Course- M.Sc. Botany Part -I Paper- VII

Topic- CHROMOSOME STRUCRTURE AND ITS ORGANISATION (CELL BIOLOGY)

Prepared by Prof. (Dr.) Jainendra Kumar

Co- ordinated by Prof. (Dr.) Shyam Nandan. Prasad

DNA and Chromosome

Introduction: Chromosomes are filamentous or rod-like bodies present in the nuclei of plant and animal cells (eukaryotic organisms). They carry genetic material (DNA). A long double helix of DNA molecule is present inside each chromosome in a tightly packaged manner Each DNA molecule contains a number of genes. Specific lengths of the DNA molecule arranged one after another in a linear fashion act as different genes which carry out their assigned functions or control assigned phenotypes of the organism. Expression of each gene is cell-specific. Genes are units of heredity and they determine, regulate and inherit their phenotypes/functions from generation to generation. Many-a-gene is involved in more than one function. In contrast, there are genes which express in group to perform a common function or make a common phenotype.

Basic features of chromosome: In a nondividing cell, the chromosomes are extremely long and thin single-thread fibrillar structure. They are so thin that it is impossible to see them with help of the common laboratory microscope that can magnify an object only up to only 20002500 times in most cases. When a cell prepares to divide, each of its chromosome threads is duplicated to form two-thread structures. The two threads are called chromatids which are temporarily joined (only till they are separated during cell division) together at a constricted point referred as centromere. These doublethread fibrillar structures of the chromosome are best observed in cells during the metaphase stage of mitosis. Structural appearance of the somatic chromosomes during mitotic metaphase is called karyotype. Karyotype of a plant or an animal species distinguishes it

from other species. DNA structure: DNA molecule is right handed double helical structure made of two complementary polynucleotide strands (polymers). Each polymer strand is a chain of units called nucleotide. Each nucleotide is composed of three components: a deoxyribose molecule (a pentose sugar), a nitrogenous base, and, a phosphate group (-H2P03).

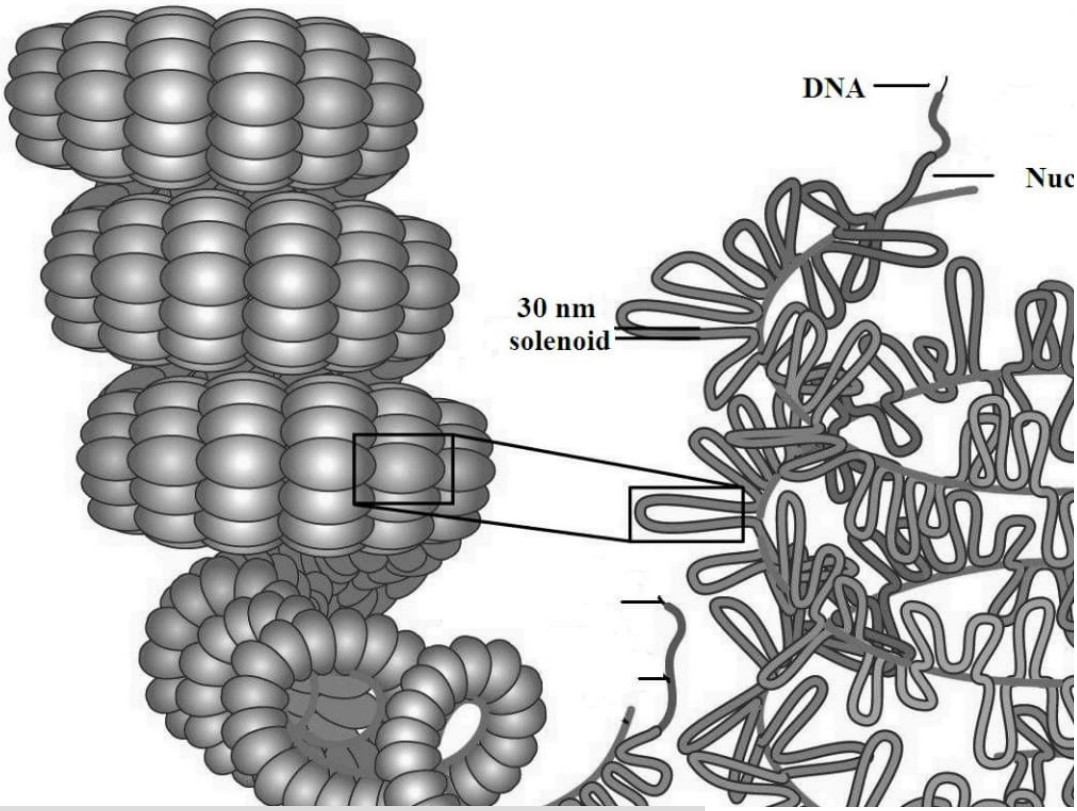
There are 4 types of nitrogenous bases which belong to two major groups(pyrimidines and purines), and, are heterocyclic rings of carbon and nitrogen atoms. A pyrimidine is a 6-membered ring with N at position 1 and 3, and, C at position 2,4,5 and 6. A purine comprises two rings: a pyrimidine ring attached to an imidazole ring. Pyrimidines are of two types: thymine (T) and cytosine (C). Purines are also of two types: adenine (A) and guanine (G). All these bases have keto oxygen (= 0) and amino groups (NH2) variously distributed at position 2 and 6 of their pyrimidine ring. These two types of groups provide uniqueness to them in context of their ability to share H atoms among themselves so that they can form stable structure of DNA by forming hydrogen bonds. In this respect, complementary bases are adenine and thymine, and, guanine and cytosine. Adenine and thymine can share two H atoms to form two hydrogen bonds, and, guanine and cytosine can share three H atoms among themselves to form three hydrogen bonds. In a nucleotide, the nitrogenous base is linked to C l’ of the deoxyribose by a glycosidic bond through removal of a water molecule, and, the phosphate is linked to its C 5' by an ester bond. A pyrimidine is attached to the sugar by its nitrogen at position 3 while a purine is attached by its nitrogen at position 9. Thus, four types of nucleotides exist in DNA molecules: (1) deoxyadenylic acid (deoxyadenosine monophospate), (2) deoxyguanylic acid (deoxyguanosine

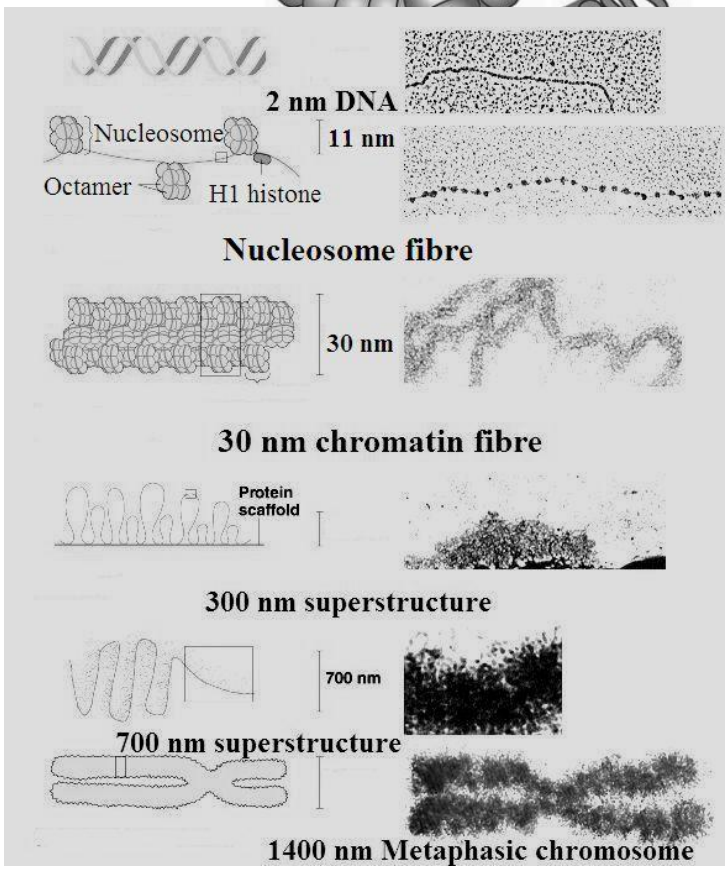
monophosphate), (3) deoxythymidylic acid (deoxythymidine monophosphate), and (4) deoxycytidylic acid (deoxycytidine monophasphate). If the deoxyribose sugar contains only a nitrogenous base at its C1' but no phosphate group at its C5', it is called nucleoside, and, would be named as deoxyadenosine, deoxyguanosine, deoxythymidine and deoxycytidine. To form a polynucleotide chain, different nucleotides join one by one through 5'-3' phosphodiester bond as per the characteristic of the molecule. The first nucleotide in the chain is a nucleoside triphosphate while others are monophosphates. Double helix: DNA typically exists as a double stranded and double helical molecule. It comprises two strands that are antiparallel (parallel strands running in oppositely) and complementary. Complementary arrangement of the two antiparallel strands is to stabilize the double helix through hydrogen bonding by forming A-T and G-C base pairs. The molecule further stabilizes by rotating double stranded and double helical molecule. It comprises two strands that are antiparallel (parallel strands running in oppositely) and complementary. Complementary arrangement of the two antiparallel strands is to stabilize the double helix through hydrogen bonding by forming A-T and G-C base pairs. The molecule further stabilizes by rotating right handedly. One turn of the helix is completed in a run of 34 A0. It is called helix pitch. A helix pitch comprises 10.4 nucleotide (base) pairs. The diameter of the double helix is about 20 AO. A double helix DNA molecule has large and small grooves on the S-P backbone side called major and minor grooves.

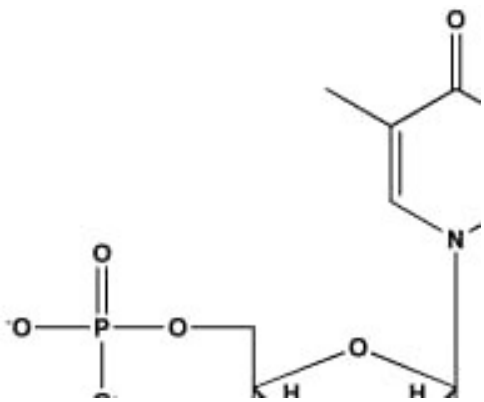
Detailed structure of chromosome: A eukaryotic chromosome is composed of DNA and proteins. The proteins involved in making of the

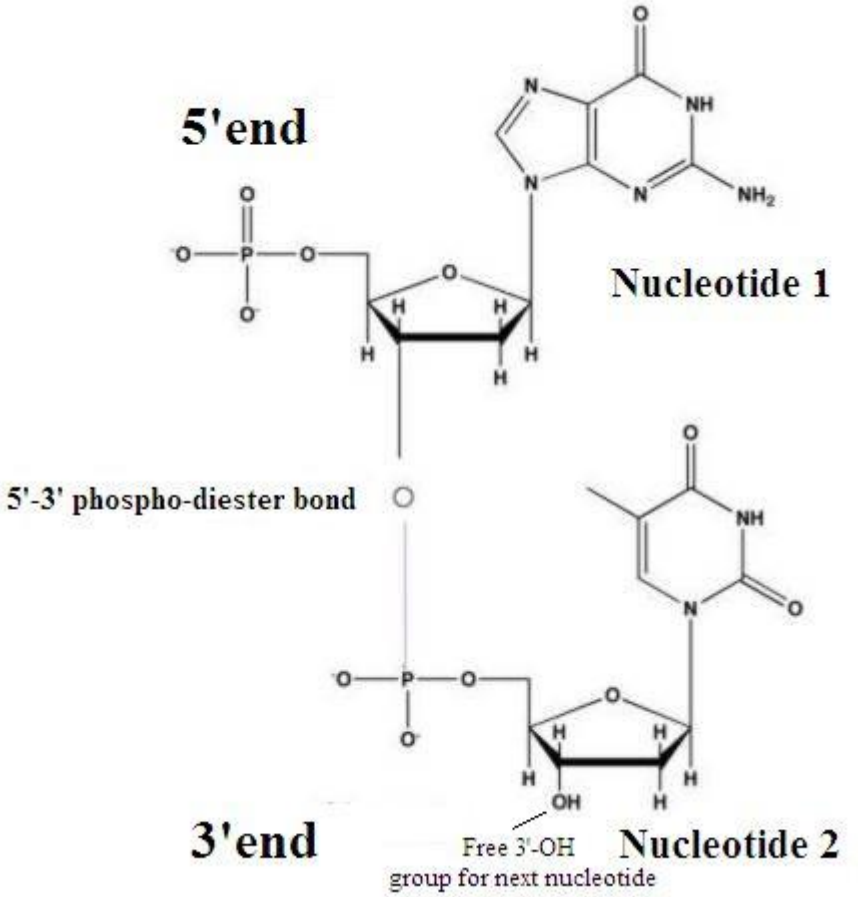
scaffold of the basic chromatin fibre are histone proteins. Histone proteins are of five types: H1, H2A, H2B, H3 and H4. Basic chromosome (chromatin) fibre is 100 AO in thickness, and, called nucleosome fibre. Each of the two sister chromatids of a chromosome is made of one nucleosome fibre that is uniquely packaged into it. Both these nucleosome fibres are identical in composition being copy of each other. In each nucleosome fibre, a DNA length is major and minor grooves. wrapped around a series of octamer particles called nucleosomes. Each nucleosome is composed of two molecules each of the histone proteins H2A, H2B, H3 and H4. The DNA and nucleosome octamer association is unique. About 146 base pairs of DNA wraps over each nucleosome. There is an H1 histone molecule associated with DNA in each linker region. It plays a definitive role in further condensation of chromatin to be comfortably packaged to produce a thread with a DNA packing ratio as much as 2000:1 or more.

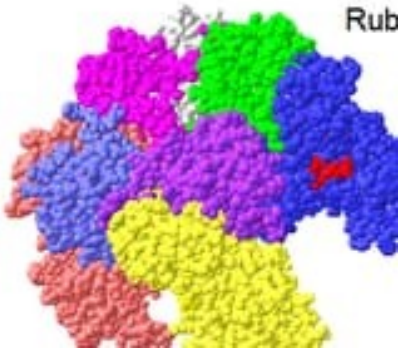
Solenoid fibre and further condensation: Condensation of the nucleosome fibre results into a 300 AO long solenoid fibre which further condenses to produce a scaffold for metaphase chromatin structure.

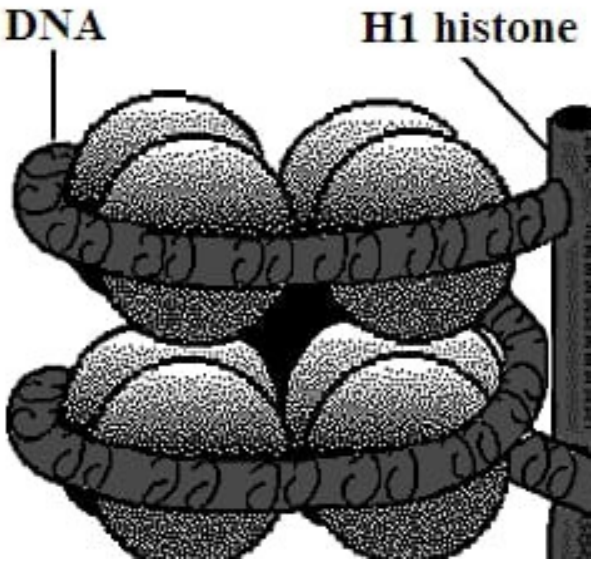

DNA
Nuc
30 nm
solenoid


2 nm DNA
Nucleosome
11 nm
Octamer
H1 histone
Nucleosome fibre
30 nm
30 nm chromatin fibre
Protein
scaffold
300 nm superstructure
700 nm
700 nm superstructure
1400 nm Metaphasic chromosome

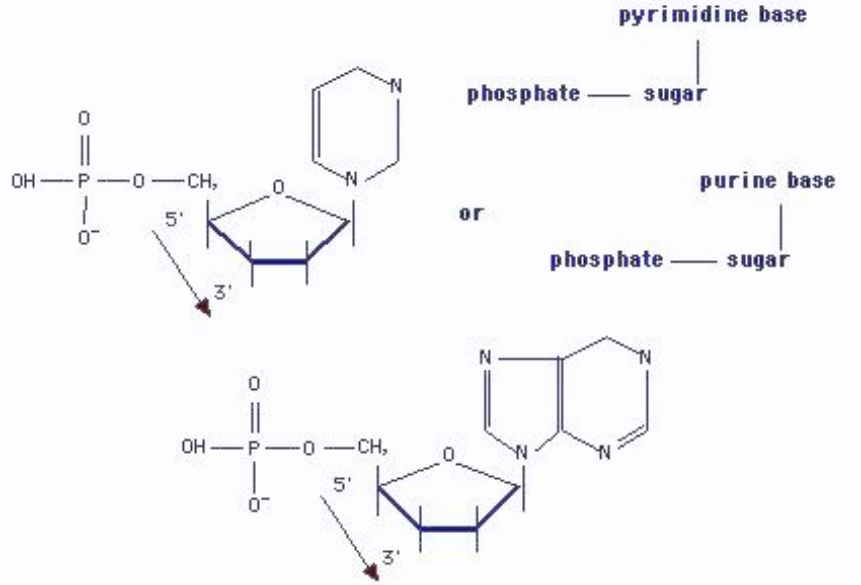

O
N
O
P
O
O
O

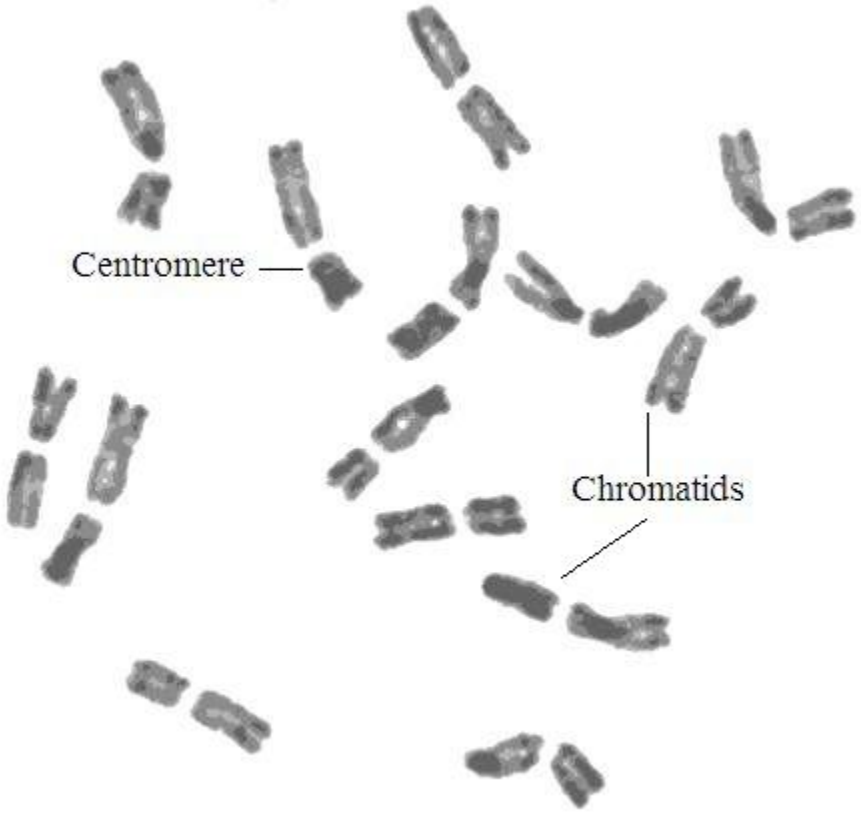

5'end
Nucleotide 1
5'-3' phospho-diester bond
3'end
Free 3'-OH group for next nucleotide
Nucleotide 2

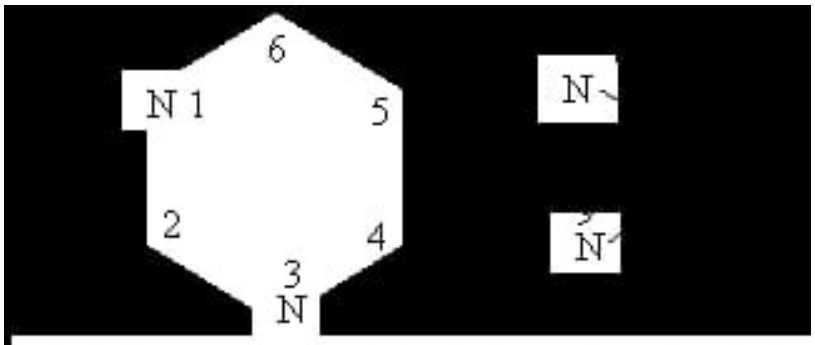

Rub

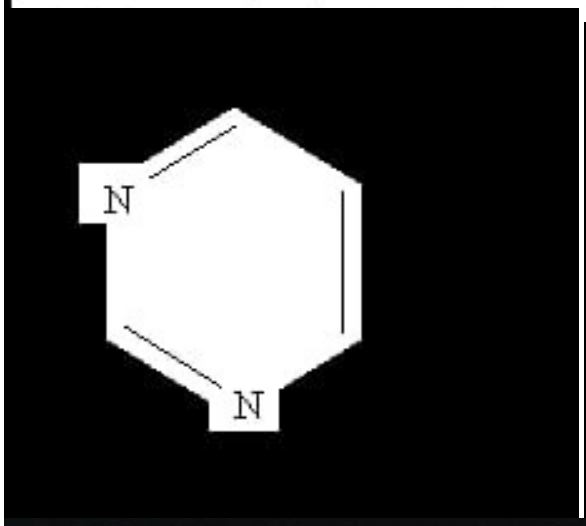

DNA
H1 histone

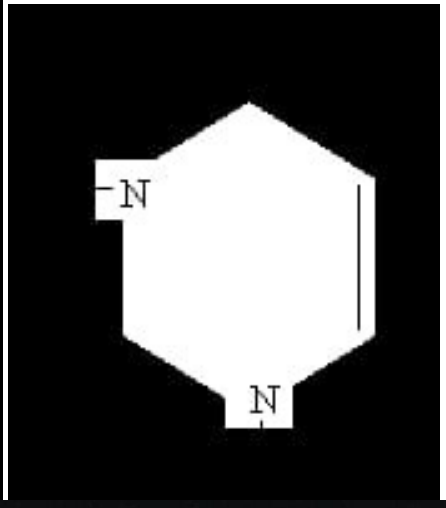
nucleoside = sugar + base
nucleotide = phosphate + sugar + base

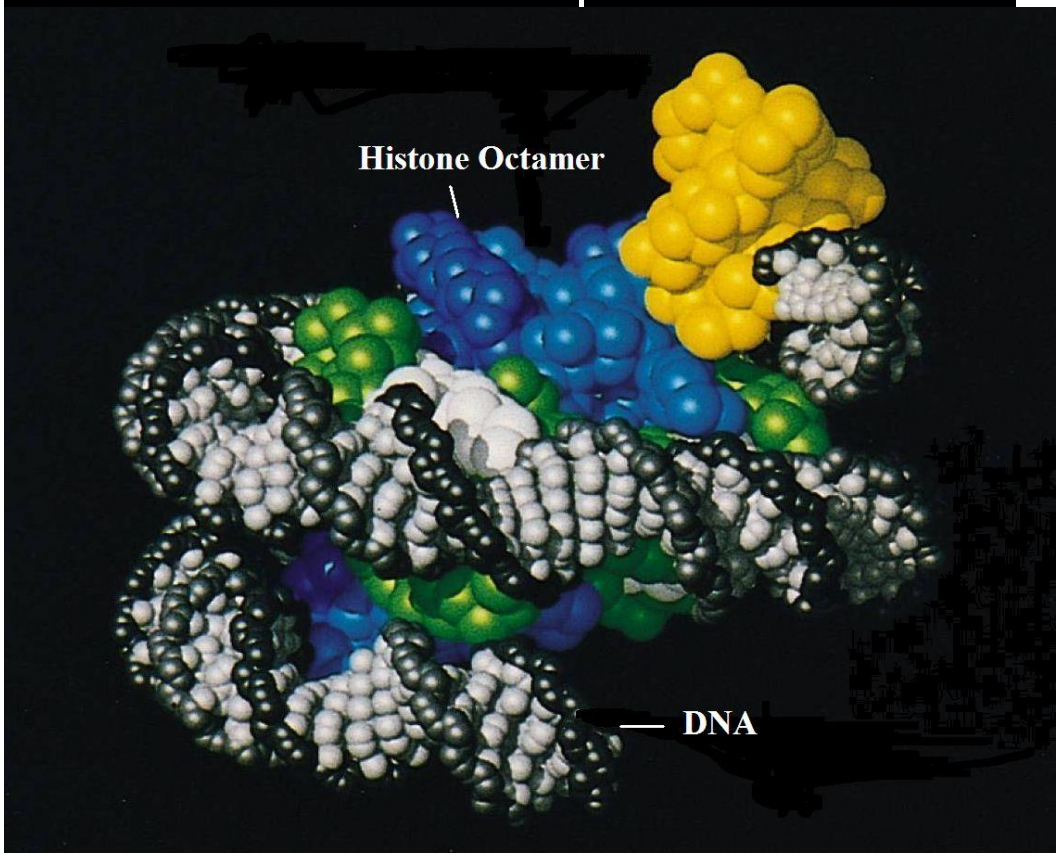


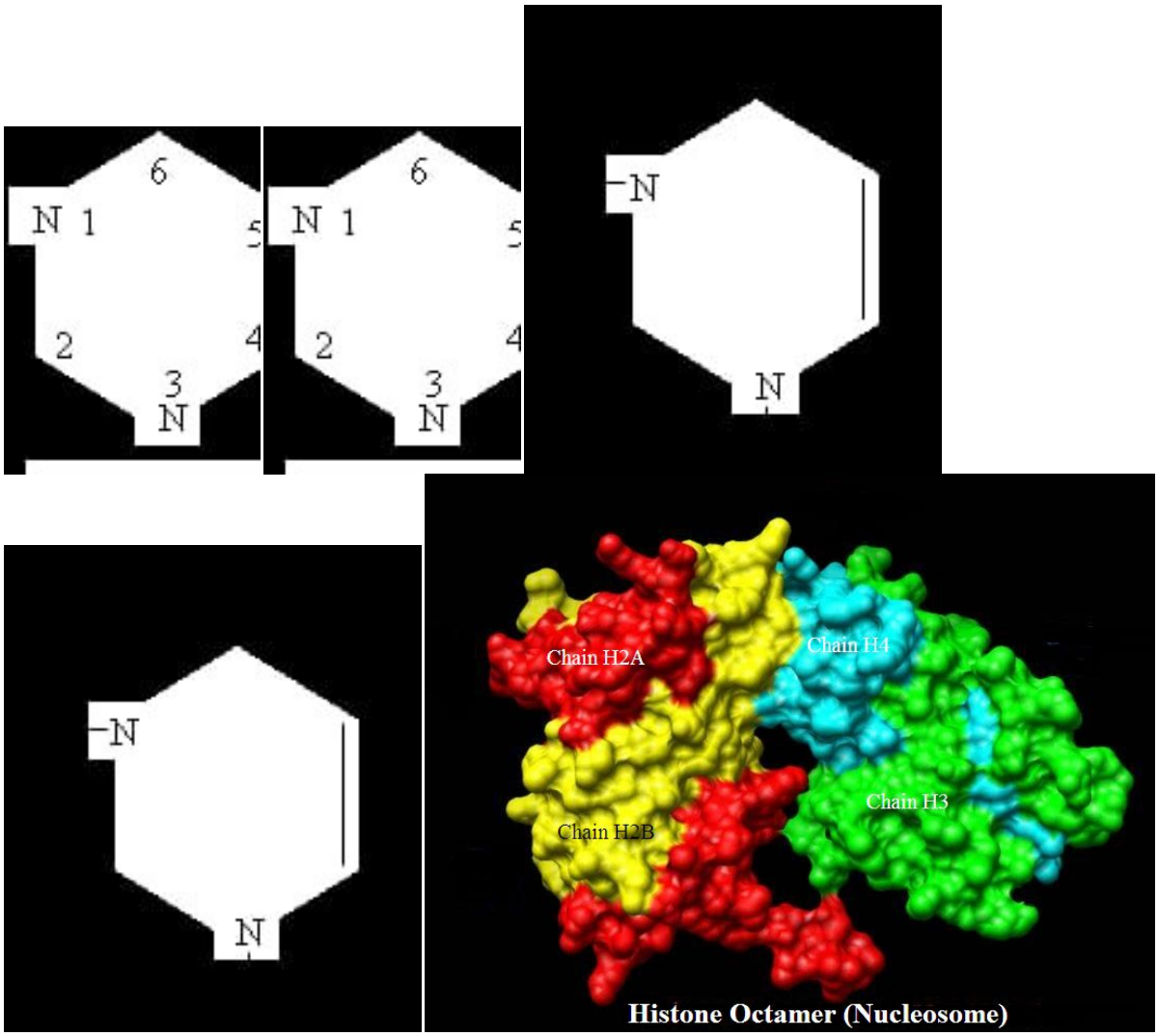


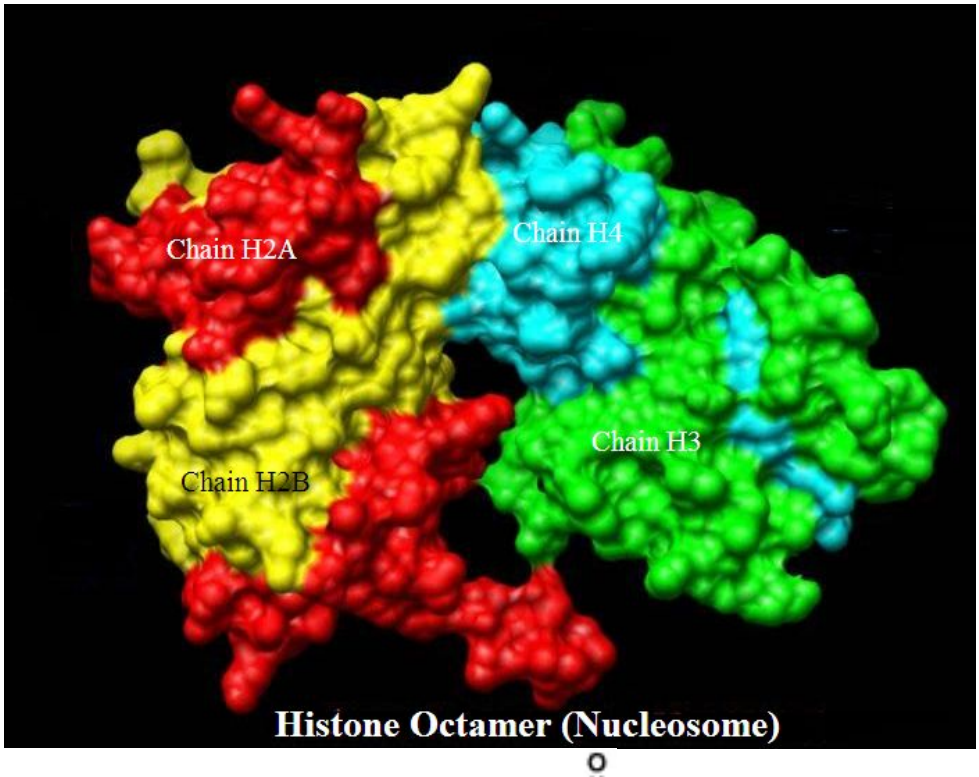

6
N 1
5
2
4
3
N
N
N

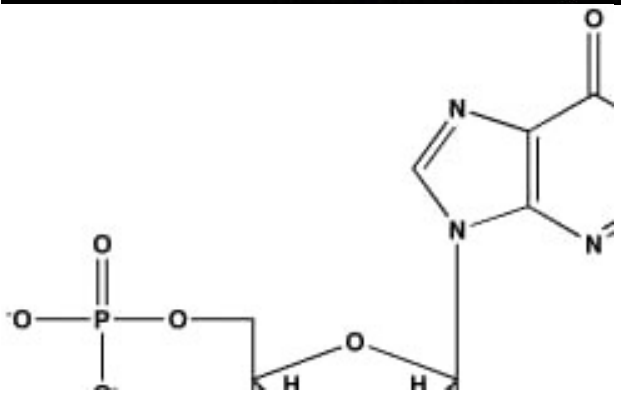

N
N

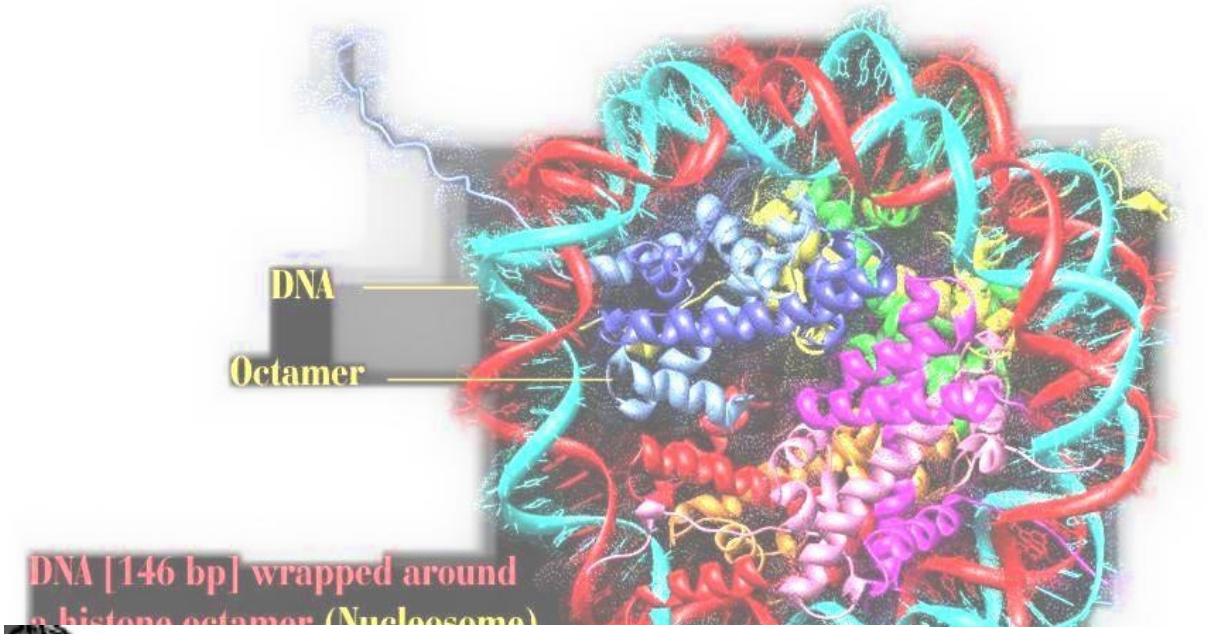

N
N

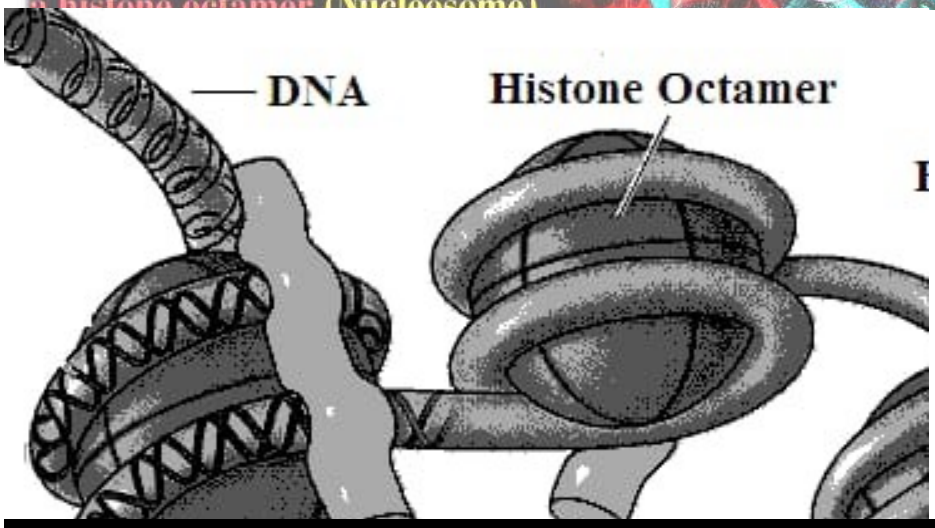

Histone Octamer
DNA

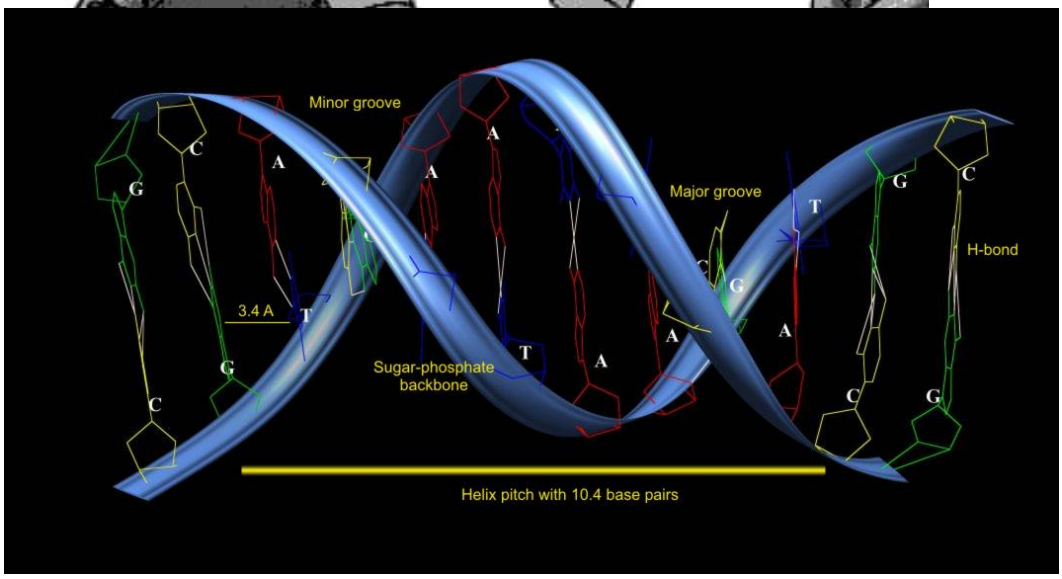

6
N 1
2
4
3
N
6
N 1
2
4
3
N
N
N
N
Chain H2A
Chain H4
Chain H3
Chain H2B
Histone Octamer (Nucleosome)

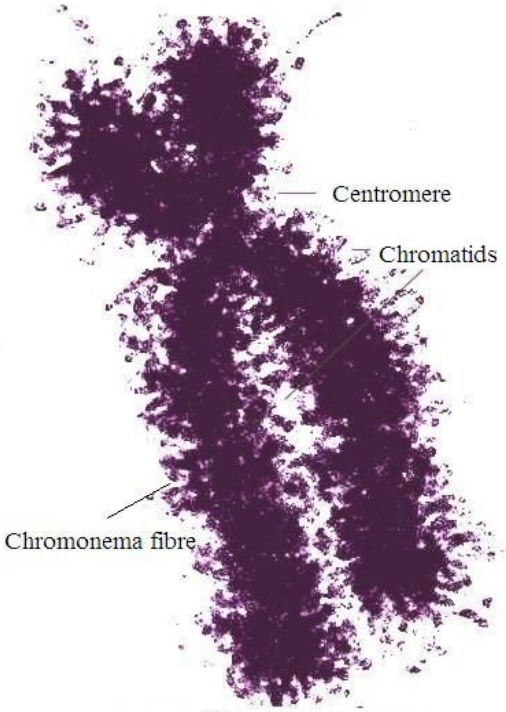

Chain H2A
Chain H4
Chain H3
Chain H2B
Histone Octamer (Nucleosome)


O
N
N
N
O
O
P
O
O
H

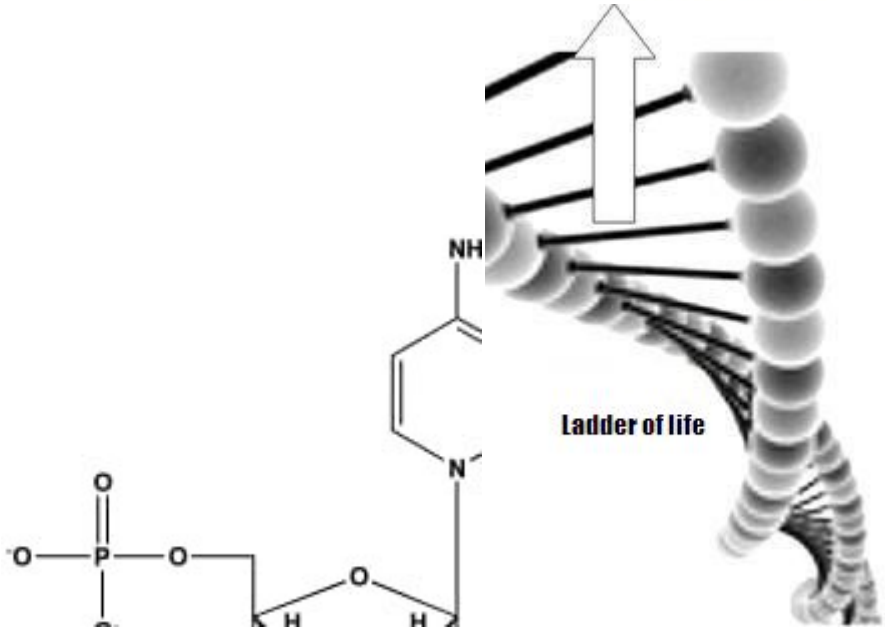

DNA
Octamer
DNA [146 bp] wrapped around

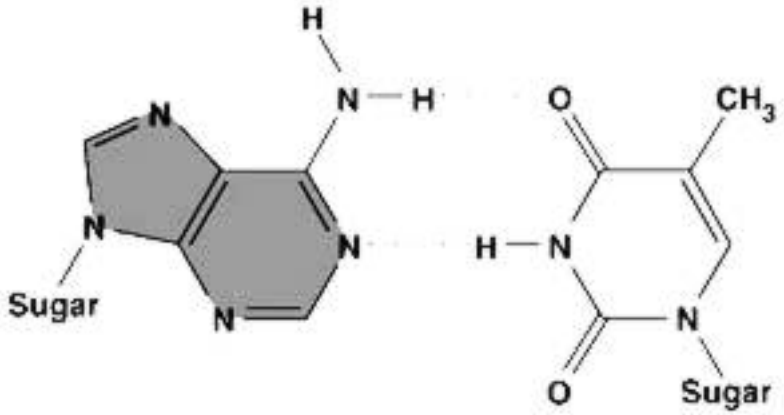

DNA
Histone Octamer


Minor groove
Major groove
H-bond
3.4 A
Sugar-phosphate backbone
Helix pitch with 10.4 base pairs


Centromere
Chromatids
Chromonema fibre

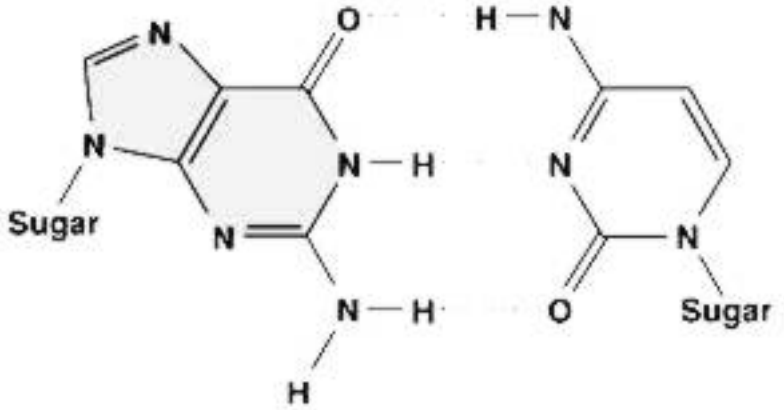
Chromosome


NH
N
O
O
P
O
O
Ladder of life

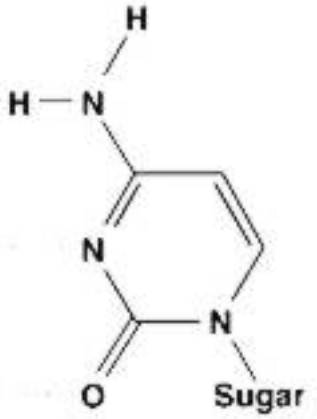


Adenine (A)

Thymine (T)



Guanine (G)



Cytosine (C)