LIPID METABOLISM LIPID CATABOLISM AND FATTY ACID OXIDATION

Topic outline

What is a Lipid?

What are the functions of Lipid?

Types of Lipid

Digestion and Absorption of Lipids

Catabolism of Lipids

Fatty Acid Beta-oxidation

What is a Lipid?

- These are nonpolar organic compounds
- Generally insoluble to water, but soluble to nonpolar solvent like; chloroform acetone - ether - benzene
- It contains a carbonyl group (-COOH)

What are the functions of lipids?

- As membrane structural component.
- As intracellular storage metabolic fuel.
- As transport form of metabolic fuel.
- As protective form of the cells of many bacteria, leaves of higher plants, exoskeleton of insects and the skin of vertebrates.
- A regulatory substances.
- As transport form of some neurotransmitters.
- As receptors in nerve ending membranes.
- As determinants of immunological specificity.
- Enzyme co-factors

Types of Lipids- simple lipid; compound lipid and derive lipid

The four main groups of lipids include:

- 1. Fatty acids (saturated and unsaturated)
- 2. Glycerides (glycerol-containing lipids)
- 3. Nonglyceride lipids (sphingolipids, steroids, waxes)
- 4. Complex lipids (lipoproteins, glycolipids)

Simple lipids: Esters of fatty acids with alcohols. These are mainly of two types

- (a) Fats and oils (triacylglycerols:)-These are **esters of fatty acids with glycerol**. The difference between fat and oil is only physical. Thus, oil is a liquid while fat is a solid at room temperature.
- (b) Waxes: **Esters of fatty acids(usually long chain) with alcohols other than** glycerol. These alcohols may be aliphatic or alicyclic. Cetyl alcohol is most commonly found in waxes.

Complex (or compound) lipids: These are esters of fatty acids with alcohols containing additional groups such as phosphate, nitrogenous base, carbohydrate, protein etc

They are further divided as follows

Phospholipids- They contain phosphoric acid and frequently a nitrogenous base This is in addition to alcohol and fatty acid.

(i) Glycerophospholipid: These **phospholipids contain glycerol** as the alcohol example- lecithin, cephalin.

(ii) Sphingophospholipid- Sphingosine is the alcohol in this group of

phospholipids e.g., sphingomyelin

Glycolipids: These lipids contain a **fatty acid, carbohydrate** and nitrogenous base.

- The alcohol is sphingosine hence they are also called as glycosphingolipids.
 glycerol and phosphate are absent e.g.- cerebrosides, gangliosides
- Lipoproteins: Macromolecular complexes of lipids with proteins

Derived lipids: These are the derivatives **obtained on the hydrolysis lipids** which These include glycerol and other alcohols, fatty acids, mono and diacylglycerols lipid (fat) **soluble vitamins**, **steroid hormones**, hydrocarbons and ketone bodies.

Fatty acid

- Fatty acids are carboxylic acids with hydrocarbon side chain. They are the simplest form of lipids.
- Most of the fatty acids that occur in natural lipids are of **even carbons** (usually 14C-2OC). This is due to the fact that biosynthesis of fatty acids mainly occurs with the **sequential addition of 2 carbon units**. **Palmitic acid (I6C) and stearic acid (18C) are the most common.**
- Among the odd chain fatty acids-propionic acid (3C) and valeric acid (5C)

Saturated and unsaturated fatty acid -

- Saturated fatty acids do not contain double bonds
- unsaturated fatty acids contain one or more double bonds.
- Fatty acids with one double bond are monounsaturated and those with 2 or more double bonds are collectively known as polyunsaturated fatty acids (PUFA)

Saturated fatty acid

Palmitic acid – 16C

Stearic acid 18C

Unsaturated fatty acid -

Oleic acid –(18:1,9)

Linoleic acid-(18: 2;9,3)

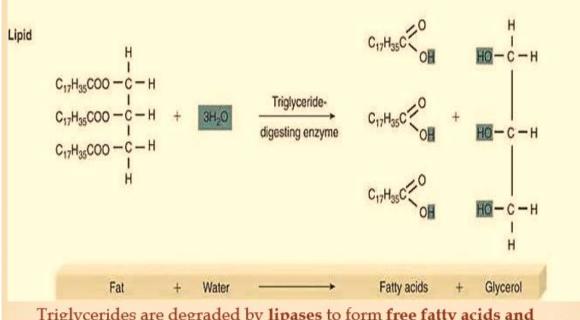
Linolenic acid-(18: 3; 9,12,15)

Lipoproteins are molecular

- complexes of lipids with proteins.
- They are the transport vehicles for lipids in the circulation.
- five types of lipoproteins, namely chylomicrons, very low density lipoproteins (VLDL), low density lipoproteins (LDL), high density Lipoproteins (HDL) and free fatty acid-albumin complexes.

Digestion and Absorption of Lipids

Triglyceride degradation



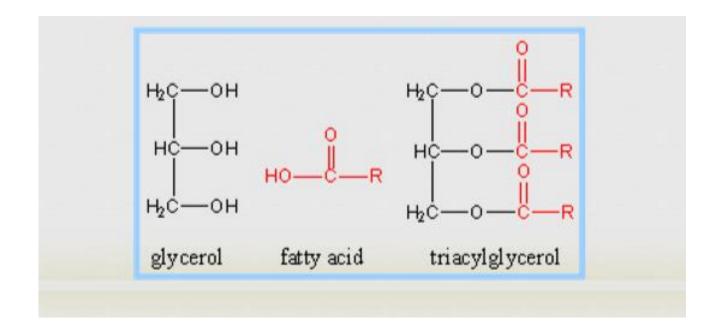
Triglycerides are degraded by **lipases** to form **free fatty acids and glycerol**

Lipid Catabolism

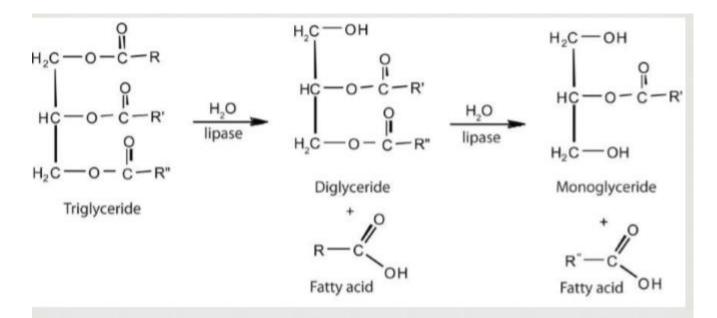
- Catabolism refers to several reactions that produce energy it is a breakdown of complex organic compounds into a simpler compounds.
- It is related to carbohydrate metabolism because the carbohydrates will turn into fats. The glycerol will participate is glycolysis.
- It is important process because the produced Fatty acids will participate in fatty acid oxidation.
- Energy is produced through a process called lipogenesis

LIPOLYSIS

- splitting of fat stimulated by epinephrine, norepinephrine and cortisol
- Triacylglycerols (triglycerides) are the most abundant dietary lipids Each triacylglycerol has a glycerol backbone to which are esterified 3 fatty acids. Most triacylglycerols are "mixed." The three fatty acids differ in chain length and number of double bonds

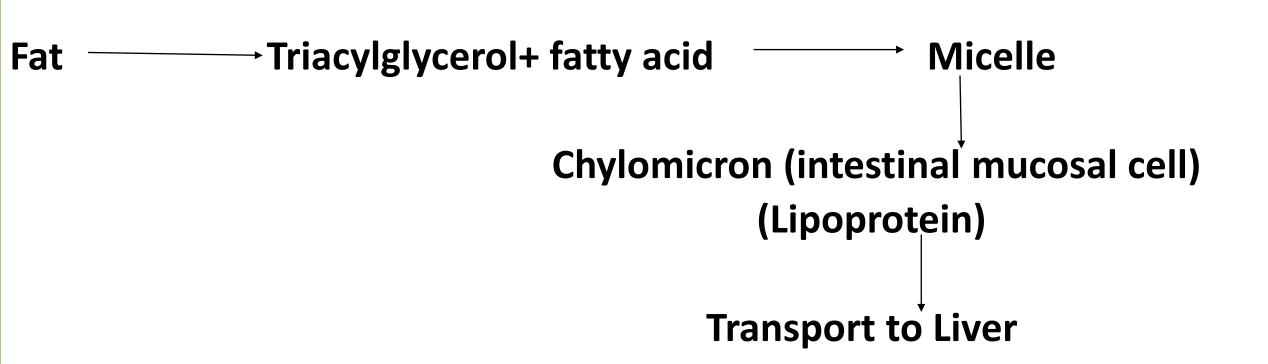


Lipid catabolism (Lipolysis)



Lipases hydrolyze triacylglycerols, releasing one fatty acid at a time, producing diacylglycerols, and eventually glycerol.

The end of the process 3 fatty acids and 1 glycerol.

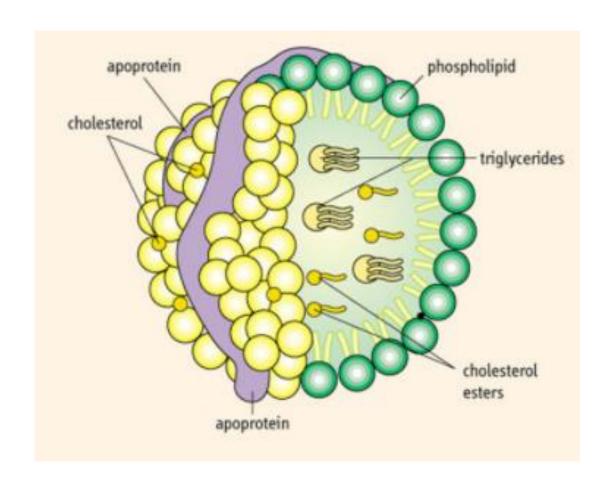


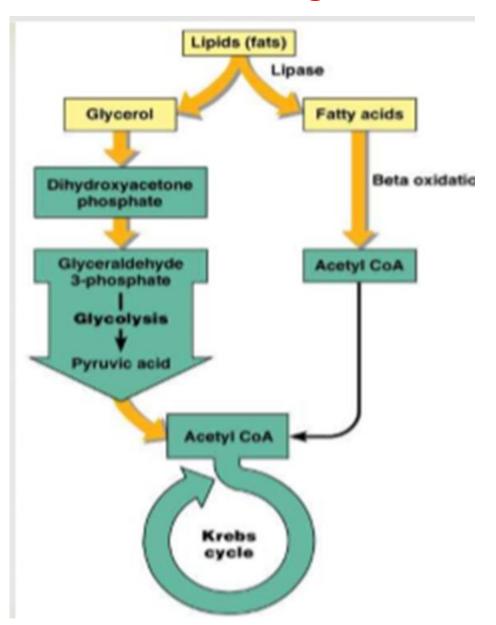
Oxidation of fatty acid

removal of successive two carbon atom unit fatty acid oxidation to form carbon dioxide

Chylomicron forms in the intestine mucosal cell and contain exogenous

(dietary) lipid





Fatty acid are activated and transported

- oxidation enzyme are located in mitochondria
- 12 C fatty acid chain are transported to mitochondria without the help of membrane transporter
- 14 C and more than 14 C chain can not pass directly mitochondria- required enzymatic reaction of carnitine shuttle
 - 1. outer membrane contain enzyme acyl CoA synthetase

Fatty Acid +CoA + ATP Fatty acyl CoA +AMP +AMP +2ip

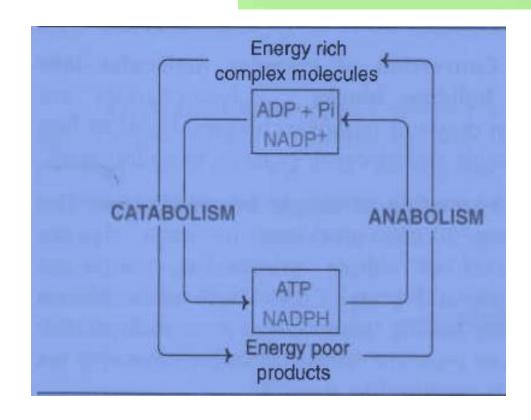
2. Transported through inner mitochondrial membrane via carnitine

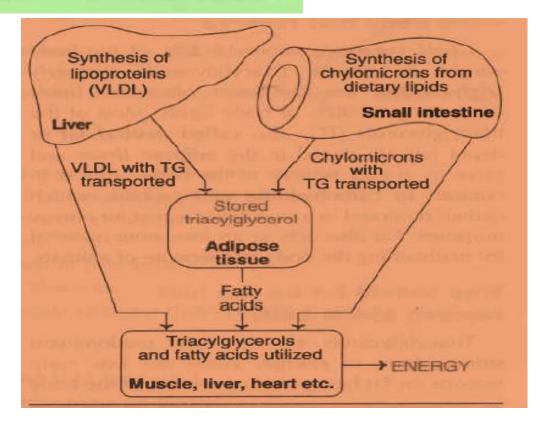
Use specific acyl carnitine transporter- carnitine acyl transporter-I (outer mitochondrial membrane) and carnitine acyl transporter-II (Inner mitochondrial membrane)

Oxidation of saturated fatty acid

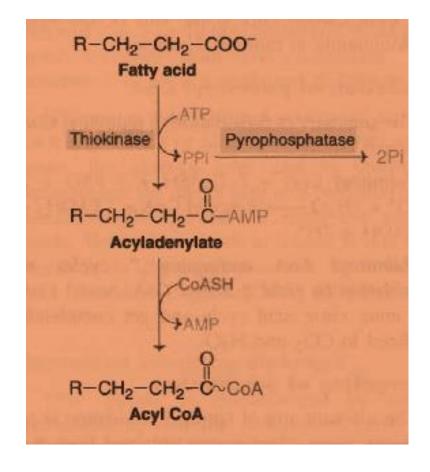
The β -oxidation of fatty acids involves three stages

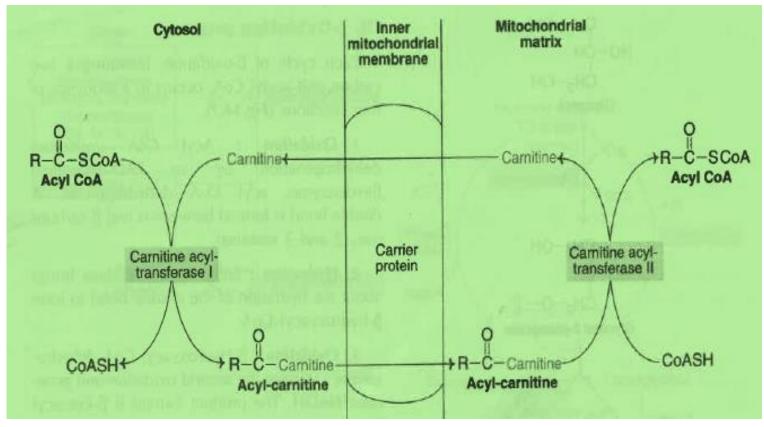
- Activation of fatty acids occurring in the cytosol;
 - II. Transport of fatty acids into mitochondria;
- III. β -Oxidation proper in the mitochondrial matrix.

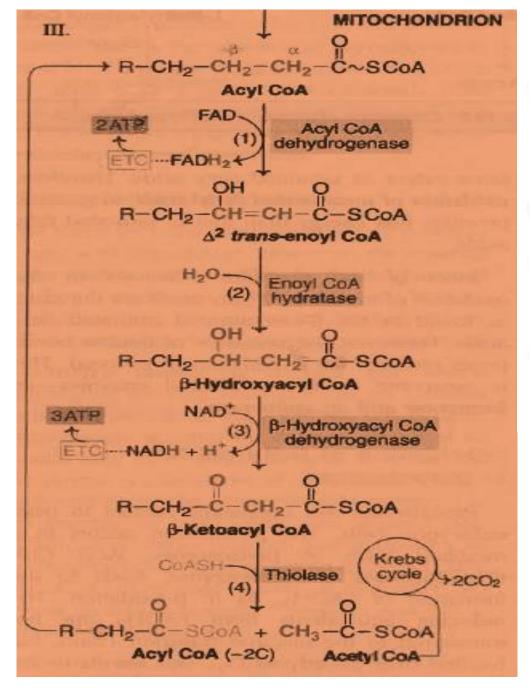




Activation

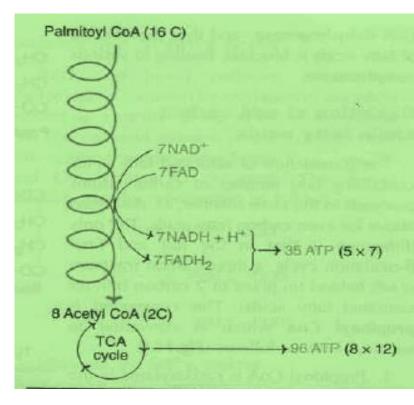




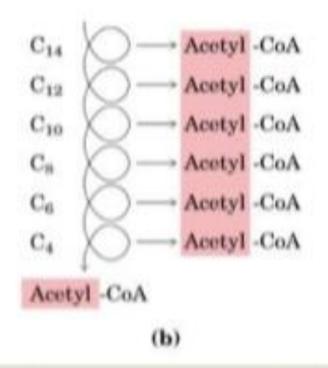


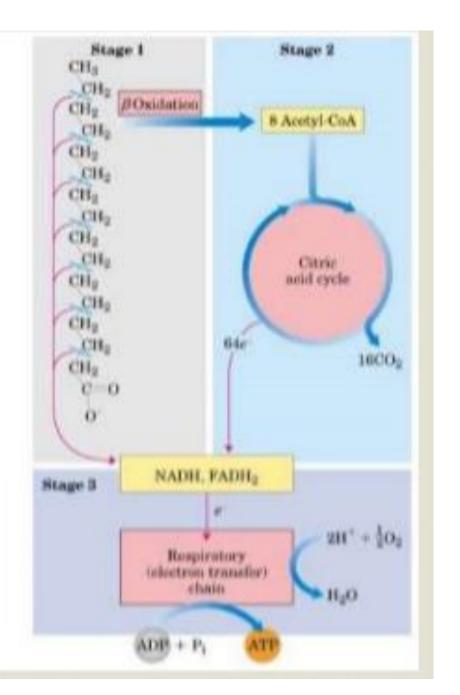
4 Steps of β-oxidation

- Dehydrogenation of the fatty acyl-CoA to make a trans double bond between and β carbon.
 - Short, medium, and long chain acyl-CoAdehydrogenases
 - e removed transferred to FAD
- 2. Hydration of the double bond
- Dehydrogenation of the β-hydroxyl group to a ketone
 - e' removed transferred to NAD*
- Acylation addition of CoA and production of acetyl-CoA



β-oxidation – first of three stages of fatty acid oxidation





Oxidation of unsaturated fatty acid

Due to the presence of double bonds, the unsaturated fatty acids are not reduced to the same extent as saturated fatty acids. Therefore, oxidation of unsaturated fatty acids, in general, provides less energy than that of saturated fatty acids.

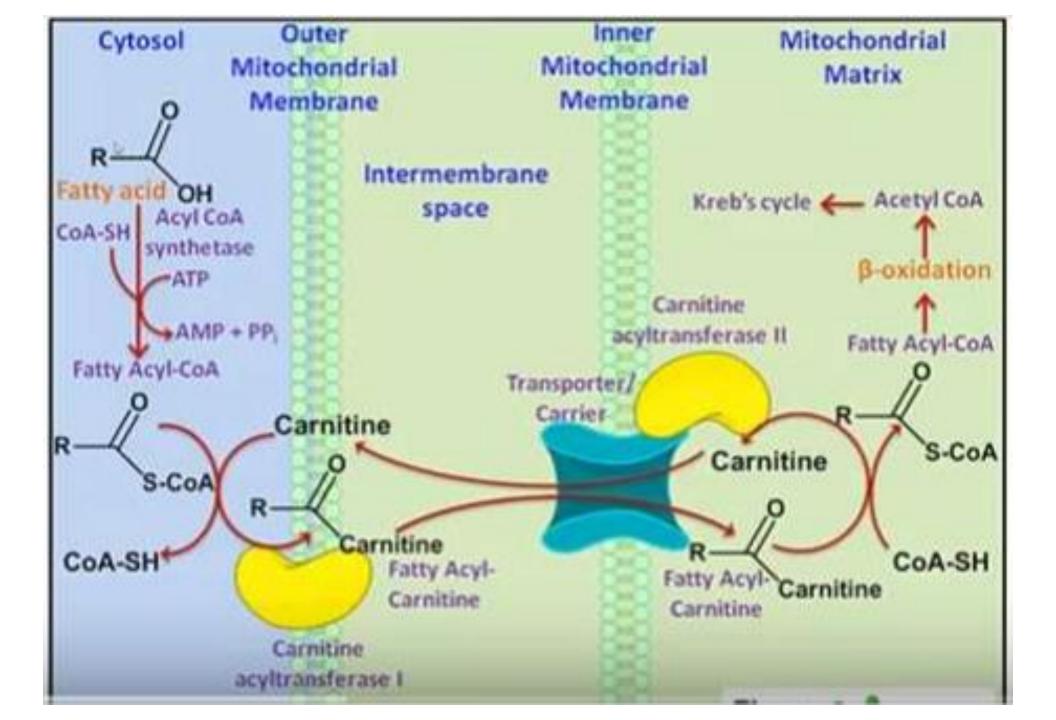
- Most of the reactions involved in the oxidation of unsaturated fatty acids are the same as found in the beta-oxidation of saturated fatty acids. However, the presence of double bonds poses problem for beta-oxidation to proceed. This is overcome by two additional enzymes-an Isomerase and an epimerase.
- Most of the fatty acid are one or more double bond. These bond are in cisconfiguration
- Both two enzyme Isomerase and epimerase beta oxidation of unsaturated fatty acid they converted to cis into trans
- are common for

Oxidation of odd no of fatty acid

- Odd no of fatty acid are found in many plant and marine organism
- Long chain odd no of fatty acid are synthesise in the same way as the even no
- The **only difference** is that in the last and final beta-oxidation cycle, a three-carbon fragment is left behind (in place of 2 carbon unit for saturated fatty acids). This compound is **propionyl CoA** which is converted to succinyl CoA.

Beta Fatty Acid Oxidation

- The end product of each cycle is the fatty acid shortened by 2 carbons and acetyl CoA.
- The series of reactions is also known as the beta-oxidation pathway because the major reaction site is the beta-carbon
- in the mitochondrial membrane
- The fatty acids must be activated and turned into acetyl CoA



Energy Yield from β-Oxidation

Yield of ATP per mole of stearic acid (C₁₈).

Step	Chemical Step	Happens	ATP
1	Activation (stearic acid -> stearyl CoA)	Once	-2
2	Oxidation (acyl CoA -> trans-enoyl CoA) produces FADH ₂	8 times	16
4	Oxidation (hydroxy- acyl CoA to ketoacyl CoA) produces NADH+1	8 times	24
	Oxidation of acetyl CoA by the common metabol pathway, etc.	9 times c	108
		TOTAL	146

Browning

- process of becoming brown, especially referring to food.
- may be desirable or undesirable.
- Browning has an important economic cost, causing deterioration of the value of products in the market of food.

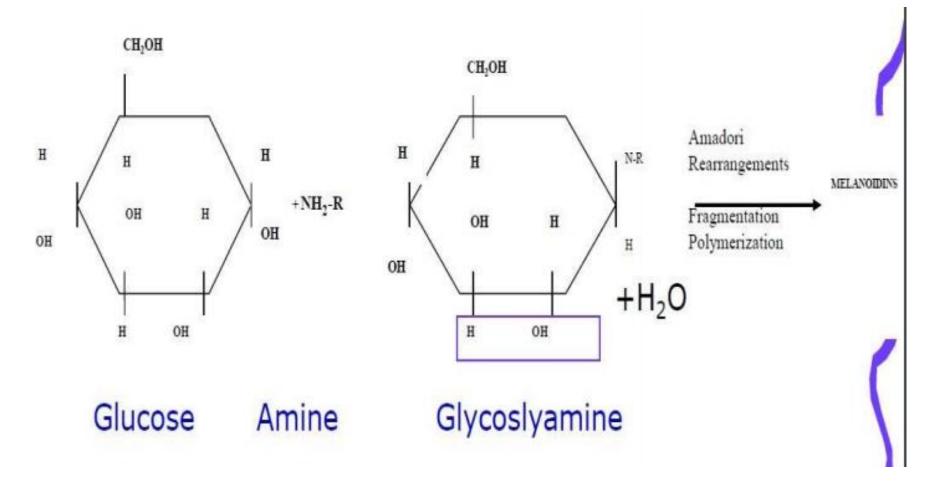
Types of browning reaction

Nonenzymatic browning and Enzymatic browning

- **Non-enzymatic browning-** the non enzymatic are no enzyme are involve to bring about to change colour
- Enzymatic browning- the non enzymatic browning reaction are involve enzyme
- The two main forms of nonenzymatic browning **Caramelization and Maillard browning**
- Caramelization- Caramelization or sugar browning occurs when any of the different types of sugars are heated over their melting points. -When heated by dry heat, granulated sugar will melt at approximately 160 degree C with continued heating the melted sugar will gradually turn brown to form Caramelized sugar
- -The extreme heat pulls water out of the sugar molecule to form furfural derivatives that undergoes a series of reactions that are polymerized to brown

Maillard browning

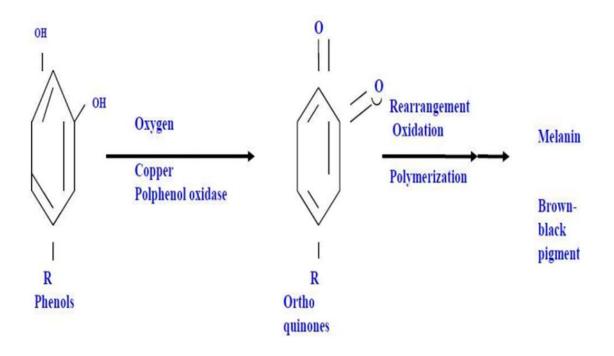
- The Maillard browning reaction or carbonyl amine browning is the reaction of the carbonyl group of a reducing sugar and an amino acid or amino group of a protein or peptide.
- The reducing sugars, in order of decreasing reactivity are; galactose, glucose, lactose and maltose the most reactive amino acids are lysine, tryptophan and arginine.



As an example:

This reaction takes place in dried milk after being stored for along time thus beginning to deteriorate and turn brown.

Enzymatic Browning



- Phenolases are found in many plants with especially high amount in potatoes, mushrooms, peaches,
 banana, avocado and tea leaves
- -However, the browning that occurs in tea leaves is beneficial as it imparts their characteristic colour.
 - -The term tannin describes the polyphenolic compounds that participate in enzymatic browning