STRUCTURE AND FUNCTION OF CHROMOSOMES

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A chromosome is a structure that occurs within cells and that contains the cell's genetic material. That genetic material, which determines how an organism develops, is a molecule of deoxyribonucleic acid (DNA). A molecule of DNA is a very long, coiled structure that contains many identifiable subunits known as genes. In prokaryotes, or cells without a nucleus, the chromosome is merely a circle of DNA. In eukaryotes, or cells with a distinct nucleus, chromosomes are much more complex in structure.

Historical background

The terms chromosome and gene were used long before biologists really understood what these structures were. When the Austrian monk and biologist Gregor Mendel (1822–1884) developed the basic ideas of heredity, he assumed that genetic traits were somehow transmitted from parents to offspring in some kind of tiny "package." That package was later given the name "gene." When the term was first suggested, no one had any idea as to what a gene might look like. The term was used simply to convey the idea that traits are transmitted from one generation to the next in certain discrete units.
The term "chromosome" was first suggested in 1888 by the German anatomist Heinrich Wilhelm Gottfried von Waldeyer-Hartz (1836–1921). Waldeyer-Hartz used the term to describe certain structures that form during the process of cell division (reproduction).

The structure of chromosomes and genes

A chromosome is an organized structure of DNA and protein that is found in cells. A chromosome is a single piece of coiled DNA containing many genes, regulatory elements and other nucleotide sequences. Chromosomes also contain DNA-bound proteins, which serve to package the DNA and control its functions. The word *chromosome* comes from the Greek chroma - color and soma - body due to their property of being very strongly stained by particular dyes. Chromosomes vary widely between different organisms. The DNA molecule may be circular or linear, and can be composed of 10,000 to 1,000,000,000 nucleotides in a long chain. Typically eukaryotic cells (cells with nuclei) have large linear chromosomes and prokaryotic cells (cells without defined nuclei) have smaller circular chromosomes, although there are many exceptions to this rule.

A chromosome has generally 8 parts; Centromere or primary constriction or kinetochore, chromatids, chromatin, secondary constriction, telomere, chromomere, chromonema, and matrix.

Centromere or Kinetochore: It is the primary constriction at the center to which the chromatids or spindle fibers are attached. Its function is to enable movement of the chromosome during the anaphase stage of cell division.

Chromatid: During cell division, a chromosome is divided into 2 identical half strands joined by a centromere. A chromatid is each half of the chromosome joined. Each chromatid contains DNA and separates at Anaphase to form a separate chromosome. Both chromatids are attached to each other by the centromere.

Chromatin: It is a complex of DNA and proteins that forms chromosomes within the nucleus of eukaryotic cells. Nuclear DNA is highly condensed and wrapped around nuclear proteins in order to fit inside the nucleus. In other words, it is not present as free linear strands. The chromatin consists of DNA, RNA, and protein.

Secondary Constriction: It is generally present for the nucleolar organization.

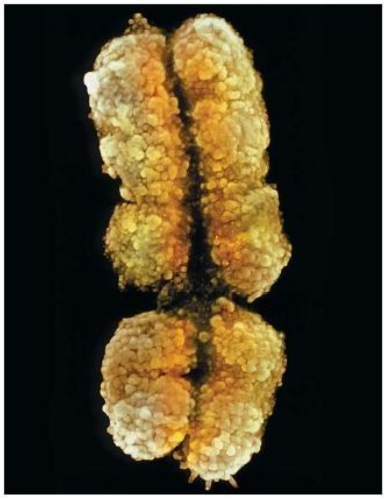
Telomere: Telomere is the terminal region of each side of the chromosome.

Chromonema: It is a threadlike coiled filamentous structure along which chromomeres are arranged. Chromonema controls the size of the chromosome and it acts as a site of gene bearing.

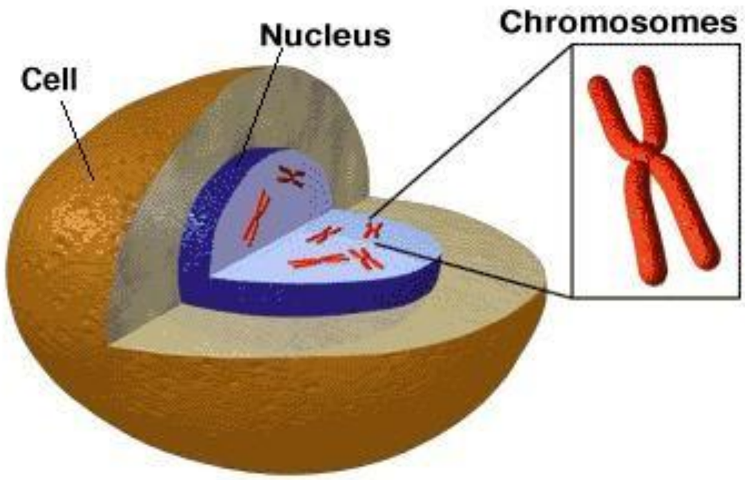
Chromomeres: These are the bead-like structures present on threads or chromonema. These are arranged in a row along the length of chromonema. The number of chromosomes is constant and it is responsible for carrying the genes during cell division to the next generation.

Matrix: Pellicle is the membrane surrounding each of the chromosomes. Matrix is the jelly-like substance present inside pellicle. It is formed of non-genetic materials.

A chromosome contains a single molecule of DNA along with several kinds of proteins. A molecule of DNA, in turn, consists of thousands and thousands of subunits, known as nucleotides, joined to each other in very long chains. A single molecule of DNA within a chromosome may be as long as 8.5 centimeters (3.3 inches). To fit within a chromosome, the DNA molecule has to be twisted and folded into a very complex shape.



Each chromosome has a constriction point called the centromere, which divides the chromosome into two sections, or "arms." The short arm of the chromosome is labeled the "p arm." The long arm of the chromosome is labeled the "q arm." The location of the centromere on each chromosome gives the chromosome its characteristic shape, and can be used to help describe the location of specific genes.



Furthermore, cells may contain more than one type of chromosome; for example, mitochondria in most eukaryotes and chloroplasts in plants have their own small chromosomes.

The following are the different types of chromosomes

Viral Chromosomes

The chromosomes of viruses are called viral chromosomes. They occur singly in a viral species and chemically may contain either DNA or RNA. The DNA containing viral chromosomes may be either of linear shape (e.g., T2, T3, T4, T5, bacteriophages) or circular shape (e.g., most animal viruses and certain bacteriophages). The RNA containing viral chromosomes are composed of a linear, single-stranded RNA molecule and occur in some animal viruses (e.g., poliomyelitis virus, influenza virus, etc.); most plant viruses, (e.g., tobacco mosaic virus, TMV) and some bacteriophages. Both types of viral chromosomes are either tightly packed within the capsids of mature virus particles (virons) or occur freely inside the host cell.

Prokaryotic Chromosomes

The prokaryotes usually consists of a single giant and circular chromosome in each of their nucloids. Each prokaryotic chromosome consists of a single circular, double-stranded DNA molecule; but has no protein and RNA around the DNA molecule like eukaryotes. Different prokaryotic species have different sizes of chromosome.

Eukaryotic Chromosomes

The eukaryotic chromosomes differ from the prokaryotic chromosomes in morphology, chemical composition and molecular structure. The eukaryotes (plants and animals) usually contain much more genetic informations than the viruses and prokaryotes, therefore, contain a great amount of genetic material, DNA molecule which here may not occur as a single unit, but, as many units called chromosomes. Different species of eukaryotes have different but always constant and characteristic number of chromosomes. In eukaryotes, nuclear chromosomes are packaged by proteins into a condensed structure called chromatin. This allows the very long DNA molecules to fit into the cell nucleus. The shape of the eukaryotic chromosomes is changeable from phase to phase in the continuous process of the cell growth and cell division. Chromosomes are the essential unit for cellular division and must be replicated, divided, and passed successfully to their daughter cells so as to ensure the genetic diversity and survival of their progeny. They are thin, coiled, elastic, contractile thread-like structures during the interphase (when no division of cell occurs) and are called chromatin threads which under low magnification look like a compact stainable mass, often called as chromatin substance or material. During metaphase stage of mitosis and prophase of meiosis, these chromatin threads become highly coiled and folded to form compact and individually distinct ribbon-shaped chromosomes. These chromosomes contain a clear zone called kinetochore or centromere along their length.

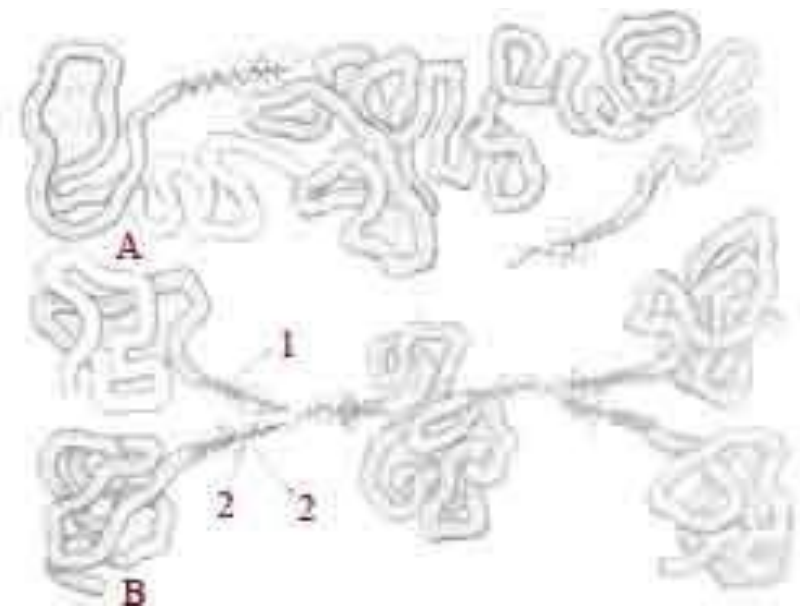
Chemical Structure of Chromosomes

Chemically, the eukaryotic chromosomes are composed of deoxyribonucleic acid (DNA), ribonucleic acid (RNA), histone and non-histone proteins and certain metallic ions. The histone proteins have basic properties and have significant role in controlling or regulating the functions of chromosomal DNA. The non-histone proteins are mostly acidic and have been considered more important than histones as regulatory molecules. Some non-histone proteins also have enzymatic activities. The most important enzymatic proteins of chromosomes are phosphoproteins, DNA polymerase, RNA-polymerase, DPN-pyropbosphorylase, and nucleoside triphosphatase. The metal ions as Ca^{+} and Mg^{+} are supposed to maintain the oragnization of chromosomes intact.

Molecular Structure of Chromosomes

According to the recent and widely accepted theory of Dupraw (1965, 1970) and Hans Ris (1967) called unistranded theory, each eukaryotic chromosome is composed of a single, greatly elongated and highly folded nucleoprotein fibre of 100A ^{0} thick. This nucleo- protein fibre in its turn is composed of a single, linear, double stranded DNA molecule which remains wrapped in equal amounts of histone and non-histone proteins and variable amounts of different kinds of RNA. Dupraw produced a “folded-fibre Model" to show the ultrastructure of chromosome.

FIBRE FOLDED MODEL



This model shows a highly folded nucleoprotein fibre in a chromosome and also suggests that how the nucleoprotein fibre of a chromosome replicates during cell division and how the nucleoprotein fibre of both chromatids remain held at the centromere by a unreplicated fibre segment to DNA until the anaphase.

A-B- The folded fibre model of Dupraw for chromosomes in Interphase

1. DNA molecule

2.Protein molecules

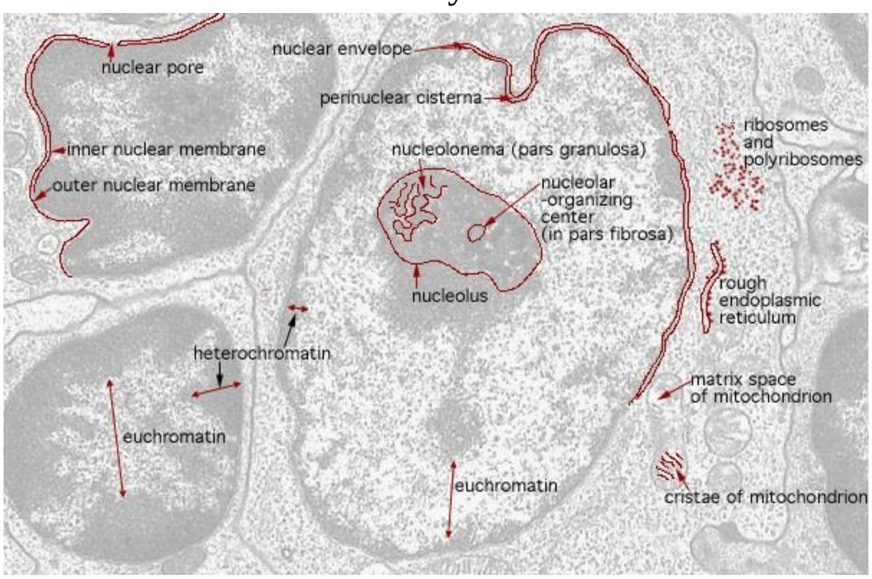
3.Chromatids

Material of Chromosomes

The chromatin material of the eukaryotic chromosomes according to its percentage of DNA, RNA and proteins and consequently due to its, staining property has been classified into following by classical cytologists:

1. **Euchromatin**

   The euchromatin is the extended form of chromatin and it forms the major, portion of chromosomes. The euchromatin has special affinity for basic stains and is genetically active because its component DNA molecule synthesizes RNA molecules only in the extended form of chromatin.



2. Heterochromatin

The heterochromatin is a condensed intercoiled state of chromatin, containing two to three times more DNA than euchromatin. However, it is genetically inert as it does not direct synthesize RNA (i.e., transcription) and protein and is often replicated at a different time from the rest of the DNA.

Functions of Chromosomes

The most important function of chromosomes is to carry the basic genetic material – DNA. DNA provides genetic information for various cellular functions. These functions are essential for growth, survival, and reproduction of the organisms.

Histones and other proteins cover the Chromosomes. These proteins protect it from chemical (e.g., enzymes) and physical forces. Thus, chromosomes also perform the function of protecting the genetic material (DNA) from damage during the process of cell division.

During cell division, spindle fibers attached to the centromeres contract and perform an important function. The contraction of centromeres of chromosomes ensures precise distribution of DNA (genetic material) to the daughter nuclei.

Chromosomes contain histone and non-histone proteins. these proteins regulate gene action. Cellular molecules that regulate genes work by activating or deactivating these proteins. This activation and deactivation expand or contract the chromosome.