

# Lipids



# Lipid Metabolism

Course Code: **ZOOL 4008 (Biochemistry and Metabolism)**

M.Sc. (Zoology), Semester –II



lipid bilayer

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phospholipid molecule





# Lipids

- A lipids are non-polar organic compounds that is insoluble in water and soluble in alcohol, ether, and chloroform.
- Lipids are an important constituent of the structure of living cells. Together with carbohydrates and proteins, lipids are the main constituents of plant and animal cells.
- Lipids are easily stored in the body and serve as a source of **Energy/Fuel**.
- Lipids includes fatty acids, neutral fats, waxes and steroids (like cortisone) etc. Almost all fat in your diet comes in the form of triglycerides
- Fatty acids rarely occur as free molecules in nature. it is found in complex molecules such as **fats** (energy-storage compounds) and **phospholipids** (the primary lipid components of cellular membranes).



# Lipids Classification

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graph TD; A[Lipids Classification] --> B[Simple Lipids: Esters of fatty acids with various alcohols. They are Saturated and Unsaturated (Ex. Fats, oil and Waxes)]; A --> C[Complex Lipids: Esters of fatty acids with various alcohols + Other Groups like phosphoric acids, sugar residue etc. for ex. A. Phospholipids (glycerophospholipids and sphingophospholipids) B. Glycolipids (glycosphingolipids): Carbohydrates containing lipids. C. Other complex lipids: Sulfolipids, aminolipids, and Lipoproteins.]; A --> D[Precursor and derived Lipids: Steroids, other alcohols, fatty aldehydes, and ketone bodies, lipid-soluble vitamins, and hormones.];
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## Simple Lipids:

Esters of fatty acids with various alcohols. They are Saturated and Unsaturated (Ex. Fats, oil and Waxes)

## Complex Lipids:

Esters of fatty acids with various alcohols + Other Groups like phosphoric acids, sugar residue etc. for ex.

A. **Phospholipids**  
(glycerophospholipids and sphingophospholipids)

B. **Glycolipids**  
(glycosphingolipids): Carbohydrates containing lipids.

C. **Other complex lipids:**  
Sulfolipids, aminolipids, and Lipoproteins.

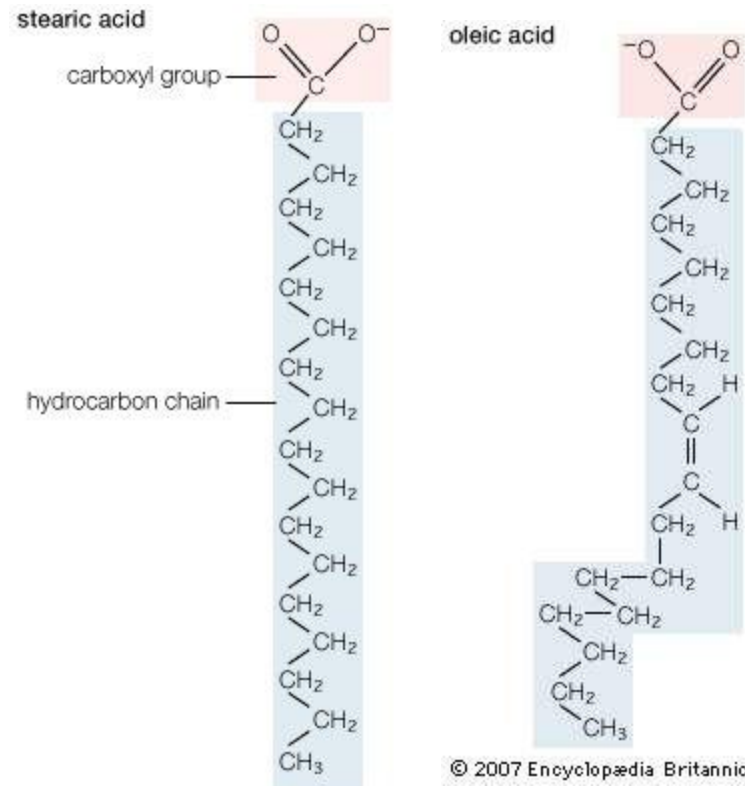
## Precursor and derived Lipids:

Steroids, other alcohols, fatty aldehydes, and ketone bodies, lipid-soluble vitamins, and hormones.



# Structure of Lipids

- Fatty acids are composed of a [hydrocarbon](#) chain with one terminal carboxyl group (COOH). At physiological condition hydrogen ion ( $H^+$ ) is lost to form a negatively charged carboxylate group ( $COO^-$ ).
- Most biological fatty acids contain an even number of [carbon](#) atoms, because the biosynthetic pathway is common to all organisms.
- Fatty acids are amphipathic in nature.
- They are found in two forms: saturated (only single bond), Ex. **myristic acid (C<sub>14</sub>)**, **palmitic acid (C<sub>16</sub>)**, **Stearic acid (C<sub>18</sub>)**, etc. and Unsaturated (double bond), Ex. **palmitoleic acid (C<sub>16</sub>)**, **Oleic acids (C<sub>18</sub>)** etc.

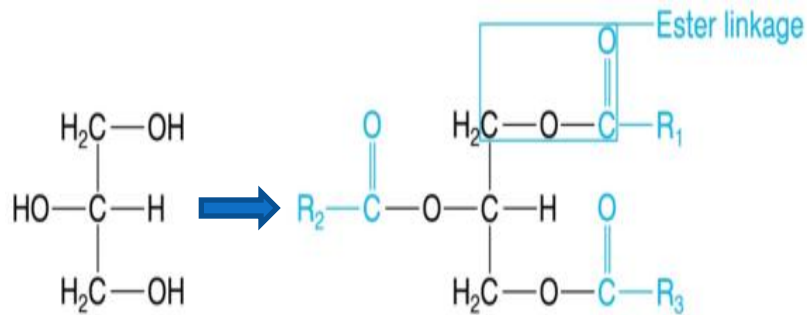


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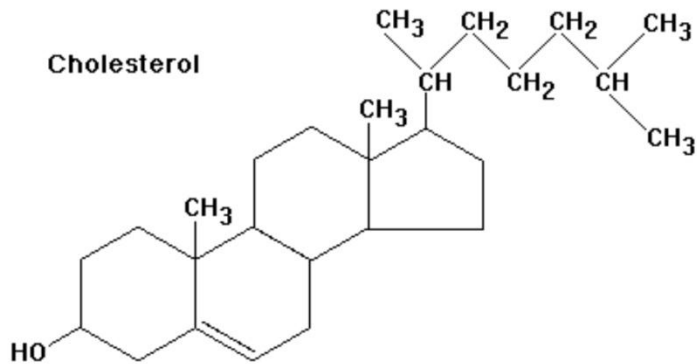
## Storage and Neutral Lipids



**Glycerol**

**Triacylglycerol**

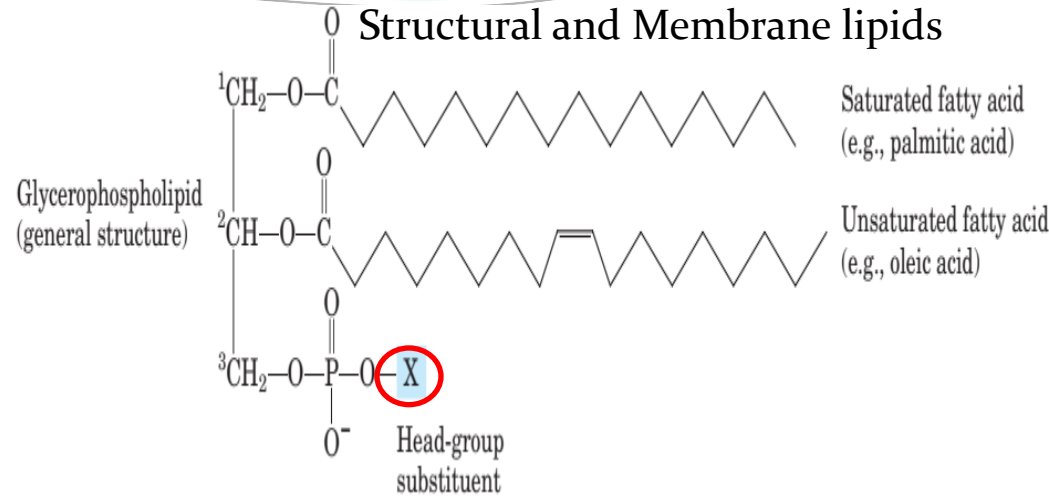
Most natural fats, found in vegetable oils, dairy products, and animal fat (complex mixtures of simple and mixed triacylglycerols).



**Cholesterol**

Cholesterol is an essential structural component of animal cell. It is a sterol type of lipid. Your body needs some **cholesterol** to make hormones, vitamin D, and substances that help you digest foods

## Structural and Membrane lipids



### Name of glycerophospholipid

### Name of X

Phosphatidic acid

—

Phosphatidylethanolamine

Ethanolamine

Phosphatidylcholine

Choline

Phosphatidylserine

Serine

Phosphatidylglycerol

Glycerol

Phosphatidylinositol  
4,5-bisphosphate

*myo*-Inositol 4,5-  
bisphosphate

Cardiolipin

Phosphatidyl-  
glycerol



# Lipid Metabolism

- Lipid metabolism is referred to the synthesis and degradation of lipids within the cells, either break down or storage of fats for energy.
- These fats are obtained from consuming food and absorbing them or they are synthesized by an animal's liver.
- Minimal amount of fat is essential in our food :
  - ✓ For essential fatty acids synthesis .
  - ✓ Help Fat-soluble vitamins absorption.
  - ✓ As a Source of energy: 1 gm supplies 9.1 calories
- Just like glucose Metabolism, the end-products of fatty acid metabolism are carbon dioxide, water and ATP.
- However, complete combustion of fatty acids requires glucose to convert it in to carbon dioxide, water and ATP, otherwise ketones are produced.



# Digestion and Absorption of the Lipids

There are following steps that start from mouth:

**Table 1. Steps of lipid digestion and absorption**

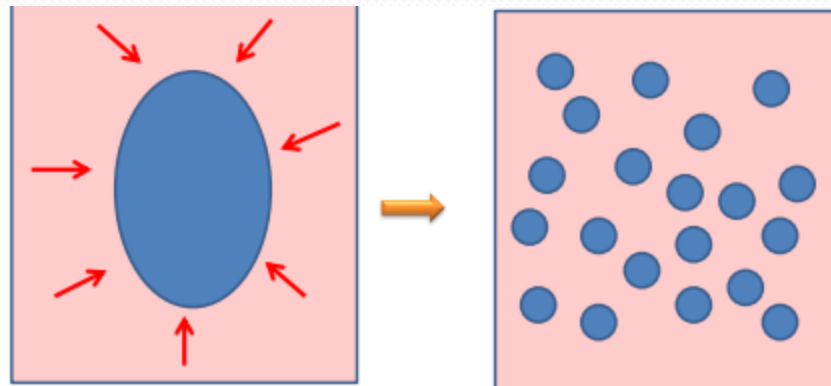
Step	Location	Enzymes
1. Minor digestion (TAGs → DAGs + FFA)	mouth and stomach	lingual/ gastric lipase
2. Major digestion (all) TAG → MAG + 2FFA (PL) CE → chol. + ester (CE) PL → FA + lysoPL (PLA)	lumen of the small intestines	pancreatic lipase (+colipase) cholesterol esterase phospholipase A <sub>2</sub>
3. Formation of mixed micelles (uses bile salts as biological detergent)	lumen of the small intestines	N/A
4. Passive absorption of lipolytic products	into intestinal epithelial cell	N/A
5. Assembly and export of chylomicrons	from intestinal cells to the lymphatics	N/A



## 1. Digestion of Triglycerides

It is a two steps process:

**A. Emulsification:** Breakdown of large fat globule smaller ones



It Occurs in:

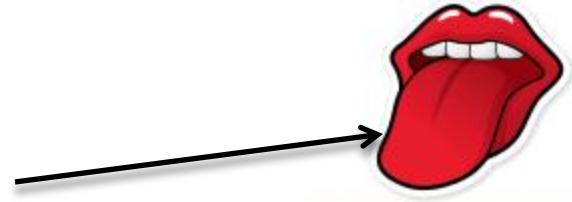
- ✓ **Mouth** by chewing.
- ✓ **Stomach** by peristaltic contractions.
- ✓ **Intestine** by peristaltic movement, bile salts, lysophospholipids



## B. Lipase Enzyme:

Types:

**1- lingual lipase:** secreted by the dorsal surface of the tongue (Von-Ebner's glands)

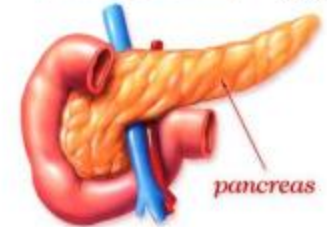
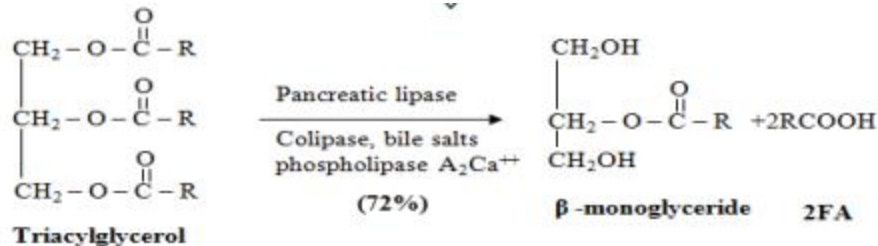


**2- Gastric lipase ( Works at pH 3-6)**

Triacylglycerols  $\xrightarrow{\text{Gastric Lipase}}$  Short and Medium free fatty acids & 1,2 Diacylglycerols



**3. Pancreatic lipase**



**4. Intestinal Lipase:** Act within intestinal mucosal cells, it hydrolyse the absorbed primary ( $\alpha$ ) monoglycerides forming glycerol and FFA,

**Note# The most active is pancreatic lipase**



## 2. Digestion of Phospholipids:

Phospholipids  $\xrightarrow{\text{Phospholipase}}$  lysophospholipids

- Intestinal phospholipase may complete the hydrolysis of lysophospholipids.
- Phospholipase A<sub>2</sub> activated by trypsin & requires bile salts for activity

## 3. Digestion of Cholesterol esters:

Cholesterol esters  $\xrightarrow{\text{cholesterol esterase}}$  FA & free cholesterol



# Absorption of Lipids

The end products of lipid digestion are: monoglycerides, FA, glycerol, cholesterol & lysophospholipids.

## 1- Glycerol and short chain FA :

Water soluble → carried through portal circulation

## 2- Long chain FA, monoglycerides, cholesterol & lysophospholipids: Need bile salts to be absorbed

**Note #** Immediately after absorption of lipids there is turbidity in plasma observed due to circulating chylomicrons (appear in plasma up to 2 hours after meals).

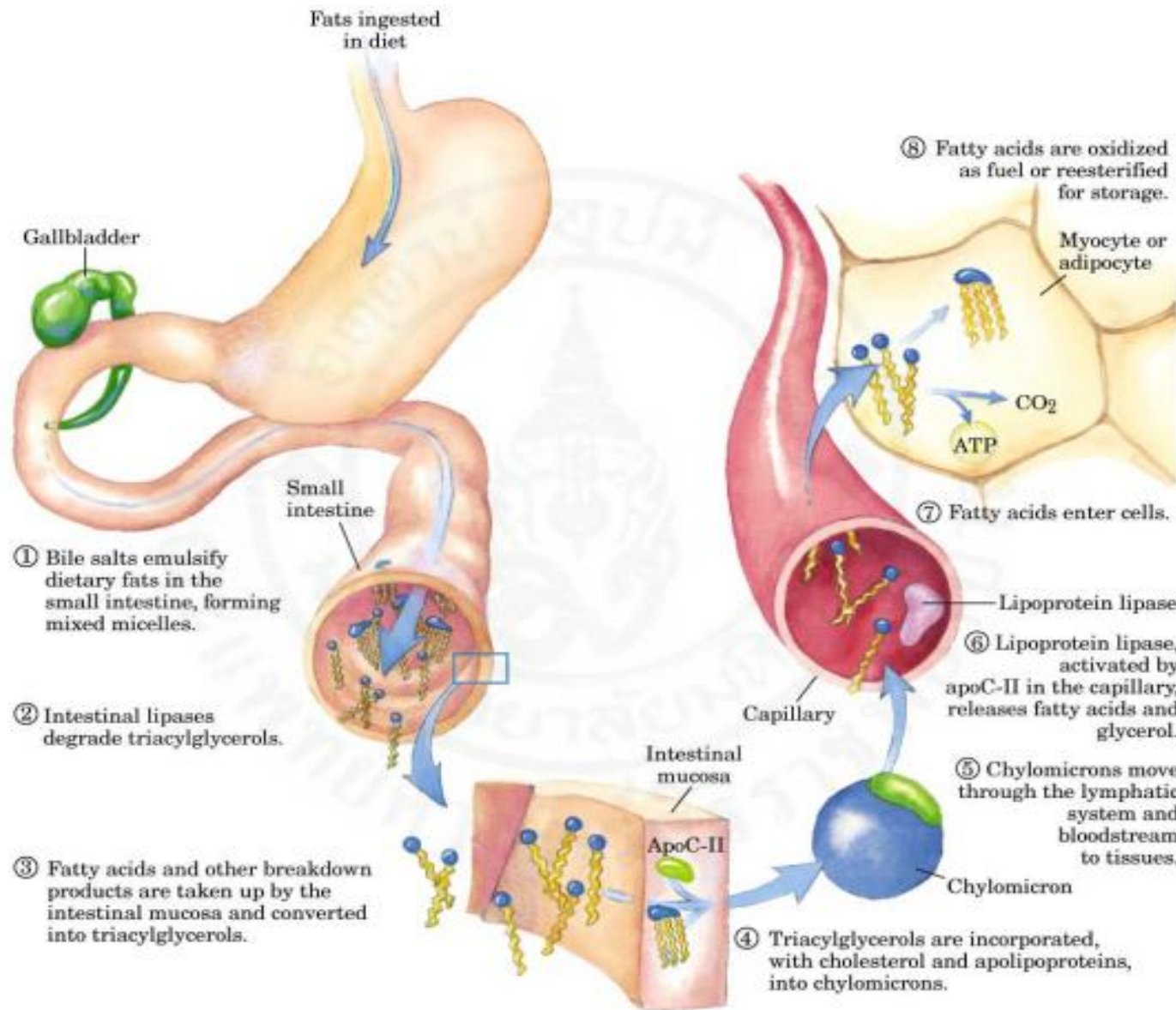
- Chylomicrons are ultra low-density lipoproteins (ULDL), that consist of triglycerides (85–92%), phospholipids (6–12%), cholesterol (1–3%), and proteins (1–2%).

- This turbidity is soon cleared by lipoprotein lipase enzyme (clearing factor). Lipoprotein lipase breaks Chylomicrons into Glycerol and FA.





# Mechanism of Lipids transport and Absorptions



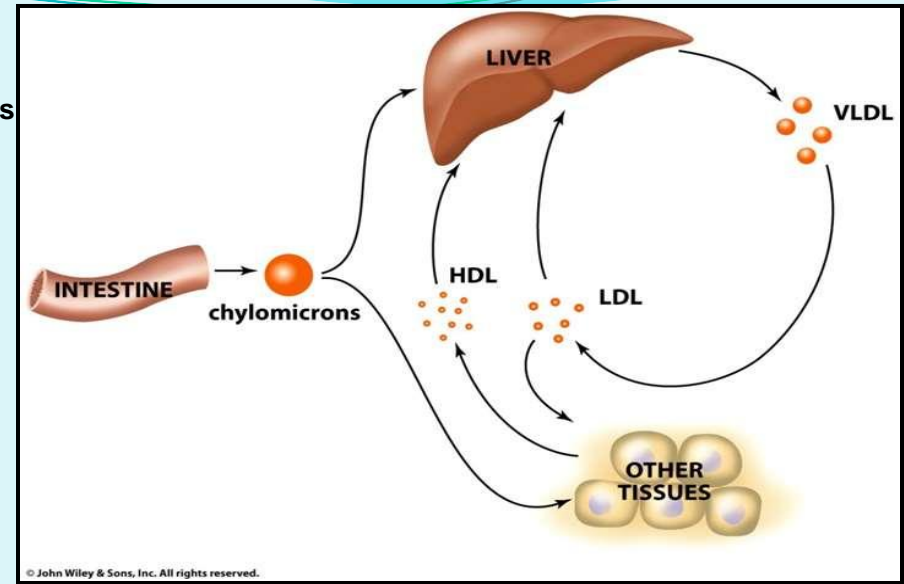
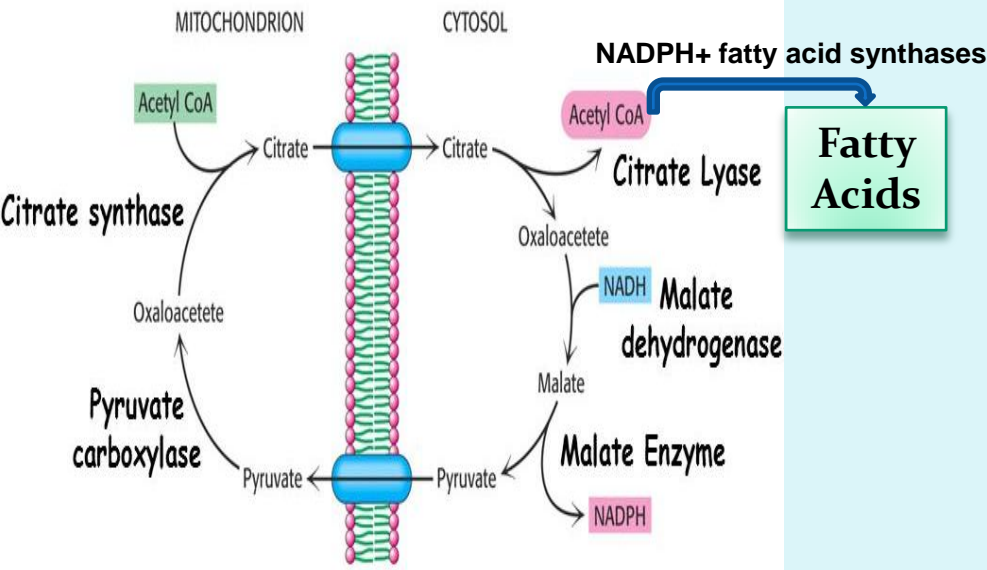


# Fatty Acid Synthesis

- Fatty acids Synthesis start in cytoplasm with help of acetyl-CoA and NADPH produced from mitochondria and Pentose phosphate Pathway (PPP) respectively using enzyme fatty acid synthases.
- First acetyl-CoA transported from mitochondria **through citrate—malate-pyruvate –Shuttle** in form of citrate, which further breaks into Acetyl-CoA and Oxaloacetate.
- Only small chain fatty acids get synthesized in to cytoplasm, so the synthesis of long chain fatty acids like Triacylglycerol required specialized organ like **Liver**.
- The liver is the major site for converting excess carbohydrates and proteins into fatty acids and triglyceride. The liver synthesizes large quantities of **cholesterol and phospholipids**.
- After synthesis, **VLDL lipoproteins** are then exported through blood circulation and stored in adipose tissue.
- A small fraction is also converted to small ketone molecules that are exported via the circulation to peripheral tissues, where they are metabolized to yield energy .



## Transport of Acetyl CoA -to Cytoplasm



**Note#** The conversion of carbohydrates to fatty acids is called **lipogenesis**.

**Lipogenesis** is the metabolic process through which acetyl-CoA is converted to triglyceride for storage in fat.

**VLDL ( very low-density lipoprotein)**: Bad" cholesterol because it contributes to the build up of plaque in arteries). It acts as transport vehicles for triglycerides.

**LDL (low density lipoproteins)**: It is also called bad" cholesterol. It carry about 75% total blood cholesterol.

**HDL (High-density lipoprotein)**: It is called good cholesterol because remove excess cholesterol, prevent plaque formation in arteries and protect from heart Diseases.



# Important Functions of Lipids

- ✓ As an energy source, lipids provide 9.1 Kcal of energy per gram.
- ✓ Triglycerides provide energy storage in adipocytes.
- ✓ Phosphoglycerides, sphingolipids and steroids are structural component of cell membrane .
- ✓ Steroids hormones are critical intracellular messengers.
- ✓ Lipid –soluble vitamins (A,E,D,K).
- ✓ As protective form of the cells of many bacteria, leaves of higher plants, exoskeleton of insects and the skin of vertebrates.
- ✓ Act as regulatory substances.
- ✓ As transport form of some neurotransmitters.
- ✓ As receptors in nerve ending membranes.
- ✓ As determinants of immunological specificity.
- ✓ Enzyme co-factors





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- Lehninger principles of biochemistry (4th ed.): Nelson, D., and Cox, M, W.H. Freeman and Company, New York, 2005 .





**Thank You**