6 April, 2020

ASSIGNMENT - 1

INNOVATIVE TECHNOLOGY AND BIO-SCIENCE

Submitted By : **YASH VINAYVANSHI**
B.TECH (2nd SEM)
SECTION C ; SR : 72 ; ID 201907070
JAMIA MILLIA ISLAMIA FET
E-Mail : yash.vinayvanshi@icloud.com

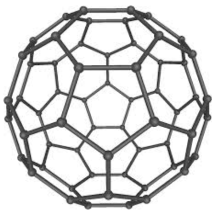
1. Explain Carbonaceous Nano materials.

1.1 INTRODUCTION

Carbon is one of the few chemical elements (including also silicon) with the ability to polymerise at the atomic level **(Catenation)**, thus able to form very long carbon chains and ring structures . Due to the four electrons in the outer electron layer carbon atoms have a valence of four and can be linked via single, double or triple covalent bonds, or also with other elements. These properties of carbon atoms can be attributed to their special electron structure and the smaller size compared with other elements of group IV. Following are some successfully synthesised Carbon nano materials.

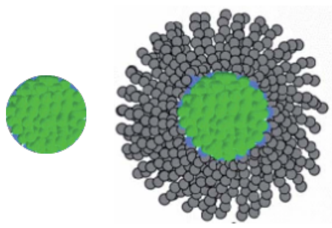
QUANTUM DOT (0 Dimensional)

FULLERENE

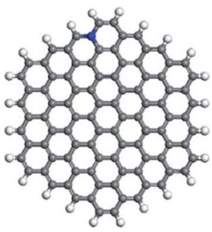


CARBON ONION

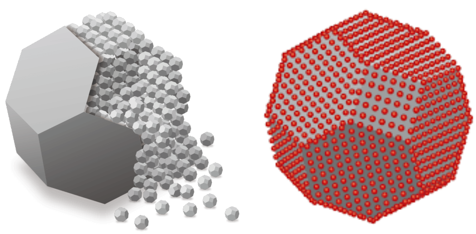
CARBON DOT



GRAPHENE DOT

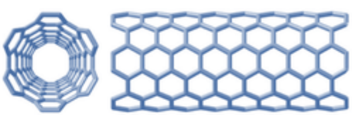


NANODIAMOND

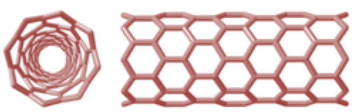


QUANTUM WIRE (1D)

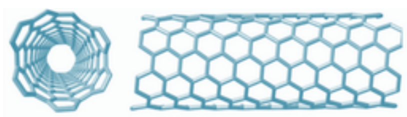
SINGLE WALLED CARBON NANOTUBE (SWCNTs)



(Armchair)

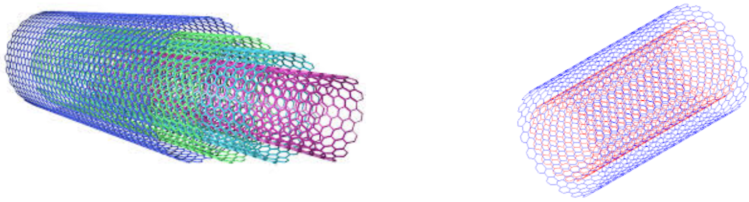


(ZigZag)

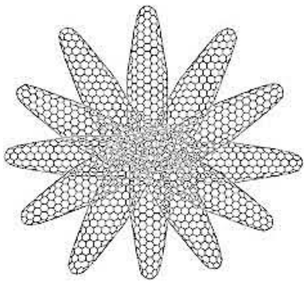


(Chiral)

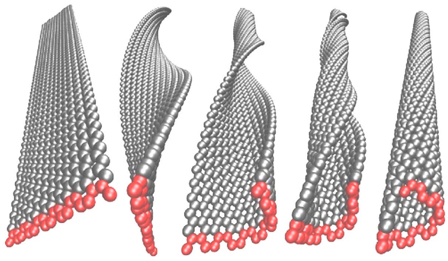
MULTI-WALLED CARBON NANOTUBES (MWCNTs)



CARBON NANOHORNS

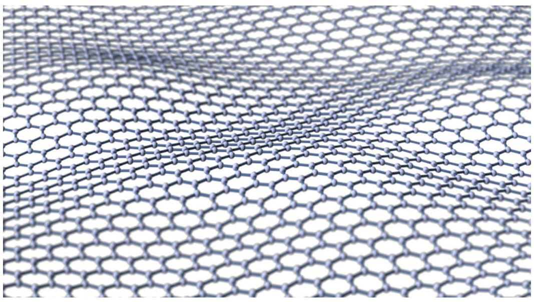


CARBON NANO-RIBBONS (UNZIPPED CNTs)

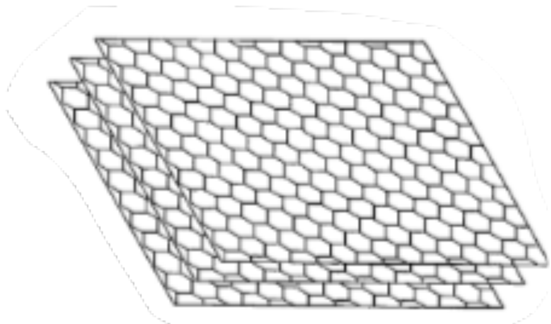


QUANTUM WELL (2D)

GRAPHENE



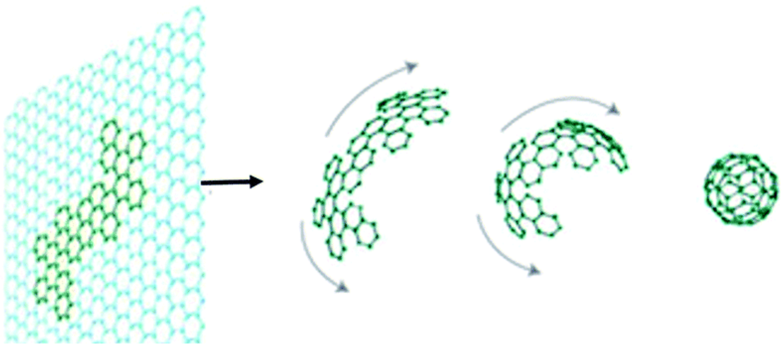
MULTILAYERED GRAPHITIC SHEETS



We can describe some popular carbon nano materials as :

1.2 FULLERENES

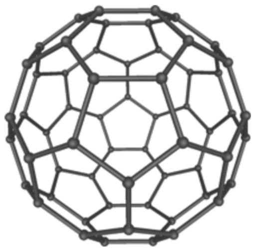
A **fullerene** is an allotrope of carbon whose molecule consists of carbon atoms connected by single and double bonds so as to form a closed or partially closed mesh, with fused rings of five to seven atoms. The molecule may be a hollow sphere, ellipsoid, tube, or many other shapes and sizes. Graphene (isolated atomic layers of graphite), which is a flat mesh of regular hexagonal rings, can be seen as an extreme member of the family.



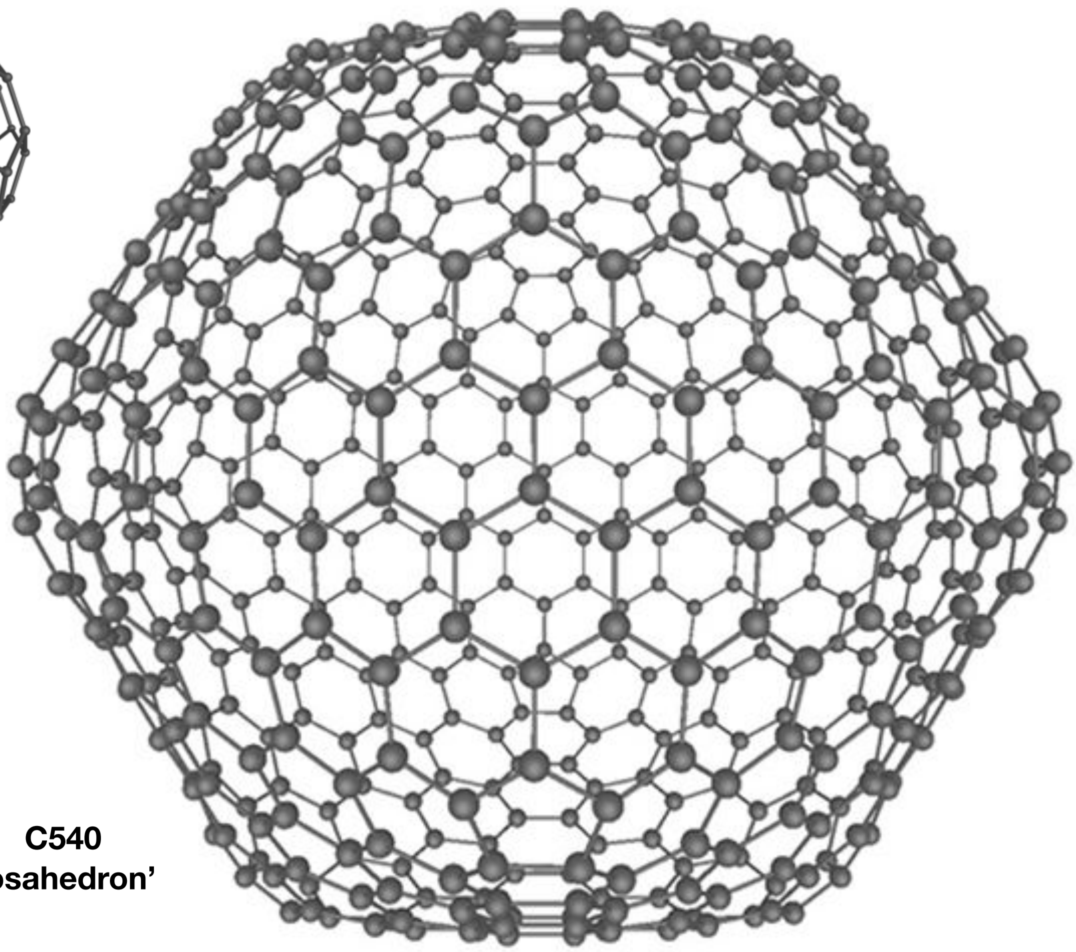
(Fig : A graphene sheet folding into a fullerene)

Fullerenes with a closed mesh topology are informally denoted by their empirical formula C_n, often written C*n*, where *n* is the number of carbon atoms. However, for some values of *n* there maybe more than one isomer.

The family is named after buckminsterfullerene (C_{60}), the most famous member, which in turn is named after Buckminster Fuller. The closed fullerenes, especially C_{60}, are also informally called **buckyballs** for their resemblance to the standard ball of association football ("soccer"). Nested closed fullerenes have been named **bucky onions**. Cylindrical fullerenes are also called carbon nanotubes or **buckytubes**. The bulk solid form of pure or mixed fullerenes is called **fullerite**



C60
‘ Soccer ’
0.7 nm

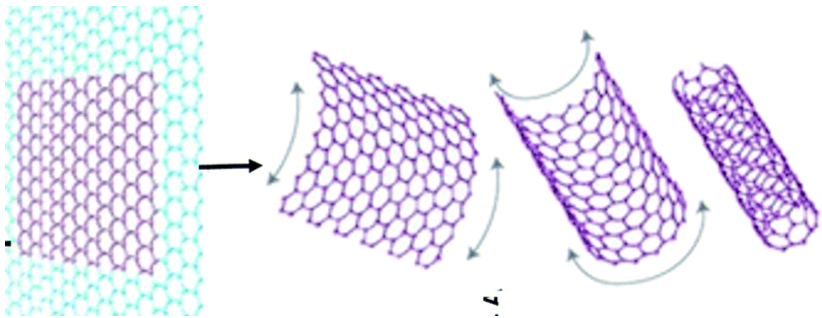


C540
‘Icosahedron’

1.3 CARBON NANO TUBES

Carbon nanotubes (CNTs) are tubes made of carbon with diameters typically measured in nanometers. Carbon nanotubes refer to **single-wall** carbon nanotubes **(SWCNTs)** or **multi-wall** carbon nanotubes **(MWCNTs)** consisting of nested single-wall carbon nanotubes or to tubes with an undetermined carbon-wall structure and diameters less than 100 nanometers. Single-wall carbon nanotubes are one of the allotropes of carbon, intermediate between fullerene cages and flat graphene.

Carbon nanotubes can exhibit **remarkable electrical conductivity**. They also have **exceptional tensile strength** and **thermal conductivity**, because of their nanostructure and strength of the bonds between carbon atoms. In addition, they can be chemically modified. These properties are expected to be valuable in many areas of technology, such as electronics, optics, composite materials (replacing or complementing carbon fibers), nanotechnology, and other applications of materials science.



(Fig : A graphene sheet folding into a nanotube)

1.3 GRAPHENE

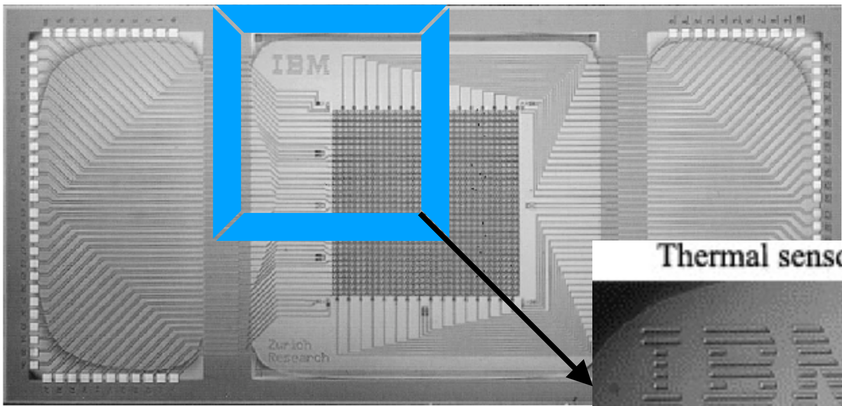
Graphene is an allotrope of carbon in the form of a single layer of atoms in a two dimensional hexagonal lattice in which one atom forms each vertex. It is the basic structural element of other allotropes, including graphite, charcoal, carbon nanotubes and fullerenes. It can also be considered as an indefinitely large aromatic molecule, the ultimate case of the family of aromatic hydrocarbons.

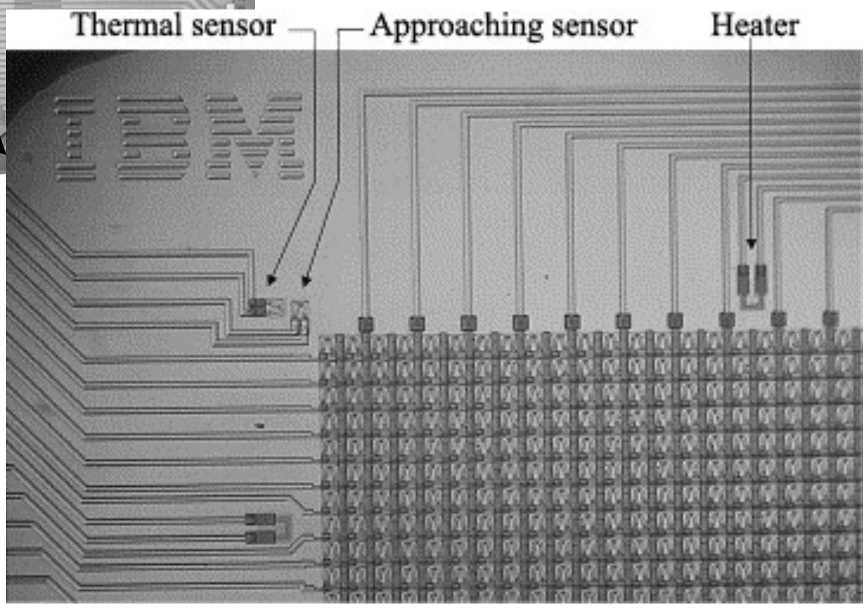
Graphene has a special set of properties which set it apart from other allotropes of carbon. In relation to its thickness, it is about 100 times stronger than the strongest steel. Yet its density is dramatically lower than any steel, with a surfacic mass of . It conducts heat and electricity very efficiently and is nearly transparent.Graphene also shows a large and nonlinear diamagnetism, even greater than graphite, and can be levitated by Nd-Fe-B magnets. Researchers have identified the bipolar transistor effect, ballistic transport of charges and large quantum oscillations in the material.

2. What is NEMS and MEMS ?

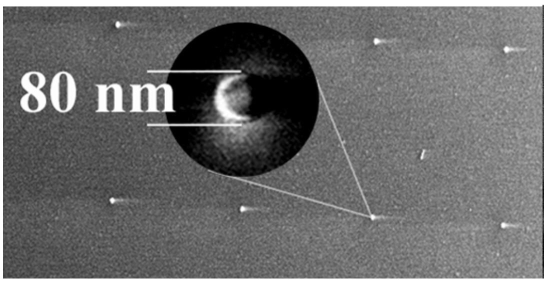
2.1 NEMS : Nanoelectromechanical Systems

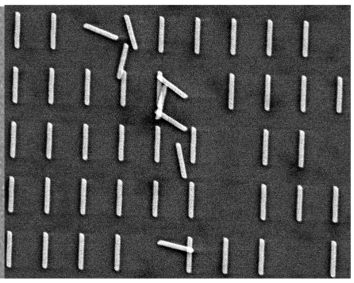
Nanoelectromechanical systems (**NEMS**) are a class of devices integrating electrical and mechanical functionality on the nanoscale. NEMS typically integrate transistor-like nanoelectronics with mechanical actuators, pumps, or motors, and may thereby form **physical, biological, and chemical sensors**. The name derives from typical device dimensions in the nanometer range, leading to **low mass**, **high mechanical resonance frequencies, potentially large quantum mechanical effects** such as zero point motion, and a high surface-to-volume ratio useful for surface-based sensing mechanisms. Applications include **accelerometers** and **sensors** to detect chemical substances in the air.

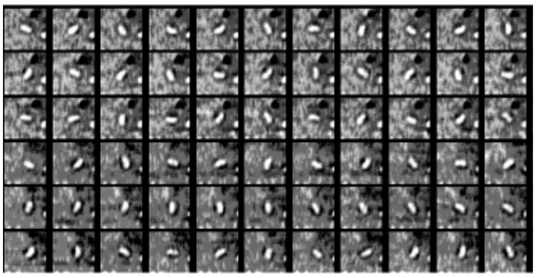




(Fig : The first very-large-scale integration (VLSI) NEMS device was demonstrated by researchers at IBM, 2000.)







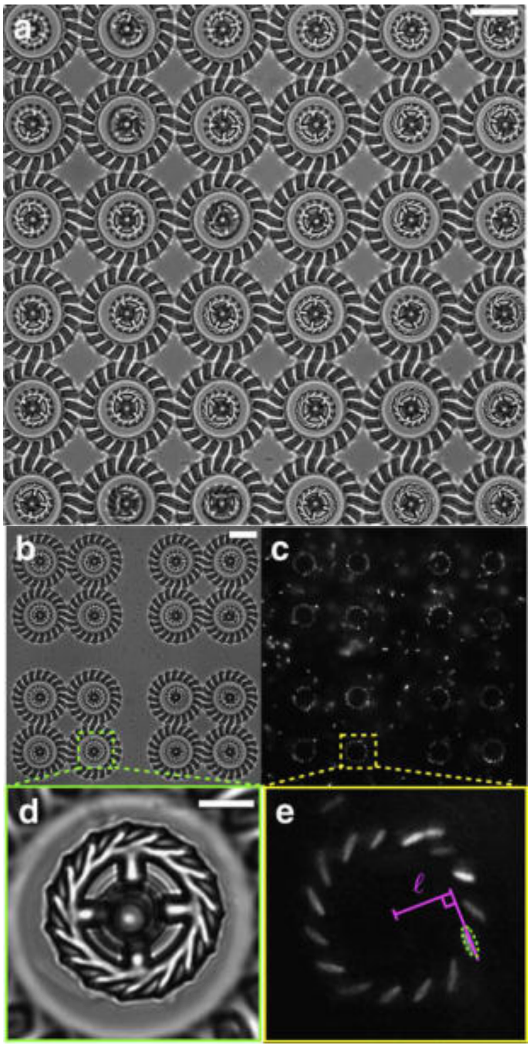
(An ATPase biomolecular motor)

(Assembling nano propellors)

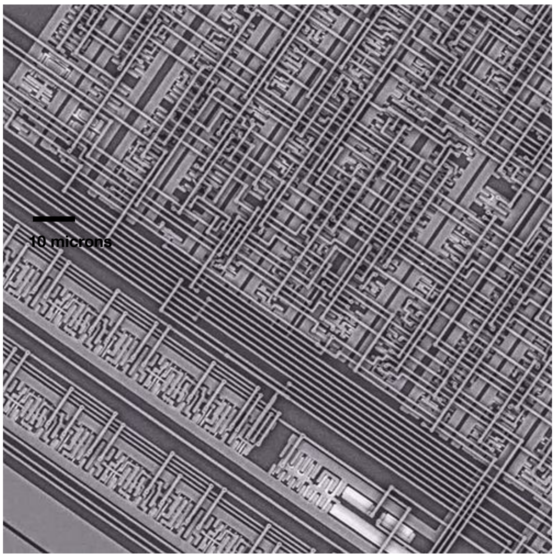
(ATPase motor driven nano-propellors rotating anticlockwise at 7.7 rps)

2.2 Microelectromechanical systems MEMS

NEMS form the next logical miniaturization step from so-called microelectromechanical systems, or MEMS devices. MEMSconstitute the technology of microscopic devices, particularly those with moving parts. They merge at the nanoscale into nanoelectromechanical systems (NEMS) and nanotechnology MEMS are made up of components between 1 and 100 micrometers in size (i.e., 0.001 to 0.1 mm), and MEMS devices generally range in size from 20 micrometres to a millimetre (i.e., 0.02 to 1.0 mm), although components arranged in arrays (e.g., digital micromirror devices) can be more than 1000 mm^2. They usually consist of a central unit that processes data (an integrated circuit chip such as microprocessor) and several components that interact with the surroundings (such as microsensors). Because of the large surface area to volume ratio of MEMS, forces produced by ambient electromagnetism (e.g., electrostatic charges and magnetic moments), and fluid dynamics (e.g., surface tension and viscosity) are more important design considerations than with larger scale mechanical devices.



(Micro gears driven By fluid like motion of swarms of E.Coli bacteria)



(A micro processor under electron microscope)

3. Explain Different Kinds of Biomolecules.

3.1 Introduction

Living Systems ara made of various complex biomolecules like carbohydrates, proteins, nucleic acids, lipids etc. These biomolecules interact with each other and constitute the molecular logic of life processes. In addition, some simple molecules like vitamins and mineral salts also play an important role in the functions of organisms. Broad categories of biomolecules are as :

3.2 Carbohydrates

Carbohydrates can be defined as optically active polyhydroxy aldehydes or ketones or the compounds which produce such units on hydrolyses. Some of the carbohydrates, which are sweet in taste are also called sugars hence thay are also called saccharides (Greek : sakcharon means sugar).

3.2.1 Classification of Carbohydrates

On the basis of their behaviour on hydrolyses :

3.2.1.1 Monosaccharides

A carbohydrate which cannot be hydrolysed into simpler unit of polyhydroxy aldehyde or ketone. There are 20 known monosaccharides found in nature like **glucose, fructose, ribose** etc.

3.2.1.2 Oligosaccharides

Carbohydrates that yield 2 - 10 monosaccharides units on hydrolyses. These are further classified based on the number of monosaccharides units provided as **disaccharides**(most common), **trisaccharides** and so on. These may or may not be made of single monomer monosaccharide like **sucrose**(glucose+fructose), **maltose**(glucose + glucose).

3.2.1.3 Polysaccharides

Carbohydrates which yield a large number of monosaccharide units on hydrolyses. These are not sweet in taste and called **non sugars**. Some common are **starch, cellulose, glycogen** etc.

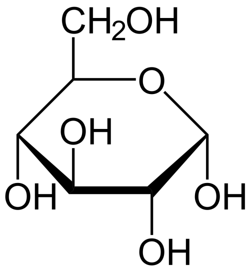
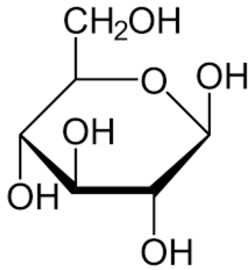
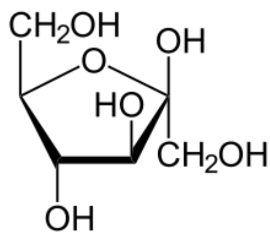
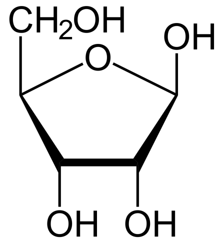
On basis of their chemical reducing character

3.2.1.1’ Reducing sugars

Which reduce **Tollen** and **Fehling** reagents. All Monosaccharides whether **aldose** or **ketose** are reducing.

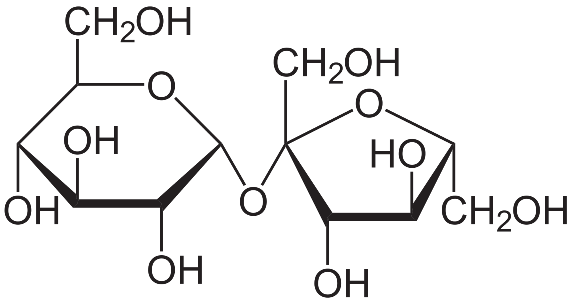
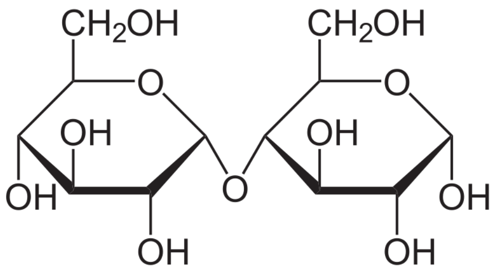
3.2.1.2’ Non reducing Sugars

If reducing groups(ie aldehydic or ketonic) of monosaccharides are bonded. Eg Sucrose

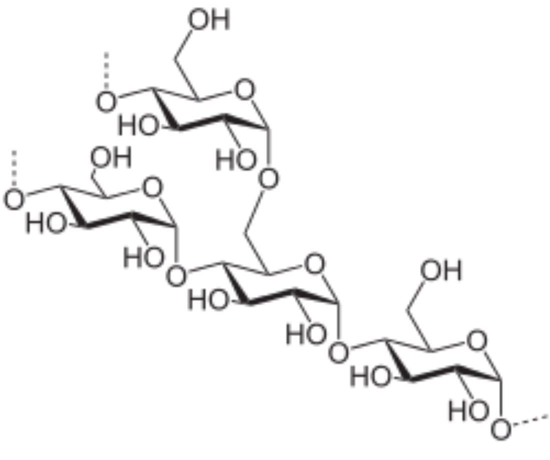
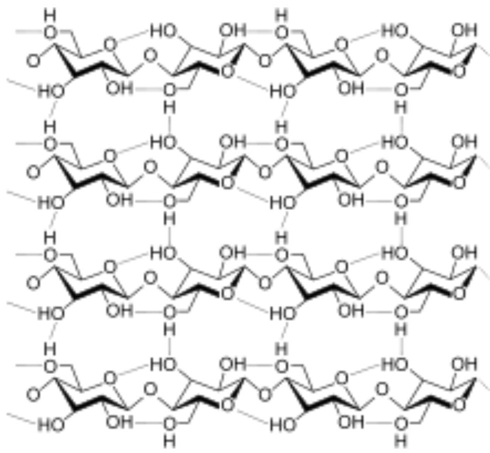
a-Glucose ***b-Glucose*** ***Fructose*** ***Ribose***

(Anomers)

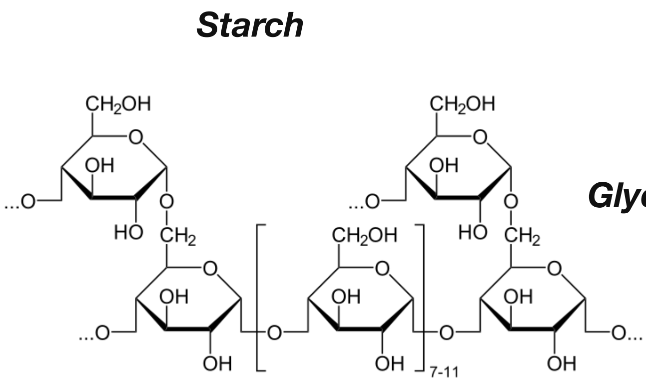



Glycosidic Linkage

Sucrose ***Maltose***

Starch ***Cellulose***

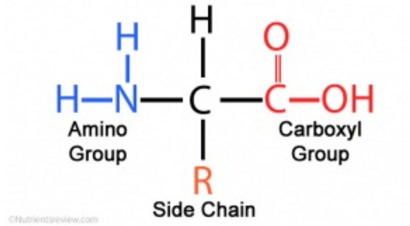


Glycogen

3.3 Proteins

All proteins are **polymers of a-Amino acids** (which are molecules containing a carbon atom attached with substituent, an animo -NH2, a carboxylic -COOH group) Proteins are most abundant biomolecules of the living system.The word protein is derived from Greek word proteios which means primary.

3.3.1 Amino Acids



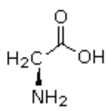
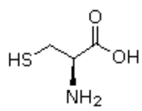
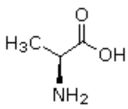
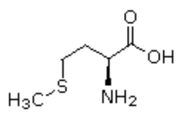
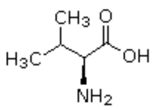
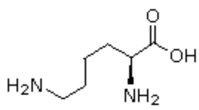
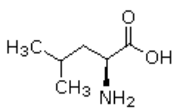
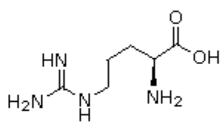
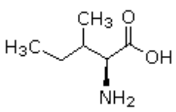
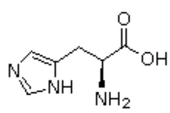
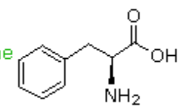
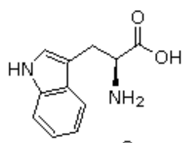
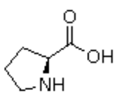
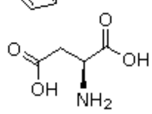
3.3.1.1 Essential Amino acids

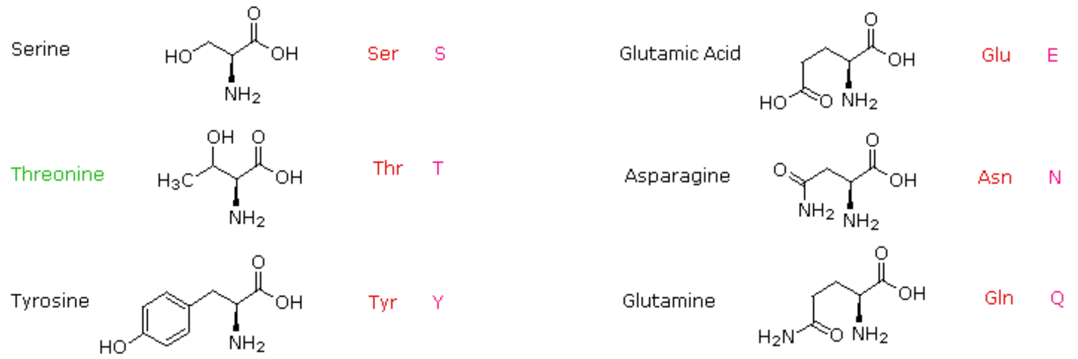
Cannot be synthesised by body and must be obtained through diet. Eg Valine, Leucine, Isoleucine, Lysine, Histidine etc.

3.3.1.2 Non Essential Amino acids

Synthesised by body itself. Eg Glycine, Alanine

3.3.1.3 Natural Amino acids

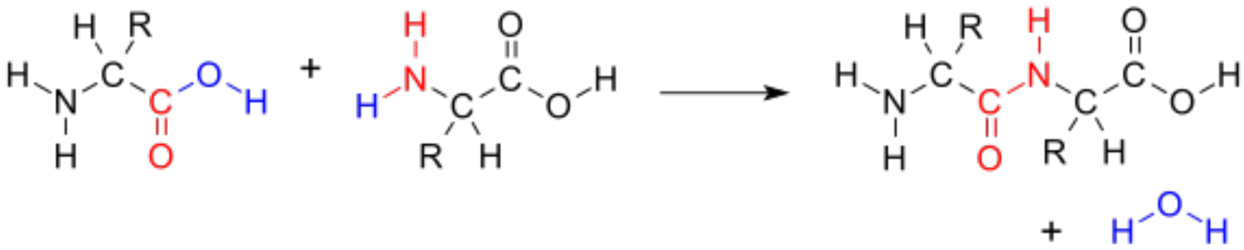
Name	Formula	Abbreviations		Name	Formula	Abbreviations	
Glycine		Gly	G	Cysteine		Cys	C
Alanine		Ala	A	Methionine		Met	M
Valine		Val	V	Lysine		Lys	K
Leucine		Leu	L	Arginine		Arg	R
Isoleucine		Ile	I	Histidine		His	H
Phenylalanine		Phe	F	Tryptophan		Trp	W
Proline		Pro	P	Aspartic Acid		Asp	D



3.3.2 Structure of proteins

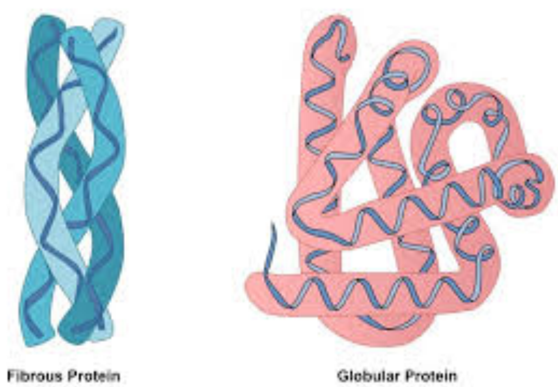
3.3.2.1 Peptide Bond

The reaction between two similar or different amino acids proceeds through combination of of the amino group of one molecule with with carboxyl of the other. This results in elimination of water molecule and formation of -CO-NH- peptide bond.



3.3.2.2 Fibrous Proteins

When polypeptide Chains run parallel and are held together by hydrogen and disulphide bonds, then fibre like structured proteins are formed which are generally insoluble in water

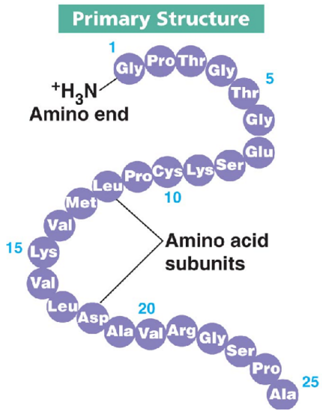


3.3.2.3 Globular Proteins

This structure results when the chains of polypeptides coil around to give a spherical. These are usually soluble in water. Eg **Insulin** and **Albumin**. Globular proteins can be studied at four levels of complexity as :

1. Primary structure

Each polypeptide in a protein has amino acid linked with each other in specific sequence which is called the primary structure of a given protein.

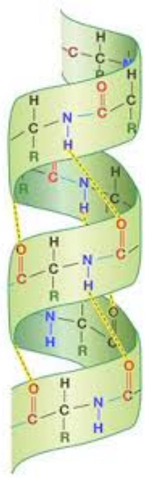


2. Secondary structure

It refers to the shape in which in which long polypeptides chains can exist. They are found to exist in two types of structures **alpha-helix and beta-pleated**. These structures arise due to regular folding of backbone of polypeptide chain due to peptide bonds.

alpha-helix : when a polypeptide chain forms all possible hydrogen bonds by twisting into a right handed screw with -NH group of each amino acid bonded to -,-c=o of the adjacent turn.

beta-pleated : All peptide chain are stretched out to nearly maximum extension and then held together side by side by intermolecular hydrogen bonds



3. Tertiary Structure

4. Quaternary structure

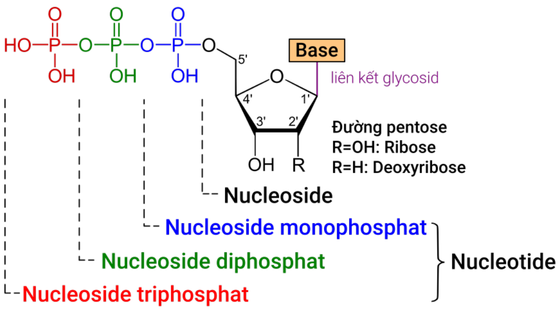
These are further foldings which are very complex.

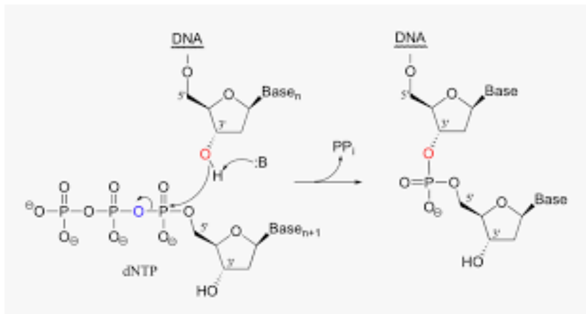
3.4 Nucleic Acids

The Particles in the nucleus of a cell, responsible for heredity are called **chromosomes** which are made up of proteins and another type of biomolecules called nucleic acids. These are mainly of two types, **Deoxyribonucleic acid (DNA)** and **ribonucleic acid (RNA)**. Since nucleic acids are long chain polymers of **nucleotides**, they are also called **polynucleotides**.

3.4.1 Structure of Nucleic Acids

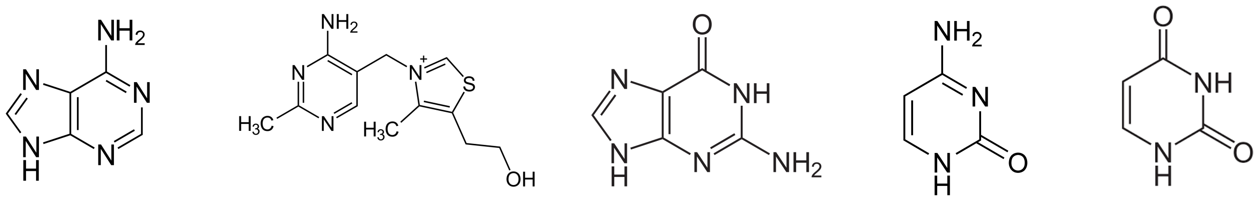
1. **Nucleotide :** Sugar+Base+Phosphate group
2. **Nucleoside :** Sugar+Base only
3. **Dinucleotide and Phosphodiester bond**





3.4.2 DNA

Complete Hydrolyses of DNA yields pentose sugar, phosphoric acid, and **nitrogen containing haterocyclic compounds** called bases, **Adenine(A), , Thiamine(T), Guanine(G), Cytocine(C)**. The sugar moiety is **beta-D-2-Deoxyribose**.DNA forms **Double Helix structure** made up of two antiparallel nucleotide chains held together by H bond between N bases in complements which are **A double H bonded with T and G triple H bonded with C.** Due to this stable structure, DNA is less vulnerable to damages or mutations, hence is used as **genetic material** to secure the genetic code (made of specific sequences go N bases).



A T G C U

3.4.3 RNA

Complete Hydrolyses of RNA gives same products as DNA except sugar moiety is **beta-D-ribose** and there is another N base **Uracil(U)** instead of thiamine which binds with A. RNA forms a S**ingle Helix structure** (ie single stranded) hence it is less stable than DNA and is used for **messaging and replication and synthesis processes transcription and translation as messenger RNA(m-RNA), ribosomal RNA(r-RNA), transfer RNA(t-RNA).**

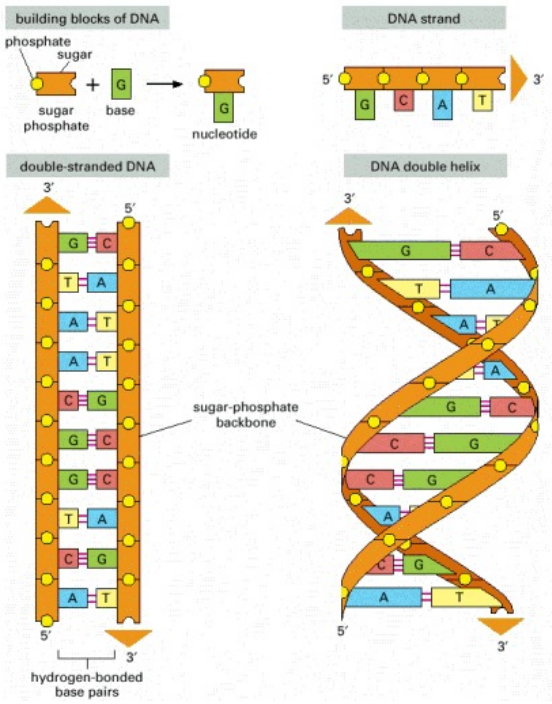
4. Describe DNA Structure

4.1 Introduction

The early x-ray diffraction results indicated that DNA was composed of two strands of the polymer wound into a helix. The observation that DNA was double-stranded was of crucial significance and provided one of the major clues that led to the Watson-Crick structure of DNA. Only when this model was proposed did DNA's potential for replication and information encoding become apparent.

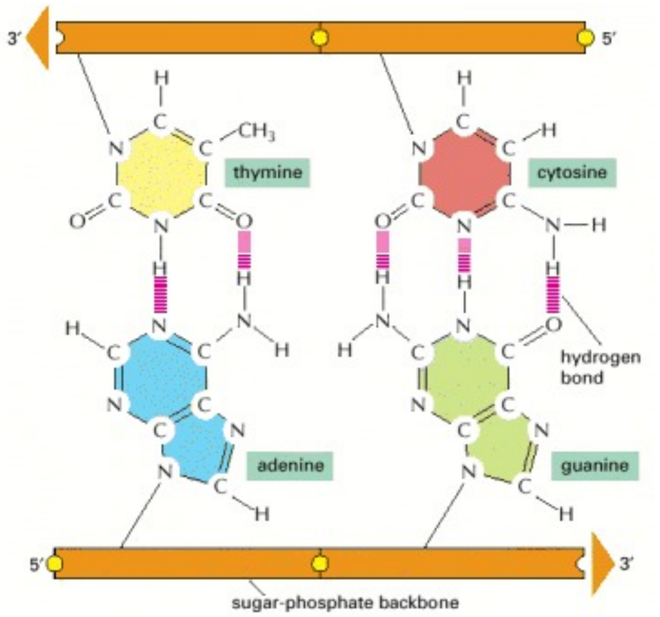
4.2 Structure

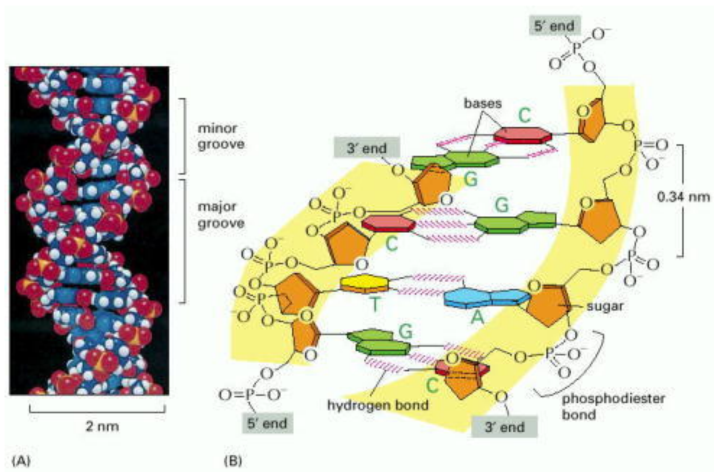
A DNA molecule consists of two long polynucleotide chains composed of four types of nucleotide subunits. Each of these chains is known as a DNA chain, or a DNA strand. Hydrogen bonds between the base portions of the nucleotides hold the two chains together. Nucleotides are composed of a five-carbon sugar to which are attached one or more phosphate groups and a nitrogen-containing base. In the case of the nucleotides in DNA, the sugar is deoxyribose attached to a single phosphate group (hence the name deoxyribonucleic acid), and the base may be either adenine (A), cytosine (C), guanine (G), or thymine (T). The nucleotides are covalently linked together in a chain through the sugars and phosphates, which thus form a "backbone" of alternating sugar-phosphate-sugar-phosphate.



The way in which the nucleotide subunits are lined together gives a DNA strand a chemical polarity. If we think of each sugar as a block with a protruding knob (the 5′ phosphate) on one side and a hole (the 3′ hydroxyl) on the other, each completed chain, formed by interlocking knobs with holes, will have all of its subunits lined up in the same orientation. Moreover, the two ends of the chain will be easily distinguishable, as one has a hole (the 3′ hydroxyl) and the other a knob (the 5′ phosphate) at its terminus. This polarity in a DNA chain is indicated by referring to one end as the *3′ end* and the other as the *5′ end*.

The three-dimensional structure of DNA—**the double helix**—arises from the chemical and structural features of its two polynucleotide chains. Because these two chains are held together by hydrogen bonding between the bases on the different strands, all the bases are on the inside of the double helix, and the sugar-phosphate backbones are on the outside. In each case, a bulkier two-ring base (a purine) is paired with a single-ring base (a pyrimidine); A always pairs with T, and G with C. This *complementary base-pairing* enables the base pairs to be packed in the energetically most favourable arrangement in the interior of the double helix. In this arrangement, each base pair is of similar width, thus holding the sugar-phosphate backbones an equal distance apart along the DNA molecule. To maximize the efficiency of base-pair packing, the two sugar-phosphate backbones wind around each other to form a double helix, with one complete turn every ten base pairs.





The members of each base pair can fit together within the double helix only if the two strands of the helix are antiparallel—that is, only if the polarity of one strand is oriented opposite to that of the other strand. A consequence of these base-pairing requirements is that each strand of a DNA molecule contains a sequence of nucleotides that is exactly complementary to the nucleotide sequence of its partner strand.

5. What is the application of nanobiotechnology in regenerative medicine ?

Stem cells are considered an important potential source for repairing damaged human tissues. The adhesion, growth, and differentiation of stem cells are likely controlled by their surrounding microenvironment, which contains both chemical and physical cues. These cues include the "nanotopography" of the complex extracellular matrix or architecture that forms a network for human tissues. This nanotopography (which includes nanosized pores, grooves, ridges, etc.) plays important roles in the behaviour and fate of stem cells. Using Nanoparticles such nanotopography may be created artificially and stem cell action can be stimulated for a **desired regeneration**. These Nanoparticles can also be used for **stem cell isolation, tracking and imaging.**

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