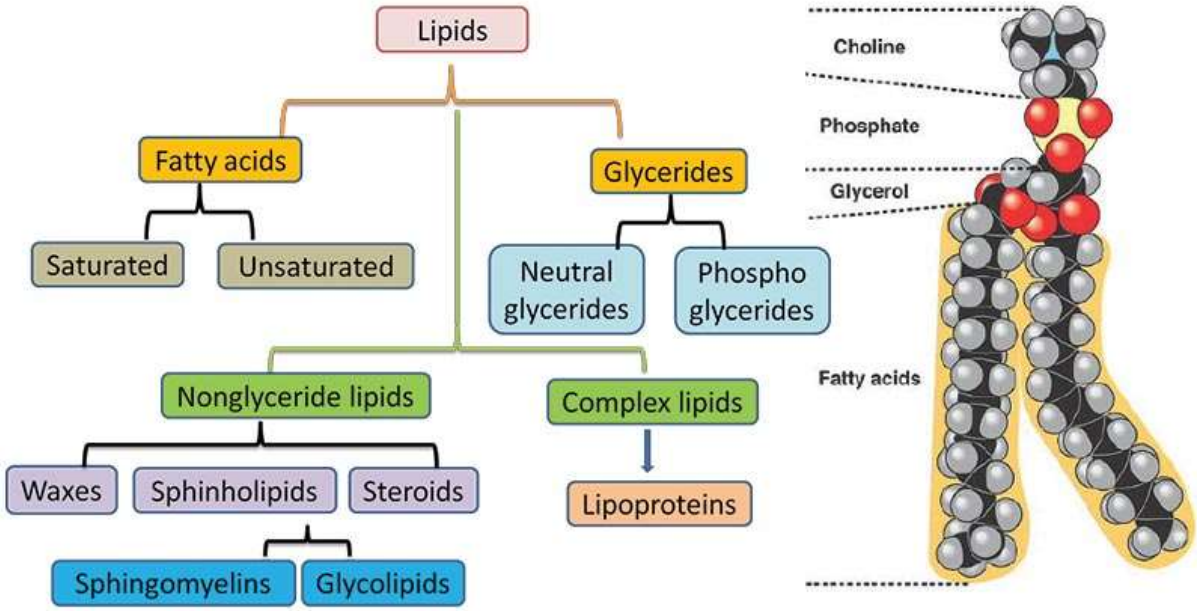
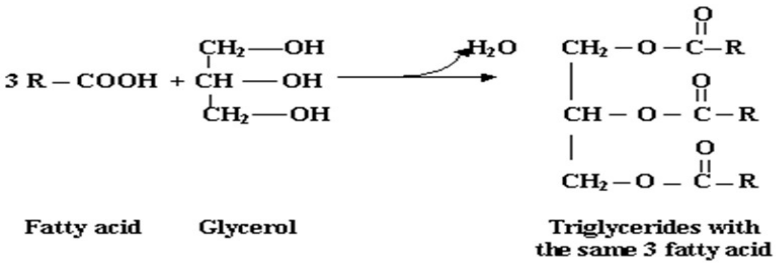
Fatty acid biosynthesis

24 August 2020 00:25

Lipids definition

- Lipids are a heterogeneous group of organic compounds that are insoluble in water and soluble in non-polar organic solvents.
- They naturally occur in most plants, animals, microorganisms and are used as cell membrane components, energy storage molecules, insulation, and hormones.





Properties of Lipids

- Lipids may be either liquids or non-crystalline solids at room temperature.
- Pure fats and oils are colorless, odorless, and tasteless.
- They are energy-rich organic molecules
- Insoluble in water
- Soluble in organic solvents like alcohol, chloroform, acetone, benzene, etc.
- No ionic charges
- Solid triglycerols (Fats) have high proportions of saturated fatty acids.
- Liquid triglycerols (Oils) have high proportions of unsaturated fatty acids.

1. Hydrolysis of triglycerols

Triglycerols like any other esters react with water to form their carboxylic acid and alcohol– a process known as hydrolysis.

2. Saponification:

Triacylglycerols may be hydrolyzed by several procedures, the most common of which utilizes alkali or enzymes called lipases. Alkaline hydrolysis is termed saponification because one of the products of the hydrolysis is a soap, generally sodium or potassium salts of fatty acids.

3. Hydrogenation

The carbon-carbon double bonds in unsaturated fatty acids can be hydrogenated by reacting with hydrogen to produce saturated fatty acids.

4. Halogenation

Unsaturated fatty acids, whether they are free or combined as esters in fats and oils, react with halogens by addition at the double bond(s). The reaction results in the decolorization of the halogen solution.

5. Rancidity:

The term rancid is applied to any fat or oil that develops a disagreeable odor. Hydrolysis and oxidation reactions are responsible for causing rancidity. Oxidative rancidity occurs in triacylglycerols containing unsaturated fatty acids.

Structure of Lipids

- Lipids are made of the elements Carbon, Hydrogen and Oxygen, but have a much lower proportion of water than other molecules such as carbohydrates.
- Unlike polysaccharides and proteins, lipids are not polymers—they lack a repeating monomeric unit.
- They are made from two molecules: **Glycerol and Fatty Acids.**
- A glycerol molecule is made up of three carbon atoms with a hydroxyl group attached to it and hydrogen atoms occupying the remaining positions.
- Fatty acids consist of an acid group at one end of the molecule and a hydrocarbon chain, which is usually denoted by the letter 'R'.
- They may be **saturated or unsaturated**.
- A fatty acid is saturated if every possible bond is made with a Hydrogen atom, such that there exist no C=C bonds.
- Unsaturated fatty acids, on the other hand, do contain C=C bonds. Monounsaturated fatty acids have one C=C bond, and polyunsaturated have more than one C=C bond.

Classification (Types) of Lipids

Lipids can be classified according to their hydrolysis products and according to similarities in their molecular structures. Three major subclasses are recognized

1. Simple lipids

(a) **Fats and oils** which yield fatty acids and glycerol upon hydrolysis.
(b) **Waxes**, which yield fatty acids and long-chain alcohols upon hydrolysis.

Fats and Oils

- Both types of compounds are called triacylglycerols because they are esters composed of three fatty acids joined to glycerol, trihydroxy alcohol.
- The difference is on the basis of their physical states at room temperature. It is customary to call a lipid a fat if it is solid at 25°C, and oil if it is a liquid at the same temperature.
- These differences in melting points reflect differences in the degree of unsaturation of the constituent fatty acids.

Waxes

- Wax is an ester of long-chain alcohol (usually mono-hydroxy) and a fatty acid.
- The acids and alcohols normally found in waxes have chains of the order of 12-34 carbon atoms in length.

2. Compound lipids

(a) **Phospholipids**, which yield fatty acids, glycerol, amino alcohol sphingosine, phosphoric acid and nitrogen-containing alcohol upon hydrolysis.
They may be **glycerophospholipids** or **sphingophospholipid** depending upon the alcohol group present (glycerol or sphingosine).
(b) **Glycolipids**, which yield fatty acids, sphingosine or glycerol, and a carbohydrate upon hydrolysis.
They may also be **glyceroglycolipids** or **sphingoglycolipid** depending upon the alcohol group present (glycerol or sphingosine).

3. Derived lipids:

Hydrolysis product of simple and compound lipids is called derived lipids. They include fatty acid, glycerol, sphingosine and steroid derivatives.
Steroid derivatives are phenanthrene structures that are quite different from lipids made up of fatty acids.

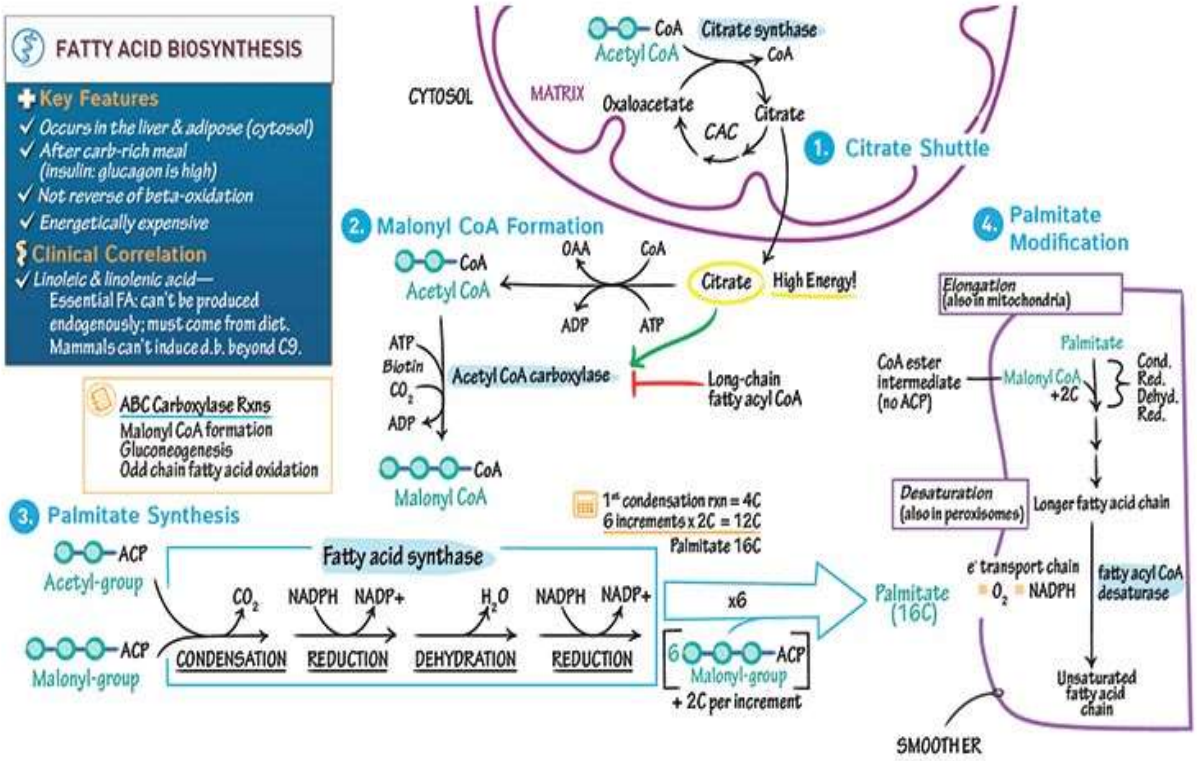
Functions

It is established that lipids play extremely important roles in the normal functions of a cell. Not only do lipids serve as highly reduced storage forms of energy, but they also play an intimate role in the structure of cell membrane and organellar membranes. Lipids perform many functions, such as:

1. Energy Storage
2. Making Biological Membranes
3. Insulation
4. Protection – e.g. protecting plant leaves from drying up
5. Buoyancy
6. Acting as hormones
7. Act as the structural component of the body and provide the hydrophobic barrier that permits partitioning of the aqueous contents of the cell and subcellular structures.
8. Lipids are major sources of energy in animals and high lipid-containing seeds.
9. Activators of enzymes eg. glucose-6-phosphatase, stearyl CoA desaturase and ω-monooxygenase, and β-hydroxybutyric dehydrogenase (a mitochondrial enzyme) require phosphatidylcholine micelles for activation.

Fatty Acid Synthesis

- Lipogenesis, the synthesis of fatty acids and their esterification to glycerol to form triacylglycerols, which occurs mainly in the liver in humans, with dietary carbohydrate as the major source of carbon.
- While the **de novo** synthesis of fatty acids from acetyl-CoA occurs in the cytosol on the fatty acid synthase complex.
- **Fatty acid synthesis** is the creation of fatty acids from acetyl-CoA and NADPH through the action of enzymes called fatty acid synthases.



Location

Fatty acid synthesis takes place in the cytosol and is carried out by a multienzyme complex called FAS (fatty acid synthase complex).

Substrates (to make one palmitate):

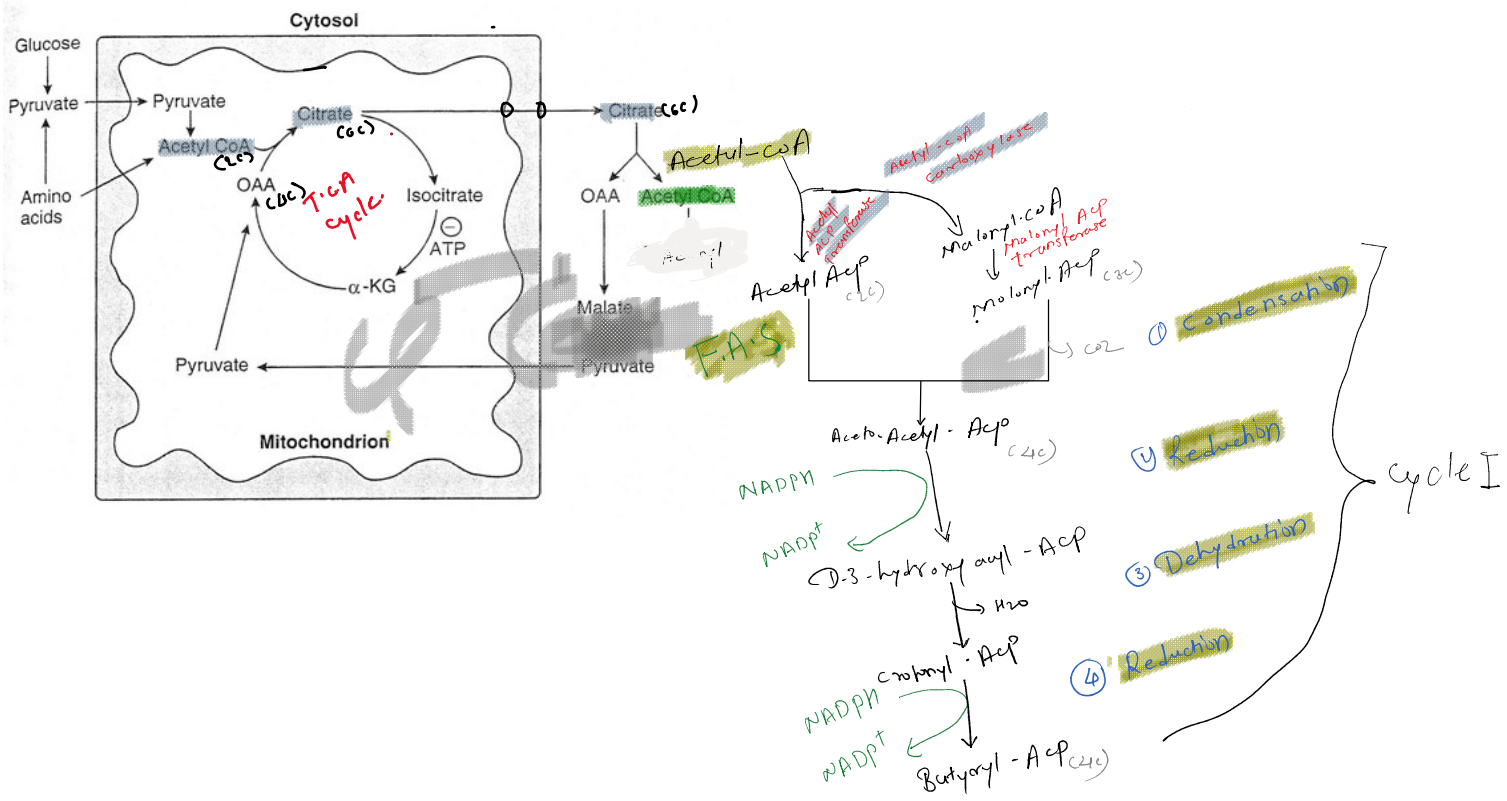
- 8 acetyl CoA
- 14 NADPH
- 7 ATP

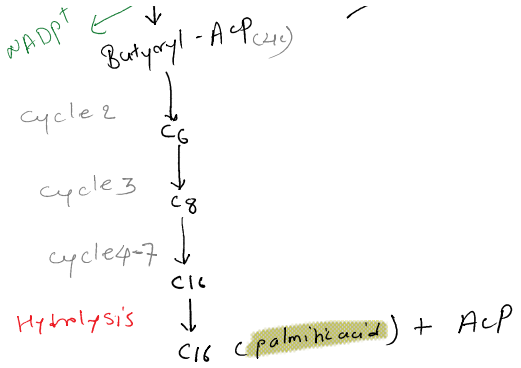
Products:

- 1 molecule of palmitate (16-carbon fatty acid)

F.A.S → Fatty acid synthase

A.C.P. → Acyl carrier protein





Fatty Acid Synthesis Pathway

- Acetyl CoA is converted to malonyl CoA by acetyl CoA carboxylase.
- Malonyl CoA is transferred to FAS.
- Through a series of condensation, reduction, and dehydration reactions, the two carbons of malonyl CoA are added to the growing fatty acyl moiety on FAS.
- FAS are then recharged with another malonyl moiety, and the cycle continues.
- Each turn of the cycle results in the addition of a two-carbon group to the fatty acid moiety as well as the use of one ATP, one acetyl CoA, and two NADPH.
- When the cycle has completed seven turns, the 16-carbon fatty acid (palmitate) is released from FAS.

Important enzymes

- **Acetyl CoA carboxylase :** Transforms acetyl CoA to malonyl CoA with the use of biotin and bicarbonate as cofactors. Requires one ATP.
- **Malonyl CoA transferase :** Transfers the malonyl CoA molecule to FAS.
- **FAS:** This collection of enzymes transfers the two carbons of malonyl CoA to the carboxyl end of the growing chain of the fatty acyl moiety. Requires two NADPH.

Activators:

- Insulin stimulates fatty acid synthesis by dephosphorylating and, therefore, activating acetyl CoA carboxylase.

Inhibitors:

- Glucagon and epinephrine inhibit fatty acid synthesis by inactivation of acetyl CoA carboxylase.

Significance

- Fatty acid synthesis is a critical anabolic pathway in most organisms.
- In addition to being the major component of membranes, fatty acids are important energy storage molecules, and fatty acyl derivatives possess a variety of physiological functions, including post-translational modification of numerous proteins.
- Fatty acid biosynthesis is important for cell growth, differentiation, and homoeostasis.