Biomolecule - Part 2

Objectives

After going through this lesson, the learners will be able to understand the following:

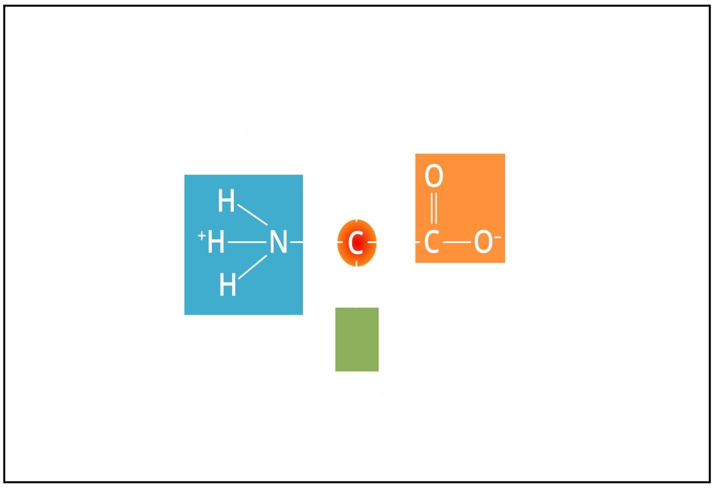
- Nature of bond linking monomers an a polymer
- Structure of proteins
- Nucleic Acids
- Bond linking monomers

Content Outline

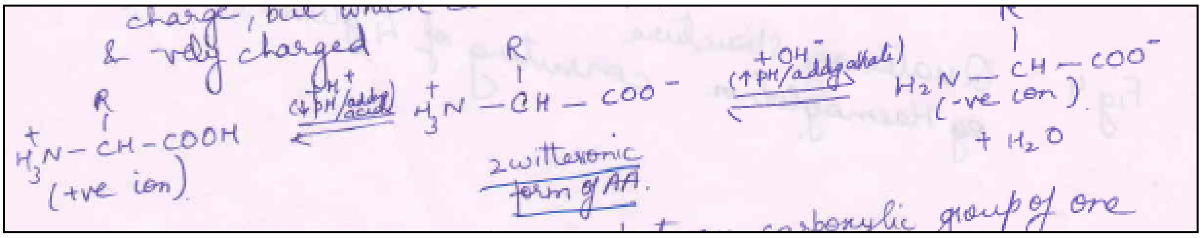
- Proteins
- Nature of bond linking monomers an a polymer
- Structure of proteins
- Nucleic Acids
- Bond linking monomers

Proteins

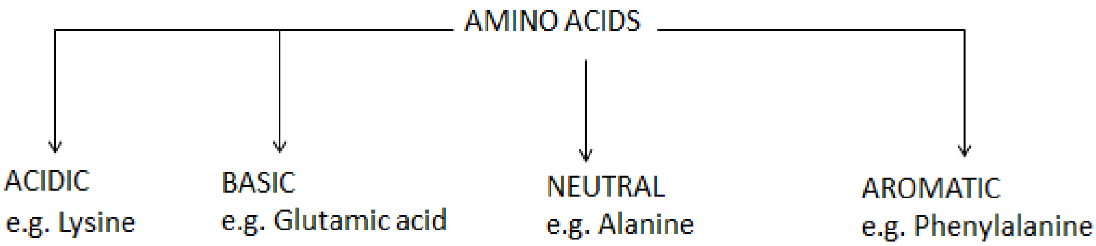
Proteins are the building blocks of life. Every cell in the human body contains protein. Proteins are polypeptides. They are linear chains of amino acids linked by peptide bonds. Each protein is a polymer of amino acids. As proteins are formed of amino acids, so defining an amino acid which is a small organic compound with an amino group ($—NH_3^+$), a carboxyl group ($—COO^-$, the acid part), a hydrogen atom, and one or more atoms, say R group.



This structure of amino acid is actually a Zwitterion. Zwitterion is a compound with no overall electrical charge, but which can get either positively charged or negatively charged. As shown in the following example.



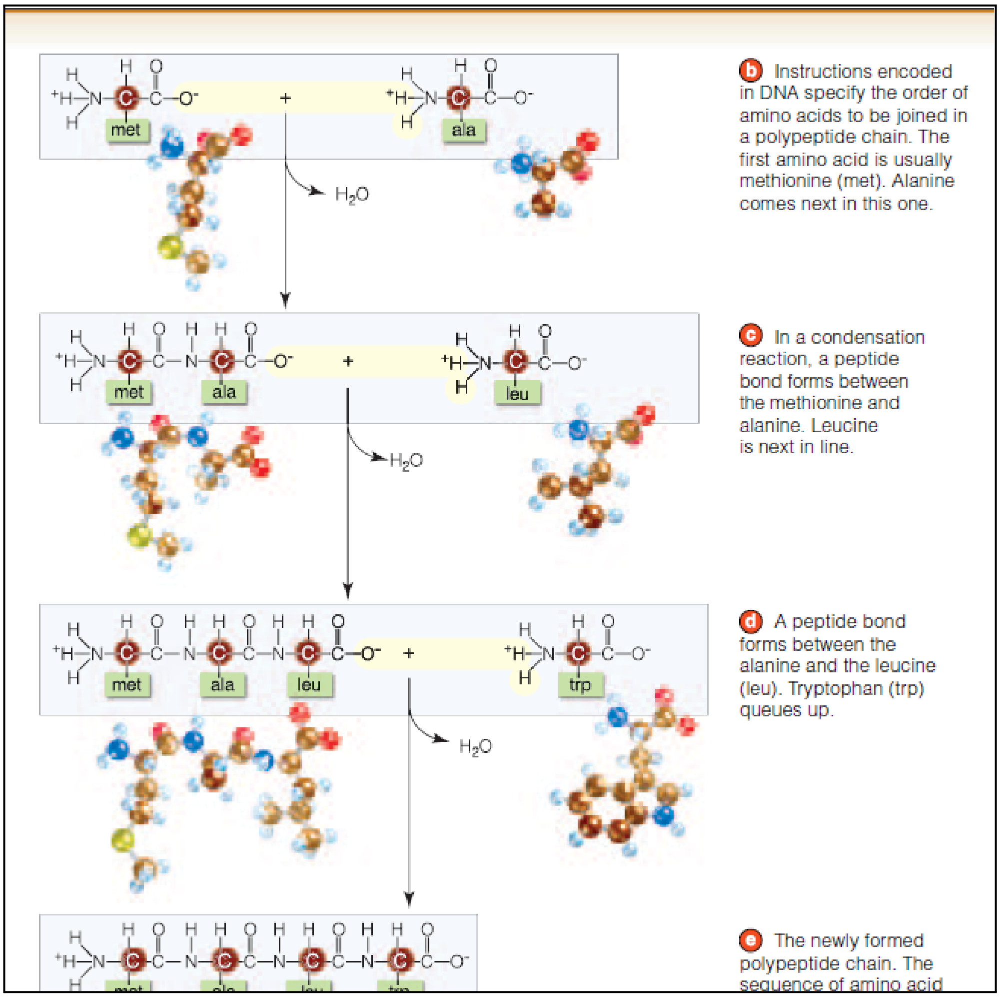
Amino acids are substituted methanes with four substituent groups, as group R is variable. Based on the variability of R group Amino acids are of four types.



As there are 20 types of amino acids, a protein is a heteropolymer and not a homopolymer. A a homopolymer has only one type of monomer repeating 'n' number of times. This information about the amino acid content is important as later in your nutrition lessons, you will learn that certain amino acids are essential for our health and they have to be supplied through our diet. Hence, dietary proteins are the source of essential amino acids. Therefore, amino acids can be essential or non-essential. The latter are those which our body can make, while we get essential amino acids through our diet/food. Proteins carry out many functions in living organisms, some transport nutrients across cell membranes, some fight infectious organisms, some are hormones, some are enzymes etc. (Table 9.5). Collagen is the most abundant protein in the animal world and Ribulose bisphosphate Carboxylase-Oxygenase (RuBisCO) is the most abundant protein in the whole of the biosphere.

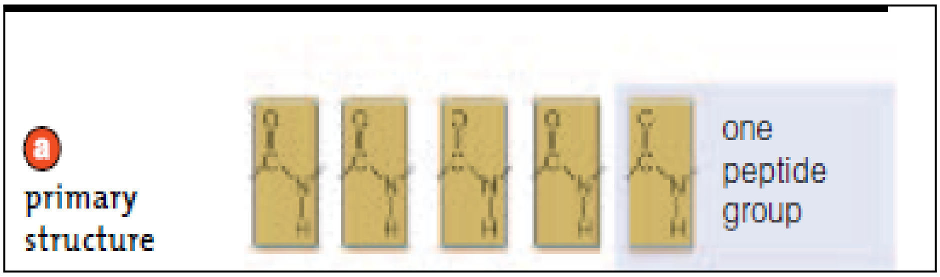
Nature of bond linking monomers an a polymer

In a polypeptide or a protein, amino acids are linked by a **peptide bond** which is formed when the carboxyl (-COOH) group of one amino acid reacts with the amino (-NH_2) group of the next amino acid with the elimination of a water moiety (the process is called dehydration).

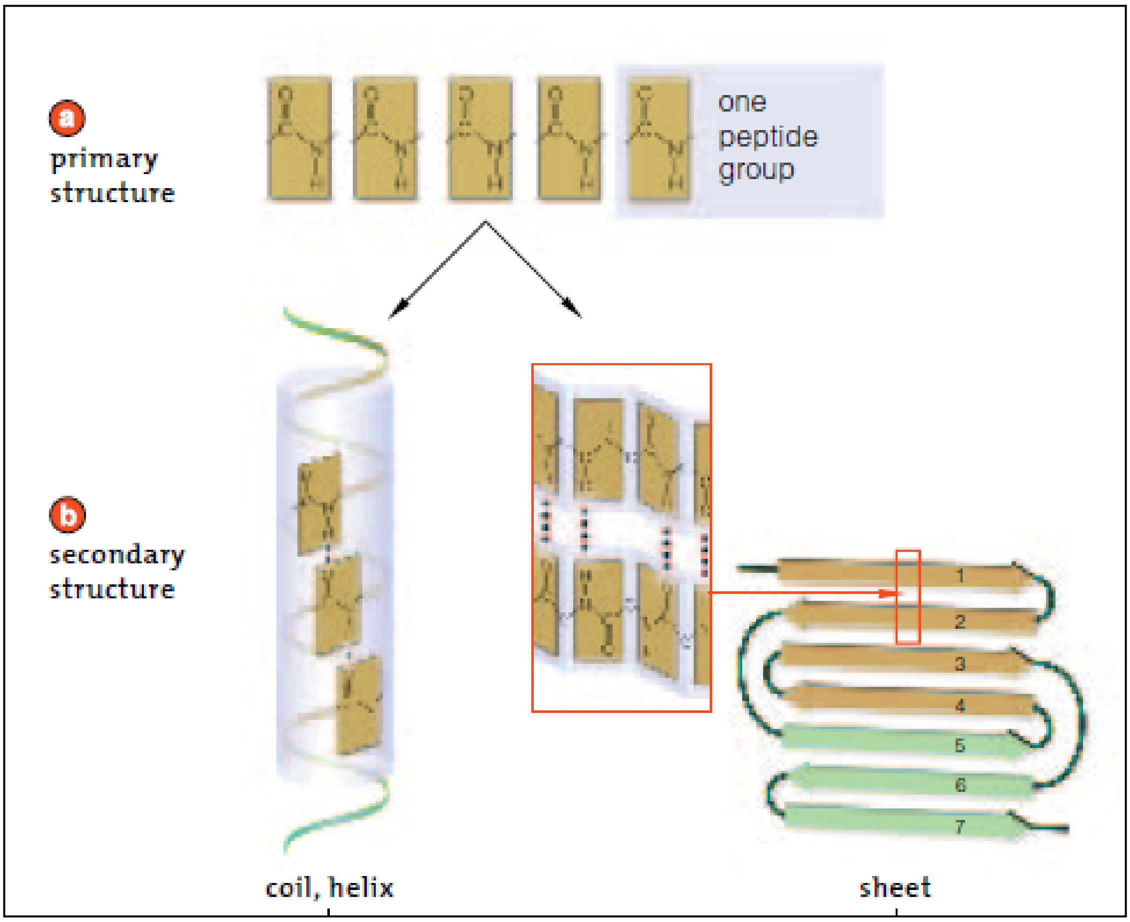


Structure of proteins

Proteins, as mentioned earlier, are heteropolymers containing strings of amino acids. Structure of molecules means different things in different contexts. In inorganic chemistry, the structure invariably refers to the molecular formulae (e.g., NaCl, $MgCl_2$, etc.). Organic chemists always write a two dimensional view of the molecules while representing the structure of the molecules (e.g., benzene, naphthalene, etc.). Physicists conjure up the three dimensional views of molecular structures while biologists describe the protein structure at four levels. The sequence of amino acids i.e., the positional information in a protein – which is the first amino acid, which is second, and so on – is called the **primary structure** of a protein. Primary structure is the long chain of Amino acids arranged in a particular sequence. It's the non-functional form.

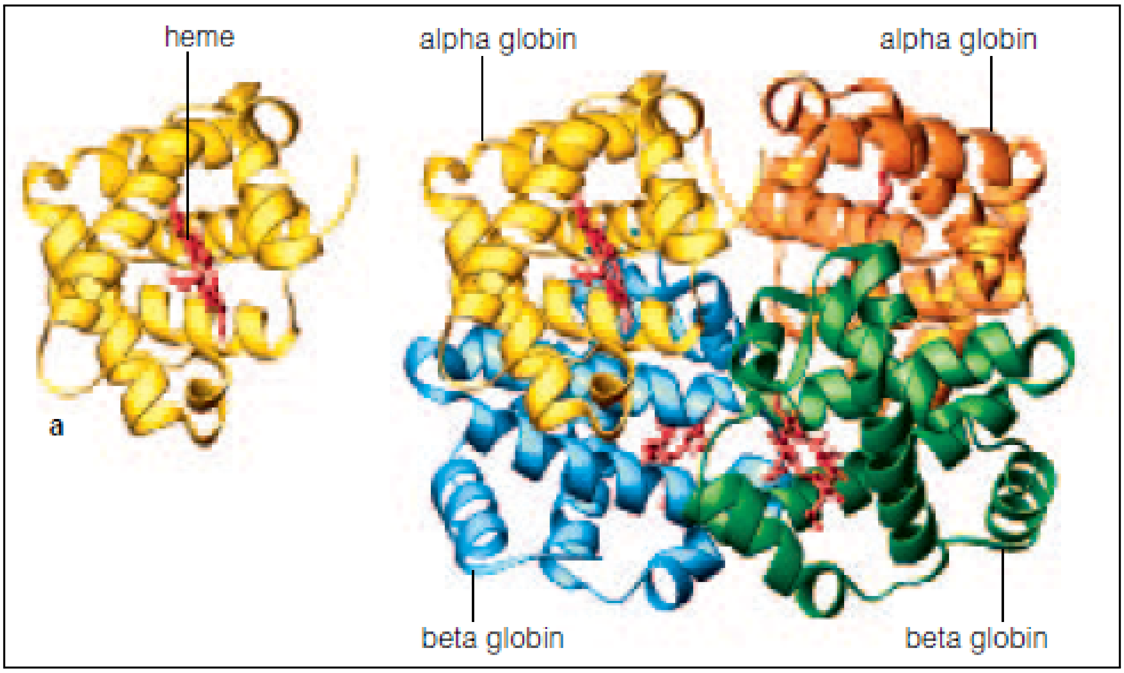


A protein is imagined as a line, the left end represented by the first amino acid and the right end represented by the last amino acid. The first amino acid is also called N-terminal amino acid. The last amino acid is called the C-terminal amino acid. A protein thread does not exist throughout as an extended rigid rod. The thread is folded in the form of a helix (similar to a revolving staircase). Of course, only some portions of the protein thread are arranged in the form of a helix. In proteins, only right handed helices are observed. Other regions of the protein thread are folded into other forms in what is called the **secondary structure**. Here, interaction between every fourth amino acid by the formation of hydrogen bonds. When two or more Polypeptides are held together by intermolecular hydrogen bonds in parallel sheets, this structure is called pleated sheet.



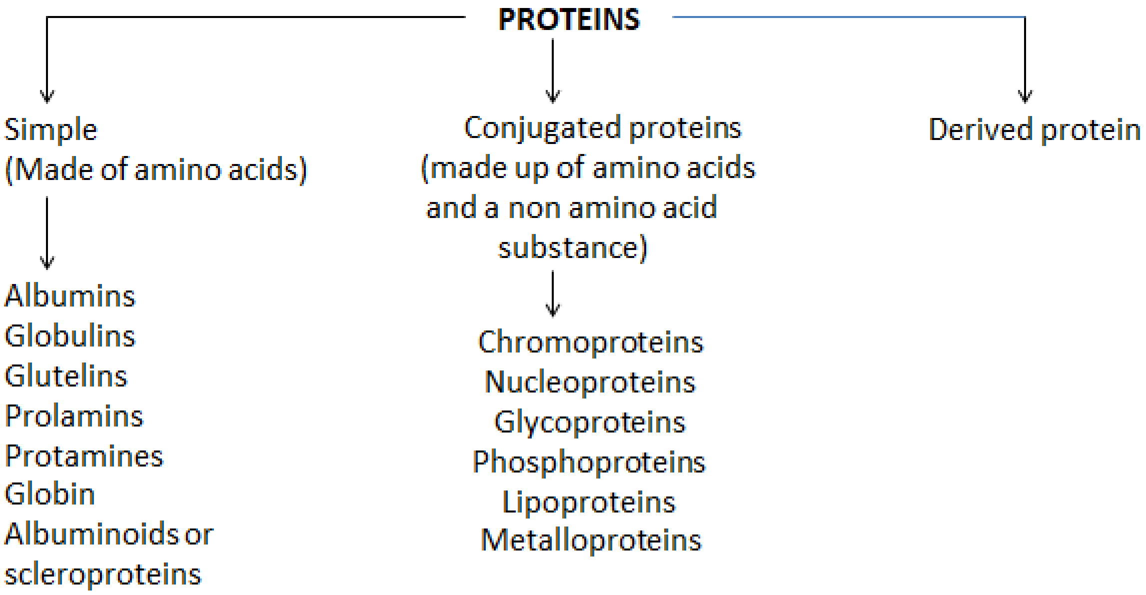
Polypeptides form a right handed helix in keratin also. Our hairs are formed of keratin. B pleated sheets are formed in silk fibers also. In addition, the long protein chain is also folded upon itself like a hollow woolen ball, giving rise to the **tertiary structure.** Here the polypeptide chain is further stabilized by folding and coiling of ionic or hydrophobic, disulphide, hydrogen bonds, bridges also. This gives us a 3-dimensional view of a protein. Tertiary structure is absolutely necessary for the many biological activities of proteins.

Some proteins are an assembly of more than one polypeptide or subunits. The manner in which these individual folded polypeptides or subunits are arranged with respect to each other (e.g. linear string of spheres, spheres arranged one upon each other in the form of a cube or plate etc.) is the architecture of a protein otherwise called the **quaternary structure** of a protein. Adult human haemoglobin consists of 4 subunits. Two of these are identical to each other. Hence, two subunits of αα type and two subunits of ββ type together constitute the human haemoglobin (Hb).



The structure of protein is important as it defines its biological activity. Shape of proteins depends on many hydrogen bonds and other Interactions; this shape can be disrupted by heat, shifts in pH, or detergents. At such times, polypeptide chains unwind and change shape in this process called **denaturation**. Take an example of albumin, a protein in the white of an egg. When you cook eggs, the heat does not disrupt the covalent bonds of albumin's primary structure. But it destroys albumin's weaker hydrogen bond, that's why the protein unfolds. When the translucent egg white turns opaque, that means albumin has been altered.

Classification of proteins based on structural complexity



Functions of proteins

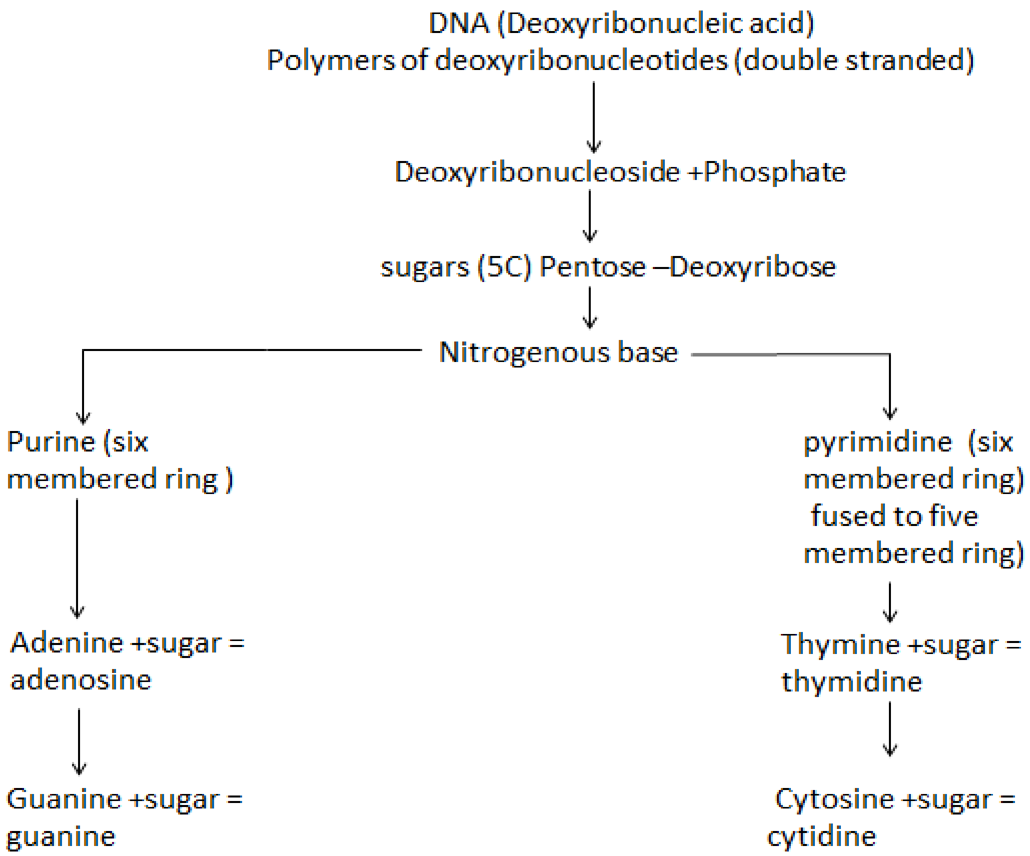
1. Body building e.g. Muscle protein Actin, Myosin
2. Support and protection e.g. collagen and Keratin
3. Biocatalysts e.g. Enzymes
4. Transporters e.g. Haemoglobin, serum albumin
5. Store and provide nutrients e.g. milk casein, ovalbumin
6. Defense e.g. immunoglobulin, fibrinogen
7. Regulator of cellular/ physiological activities
8. Part of hormones like Insulin, Growth hormone

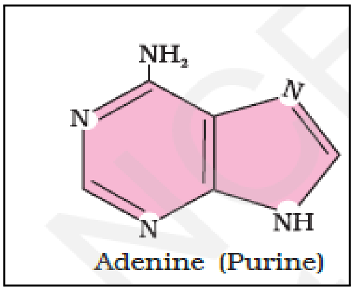
Proteins have a major role in building up an organism. All the proteins have the same fundamental unit, the amino acids. The Hormone insulin which is a protein having quaternary structure which stimulates cells to take up glucose, when body is not able to respond to or not able to make insulin this results in DIABETES.

Nucleic Acids

The other type of macromolecule that one would find in the acid insoluble fraction of any living tissue is the nucleic acid. These are polynucleotides. Together with polysaccharides and polypeptides these comprise the true macromolecular fraction of any living tissue or cell. For nucleic acids, the building block is a nucleotide. A nucleotide has three chemically distinct components. One is a heterocyclic compound, the second is a monosaccharide and the third a phosphoric acid or phosphate. The heterocyclic compounds in nucleic acids are the nitrogenous bases named adenine, guanine, uracil, cytosine, and thymine. Adenine and Guanine are substituted purines while the rest are substituted pyrimidines. The skeletal heterocyclic ring is called purine and pyrimidine respectively. The sugar found in polynucleotides is either ribose (a monosaccharide pentose) or 2' deoxyribose. A nucleic acid containing deoxyribose is called deoxyribonucleic acid (DNA) while that which contains ribose is called ribonucleic acid (RNA).

Nucleic Acids



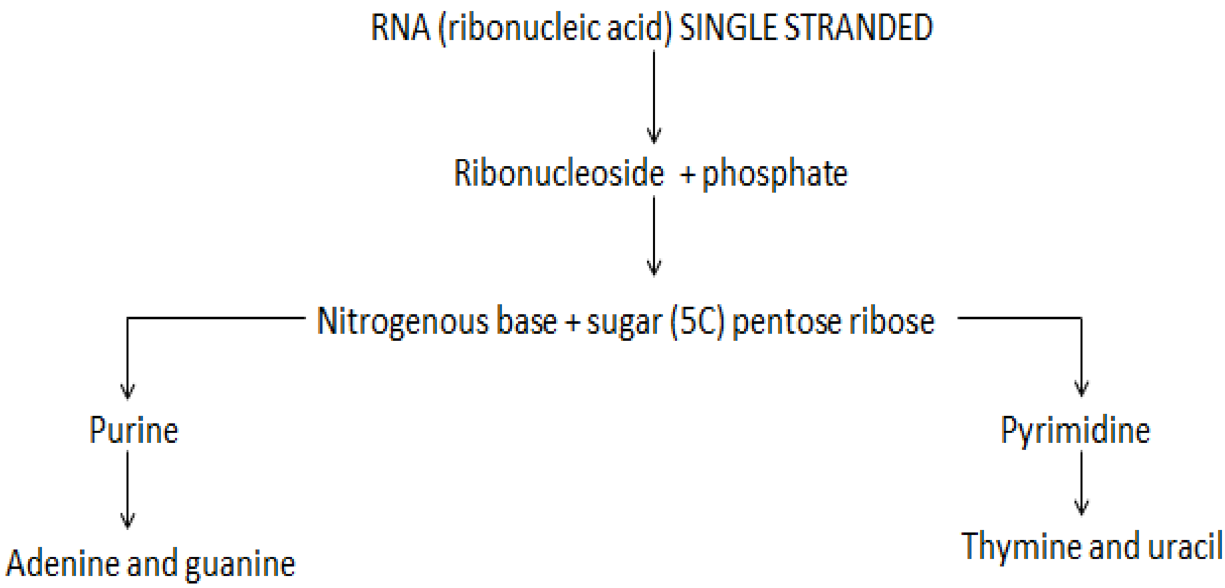


Adenine (Purine)

These four are nucleosides.

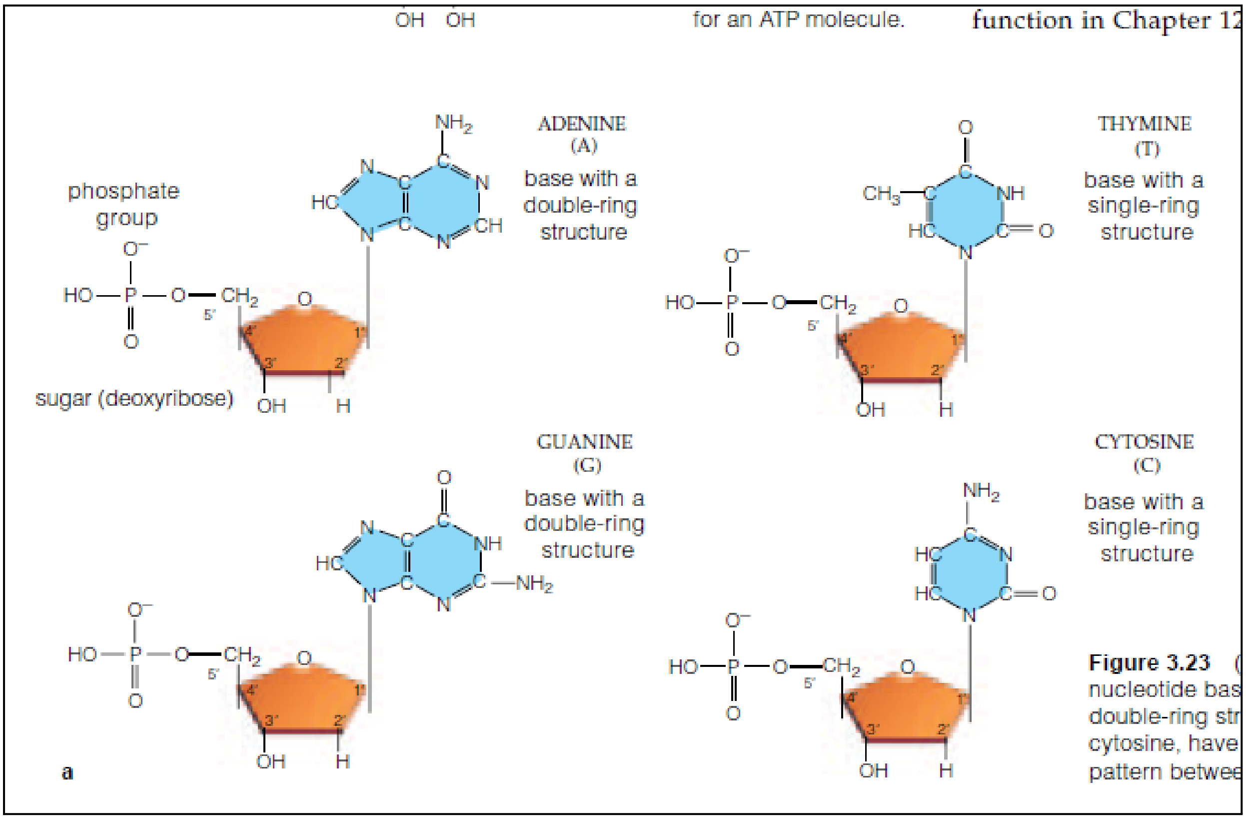
Nucleosides + phosphate =Nucleotides (phosphorylated nucleosides)

RNA (ribonucleic acid) Single Stranded



Types of RNA

1. mRNA- carries information from DNA to the ribosome decides sequence of amino acids and proteins
2. tRNA- carries an amino acid from cytoplasm to ribosome.
3. rRNA- it forms ribosomes.



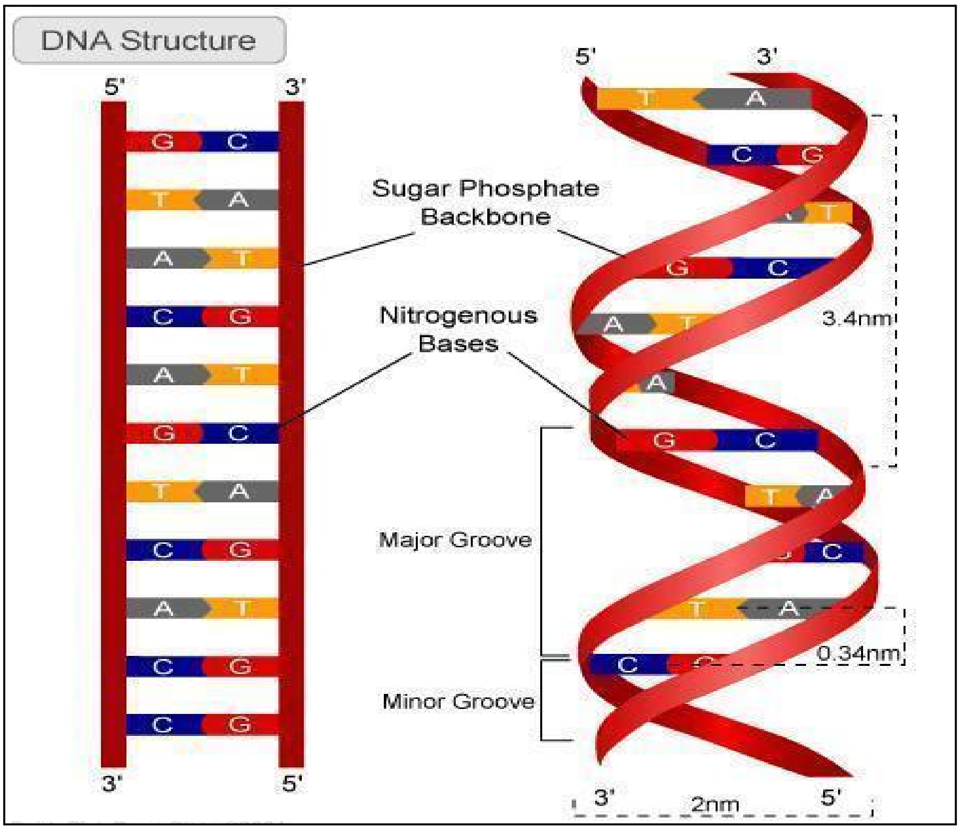
Nature of bond linking monomers in a polymer

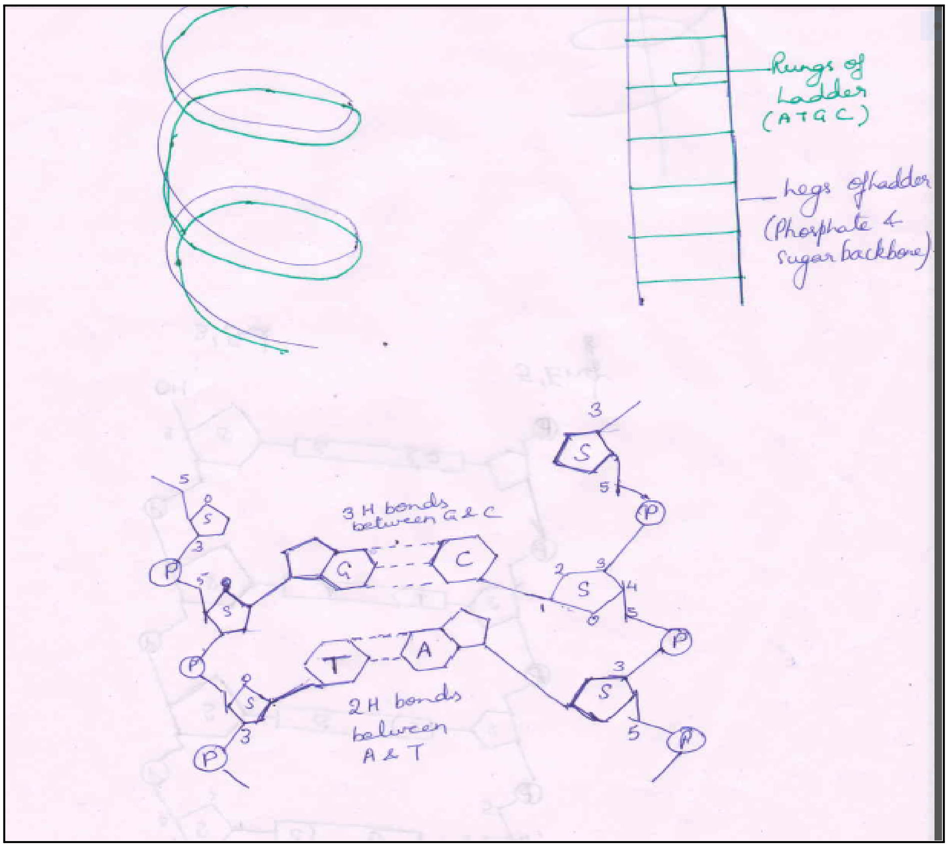
In a nucleic acid a phosphate moiety links the 3'-carbon of one sugar of one nucleotide to the 5'-carbon of the sugar of the succeeding nucleotide. The bond between the phosphate and hydroxyl group of sugar is an ester bond. As there is one such ester bond on either side, it is called phosphodiester bond (Figure 9.5). Nucleic acids exhibit a wide variety of secondary structures. For example, one of the secondary structures exhibited by DNA is the famous Watson-Crick model. This model defines the structure of the DNA. This model says that DNA exists as a double helix. This model has three sets of data:

- Rosalind franklin's X-ray crystallography
- Chargaff's rule – this rule says that no matter what type of species A=T and G=C or A+G = T+C
- Chemical structure of nucleotides

As DNA is a double helical structure like a spiral staircase made up of two strands of polynucleotide. These two strands of polynucleotide are antiparallel, i.e., run in the opposite direction joined by hydrogen bonds. The backbone is formed by the sugar-phosphate-sugar chain by phosphodiester bonds. The nitrogen bases are projected more or less perpendicular to this backbone but face inside. A and G of one strand compulsorily base pairs with T and C, respectively, on the other strand. Purine base always pairs up with pyrimidine base; this is known as complementary base pairing. There are two hydrogen bonds between A and T and three hydrogen bonds between G and C.

Each strand appears like a helical staircase. Each step of ascent is represented by a pair of bases. At each step of ascent, the strand turns 36°. One full turn of the helical strand would involve ten steps or ten base pairs. Attempt drawing a line diagram. The pitch would be 34Å. Diameter and periodicity are consistent i.e. 2.0nm/20A^{0} ten base pairs per turn, 3.4nm/34A^{0} is height of turn, width is consistent because of purine/pyrimidine pairing.The rise per base pair would be 3.4Å. This form of DNA with the above mentioned salient features is called B-DNA. In higher classes, you will be told that there are more than a dozen forms of DNA named after English alphabets with unique structural features.





Rungs of Ladder (ATGC)
Legs of ladder (Phosphate & sugar backbone)
3 H bonds between G & C
2 H bonds between A & T