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PG DEPARTMENT OF ZOOLOGY

LEARNING RESOURCES

BIOCHEMISTRY

Summary of Carbohydrates

Carbohydrates are a group of macromolecules that are a vital energy source for the cell and provide structural support to plant cells, fungi, and all of the arthropods that include lobsters, crabs, shrimp, insects, and spiders. Carbohydrates are classified as monosaccharides, disaccharides, and polysaccharides depending on the number of monomers in the molecule. Monosaccharides are linked by glycosidic bonds that are formed as a result of dehydration reactions, forming disaccharides and polysaccharides with the elimination of a water molecule for each bond formed. Glucose, galactose, and fructose are common monosaccharides, whereas common disaccharides include lactose, maltose, and sucrose. Starch and glycogen, examples of polysaccharides, are the storage forms of glucose in plants and animals, respectively. The long polysaccharide chains may be branched or unbranched. Cellulose is an example of an unbranched polysaccharide, whereas amylopectin, a constituent of starch, is a highly branched molecule. Storage of glucose, in the form of polymers like starch of glycogen, makes it slightly less accessible for metabolism; however, this prevents it from leaking out of the cell or creating a high osmotic pressure that could cause excessive water uptake by the cell.

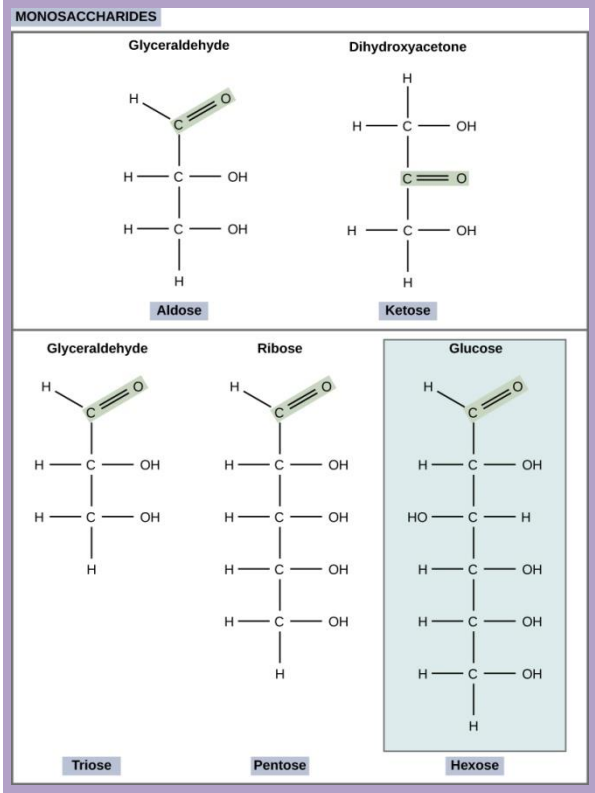
Molecular Structures

Carbohydrates can be represented by the stoichiometric formula $(CH_2O)_n$, where n is the number of carbons in the molecule. In other words, the ratio of carbon to hydrogen to oxygen is 1:2:1 in carbohydrate molecules. This formula also explains the origin of the term “carbohydrate”: the components are carbon (“carbo”) and the components of water (hence, “hydrate”). Carbohydrates are classified into three subtypes: monosaccharides, disaccharides, and polysaccharides.

Monosaccharides

Monosaccharides (mono- = “one”; sacchar- = “sweet”) are simple sugars, the most common of which is glucose. In monosaccharides, the number of carbons usually ranges from three to seven. Most monosaccharide names end with the suffix -ose. If the sugar has an aldehyde group (the functional group with the structure R-CHO), it is known as an aldose, and if it has a ketone group (the functional group with the structure RC(=O)R’), it is known as a ketose.

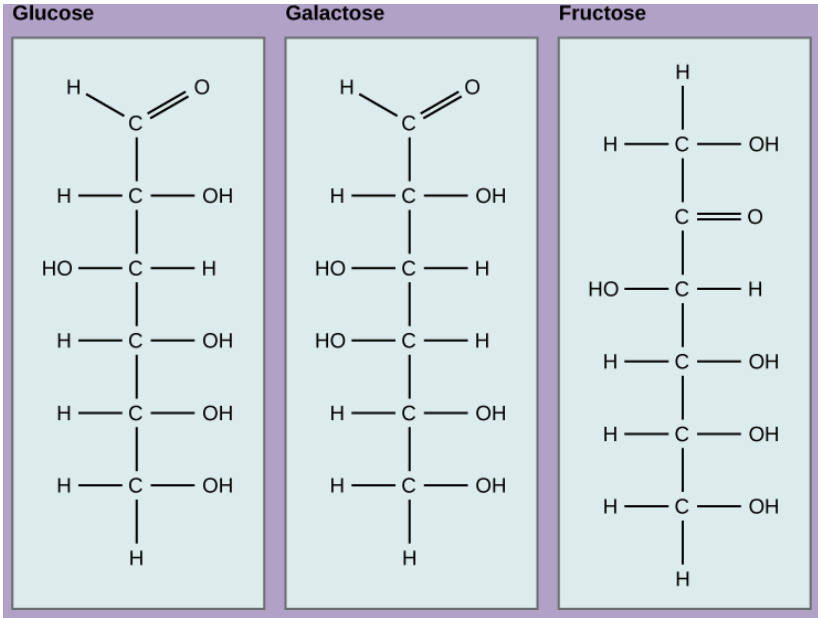
Depending on the number of carbons in the sugar, they also may be known as trioses (three carbons), pentoses (five carbons), and or hexoses (six carbons).



The chemical formula for glucose is $C_6H_{12}O_6$. In humans, glucose is an important source of energy. During cellular respiration, energy is released from glucose, and that energy is used to help make adenosine triphosphate (ATP). Plants synthesize glucose using carbon dioxide and water, and glucose in turn is used for energy requirements for the plant. Excess glucose is often stored as starch that is catabolized (the breakdown of larger molecules by cells) by humans and other animals that feed on plants.

Galactose (part of lactose, or milk sugar) and fructose (found in sucrose, in fruit) are other common monosaccharides. Although glucose, galactose, and fructose all have the same chemical formula ($C_6H_{12}O_6$), they differ structurally and chemically (and are known as isomers) because of the different arrangement of functional groups around the asymmetric carbon; all of these monosaccharides have more than one asymmetric carbon

Glucose, galactose, and fructose are all hexoses. They are structural isomers, meaning they have the same chemical formula ($C_6H_{12}O_6$) but a different arrangement of atoms.



Glucose, galactose, and fructose are isomeric monosaccharides (hexoses), meaning they have the same chemical formula but have slightly different structures. Glucose and galactose are aldoses, and fructose is a ketose.

Monosaccharides can exist as a linear chain or as ring-shaped molecules; in aqueous solutions they are usually found in ring forms. Glucose in a ring form can have two different arrangements of the hydroxyl group (OH) around the anomeric carbon (carbon 1 that becomes asymmetric in the process of ring formation). If the hydroxyl group is below carbon number 1 in the sugar, it is said to be in the alpha (α) position, and if it is above the plane, it is said to be in the beta (β) position.

Five and six carbon monosaccharides exist in equilibrium between linear and ring forms. When the ring forms, the side chain it closes on is locked into an α or β position. Fructose and ribose also form rings, although they form five-membered rings as opposed to the six-membered ring of glucose.

Benefits of Carbohydrates

Are carbohydrates good for you? People who wish to lose weight are often told that carbohydrates are bad for them and should be avoided. Some diets completely forbid carbohydrate consumption, claiming that a low-carbohydrate diet helps people to lose weight faster. However, carbohydrates have been an important part of the human diet for thousands of years; artifacts from ancient civilizations show the presence of wheat, rice, and corn in our ancestors' storage areas.

Carbohydrates should be supplemented with proteins, vitamins, and fats to be parts of a well-balanced diet. Calorie-wise, a gram of carbohydrate provides 4.3 Kcal. For comparison, fats

provide 9 Kcal/g, a less desirable ratio. Carbohydrates contain soluble and insoluble elements; the insoluble part is known as fiber, which is mostly cellulose. Fiber has many uses; it promotes regular bowel movement by adding bulk, and it regulates the rate of consumption of blood glucose. Fiber also helps to remove excess cholesterol from the body: fiber binds to the cholesterol in the small intestine, then attaches to the cholesterol and prevents the cholesterol particles from entering the bloodstream, and then cholesterol exits the body via the feces. Fiber-rich diets also have a protective role in reducing the occurrence of colon cancer. In addition, a meal containing whole grains and vegetables gives a feeling of fullness. As an immediate source of energy, glucose is broken down during the process of cellular respiration, which produces ATP, the energy currency of the cell. Without the consumption of carbohydrates, the availability of "instant energy" would be reduced. Eliminating carbohydrates from the diet is not the best way to lose weight. A low-calorie diet that is rich in whole grains, fruits, vegetables, and lean meat, together with plenty of exercise and plenty of water, is the more sensible way to lose weight.

Review Questions

An example of a monosaccharide is _____.

1. fructose
2. glucose
3. galactose
4. all of the above

D

Cellulose and starch are examples of:

1. monosaccharides
2. disaccharides
3. lipids
4. polysaccharides

D

Plant cell walls contain which of the following in abundance?

1. starch
2. cellulose
3. glycogen
4. lactose

B

Lactose is a disaccharide formed by the formation of a _____ bond between glucose and _____.

1. glycosidic; lactose
2. glycosidic; galactose
3. hydrogen; sucrose
4. hydrogen; fructose

B

PROTEIN - STRUCTURE & TYPES

Protein structures are made by condensation of amino acids forming peptide bonds. The sequence of amino acids in a protein is called its primary structure. The secondary structure is determined by the dihedral angles of the peptide bonds, the tertiary structure by the folding of protein chains in space. Association of folded polypeptide molecules to complex functional proteins results in quaternary structure.

Classification of Proteins

Based on the molecular shape, proteins can be classified into two types.

1. Fibrous Proteins:

When the polypeptide chains run ***parallel*** and are held together by hydrogen and disulfide bonds, then the fiber-like structure is formed. Such proteins are generally insoluble in water. These are water-insoluble proteins.

Example – keratin (present in hair, wool, and silk) and myosin (present in muscles), etc.

2. Globular Proteins:

This structure results when the chains of polypeptides ***coil around*** to give a spherical shape. These are usually soluble in water.

Example – Insulin and albumins are common examples of globular proteins.

Levels of Protein Structure

1. Primary Structure of Protein

- The Primary structure of proteins is the exact ordering of amino acids forming their chains.
- The exact sequence of the proteins is very important as it determines the final fold and therefore the function of the protein.
- The number of polypeptide chains together form proteins. These chains have amino acids arranged in a particular sequence which is characteristic of the specific protein. Any change in the sequence changes the entire protein.

The following picture represents the primary protein structure (an amino acid chain). As you might expect, the amino acid sequence within the polypeptide chain is crucial for the protein's proper functioning. This sequence is encrypted in the DNA genetic code. If mutation is present in the DNA and the amino acid sequence is changed, the protein function may be affected.

The protein ‘s primary structure is the amino acid sequence in its polypeptide chain. If proteins were popcorn stringers designed to decorate a Christmas tree, a protein ‘s primary structure is the sequence in which various shapes and varieties of popped maize are strung together.

Covalent, peptide bonds which connect the amino acids together maintain the primary structure of a protein.

All documented genetic disorders, such as cystic fibrosis, sickle cell anemia, albinism, etc., are caused by mutations resulting in alterations in the primary protein structures, which in turn lead to alterations in the secondary , tertiary and probably quarterly structure.

Amino acids are small organic molecules consisting of a chiral carbon with four substituents. Of those only the fourth the side chain is different among amino acids.

2. Secondary Structure of Protein

Secondary structure of protein refers to local folded structures that form within a polypeptide due to interactions between atoms of the backbone.

- The proteins do not exist in just simple chains of polypeptides.
- These polypeptide chains usually fold due to the interaction between the amine and carboxyl group of the peptide link.
- The structure refers to the shape in which a long polypeptide chain can exist.
- They are found to exist in two different types of structures α – helix and β – pleated sheet structures.
- This structure arises due to the regular folding of the backbone of the polypeptide chain due to hydrogen bonding between -CO group and -NH groups of the peptide bond.
- However, segments of the protein chain may acquire their own local fold, which is much simpler and usually takes the shape of a spiral an extended shape or a loop. These local folds are termed secondary elements and form the proteins secondary structure.

(a) α – Helix:

α – Helix is one of the most common ways in which a polypeptide chain forms all possible hydrogen bonds by twisting into a right-handed screw with the -NH group of each amino acid residue hydrogen-bonded to the -CO of the adjacent turn of the helix. The polypeptide chains twisted into a right-handed screw.

(b) β – pleated sheet:

In this arrangement, the polypeptide chains are stretched out beside one another and then bonded by intermolecular H-bonds. In this structure, all peptide chains are stretched out to nearly maximum extension and then laid side by side which is held together by intermolecular hydrogen bonds. The structure resembles the pleated folds of drapery and therefore is known as β – pleated sheet

3. Tertiary Structure of Protein

- This structure arises from further folding of the secondary structure of the protein.
- H-bonds, electrostatic forces, disulphide linkages, and Vander Waals forces stabilize this structure.
- The tertiary structure of proteins represents overall folding of the polypeptide chains, further folding of the secondary structure.
- It gives rise to two major molecular shapes called fibrous and globular.
- The main forces which stabilize the secondary and tertiary structures of proteins are hydrogen bonds, disulphide linkages, van der Waals and electrostatic forces of attraction.

4. Quaternary Structure of Protein

The spatial arrangement of various tertiary structures gives rise to the quaternary structure. Some of the proteins are composed of two or more polypeptide chains referred to as sub-units. The spatial arrangement of these subunits with respect to each other is known as quaternary structure.

The exact amino acid sequence of each protein drives it to fold into its own unique and biologically active three-dimensional fold also known as the tertiary structure. Proteins consist of different combinations of secondary elements some of which are simple whereas others are more complex. Parts of the protein chain, which have their own three-dimensional fold and can be attributed to some function are called ***"domains"***. These are considered today as the evolutionary and functional building blocks of proteins.

Many proteins, most of which are enzymes contain organic or elemental components needed for their activity and stability. Thus the study of protein evolution not only gives structural insight but also connects proteins of quite different parts of the metabolism.

The biological importance of proteins are :
(1) Fibrous protein keratin forms external protective structures of animals like nails, hooks, scales, hair, feathers, horny layer of skin etc.
(2) Immunoglobins or antibodies are proteins produced by lymphocytes. They are meant for recognizing and neutralizing foreign proteins, toxins, viruses and other pathogens.
(3) They are both defensive and offensive proteins produced by certain animals, bacteria and some plants, e.g., Snake venom.
(4) Proteins constitute more than 50% of the dry weight of protoplast. They take part in formation of colloidal complex ofprotoplast, cell organelles, cell membranes and cell products.
(5) Pollen grains possess specific proteins in their walls for compatibility incompatibility reaction with the stigma during pollination.
(6) Some hormones are proteinaceous, e.g., insulin, growth, hormone of pituitary etc.
(7) Fibrinogen and thrombin prevent blood loss from injured vessels by causing clothing of blood.
(8) Antibodies are formed of proteins.

Enzyme Active Site and Substrate Specificity

The chemical reactants to which an enzyme binds are the enzyme's **substrates**. There may be one or more substrates, depending on the particular chemical reaction. In some reactions, a single-reactant substrate is broken down into multiple products. In others, two substrates may come together to create one larger molecule. Two reactants might also enter a reaction, both become modified, and leave the reaction as two products. The location within the enzyme where the substrate binds is called the enzyme's active site. The active site is where the "action" happens, so to speak. Since enzymes are proteins, there is a unique combination of amino acid residues (also called side chains, or R groups) within the active site. Each residue is characterized by different properties. Residues can be large or small, weakly acidic or basic, hydrophilic or hydrophobic, positively or negatively charged, or neutral. The unique combination of amino acid residues, their positions, sequences, structures, and properties, creates a very specific chemical environment within the active site. This specific environment is suited to bind, albeit briefly, to a specific chemical substrate (or substrates). Due to this jigsaw puzzle-like match between an enzyme and its substrates (which adapts to find the best fit between the transition state and the active site), enzymes are known for their specificity. The "best fit" results from the shape and the amino acid functional group's attraction to the substrate. There is a specifically matched enzyme for each substrate and, thus, for each chemical reaction; however, there is flexibility as well.

The fact that active sites are so perfectly suited to provide specific environmental conditions also means that they are subject to influences by the local environment. It is true that increasing the environmental temperature generally increases reaction rates, enzyme-catalyzed or otherwise. However, increasing or decreasing the temperature outside of an optimal range can affect chemical bonds within the active site in such a way that they are less well suited to bind substrates. High temperatures will eventually cause enzymes, like other biological molecules, to denature, a process that changes the natural properties of a substance. Likewise, the pH of the local environment can also affect enzyme function. Active site amino acid residues have their own acidic or basic properties that are optimal for catalysis. These residues are sensitive to changes in pH that can impair the way substrate molecules bind. Enzymes are suited to function best within a certain pH range, and, as with temperature, extreme pH values (acidic or basic) of the environment can cause enzymes to denature.

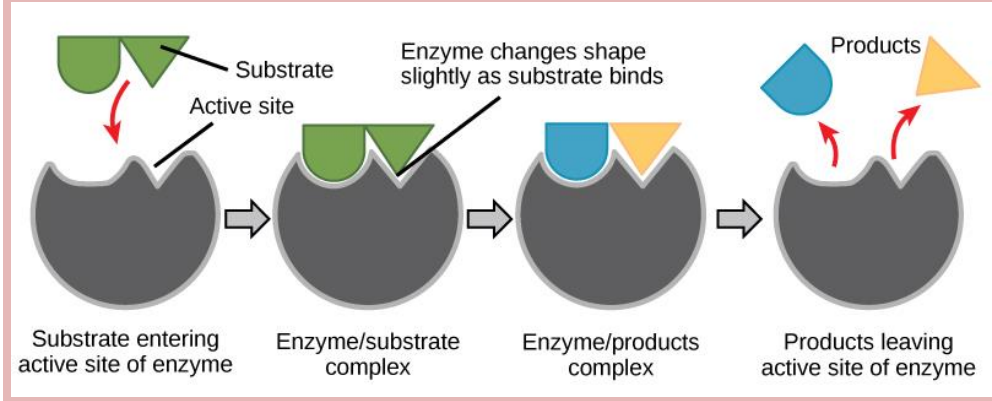
Induced Fit and Enzyme Function

For many years, scientists thought that enzyme-substrate binding took place in a simple "lock-and-key" fashion. This model asserted that the enzyme and substrate fit together perfectly in one instantaneous step. However, current research supports a more refined view called induced fit . The induced-fit model expands upon the lock-and-key model by describing a more dynamic interaction between enzyme and substrate. As the enzyme and substrate come together, their interaction causes a mild shift in the enzyme's structure that confirms an ideal binding arrangement between the enzyme and the transition state of the substrate. This ideal binding maximizes the enzyme's ability to catalyze its reaction.

When an enzyme binds its substrate, an enzyme-substrate complex is formed. This complex lowers the activation energy of the reaction and promotes its rapid progression in one of many ways. On a basic level, enzymes promote chemical reactions that involve more than one substrate by bringing the substrates together in an optimal orientation. The appropriate

region (atoms and bonds) of one molecule is juxtaposed to the appropriate region of the other molecule with which it must react. Another way in which enzymes promote the reaction of their substrates is by creating an optimal environment within the active site for the reaction to occur. Certain chemical reactions might proceed best in a slightly acidic or non-polar environment. The chemical properties that emerge from the particular arrangement of amino acid residues within an active site create the perfect environment for an enzyme's specific substrates to react.

You've learned that the activation energy required for many reactions includes the energy involved in manipulating or slightly contorting chemical bonds so that they can easily break and allow others to reform. Enzymatic action can aid this process. The enzyme-substrate complex can lower the activation energy by contorting substrate molecules in such a way as to facilitate bond-breaking, helping to reach the transition state. Finally, enzymes can also lower activation energies by taking part in the chemical reaction itself. The amino acid residues can provide certain ions or chemical groups that actually form covalent bonds with substrate molecules as a necessary step of the reaction process. In these cases, it is important to remember that the enzyme will always return to its original state at the completion of the reaction. One of the hallmark properties of enzymes is that they remain ultimately unchanged by the reactions they catalyze. After an enzyme is done catalyzing a reaction, it releases its product(s).



According to the induced-fit model, both enzyme and substrate undergo dynamic conformational changes upon binding. The enzyme contorts the substrate into its transition state, thereby increasing the rate of the reaction.

AMINO ACID

Amino acids are organic compounds that combine to form proteins. The general formula of an amino acid is R-CH(NH_2)-COOH.

Amino acids are known to contain amine and carboxyl functional groups. They also contain a side chain that is made up of an R-group (where 'R' can denote any alkyl or aryl group). These R-groups are what differentiate amino acids and are responsible for their unique properties.

Structure of Amino Acid

The general structure of an amino acid is illustrated below.

From the illustration, it can be noted that the key elements that make up amino acids are hydrogen, carbon, nitrogen, and oxygen. However, it is not uncommon for other elements to be found in the side chain of an amino acid. It can also be noted that there are over 500 naturally occurring amino acids known to us. Of these, only 20 amino acids are known to appear in genetic code.

In the human body, these biomolecules are involved in many biological and chemical functions and are important ingredients for human growth and development. Amino acids usually have a melting and boiling point that is very high. They usually exist in the form of white, crystalline, stable compounds. A few amino acids are known to be sweet, tasteless, and bitter in flavour. Most amino acids are water soluble. However, it can also be noted that most amino acids are insoluble in organic solvents.

Classification of Amino Acids

Amino Acid can be classified ***based on their structure*** and the structure of their side chains i.e. the R chains. Now two basic subcategories are

1] Non-Polar Amino Acids

These are also known as Hydrophobic. The R group can be either of Alkyl groups (with an alkyl chain) or Aromatic groups. The acids falling in this group are stated below. Numbers one to seven are Alkyl and the last two are aromatic

i. Glycine (H)
ii. Alanine (CH3)
iii. Valine (CH (CH3)2)
iv. Methionine (CH2CH2SCH3)
v. Leucine (CH2CH(CH3)2)
vi. Isoleucine (-CH(CH3)CH2CH3)
vii. Proline (special structure)
viii. Phenylalanine

ix. Tryptophan

2] Polar Amino Acids

If the side chains of amino acid contain different polar groups like amines, alcohols or acids they are polar in nature. These are also known as Hydrophilic Acids. These are further divided into three further categories.

a) Acidic: If the side chain contains an extra element of carboxylic acid component these are acid-polar amino acids. They tend to donate their hydrogen atom. These are:

i. Aspartic Acid (CH2COOH)
ii. Glutamic Acid (CH2CH2COOH)

b) Basic: These have an extra nitrogen group that tend to attract a hydrogen atom. The three basic polar amino acids are

i. Histidine
ii. Lysine (CH2(CH2)2NH2)
iii. Arginine

c) Neutral: These are neither acidic nor basic. They have an equal number of amino and carboxyl groups. Also, they have at least one hydrogen component connected to electronegative atoms. Some of these neutral acids are

i. Serine (CH2OH)
ii. Threonine (CH(OH)CH3)
iii. Asparagine (CH2OHNH2)
iv. Glutamine (CH2CH2CONH2)
v. Cysteine (CH2SH)
vi. Tyrosine

Amino acid can also be classified on the basis of their need to the human body and their ***availability in the human body***

1] Essential Amino Acids

These are the acids that cannot be synthesized in our bodies. We must rely on food sources to obtain these amino acids. They are

- Leucine
- Isoleucine
- Lysine
- Theorine
- Methionine
- Phenylalanine
- Valine
- Tryptophan
- Histidine (conditionally essential)

2] Non-Essential

These acids are synthesized in our bodies itself and we need not rely on outside sources for them. They are either produced in our bodies or obtained from protein breakdowns.

Properties of Amino Acids

Now that we have seen the structure and types of amino acids. Now from this information, we can arrive at the properties of amino acids.

- Each amino acid has both an acidic and basic group as you can see from its structure. This is the reason they behave like salts.
- Any amino acid in the dry state is in crystalline form. They exist as a dipolar ion. The COOH group exists as an anion. And the NH2 group exists as a cation. This dipolar ion has a special name *"Zwitter ions'.*
- In aqueous solution, alpha amino acids exist in equilibrium between a cationic form, an anionic form and dipolar ion.
- The Isoelectric point is the pH point at which the concentration of zwitter ions is the highest ad the concentration of cationic and anionic form is equal. This point is definite for every α-amino acid.
- They are generally water soluble and also have high melting points.

Some Common Amino Acids and Their Structures

The structures of some common amino acids, such as glycine, serine, leucine, cysteine, and valine have been illustrated below.

Glycine

Glycine is an amino acid that contains, in its side chain, only a single hydrogen atom. It is known to be the simplest amino acid with the chemical formula NH2-CH2-COOH (because carbamic acid is known to be unstable). Glycine is known to be a protein-genic amino acid. Glycine, due to its compact shape, is integral to the formation of alpha-helices in the secondary protein structure. For the same explanation, in collagen triple-helices, it is the most abundant amino acid. It is important to note that glycine is an inhibitory neurotransmitter. Because of uninhibited muscle contraction, interference with its release inside the spinal cord, such as in clostridium tetani infections for example, can trigger spastic paralysis.

Serine

Serine is an alpha-amino acid which is often used in protein biosynthesis. It comprises an alpha-amino group which, under biological conditions, is in the protonated $-NH_3^+$ form. It also contains a carboxyl group which, under biological conditions, is in the deprotonated $-COO^-$ form. Serine is also known to contain a side chain consisting of a hydroxymethyl group and can, therefore, be classified as a polar amino acid. Under normal physiological

conditions, it can be synthesised in the human body, rendering it a nonessential amino acid.

Leucine

Leucine is an important amino acid which is used in protein biosynthesis. Leucine is an alpha-amino acid, which implies that it contains an alpha-amino group (which, under biological conditions, is in the protonated $-NH_3^+$ form), an alpha-carboxylic acid group (which, under biological conditions, is in the deprotonated $-COO^-$ form), and a side chain isobutyl group, making it a non-polar aliphatic amino acid. In human beings, it is an essential amino acid, implying that it can not be synthesised by the body. It must, therefore, be derived from the diet. The foods that produce protein, such as dairy products, meats, beans, soy products, and other legumes are human dietary sources of this amino acid.

Cysteine

Cysteine is a proteinogenic amino acid which is generally categorized as a semi-essential amino acid. Since it functions as a nucleophile, the thiol side chain in this amino acid also participates in several enzymatic reactions. The disulfide derivative cystine, which is known to play an essential structural role in a large number of proteins, is known to be susceptible to oxidation by thiol. Cysteine has the general same structure as serine, but with one of its oxygen atoms substituted by sulphur. Selenocysteine can be obtained by replacing the same oxygen atom with selenium instead of sulfur.

Cysteine, along with its oxidised dimeric form, cystine, like other common amino acids, can be found in most high-protein foods. While it is listed as a non-essential amino acid, cysteine can be essential in some rare cases the elderly, for children, and people with certain metabolic disorders or those who have syndromes of malabsorption. Under normal physiological conditions, cysteine is normally synthesised by the human body as long as an adequate quantity of methionine is available in it.

Valine

Valine is an important amino acid which is used in protein biosynthesis. Valine is an alpha-amino acid, which implies that it contains an alpha-amino group (which, under biological conditions, is in the protonated $-NH_3^+$ form), an alpha-carboxylic acid group (which, under biological conditions, is in the deprotonated $-COO^-$ form), and a side chain containing the isopropyl group. It can, therefore, be referred to as a non-polar aliphatic amino acid.

Most Basic Amino Acid

There are three amino acids that have basic side chains at neutral pH. These are arginine (Arg), lysine (Lys), and histidine (His). Their side chains contain nitrogen and resemble ammonia, which is a base. Lysine has two amine groups, which makes it overall basic. It is the lone pair of nitrogen, in amines, which gives them basicity.

CLASSIFICATION OF LIPIDS

Introduction

Lipids are one of the major macromolecules present in our body, and others include nucleic acids, carbohydrates, and proteins. But unlike the other macro biomolecules, lipids are not polymers – they aren't composed of monomers. They are hydrophobic in nature because of the predominance of hydrocarbon chains (–CH2–CH2–CH2–CH2–) in their structures.

Lipids have diverse roles in many key biological functions, such as acting as structural components of cell membranes, serving as energy storage sources, and participating in signaling pathways.

In 1665, Robert Boyle observed a milky appearance in animal's blood collected after their feed. Later, the milky liquid was determined to contain fat, by Henson in 1774. The 18th-19th century marks the era of extensive study of these molecules. And it was in 1827, that fat, along with carbohydrate and protein, were believed to be an essential nutrient for humans and animals.

Lipids and Their General Properties

Lipids are defined as heterogeneous groups of organic molecules soluble in non-polar solvents. Structurally, they are esters or amides of fatty acids. This class includes a range of molecules, such as fats, oils, hormones, and certain components of membranes. These molecules are either non-soluble or are poorly soluble in water.

General Physical Properties of Lipids

1. They are soluble in non-polar solvents, such as ether, alcohol, chloroform, acetone, and benzene.
2. Lipids are insoluble in water.
3. Lipid molecules have no ionic charges.
4. Pure fats and oils are colorless, odorless, and tasteless.
5. Lipids are considered hydrophobic or amphiphilic small molecules.
6. Lipids are greasy in texture and stored in adipose tissues inside the body.
7. Lipids are either liquid or non-crystalline solid at room temperature.
8. Lipids can either be present in saturated (having only single bonds) or unsaturated (having one or more double bonds) structural form.

Chemical Properties of Lipids

1. **Hydrolysis of triglycerides:** Triglycerides (neutral lipids) on reacting with water form carboxylic acid and alcohol.

2. **Saponification:** Triglycerides on hydrolysis with alkali (NaOH or KOH) or lipase enzymes (termed alkaline hydrolysis) lead to the formation of two products: soap or fatty acid salts of sodium or potassium, and glycerol.
3. **Hydrogenation:** The breakage of double bonds occurs after the reaction of unsaturated fatty acids with hydrogen. This turns the molecules into saturated fatty acids.
4. **Halogenation:** Free or combined fatty acids in the reaction with halogens gain double bonds and cause decolorization of halogen solutions.
5. **Rancidity:** Oxidation and hydrolysis of fats and oil to generate a disagreeable odor – this is known as rancidity.

Classification of Lipids

Lipids were first classified in 1815 by Henri Braconnot in two categories of solid grease and fluid oil. But the true classification was proposed in 1947 by T. P. Hidlich, he divided the simple lipids into grease and waxes.

Lipids can be classified in four ways, depending on:

- chemical composition,
- fatty acids,
- requirements,
- and sources.

Based on the Chemical Composition

Lipids based on chemical composition are divided into three categories: simple lipids, compound lipids, and derived lipids.

1. Simple Lipids

It includes esters of fatty acids and glycerol that are also termed neutral fats or triglycerides. They make up 98-99% of food and body fats and oil.Its three classes are fatty acids, triglycerides, and waxes.

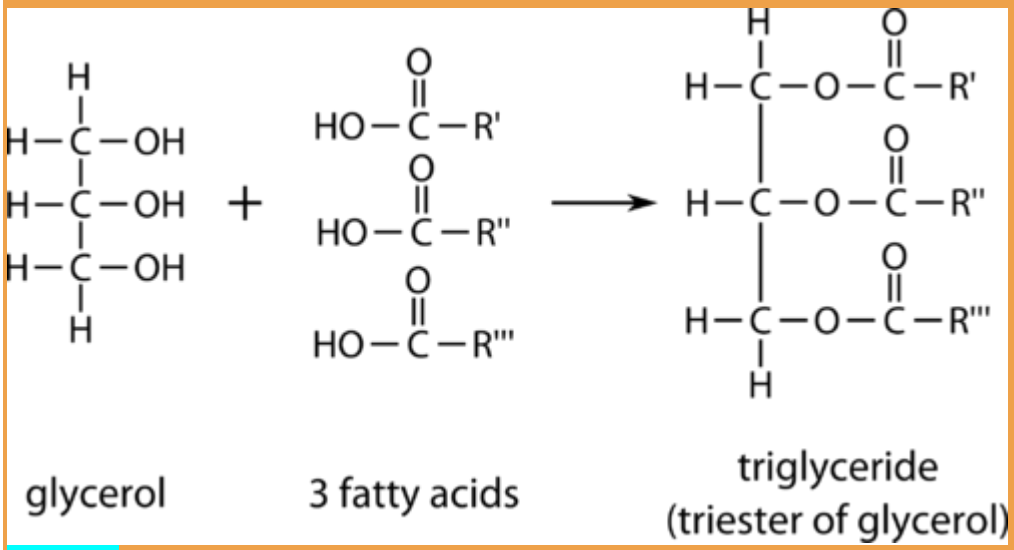
A. Fatty Acids

Fatty acids are the simplest form of lipids. They are a long chain of hydrocarbons (4 to 36 carbons long) with one carboxyl group. These molecules serve as constituents in a large number of complex lipids. In biological systems, fatty acids contain an even number of carbon atoms. Among all fatty acids, 16-18 carbon fatty acids are the most common.Fatty acids are amphipathic, having both polar and nonpolar ends. The alkyl chains present in their structure can either be saturated or unsaturated.

Triacylglycerols

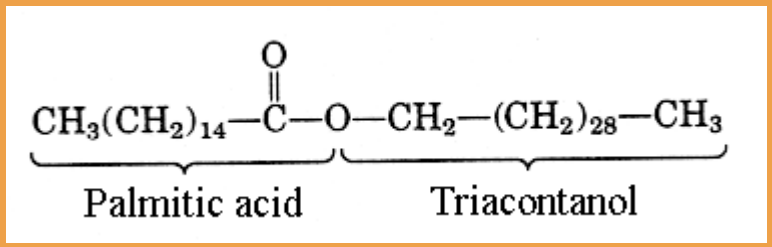
Triacylglycerols (or triglycerides) are tri-esters of fatty acids and glycerol.[4] They are nonpolar and hydrophobic in nature. They do not possess any charge and are termed neutral lipids. Triacylglycerol contains varying lengths of fatty acids that can be saturated or unsaturated.

The two types of triacylglycerols include simple and mixed types. The triglycerides containing only a single type of fatty acids are called simple triglycerides, while those with two or more different types of fatty acids are called mixed triglycerides.



C. Waxes

Waxes are esters of long-chain fatty acids and long-chain alcohol. They are solid at room temperature and completely water-insoluble. They are formed by the esterification of long-chain fatty acids and monohydroxy alcohol of higher molecular weight. The popularly known beeswax contains triacontanyl palmitate as a major molecule.



The hydrophobic nature of waxes allows them to function as water repellents on leaves of some plants, feathers, and cuticles of insects. They also serve as energy storage for planktons and higher aquatic animals.

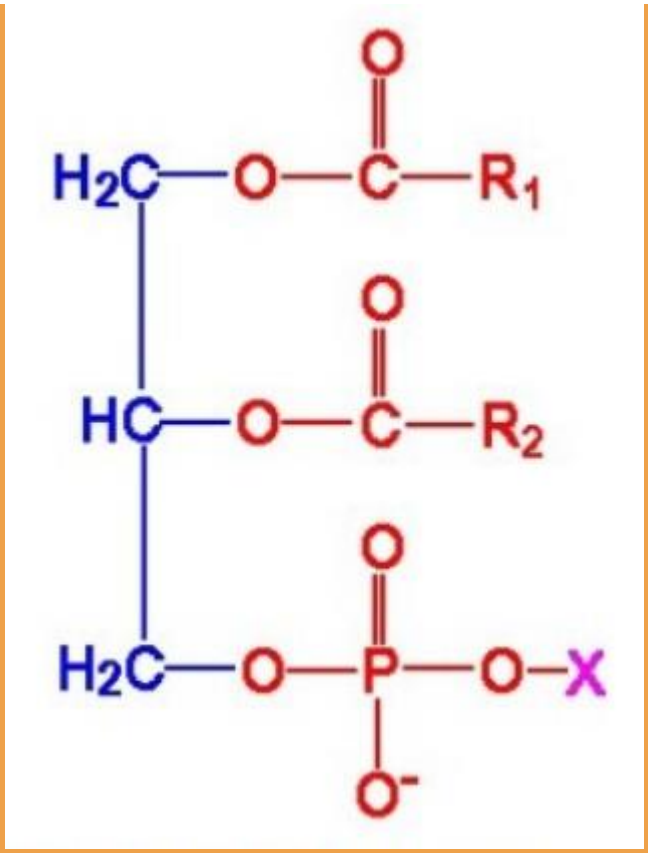
2. Compound Lipids

The complex or compound lipids contain some other organic molecules in addition to fatty acids and glycerols. They include phospholipids, glycolipids, and lipoproteins.

A. Phospholipids

Phospholipids consist of four components: fatty acids, glycerol or sphingosine, phosphate, and alcohol attached to phosphate. It includes phosphoglycerides, ether glycerophospholipids, and sphingophospholipids. These molecules are amphipathic in nature.

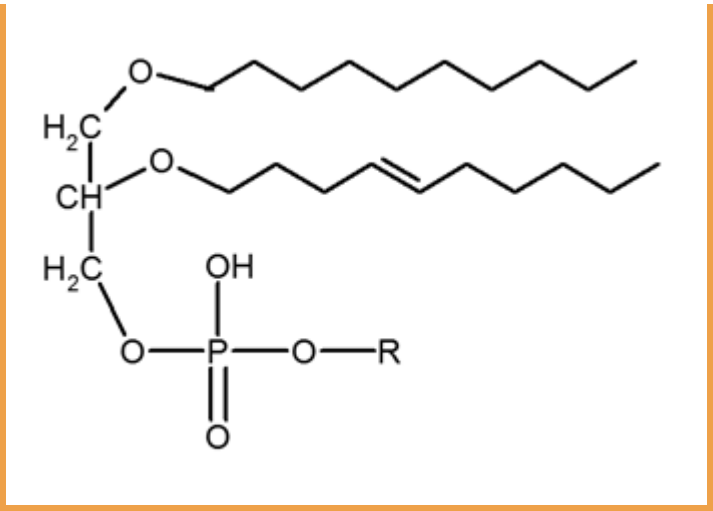
- **Phosphoglycerides** consist of glycerol, two fatty acid molecules, a phosphate, and alcohol. They are the most abundant phospholipids found in the cell membrane, among all the other phospholipids. The simplest form of phosphoglyceride is phosphatidic acid. Structurally, the hydroxyl group at C1 and C2 carbon of glycerol are esterified with the carboxyl group of two fatty acid chains, and the hydroxyl group at C3 is esterified with the phosphoric acid.The common alcohol moieties of phosphoglycerides include serine, ethanolamine, choline, glycerol, and inositol.



A general structure of phosphoglycerides

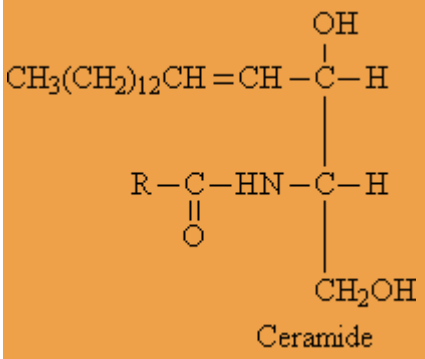
- **Ether glycerophospholipids** have ether linkage at the C1 position of glycerol. The ether-linked chain may be saturated or unsaturated, containing a double bond between C1 and C2 atoms. The compound with cis alpha, beta-unsaturated alkyl moiety is called plasmalogen.

One most common example of ether glycerophospholipids is the platelet-activating factor (PAF) which functions in platelet aggregation and dilation of the blood vessels.



A general structure of ether glycerophospholipids.

Sphingophospholipids are sphingosine (18-carbon containing amino alcohol) derived phospholipids. Its parent structure consists of ceramide, which is a fatty acid joined to sphingosine via an amide linkage.



The structure of ceramide.

One example of sphingophospholipids is sphingomyelin which is a major constituent of the nervous system in higher animals.

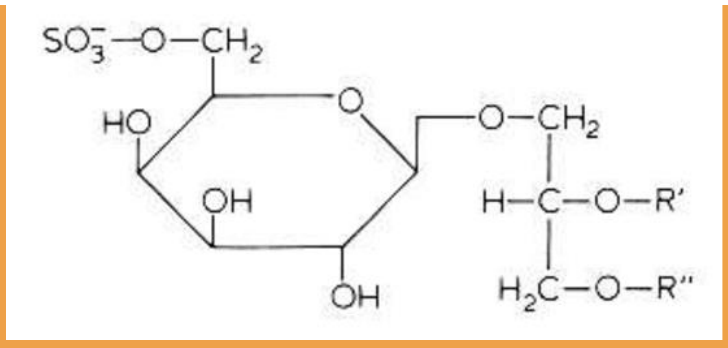
B. Glycolipids

Glycolipids contain a carbohydrate group (attached through a glycosidic bond) in combination with glycerol and fatty acids. It's the third major class of membrane lipids.[4] The head group of the molecule contains sugar (one or more) connected directly to the hydroxyl group at C1 of the ceramide moiety.

Some examples of glycolipids are cerebroside that has a single sugar moiety attached to ceramide; globoside, having multiple sugar moiety attached to ceramide; and ganglioside, which is a globoside with the head group containing one or more residues of N-acetylneuraminic acid (sialic acid).

Some diseases associated with sphingolipid storage are given below:

1	Tay Sach	Ganglioside GM2	Beta-hexosaminidase A
2	Niemann Pack	Sphingomyelin	Sphingomyelinase
3	Fabry's	Trihex Acyl Ceramide	alpha-Galactosidase A



The structure of glycolipids.

Source: Production and characterization of biosurfactant from bacterial isolates.

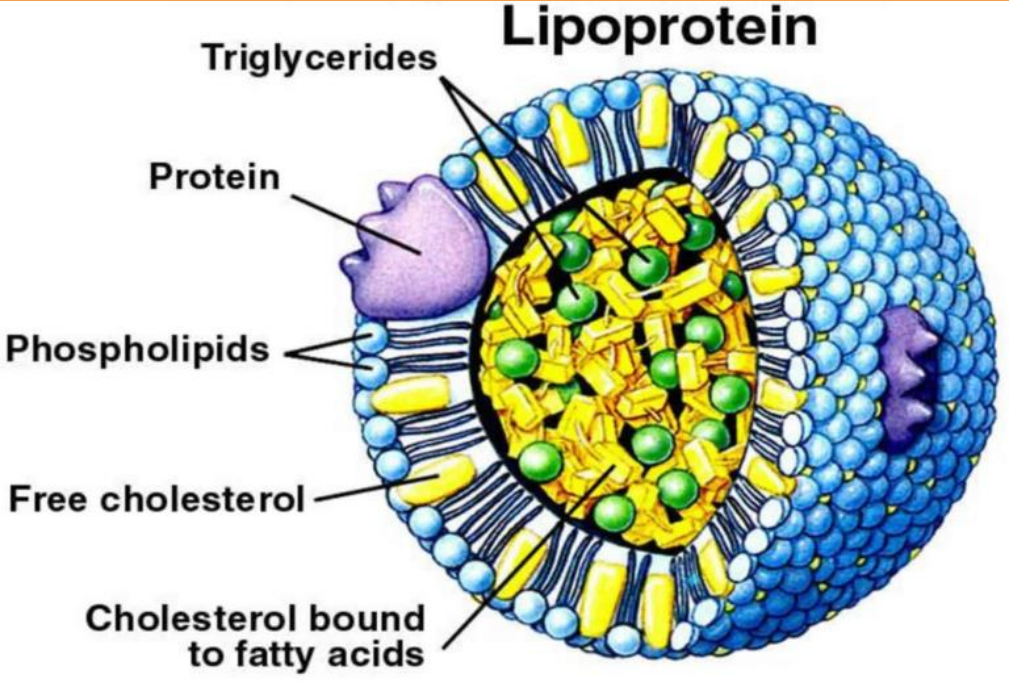
C. Lipoproteins

Lipoproteins are lipid-protein complexes. They help lipids derived from food or synthesized in one organ, such as triglycerides, phospholipids, cholesterol, and cholesterol esters, to be transported throughout the body.

Lipoproteins soluble in the blood are categorized into four groups based on their densities:

- Chylomicrons
- Very Low-Density Lipoproteins (VLDL)
- Low-Density Lipoproteins (LDL)
- High-Density Lipoproteins (HDL)

The lipoproteins have a core containing neutral lipids, triacylglycerols and cholesterol esters. The core is coated with a single layer of phospholipids, embedded with apolipoproteins and cholesterol.



labeled illustrative diagram of lipoproteins.

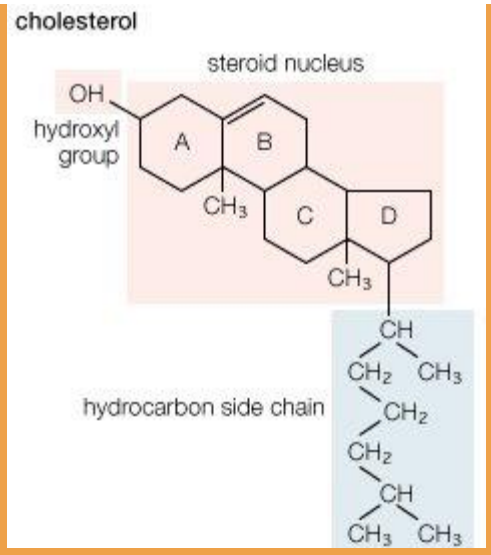
3. Derived Lipids

Derived lipids are released during hydrolysis of simple and compound lipids. They include steroids and some fatty acids.

A. Steroids

Steroids consist of four fused rings called steroid nucleus. They are complex derivatives of triterpenes.One example is cholesterol which is an essential component in animal cell membranes. It's stored in cells as fatty acid esters and act as precursors for the biosynthesis of steroid hormones and bile salts.

Cholesterol is absent in fungi and plants. Some other steroids that are common in plants include stigmasterol, sitosterol, and campesterol. In fungi, ergosterol is present in their cell membrane.

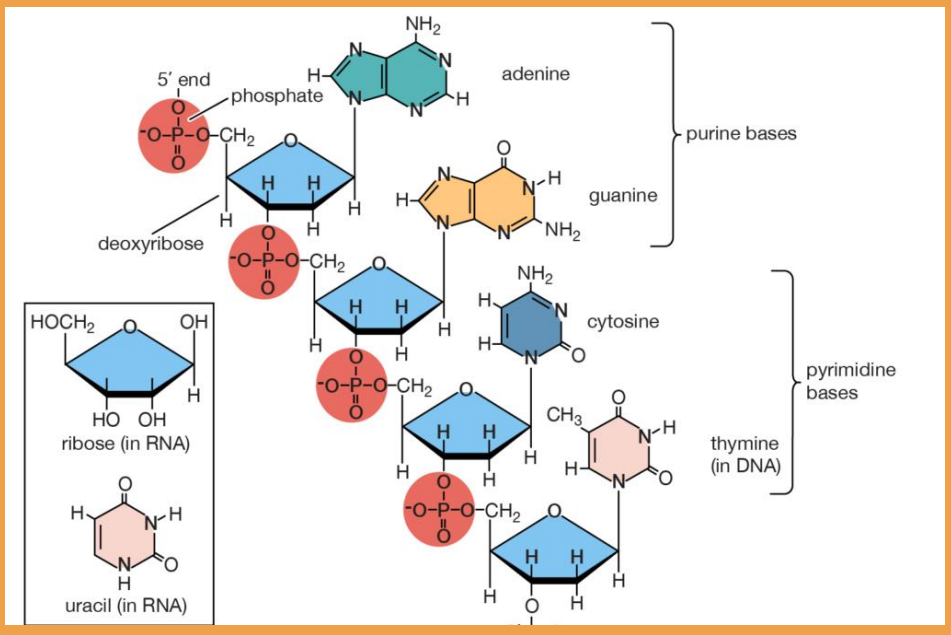


The structure of Cholesterol.

B. Eicosanoids

They are a family of biological signaling molecules that act as short-range messengers. They originated from 20 carbon arachidonic acids, and include prostanoids and leukotrienes.

These molecules are formed from two molecular pathways which include cyclooxygenase (cyclic pathway) and lipoxygenase (linear) pathways. The cyclooxygenase pathway is followed by prostanoids which include prostaglandins, prostacyclins, and thrombooxygenase. The lipoxygenase pathway produces leukotrienes.



The structural representation of eicosanoids (prostaglandin, thromboxane, and leukotrienes).

Based on Fatty Acids

Lipids are divided into two categories based on the type of fatty acids present in them: saturated and unsaturated fatty acids.

1. Saturated Fatty Acids

Saturated fatty acids have no double or triple bonds. They are a simple, unbranched, and linear chain of CH2 groups connected with a carbon-carbon single bond and one carboxylic acid at its end. Their general formula is CH3 – (CH2)n – COOH., where n represents the number of methylene groups.

Some examples of saturated fatty acids include lauric, myristic, palmitic, stearic, behenic, and lignoceric acids.

2. Unsaturated Fatty Acids

Unsaturated fatty acids have one or more double or triple bonds. So, they can either be monounsaturated or polyunsaturated. The naturally occurring fatty acids are generally in the cis configuration, rather than in trans configuration. There are only a few naturally occurring fatty acids with triple bonds and they're often of plant origin, for example stearolic acid.

The unsaturated fatty acids are named referring to the number of carbons they contain with the suffix *-anoic* (for saturated fatty acids) and *-enoic* (for unsaturated fatty acids). For example, stearic acid contains 18 carbons and is named octadecanoic acid (18:0). Here, 18:0 refers to 18 carbon fatty acids with zero double bonds.

The other way of naming these molecules is by using the delta numeric system. For, example, cis-Δ^9 represents the cis double bond between carbons 9 and 10. Similarly, trans-Δ^4 represents trans double bonds between carbons 4 and 5.

Some examples of monounsaturated fatty acids are palmitoleic acid, oleic acid, gadoleic acid, erucic acid, nervonic acid. And, some common polyunsaturated fatty acids include linoleic acid, linolenic acid, and arachidonic acid.

Based on Requirements by the Human Body

Lipids on the basis of requirements are divided into two groups: essential and non-essential fatty acids.

1. Essential Fatty Acids

Fatty acids that cannot be produced or synthesized in our bodies are called essential fatty acids. These fatty acids need to be taken through a diet to fulfill the body's requirement for different metabolic functions. It includes linoleic acid, linolenic acid, and arachidonic acid.

2. Non-essential Fatty Acids

Non-essential fatty acids include those lipids that are synthesized by our body. They are not needed to be taken through any outside food source. It includes palmitic acid, oleic acid, and butyric acid.

Biological Significance of Lipids

Lipids being one of the major biomolecules in organisms play several roles. Here's a list of key metabolic functions of lipids in organisms.

1. Chemical Messenger

Lipids of different classes function as signaling molecules or cellular messengers. They activate different signaling pathways either by binding with G-coupled receptors or nuclear receptors. Some of the lipid molecules involved in signaling functions include

- Sphingosine-1-phosphate: It's a potent messenger molecule, involved in calcium mobilizing regulations, cell growth, and apoptosis.
- Diacylglycerol and phosphatidylinositol phosphate: They are involved in calcium-mediated activation of protein kinase C.
- Prostaglandins: It's an eicosanoid, involved in inflammation and immunity.
- Estrogen, testosterone, and cortisol: These are hormones, modulating several functions including metabolism, reproduction, and blood pressure.
- Oxysterol: It's involved in regulating biological responses by binding to liver X receptors which is a nuclear receptor essential for cholesterol, fatty acid, and glucose homeostasis.
- Phosphatidylserine: It's involved in signaling phagocytosis of apoptotic cells by exposing themselves to the outer leaflet of the bilayer cell membrane.

2. Energy Storage

Triacylglycerols or triglycerides, residing in adipose tissues, are a major source of energy in both plants and animals. The complete breakdown of fatty acids releases about 38 kJ/g (9 kcal/g) caloric content. The breakdown of triglycerides in the body is controlled by the enzyme lipase.

3. The Structural Component of the Cell Membrane

The plasma membrane of cells is made of a lipid bilayer with proteins embedded in it. The lipid bilayer is composed of amphipathic glycerophospholipid molecules.All the glycolipids and phospholipids present in the cell membrane act as structural components of the membrane.The cellular membrane also contains some non-glyceride lipids, which include sphingomyelin and sterols that are involved in membrane flexibility.

4. Other Functions

- Apart from the above-mentioned functions, lipids also serve as pigments (carotene), hormones (vitamin D derivative and sex hormone), cofactors (vitamin K), and detergents (bile salt).
- A subcutaneous layer of lipids helps to insulate and protect the body against cold. Further, fats are also involved in maintaining body temperature.
- Prostaglandins stimulate uterine contraction, lower blood pressure, vasodilation, inflammation, and pain.
- Thromboxanes function as vasoconstrictors and stimulate platelet aggregation.
- Prostacyclins act as antagonists of thromboxanes – it's a potent vasodilator.
- Leukotrienes play functional roles in chemotaxis, inflammation, and allergic reactions.

Conclusion

Lipids are one of the major biomolecules playing key functions in different organisms. From their first appearance in 1665, the research on these molecules has come a long way. Now, it's a big family containing different types of lipids including phosphoglycerides, glycolipids, lipoproteins, steroids, sphingomyelins, and eicosanoids.

These molecules regulate diverse bodily functions essential for the living of organisms. Further, current researches are focused on using these lipids in treating and diagnosing life-threatening diseases. For example, several scientists are working on delivering nanoparticles using lipoproteins as drug-delivery systems.

Understanding the role of lipids in diseases can be fruitful in creating effective, targeted, and sustainable solutions in the healthcare sector.

β-oxidation of Palmitic acid

Introduction

Digestion of dietary lipids releases two important primary end products namely; fatty acids and glycerol.Fatty acids thus formed release a large amount of energy on oxidation, which involves three major steps.In the first stage called β oxidation, fatty acids undergo oxidative removal of successive two-carbon units in the form of acetyl-CoA, starting from the carboxyl end of the fatty acyl chain.In the second stage of fatty acid oxidation, the acetyl groups of acetyl CoA are oxidized to CO_2 in the citric acid cycle, which also takes place in the mitochondrial matrix. Acetyl CoA derived from fatty acids thus enters a final common pathway of oxidation with the acetyl CoA derived from glucose via glycolysis and pyruvate oxidation.The first two stages of fatty acid oxidation produce the reduced electron carriers NADH and $FADH_2$.In the third stage, NADH and $FADH_2$ donate electrons to the mitochondrial respiratory chain, through which the electrons pass to oxygen with the concomitant phosphorylation of ADP to ATP. The energy released by fatty acid oxidation is thus conserved as ATP.

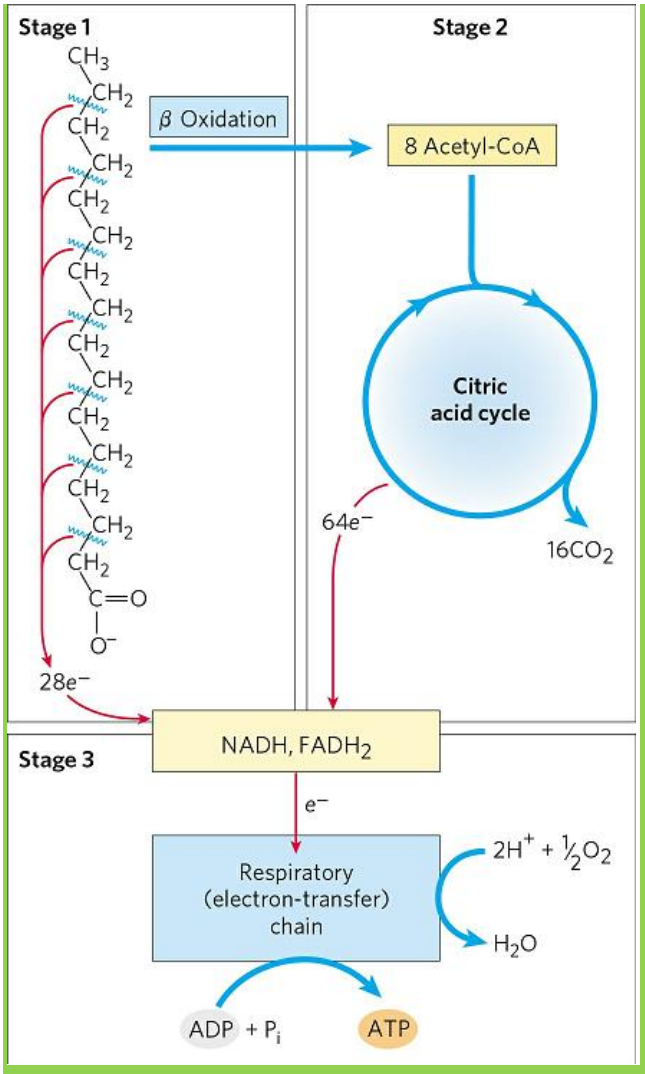
Sites of Beta-oxidation

A. Mitochondria:

- Short/Medium chain FA (2-12 C): Diffuse directly into mitochondria
- Long chain FA or LCFA (12-20 C): Uses carnitine shuttle to enter mitochondria (inner mitochondrial membrane is impermeable to FA)

B. Perioxisomes:

- Very long chain FA or VLCFA (>20 C)
- After shortening of VLCFA in perioxisome, it is transferred to mitochondria for further oxidation.
- Perioxismoes are also the site of alpha-oxidation (FA with methyl-group at beta-carbon which block beta-oxidation).

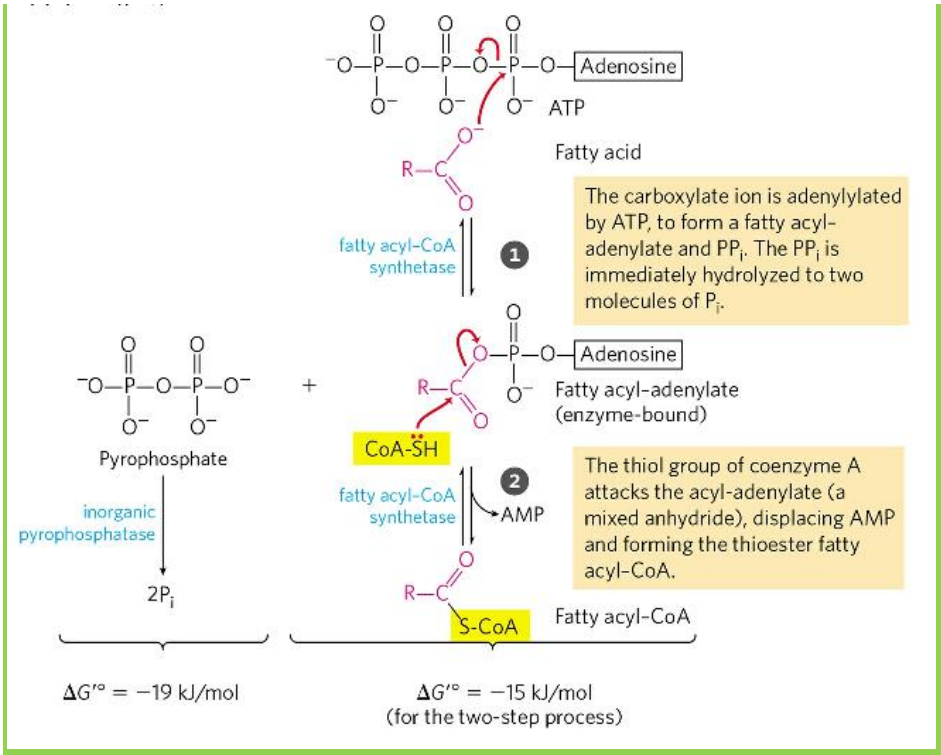


Steps in beta-oxidation of fatty acids:

1. Step I: Activation of a fatty acid by conversion to a fatty acyl CoA

After fatty acid enters into the cell, it is converted into fatty acyl CoA.

The conversion is catalyzed by fatty acyl-CoA synthetase or thiokinase and inorganic pyrophosphatase. Formation of the fatty acyl CoA derivative occurs in two steps.



2. Step II: Transport of fatty acid from cytosol into mitochondria via the acyl carnitine/carnitine transporte

Fatty acyl CoA must enter into mitochondrial matrix where β-oxidation occurs.

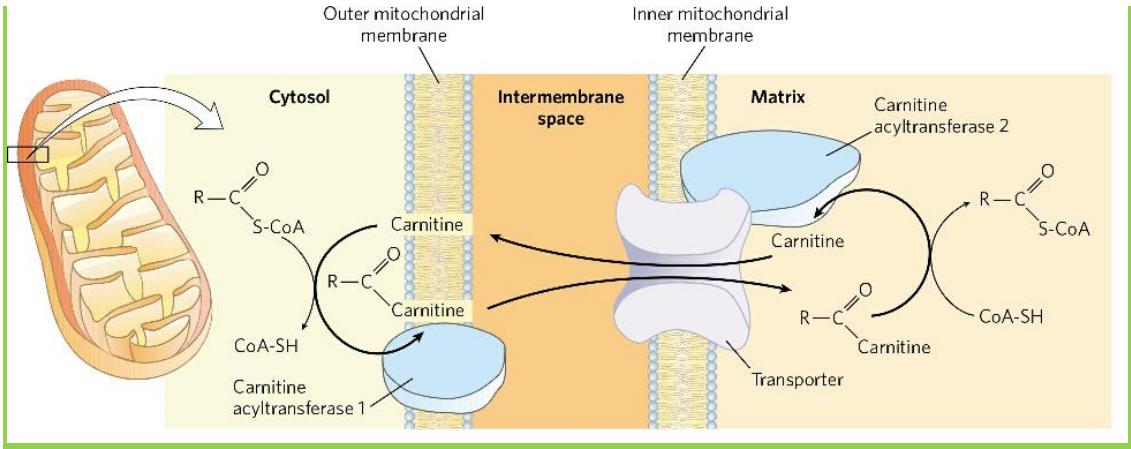
Shorter chain fatty acids (less than 12 Carbon atoms) cross mitochondrial membranes by themselves and enter into the matrix.

Longer chain fatty acids however, need carnitine shuttle to cross the mitochondrial membranes.

First, acyl group of fatty acyl CoA is transported to carnitine to form fatty acyl carnitine and free CoA. This reaction is catalyzed by carnitine acyl transferase I (CPT-I) present on the outer membrane of mitochondria.

Fatty acyl carnitine then enters into mitochondrial matrix with the help of carnitine-acyl-carnitine transporter protein (carnitine shuttle).

Finally, carnitine acyl transferase II (CAT-II) transfers acyl group from fatty acyl carnitine to mitochondrial coenzyme A, freeing carnitine to return to the inter-membrane space through the same transporter protein. The carnitine is released and return to cytosol for reuse.



3. Step III: Beta oxidation

a. β-oxidation of saturated fatty acids (E.g. Palmitic acid)

- The first cycle of beta oxidation of saturated fatty acids consists of a sequence of four enzyme-catalyzed reactions that result in the shortening of fatty acid chain by two-carbon atoms.

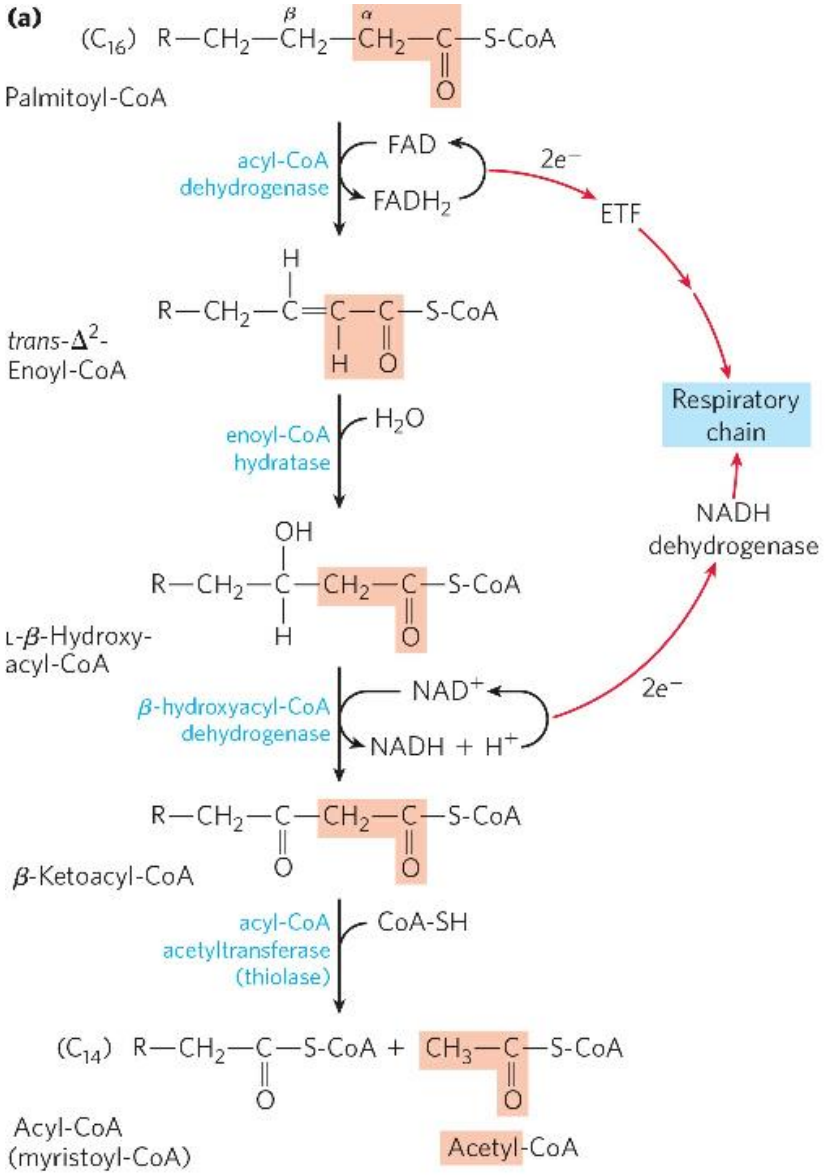
i. First Oxidation step: In the first step, dehydrogenation of fatty acyl CoA produces a double bond between α and β carbon atoms (C-2 and C-3), yielding an enoyl CoA and $FADH_2$ in the presence of an enzyme fatty acyl CoA dehydrogenase.

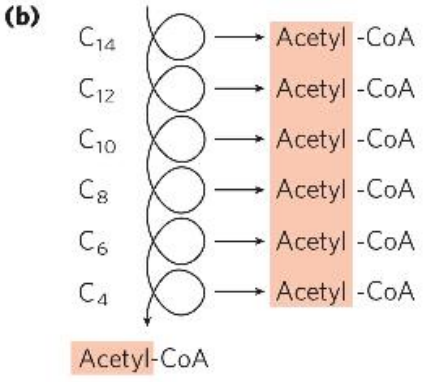
ii. Hydration step: In the second step, water is added to the double bond of enoyl CoA to form β-hydroxyacyl CoA (3-hydroxyacyl-CoA). This reaction is catalyzed by enoyl CoA hydratase.

iii. Second oxidation step: In the third step, β-hydroxyacyl CoA is dehydrogenated to form β-ketoacyl CoA (3-ketoacyl CoA), by the action of β-hydroxyacyl CoA dehydrogenase. NADH is produced in this step.

iv. Thiolysis or Thiolytic cleavage step: The fourth and last step of the β-oxidation cycle is catalyzed by acyl CoA acetyl transferase, more commonly called thiolase, which promotes reaction of β-ketoacyl CoA with a molecule of free coA to split off the carboxyl terminal (two-carbon fragment) of the original fatty acid as acetyl CoA. The other product is fatty acyl CoA, now shortened by two carbon atoms. This reaction is called thiolysis.

- These four steps make one complete cycle of beta oxidation. In each cycle, one acetyl CoA, one $FADH_2$ and one NADH are produced.


(a)
(C16) R—CH2—CH2—CH2—C—S-CoA
Palmitoyl-CoA
acyl-CoA dehydrogenase
FAD
FADH2
2e−
ETF
Respiratory chain
trans-Δ2-Enoyl-CoA
enoyl-CoA hydratase
H2O
NADH dehydrogenase
L-β-Hydroxy-acyl-CoA
β-hydroxyacyl-CoA dehydrogenase
NAD+
NADH + H+
2e−
β-Ketoacyl-CoA
acyl-CoA acetyltransferase (thiolase)
CoA-SH
(C14) R—CH2—C—S-CoA + CH3—C—S-CoA
Acyl-CoA (myristoyl-CoA)
Acetyl-CoA


(b)
C14 → Acetyl-CoA
C12 → Acetyl-CoA
C10 → Acetyl-CoA
C8 → Acetyl-CoA
C6 → Acetyl-CoA
C4 → Acetyl-CoA
Acetyl-CoA

Energy yield from β-oxidation of Palmitic acid:

The energetics or the energy conserved in terms of ATP by oxidation of a molecule of palmitic acid is given below:

Palmitic acid (16 carbons) undergoes -oxidation forming eight molecules of acetyl CoA by undergoing **seven -oxidation spirals.**

When one cycle of -oxidation takes place, one molecule of FADH2, one molecule of NADH and one molecule of acetyl CoA are produced.

Electrons from these reducing equivalents (FADH2 and NADH) are transported through the **respiratory chain in mitochondria** with simultaneous regeneration of high-energy phosphate bonds.

Mitochondrial oxidation of FADH2 eventually results in the net formation of about 2 ATP.

Likewise, oxidation of electrons from NADH. Hence, a total of **four ATP molecules** are formed per cycle and **ten molecules of ATP** are formed through Krebs's cycle from each molecule of acetyl CoA.

8 Acetyl CoA through TCA cycle yield (8x12) =96ATP

7-oxidationspiralreactionsyield (7x5) =35ATP

Total **131 ATP**

ATP utilized in the initial step =1ATP

Hence, **complete oxidation of palmitic acid** yields 130 **ATP.**

Health Implications

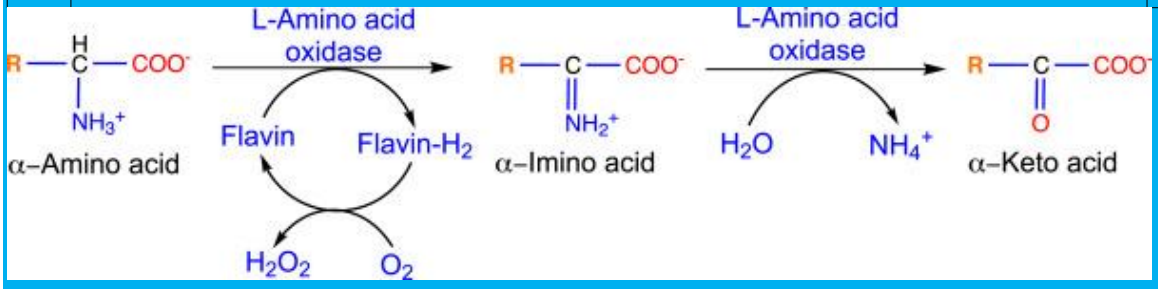
A well-functioning beta oxidation process is crucial for overall health. Defects or disruptions in this pathway can lead to serious metabolic disorders. For instance, conditions like fatty acid oxidation disorders (FAODs) are genetic disorders where the body is unable to effectively utilize fatty acids for energy. This results in an accumulation of toxic fatty acid intermediates, leading to potentially life-threatening complications.

Moreover, beta oxidation plays a pivotal role in maintaining lipid homeostasis, preventing fat accumulation in non-adipose tissues,such as the liver and muscles. Dysregulation of this process may contribute to metabolic disorders like non-alcoholic fatty liver disease (NAFLD) and insulin resistance, which are associated with obesity and diabetes.

An overview of the consequences of dysfunctional beta-oxidation is that it can cause; energy depletion (FAODs), hypoglycemia, accumulation of toxic intermediates in the body, cardiac dysfunction, muscular weakness and pain, rhabdomyolysis (breakdown of muscles), kidney damage, neurological impairment, and metabolic crisis such as coma.

PROTEIN METABOLISM DEAMINATION AND TRANSAMINATION

Deamination Deamination is the removal of the amine group from α-amino acid as ammonia (NH3) with formation of α-keto acid. The liver and kidney are the main sites for deamination. Deamination may be oxidative or non-oxidative. A. Oxidative deamination: It is catalysed by one of the following enzymes: 1. L-amino acid oxidases – This enzyme is present in the liver and kidney. Its activity is low. It is an aerobic dehydrogenase that needs FMN as a coenzyme. It deaminates most of the naturally occurring L-amino acids. 2. D-amino acid oxidases – D-amino acids are present in plants and bacterial cell wall



2. D-amino acid oxidases –

 D-amino acids are present in plants and bacterial cell wall.

 They are not used in protein biosynthesis in humans &

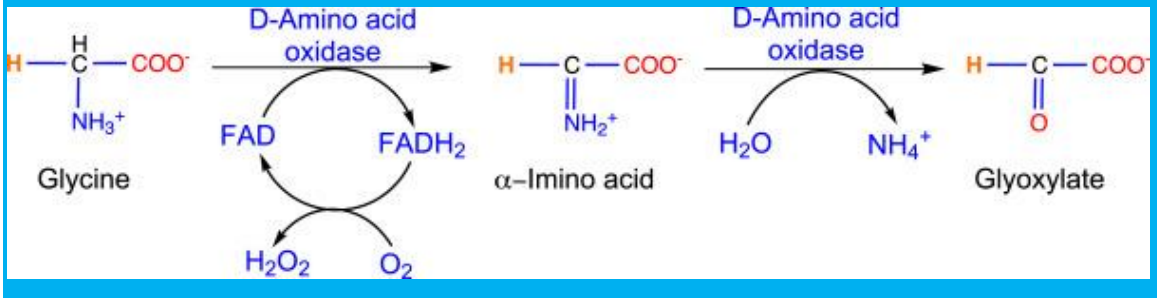
animals. D-amino acids are deaminated by D-amino acid oxidase

resulting in ammonia & α-keto acids.

 This is present in liver.

 It is an aerobic dehydrogenase.

 It needs FAD as a coenzyme.

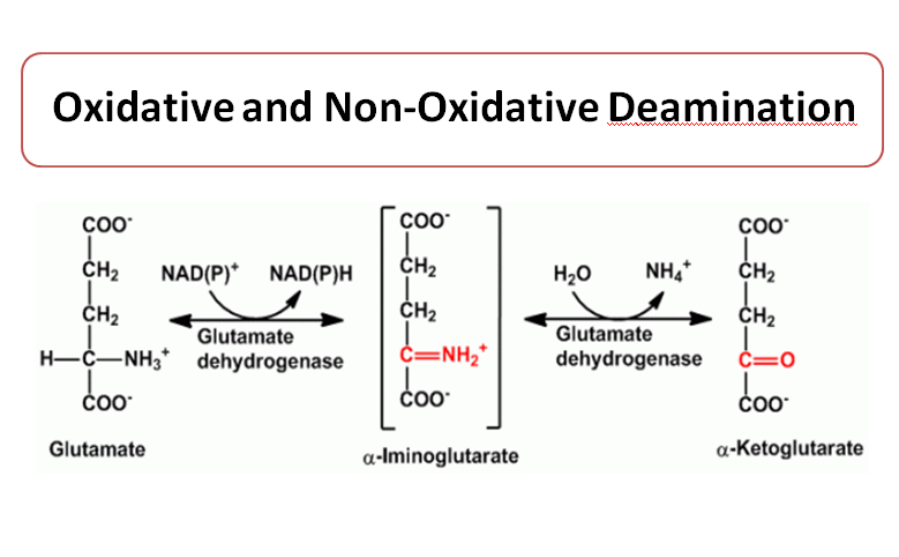


3. *Glutamate dehydrogenase* –

 This enzyme is present in cytoplasm & mitochondria in most tissues. Its activity is high.

 It is an anaerobic dehydrogenase. Needs NAD or NADP as a coenzyme.

 It deaminates glutamic acid resulting in α-ketoglutaric acid and ammonia.



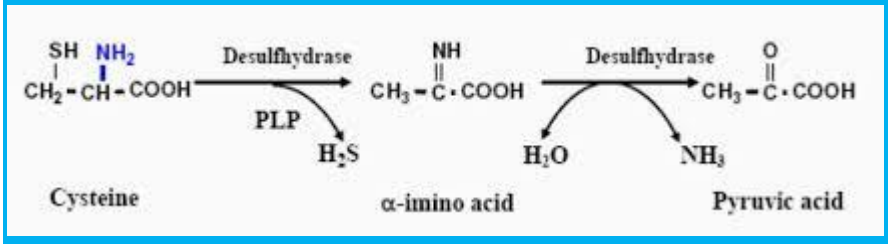
Non-oxidative deamination:

It is catalysed by one of the following enzymes:

Desulfhydrase –

 This enzyme deaminates sulphur containing amino acids e.g. cysteine and cystine.

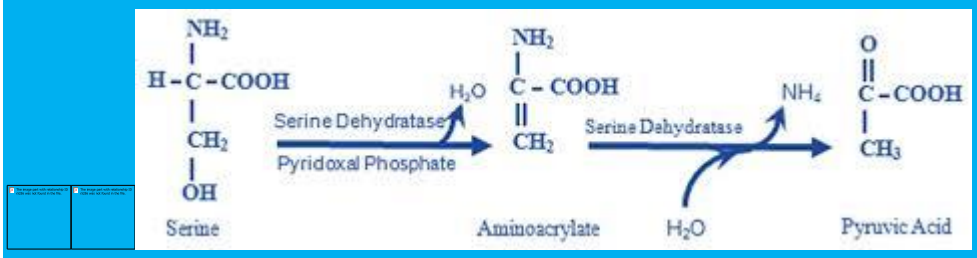
 It needs pyridoxal phosphate as a coenzyme.



Dehydratases –

 This enzyme deaminates amino acids containing hydroxyl group e.g. serine, homoserine & threonine.

 It needs pyridoxal phosphate as coenzy



Transamination

Transamination is the transfer of an amine group from α-amino acid to α-keto acid (amino acid without an amine group), thus creating a new α-amino acid and α-keto acid. This pathway is responsible for the deamination of most amino acids. This is one of the major degradation pathways which convert essential amino acids to non-essential amino acids (amino acids that can be synthesized de novo by the organism).

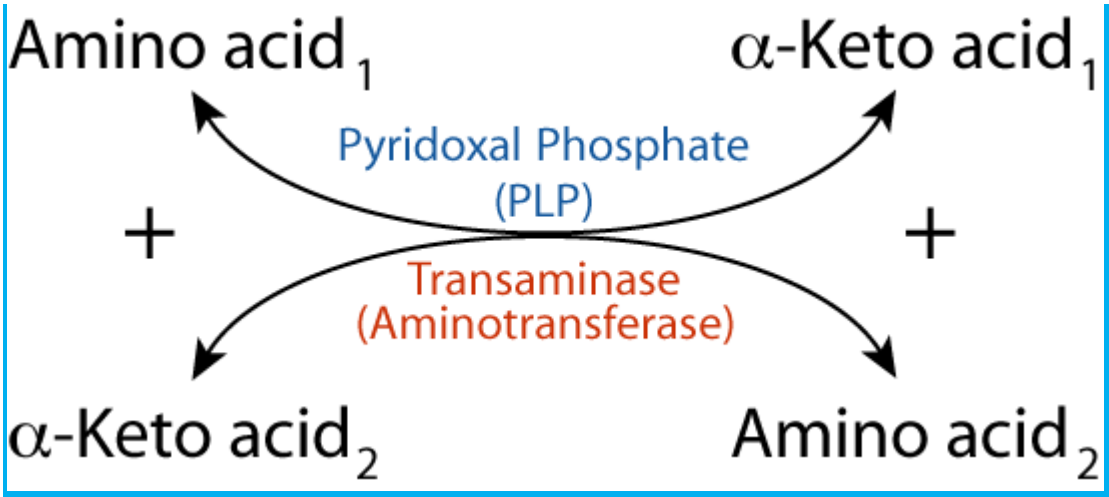
 The liver is the main site for transamination.

 All amino acids can be transaminated except lys, thr, pro & hy-Pro.

 All transamination reactions are reversible.

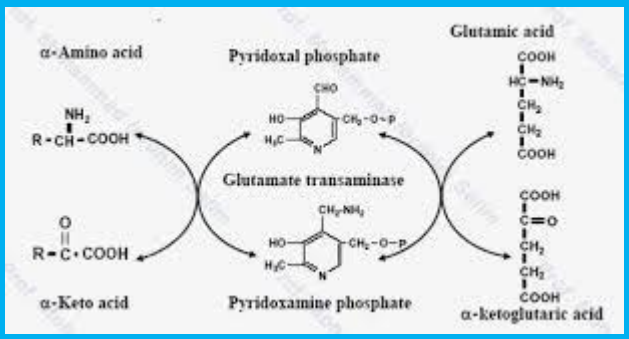
 It is catalysed by aminotransferases (transaminases).

 It needs pyridoxal phosphate as a coenzyme.



Role of pyridoxal phosphate in transamination:

Pyridoxal phosphate acts as an intermediate carrier for amino group. It accepts the amino group from amino acid to form pyridoxamine phosphate which in turn gives the amino group to α-keto acid.



Examples of transaminases:

A. Alanine transaminase

B. Aspartate transaminase

C. Glutamate transaminase

A. Alanine transaminase (ALT):

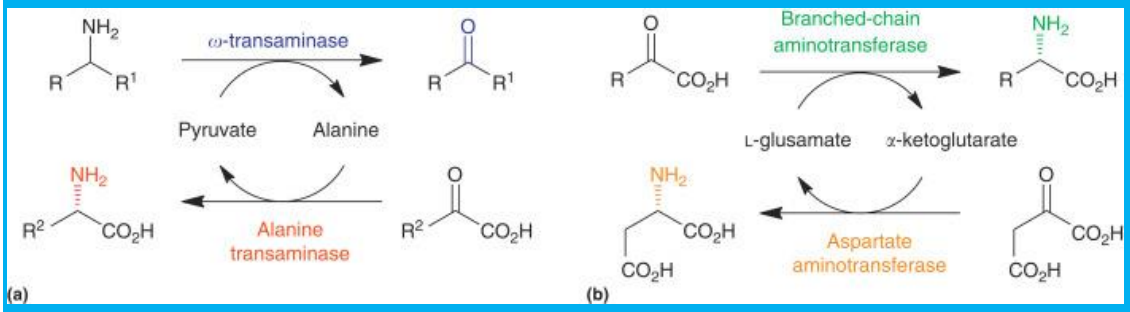
 It is also called glutamic pyruvic transaminase (GPT).

 It also catalyses the reverse reaction.

 It catalyses the transfer of amino group from glutamic acid to

pyruvic acid to form alanine and α-ketoglutaric acid.

 It is present in the cytoplasm of liver cells.



B. Aspartate transaminase (AST):

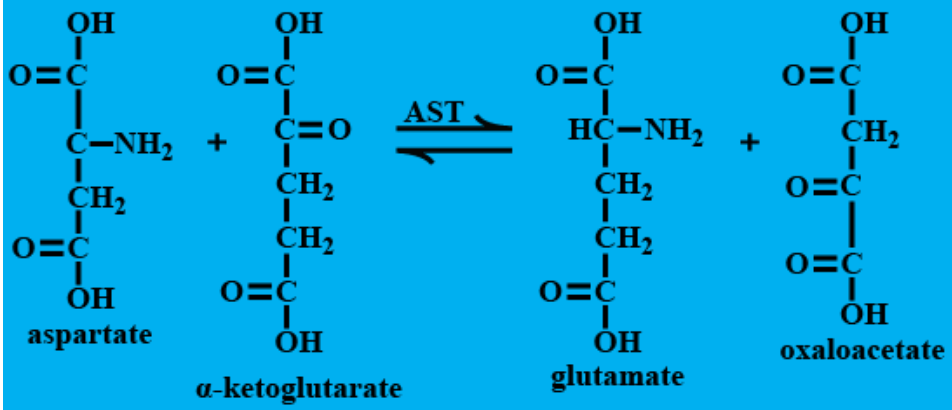
 It is also called glutamic oxalacetic transaminase (GOT).

 It also catalyses the reverse reaction.

 It catalyses the transfer of amino group from glutamic acid to

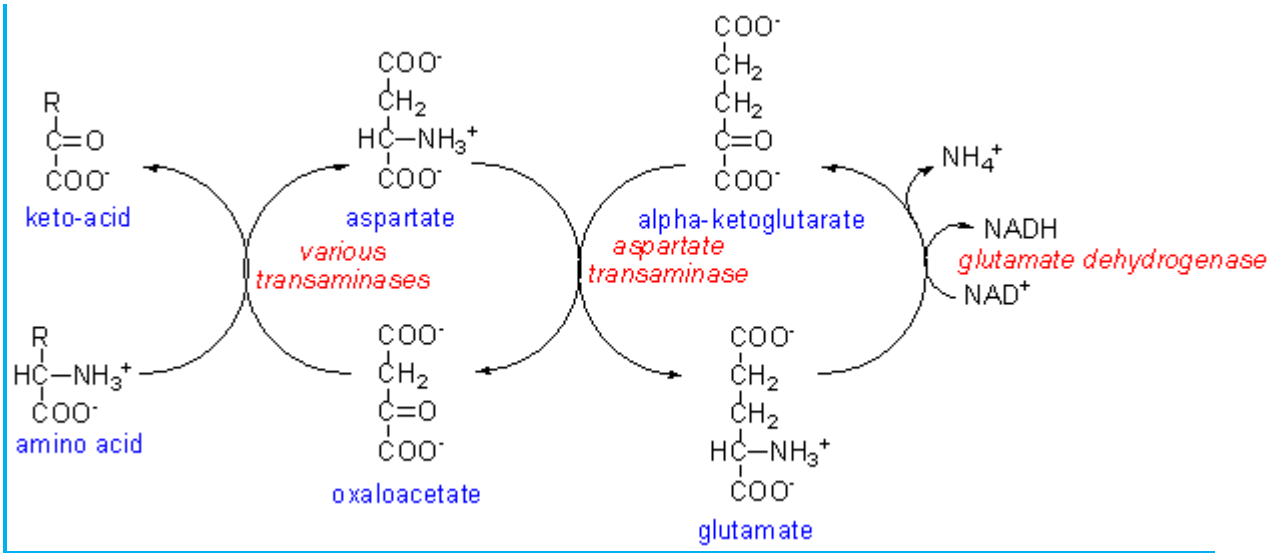
oxalacetic acid to form aspartic acid and α-ketoglutaric acid. It is present in both cytoplasm and mitochondria of liver, heart and

skeletal muscle cells.



C. Glutamate transaminase:

- It also catalyses the reverse reaction.
- It catalyses the transfer of amino group from any amino acid (except lys, thr, pro and Hy-Pro) to α-ketoglutaric acid to form glutamic acid and the corresponding α-keto acid.
- It is widely distributed in all tissues.



Clinical significance of transaminases:

- Transaminases are intracellular enzymes.
- Their levels in blood plasma are low under normal conditions.
- Any damage to the organs associated with these enzymes (liver, heart, skeletal muscles) will increase the level of transaminases in blood.
- In liver diseases, there is an increase in both serum ALT (SGPT) and AST (SGOT) levels.
- In acute liver diseases (acute viral hepatitis), the increase is more in SGPT.
- In chronic liver diseases (liver cirrhosis), the increase is more in SGOT.
- In heart diseases (myocardial infarction) and skeletal muscle diseases (myasthenia gravis).

Differences between transamination and deamination:

TRANSAMINATION	DEAMINATION
The transfer of an amino group from one molecule to another, especially from an amino acid to a keto acid	The removal of an amino group from an amino acid or other compounds
Involves in the synthesis of nonessential amino acids	Involves in the breakdown of excess proteins
Occurs in all cell of the body	Occurs in the liver
Transaminases or aminotransferases catalyze transamination	Deaminases catalyze deamination
Results in an exchange of an amine group with a keto group	Results in the elimination of ammonia
Glutamic acid is the main form of amino acid produced in transamination reactions	Glutamic acid is the primary form of amino acid, which undergo deamination
Reversible	Irreversible