KARPAGAM ACADEMY OF HIGHER EDUCATION

(Deemed to be University Established Under Section 3 of UGC Act 1956)
Pollachi Main Road, Eachanari Post, Coimbatore - 641 021. INDIA
Phone : 0422-6471113-5, 6453777 Fax No : 0422 -2980022-3
Email : info@karpagam.com Web : www.kahedu.edu.in

DEPARTMENT OF BIOCHEMISTRY

SYLLABUS

SUBJECT NAME : MOLECULES OF LIFE
SUB.CODE : 17BCU101
SEMESTER : I
CLASS : I B.Sc., BIOCHEMISTRY

Programme Objective

The study of the structure and properties of carbohydrates, enzymes, proteins, vitamins, genes and fats form the basis of biomolecules. It provides impressive knowledge about the structure, properties, classification and functions of various biomolecules such as carbohydrates, lipids, amino acids, nucleic acids and vitamins.

Programme Learning Outcome

At the end of this course, students will be able to understand the properties shared by all living things and chemistry of water and its unique, describe the general strategies for carbohydrates, lipids, amino acids, nucleic acids and vitamins synthesis and this encourages them to describe their physical and chemical properties and their function in living organisms.

Unit 1

The foundations of biochemistry and water: Cellular and chemical foundations of life. Unique properties, weak interactions in aqueous systems, ionization of water, buffers, water as a reactant and fitness of the aqueous environment.

Unit 2

Carbohydrates and glycobiology: Monosaccharides - structure of aldoses and ketoses, ring structure of sugars, conformations of sugars, mutarotation, anomers, epimers and enantiomers, structure of biologically important sugar derivatives, oxidation of sugars. Formation of disaccharides, reducing and non-reducing disaccharides. Polysaccharides – homo- and heteropolysaccharides, structural and storage polysaccharides. Structure and role of proteoglycans, glycoproteins and glycolipids (gangliosides and lipopolysaccharides). Carbohydrates as informational molecules, working with carbohydrates.

Unit 3

Lipids :Building blocks of lipids - fatty acids, glycerol, ceramide. Storage lipids - triacyl glycerol and waxes. Structural lipids in membranes – glycerophospholipids, galactolipids and sulpholipids, sphingolipids and sterols, structure, distribution and role of membrane lipids. Plant steroids. Lipids as signals, cofactors and pigments.

Unit 4
Amino acids and Nucleic acids: Structure and classification, physical, chemical and optical properties of amino acids. Nucleotides - structure and properties. Nucleic acid structure – Watson-Crick model of DNA. Structure of major species of RNA - mRNA, tRNA and rRNA. Nucleic acid chemistry - UV absorption, effect of acid and alkali on DNA. Other functions of nucleotides - source of energy, component of coenzymes, second messengers.

Unit 5
Vitamins: Structure and active forms of water soluble and fat soluble vitamins, deficiency diseases and symptoms, hypervitaminosis

TEXT BOOKS

Ambika, S, 2004. Fundamentals of Biochemistry for Medical Students, CIT Chennai.

Deb C., 2011, Fundamentals of Biochemistry, 9th edition New Central Book Agency, Calcutta.

Jain, J.L, Sunjay Jain and Nitin Jain, 2005. Fundamentals of Biochemistry, S. Chand and Company Ltd, New Delhi.

REFERENCE BOOKS

Lehninger L, D.L. Nelson and M.M. Cox, 2012, Principles of Biochemistry, 6th edition WH Freeman and Company, New York.

Lubert Stryer, L. 2009, Biochemistry, W.H. Freeman and Company, New York.

Robert K. Murray, Daryl K. Granner, Peter A. Mayes, Victor W. Rodwell, 2012,
Harper's Biochemistry, 29th edition, McGraw-Hill Medical, London.

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LECTURE PLAN
DEPARTMENT OF BIOCHEMISTRY

STAFF NAME : Dr.J.ANITHA
SUBJECT NAME : MOLECULES OF LIFE   SUB.CODE : 17BCU101
SEMESTER : I   CLASS : I B.Sc (BC)

S. No	Duration of period	Topics covered	Books referred	Page No	Web page referred
UNIT-I					
1	1	The foundations of biochemistry and water	T1	3-11	-
2	1	Cellular foundations of life	T1	12-21	-
3	2	Chemical foundations of life			
4	1	Unique properties			-
5	1	Weak interactions in aqueous systems	T1	47-58	-
6	2	Ionization of water, buffers	T2	13-15; 60-68	-
7	1	Water as a reactant	T1	69-70	-
8	1	Fitness of the aqueous environment	T1	90	-
Total	10				
UNIT-II					
1	2	Carbohydrates and glycobiology: Monosaccharides - structure of aldoses and ketoses, ring structure of sugars	T1	238-249	-
2	1	Conformations of sugars, mutarotation, anomers			
3	2	Epimers and enantiomers, structure of biologically important sugar derivatives	T2	39-47	-
4	1	Oxidation of sugars. Formation of disaccharides	T1	245-246	-
5	4	Reducing and non-reducing disaccharides	T2	48	-
6	2	Polysaccharides – homo and heteropolysaccharides, structural and storage polysaccharides	T1 T2	247-254 49-52	-
7	1	Structure and role of proteoglycans	T1	255-258	-
8	2	Glycoproteins and glycolipids (gangliosides and lipopolysaccharides)	T2	56-59 259-261	-
9	1	Carbohydrates as informational molecules, working with carbohydrates	T1	261-265 267-268	-

			T2	52-53	
Total	14				
UNIT-III					
1	1	Lipids :Building blocks of lipids - fatty acids, glycerol, ceramide	T1	343-345	-
2	2	Storage lipids - triacyl glycerol and waxes	T1 T2	346-348, 56, 290	-
3	2	Structural lipids in membranes – glycerophospholipids	T1	348-350	-
4	2	galactolipids and sulpholipids,	T1	351-353	-
5	1	sphingolipids and sterols	T1	353-355	-
6	2	structure, distribution and role of membrane lipids.			
7	1	Plant steroids	T1	360-361	-
8	1	Lipids as signals	T2	66	-
9	2	cofactors and pigments	T1	357-359	-
Total	14				
UNIT-IV					
1	2	Amino acids and Nucleic acids: Structure and classification	T1	75-84	-
2	1	physical, chemical and optical properties of amino acids			
3	2	Nucleotides - structure and properties	T1 T2	273-278 89-94	-
4	1	Nucleic acid structure – Watson-Crick model of DNA	T1 T2	279-280 95-96	-
5	2	Structure of major species of RNA - mRNA, tRNA and rRNA	T1 T2	1008-1020 97-100	-
6	2	Nucleic acid chemistry - UV absorption, effect of acid and alkali on DNA	T1	291-293	-
7	2	Other functions of nucleotides - source of energy, component of coenzymes, second messengers.	T1	300-302	-
Total	12				
UNIT-V					
1	1	Structure and active forms of water soluble	T2	191-214	-
2	1	Structure and active forms of water soluble	T2	191-214	-
3	2	Structure and active forms of fat soluble	T1	360-363	-
4	2	Water soluble vitamins, deficiency diseases and symptoms,	T2	178-190	-
5	2	Fat soluble vitamins, deficiency diseases and symptoms,			
6	1	Hypervitaminosis	-	-	W1
Total	9				

Previous year ESE question paper discussion-					
1	1	Previous year question paper discussion	-	-	-
Total	1				
Grand Total	60				

TEXT BOOKS

T1- Lehninger L, D.L. Nelson and M.M. Cox, 2012, Principles of Biochemistry, 6th edition WH Freeman and Company, New York.

T2- Deb C., 2011, Fundamentals of Biochemistry, 9th edition New Central Book Agency, Calcutta.

Web

W1- http://en.wikipedia.org/wiki/hypervitaminosis

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UNIT 1

The foundations of biochemistry and water: Cellular and chemical foundations of life. Unique properties, weak interactions in aqueous systems, ionization of water, buffers, water as a reactant and fitness of the aqueous environment.

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The foundations of biochemistry and water

Fifteen to twenty billion years ago, the universe arose as a cataclysmic eruption of hot, energy-rich subatomic particles. Within seconds, the simplest elements (hydrogen and helium) were formed. As the universe expanded and cooled, material condensed under the influence of gravity to form stars. Some stars became enormous and then exploded as supernovae, releasing the energy needed to fuse simpler atomic nuclei into the more complex elements. Thus were produced, over billions of years, the Earth itself and the chemical elements found on the Earth today. About four billion years ago, life arose—simple microorganisms with the ability to extract energy from organic compounds or from sunlight, which they used to make a vast array of more complex biomolecules from the simple **elements and compounds on the Earth's surface.**

Biochemistry asks how the remarkable properties of living organisms arise from the thousands of different lifeless biomolecules. When these molecules are isolated and examined individually, they conform to all the physical and chemical laws that describe the behavior of inanimate matter—as do all the processes occurring in living organisms. The study of biochemistry shows how the collections of inanimate molecules that constitute living organisms interact to maintain and perpetuate life animated solely by the physical and chemical laws that govern the nonliving universe

Cellular Foundations

The unity and diversity of organisms become apparent even at the cellular level. The smallest organisms consist of single cells and are microscopic. Larger, multicellular organisms contain many different types of cells, which vary in size, shape, and specialized function. Despite these obvious differences, all cells of the simplest and most complex organisms share certain fundamental properties, which can be seen at the biochemical level. Cells Are the Structural and Functional Units of All Living Organisms Cells of all kinds share certain structural features. The plasma membrane defines the periphery of the cell, separating its contents from the surroundings. It is composed of lipid and protein molecules that form a thin, tough, pliable, hydrophobic barrier around the cell. The membrane is a barrier to the free passage of inorganic ions and most other charged or polar compounds. Transport proteins in the plasma membrane allow the passage of certain ions and molecules; receptor proteins transmit signals into the cell; and membrane enzymes participate in some reaction pathways. Because the individual lipids and proteins of the plasma membrane are not covalently linked, the entire structure is remarkably flexible, allowing changes in the shape and size of the cell. As a cell grows, newly made lipid and protein molecules are inserted into its plasma membrane; cell division produces two cells, each with its own membrane. This growth and cell division (fission) occurs without loss of membrane integrity.

Introduction

1. All organisms are assembled from simple atoms and molecules
2. Atoms in soils are very similar to atoms in a tree
3. How do some atoms form life, and others do not - answer lies in structure of the atoms and how they interact

Chemical Foundations of Life

1. the atoms of all living things flow from one living thing to another
2. not all chemicals sustain life, some damage it, such as pollutants
3. mountain pines - ozone damage from pollution yellows the needles
4. the pollution started around world war II
5. matter is things that takes up space and has mass
6. core of atom - nucleus, has protons and neutrons, protons have + charge
7. around neutrons are electrons in motion, have a - charge
8. neutral atoms have same number of protons as electrons
9. atoms of a given element have same number of protons
10. isotopes are atoms of the same element with a different mass because they have a different number of neutrons
11. isotope compositions of water and air can allow scientists to see where pollution is coming from
12. to measure pollutants - one can directly measure plant stems and needle growth
13. compounds are made of two or more elements, chemically combined
14. ozone is made of 3 atoms of oxygen per molecule
15. electrons move in energy levels or shells around a nucleus, each shell can hold only specific numbers of atoms
16. when sodium loses its lone electron in its outer shell to chlorine, it leaves the sodium with full shells and chlorine with full shells, but they have opposite charge so they stick together in an ionic bond
17. many atoms share electrons to form covalent bonds - the electrons move around both atoms within combined shells
18. when hydrogen bonds to water the electrons are not shared equally, causing oxygen to be slightly negative and hydrogen slightly positive - giving water molecules polarity
19. the soil near the surface has more organic material, deeper soils have more inorganic material
20. rain washes pollutants from the sky into the soil, damaging roots
21. the newest young trees are more resistant to the pollution because they are produced from parents that survived the initial pulse of pollution before pollution controls went into effect

Water

Water is a essential for life, miracle of nature, and sustainer of life. Its important is known since there is no life without water. From water only the origin of life has started. All aspects of cell structure and function are adapted to the physical and chemical properties of water. Few examples:

- Structure and function of biomolecules.

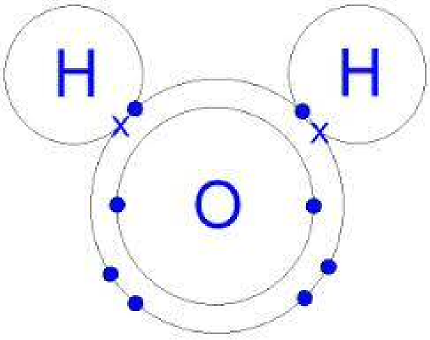
- Assemblage of cellular components
- Including enzymes and other proteins, nucleic acid and lipids
- Its used for biochemical reactions
- Transporting substances
- Maintaining body temperature
- Dissolving waste products for excretion and producing digestive fluids.

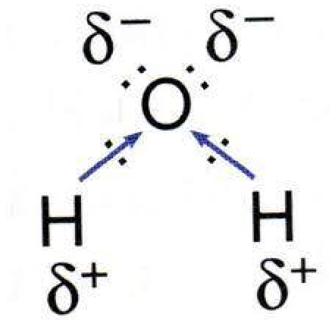
1. water is the most important chemical on earth - makes up most of the body of all organisms
2. everything needs water, near dry coasts people are trying to desalinate water to make fresh water from ocean water
3. the large scale cost of heating water to evaporate and condense it to make it pure is too high to make it worthwhile
4. **water's polarity makes it difficult to boil**
5. as pressure is decreased (in a vacuum) the water boils at lower temperatures which are easier to attain
6. as the water boils away, the brine that remains is very corrosive to the metal piping of the desalination plant
7. an ion trap is used to screen the water before it goes into the desalination plant so that the water cannot corrode the aluminum piping in the plant
8. the desalination plant will need a power plant nearby to run the facility, waste heat from the power plant would be used to heat the water to run the desalination plant

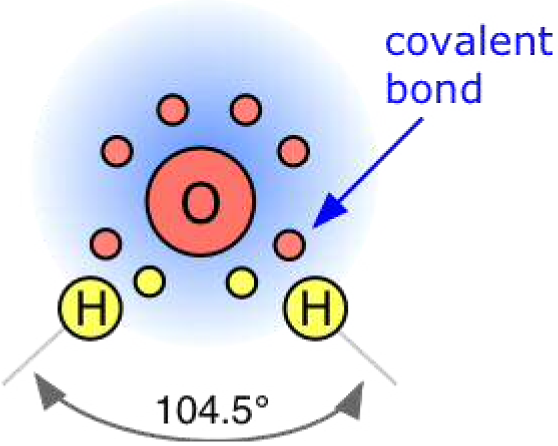
- No other substance on earth is as abundant as water (1/3)
- It is almost everywhere in air, clouds, oceans, lakes, rivers, springs or glaciers.
- Water is nearly 6 times as abundant as all other substances put together.
- None of other occurs in 3 states ie ., solid, liquid and gaseous- at the same time.
- It is water that had conditioned our climate. In hot weather, it absorbs heat and in cold, it gives up heat.
- Without water, our planet would be cooled to subzero temperatures long ago and all forms of life would have perished.
- In human, 70 % of weight is due to water (Intracellular fluids and extracellular fluids).
- 2.8 litres of water is excreted as urine so nearly 3 liters of water ahs to be taken every day. Metabolic water is also produced in our body.
- Water balance is very important. If the output of water significantly exceeds or decrease, dehydration and edema occurs respectively.
- By knowing the importance of water, NASA has launched a satellite named *Aqua* to study the effect of water in various forms on climate.

Structure of water

In water, each hydrogen nucleus is bound to the central oxygen atom by a pair of electrons that are shared between them The Molecular formula of water is H_2O: One molecule of water has two hydrogen atoms covalently bonded to a single oxygen atom.
The structure of water molecule is depicted as follows







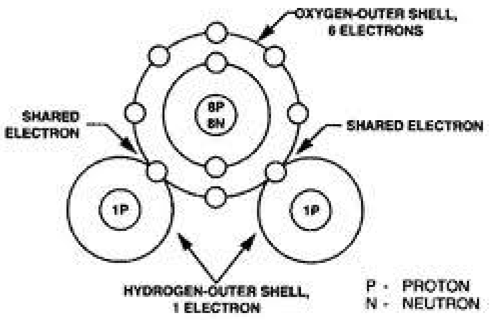
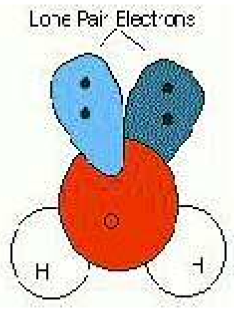
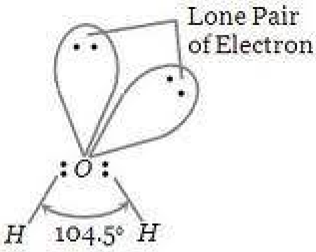
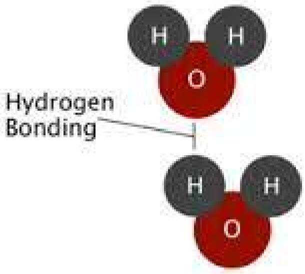


Figure 2-II. Illustration of a Molecule (H_2O)

Tetra hedral arrangement of water:
The water molecule maintains a bent shape (bent at 107.5 degrees actually) because of two considerations. First the tetrahedral arrangment around the oxygen and Second the presence of lone pair electrons on the oxygen.
These are the electrons that are not involved in the covalent bonds. The pairs of electrons are left alone. In our picture they are represented by the double dots. These lone pairs are very negative - containing two negative electrons each - and want to stay away from each other as much as possible. These repulsive forces act to push the hydrogens closer together.







The bond angles for water are not 109.5. Because of the presence of the very negative lone pair electrons, the two hydrogens are squeezed together as the two lone pairs try to get away from each other as far as possible. The resulting angle gives water a 104.5 bond angle and the resulting tetrahedron "looks" BENT.

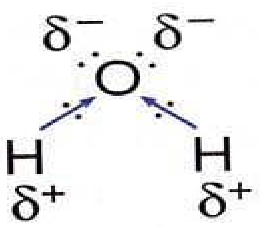
Properties of water:

- Have high melting point- **0˚C**
- Have high boiling point- **100˚C**
- Heat of vaporization - 540
- Surface tension – 72.8

Vapourization of ice is called sublimation, vapourization of liquid is called vaporation.Both occur more rapidly as the temperature increases. Evaporation occur when water is heated above its boiling point. Heat lost at the point of evaporation returns at the point of condensation. Such phenomena play an important role in meteorological cycle.
Some of the other properties of water are

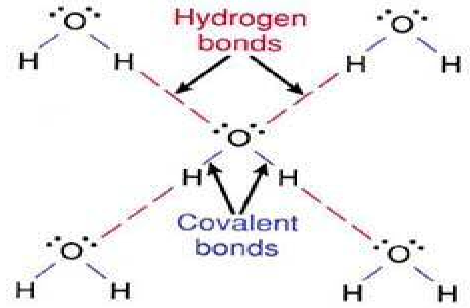
- Water is a liquid at standard temperature and pressure.
- Water is is tasteless and odorless.
- Water is transparent in the visible electromagnetic spectrum.
- Water can act as either an acid or a base.
- Water is a universal solvent, dissolving many substances found in nature.

Electric dipole nature of Water:
The hydrogens *are* slightly positive. They get this way because of the "electronegativity" of oxygen. Electronegativity is a measure of how much one atom wants to have electrons, and oxygen wants to have electrons more than hydrogen does. Oxygen has a higher electronegativity. Because of this difference in electronegativity, the electrons in the covalent bonds between oxygen and hydrogen get pulled slightly toward the oxygen. This leaves the hydrogens a little bit electron-deficient and thus slightly positive. We can draw this polarization like this:



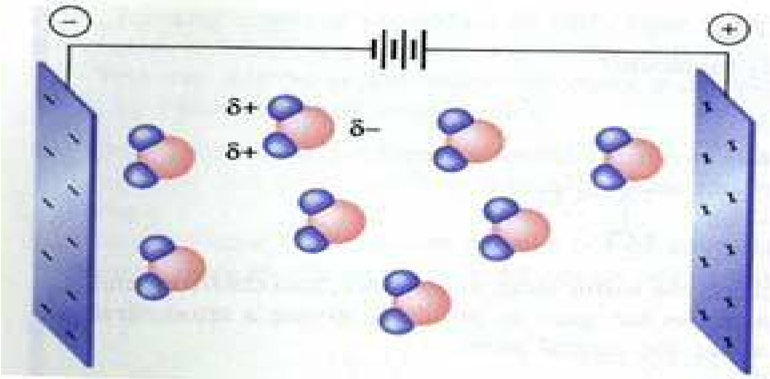
The polarization is responsible for allthe properties of water. Because water has a slightly negative end and a slightly positive end, it can interact with itself and form a highly organized 'inter-molecular' network. The positive hydrogen end of one molecule can interact favorably with the negative lone pair of another water molecule. This interaction is call "Hydrogen Bonding". It is a type of weak electrostatic attraction (positive to negative).

Because each and every one of the water molecules can form four hydrogen Bonds, an elaborate network of molecules is formed.

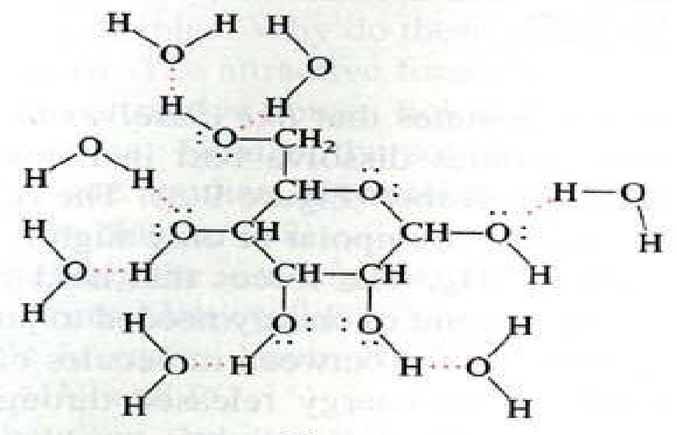


Hydrogen bonding in water.

The polarity also allows water interact with an electric field:



And to interact with other polar molecules - which is how substances become dissolved in water.



Glucose
(soluble in water)

Important properties of water that have physiological relevance:

(i) Expansion of freezing:

- Almost all substance contracts on water but water expands: If it contracts it become heavier and sink to bottom. So all water in earth would gradually become ice
- **When temperature of water is raised above 0˚C its volume decreases upto 4˚C and thereafter it increases. So water has a minimum volume at 4˚C. So 4˚C is a critical** point above or below the volume change. (heating/cooling- it increases its volume)
- Almost all substances increases in volume when they melted but volume of ice decreases when melted.

(ii) Uniquely high surface tension

Surface tension: The surface of liquid tends to contact as much as possible- Water has highest surface tension of 72.8 of any known liquid. This is the reason why water rises to unusually high levels in narrow capillary tubes. This has great importance in physiology.

(iii) Uniquely high heat capacity

There occurs a smaller temperature rise in water as compared to most other substances, when a given amount of heat is applied. Thus, water acts as a temperature buffer. It maintains its temperature more successfully than most other substances. Thus, it has high heat capacity (1,000 cal/g).

(iv) High solvent power

Water has positive and negative charge and this polarity is responsible for its high solvent capacity. Universal solvent facilitates chemical reactions both outside and within biological system.

Weak Interactions in Aqueous Systems

Hydrogen bonds between water molecules provide the cohesive forces that make water a liquid at room temperature and that favor the extreme ordering of molecules typical of crystalline water (ice). Polar biomolecules dissolve readily in water because they can replace energetically favorable water-water interactions with even more favorable water-solute interactions (hydrogen bonds and electrostatic interactions). In contrast, nonpolar biomolecules interfere with favorable water-water interactions and are poorly soluble in water. In aqueous solutions, these molecules tend to cluster together to minimize the energetically unfavorable effects of their presence.

• **The attractions between adjacent water molecules gives liquid water great internal cohesion** and leads to its unusual properties.

• **The e**lectrostatic interaction between the hydrogen atom of one water molecule and the oxygen atom of another yields the hydrogen bond.

• **This bonds are relatively weak with bond dissociation energies of about 23 kJ/mol** compared to 470 kJ/mol for the covalent hydroxyl bond. The tetrahedral arrangement of the water molecule gives each molecule the potential to form 4 hydrogen bonds (1 for each hydrogen and 2 for the oxygen)

• **In the liquid state, the disorganization of the molecules yields an average of 3.4 bond**s per molecule

- In the solid state, the fixed nature of the molecule in the crystal lattice yields the full hydrogen bonding compliment
- The number of hydrogen bonds possible in both states results in the high melting and boiling points for water
- This hydrogen bonding pattern gives water unique properties: – High boiling and melting points – High surface tension – A lower density in the solid state compared to the liquid state

Ionization of Water, Weak Acids, and Weak Bases

Although many of the solvent properties of water can be explained in terms of the uncharged H_20 molecule, the small degree of ionization of water to hydrogen ions (H^+) and hydroxide ions (OH^+) must also be taken into account. Like all reversible reactions, the ionization of water can be described by an equilibrium constant. When weak acids or weak bases are dissolved in water, they can contribute H^+ by ionizing (if acids) or consume H^+ by being protonated (if bases); these processes are also governed by equilibrium constants. The total hydrogen ion concentration from all sources is experimentally measurable; it is expressed as the pH of the solution. To predict the state of ionization of solutes in water, we must take into account the relevant equilibrium constants for each ionization reaction. We therefore turn now to a brief discussion of the ionization of water and of weak acids and bases dissolved in water.

BUFFER

A buffer is an aqueous solution that has a highly stable pH. If you add acid or base to a buffered solution, its pH will not change significantly. Similarly, adding water to a buffer or allowing water to evaporate will not change the pH of a buffer.

MAKE A BUFFER

A buffer is made by mixing a large volume of a weak acid or weak base together with its conjugate. A weak acid and its conjugate base can remain in solution without neutralizing each other. The same is true for a weak base and its conjugate acid.

BUFFERS WORK

When hydrogen ions are added to a buffer, they will be neutralized by the base in the buffer. Hydroxide ions will be neutralized by the acid. These neutralization reactions will not have much effect on the overall pH of the buffer solution. When you select an acid for a buffer solution, try to choose an acid that has a pK_a close to your desired pH. This will give your buffer nearly equivalent amounts of acid and conjugate base so it will be able to neutralize as much H^+ and OH^- as possible.

A buffer is a solution containing either a weak acid and its salt or a weak base and its salt, which is resistant to changes in pH. In other words, a buffer is an aqueous solution of either a weak acid and its conjugate base or a weak base and its conjugate acid.

Buffers are used to maintain a stable pH in a solution, as they can neutralize small quantities of additional acid of base. For a given buffer solution, there is a working pH range and a set amount of acid or base that can be neutralized before the pH will change. The amount of acid or base that can be added to a buffer before changing its pH is called its buffer capacity.

The Henderson-Hasselbalch equation may be used to gauge the approximate pH of a buffer. In order to use the equation, the initial concentration or stoichiometric concentration is entered instead of the equilibrium concentration.

The general form of a buffer chemical reaction is:

$$HA \quad H^+ + A^-$$

Also Known As: Buffers are also called hydrogen ion buffers or pH buffers.

EXAMPLES OF BUFFERS

- blood - contains a bicarbonate buffer system
- TRIS buffer
- phosphate buffer

As stated, buffers are useful over specific pH ranges. For example, here is the pH range of common buffering agents:

Buffer	pKa	pH range
citric acid	3.13., 4.76, 6.40	2.1 to 7.4
acetic acid	4.8	3.8 to 5.8
KH_2PO_4	7.2	6.2 to 8.2
borate	9.24	8.25 to 10.25
CHES	9.3	8.3 to 10.3

When a buffer solution is prepared, the pH of the solution is adjusted to get it within the correct effective range. Typically a strong acid, such as hydrochloric acid (HCl) is added to lower the pH of acidic buffers. A strong base, such as sodium hydroxide solution (NaOH), is added to raise the pH of alkaline buffers.

HOW BUFFERS WORK

In order to understand how a buffer works, consider the example of a buffer solution made by dissolving sodium acetate into acetic acid. Acetic acid is (as you can tell from the name) an acid: CH_3COOH, while the sodium acetate dissociates in solution to yield the conjugate base, acetate ions of CH_3COO^-. The equation for the reaction is:

$$CH_3COOH(aq) + OH^-(aq) \qquad CH_3COO^-(aq) + H_2O(aq)$$

If a strong acid is added to this solution, the acetate ion neutralizes it:

$$CH_3COO^-(aq) + H^+(aq) \qquad CH_3COOH(aq)$$

This shifts the equilibrium of the initial buffer reaction, keeping the pH stable. A strong base, on the other hand, would react with the acetic acid.

UNIVERSAL BUFFERS

Most buffers work over a relative narrow pH range. An exception is citric acid because it has three pKa values. When a compound has multiple pKa values, a larger pH range becomes available for a buffer. It's also possible to combine buffers, providing their pKa values are close (differing by 2 or less), and adjusting the pH with strong base or acid to reach the required range. For example, Mclvaine's buffer is prepared by combining mixtures of Na_2PO_4 and citric acid. Depending on the ratio between the compounds, the buffer may be effective from pH 3.0 to 8.0. A mixture of citric acid, boric acid, monopotassium phosphate, and diethyl barbituic acid can cover the pH range from 2.6 to 12

Water as a Reactant

Water is not just the solvent in which the chemical reactions of living cells occur; it is very often a direct participant in those reactions. The formation of ATP from ADP and inorganic phosphate is a condensation reaction in which the elements of water are eliminate. The compound formed by this condensation is called ; phosphate anhydride. Hydrolysis reactions are responsible for the enzymatic depolymerization of proteins, carbohydrates, and nucleic acids ingested in the diet. Hydrolytic enzymes (hydrolases) catalyzes the addition of the elements of water to the bonds that connect mono meric subunits in these macromolecules. Hydrolysis reactions are almost invariably exergonic, and the formation of cellular: polymers from their subunits by simple reversal of hydrolysis would be endergonic and as such does not occur. We shall see that cells circum vent this thermodynamic obstacle by coupling the endergonic condensation reactions to exergonic processes, such as breakage of the anhydride bond in ATP.

Water and carbon dioxide are the end products of the oxidation of fuels such as glucose. The overall reaction of this process can be summarized by the equation:

$C_6H_{12}O_6 + 6O2 - > 6CO_2 + 6H_2O$ Glucose

The "metabolic water" thus formed from stored fuels is actually enough to allow some animals in very dry habitats (gerbils, kangaroo rats, camels) to survive without drinking water for extended periods.

Green plants and algae use the energy of sunlight (represented by h v, the energy of light of frequency v; h is Planck's constant) to split water in the process of photosynthesis:

$$2\,H_2O + 2A \xrightarrow{hv} O_2 + 2AH_2$$

In this reaction, A is an electron-accepting species, which varies with the type of photosynthetic organism.

The Fitness of the Aqueous Environment for Living Organisms

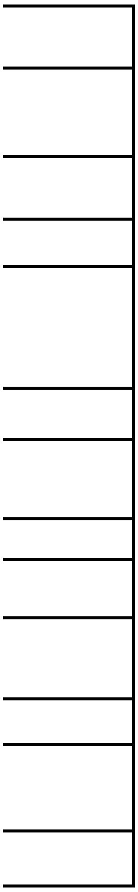
Organisms have effectively adapted to their aqueous environment and have even evolved means of exploiting the unusual properties of water. The high specific heat of water (the heat energy required to raise the temperature of 1 g of water by 1) is useful to cells and organisms because it allows water to act as a "heat buffer," permitting the temperature of an organism to remain relatively constant as the temperature of the air fluctuates and as heat is generated as a by product of metabolism. Furthermore, some vertebrates exploit the high heat of vaporization of water by using (thus losing) excess body heat to evaporate sweat. The high degree of internal cohesion of liquid water, due to hydrogen bonding, is exploited by plants as a means of transporting dissolved nutrients from the roots to the leaves during the process of transpiration. Even the lower density of ice than of liquid water has important biological consequences in the life cycles of aquatic organisms. Ponds freeze from the top down, and the layer of ice at the top insulates the water below from frigid air, preventing the pond (and the organisms in it) from freezing solid. Most fundamental to all living organisms is the fact that many physical and biological properties of cell macromolecules, particularly the proteins and nucleic acids, derive from their interactions with water molecules of the surrounding medium. The influence of water on the course of biological evolution has been profound and determinative. If life forms have evolved elsewhere in the universe, it is unlikely that they resemble those of earth, unless their extraterrestrial origin is also a place in which plentiful liquid water is available as solvent.

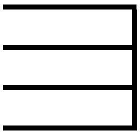
Karpagam Academy of Higher Education
Department of Biochemistry
I B.Sc., Biochemistry
17BCU101- Molecules of life
Prepared By Dr. J. Anitha

Question number	Unit	Question	Option I	Option II	Option	Option IV	Answer
1	1	The general formula for polysaccharides	**$(C_6H_{10}O_5)$n**	$(C_6H_{12}O_6)$n	$(C_6H_{12}O_5)$	$(C_6H_{10}O_6)$n	**$(C_6H_{10}O_5)$n**
2	1	The simplest of aldoses is	Glucose	Arabin	**Glycerald**	Ribose	**Glyceraldehyde**
3	1	The number of isomers of	4	8	12	**16**	**16**
4	1	The epimers of glucose	Fructose	**galactose**	ribose	deoxy ribose	**galactose**
5	1	The reducing property of glucose is due to	OH group	Hemiacetal	**Aldehyde**	Acid group	**Aldehyde group**
6	1	Oxidation of glucose with hydrogen peroxide gives	**Glucuronic acid**	Glucaric acid	Gluconic	Tartaric acid	**Glucuronic acid**
7	1	Human heart muscle	D-	D-	**D-**	L-	**D-Xylose**
8	1	Lobry de Bruyn Alberda	**Glucose**	Lactos	sucro	starch	**Glucose with**
9	1	Fucose is a	Glycoside	**Hexose**	Triose	methyl pentose	**Hexose**
10	1	Example for a fructosan is	**Starch**	inulin	cellul	Chitin	**Starch**
11	1	Glucose reacts with phenyl hydrazine to give	**osazone**	glucocyanohy	gluconic	None	**osazone**
12	1	The dissacharide which does not show mutarotation	**Sucrose**	Lactose	Maltose	Cellobiose	**Sucrose**
13	1	Glycoside are found in many	Vitamins	**drugs**	Minerals	Nucleoproteins	**drugs**
14	1	Trehalose is a	**Disaccharide**	trisaccharide	poly saccharide	Monosaccharide	**Disaccharide**
15	1	Galactose on oxidation with conc. HNO3 produces	Gluconic acid	saccharic acid	**mucic**	both a and b	**mucic acid**
16	1	Digitonin is a	Protein	**Glycos**	lipid	Alkaloid	**Glycoside**
17	1	The following sugar exhibits inversion of optical rotation	Sucrose	glucose	fruct	**Lactose**	**Lactose**
18	1	Hydrolysis of sucrose yields	Glucose	Glucose	Maltose	**Fructose +**	**Fructose + glucose**
19	1	Osazone formation is due to	Presence	presen	**prese**	presence	**presence of**
20	1	Raffinose is composed of	Glucose,	glucos	**gluco**	glucose	**glucose,**

21	1	A reducing disaccharide	maltose				**trehalose**
22	1	The reagent used for distinguishing a reducing	**Benedict's reagent**	Barfoed's	Fehling's	Seliwanoff's	**Benedict's reagent**
23	1	The arrangements of sugars into D&L configuration is based upon their	**Glyceraldehydes**	lactic acid	glucose	Ribose	**Glyceraldehydes**
24	1	Starch is composed of	**Maltose**	Glucos			**Maltose**
25	1	β (1-4) linkage is present in	Starch	Glycog	**cellul**	Amylos	**cellulose**
26	1	Amylose contains glucose	100-200	200-	**300-**	500-600	**300-400**
27	1	Each branch of amylopectin is an interval of glucose	14-20	**24-30**	34-40	44-50	**24-30**
28	1	The end product of hydrolysis of strach by	**Soluble starch**	Glucose	dextrin	maltose	**Soluble starch**
29	1	The component present in starch that gives blue colour	**Amylase**	amylopectin	amylose	Fructose	**Amylase**
30	1	Amylopectins are present in	**Hyaluronic acid**	strach	sucrose	Glycogen	**Hyaluronic acid**
31	1	Erythrodextrin gives colour	blue	violet	**red**	no	**red**
32	1	Cellulose is made up of	α-glucose	**β-**	fruct	mannose	**β-glucose**
33	1	Hyaluronidase is the	homopoly	**hetero**	disac	trisaccha	**heteropolysacc**
34	1	In place of glucuronic acid chondroitin sulphate B	gluconic acid	glucamic acid	**iduro**	Sulphon	**iduronic acid**
35	1	Heparin has a molecular	14,000	15,000	####	**17,000**	**17,000**
36	1	Blood group subtances	lactose	maltos	**fucos**	Mucosa	**fucose**
37	1	The component of cartilage & cornea is	**Keratosulphate**	chondroitin	cadmium	antimony	**Keratosulphate**
38	1	The compound which is an acid mucopolysacchride	dicoumarol	EDTA	**Hyaluroni**	Glycogen	**Hyaluronic acid**
39	1	A polymer of N-acetylated glucosamine is	dextran	heparin	**chitin**	dextrin	**chitin**
40	1	Change in optical rotation is	specific	**mutar**	epim	Anomeri	**mutarotation**
41	1	The polymer of fructose is	Strach	glycog	cellul	**insulin**	**insulin**
42	1	The glycosaminoglycan which acts as an	**Heparin**	Hyaluronic	dextrin	dermatin sulphart	**Heparin**
43	1	The glycosaminoglycan which is present in synovial	Heparin	**Hyalu**	dextri	dermatin	**Hyaluronic acid**
44	1	2 carbon epimer of glucose	Fructose	galacto	**Man**	Ribulose	**Mannose**
45	1	The mirror images are	Enantiom	Anome	**Epim**	All	**Epimers**
46	1	Chitin is composed of	fructofura	D-	**N-**	Fructose	**N-acetyl**
47	1	the mucopolysaccharide	heparin	chondr	**hyal**	cellulose	**hyaluronic acid**
48	1	All carbohydrates contain	sodium	burnin	**heati**	Hydroch	**heating with**
49	1	The buffer acting in the osazone reaction is	**phenyl hydrazine**	acetic acid	sodium	sodium acetate	**phenyl hydrazine**

50	1	The monosaccharide units of hyaluronic acid are	**glucuronic acid &**	glucuronic	iduronic	iduronic acid &	**glucuronic acid & N-acetyl D-**
51	1	NASA has launched a satellite named ____ to	***Aqua***	*Hydro*	*Hi*	*Water*	***Aqua***
52	1	Water is	Tasteless	Odorless	**both a and**	low boiling	**both a and b**
53	1	The epimers of glucose	Fructose	**galactose**	ribose	deoxy ribose	**galactose**
54	1	The dissacharide which does not show mutarotation	**sucrose**	lactose	malto	cellobiose	**sucrose**
55	1	Polysaccharides produce more than ___	Eight	**Ten**	Six	five	**Ten**
56	1	Stereoisomer classified into	**Two**	Three	Four	Seven	**Two**
57	1	D isomer rotate the plane polarized light to	Left	**Right**	DL mixtu	Interchange	**Right**
58	1	Isomers formed by the interchange of H and OH groups on Carbon atom2, 3	Monomer	Dimer	**Epimers**	Tetramer	**Epimers**
59	1	Sugars forming six member ring are known as	Furanose	racemixture	mannose	**Pyranose**	**Pyranose**
60	1	Maltose is composed of	**two glucose**	three glucos	four gluco	six glucose	**two glucose molecules**





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DEPARTMENT OF BIOCHEMISTRY

SUBJECT NAME : MOLECULES OF LIFE
SUB.CODE : 17BCU101
SEMESTER : I
CLASS : I B.Sc., BIOCHEMISTRY

UNIT 2

Carbohydrates and glycobiology: Monosaccharides – structure of aldoses and ketoses, ring structure of sugars, conformations of sugars, mutarotation, anomers, epimers and enantiomers, structure of biologically important sugar derivatives, oxidation of sugars. Formation of disaccharides, reducing and non-reducing disaccharides. Polysaccharides – homo– and heteropolysaccharides, structural and storage polysaccharides. Structure and role of proteoglycans, glycoproteins and glycolipids (gangliosides and lipopolysaccharides). Carbohydrates as informational molecules, working with carbohydrates.

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Ambika, S, 2004. Fundamentals of Biochemistry for Medical Students, CIT Chennai.

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Jain, J.L, Sunjay Jain and Nitin Jain, 2005. Fundamentals of Biochemistry, S. Chand and Company Ltd, New Delhi.

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CARBOHYDRATES AND GLYCOBIOLOGY

Introduction:

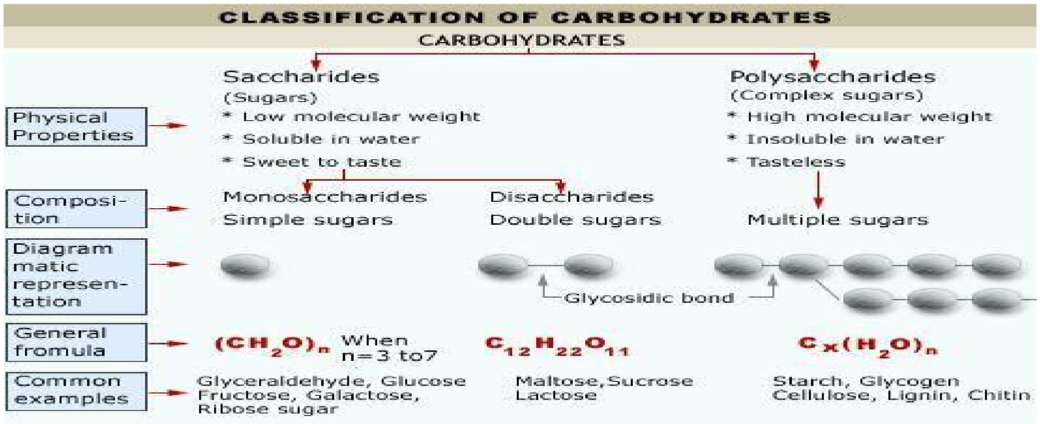
A carbohydrate is an organic compound with the empirical formula $C_m (H_2O)_n$; that is, consists only of carbon, hydrogen, and oxygen, with hydrogen: oxygen atom ratio of 2:1 (as in water).

FUNCTIONS OF CARBOHYDRATES:

Carbohydrates participate in a wide range of functions

- They are the most abundant dietary source of energy (a Cal/S) for all organisms.
- Carbohydrates are precursors for many organic compounds (fats, amino acids).
- Carbohydrates (as glycoproteins and glycol-lipids) participate in the structure of cell membrane and cellular functions such as cell growth, adhesion and fertilization.
- They are structural components of many organisms. These include the fiber (cellulose) of plants, exoskeleton of some insects and the cell wall of microorganisms.
- Carbohydrates also serve as the storage form of energy (glycogen) to meet the immediate energy demands of the body.

CLASSIFICATION:



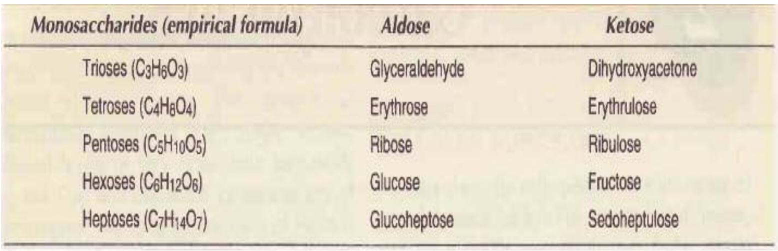
CLASSIFICATION OF CARBOHYDRATES

CARBOHYDRATES

	Saccharides (Sugars)		Polysaccharides (Complex sugars)
Physical Properties	* Low molecular weight * Soluble in water * Sweet to taste		* High molecular weight * Insoluble in water * Tasteless
Composition	Monosaccharides Simple sugars	Disaccharides Double sugars	Multiple sugars
Diagram matic represen-tation		Glycosidic bond	
General formula	$(CH_2O)_n$ When n=3 to7	$C_{12}H_{22}O_{11}$	$C_x(H_2O)_n$
Common examples	Glyceraldehyde, Glucose Fructose, Galactose, Ribose sugar	Maltose,Sucrose Lactose	Starch, Glycogen Cellulose, Lignin, Chitin

MONOSACCHARIDES:

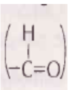
- Monosaccharides (Greek: mono-one) are the simplest group of carbohydrates and are often referred to as simple sugars.
- They have the general formula $Cn(H_2O)_n$, and they cannot be further hydrolysed.
- The monosaccharides are divided into different categories, based on the functional group and the number of carbon atoms.



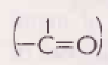
Monosaccharides (empirical formula)	Aldose	Ketose
Trioses ($C_3H_6O_3$)	Glyceraldehyde	Dihydroxyacetone
Tetroses ($C_4H_8O_4$)	Erythrose	Erythrulose
Pentoses ($C_5H_{10}O_5$)	Ribose	Ribulose
Hexoses ($C_6H_{12}O_6$)	Glucose	Fructose
Heptoses ($C_7H_{14}O_7$)	Glucoheptose	Sedoheptulose

Classification of monosaccharide with selected examples

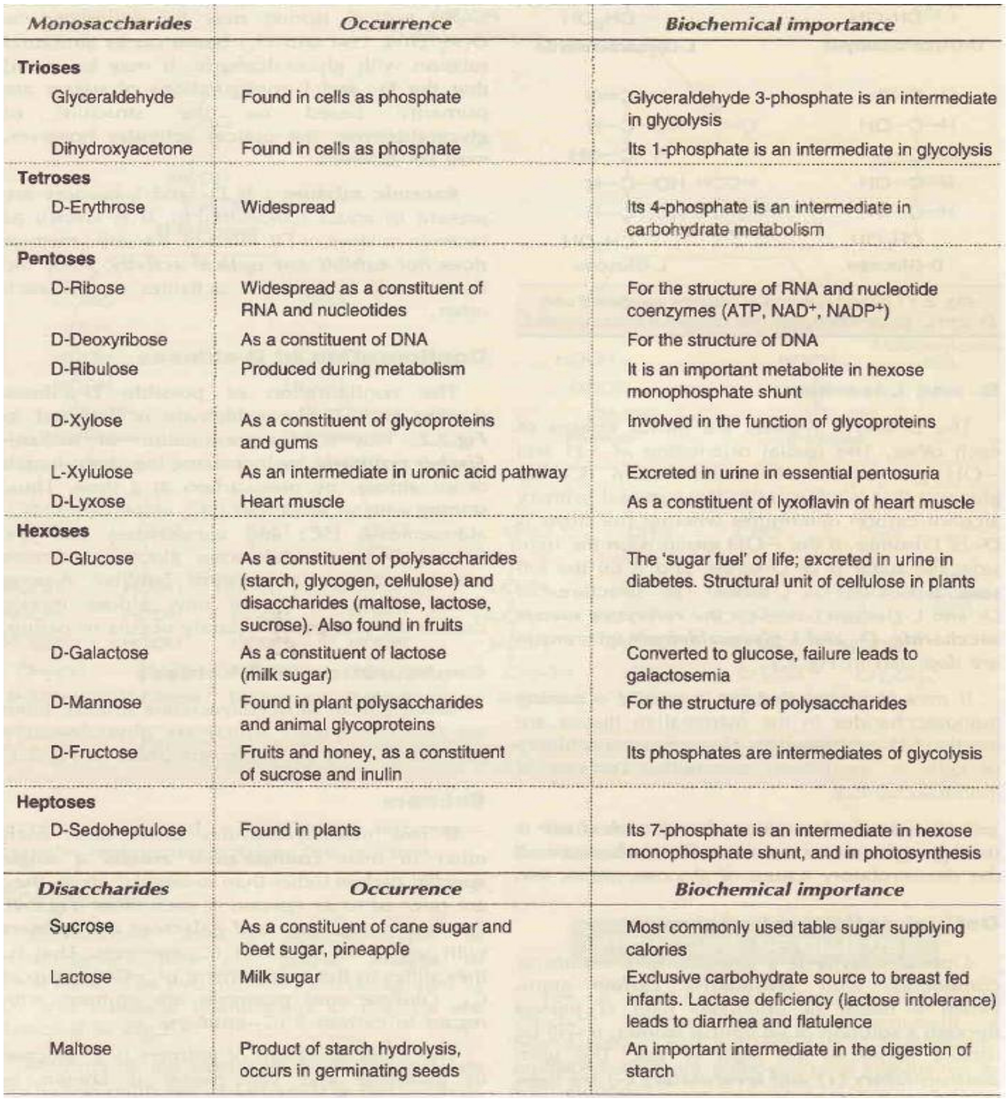
Aldoses :

When the functional group in monosaccharides in aldehyde  $\left(-\overset{H}{\overset{|}{C}}=O\right)$ they are known as aldoses e.g. glyceraldehyde, glucose.

Ketoses:

When the functional group is a keto  $\left(-\overset{|}{C}=O\right)$ group, they are referred to as ketoses e.g. dihydroxyacetone, fructose.

- Based on the number of carbon atoms, the monosaccharides are regarded as trioses (3C), tetroses (4C), pentoses (5C), hexoses (6C) and heptoses (7C).
- These terms along with functional groups are used while naming monosaccharides.
- For instance, glucose is an aldohexose while fructose is a ketohexose.
- The common monosaccharides and disaccharides of biological importance are given.



Monosaccharides	*Occurrence*	*Biochemical importance*
Trioses		
Glyceraldehyde	Found in cells as phosphate	Glyceraldehyde 3-phosphate is an intermediate in glycolysis
Dihydroxyacetone	Found in cells as phosphate	Its 1-phosphate is an intermediate in glycolysis
Tetroses		
D-Erythrose	Widespread	Its 4-phosphate is an intermediate in carbohydrate metabolism
Pentoses		
D-Ribose	Widespread as a constituent of RNA and nucleotides	For the structure of RNA and nucleotide coenzymes (ATP, NAD^+, $NADP^+$)
D-Deoxyribose	As a constituent of DNA	For the structure of DNA
D-Ribulose	Produced during metabolism	It is an important metabolite in hexose monophosphate shunt
D-Xylose	As a constituent of glycoproteins and gums	Involved in the function of glycoproteins
L-Xylulose	As an intermediate in uronic acid pathway	Excreted in urine in essential pentosuria
D-Lyxose	Heart muscle	As a constituent of lyxoflavin of heart muscle
Hexoses		
D-Glucose	As a constituent of polysaccharides (starch, glycogen, cellulose) and disaccharides (maltose, lactose, sucrose). Also found in fruits	The 'sugar fuel' of life; excreted in urine in diabetes. Structural unit of cellulose in plants
D-Galactose	As a constituent of lactose (milk sugar)	Converted to glucose, failure leads to galactosemia
D-Mannose	Found in plant polysaccharides and animal glycoproteins	For the structure of polysaccharides
D-Fructose	Fruits and honey, as a constituent of sucrose and inulin	Its phosphates are intermediates of glycolysis
Heptoses		
D-Sedoheptulose	Found in plants	Its 7-phosphate is an intermediate in hexose monophosphate shunt, and in photosynthesis
Disaccharides	***Occurrence***	***Biochemical importance***
Sucrose	As a constituent of cane sugar and beet sugar, pineapple	Most commonly used table sugar supplying calories
Lactose	Milk sugar	Exclusive carbohydrate source to breast fed infants. Lactase deficiency (lactose intolerance) leads to diarrhea and flatulence
Maltose	Product of starch hydrolysis, occurs in germinating seeds	An important intermediate in the digestion of starch

STEREOCHEMISTRY:

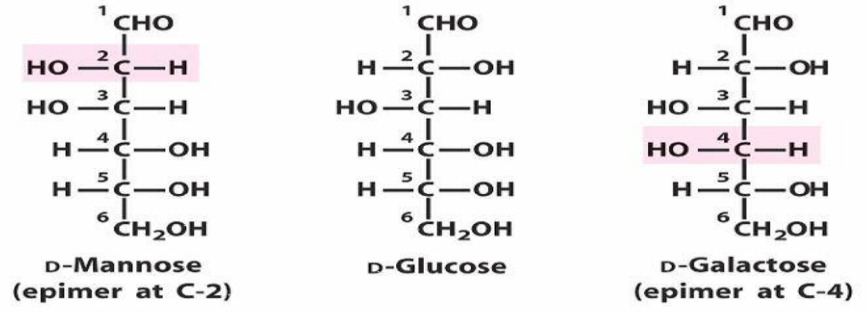
- Carbon 2 of glyceradehyde is a chiral center.
- There are thus 3 steroisomers of glyceraldehydes: D–glyceraldehyde and L–glyceraldehyde.
- By convention, sugars are written with the most oxidized carbon (i.e. aldehyde or ketone) at the top.
- The chiral center farthest from the most oxidized carbon determines if it is D or L.
- If the hydroxyl points to the left, then it is the L configuration if to the right then it is D.
- In general, only the D isomers are used biologically, but there are many exceptions to this generalization.
- Sugars can be conveniently written as Fischer projections to indicate stereochemistry.

- The most oxidized carbon is placed at the top and each carbon between it and the last carbon is a cross from which are appended the hydrogen and hydroxyl group.
- It makes a difference if the hydroxyl group is written to the or lift.
- It is important tp recognize that a Fischer projection indicates the stereochemistry of each chiral center.
- One must imagine that the groups to the left and right (-H and –OH) are coming out the plane towards the viewer, while the substituents above and below are out of the plane directed away from the viewer.

Epimers

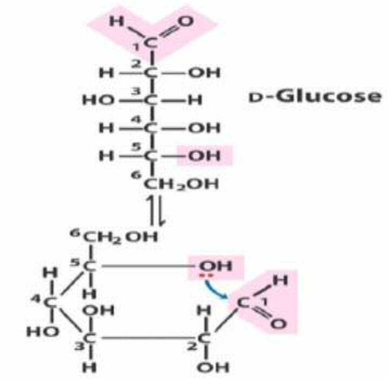
Carbohydrates that differ only in their stereochemistry at one position are called Epimers.

- Eg. Glucose and mannose (C-2)
- Glucose and galactose (C-4)



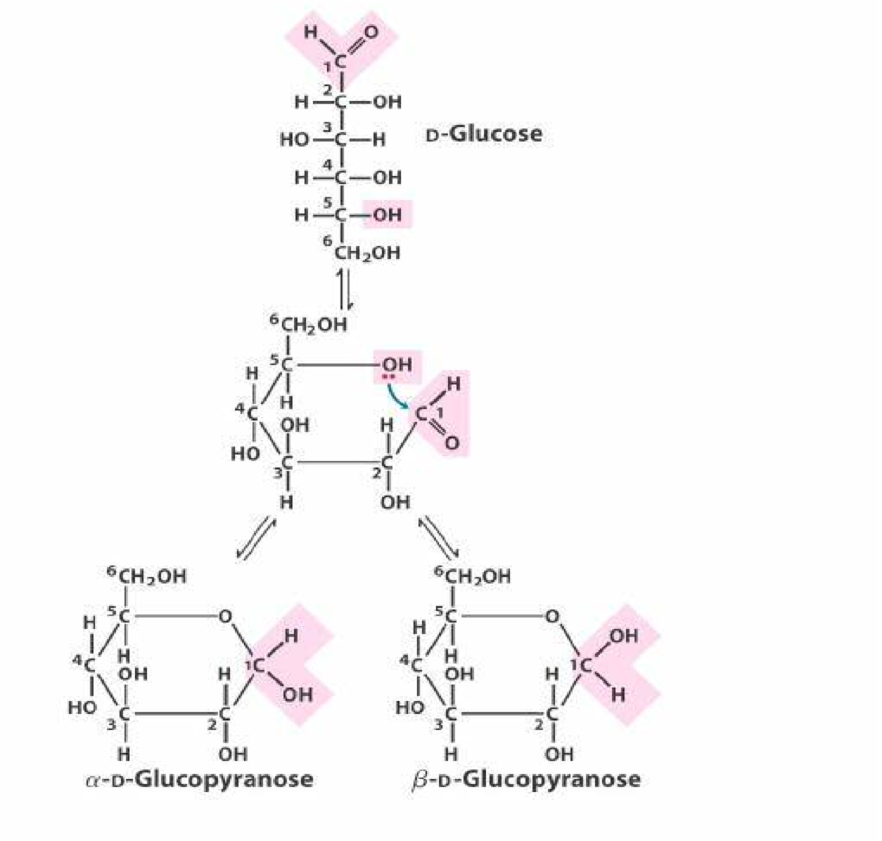
CYCLIC STRUCTURE AND ANOMERIC FORMS:

- In aqueous solution, D-glucose exists in one of 2 forms: α-D-glucose and ß-D-glucose.
- This is because Aldehydes can react with alcohols to form a hemiacetal.
- In this case, the hydroxyl oxygen attacking the molecule it is an interamolecular reaction, which results in formation of a ring.
- Rings with 6 members are the most stable, but 5-membered rings are possible.
- The oxygen that attacked the carbonyl carbon will be a member of the ring.
- The carbonyl oxygen is converted to a hydroxyl group in the process.
- The stereochemistry of this hydroxyl group is determined by the position of the carbonyl during the attack; it can be one of 2 possible configurations: α or ß.
- Six-member rings resemble pyran and are referred to as pyranosides.
- Five – member rings resemble furan and are referred to as furanosides.



Anomers

- The different stereo isomers (α and β) are called Anomers.
- The aldehyde or ketone carbon is referred to as the anomeric carbon, as this is the chiral center that differs between 2 Anomers.
- For D–sugars the α anomer has the hydroxyl group down in the
- Haworth projection and on the same side as the ring oxygen in the Fisher projection.



HAWORTH PROJECTIONS:

1. If the ring closes on a hydroxyl which points to the right (which it always does), then the hydroxymethyl (hydroxyalkyl) group point up. If the ring closes on a

hydroxyl which points to the lift, then the hydroxymethyl (hydroxyalkyl) group points town.

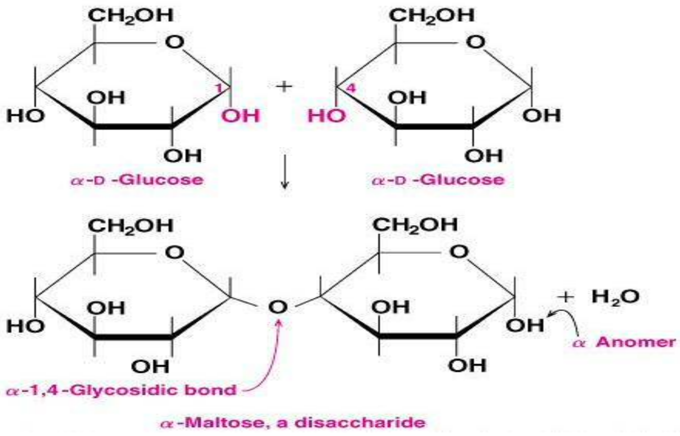
2. The hydroxyls that point to the right in the Fischer projection, point down in the Haworth projection. The hydroxyls that point to the left in the Fischer projection point up in the Haworth projection.
3. For the D series: If the hydroxyl on the anomeric carbon points down, then it is α. It points up, and then the sugar is ß.

DISACCHARIDES:

- A disaccharide is formed when a hydroxyl group on one monosaccharide reacts with the anomeric carbon of another monosaccharide to form a glycosidic bond.
- Each disaccharide has a specific glycosidic linkage (depending on which hydroxyl reacts with which anomer).
- The three most common disaccharides are maltose, lactose and sucrose.
- When hydrolyzed using acid or an enzyme, the following monosaccharide are produced.
- The disaccharides are of two types
  1. Reducing disaccharides with free aldehyde or keto group e.g. maltose, lactose.
  2. Non-reducing disaccharides with no free aldehyde or keto group e.g. sucrose, Trehalose.

MALTOSE:

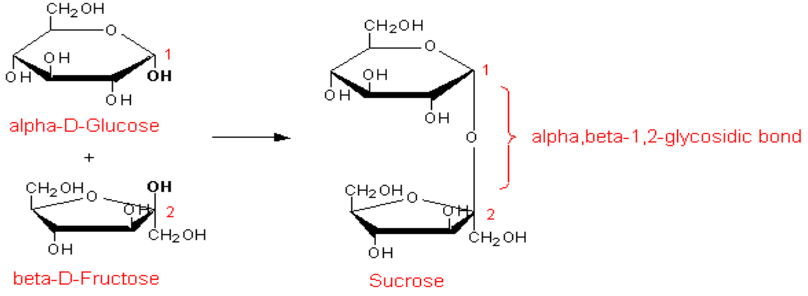
- Maltose (malt sugar or corn sugar) consists of two glucose molecules linked by an α-1, 4-glycosidic bond.
- It comes from partial hydrolysis of starch by the enzyme amylase, which is in saliva and also in grains (like barley).
- Maltose can be fermented by yeast to produce ethanol.
- Maltose is also used in cereals, candies and malted milk.
- Because one of the glucose molecules is a hemiacetal, it can undergo mutorotation, and so maltose is a reducing sugar.



SUCROSE:

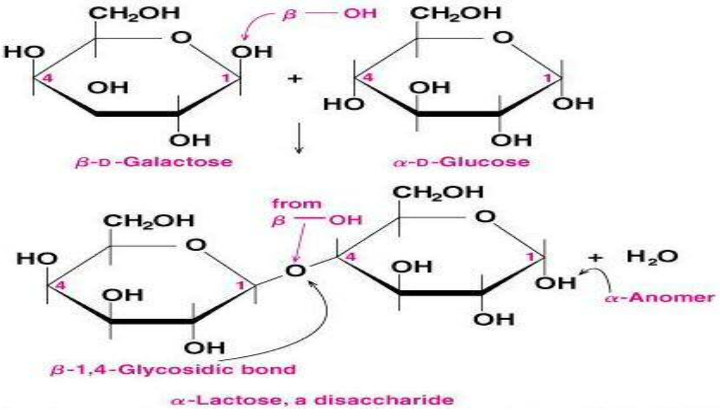
- Sucrose (table sugar) consists of one glucose molecule and one fructose molecule linked by an α,β-1,2-glycosidic bond.

- Sucrose is the most abundant disaccharide and is commercially produced from sugar cane and sugar beets.
- Because the glycosidic bond in sucrose involves both anomeric carbons, neither monosaccharide can undergo mutorotation, and so sucrose is not a reducing sugar.



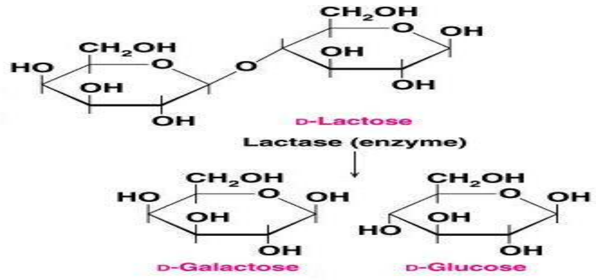
LACTOSE:

- Lactose (milk sugar) consists of one glucose molecule and one galactose molecule linked by a β–1,4 glycosidic bond.
- It comes from milk products (about 4–5% of cow's milk).
- Because the glucose is a hemiacetal, it can undergo mutorotation, and so lactose is a reducing sugar.



Hydrolysis of Lactose:

- Some people don't produce enough lactase, the enzyme that hydrolyzes lactose, and so can't digest lactose.
- Many adults become lactose intolerant, and develop abdominal cramps, nausea and diarrhea.
- Lactase can be added to milk products (or taken as a supplement) to combat this problem.

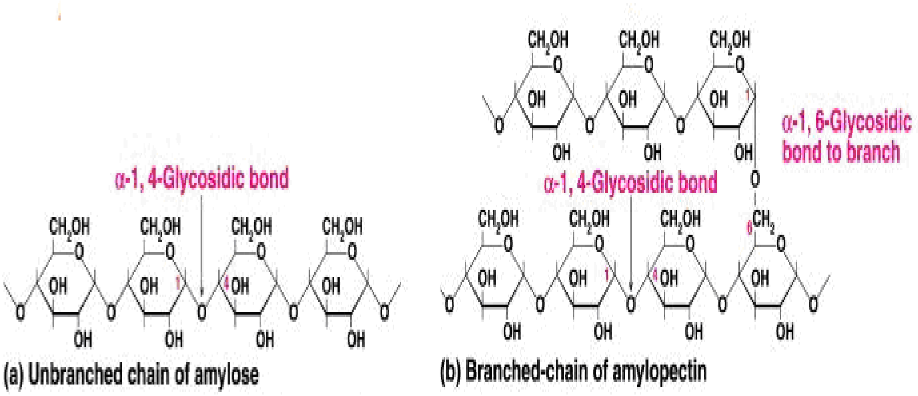


OLIGOSACCHARIDES:

- Oligosaccharides (Greek: oligo–few) contain 2–10 monosaccharide molecules which are liberated on hydrolysis.
- Based on the number of monosaccharide units present, the oligosaccharides are further subdivided to disaccharides, trisaccharides etc.

POLYSACCHARIDES:

- A polysaccharide is a polymer consisting of hundreds to thousands of monosaccharide joined together by glycosidic linkages.
- Three biologically important polysaccharides are starch, glycogen and cellulose
  – all three are polymers of D–glucose, but they differ in the type of glycosidic bond and/or the amount of branching
- Starch and glycogen are used for storage of carbohydrates
  –Starch is found in plants and glycogen in animals
  –The polymers take up less room than would the individual glucose molecules, so are more efficient for storage
- Cellulose is a structural material used in formation of cell walls in plants Plant Starch (Amylose and Amylopectin)



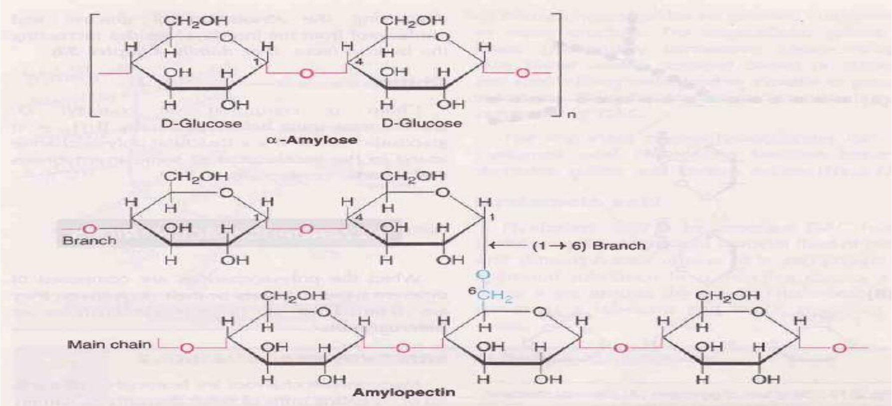
STORAGE POLYSACCHARIDES:

STARCH:

- Starch is the carbohydrate reserve of plants which is the most important dietary source for higher animals, including man.
- High content of starch is found in cereals, roots, tubers, vegetables etc.
- Starch is a homopolymer composed of D–glucose units held by a–glycosidic bonds.
- It is known as glucosan or glucan.
- Starch consists of two polysaccharide components–water soluble amylose (15–20%) and a water insoluble amylopectin (80–85%).
- Chemically, amylose is a long unbranched chain with 200–1,00O D–glucose units held by α (1 → 4) glycosidic linkages.
- Amylopectin on the other hand, is a branched chain with α (1 → 6) glycosidic bonds at the branching points and α (1 → 4) linkages everywhere else

Amylopectin molecule containing a few thousand glucose units looks like a branched tree (20–30 glucose units per branch).

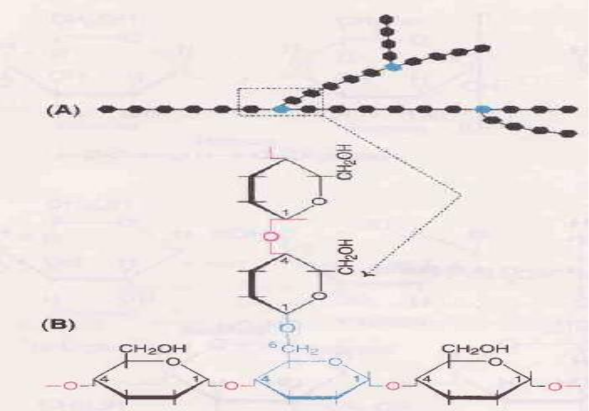
- Starches are hydrolysed by amylase (pancreatic or salivary) to liberate dextrins, and finally maltose and glucose units.
- Amylase acts specifically on a (1 → 4) glycosidic bonds.



Structure of starch (α-amylose and amylopectin)

GLYCOGEN:

- Glycogen is the carbohydrate reserve in animals, hence often referred to as animal starch.
- It is present in high concentration in liver, followed by muscle, brain etc. Glycogen is also found in plants that do not possess chlorophyll (e.g. yeast, fungi).
- The structure of glycogen is similar to that of amylopectin with more number of branches.
- Glucose is the repeating unit in glycogen joined together by α (1 → 4) glycosidic bonds, and α (1 → 6) glycosidic bonds at branching points.
- The molecular weight (up to 1 x 10^8) and the number of glucose units (up to 25,000) vary in glycogen depending on the source from which glycogen is obtained.



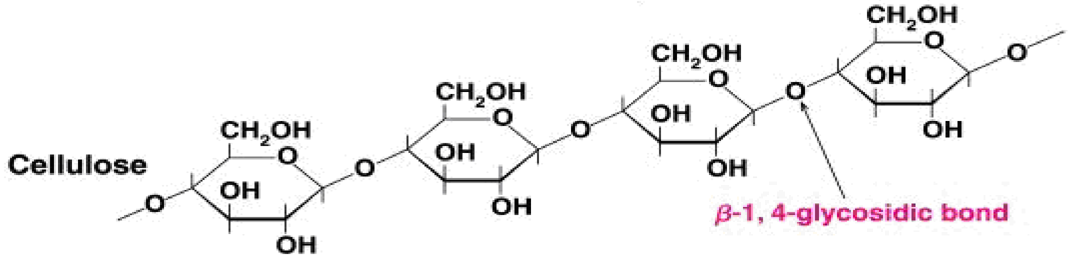
Structure of glycogen (A) General structure (B) Enlarged at a branch point

STRUCTURAL POLYSACCHARIDES:

- Structural polysaccharides are the polysaccharides that are found to form the structure of an organism.
  Eg. Cellulose –in plants
  Chitin –found in outer skeleton of insects and crabs
  Lignin –wood

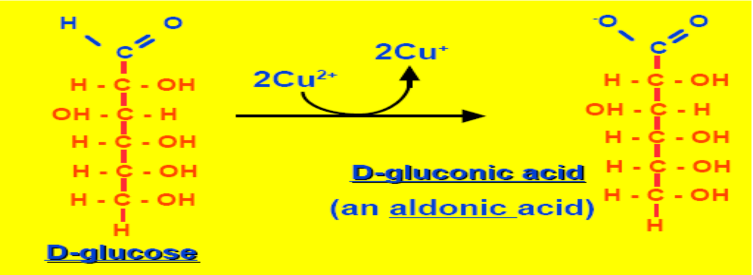
CELLULOSE:

- The structural components of plants are formed primarily from cellulose.
- Wood is largely cellulose and lignin, while paper and cotton are nearly pure cellulose.
- Cellulose is a polymer made with repeated glucose units bonded together by *beta*-linkages.
- Humans and many other animals lack an enzyme to break the *beta*-linkages, so they do not digest cellulose.
- Certain animals such as termites can digest cellulose, because bacteria possessing the enzyme are present in their gut.
- Cellulose is insoluble in water. It does not change color when mixed with iodine. On hydrolysis, it yields glucose. It is the most abundant carbohydrate in nature.

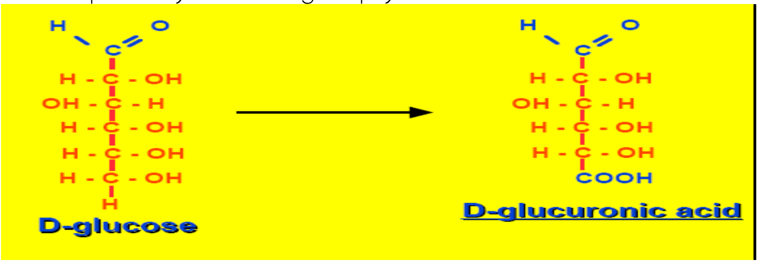


REACTIONS OF MONOSACCHARIDE:

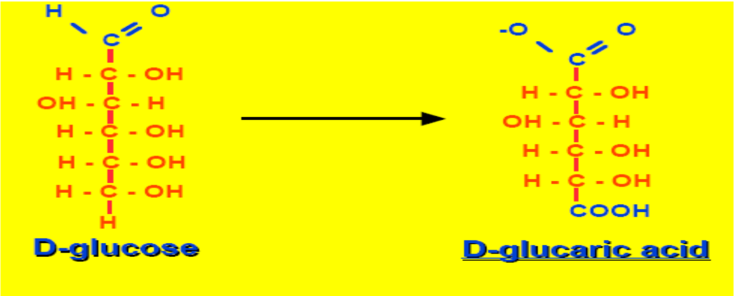
- Can be oxidized by mild oxidizing agents (i.e., ferric or cupric ions). Carbonyl goup is oxidized to a carboxylic acid.



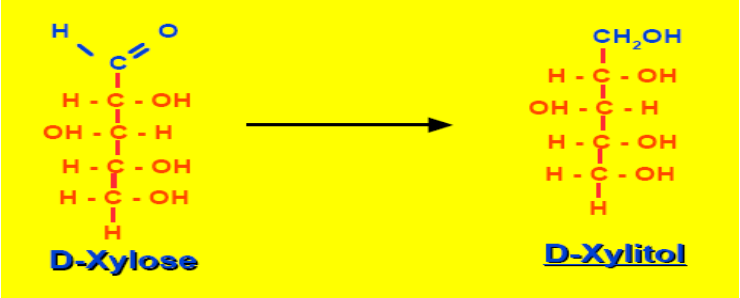
- Oxidation of the primary alcohol group yields a uronic acid:



- Aldoses can be oxidized at both c1 and c6 to yield aldaric acids.



- Aldoses and ketoses can be reduced to yield alditols.



- Sorbitol, mannitol (gum sweetener); glycerol (component of lipids)

Important Reactions of Sugars:

1) Oxidation of Aldehydes

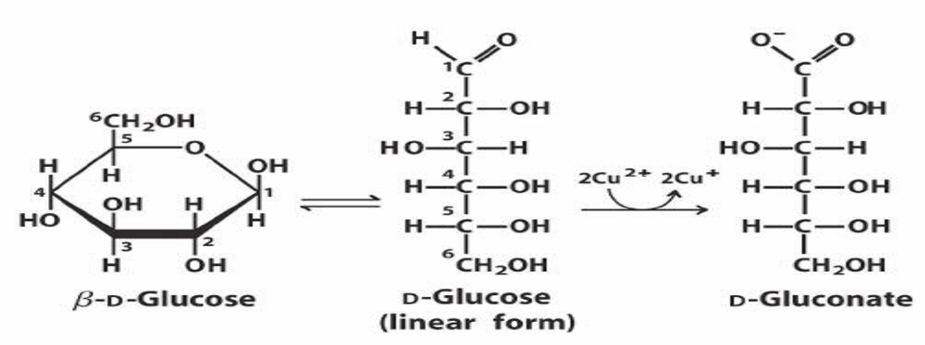
Aldehydes can be oxidized to carboxylic acids. Thus, aldoses are reducing agents. Any sugar that has (or potentially has) a free aldehyde is referred to as a reducing sugar. The name is made by changing the –ose ending to – onic acid (or onate).

Tests for reducing sugars:

a) **Fehling's reaction [Cu (II)→** Cu (I)]:

$R\text{-}CHO + 2Cu^{2+} + 5\ OH^- \rightarrow R\text{-}CO_2^- + Cu_2O + 3\ H_2O$

Visualizad as deposition of Cu_2O (red).



b) **Tollen's reaction** [Ag(I) → Ag(o)]:

$R\text{-}CHO + 2\ Ag\ (NH_3)_2^+ + 2\ OH^- \rightarrow R\text{-}Co_2^{-+2\ Ag + 3\ NH}{}_3 + NH_4^+ + H_2O$

(Visualized as deposition of metabolic silver).

c) Aldehyde can also be oxidized to carboxylic acid by Br_2.

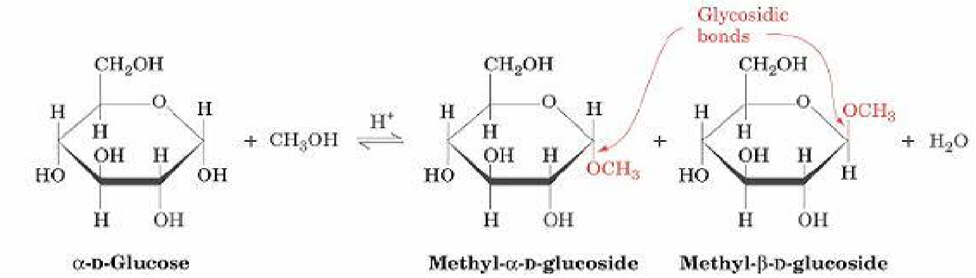
2) Oxidation of primary alcohol:

The CH_2OH group can be oxidized with dilute HNO_3 to a carboxylic acid. These are named with the root of the sugar plus – uronic acid or – aric acid.

(e.g. glucuronic acid is formed by oxidation of glucose).

3) Reaction with alcohols: formation of acetals:

This is one of the most important reactions of sugars, because this is the way they are linked together to form polymers. In its simplest form, one can consider the reaction of methanol with a pyranose:



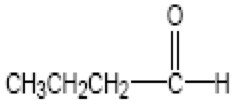
L - Sugars:

- It is important to realize that the identity stereoisomer is determined by the relative orientations of its substituents (i.e. hydroxyls, etc). The L carbohydrate series represent mirror images to the D sugars.
- To get the configuration of L sugar, start with the D configuration and reverse it:
    - Fischer projection: Change the orientation of every chiral center – if the Hydroxyl points to the left, point it to the right and vice–versa.
    - Haworth projection: Move tham from up to down and vice versa. (The **rules for α and β Anomers are reversed: the hydroxyl points up in α and down in β).**
- Thus the relative orientation of the substituents is maintained, but you have a mirror image: the enantiomer.

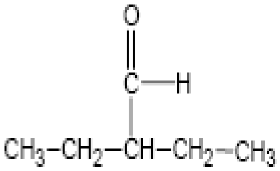
CHARACTERISTICS OF ALDEHYDE AND KETO GROUPS:

Aldehyde:

- Select the longest carbon chain containing the carbonyl carbon.
- The –e ending of the parent alkane name is replaced by the suffix –al.
- **The carbonyl carbon is always numbered “1.” (It is** not necessary to include the number in the name.)
- Name the substituents attached to the chain in the usual way.



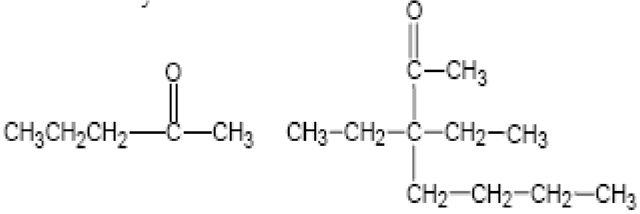
$CH_3CH_2CH_2{-}\overset{\displaystyle O}{\overset{\|}{C}}{-}H$



Ketones

- Select the longest carbon chain containing the carbonyl carbon.
- The –e ending of the parent alkane name is replaced by the suffix –one.

- Number the chain starting with the end closest to the ketone group (i.e., the carbonyl carbon should have the lowest possible number).
- Name the substituents attached to the chain in the usual way.



ACTION OF ACIDS AND ALKALIES ON SUGARS:

- A sugar loses water on being heated with strong mineral acid, and forms furtural derivatives.
- These furfurals may from colored complexes with α-naphthol, thymol, resorcinol, orinol and phloroglucinol.
- On treatment with dilute aqucous alkali solutions, both aldose and ketose are changed to enediols which are good reducing agents.
- Only sugars with a free aldehyde or ketose group can form enediols because the reaction involves the free aldehyde or ketonyl C= O group.
- Glucose and fructose form a common 1,2 enediol in dilute alkaline solutions.

Glycoconjugates

Besides, carbohydrate's role as energy storage and structural materials, carbohydrates (polysaccharides and oligosaccharides) play significant roles as information carriers. In order to act as information carrier, many of the carbohydrates are covalently attached to a protein or a lipid to constitute glycoconjugates.

Functions of glycoconjugates

- Some of them provide communication between cells and their extracellular surroundings. Others label proteins for transport to and localization in specific organelles or for destruction when the protein is malformed or superfluous.
- Others serve as recognition sites for extracellular signal molecules (growth factors, for example) or extracellular parasites (bacteria or viruses).
- On almost every eukaryotic cell, specific oligosaccharide chains attached to components of the plasma membrane form a carbohydrate layer (the glycocalyx), several nanometers thick, that serves as an information-rich surface that a cell shows to its surroundings.
- These oligosaccharides have central roles in cell-cell recognition and adhesion, cell movement during development, blood clotting, immune response, wound healing and other cellular processes.

Classifications of glycoconjugates

Three major classes of glycoconjugates: Proteoglycans, Glycoproteins, Glycolipids are discussed below

1.Proteoglycans

Proteoglycans resemble more to polysaccharides than to proteins as it contains 95% carbohydrate moieties by weight.

Structure:

- Proteoglycans are structural constituent of extracellular matrix in which one or more sulfated glycosaminoglycan chains are attached covalently to a membrane protein or a secreted protein termed as "core protein".
- The point of attachment is a Serine (Ser) residue, to which the glycosaminoglycan such as chondroitin sulfate is attached through a trisaccharide bridge i.e. Gal–Gal–Xyl (shown in Fig. 12).
- The Serine residue is usually in the sequence –Ser–Gly–X–Gly–(where X is any amino acid residue), although not every protein with this sequence has an attached glycosaminoglycan.

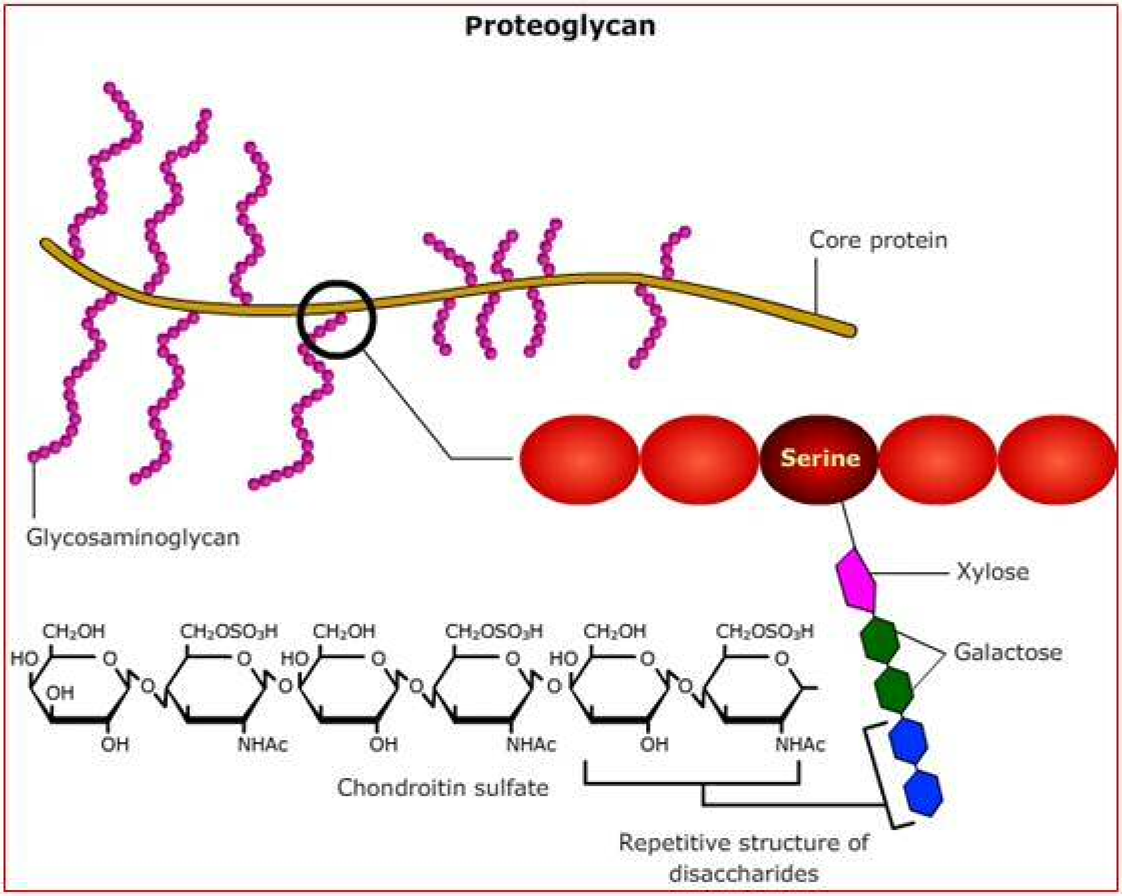


Fig. 12. Proteoglycan structure, showing the trisaccharide bridge.

Source: ILLL in house

Importance:

- Proteoglycans are major components of all extracellular matrices.
- Proteoglycans work as lubricants and structural components in connective tissue, mediate adhesion of cells to the extracellular matrix and bind factors that stimulate cell proliferation.
- Mammalian cells can synthesize 40 types of proteoglycans. These molecules act as tissue organizers and they influence various cellular activities, for instance, growth factor activation and adhesion.

Types of Proteoglycans:

There are two major families of membrane heparan sulfate proteoglycans. Syndecans have a single trans-membrane domain and an extracellular domain bearing three to five chains of heparin sulfate and in some cases chondroitin sulfate (Fig. 13). Glypicans are linked to the membrane through a lipid anchor, a derivative of the membrane lipid phosphatidylinositol. Both syndecans and glypicans may be shed into the extracellular space. A protease in the ECM that cuts close to the membrane surface liberates syndecan ectodomains (those domains outside the plasma membrane) and a phospholipase which breaks the connection to the membrane lipid releases glypicans. Many chondroitin sulfate and dermatan sulfate proteoglycans also exist, some as membrane-bound entities, others as secreted products in the ECM.

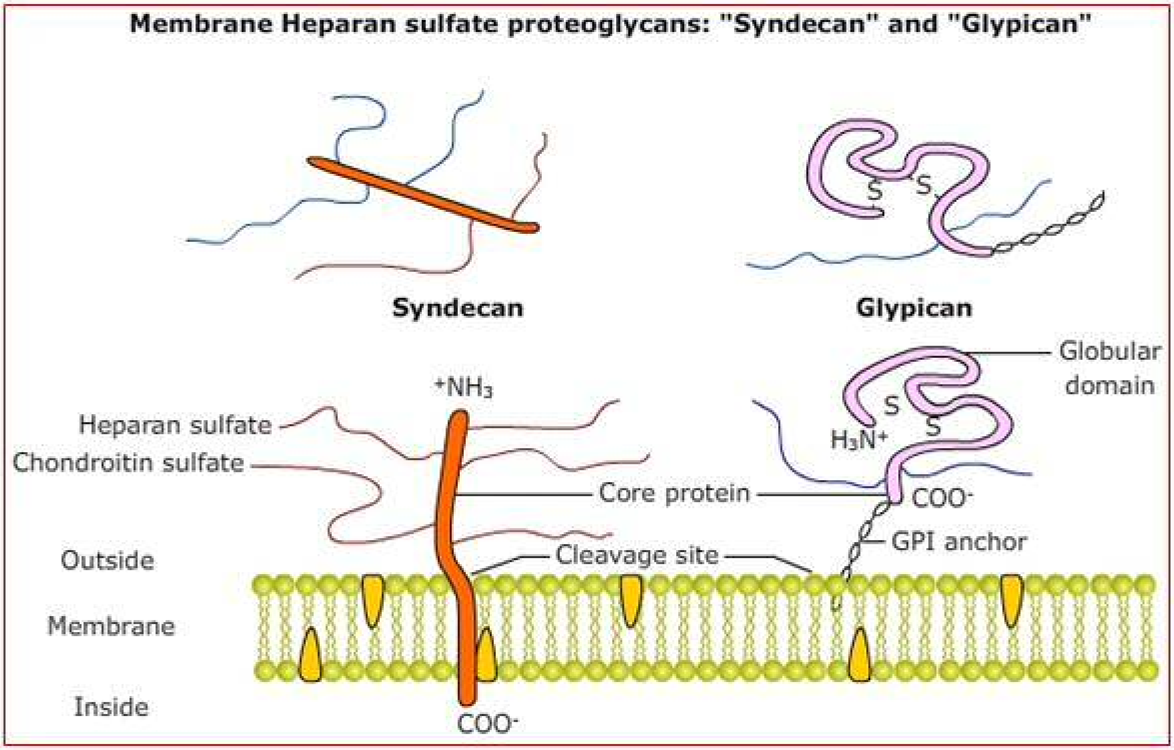


Fig. 13. Two major families of membrane heparan sulfate proteoglycans. Schematic diagram of a syndecan and a glypican in the plasma membrane. Syndecans are held in the membrane by hydrophobic interactions between a sequence of non polar amino acid residues and plasma membrane lipids they can be released by a single proteolytic cut near the membrane surface. Glypicans are held in the membrane by a covalently attached membrane lipid GPI–anchor(glycosylphosphatidylinositol–GPI).

Source: ILLL in house

2. Glycoproteins

Structure:

- Glycoproteins constitute one or more oligosaccharides that attached covalently to a protein. Thus, glycoproteins are carbohydrate–protein conjugates.
- Glycans are smaller, branched and more structurally diverse oligosaccharides than the glycosaminoglycans of proteoglycans.
- About half of all proteins of mammals are glycosylated, and about l% of all mammalian genes encode enzymes involved in the synthesis and attachment of these oligosaccharide chains.

Significance:

- Glycoproteins are generally present on the outer surface of the plasma membrane (as part of the glycocalyx), in the extracellular matrix and in the blood.
- Inside cells, these are particularly present in organelle e.g. golgi complexes, lysosomes and secretory granules. A few cytosolic and nuclear proteins can also be glycosylated.
- Like glycosaminoglycans, the oligosaccharide moieties of glycoproteins are rich in information, forming highly specific sites for recognition and high affinity binding by carbohydrate–binding proteins called lectins.
- Many of the proteins secreted by eukaryotic cells are glycoproteins, such as most of the proteins of blood. Immunoglobulins (antibodies) and some hormones, like follicle–stimulating hormone, luteinizing hormone, and thyroid–stimulating hormone are glycoproteins. Several milk proteins e.g. lactalbumin and some proteins secreted in the pancreas (for instance ribonuclease) are glycosylated.

Oligosaccharide linkages in glycoproteins:

(a) *O*-linked oligosaccharides contain a glycosidic linkage to the hydroxyl group of Serine or Threonine residues (pink), exemplified here with GalNAc as the sugar at the reducing end of the oligosaccharide. One simple chain and one complex chain are shown.

(b) *N*-linked oligosaccharides contain an *N*–glycosyl bond to the amide nitrogen of an Asn residue(green), exemplified here with GlcNAc as the terminal sugar (Fig. 14).

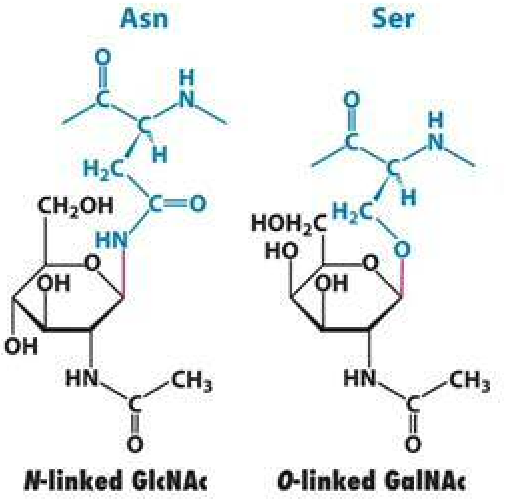


Fig. 14. Oligosaccharide linkages in glycoproteins.

Source: ILLL in house

Mucins are glycoprotein components of mucus

Structure:

- Mucins (mucoproteins) are secreted or membrane glycoproteins that can contain large numbers of *O*-linked oligosaccharide chains.
- In mucins, the protein component is extensively glycosylated to Serine or Threonine residues by *N*-acetylgalactosamine. Mucins are capable of forming large polymeric structures and are common in mucous secretions (Fig. 15).

Significance:

- Mucins are present in most secretions they give mucus its characteristic slipperiness.
- These glycoproteins are synthesized by specialized cells in the tracheobronchial, gastrointestinal, and genitourinary tracts.
- Because a key function of mucins is to act as a lubricant, mucins are abundant in saliva.
- The important feature of the mucins is a region of the protein backbone termed the variable number of tandem repeats (VNTR) region that is rich in serine and threonine residues that are *O*-glycosylated. Indeed, the carbohydrate moiety can account for as much as 80% of the molecule by weight.
- Mucins adhere to epithelial cells and act as a protective barrier; they also moist the underlying cells.
- Mucins protect cells from environmental abrasions, such as stomach acid, inhaled chemicals in the lungs and bacterial infections.
- Mucins have roles in fertilization, the immune response, and cell adhesion.
- Mucins are over–expressed in bronchitis and cyctic fibrosis, and the over–expression of mucins is characteristic of adenocarcinomas– cancers of glandular cells of epithelial origin.

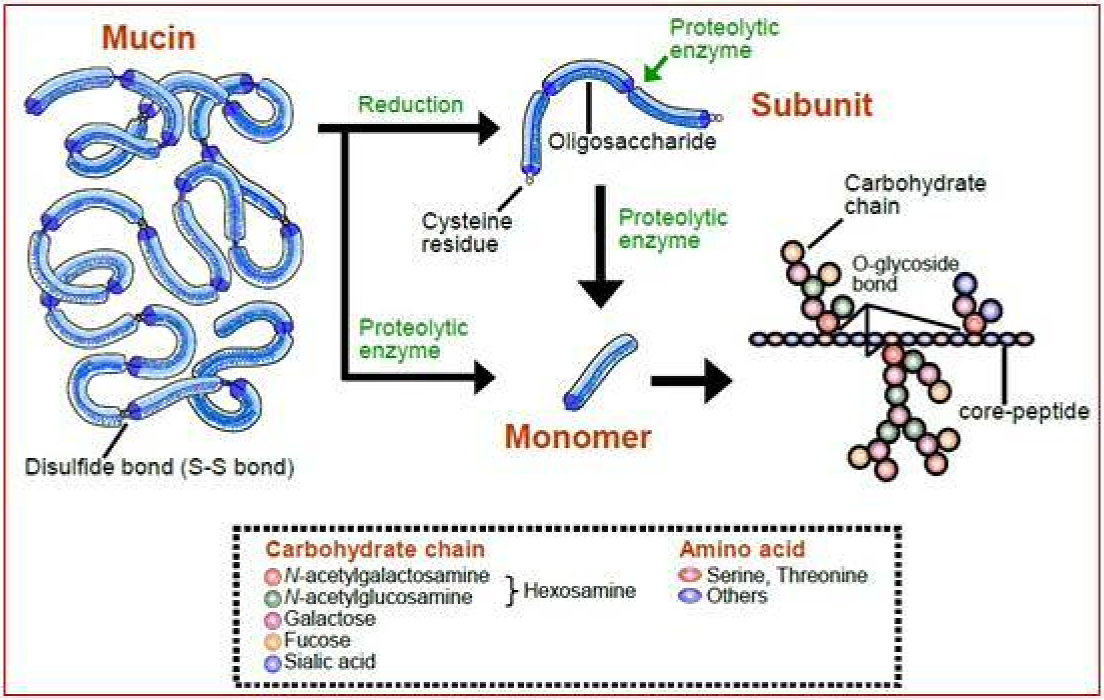


Fig. 15. Polymeric structure of mucin molecules.

3. Glycolipids

Structure:

- Glycolipids are membrane sphingolipids in which the hydrophilic head groups are oligosaccharides.

Significance:

- As in glycoproteins the oligosaccharides act as specific sites for recognition through protein called lectins.
- The brain and neurons are rich in glycolipids, which help in nerve conduction and myelin formation.
- Glycolipids also play a role in signal transduction in cells.

Gangliosides: A type of glycolipids

Structure: These are membrane lipids of eukaryotic cells in which the polar head group, the part of the lipid that forms the outer surface of the membrane, is a complex oligosaccharide containing a sialic acid and other monosaccharide residues.

Significance: Like glycoprotein, a few oligosaccharide moieties of gangliosides determine human blood groups (Fig. 16). Like the oligosaccharide residues of glycoproteins, those of membrane lipids are generally found on the outer face of the plasma membrane.

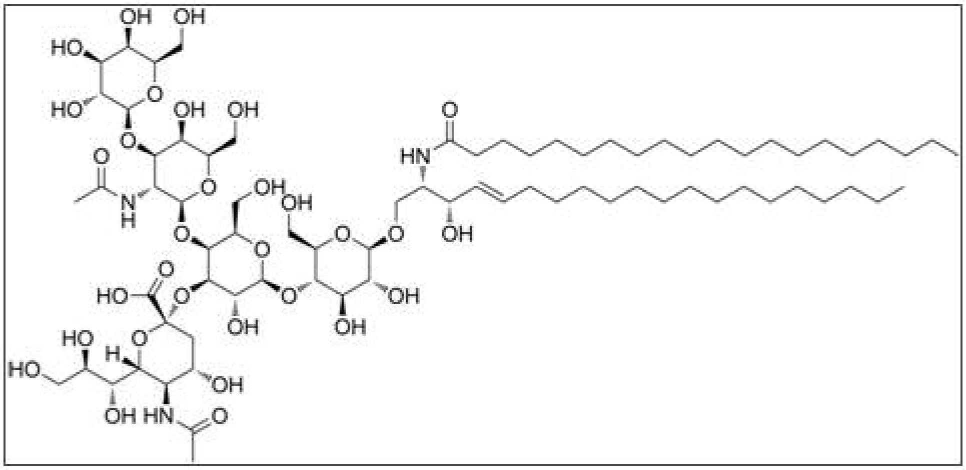


Fig. 15. Gangliosides, a glycolipid contain carbohydrate moiety.

Carbohydrate moieties determine the blood group
Carbohydrates are important constituent of blood group system in human blood transfusion. The associated anti-A antibodies and anti-B antibodies are usually immunoglobulin M, abbreviated as IgM antibodies. IgM antibodies are generally synthesized in the first years of life through sensitization to ambient substances for instance food and microbes. The corresponding blood group carbohydrate structures, designated ABH, are found at the termini of oligosaccharide chains on glycoproteins and glycolipids on the surface of RBC and endothelial & most epithelial cells. The **immunodominant monosaccharide that determines blood group A, is a terminal α**-1,3-linked N-acetylgalactosamine (GalNAc), whereas the corresponding monosaccharide of **blood group B specificity is an α**-1,3-linked galactose. Group O cells lack chains, which **instead are terminated with α**-1,2-linked-fucose.

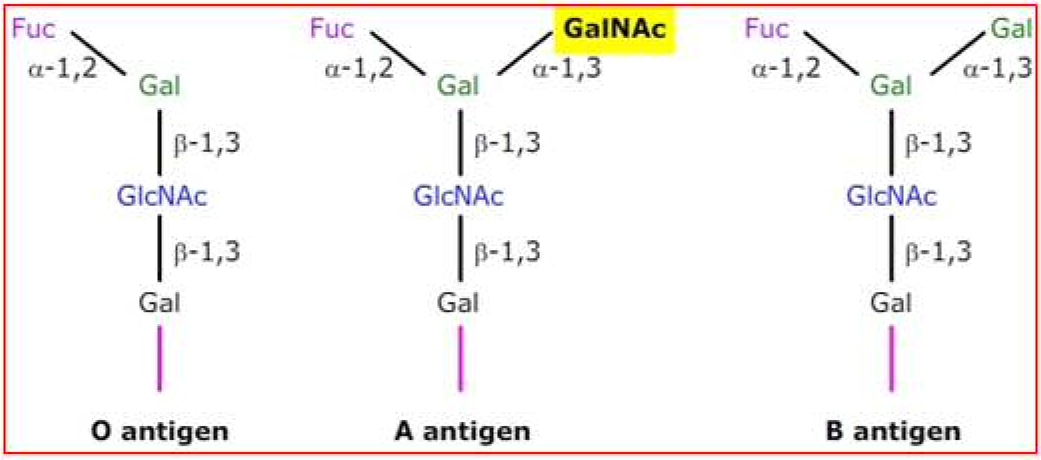


Fig. 17. Structures of A, B and O Oligosaccharide Antigens.

Abbreviations: Fuc, fucose; Gal, galactose; GalNAc, *N*-acetylgalactosamine; GlcNAc, *N*-acetylglucosamine.

Carbohydrates as informational molecules, working with carbohydrates.

Glycobiology is the last important frontier in biochemistry. Complexity of carbohydrate research is due to the variety of the structure. In last few years, the determination of carbohydrate structure, especially the carbohydratemoiety of glycocon jugates has been developed rapidly. On the other hand, owing to complexity of structures, carbohydrates become biomolecules carrying large amounts of information. As informational molecules, carbohydrates play essential roles in living organisms, including determination of antigenecity of molecules and phenotype of cells, recognition in many physiological and pathological events, and as signals of dynamic regulations and of regulation on time and space.

Glycobiology is the study of the structure and function of glycoconjugates. Cells use specific oligosaccharides to encode important information about intracellular targeting of proteins, cell–cell interactions, cell differentiation and tissue development, and extracellular signals. The oligosaccharides of glycoproteins and glycolipids are highly complex and diverse. Oligosaccharides of typical glycoproteins can contain a dozen or more monosaccharide residues in a variety of branched and linear structures, and in a variety of linkages. (See the *N*-linked oligosaccharides in the glycoprotein examples shown in Fig. 7–30). With the assumption that 20 different monosaccharide subunits are available for the construction of oligosaccharides, it can be calculated that many billions of different hexameric oligosaccharides, for example, are possible. This compares with 6.4×10^7 (20^6) different hexapeptides possible from the 20 common amino acids, and 4,096 (4^6) different hexanucleotides with the four bases. The structural information potentially present in glycans thus actually surpasses that of nucleic acids for molecules of modest size. Each of the oligosaccharides attached to a glycoprotein for example, presents a unique three-dimensional structure—a word in the sugar code—that is readable by the proteins that interact with it.

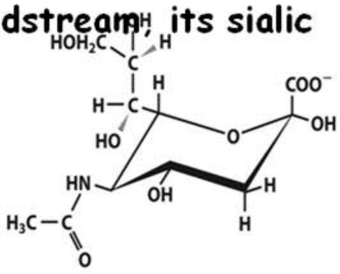
Lectins are proteins that read the sugar code and mediate many biological processes. Lectin–carbohydrate interactions are very strong and highly specific. Carbohydrates as Informational Molecules: The Sugar Code. Glycobiology: the study of the structure and function of glycoconjugates.

Lectin Functions (I)

Lectins, found in all organisms, are proteins that bind carbohydrates with high specificity and with moderate to high affinity. Lectins play roles in a wide variety of cell-cell recognition, signaling, and adhesion processes and in intracellular targeting of newly synthesized proteins. Some examples of these functions are covered in the next few slides.

The first example covered concerns the role of the asialoglycoprotein receptor (a lectin) of the liver which is important in the clearance of many plasma glycoproteins from the circulation. Normally, many plasma glycoproteins are synthesized with oligosaccharide chains that terminate with N-acetylneuraminic acid (a sialic acid) (see figure). This sugar protects the glycoproteins initially from uptake and degradation by hepatocytes. However, during the lifetime of the glycoprotein in the bloodstream, its sialic

acid residues are gradually removed by enzymes called neuraminidases (sialidases) of unknown origin. These asialo- versions of the original glycoproteins are then taken up by the liver and degraded. Note that a similar mechanism is apparently responsible for the removal of old erythrocytes from the bloodstream by the spleen.



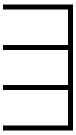
N-Acetylneuraminic acid (Neu5Ac)
(a sialic acid)

Karpagam Academy of Higher Education
Department of Biochemistry
I B.Sc., Biochemistry
17BCU101- Molecules of life
Prepared By Dr. J. Anitha

Question number	**Unit**	**Question**	**Option I**	**Option II**	**Option III**	**Option IV**	**Answer**
	UNIT-II						
1	2	Fats are solids at	10^0C	**20^0C**	30^0C	40^0C	**20^0C**
2	2	Hydrolysis of vegetable oil gives	fatty acid & glycine	fatty acid & glycol	**fatty acid & glycerol**	fatty acid & glyoxal	**fatty acid & glycerol**
3	2	Fatty acid 18:1:9 is	Staric acid	Linoleic acid	Palmitic acid	**Oleic acid**	**Oleic acid**
4	2	Essential fatty acid is	**lenoleic acid**	Palmitic acid	Stearic acid	Myristic acid	**lenoleic acid**
5	2	The lipid which is also having	Vitamin A	**Vitamin D**	Stearic acid	Etanolamine	**Vitamin D**
6	2	Oils which do not solidify at low temperature contain	More of saturated fatty acids	**more of unsaturated fatty acids**	less ofunsaturated fatty acid	saturated	**more of unsaturated fatty acids**
7	2	The melting point of	higher	higher short	**higher**	lower	**higher**
8	2	The structure of lenoleic acid is	18:00	18:19	**$18:2^{9,12}$**	$8:3^{9,12,15}$	**$18:2^{9,12}$**
9	2	Butter contains	**more of saturated fatty acid**	more of unsaturated fatty acids	arachidonic acid	fatty acid & glyoxal	**more of saturated fatty acid**
10	2	Esters of fatty acids with higher alcoholsother than	**Waxes**	Fats	Both	cholestrol	**Waxes**
11	2	The combination of an amino alcohol, fatty acid & sialic	Phospholipids	sulpholipids	**Glycolipids**	amino lipids	**Glycolipids**
12	2	The rate of fatty acid oxidation is	**Phospholipids**	Glyco lipids	amino lipids	all of the above	**Phospholipids**
13	2	Cardiolipin found in mitochondria is	Lipositol	Phosphotidyl ethanolamine	**Phosphatidyl Glycerol**	glycerol	**Phosphatidyl Glycerol**

14	2	Iodine value of an shows the extent of	Polymerisation	molecular size	unsaturation	**esterification**	**esterification**
15	2	Hydrolysis of fat by alkali is called	**Saponification**	acid number	iodine number	both b and c	**Saponification**
16	2	The number of milliliters of 0.1N KOH required to neutralize the	Acid number	Acetyl number	Halogen number	**Polenske number**	**Polenske number**
17	2	Lecithin contains a nitrogenous base	Ethanolamine	**choline**	inositol	aminogroup	**choline**
18	2	Lecithin contains an	α	α+β	αβ	**β**	**β**
19	2	Lecithins are soluble	Benzene	**ethyl alcohol**	methanol	metyl	**ethyl**
20	2	When lecithins are	Black	**Brown**	yellow	Red	**Brown**
21	2	The most abundant	phosphatid	**lecithins**	cephalins	phosphatid	**lecithins**
22	2	contains	**18 carbon**	12 carbon	13 carbon	15 carbon	**18 carbon**
23	2	Lecithins combine to	phospoho	muco protein	**lipo protein**	n	**lipo protein**
24	2	Phosphotidyl	Cabbage	**soybean**	cauliflower	Apples	**soybean**
25	2	Instead of ester link	β	**α**	γ	both alpha	**α**
26	2	The alkyl radical in	saturated	unsaturated	both	**all of the**	**all of the**
27	2	Spingosine is	**cardiolipi**	diacylglycerol	ceramide	Lecithin	**cardiolipin**
28	2	The nitrogen base in	**choline**	serine	ethanolamine	amino	**choline**
29	2	The concentrations	Gaucher's	fabry' disease	febrile disease	**Niemann-**	**pick**
30	2	Spingomyelins	Sedddddri	lyso lecithin	**spingosine**	Glycol	**spingosine**
31	2	Glcolipids contain	spingosins	iso spingosine	both	**all of the**	**all of the**
32	2	kerasin contains	**nervonic**	hydroxy	cerebronic acid	acid	**nervonic**
33	2	Oxynervon contains	nervonic	**hydroxy nervonic acid**	cerebronic acid	lignoceric acid	**hydroxy**
34	2	Gaucher's disease is	Lignoceric	nervonic acid	**cerebronic**	nervonic	**cerebronic**
35	2	Gangliosides are the	Liver	**Brain**	Kidney	Muscle	**Brain**
36	2	The most abundant	**Triglyceri**	Waxes	phospholipid	Cholesterol	**Triglycerid**
37	2	Gangliosides are	**Glycospin**	lipoproteins	glycophospholi	waxes	**Glycosping**
38	2	The lipoprotein	LDL	HDL	VLDL	**ons**	**ns**
39	2	Lipoproteins precent	hydrophob	Hydrophilic	both	**all of the**	**all of the**
40	2	The density of	**rises**	decreases	highly	promptly	**rises**
41	2	Lipo proteins may	Electropho	centrifugation	**Immuno**	centrifugati	**Immuno**
42	2	Very low density	β-lipoprot -	**preoproteins**	α- lipo proteins	beta lipo	**preoprotein**
43	2	milligrams of phosphorus daily.	**700**	500	600	400	**700**

44	2	The protein moiety	**Apoprotei**	preprotein	post protein	Pseudoprot	Apoprotein
45	2	The β-lipoprotein	**Diabetes**	Uremia	nephritis	muscular	**Diabetes**
46	2	Adultration of butter	Acid	iodine number	**RM number**	All	**RM**
47	2	Bee wax contains	Stearic	**palmitate**	Oleic acid	Linolenic	**palmitate**
48	2	Rancidity occurs	air	moisture	light	**All**	**All**
49	2	A lipid containing	Plasmalog	sphingomyelin	**cholesterol**	none	**cholesterol**
50	2	NANA is a	spingomye	ganglioside	**cardiolipin**	Plasmaloge	**cardiolipin**
51	2	The phospholipid	**Plasmalog**	Cardiolipin s	Cephalin	Lecithin	**Plasmaloge**
52	2	Which one of the	**Triacylgly**	Glycolipid	phospholipid	Cholesterol	**Triacylglyc**
53	2	The degree of adulteration of given oil is determined by	saponification number	Acid number	**RM number**	iodine number	**RM number**
54	2	Fat serve as a efficient source of	metabolic activity	**energy storage**	e**nez**yme activity	starch	**energy storage**
55	2	Lipid serve as a	cell	signaling	**both a & b**	cell	**both a & b**
56	2	Hydrocarbons may be formed at	low temperature	**high temperature**	low boiling point	high boiling point	**high temperature**
57	2	found in large quantities in	brain	nerves tissues	**both a & b**	kidney	**both a & b**
58	2	Gangliosides are glycolipids occur in	kidney	liver	**brain**	spleen	**brain**
59	2	Predominant lipids in cholesterol	**LDL**	HDL	VLDL	sterol	**LDL**
60	2	Predominant lipids in phospholipids	LDL	**HDL**	VLDL	sterol	**HDL**



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DEPARTMENT OF BIOCHEMISTRY

SUBJECT NAME : MOLECULES OF LIFE
SUB.CODE : 17BCU101
SEMESTER : I
CLASS : I B.Sc., BIOCHEMISTRY

UNIT III

Lipids :Building blocks of lipids –fatty acids, glycerol, ceramide. Storage lipids –triacyl glycerol and waxes. Structural lipids in membranes – glycerophospholipids, galactolipids and sulpholipids, sphingolipids and sterols, structure, distribution and role of membrane lipids. Plant steroids. Lipids as signals, cofactors and pigments.

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Lipids

Definition

- Lipids constitute a broad group of naturally occurring molecules that include fats, waxes, sterols, fat-soluble vitamins (such as vitamins A, D, E, and K), monoglycerides, diglycerides, triglycerides, phospholipids, and others.
- The main biological functions of lipids include energy storage, as structural components of cell membranes, and as important signaling molecules.

CLASSIFICATION OF LIPIDS:

- They are broadly classified into simple lipids, complex lipids, derived lipids and miscellaneous lipids based on their chemical composition.

1. Simple lipids:

Esters of fatty acids with alcohols. These are mainly of two types

(a) Fats and oils (triacylglycerols):

- These are esters of fatty acids with glycerol.
- The difference between fat and oil is only physical.
- Thus, oil is a liquid while fat is a solid at room temperature.

(b) Waxes:

- Esters of fatty acids (usually long chain) with alcohols other than glycerol.
- These alcohols may be aliphatic or alicyclic.
- Cetyl alcohol is most commonly found in waxes.

2. Complex (or compound) lipids:

- These are esters of fatty acids with alcohols containing additional groups such as phosphate, nitrogenous base, carbohydrate, protein etc.
- They are further divided as follows

(a) Phospholipids:

- They contain phosphoric acid and frequently a nitrogenous base.
- This is in addition to alcohol and fatty acids.

(i) Glycerophospholipids: These phospholipids contain glycerol as the alcohol e.g., lecithin, cephalin.

(ii) Sphingophospholipids: Sphingosine is the alcohol in this group of Phospholipids e.g., sphingomyelin.

(b) Glycolipids:

- These lipids contain a fatty acid, carbohydrate and nitrogenous base.
- The alcohol is sphingosine, hence they are also called as glycosphingolipids.
- Glycerol and phosphate are absent e.g., cerebrosides, gangliosides.

(c) Lipoproteins:

- Macromolecular complexes of lipids with proteins.

(d) Other complex lipids:

- Sulfolipids, amino – lipids and lipopolysaccharides are among the other complex lipids.

3. Derived lipids:

- These are the derivatives obtained on the hydrolysis of group 1 and group 2 lipids which possess the characteristics of lipids.

- These include glycerol and other alcohols, fatty acids, mono–and diacylglycerols, lipid (fat) soluble vitamins, steroid hormones, hydrocarbons and ketone bodies.

4. Miscellaneous lipids:

- These include a large number of compounds possessing the characteristics of lipids e.g., carotenoids, squalene, hydrocarbons such as pentacosane (in bees wax), terpenes etc.

SIMPLE LIPIDS:

FATS:

- Fat, any substance of plant or animal origin that is nonvolatile, insoluble in water, and oily or greasy to the touch. Fats are usually solid at ordinary temperatures, such as 25 °C (77 °F), but they begin to liquefy at somewhat higher temperatures.
- Chemically, fats are identical to animal and vegetable oils, consisting primarily of glycerides, which are esters formed by the reaction of three molecules of fatty acids with one molecule of glycerol.

PHYSICAL AND CHEMICAL PROPERTIES:

- Fats (and oils) may be divided into animal and vegetable fats according to source. Further, they may be classified according to their degree of unsaturation as measured by their ability to absorb iodine at the double bonds.
- This degree of unsaturation determines to a large extent the ultimate use of the fat.
- Liquid fats (i.e., vegetable and marine oils) have the highest degree of unsaturation, while solid fats (vegetable and animal fats) are highly saturated.
- Solid vegetable fats melting between 20 and 35 °C (68 and 95 °F) are found mainly in the kernels and seeds of tropical fruits.
- They have relatively low iodine values and consist of glycerides containing high percentages of such saturated acids as lauric, myristic, and palmitic.
- Fats are practically insoluble in water and, with the exception of castor oil, are insoluble in cold alcohol and only sparingly soluble in hot alcohol.
- They are soluble in ether, carbon disulfide, chloroform, carbon tetrachloride, petroleum benzin, and benzene. Fats have no distinct melting points or solidifying points because they are such complex mixtures of glycerides, each of which has a different melting point.
- Glycerides, further, have several polymorphic forms with different melting or transition points.
- Fats can be heated to between 200 and 250 °C (392 and 482 °F) without undergoing significant changes provided contact with air or oxygen is avoided.
- Above 300 °C (572 °F), fats may decompose, with the formation of acrolein (the decomposition product of glycerol), which imparts the characteristic pungent odour of burning fat.
- Hydrocarbons also may be formed at high temperatures.
- Fats are hydrolyzed readily.
- This property is used extensively in the manufacture of soaps and in the preparation of fatty acids for industrial applications.

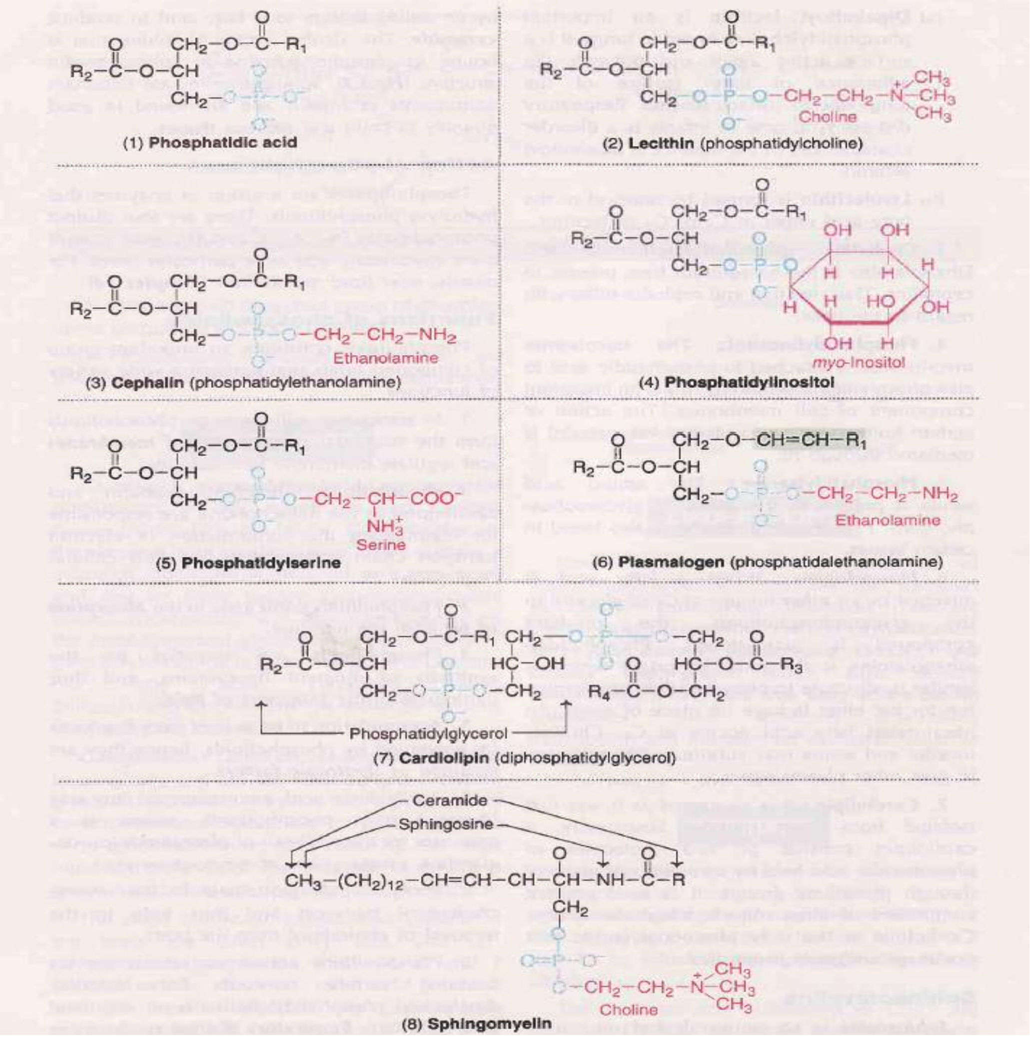
COMPOUND LIPIDS:

PHOSPHOLIPIDS

- These are complex or compound lipids containing phosphoric acid, in addition to fatty acids, nitrogenous base and alcohol.
- There are two classes of phospholipids
- Glycerophospholipids (or phosphoglycerides) that contain glycerol as the alcohol.
- Sphingophospholipid (or sphingomyelins) that contains phingosine as the alcohol

STRUCTURE

- Phosphatidic acid: This is the simplest phospholipid. It does not occur in good concentration in the tissues.
- Lecithins (phosphatidylcholine): These are the most abundant group of phospholipids in the cell membranes.
- Cephafins (phosphatidylethanolamine): Ethanolamine is the nitrogenous base present in cephalins, thus lecithin and cephalin differ with regard to the base.
- Phosphatidylinositol: The steroisomer myo–inositol is attached to phosphatidic acid to give Phosphatidylinositol.
- Phosphatidylserine: The amino acid serine is present in this group of glycerophospholipids. Phosphatidylthreoninise also found in certain tissues.
- Plasmalogens: When a fatty acid is attached by an ether linkage at C1 of glycerol in the glycerophospholipids, the resultant compound is plasmaloge.
- Cardiolipin : It is so named as it was first isolated from heart muscle. Structurally, a cardiolipin consists of two molecules of phosphatidic acid held by an additional glycerol through phosphate groups.



Structure of phospholipids

FUNCTION OF PHOSPHOLIPIDS:

- Phospholipids constitute an important group of compound lipids that perform a wide variety of functions.
- In association with proteins, phospholipids form the structural components of membranes and regulate membrane permeability.
- Phospholipids (lecithin, cephalin and cardiolipin) in the mitochondria are responsible for maintaining the conformation of electron transport chain components, and thus cellular respiration.
- Phospholipids participate in the absorption of fat from the intestine.
- Phospholipids are essential for the synthesis of different lipoproteins, and thus participate in the transport of lipids.
- Accumulation of fat in liver (fatty liver) can be prevented by phospholipids, hence they are regarded as lipotropic factors.

- Arachidonic acid, an unsaturated fatty acid liberated from phospholipids, serves as a precursor for the synthesis of eicosanoid s (prostaglandins, prostacyclinst, hromboxanese tc.).
- Phospholipids participate in the reverse cholesterol transport and thus help in the removal of cholesterol from the body.
- Phospholipids act as surfactants (agents. lowering surface tension). For instance dipalmitoyl phosphatidylcholinies an important lung surfactant. Respiratory distress syndrome infants is associated with insufficient production of this surfactant.
- Cephalins, an important group of phospholipids participate in blood clotting.
- Phospholipids (phosphatidylinositol) are involved in signal transmission across membranes.

DERIVED LIPIDS:

FATTY ACIDS:

- In chemistry, especially biochemistry, a fatty acid is a carboxylic acid with a long aliphatic tail (chain), which is either saturated or unsaturated.
- Most naturally occurring fatty acids have a chain of an even number of carbon atoms, from 4 to 28.
- Fatty acids are usually derived from triglycerides or phospholipids.
- When they are not attached to other molecules, they are known as "free" fatty acids.
- Fatty acids are important sources of fuel because, metabolized, they yield large quantities of ATP.
- Many cell types can use either glucose or fatty acids for this purpose.
- In particular, heart and skeletal muscle prefer fatty acids.
- The brain cannot use fatty acids as a source of fuel; it relies on glucose or ketone bodies

SATURATED AND UNSATURATED FATTY ACIDS:

- Saturated fatty acids do not contain double bonds, while unsaturated fatty acids contain one or more double bonds.
- Both saturated and unsaturated fatty acids almost equally occur in the natural lipids.
- Fatty acids with one double bond are monounsaturated and those with 2 or more double bonds are collectively known as polyunsaturated fatty acids (PIJFA).

CHOLESTEROL AND SIGNIFICANCE:

Cholesterol:

- Cholesterol, exclusively found in animals, is the most abundant animal sterol.
- It is widely distributed in all cells and is a major component of cell membranes and lipoproteins.
- Cholesterol (Creek: chole-bile) was first isolated from bile.
- Cholesterol literally means 'solid alcohol from bile.'

FUNCTIONS OF CHOLESTEROL:

- Cholesterol is a poor conductor of heat and electricity, since it has a high dielectric constant.
- It is present in abundance in nervous tissues.
- It appears that cholesterol functions as an insulating cover for the transmission of electrical impulses in the nervous tissue.
- Cholesterol performs several other biochemical functions which include its role in membrane structure and function, in the synthesis of bile acids, hormones (sex and cortical) and vitamin D.

SIGNIFICANCE:

- **Essential Fatty Acids (EFA's) are considered the building blocks of the** membranes for every cell in our body.
- The term essential means that our bodies do not produce these acids; therefore we must consume them in the foods we eat.
- T**wenty different fatty acids that our body's need. Surprisingly they are all made** from two basic acids, Linoleic Acid and Linolenic Acid. Linoleic Acid is part of the Omega–6 acids and Linolenic Acid is part of the Omega–3 acids.
- These two fatty acids are needed by our bodies to create and maintain the integrity of our cell membranes, regulate chemical processes that occur in our cells, and to maintain proper kidney functions.
- One part of the definition of oleic means derived from oil.
- Most people get plenty of Omega–6 fatty acids in their diet by consuming approximately a tablespoon of polyunsaturated plant oils per day.
- It would be easy if simply consuming Omega–3 and Omega–6 fatty acids would get us the needed nutrition for cell functions.
- Unfortunately studies on these important acids indicate that a proper balance or ratio of Omega–3 to Omega–6 is needed by our bodies to use them efficiently.
- **An easy way to check if you are getting enough EFA's in your diet is to** monitor the dryness of your skin.
- If your skin is too dry (watch during the changing of the seasons), your body may be indicating to you that it needs more Essential Fatty Acids.
- **If you're getting enough EFA's your skin should be soft to the touch.**

Plant steroids

Plant sterols and stanols are phytosterols, a general term for sterols produced in plants. They have a similar structure to cholesterol, which is a type of *zoo*sterol or a sterol produced in animals, and ergosterols found in fungi, like mushrooms. Chemically, and in the simplest of terms, a sterol is a steroid plus an alcohol group. Phytosterols and **zoosterols (cholesterol) differ from each other based on the components of their "tails", a** string of attached elements. Similar to fatty acids, sterols and stanols differ due to the presence of a double bond. Like unsaturated fatty acids, sterols have at least one double bond in their chemical structure. Stanols do not have a double bond present, like saturated fatty acids. Phytosterols have not been shown to have potentially negative impacts like animal cholesterol may. Plant steroids constitute a diverse group of natural products.

Biosynthetically, they are derived from *S*–squalene–2,3–epoxide via acetate–mevalonate pathway. Among the plant steroids, phytosterols are ubiquitous in the plant kingdom. It is significant that some phytosterols have been reported to possess hypocholesterolemic activity. Withanolides are a large group of steroidal lactones with various biological activities. Brassinosteroids are a small group of plant steroids exhibiting plant growth hormonal activity. Phytoecdysteroids are polyhydroxylated plant steroids, many of which are known to exhibit anabolic effects with no undesirable side effects. Steroidal alkaloids are nitrogen–containing plant steroids with an array of biological activities. It is noteworthy that trace amounts of cholesterol and mammalian steroidal hormones including progesterone have been detected in some plants.

Phytosterols (and ergosterols) are another player on the team to combat high cholesterol levels. Due to their very similar structure to animal cholesterol, they compete for absorption and reduce the amount of animal cholesterol absorbed. Use of plant sterols has been shown to significantly reduce LDL and total cholesterol, without impacting HDL. 4,5,6,7,8 The average reduction in total cholesterol ranged from roughly 5–10% and 5–20% in LDL cholesterol. As with most interventions, the law of diminishing returns applies: the larger the opportunity for improvement, the larger the effect. There also appears to be a dose response to sterols, meaning that when more is consumed, greater reductions in cholesterol are observed. One study showed a jump in the percentage of reduction in LDL from 7.4% to 17.4% when the dose was increased threefold.

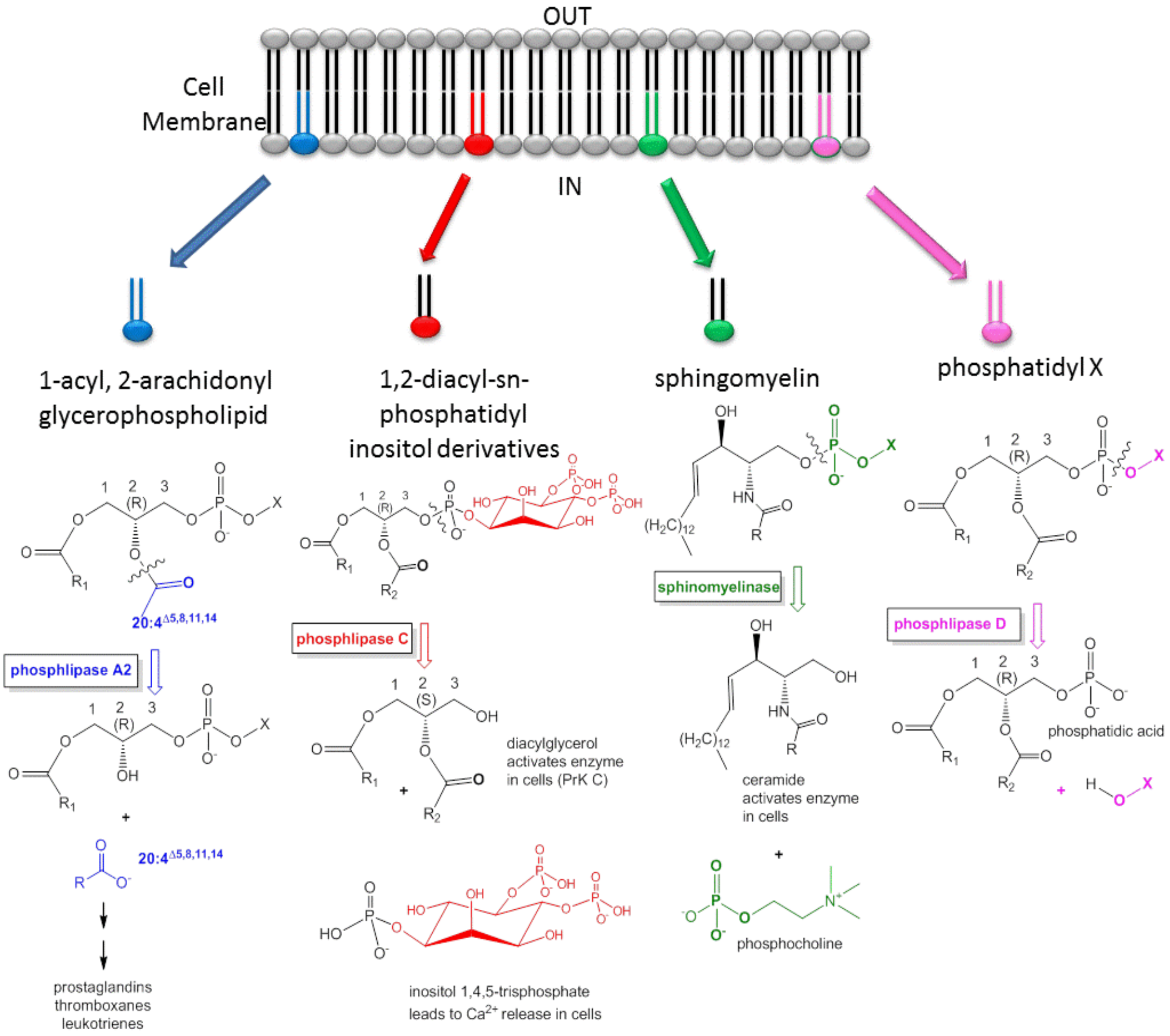
Where to get them?

We recommend 4 grams of plant sterols daily. They should be consumed with **meals in order to "block" the absorption of cholesterol from animal sources eaten during** the meals.

Plant sterols exist naturally in plants, obviously, with the largest amounts in the typical American diet coming from vegetables oils due to the quantity consumed. Nuts and seeds are actually the best source of plant sterols, but they are typically consumed in a much lower quantity. Plant sterols are also present in whole grains since whole grains still have the germ and bran intact, which contain fat. Processed grains remove the germ and bran and, therefore, the sterols are also removed. Rounding out the plant family, fruits and vegetables also contain comparable amounts to grains and nuts but with more variation between types.

Lipid as Signals

Lipids are not just used as a passive component of membranes, or as a source of stored energy. They are involved in the process of signal transduction at the cell membrane, a process by which the interior components of the cell respond to a signal external to the cell, allowing the cell to respond to their local environment. Usually a chemical signal on the outside of the cell is the "primary messenger" that causes the cell to respond. Usually the chemical transmitter of information does not get into the cell. Rather it binds to surface receptors on the cell membrane surface. Somehow, the cells senses that a ligand is bound to the outside. Enzymes, usually in the membrane or at the intracellular surface of the lipid bilayer are activated. Many of these enzymes cleave lipids in the membrane. The cleaved fragments of the lipid molecules serve as intracellular signals or "secondary messengers" , which can bind to intracellular enzymes to activate intracellular processes. The following diagram shows some of the lipid mediators which are generated by the process and signal the cell to respond.



Recently, fatty acid amides have been shown to be potent mediators of neurological processes. In one interesting experiment, sheep were sleep deprived. Reasoning that the brain might release a biochemical signal into cerebrospinal fluid to induce sleep, scientists at Scripps removed some of this fluid and isolated a substance that was not found in rested sheep. On analysis, the structure was shown to be an amide of oleic acid.. Oleylethanolamide has been shown to bind to the peroxisome–proliferator–activated receptor–α (PPAR–α) which resides in the nucleus. This ligand, by affecting gene transcription, appears to regulate body weight and the feeling of fullness after eating (satiety) as it ieads to reduced eating.

In an analogous fashion, people have sought the natural neurotransmitter which binds to the same receptor in the brain as THC, the active ingredient of marijuana. This was found several years ago and was shown to be the amide of arachidonic acid, called anandamide. See the figure below for structures.

Lipids as Signals Cofactors and Pigments

The two functional classes of lipids considered thus far (storage lipids and structural lipids) are major cellular components; membrane lipids make up 5% to 10% of the dry mass of most cells, and storage lipids more than 80% of the mass of an adipocyte. With some important exceptions, these lipids play a passive role in the cell; lipid fuels are stored until oxidized by enzymes, and membrane lipids form impermeable barriers around cells and cellular compartments. Another group of lipids, present in much smaller amounts, have active roles in the metabolic traffic as metabolites and messengers. Some serve as potent signals—as hormones, carried in the blood from one tissue to another, or as in-tracellular messengers generated in response to an extracellular signal (hormone or growth factor). Others function as enzyme cofactors in electron-transfer reactions in chloroplasts and mitochondria, or in the transfer of sugar moieties in a variety of glycosylation (addition of sugar) reactions. A third group consists of lipids with a system of conjugated double bonds: pigment molecules that absorb visible light. Some of these act as light-capturing pigments in vision and photosynthesis; others produce natural colorations, such as the orange of pumpkins and carrots and the yellow of canary feathers. Specialized lipids such as these are derived from lipids of the plasma membrane or from the fat-soluble vitamins A, D, E, and K. We describe in this section a few of these biologically active lipids. In later chapters, their synthesis and biological roles are considered in more detail.

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Department of Biochemistry
I B.Sc., Biochemistry
17BCU101- Molecules of life
Prepared By Dr. J . Anitha

Question number	Unit	Question	Option I	Option II	Option III	Option IV	Answer
1	3	Out of 200 different amino acids found in nature the number of aminoacids present in protein	20	25	43	30	20
2	3	At iso electric pH amino	anion	cation	zwitter ion	a&b	zwitter ion
3	3	Ampholytes have	only	only	both	all of the	all of the
4	3	The ionisable groups of	1			4	2
5	3	The ionisable groups of amino acids exist almost entirely as the conjugated base at	6.6	6.8	7.2	7.4	7.4
6	3	The melting point of amino	100^0C	180^0C	200^0C	220^0C	200^0C
7	3	Amino acids are insoluble in	Lactic acid	cholorofo	ethanol	benzone	benzone
8	3	the reagent for the detection	**Molisch's**	Dicholor	ninhydrin	both a	ninhydrin
9	3	Which among the following	Cysteine	leucine	tyrosine	Aspartic	leucine
10	3	The neutral amino acid is	leucine	lysine	proline	serine	leucine
11	3	Which amino acid is a	Lysine	leucine	tryptophan	tryptopha	methionin
12	3	The basic amino acid	Glycine	Histidine	proline	Cysteine	Histidine
13	3	Which among the following	Alanine	Glycine	tyrosine	imidazol	tryptopha
14	3	All amino acids are optically	Glycine	serine	threonine	methyl	Glycine
15	3	Which one of the following	methionine	cystine	Lysine	Ketones	Lysine
16	3	Arginine has a	Thiol group	Guanidi	phenolic	Serine	Guanidine
17	3	Formaldehyde reacts with	Carboxyl	amino	hydroxyl	methyl	amino
18	3	Ninhydrin reaction is	Amino &	carboxyli	Aldehydes	Ketones	Amino &
19	3	Serotonin is derived in the	Phenyl	histidine	tryptopha	Serine	tryptopha
20	3	The amino acid which	Histidine	arginine	attulin	Tryptop	Tryptoph
21	3	The amino acid which	Histidine	arginine	attulin	Ornithine	arginine
22	3	The amino acid which	Valine	alanine	Phenylalani	Histidien	alanine
23	3	Sakaguchi reaction is	cystine	ornithine	arginine	Arginino	arginine
24	3	The isoelecrtic point of an	optical	dissociati	diffusion	chain	optical
25	3	The amino acids exist as	solid state	acidic	alkaline	neutral	solid state

26	3	are absorbed into portal	are	are	are	converte	are
27	3	An amino acid which	lysine	methioni	homocystei	Cystine	Cystine
28	3	Amino acids are insoluble in	Acetic acid	Chlorofo	Ethanol	Benzene	Benzene
29	3	Owing to the opposite	Amphibolic	Ampholy	Both	ambhipat	Ampholyti
30	3	This protein has a pigment as	heme	haemogl	hematin	Collagen	haemoglo
31	3	Which of the following is	Proline	Asparagi	Lysine	Tryptoph	Proline
32	3	The amino acid which is not	Proline	Taurine	Semiessenti	Essential	Taurine
33	3	Haemoglobin is a	Glycoprotei	lipoprotei	mucoprotei	Chromo	Chromopr
34	3	Myoglobin consists of	**α- helices**	**β-Parallel**	antiparallel	**α-helix**	**α-helix &**
35	3	The naturally occuring amino acids are	**L- α-amino** acids	**L- β** amino	**D α- amino** acids	D-β amino	**D α-** amino
36	3						
37	3	Van der Waals force arise	ions	Transien	Electrons	Free	Transient
38	3	**Sanger's reagent is**	Phenol	phenyl	1-	Dinitrobe	1-
39	3	The neutral amino acid is	Glycine	Aspartic	Glutamic	lycine	Glycine
40	3	The dipole molecule is	Carbohydra	proline	Amino	Cholester	Amino
41	3	Which one the following	Phenyl	Alanine	Aspartic	Serine	Phenyl
42	3	Sakaguchi test is specific for	Arginine	serine	Alanine	Tyrosine	Arginine
43	3	Precipitation of protein by	neutralisati	dehydrati	dehydration	protein	neutralisa
44	3	**Millon's reagent is used to**	indole ring	imidazol	phenolic	benzene	phenolic
45	3	The peptide functions in	Vasopressin	Bradykin	Angiotensi	oxytocin	oxytocin
46	3	The peptide acts in the	Vasopressi	Bradykin	Angiotensi	oxytocin	Vasopress
47	3	The peptide involved in	vasopressin	glutathio	oxytocin	bradykini	glutathion
48	3	The melting point of amino	100^0C	180^0C	200^0C	220^0C	200^0C
49	3	Zwitter ion is the one which	no	one	two	no	no
50	3	The peptide involved in	vasopressin	glutathio	oxytocin	bradykini	glutathion
51	3	The melting point of amino	100^0C	180^0C	200^0C	220^0C	200^0C
52	3	Zwitter ion is the one which has in aqueous solution	one positive	two positive	two negative	no electrical	one positive
53	3	From two amino acids peptide bond formation	Water	Ammoni a	Carbondiox ide	Carboxyl ic acid	Water
54	3	The backbone of nucliec acid structure is contributed by	Hydrophobi c forces	hydrogen bonds	phosphodi ester linkages	ionic bonds	phosphodi ester linkages
55	3	The pyrimidine base of the DNA is	cytosine	Guanine	Uracil	Adenine	cytosine
56	3	There are three hydrogen bonds between Cytosine and	Adenine	guanine	cytosine	thymine	thymine
57	3	An increased melting temperature for duplex DNA results from a high content of	Adenine & Guanine	Cytosine &thymin e	Adenine &thymine	Cytosine &guanin e	Cytosine &guanine
58	3	The base which is absent in RNA is	Cytosine	Uracil	thymine	Adenine	thymine

59	3	The following facts are true of all transfer (t)RNA except	**the 5’ end is phosphoryl**	they are single	methylated bases are	the anticodo	the anticodon
60	3	Z-DNA was discovered by	Watson&Crick	Hoogsten	Chargaff	warg &Rich	Hoogsten

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DEPARTMENT OF BIOCHEMISTRY

SUBJECT NAME	: MOLECULES OF LIFE
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SEMESTER	: I
CLASS	: I B.Sc., BIOCHEMISTRY

UNIT IV

Amino acids and Nucleic acids: Structure and classification, physical, chemical and optical properties of amino acids. Nucleotides - structure and properties. Nucleic acid structure – Watson-Crick model of DNA. Structure of major species of RNA - mRNA, tRNA and rRNA. Nucleic acid chemistry - UV absorption, effect of acid and alkali on DNA. Other functions of nucleotides - source of energy, component of coenzymes, second messengers.

TEXT BOOKS

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Jain, J.L, Sunjay Jain and Nitin Jain, 2005. Fundamentals of Biochemistry, S. Chand and Company Ltd, New Delhi.

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Lubert Stryer, L. 2009, Biochemistry, W.H. Freeman and Company, New York.

Robert K. Murray, Daryl K. Granner, Peter A. Mayes, Victor W. Rodwell, 2012, **Harper's Biochemistry, 29th** edition, McGraw-Hill Medical, London.

AMINO ACIDS:

Definition:

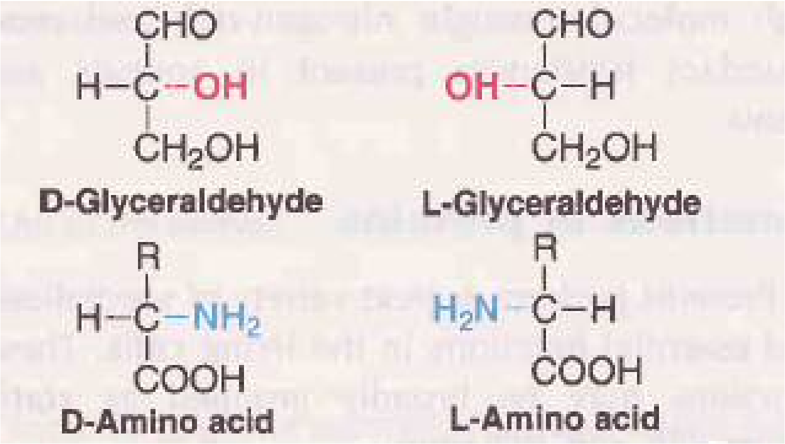
Amino acids are a group of organic compounds containing two functional groups amino and carboxyl. The amino group (-NH2) is basic while the carboxyl group (-COOH) is acidic in nature.

CLASSIFICATION:

There are different ways of classifying the amino acids based on the structure and chemical nature nutritional requirement, metabolic fate etc.

A. Amino acid classification based on the structure:

- A comprehensive classification of amino acids is based on their structure and chemical nature.
- Each amino acid is assigned a 3 letter or 1 letter symbol.
- These symbols are commonly used to represent the amino acids in protein structure.
- The 20 amino acids found in proteins are divided into seven distinct groups.
- The different groups of amino acids, their symbols and structures are given.
- The salient features of different groups are described next.



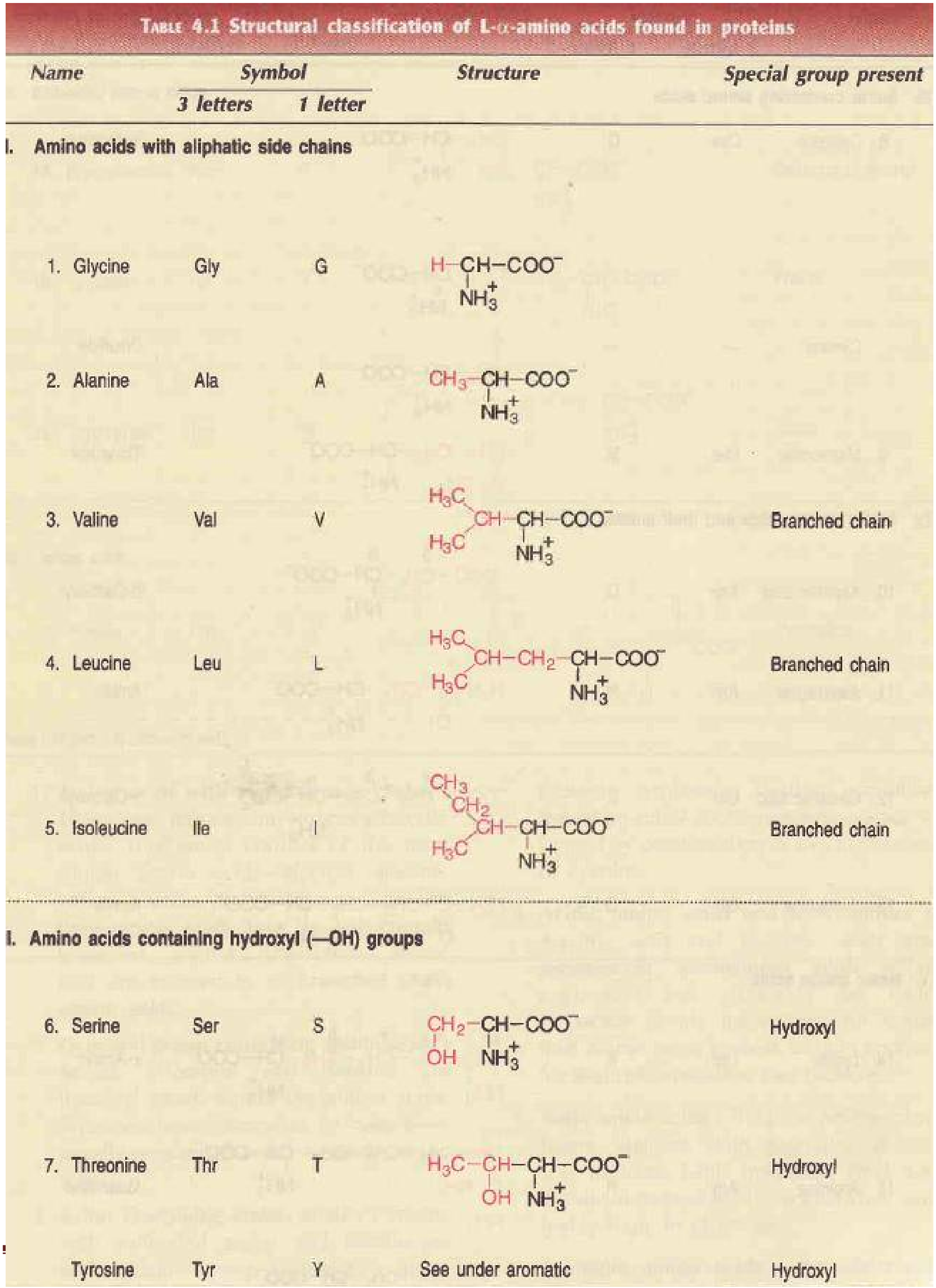
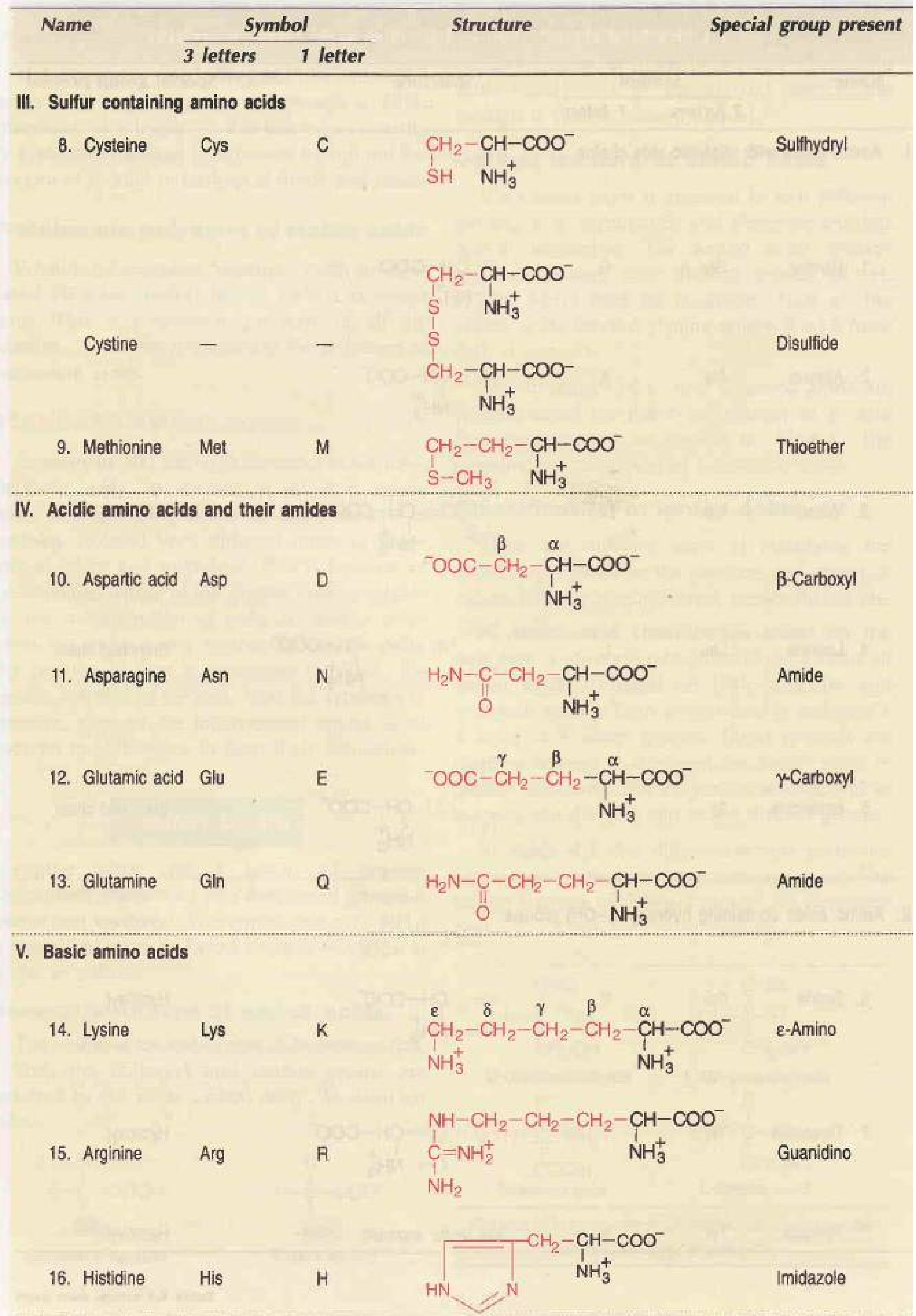
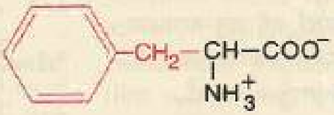
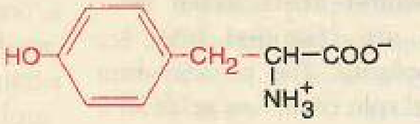
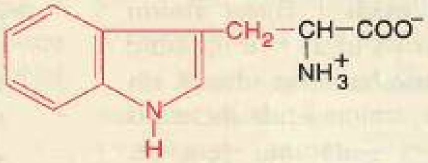
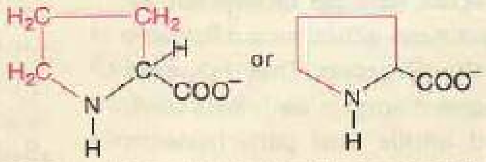


TABLE 4.1 Structural classification of L-α-amino acids found in proteins

Name	Symbol: 3 letters	Symbol: 1 letter	Structure	Special group present
I. Amino acids with aliphatic side chains				
1. Glycine	Gly	G	$\mathrm{H{-}\underset{NH_3^+}{\underset{\mid}{CH}}{-}COO^-}$	
2. Alanine	Ala	A	$\mathrm{CH_3{-}\underset{NH_3^+}{\underset{\mid}{CH}}{-}COO^-}$	
3. Valine	Val	V	$\mathrm{\overset{H_3C}{\underset{H_3C}{>}}CH{-}\underset{NH_3^+}{\underset{\mid}{CH}}{-}COO^-}$	Branched chain
4. Leucine	Leu	L	$\mathrm{\overset{H_3C}{\underset{H_3C}{>}}CH{-}CH_2{-}\underset{NH_3^+}{\underset{\mid}{CH}}{-}COO^-}$	Branched chain
5. Isoleucine	Ile	I	$\mathrm{\overset{CH_3{-}CH_2}{\underset{H_3C}{>}}CH{-}\underset{NH_3^+}{\underset{\mid}{CH}}{-}COO^-}$	Branched chain
I. Amino acids containing hydroxyl (—OH) groups				
6. Serine	Ser	S	$\mathrm{\underset{OH}{\underset{\mid}{CH_2}}{-}\underset{NH_3^+}{\underset{\mid}{CH}}{-}COO^-}$	Hydroxyl
7. Threonine	Thr	T	$\mathrm{H_3C{-}\underset{OH}{\underset{\mid}{CH}}{-}\underset{NH_3^+}{\underset{\mid}{CH}}{-}COO^-}$	Hydroxyl
Tyrosine	Tyr	Y	See under aromatic	Hydroxyl



Name	*Symbol*		*Structure*	*Special group present*
	3 letters	*1 letter*		
III. Sulfur containing amino acids				
8. Cysteine	Cys	C	$\underset{SH}{CH_2}-\underset{NH_3^+}{CH}-COO^-$	Sulfhydryl
Cystine	—	—	$CH_2-\underset{NH_3^+}{CH}-COO^-$ S S $CH_2-\underset{NH_3^+}{CH}-COO^-$	Disulfide
9. Methionine	Met	M	$\underset{S-CH_3}{CH_2}-CH_2-\underset{NH_3^+}{CH}-COO^-$	Thioether
IV. Acidic amino acids and their amides				
10. Aspartic acid	Asp	D	$^-OOC-\overset{\beta}{CH_2}-\underset{NH_3^+}{\overset{\alpha}{CH}}-COO^-$	β-Carboxyl
11. Asparagine	Asn	N	$H_2N-\underset{O}{\underset{\|}{C}}-CH_2-\underset{NH_3^+}{CH}-COO^-$	Amide
12. Glutamic acid	Glu	E	$^-OOC-\overset{\gamma}{CH_2}-\overset{\beta}{CH_2}-\underset{NH_3^+}{\overset{\alpha}{CH}}-COO^-$	γ-Carboxyl
13. Glutamine	Gln	Q	$H_2N-\underset{O}{\underset{\|}{C}}-CH_2-CH_2-\underset{NH_3^+}{CH}-COO^-$	Amide
V. Basic amino acids				
14. Lysine	Lys	K	$\underset{NH_3^+}{\overset{\varepsilon}{CH_2}}-\overset{\delta}{CH_2}-\overset{\gamma}{CH_2}-\overset{\beta}{CH_2}-\underset{NH_3^+}{\overset{\alpha}{CH}}-COO^-$	ε-Amino
15. Arginine	Arg	R	$\underset{\underset{NH_2}{C=NH_2^+}}{NH}-CH_2-CH_2-CH_2-\underset{NH_3^+}{CH}-COO^-$	Guanidino
16. Histidine	His	H	HN N $-CH_2-\underset{NH_3^+}{CH}-COO^-$	Imidazole

Name	Symbol		Structure	Special group present
	3 letters	1 letter		
VI. Aromatic amino acids				
17. Phenylalanine	Phe	F		Benzene or phenyl
18. Tyrosine	Tyr	Y		Phenol
19. Tryptophan	Trp	W		Indole
VII. Imino acid				
20. Proline	Pro	P		Pyrrolidine

(Note : R group is shown in red)

- Amino acids with aliphatic side chains: These are monoamino monocarboxylic acids. This group consists of the most simple amino acids-glycine, alanine, valine, leucine and isoleucine. The last three amino acids (Leu, Ile, Val) contain branched aliphatic side chains, hence they are referred to as branched chain amino acids.
- Hydroxyl group containing amino acids: Serine, threonine and tyrosine are hydroxyl group containing amino acids. Tyrosine-being aromatic in nature-is usually considered under aromatic amino acids.
- Sulfur containing amino acids: Cysteine with sulfhydryl group and methionine with thioether group are the two amino acids incorporated during the course of protein synthesis. Cystine, another important sulfur containing amino acid, is formed by condensation of two molecules of cysteine.
- Acidic amino acids and their amides: Aspartic acid and glutamic acids are dicarboxylic monoamino acids while asparagine and glutamine are their resoective amide derivatives. All these four amino acids possess distinct codons for their incorporation into proteins.

- Basic amino acids: The three amino acids lysine, arginine (with guanidino group) and histidine (with imidazole ring) are dibasic monocarboxylic acids. They are highly basic in character.
- Aromatic amino acids: Phenylalanine, tyrosine and tryptophan (with indole ring) are aromatic amino acids. Besides these, histidine may also be considered under this category.
- Imino acids: Proline containing pyrrolidine ring is a unique amino acid. It has an amino group (=NH), instead of an amino group (-NH2) found in other amino acids. Therefore proline is an aimino acid.

B. Classification of amino acids based on polarity:

- Amino acids are classified into 4 groups based on their polarity. The polarity in turn reflects the functional role of amino acids in protein structure.
- Non-polar amino acids : These amino acids are also referred to as hydrophobic (water hating). They have no charge on the 'R' group. The amino acids included in this group are - alanine, leucine, isoleucine, valine, methionine, phenylalanine, tryptophan and proline.
- Polar amino acids with no charge on 'R' group: These amino acids, as such, carry no charge on the 'R'group. They however possess groups such as hydroxyl, sulfhydryl and amide and participate in hydrogen bonding of protein structure. The simple amino acid glycine (where R = H) is also considered in this category. The amino acids in this group are glycine, serine, threonine, cysteine, glutamine, asparagine and tyrosine.
- Polar amino acids with positive 'R' group: The three amino acids lysine, arginine and histidine are included in this group.
- Polar amino acids with negative 'R'group: The dicarboxylic monoamino acids aspartic acid and glutamic acid are considered in this group.

C. Nutritional classification of amino acids:

- The twenty amino acids are required for the synthesis of variety of proteins, besides other biological functions.
- However, all these 20 amino acids need not be taken in the diet. Based on the nutritional requirements amino acids are grouped into two classes essential and nonessential.
- Essential or indispensable amino acids: The amino acids which cannot be synthesized by the body and, therefore, need to be supplied through the diet are called essential amino acids. They are required for proper growth and maintenance of the individual. The ten amino acids listed below are essential for humans.
- Non - essential or dispensable amino acids : The body can synthesize about '10 amino acids to meet the biological needs, hence they need not be consumed in the diet. These are-glycine, alanine, serine, cystein e, aspartate,a sparagnie, glutamate, glutamine, tyrosine and proline.

D. Amino acid classification based on their metabolic fate:

- The carbon skeleton of amino acids can serve as a precursor for the synthesis of glucose.

- From metabolic view point, amino acids are divided into three
- Glycogenic amino acids: These amino acids can serve as precursors for the formation of glucose or glycogen. e.g. alanine, aspartate, glycine, methionine etc.
- Ketogenic amino acids: Fat can be synthesized from these amino acids. Two amino acids leucine and lysine are exclusively ketogenic.
- Glycogenic and ketogenic amino acids: The four amino acids isoleucinep, henylalanine, tryptophan, tyrosine are precursors for synthesis of glucose as well as fat.

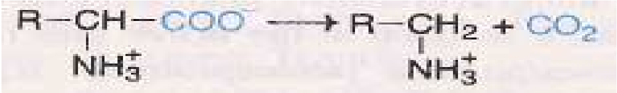
CHEMICAL REACTIONS OF AMINO ACIDS:

- The general reactions of amino acids are mostly due to the presence of two functional groups namely carboxyl (-COOH) group and amino (-NH2) group.

REACTIONS DUE TO -COOH GROUP:

1. Amino acids form salts (-COONa) with bases and esters (-COOR') with alcohols.

2. Decarboxylation: Amino acids undergo decarboxylation to produce corresponding amines.



$$R-\underset{NH_3^+}{CH}-COO^- \longrightarrow R-\underset{NH_3^+}{CH_2} + CO_2$$

- This reaction assumes significance in the living cells due to the formation of many biologically important amines.
- These include histamine, tyramine and y-amino butyric acid (CABA) from the amino acids histidine, tyrosine and glutamate, respectively.

3. Reaction with ammonia: The carboxyl group of dicarboxylic amino acids reacts with NH3 to form amide

  - Aspartic acid + NH, ------ Asparagine
  - Glutamic acid + NH. ------Glutamine

REACTIONS DUE TO -NH_2 GROUP:

4. The amino groups behave as bases and combine with acids (e.g. HCl) to form salts (-NHiCl-).

5. Reaction with ninhydrin : The a-amino acids react with ninhydrin to form a purple, blue or pink colour complex (Ruhemann's purple).

  - Amino acid + Ninhydrin ----- Keto acid + NH_3+CO_2+Hydrindantin
  - Hydrindantin + NH_3 + Ninhydrin- ---- Ruhemann's purple
  - Ninhydrin reaction is effectively used for the quantitative determination of amino acids and proteins.

6. Colour reactions of amino acids: Amino acids can be identified by specific colour reactions

7. Transamination: Transfer of an amino group from an amino acid to a keto acid to form a new amino acid is a very important reaction in amino acid metabolism.

8. Oxidative deamination: The amino acids undergo oxidative deamination to liberate free ammonia.

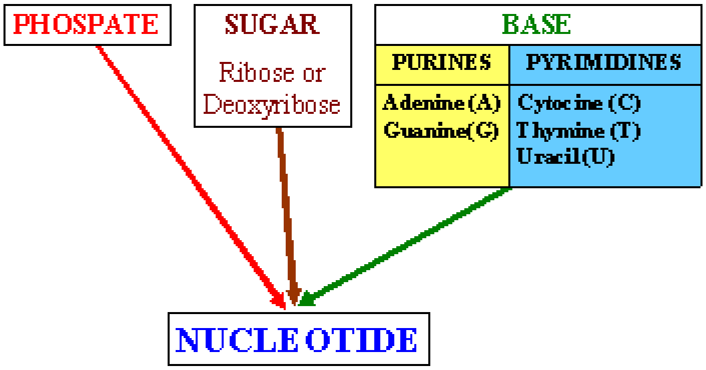
NUCLEIC ACIDS:

Nucleic acids consist of nucleotides that have a sugar, nitrogen base, and phosphate. Two types of nucleic acid are found.

- Deoxyribonucleic acid (DNA)
- Ribonucleic acid (RNA)

Nucleic Acid Structure

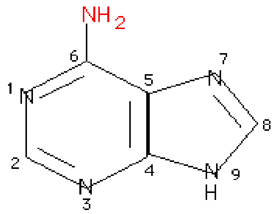
- Polymers of four nucleotides
- Linked by alternating sugar-phosphate bonds
- RNA: ribose and A, G, C, U
- DNA: deoxyribose and A,G,C,T
- Nucleic acids are polynucleotides
- Their building blocks are nucleotides



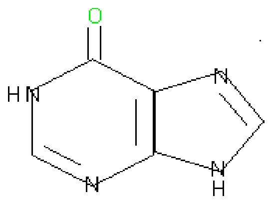
STRUCTURE OF PURINES AND PYRIMIDINES:

PURINES:

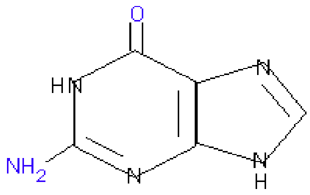
- A purine is a heterocyclic aromatic organic compound, consisting of a pyrimidine ring fused to an imidazole ring.
- Adenine = 6-amino purine
- Guanine = 2-amino-6-oxy purine
- Hypoxanthine = 6-oxy purine
- Xanthine = 2,6-dioxy purine



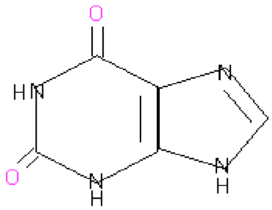
Adenine



Hypoxanthine



Guanine

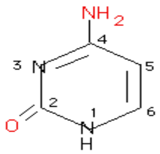


Xanthine

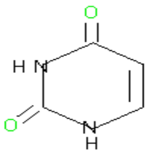
- Adenine and guanine are found in both DNA and RNA.
- Hypoxanthine and xanthine are not incorporated into the nucleic acids as they are being synthesized but are important intermediates in the synthesis and degradation of the purine nucleotides.

PYRIMIDINES:

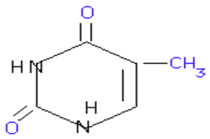
- Uracil = 2,4-dioxy pyrimidine
- Thymine = 2,4-dioxy-5-methyl pyrimidine
- Cytosine = 2-oxy-4-amino pyrimidine
- Orotic acid = 2,4-dioxy-6-carboxy pyrimidine



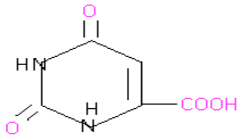
Cytosine



Uracil



Thymine



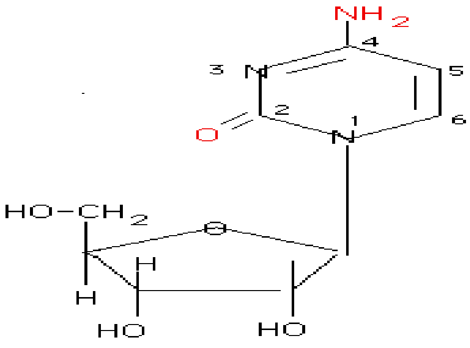
Orotic Acid

- Cytosine is found in both DNA and RNA.
- Uracil is found only in RNA.
- Thymine is normally found in DNA.
- Sometimes tRNA will contain some thymine as well as uracil.

NUCLEOSIDES:

- If a sugar, either ribose or 2-deoxyribose, is added to a nitrogen base, the resulting compound is called a nucleoside.
- Carbon 1 of the sugar is attached to nitrogen 9 of a purine base or to nitrogen 1 of a pyrimidine base.

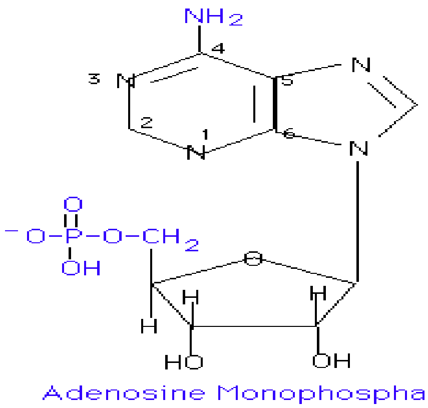
- The names of purine nucleosides end in -osine and the names of pyrimidine nucleosides end in -idine.
- The convention is to number the ring atoms of the base normally and to use l', etc. to distinguish the ring atoms of the sugar.
- Unless otherwise specified, the sugar is assumed to be ribose.
- To indicate that the sugar is 2'-deoxyribose, a d- is placed before the name.
    - Adenosine
    - Guanosine
    - Inosine - the base in inosine is hypoxanthine
    - Uridine
    - Thymidine
    - Cytidine



Cytidine

NUCLEOTIDES:

- Adding one or more phosphates to the sugar portion of a nucleoside results in a nucleotide.
- Generally, the phosphate is in ester linkage to carbon 5' of the sugar.
- If more than one phosphate is present, they are generally in acid anhydride linkages to each other.
- If such is the case, no position designation in the name is required.
- If the phosphate is in any other position, however, the position must be designated.
- For example, 3'-5' cAMP indicates that a phosphate is in ester linkage to both the 3' and 5' hydroxyl groups of an adenosine molecule and forms a cyclic structure.
- 2'-GMP would indicate that a phosphate is in ester linkage to the 2' hydroxyl group of a guanosine. Some representative names are:
    - AMP = adenosine monophosphate = adenylic acid
    - CDP = cytidine diphosphate
    - dGTP = deoxy guanosine triphosphate
    - dTTP = deoxy thymidine triphosphate (more commonly designated TTP)
    - cAMP = 3'-5' cyclic adenosine monophosphate



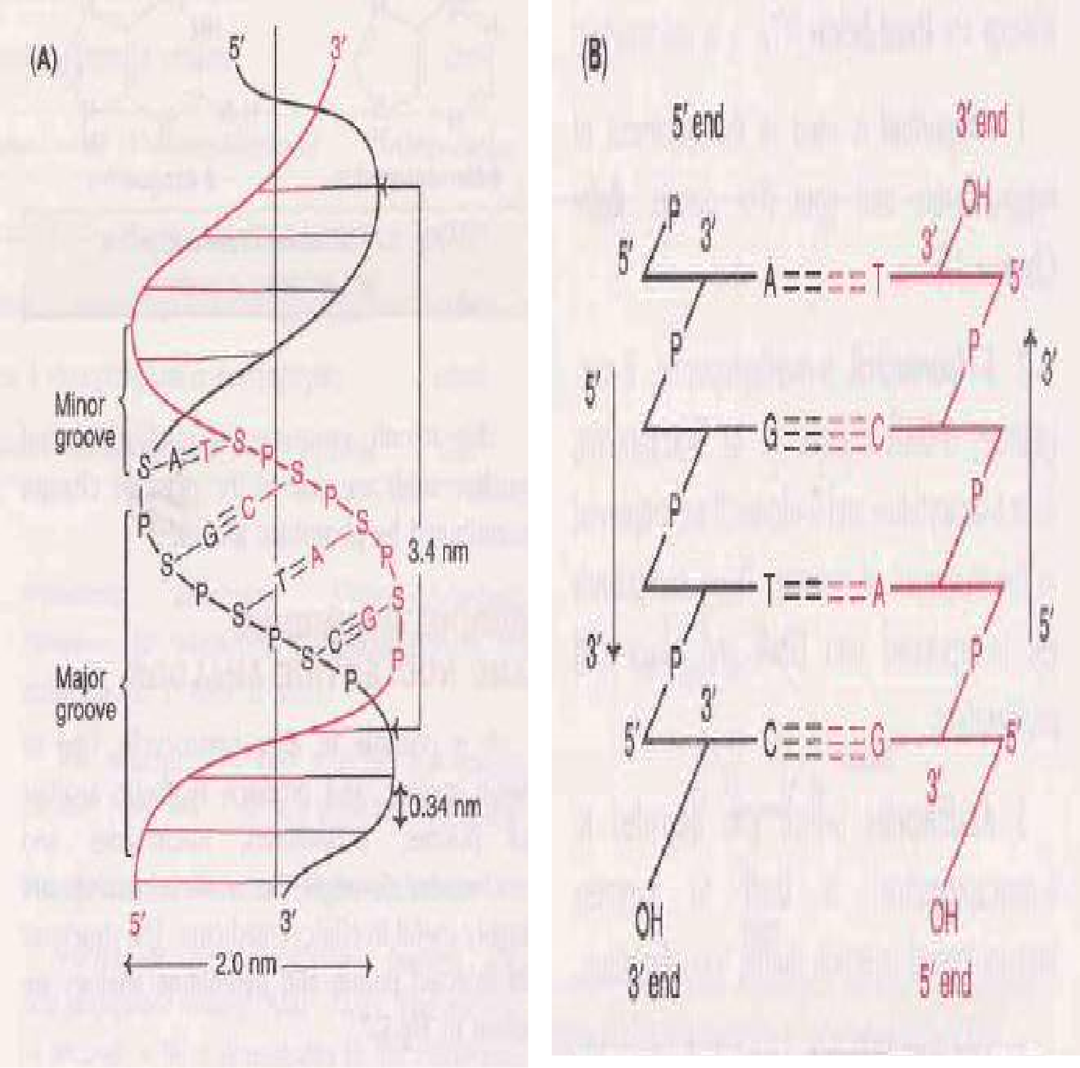
Adenosine Monophosphate
AMP

DNA:

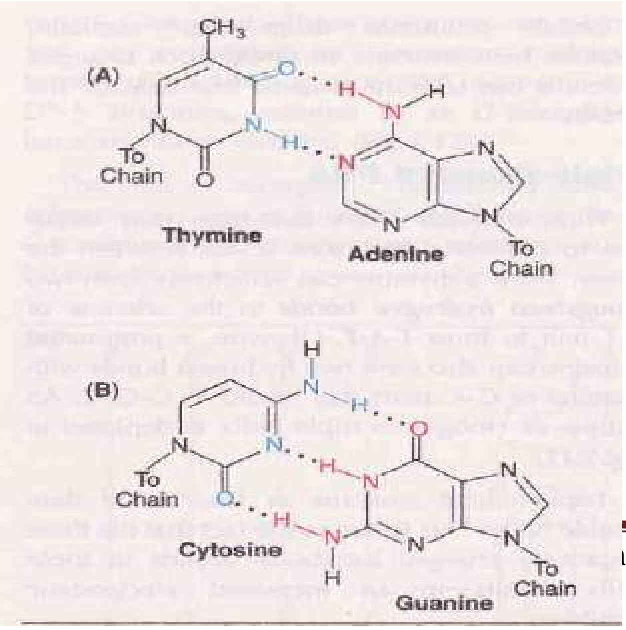
- DNA is a polymer of deoxyribonucleotides (or simply deoxynucleotides).
- It is composed of monomeric units namely deoxyadenylate (dAMP), eoxyguanylate (dGMP), deoxycytidylate(dCMP) and deoxythymidylate(d TMP) (It may be noted here that some authors prefer to use TMP for deoxythymidylate, since it is found only in DNA).
- The details of the nucleotide structure are given above.

DNA DOUBLE HELIX:

- The double helical structure of DNA was proposed by lames Watson and Francis Crick in 1953 (Nobel Prize, 1962).
- The elucidation of DNA structure is considered as a milestone in the era of modern biology.
- The structure of DNA double helix is comparable to a twisted ladder.
- The salient features of Watson - Crick Model of DNA (now known as B-DNA) are described next.



(A) Watson-Crick model of DNA helix (B) Complementary base pairing in DNA helix.

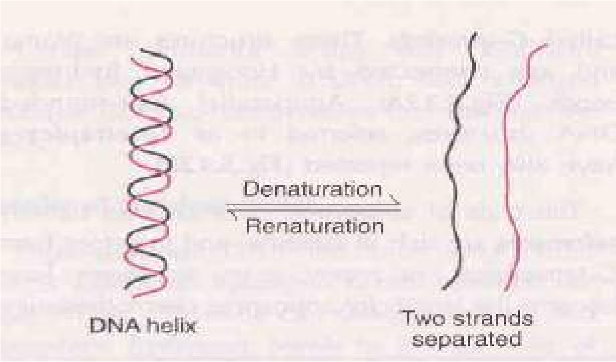


Complementary base paring in DNA
(A) Thymine pairs with adenine by 2 hydrogen bonds
(B) Cytosine pairs with guanine by 3 hydrogen bonds.

- The DNA is a right handed double helix.
- It consists of two polydeoxyribonucleotide chains (strands) twisted around each other on a common axis.
- The two strands are antiparallel, i.e., one strand runs in the 5' to 3' direction while the other in 3'to 5'direction.T his is comparable to two parallel adjacent roads carrying traffic in opposite direction.
- The width (or diameter) of a double helix is 20 A° (2 nm).
- Each turn (pitch) of the helix is 34 A" (3.4 nm) with 10 pairs of nucleotides each pair placed at a distance of about 3.4 A°.
- Each strand of DNA has a hydrophilic deoxyribose phosphate backbone (3'-5' phosphor diester bonds)o n the outside (periphery) of the molecule while the hydrophobic bases are stacked inside (core).
- The two polynucleotide chains are not identical but complementary to each other due to base pairing.
- The two strands are held together by hydrogen bonds formed by complementary base pairs.
- The A-T pair has 2 hydrogen bonds while G-C pair has 3 hydrogen bonds. The G = C is stronger by about 50% than A=T.
- The hydrogen bonds are formed between a purine and a pyrimidine only.
- If two purines face each other, they would not fit into the allowable space. And two pyrimidines would be too far to form hydrogen bonds.
- The only base arrangement possible in DNA structure, from spatial considerations is A-T, T-A, G-C and C-C.
- The complementary base pairing in DNA helix proves Chargaffs rule.
- The content of adenine equals to that of thymine (A = T) and guanine equals to that of cytosine (G = C). 10.
- The genetic information resides on one of the two strands known as template strand or sense strand.
- The opposite strand is antisense strand.
- The double helix has (wide) major grooves and (narrow) minor grooves along the phosphodiester backbone.
- Proteins interact with DNA at these grooves, without disrupting the base pairs and double helix.

DENATURATION OF DNA STRANDS:

- The two strands of DNA helix are held together by hydrogen bonds.
- Disruption of hydrogen bonds (by change in pH or increase in temperature) results in the separation of polynucleotide strands.
- This phenomenon of loss of helical structure of DNA is known as denaturation.
- The phosphodiester bonds are not broken by denaturation.
- Loss of helical structure can be measured by increase in absorbance at 260 nm (in a spectrophotometer).



denaturation and renaturation of DNA.

- Melting temperature (Tm) is defined as the temperature at which half of the helical structure of DNA is lost.
- Since C-C base pairs are more stable (due to 3 hydrogen bonds) than A-T base pairs(2 hydrogen bonds), the Tm is greater for DNAs with higher C-C content.
- Thus, the Tm is 65°C for 35% G-C content while it is 70°C for 50% G-C content.
- Formamide destabilizes hydrogen bonds of base pairs and, therefore, lowers Tm.
- This chemical compound is effectively used in recombinant DNA experiments.

RENATURATION:

- Renaturation or reannealing is the process in which the separated complementary DNA strands can form a double helix.

RNA:

- Ribonucleic acid or RNA, is one of the three major macromolecules (along with DNA and proteins) essential for all known forms of life.

TYPES OF RNA:

- The three major types of RNAs with their respective cellular composition are given below
  1. Messenger RNA (mRNA): 5-1O"/"
  2. Transfer RNA (tRNA): 10-200/"
  3. Ribosomal RNA (rRNA): 50-80%

Messenger RNA (mRNA)

- The mRNA is synthesized in the nucleus (in eukaryotes) as heterogeneous nuclear RNA (hnRNA).
- hnRNA, on processing, liberates the functional mRNA which enters the cytoplasm to participate in protein synthesis.
- mRNA has high molecular weight with a short half-life.
- The eukaryotic mRNA is capped at the S'-terminal end by 7- methylguanosine triphosphate.
- It is believed that this cap helps to prevent the hydrolysis of mRNA by 5'-exonucleases.
- Further,t he cap may be also involved in the recognition of mRNA for protein synthesis.

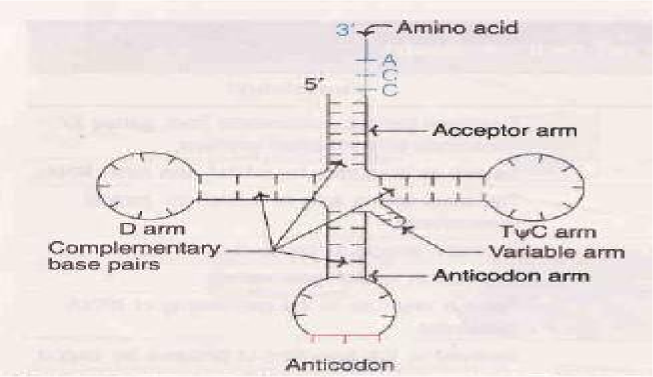
- The 3'-terminal end of mRNA contains a polymer of adenylate residues (20-250 nucleotides) which is known as poly (A) tail.
- This tail may provide stability to mRNA, besides preventing it from the attack of 3'-exonucleases.mRNA molecules often contain certain modified bases such as 6-methyladenylatesin the internal structure.

Transfer RNA (tRNA)

- Transfer RNA (soluble RNA) molecule contains 71-80 nucleotides (mostly 75) with a molecular weight of about 25,000.
- There are at least2 0 species of tRNAs, corresponding to 20 amino acids present in protein structure.
- The structure of tRNA (for alanine) was first elucidated by Holley.
- The structure of IRNA, depicted in resembles that of a clover leaf tRNA contains mainly four arms, each arm with a base paired stem.

  1. The acceptor arm: This arm is capped with a sequence C CA (5'to 3'). The amino acid is attached to the acceptor arm.

  2. The anticodon arm: This arm, with the three specific nucleotide bases (anticodon), is responsible for the recognition of triplet codon of mRNA. The codon and anticodon are complementary to each other.



Structure of transfer RNA.

  3. The D arm : It is so named due to the presence of dihydrouridine.
  4. The TΨC arm : This arm contains a sequence of T, pseudouridine (represented by Psi, Ψ) and C.
  5. The variable arm : This arm is the most variable in tRNA. Based on this variability, tRNAs are classified into 2 categories :
  (a) Class I tRNAs : The most predominant (about 75"/") form with 3-5 base pairs length"
  (b) Class II tRNAs : They contain 13-20 base pair long arm.

- Base pairs in tRNA : The structure of tRNA is maintained due to the complementary base pairing in the arms.
- The four arms with their respective base pairs are given below
  - The acceptor arm - 7 bp

- The TΨC arm - 5 bp
- The anticodon arm - 5 bp
- The Darm -4bp

Ribosomal RNA (rRNA)

- The ribosomes are the factories of protein synthesis.
- The eukaryotic ribosomes are composed of two major nucleoprotein complexes-60S subunit and 40S subunit.
- The 605 subunit contains 28S rRNA, 55 rRNA and 5.8S rRNA while the 40S subunit contains 18S rRNA.
- The function of rRNAs in ribosomes is not clearly known.
- It is believed that they play a significant role in the binding of mRNA to ribosomes and protein synthesis.

STRUCTURE:

- RNA is a polymer of ribonucleotides held together by 3',5'-phosphodiester bridges.
- Although RNA has certain similarities with DNA structure, they have specific differences.
- Pentose: The sugar in RNA is ribose in contrast to deoxyribose in DNA.
- Pyrimidine : RNA contains the pyrimidines uracil in place of thymine (in DNA).
- Single strand: RNA is usually a singlestranded polynucleotide. However, this strand may fold at certain places to give a doublestranded structure, if complementary base pairs are in close proximity.
- Chargaff's rule-not obeyed: Due to the single-stranded nature, there is no specific relation between purine and pyrimidines contents. Thus the guanine content is not equal to cytosine (as is the case in DNA).
- Susceptibility to alkali hydrolysis: Alkali can hydrolyse RNA to 2',3'-cyclic diesters. This is possible due to the presence of a hydroxyl group at 2' position. DNA cannot be subjected to alkali hydrolysis due to lack of this group.
- Orcinol colour reaction : RNAs can be histologically identified by orcinol colour reaction due to the presence of ribose.

FUNCTIONS OF RNA

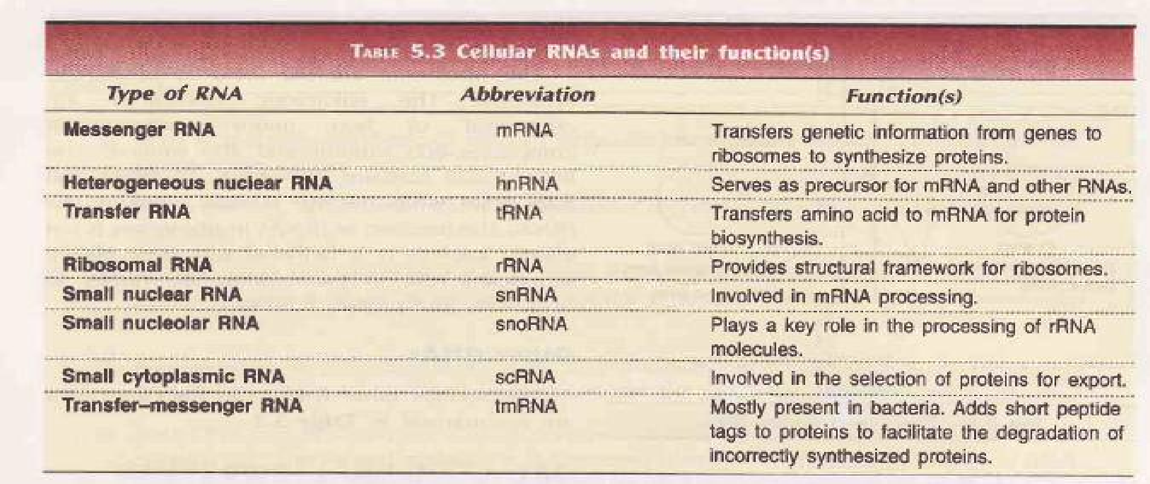


TABLE 5.3 Cellular RNAs and their function(s)

Type of RNA	*Abbreviation*	*Function(s)*
Messenger RNA	mRNA	Transfers genetic information from genes to ribosomes to synthesize proteins.
Heterogeneous nuclear RNA	hnRNA	Serves as precursor for mRNA and other RNAs.
Transfer RNA	tRNA	Transfers amino acid to mRNA for protein biosynthesis.
Ribosomal RNA	rRNA	Provides structural framework for ribosomes.
Small nuclear RNA	snRNA	Involved in mRNA processing.
Small nucleolar RNA	snoRNA	Plays a key role in the processing of rRNA molecules.
Small cytoplasmic RNA	scRNA	Involved in the selection of proteins for export.
Transfer–messenger RNA	tmRNA	Mostly present in bacteria. Adds short peptide tags to proteins to facilitate the degradation of incorrectly synthesized proteins.

Nucleic acid chemistry

UV Absorbance

UV Absorbance of Pyrimidines and Purines

- **Both Pyrimidines and Purines have strong absorbance in the ultraviolet around 260 nm**
- **This is a useful property in measuring quantitie**s of nucleic acid in a sample.

Effect of acid and alkali on DNA

Ordinarily each DNA molecule inside your cells contains two strands joined together by interactions called hydrogen bonds. Change in conditions, however, can "denature" the DNA and cause these strands to separate. Adding strong bases, like NaOH, dramatically increases the pH, thus decreasing the hydrogen ion concentration of the solution and denaturing double-stranded DNA.

The chemical difference between RNA and DNA polymers (the absence of the 2' hydroxyl group) results in differences between the reaction of DNA and RNA to alkaline conditions. Because ribose has both 2' and 3' hydroxyl groups, the 2' hydroxyl can "attack" the phosphodiester bond in the presence of hydroxyl (OH-) radicals, which results in the phosphate backbone being broken. Because DNA does not have a 2' hydroxyl group, DNA polymers cannot undergo this alkaline clevage.

EFFECTS OF PH

The hydroxide ion concentration and pH have a direct correlation, meaning the higher the pH, the higher the hydroxide concentration. Likewise, the lower the hydrogen ion concentration falls. At high pH, then, the solution is rich in hydroxide ions, and these negatively-charged ions can pull hydrogen ions off of molecules like the base pairs in DNA. This process disrupts the hydrogen bonding that holds the two DNA strands together, causing them to separate.

RNA VS. DNA

Unlike RNA, DNA lacks a hydroxyl group on the 2' position in each sugar group. This difference makes DNA much more stable in alkaline solution. In RNA, the hydroxyl group on the 2' position can give up a hydrogen ion to the solution at high pH, creating a highly reactive alkoxide ion that attacks the phosphate group holding two neighboring nucleotides together. DNA does not suffer from this defect and thus enjoys remarkable stability at high pH.

ALKALINE LYSIS

Molecular biologists often make use of alkaline denaturation to isolate plasmid DNA from bacteria. Plasmids are little loops of DNA separate from the bacterial chromosome. In an alkaline lysis miniprep, biologists add detergent and sodium hydroxide to bacteria suspended in solution. The detergent dissolves the bacterial cell membrane while the sodium hydroxide boosts the pH and makes the solution highly alkaline. As the broken cells release their contents, the DNA inside separates into its component strands, or denatures.

REANNEALING

Once the biologist extracts the DNA from the cell, he adds another reagent to return the solution to a more neutral pH and precipitate the detergent. The change in pH allows the plasmid strands to reanneal; the bulky chromosome, however, cannot do the same, so the biologist can remove it together with the detergent, denatured proteins and other assorted junk, leaving the plasmid behind. Alkaline lysis does not completely purify the plasmid DNA; rather, it serves as a "quick and dirty" way to extract it from the cell and remove most other contaminants.

Other Functions of Nucleotides

In addition to their roles as the subunits of nucleic acids, nucleotides have a variety of other functions in every cell: as energy carriers, components of enzyme cofactors, and chemical messengers.

Nucleotides Carry Chemical Energy in Cells

Nucleotides may have one, two, or three phosphate groups covalently linked at the 5' hydroxyl of ribose. These are referred to as nucleoside mono-, di-, and triphosphates, respectively (Fig. 12-39). Starting from the ribose, the three phosphates are generally labeled α, β, and γ. Nucleoside triphosphates are used as a source of chemical energy to drive a wide variety of biochemical reactions. ATP is by far the most widely used, but UTP, GTP, and CTP are used in specific reactions. Nucleoside triphosphates also serve as the activated precursors of DNA and RNA synthesis.

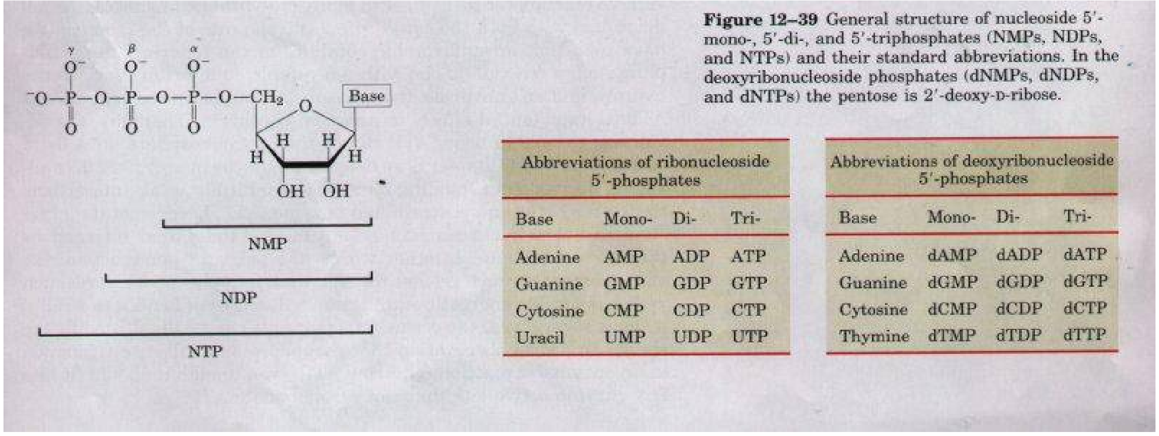


Figure 12–39 General structure of nucleoside 5'-mono-, 5'-di-, and 5'-triphosphates (NMPs, NDPs, and NTPs) and their standard abbreviations. In the deoxyribonucleoside phosphates (dNMPs, dNDPs, and dNTPs) the pentose is 2'-deoxy-D-ribose.

Abbreviations of ribonucleoside 5'-phosphates

Base	Mono-	Di-	Tri-
Adenine	AMP	ADP	ATP
Guanine	GMP	GDP	GTP
Cytosine	CMP	CDP	CTP
Uracil	UMP	UDP	UTP

Abbreviations of deoxyribonucleoside 5'-phosphates

Base	Mono-	Di-	Tri-
Adenine	dAMP	dADP	dATP
Guanine	dGMP	dGDP	dGTP
Cytosine	dCMP	dCDP	dCTP
Thymine	dTMP	dTDP	dTTP

The hydrolysis of ATP and the other nucleoside triphosphates is an energy-yielding reaction because of the chemistry of the triphosphate structure. The bond between the ribose **and the αphosphate is an ester linkage. The α-β and β-γ linkages** are phosphoric acid anhydrides (Fig. 12-40). Hydrolysis of the ester linkage yields about 14 kJ/mol, whereas hydrolysis of each of the anhydride bonds yields about 30 kJ/mol. In biosynthesis, ATP hydrolysis often drives less favorable metabolic **reactions (i.e., those with** $\Delta G^{0'} > 0$). When coupled to a reaction with a positive free-energy change, ATP hydrolysis shifts the equilibrium of the overall process to favor product formation.

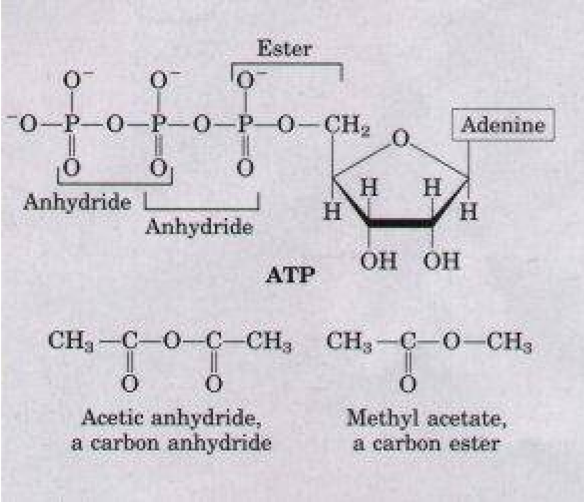


Figure 12-40 The phosphate ester and phosphoric acid anhydride bonds of ATP. Hydrolysis of an anhydride bond yields more energy than hydrolysis of the ester. A carbon anhydride and ester are shown for comparison

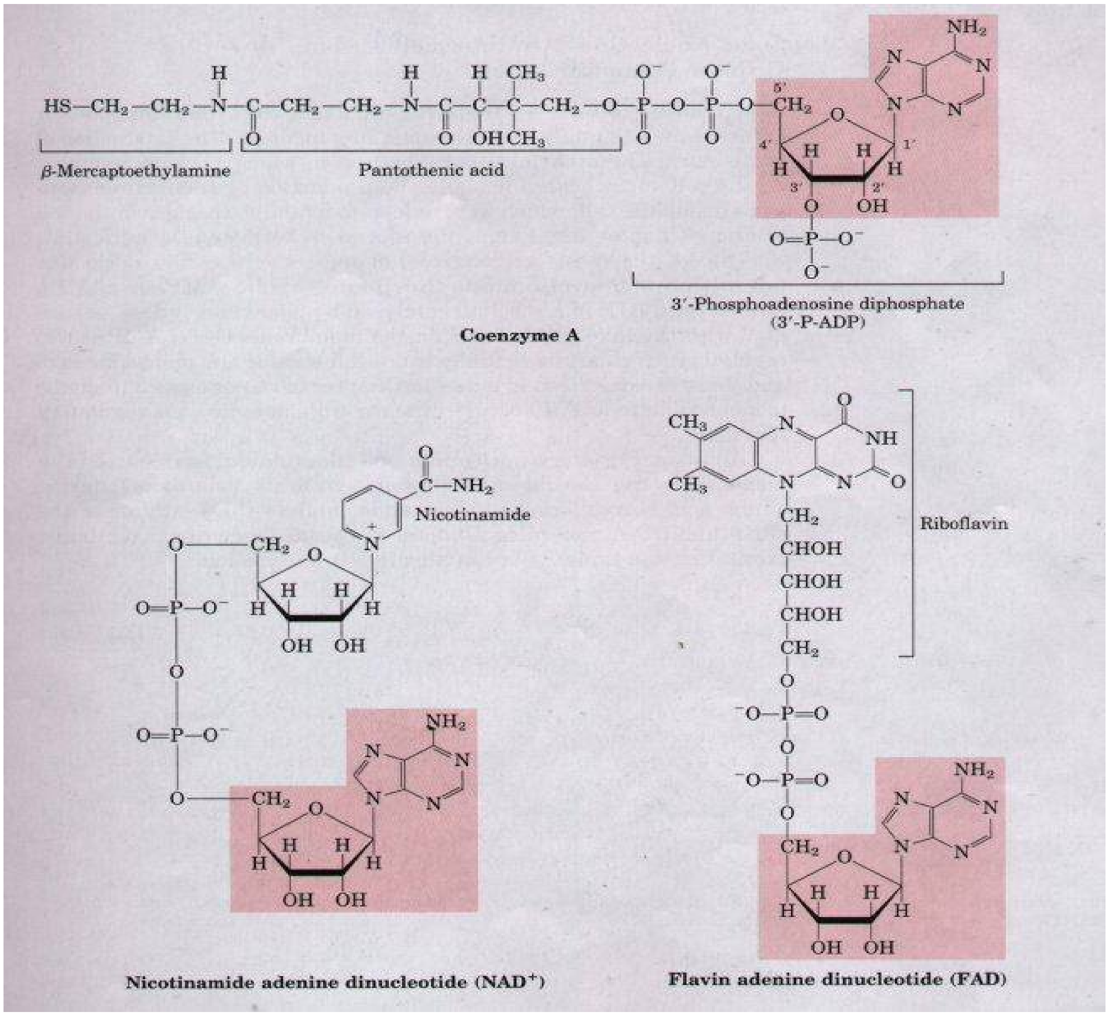
It is appropriate to ask why ATP serves as the primary carrier of energy in the cell. The chemical energy potential of pyrophosphate (~33 kJ/mol), a much simpler molecule, is almost identical to that of ATP because pyrophosphate also contains a phosphoric acid anhydride. Pyrophosphate would be so much easier to synthesize than ATP that the selection of ATP at first seems to contradict evolutionary logic.

The explanation can be found in the fundamental energetic principles governing every chemical reaction. In promoting chemically unfavorable reactions such as those in many biosynthetic processes, the cell must deal with both the equilibrium and the rate of the reaction. We have seen that an unfavorable equilibrium can be overcome by coupling such a reaction to one with a favorable equilibrium, such as the hydrolysis of an anhydride. Pyrophosphate would be just as effective as ATP in its potential effects on reaction equilibria. Therefore, the advantage to cells in using ATP rather than pyrophosphate must lie in reaction rates. In Chapter 8 we described how the energy used in catalysis is derived from binding energy, the multiple weak interactions that occur between substrate and enzyme. ATP, because of its larger structure, clearly can contribute many more of these weak interactions than pyrophosphate. In other words, the potential for reaction rate enhancement is much greater for ATP than pyrophosphate. A reaction with a favorable energetic equilibrium will not be of benefit to a cell if it takes several years to occur. This principle can by the simple empirical observation that pyrophosphate will rarely function in an enzymatic reaction requiring ATP, even though it should fit into any enzyme active site that can accommodate ATP.

Nucleotides Are Components of Many Enzyme Cofactors

A variety of enzyme cofactors serving a wide range of chemical functions include adenosine as part of their structure. They are unrelated structurally except for the presence of adenosine. In none of these cofactors does the adenosine portion participate directly in the primary function, but removal of adenosine from these structures generally results in a drastic reduction of their activities. For example, removal of the adenosine nucleotide (3'-P-ADP) from acetoacetyl-CoA reduces its reactivity as a substrate for β-ketoacylCoA transferase (an enzyme of lipid metabolism) by a factor of 106. Although the reason for this requirement for adenosine has not been examined in detail, it must involve the binding energy between enzyme and substrate (or cofactor) that is used both in catalysis and to stabilize the initial ES complex. In the case of CoA transferase, the nucleotide appears to be a binding "handle" that helps to pull the substrate into the active site. Similar roles may be found for the nucleoside portion of other nucleotide cofactors.

Now we may ask why adenosine, rather than some other large molecule, is used in these structures. The answer here may involve a kind of evolutionary economy. Adenosine is certainly not unique in the amount of potential binding energy it can contribute. The importance of adenosine probably lies not so much in some special chemical characteristic, but rather that an advantage existed in making one compound a standard. Once ATP became the standard source of chemical energy, systems developed to synthesize ATP more efficiently than the other nucleotides; because it is abundant, it becomes the logical choice for incorporation into a wide variety of structures. The economy extends to protein structure. A protein domain that binds adenosine can be used in a wide variety of different enzymes. Such a structure, called a nucleotide-binding fold, is found in many enzymes that bind ATP and nucleotide cofactors.



Enzyme cofactors and coenzymes incorporating adenosine in their structure. The adenosine portion is shaded in red. Coenzyme A functions in acyl group transfer reactions; NAD' participates in hydride transfers; FAD, the active form of vitamin B2 (riboflavin), participates in electron transfers. Another coenzyme incorporating adenosine in its structure is 5'-deoxyadenosylcobalamin, the active form of vitamin B12. This coenzyme is involved in intramolecular group transfers between adjacent carbons.

Some Nucleotides Are Intermediates in Cellular Communication

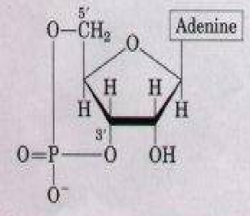
Cells respond to their environment by taking cues from hormones or other chemical signals in the surrounding medium. The interaction of these extracellular chemical signals (first messengers) with receptors on the cell surface often leads to the production of second messengers inside the cell, which in turn lead to adaptive changes in the cell interior. Often, the second messenger is a nucleotide.

second messengers

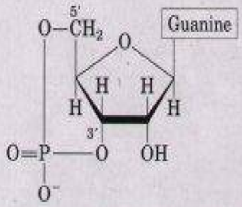
One of the most common second messengers is the nucleotide adenosine 3',5'-cyclic monophosphate (cyclic AMP, or cAMP), formed from ATP in a reaction catalyzed by adenylate cyclase, associated with the inner face of the plasma membrane. Cyclic AMP serves regulatory functions in virtually every cell outside the plant kingdom.

Guanosine 3',5'-cyclic monophosphate (cGMP) occurs in many cells and also has regulatory functions.

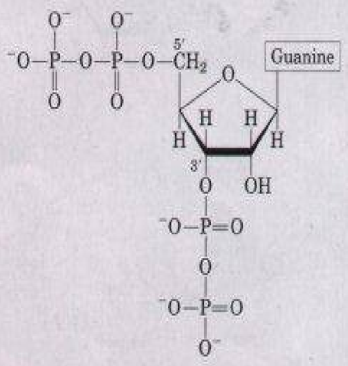
Another regulatory nucleotide, ppGpp, is produced in bacteria in response to the slowdown in protein synthesis that occurs during amino acid starvation. This nucleotide inhibits the synthesis of the rRNA and tRNA molecules needed for protein synthesis, preventing the unnecessary production of nucleic acids.



Adenosine 3′,5′-cyclic monophosphate
(cyclic AMP; cAMP)



Guanosine 3′,5′-cyclic monophosphate
(cyclic GMP; cGMP)



Guanosine 3′-diphosphate,5′-diphosphate
(guanosine tetraphosphate)
(ppGpp)

Karpagam Academy of Higher Education
Department of Biochemistry
I B.Sc., Biochemistry
17BCU101- Molecules of life
Prepared By Dr. J. Anitha

Question number	**Unit**	**Question**	**Option I**	**Option II**	**Option III**	**Option IV**	**Answer**
1	4	The backbone of nucliec acid structure	Hydrophobic forces	hydrogen bonds	**phosphodiester**	ionic bonds	**phosphodiester linkages**
2	4	The pyrimidine base	**cytosine**	Guanine	Uracil	Adenine	**cytosine**
3	4	There are three hydrogen bonds between Cytosine and	Adenine	guanine	cytosine	**thymine**	**thymine**
4	4	An increased melting temperature for duplex DNA results from a high content of	Adenine & Guanine	Cytosine &thymine	Adenine &thymine	**Cytosine &guanine**	**Cytosine &guanine**
5	4	The base which is absent in RNA is	Cytosine	Uracil	**thymine**	Adenine	**thymine**
6	4	The following facts	the 5' end	they are	methylated	**the**	**the anticodon**
7	4	Z-DNA was	Watson&	**Hoogsten**	Chargaff	warg	**Hoogsten**
8	4	The base sequence at	**CCA**	CAA	CCC	AAA	**CCA**
9	4	Deoxy ribose has no	5' position	**2' position**	3' position	4' position	**2' position**
10	4	Among the RNA's	rRNA	tRNA	**mRNA**	5SRNA	**mRNA**
	4	Ribose is linked with purine by	C_1 to N_1	**C_1 to N_9**	C_5 to N_9	C_1 to N_7	**C_1 to N_9**
12	4	mRNA has	C-DNA	**t-RNA**	RNA	r-RNA	**t-RNA**
13	4	The higher percentage	**Nucleus**	Mitochondri	microsomes	golgibodie	**Nucleus**
14	4	RNA is easily hydrolysed by base due to	**presence of OH group in position 2**	Differences in the bases	Low molecular weight	both a and b	**presence of OH group in position 2 of the ribose**
15	4	The best role of purine & pyrimidine nucleotides is to serve as the monomeric	RNA	DNA	**Both**	all of the above	**Both**

16	4	Melting temperature or Tm is high in DNA containing	rich in A, T pair	**rich in G,C pair**	Both in equal ratio	All	**rich in G,C pair**
17	4	The purine nucleotides act as the	FAD+	NAD+	NADP+	All	
18	4	When pancreatic	3’	5’	**5’3’**	2’3’	**5’3’**
19	4	The pyrimidine	**UDPG**	ATP	ADP	GDP	**UDPG**
20	4	The chemical name of	2-Oxy –4-	**2,4-dioxy –5-**	2,4- dioxy	Purine	**2,4-dioxy –5-**
21	4	S1 nuclease	degrades	**degrades**	**degrades**	single	**degrades single**
22	4	An increased melting temperature for	A+G	C+T	A+T	**G+C**	**G+C**
23	4	The strucutre of RNA is in the form of	Hairpin loop	**clover-leaf like**	double helical	alpha helix	**clover-leaf like structure**
24	4	6-Amino purine is	Guanine	**adenine**	cytosine	adenine	**adenine**
25	4	The chemical name of	Adenine	xanthine	**guanine**	Cytosine	**guanine**
26	4	The lactom form is the	**uracil**	cytosine	xanthine	Guanine	**uracil**
27	4	N7-methyl guanine	Bacteria	yeast	**mammals**	plants	**mammals**
28	4	Hypoxanyhine and	Adenosine	**inosine**	guanosine	cytidine	**inosine**
29	4	Thymine and deoxy	deoxycyti	deoxyadenos	**deoxythym**	deoxywidi	**deoxythymidin**
30	4	The most abundant	**ATP**	FAD	NAD+	NADP+	**ATP**
31	4	The concentration of	0.2	0.3	0.4	**1**	**1**
32	4	The intracellular	3	2	**1**	0.5	**1**
33	4	The epinelisation of	**UTP**	CTP	GTP	ATP	**UTP**
34	4	The biosynthesis of	ATP	**GTP**	CTP	TPP	**GTP**
35	4	The chemical name 4-hydro-xypyrazole pyrimidines is used	Thioguanine	mercaptopurine	Axatheeopurine	**Allopurinol**	**Allopurinol**
36	4	Transforming factor is	RNA	**DNA**	tRNA	r-RNA	**DNA**
37	4	Guanosine nucletide is	1	**2**	3	4	**2**
38	4	Within single turn of	4	6	8	**10**	**10**
39	4	Each turn of DNA	1.4	2.4	**3.4**	4.4	**3.4**
40	4	The double stranded	**Denatura**	Filteration	sedimentati	concentrati	**Denaturation**
41	4	DNA molecule	800-4000	1000-6000	1200-8000	**1600-9000**	**1600-9000**
42	4	DNA is denatured by	heat	Acid	Alkali	**All**	**All**
43	4	Chromatin contains	**10**	15	20	25	**10**
44	4	Each RNA molecule	40-4000	50-5000	**60-6000**	70-7000	**60-6000**
45	4	RNA molecule has a	15000-	20000-	25000-	**30000-**	**30000-50000**
46	4	Each tRNA molecule	70	**75**	80	85	**75**
47	4	In every cell the	10	15	**20**	25	**20**
48	4	All tRNA molecules	**3’ termini**	5’ termini	3’5’ termini	All	**3’ termini**
49	4	In nearly all tRNA molecules there is a	Cytidine	thymidine	**ribothymidine &**	cytidine	**ribothymidine &**

50	4	In tRNA molecules, there is another loop	Uracil	**Dihydro uracil**	cytosine	Dihydrocytosine	**Dihydro uracil**
51	4	Because DNA is a highly charged	does not depend on	**increases with**	independent of G - C	decreases with	**increases with increasing salt**
52	4	The sugar in RNA is __________ , the sugar in DNA is	deoxyribose, ribose	ribose, deoxyribose	**ribose, phosphate**	ribose, uracil	**ribose, phosphate**
53	4	Thymidine	can participate in hydrophobic interaction	**is replaced by uracil in RNA**	normally forms two hydrogen bonds with adenosine	all of the above	**is replaced by uracil in RNA**
54	4	A nucleotide consists of	**a sugar, a base and a phosphate**	a sugar and a phosphate	paired bases	a sugar, a base and three phosphates	**a sugar, a base and a phosphate**
55	4	Which of the following is found on RNA but not DNA?	**Uracil**	Deoxyribose	Phosphate	Adenine	**Uracil**
56	4	The most stabilizing force for nucleic acids	**hydrogen bonds**	electrostatic bond	Van der Waals	conformational	**hydrogen bonds**
57	4	__________ together to form an mRNA	Splicing	**Introns**	exons	transcription	**Introns**
58	4	Oligonucleotides are formed from 2 to 10 __________.	strands	hydrogen bonds	nucleosides	**nucleotides**	**nucleotides**
59	4	The variable portion of DNA is the sequence of	phosphoric acids	sugars	**bases**	phosphates	**bases**
60	4	Which pair is a complementary base pair?	C-G	**A-G**	A-C	G-G	**A-G**

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DEPARTMENT OF BIOCHEMISTRY

SUBJECT NAME : MOLECULES OF LIFE
SUB.CODE : 17BCU101
SEMESTER : I
CLASS : I B.Sc., BIOCHEMISTRY

UNIT V

Vitamins: Structure and active forms of water soluble and fat soluble vitamins, deficiency diseases and symptoms, hypervitaminosis

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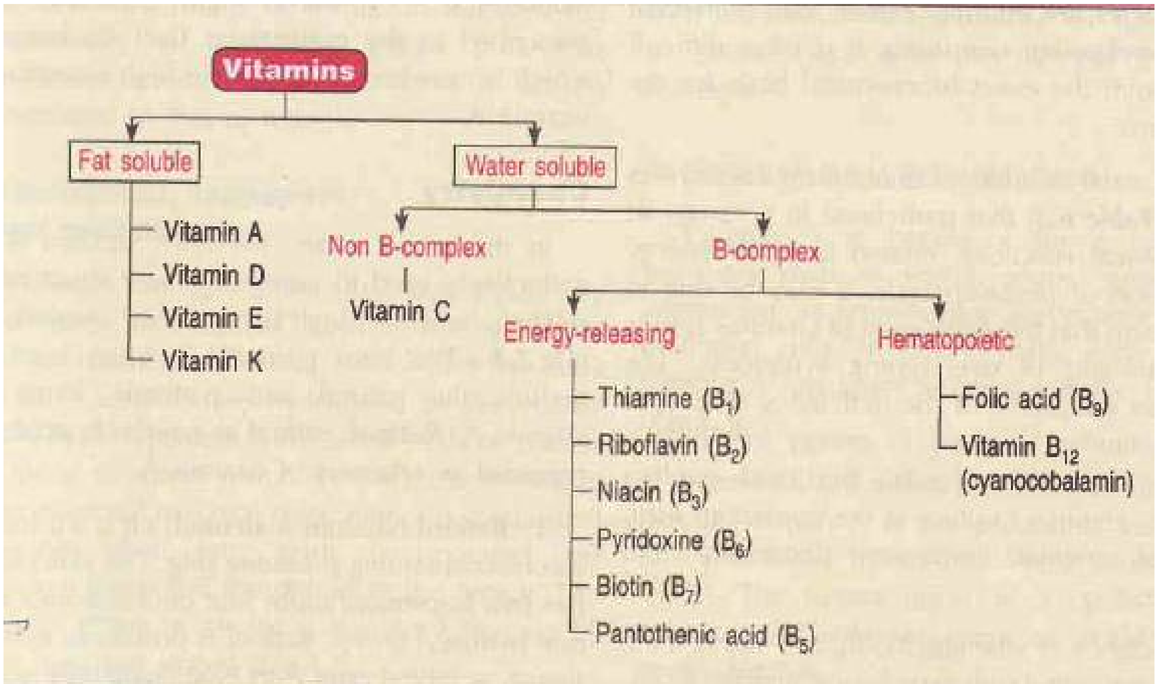
VITAMINS

Definition:

Vitamins are natural substances found in plants and animals and known as Essential nutrients for human beings.

CLASSIFICATION OF VITAMINS:

- Vitamins are classified according to their solubility, namely: the fat–solubles and the water solubles.
- Fat–soluble vitamins include vitamin A, D, E, and K, while the water–soluble vitamins include vitamins C or ascorbic acid and B complex which include thiamin, riboflavin, niacin, pyridoxine, cobalamin, panthotenic and folic acid, chlorine, inositol, and biotin.



Classification of Vitamins

FAT SOLUBLE VITAMINS:

- The fat–soluble vitamins include vitamins A, D, E and K – since they are soluble in fat and are absorbed by the body from the intestinal tract.
- The human body has to use bile acids to absorb fat–soluble vitamins.
- Once these vitamins are absorbed, the body stores them in body fat.
- When you need them, your body takes them out of storage to be used.
- Eating fats or oils that are not digested can cause shortages of fat–soluble vitamins.

Characteristics of the vitamins are:

- Most of the vitamins have been artificially synthesized.

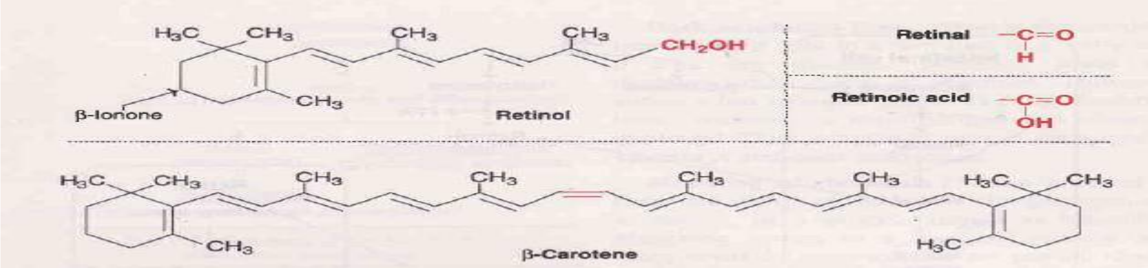
- Some of vitamins are soluble in water and others are fat–soluble.
- Some vitamins are synthesized in the body.
- Some members of vitamin B complex are synthesized by microorganisms in the intestinal tract.
- Vitamins are partly destroyed and are partly excreted.
- Vitamins can be stored in the body to some extent, for example the fat–soluble vitamins are stored in the liver and subcutaneous tissue.
- Vitamins can perform their work in very small quantities.
- Hence, the total daily requirement is usually very small.

VITAMIN A:

The fat soluble vitamin A, as such is present only in foods of animal origin. However, its provitamins carotenes are found in plants.

Chemistry:

- In the recent years, the term vitamin A is collectively used to represent many structurally related and biologically active molecules.
- The term retinoids is often used to include the natural and synthetic forms of vitamin A. Retinol, retinal and retinoic acids are regarded as vitamers of vitamin A.
- Retinol (vitamin A alcohol): It is a primary alcohol containing p–ionone ring. The side chain has two isoprenoid units, four double bonds and one hydroxyl group. Retinol is present in animal tissues as retinyl ester with long chain fatty acids.
- Retinal (vitamin A aldehyde): This is an aldehyde form obtained by the oxidation of retinol. Retinal and retinol are interconvertible. Previously, the name retinine was used for retinal.
- Retinoic acid (vitamin A acid): This is produced by the oxidation of retinal. However, retinoic acid cannot give rise to the formation of retinal or retinol.
- **β**-Carotene (provitamin A): This is found in plant foods. It is cleaved in the intestine to produce two moles of retinal. in humans, this conversion is inefficient, hence β–carotene possesses about one–sixth vitamin A activity compared to that of retinol.



Structures of vitamin A and related compounds (Red color represents the substituents groups in the respective compounds).

Sources:

Vitamin A: liver, vitamin A fortified milk and dairy products, butter, whole milk, cheese, egg yolk. Provitamin A: carrots, leafy green vegetables, sweet potatoes, pumpkins, winter squash, apricots, cantaloupe.

Physiological Functions:

Helps to form skin and mucous membranes and keep them healthy, thus increasing resistance to infections; essential for night vision; promotes bones and tooth development. Beta carotene is an antioxidant and may protect against cancer.

DEFICIENCY

- Deficiency manifestations of the eyes: Night blindness (nyctalopia) is one of the earliest symptoms of vitamin A deficiency. The individuals have difficulty to see in dim light since the dark adaptation time is increased. Prolonged deficiency irreversibly damages a number of visual cells. Severe deficiency of vitamin A leads to xerophthalmia
- Effect on reproduction: The reproductive system is adversely affected in vitamin A deficiency generation of germinal epithelium leads to sterility in males.
- Effect on skin and epithelial cells: The skin becomes rough and dry. Keratinization of epithelial cells of gastrointestinal act, urinary tract and respiratory tract is noticed. This leads to increased bacterial infection. Vitamin A deficiency is associated with formation of urinary stones

SYMPTOMS:

Mild: nausea, irritability, blurred vision. Severe: growth retardation, enlargement of liver and spleen, loss of hair, bone pain, increased pressure in skull, skin changes. Mild: night blindness, diarrhea, intestinal infects ions, impaired vision.

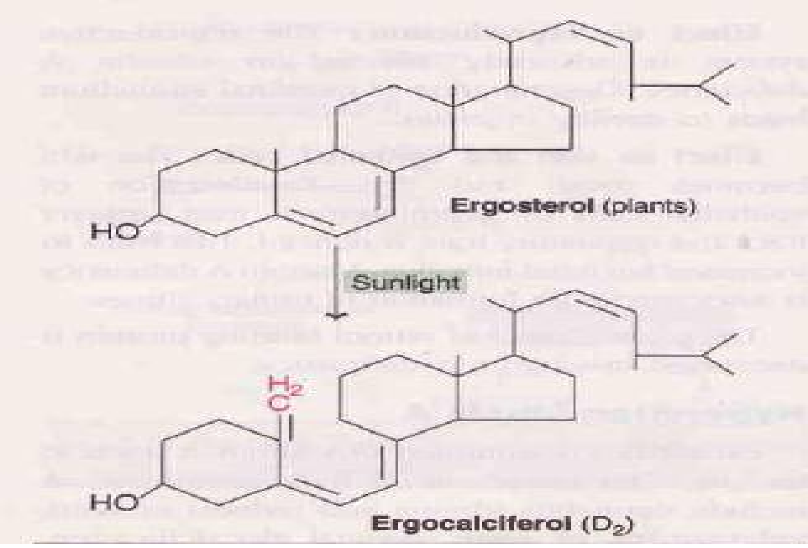
Severe: inflammation of eyes, keratinization of skin and eyes. Blindness in children.

VITAMIN D:

Vitamin D is a fat soluble vitamin. It resembles sterols in structure and functions like a hormone.

Chemistry:

Ergo calciferol (Vitamin D2) is formed ergosterol and is present in plants. Ergocalciferol and cholecalciferol are sources of for vitamin D activity and referred to as provitamins.



Formation of ergocalciferol from ergosterol

Absorption, transport and storage:

- Vitamin D is absorbed in the small intestine for which bile is essential.
- Through lymph, vitamin D enters the circulation bound to plasma β2–globulin and is distributed throughout the body.
- Liver and other tissues stores small amounts of vitamin D

SOURCES:

Good sources of vitamin D include fatty fish, fish liver oils, egg yolk etc. Milk is not a good source of vitamin D.

Vitamin D can be provided to the body in three ways:

1. Exposure of skin to sunlight for synthesis of vitamin D
2. Consumption of natural foods;
3. by irradiating foods (like yeast) that contain precursors of vitamin D and fortification of foods (milk, butter etc.)

BIOCHEMICAL FUNCTIONS OF VITAMIN D:

- Calcitriol is the biologically active form of vitamin D.
- It regulates the plasma levels of calcium and phosphorus.
- Calcitriol acts at 3 different levels ie., Intestine, bone and kidney to maintain plasma calcium.

Action of calcitriol in the intestine:

- Calcitriol increases the intestinal absorption of calcium and phosphorus.
- In the intestinal cells calcitriol binds with a cytosolic receptor to from a calcitriol, receptor complex.
- This complex approaches the nucleus and interacts with a specific DNA leading to the synthesis of a specific calcium binding protein.
- The protein increases the calcium uptake by intestine.

Action of calcitriol on the bone:

- In the osteoblasts of bone, calcitriol stimulate calcium uptake for deposition as calcium phosphate.
- Thus calcitriol is essential for bone formation. Calcitriol along with PTH increases mobilization of Ca and Po4 from the bone.
- This causes elevation of plasma Ca and Po4 levels.

Action of calcitriol on the kidney:

- Calcitriol is also involved in minimizing the excretion of ca and Po4 through the kidney, by decreasing their excretion and enhancing reabsorption.

Vitamin D and a hormone:

- Calcitriol is now considered as a hormone because calcitriol is produced in the kidney which acts on target organs; intestine, bone and kidney.
- The calcitriol action is similar to steroid hormones. Calcitriol acts in association with other hormone PTH.

DEFICIENCY AND SYMPTOMS:

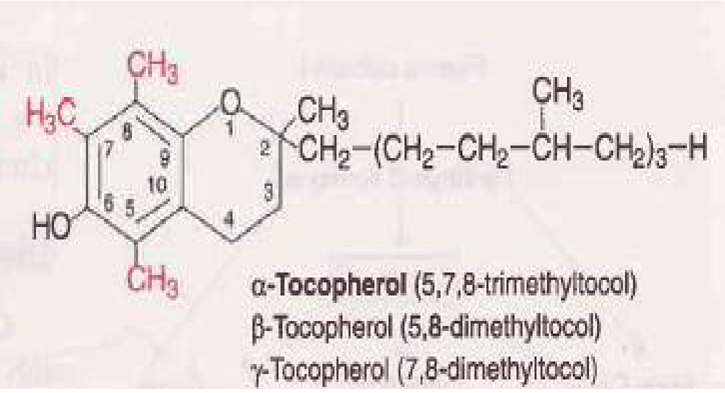
- Deficiency of vitamin D leads to demineralization of bone.
- The result is rickets in children and osteomalacia in adults.
- Rickets is characterized by bone deformities ie. Enlarged wrists and ankles, bowed legs and knock knees.
- Biochemically, in rickets, there is decrease in serum calcium and phosphours as well as increase in serum alkaline phosphates.
- In osteomalacia, bones become softer and become susceptible to fractures.
- Renal rickets is seen in patients with chronic renal failure due to decreased synthesis of calcitriol in kidney.
- Hyper vitaminosis D may lead to hyper calcemia. Hyper phosphatemia, anorexia, vomiting, nausea and diarrhoea etc.

VITAMIN E:

- Vitamin E (tocopherol) is a naturally occurring antioxidant.
- It is essential for normal reproduction in many animals, hence known as anti–sterility vitamin.

Chemistry:

Vitamin E is a group of tocopherols. About 8 tocopherols have been identified among these α tocopherol is the most active.



Structure of α-tocopherol

Absorption, transport and storage:

Vitamin E is absorbed along with fat in the small intestine. Bile salts are necessary for the absorption. In the liver, it is incorporated into lipoproteins (VLDL and LDL) and transported. Vitamin E is stored in adipose tissue, liver and muscle. The normal plasma level of tocopherol is less than 1 mg/dl.

BIOCHEMICAL FUNCTIONS:

- Most important function of vitamin E is that it acts as an antioxidant.
- The biochemical functions of vitamin E related either directly or indirectly to its antioxidant property.
- Vitamin E is essential for the membrane structure and integrity of the cell.
- It prevents the peroxidation of polyunsaturated fatty acids in various tissues.
- It protects RBC from hemolysis.
- It is closely associated with reproductive functions and prevents sterility.
- Vitamin E protects liver from being damaged by toxic compounds such as carbon tetrachloride.
- It works in association with vitamins A, C and β carotene, to delay the onset of cataract.
- High intake of vitamin E (200 – 300 mcg / day) protects against the development of heart diseases.

DIETARY SOURCES:

- Many vegetable oils are rich sources of vitamin E.
- Wheat germ oil, cotton seed oil, peanut oil, corn oil and sunflower oil are the good source of this vitamin.
- It is also present in meat, milk, butter and eggs.

DEFICIENCY SYMPTOMS:

- The symptoms of vitamin E deficiency vary from one animal species to another. In many animals, the deficiency is associated with sterility, degenerative changes in muscle, megaloblastic anaemia and changes in central nervous system Severe symptoms of vitamin E deficiency are not seen in humans except increased fragility of erythrocyte and minor neurological symptoms,

Toxicity of vitamin E:

Among the fat soluble vitamins (A, D, E, K), vitamin E is the least toxic. No toxic effect has been reported even after ingestion of 300 mg/ day for 23 years

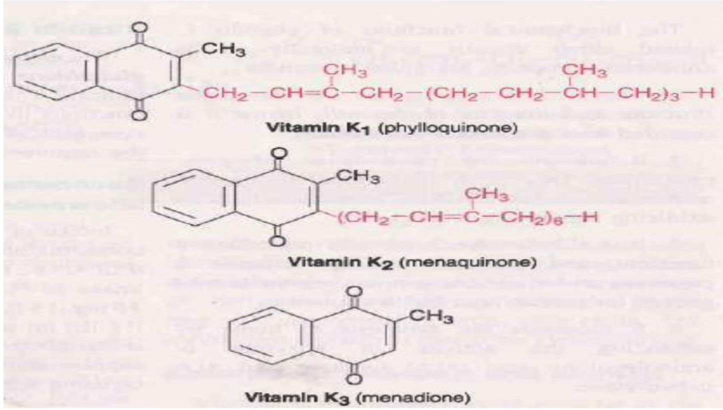
VITAMIN K:

- Vitamin K is the only fat soluble vitamin with a specific coenzyme function.
- It is required for the production of blood clotting factors essential for coagulation (in German–Koagulation; hence the name K for this vitamin).

Chemistry:

- Vitamin K is present in different forms.
- Vitamin K_1 (Phylloquinone) is present in plants.
- Vitamin K_2 (menaquinone) is produced by the intestinal bacteria and animals.

- Vitamin K_3 (menadione) is a synthetic form.



Structure of Vitamin K

Absorption, transport and storage:

- Vitamin K is taken in the diet or synthesized by the intestinal bacteria.
- Its absorption takes place along with fat (chylomicrons) and is dependent on bile salts.
- Vitamin K is transported along with LDL and is stored mainly in liver and, to a lesser extent, in other tissues.

BIOCHEMICAL FUNCTIONS:

Vitamin K is essential for the maintenance of normal levels of various blood clotting factors such as prothrombin, factor VII factor, IX and factor X. Vitamin K acts as a coenzyme for the carboxylation of glutamic acid residues present in the proteins.

SOURCES:

Cabbage, cauliflower, tomatoes, alfa alfa, spinach and other green vegetables are good sources. It is also present in egg yolk, meat, liver, cheese and dairy products

DEFICIENCY SYMPTOMS

- The deficiency of vitamin K is uncommon, since it is present in the diet in sufficient quantity and/or is adequately synthesized by the intestinal bacteria.
- However, vitamin K deficiency may occur due to its faulty absorption (lack of bile salts), loss of vitamin into feces (diarrheal diseases) and administration of antibiotics (killing of intestinal flora).
- Deficiency of vitamin K leads to the lack of active prothrombin in the circulation. The result is that blood coagulation is adversely affected.
- The individual bleeds profusely even for minor injuries. The blood clotting time is increased

WATER SOLUBLE VITAMINS:

Characteristics:

- They are polar molecules.Diverse chemical nature or no similarity of chemical structure between them.
- Not stored in body except Vitamin B_{12}.

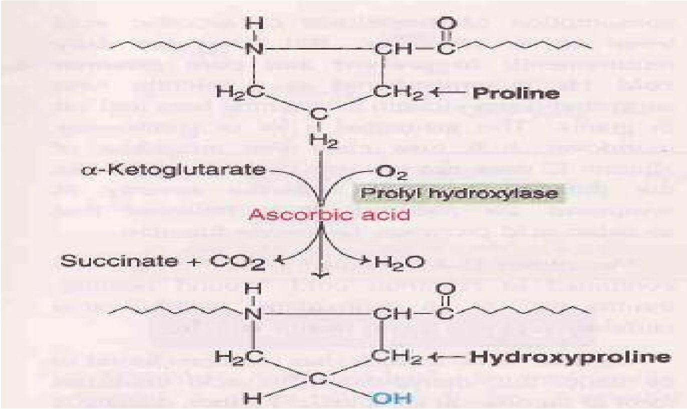
- Act as a co-enzyme of different enzyme catalyze reaction except Vitamin C acts as an enzymes.
- Synthesized from plant tissue such as cereals, green leafy vegetables, meat milk ets.,
- Except cobalamine stored in liver and not synthesized in plant tissue.

ASCORBIC ACID (Vitamin C)

- Vitamin C is a water soluble Vitamin.
- Important role in human health and disease.
- Vitamin C is also known as ascorbic acid or antiscurvy factor.

Chemistry:

- Isolation of vitamin C Zilva during 1917-1927.
- Haworth and co-workers in 1933 established chemical structure of ascorbic acid.
- Synthesis of vitamin C reported in 1933 Haworth and co-workers in England.
- Chemical structure of L-ascorbic acid and L-dehydroascorbic acid.
- Structure of L-ascorbic acid derivative of hexose called L-glucose.



Ascorbic acid dependent hydroxylation of proline of protocollagen.

SOURCES:

- Citrus fruits, gooseberry (amla), guava/ green vegetables (cabbage, spinach), tomatoes, potatoes (particularly skin) are rich in ascorbic acid.
- High content of vitamin C is found in adrenal gland and gonads.
- Milk is a poor source of ascorbic acid.

PHYSIOLOGICAL FUNCTIONS:

- Very sensitive to reversible oxidation (ascorbic acid ←→ dehydroascorbic acid involved in the oxidation reduction reactions of the cell.
- Conversion of folic acid to folinic acid (citrovorum factor).
- The hydroxylation of steroids in the adrenal cortex.
- Metabolism of tyrosine and phenylalanine and also in tryptophan.
- Required for the absorption of ion and incorporation of plasma iron is ferritin.
- Involved in the formation of neorepinephrine.

DEFICIENCY AND SYMPTOMS

- The deficiency of ascorbic acid results in scurvy.

- This disease is characterized by spongy and sore gums, loose teeth, anemia, swollen joints, fragile blood vessels; decreased immunocompetence delayed wound healing, sluggish hormonal function of adrenal cortex and gonads, hemorrhage, osteoporosis etc.
- Most of these symptoms are related to impairment in the synthesis of collagen and/or the antioxidant property of vitamin C.

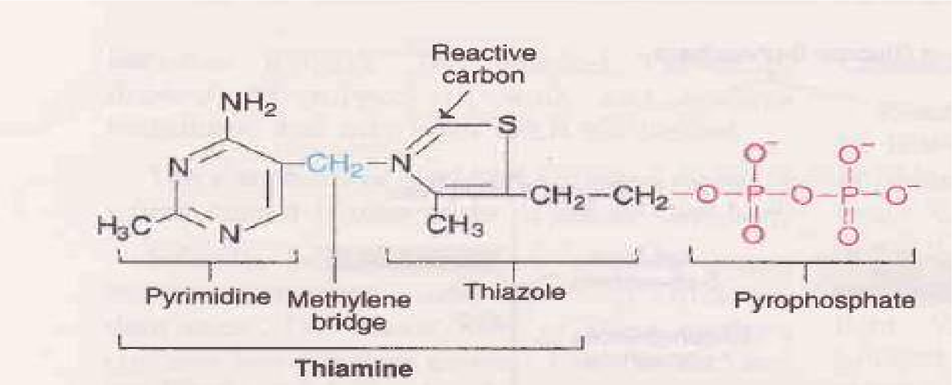
VITAMINS B-COMPLEX:

VITAMIN B_1 (Thiamine)

- Sulfur containing and nitrogen containing rings attached to carbon atoms Part of nerve cell membranes—synthesize and regulate neurotransmitters.
- Functions in energy metabolism—vitamin portion of TPP; plays role in decarboxylation and helps form Acetyl Co A from pyruvate

Chemistry:

- Thiamine contains a pyrimidine ring and a thiazole ring held by a methylene bridge.
- Thiamine is the only natural compound with thiazole ring.
- The alcohol (OH) group of thiamine is esterfied with phosphate (2 moles) to form the coenzyme, thiamine pyrophosphate (TPP or cocarboxylase).
- The pyrophosphate moiety is donated by ATP and the reaction is catalyzed by the enzyme thiamine pyrophosphate transferase



Structure of thiamine and thiamine catalyses the oxidative decarboxylation Pyrophosphate (TPP)

SOURCES:

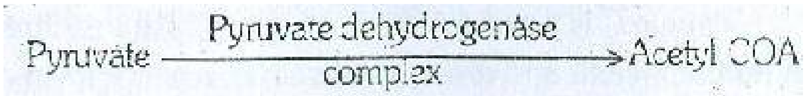
- Cereals, pulses, oil seeds, nuts and yeast are good sources.
- Thiamine is mostly concentrated in the outer layer (bran) of cereals Polishing of rice removes about 80% of thiamine.
- Vitamin B, is also present in animal foods like pork, liver, heart, kidney, milk etc.
- In the parboiled (boiling of paddy with husk) and milled rice, thiamine is not lost in polishing.
- Since thiamine is a water soluble vitamin, it is extracted into the water during cooking process.

- Such water should not be discarded.

BIOCHEMICAL FUNCTIONS:

The coenzyme TPP is intimately connected with the energy releasing reactions in the carbohydrate metabolism.

1. The enzyme pyruvate dehydrogenase complex catalyses the irreversible conversion of Pyruvate to acetyl CoA. This reaction is depended on TPP.



2. The enzyme a ketoglutarate dehydrogenase of the citric acid cycle requires TPP.
3. TPP is also used as a coenzyme with transketolase in the hexose monophosphate shunt.
4. Thee branched chain a ketoacid dehydrogenase catalyzes the oxidative decarboxylation of branched..chain amino acids to the respective ketoacids. This enzyme requires TPP.
5. TPP plays an important role in the transmission of nerve impulse.

DEFICIENCY:

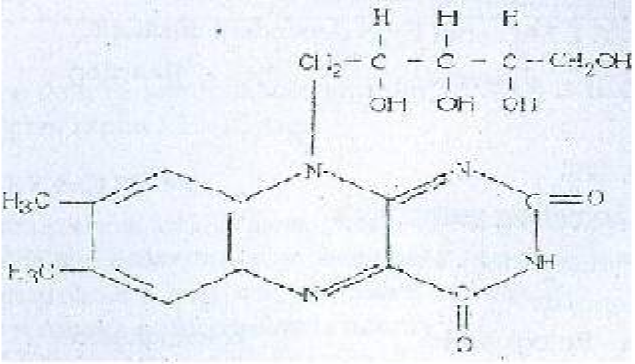
- Heavy alcohol consumption with inadequate food consumption; alcohol interferes with absorption (Wernicke–Korsakoff syndrome); poor and elderly at risk for not eating sufficient energy.
- Beri Beri
- Impaired muscle contractions
- Impaired cardiac function, edema and muscle twitches
- Decreased neurological function and memory loss

VITAMIN B_2 (Riboflavin)

Riboflavin through its coenzymes takes part in a variety of cellular oxidation reduction reactions.

Chemistry:

Riboflavin contains an isoalloxazine ring with a ribitol side chain.



Structure of Riboflavin

SOURCES:

Milk and milk products, meat, eggs, liver, kidney are rich sources. Cereals, fruits, vegetables and fish are moderate sources.

BIOCHEMICAL FUNCTIONS:

- The flavin coenzymes (mostly FAD) participate in many oxidation reduction reactions` responsible for energy production.
- FMN and FAD undergo identical reversible reactions, accepting two hydrogen atoms to form FM NH2 or FADH2.
- The coenzymes FMN and FAD are associated with certain enzyme involved in carbohydrate, lipid, protein and purine metablism besides the electron transport.
- Few examples are shown in the table.

DEFICIENCY SYMPTOMS

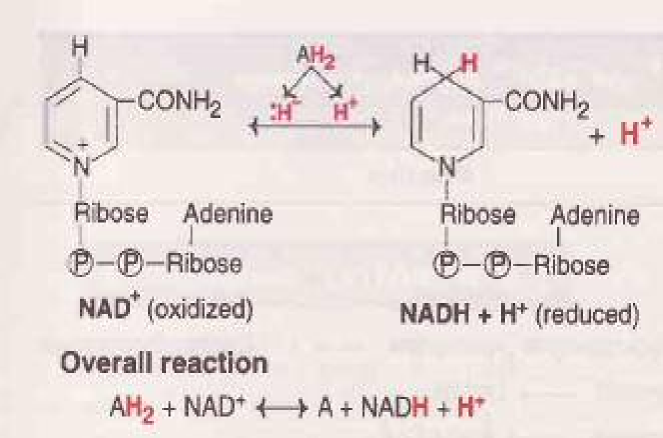
- Riboflavin deficiency symptoms include cheilosis (fissures at the corners of the mouth), glossitis (tongue smooth and purplish) and dermatitis.
- Riboflavin deficiency as such is uncommon.
- It is mostly seen along with other vitamin deficiencies.
- Chronic alcoholics are susceptible to 82 deficiencies.
- Assay of the enzyme glutathione reductase in erythrocytes will be useful in assessing riboflavin deficiency.
- Antimetabolite: Galactoflavin is an antimetabolite of riboflavin

VITAMIN B_3 (Niacin)

- Niacin or nicotinic acid is also known as pellagra preventive factor of Goldenberg.
- The coenzymes of niacin (NAD^+ and $NADP^+$) can be synthesized by the essential amino acid tryptophan.

Chemistry:

- Niacin is a pyridine derivative. Structurally pyridine 3 carboxylic acid.
- The amide form of niacin is known as niacinamide or nicotinamide.
- Dietary nicotinamide, niacin and an essential amino acid, tryptophan contribute to the synthesis of the coenzyme NAD and NADP. 60 mgs of tryptophan is equivalent to 1 mg of niacin for the synthesis of niacin.



Mechanism of oxidation and reduction of nicotinamide coenzyme-NAD^+

SOURCES:

- Rich sources include liver, yeast, whole grains, cereals, pulses like beans and peanuts.
- On an average 1g of good quality protein containing about 60 mg of tryptophan is equivalent to 1 mg of niacin for the synthesis of nicotinamide coenzyme.

BIOCHEMICAL FUNCTIONS:

- The coenzymes NAD^+ and $NADP^+$ are involved in a variety of oxidation reduction reactions.
- They accept hydride ion (hydrogen atom and one electron: H^-) and undergo reduction in the pyridine ring.
- This results in the neutralization of positive charges.
- The nitrogen atom and the fourth carbon atom of nicotinamide ring participate in the reaction.
- While one atom of hydrogen (as hydride ion) from the substrate (AH_2) is accepted by the coenzyme, the other hydrogen ion (H^+) is released in to the surrounding medium.
- This reaction is reversed when NADH is oxidized to NAD+. NADP+ also functions like NAD^+ in the oxidation–reduction reactions.
- A large number of enzymes (about 40) belonging to the class oxidoreductases are dependent on NAD^+ or $NADP^+$.
- The coenzymes are loosely bound to the enzymes and can be separated easily by dialysis.
- NAD^+ and $NADP^+$ participate in almost all the metabolisms (carbohydrate lipid, protein etc.).
- Some enzymes are exclusively dependent on NAD^+ whereas some require only $NADP^+$.
- A few enzymes can use either NAD^+ or $NADP^+$. Selected examples of enzymes and the reactions they catalyse.
- NADH produced is oxidized in the electron transport chain to generate ATP.
- ADPH is also important for many biosynthetic reactions as it donates reducing equivalents

DEFICIENCY:

- Niacin deficiency results in a condition called pellagra (rough skin).
- The diseases pellagra involves skin, gastrointestinal tract and central nervous system.
- **The symptoms of pellagra are commonly referred to as three D's ie. Dermatitis** (Inflammation of skin), dementia (anxiety, poor memory), diarrohea (dysentery) and rarely to fourth D (death).

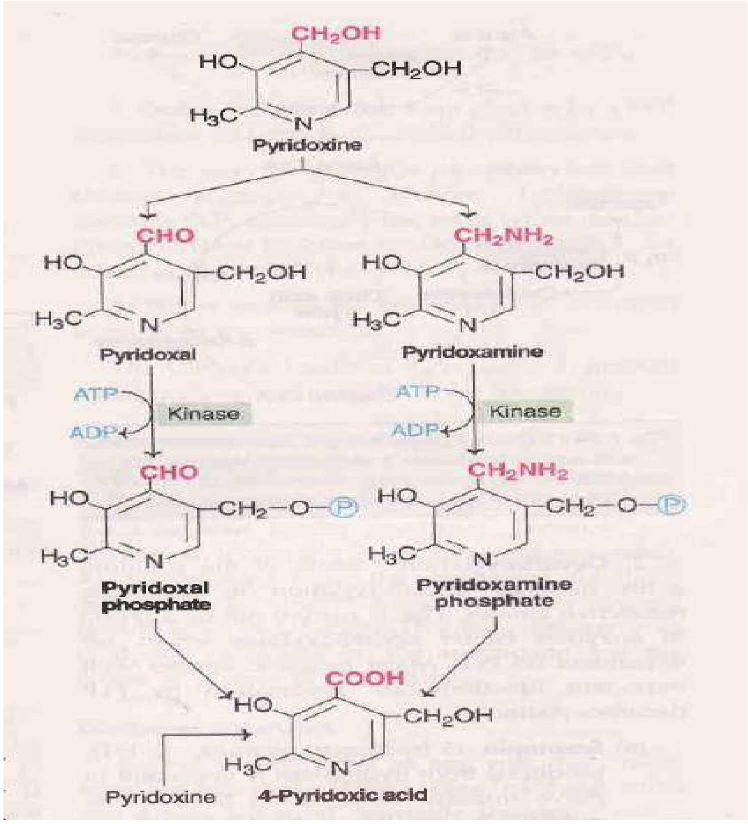
VITAMIN B_6 (Pyridoxine)

Vitamin $B_6$is used to collectively represent the three compounds namely pyridoxine, pyridoxal and pyridoxamine.

Chemistry:

- Vitamin B_6 compounds are pyridine derivatives.

- They differ from each other in the structure of a functional group attached to 4th carbon in the pyridine ring.
- Pyridoxine is a primary alcohol.
- Pyridoxal is an aldehyde.
- Pyridoxamine is an amine.
- The active form of vitamin B_6 is the coenzyme pyridoxal 5 phosphate (PLP)



Pyridoxine, its derivatives and coenzyme

SOURCES:

Animal sources such as egg yolk, fish, milk, meat are rich in B_6. Wheat, corn, cabbage, roots, tubers are good vegetables sources.

BIOCHEMICAL FUNCTIONS:

- Pyridoxal phosphate (PLP) the coenzyme of vitamins B_6 is found attached to the amino group of lysine in the enzyme.
- PLP is closely associated with the metabolism of amino acids. PLP participate in reactions like transmination, decarboxylation, deamination, transsulfuration etc.
- Transamination: PLP is involved in the transmination reaction converting amino acid to keto acids.
- **Decarboxylation: Some α amino acid**s undergo decarboxylation to form respective amines. This is carried out by decarboxylases which require PLP.

- Pyridoxal Po_4 (PLP) is required for the synthesis of amino levulinic acid precursor of heme synthesis.
- Vitamin B_6 is an energy releasing vitamin. It integrates carbohydrate and amino acid metabolism.
- PLP plays an important role in the metabolism of sulfur containing amino acids.
- Since is synthesized from glycine by a PLP dependent enzyme hydroxyl methyltransferase.
- Vitamin B_6 is required for absorption of amino acids.

DEFICIENCY AND SYMPTOMS:

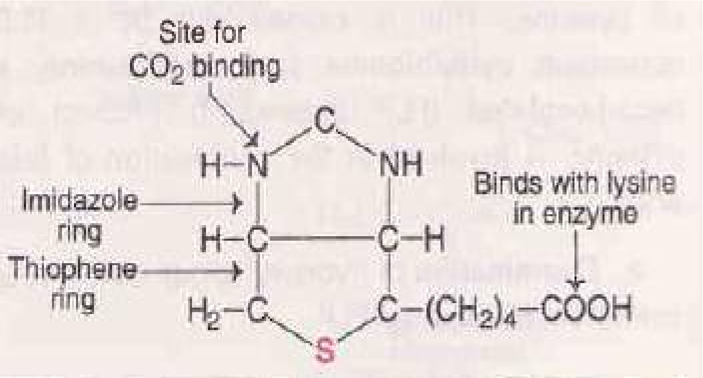
- Pyridoxine deficiency is associated with neurological symptoms such as depression, irritability, nervousness and mental confusion.
- Convulsions and peripheral neuropathy are observed in several deficiencies.

VITAMIN B_7 (Biotin)

Biotin (formerly known as anti–egg white injury factor, vitamin 87 or vitamin H) is a sulfur containing B –complex vitamin. It directly participates as a coenzyme in the carboxylation reactions.

Chemistry:

Biotin is heterocyclic sulfur containing monocarboxylic acid. The structure is formed by fusion of imidazole and thiophene rings with a valeric acid side chain (Biotin is covalently bound to e–amino group of lysine to form biocytin in the enzymes. Biocytin may be regarded as the coenzyme of biotin.



Structure of biotin with binding sites

SOURCES:

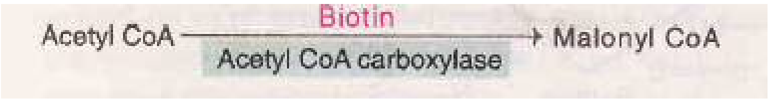
Biotin is widely distributed in both animal and plant foods. The rich sources are liver, kidney, egg yolk, milk, tomatoes, grains etc.

BIOCHEMICAL FUNCTIONS:

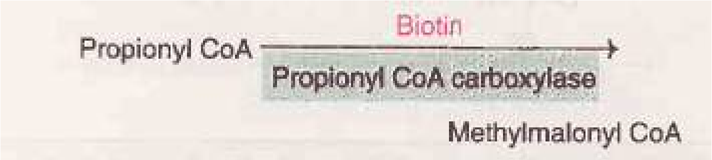
- Biotin serves as a carrier of CO_2 in carboxylation reactions.
- The reaction catalyzed by pyruvate carboxylase, converting pyruvate to oxaloacetate has been investigated in detail.
- This enzyme has biotin bound to the apoenzyme linked to the e–amino group of lysine, forming the active enzyme (holoenzyme) Biotin–enzyme reacts with CO2 in presence of ATP (provides energy) to form a carboxybiotin–enzyme complex.

- This high energy complex hands over the CO_2 to pyruvate (carboxylation reaction) to produce oxaloacetate.
- As a coenzyme, biotin is involved in various metabolic reactions.

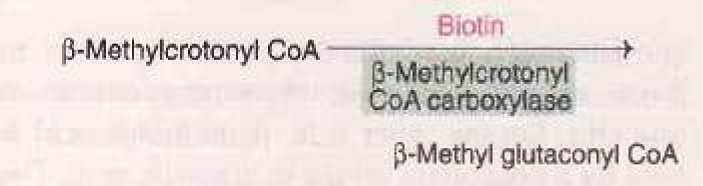
1. Gluconeogenesis and citric acid cycle: The conversion of pyruvate to oxaloacetate by biotin dependent pyruvate carboxylase (described above) is essential or the synthesis of glucose from many non–carbohydrate sources. Oxaloacetate so formed is also required for the continuous operation of citric acid cycle.
2. Fatty acid synthesis: Acetyl CoA is the starting material for the synthesis of fatty acids. The very first step in fatty acid synthesis is a carboxylation reaction.



3. Propionyl CoA is produced in the metabolism of certain amino acids (valine, isoleucine, threonine etc.) and degradation of odd chain fatty acids. Its further metabolism is dependent on biotin.



1. In the metabolism of leucine, the following reaction is dependent on biotin.



DEFICIENCY AND SYMPTOMS:

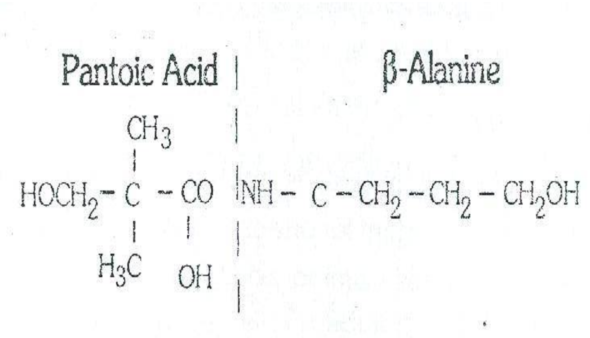
- The symptoms of biotin deficiency include anemia, loss of appetite, nausea, dermatitis, glossitis etc.
- Biotin deficiency may also result in depression, hallucinations, muscle pain and dermatitis, Biotin deficiency is uncommon, since it is well distributed in foods and also supplied by the intestinal bacteria.
- The deficiency may however, be associated with the following two causes.
- Destruction of intestinal flora due to prolonged use of drugs such as sulfonamides.
- High consumption of raw eggs.
- The raw egg white contains a glycoprotein –avidin, which tightly binds with biotin and blocks its absorption from the intestine.
- An intake of about 20 raw eggs per day is needed to produce biotin deficiency symptoms in humans.
- Consumption of an occasional raw egg will not result in deficiency.

PANTOTHENIC ACID

Pantothenic acid is widely distributed in nature. Its metabolic role as coenzyme A is well known.

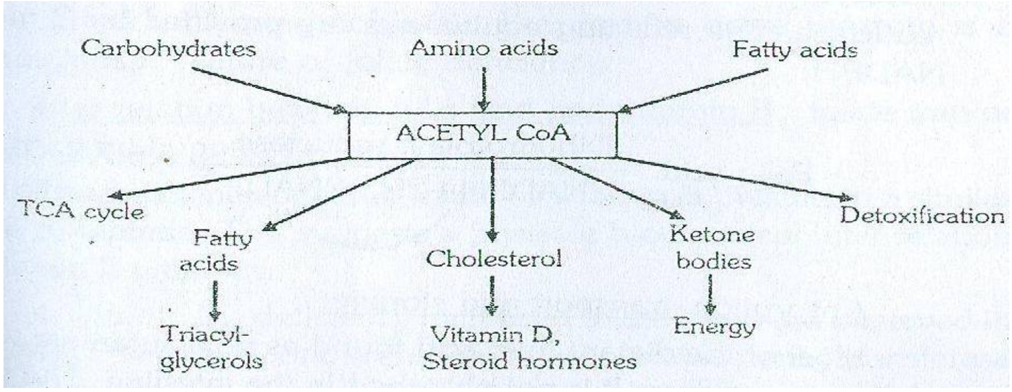
Chemistry:

Pantothenic acid consists of two components pantothenic acid and β alanine held together by a peptide linkage.



BIOCHEMICAL FUNCTIONS:

- The functions of pantothenic acid are excreted through coenzyme A or CoA.
- Coenzyme A is the central molecule involved in all the metabolisms (carbohydrate, lipid and protein) and hence it is called as a coenzyme of metabolic integration.



Coenzyme A – Metabolic Integration

Metabolic integration due to coenzyme A. coenzyme A serves as a carrier activated acetyl groups. A few examples of enzymes involved in the participation of coenzyme A are given below.

$$\text{i. Pyruvate} \xrightarrow[\text{PDH}]{\text{COA}} \text{AcetylCOA}$$

$$\text{ii. } \alpha \text{ keto glutarate} \xrightarrow[\alpha\text{-keto dehydrogenase}]{\text{COA}} \text{Succinyl COA}$$

$$\text{iii. Fatty acid} \xrightarrow[\text{Thiokinase}]{\text{COA}} \text{Acetyl COA}$$

SOURCES:

- Pantothenic acid is one of the most widely distributed vitamins found in plants and animals. The rich sources are egg, liver, meat, yeast, milk, etc.

DEFICIENCY SYMPTOMS:

- It is a surprise to biochemists that despite the involvement of pantothenic acid (as coenzyme A) in a great number of metabolic reactions, its deficiency manifestations have not been reported in humans.
- This may be due to the widespread distribution of this vitamin or the symptoms of pantothenic acid may be similar to other vitamin deficiencies Dr. Gopalan a world renowned nutritionist from India, linked the burning feet syndrome (pain and numbness in the toes, sleeplessness, fatigue etc.) with pantothenic acid deficiency.
- Pantothenic acid deficiency in experimental animals results in anemia, fatty liver, decreased steroid synthesis etc.

VITAMIN B_{12} (Cyanocobalamin)

- Vitamin B_{12} is also known as anti–pernicious anemia vitamin.
- It is a unique vitamin, Synthesized by only microorganisms and not by animals and plants.
- It was the last vitamin to be discovered.

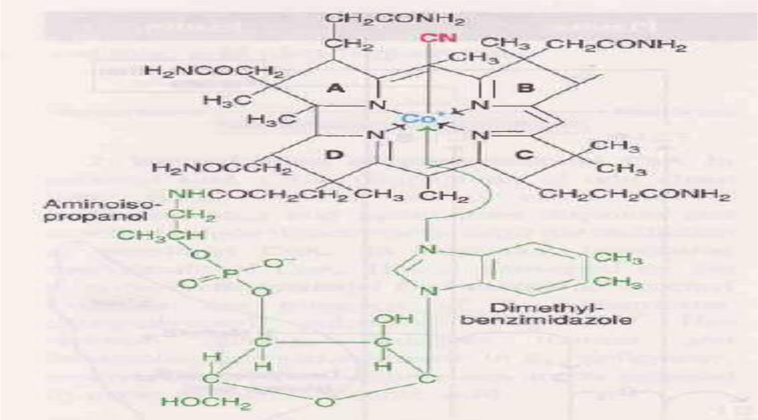
Chemistry:

- Due to the presence of a cyano group and a cobalt atom, vitamin B_{12} is also referred to as Cyanocobalamin.
- The structure of vitamin B_{12} consists of a corrin ring with a central cobalt atom.
- Cyanide (predominant) in Cyanocobalamin(B_{12a})
- Hydroxyl in hydroxycobalamin (B_{12b})
- Nitrite in nitrocobalamin (B_{12c}).

There are two coenzyme forms of vitamin B_{12}

(a) 5' –Deoxyadenosyl cobalamin, cyanide is replaced by 5' deoxyadenosine forming an unusual carbon cobalt bond.

(b) Methylcobalamin in which cyanide is replaced by methyl group.



Structure of vitamin B_{12} (Cyanocobalamin)

BIOCHEMICAL FUNCTIONS:

- About ten enzymes requiring vitamin B_{12} have been identified. Most of them are found inbacteria (glutamate mutase, ribonucleotide reductase etc.).
- There are only two reactions in mammals that is dependent on vitamin B_{12}.
- Synthesis of methionine from homocysteine: Vitamin B_{12}, as Methylcobalamin is used in this reaction. This is an important reaction involving Ns–methyl tetrahydrofolate from which tetrahydrofolate is liberated (enzyme–homocysteine methyltransferase or npthionine syntheses). This metabolic step signifies the interrelation between vitamin B_{12} folic acid.
- Isomerization of methymalonyl CoA to succinyl CoA: The degradation of odd chain fatty acids, certain amino acids and pyrimidines produce directly or through the mediation of propionyl CoA, an important compound methylmalonyl CoA. This is converted by the enzyme methylmalonyl CoA mutase to succinyl CoA in the presence of B_{12} coenzyme, deoxyadenosyl cobalamin.
- This reaction involves hydrogen transfer and intramolecular rearrangement. In B12 deficiency, methylmalonyl CoA accumulates and is excreted in urine as methylmalonic acid.

SOURCES:

Liver, Kidney, egg fish and milk are good sources of vitamin B_{12}.

DEFICIENCY AND SYMPTOMS:

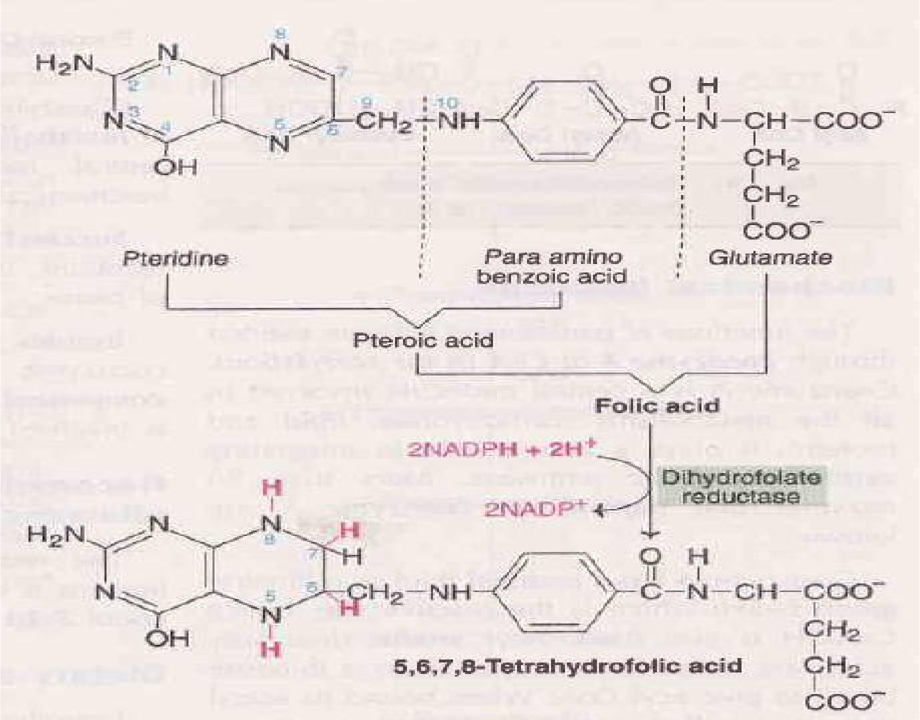
- The most important disease associated with B_{12} deficiency pernicious anemia.
- It is characterized by low hemoglobin level decreased number of erythrocytes and neurological manifestation vitamin B_{12} deficiency is also associated with neuron degeneration and demyelization of nervous system.
- The symptoms are numbness in fingers and toes.

FOLIC ACID

- Folic acid is abundantly found in green leafy vegetables.
- It is important for one carbon metabolism and is required for synthesis of certain amino acids, purines and the pyrimidines and thymine.

Chemistry:

- Folic acid consists of three components pteridine ring, p–amino benzoic acid (PABA) and Glutamic acid (1 to 7 residues).
- Folic acid mostly has one glutamic acid residue and is known as pteroyl–glutamic acid (PGA).
- The active form of folic acid is tetrahydrofolate (THF or FH_4).
- It is synthesized from folic acid by the enzyme dihydrofolate reductase.
- The reducing equivalents are provided by 2 moles of NADPH.
- The hydrogen atoms are present at positions 5, 6, 7 and 8 of THF.



Conversion of folic acid to tetrahydrofolic acid (THF)

BIOCHEMICAL FUNCTIONS:

- Tetrahydrofolate (THF or FH_4) the coenzyme of folic acid is actively involved in the one carbon metabolism, many important compounds are synthesized in one carbon metabolism.
- Purines which are incorporated into DNA and RNA.
- Pyrimidines nucleotide–deoxy thymidilic acid is involved in the synthesis of DNA.
- Glycine, serine, ethanolamine and choline are produced.
- N formylmethionine, the initiator of protein biosynthesis is formed.

SOURCES

The rich sources are green leafy vegetables, whole grains, cereals, liver, kidney, yeast and eggs.

DEFICIENCY AND SYMPTOMS:

- Folate deficiency results in complications nearly identical to those described for vitamin B_{12} deficiency.
- The most pronounced effect of folate deficiency on cellular processes is upon DNA synthesis.
- This is due to impairment in dTMP synthesis which leads to cell cycle arrest in S–phase of rapidly proliferating cells, in particular hematopoietic cells.
- The result is megaloblastic anemia as for vitamin B_{12} deficiency.
- The inability to synthesize DNA during erythrocyte maturation leads to abnormally large erythrocytes termed macrocytic anemia.
- Folate deficiencies are rare due to the adequate presence of folate in food.
- Poor dietary habits as those of chronic alcoholics can lead to folate deficiency.
- The predominant causes of folate deficiency in non–alcoholics are impaired absorption or metabolism or an increased demand for the vitamin.
- The predominant condition requiring an increase in the daily intake of folate is pregnancy.
- This is due to an increased number of rapidly proliferating cells present in the blood.
- The need for folate will nearly double by the third trimester of pregnancy.
- Certain drugs such as anticonvulsants and oral contraceptives can impair the absorption of folate.
- Anticonvulsants also increase the rate of folate metabolism.

HYPERVITAMINOSIS

Hypervitaminosis is a condition of abnormally high storage levels of vitamins, which can lead to toxic symptoms. Specific medical names of the different conditions are derived from the vitamin involved: an excess of vitamin A, for example, is called hypervitaminosis A.

Hypervitaminoses are primarily caused by fat–soluble vitamins (D, E, K and A), as these are stored by the body for longer period than the water–soluble vitamins. Generally, toxic levels of vitamins stem from high supplement intake and not from natural food. Toxicities of fat–soluble vitamins can also be caused by a large intake of highly fortified foods, but natural food rarely deliver dangerous levels of fat–soluble vitamins. The Dietary Reference Intake recommendations from the United States Department of Agriculture define a "tolerable upper intake level" for most vitamins

CAUSES

With few exceptions, like some vitamins from B–complex, hypervitaminosis usually occurs more with fat–soluble vitamins (D, E, K and A or 'DEKA'), which are stored in the liver and fatty tissues of the body. These vitamins build up and remain for a longer time in the body than water–soluble vitamins.

Conditions include:

- Hypervitaminosis A
- Hypervitaminosis D
- Hypervitaminosis E

- Hypervitaminosis K, unique as the true upper limit is less clear as is its bioavailability.

According to Williams' Essentials of Diet and Nutrition Therapy it is difficult to set a DRI for vitamin K because part of the requirement can be met by intestinal bacterial synthesis.

- Reliable information is lacking as to the vitamin K content of many foods or its bioavailability. With this in mind the Expert Committee established an AI rather than an RDA.
- This RDA (AI for men age 19 and older is 120 µg/day, AI for women is 90 µg/day) is adequate to preserve blood clotting, but the correct intake needed for optimum bone health is unknown. Toxicity has not been reported.

  High-dosage A; high-dosage, slow-release vitamin B_3; and very high-dosage vitamin B_6 alone (i.e. without vitamin B complex) hypervitaminoses are sometimes associated with side effects that usually rapidly cease with supplement reduction or cessation.

  High doses of mineral supplements can also lead to side effects and toxicity. Mineral-supplement poisoning does occur occasionally, most often due to excessive intake of iron-containing supplements.

Individual hypervitaminosis: The features of hypervitaminosis are usually due to exaggerations of their normal physiological and biochemical actions.

1 Hypervitaminosis A:

It may occur as acute and chronic. In acute cases the features of hypervitaminosis are mainly due to exaggeration of their normal physiological and biochemical actions. Features in acute case are dizziness, headache, and lassitude, Irritability, pain abdomen, nausea, visual disturbances like diplopia, and bulging fontanels in infants, pruritus and excoriation of skin all over the body. Chronic cases are manifested by low grade fever, alopecia, dry fissured lip, ache in bones and joints, hyperostosis, anorexia, weight loss, hepatosplenomegaly, papilloedema, pseudotumour cerebri, if daily 25,000 IU or more vitamin A is consumed for many days. Other features suggestive of raised intracranial pressure, such as bulging fontanels (in an infant), papilloedema and diplopia, may also occur. Anemia and thrombocytopenia have also been described.Complications include: Hypocalcaemia, Hypercalciuria and renal stones. It may be unwise to give vitamin A supplements to older patients with good diets, particularly if at risk of osteoporosis.Experimentally chronic condition is produced when we take in excess of 50,000 units/day for more than three months. Complications include Hypocalcaemia, Hypercalciuria, renal stones and benign intracranial hypertension. Management is by stopping the supplements. If there are changes in mental state, admission to hospital is required. As far as prognosis is concerned, mortality is rare. Once identified, the prognosis is good. The yellow coloration of skin will reverse with time.

2. Hypervitaminosis D:

Usually this is caused by excessive ingestion or over prescription of prescribed medications such as calcium with vitamin D. occasionally there is increased calcitriol production as in hyperparathyroidism or malignancy including some renal adenomas, sarcomas and lymphomas. In sarcoidosis there is a hypersensitivity to vitamin D.

Excessive levels of vitamin D do not result from excessive exposure to sunlight because of further breakdown of D3 into products which have no effect on calcium metabolism. Recent concerns about vitamin D deficiency have led to increased use of supplements. Most symptoms occur because of secondary hypercalcaemia with increased bone resorption and hypercalciuria. They include: Polyuria, Polydipsia, Vomiting, Anorexia, and Lethargy, Dehydration, Constipation, Hypertension, Tetany, Seizures can be fatal. The traditional description of hypercalcaemia is stones, bones and groans. Hypervitaminosis D is also recognized as a cause of depression.In children it can result in dental enamel hypoplasia and focal pulp calcification.Investigations include serum calcium and phosphate and 25 hydroxy-vitamin D and 1, 25 dihydroxy-vitamin D levels. Management is by stopping the supplements and treats the cause. Bisphosphonates such as pamidronate may be used to treathypercalcaemia. Glucocorticoids are occasionally used for a short while in severe cases of vitamin D intoxication. Complications may include nephrolithiasis, nephrocalcinosis (calcium oxalate and calcium phosphate are radio opaque stones), calcinosis of the joints and peri articular tissues, and chronic kidney disease. As far as Prognosis is concerned renal disease is usually reversible if recognized early. An outbreak of hypervitaminosis D associated with the over fortification of milk from a home-delivery dairy.

3. Hypervitaminosis E:

Vitamin E is present in a great many foods, particularly vegetable oils, unprocessed cereal grains, nuts and seeds. There is no evidence of any adverse effects from consuming vitamin E in food. However, high doses of alpha-tocopherol supplements can affect blood clotting inhibit platelet aggregation and cause hemorrhage. Studies have also shown an increase in all-cause mortality associated with vitamin E supplements.

Vitamin E, 3 or 4 decades ago it appeared to be 'a vitamin in search of a deficiency'. Its importance had been demonstrated only for reproductive efficacy in rats. Vitamin E (alpha tocopherol) is a fat-soluble vitamin which acts as an antioxidant and disposes of free radicals. Problems only usually occur after a very large overdose.The recommended daily dose is 30 mg per day, and side-effects are usually experienced at doses above 1 g/kg. Excess of vitamin E inhibits vitamin K, causes increased bleeding and impaired immune system leading to necrotic enter-colitis. Bruising and bleeding with increased prothrombin time is mediated by the inhibition of vitamin K-dependent carboxylase, and reversed by administering vitamin K. Platelet thromboxane production is also reduced. Some studies have also reported fatigue, weakness, headache and gastrointestinal upset. Management includes stop the supplements. Consider vitamin K if prothrombin time is prolonged.

4 Hypervitaminosis B-complex:

In many cases skin changes, intestinal ulcers, fatty liver, hyperglycemia, hyperuricaemia, nausea and indigestion are found.

i). Thiamine (B1):

Over dose produce curare like action, paralysis. Blocks nerve transmission. Restlessness, convulsions, labored respiration, death (respiratory paralysis and cardiac failure).Disrupt other B-Vitamins, disrupt insulin and thyroid functions.

ii). Riboflavin (B2):

Over dose produces bright yellow urine, fatigue, vomiting, itching, numbness, burning or prickling sensation, sensitivity to light and hypotension occurs.

iii). Niacin (B3):

Overconsumption of niacin causes flushing syndrome, hyperemia of skin, Pruritus, GIT disturbances and acanthosis nigricans. More than 3gm niacin daily causes aggravation of bronchial asthma, gout and fasting hyperglycemia. Low blood pressure, light headedness, insomnia, liver damage, peptic ulcer, skin rash, altered liver function tests may occur.

iv). Pantothenic acid (B 5):

Overdose produce diarrhea, GIT problems, water retention may occur.

v). Pyridoxine (B6): Vitamin B6 is a water-soluble vitamin and one of eight B vitamins. As such, it might be considered safe but at doses over 200 micrograms per day it can cause neurological disorders when taken over a prolonged period.It used to be prescribed extensively for carpal tunnel syndrome and premenstrual tension. A sensory neuropathy mimicking multiple sclerosis may be seen, if B6 more than 2 gm is taken daily Progressive ataxia, impaired vision and vibration senses, and loss of deep tendon reflexes are seen. Preserved motor strength, perioral numbness and clumpsy limbs are present. Loss of appetite, stomach upset and skin lesions also occurs.

High intakes of vitamin B6 from food sources have not been reported to cause adverse effects. However, long-term use of supplements can cause severe and progressive sensory neuropathy with ataxia. The severity of symptoms is dose-dependent and the symptoms usually stop when the supplements are discontinued. Other adverse effects of excessive vitamin B6 intake include painful skin rashes, photosensitivity, nausea and heart burn.Symptoms include excessive doses damage sensory nerves. This can cause paraesthesia in the hands and feet, difficulty walking (poor co-ordination, 'staggering'), reduced sensation to touch, temperature, and to vibration and tiredness. Management is by stopping the vitamin B6 resolves symptoms in all cases. Failure to do so suggests another cause for symptoms. Vitamin B6 functions in protein and amino acid metabolism. Pyridoxine is the treatment for isoniazid overdose. It is also used by body builders with varying results, depending on dosage.

vi). Biotin (B 7) (vitamin H):

Biotin causes Scurfy skin due to hyperkeratosis of superficial follicular epithelium.

vii). Folic acid (B 9):

Folic acid is useful for the RBC and DNA production. Over dosage produce convulsions in epileptics. Inhibit hepatic alcohol dehydrogenase. Stomach, sleep and skin problems occurs.

viii. Cobalamine (B12):

Over dose of B12 causes reduction in size of vascular controlled reflexes, palpitation, tingling sensation and numbness of limbs.

ix. Ascorbic acid (C):

Vitamin C is found in citrus fruits and vegetables. An anti-oxidant and reducing agent, its controversial uses include treatment of upper respiratory tract infections and cancer.[17] The worst effect is the formation of oxalate stone in the kidney. It may also cause uricosuria. Large doses if taken by pregnant women that induce the metabolic enzymes in the fetus and this may lead to rebound scurvy. Absorption of vitamin B12 is interfered with high doses of vitamin C. Vitamin C interferes with healthy antioxidant, pro-oxidant balance in body. In thalassemia or hemochromatosis increased iron overload occurs. Premature infants get hemolytic anemia due to the fragility of RBC.

x). Choline:

More than 3.5 gm/day in take causes skin rash and increased blood sugar.

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Questi	**Unit**	**Question**	**Option I**	**Option II**	**Option III**	**Option IV**	**Answer**
1	5	Metyl malonic aciduria is seen in a	**Vitamin B6**	folic acid	thiamin	vitamin B12	**Vitamin B6**
2	5	What is caused by thiamin defiency	nyctalopia	**Scurvy**	Rickets	Beri beri	**Scurvy**
3	5	retinal and retinal binding protein	albumin	**prealbumin**	a2 globulin	b globulin	**prealbumin**
4	5	Megaloblastic anemia is caused by	**folic acid**	vitamin B6	iron	protein	**folic acid**
5	5	This vitamin acts as antioxidant	vitamin A	vitamin D	**vitamin E**	vitamin K	**vitamin E**
6	5	Calcitriol is	hydroxy cholecalcif	25 hydroxy cholecalcife	**24,25 di hydroxy**	1, 25 dihydroxy	**24,25 di hydroxy**
7	5	25 hydroxilation of vitamin D3 takes	Liver	Intestines	**Kidneys**	Pancreas	**Kidneys**
8	5	The egg injury factor in raw egg white is	biotin	**avidin**	albumin	calcium salts	**avidin**
9	5	the human species can biosynthesize	vitamin C	**Vitamin B12**	vitamin A	Niacin	**Vitamin B12**
10	5	Retina contains this photo sensitive	**rhodopsin**	opsin	retinal	melanin	**rhodopsin**
11	5	Antixerophthalmic vitamin is	Vitamin B1	Vitamin B2	Vitamin B6	**Vitamin A**	**Vitamin A**
12	5	One of the following is not a symptom of	**hypoglycemia**	hyponatremia	hypokalemia	hypochloremia	**hypoglycemia**
13	5	Gammaxane is an antimetabolite of	Thiamine	Riboflavin	Pyridoxine	Inositol	**vitamin B12**
14	5	Sulpha drugs are antimetabolites of	vitamin K	pyridoxine	**folic acid**	vitamin B12	**folic acid**

15	5	Pyridoxine defiency may lead to	**GABA**	PABA	EFA	SAM	**GABA**
16	5	This abnormal metabolite may be	taurine	**metyl malonic**	xanthurenic acid	phenyl pyruvic acid	**metyl malonic acid**
17	5	Choic acid is not required for the	lecithins	acetyl choline	sphigomyelin	**cholic acid**	**cholic acid**
18	5	Biotin is required for the reaction of Co2	water	**acetyl CoA**	ammonia	incorporaion of carbon	**acetyl CoA**
19	5	A defiency of folate leads to	**megaloblastic**	aplastic anemia	pernicious anemia	hypochromaic	**megaloblastic anemia**
20	5	A deficiency of Iron leads to	megaloblastic anemia	aplastic anemia	pernicious anemia	**hypochromaic**	**hypochromaic microcytic**
21	5	Vitmin B12 initially binds to the proteins	Transcobalamine I	**R. proteins**	Transcobalamine II	Intrinsic factor of	**R. proteins**
22	5	Extrinsic factor of castle is	vitamin B12	glycoprotein	Sigma proteins	**R-protein**	**R-protein**
23	5	Antiracnite vitamin is	vitamin A	**vitamin D**	vitamin E	vitamin K	**vitamin D**
24	5	Angular stomatitis is due to	Ariboflavinosis	Def. Of vitamin C	**Def. Of vitamin B1**	Def. Of folate	**Def. Of vitamin B1**
25	5	Prothrombin time is prolonged by	Vitamin K	**Dicoumarol**	Calcium	Prothrombin	**Dicoumarol**
26	5	This vitamin acts as an antioxidant	Vitamin A	Vitamin D	**Vitamin E**	Vitamin K	**Vitamin E**
27	5	This is a photo labile vitamin	thiamin	**riboflavin**	niacin’	cholecalciferol	**riboflavin**
28	5	Convulsive episodes occur when there is a	**pyridoxine**	folic acid	thiamine	riboflavin	**pyridoxine**
29	5	Metastatic calcification is seen	A	K	**D**	E	**D**
30	5	The anti vitamin for para amino benzoic	aminopterin	dicoumarol	**sulphanamides**	thiopanic acid	**sulphanamides**
31	5	Severe pantothenic acid defiency	**burning feet**	Scurvy	cataract	xerophthal	**burning feet syndrome**
32	5	cholesterol is a precursor in the	Vitamin A	Vitamin E	Vitamin E	**Vitamin D**	**Vitamin D**
33	5	This Vitamin is a potent antioxidant of	Vitamin B	Vitamin D	**Vitamin D**	Vitamin K	**Vitamin D**
34	5	Convulsions and delirium could be	thiamine	glutamate	glutamate	**magnesium**	**magnesium**
35	5	In the muscle cells these ions move with	calcium	magnesium	sodium	**potassium**	**potassium**
36	5	In the intestinal cells these ions move with	Calcium	magnesium	**sodium**	potassium	**sodium**
37	5	Selenium is contained in	Glutathione redutase	**Glutathione**	Glutamate dehyderoge	Glutamin synthetase	**Glutathione peroxidase**

38	5	Soon after absorbtion copper is	a1 globulin	b globulin	**albumin**	prealbumin	**albumin**
39	5	Electrolytes in sweat are increased	Diabetes mellitus	Peptic ulcer	**Fibrocystic disease of**	Infective hepatitis	**Fibrocystic disease of**
40	5	The most potent cortical hormone	cortisone	Deoxy cortisone	progesterone	**aldosterone**	**aldosterone**
41	5	Ceruloplasmin contains	Iron	Magnesium	H+ ion concentratio	**Copper**	**Copper**
42	5	Metabolism of sodium is influenced	Thyroxine	Glutathione	Insulin	**Adrenocortical**	**Adrenocortical steroids**
43	5	The major pathway of calcium excretion	Intestinal tract	**Kidneys**	Liver	Sweat	**Kidneys**
44	5	Rice polishings contain this vitamin	riboflavin	niacin	**thiamin**	vitamin B12	**thiamin**
45	5	In beri beri there will be accumulation of	Aceto acetic acid	Beta hydroxy	**Pyruvic acid**	Metyl malonic	**Pyruvic acid**
46	5	The significant ocular lesion in	keratomalacia	Bitot’s spots	**Vascularisation of**	Lachrymal metaplasis	**Vascularisation of cornea**
47	5	Irradiation of food rises the content of	Vitamin A	**niacin**	Vitamin D	Vitamin K	**niacin**
48	5	Defiency of the mineral results in	selenium	fluorine	**iodine**	molybdenum	**iodine**
49	5	One among the following minerals is	manganese	magnesium	**mercury**	molybdenum	**mercury**
50	5	Wilson’s disease is characterized by the	Fe	**Cu**	Hg	Ag	**Cu**
51	5	Progesteron causes retention of	**sodium**	potassium	Zinc	Copper	**sodium**
52	5	Biotin is widely distributed in	animal foods	plant foods	**both a and b**	milk	**both a and b**
53	5	Pantothenic acid consists of two	**beta alanine**	alpha alanine	gamma alanine	omega alanine	**beta alanine**
54	5	last vitamin to be discovered is	Vitamin C	Vitamin K	**Vitamin B_{12}**	Vitamin A	**Vitamin B_{12}**
55	5	Methylcobalamin in which cyanide is	hydroxyl group	carboxyl group	amino group	**methyl group**	**methyl group**
56	5	Purines which are incorporated into	STS	SNP	EST	**DNA and RNA.**	**DNA and RNA.**
57	5	Folic acid is abundantly found in	cauliflower	cabbage	**green leafy vegetables**	tumeric	**green leafy vegetables**
58	5	Macro minerals make up about of	**0.01%**	0.02%	0.03%	0.04%	**0.01%**
59	5	Trace minerals are those that are	20	30	50	**100**	**100**
60	5	About ___ of the body calcium is	100%	**99%**	88%	77%	**99%**

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DEPARTMENT OF BIOCHEMISTRY

SUBJECT : MOLECULESOF LIFE
SEMESTER : I
SUBJECT CODE : 17BCU101 CLASS : I B.Sc., BC

POSSIBLE QUESTIONS

UNIT I

2 MARKS

1. Define cell
2. List any two unique properties of water
3. What do you mean by buffer
4. Why water is so called reactant and fitness of the aqueous environment? Justify
5. List out the important features of ribosomes

6 MARKS

1. Explain the structure and properties of water
2. Explain about chemical foundation of life
3. Discuss about weak interactions in aqueous system
4. Explain any four organelles in plant cell and its functions
5. Explain in detail about water as a reactant molecule
6. Discuss about the chemical foundation of life
7. Discuss about cellular foundation of life
8. Give a detail account on buffer
9. Discuss in detail about ionization of water
10. Explain in detail about cellular foundation of life

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POSSIBLE QUESTIONS

UNIT II

2 MARKS

1. What do you mean by mutarotation
2. Mention the importance of storage polysaccharides
3. Write short notes on proteoglycans
4. List out the importance of carbohydrates
5. Differentiate between homopolysaccharides and heteropolysaccharides

6 MARKS

1. Explain about the classification of monosaccharides
2. Discuss in detail about storage polysaccharides
3. What are all the properties and functions of trisaccharides
4. Explain the structures of disaccharides
5. Write notes on Stereochemistry of Monosaccharide
6. Explain
    i) Glycogen
    ii) Dextrin
7. Describe the Properties and functions of polysaccharide
8. Briefly describe about classification and functions of disaccharides
9. Give detail account on
    i) Cellulose
    ii) Chitin

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POSSIBLE QUESTIONS

UNIT III

2 MARKS

1. Define lipids
2. Draw the structure of sterols
3. List out the importance of glycerophospholipids
4. Brief about galactolipids
5. Write short notes on cofactors

6 MARKS

1. Given account of physical properties of fat
2. Write the structure and functions of galactolipids
3. Explain about the classification of lipids
4. Write the structure and functions of glycerophospholipids
5. Give an account on chemical properties of fat
6. Write the difference between galactolipids and sulpholipids
7. Write the structure, distribution and role of membrane lipids
8. Explain in detail about storage lipids
9. What is the role of lipids in bio membranes
10. Describe in detail plant steroids

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DEPARTMENT OF BIOCHEMISTRY

SUBJECT : MOLECULESOF LIFE
SEMESTER : I
SUBJECT CODE : 17BCU101 CLASS : I B.Sc., BC

POSSIBLE QUESTIONS

UNIT IV

2 MARKS

1. Define amino acids
2. Draw the structure of glycine
3. Draw the structure of proline
4. Write short notes on aliphatic amino acids
5. Write notes on different types of RNA

6 MARKS

1. Explain in detail about
    i. aromatic amino acids
    ii. unusual amino acids
2. Draw the structure of purines
3. Write about the classification of amino acids
4. Draw the structure of pyrimidines and explain in detail
5. Describe the structure and properties of aliphatic amino acids
6. Explain in detail about double helix structure of DNA
7. Explain the structure and properties of aromatic and basic groups of amino acids
8. Briefly describe the different forms of DNA
9. Discuss in detail about tRNA
10. Discuss in detail about rRNA

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POSSIBLE QUESTIONS

UNIT V

2 MARKS

1. Write short notes on Vitamin A
2. Mention the symptoms of Vitamin K
3. List out fat soluble vitamins
4. Draw the structure of Vitamin D
5. List out water soluble vitamins
6. How Vitamin D is provided to the body? List out the three ways

6 MARKS

1. Describe the structure and physiological functions of Vitamin A and D
2. What are all the source and functions of Vitamin C?
3. Explain in detail about structure and active form of Vitamin A
4. What are all the sources and functions of Vitamin K?
5. Explain in detail about Vitamin K its sources, deficiency and symptoms
6. Discuss in detail Vitamin D
7. Write in details about deficiency and symptoms of Vitamin C
8. Discuss about hypervitaminosis
9. Explain the sources of Vitamin B complex
10. Brief about Vitamin E

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DEPARTMENT OF BIOCHEMISTRY

SUBJECT NAME : MOLECULES OF LIFE
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CLASS : I B.Sc., BIOCHEMISTRY

Maximum: 50 marks

PART A (20 x 1 = 20 marks)
Answer ALL questions

1. Endoplasmic reticulum

2. The enclosure is made up of two membranes

3.16

4.Galactose

5.Aldehyde groups

6. on the surface of inner membranes

7. 2 subunits

8.Expanted from the cell

9. a central vacuole

10. Osazone

11. Sucrose

12.Drugs

13.Disaccharides

14. acid

15.Glycoside

16.Lactose

17. Fructose+ glucose

18. More of saturated fatty acid

19. RNA

20.Ribosomes

PART B

21.Cell

The cell is the basic structural, functional, and biological unit of all known living organisms. A cell is the smallest unit of life that can replicate independently, and cells are often called the "building blocks of life". The study of cells is called cell biology.

22. Unique Properties of water:

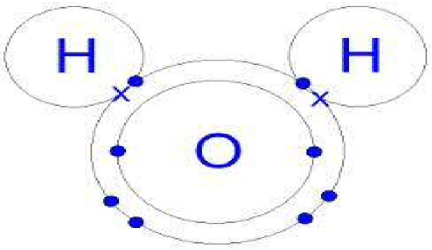
- Have high melting point- 0°C
- Have high boiling point- 100°C
- Heat of vaporization - 540
- Surface tension – 72.8

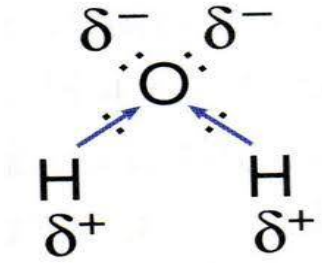
23. Proteoglycans

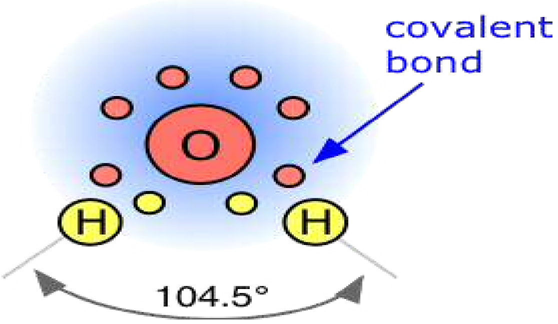
Proteoglycans are proteins that are heavily glycosylated. The basic proteoglycan unit consists of a "core protein" with one or more covalently attached glycosaminoglycan (GAG) chain(s). The point of attachment is a serine (Ser) residue to which the glycosaminoglycan is joined through a tetrasaccharide bridge.

PART B

24. a) The structure of water molecule is depicted as follows







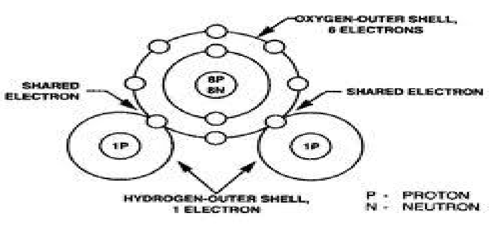
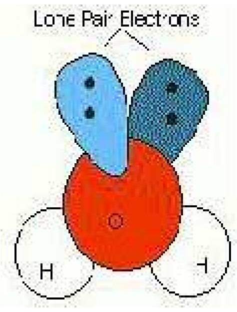
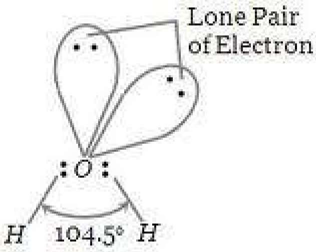
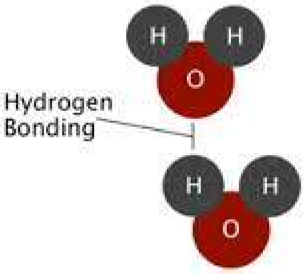


Figure 2-II. Illustration of a Molecule (H_2O)

Tetra hedral arrangement of water:
The water molecule maintains a bent shape (bent at 107.5 degrees actually) because of two considerations. First the tetrahedral arrangment around the oxygen and Second the presence of lone pair electrons on the oxygen.
These are the electrons that are not involved in the covalent bonds. The pairs of electrons are left alone. In our picture they are represented by the double dots. These lone pairs are very negative - containing two negative electrons each - and want to stay away from each other as much as possible. These repulsive forces act to push the hydrogens closer together.







The bond angles for water are not 109.5. Because of the presence of the very negative lone pair electrons, the two hydrogens are squeezed together as the two lone pairs try to get away from each other as far as possible. The resulting angle gives water a 104.5 bond angle and the resulting tetrahedron "looks" BENT.

Properties of water:

- Have high melting point- 0°C
- Have high boiling point- 100°C
- Heat of vaporization - 540
- Surface tension – 72.8

Vapourization of ice is called sublimation, vapourization of liquid is called vaporation.Both occur more rapidly as the temperature increases. Evaporation occur when water is heated above its boiling point. Heat lost at the point of evaporation returns at the point of condensation. Such phenomena play an important role in meteorological cycle.
Some of the other properties of water are

- Water is a liquid at standard temperature and pressure.
- Water is tasteless and odorless.
- Water is transparent in the visible electromagnetic spectrum.
- Water can act as either an acid or a base.
- Water is a universal solvent, dissolving many substances found in nature.

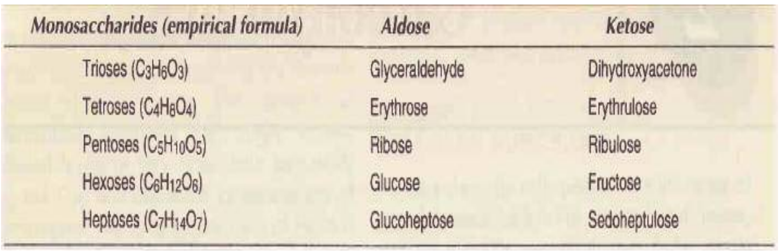
24. b) Chemical Foundations of Life

1. the atoms of all living things flow from one living thing to another
2. not all chemicals sustain life, some damage it, such as pollutants
3. mountain pines - ozone damage from pollution yellows the needles

4. the pollution started around world war II
5. matter is things that takes up space and has mass
6. core of atom - nucleus, has protons and neutrons, protons have + charge
7. around neutrons are electrons in motion, have a - charge
8. neutral atoms have same number of protons as electrons
9. atoms of a given element have same number of protons
10. isotopes are atoms of the same element with a different mass because they have a different number of neutrons
11. isotope compositions of water and air can allow scientists to see where pollution is coming from
12. to measure pollutants - one can directly measure plant stems and needle growth
13. compounds are made of two or more elements, chemically combined
14. ozone is made of 3 atoms of oxygen per molecule
15. electrons move in energy levels or shells around a nucleus, each shell can hold only specific numbers of atoms
16. when sodium loses its lone electron in its outer shell to chlorine, it leaves the sodium with full shells and chlorine with full shells, but they have opposite charge so they stick together in an ionic bond
17. many atoms share electrons to form covalent bonds - the electrons move around both atoms within combined shells
18. when hydrogen bonds to water the electrons are not shared equally, causing oxygen to be slightly negative and hydrogen slightly positive - giving water molecules polarity
19. the soil near the surface has more organic material, deeper soils have more inorganic material
20. rain washes pollutants from the sky into the soil, damaging roots
21. the newest young trees are more resistant to the pollution because they are produced from parents that survived the initial pulse of pollution before pollution controls went into effect

25.a) CLASSIFICATION OF MONOSACCHARIDES:

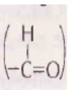
- Monosaccharides (G reek: mono-one) are the simplest group of carbohydrates and are often referred to as simple sugars.
- They have the general formula Cn(H_2O)$_n$, and they cannot be further hydrolysed.
- The monosaccharides are divided into different categories, based on the functional group and the number of carbon atoms.



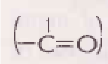
Monosaccharides (empirical formula)	*Aldose*	*Ketose*
Trioses ($C_3H_6O_3$)	Glyceraldehyde	Dihydroxyacetone
Tetroses ($C_4H_8O_4$)	Erythrose	Erythrulose
Pentoses ($C_5H_{10}O_5$)	Ribose	Ribulose
Hexoses ($C_6H_{12}O_6$)	Glucose	Fructose
Heptoses ($C_7H_{14}O_7$)	Glucoheptose	Sedoheptulose

Classification of monosaccharide with selected examples

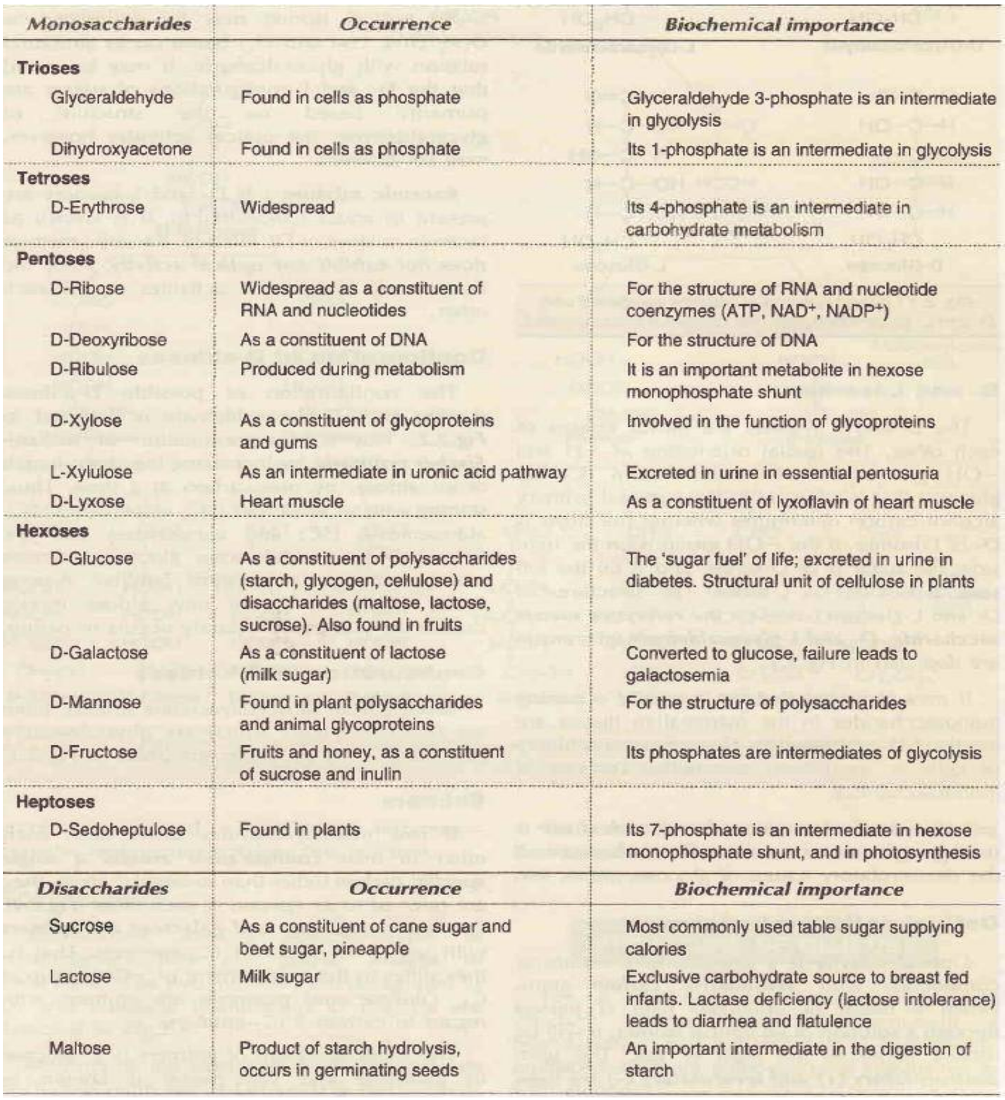
Aldoses :

When the functional group in monosaccharides in aldehyde  $\left(\overset{\text{H}}{\underset{|}{\text{-C=O}}}\right)$ they are known as aldoses e.g. glyceraldehyde, glucose.

Ketoses:

When the functional group is a keto  $\left(\overset{|}{\text{-C=O}}\right)$ group, they are referred to as ketoses e.g. dihydroxyacetone, fructose.

- Based on the number of carbon atoms, the monosaccharides are regarded as trioses (3C), tetroses (4C), pentoses (5C), hexoses (6C) and heptoses (7C).
- These terms along with functional groups are used while naming monosaccharides.
- For instance, glucose is an aldohexose while fructose is a ketohexose.
- The common monosaccharides and disaccharides of biological importance are given.



Monosaccharides	*Occurrence*	*Biochemical importance*
Trioses		
Glyceraldehyde	Found in cells as phosphate	Glyceraldehyde 3-phosphate is an intermediate in glycolysis
Dihydroxyacetone	Found in cells as phosphate	Its 1-phosphate is an intermediate in glycolysis
Tetroses		
D-Erythrose	Widespread	Its 4-phosphate is an intermediate in carbohydrate metabolism
Pentoses		
D-Ribose	Widespread as a constituent of RNA and nucleotides	For the structure of RNA and nucleotide coenzymes (ATP, NAD^+, $NADP^+$)
D-Deoxyribose	As a constituent of DNA	For the structure of DNA
D-Ribulose	Produced during metabolism	It is an important metabolite in hexose monophosphate shunt
D-Xylose	As a constituent of glycoproteins and gums	Involved in the function of glycoproteins
L-Xylulose	As an intermediate in uronic acid pathway	Excreted in urine in essential pentosuria
D-Lyxose	Heart muscle	As a constituent of lyxoflavin of heart muscle
Hexoses		
D-Glucose	As a constituent of polysaccharides (starch, glycogen, cellulose) and disaccharides (maltose, lactose, sucrose). Also found in fruits	The 'sugar fuel' of life; excreted in urine in diabetes. Structural unit of cellulose in plants
D-Galactose	As a constituent of lactose (milk sugar)	Converted to glucose, failure leads to galactosemia
D-Mannose	Found in plant polysaccharides and animal glycoproteins	For the structure of polysaccharides
D-Fructose	Fruits and honey, as a constituent of sucrose and inulin	Its phosphates are intermediates of glycolysis
Heptoses		
D-Sedoheptulose	Found in plants	Its 7-phosphate is an intermediate in hexose monophosphate shunt, and in photosynthesis
Disaccharides	***Occurrence***	***Biochemical importance***
Sucrose	As a constituent of cane sugar and beet sugar, pineapple	Most commonly used table sugar supplying calories
Lactose	Milk sugar	Exclusive carbohydrate source to breast fed infants. Lactase deficiency (lactose intolerance) leads to diarrhea and flatulence
Maltose	Product of starch hydrolysis, occurs in germinating seeds	An important intermediate in the digestion of starch

25 b) Storage polysaccharides

Starch is the stored form of sugars in plants and is made up of a mixture of two polysaccharides (both polymers of glucose):

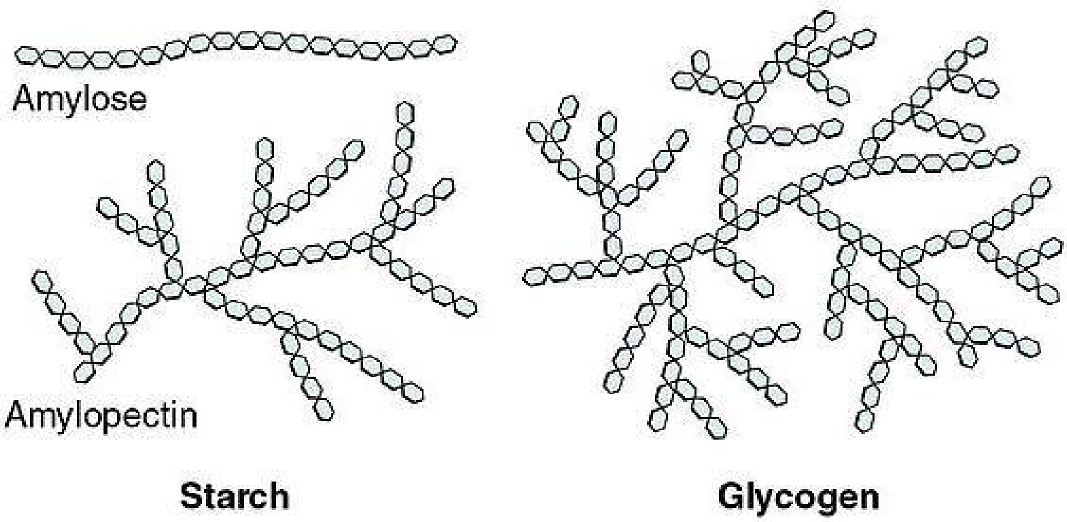
- amylose
- amylopectin

Plants are able to synthesize glucose using light energy gathered in photosynthesis, and the **excess glucose, beyond the plant's immediate energy needs, is stored as starch in different** plant parts:

- roots
- seeds (The starch in the seeds provides food for the embryo as it germinates and can also serve as a food source for humans and animals, who will break it down into glucose monomers using digestive enzymes)

In starch, the glucose monomers are in the α form (with the hydroxyl group of carbon 1 sticking down below the ring), and they are connected primarily by 1-4 glycosidic linkages (i.e., linkages in which carbon atoms 1 and 4 of the two monomers form a glycosidic bond).

- Amylose consists entirely of unbranched chains of glucose monomers connected by 1-4 linkages.
- Amylopectin is a branched polysaccharide. Although most of its monomers are connected by 1-4 linkages, additional 1-6 linkages occur periodically and result in branch points.



Because of the way the subunits are joined, the glucose chains in amylose and amylopectin typically have a helical structure. Glycogen is the storage form of glucose in humans and other vertebrates. Like starch, glycogen is a polymer of glucose monomers, and it is even more highly branched than amylopectin. Glycogen is usually stored in liver and muscle cells. Whenever blood glucose levels decrease, glycogen is broken down via hydrolysis to release glucose monomers that cells can absorb and use.

26. a) TRISACCHARIDES

Trisaccharides are oligosaccharides composed of three monosaccharides with two glycosidic bonds connecting them. Similar to the disaccharides, each glycosidic bond can be formed between any hydroxyl group on the component monosaccharides. Even if all three component sugars are the same (e.g., glucose), different bond combinations (regiochemistry) and stereochemistry (alpha- or beta-) result in trisaccharides that are diastereoisomers with different chemical and physical properties. Trisaccharides - combinations of three monosaccharides

Examples:

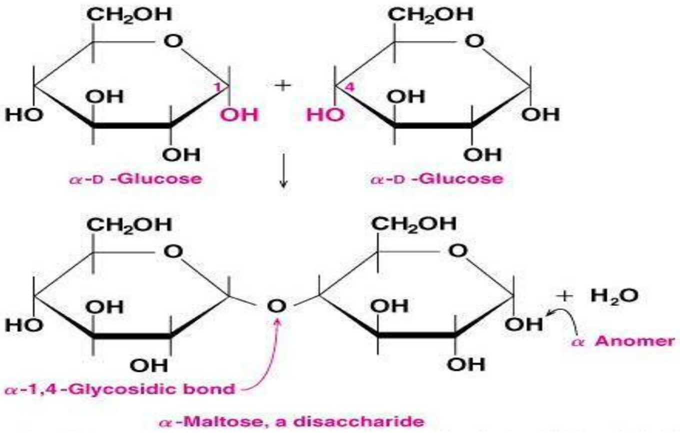
Trisaccharide	Unit 1	Bond	Unit 2	Bond	Unit 3
Isomaltotriose	glucose	α(1→6)	glucose	α(1→6)	glucose
Nigerotriose	glucose	α(1→3)	glucose	α(1→3)	glucose
Maltotriose	glucose	α(1→4)	glucose	α(1→4)	glucose
Melezitose	glucose	α(1→2)	fructose	α(1→3)	glucose
Maltotriulose	glucose	α(1→4)	glucose	α(1→4)	fructose
Raffinose	galactose	α(1→6)	glucose	β(1→2)	fructose
Kestose	glucose	α(1↔2)	fructose	β(1←2)	fructose

26. b) DISACCHARIDES:

- A disaccharide is formed when a hydroxyl group on one monosaccharide reacts with the anomeric carbon of another monosaccharide to form a glycosidic bond.
- Each disaccharide has a specific glycosidic linkage (depending on which hydroxyl reacts with which anomer).
- The three most common disaccharides are maltose, lactose and sucrose.
- When hydrolyzed using acid or an enzyme, the following monosaccharide are produced.
- The disaccharides are of two types
  1. Reducing disaccharides with free aldehyde or keto group e.g. maltose, lactose.
  2. Non-reducing disaccharides with no free aldehyde or keto group e.g. sucrose, Trehalose.

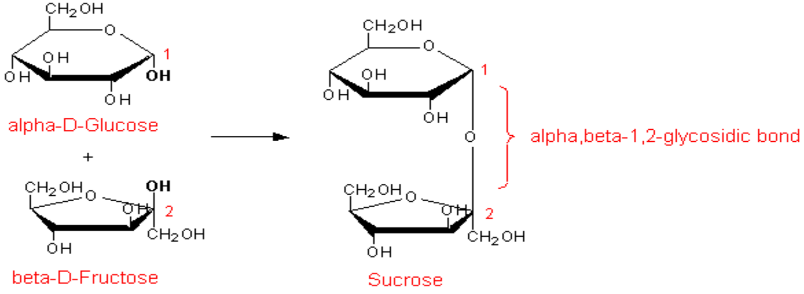
MALTOSE:

- Maltose (malt sugar or corn sugar) consists of two glucose molecules linked by an α-1, 4-glycosidic bond.
- It comes from partial hydrolysis of starch by the enzyme amylase, which is in saliva and also in grains (like barley).
- Maltose can be fermented by yeast to produce ethanol.
- Maltose is also used in cereals, candies and malted milk.
- Because one of the glucose molecules is a hemiacetal, it can undergo mutorotation, and so maltose is a reducing sugar.



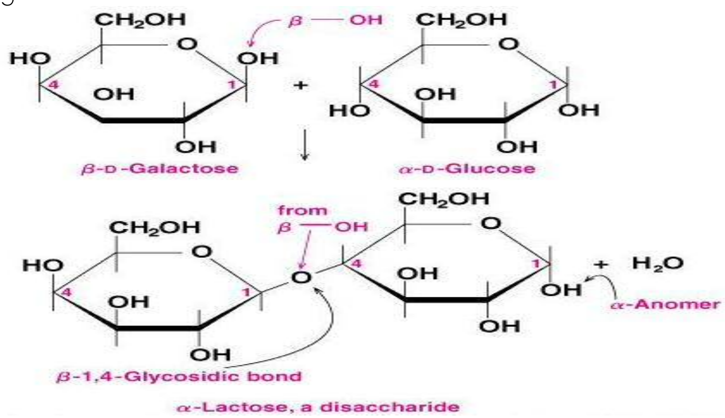
SUCROSE:

- Sucrose (table sugar) consists of one glucose molecule and one fructose molecule linked by an α,β-1,2-glycosidic bond.
- Sucrose is the most abundant disaccharide and is commercially produced from sugar cane and sugar beets.
- Because the glycosidic bond in sucrose involves both anomeric carbons, neither monosaccharide can undergo mutorotation, and so sucrose is not a reducing sugar.



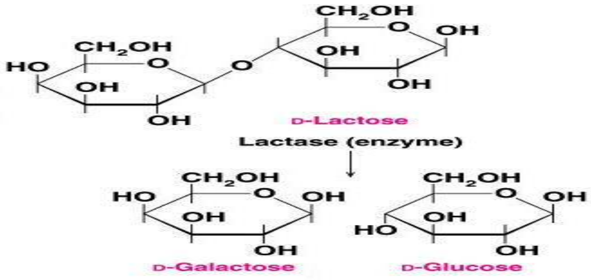
LACTOSE:

- Lactose (milk sugar) consists of one glucose molecule and one galactose molecule linked by a β-1,4 glycosidic bond.
- It comes from milk products (about 4-5% of cow's milk).
- Because the glucose is a hemiacetal, it can undergo mutorotation, and so lactose is a reducing sugar.



Hydrolysis of Lactose:

- Some people don't produce enough lactase, the enzyme that hydrolyzes lactose, and so can't digest lactose.
- Many adults become lactose intolerant, and develop abdominal cramps, nausea and diarrhea.
- Lactase can be added to milk products (or taken as a supplement) to combat this problem.



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DEPARTMENT OF BIOCHEMISTRY

SUBJECT NAME : MOLECULES OF LIFE
SUB.CODE : 17BCU101
SEMESTER : I
CLASS : I B.Sc., BIOCHEMISTRY

Maximum: 50 marks

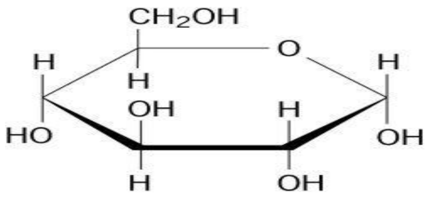
PART A (20 x 1 = 20 marks)
Answer ALL questions

1. a) $(C_6H_{10}O_5)n$
2. c) 16
3. b) Galactose
4. Aldehyde group
5. Glucuronic acid
6.a) Osazone
7.a) Sucrose
8. d)Fructose+ glucose
9. c)Presence of either aldehyde or keto group
10. d) Insulin
11. a) Heparin
12. a) Sucrose
13. a) Lenolic acis
14. a) more of saturated fatty acid
15.b) lectithins
16.b) Hyaluronic acid
17.c) Mannose
18.c) Epimers
19.c) N-acetyl glucoseamine
20. c) Hyaluronic acid

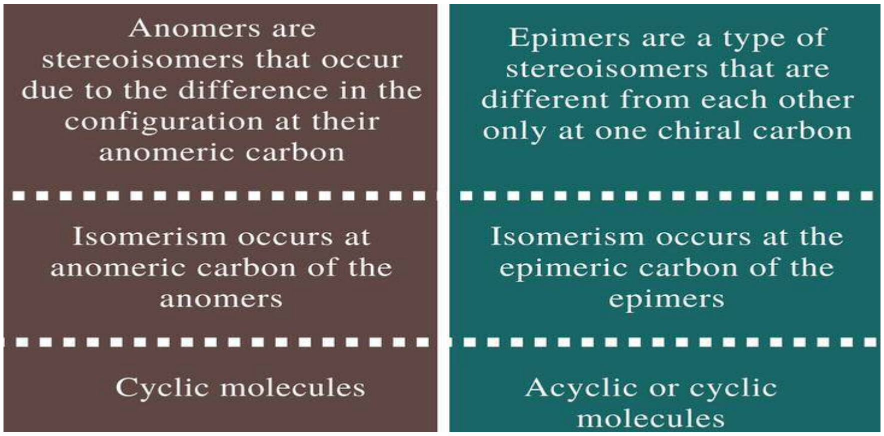
PART B (3 x 2 = 6 marks)
Answer ALL questions

21. Draw the structure of glucose and add note on it

Glucose is a simple sugar with the molecular formula C H O . Glucose circulates in the blood of animals as blood sugar. It is made during photosynthesis from water and carbon dioxide, using energy from sunlight.



22. Differentiate anomers and epimers



Anomers are stereoisomers that occur due to the difference in the configuration at their anomeric carbon	Epimers are a type of stereoisomers that are different from each other only at one chiral carbon
Isomerism occurs at anomeric carbon of the anomers	Isomerism occurs at the epimeric carbon of the epimers
Cyclic molecules	Acyclic or cyclic molecules

23.Give note of fatty acids.

Fatty acids are the building blocks of the fat in our bodies and in the food we eat. During digestion, the body breaks down fats into fatty acids, which can then be absorbed into the blood. Fatty acid molecules are usually joined together in groups of three, forming a molecule called a triglyceride. Triglycerides are also made in our bodies from the carbohydrates that we eat.

PART C (3 x 8 = 24 marks)
Answer ALL questions

24. a) Explain in detail about the disaccharides

DISACCHARIDES:

- A disaccharide is formed when a hydroxyl group on one monosaccharide reacts with the anomeric carbon of another monosaccharide to form a glycosidic bond.
- Each disaccharide has a specific glycosidic linkage (depending on which hydroxyl reacts with which anomer).
- The three most common disaccharides are maltose, lactose and sucrose.
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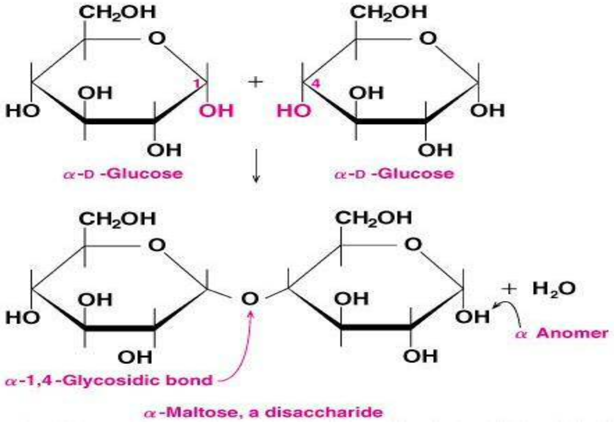

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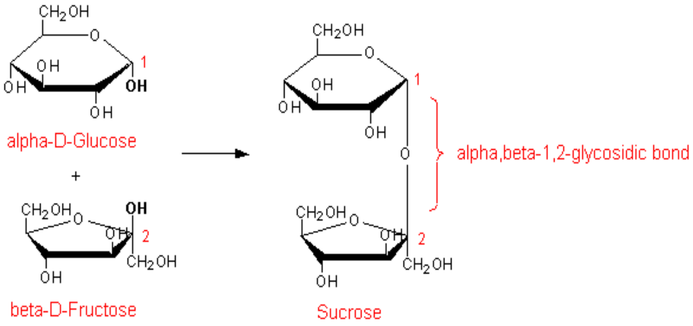


Or

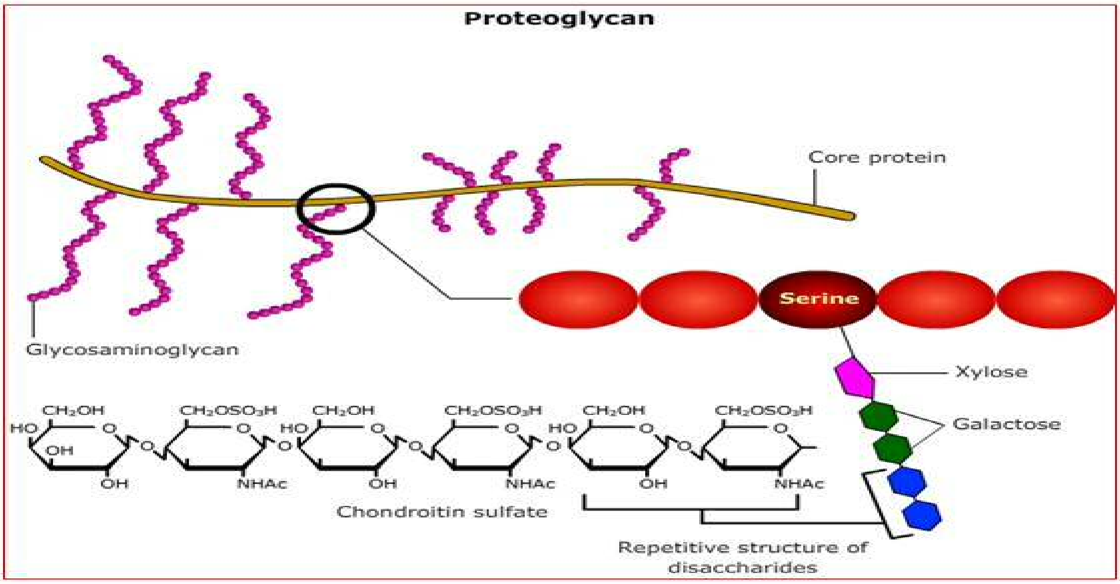
b) Give an elaborate note on proteoglycans and glycolipids

Proteoglycans

Proteoglycans resemble more to polysaccharides than to proteins as it contains 95% carbohydrate moieties by weight.

Structure:

- Proteoglycans are structural constituent of extracellular matrix in which one or more sulfated glycosaminoglycan chains are attached covalently to a membrane protein or a secreted protein termed as "core protein".
- The point of attachment is a Serine (Ser) residue, to which the glycosaminoglycan such as chondroitin sulfate is attached through a trisaccharide bridge i.e. Gal-Gal-Xyl
- The Serine residue is usually in the sequence -Ser-Gly-X-Gly- (where X is any amino acid residue), although not every protein with this sequence has an attached glycosaminoglycan.



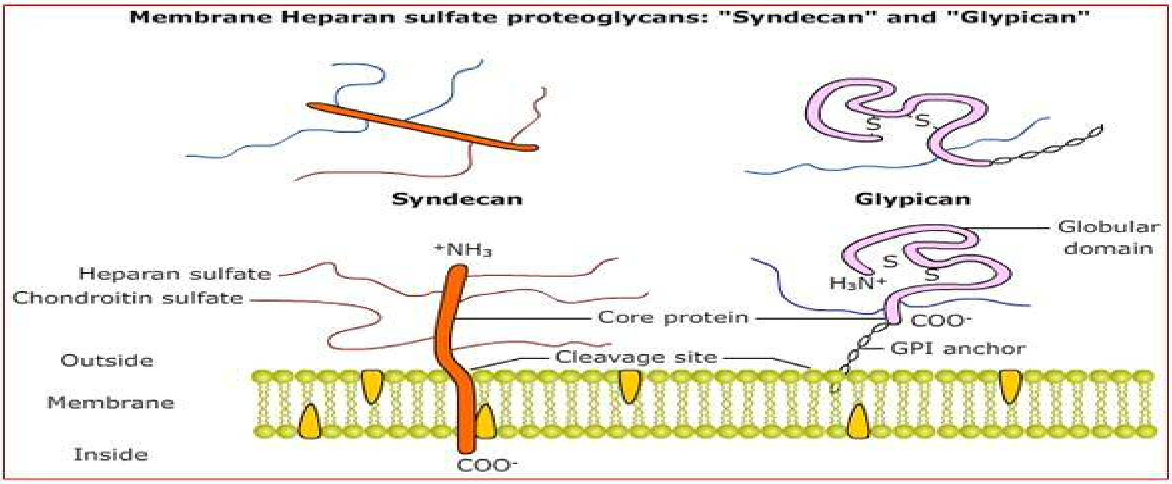
Proteoglycan structure, showing the trisaccharide bridge.

Importance:

- Proteoglycans are major components of all extracellular matrices.
- Proteoglycans work as lubricants and structural components in connective tissue, mediate adhesion of cells to the extracellular matrix and bind factors that stimulate cell proliferation.
- Mammalian cells can synthesize 40 types of proteoglycans. These molecules act as tissue organizers and they influence various cellular activities, for instance, growth factor activation and adhesion.

Types of Proteoglycans:

There are two major families of membrane heparan sulfate proteoglycans. Syndecans have a single trans-membrane domain and an extracellular domain bearing three to five chains of heparin sulfate and in some cases chondroitin sulfate (Fig. 13). Glypicans are linked to the membrane through a lipid anchor, a derivative of the membrane lipid phosphatidylinositol. Both syndecans and glypicans may be shed into the extracellular space. A protease in the ECM that cuts close to the membrane surface liberates syndecan ectodomains (those domains outside the plasma membrane) and a phospholipase which breaks the connection to the membrane lipid releases glypicans. Many chondroitin sulfate and dermatan sulfate proteoglycans also exist, some as membrane-bound entities, others as secreted products in the ECM.



Glycolipids

Structure:

- Glycolipids are membrane sphingolipids in which the hydrophilic head groups are oligosaccharides.

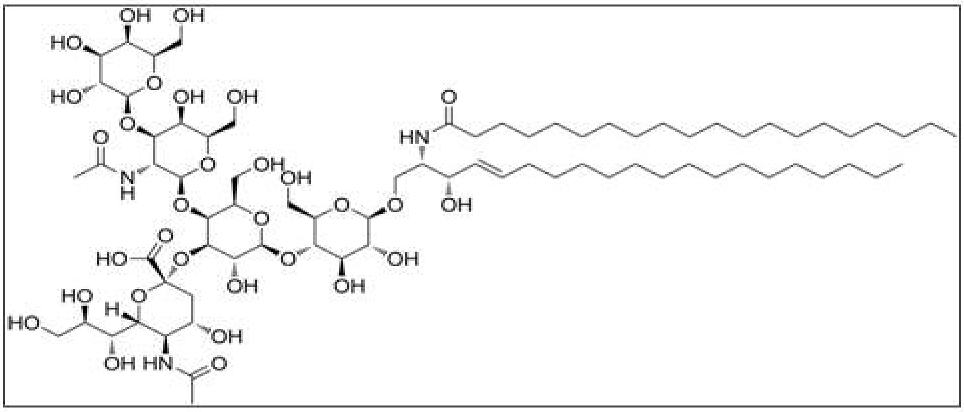
Significance:

- As in glycoproteins the oligosaccharides act as specific sites for recognition through protein called lectins.
- The brain and neurons are rich in glycolipids, which help in nerve conduction and myelin formation.
- Glycolipids also play a role in signal transduction in cells.

Gangliosides: A type of glycolipids

Structure: These are membrane lipids of eukaryotic cells in which the polar head group, the part of the lipid that forms the outer surface of the membrane, is a complex oligosaccharide containing a sialic acid and other monosaccharide residues.

Significance: Like glycoprotein, a few oligosaccharide moieties of gangliosides determine human blood groups (Fig. 16). Like the oligosaccharide residues of glycoproteins, those of membrane lipids are generally found on the outer face of the plasma membrane.



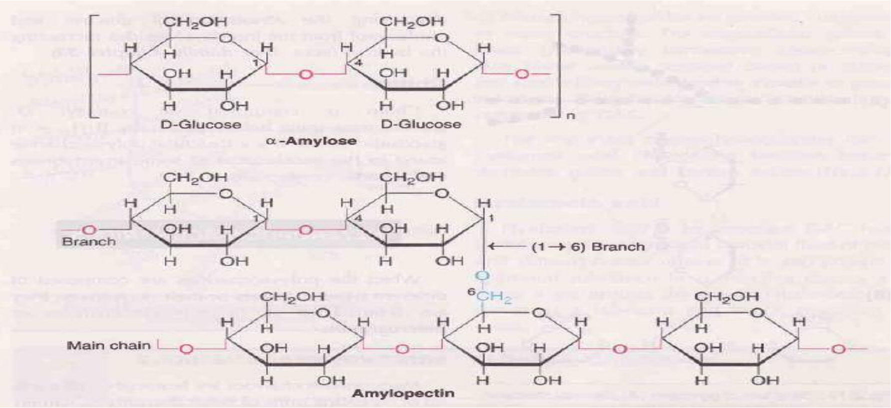
Gangliosides, a glycolipid contain carbohydrate

25. a) Discuss on homopolysaccharides with special reference to starch

- A polysaccharide is a polymer consisting of hundreds to thousands of monosaccharide joined together by glycosidic linkages.
- Three biologically important polysaccharides are starch, glycogen and cellulose
  - all three are polymers of D-glucose, but they differ in the type of glycosidic bond and/or the amount of branching
- Starch and glycogen are used for storage of carbohydrates
  - Starch is found in plants and glycogen in animals
  - The polymers take up less room than would the individual glucose molecules, so are more efficient for storage

STARCH:

- Starch is the carbohydrate reserve of plants which is the most important dietary source for higher animals, including man.
- High content of starch is found in cereals, roots, tubers, vegetables etc.
- Starch is a homopolymer composed of D-glucose units held by a-glycosidic bonds.
- It is known as glucosan or glucan.
- Starch consists of two polysaccharide components-water soluble amylose (15-20%) and a water insoluble amylopectin (80-85%).
- Chemically, amylose is a long unbranched chain with 200-1,000 D-glucose units held by α (1 → 4) glycosidic linkages.
- Amylopectin on the other hand, is a branched chain with α (1 → 6) glycosidic bonds at the branching points and α (1 → 4) linkages everywhere else Amylopectin molecule containing a few thousand glucose units looks like a branched tree (20-30 glucose units per branch).
- Starches are hydrolysed by amylase (pancreatic or salivary) to liberate dextrins, and finally maltose and glucose units.
- Amylase acts specifically on a (1 → 4) glycosidic bonds.



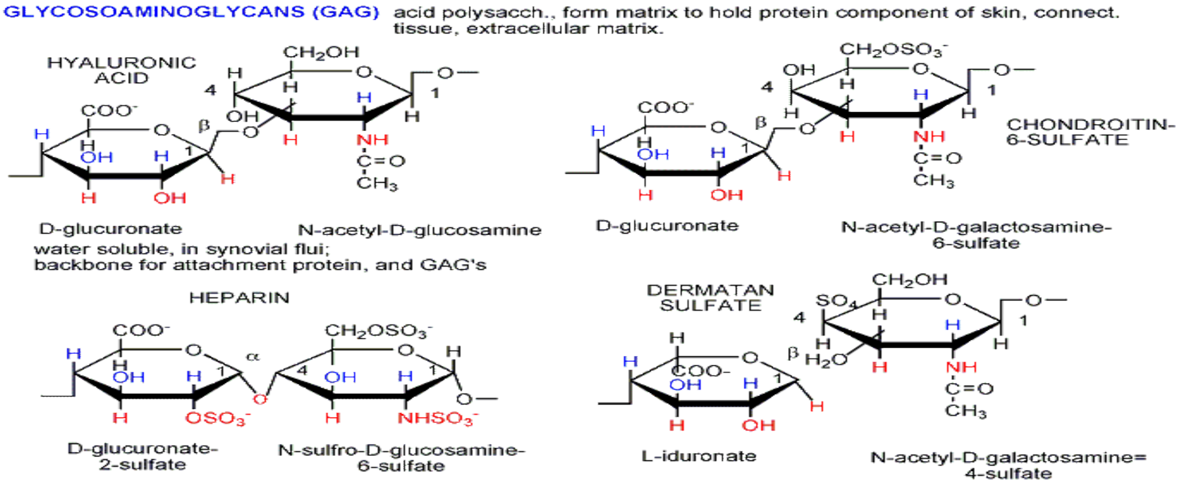
Structure of starch (α-amylose and amylopectin)

Or

b) Explain the structure and functions of heteropolysaccharides

Heteropolysaccarides contain two or more different kind of monosaccharides. Usually they provide extracellular support for organisms of all kingdoms: the bacteria cell envelope, or the matrix that holds individual cells together in animal tissues, and provides protection, shape and support to cells, tissues and organs.

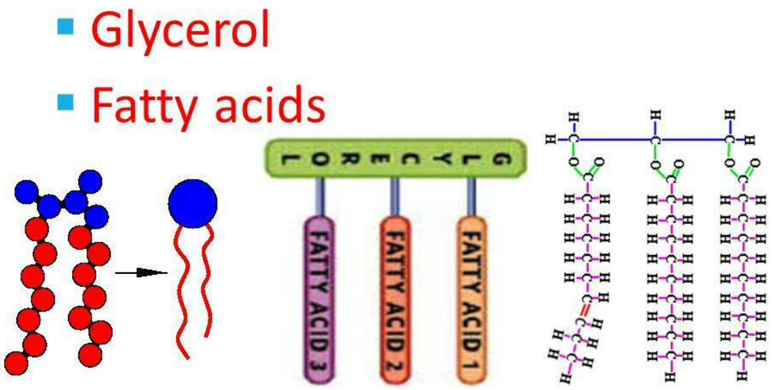
Heteropolysaccharides provide extracellular support to very different organisms, from bacteria to humans; together with fibrous proteins, like collagen, elastin, fibronectin, laminin and others, heteropolysaccharides are the most important components of the extracellular matrix. Hyaluronic acid, condroitin sulfates and dermatan sulfates are important heteropolysaccharides in the extracellular matrix. These heteropolysaccharides usually are formed by the repetition of a disaccharide unit of an aminosugar and an acid sugar.



They have a structural role, and the structures of individual connective-tissue polysaccharides are related to specific animal functions; hyaluronic acid, for example, the major component of joint fluid in animals, functions as a lubricating agent and shock absorber.

26. a) Explain about the building block units of lipids

Glycerol is a simple sugar alcohol compound $C_3H_8O_3$. Fatty acids, the main building blocks of lipids, are carboxylic acids with hydrocarbon chains typically ranging from 10 to 30 carbons in length. These hydrocarbon chains are nonpolar. Fatty acids can be saturated or unsaturated. Saturated fatty acids have all bonding positions occupied by hydrogens, whereas unsaturated fats have one or more double bonds between carbons. Some common fatty acids include lauric, palmitic, stearic, oleic, linoleic, linolenic and arachidonic acids.



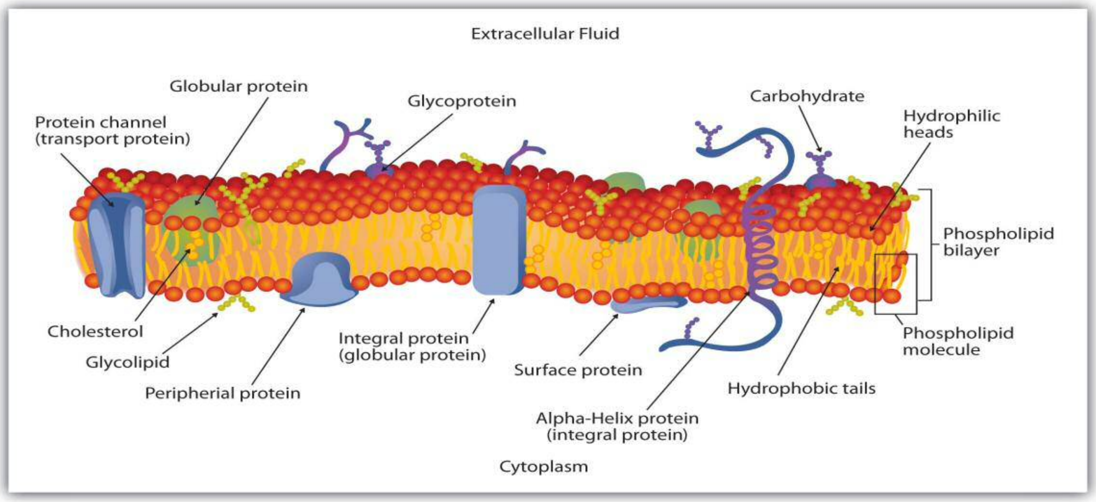
Or

b) Describe the lipids in membrane

A membrane lipid is a compound which belongs to a group of (structurally similar to fats and oils) which form the double-layered surface of all cells (lipid bilayer). The three major classes of membrane lipids are phospholipids, glycolipids, and cholesterol.

The lipid bilayer is a universal component of all cell membranes. Its role is critical because its structural components provide the barrier that marks the boundaries of acell. The structure is called a "lipid bilayer" because it is composed of two layers of fat cells organized in two sheets.

Phospholipids are abundant in all biological membranes. A phospholipid molecule is constructed from four components: fatty acids, a platform to which thefatty acids are attached, a phosphate, and an alcohol attached to the phosphate.



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DEPARTMENT OF BIOCHEMISTRY

SUBJECT NAME : MOLECULES OF LIFE
SUB.CODE : 17BCU101
SEMESTER : I
CLASS : I B.Sc., BIOCHEMISTRY

Maximum: 50 marks

PART A (20 x 1 = 20 marks)

Answer ALL questions

1.b) Leucine
2. a) 20
3. a) Glycine
4. a) Optical rotation
5. d) Chromoprotein
6. a) a sugar
7. a) Uracil
8. a) hydrogen bonds
9. c) bases
10. b) Hoogsten
11.b) Scravy
12. a) Folic acid
13. c) vitamin E
14. a) GABA
15. b) vitamin D
16. b) riboflavin
17. c) thiamin
18. b) vitamin D
19. d) vitamin A
20. b) metyl malonic acid

PART B (3 x 2 = 6 marks)

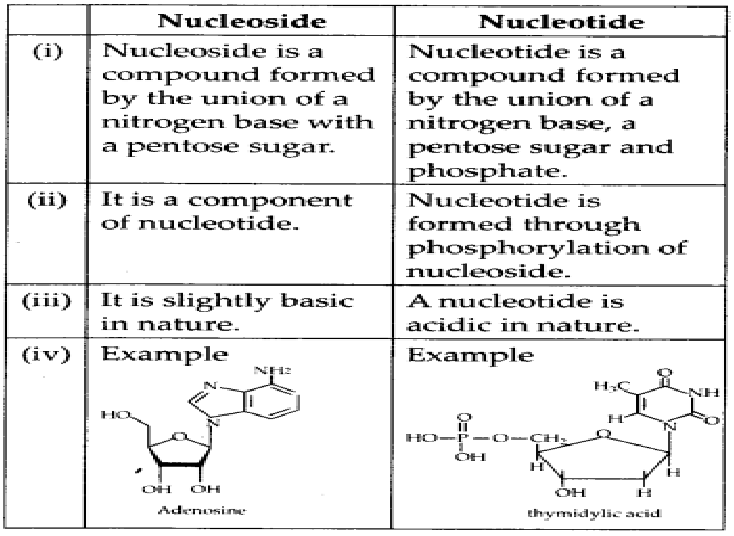
Answer ALL questions

21. UV Absorbance

UV Absorbance of Pyrimidines and Purines

- Both Pyrimidines and Purines have strong absorbance in the ultraviolet around 260 nm
- This is a useful property in measuring quantities of nucleic acid in a sample.

22. Differentiate nucleotide from nucleoside



	Nucleoside	Nucleotide
(i)	Nucleoside is a compound formed by the union of a nitrogen base with a pentose sugar.	Nucleotide is a compound formed by the union of a nitrogen base, a pentose sugar and phosphate.
(ii)	It is a component of nucleotide.	Nucleotide is formed through phosphorylation of nucleoside.
(iii)	It is slightly basic in nature.	A nucleotide is acidic in nature.
(iv)	Example Adenosine	Example thymidylic acid

23. Hypervitaminosis is a condition of abnormally high storage levels of vitamins, which can lead to toxic symptoms. Specific medical names of the different conditions are derived from the vitamin involved: an excess of vitamin A, for example, is called hypervitaminosis A.

PART B (3 x 8 = 24 marks)
Answer ALL questions

24. a) Structure and classification of amino acids

Definition:

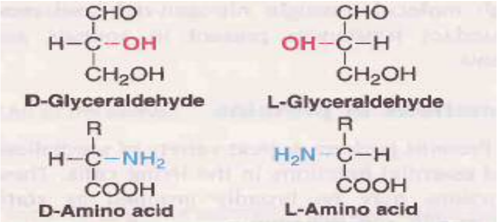
Amino acids are a group of organic compounds containing two functional groups amino and carboxyl. The amino group (-NH2) is basic while the carboxyl group (-COOH) is acidic in nature.

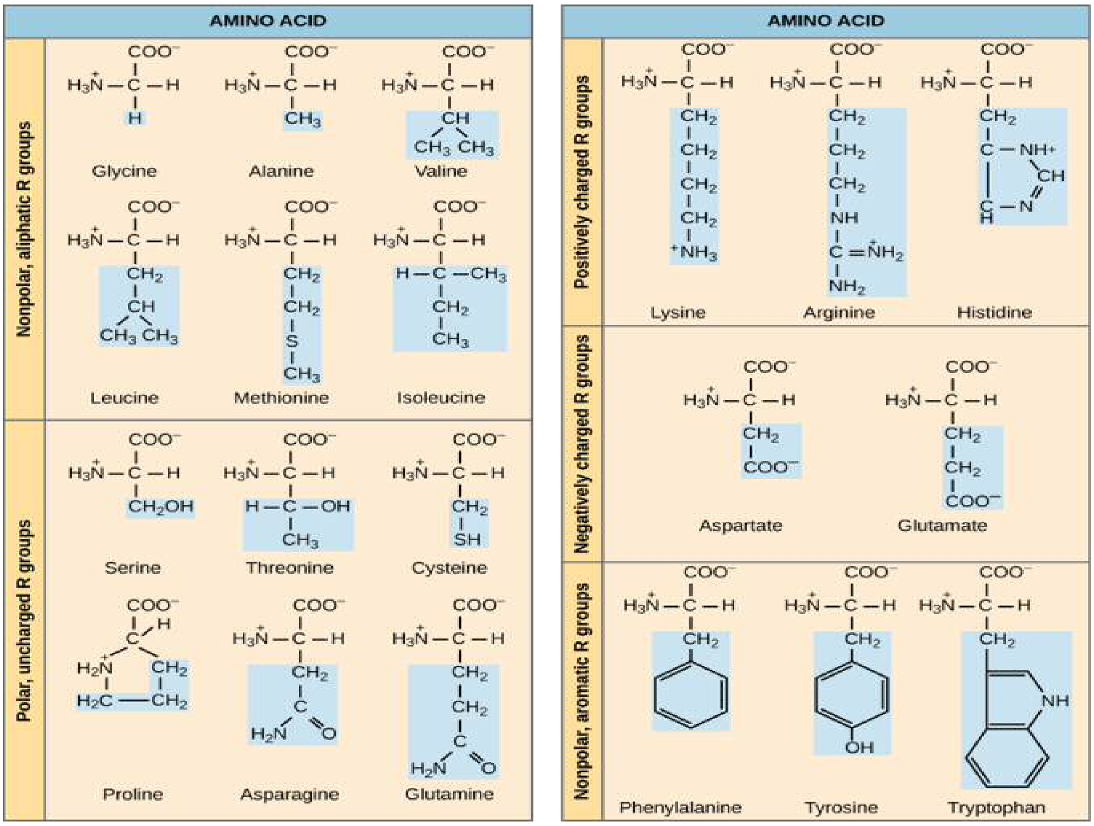
CLASSIFICATION:

There are different ways of classifying the amino acids based on the structure and chemical nature nutritional requirement, metabolic fate etc.

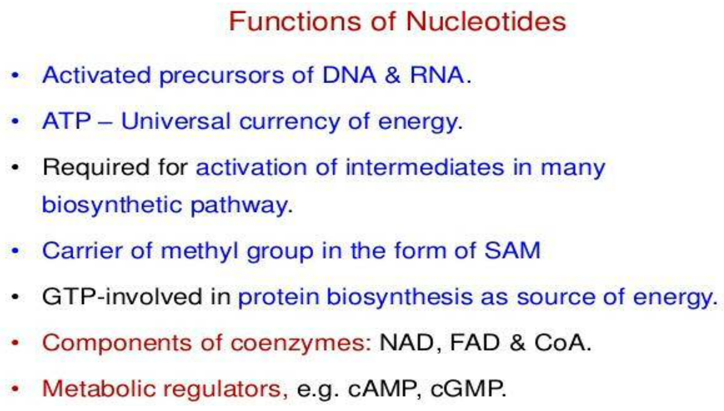
A. Amino acid classification based on the structure:

- A comprehensive classification of amino acids is based on their structure and chemical nature.
- Each amino acid is assigned a 3 letter or 1 letter symbol.
- These symbols are commonly used to represent the amino acids in protein structure.
- The 20 amino acids found in proteins are divided into seven distinct groups.
- The different groups of amino acids, their symbols and structures are given.
- The salient features of different groups are described next.





b).

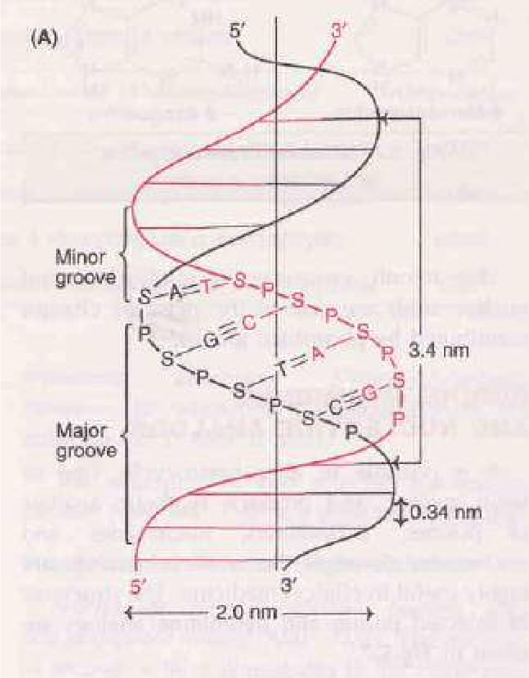


Functions of Nucleotides

- Activated precursors of DNA & RNA.
- ATP – Universal currency of energy.
- Required for activation of intermediates in many biosynthetic pathway.
- Carrier of methyl group in the form of SAM
- GTP-involved in protein biosynthesis as source of energy.
- Components of coenzymes: NAD, FAD & CoA.
- Metabolic regulators, e.g. cAMP, cGMP.

25.a) Watson and Crick model of DNA

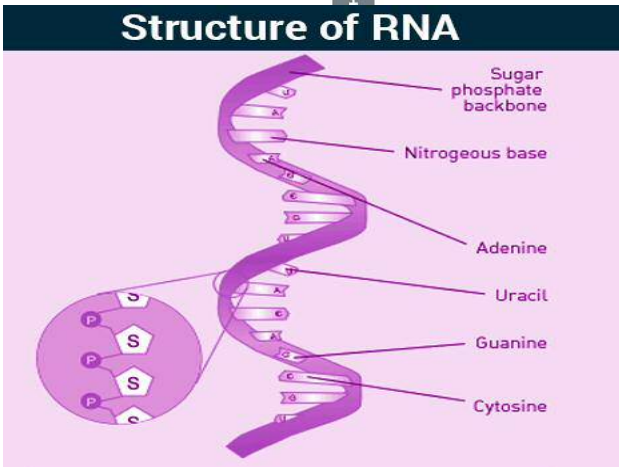
The DNA is a right handed double helix. It consists of two polydeoxyribonucleotide chains (strands) twisted around each other on a common axis.The two strands are antiparallel, i.e., one strand runs in the 5' to 3' direction while the other in 3'to 5'direction.T his is comparable to two parallel adjacent roads carrying traffic in opposite direction. The width (or diameter) of a double helix is 20 A° (2 nm).Each turn (pitch) of the helix is 34 A" (3.4 nm) with 10 pairs of nucleotides each pair placed at a distance of about 3.4 A°. Each strand of DNA has a hydrophilic deoxyribose phosphate backbone (3'-5' phosphor diester bonds)on the outside (periphery) of the molecule while the hydrophobic bases are stacked inside (core).The



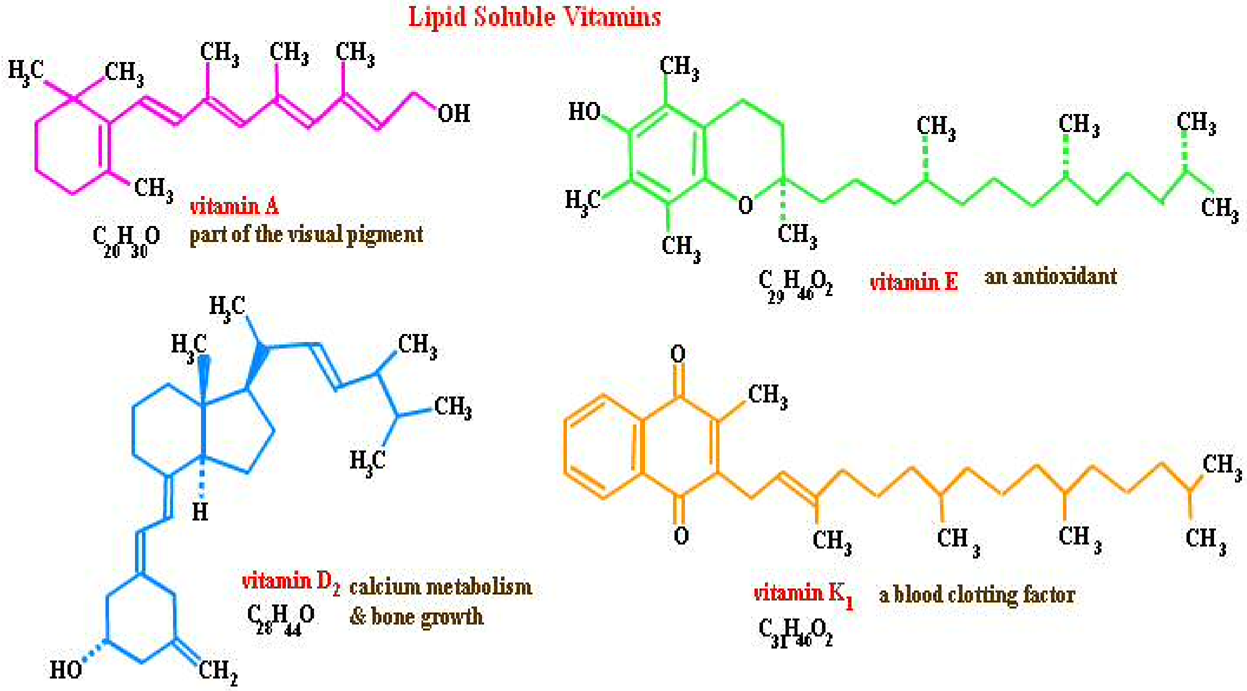
two polynucleotide chains are not identical but complementary to each other due to base pairing. The two strands are held together by hydrogen bonds formed by complementary base pairs.The A-T pair has 2 hydrogen bonds while G-C pair has 3 hydrogen bonds. The G = C is stronger by about 50% than A=T.The hydrogen bonds are formed between a purine and a pyrimidine only. If two purines face each other, they would not fit into the allowable space. And two pyrimidines would be too far to form hydrogen bonds. The only base arrangement possible in DNA structure, from spatial considerations is A-T, T-A, G-C and C-C.The complementary base pairing in DNA helix proves Chargaffs rule.The content of adenine equals to that of thymine (A = T) and guanine equals to that of cytosine (G = C).

b) Describe the classification of RNA

NAME	*BASIC FUNCTION*
message RNA(mRNA)	RNA carries genetic information transcribed form DNA.
transfer ribonucleic acidt RNA(tRNA)	RNA is responsible to transport in protein synthesis.
ribosomalRNA(rRNA)	The main part of ribosome
MicroRNAs(miRNAs)	A kind of non-coding RNA in eucaryon with regulative function
Small RNA	Small RNA can be formed complex with protein, play an important role in the activity of cells.
telomeraseRNA	telomeraseRNA is related to the replication of chromosomes
antisenseRNA	antisenseRNA involves in the regulation of gene expression.
long non-coding RNA(lnc RNA)	Non encoding protein RNA but participate in the regulation of cells.



26.a)Structure and deficiency diseases of fat soluble vitamins

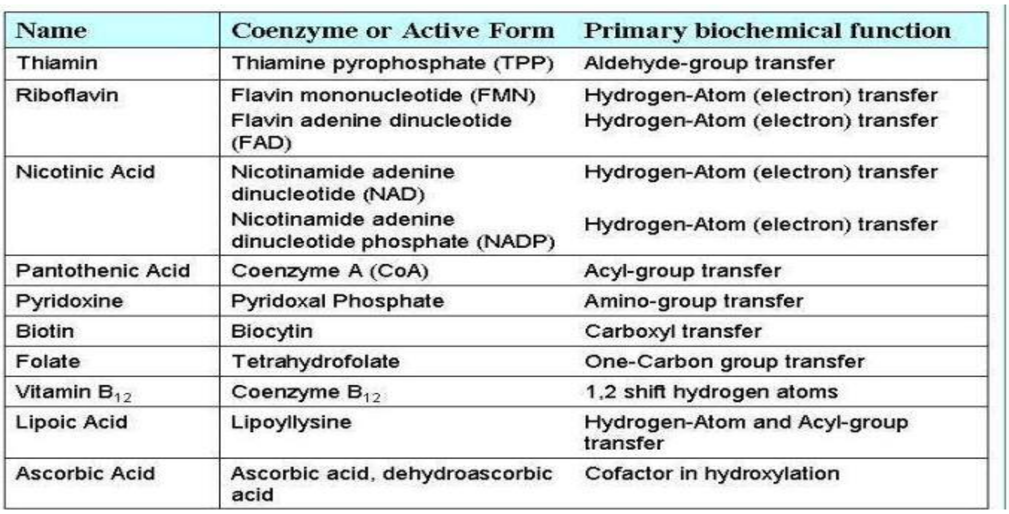


Vitamin	Function	Consequences of Deficiency	Toxic Effects
A – Retinoids	Epithelial integrity; immune response and infection	Loss od night vision; xerophtalmia, decreased resistance to infection. Dry skin	"drawsiness, headache, vomiting, amnd excessive peeling of the skin." Sun sensitivity
D-Cholecalciferol	Absorbtion of calcium and remodeling of osteod	Rickets and osteomalacia	"hypercalcemia.... anorexia, naussea, headache." Signs of menisngitis (pseudotumor cerebrii) Nephrocalcinosis.
E- Tocopherols	An antioxidant *Possibly* preventing degenreative conditions. High	Sterility in rats. Degeerative neurologic effects in humans, hemolysis in premature neonates	Supra oxidant effects. Study in Finland to prevent oxidation od cholesterol and reduce risk of CHD resulted in increased incidence oflung cancer.
K- -naphthoquinone	Essentila for clotting	Hemolystic disease in newborn.	None recorded

b). Water soluble vitamins

- B-complex Vitamins. ...
- Thiamin: Vitamin B1. ...
- Riboflavin: Vitamin B2. ...
- Niacin: Vitamin B3, Nicotinamide, Nicotinic Acid. ...
- Vitamin B6: Pyridoxine, Pyridoxal, Pyridoxamine. ...
- Folate: Folic Acid, Folacin. ...

- Vitamin B12: Cobalamin. ...
- Biotin.



Name	Coenzyme or Active Form	Primary biochemical function
Thiamin	Thiamine pyrophosphate (TPP)	Aldehyde-group transfer
Riboflavin	Flavin mononucleotide (FMN) Flavin adenine dinucleotide (FAD)	Hydrogen-Atom (electron) transfer Hydrogen-Atom (electron) transfer
Nicotinic Acid	Nicotinamide adenine dinucleotide (NAD) Nicotinamide adenine dinucleotide phosphate (NADP)	Hydrogen-Atom (electron) transfer Hydrogen-Atom (electron) transfer
Pantothenic Acid	Coenzyme A (CoA)	Acyl-group transfer
Pyridoxine	Pyridoxal Phosphate	Amino-group transfer
Biotin	Biocytin	Carboxyl transfer
Folate	Tetrahydrofolate	One-Carbon group transfer
Vitamin B_{12}	Coenzyme B_{12}	1,2 shift hydrogen atoms
Lipoic Acid	Lipoyllysine	Hydrogen-Atom and Acyl-group transfer
Ascorbic Acid	Ascorbic acid, dehydroascorbic acid	Cofactor in hydroxylation