Biomolecules

Carbon atoms

3

Glucose

A living system grows, sustains and reproduces itself. The most amazing thing about a living system is that it is composed of non-living atoms and molecules. The pursuit of knowledge of what goes on chemically within a living system falls in the domain of biochemistry. Living systems are made up of various complex biomolecules like carbohydrates, proteins, nucleic acids, lipids, etc. Proteins and carbohydrates are essential constituents of our food. These biomolecules interact with each other and constitute the molecular logic of life processes. In addition, some simple

molecules like vitamins and mineral salts also play an important role in the functions of organisms. Carbohydrates: Carbohydrates are primarily produced by plants and form a very large group of naturally occurring organic compounds. Some common examples of carbohydrates are cane sugar, glucose, starch, etc. Most of them have a general formula, $C_x(H_2O)y$, and were considered as hydrates of carbon from where the name carbohydrate was derived. For example, the molecular formula of glucose (C₆H₁₂O₆) fits into this general formula, C₆(H₂O)₆. But all the compounds which fit into this formula may not be classified as carbohydrates. For example acetic acid (CH₃COOH) fits into this general formula, C₂(H₂O)₂ but is not a carbohydrate. Similarly, rhamnose, C₆H₁₂O₅ is a carbohydrate but does not fit in this definition. A large number of their reactions have shown that they contain specific functional groups. Chemically, the carbohydrates may be defined as optically active polyhydroxy aldehydes or ketones or the compounds which produce such units on hydrolysis. Some of the carbohydrates, which are sweet in taste, are also called sugars. The most common sugar, used in our homes is named as sucrose whereas the sugar present in milk is known as lactose. Carbohydrates are also called saccharides (Greek: sakcharon means sugar).

Classification of Carbohydrates: Carbohydrates are classified on the basis of their behaviour on hydrolysis. They have been broadly divided into following three groups. (i) Monosaccharides: A carbohydrate that cannot be hydrolysed further to give simpler unit of polyhydroxy aldehyde or ketone is called a monosaccharide. About 20 monosaccharides are known to occur in nature. Some common examples are glucose, fructose, ribose, etc. (ii) Oligosaccharides: Carbohydrates that yield two to ten monosaccharide units, on hydrolysis, are called oligosaccharides. They are further classified as disaccharides, trisaccharides, tetrasaccharides, etc., depending upon the number of monosaccharides, they provide on hydrolysis. Amongst these the most common are disaccharides. The two monosaccharide units obtained on hydrolysis of a disaccharide may be same or different. For example, one molecule of sucrose on hydrolysis gives one molecule of glucose and one molecule of fructose whereas maltose gives two molecules of only glucose. (iii) Polysaccharides: Carbohydrates which yield a large number of monosaccharide units on hydrolysis are called polysaccharides. Some common examples are starch, cellulose, glycogen, gums, etc. Polysaccharides are not sweet in taste, hence they are also called non-sugars. The carbohydrates may also be classified as either reducing or nonreducing sugars. All those carbohydrates which reduce Fehling's solution and Tollens' reagent are referred to as reducing sugars. All monosaccharides whether aldose or ketose are reducing sugars. Monosaccharides are further classified on the basis of number of carbon atoms and the functional group present in them. If a monosaccharide contains an aldehyde group, it is known as an aldose and if it contains a keto group, it is known as a ketose. Number of carbon atoms constituting the monosaccharide is also introduced in the name as is evident from the examples given in the following Table.

Ketone

Ketotriose

4 Tetrose Aldotetrose Ketotetrose Pentose 5 Aldopentose Ketopentose Aldohexose 6 Ketohexose Hexose 7 Heptose Aldoheptose Ketoheptose Glucose Glucose occurs freely in nature as well as in the combined form. It is present in sweet fruits and honey. Ripe grapes also contain glucose in large amounts. It is prepared as follows: **Preparation of Glucose** 1. From sucrose (Cane sugar): If sucrose is boiled with dilute HCl or H₂SO₄ in alcoholic solution, glucose and fructose are obtained in equal amounts. $C_{12}H_{22}O_{11} + H_2O \xrightarrow{H^*} C_6H_{12}O_6 + C_6H_{12}O_6$

Glucose

Above structure was given on the basis of the following evidences:

 $(C_6H_{10}O_5)_n + nH_2O \xrightarrow{H^+} nC_6H_{12}O_6$

1. Its molecular formula was found to be $C_6H_{12}O_6$.

Saccharic

explained by this structure.

aqueous solution at 371 K.

Pyran

CH₂OH $\dot{c} = 0$

OH

CH2OH D - (-) - Fructose

four carbon atoms.

CH,OH

α − D − Glucose

CH,OH

H

α − D − Glucose

CH₂OH

OН

CH₂OH

HOH,C

OH

paper, lacquers and breweries.

polymers of a-amino acids.

They may contain other functional groups also.

and 1-letter symbols are given in the following Table.

Ala

Val

Gha

Asp

К

Q

known as zwitter ion. This is neutral but contains both positive and negative charges.

In zwitter ionic form, amino acids show amphoteric behaviour as they react both with acids and bases.

(Zwitter ion)

Natural Amino Acids H₂N H

- CH-

(H₂C)₂CH-

(H₃C)₂CH-CH₂

HN=C-NH-(CH₂)₃ NH. H₂N-(CH₂)₄-

HOOC-CH₂-CH₂

HOOC-CH2-

H,N-C-CH₂-CH₂

proteins and lipids.

R-CH-COOH

 NH_2 α-amino acid $(R = side\ chain)$

1. Glyctne 2. Alantne

3. Valtnet

Leucine

7. Lystne*

10. Glutamine

8. Glutamic acid

9. Aspartte actd

:NH2

dipeptide, glycylalanine.

 $H_2N - CH_2 - CO - NH$

Peptide linkage

α-Helix

structure of proteins

HCR

proteins

by the bacteria present in milk.

 $C_{12}H_{22}O_{11} \xrightarrow{Maltase} 2 C_6H_{12}O_6$

They are stored in liver and adipose (fat storing) tissues.

Sources

wheat germ oil,

sunflower oil, etc.

Vitamin K Green leafy vegetables

OH

as in DNA but the fourth one is uracil (U).

OH

 β -D-ribose

Adenine (A)

Cytosine (C)

sugar moiety, we get a nucleotide

OH

OH

SUGAR

SUGAR

OH

CH₂

BASE

Base

with guanine.

Some important Vitamins, their Sources and their Deficiency Diseases

Maltose

Name of

Vitamins

Vitamin E

HOH,C

β-Pleated sheet structure of

 $H_2N - CH_2 - COOH + H_2N - CH - COOH$

Glycylalanine (Gly-Ala)

 CH_3

 CH_3

-сн – соон

ÓН

H OH

Η

HO

HO— H

н — он

equilibrium with open chain structure.

Gluconic acid

related to letter 'd' and 'l'. The meaning of D- and L- notations is as follows.

Different Types of Monosaccharides

Aldehyde

Aldotriose

General Term

Triose

Starch or cellulose Structure of Glucose: Glucose is an aldohexose and is also known as dextrose. It is the monomer of many of the larger carbohydrates, namely starch, cellulose. It is probably the most abundant organic compound on earth. It was assigned the structure given below: CHO (CHOH), CH,OH

2. From starch: Commercially glucose is obtained by hydrolysis of starch by boiling it with dilute H₂SO₄ at 393 K under pressure.

2. On prolonged heating with HI, it forms n-hexane, suggesting that all the six carbon atoms are linked in a straight chain. CHO (CHOH), HI, A CH3-CH2-CH2-CH2-CH3-CH3 (n-Hexane) CH2OH 3. Glucose reacts with hydroxylamine to form an oxime and adds a molecule of hydrogen cyanide to give cyanohydrin. These reactions confirm the

presence of a carbonyl group (>C = O) in glucose. $\begin{array}{ccc} \text{CHO} & & \text{CH} & \stackrel{\text{CN}}{\searrow} \\ \text{(CHOH)}_{4} & \xrightarrow{\text{HCN}} & \text{(CHOH)}_{4} \end{array}$ CHO $(CHOH)_4 \xrightarrow{NH_2OH} (CHOH)_4$ сн,он CH₂OH CH,OH CH,OH

that the carbonyl group is present as an aldehydic group. COOH CHO

4. Glucose gets oxidised to six carbon carboxylic acid (gluconic acid) on reaction with a mild oxidising agent like bromine water. This indicates Br₂ water (CHOH) (CH**OH**)₄

CH,OH CH₂OH

Gluconic acid 5. Acetylation of glucose with acetic anhydride gives glucose pentaacetate which confirms the presence of five –OH groups. Since it exists as a stable compound, five -OH groups should be attached to different carbon atoms. CHO (CHOH)₄ Acetic anhydride (CH-O-C-CH₃)₄

CH,OH

6. On oxidation with nitric acid, glucose as well as gluconic acid both yield a dicarboxylic acid, saccharic acid. This indicates the presence of a primary alcoholic (–OH) group in glucose. CHO COOH (CHOH)₄ ^{Oxidation} (CHOH)₄ Oxidation (CHOH), CH2OH COOH CH,OH

The exact spatial arrangement of different —OH groups was given by Fischer after studying many other properties. Its configuration is correctly represented as I. So gluconic acid is represented as II and saccharic acid as III. CHO COOH Н — ОН н — он но — н $H \longrightarrow OH$ H — OH COOH CH2OH CH2OH

Glucose is correctly named as D(+)-glucose. 'D' before the name of glucose represents the configuration whereas '(+)' represents dextrorotatory nature of the molecule. It should be remembered that 'D' and 'L' have no relation with the optical activity of the compound. They are also not

The letters 'D' or 'L' before the name of any compound indicate the relative configuration of a particular stereoisomer of a compound with respect

are said to have Dconfiguration whereas those which can be correlated to 'L' (–) isomer of glyceraldehyde are said to have L—configuration. In L

asymmetric carbon atom (as shown below) which is compared. As in (+) glucose, —OH on the lowest asymmetric carbon is on the right side which is comparable to (+) glyceraldehyde, so (+) glucose is assigned D-configuration. Other asymmetric carbon atoms of glucose are not considered for

(-) isomer -OH group is on left hand side as you can see in the structure. For assigning the configuration of monosaccharides, it is the lowest

to configuration of some other compound, configuration of which is known. In the case of carbohydrates, this refers to their relation with a particular isomer of glyceraldehyde. Glyceraldehyde contains one asymmetric carbon atom and exists in two enantiomeric forms as shown below. CHO HO --OH CH₂OH CH₂OH (-) - Glyceraldehyde (+) - Glyceraldehyde (+) Isomer of glyceraldehyde has 'D' configuration. It means that when its structural formula is written on paper following specific conventions, the –OH group lies on right hand side in the structure. All those compounds which can be chemically correlated to D (+) isomer of glyceraldehyde

this comparison. Also, the structure of glucose and glyceraldehyde is written in a way that most oxidised carbon (in this case –CHO)is at the top. CHO $H \longrightarrow OH$ но—н CHO — OH — OН CH₂OH CH2OH D- (+) - Glyceraldehyde D-(+) - Glucose

Cyclic Structure of Glucose: The structure (I) of glucose explained most of its properties but the following reactions and facts could not be

3. Glucose is found to exist in two different crystalline forms which are named as a and b. The a-form of glucose (m.p. 419 K) is obtained by

crystallisation from concentrated solution of glucose at 303 K while the b-form (m.p. 423 K) is obtained by crystallisation from hot and saturated

This behaviour could not be explained by the open chain structure (I) for glucose. It was proposed that one of the —OH groups may add to the — CHO group and form a cyclic hemiacetal structure. It was found that glucose forms a six-membered ring in which —OH at C-5 is involved in ring formation. This explains the absence of —CHO group and also existence of glucose in two forms as shown below. These two cyclic forms exist in

2. The pentaacetate of glucose does not react with hydroxylamine indicating the absence of free —CHO group.

The cyclic structure of glucose is more correctly represented by Haworth structure as given below.

compound. It is appropriately written as D-(–)-fructose. Its open chain structure is as shown.

linkage between two monosaccharide units through oxygen atom is called **glycosidic linkage**.

groups of glucose and fructose are involved in glycosidic bond formation, sucrose is a **non reducing sugar**.

CH₂OH

D-(+)-Glucose D-(-)-Fructose

OH

HO

Н

β – D – Fructose

rotation, from dextro (+) to laevo (-) and the product is named as **invert sugar**.

CH,OH

OH

commonly encountered carbohydrates in nature. They mainly act as the food storage or structural materials.

CH₂OH

OH

H

CH₂OH

 α -Link

Branch at Ce

 β -links

glycogen down to glucose. Glycogen is also found in yeast and fungi.

formed by C1–C4 glycosidic linkage whereas branching occurs by C1–C6 glycosidic linkage.

α−D−Glucose

Н OH

Η

Maltose

D-(+)-glucose units held together by C1– C4 glycosidic linkage.

CH,OH

OH

ÓН

Amylose

H

 α -Link

ÓН

 $C_{12} H_{22} O_{11} + H_2 O \longrightarrow C_6 H_{12} O_6 + C_6 H_{12} O_6$

^{−O} H HOH₂C

OH

Glycosidic

linkage

Sucrose

CH₂OH

 α – D – (+) – Glucopyranose

CH,OH

 β -D - (+) - Glucopyranose

monosaccharide found in fruits, honey and vegetables. In its pure form it is used as a sweetner. It is also an important ketohexose.

Fructose: Fructose is an important ketohexose. It is obtained along with glucose by the hydrolysis of disaccharide, sucrose. It is a natural

Structure of Fructose: Fructose also has the molecular formula $C_6H_{12}O_6$ and on the basis of its reactions it was found to contain a ketonic functional group at carbon number 2 and six carbons in straight chain as in the case of glucose. It belongs to D-series and is a laevorotatory

It also exists in two cyclic forms which are obtained by the addition of —OH at C5 to the (>C = O) group. The ring, thus formed is a five

membered ring and is named as furanose with analogy to the compound furan. Furan is a five membered cyclic compound with one oxygen and

1. Despite having the aldehyde group, glucose does not give Schiff's test and it does not form the hydrogensulphite addition product with NaHSO₃.

Η ČH,OH CH₂OH CH₂OH β – D– (+) – Glucose $\alpha - D - (+) - Glucose$ The two cyclic hemiacetal forms of glucose differ only in the configuration of the hydroxyl group at C1, called **anomeric carbon** (the aldehyde carbon before cyclisation). Such isomers, i.e., a-form and b-form, are called anomers. The six membered cyclic structure of glucose is called pyranose structure (a– or b–), in analogy with pyran. Pyran is a cyclic organic compound with one oxygen atom and five carbon atoms in the ring.

HOH, C-C-OH CH2OH Furan α – D – (–) – Fructofuranose β-D-(-) - Fructofuranose The cyclic structures of two anomers of fructose are represented by Haworth structures as given. ČH₄OH HOH,C α – D – (–) – Fructofuranose β – D – (–) – Fructofuranose

Disaccharides: You have already read that disaccharides on hydrolysis with dilute acids or enzymes yield two molecules of either the same or different monosaccharides. The two monosaccharides are joined together by an oxide linkage formed by the loss of a water molecule. Such a

In disaccharides, if the reducing groups of monosaccharides i.e., aldehydic or ketonic groups are bonded, these are non-reducing sugars, e.g., sucrose. On the other hand, sugars in which these functional groups are free, are called reducing sugars, for example, maltose and lactose. (i) Sucrose: One of the common disaccharides is sucrose which on hydrolysis gives equimolar mixture of D-(+)-glucose and D-(-) fructose.

These two monosaccharides are held together by a glycosidic linkage between C1 of a-D-glucose and C2 of b-D-fructose. Since the reducing

Sucrose is dextrorotatory but after hydrolysis gives dextrorotatory glucose and laevorotatory fructose. Since the laevorotation of fructose (-92.4°) is

(ii) Maltose: Another disaccharide, maltose is composed of two a-D-glucose units in which C1 of one glucose (I) is linked to C4 of another glucose unit (II). The free aldehyde group can be produced at C1 of second glucose in solution and it shows reducing properties so it is a reducing sugar.

more than dextrorotation of glucose (+ 52.5°), the mixture is laevorotatory. Thus, hydrolysis of sucrose brings about a change in the sign of

The linkage is between C1 of galactose and C4 of glucose. Free aldehyde group may be produced at C-1 of glucose unit, hence it is also a reducing sugar. CH₂OH CH₂OH HO OH OH Η OH Η Η OH Η OH β− D − Glucose β – D – Galactose Lactose **Polysaccharides:** Polysaccharides contain a large number of monosaccharide units joined together by glycosidic linkages. These are the most

(i) **Starch:** Starch is the main storage polysaccharide of plants. It is the most important dietary source for human beings. High content of starch is found in cereals, roots, tubers and some vegetables. It is a polymer of a-glucose and consists of two components— Amylose and Amylopectin. Amylose is water soluble component which constitutes about 15-20% of starch. Chemically amylose is a long unbranched chain with 200-1000 a-

Amylopectin is insoluble in water and constitutes about 80-85% of starch. It is a branched chain polymer of a-D-glucose units in which chain is

(iii) Lactose: It is more commonly known as milk sugar since this disaccharide is found in milk. It is composed of b-D-galactose and b-D-glucose.

 α -Link Amylopectin (ii) Cellulose: Cellulose occurs exclusively in plants and it is the most abundant organic substance in plant kingdom. It is a predominant constituent of cell wall of plant cells. Cellulose is a straight chain polysaccharide composed only of b-D-glucose units which are joined by glycosidic linkage between C1 of one glucose unit and C4 of the next glucose unit. HOH,C HOH,C

(iii) Glycogen: The carbohydrates are stored in animal body as glycogen. It is also known as animal starch because its structure is similar to amylopectin and is rather more highly branched. It is present in liver, muscles and brain. When the body needs glucose, enzymes break the

Importance of Carbohydrates: Carbohydrates are essential for life in both plants and animals. They form a major portion of our food. Honey has been used for a long time as an instant source of energy by 'Vaids' in ayurvedic system of medicine. Carbohydrates are used as storage molecules as starch in plants and glycogen in animals. Cell wall of bacteria and plants is made up of cellulose. We build furniture, etc. from cellulose in the form of wood and clothe ourselves with cellulose in the form of cotton fibre. They provide raw materials for many important industries like textiles,

Two aldopentoses viz. D-ribose and 2-deoxy-D-ribose are present in nucleic acids. Carbohydrates are found in biosystem in combination with many

Proteins: Proteins are the most abundant biomolecules of the living system. Chief sources of proteins are milk, cheese, pulses, peanuts, fish, meat, etc. They occur in every part of the body and form the fundamental basis of structure and functions of life. They are also required for growth and maintenance of body. The word protein is derived from Greek word, "proteios" which means primary or of prime importance. All proteins are

Amino Acids: Amino acids contain amino (–NH₂) and carboxyl (–COOH) functional groups. Depending upon the relative position of amino group with respect to carboxyl group, the amino acids can be classified as α , β , γ , δ and so on. Only α -amino acids are obtained on hydrolysis of proteins.

All a-amino acids have trivial names, which usually reflect the property of that compound or its source. Glycine is so named since it has sweet taste (in Greek glykos means sweet) and tyrosine was first obtained from cheese (in Greek, tyros means cheese.) Amino acids are generally represented by a three letter symbol, sometimes one letter symbol is also used. Structures of some commonly occurring amino acids along with their 3-letter

11. Asparagine H₂C-CHOH HO-CH₂-13. Serine 14. Cysteine HS-CH-Cys 15. Methtonine H-C-S-CH--CH-M 16. Phenylalantne C.H.-CH. Phe (p)HO-C₄H₄-CH₂-17. Tyrosine Tyr 18. Tryptophan Trp essential amino acid, a = entire structure Classification of Amino Acids: Amino acids are classified as acidic, basic or neutral depending upon the relative number of amino and carboxyl

groups in their molecule. Equal number of amino and carboxyl groups makes it neutral; more number of amino than carboxyl groups makes it basic

rather than simple amines or carboxylic acids. This behaviour is due to the presence of both acidic (carboxyl group) and basic (amino group) groups in the same molecule. In aqueous solution, the carboxyl group can lose a proton and amino group can accept a proton, giving rise to a dipolar ion

Except glycine, all other naturally occurring α -amino acids are optically active, since the a-carbon atom is asymmetric. These exist both in 'D' and 'L' forms. Most naturally occurring amino acids have L-configuration. L-Aminoacids are represented by writing the –NH₂ group on left hand side. Structure of Proteins: You have already read that proteins are the polymers of a-amino acids and they are connected to each other by peptide bond or peptide linkage. Chemically, peptide linkage is an amide formed between –COOH group and –NH₂ group. The reaction between two molecules

of similar or different amino acids, proceeds through the combination of the amino group of one molecule with the carboxyl group of the other. This results in the elimination of a water molecule and formation of a peptide bond –CO–NH–. The product of the reaction is called a dipeptide because it is made up of two amino acids. For example, when carboxyl group of glycine combines with the amino group of alanine we get a

If a third amino acid combines to a dipeptide, the product is called a tripeptide. A tripeptide contains three amino acids linked by two peptide linkages. Similarly when four, five or six amino acids are linked, the respective products are known as tetrapeptide, pentapeptide or hexapeptide, respectively. When the number of such amino acids is more than ten, then the products are called polypeptides. A polypeptide with more than

and more carboxyl groups as compared to amino groups makes it acidic. The amino acids, which can be synthesised in the body, are known as nonessential amino acids. On the other hand, those which cannot be synthesised in the body and must be obtained through diet, are known as essential amino acids Amino acids are usually colourless, crystalline solids. These are water-soluble, high melting solids and behave like salts

protein is not very sharp. Polypeptides with fewer amino acids are likely to be called proteins if they ordinarily have a well defined conformation of a protein such as insulin which contains 51 amino acids. Proteins can be classified into two types on the basis of their molecular shape. (a) **Fibrous proteins**: When the polypeptide chains run parallel and are held together by hydrogen and disulphide bonds, then fibre—like structure is formed. Such proteins are generally insoluble in water. Some common examples are keratin (present in hair, wool, silk) and myosin (present in muscles), etc. (b) Globular proteins: This structure results when the chains of polypeptides coil around to give a spherical shape. These are usually soluble in water. Insulin and albumins are the common examples of globular proteins. Structure and shape of proteins can be studied at four different levels, i.e., primary, secondary, tertiary and quaternary, each level being more complex than the previous one. (i) Primary structure of proteins: Proteins may have one or more polypeptide chains. Each polypeptide in a

> protein has amino acids linked with each other in a specific sequence and it is this sequence of amino acids that is said to be the primary structure of that protein. Any change in this primary structure i.e., the sequence

> (ii) Secondary structure of proteins: The secondary structure of protein refers to the shape in which a long polypeptide chain can exist. They are found to exist in two different types of structures viz. α-helix and β-pleated sheet structure. These structures arise due to the regular folding of the backbone of the polypeptide

> > 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 (helix) with the

In β-pleated sheet structure all peptide chains are stretched out to nearly maximum extension and then laid side by side which are held together by intermolecular hydrogen bonds. The structure resembles the pleated folds of drapery and therefore is known as

of amino acids creates a different protein.

chain due to hydrogen bonding between

–NH group of each amino acid residue hydrogen bonded to the

C=O of an adjacent turn of the helix as shown in the figure.

(iii) Tertiary structure of proteins: The tertiary structure of proteins represents overall folding of the polypeptide chains i.e., further folding of the secondary structure. It gives rise to two major molecular shapes viz. fibrous and globular. The main forces which stabilise the 2° and 3° structures of proteins are

hydrogen bonds, disulphide linkages, van der Waals

(iv) Quaternary structure of proteins: 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

hydrogen bonds are disturbed. Due to this, globules unfold and helix get uncoiled and protein loses its biological activity. This is called

Enzymes: Life is possible due to the coordination of various chemical reactions in living organisms. An example is the digestion of food,

compounds upon which they work. For example, the enzyme that catalyses hydrolysis of maltose into glucose is named as maltase.

with simultaneous reduction of another substrate are named as oxidoreductase enzymes. The ending of the name of an enzyme is -ase.

Mechanism of Enzyme action: Enzymes are needed only in small quantities for the progress of a reaction. Similar to the action of chemical catalysts, enzymes are said to reduce the magnitude of activation energy. For example, activation energy for acid hydrolysis of sucrose is 6.22 kJ

Vitamins: It has been observed that certain organic compounds are required in small amounts in our diet but their deficiency causes specific diseases. These compounds are called vitamins. Most of the vitamins cannot be synthesised in our body but plants can synthesise almost all of them, so they are considered as essential food factors. However, the bacteria of the gut can produce some of the vitamins required by us. All the vitamins are generally available in our diet. Different vitamins belong to various chemical classes and it is difficult to define them on the basis of

structure. They are generally regarded as organic compounds required in the diet in small amounts to perform specific biological functions for

named as sub-groups e.g. B₁, B₂, B₆, B₁₂, etc. Excess of vitamins is also harmful and vitamin pills should not be taken without the advice of

that most of them did not contain amino groups, so the letter 'e' was dropped and the term vitamin is used these days. Classification of Vitamins: Vitamins are classified into two groups depending upon their solubility in water or fat.

supplied regularly in diet because they are readily excreted in urine and cannot be stored (except vitamin B₁₂) in our body.

Some important vitamins, their sources and diseases caused by their deficiency are listed in the following Table:

Deficiency Diseases

weakness

Increased blood clotting time

acids are long chain polymers of nucleotides, so they are also called **polynucleotides**.

 β -D-2-deoxyribose

Thymine (T)

Guanine (G)

Uracil (U)

OH

OH

Phosphodiester

A simplified version of nucleic acid chain is as shown below.

Base

Information regarding the sequence of nucleotides in the chain of a nucleic acid is called its primary structure. Nucleic acids have a secondary structure also. James Watson and Francis Crick gave a double strand helix structure for DNA (Fig. 10.7). Two nucleic acid chains are wound about each other and held together by hydrogen bonds between pairs of bases. The two strands are complementary to each other because the hydrogen bonds are formed between specific pairs of bases. Adenine forms hydrogen bonds with thymine whereas cytosine forms hydrogen bonds

In secondary structure of RNA single stranded helics is present which sometimes foldsback on itself. RNA molecules are of three types and they perform different functions. They are named as

· Sugar — Phosphate-

linkage

Fig. 10.6: Formation of a dinucleotide

– Phosphate -

normal maintenance of optimum growth and health of the organism. Vitamins are designated by alphabets A, B, C, D, etc. Some of them are further

doctor. The term "Vitamine" was coined from the word vital + amine since the earlier identified compounds had amino groups. Later work showed

(i) **Fat soluble vitamins**: Vitamins which are soluble in fat and oils but insoluble in water are kept in this group. These are vitamins A, D, E and K.

(ii) Water soluble vitamins: B group vitamins and vitamin C are soluble in water so they are grouped together. Water soluble vitamins must be

in the body under very mild conditions. This occurs with the help of certain biocatalysts called enzymes. Almost all the enzymes are globular

Denaturation of Proteins: Protein found in a biological system with a unique three-dimensional structure and biological activity is called a native protein. When a protein in its native form, is subjected to physical change like change in temperature or chemical change like change in pH, the

denaturation of protein. During denaturation secondary and tertiary structures are destroyed but primary structure remains intact. The coagulation of egg white on boiling is a common example of denaturation. Another example is curdling of milk which is caused due to the formation of lactic acid

absorption of appropriate molecules and ultimately production of energy. This process involves a sequence of reactions and all these reactions occur

proteins. Enzymes are very specific for a particular reaction and for a particular substrate. They are generally named after the compound or class of

Sometimes enzymes are also named after the reaction, where they are used. For example, the enzymes which catalyse the oxidation of one substrate

and electrostatic forces of attraction.

other is known as quaternary structure.

-NH- groups of the peptide bond.

β-pleated sheet.

mol⁻¹, while the activation energy is only 2.15 kJ mol⁻¹ when hydrolysed by the enzyme, sucrase.

hundred amino acid residues, having molecular mass higher than 10,000u is called a protein. However, the distinction between a polypeptide and a

Fish liver oil, carrots, X e r o p h t h a l m i a (hardening of cornea of Vitamin A butter and milk eye) Night blindness Vitamin B₁ Yeast, milk, green 2 Beri beri (loss of appetite, retarded growth) vegetables and cereals (Thiamine) Cheilosis (fissuring at corners of mouth and Vitamin B₂ Milk, eggwhite, liver, 3 lips), digestive disorders and burning (Riboflavin) kidney sensation of the skin. Yeast, milk, egg yolk, Vitamin B₆ Convulsions (Pyridoxine) cereals and grams Meat, fish, egg and Pernicious anaemia (RBC deficient in Vitamin B₁₂ curd haemoglobin) Vitamin C Citrus fruits, amla and 6 (Ascorbic Scurvy (bleeding gums) green leafy vegetables acid) Rickets (bone deformities in children) and Exposure to sunlight, Vitamin D osteomalacia (soft bones and joint pain in fish and egg yolk adults) Vegetable oils like Increased fragility of RBCs and muscular

Nucleic Acids: Every generation of each and every species resembles its ancestors in many ways. How are these characteristics transmitted from one generation to the next? It has been observed that nucleus of a living cell is responsible for this transmission of inherent characters, also called heredity. The particles in nucleus of the cell, responsible for heredity, are called chromosomes which are made up of proteins and another type of biomolecules called nucleic acids. These are mainly of two types, the deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). Since nucleic

Chemical composition of Nucleic Acids: Complete hydrolysis of DNA (or RNA) yields a pentose sugar, phosphoric acid and nitrogen containing

DNA contains four bases viz. adenine (A), guanine (G), cytosine (C) and thymine (T). RNA also contains four bases, the first three bases are same

heterocyclic compounds (called bases). In DNA molecules, the sugar moiety is β -D-2-deoxyribose whereas in RNA molecule, it is β -D-ribose.

(a) (b) Fig. 10.5: Structure of (a) a nucleoside and (b) a nucleotide Nucleotides are joined together by phosphodiester linkage between 5' and 3' carbon atoms of the pentose sugar. The formation of a typical dinucleotide is shown in the following figure. 5' end of chain BASE CH_2 SUGAR

5′ÇH2

SUGAR

3' end of chain

BASE

Base

Structure of Nucleic Acids: A unit formed by the attachment of a base to 1' position of sugar is known as nucleoside. In nucleosides, the sugar carbons are numbered as 1', 2', 3', etc. in order to distinguish these from the bases. When nucleoside is linked to phosphoric acid at 5'-position of

messenger RNA (m-RNA), ribosomal RNA (r-RNA) and transfer RNA (t-RNA). Fig. 10.7: Double strand helix structure for DNA DNA Fingerprinting: It is known that every individual has unique fingerprints. These occur at the tips of the fingers and have been used for identification for a long time but these can be altered by surgery. A sequence of bases on DNA is also unique for a person and information regarding this is called DNA fingerprinting. It is same for every cell and

(iii) to identify the dead bodies in any accident by comparing the DNA's of parents or

cannot be altered by any known treatment. DNA fingerprinting is now used

(i) in forensic laboratories for identification of criminals.

(ii) to determine paternity of an individual.

commercial table salt ("Iodised" salt).

for preparing the uterus for implantation of fertilised egg.

children.

(iv) to identify racial groups to rewrite biological evolution. **Biological Functions of Nucleic Acids:** DNA is the chemical basis of heredity and may be regarded as the reserve of genetic information. DNA is exclusively responsible for maintaining the identity of different species of organisms over millions of years. A DNA molecule is capable of self duplication during cell division and identical DNA strands are transferred to daughter cells. Another important function of nucleic acids is the protein synthesis in the cell. Actually, the proteins are synthesised by various RNA molecules in the cell but the message for the synthesis of a particular protein is present in DNA. **Hormones:** Hormones are molecules that act as intercellular messengers. These are produced by endocrine glands in the body and are poured directly in the blood stream which transports them to the site of action. In terms of chemical nature, some of these are steroids, e.g., estrogens and androgens; some are poly peptides for example insulin and endorphins and some others are amino acid derivatives such as epinephrine and norepinephrine. Hormones have several functions in the body. They help to maintain the balance of biological activities in the body. The role of insulin in keeping the blood glucose level within the narrow limit is an example of this function. Insulin is released in response to the rapid rise in blood glucose level. On the other hand hormone glucagon tends to increase the glucose level in the blood. The two hormones together regulate the glucose level in the blood. Epinephrine and norepinephrine mediate responses to external stimuli. Growth hormones and sex hormones play role in growth and

development. Thyroxine produced in the thyroid gland is an iodinated derivative of amino acid tyrosine. Abnormally low level of thyroxine leads to hypothyroidism which is characterised by lethargyness and obesity. Increased level of thyroxine causes hyperthyroidism. Low level of iodine in the

Steroid hormones are produced by adrenal cortex and gonads (testes in males and ovaries in females). Hormones released by the adrenal cortex play

development of secondary male characteristics (deep voice, facial hair, general physical constitution) and estradiol is the main female sex hormone. It is responsible for development of secondary female characteristics and participates in the control of menstrual cycle. Progesterone is responsible

diet may lead to hypothyroidism and enlargement of the thyroid gland. This condition is largely being controlled by adding sodium iodide to

very important role in the functions of the body. For example, glucocorticoids control the carbohydrate metabolism, modulate inflammatory

cortex does not function properly then one of the results may be Addison's disease characterised by hypoglycemia, weakness and increased susceptibility to stress. The disease is fatal unless it is treated by glucocorticoids and mineralocorticoids. Hormones released by gonads are responsible for development of secondary sex characters. Testosterone is the major sex hormone produced in males. It is responsible for

reactions, and are involved in reactions to stress. The mineralocorticoids control the level of excretion of water and salt by the kidney. If adrenal