LIPIDS

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Biological lipids are a chemically diverse group of compounds, the common and defining feature of which is their insolubility in water.

LIPIDS

Lipids are a large and diverse group of naturally occurring organic compounds that are soluble in non polar organic solvents (e.g. ether, chloroform, acetone & benzene) and general insoluble in water

Classification

Lipids can be classified based on the following:

I. **its chemical nature.**

II. **Its biological function**

Classification

A. Lipids can be classified based on its chemical nature into three groups namely:

I. Simple lipids

II. Compound or complex lipids

III. Derived lipids or precursors

Classification

B. Lipids can be classified based on Its biological function into two groups namely:

I. Storage lipids

II. Structural lipids

Classification

1. **Simple lipids:**

   Simple lipids are esters of fatty acids with various alcohols.

   These simple esters upon hydrolysis yield fatty acids and alcohols.

   Usually the alcohol is glycerol

Classification

1. **Simple lipids:**

   Examples include fats, oils and waxes

   - **Fats: Esters of predominatly saturated fatty acids with glycerols. hence are in solid state**

   - **Oils: Esters of predominatly unsaturated fatty acids with glycerols, hence are lipids in liquid state**

   - **Waxes: Esters of fatty acids with higher molecular weight monohydric alcohols**

Classification

2. Complex lipids:

Esters or amide of fatty acids with alcohol and other additional groups (in addition to an alcohol and a fatty acid)

Examples include Phospholipids and Sphingolipids

- **Phospholipids: Lipids containing in addition to fatty acids and an alcohol, a phosphoric acid residue. Frequently have nitrogen containing bases and other substituents. Example of Phospholipids include**
  - **(a) Glycerolphospholipids in which the alcohol is glycerol**
  - **(b) Sphingophospholipids in which the alcohol is sphingosine**

- **Glycolipids (glycosphingolipids): lipids containing a fatty acid, sphingosine, and carbohydrate**

- **Other complex lipids: Sulfolipids, aminolipids, lipoproteins**

3. Derived lipids or precursors

Derivatives of hydrolysis of simple and complex lipids which possess characteristics of lipids

- steroids,
- Eicosanoids
- Terpenes
- other alcohols,
- fatty aldehydes,
- ketone bodies,

Classification

- hydrocarbons,
- lipid soluble vitamins, and
- Hormones
- Acyl glycerols,
- Cholesterol
- Cholesteryl esters are uncharged – neutral lipids

4. **Neutral lipids**

These are lipids which are uncharged

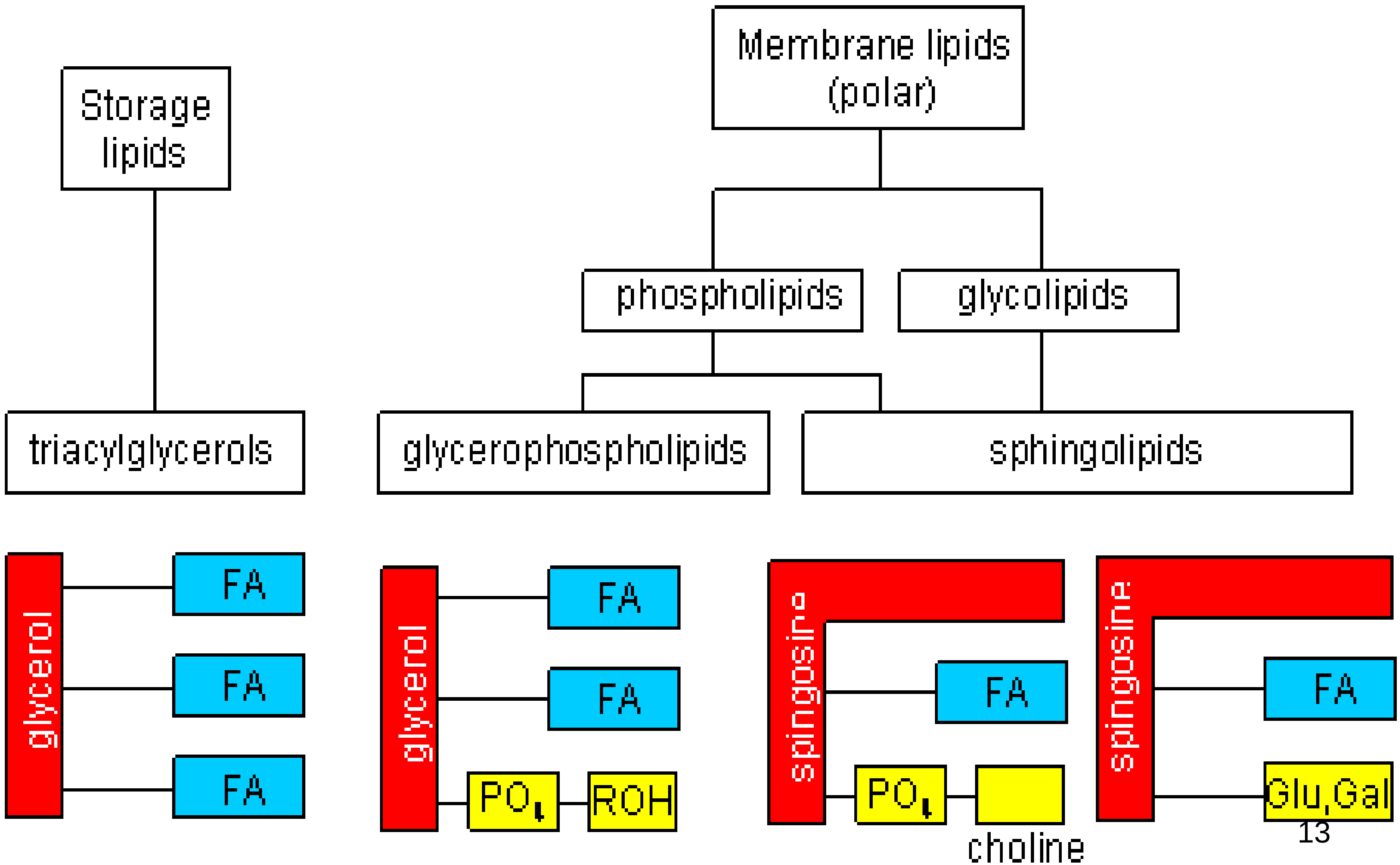
These are mono, di and triacylglycerols, cholesterol and cholesteryl esters

5. **Miscellaneous lipids**

A large number of compounds possess characteristics of lipids, such compounds come under this category.

Examples are carotenoids, squalene, hydrocarbons like terpenes.

Classification of lipids and their derivatives



after Lehninger et al., Principles of Biochemistry, 2nd ed.

Function of Lipids

1.Structural components of biological membranes

- They are building blocks of phospholipids and glycolipids.
- The phospholipids and glycolipids which are amphipathic molecules are important components of biological membranes.
- They serve as structural components of biological membranes

Function of Lipids

2. Energy reserves :

- Fatty acids are fuel molecules. Stored as triacylglycerols which are uncharged esters of glycerol
- They provide energy reserves, predominantly in the form of triacylglycerols.
-
- .

Function of Lipids

3. Hormones

- Fatty acid derivatives serve as hormones and
- Both lipids and lipid derivatives serve as hormones.

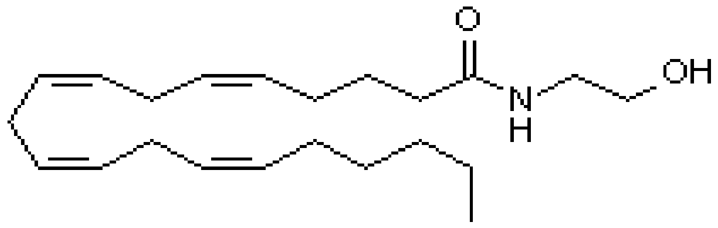
Function of Lipids

4. Intracellular messengers

- Fatty acid derivatives serve as hormones and intracellular messengers
- Both lipids and lipid derivatives serve as intracellular messengers.

Function of Lipids

5. Lipophilic bile acids aid in lipid solubilization
6. Insulation
7. Cushioning.(shock absorbers)
8. Signal transduction.
9. Sleep induction lipids such as a fatty acid primary amide called oleamide.(cis-9-Octadecenamide)
10. Endogenous cannabinoids. Such asAnandamide(*N*-arachidonoylethanolamine)



anandamide

STORAGE LIPIDS

- Fats or oils used as storage forms of energy in living organisms are derivatives of fatty acids

- Fatty acids are fuel molecules which are stored as triacylglycerols which are uncharged esters of glycerol

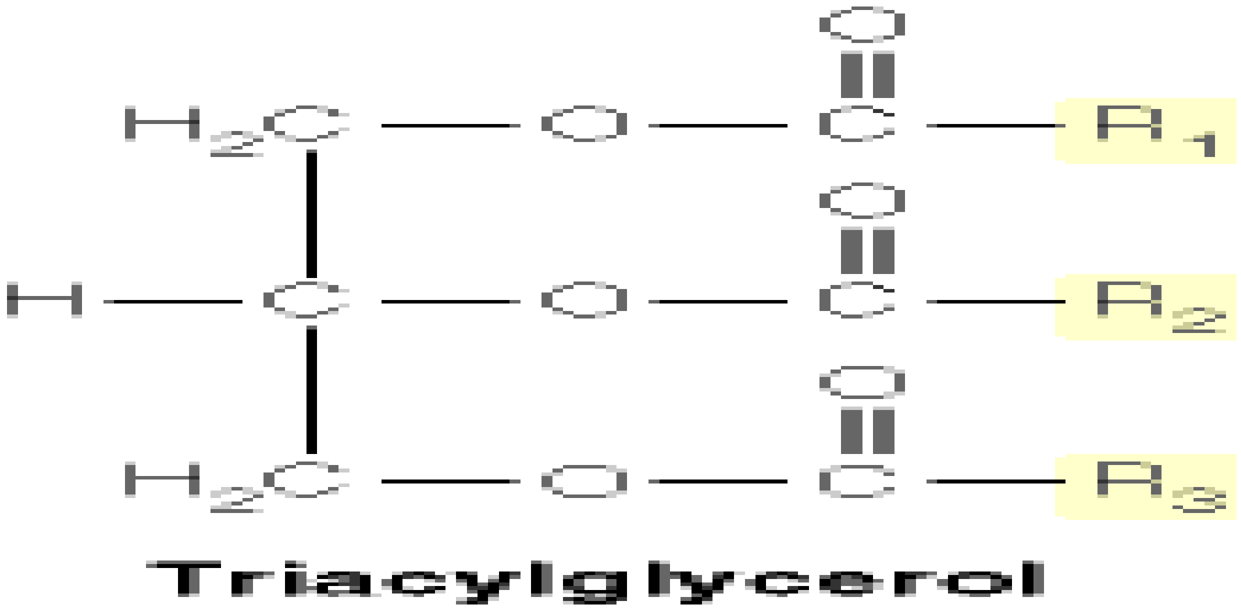
- The cellular oxidation of fatty acids is highly exergonic

- Triacylglycerols and waxes are fatty acid-containing molecules

STORAGE LIPIDS

- The triacylglycerols are made of fatty acids and glycerol
- Fatty acids are organic acids
- Glycerols are organic alcohols

STORAGE LIPIDS



Fatty acids

- Fatty acids are organic acids

- These are weak acids that partially ionise.
- Fatty acids consist of a hydrocarbon chain with a carboxylic acid at one end
- The hydrocarbon chain is non polar and the carboxylic acid end is the polar end.

- The most commonly occurring fatty acids have even numbers of carbon atoms because synthesis involves condensation of acetate (two-carbon) units

Fatty acids

- Occurance
  - Esters in natural fats and oils
  - Free fatty acids, a transport form found in plasma
  - Natural fats – usually straight chain derivatives containing an even number of carbon atoms

Fatty acids

- Occurance
  - Fatty acids may be **saturated** – i.e no double bonds or be
  - **Unsaturated –**
  - **monounsaturated (monoethenoid) acids**
  - **Polyunsaturated (polyethenoid) acids**
  - **The double bonds** in fatty acids usually have the **cis** configuration.
  - Most naturally occurring fatty acids have an **even number** of carbon atoms.

Pattern of unsaturation

- In most monounsaturated fatty acids the double bond is between C-9 and C-10

- Other double bonds of polyunsaturated fatty acids are generally at $\Delta 12$ and $\Delta 15$

- Arachidonic acid is an exception to this generalization ($\Delta 5,8,11,14$)

- The double bonds are never conjugated but are separated by methylene bridges

- **In nearly all naturally occurring unsaturated fatty acids the double bonds are in the cis configuration**

Fatty acids

- **Occurance**

  - Eicosanoids (role as messengers)

  - Free fatty acids (unesterified having a free carboxylate group) circulate in blood bound non-covalently to a protein carrier, serum albumin

PHYSICAL PROPERTIES

- The physical properties of fatty acids are largely **determined by the length and degree of unsaturation of fatty acids**

1. Solubility

- Fatty acids are non-soluble in water and soluble in non polar solvents
- The nonpolar hydrocarbon chain accounts for their poor solubility in water

PHYSICAL PROPERTIES

1. Solubility

- The longer the side chain and the fewer the double bonds the lower is the solubility in water
- The carboxylic acid group is polar and this accounts for the slight solubility of short-chain fatty acids in water

Melting points

- Also influenced by the length and degree of unsaturation
- At room temperature saturated fatty acids from 12:0 to 24:0 have a waxy consistency.
- At room temperature unsaturated fatty acids from 12:0 to 24:0 are oily liquids
- The difference is due to the packing of the fatty acid molecules.

Melting points

- In fully saturated form there is freedom of rotation around each carbon-carbon bond which gives the hydrocarbon chain greater flexibility.

- The most stable conformation is the fully extended chain in which steric hindrances are minimal.

Melting points

- Molecules can pack in crystalline arrays with atoms all along their lengths in van der Waals contact with atoms of neighbouring chains

Melting points

- In unsaturated fatty acids, a cis double bond forms a kink in the hydrocarbon chain.

- As a result molecules can not pack as tightly as fully saturated fatty acids and their interactions with each other is weaker.

Melting points

- Because it takes less thermal energy to disorder the poorly ordered arrays of unsaturated fatty acids, **they have lower melting points than saturated fatty acids of the same chain length**

Melting Point is Proportional to chain length

Symbol	common name	systematic name	structure	mp(C)
•				
12:0	Lauric acid	dodecanoic acid	$CH_3(CH_2)_{10}COOH$	44.2
14:0	Myristic acid	tetradecanoic acid	$CH_3(CH_2)_{12}COOH$	52
16:0	Palmitic acid	Hexadecanoic acid	$CH_3(CH_2)_{14}COOH$	63.1
18:0	Stearic acid	Octadecanoic acid	$CH_3(CH_2)_{16}COOH$	69.6
20:0	Arachidic aicd	Eicosanoic acid	$CH_3(CH_2)_{18}COOH$	75.4

Unsaturation lowers the melting point

Fatty acid	# of carbon atoms	Structure	Melting point (°C)
• Myristic acid	14	$CH_3(CH_2)_{12}COOH$	54
Palmitic acid	16	$CH_3(CH_2)_{14}COOH$	63
Stearic acid	18	$CH_3(CH_2)_{16}COOH$	70
Oleic acid	18	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	4
Linoleic acid	18	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	-5
Linolenic acid	18	$CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	-11

Chain length ,saturation and MP

Unsaturated		
Formula	Common Name	Melting Point
$CH_3(CH_2)_5CH=CH(CH_2)_7CO_2H$	palmitoleic acid	0 ºC
$CH_3(CH_2)_7CH=CH(CH_2)_7CO_2H$	oleic acid	13 ºC
$CH_3(CH_2)_4CH=CHCH_2CH=CH(CH_2)_7CO_2H$	linoleic acid	-5 ºC
$CH_3CH_2CH=CHCH_2CH=CHCH_2CH=CH(CH_2)_7CO_2H$	linolenic acid	-11 ºC

Melting points

- Therefore membrane lipids which must be fluid at all environmental temperatures are more unsaturated than storage lipids.

- In hibernators or extremities of animals the lipids are more unsaturated

NOMENCLATURE

- **There three main ways of naming fatty acids namely :**

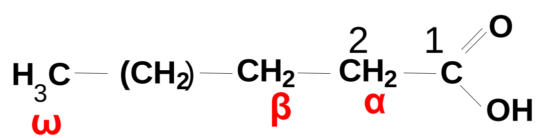
  - The systematic naming

  - Common naming

  - Alphabetic notation

Nomenclature

The systematic name of a fatty acid is derived from the name of its parent hydrocarbon by substitution of **oic** for the final e

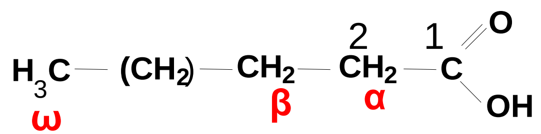


- For instance the C18 saturated fatty acid is called **octadecanoic acid because the parent hydrocarbon is octadecane**

Nomenclature

- A C18 fatty acid with double bonds is called octadecadienoic acid;

- A C18 fatty acid with three double bonds is called octadecatrienoic acid



- Carbon atoms 2 and 3 are referred to as α and β respectively

SYMBOLIC NOTATION

- The symbol 18:0 denotes a C18 fatty acid with no double bond,
- The symbol 18:2 denotes a C18 fatty acid with two double bonds
- The symbol 18:3 denotes a C18 fatty acid with three double bonds

SYMBOLIC NOTATION

- The double bond position is represented by the Δ symbol followed by a superscript number
  - cis- Δ9 means there is a cis double bond between carbon atoms 9 and 10
  - trans – Δ2 means there is a trans double bond between carbon atoms 2 and 3

SYMBOLIC NOTATION

- The double bond position is represented by the Δ symbol followed by a superscript number
- cis- Δ9 means there is a cis double bond between carbon atoms 9 and 10
- trans – Δ2 means there is a trans double bond between carbon atoms 2 and 3

- Alternatively the position of a double bond can be denoted by counting from the distal end with the ω carbon atom as number 1.

- We use the Greek alphabet (α, β, γ, ω) to identify the location of the double bonds in unsaturated fatty acids.
- The "alpha" carbon is the carbon closest to the carboxyl group (carbon number 2), and the "omega" is the last carbon of the chain because omega is the last letter of the Greek alphabet

- A ω-3 fatty acid has a double bond between carbon atoms 3 and 4 from the ω end or distal end
- A ω-6 fatty acid has a double bond between carbon atoms 6 and 7 from the ω end or distal end
- A ω-9 fatty acid has a double bond between carbon atoms 9 and 10 from the ω end or distal end

Examples of fatty acids with their common names

- 14:0 myristic acid
- 16:0 palmitic acid
- 18:0 stearic acid
- 18:1 cisΔ^{9} oleic acid
- 18:2 cis $\Delta^{9,12}$ linoleic acid
- 18:3 cis $\Delta^{9,12,15}$ linonenic acid
- 20:4 cis $\Delta^{5,8,11,14}$ arachidonic acid
- 20:5 cis $\Delta^{5,8,11,14,17}$ eicosapentaenoic acid (an omega-3 fatty acid because of double bond 3 C from distal end)

- **Common names**

- Common names are used in the naming of fatty acids rather than those derived from hydrocarbon chains

- For instance a fatty acid with 12 carbon atoms is called lauric acid while its systematic name is dodecanoic acid

- Do means two and deca means ten (10)

- A fatty acids with 14 carbons is called **tetradecanoic acid** and its common name is Myristic acid

- A fatty acids with 16 carbons is called **Hexadecanoic acid** and its common names is Palmitic acid

- A Fatty acids with 18 carbons is called **octadecanoic acid** and its common name is Stearic acid

	Saturated fatty acids	
# of carbons	Formula	Common name
12	$CH_3(CH_2)_{10}CO_2H$	Lauric acid
14	$CH_3(CH_2)_{12}CO_2H$	Myristic acid
16	$CH_3(CH_2)_{14}CO_2H$	Palmitic acid
18	$CH_3(CH_2)_{16}CO_2H$	Stearic acid
20	$CH_3(CH_2)_{18}CO_2H$	Arachidic acid

Nomenclature cont'd

Unsaturated fatty acids	
Formula	Common name
$CH_3(CH_2)_5CH=CH(CH_2)_7CO_2H$	Palmitoleic acid
$CH_3(CH_2)_7CH=CH(CH_2)_7CO_2H$	Oleic acid
$CH_3(CH_2)_4CH=CHCH_2CH=CH(CH_2)_7CO_2H$	Linoleic acid
$CH_3CH_2CH=CHCH_2CH=CHCH_2CH=CH(CH_2)_7CO_2H$	Linolenic acid
$CH_3(CH_2)_4(CH=CHCH_2)_4(CH_2)_2CO_2H$	Arachidonic acid

Functional significance of some fatty acids

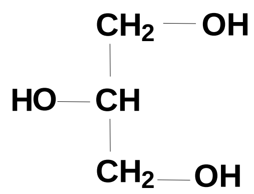
<table>
<tr><th>Common name</th><th>Short form</th><th colspan="2">Functional significance</th></tr>
<tr><td>Butyric acid</td><td>4:0</td><td colspan="2" rowspan="2">FA's with chain lengths of 4 to 10 carbons are found in significant amounts in milk</td></tr>
<tr><td>Capric acid</td><td>10:0</td></tr>
<tr><td>Palmitic acid</td><td>16:0</td><td colspan="2" rowspan="2">Structural lipids and triacylglycerols primarily contain fatty acids with at least 16 carbons</td></tr>
<tr><td>Palmitoleic acid</td><td>$16:1^{\Delta 9}$</td></tr>
<tr><td>Linoleic acid</td><td>$18:2^{\Delta 9,12}$</td><td>Omega 6 FA</td><td rowspan="2">Essential FA's and need to be supplied in the diet</td></tr>
<tr><td>Linolenic acid</td><td>$18:3^{\Delta 9,12,15}$</td><td>Omega 3 FA</td></tr>
<tr><td>Arachidonic acid</td><td>$20:4^{\Delta 5,8,11,14}$</td><td colspan="2">This is a precursor of prostaglandins</td></tr>
</table>

No of Carbons	No of D bonds	C' name	S'name	Formula
16	0	Palmitic	*n*-hexadecanoic	$CH_3(CH_2)_{14}COO^-$
18	0	Stearic	*n*-octadecanoic	$CH_3(CH_2)_{16}COO^-$
20	0	Arachidic	*n*-eicosanoic	$CH_3(CH_2)_{18}COO^-$
16:1(Δ^9)	1	Palmitoleic	*cis*-9-hexadecenoic	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COO^–$
18:1(Δ^9)	1	Oleic	*cis*-9-octadecenoic	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COO^–$
18:2($\Delta^{9,12}$)	2	Linoleic	cis,cis-9,12-octadecadienoic	$CH_3(CH_2)_4(CH{=}CHCH_2)_2(CH_2)_6COO^–$
18:3($\Delta^{9,12,15}$)	3	Linolenic	*cis*,*cis*, *cis*-9,12,15-octadecatrienoic	$CH_3CH_2(CH{=}CHCH_2)_3(CH_2)_6COO^–$
20:4 ($\Delta^{5,8,11,14}$)	4	Arachidonic	*cis*,*cis*, *cis*,*cis*-5,8,11,14-Eicosatetraenoic acid	$CH_3(CH)_4(CH{=}CHCH_2)_4(CH_2)_2COO^–$

Triacylglycerides

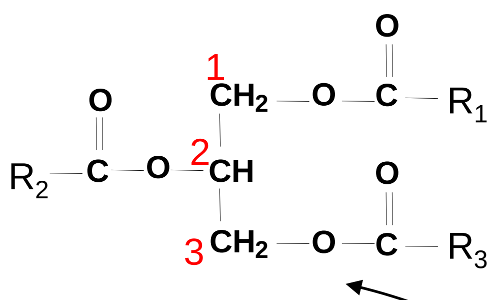
- Also called triglycerides
- Are lipids consisting of glycerol and three fatty acids
- They are the main storage form of lipids in tissues

• Structure triacylglycerols



Glycerol

Carbons 1 and 3 are not identical when viewed in three dimensions. Enzymes can distinguish between them eg Glycerol kinase phosphorylates glycerol to give glycerol 3-phosphate not 1-phosphate



Triacyglycerol

Polar hydroxyls of glycerol and polar carboxylates of fatty acids are bound in ester linkage – triacyglycerols are therefore nonpolar and hydrophobic, insoluble in water

- Triacylglycerols (triglycerides) are nonpolar, hydrophobic molecules

- **They do not possesse electrically charged or highly polar functional groups, therefore they are called neutral lipids of fats**

TYPES OF TRIACYLGLYCEROLS (TRIGLYCERIDES)

- Triacylglycerols (triglycerides) occur in many different types, depending on the identity and position of the three fatty acid components esterified to glycerol
- **The main types include :**

- **Simple Triacylglycerols (triglycerides)**
- **Mixed Triacylglycerols (triglycerides)**

Properties of TAGs

1. Hydrolysis

- TAGs are hydrolysed via stepwise reactions by lipases to form glycerol + 3 Fas
- This reaction is vital for digestion of TAGs in the digestive tract and fat mobilization.

2. **Saponification**

- Hydrolysis of TAG by alkali to produce glycerol and soaps
- Soaps are cleansing agents due to their emulsifying action
- Soaps of High Molecular Weights and high degree of unsaturation are germicides

3. **Hydrogenation of TAGs**

- Hydrogenation of unsaturated fats in the presence of a catalyst (Nickel) is called hardening
- Liquid fats of plant origin are converted into solid fats by hardening e.g. margarine

4. **Peroxidation of lipids**

- Lipids exposed to oxygen deteriorate food (rancidity) and damages tissue in vivo.
- **Rancidity** – the unpleasant odour and taste, developed by natural fats upon ageing
- **Lipid peroxidation** is a chain rxn which produces oxygen free radicals which cause further peroxidation
- **Overheating/repeated** heating of oils leads to peroxidation
- Antioxidants such as Vitamin E prevent peroxidation
- Examples of naturally occurring antioxidants are Vitamin C, Carotene, Vit E
- Antioxidants in some food- Butylated hydroxyanisole (BHA), Butylated hydroxytoluene (BHT)

5. **Trans fatty acids (TFA)**

- TFA posses double bonds and are formed during hydrogenation of natural oils
- TFA are used in food industry (fast foods) and lead to packaged foods to increase the shelf life.
- TFAs are produced by fermentation in the rumen of dairy animals (present in dairy products, meat)
- TFAs are also produced during catalytic hydrogenation of vegetable oils to form margarine
- **TFAs are little and hence compete with essential Fas,** hence aggravate essential fatty acid deficiency
- TFAs raise **LDL (bad cholesterol)** and lower HDL (**good cholesterol)**
- **TFAs** increase the body's inflammatory response
- **Long term use may lead to increased risk of cardiovascular diseases**

Types of triacylglycerols (triglycerides)

- Those containing the same kind of fatty acid in all three positions are simple triacylglycerols (rare in natural fats)

- These are named after the fatty acid they contain

Types of triacylglycerols (triglycerides)

- **Examples include**

- **Tristearoylglycerol....tristearin (Trivial name)**

- **Tripalmitoylglycerol....Tripalmitin (Trivial name)**

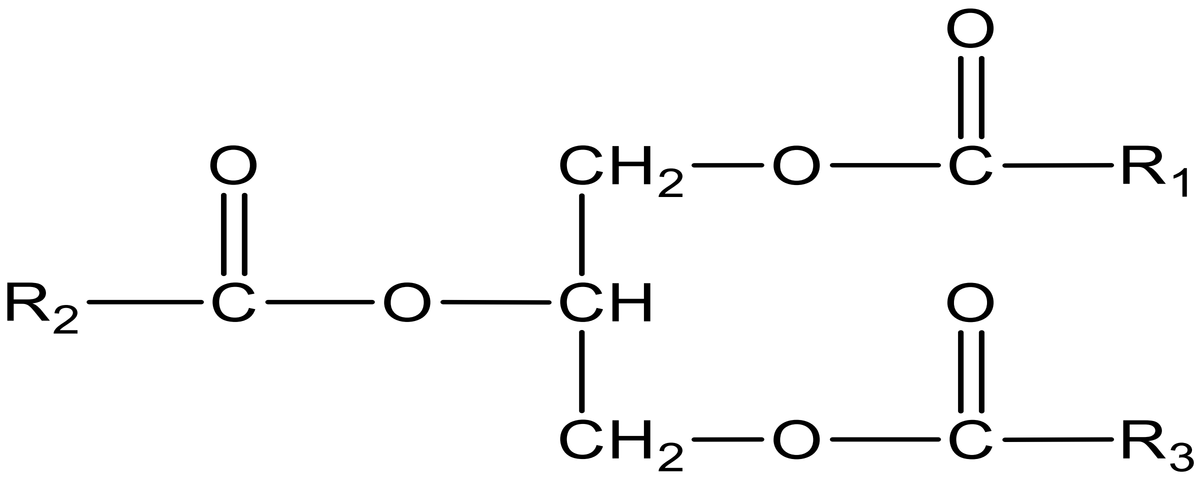
- **Trioleylglycerol............triolein (Trivial name)**

Types of triacylglycerols (triglycerides)

- When they contain two or more different fatty acids they are mixed triacylglycerols

- Nearly in all naturally occurring fats such as olive oil, butter, other food fats are complex mixture of simple and mixed triacylglycerols containing a variety of fatty acids differing in chain length and degree of saturation

Naming of triacylglycerols



Triacylglycerol e.g.Tripalmitoylglycerol and 1-Palmitoleoyl-2linoleoyl-3-stearoylglycerol

Note: the name of the fatty acid changes from -ate to -oyl in the triacylglycerol

Types of triacylglycerols (triglycerides)

- These are named after the fatty acid they contain

  Examples include

- **1-Palmitoleoyl-2-Linoleoyl-3-Stearoyl-glycerol**

Contains Palmitoleic acid, Linoleic

and Stearic acid at position 1,2 and 3

Function of Triacylglycerols

- There are two significant advantages for using triacylglycerols as stored fuels rather than polysaccharides such as glycogen or starch

- **Carbon atoms of fatty acids are more reduced than those of sugars – oxidation of triacylglycerols yields more than twice as much energy gram for gram, as oxidation of carbohydrates.**
- **Triacylglycerols are hydrophobic and therefore unhydrated – no extra weight of water that as associated with stored polysaccharides**

    - **Energy needs can be met for months by drawing on fat stores**

    - **Human body can store less than a day's energy supply in the form of glycogen**
- **In some animals, triacylglycerols under the skin in addition to energy storage, also insulate against low temperatures**

STRUCTURAL LIPIDS IN MEMBRANES

- Glycerophospholipids (phospholipids) are derivatives of phosphatidic acid
  - Glycerophospholipids
  - Sphingolipids
  - Cholesterol

STRUCTURAL LIPIDS IN MEMBRANES

1. Glycerophospholipids (phospholipids) are also called phosphoglycerides.

2. Glycerophospholipids (phospholipids) are derivatives of phosphatidic acid

3. These are the major lipid component of biological membrane.

STRUCTURAL LIPIDS IN MEMBRANES

1. They consist of sn-glycerol-3-phosphate

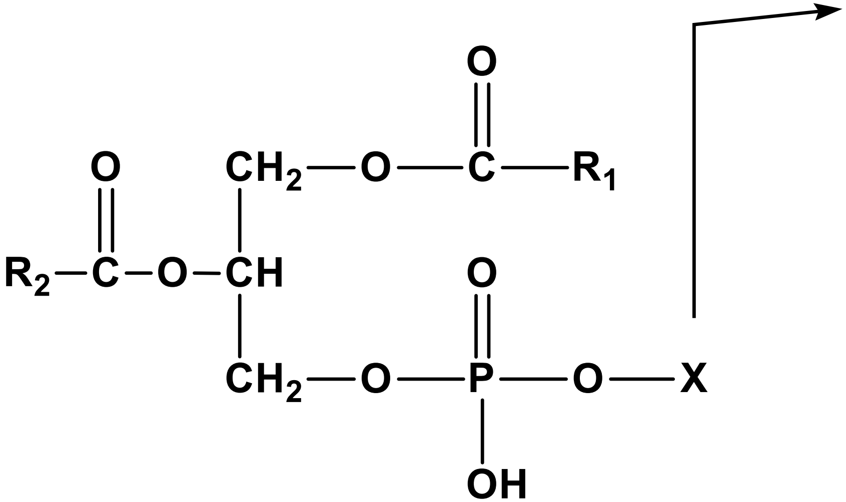
- Two fatty acids are attached in ester linkage to the first and second carbon, and

- A highly polar or charged group is attached through a phosphodiester linkage to the third carbon.

STRUCTURAL LIPIDS IN MEMBRANES

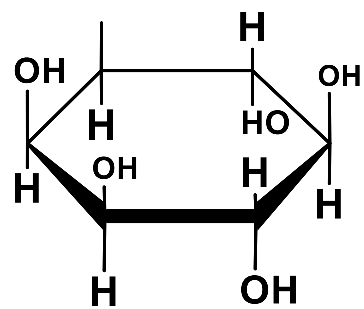
- Attachment of phosphate at either end converts glycerol into chiral compound.

- Phosphoglycerides are therefore amphiphilic molecules with nonpolar aliphatic tails and polar phosphoryl- X – heads



Glycerolphospholipid

polar group

—X	Name of phospholipid
—H	phosphatidic acid
—$CH_2CH_2NH_3^+$	phosphatidylethanolamine
—$CH_2CH_2N(CH_3)_3^+$	phosphatidylcholine
—$CH_2CH(NH_3^+)COO^-$	phosphatidylserine
	phosphatidylinositol

- The head group is joined to the glycerol through a phosphodiester bond, in which the phosphate group bears a negative charge at neutral pH

- Polar head groups may be
  - negatively charged (eg phosphatidylinositol 4,5-bisphosphate),
  - neutral (phosphatidylserine), or
  - positively charged (phosphatidylcholine, phosphatidylethanolamine)

- A given phospholipid (eg phosphatidylcholine) may consist of a number of molecular species, each with its unique compliment of fatty acids

- The distribution of molecular species is specific for different organisms, different tissues of the same organism

- In general, glycerophospholipids contain a
  - C16 or C18 saturated fatty acid at C-1 and
  - a C18 to C20 unsaturated fatty acid at C-2

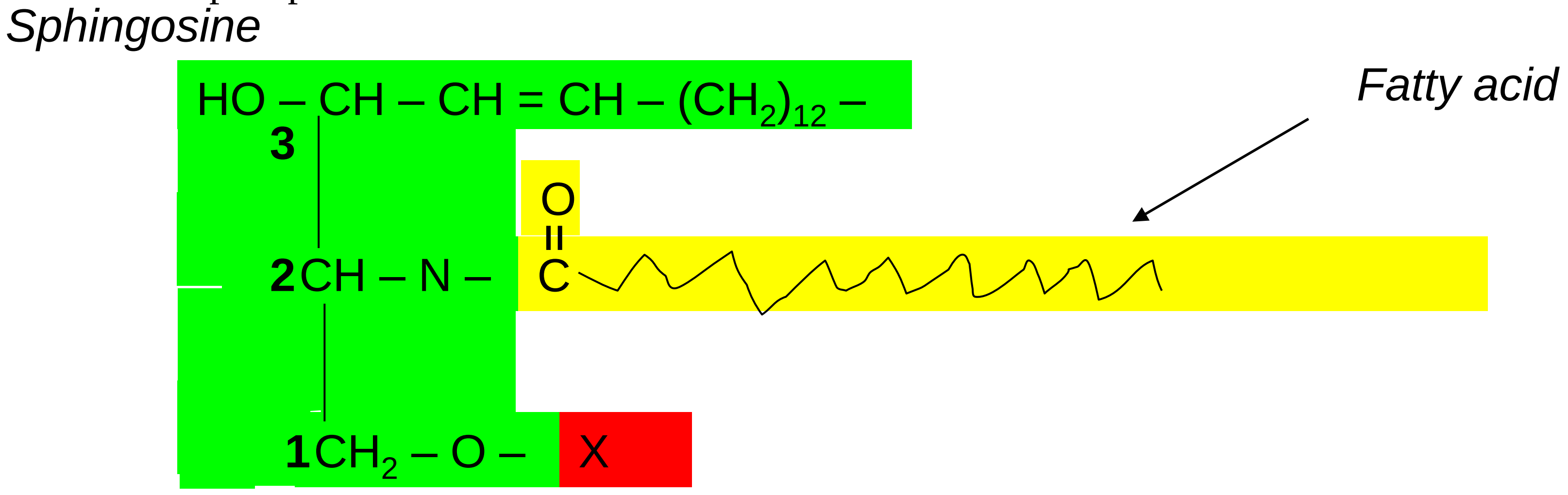
Non glycerol based phospholipids

Derived from sphingosine- a C18 amino alcohol

N –acyl fatty acid derivatives of sphingosine are called Ceramides

Sphingolipids are derivatives of sphingosine

- **These are the Fourth** large class of membrane lipids.
- These are in large quantities in the brain and nervous tissues
- Have a polar head group and two nonpolar tails
- Composition
    - One molecule of the long-chain amino alcohol sphingosine or one of its derivatives
    - One molecule of long-chain fatty acid
    - Polar head group that is joined by either a glycosidic bond or in some cases a phosphodiester bond



Sphingolipid (general structure)

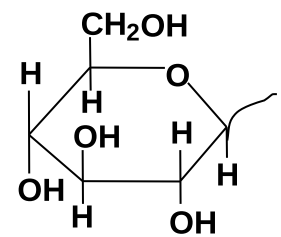
Name of sphingolipid | **Name of X** | **Formular of X**

Ceramide — $-H$

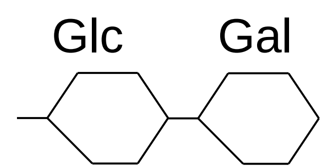
Sphingomyelin — Phosphocholine — $-\overset{\overset{\displaystyle O}{\|}}{\underset{\underset{\displaystyle O^-}{|}}{P}}-O-CH_2-CH_2-N(CH_3)_3^{+}$

Neutral lipids

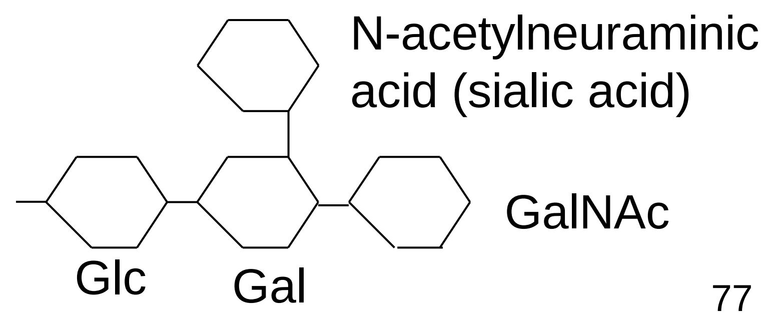
Glucosylcerebroside — Glucose



Lactosylceramide (A globoside) — Di-,tri, or tetrasaccharide



Ganglioside GM2 — Complex oligosaccharides



- When a fatty acid is attached in amide linkage to the –NH_2 on C-2 the resulting compound is a ceramide;

- Ceramide is the structural parent of all sphingolipids.

- There are three classes of sphingolipids all are derivatives of ceramide namely:
    - Sphingomyelins
    - Glycosphingolipids (neutral glycolipids)
    - Gangliosides

- **Sphingomyelins**
  - contain phosphocholine or phosphoethanolamine as their polar head group
  - Have no net negative charge on their head groups
  - Present in the plasma membrane of animal cells –especially prominent in the myelin sheath

- Glycosphingolipids (neutral glycolipids)
  - –Occur largely in the outer face of the plasma membrane
  - –Have one or more sugars linked directly to the –OH at C-1 of ceramide
  - –Do not contain phosphate
- Glycosphingolipids are divide into
  - Cerebrosides
  - Globosides

Cerebrosides

- Cerebrosides have a single sugar linked to ceramide.
- Those with galactose characteristically are found in plasma membranes of cells in neural tissues.
- Those with glucose are found in plasma membranes in non-neural tissues

Globosides

- Globosides have two or more sugars usually D-glucose, D-galactose or N-acetyl-D-galactosamine

Gangliosides

- Gangliosides are the most complex sphingolipids.

- Have oligosaccharide moieties as their polar head groups and one or more residues of N-acetylneuraminic acid (sialic acid)

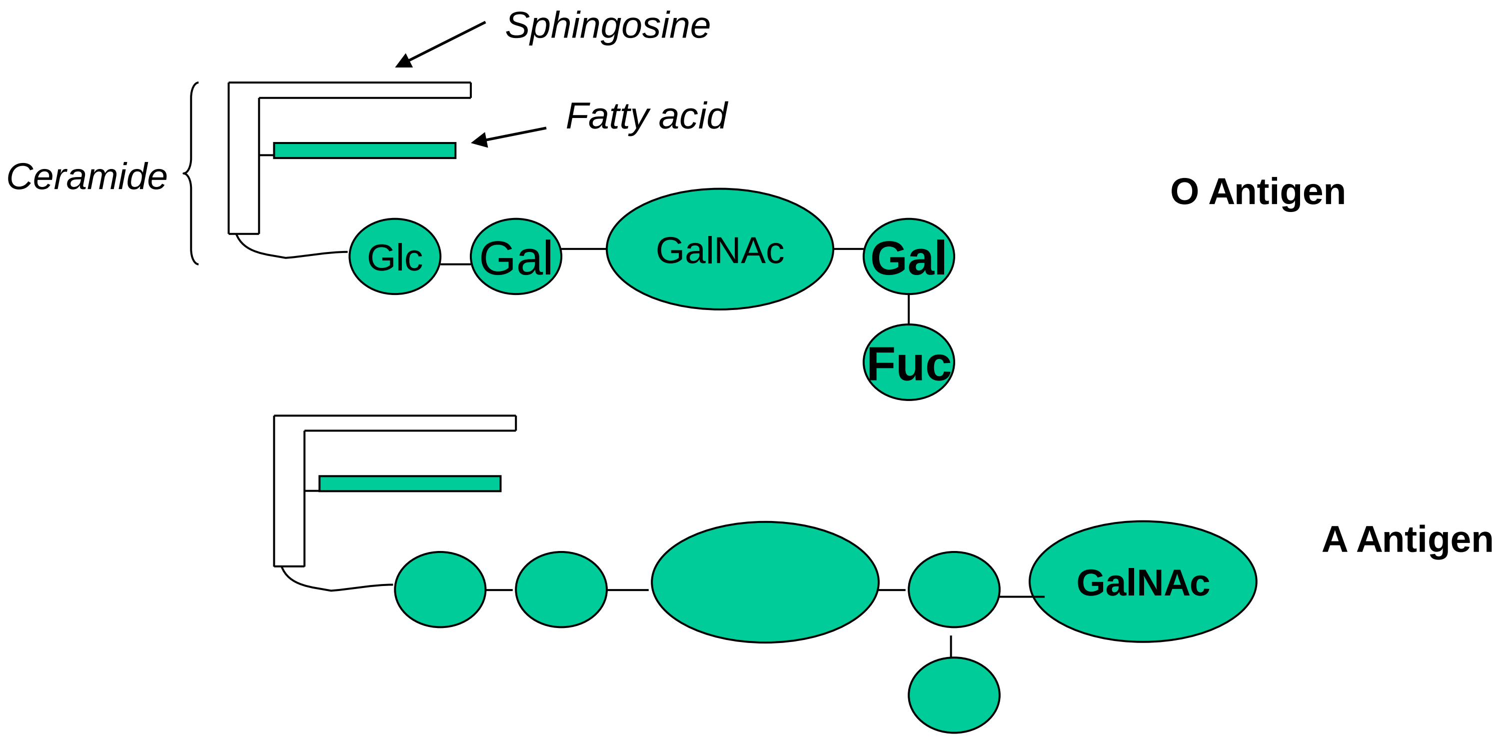
- Sialic acid gives gangliosides the negative charge at pH 7.0 that distinguishes them from globosides

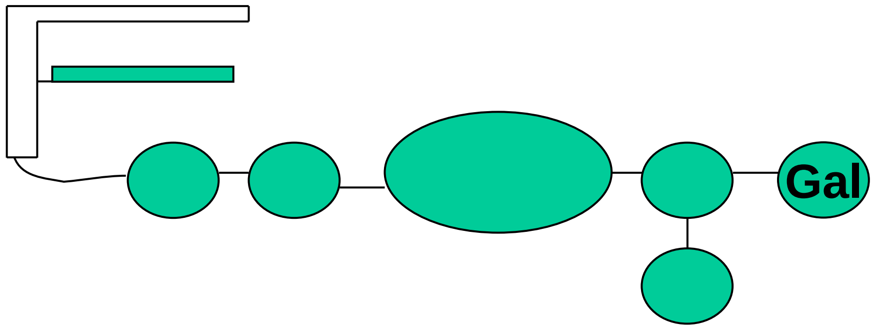
Gangliosides

- Gangliosides with one sialic acid residue are in the GM (M for mono-) series, those with two sialic acid residues are in the GD (D for Di-) series ….

Functions of Sphingolipds

- Sphingolipids at cell surfaces are sites of biological recognition.
- The carbohydrate moieties of certain sphingolipids define the human blood groups





B Antigen

- The human blood groups are determined in part by the oligosaccharide head groups of the glycosphingolipids
- The same three oligosaccharides are also found attached to certain blood proteins of individuals of blood types O, A, and B
- The ABO blood group is determined by variation of sugar head groups on ceramide

Cholesterol

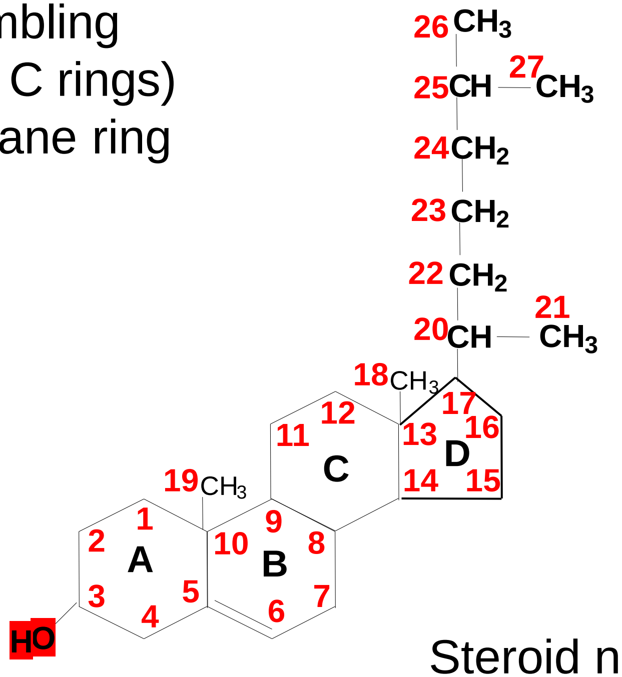
Cholesterol the major sterol in animal tissues

- It has a polar head group (the hydroxyl group of C-3) and a nonpolar hydrocarbon body
- It is widely distributed in all tissues. Does not occur in plants
- A major constituent of plasma membranes and lipoproteins
- Offten found as cholesterylester where the hydroxyl group at C-3 is esterified to a long-chain fatty acid

Sterols Are Also Precursors Of

- Steroid hormones
- Bile acids are polar derivatives of cholesterol that act as detergents in the intestine

Cyclic nucleus resembling phenanthrene (A, B, C rings) to which a cyclopentane ring (D) is attached



Cholesterol

Polar head

Steroid nucleus

In naturally occurring steroids virtually all the rings are in the chair form.

The End