Biology of chromosome & Ultra structure of chromatin

(9) Q. Biology of chromosome, ultrastructure of chromatin fibre.

→ In resting nondividing eukaryotic cells, the genome is nucleoprotein complex, called chromatin. It is amorphous and is randomly dispersed in the nuclear matrix as interwoven network of fine chromatin threads. When cell prepares to divide, the chromatin condenses into a species-specific ~~de~~ number of well defined chromosomes.

Chromosomes were first found by W. Hoff Meister in 1848.

Number ⇒ The number of chromosomes in the somatic cells of higher animals and plants is known as diploid or somatic or zygotic number, while in the gametes (sperms and eggs) it is haploid, gametic or reduced. The number of chromosomes is constant in all the somatic cells of all the individuals of a species.

Size ⇒ Chromosomes differ ~~in~~ greatly in size in different organisms, in unlike tissues and to some degree in plants grown in different nutrient solutions. Even the chromosomes of different pairs in the nucleus of the same cell have different sizes.

Chromosome cycle ⇒ Chromosome exhibit cyclic changes in shape and size during cell cycle. In the nondividing interphase nucleus, the chromosomes form an interwoven network of fine twisted but uncoiled threads of chromatin, and are invisible. In prophase of cell division the chromosomes appear as distinct threads & by metaphase and also in anaphase these become short, compact bodies having definite shapes & sizes. In anaphase these appear as rod-shaped, V-shaped, L-shaped or J-shaped.

Different Regions Recognized in chromosomes :→

(1.) Primary constriction and centromere→

A part of the chromosome is marked by a constriction. It is comparatively narrow than the remaining chromosome. It is known as primary constriction. The primary constriction divides the chromosomes into two arms. It shows a faintly positive feulgen reaction, indicating presence of DNA of repetitive type. This DNA is called centromeric heterochromatin.

Location → centromere or kinetochore lies in the region of primary ~~cons~~ constriction.

(A) Types of chromosomes Based on Number of chromosomes :→ usually, there are two centromeres one on each chromatid but there may be more or none. Depending upon the number of centromeres, the chromosomes may be :-

(i) Monocentric :→ with one ~~centr~~ centromere.

(ii) Dicentric with two centromeres.
(iii) Polycentric with more than two centromeres
(iv) Acentric without centromere.
(v) Diffused or non-located with indistinct centromere centromere diffused throughout the length of chromosome.

(B) Types of chromosomes Based on Position of ~~chromosome~~ centromere :→

Based on the location of centromere the chromosomes are categorized as follows :-

(i) Acrocentric are rod-shaped chromosomes with centromere occupying a terminal position.
(ii) Telocentric are rod-shaped chromosomes having Subterminal centromeres.
(iii) Submetacentric are ~~±~~ S-shaped chromosomes with centromere slightly away from the mid point so that the two arms are unequal.
(iv) Metacentric ~~are~~ V-shaped chromosomes ~~&~~ in which centromere ~~is~~ lies in the middle of chromosome so that the two arms are almost equal.

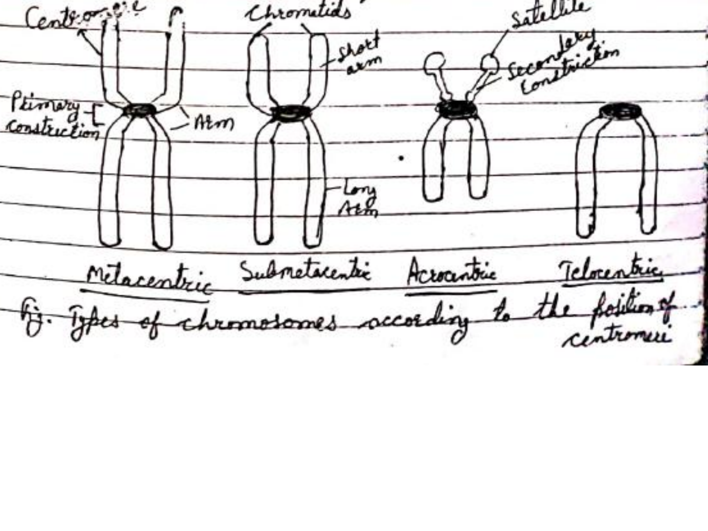

Fig. Types of chromosomes according to the position of centromere

Ultrastructure of centromere :→ under electron microscope the centromere appears as a plate-like or cup-like disc, plastered upon the primary constriction. It is about 0·20 - 0·25 μ in diameter and is formed of some nonchromatin material. In cross section it usually appears to consist of :- An electron dense layer, An inner less dense layer, An outer fibrillar material.

Functions of centromere :→ The centromere is considered to perform following two functions:-

(i) Attachment of microtubules of chromosomal spindle fibres and help in chromosomal movement during cell division.

(ii) The centromere serves as a nucleation centre for the polymerisation of tubulin, the protein used in the formation of microtubules.

(2.) Secondary constriction or Nucleus organiser :→ Sometimes one or both the arms of a chromosome are marked by a constriction other than the primary constriction. During interphase this area is associated with the nucleolus and is found to participate in the formation of nucleolus. It is, therefore, known as the secondary constriction.

(3.) Nucleolar organiser Region (NOR) :→ In certain chromosomes, the secondary constriction is intimately associated with the nucleolus during interphase. It contains genes coding for 18S and 28S ribosomal RNA and is responsible for the formation of nucleolus. It is, therefore, known as NOR.

(4.) Tertiary constriction :→ The tertiary constrictions are present in nearly all the chromosomes. Their significance is not known. However, these help to distinguish one chromosome from others.

(5.) Telomere → The tips of the chromosomes are rounded and sealed and are called telomeres. These provide stability to chromosomes.

(6) chromatids :→ At metaphase stage a chromosome consists of two chromatids joined at the common centromere. In the beginning of anaphase when centromere divides, the two chromatids acquire independent centromere & each one changes into a chromosome.

Molecular organisation of Chromosomes :→

According to Dupraw (1965-76) & Hans Ris (1976), each chromatid of eukaryotic chromosomes is formed of a single greatly elongated & highly folded fibre of DNA with its associated protein. This is known as unistranded or unineme concept.

The chromatin is formed of about 60% proteins, 35% DNA & 5% RNA. The information stored in DNA is organised, replicated and read by a variety of DNA-binding proteins. These fall into two categories :-

(A) Structural proteins :→ These are non-specifically binding proteins. These are bound to DNA along most of its length and help to package it without preventing the access of other DNA-binding proteins. These are :- histones and the nonhistones.

(A) Histones :→ Histones are main structural proteins found in eukaryotic cells. These are low molecular weight proteins with high proportion of positively charged amino acids. The positive charge helps histones to bind to DNA and a play a crucial part in packing long DNA molecules.

Types of histones :→ There are five different types of histones that fall into two categories :-

(i) Nucleosomal histones :→ There are eight molecules of four types of small proteins. These are responsible for coiling of DNA into nucleosome. These are $(H_2A)_2$, $(H_2B)_2$, $(H_3)_2$ & $(H_4)_2$

(ii) H_1 Histones :→ These are large & are tissue specific. They are present one per 200 base pairs. These are loosely associated with DNA. These are responsible for packing of nucleosomes in 30 nm fibre.

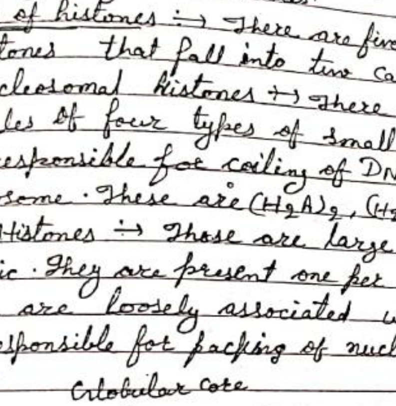

Fig. Diagram showing role of H_1 histone in nucleosome packaging.

Functions of Histones :→ Histones in eukaryotic chromosomes serve two functions :-

(i) These either serve as structural elements & help in coiling & packing of long DNA molecules.

(ii) These cover or repress specific segments of DNA so that these segments are unable to transcribe. Their transcription is possible only by the dissolution of histones.

(B) Nucleosomes :→

Nucleosomes are the fundamental packing units of chromatin & give chromatin the 'beads on a string' appearance. Each nucleosome is disc-shaped about 11nm in diameter. It consists of a core particle and a smaller spacer or linker DNA.

Nucleosome packing or Formation of Chromatin Fibre :→

Nucleosomes are packed upon one another to form a chromatin fibre or nucleoprotein fibre with a diameter of about 30 nm. It appears to have a beaded appearance. The beads are nucleosomes. These are connected by linker DNA.

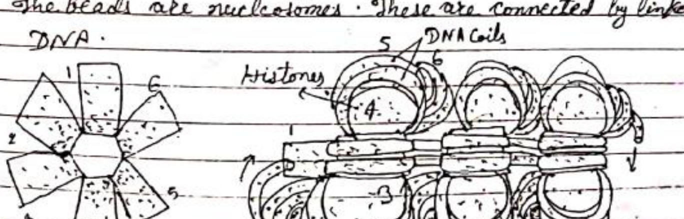

Fig. A model suggesting the nucleosome packing in 30 nm nucleoprotein fibre.

The 11 nm nucleoprotein fibre represents the first.

level of organisation of chromatin and is seen in the interphase nucleus. The thick chromatin fibre of 30 nm arises by spiral coiling of thin 11 nm chromatin fibre. It has a solenoid types of ultrastructure & has 6-7 nucleosomes per turn.

This type of packing requires one molecule of histones H_1 per nucleosome. H_1 gives polarity to chromatin fibre. The 30 nm fibre is called a solenoid. Inside the cells this solenoid is further folded & packed into the supersolenoid of 300 nm diameter. In mitotic chromosomes, the supersolenoid is further condensed to produced the final shape and dimension of metaphase or anaphase chromosome. In metaphase chromosome, the two daughter DNA molecules are separately folded to produce two sister chromosomes called sister chromatids, held together by a single centromere.

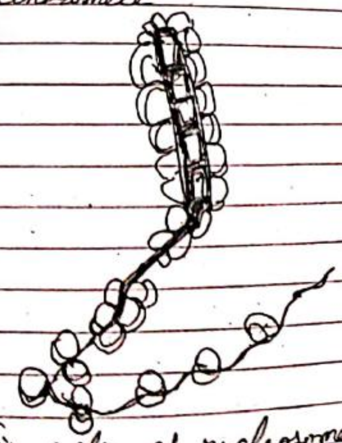

Fig. coiling of nucleosome fibre (solenoid struct

Physiology of chromosomes :-

"Chromosomes are known as

hereditary vehicles. These are formed of strands of DNA molecules which contain information for the development of different characteristics & performance of various activities of the cells.