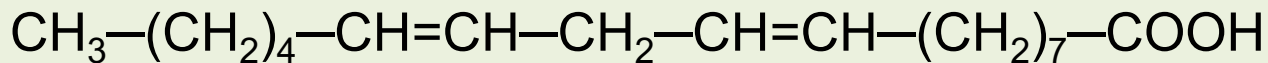
linoleic acid mp -17°C most unsaturated

Omega-6 and Omega 3- Fatty Acids

Fatty acids

- In vegetable oils are mostly **omega-6** with the first C=C at C6.

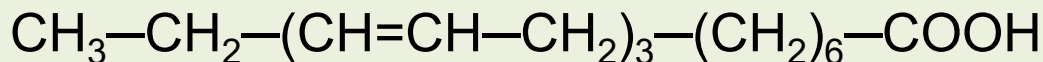
linoleic acid



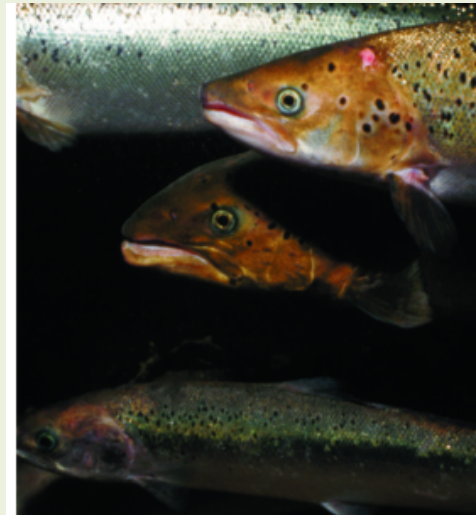
6

- In fish oils are mostly **omega-3** with the first C=C at C3.

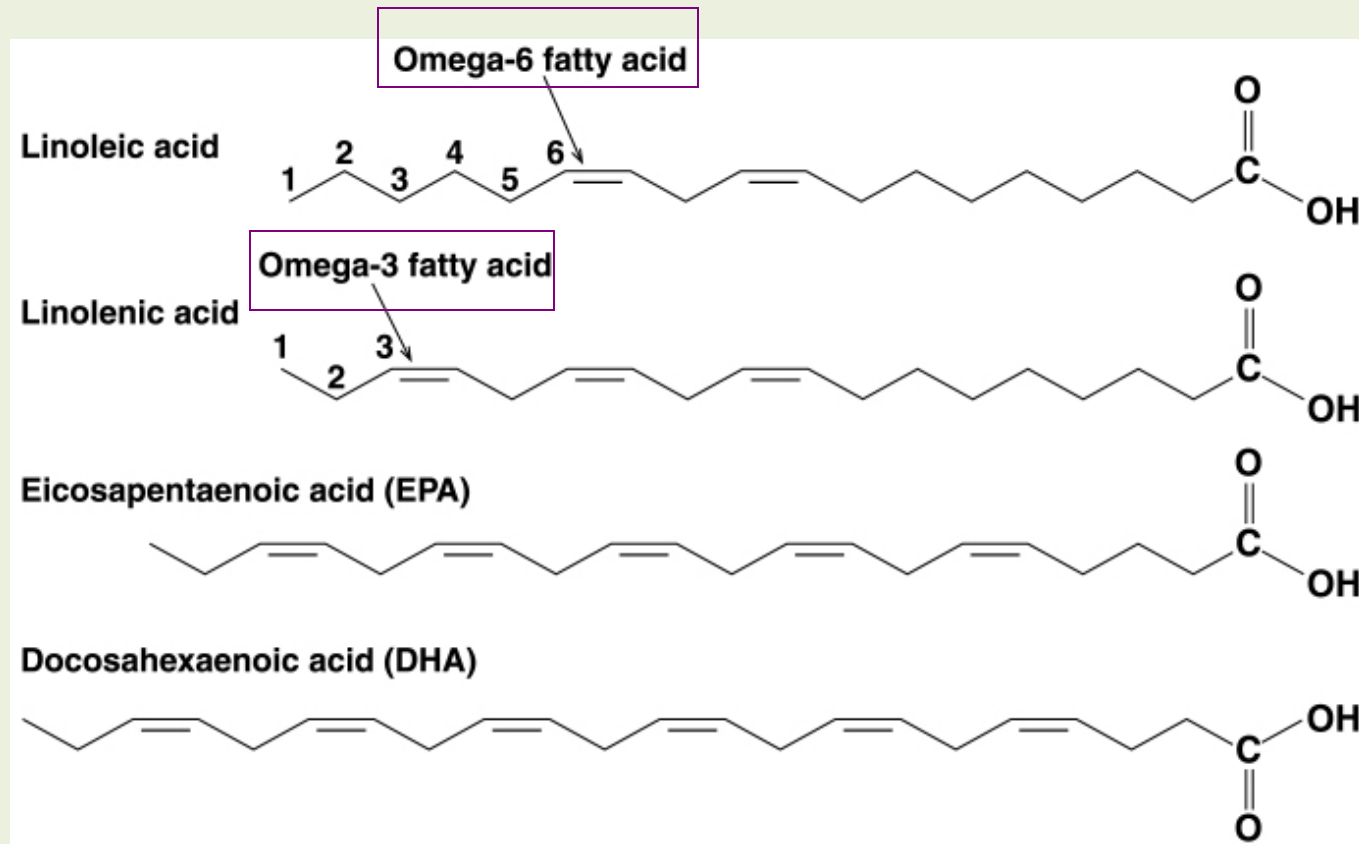
linolenic acid



3



Some Omega-6 and Omega-3 Fatty Acids



Learning Check

Write a fatty acid with 10 carbon atoms that is:

A. saturated

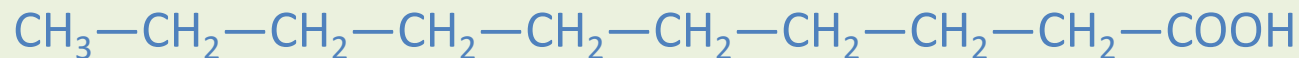
B. monounsaturated omega-3

C. monounsaturated omega-6

Solution

Write a fatty acid with 10 carbon atoms that is:

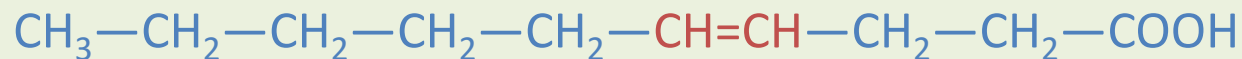
A. saturated



B. monounsaturated omega-3



C. monounsaturated omega-6



<https://youtu.be/Os22YEYObDs>

Lipids

Fats and Oils



Fats and Oils: Triacylglycerols

Fats and oils are

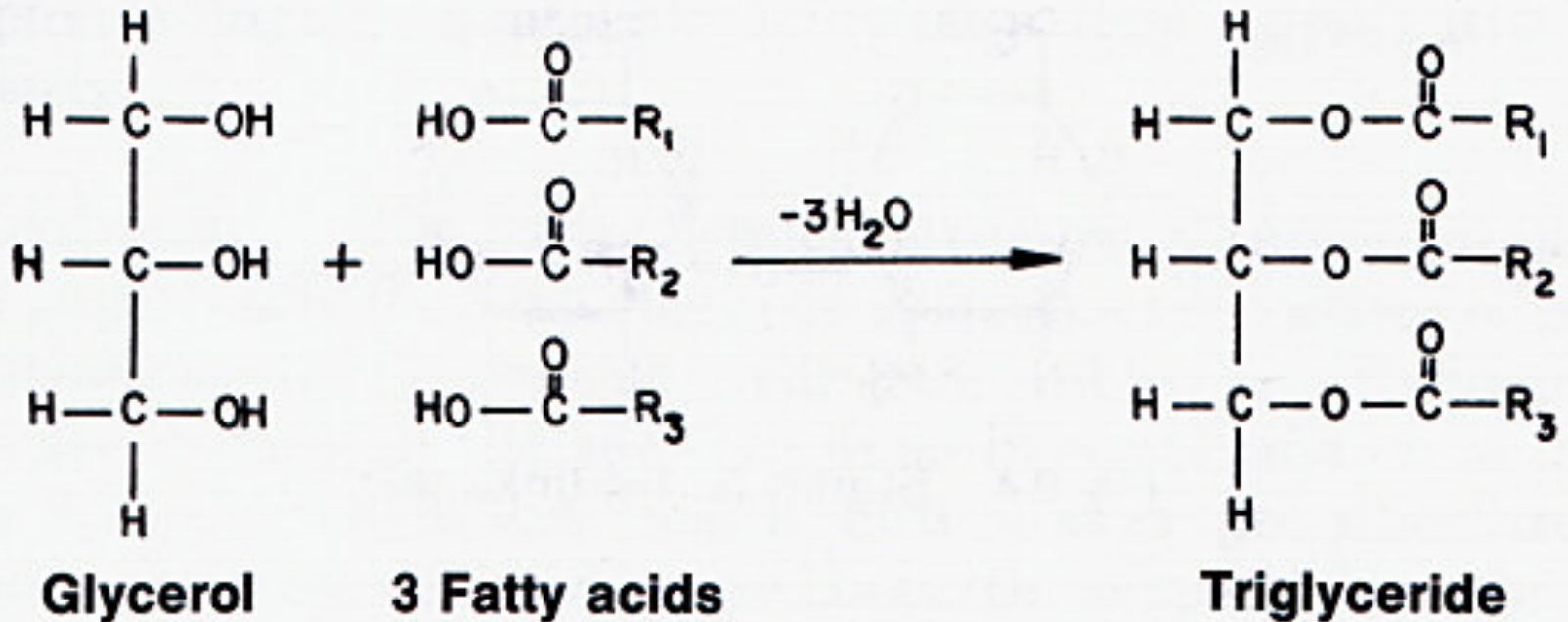
- Also called **triacylglycerols (TG)**.
- Esters of glycerol.
- Produced by esterification.
- Formed when OH groups of glycerol react with the COOH of F.As and liberate H₂O



Copyright © 2007 by Pearson Education, Inc.
Publishing as Benjamin Cummings

Fats

Fats are mostly Triglycerides (TG):



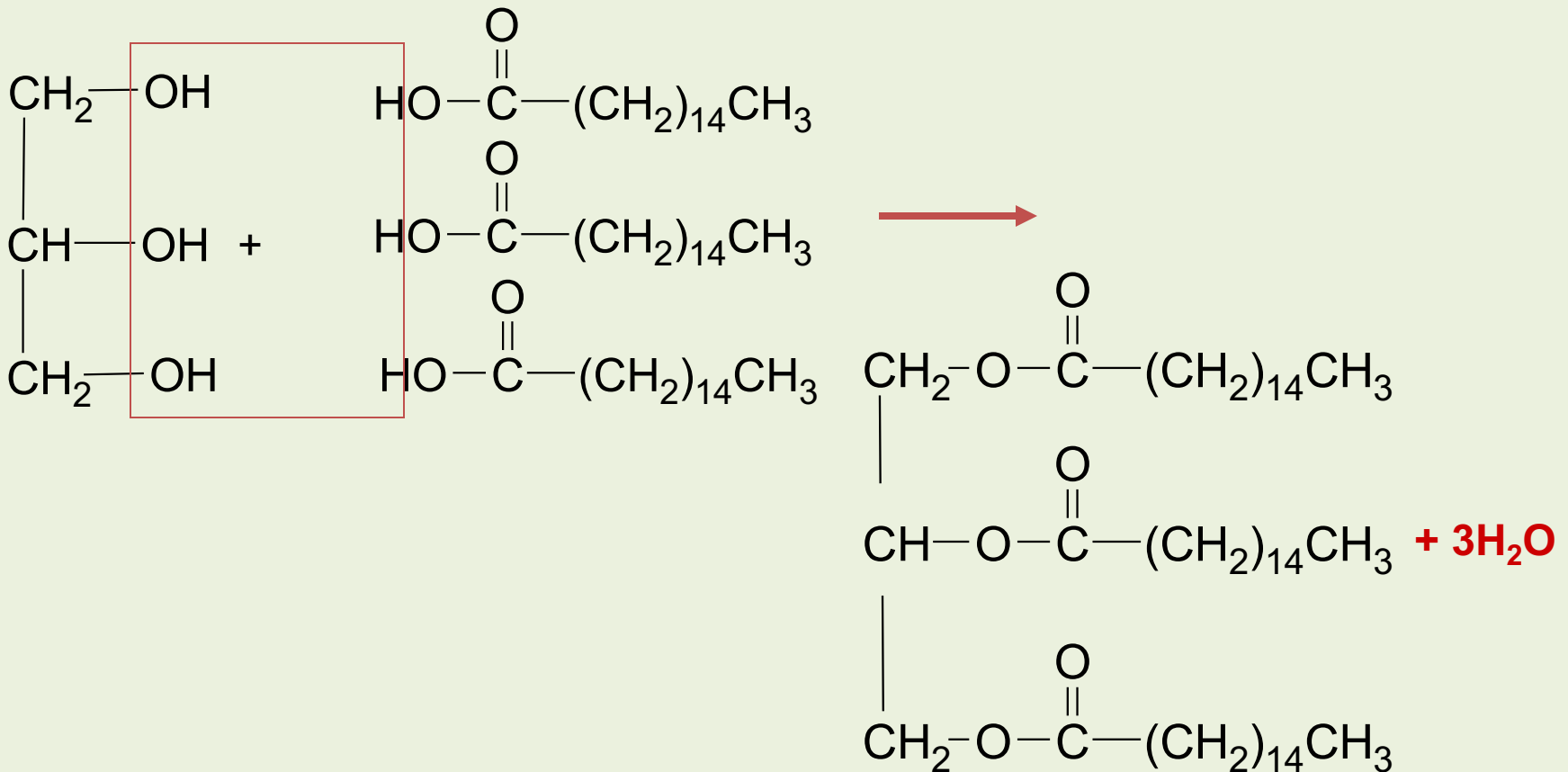
Solid

Formation of a Triacylglycerol

glycerol +

three fatty acids

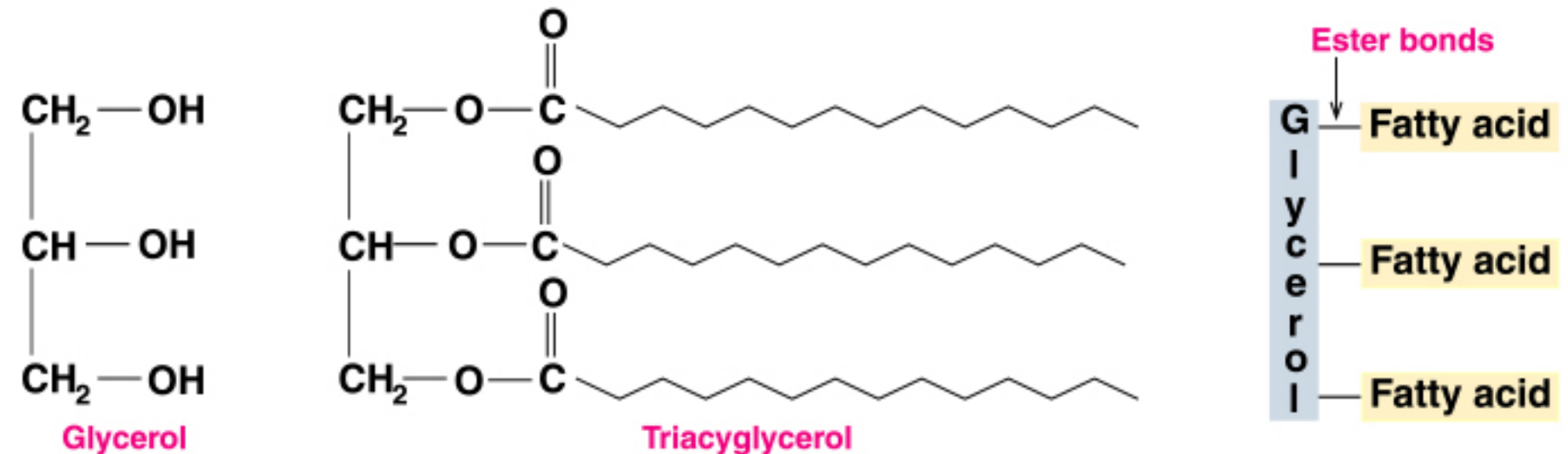
triacylglycerol



Triacylglycerols

In a **triacylglycerol**,

- Glycerol forms ester bonds with three fatty acids.



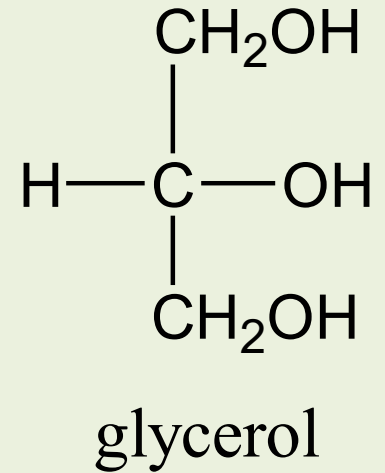
Glycerophospholipids

Glycerophospholipids (phosphoglycerides):

-common constituents of cellular membranes.

-They have a **glycerol** backbone.

-Hydroxyls at **C1** & **C2** are esterified to **fatty acids**.

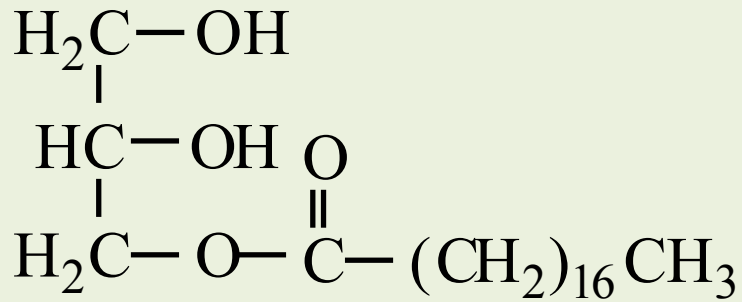


Formation of an ester:

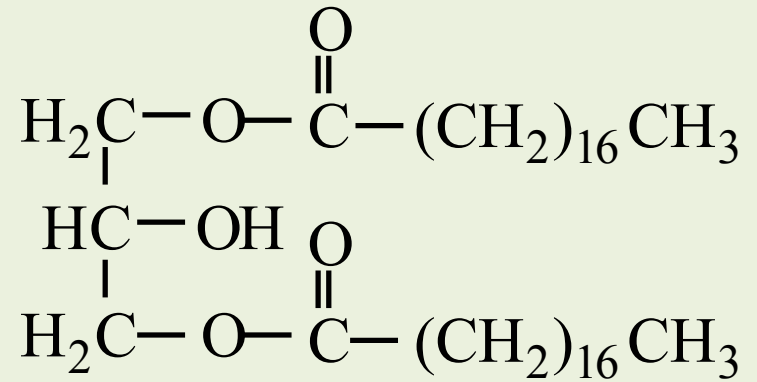


An **ester** forms when a hydroxyl reacts with a carboxylic acid, with loss of H₂O.

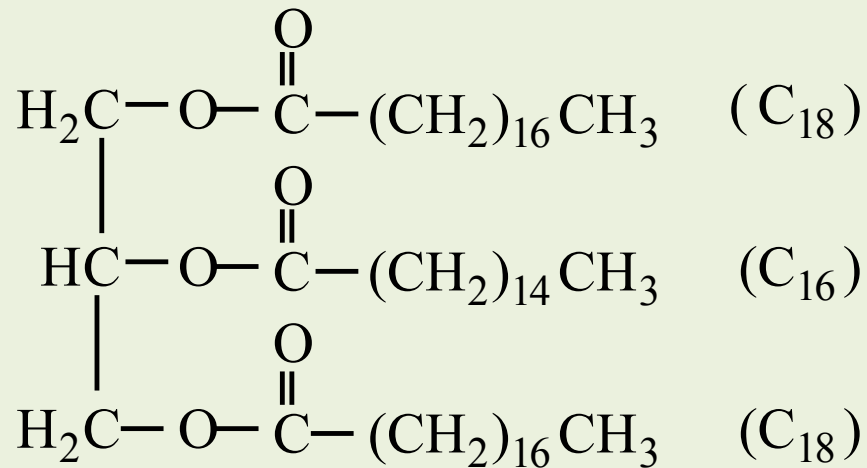
Glycerides



Monoglyceride (α - monostearin)



Diglyceride (α, α' - distearin)



Triglyceride (β - palmityl distearin)

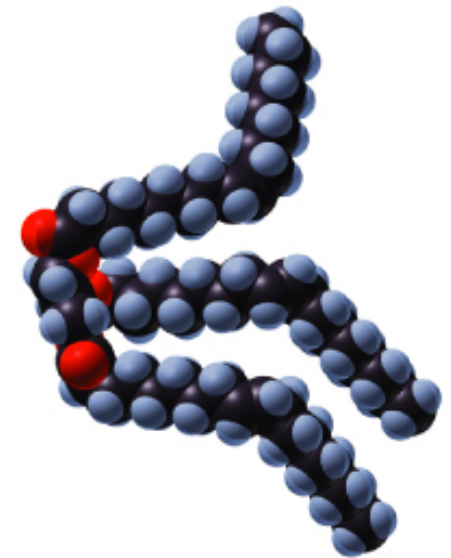
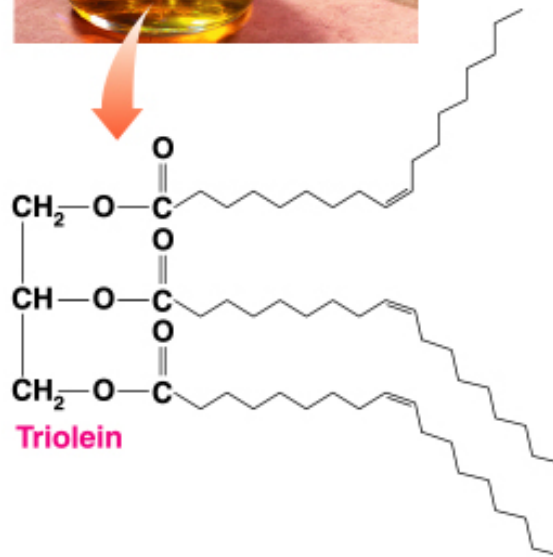
Oils

Olive oil

- Contains a high percentage of oleic acid, which is a monounsaturated fatty acid with one cis double bond.

(TG + 3 Oleic acid)

Liquid

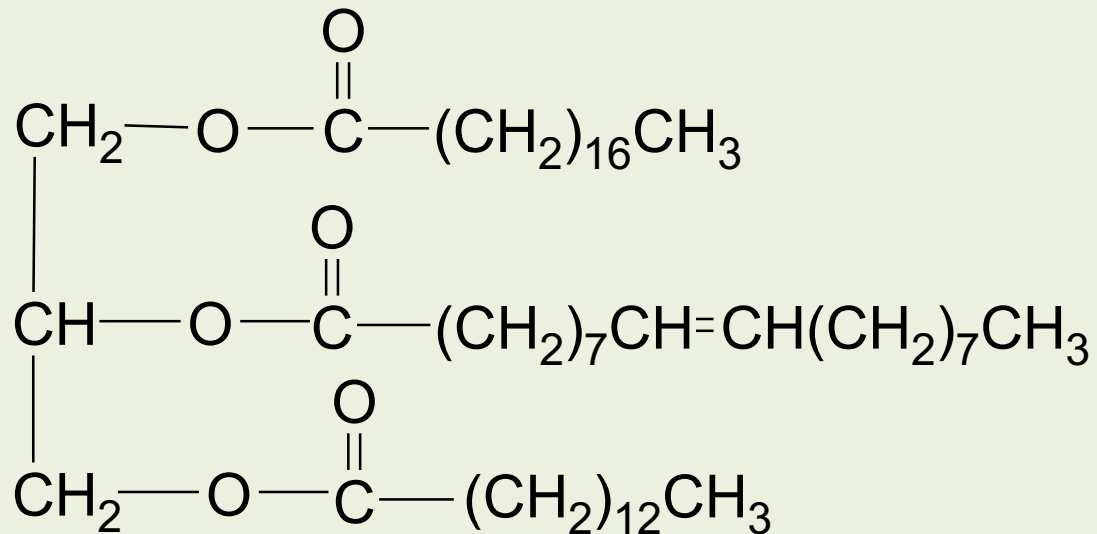


Unsaturated fatty acid chains have kinks that do not allow close packing.

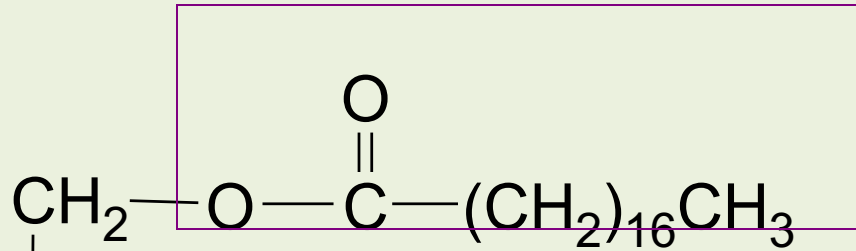
Timberlake, *General, Organic, and Biological Chemistry*. Copyright © Pearson Education Inc., publishing as Benjamin Cummings

Learning Check

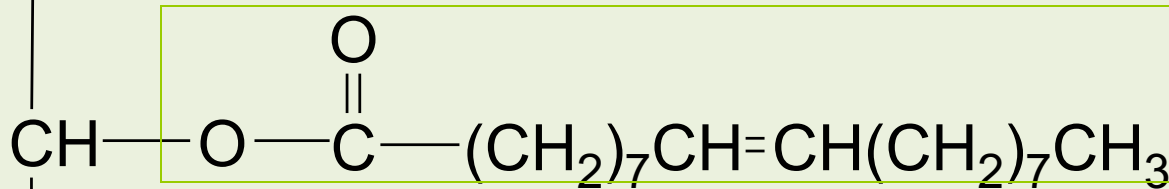
What are the fatty acids in the following triacylglycerol?



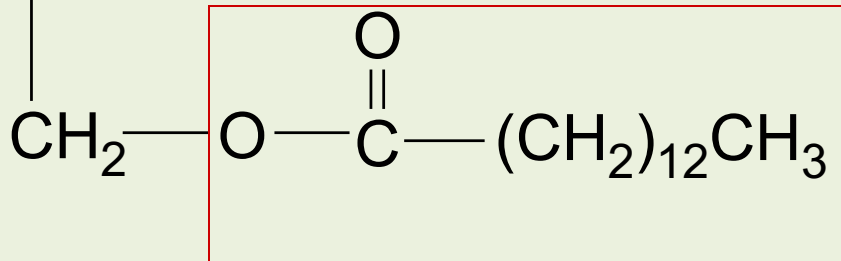
Solution



Stearic acid



Oleic acid



Myristic acid

MELTING POINTS OF TRIGLYCERIDES

Triglyceride	Melting Point (°C)
C6	-15
C12	15
C14	33
C16	45
C18	55
C18:1 (cis)	-32
C18:1 (trans)	15

Melting Points of Fats and Oils

A triacylglycerol that is a **fat**

- Is solid at room temperature.
- Is prevalent in meats, whole milk, butter, and cheese.

A triacylglycerol that is an **oil**

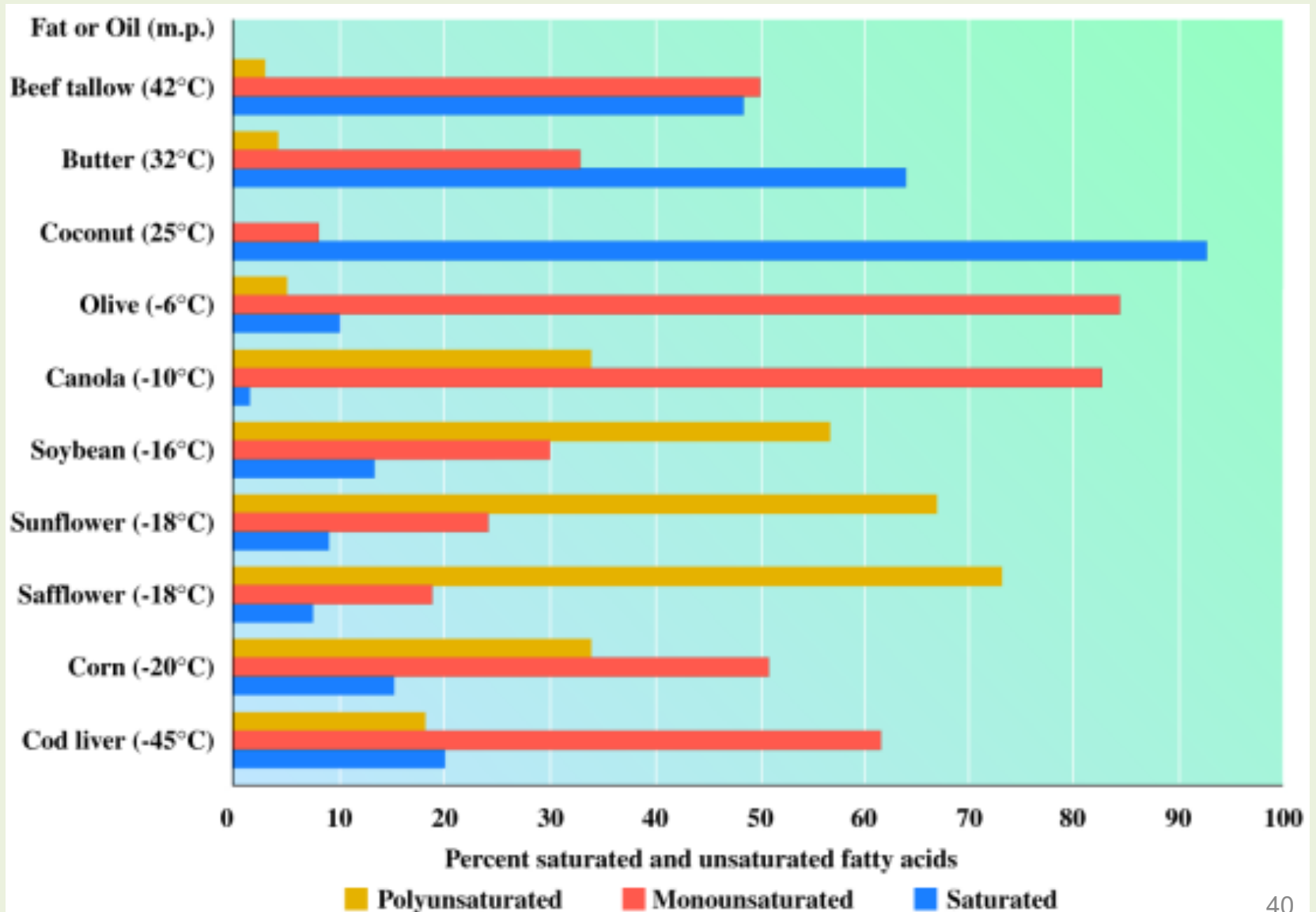
- Is liquid at room temperature.
- Is prevalent in plants such as olive and safflower.

Oils with Unsaturated Fatty Acids

Oils

- Have more unsaturated fats.
- Have *cis* double bonds that cause “kinks” in the fatty acid chains.
- Cannot pack triacylglycerol molecules as close together as in fats.
- Have lower melting points than saturated fats.
- Are liquids at room temperature.

Saturated and Unsaturated Fatty Acids In Fats and Oils



Waxes

Waxes are

- Esters of saturated fatty acids and long-chain alcohols.
- Coatings that prevent loss of water by leaves of plants.

Table 18.2 Some Typical Waxes

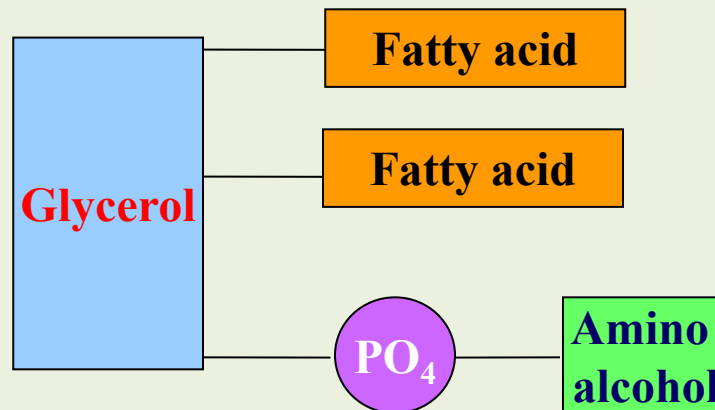
Type	Structural Formula	Source	Uses
Beeswax	$\text{CH}_3(\text{CH}_2)_{14}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-(\text{CH}_2)_{29}\text{CH}_3$	Honeycomb	Candles, shoe polish, wax paper
Carnauba wax	$\text{CH}_3(\text{CH}_2)_{24}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-(\text{CH}_2)_{29}\text{CH}_3$	Brazilian palm tree	Waxes for furniture, cars, floors, shoes
Jojoba wax	$\text{CH}_3(\text{CH}_2)_{18}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-(\text{CH}_2)_{19}\text{CH}_3$	Jojoba	Candles, soaps, cosmetics

Lipids

Phospholipids

&

Glycerophospholipids

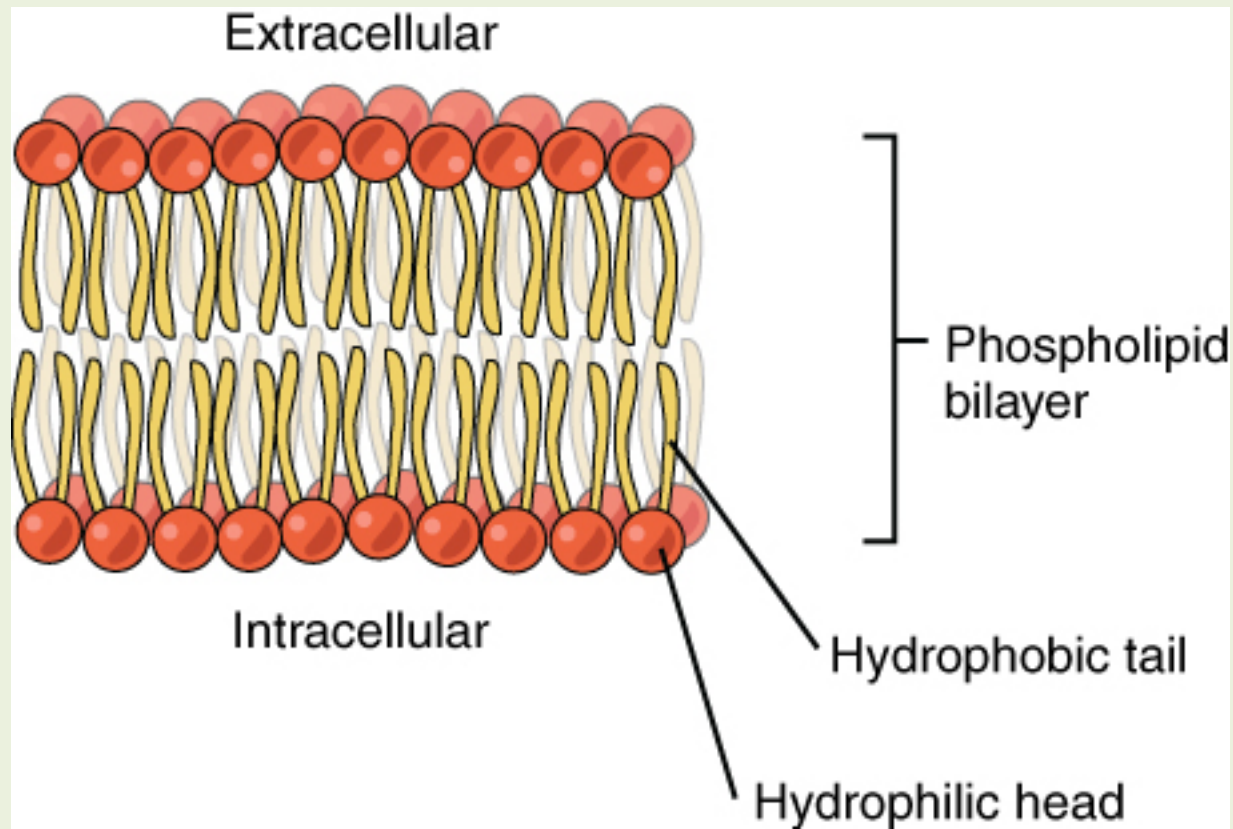


Phospholipids

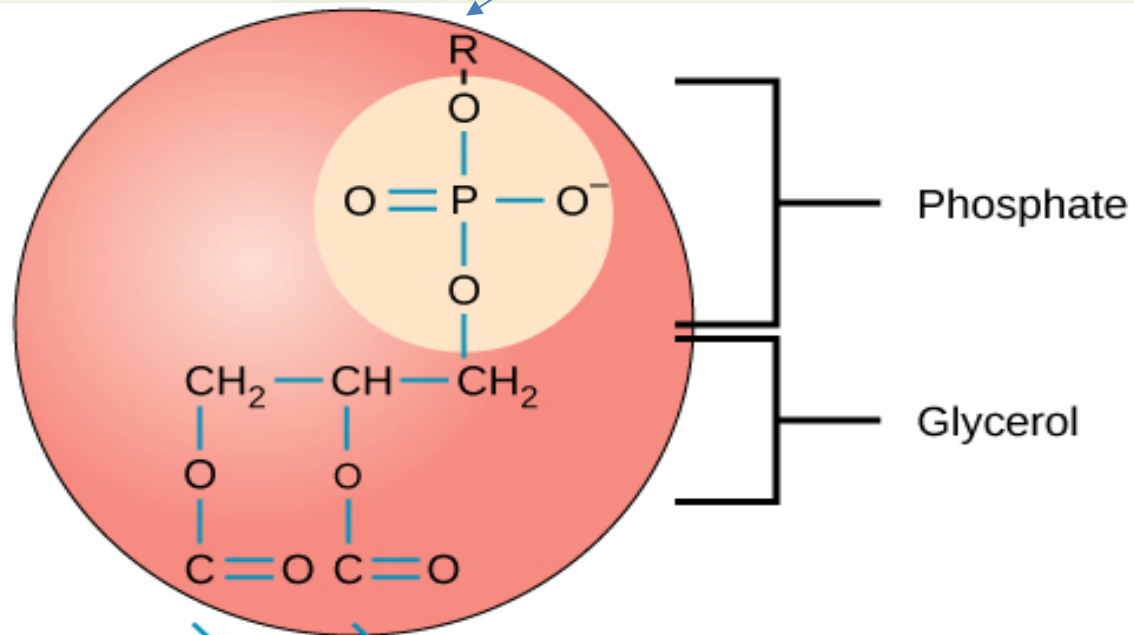
Phospholipids are the major component of all cell membranes.

Phospholipid = two hydrophobic F.As "tails" + a hydrophilic "head" which is consisting of a phosphate group.

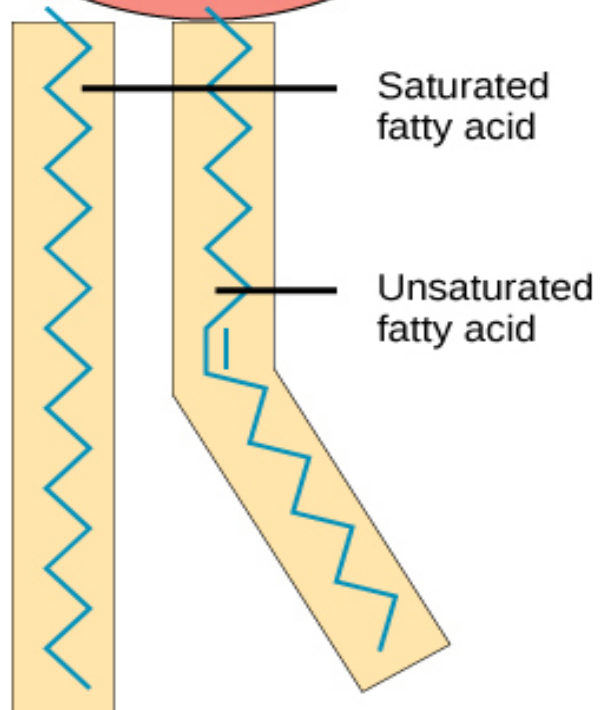
-They can form lipid bilayers because of their amphiphilic characteristic.



Hydrophilic head



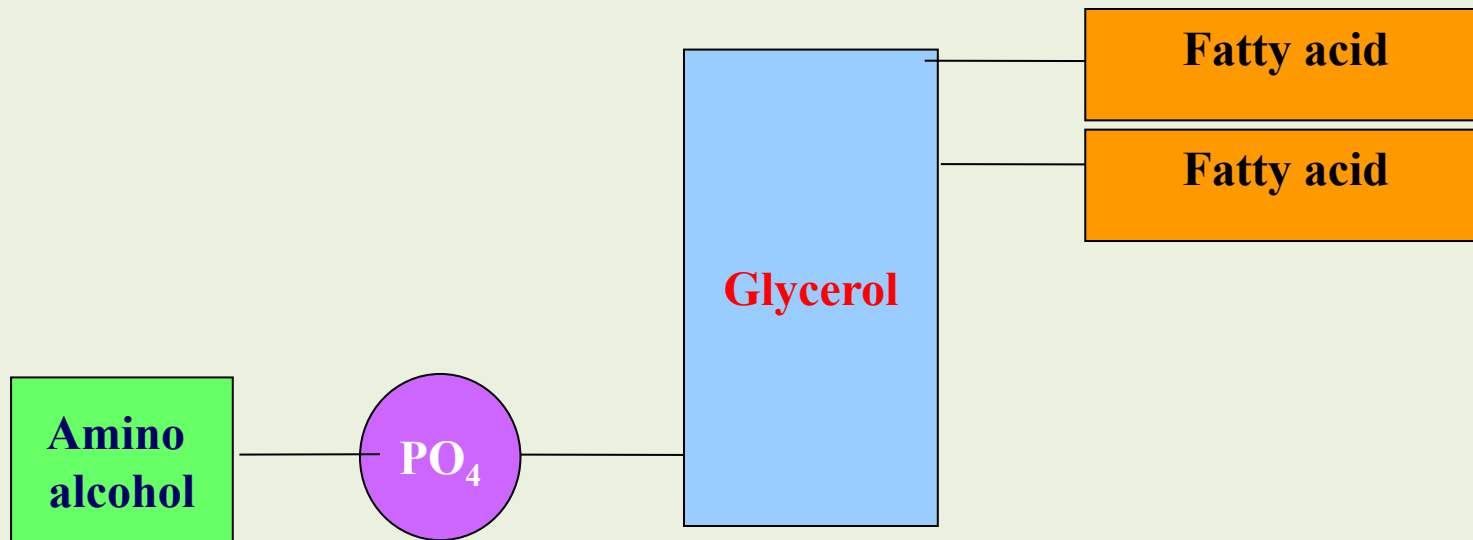
Hydrophobic tails



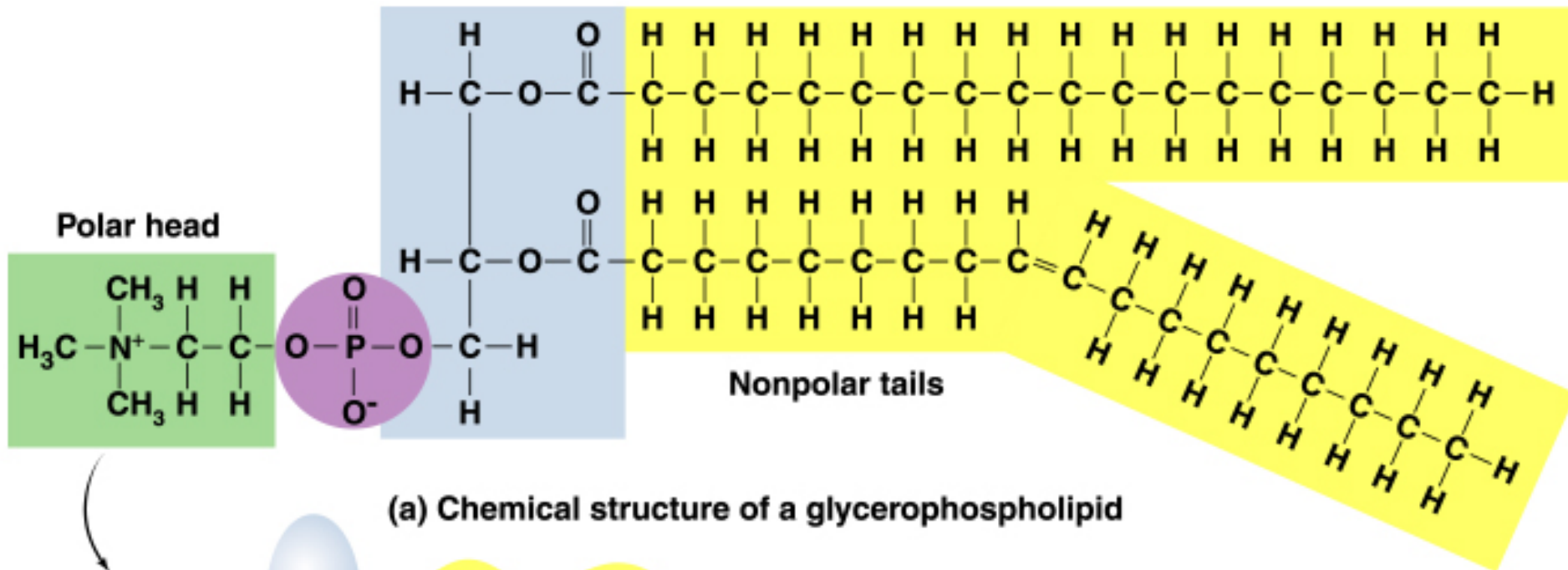
Glycerophospholipids (GPL)

Glycerophospholipids (GPL) are polar:

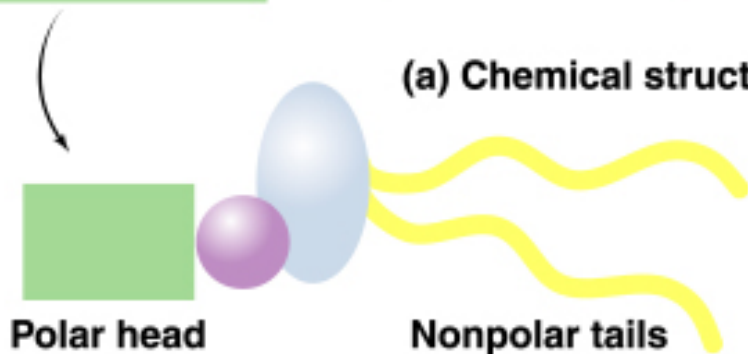
- The most abundant lipids in cell membranes.
- GPL= two chains of fatty acids+ phosphate + an amino alcohol.



Structure and Polarity of A Glycerophospholipid



(a) Chemical structure of a glycerophospholipid

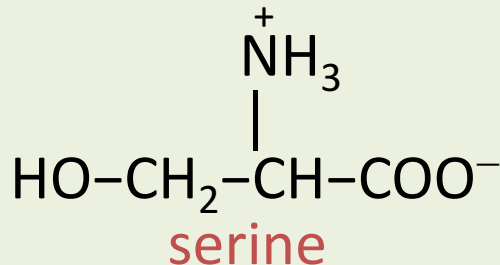
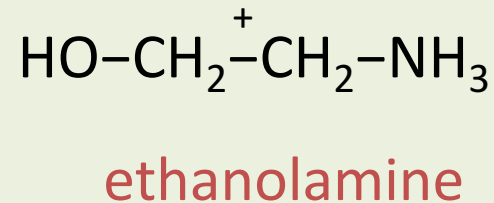
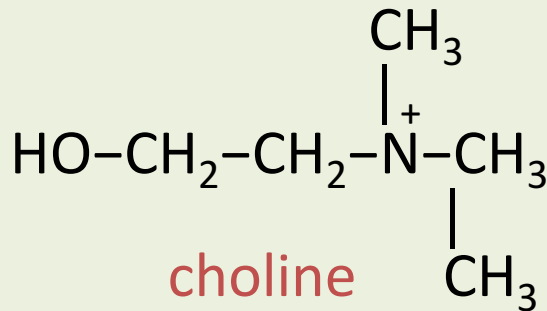


(b) Simplified way to draw a glycerophospholipid

Glycerophospholipids

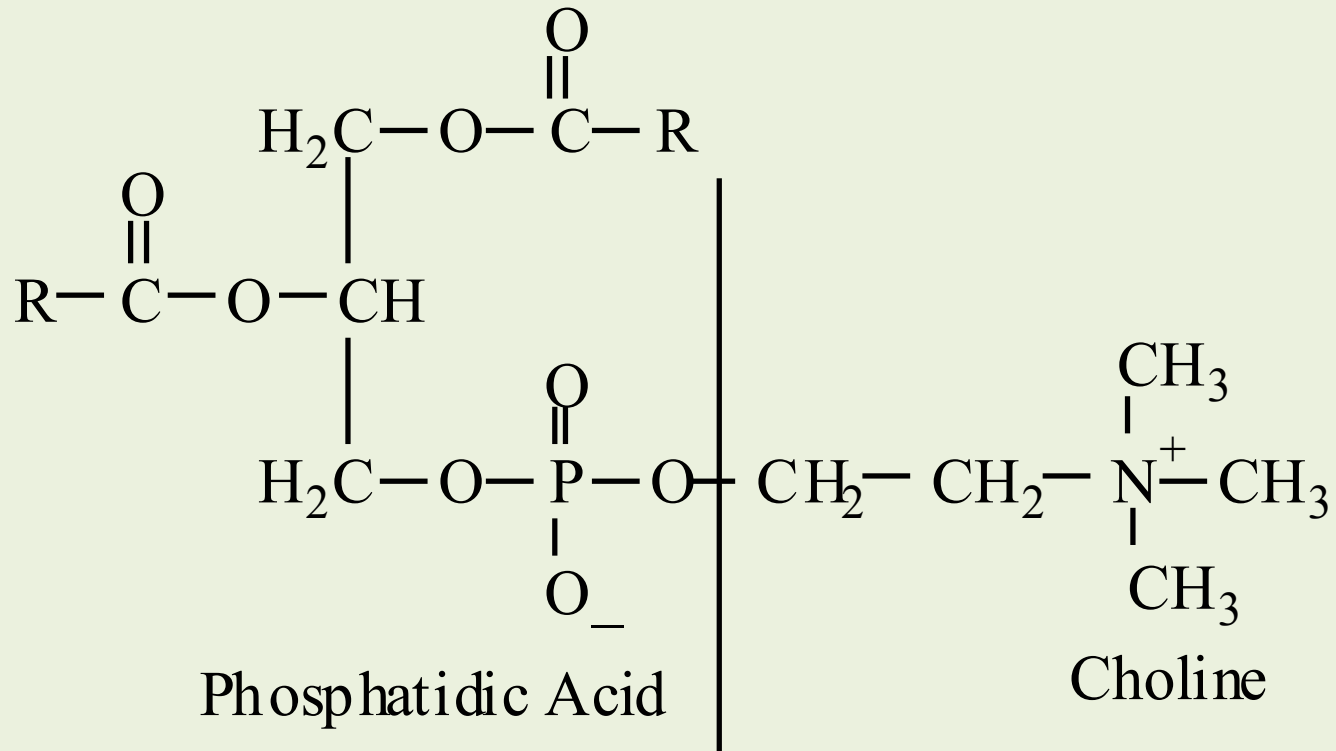
Glycerophospholipids are polar:

- The polar amino alcohol are ethanolamine or choline and Ser



Amino alcohols

Glycerophospholipids

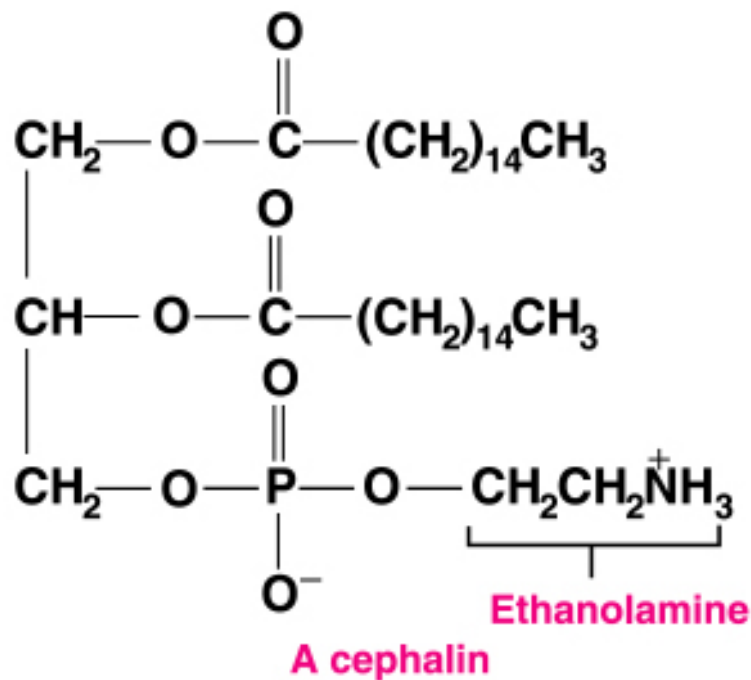
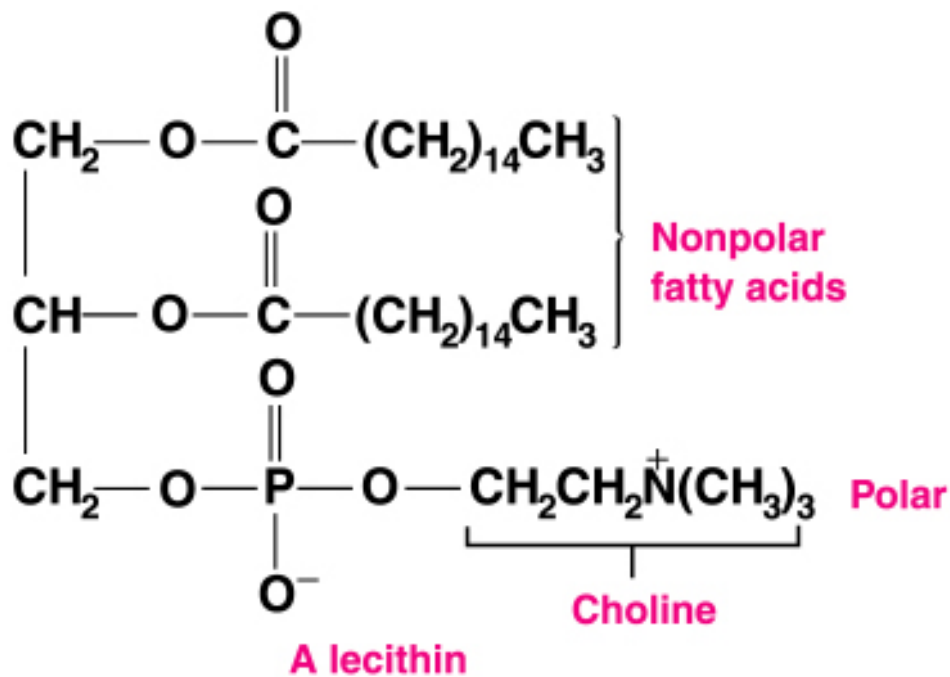


Examples of glycerophospholipids

Lecithin and Cephalin

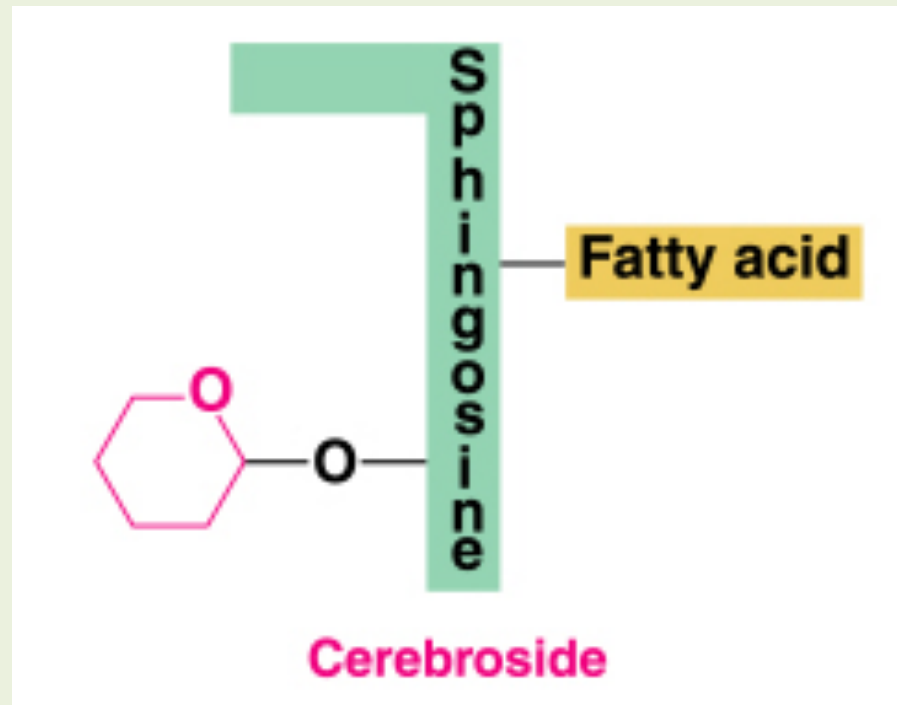
Lecithin and cephalin are glycerophospholipids

- Abundant in brain and nerve tissues.
- Found in egg yolk, wheat germ, and yeast.



Lipids

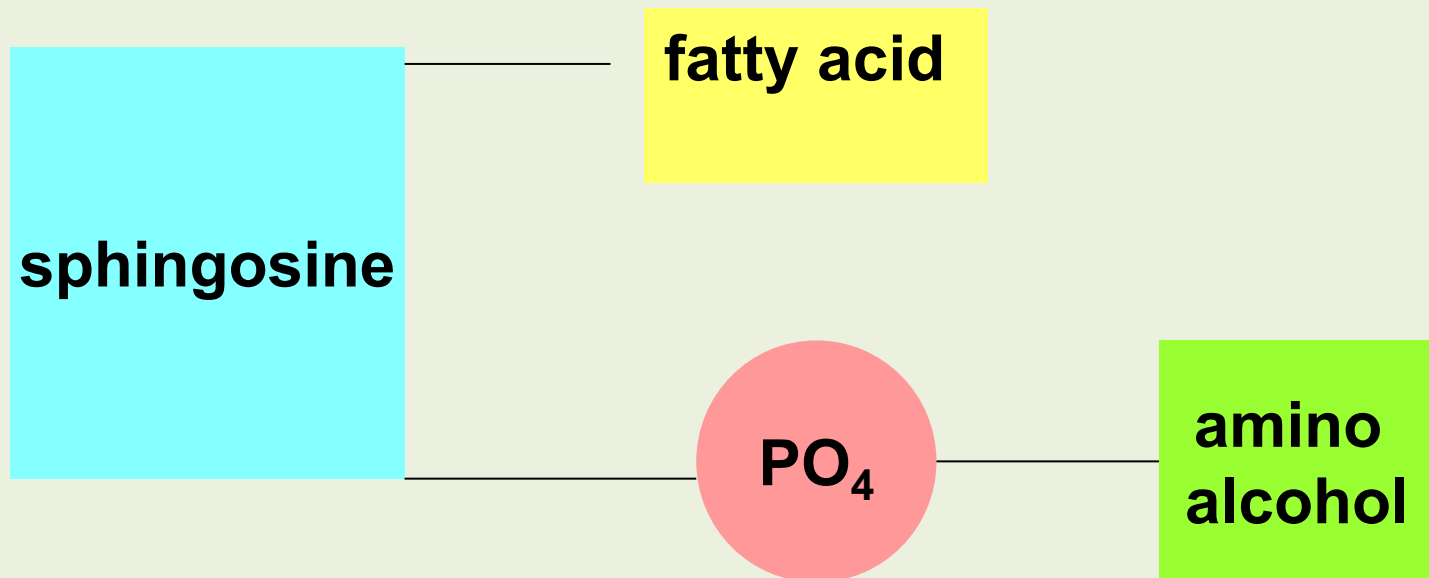
Sphingolipids



Sphingolipids

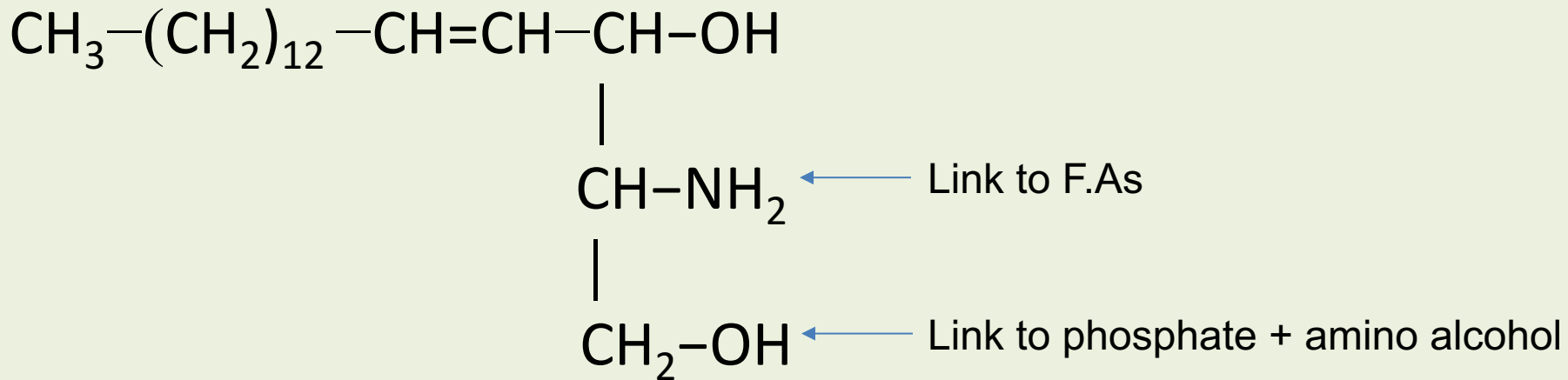
Sphingolipids

- Are similar to phospholipids.
- Contain *sphingosine* (a long-chain amino alcohol)+ a fatty acid+ phosphate+ a small amino alcohol.
- Have polar and nonpolar regions.



Sphingosine

Sphingosine is a long-chain unsaturated amino alcohol.



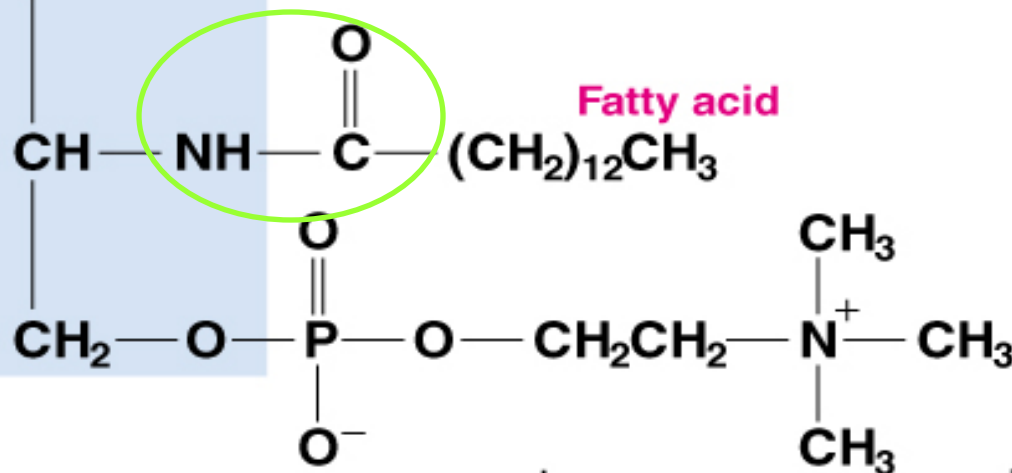
Sphingosine

Sphingolipids

In sphingomyelin, a sphingolipid found in nerve cells

- There is an amide bond between a fatty acid and sphingosine, an 18-carbon alcohol.

Sphingosine



Fatty acid

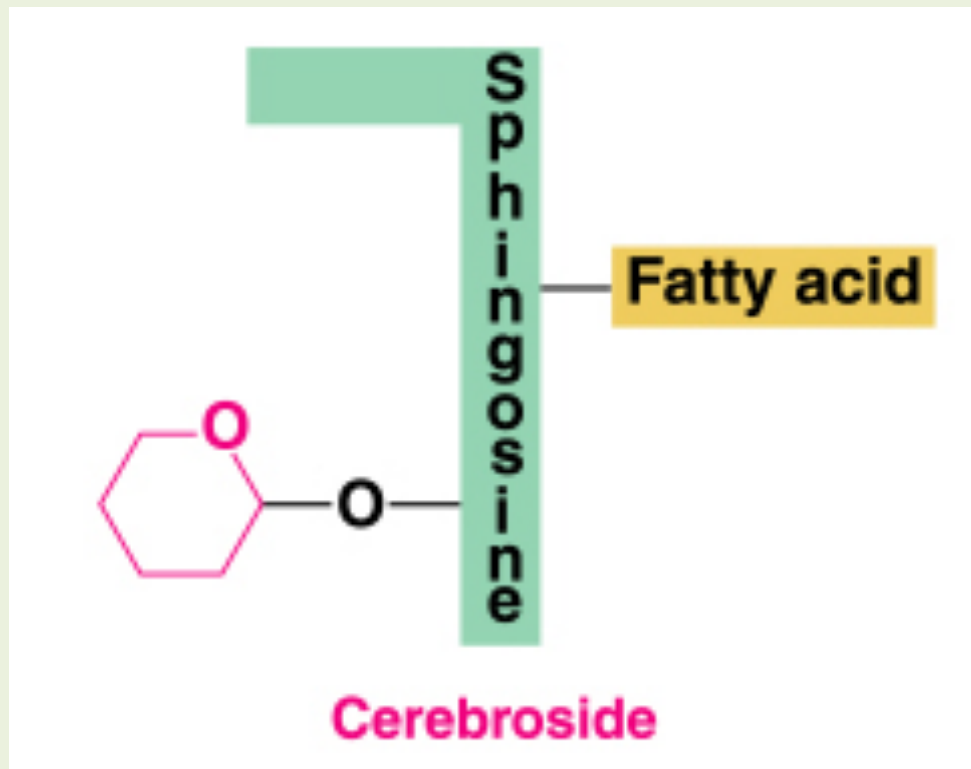
Choline

Sphingomyelin, a sphingolipid

Timberlake, *General, Organic, and Biological Chemistry*. Copyright © Pearson Education Inc., publishing as Benjamin Cummings

Glycosphingolipids

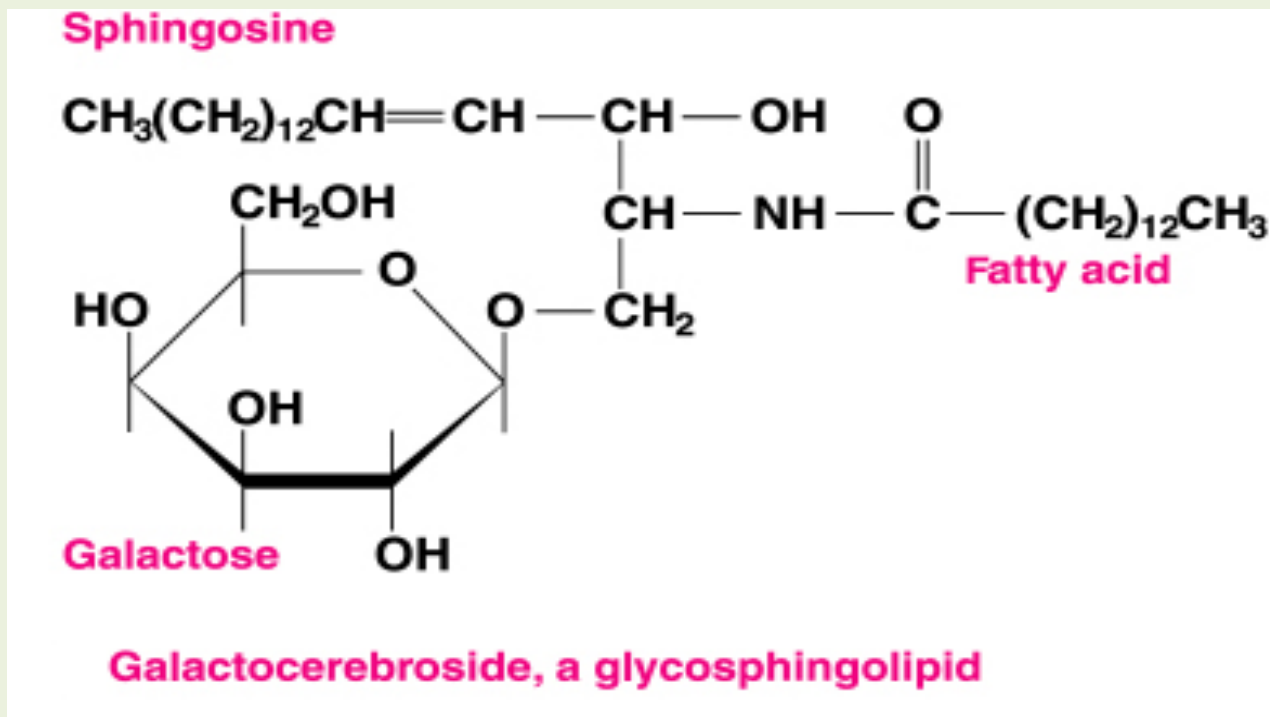
- **Glycosphingolipids** contain monosaccharides bonded to the $-OH$ of sphingosine by a glycosidic bond.



Glycosphingolipids and Cerebrosides

Glycosphingolipids .

- Can be a cerebroside when linked with galactose.



Lipids

Fatty acids  COOH

Prostaglandins

Waxes

Fatty acid — Long-chain alcohol

Triacylglycerols

Glycerol — Fatty acid
— Fatty acid
— Fatty acid

Glycerophospholipids

Glycerol — Fatty acid
— Fatty acid
— PO₄ — Amino alcohol

Sphingolipids

Sphingosine — Fatty acid
— PO₄ — Amino alcohol

Glycosphingolipids

Sphingosine — Fatty acid
— Sugar

Steroids



Cholesterol

Bile salts

Steroid hormones