Chapter
4 Biochemistry

Time Allocation

Teaching periods = 11
Assessment period = 02
Weightage = 11%

MAJOR CONCEPTS:

4.1 Carbohydrates
4.2 Proteins
4.3 Lipids
4.4 Nucleic acids
4.5 Vitamins

STUDENTS LEARNING OUT COMES (SLO'S)

Students will be able to:

- Describe the composition of carbohydrates.
- Distinguish between mono-, di- and trisacchrides.
- Describe the bonding in protein molecule.
- Describe the sources and uses of carbohydrates, proteins and lipids.
- Differentiate between fats and oils.
- Describe the importance of nucleic acids.
- Explain the types of nucleic acids [deoxyribonucleic acid (DNA) and ribonucleic acid (RNA)].
- Define and explain the vitamins and their importance.

Introduction:

The word Biochemistry (Bio=Life + Chemistry) means chemistry of life. This branch of chemistry deals with the study of chemical and physical processes inside living system which involve chemical compounds such as carbohydrates, vitamins, proteins, lipids and nucleic acids. It focuses on what is happening inside our cells and looks at how cells communicate with each other. Thus biochemistry can be defined as, The branch of chemistry which deals with the study of chemical substances and processes that occur in living organisms (plants and animals) is known as biochemistry.

The history of biochemistry may be considered from Ancient Greeks. However, biochemistry as a specific discipline was accepted a little before 19th century. First time the word biochemistry was used by a German chemist Carl Neuberg in 1903.

Do You Know?

Food is essential for life on Earth and is a complex mixture of chemical substances. Food fuels metabolic processes. In living beings, certain complex organic molecules are broken down into simpler ones to provide energy (catabolism), while others are transformed into complex organic compounds to store energy (anabolism), such as starch and glycogen. Both biology and chemistry cope with these opposing processes. Thus a new science was introduced called biochemistry.

4.1 Carbohydrates

Carbohydrates are naturally occurring organic compounds and are important component of our food. Generally they contain elements like carbon, hydrogen and oxygen. Mostly carbohydrates are represented by general formula $Cx(H_2O)y$ because in these compounds hydrogen and oxygen are in the ratio as in H_2O. Actually these compounds do not contain water molecules.

The structural analysis shows that these compounds contain aldehyde group (-CHO), ketone group (>C=O) along with alcoholic hydroxyl groups (-OH). Thus carbohydrates are defined as, "polyhydroxy aldehydes or poly hydroxy ketones or large molecules that produce these compounds on hydrolysis". The carbohydrates which contain aldehyde group are generally termed as aldoses and those which contain ketone group are termed as ketoses.

Majority of carbohydrates are sweet in taste so they are also called Sacchrides (Latin, saccharum = sugar). Carbohydrates also have property to rotate the plane polarized light.

Do You Know?

Those carbohydrates which rotate plane polarized light to clock wise are known as dextrorotatory (indicated by D or +) while those which rotate anti-clock wise are known as levorotatary (indicated by L or -).

Classification of carbohydrates

On the basis of hydrolysis, there are three types of carbohydrates.

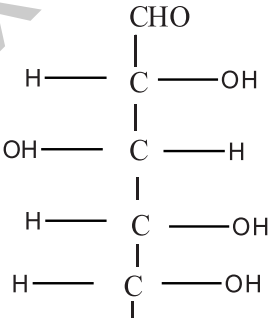
4.1.1 Monosacchrides (Greek mono = one)

These are also called simple sugars. These carbohydrates cannot be further simplified on hydrolysis. Monosacchrides contain 3 to 10 carbon atoms and may be subdivided into trioses, tetroses, pentoses, hexoses etc depending upon the number of carbon atoms they possess. Glucose (grape sugar) belongs to aldoses and fructose (honey) to ketoses are examples of monosacchrides.

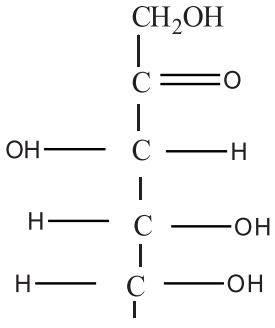
$$\text{Monosacchride} + \text{water} \xrightarrow{\text{Hydrolysis}} \text{No reaction}$$

$$C_6H_{12}O_6 + \text{water} \xrightarrow{\text{Hydrolysis}} \text{No reaction}$$

Glucose is obtained naturally as dextrorotatory and is present in most delicious foods, such as grapes (20-30 percent). It can also be found in honey. It may be found in the combined state in cane sugar, cellulose, and starch. Photosynthesis is how plants synthesize glucose. Glucose is generated when carbon dioxide reacts with water in the presence of sunlight and chlorophyll (catalyst). Plants also use glucose to make starch and cellulose. Because glucose is a necessary component of human blood, it is also known as blood sugar. The normal range for blood glucose is 65-110 mg (0.06-0.1%) per 100 mL. Glucose is commonly thought to be a rapid source of energy for patients.
Fructose (Latin fructus = fruit) occurs in ripe fruits, honey, cane sugar etc.



Glucose
(It is an aldose sugar)



Fructose
(It is ketose sugar)

Monosacchrides are crystalline solids, sweet in taste and are soluble in water.

4.1.2 Oligosacchrides (Greek oligo = few)

These carbohydrates produce 2 to 10 monosacchride's on hydrolysis. The oligosaccharides which contain two monosacchrides are called disaccharides and those which contain three are known as trisacchrides and so on.

Oligosacchrides + water $\xrightarrow{\text{Hydrolysis}}$ 2-10 monosacchrides

$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{Hydrolysis}} C_6H_{12}H_6 + C_6H_{12}O_6$

Sucrose Water Glucose Fructose

In oligosaccharides, monosacchrides are connected with each other by glycosidic bond/ linkage. Sucrose, maltose, lactose (milk sugar) etc are important members of oligosaccharides. Like monosacchrides, oligosaccharides are crystalline solids, sweet in taste and soluble in water.

4.1.3 Polysacchrides (Greek poly = many)

These carbohydrates produce more than ten monosacchrides on hydrolysis. These are also called polymeric carbohydrates. In these carbohydrates, monosacchrides are connected by glycosidic linkage.

Polysacchrides + water $\longrightarrow$ More than10 monosacchrides

$(C_6H_{10}O_5)_n + H_2O \longrightarrow n\,(C_6H_{12}H_6)$

Cellulose or starch Water Glucose

Cellulose, starch (plant origin), glycogen (animal origin), amylose etc are common polysaccharides. Cellulose is found in the cell walls, wood, linen, paper, cotton etc. Cotton contains 95% cellulose. Starch occurs in cereals like wheat, rice barley etc and roots of potatoes. Glycogen is also called animal starch, found in muscles and liver of animals.

Unlike monosacchrides and oligosaccharides, polysaccharides are amorphous solids, tasteless and insoluble in water.

4.1.4 Sources and uses of carbohydrates

Carbohydrates are important food factor and obtained from various sources like fruits, vegetables and dairy products.

Table 4.1 carbohydrates and their sources

Carbohydrates	Sources
Monosacchrides **Glucose** **Fructose**	Grapes, honey, guava, molasses ,honey etc
Oligosacchrides **Sucrose** **Lactose** **Maltose** **Raffinose**	Sugarcane , sugar beet, beet root, carrots, maple, pine apple etc Milk Wheat, barley etc Legumes
Polysacchrides **Cellulose** **Starch** **Glycogen (also called animal starch)**	 Cell wall of all land plants, cotton etc Cereal foods (Wheat, barley), potato, legumes, small amount in root vegetables Liver, muscles etc

Figure 4.1 Sources of carbohydrate

Do You Know?

Insulin is hormone which enables our body to use glucose obtained from food or glycogen (stored food) for the production of energy. If body lacks insulin, the glucose level will be increased in blood which leads to the diabates.

Uses of carbohydrates

1. They are required as a energy source for the survival of both plants and animals.
2. They sustain structure of plants.
3. Carbohydrates, in the form of starch in plants and glucose in mammals, serve as energy storage.
4. They keep our blood sugar levels in check.
5. Sucrose is a food additive. It's found in confectioneries, condensed milk, canned fruits, jams, and jellies, among other things.
6. Carbohydrate fiber helps in cholesterol reduction and blood pressure regulation.
7. Carbohydrates coexist with a variety of proteins and lipids in biosystems.
8. Celluloses provide food its bulk and fibre. It promotes peristalsis in the intestine.
9. Cellulose is used as a raw material in a variety of industries, including textiles and paper.
10. Starch is used to improve the writing characteristics of paper by coating and sizing it.
11. Starch is utilized in the production of ethanol and in laundries.

Test Yourself

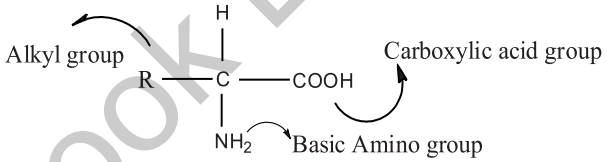
1. What are the carbohydrates?
2. What is the difference between monosacchrides and oligosacchrides?

4.2 Proteins

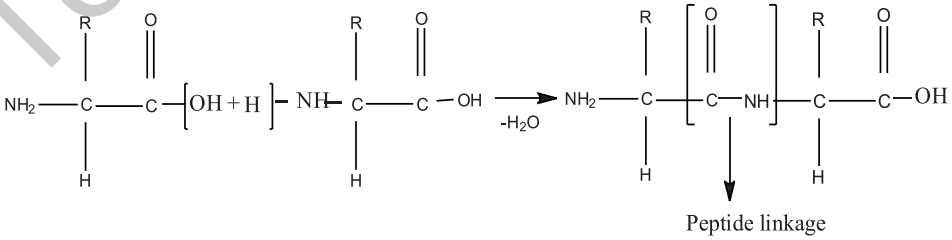
The word protein is taken from Greek Proteios means first. These are nitrogenous macro-molecules found in all the cells of living organisms. Proteins have central position in architecture and functioning of living matter. They are composed of carbon, hydrogen, nitrogen, oxygen and very rarely sulphur and phosphorus. Proteins are defined as: The polymers (macro-molecules formed of simple units called monomers) of amino acids are called proteins.

4.2.1 Amino acids as a monomers or building blocks of proteins

Amino acids are building blocks of proteins. They are bi-functional compounds and contain basic amino ($-NH_2$) and acidic carboxyl group (-COOH) groups. Upto twenty amino acids have been found in nature, ten are essential and remaining ten non-essential. Body can only synthesize non-essential ten amino acids. The general formula for amino acids is:



Where 'R' is the chain of carbon atoms. During the condensation of amino acids, –OH (from carboxyl group) of one amino acid and H (from amino group) of another amino acid are combined and eliminated as water (H_2O) molecule. Thus a new linkage is formed between two amino acid units known as peptide linkage/ bond. Due to this linkage protein is formed.



Proteins may contain 60 to 6000 amino acid molecules. A protein molecule is formed with two amino acids is termed as dipeptide, with three tripeptide and so on. Generally the molecular weight of proteins ranges from 43000 – 50,000,000 daltons (1dalton =1a.m.u).

4.2.3 Sources and uses of proteins

The important sources of proteins are eggs, meat, pulses, nuts, edible seeds, beans, peas, cheese etc.

Uses of proteins:

1. Animal proteins can be found in meat, mutton, poultry, fish, and eggs. Humans consume them as food since they are required for protoplasm production.
2. Enzymes are proteins generated by living organisms. They help to stimulate chemical processes in our body. They are highly specialized and extremely efficient. Many enzymes are utilized in pharmaceuticals. They cure blood cancer as well as decrease bleeding.
3. Proteins are hides. These are used in the tanning process to create leather. Leather is used to produce shoes, coats, and sports equipment, among other things.
4. Bones are rich in proteins. When bones are cooked, gelatin is produced. Bakery goods are made with gelatin.
5. Plants, such as pulses, beans, and other legumes, manufacture proteins as well. These are utilized as a source of food.

Figure 4.2 Sources of protiens

4.3 Lipids

A group of naturally occurring heterogeneous organic compounds which includes fats, oils, waxes and are insoluble in water means hydrophobic (water repellent) but easily soluble in Bloor's reagent (mixture of diethyl ether and ethyl alcohol in the ratio of 2:1) and organic solvents like ether, benzene, acetone, carbon tetra chloride and chloroform. Generally lipids are composed of elements like carbon, hydrogen and oxygen, but there are some lipids which contain nitrogen and phosphorous too. Lipids are the building blocks of cells.

Figure 4.3 Sources of lipids

Do You Know?

How vegetable oil is converted into saturated fat (ghee)? The chemical process used for this is hydrogenation, in this process vegetable oil (unsaturated organic compound) is treated with molecular hydrogen (H_2) in the presence of catalyst nickel (Ni) or palladium (Pd). Thus fat is formed by addition reaction of H_2 with oil.

4.3.1 Fatty Acids

Fatty acids are lipids' building components. They're carboxylic acids with a lengthy chain, either saturated or unsaturated. For example:

$C_{15}H_{31}COOH$ Palmitic acid
$C_{17}H_{35}COOH$ Stearic acid

In the presence of mineral acids, these acids produce esters (oils or fats) with glycerol.

Table 4.2 Differentiate between fats and oils.

S.No	Fats	Oils
1	These are solids at ordinary room temperature.	These are liquids at ordinary room temperature.
2	They are obtained mainly from animals.	They are obtained mainly from plants.
3	These are saturated compounds.	These are unsaturated compounds.
4	They have high melting points.	They have low melting points.
5	They increase cholesterol level in body.	They maintain cholesterol level in body.

4.3.2 Sources and uses of lipids

Sources of lipids

Animals:

Marine animals like salmon and whales are rich sources of lipids. Butter, ghee, cheese are obtained from animals.

Plants:

Sun flower, coconut, ground nuts, corn, cotton seed, olive etc are important plant sources of lipids.

Uses of lipids:

(i) They act as transporter of fatty acids and fat soluble vitamins (vitamin A, D, E & K) in body.

(ii) Some lipids reduce cholesterol level in body.

(iii) Fats and oils are used for cooking and frying of food.

(iv) Fats and oils are used in detergents, soaps, cosmetic, polishes and paints.

(v) They activate the enzymes.

(vi) Animal fats are found in adipose tissue cells. Animals secrete milk from which butter and ghee is obtained. Butter and ghee are used for cooking and frying of food, for preparing bakery products and sweets.

4.4 Nucleic acids

The name nucleic acid implies that they generally occur in nuclei of the cells. But some nucleic acids are also present in cytoplasm. Like proteins, nucleic acids are biopolymers. They are most important of all biomolecules because they store and transmit hereditary information from parents to children. In living organisms, even single fertilized egg carries the information for making the different organs like heart, liver, eyes, kidneys, hands, legs, heads etc. They contain elements like carbon, hydrogen, oxygen, nitrogen and rarely phosphorous etc. Nucleic acids are simply defined as, "The macromolecules which are formed by the polymerization of nucleotides (monomers) are called nucleic acid". Each nucleotide is composed of:

(i) Pentose sugar

(ii) Phosphate group

(iii) Nitrogenous base (purines and pyrimidines)

4.4.1 Types of nucleic acids

There are two types of nucleic acids. These both types of nucleic acids are present in all animals and plants.

Deoxyribonucleic acid (DNA)

Deoxyribose sugar is found in DNA. J. Watson and F. Crick identified its structure in 1953. It's a two-chained double-stranded molecule with a considerable length. Sugar, phosphate, and a base make up each chain. The backbone of the chains is made up of sugar and phosphate groups, and two chains are joined by bases. Figure 4.4 shows how the chains are wrapped around each other in a double helix shape.

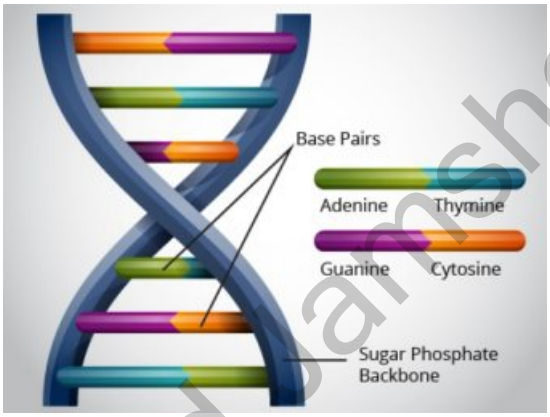


Figure 4.4 Structure of DNA

In the nucleus of a cell, DNA is the permanent storage site for genetic information. It transports and stores all of the cell's genetic information. It conveys these instructions on how to build certain proteins from amino acids from generation to generation. These instructions are referred to as the "genetic code of life." They decide whether a cell is a nerve cell or a muscle cell, and if an organism is a man, a tree, or a buffalo.

Protein formation in new cells is determined by the sequence of nitrogenous bases in DNA. The purpose of DNA's double helix construction is to ensure that there is no disorder. DNA contains genes that regulate RNA production. Errors in the genes cause incorrect RNA to be produced. It makes defective proteins that don't work the way they're meant to. Genetic disorders are caused by this ailment.

Ribonucleic acid (RNA)

It is made up of ribose sugar. It's a molecule with only one strand. It is in charge of putting genetic information to work in the cell in order to produce proteins. Its function is similar to that of a messenger.

DNA produces RNA in order to convey genetic information. The information sent to RNA is received, read, decoded, and used to build new proteins. As a result, RNA is in charge of guiding the production of new proteins.

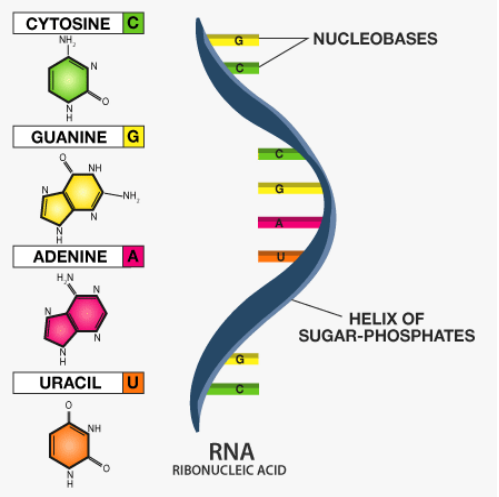


Figure 4.5 Structure of RNA

4.4.2 Importance of Nucleic Acid

1. Nucleic acid are the most vital ,material for cell functioning.
2. Nucleic acids are the storage of genetic information
3. Nucleic acid work for mutation to save the cells and body from threatening diseases.
4. Nucleic acids transfer heredity characters from one generation to another generation.
5. Nucleic acids serve as source of energy in the form of ATP.

4.5 Vitamins

Hopkins discovered in 1912 that there are other nutrients required for optimal development in addition to carbohydrates, proteins, and lipids. Despite the fact that these compounds were only required in modest amounts, they were considered Accessory Growth Factors. These compounds were later given the name Vitamin by Funk. Vitamin B_1 (Thiamin) was discovered by him.

4.5.1 Types of vitamins

On the basis of solubility, there are two types of vitamins.

(i) Water soluble vitamins

Those vitamins which are soluble in water are called water soluble vitamins. These vitamins are obtained from cereals and fruits. Generally, vitamin B (complex) and vitamin C are water soluble vitamins. These vitamins are not stored in body. If we take these vitamins in excess, they cannot harm us. Further, these vitamins are easily excreted from our body.

Figure 4.6 Beriberi affected child (Deficiency of vitamin B)

Figure 4.7 Rickets affected child (Deficiency of vitamin D)

(ii) Fat soluble vitamins

Those vitamins which are soluble in fats and organic solvents are called fat soluble vitamins. Vitamins A, D (sunshine vitamin), E and K are fat soluble vitamins and are stored in the body for long period of time. These vitamins are obtained from lipids. If we take over doses of vitamins, they may harm us and cause diseases. For example excess of vitamin A causes irritation and head ache, vitamin D calcification and pain in bones, vitamin E fatigue and headache and vitamin K liver and kidney diseases.

Table 4.3 Vitamins, their sources, importance and deficiency caused diseases

S.No	Vitamins	Sources	importance	Deficiency diseases
1.	A	Butter, fish, eggs, milk, cheese, carrots etc. It may be obtained from the coloring matter of green and yellow vegetables.	Eyes (form visual pigments), skin	Night blindness (an inability to see in dim light), Xerophthalmia (tear glands cease to function), dryness of skin etc.
2.	B (complex)	Wheat, rice, eggs, milk, meat, liver, nuts, yeast etc.	Nerves, skin	Beriberi (causes inflammation of nerves and heart failure), Dermatitis (red and swollen skin), loss of hairs, tongue inflammation, inflammation of lips, burning of eyes, thickening of skin etc
3.	C (Ascorbic acid)	Oranges, lemon, tomatoes, green peepers etc.	Heal wounds, prevent gum bleeding and cold.	Scurvy (swelling gums and opening of healed wounds).
4.	D (Anthracitic vitamin)	Fish, Milk, butter, mushrooms sunshine etc.	Bones, teeth (controls the metabolism of calcium and phosphorus in body).	Rickets (softening and weakening of bones in children).
5.	E (Sometimes it is called fertility factor)	Plant oils like wheat germ oil, cotton seed oil, corn germ oil, soyabean oil, peanut oil etc. It also occurs in green leafy vegetables.	Maintain cell membrane and proper functioning of reproductive system.	Sterility, haemolysis (fragility of R.B.C) etc.
6.	K	Green vegetables like spinach, alfalfa, cabbage, cereals etc.	Form blood clotting factor.	Hemorrhage (increase blood clotting time).

Society, Technology and Science

Commercial uses of enzymes

On a commercial basis, enzymes are used for a variety of applications. The following are some examples of enzymes and their use in industry:

Commercially, yeast enzymes are utilized in the fermentation of molasses and starch to make alcohol (Ethanol). Diastase, invertase, and zymase are the enzymes in question.

Detergents include microbial enzymes (powder or liquid). Lipases are enzymes that break down fats into more water-soluble molecules. Amylase is a starch-based stain remover. Cellulase breaks down cellulose into glucose, which is a water-soluble substance. Protein stains on garments are broken down by bacterial proteases. As a result, enzyme-based detergents efficiently clean and eliminate all stains and grime.

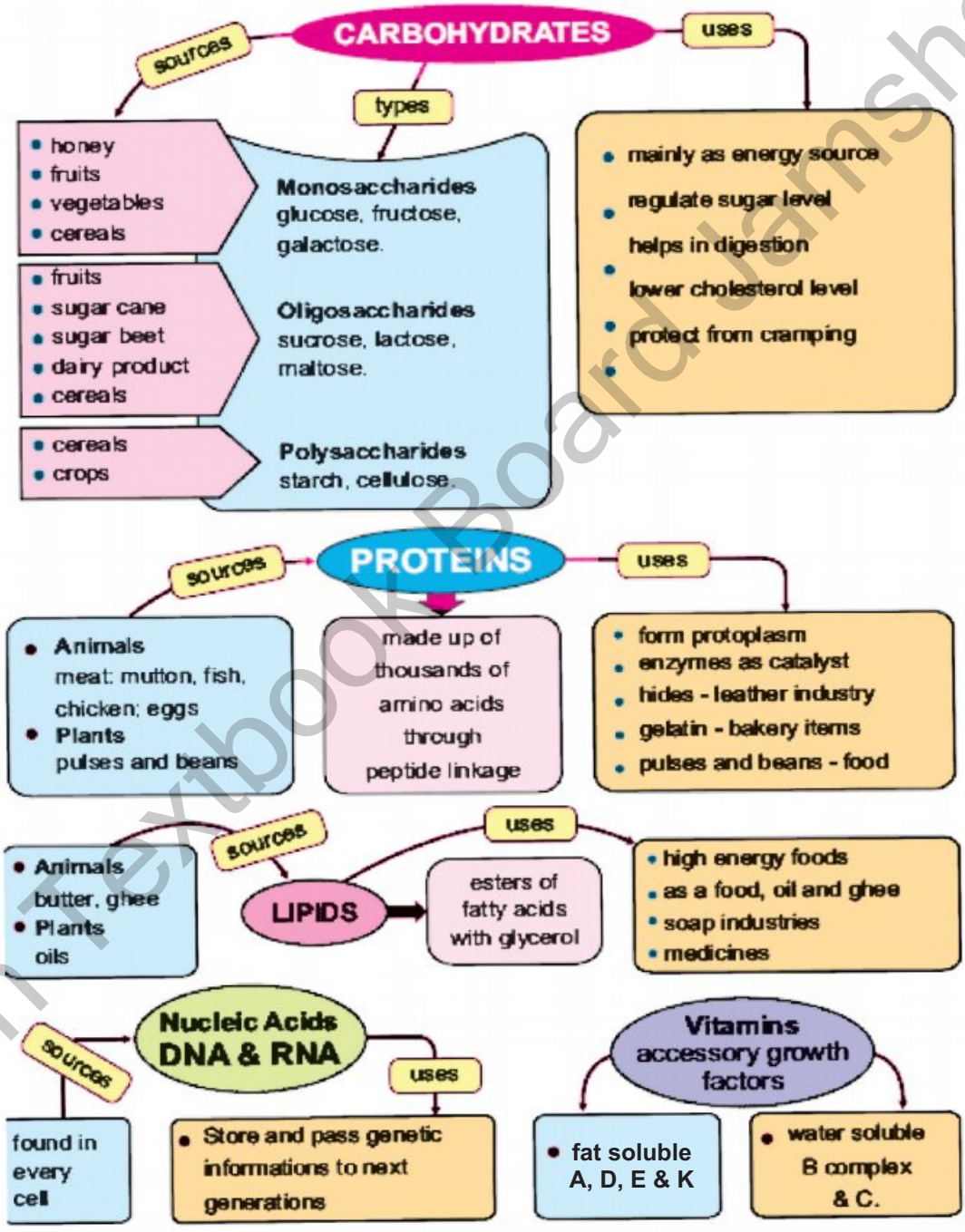
Fruit juices are purified with the help of enzymes. They're used in fruit that's been crushed, such as grapes. By eliminating suspended particles, the yield of the juice produced is increased. It also helps to enhance the color of the fruit skins.

Amylase enzymes are utilized in the production of bread because they can increase the amount of starch in the flour. Even they are capable of converting starch to sugary glucose syrup. This may be used as a sweetener in cuisine as well as in the baking of bread.

The lactase enzyme is used to make ice cream sweeter. Lactose is broken down in milk to galactose and glucose, both of which are sweeter than lactose.

Enzymes are used in the dairy sector to make cheeses, yogurt, and other dairy products, while others are employed to improve the texture or flavor of the product.

CONCEPT DIAGRAM



Summary

- Biochemistry deals with the study of chemical reactions taking place in the living organisms.
- In 1903, first time Carl Neuberg used the word 'Biochemistry'.
- Carbohydrates contain aldehyde group (-CHO) or ketone group (>C=O) along with many hydroxyl groups (-OH).
- The general formula for carbohydrates is $C_x(H_2O)_y$.

  Aldoses, a family of carbohydrates, contain aldehyde group and many hydroxyl groups.

  Ketoses, a family of carbohydrates, contain ketone group and many hydroxyl groups
- On the basis of hydrolysis, carbohydrates are divided into main three types-mono-, di- and trisacchrides.
- Carbohydrates provide 2 to 10 monosacchrides on hydrolysis are called oligosaccharides.
- Carbohydrates provide more than 10 monosacchride's on hydrolysis are called polysaccharides.
- Cellulose and starch are the common plant origin polysaccharides.
- Proteins are the polymers of amino acids.
- Through peptide bonds amino acids are connected with each other in proteins.
- A protein may contain 60 to 6000 amino acid molecules.
- Proteins are building blocks of body.
- Enzymes are proteins which catalyze the biological reactions. Enzymes are also called biocatalysts.
- Haemoglobin is a protein which transports the oxygen to various parts of body.
- Fats are solids at room temperature and increase the cholesterol level in body.
- Nucleic acids are biomolecules which store and transmit hereditary information from parents to children.
- Nucleotides are the monomers of nucleic acids.
- DNA is store house of information. It encodes genetic information and transfers it to generation to generation.
- RNA receives, decodes, reads and uses the information obtained from DNA.
- Vitamin B complex and vitamin C are water soluble vitamins. Excess of these vitamins cannot harm us.
- Fat soluble vitamins (A, D, E and K) are stored in the body. If quantity of these vitamins exceeds, body is affected by various diseases like vitamin A causes irritation and head ache; vitamin D calcification and pain in bones; vitamin E fatigue and headache; vitamin K liver and kidney diseases.

Exercise

SECTION- A: MULTIPLE CHOICE QUESTIONS

(i) **Glucose is:**

(a) vitamin (b) protein (c) carbohydrate (d) lipid

(ii) **The deficiency of vitamin D causes:**

(a) beriberi (b) rickets (c) scurvy (d) haemorhage

(iii) **….. encodes a genetic information.**

(a) R.N.A (b) D.N.A (c) progesterone (d) cholesterol

(iv) **The carbohydrates which contain aldehyde group are called:**

(a) sacchrides (b) ketoses (c) pentoses (d) aldoses

(v) **Amino acids are building blocks of:**

(a) nucleic acids (b) protein (c) vitamins (d) lipid

(vi) **Which one of the following is polysacchride.**

(a) Fructose (b) maltose (c) starch (d) None of these

(vii) **Lactose is:**

(a) Grape sugar (b) honey sugar

(c) milk sugar (d) cane sugar

(viii) **What is true about a peptide?**

(a) It is a protein
(b) It is an anhydride of a carboxylic acids
(c) It is an anhydride of an amine
(d) It is a polyamide.

(ix) **Fats are solids at:**

(a) ordinary room temperature (b) high temperature

(c) higher than 50°C temperature (d) None of these

(x) **Cotton contains … cellulose.**

(a) 30% (b) 65% (c) 85% (d) 95%

SECTION- B: SHORT QUESTIONS:

(i) What are the proteins?

(ii) Define the importance of deoxyribose nucleic acid (DNA).

(iii) Differentiate between fats and oils.

(iv) What are the polysaccharides? How monosaccharides are produced from polysaccharides?

(v) What is peptide bond? How it is formed? And also explain dipeptides and tripeptides.

(vi) Enumerate the important uses of lipids.

(vii) What are the amino acids and give their general structure?

(viii) What is vitamin D? Give its sources and importance.

(ix) Distinguish between fat soluble and water soluble vitamins.

SECTION- C: DETAILED QUESTIONS:

(i) What are the carbohydrates? Explain sources and uses of carbohydrates.

(ii) What are lipids? Write down the sources and uses of lipids.

(iii) Describe vitamins and types of vitamins.

(iv) Describe in detail nucleic acids, RNA and DNA.

(v) How you can justify that deficiency of different types of vitamins causes diseases in human beings