Clinical Biochemistry

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DMLT IST YEAR

Lipids
Triacylglycerol
Cholesterol
Carbohydrate

LIPIDS

Lipids (***Greek : lipos–fat***) are of great importance to the body as the chief concentrated storage form of energy, besides their role in cellular structure and various other biochemical functions. Lipids may be regarded as organic substances relatively insoluble in water, soluble in organic solvents (alcohol, ether etc.), actually or potentially related to fatty acids and utilized by the living cells. Unlike the polysaccharides, proteins and nucleic acids, lipids are not polymers. Further, lipids are mostly small molecules.

Classification of lipids:

Lipids are broadly classified into simple, complex, derived and miscellaneous lipids; which are further subdivided into different groups:

1. 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. Waxes are used in the preparation of candles, lubricants, cosmotics, ointments, polishes etc.

2. 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:

(a) Phospholipids:

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

(i) Glycerophospholipids :

These phospho- lipids contain glycerol as the alcohol e.g., lecithin, cephalin.

(ii) Sphingophospholipids:

Sphingosine is the alcohol in this group of phospho- lipids e.g., sphingomyelin.

(b) 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.

(c) Lipoproteins:

Macromolecular complexes of lipids with proteins.

(d) Other complex lipids:

Sulfolipids, aminolipids and lipopolysaccharides are among the other complex lipids.

3. Derived lipids:

These are the derivatives obtained on the hydrolysis of group 1 and group 2 lipids which possess the characteristics of lipids. These include glycerol and other alcohols, fatty acids, mono- and diacylglycerols, lipid (fat) soluble vitamins, steroid hormones, hydro-carbons and ketone bodies.

NEUTRAL LIPIDS: The lipids which are uncharged are referred to as neutral lipids. These are mono-, di-, and triacylglycerols, cholesterol and cholesteryl esters.

FUNCTIONS OF LIPIDS:

Lipids perform several important functions:

1.They are the concentrated fuel reserve of the body (triacylglycerols).

2. Lipids are the constituents of membrane structure and regulate the membrane permeability (phospholipids and cholesterol).

3. They serve as a source of fat soluble vitamins (A, D, E and K).

4. Lipids are important as cellular metabolic regulators (steroid hormones and prostaglandins).

5. Lipids protect the internal organs, serve as insulating materials and give shape and smooth appearance to the body.

FATTY ACIDS

Fatty acids are carboxylic acids with hydrocarbon side chain. They are the simplest form of lipids.

Saturated and unsaturated fatty acids

Saturated fatty acids do not contain double bonds, while unsaturated fatty acids contain one or more double bonds. Both saturated and unsaturated fatty acids almost equally occur in the natural lipids. Fatty acids with one double bond are monounsaturated, and those with 2 or more double bonds are collectively known as ***polyunsaturated fatty acids (PUFA).***

TRIACYLGLYCEROLS

Triacylglycerols (formerly triglycerides) are the esters of glycerol with fatty acids. The fats and oils that are widely distributed in both plants and animals are chemically triacylglycerols. They are insoluble in water and non-polar in character and commonly known as neutral fats.

Fats as stored fuel:

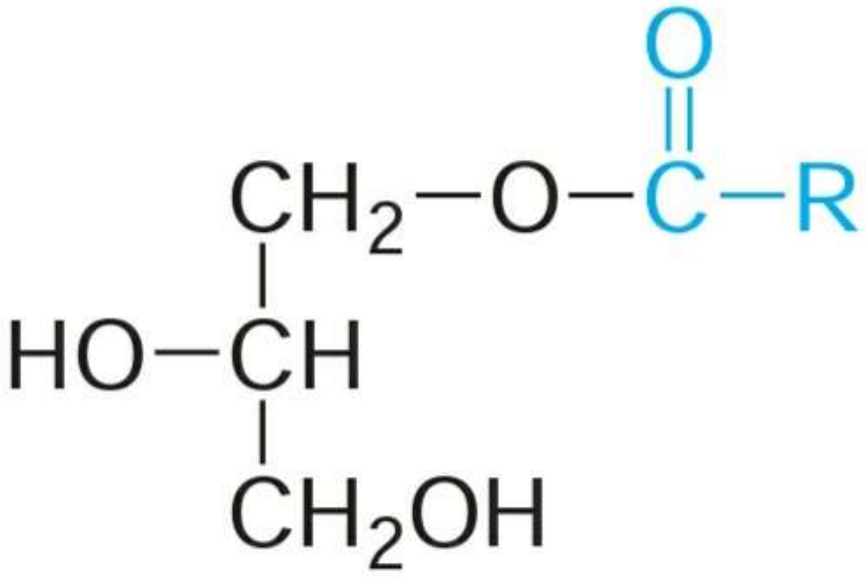
Triacylglycerols are the most abundant group of lipids that primarily function as fuel reserves of animals. The fat reserve of normal humans (men 20%, women 25% by weight) is sufficient to meet the body's caloric requirements for 2-3 months.

Fats primarily occur in adipose tissue:

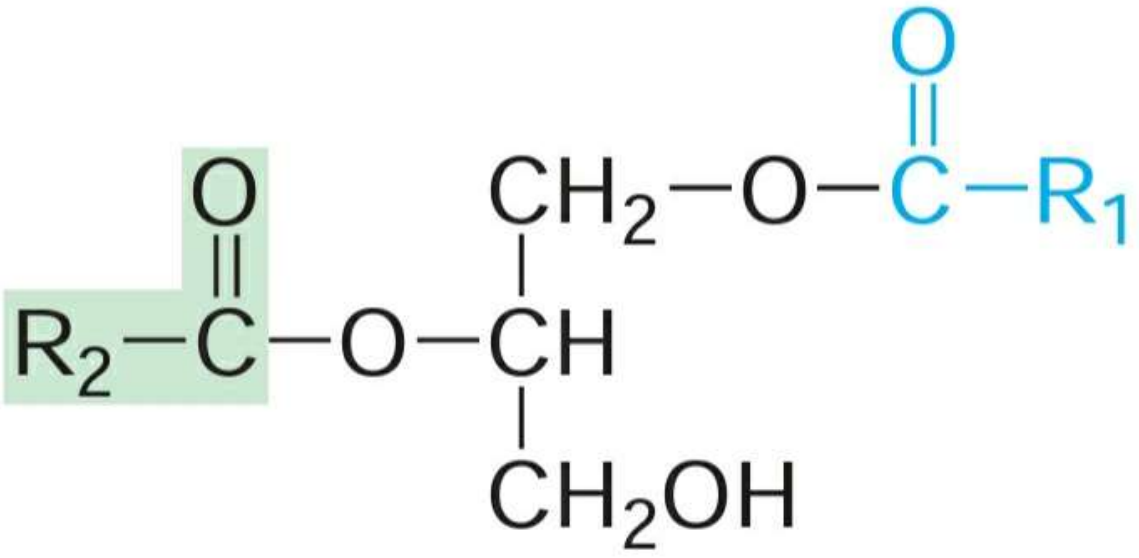
Adipocytes of adipose tissue—predominantly found in the subcutaneous layer and in the abdominal cavity—are specialized for storage of triacylglycerols.

Structures of Acylglycerols :

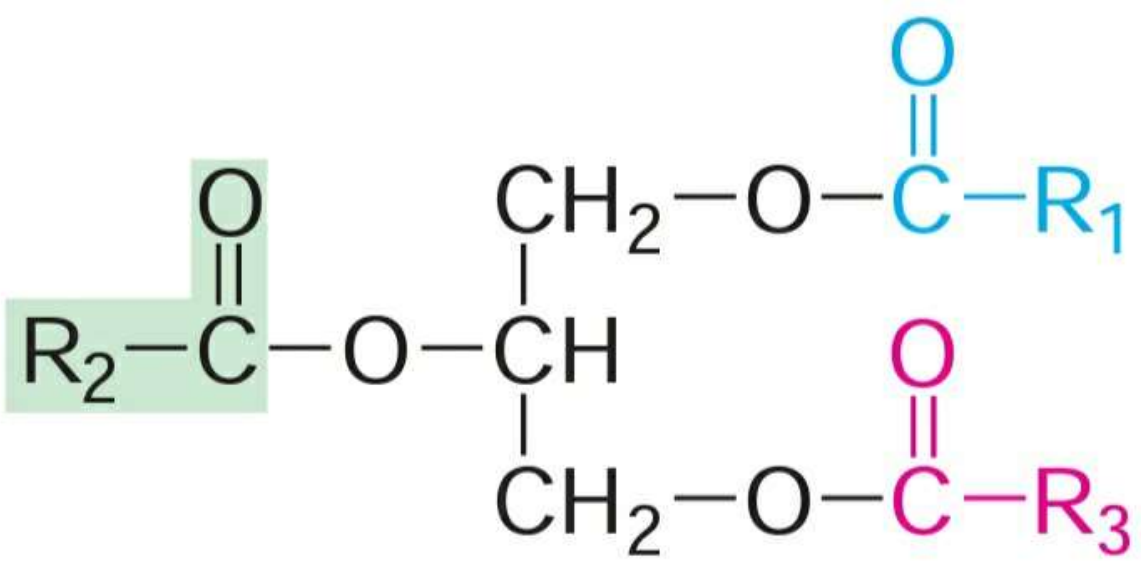
Monoacylglycerols, diacylglycerols and triacylglycerols, respectively consisting of one, two and three molecules of fatty acids esterified to a molecule of glycerol, are known (Fig.3.2). Among these, triacylglycerols are the most important biochemically.



1-Monoacylglycerol



1,2-Diacylglycerol



Triacylglycerol

PROPERTIES OF TRIACYLGLYCEROLS:

A few important properties of triacylglycerols, which have biochemical relevance, are discussed below:

1. Hydrolysis:

Triacylglycerols undergo stepwise enzymatic hydrolysis to finally liberate free fatty acids and glycerol. The process of hydrolysis, catalysed by lipases is important for digestion of fat in the gastrointestinal tract and fat mobilization from the adipose tissues.

2. Saponification :

The hydrolysis of triacylglycerols by alkali to produce glycerol and soaps is known as saponification. Triacylglycerol + 3 NaOH □□ Glycerol + 3 R-COONa (soaps)

3. Rancidity :

Rancidity is the term used to represent the deterioration of fats and oils resulting in an unpleasant taste. Fats containing unsaturated fatty acids are more susceptible to rancidity. Rancidity occurs when fats and oils are exposed to air, moisture, light, bacteria etc.

Antioxidants: The substances which can prevent the occurrence of oxidative rancidity are known as antioxidants. Trace amounts of antioxidants such as tocopherols (vitamin E), hydroquinone, gallic acid and D-naphthol are added to the commercial preparations of fats and oils to prevent rancidity.

STEROIDS

Steroids are the compounds containing a cyclic steroid nucleus (or ring) namely ***cyclopentanoperhydrophenanthrene (CPPP).*** It consists of a phenanthrene nucleus (rings A, B and C) to which a cyclopentane ring (D) is attached. The structure and numbering of CPPP are shown in Fig.3.5.

There are several steroids in the biological system. These include:

- Cholesterol
- Bile acids
- Vitamin D
- Sex hormones
- Adrenocortical hormones
- Sitosterols
- Cardiac glycosides and
- Alkaloids.

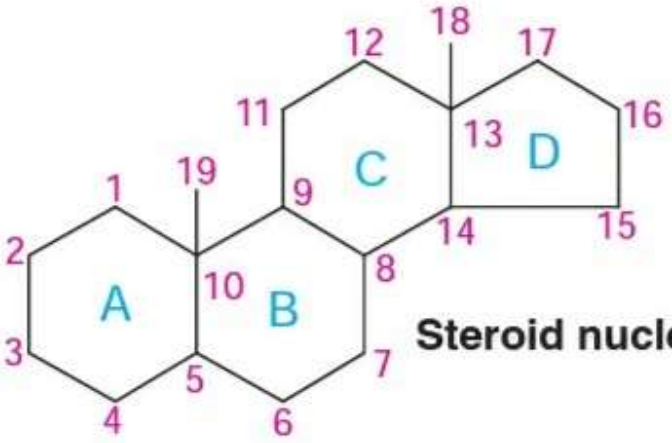
If the steroid contains one or more hydroxyl groups it is commonly known as sterol (means solid alcohol).

CHOLESTEROL

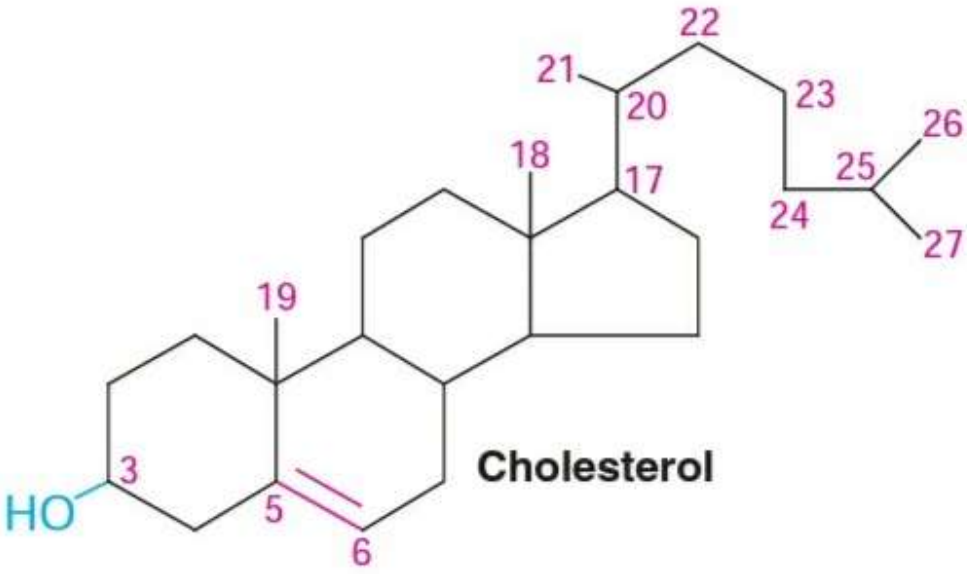
Cholesterol, exclusively found in animals, is the most abundant animal sterol. It is widely distributed in all cells and is a major component of cell membranes and lipoproteins.

Cholesterol (Greek: chole–bile) was first isolated from bile. Cholesterol literally means ‘solid alcohol from bile.’ Cholesterol is an yellowish crystalline solid. Cholesterol is insoluble in water and soluble in organic solvents such as chloroform, benzene, ether etc.

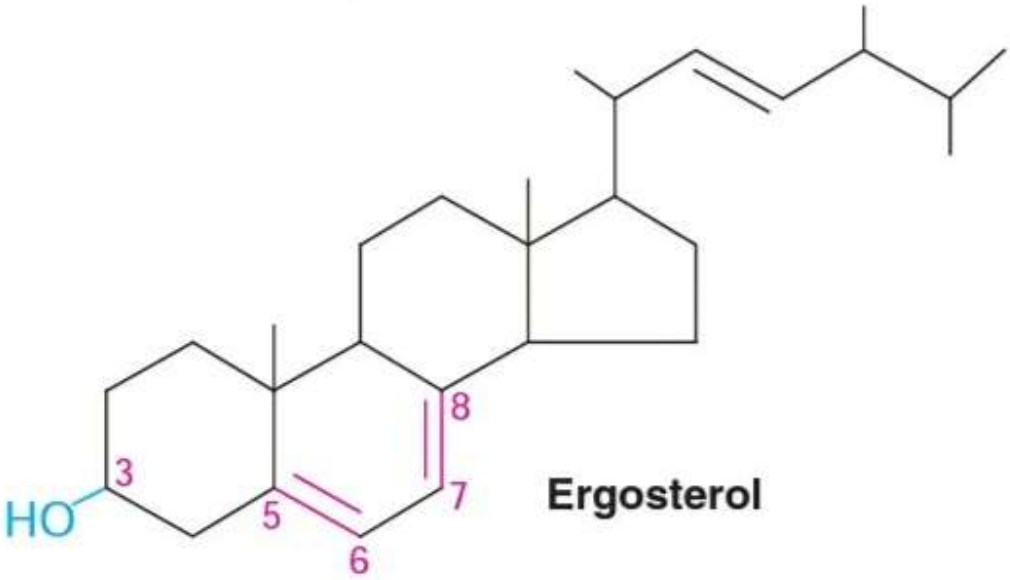
The structure of cholesterol (C27H46O) is depicted in Fig. below



Steroid nucleus



Cholesterol



Ergosterol

Due to the presence of an –OH group, cholesterol is weakly amphiphilic. As a structural component of plasma membranes, cholesterol is an important determinant of membrane permeability properties. Cholesterol is found in association with fatty acids to form cholesteryl esters (esterification occurs at the OH group of C3).

FUNCTIONS OF CHOLESTEROL

It is present in abundance in nervous tissues. It appears that cholesterol functions as an insulating cover for the transmission of electrical impulses in the nervous tissue. Cholesterol performs several other biochemical functions which include its role in membrane structure and function, in the synthesis of bile acids, hormones (sex and cortical) and vitamin D.

ERGOSTEROL:

Ergosterol occurs in plants. It is also found as a structural constituent of membranes in yeast and fungi.

The other sterols present in plant cells include stigmasterol and sitosterol .

CARBOHYDRATES

Carbohydrates are the most abundant organic molecules in nature. They are primarily composed of the elements carbon, hydrogen and oxygen. The name carbohydrate literally means ‘hydrates of carbon ’. Some of the carbohydrates possess the empirical formula $(C.H_2O)$ n where $n \leq 3$, satisfying that these carbohydrates are in fact carbon hydrates.

Carbohydrates may be defined as polyhydroxy aldehydes or ketones or compounds which produce them on hydrolysis . The term ‘sugar’ is applied to carbohydrates soluble in water and sweet to taste.

FUNCTIONS OF CARBOHYDRATES:

Carbohydrates participate in a wide range of functions:

1. They are the most abundant dietary source of energy (4 Cal/g) for all organisms.

2. Carbohydrates are precursors for many organic compounds (fats, amino acids).

3. Carbohydrates (as glycoproteins and glycolipids) participate in the structure of cell membrane and cellular functions such as cell growth, adhesion and fertilization.

4. They are structural components of many organisms. These include the fiber (cellulose) of plants, exoskeleton of some insects and the cell wall of microorganisms.

5. Carbohydrates also serve as the storage form of energy (glycogen) to meet the immediate energy demands of the body.

CLASSIFICATION OF CARBOHYDRATES:

Carbohydrates are often referred to as saccharides (Greek: sakcharon–sugar). They are broadly classified into three major groups—monosaccharides, oligosaccharides and polysaccharides. This categorization is based on the number of sugar units. Mono- and oligo-saccharides are sweet to taste, crystalline in character and soluble in water, hence they are commonly known as sugars.

Monosaccharides:

Monosaccharides (Greek : mono-one) are the simplest group of carbohydrates and are often referred to as simple sugars. They have the general formula Cn(H2O)n, and they cannot be further

hydrolysed. The monosaccharides are divided into different categories, based on the functional group and the number of carbon atoms.

Aldoses: When the functional group in monosaccharides is an aldehyde (CHO) , they are known as aldoses e.g. glyceraldehyde, glucose.

Ketoses: When the functional group is a keto (-CO) group, they are referred to as ketoses e.g. dihydroxyacetone, fructose.

Based on the number of carbon atoms, the monosaccharides are regarded as trioses (3C), tetroses (4C), pentoses (5C), hexoses (6C) and heptoses (7C) .

The common monosaccharides and disaccha- rides of biological importance are given in the Table 2.2

Table 2.2 Monosaccharides and disaccharides of biological importance

Monosaccharides	*Occurrence*	*Biochemical importance*
Trioses		
Glyceraldehyde	Found in cells as phosphate	Glyceraldehyde 3-phosphate is an intermediate in glycolysis
Dihydroxyacetone	Found in cells as phosphate	Its 1-phosphate is an intermediate in glycolysis
Tetroses		
D-Erythrose	Widespread	Its 4-phosphate is an intermediate in carbohydrate metabolism
Pentoses		
D-Ribose	Widespread as a constituent of RNA and nucleotides	For the structure of RNA and nucleotide coenzymes (ATP, NAD^+, $NADP^+$)
D-Deoxyribose	As a constituent of DNA	For the structure of DNA
D-Ribulose	Produced during metabolism	It is an important metabolite in hexose monophosphate shunt
D-Xylose	As a constituent of glycoproteins and gums	Involved in the function of glycoproteins
L-Xylulose	As an intermediate in uronic acid pathway	Excreted in urine in essential pentosuria
D-Lyxose	Heart muscle	As a constituent of lyxoflavin of heart muscle
Hexoses		
D-Glucose	As a constituent of polysaccharides (starch, glycogen, cellulose) and disaccharides (maltose, lactose, sucrose). Also found in fruits	The 'sugar fuel' of life; excreted in urine in diabetes. Structural unit of cellulose in plants
D-Galactose	As a constituent of lactose (milk sugar)	Converted to glucose, failure leads to galactosemia
D-Mannose	Found in plant polysaccharides and animal glycoproteins	For the structure of polysaccharides
D-Fructose	Fruits and honey, as a constituent of sucrose and inulin	Its phosphates are intermediates of glycolysis
Heptoses		
D-Sedoheptulose	Found in plants	Its 7-phosphate is an intermediate in hexose monophosphate shunt, and in photosynthesis
Disaccharides	*Occurrence*	*Biochemical importance*
Sucrose	As a constituent of cane sugar and beet sugar, pineapple	Most commonly used table sugar supplying calories
Lactose	Milk sugar	Exclusive carbohydrate source to breast fed infants. Lactase deficiency (lactose intolerance) leads to diarrhea and flatulence
Maltose	Product of starch hydrolysis, occurs in germinating seeds	An important intermediate in the digestion of starch

Oligosaccharides:

Oligosaccharides (Greek : oligo-few) contain 2-10 monosaccharide molecules which are liberated on hydrolysis. Based on the number of monosaccharide units present, the oligo-saccharides are further subdivided to disaccharides, trisaccharides etc.

Polysaccharides:

Polysaccharides (Greek: poly-many) are polymers of monosaccharide units with high molecular weight (up to a million). They are usually tasteless (non-sugars) and form colloids with water. The polysaccharides are of two types – ***homopolysaccharides and heteropolysaccharides.***