Lipids

8th lect. of medical chemistry

Dr. Salih Mahdi Salman

Introduction

- Lipids are hydrophobic, nonpolar molecules.
  - They are soluble in nonpolar solvent.
  - They are insoluble in polar solvents, such as water.
- They are isolated from the other biological molecules by extracting them with nonpolar solvents.

Biological Functions of Lipids

1. As an energy source, lipids provide 9 kcal of energy per gram
2. Triglycerides provide energy storage in adipocytes
3. Phosphoglycerides, sphingolipids, and steroids are structural components of cell membranes
4. Steroid hormones are critical intercellular messengers
5. Lipid-soluble vitamins (A, E, D, K)
6. Dietary fat acts as a carrier of lipid-soluble vitamins into cells of small intestine
7. Provide shock absorption and insulation

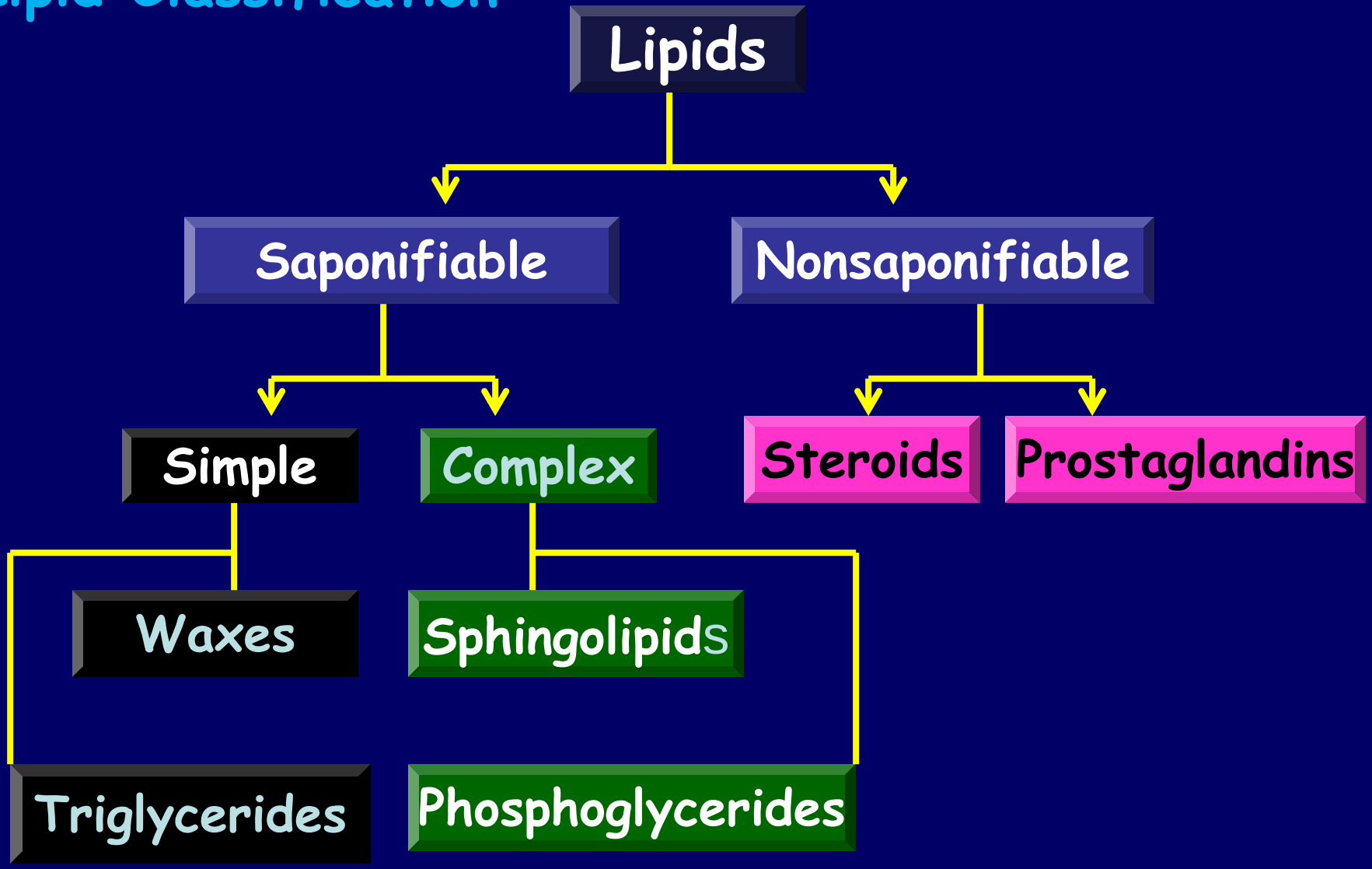
First Classification of Lipids

Based on groups

1. **Saponifiable** lipids have two subclasses
   Simple saponifable has two sub-categories
   - ✓Waxes
   - ✓Triglycerides

   Complex saponifable has two sub-categories
   - ➢Phosphoglycerides
   - ➢Sphingolipids
2. **Nonsaponifiable** have two subclasses
   Steroids
   Prostaglandins

Lipid Classification

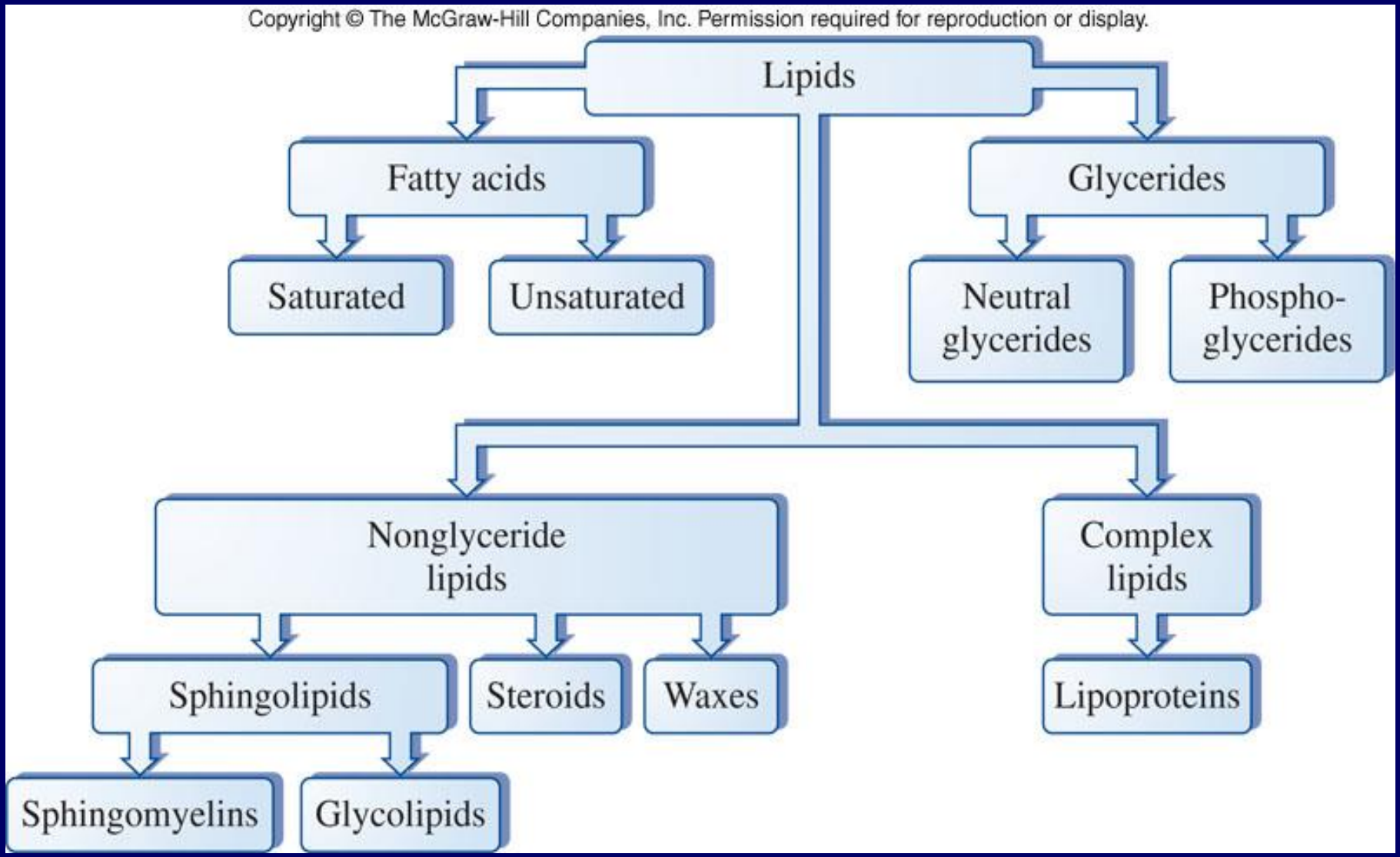


Second Classification of Lipids

Four Main Groups

1. Fatty Acids
   - Saturated
   - Unsaturated
2. Glycerides glycerol-containing lipids
3. Nonglyceride lipids
   - Sphingolipids
   - Steroids
   - Waxes
4. Complex lipids lipoproteins

A Scheme to Classify Lipids



Simple and Complex Lipids

Simple: an ester-containing lipid with just two types of components

- An alcohol
- One or more fatty acids

Complex: an ester-containing lipid with more than two components

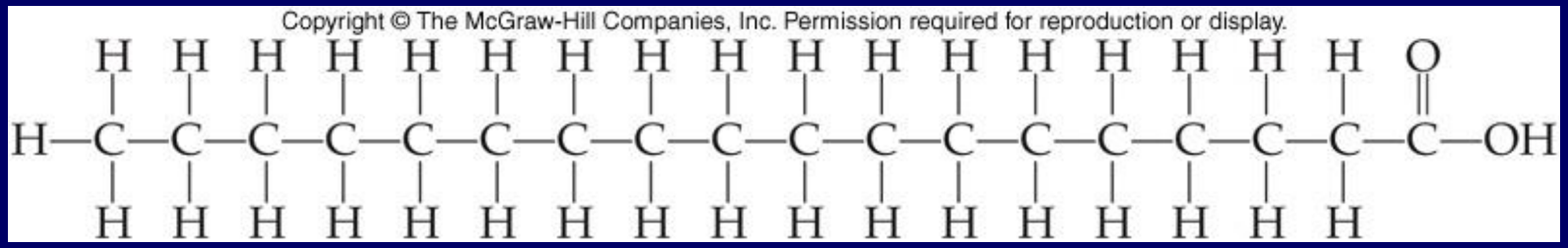
- An alcohol
- Fatty acids
- Plus others

Fatty Acids

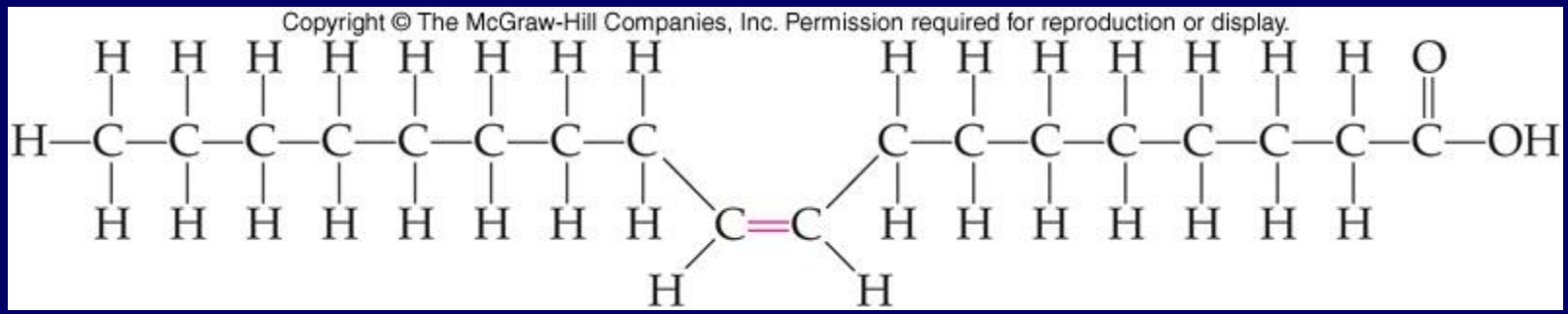
- ✓Long chain straight or branched carboxylic acids.
- ✓Most common chains range from 10-20 carbons in length
- ✓Usually, an even number of carbons in the chain, including the carboxyl carbon
- ✓Can be saturated or unsaturated, but usually no other functional groups present.
- ✓Any fatty acid that cannot be synthesized by the body is called an essential fatty acid

Structure

Stearic acid: a typical saturated fatty acid with 18 carbons in the chain



Oleic acid: a typical unsaturated fatty acid with 18 carbons in the chain



Saturated and Unsaturated Fatty Acids

- Saturated fatty acids have no double bonds
- Unsaturated fatty acids do contain double bonds
- The double bond is normally in a *cis* configuration
- Double bonds lower the melting temperature
- The *cis* configuration doesn't allow fatty acids to pack as close together

Fatty Acid Properties

1. Melting point increases with increasing carbon number
2. Melting point of a saturated fatty acid is higher than an unsaturated fatty acid with the same number of carbons
3. Typical saturated fatty acids are tightly packed together
4. ***cis*** double bonds prevent good alignment of molecules in unsaturated fatty acids leading to poor packing
5. Double bonds lower melting point relative to saturated acid

Common Fatty Acids

TABLE 17.1 Common Saturated and Unsaturated Fatty Acids

Common Saturated Fatty Acids

Common Name	I.U.P.A.C. Name	Melting Point (°C)	RCOOH Formula	Condensed Formula
Capric	Decanoic	32	$C_9H_{19}COOH$	$CH_3(CH_2)_8COOH$
Lauric	Dodecanoic	44	$C_{11}H_{23}COOH$	$CH_3(CH_2)_{10}COOH$
Myristic	Tetradecanoic	54	$C_{13}H_{27}COOH$	$CH_3(CH_2)_{12}COOH$
Palmitic	Hexadecanoic	63	$C_{15}H_{31}COOH$	$CH_3(CH_2)_{14}COOH$
Stearic	Octadecanoic	70	$C_{17}H_{35}COOH$	$CH_3(CH_2)_{16}COOH$
Arachidic	Eicosanoic	77	$C_{19}H_{39}COOH$	$CH_3(CH_2)_{18}COOH$

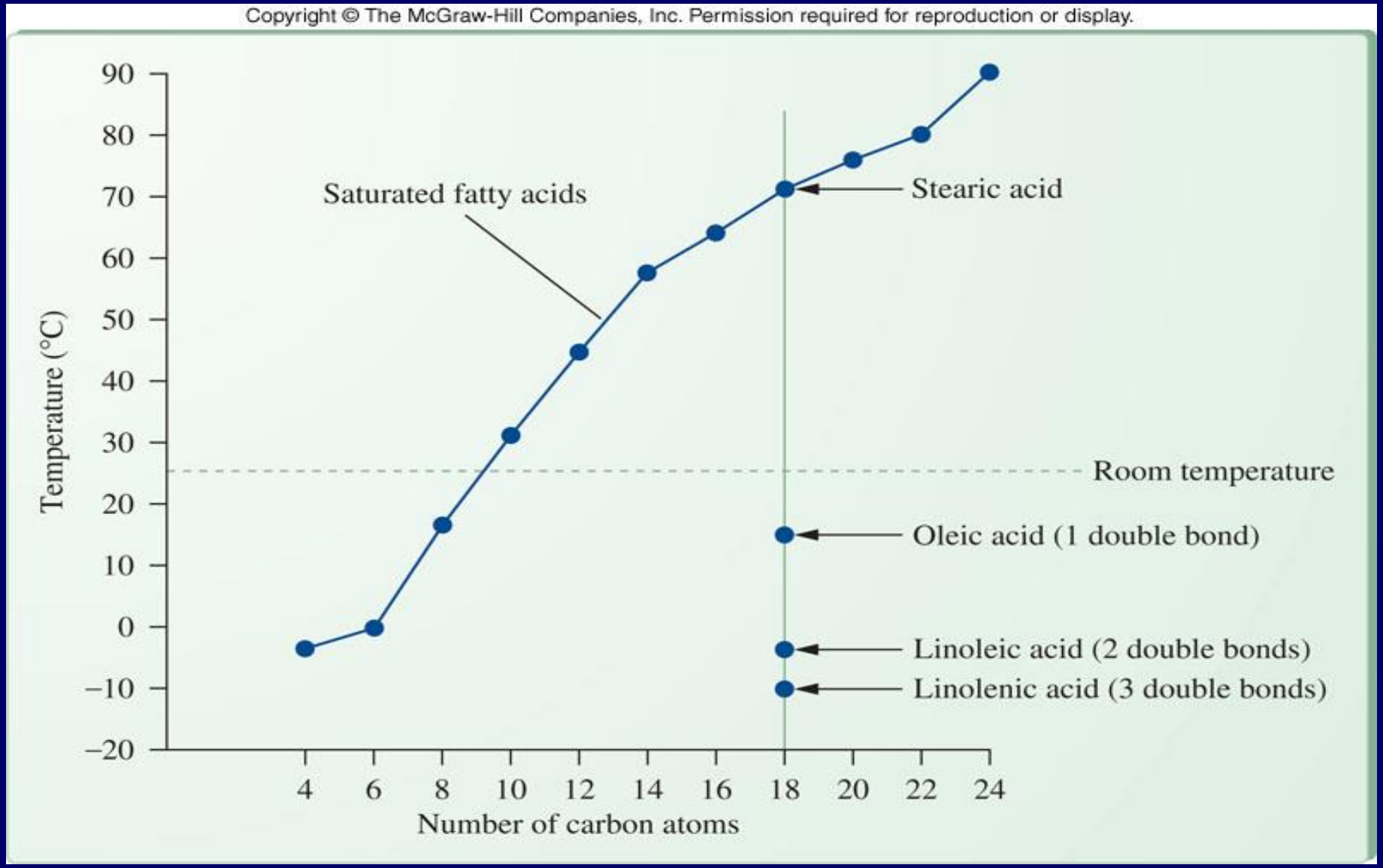
Common Unsaturated Fatty Acids

Common Name	I.U.P.A.C. Name	Melting Point (°C)	RCOOH Formula	Number of Double Bonds	Position of Double Bonds
Palmitoleic	*cis*-9-Hexadecenoic	0	$C_{15}H_{29}COOH$	1	9
Oleic	*cis*-9-Octadecenoic	16	$C_{17}H_{33}COOH$	1	9
Linoleic	*cis,cis*-9,12-Octadecadienoic	5	$C_{17}H_{31}COOH$	2	9, 12
Linolenic	All *cis*-9,12,15-Octadecatrienoic	−11	$C_{17}H_{29}COOH$	3	9, 12, 15
Arachidonic	All *cis*-5,8,11,14-Eicosatetraenoic	−50	$C_{19}H_{31}COOH$	4	5, 8, 11, 14

Condensed Formula

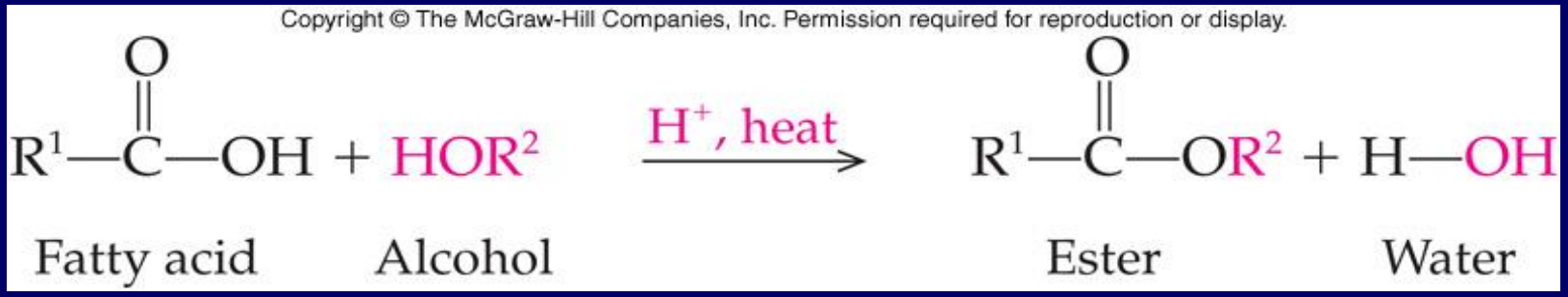
Palmitoleic	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$
Oleic	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$
Linoleic	$CH_3(CH_2)_4CH{=}CH{-}CH_2{-}CH{=}CH(CH_2)_7COOH$
Linolenic	$CH_3CH_2CH{=}CH{-}CH_2{-}CH{=}CH{-}CH_2{-}CH{=}CH(CH_2)_7COOH$
Arachidonic	$CH_3(CH_2)_4CH{=}CH{-}CH_2{-}CH{=}CH{-}CH_2{-}CH{=}CH{-}CH_2{-}CH{=}CH{-}(CH_2)_3COOH$

Melting Points of Fatty Acids

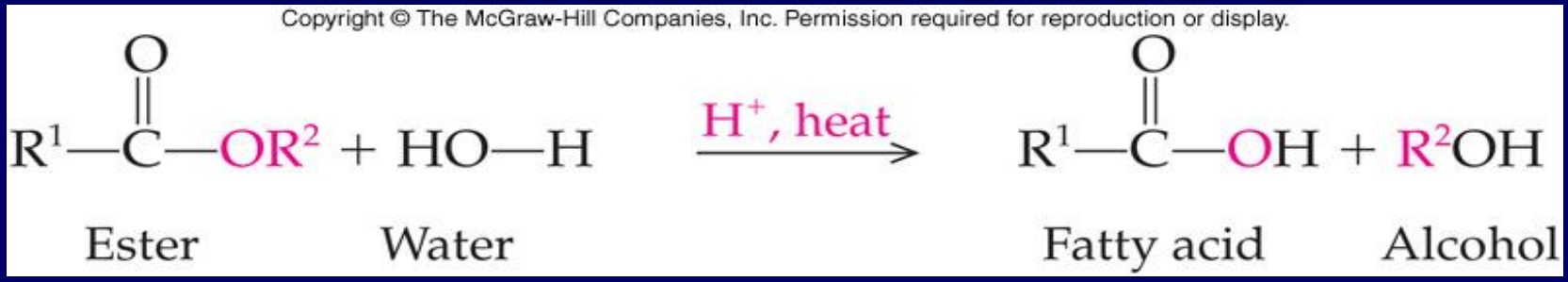


Chemical Reactions of Fatty Acids

1. **Esterification** reacts fatty acids with alcohols to form esters and water



2. **Fatty Acid hydrolysis** Acid Hydrolysis reverses esterification fatty acids are produced from esters



3. Saponification

Saponification is the base-catalyzed hydrolysis of an ester.

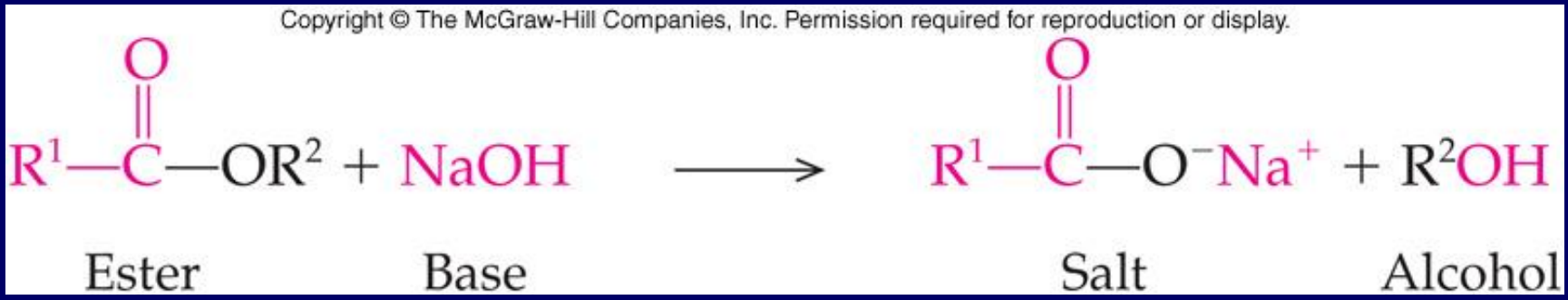
Products of the reaction are:

- An alcohol
- An ionized salt which is **a soap**

Soaps have a long uncharged hydrocarbon tail

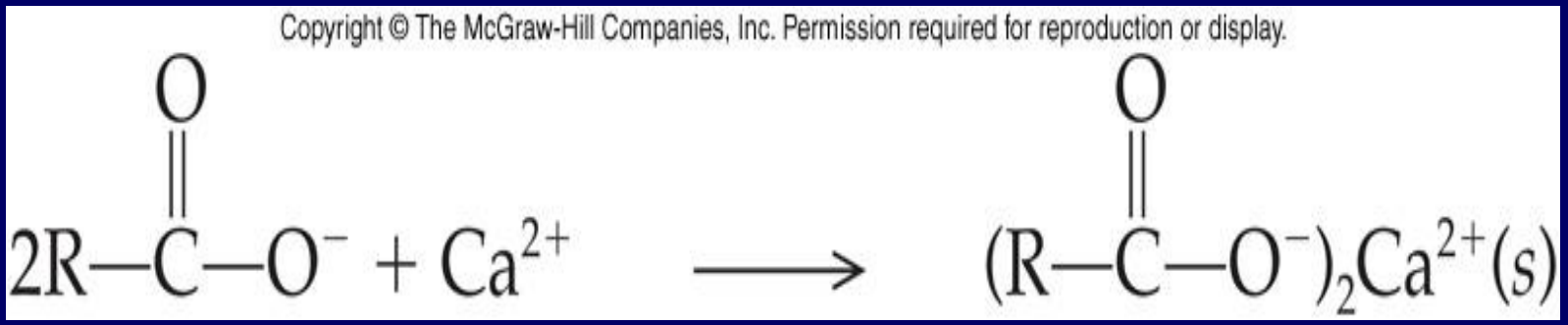
Also have a negatively charged carboxylate group at end.

Form micelles that dissolve oil and dirt particles



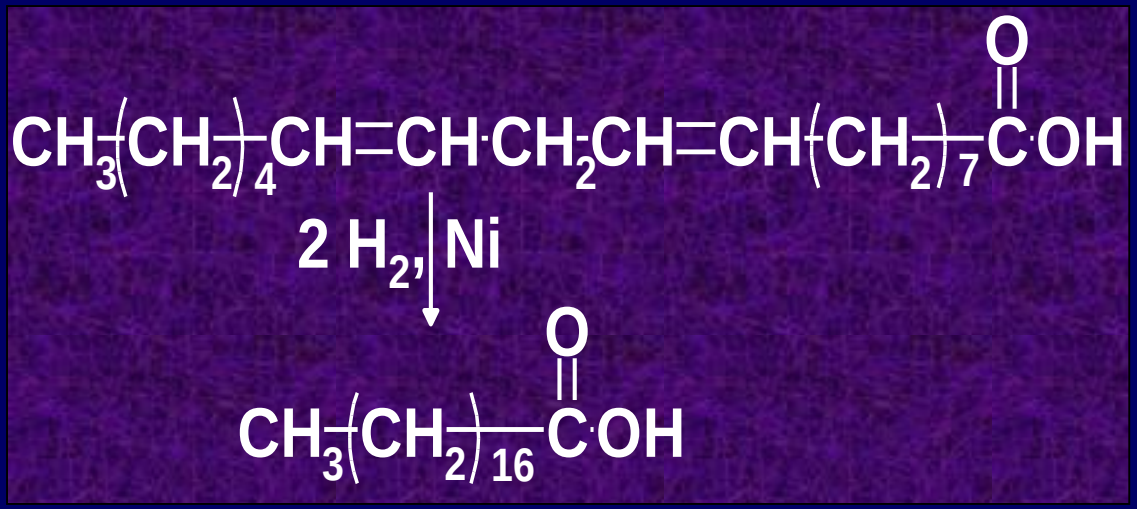
Saponification Problems

- When "hard" water is used with soaps "Hard" water contains high concentrations of Ca^{2+} and Mg^{2+}
- Cations in the water form fatty acid salts which precipitate.
- Interferes with emulsifying action of the soap Leaves a crusty scum on the surface of the sink



Reaction at the Double Bond

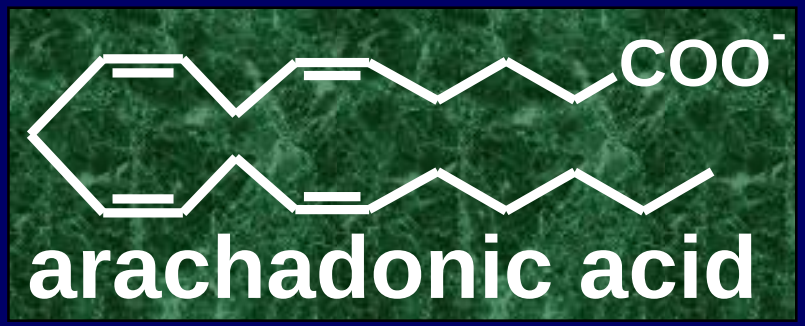
- Hydrogenation is an addition reaction
- Unsaturated fatty acids can be converted to saturated fatty acids
- Hydrogenation is used in the food industry



Eicosanoids

- Fatty acids which can't be synthesized by the body are essential fatty acids
- Linoleic acid is an essential fatty acid required to make arachadonic acid

- Arachidonic acid (20 C) is the eicosanoid precursor



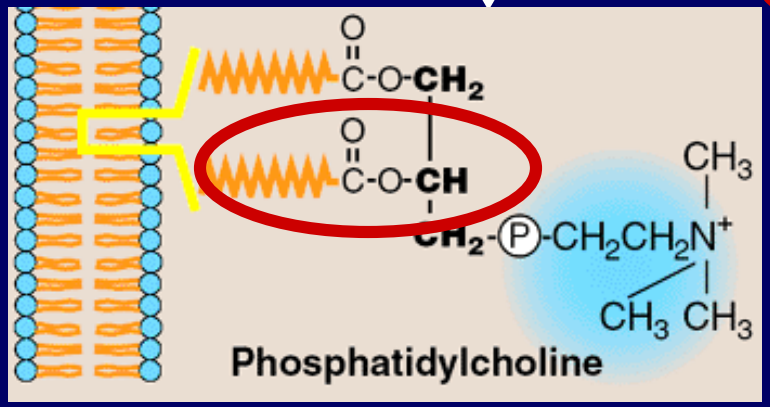
- Eicosanoids are three groups of structurally related compounds
  1. Prostaglandins
  2. Leukotrienes
  3. Thromboxanes

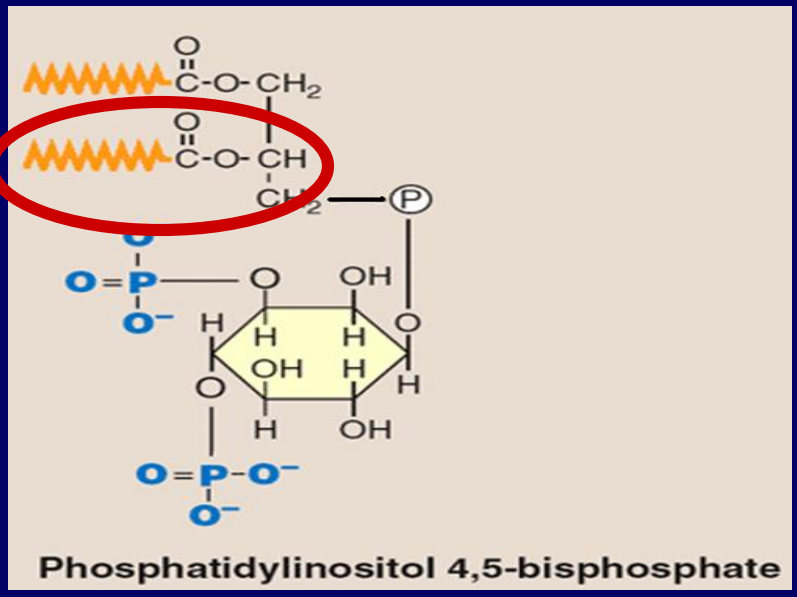
Dietary Linoleic Acid (C18: $\Delta^{9,12}$) (from plant oils)

Elongase

Desaturase

Arachidonic Acid (C20: $\Delta^{5,8,11,14}$)

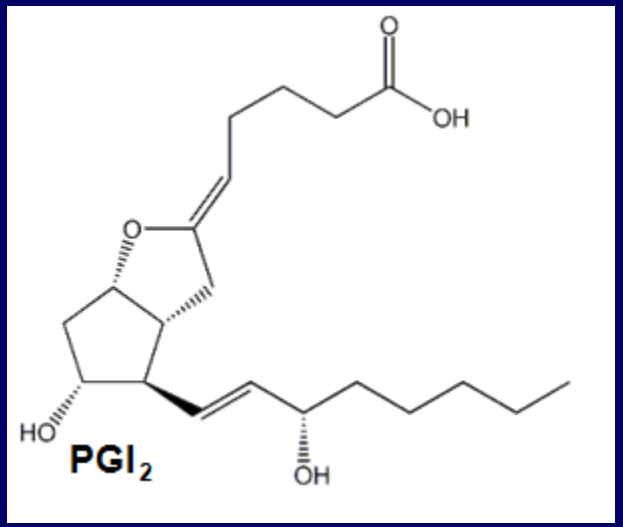




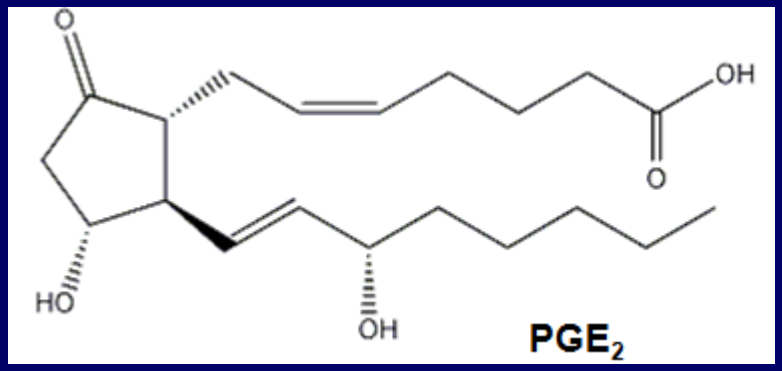
Membrane Phospholipids

Prostaglandins

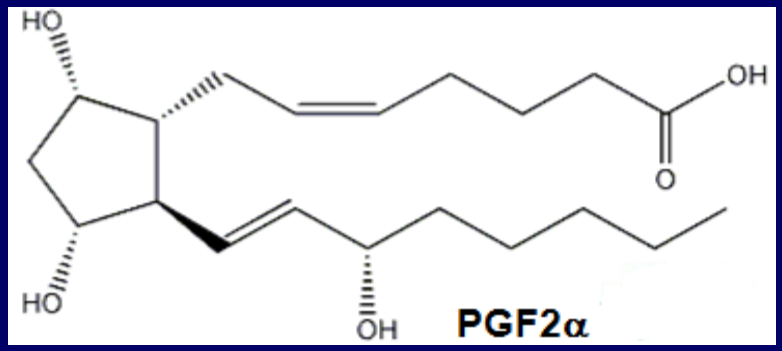
Prostaglandins (PG) = eicosanoids having a bridge making a 5-carbon ring, and either 1, 2 or 3 double bonds. Roughly a dozen different PG's have widely different effects (not all covered here).



PGI_2



PGE_2



PGF2α

Prostaglandins

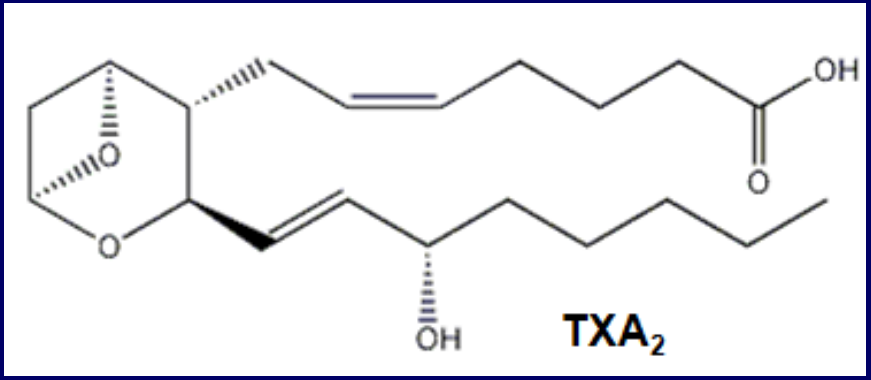
- Unlike most hormones, the prostaglandins are not secreted from a gland to be carried in the bloodstream and work on specific areas around the body.
- Instead, they are made by a chemical reaction at the site where they are needed and can be made in nearly all the organs in the body.
- Prostaglandins are part of the body's way of dealing with injury and illness.

- Potent biological molecules
- They act like hormones in controlling the body's processes
- Synthesized from 20-carbon unsaturated fatty acids
- Cyclic compounds including a 5-carbon ring
- Names are based on ring substituents and number of side-chain double bonds
- Made in most tissues
- Exert their effects on cells that produce them and cells in the immediate vicinity

Thromboxanes

Thromboxanes (TX) = eicosanoids that have a 6-member oxygen-containing ring.
TXA2, a platelet activator, is the main one.

cyclooxygenase (COX), the enzyme that makes AA into PG's and TX's.



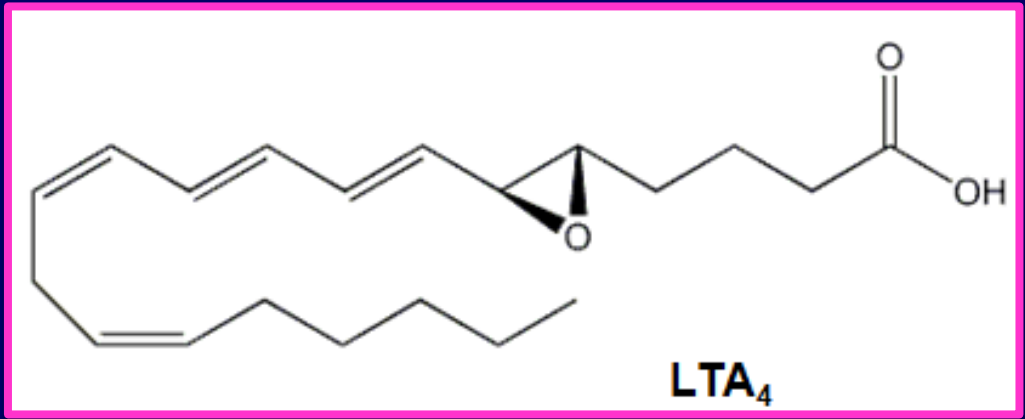
TXA_2

Leukotriene

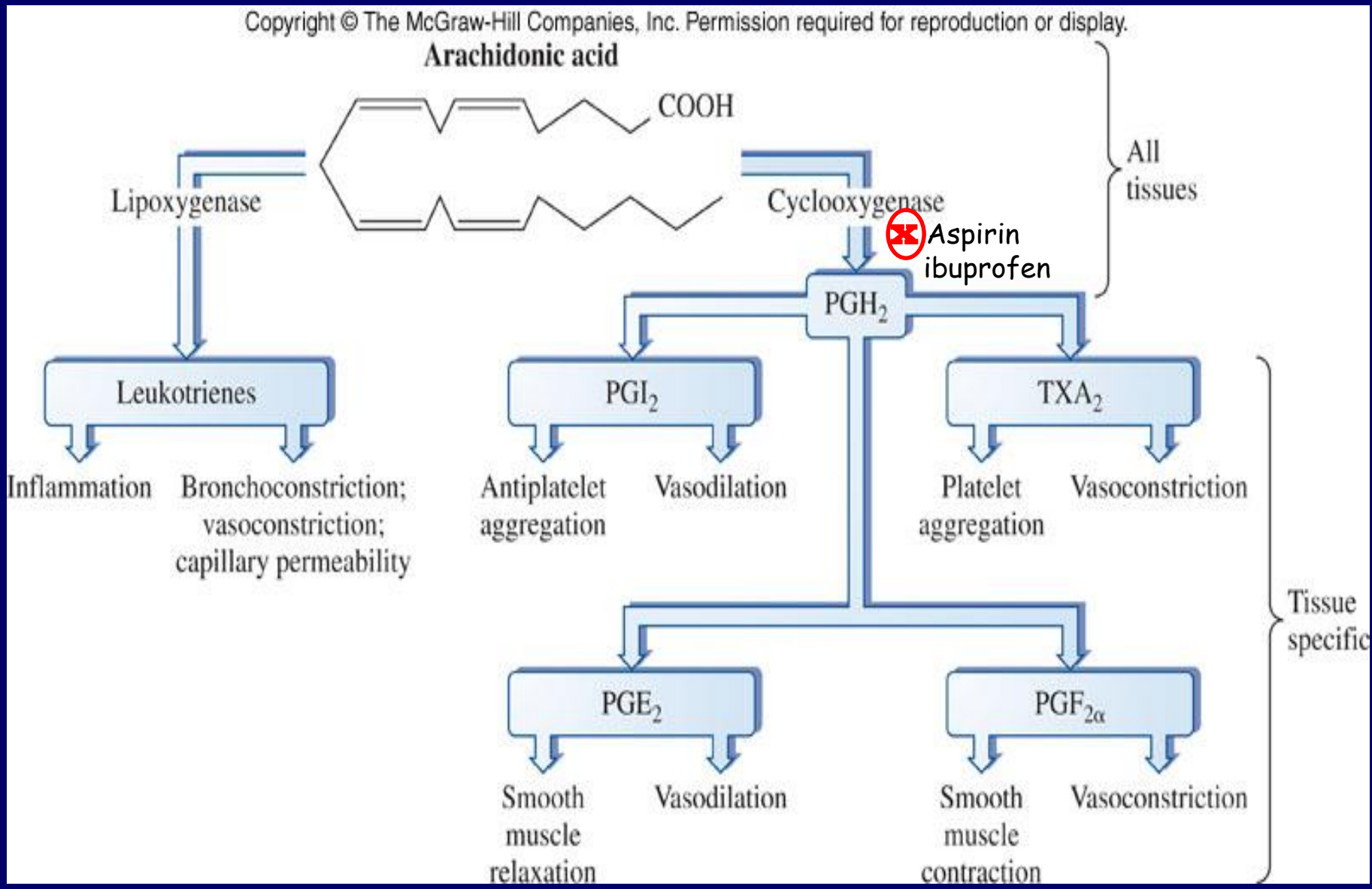
Leukotriene (LT) = eicosanoids that have an open backbone.

- LTA4 is the intermediate.
- LTB4 is a major chemotaxin
- LTC4, D4 and E4 are important in asthma.

5-lipoxygenase **(5-LO)**, the enzyme that makes AA into LT's.

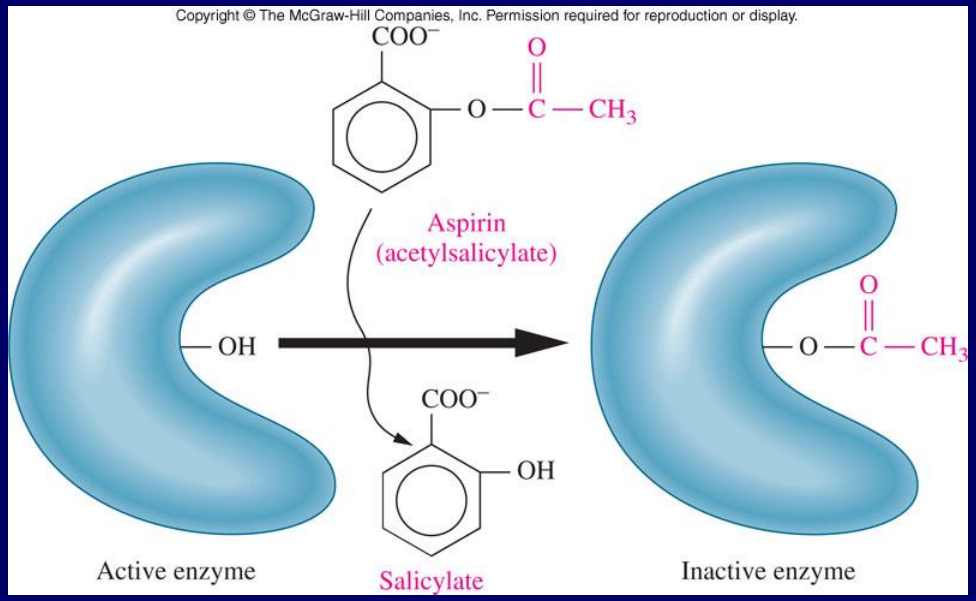


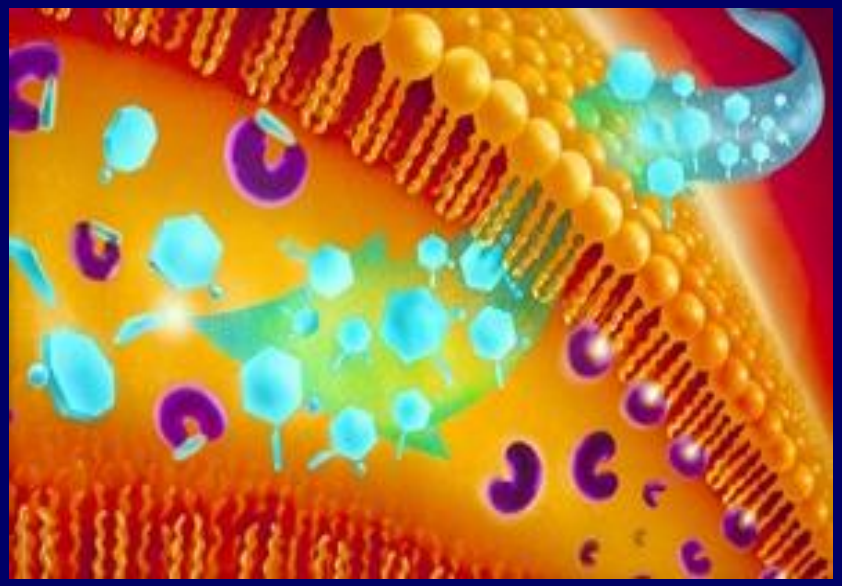
Synthesis of PG's and TX's



Aspirin and Prostaglandins

Aspirin inhibits prostaglandin synthesis by acetylating cyclooxygenase, an enzyme necessary for prostaglandin synthesis





Mechanism of action of the drug aspirin. Aspirin works by preventing the production of prostaglandin: aspirin molecules (blue hexagons) enter the cell and chemically modify the cyclooxygenase enzyme (purple) to prevent prostaglandin synthesis.

Biological Processes Regulated by Eicosanoids

1. Blood clotting
   - Thromboxane A_2 stimulates constriction of blood vessels and platelet aggregation
   - Prostacyclin dilates blood vessels and inhibits platelet aggregation

2. Inflammatory response :prostaglandins mediate aspects of inflammatory response

3. Reproductive system: stimulation of smooth muscle by PGE_2

4. Gastrointestinal tract:
   - Prostaglandins inhibit gastric secretion
   - Prostaglandins increase secretion of protective mucus
   - Inhibition of hormone-sensitive lipases
5. Kidneys:
   - Prostaglandins dilate renal blood vessels results in increased water and electrolyte excretion
6. Respiratory tract:
   - Leukotrienes promote the constriction of bronchi
   - Prostaglandins promote bronchodilation


Thank you for your attention