

DNA and chromosomes



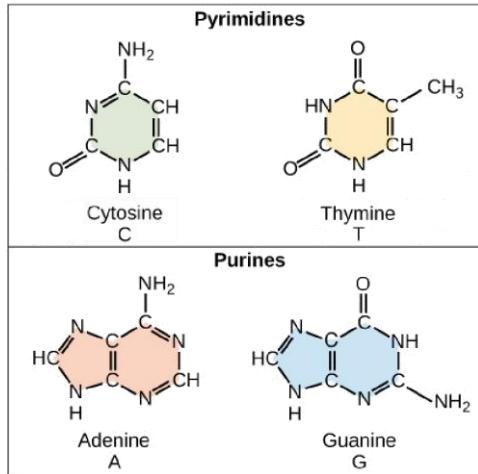
INDRAPRASTHA INSTITUTE of
INFORMATION TECHNOLOGY **DELHI**

Dr. Jaspreet Kaur Dhanjal
Assistant Professor, Center for Computational Biology

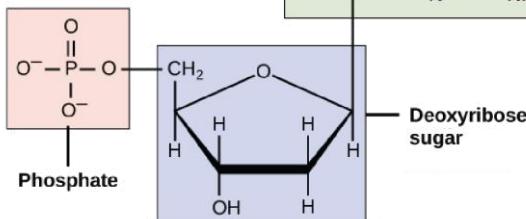
Email ID: jaspreet@iiitd.ac.in

January 13, 2025

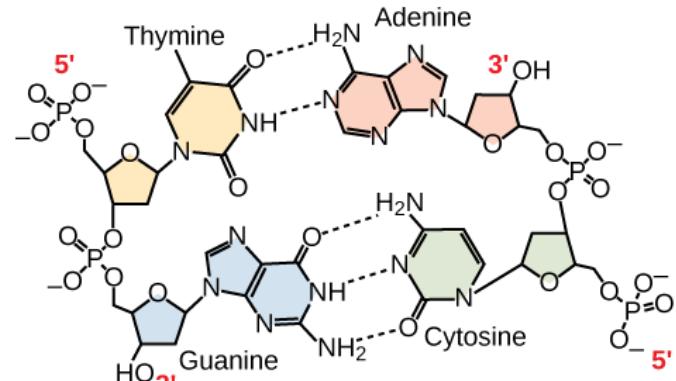
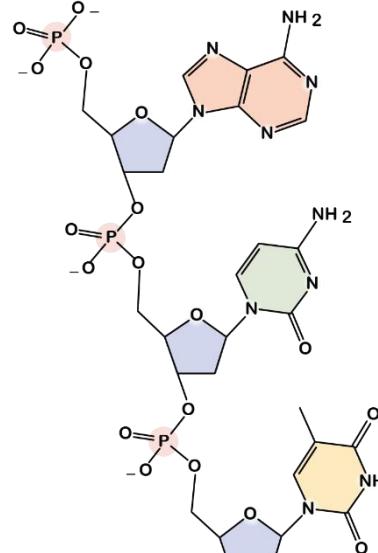
Structure of DNA



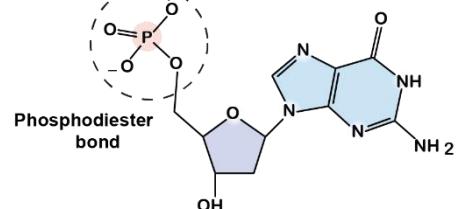
Nucleotide



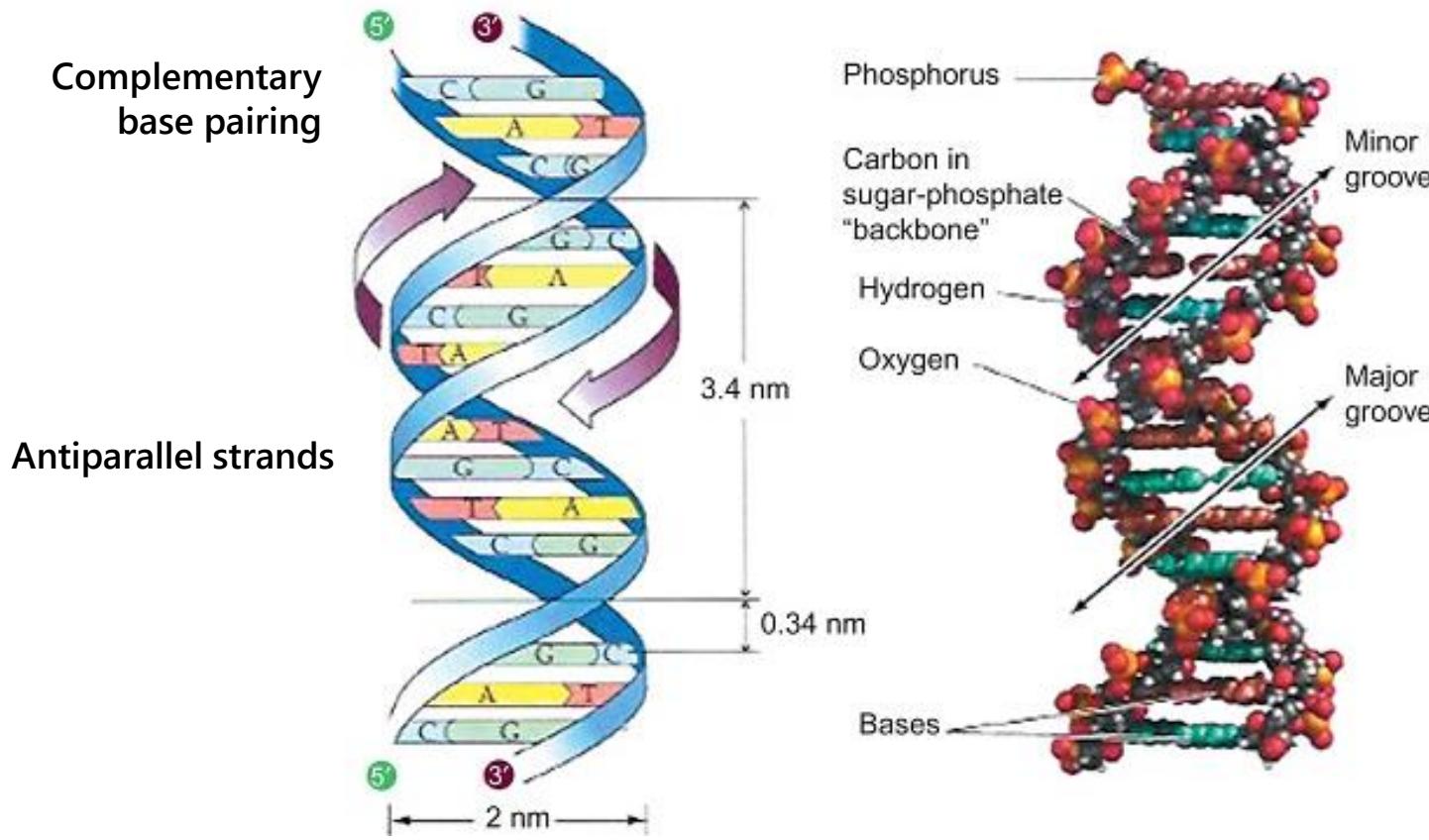
Single strand of DNA



Double stranded DNA

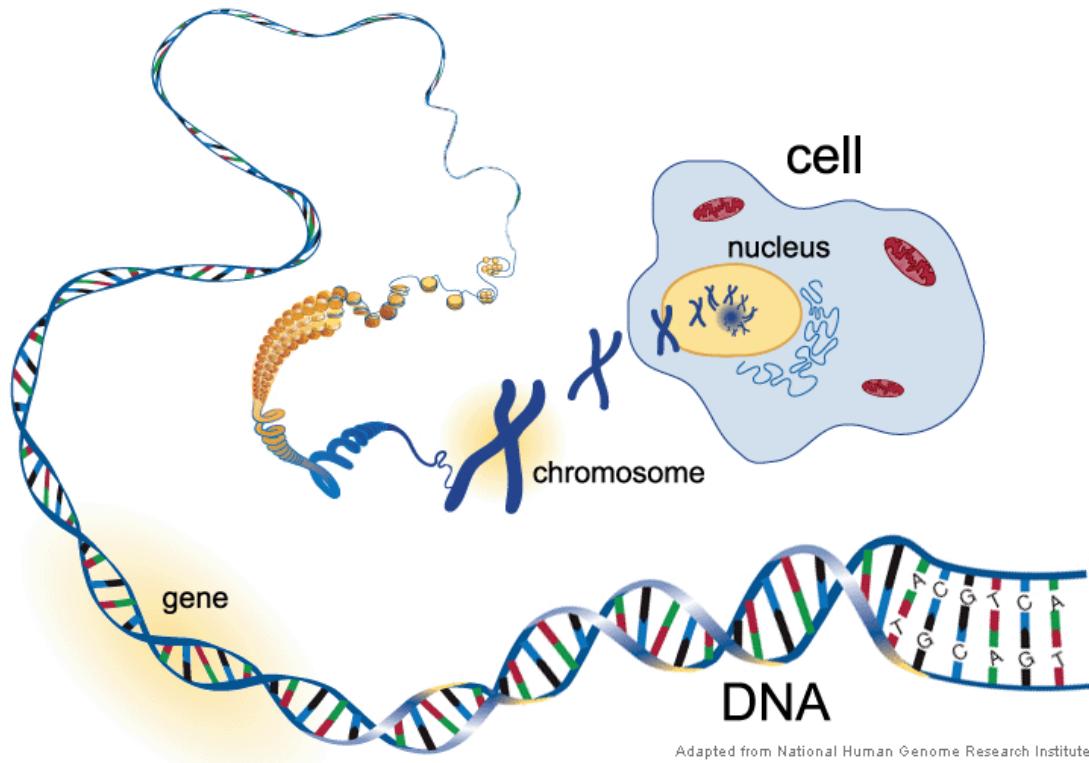


Structure of DNA



Human genome

- The genome is the entire set of DNA instructions (haploid) found in a cell.
- Human genome consists of approximately 3.2 billion base pairs of nuclear DNA, as well as a small double-stranded, circular chromosome in the cell's mitochondria of 16569 bp.
- Human nuclear DNA is distributed across 23 chromosomes, each ranging in size from about 50 million to 300 million base pairs.



Adapted from National Human Genome Research Institute

DNA are very long molecules

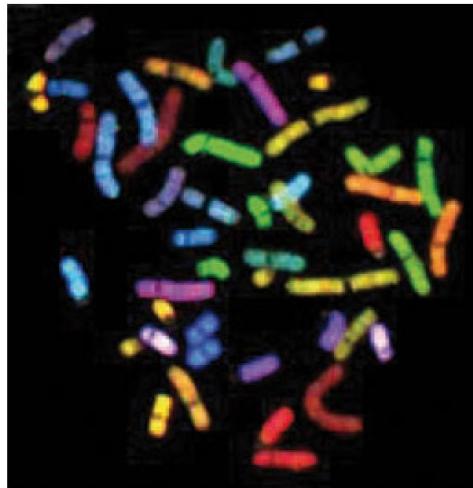
- The average size of a human cell is around 10–100 micrometers in diameter.
- Cell nucleus is only 5–8 μm in diameter.
- Each human cell contains about 2 meters of DNA.
- All the DNA is packed inside the nucleus of a cell.
- Tucking all this material into such a small space is the equivalent of trying to fold 40 km (24 miles) of extremely fine thread into a tennis ball.

Chromosomes – condensed DNA structure

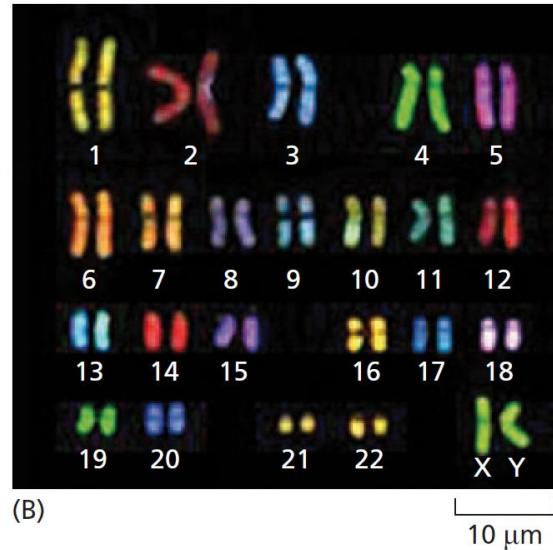
- In eukaryotic cells, very long double-stranded DNA molecules are packaged into chromosomes.
- The complex task of packaging DNA is accomplished by specialized proteins that bind to and fold the DNA, generating a series of coils and loops that provide increasingly higher levels of organization.
- The DNA in the nucleus is distributed among a set of different chromosomes.
- The DNA in a human nucleus, for example, contains approximately 3.2×10^9 nucleotides parceled out into 23 or 24 different types of chromosome.

Human chromosomes

Human cells each contain two copies of each chromosome, one inherited from the mother and one from the father.



(A)



(B)

Homologous chromosomes

An ordered display of the full set of 46 human chromosomes is called the **human karyotype**.

Complexity of genomes

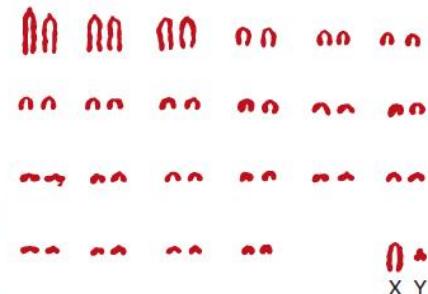
In general, the more complex an organism, the larger is its genome.

But this relationship does not always hold true. The human genome, for example, is 200 times larger than that of the yeast *S. cerevisiae*, but 30 times smaller than that of some plants and at least 60 times smaller than some species of amoeba.

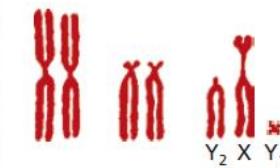
Furthermore, how the DNA is apportioned over chromosomes also differs from one species to another. Humans have a total of 46 chromosomes (including both maternal and paternal sets), but a species of small deer has only 7, while some carp species have more than 100. Even closely related species with similar genome sizes can have very different numbers and sizes of chromosomes



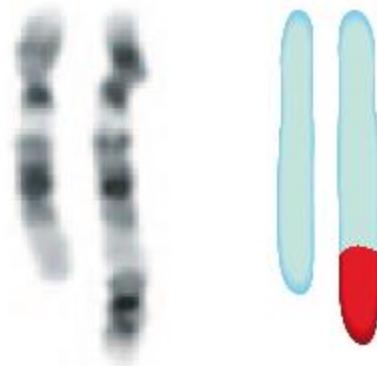
Chinese muntjac



Indian muntjac



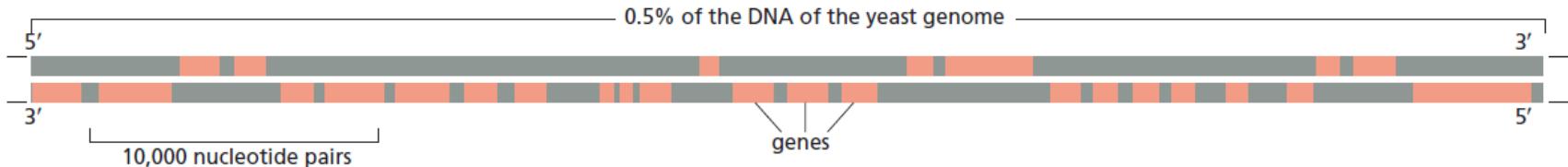
Human chromosomes



Abnormal chromosomes are associated with some inherited genetic defects.

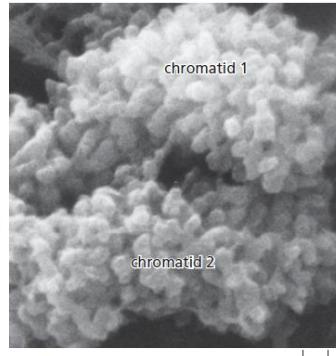
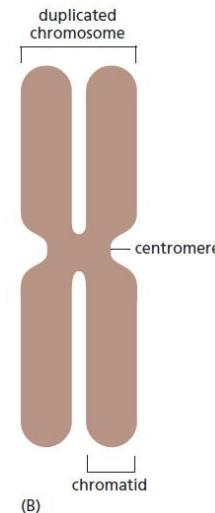
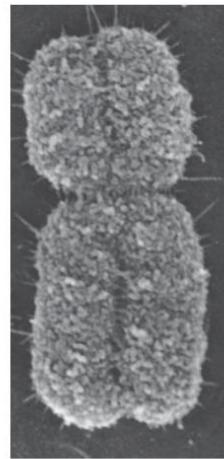
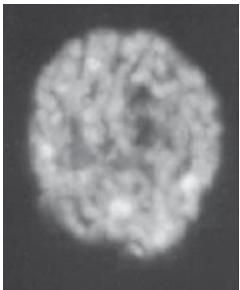
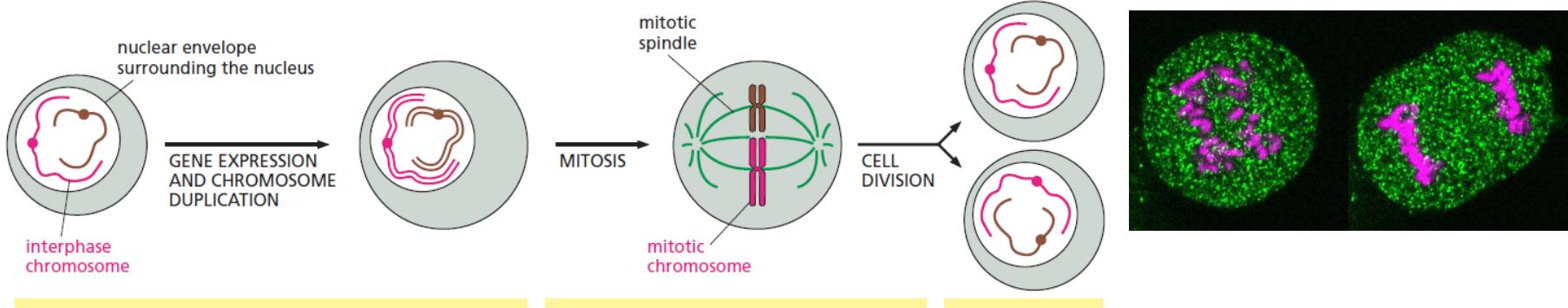
A pair of chromosome 12 from a patient with inherited ataxia, a genetic disease of the brain characterized by progressive deterioration of motor skills. The patient has one normal Chromosome 12 (left) and one abnormally long Chromosome 12, which contains a piece of Chromosome 4 as identified by its banding pattern.

Genes are arranged along the chromosomes



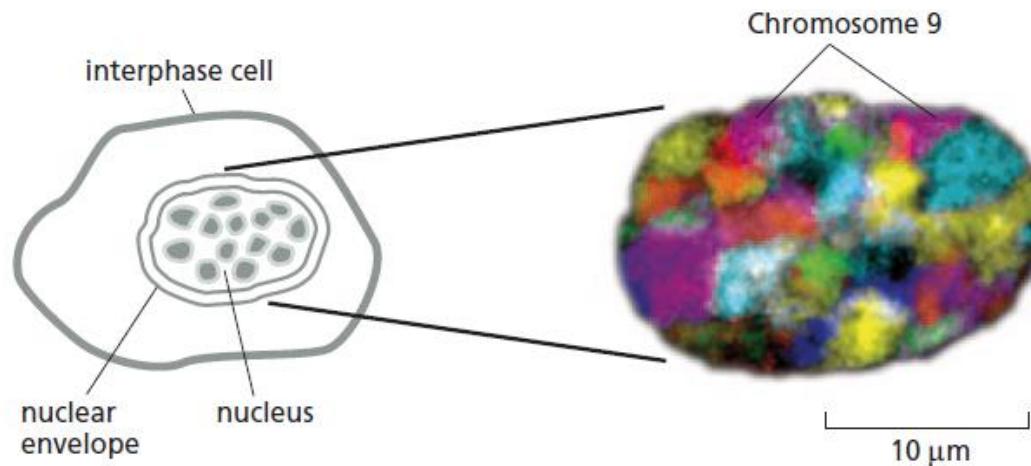
The *S. cerevisiae* genome contains about 12 million nucleotide pairs and 6600 genes—spread across 16 chromosomes.

Chromosomes during cell division



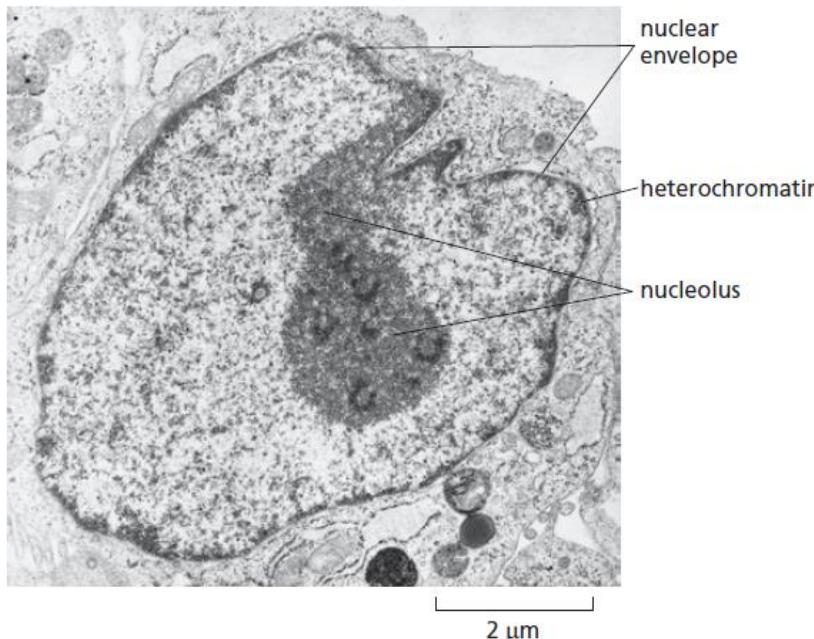
Interphase Chromosomes

- Inside the nucleus, the interphase chromosomes—although longer and finer than mitotic chromosomes—are nonetheless organized in various ways.
- First, each chromosome tends to occupy a particular region of the interphase nucleus, and so different chromosomes do not become extensively entangled with one another. In addition, some chromosomes are attached to particular sites on the nuclear envelope—the pair of concentric membranes that surround the nucleus—or to the underlying nuclear lamina, the protein meshwork that supports the envelope

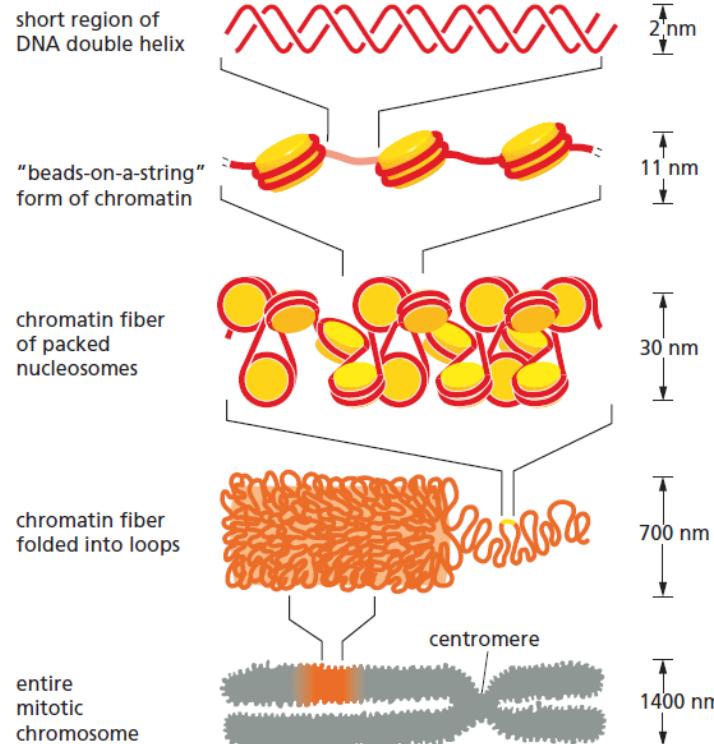


Interphase Chromosomes

- The most obvious example of chromosome organization in the interphase nucleus is the nucleolus. The nucleolus is where the parts of the different chromosomes carrying genes that encode ribosomal RNAs cluster together. Here, ribosomal RNAs are synthesized and combine with proteins to form ribosomes, the cell's protein-synthesizing machines.



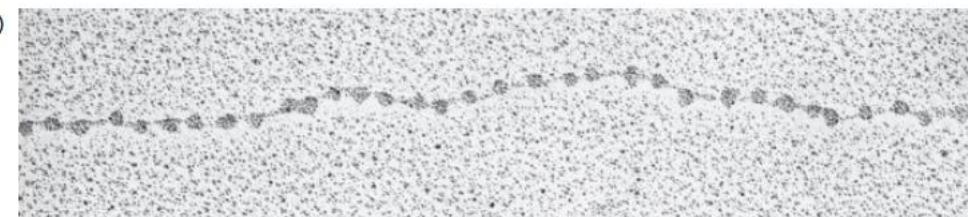
Specialized proteins pack the DNA into chromosomes



NET RESULT: EACH DNA MOLECULE HAS BEEN
PACKAGED INTO A MITOTIC CHROMOSOME THAT
IS 10,000-FOLD SHORTER THAN ITS FULLY
EXTENDED LENGTH



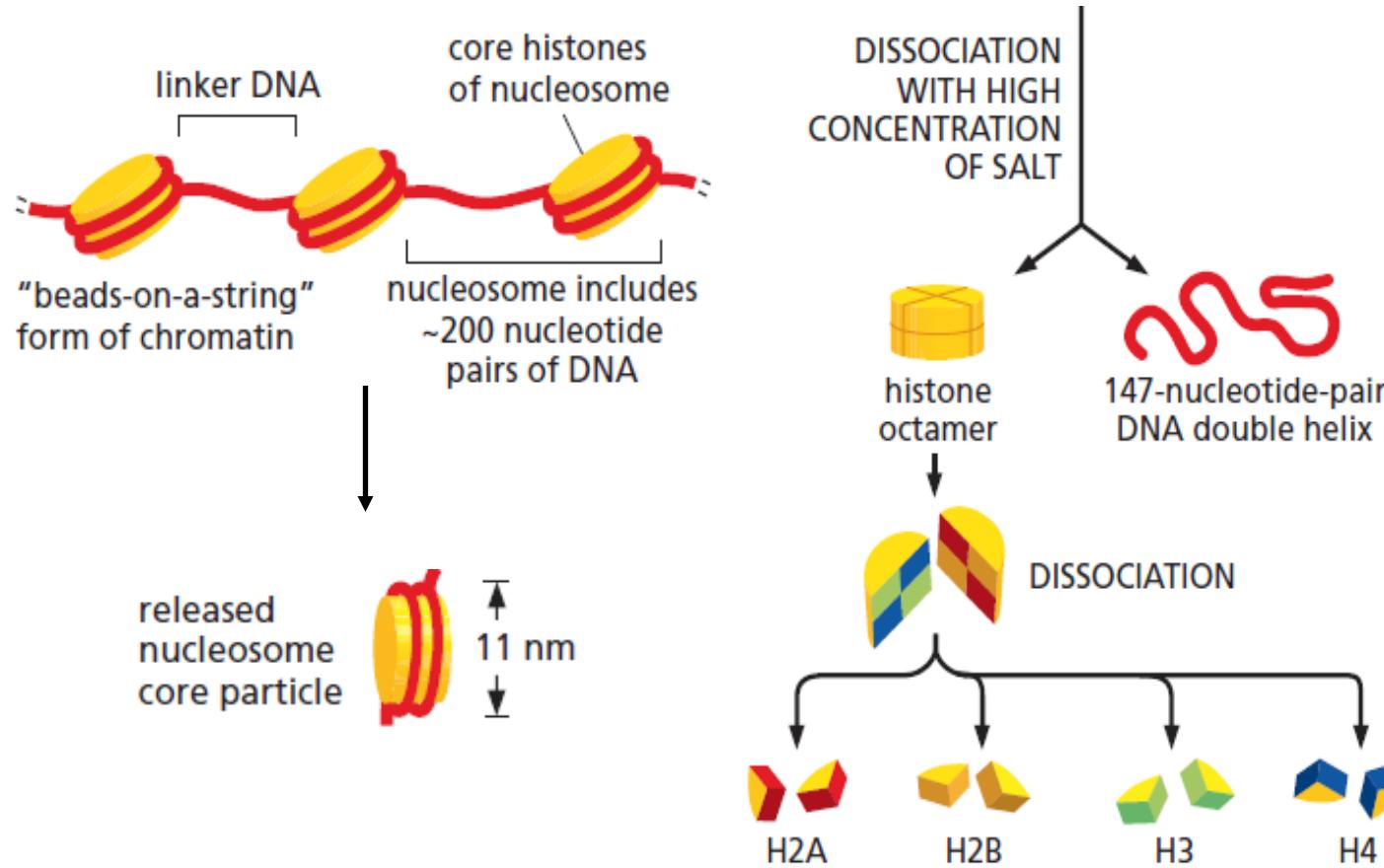
Chromatin isolated directly from an interphase nucleus (30-nm thick)



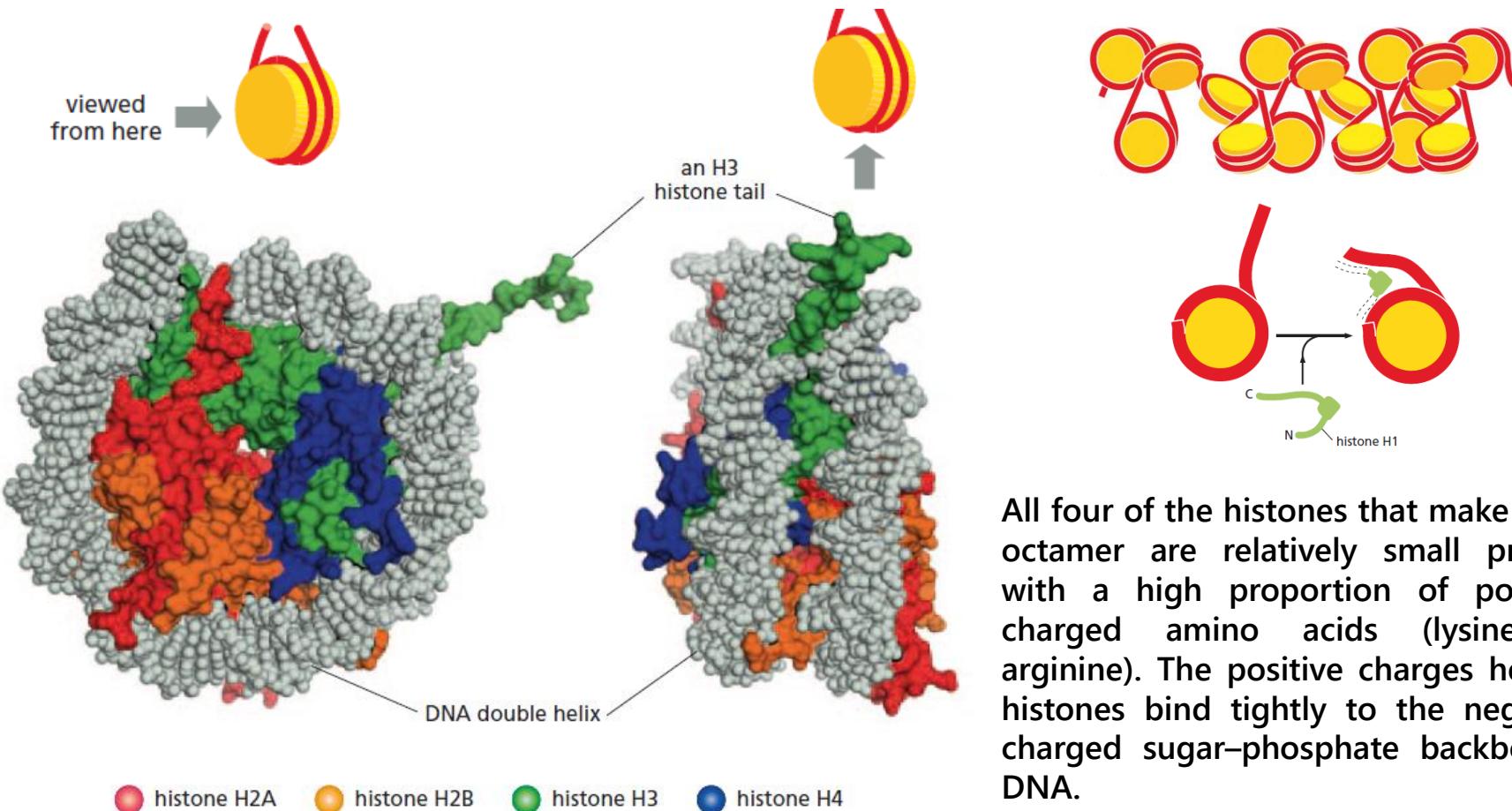
Chromatin fiber that has been experimentally unpacked, or
decondensed, beads-on-a-string structure.

50 nm

Nucleosome = DNA + Protein

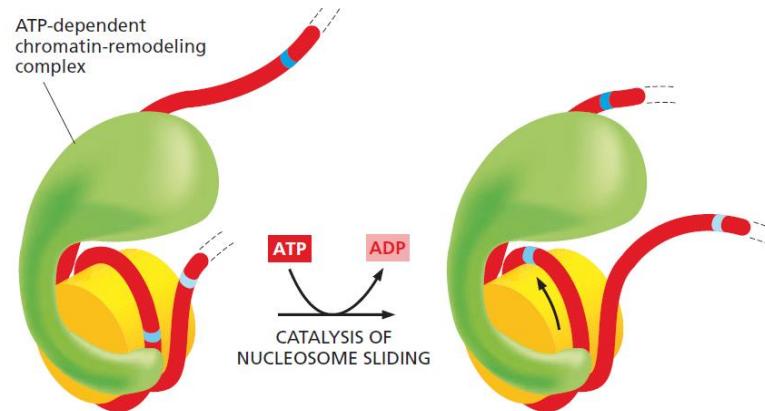


Nucleosome structure

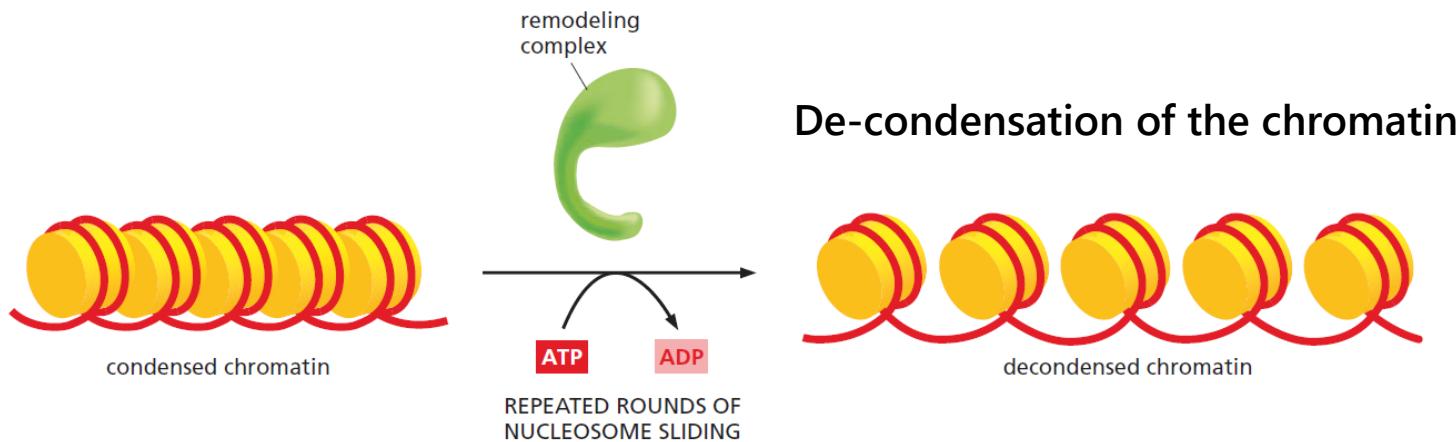


All four of the histones that make up the octamer are relatively small proteins, with a high proportion of positively charged amino acids (lysine and arginine). The positive charges help the histones bind tightly to the negatively charged sugar-phosphate backbone of DNA.

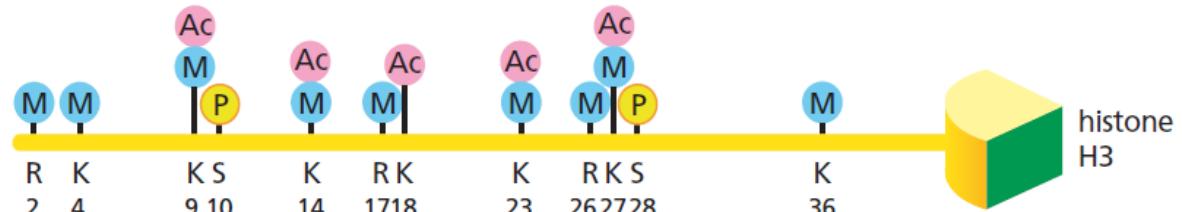
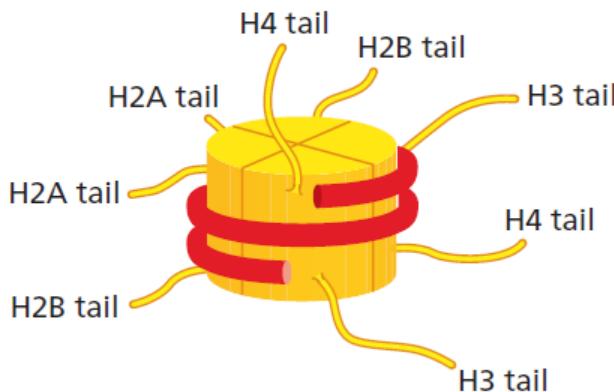
Chromatin remodelling



Reposition the DNA wrapped around nucleosomes

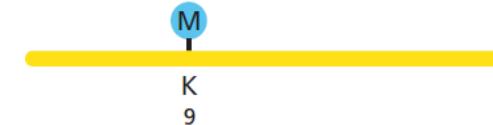


Histone modification



H3 histone modification state

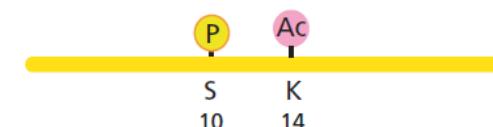
meaning



heterochromatin formation,
gene silencing

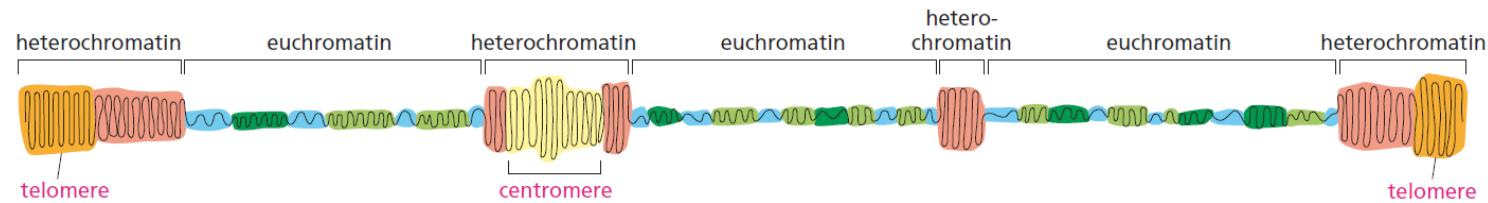


gene expression

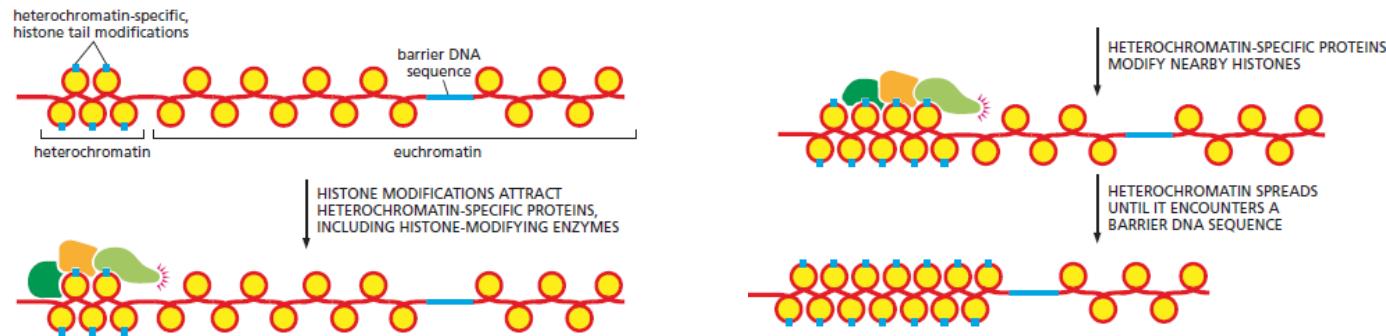


gene expression

Heterochromatin and Euchromatin



Structure of chromatin changes as per the cell requirements



Inappropriate packaging of genes in heterochromatin can cause disease:

In humans, the gene that encodes β -globin—which forms part of the oxygen-carrying hemoglobin molecule—is situated next to a region of heterochromatin. If, because of an inherited DNA deletion, that heterochromatin spreads, the β -globin gene is poorly expressed and the person develops a severe form of anemia.

Inactivation of X chromosome in females

In mammals, female cells contain two X chromosomes, whereas male cells contain one X and one Y. Because a double dose of X-chromosome products would be lethal, female mammals have evolved a mechanism for permanently inactivating one of the two X chromosomes in each cell. At random, one or other of the two X chromosomes in each cell becomes highly condensed into heterochromatin early in embryonic development.

