CHAPTER

13

Biochemistry

Animation 13.1: Biochemistry
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Students Learning Outcomes

Students will be able to:

- Distinguish between mono-, di-and trisaccharides. (Understanding);
- Describe the bonding in a protein. (Understanding);
- Explain the sources and uses of carbohydrates, proteins and lipids. (Understanding);
- Differentiate between fats and oils. (Applying); describe the importance of nucleic acids. (Understanding) and
- Define and explain vitamins and their importance. (Understanding).

Introduction

Biochemistry is a field that has a great importance today. It deals with the naturally occurring macromolecules such as carbohydrates, proteins, lipids, nucleic acids and vitamins. These macromolecules are synthesized by living organisms from simple molecules present in the environment. Macromolecules are essential for us as they are reservoirs of energy. For example, carbohydrates we eat, provide us energy. Lipids are major source of energy. They are stored in the body to provide emergency energy supplies. They help us to work during tough times. Proteins not only provide us energy, they help us to stay strong by forming new bones and muscular tissues. Moreover, proteins protect us against the diseases. Nucleic acids are responsible for transmitting genetic information from generation to generation.

13.1 CARBOHYDRATES

Carbohydrates are macromolecules defined as polyhydroxy aldehydes or ketones. They have general formula $C_n(H_2O)_n$.

Carbohydrates are synthesized by plants through photosynthesis process from carbon dioxide and water in the presence of sunlight and green pigment chlorophyll.

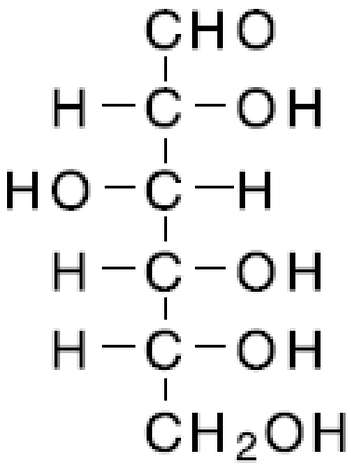
$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$

The glucose is further polymerized to form starch and cellulose. Carbohydrates are classified as

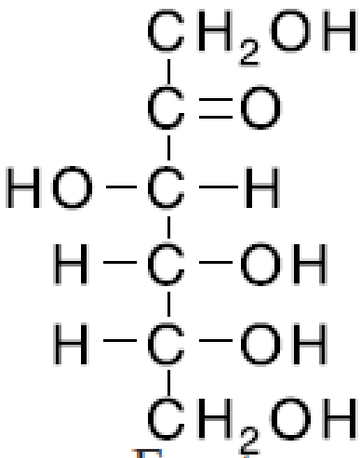
1. Monosaccharides 2. Oligosaccharides 3. Polysaccharides

13.1.1 Monosaccharides

Monosaccharides are the simplest sugars which cannot be hydrolyzed. They consist of 3 to 9 carbon atoms. Therefore, they are classified according to the number of carbon atoms in their molecules as trioses, tetroses, pentoses, hexoses, and so on. The important monosaccharides are hexoses like glucose and fructose, etc. Glucose is a pentahydroxy aldehyde while fructose is pentahydroxy ketone having the open chain structures as follows and general formula $C_6H_{12}O_6$



Glucose



Fructose

Monosaccharides are white crystalline solids. They are soluble in water and have sweet taste. They cannot be hydrolyzed. They are reducing in nature, therefore, these are called reducing sugars.

13.1.2 Oligosaccharides

Oligosaccharides give 2 to 9 *units of monosaccharides on hydrolysis*. Therefore, they are classified as disaccharides, trisaccharides, tetrasaccharides, etc., depending upon the number of units they produce on hydrolysis. The most important oligosaccharides are disaccharides like sucrose. On hydrolysis, sucrose produces one unit of glucose and one unit of fructose.

$$\underset{\text{sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow[\text{heat}]{\text{Dil. HCl}} \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6}$$

These carbohydrates are white, crystalline solids easily soluble in water. They are also sweet in taste. They may be reducing or non-reducing.

13.1.3 Polysaccharides

Polysaccharides are macromolecular carbohydrates consisting of hundreds to thousands of monosaccharides. Examples of polysaccharides are starch and cellulose. They are amorphous solids. They are tasteless and insoluble in water. They are non-reducing in nature.

13.1.4 Sources and Uses of Carbohydrates

Carbohydrates range from simple to complex ones. They have varied sources and uses. Sources of simple sugars e.g. glucose, fructose and galactose are fruits, vegetables, honey and cereals.
Disaccharides are sucrose, lactose and maltose. Sucrose is found in sugar beet, sugar cane and fruits.
Lactose consisting of glucose and galactose is the main sugar in milk and dairy products.
Maltose, a disaccharide of two glucose molecules is found in cereals.
Polysaccharides are starch and cellulose. Starch is found in cereal crops; wheat, barley, maize, rice, etc. Cotton is pure cellulose.

Our body uses carbohydrates in the form of glucose. Glucose is the only form of carbohydrates that is used directly by muscles for energy. It is important to note that brain needs glucose as an energy source, because it cannot use fat for this purpose.
Besides, the energy providing materials, carbohydrates also provide the following usage to our body.

1. They regulate the amount of sugar level in our body. Low sugar level in body results in hypoglycemia.

2. They provide essential nutrients for bacteria in intestinal tract that helps in digestion.
3. Dietary fibre helps to keep the bowel functioning properly.
4. Fibre helps in lowering of cholesterol level and regulates blood pressure.
5. Carbohydrates protect our muscles from cramping.

Carbohydrates as source of energy:

Carbohydrates provide 17 kilojoules of energy per gram. We take carbohydrates as food. Long chains of starch (carbohydrates) are broken down into simple sugars (glucose) by digestive enzymes. The glucose is absorbed directly by small intestine into the blood stream. Blood stream transports the glucose to its place of use, e.g., muscles.

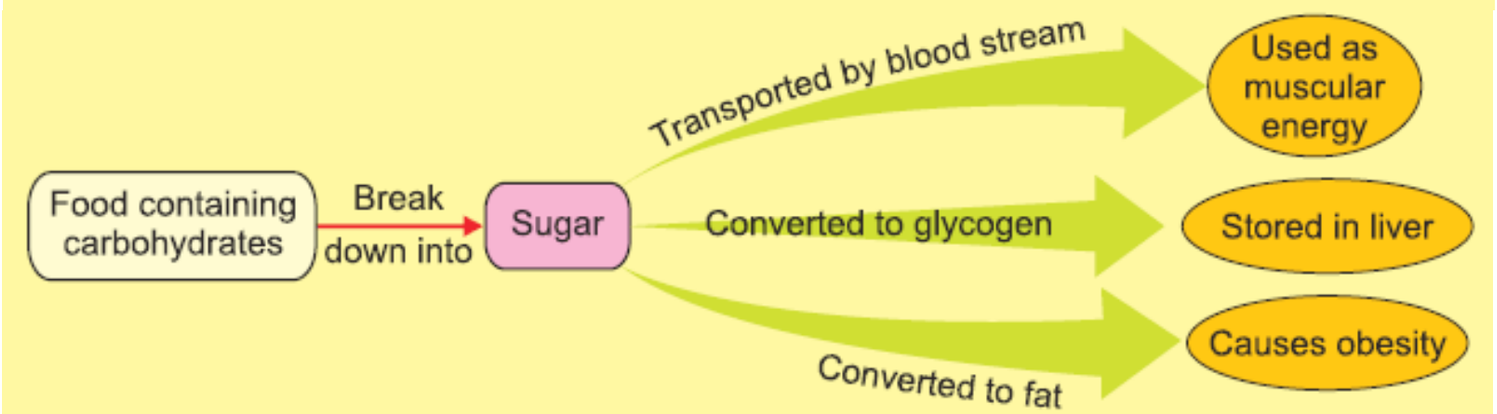


Fig. 13.1 Showing carbohydrates as a source of energy.

Test Yourself 13.1

1. Define carbohydrates.
2. Give the characteristics of disaccharides.
3. Give the balanced equation for the formation of glucose.
4. Draw the structure of glucose.
5. Give the balanced equation for the hydrolysis of sucrose.

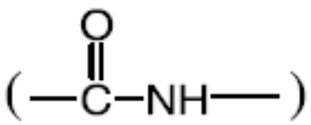
The use of dextrose in drips:

Dextrose is crystallized glucose (natural sugar found in starchy foods). It provides simple carbohydrates to the body that can be easily broken down and processed. Dextrose solution is available in several concentrations. For example, five percent dextrose solution (D5W) consists of 5 grams of dextrose in each 100 ml of solution. It is used to provide fluid replacement and energy to the body.

It contains approximately 170 calories of energy, but does not contain electrolytes. Therefore, electrolytes are added according to requirements in solution. Dextrose is given to patients directly into vein called intravenous (IV) therapy. It is commonly called drip system. It is the fastest way to deliver fluids, electrolytes and medications throughout the body. It prevents air entering into blood stream.

13.2 PROTEIN

Proteins are highly complicated nitrogenous compounds made up of amino acids. Proteins consist of carbon, hydrogen, oxygen, nitrogen and sulphur. They are polymers of amino acids. Amino acids are linked with each other through peptide

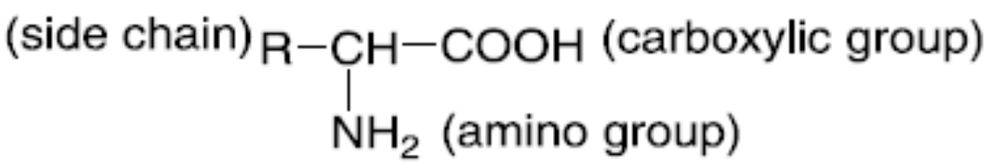
linkage 

Protein has more than 10,000 amino acids. All proteins yield amino acids upon hydrolysis.

Proteins are present in all living organisms. They make up bulk of the non-bony structure of the animal bodies. They are major component of all cells and tissues of animals. About 50% of the dry weight of cell is made up of proteins. They are found in muscles, skin, hair, nails, wool, feathers, etc.

Amino acids

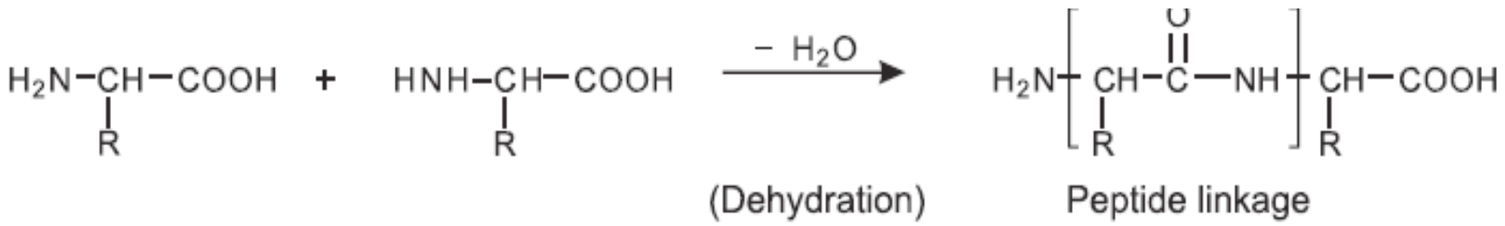
Amino acids are organic compounds consisting of both amino and carboxyl groups. They have the general formula:



Side chain 'R' is different for different amino acids. There are 20 amino acids. Ten out of twenty amino acids can be synthesized by human body. These amino acids are called *non-essential amino acids*. While the other ten which cannot be synthesized by our bodies are called essential amino acids. Essential amino acids are required by our bodies and must be supplied through diet.

13.2.1 Amino acids are Building Blocks of Proteins:

Two amino acids link through peptide linkage. Peptide linkage (bond) is formed by the elimination of water molecule between the amino group of one amino acid and carboxyl acid group of another, such as:



When thousands of amino acids polymerize they form protein.

13.2.2 Sources and Uses of Proteins:

Proteins make up more than 50% of the dry weight of animals. Each protein has its source and carries out a specific function. Sources and uses of protein are as follows:

1. Sources of animal's proteins are meat, mutton, chicken, fish, eggs. These are used as food by human beings as they are essential for the formation of protoplasm.

2. Enzymes are proteins that are produced by the living cells. They catalyze the chemical reactions taking place in the bodies. They are highly specific and have extraordinary efficiency. Many enzymes are used as drugs. They control the bleeding and treat blood cancer.

3. Hides are proteins. These are used to make leather by tanning. Leather is used to make shoes, jackets, sports items, etc.

4. Proteins are found in bones. When bones are heated they give gelatin. Gelatin is used to make bakery items.

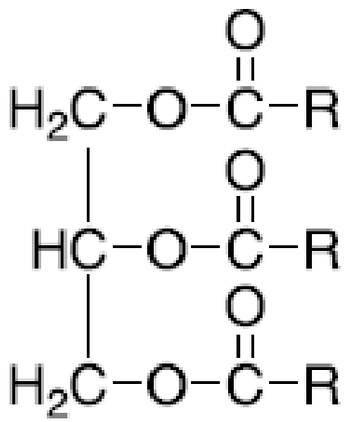
5. Plants also synthesize proteins, such as pulses, beans, etc. These are used as food.

Test Yourself 13.2

1. Which elements are found in proteins?
2. How are amino acids bonded with each other?
3. Give the general formula of amino acid.
4. What do you mean by non-essential amino acids?

13.3 LIPIDS

Lipids are macromolecules made up of fatty acids. Lipids include oils and fats. Oils and fats are esters of long chain carboxylic (fatty) acids with glycerol. These esters are made of three fatty acids, therefore, they are called triglycerides. General formula of triglycerides is as under.



Oils exist in liquid form at room temperature. They are triglycerides of unsaturated fatty acids. While fats exist in solid form at room temperature. They are triglycerides of saturated fatty acids.

13.3.1 Fatty Acids

Fatty acids are building blocks of lipids. They are long chain saturated or unsaturated carboxylic acids. Examples are:

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

These acids form esters (oils or fats) with glycerol in the presence of mineral acids.

13.3.2 Sources and Uses of Lipids

Fats and oils are high energy foods. They are source of vitamins A, D and E. They are used to build brain cells, nerve cells and cell membranes. They are insoluble in water but soluble in organic solvents. The fats stored in the body insulate it as they are poor conductor of heat and electricity.

Fats and oils are synthesized naturally by animals, plants and marine organisms.

1. 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.

2. Animal fats are used in soap industry.
3. Plants synthesize oils and store them in seeds, such as sunflower oil, coconut oil, groundnut oil and corn oil. These oils are used as vegetable oils or ghee for cooking and other purposes.
4. Marine animals like salmon and whales are also source of oils. These oils are used as medicines, e.g. cod liver oil.

Test Yourself 13.3

i. What is the difference between ghee and oil?
ii. Give the characteristics of fats.
iii. Give the sources and uses of animal fats.
iv. Plants are source of oils, justify.

Hydrogenation of vegetable oil:
Vegetable oils are triester of glycerol and fatty acids of unsaturated long chains. These oils are hydrogenated in the presence of nickel catalyst at 250 to 300 °C to form vegetable ghee.

$$\underset{\text{(unsaturated triester)}}{\text{vegetable oil}} + H_2 \xrightarrow[250°C]{Ni} \underset{\text{(saturated triester)}}{\text{vegetable ghee}}$$

Interesting Information

Margarine is produced by adding hydrogen to vegetable oil at 200 °C in the presence of catalyst. Greater the amount of hydrogen added, the more solid the margarine becomes.

Interesting Information

Rancid butter has a foul smell because of butanoic acid. However, the esters of butanoic acid have fruity smell. For example, methyl butanoate smells like apples and ethyl butanoate smells like pineapple.

13.4 NUCLEIC ACIDS

Nucleic acids are essential components of every living cell. They are generally long chain molecules made up of nucleotides. Each nucleotide consists of three components; nitrogenous base, a pentose sugar and a phosphate group. There are two types of nucleic acids:

13.4.1 Deoxyribonucleic Acid (DNA)

DNA consists of deoxyribose sugar. Its structure was discovered by J. Watson and F. Crick in 1953. It is long double stranded molecule consisting of two chains. Each chain is made up of sugar, phosphate and a base. The sugar and phosphate groups make the backbone of the chains and two chains are linked through bases. The chains are wrapped around each other in a double helix form as shown in figure 13.2.

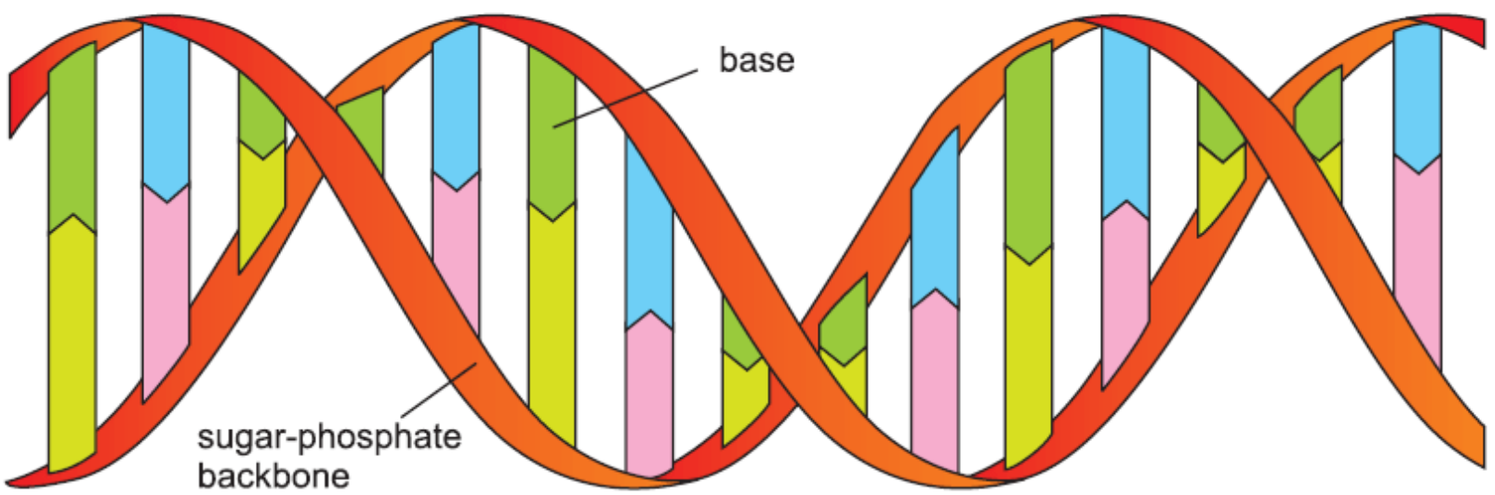


Fig. 13.2 DNA Structure

DNA is the permanent storage place for genetic information in the nucleus of a cell. It carries and stores all genetic informations of the cell. It passes these informations as instructions from generation to generation how to synthesize particular proteins from amino acids. These instructions are 'genetic code of life'. They determine whether an organism is a man or a tree or a donkey and whether a cell is a nerve cell or a muscle cell.

The sequence of nitrogenous bases in DNA determines the protein development in new cells. The function of the double helix formation of DNA is to ensure that no disorder takes place.

DNA carries genes that controls the synthesis of RNA. Errors introduced into the genes synthesize faulty RNA. It synthesizes faulty proteins that do not function the way they are supposed to. This disorder causes genetic diseases.

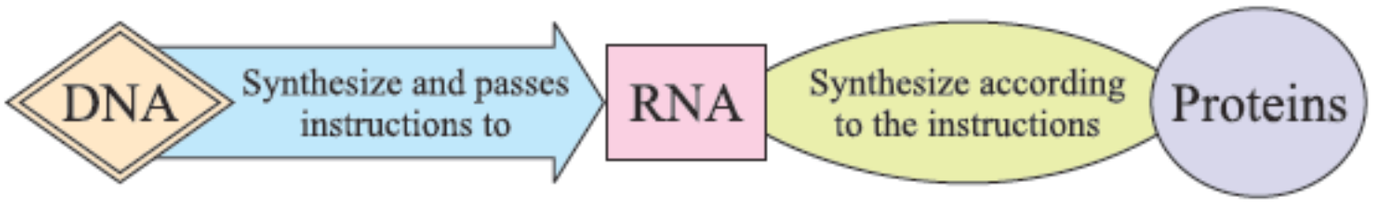
13.4.2 Ribonucleic acid (RNA)

It consists of ribose sugar. It is a single stranded molecule. It is responsible for putting the genetic information to work in the cell to build proteins. Its role is like a messenger.

RNA is synthesized by DNA to transmit the genetic information. RNA receives, reads, decodes and uses the given information to synthesize new proteins. Thus RNA is responsible for directing the synthesis of new proteins.

Interesting Information

Cancer is caused by damage to DNA or interfering with the mechanism of its replication or passing informations. So, by understanding the mechanism of action of DNA, cancer can be cured.



13.5 VITAMINS

In 1912 Hopkins noticed that in addition to carbohydrates, proteins and fats there are other substances needed for normal growth. Although these substances were needed in small quantity, yet these substances were called Accessory Growth Factors. Later Funk proposed the name Vitamin for these substances. He discovered Vitamin Bi (Thiamin).

13.5.1 Types of Vitamins

Vitamins are divided into two types:

(i) Fat Soluble Vitamins

The vitamins which dissolve in fats are called fat soluble vitamins. These are vitamin A, D, E and K. If these vitamins are taken in large quantity, they accumulate in the body and cause diseases. For example, accumulation of vitamin D in the body causes bone-pain and bone-like deposits in the kidney. However, their deficiency also causes diseases. Sources, uses and diseases because of deficiency are provided in the Table 13.1.

Table 13.1: Sources, uses and diseases due to deficiency of some fat soluble vitamins.

No	Vitamin	Sources	Uses	Diseases
i	Vitamin A	Dairy products, eggs, oils and fats, fish. It can also be obtained from the beta-carotene found in green vegetables, carrots and liver.	Maintain the health of the epithelium and acts on the retina's dark adaptation mechanism.	Night blindness, eye inflammation.
ii	Vitamin D	Fish liver, dairy products, oils and fats, Vitamin D is formed in the skin when it is exposed to sunlight.	Has a role in the absorption of calcium, which is essential for the maintenance of healthy bones.	Rickets

(ii) Water Soluble Vitamins

The vitamins that dissolve in water are called water soluble vitamins. These vitamins are B complex (this include 10 vitamins) and vitamin C (ascorbic acid). Water soluble vitamins are rapidly excreted from the body. Hence, these vitamins are not toxic even if taken in large quantity. However, their deficiency causes disease.

13.5.2 Importance of Vitamins

1. Each vitamin plays an important role in the healthy development of our body.
2. Natural vitamins are organic food substances found only in plants and animals. Our body is unable to synthesize vitamins. Because of this, they must be supplied either directly in the diet or by way of dietary supplements. They are absolutely necessary for our normal growth.
3. Vitamins cannot be assimilated without ingesting food. This is why, it is suggested that vitamins must be taken with meal. They help to regulate our body's metabolism.

Test Yourself 13.4

1. What are the disadvantages of fats soluble vitamins?
2. What are advantages of water soluble vitamins?
3. Give examples of fats soluble vitamins.
4. What are the components of nucleotide?
5. What is the function of DNA ?
6. Why is RNA called a messenger?

Commercial uses of enzymes.

Enzymes are used on commercial scale for different purposes.
Common types of enzymes and their role in industry is described as:

1. *Enzymes present in the yeast are commercially used for the fermentation of molasses and starch to produce alcohol (Ethanol). These enzymes are diastase, invertase and zymase.*
2. *Microbial enzymes are used in detergents (powder or liquid). Lipases decompose fats into more water soluble compounds. Amylase removes starch based stains. Cellulase degrades cellulose to glucose, a water soluble compound. Bacterial proteases break down protein stains on the clothes. Thus, enzymes containing detergents clean effectively and remove all stains and dirt.*
3. *Enzymes are used for the purification of fruit juices. They are added to fruit that has been crushed like grapes. This increases the yield of the juice extracted by removing suspended particles. It also improves the colour derived from the fruit skins.*
4. *Amylase enzymes are used in bread making because they can yield more starch of the flour. Even they are efficient enough to convert starch to sweet glucose syrup. This can be used as sweetner in the food as well as bread making.*
5. *Lactase enzyme is used to increase sweetness in ice cream. As lactose in milk is broken down to galactose and glucos ,which are sweeter than lactose.*
6. *In the dairy industry, some enzymes are used for the production of cheeses, yogurt and other dairy products while others are used to improve texture or flavours of the product.*

Key Points

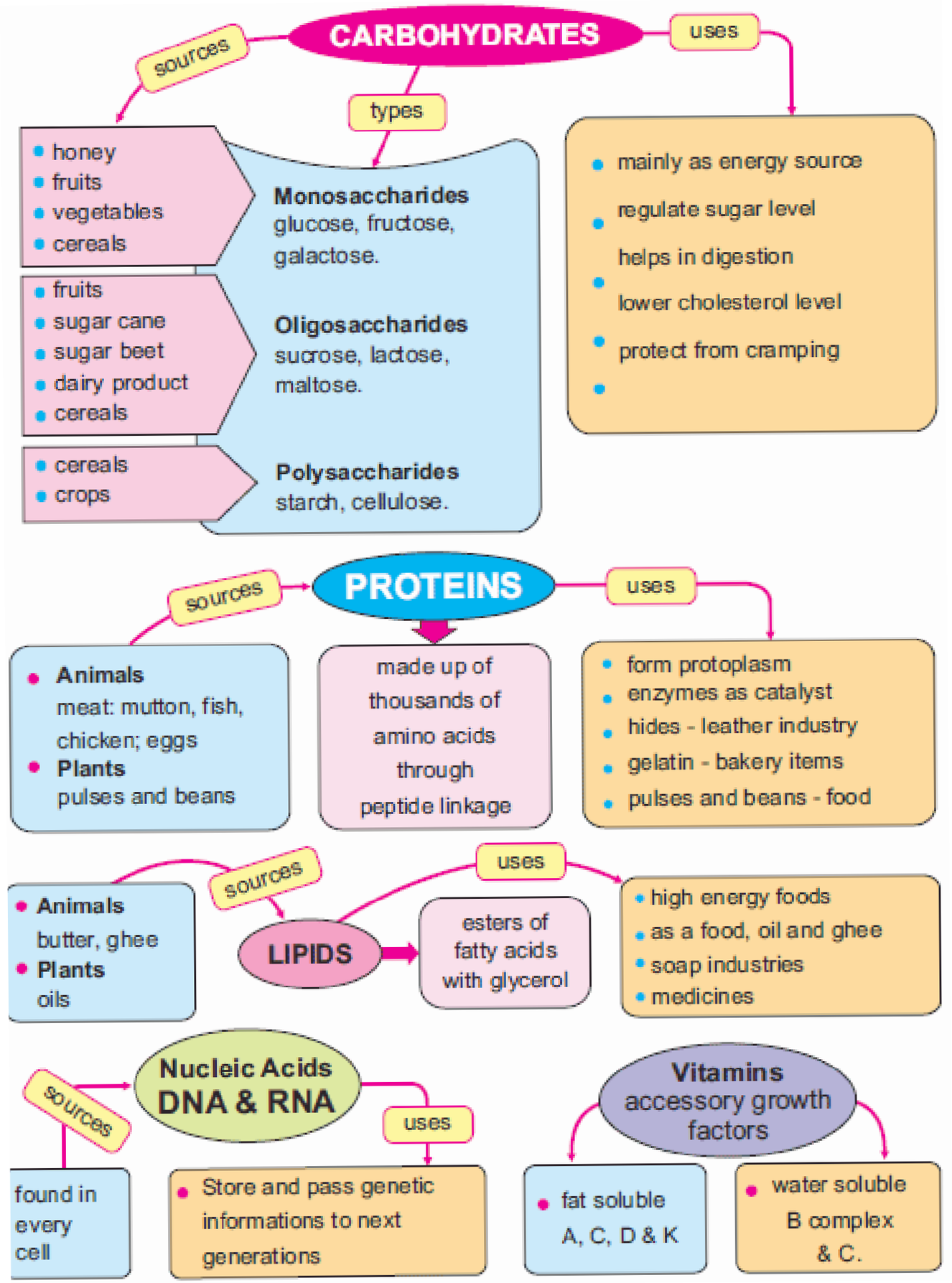
- Carbohydrates are polyhydroxy aldehydes or ketones. They are classified as monosaccharides, oligosaccharides and polysaccharides.
- Monosaccharides are unhydrolyzable consisting of 3 to 9 carbon atoms. They are sweet, crystalline solids soluble in water.
- Oligosaccharides hydrolyze to give 2 to 9 units of monosaccharides. They are also sweet, crystalline solids soluble in water.
- Polysaccharides consist of hundreds to thousands of monosaccharides. They are tasteless, amorphous solids insoluble in water.
- Carbohydrates are naturally synthesized macromolecules. They are found in fruits, vegetables, cereal foods and milk.
- Carbohydrates are main source of energy.
- Proteins are nitrogenous compounds made up of amino acids. Thousands of amino acids are bonded through peptide linkage to form proteins.
- Sources of animal proteins are meat, butter, chicken, fish and eggs.
- Proteins are used by human beings as they are essential to form protoplasm.
- Lipids are macromolecules made up of fatty acids. They are oils and fats.
- Fatty acids are long chain saturated or unsaturated carboxylic acids.
- Lipids are high energy compounds. They are synthesized naturally by animals, plants and microorganisms.
- Nucleic acids are long chain molecules made up of nucleotides.
- Deoxyribonucleic acid (DNA) is a long double stranded molecule and is responsible for transmitting genetic information to next generations.
- Ribonucleic acid (RNA) is a single stranded molecule. It is responsible for formation of proteins.
- Vitamins are necessary growth factors. They are divided into two types:
- Fat soluble (A, D, E and K) and water soluble vitamins (B complex and vitamin C).
- Vitamins play a significant role for proper growth and development of our body.

SKILLS:

Solubility of starch and sugar: solubility of starch and sugar in water can be checked in laboratory as well as at home. Starch is insoluble in water while sugar is soluble in water forming a clear solution in water.

Denaturing of Protein Denaturing of protein means precipitation or coagulation of protein. It can be carried out by heating or changing pH. A simple common method for denaturing of protein is boiling of an egg. White viscous fluid (albumen) present in an egg is protein. When egg is boiled for a few minutes, albumen coagulates i.e. solidifies.

CONCEPT DIAGRAM



Short Answer Questions

1. How plants synthesize carbohydrates?
2. Give the characteristics of monosaccharides.
3. What is the difference between glucose and fructose?
4. Give an example of a disaccharide. How is it hydrolyzed into monosaccharides?
5. Give the characteristics of polysaccharides.
6. Where are the proteins found?
7. Describe the uses of carbohydrates.
8. Lactose is disaccharide; which monosaccharides are present in it?
9. Why are the ten amino acids essential for us?
10. How are proteins formed?
11. How is gelatin obtained?
12. Give the general formula of the lipids.
13. Name two fatty acids with their formulae.
14. Give the types of vitamins.
15. What is the significance of vitamins?
16. Describe the sources and uses of vitamin A.
17. Justify that water soluble vitamins are not injurious to health.
18. What do you mean by genetic code of life?
19. What is the function of DNA?
20. How do you justify that RNA works like a messenger?

Long Answer Questions

1. What are carbohydrates? How monosaccharides are prepared? Give their characteristics.
2. Explain oligosaccharides.
3. What are polysaccharides? Give their properties.
4. Explain the sources and uses of proteins.
5. Explain that amino acids are building blocks of proteins.
6. Explain the sources and uses of lipids.
7. Give the importance of vitamins.
8. Describe the sources, uses and deficiency symptoms of water soluble vitamins.