

## Amino Acid-Essentiality to Human Body

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### Abstract

*An amino acid is one of the major building blocks of protein unit, arranged around the carbon atom in tetrahedral manner. These are classified into essential and non-essential amino acids based on their availability on the body. As many as 300 amino acids, only 20 are standard amino acids for their functional view. Each amino acid i.e. monomers joined with peptide linkage as a result biggest molecule of amino acid forms where larger molecule represented by R-group/s. Rich sources of it are pulses, seeds, non-veg foods as well as animal products. Amino acids play major role in metabolic activities for human beings and supply the energy to the body and get healthy fitness as well as neurotransmitters. Excretion of urea and CO<sub>2</sub> also results due to the different reaction occurring in liver and kidney. Metabolic disorder causes phenylketonuria, alkaptonuria, albinism like problems. Detection of amino acids can be done by various measures but mostly utilized method is ninhydrin test, is a chemical process where the development of coloration confirms the presence of amino acid.*

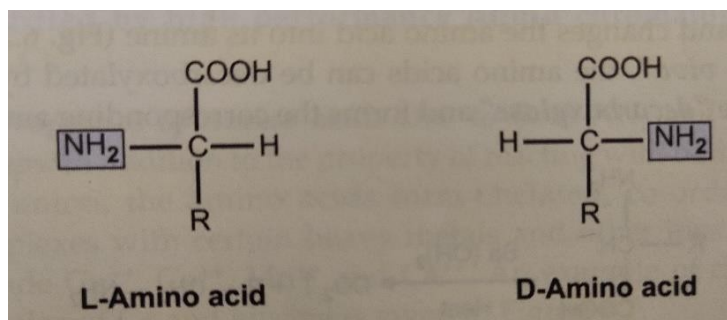
**Keywords:** building-block, tetrahedral, R-groups, transamination, metabolism, neurotransmitter

### Introduction

Amino acid, often referred as building block of protein, any of a group of organic molecules that consist of a basic amino group (-NH<sub>2</sub>), an acidic carboxyl group (-COOH), and an organic R group (or side chain) that is unique to each amino acid. The term amino acid is short for  $\alpha$ -amino [alpha-amino] carboxylic acid. Each molecule contains a central carbon (C) atom, called the  $\alpha$ -carbon, to which both an amino and a carboxyl group are attached. Because of tetrahedral arrangement of bonding around the alpha carbon, four different groups can occupy two possible stereoisomers. Since they are superposable mirror image of each other, they represent a class of stereoisomers called enantiomers. [1,4]

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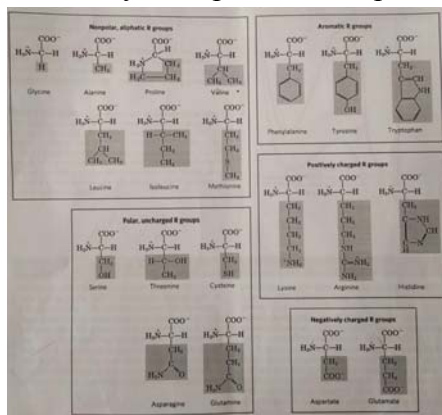


**Fig 1:** L and D form of amino acid Alanine)  
(Enantiomers)

**Chemistry of amino acids**

Out of more than 300 amino acids that have been described in nature, only 20 amino acids are naturally incorporated into polypeptides and are called proteinogenic or standard amino acids. These twenty amino acids are encoded by universal genetic code. Out of 20, 10 standard amino acids (histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine and arginine {required for youngs, but not for adults}) are called essential for humans because they cannot be created from other compounds by the human body, so must be taken in as food. [3,6]

The 10 amino acids that we can produce are alanine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine and tyrosine, known as nonessential amino acids. Tyrosine is produced from phenylalanine, so if the diet is deficient in phenylalanine, tyrosine will be required as well. Beside these 20 amino acids, recently two new amino acids are known (Selenocystine-21<sup>st</sup> amino acid and pyrrolysine-22<sup>nd</sup> amino acid). These two amino acids are directly incorporated into protein during translation.



**Fig 2:** Structural classification of amino acids

(Unshaded and shaded portion indicates common to all amino acids and R-groups respectively)

### Acid-Base properties

Amino acids can act as either an acid or a base, are called amphoteric. The basic amino group typically has a pKa between 9 and 10, while the acidic  $\alpha$ -carboxyl group has a pKa that is usually close to 2 (a very low value for carboxyls). The pKa of a group is the pH value at which the concentration of the protonated group equals that of the unprotonated group. Thus, at physiological pH (about 7–7.4), the free amino acids exist largely as dipolar ions or “zwitterions” (a zwitterion carries an equal number of positively and negatively charged groups). Any free amino acid and likewise any protein will, at some specific pH, exist in the form of a zwitterion. That is, all amino acids and all proteins, when subjected to changes in pH, pass through a state at which there is an equal number of positive and negative charges on the molecule. The pH at which this occurs is known as the isoelectric point (or isoelectric pH) and is denoted as pI. When dissolved in water, all amino acids and all proteins are present predominantly in their isoelectric form. Stated another way, there is a pH (the isoelectric point) at which the molecule has a net zero charge (equal number of positive and negative charges), but there is no pH at which the molecule has an absolute zero charge (complete absence of positive and negative charges). That is, amino acids and proteins are always in the form of ions; they always carry charged groups. This fact is vitally important in considering further the biochemistry of amino acids and proteins. All amino acid contains an acidic carboxylic group and a basic amino group. It can form a zwitter ion at pH=7. Zwitter ion forms when carboxylic group releases its proton and remains in an anionic form and  $\text{NH}_2$  group takes a proton and remains in a cationic form. At this pH it is called isoelectronic point. At this isoelectric point, the positive ion does not move towards anode and negative charge does not move towards cathode. When a base is added to the amino acid increasing the pH of the solution, then positive charge on the  $\text{NH}_3^+$  is removed and the molecule becomes an anion. This anion moves toward the positively charged anode. In the presence of an acid, the carboxylate anion takes one proton from the acid solution and becomes neutral. The net amino acid becomes cationic charged and moves towards the anionic charged cathode. [3,6]

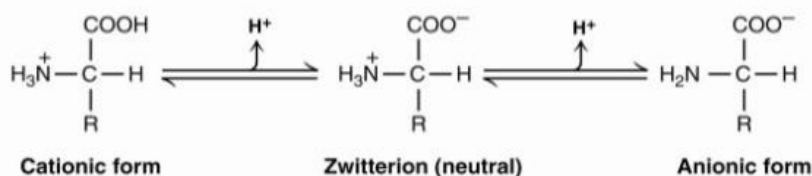
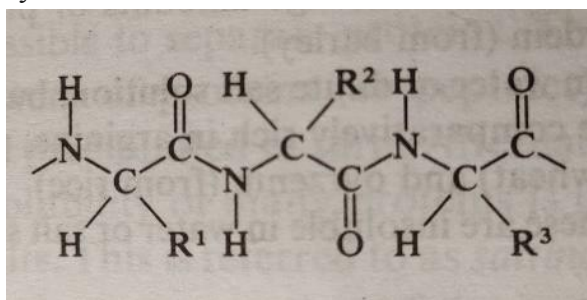


Fig 3: Ionic state of amino acid [6]

## Peptide bond formation

The covalent binding of an alpha-amino group of one amino acid with the carboxyl group of a second amino acid with the elimination of water are joined in linear fashion, results in the formation of a peptide bond (-CONH-). A dipeptide contains two amino acid residues whereas a tripeptide contains three. An amino acid residues is called on oligopeptide while a polypeptide has more than 25 amino acids. Normally, the amino acid residues found in peptides are named in the order starting from the N-terminal end, while the carboxyl end is said to be C-terminal.



**Fig 4:** Peptide linkage [6]

## Amino Acid biosynthesis

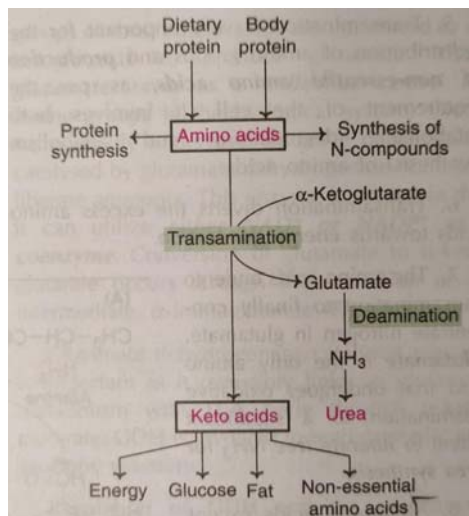
Certain amino acids cannot be synthesized and must be provided in the diet. Non-essential amino acids can be synthesized in the body and the absence of one of these in the diet doesnot impair protein synthesis. Eight of the ten amino acids (leucine, isoleucine, valine, methionine, threonine, tryptophan, phenylalanine and lysine) are essential at all times, whereas arginine and histidine are required only during periods of rapid tissue growth. Cysteine and tyrosine are synthesized from essential amino acids. For example, when cysteine is absent from the diet, methionine requirement increases by about 30% because cysteine is synthesized from methionine. When sufficient cysteine is present in the diet, the requirement for dietary methionine will be decreased. Similarly, the absence of tyrosine increases the phenylalanine requirement because phenylalanine is irreversibly converted to tyrosine. The presence of sufficient tyrosine in the diet has a sparing effect on phenylalanine. [4,8]

General principles governing synthesis of amino acids:

- The synthesis of most amino acids occurs by transamination of the corresponding keto acids, glutamate generally supplies the aminogroup.
- The enzymes for the synthesis of the carbon chains of non-essential amino acids are contained in the liver.
- The rates of amino acid synthesis can be controlled by allosteric inhibition of

enzymes in the biosynthetic pathway; the first reaction in the biosynthetic sequence is inhibited by the product of the pathway so that it operated only if there is deficiency of the product.

### Metabolism of Amino acid



**Fig 5:** Overview of amino acid metabolism (Source: U. Satyanarayan, U. Chakrapani-Biochemistry)

Metabolism of amino acid involves for utilizing to generate energy. Most of the amino acid are metabolized by transamination (transfer of an amino group from an amino acid to keto acid) in the liver to yield the corresponding oxoacid, the amino group being transferred to 2-oxoglutarate to form glutamate. Glutamate undergoes oxidative deamination, the amino group being converted to ammonium. Amino acid nitrogen form ammonia, which is toxic. The liver is the major site of amino acid metabolism in the body and the major site of urea synthesis. The liver is also major site amino acid degradation and partially oxidizes amino acids, converting the carbon skeleton to glucose, ketone bodies or CO<sub>2</sub>. Amino acid metabolism is reprogrammed due to its important role in energy metabolism abnormality in tumor cells, glutamine, these cond important energy resources of tumor cell, produces abundant ATP for tumor growth. During digestion in the gut, proteins are broken down to their constituent amino acids, animals and humans obtain many important metabolites from their food. All amino acid contain at least one nitrogen atom, which forms their alpha amino group, several amino acids contain additional nitrogen atoms in their side chains. Some nitrogen is used in biosynthesis. To this end, the liver incorporates it into urea, which is released into the blood stream and excreted by the kidney. Removal of nitrogen is typically an early step in the degradation and leaves behind the carbon skeleton. Vitamin B6 pure crystalline powder acts as a coenzyme in the amino acid metabolism and

maintains healthy skin, it also controls skin oils. Liver is one of the most important organ to synthesize proteins. It produces or transform protein molecules. [4,8]

### **Sources of amino acid**

The foods in the following list are the most common sources of essential amino acids: Lysine is in meat, eggs, soy, black beans, quinoa, and pumpkin seeds.

Meat, fish, poultry, nuts, seeds, and whole grains contain large amounts of histidine. Cottage cheese and wheat germ contain high quantities of threonine.

Methionine is in eggs, grains, nuts, and seeds.

Valine is in soy, cheese, peanuts, mushrooms, whole grains, and vegetables. Isoleucine is plentiful in meat, fish, poultry, eggs, cheese, lentils, nuts, and seeds. Dairy, soy, beans, and legumes are sources of leucine.

Phenylalanine is in dairy, meat, poultry, soy, fish, beans, and nuts.

Tryptophan is in most high-protein foods, including wheat germ, cottage cheese, chicken, and turkey.

Arginine is in dairy, fish, poultry, turkey and beef. [1, 2, 4]

### **Role of amino acids**

Amino acid often referred to as the building block of protein, are compounds that play many critical roles in the body. They are needed for vital processes like building of protein and synthesis of hormones and neurotransmitters. Some amino acids with their respective functions are given below: [2,7,8]

**Phenylalanine:** Phenylalanine is a precursor for the neurotransmitters tyrosine, dopamine, epinephrine and norepinephrine, which is necessary for specific brain functions. It plays an integral role in the structure and function of proteins and enzymes and the production of other amino acids. Phenylalanine deficiency, though rare, can lead to poor weight gain in infants. It may also cause eczema, fatigue, and memory problems in adults. People with a rare genetic disorder called phenylketonuria (PKU) are unable to metabolize phenylalanine.

**Valine:** Valine is one of three branched-chain amino acids, meaning it has a chain branching off to one side of its molecular structure. Valine helps stimulate muscle growth and regeneration, energy production, mental focus and emotional calm. People may use valine supplements for muscle growth, tissue repair, and energy.

**Threonine:** Threonine is a principal part of structural proteins such as collagen and elastin, which are important components of the skin and connective tissue. It also plays

a role in fat metabolism, immune function and may be beneficial for people with indigestion, anxiety, and mild depression.

**Tryptophan:** Though often associated with causing drowsiness, tryptophan has many other functions. It's needed to maintain proper nitrogen balance, proper growth in infants and is a precursor to serotonin, a neurotransmitter that regulates your appetite, sleep and mood.

**Methionine:** Methionine plays an important role in metabolism and detoxification. It's also necessary for tissue growth, flexibility of skin and hair and the absorption of zinc and selenium, minerals that are vital to your health. Methionine also helps keep nails strong.

**Leucine:** Like valine, leucine is a branched-chain amino acid that is critical for protein synthesis and muscle repair. It also helps regulate blood sugar levels, stimulates wound healing and produces growth hormones.

**Isoleucine:** The last of the three branched-chain amino acids, isoleucine is involved in muscle metabolism and is heavily concentrated in muscle tissue. It's also important for immune function, hemoglobin production, energy regulation, blood sugar regulation and hormone production.

**Lysine:** Lysine plays major roles in protein synthesis, hormone and enzyme production and the absorption of calcium. It's also important for energy production, immune function, production of collagen and elastin, maintaining bone strength, aiding recovery from injury or surgery, and regulating hormones, antibodies, and enzymes. It may also have antiviral effects.

**Histidine:** Histidine is used to produce histamine, a neuro-transmitter that is vital to immune response, digestion, sexual function and sleep-wake cycles. It's critical for maintaining the myelin sheath, a protective barrier that surrounds nerve cells.

**Arginine:** It is the precursor for the synthesis of nitric oxide, ornithine, polyamines, proline, glutamate, creatine, dimethylarginine and urea. For youngs, arginine is essential for optimal growth and development. It is also used to maintain blood pressure, wound healing and to treat burns.

Selenocystine found in the mammalian blood has an antioxidant function. Its concentration falls in selenium deficiency. The stop codon UAG can code for pyrrolysine.

**Health benefits of amino acids**

1. Help improve sleep and mood: Tryptophan is needed for the production of serotonin, a chemical that acts as a neurotransmitter in your body. Serotonin is an essential regulator of mood, sleep and behaviors. While low serotonin levels have been linked to depressed mood and sleep disturbances, several studies have shown that supplementing with tryptophan can reduce symptoms of depression, boost mood and improvesleep.
2. Boost exercise performance: During exercise, causing level of amino acid in blood to decrease and increases its level in brain, which is then converted to serotonin, that is thought to contribute to the development of fatigue during exercise. The three branched-chain essential amino acid are widely used to alleviate fatigue, improve athletic performance and stimulate muscle recovery after exercise. Amino acid supplements improved performance and muscle recovery and decreased muscle soreness. It is used in promoting muscle recovery and reducing soreness after exhaustive exercise.
3. Can Prevent Muscle Loss: Muscle loss is a common side effect of prolonged illnesses and bed rest, especially in older adults. Essential amino acids have been found to prevent muscle breakdown and preserve lean body mass. Essential amino acid supplements have also been found to be effective in preserving lean body mass in elderly people andathletes.
4. Increased mental focus: By keeping the tryptophan away, amino acid supplements improve short term memory and processingabilities.
5. Greater fat burn: For those trying to loss some body fat or athletes training on a low carb diet, then branch chain amino acids will help body make the switch to depending on fat for fuel. Burning of fat is related to weight loss. [2, 5]

**Role of Amino acid in Urea cycle (Krebs-Henseleit cycle)**

Urea is the end product of amino acid metabolism. Sequential chemical reaction occurring primarily in the liver that results in the production of urea; urea cycle. The cycle converts highly toxic ammonia and carbondioxide to urea for excretion. The steps are taken in the mitochondria and cytoplasm of hepatocytes. In urea cycle, firstly carbamoyl phosphate is converted to citrulline. With catalysis by ornithine transcarbamolyase, the carbomoyl phosphate group is donated to ornithine and releases a phosphate group. A condensation reaction occurs between the amino group of aspartate and the carbonyl group of citrulline to form argininosuccinate. This reaction is ATP dependent and is catalyzed by argininosuccinatesynthetase, argininosuccinate undergoes cleavage by argininisuccinase to form arginine and ornithine. The ornithine is then transported back to the mitochondria to begin the urea cycle again.



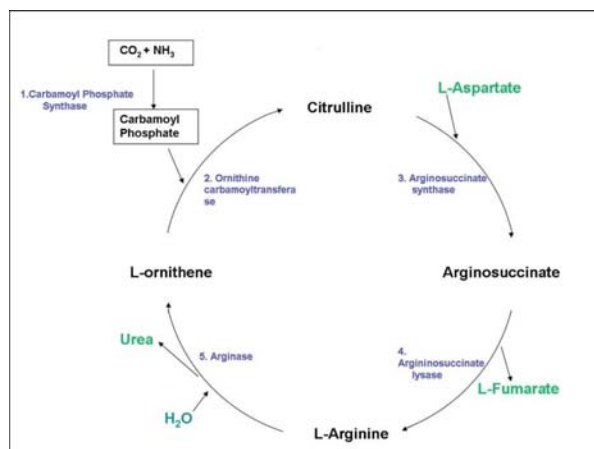


Fig 6: Krebs-Hensleit cycle (source: toppr.com)

### Amino acid metabolism disorder

**Phenylketouria (PKU):** It occurs due to defect in the gene that helps create phenylalanine hydroxylase and causes problem in breakdown of phenylalanine. This leads to a buildup of phenylalanine in the body. Its symptoms include seizure, skin condition such as tremors, musty odour in the breath, eczema, skin or urine, caused by high level of phenylalanine in the body.

**Alkaptonuria:** It is also known as black urine disease, occurs when the body can't produce enough of an enzyme called homogentisic dioxygenase (HGD), used to break down a toxic substance called homogentisic acid. If there is lack of HGD, homogentisic acid builds up in the body. The buildup of homogentisic acid causes bone and cartilage to become discoloured and brittle. Its symptoms include dark spots in the sclera (white) of your eyes, blue speckled discoloration of your skin, particularly around sweat glands, thickened and darkened cartilage in your ears, dark-colored sweat or sweat stains, black earwax, kidney stones, prostate stones and arthritis (especially hip and knee joints).

**Albinism:** It occurs due to absence or defect in tyrosinase enzyme (enzyme involved in the production of melanin). It is characterized by a lack of pigment melanin due to a defect in the biochemical pathway that converts phenylalanine to melanin. Its symptoms include an absence of color or lighter than normal colouring in the hair, skin, or eyes and patches of skin that have an absence of color. Oculocutaneous albinism occurs with vision problems, which may include strabismus (crossed eyes), nystagmus (involuntary rapid eye movements), photophobia (sensitivity to light), impaired vision or blindness and astigmatism.

**Maple syrup urine disease (MSUD):** It is characterized by deficiency of branched-chain alpha-keto acid dehydrogenase complex in a gene on chromosome 19 that is required to break down the three branched-chain amino acids (Leucine, Isoleucine and Valine) in the body. The result of this metabolic failure is that all three branched-chain amino acids, along with their various byproducts, accumulate abnormally throughout the body. Its symptoms include

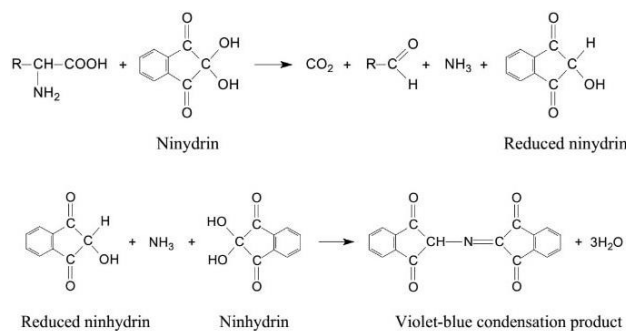
lethargy, weak sucking ability, irritability, poor appetite, weight loss, a distinctive maple sugar odor in earwax, sweat, and urine and irregular sleep patterns.

**Homocystinuria:** It is characterized by defect in the enzyme, cystathionine beta-synthase that converts homocysteine to cystathionine and therefore unable to metabolize homocysteine. Its symptoms include dislocation of the lenses in the eyes, osteoporosis, learning disabilities, nearsightedness, abnormal blood clots, chest deformities, such as a protrusion or a caved-in appearance of the breastbone, long, spindly arms and legs and scoliosis. [4, 5, 11]

### Determination of Amino Acid (ninhydrin test)

#### Principle

This method is based on the fact that two molecules of ninhydrin (2, 2- dihydroxyindane-1, 3-dione) react with a free alpha-amino acid to produce a deep purple or blue color known as Ruhemann's purple. In this reaction, ninhydrin acts as an oxidizing agent and causes the deamination and decarboxylation of the amino acids at an elevated temperature. This reaction is then followed by condensation between the reduced ninhydrin molecules, released ammonia, and the second molecule of ninhydrin. By the end of the reaction, a diketohydrin complex is formed which has a deep purple color (Ruhemann's purple). Amino acids like proline and hydroxyproline yields an iminium salt, which is yellow-orange in color. Proteins with a free amino group like asparagine, react with the ninhydrin reagent to form a brown colored product. The intensity of the formed complex is proportional to the concentration of amino acids in the solution. [9,10]



**Fig 7 :** Reaction (source: Biocheminfo.com)

#### Reagents:

##### I. Preparation of 2% ninhydrin solution:

- weight 0.2 gm of Ninhydrin and dissolve in 10ml of acetone or ethanol II. Preparation of test solution:
- prepare 1% amino acid solution in distilled water.

#### Procedure:

- Take 1 ml of the sample solution in a test tube, pour few drops of ninhydrin solution.

- Heat the tube at 95°C for 2-5 mins or heat in the water bath and observe the development of purple colour.
- The development of violet-blue colour confirms the presence of amino acid.

**Result interpretation:**

- For ammonia, primary/secondary amines, and amino acids, deep purple colour is obtained.
- For hydroxyproline and proline, a yellow colour is obtained.
- For asparagine, brown colour is obtained.
- If no colour change is observed, the analyte does not contain amino acids, amines, or ammonia.

**Closure**

As the amino acid is basic unit of protein, union of nitrogen, hydrogen, carbon, oxygen and sometimes heteroatom like Sulphur by covalent bond can show acid-base character. It acts major role for metabolism and also excrete toxic ammonia and carbon dioxide during urea cycle.

It has tendency to release fat, building muscles, mental improvement, etc. Commonly, it can be detected by ninhydrin test.

**References**

- Chatarjee MN, Shinde Rama, Textbook of medical Biochemistry, Jaypee Brothers Medical Publishers (P) Ltd., New Delhi, 7<sup>th</sup> edition.
- Vasudevan DM, S Sreekumari, Vaidanathan Kannan, Textbook of Biochemistry for medical students, Jaypee Brothers Medical Publishers (P) Ltd., New Delhi.
- Finar, I. L., Organic Chemistry (VOL. 2), Dorling Kindersley (India) Pvt. Ltd. 5<sup>th</sup> edition.
- Satyanarayan U., Chakarpani U., Biochemistry, Relax India Publication Limited and Books and Allied (P) Ltd., 5<sup>th</sup> edition.
- Harvey Richard, Ferrier Demise, Biochemistry, Walters Kluwer (India) Pvt. Ltd., New Delhi, 5<sup>th</sup> edition.
- Morrison and Boyd, Organic Chemistry, Allyn and Bacon, Inc., Universal Book Stall, New Delhi, 4<sup>th</sup> edition.
- Berg Jeremy M., Tymoczko John L., Gatto Gregory J., Stryer Jr. Lubert, Biochemistry, W. H. Freeman and Company, New York, 8<sup>th</sup> edition.
- Jain Dr. J. L., Jain Sanjay, Jain Nitin, Fundamentals of Biochemistry, S. Chand and Company Ltd., Ram Nagar, New Delhi.
- Perrette D., Nayuni N.K., Decontamination of hospital and health, second edition 2019, Jimmy Walker editor
- Gupta Prem Prakash, Gupta Nilu, Essential of practical biochemistry, 2017, DOI No. 10.5005/JP/books/12972\_5
- Pearl Philip L., Movement disorder and inherited metabolic disorder, Cambridge university press, 2020, doi.org/10.1017/9781108556767.