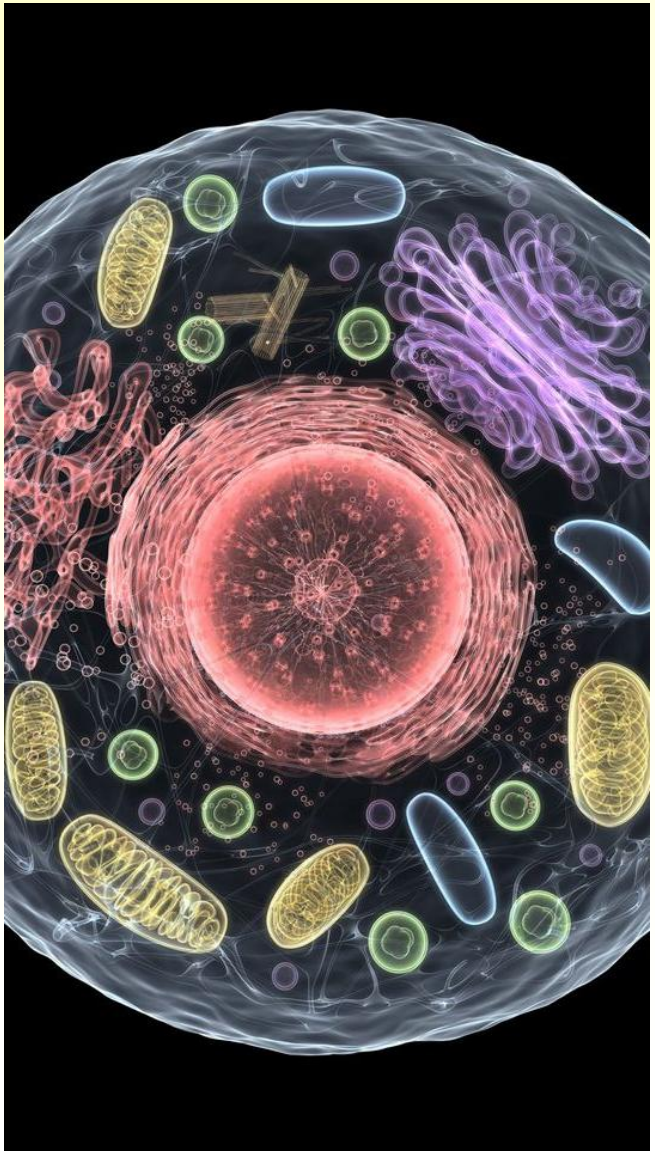
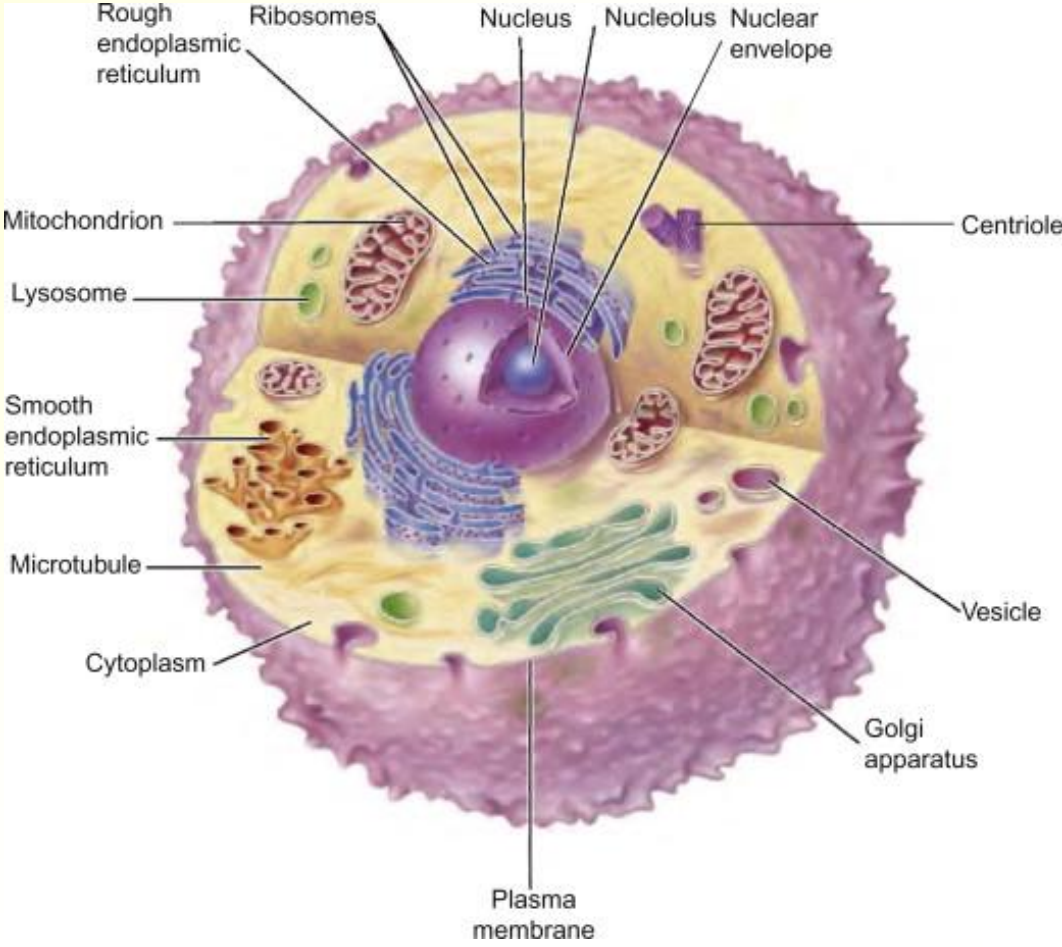
University of Teramo

Degree Program in Biotechnology

COURSE OF CYTOLOGY AND HISTOLOGY
Prof. Mauro

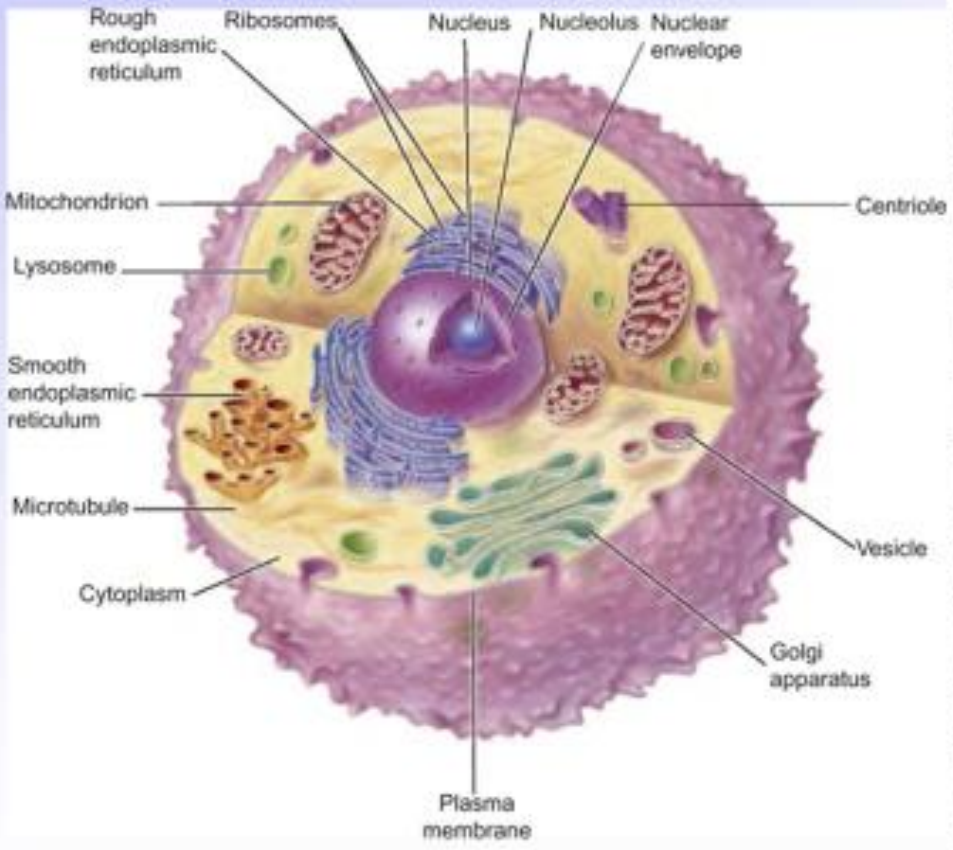
Eukaryotic cell

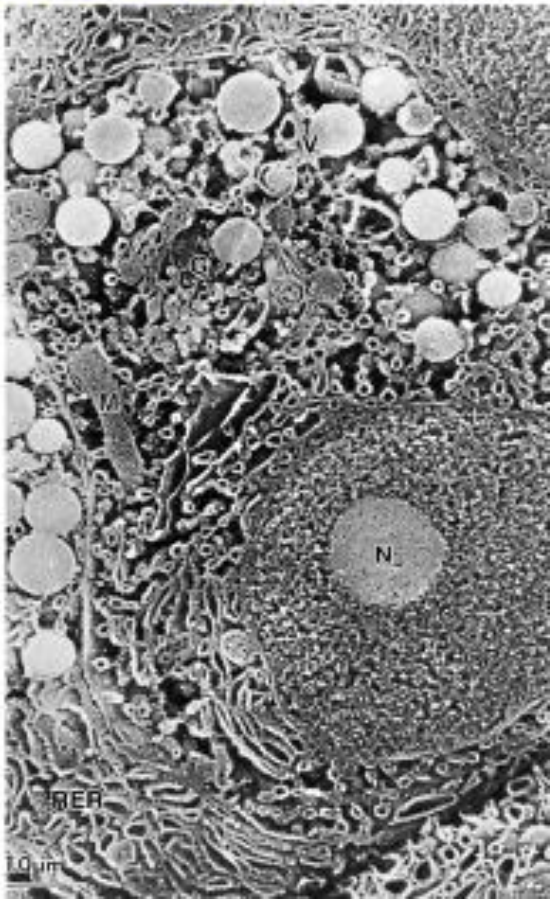




CITOPLASM AND ORGANELLES

Organization of the protoplasm of a eukaryotic cell





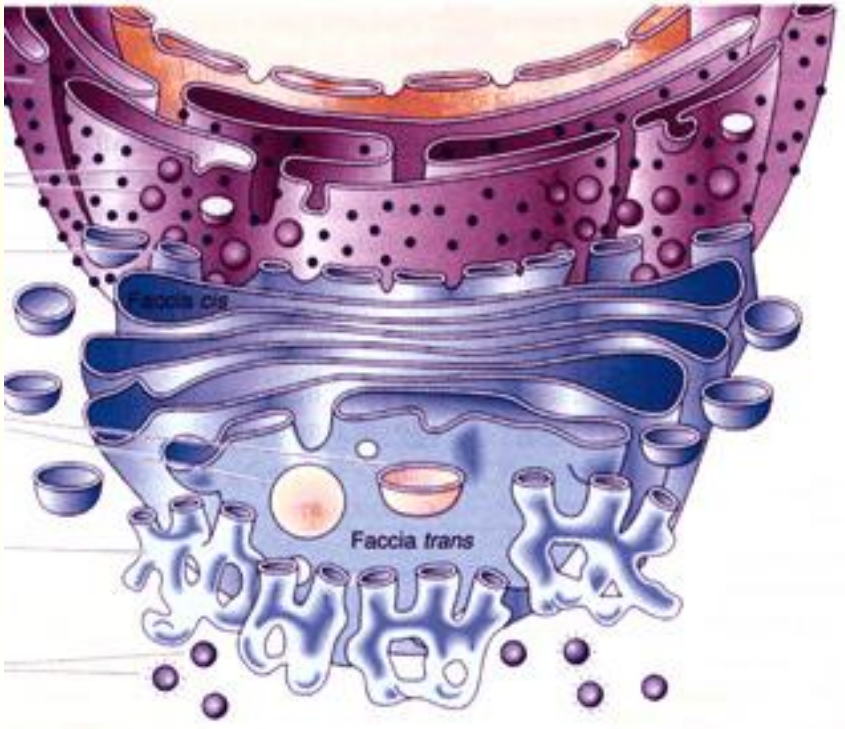
CELL ORGANELLES

Nucleus

Endoplasmic Reticulum

Golgi Apparatus

Membrane Vacuolar System



Mitochondria

Lysosomes

NUCLEUS: structure

The nucleus is made up of four main components:

1. Nuclear membrane or nuclear envelope

2. Nucleoskeleton

3. Chromatin

4. Nucleolus

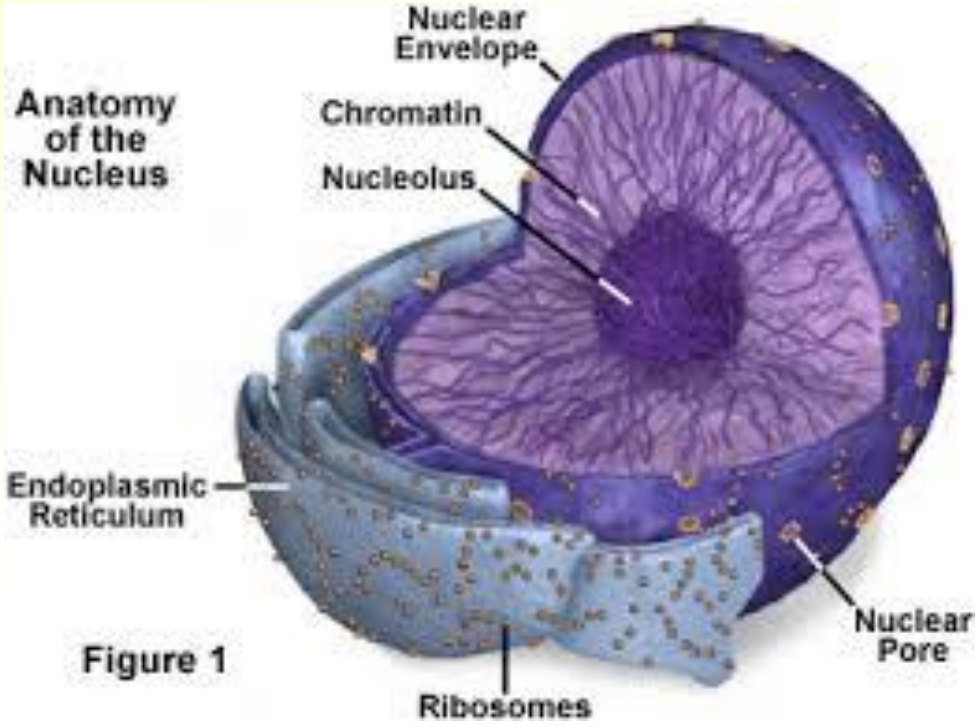


Figure 1

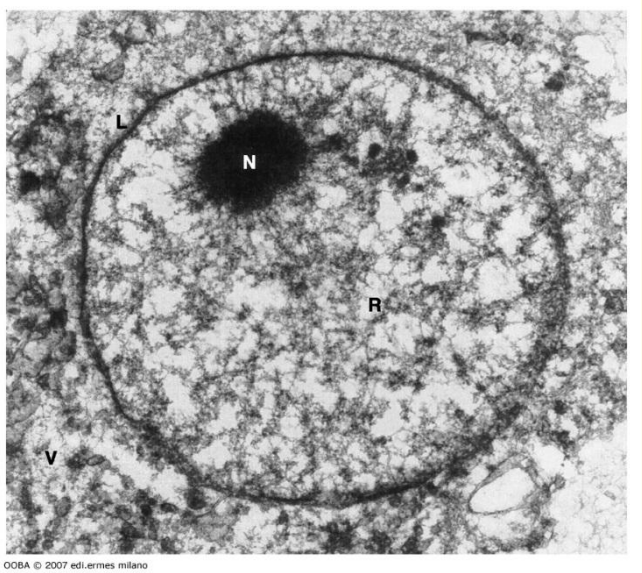
NUCLEOSKELETON: Nuclear Matrix and Nuclear Lamina

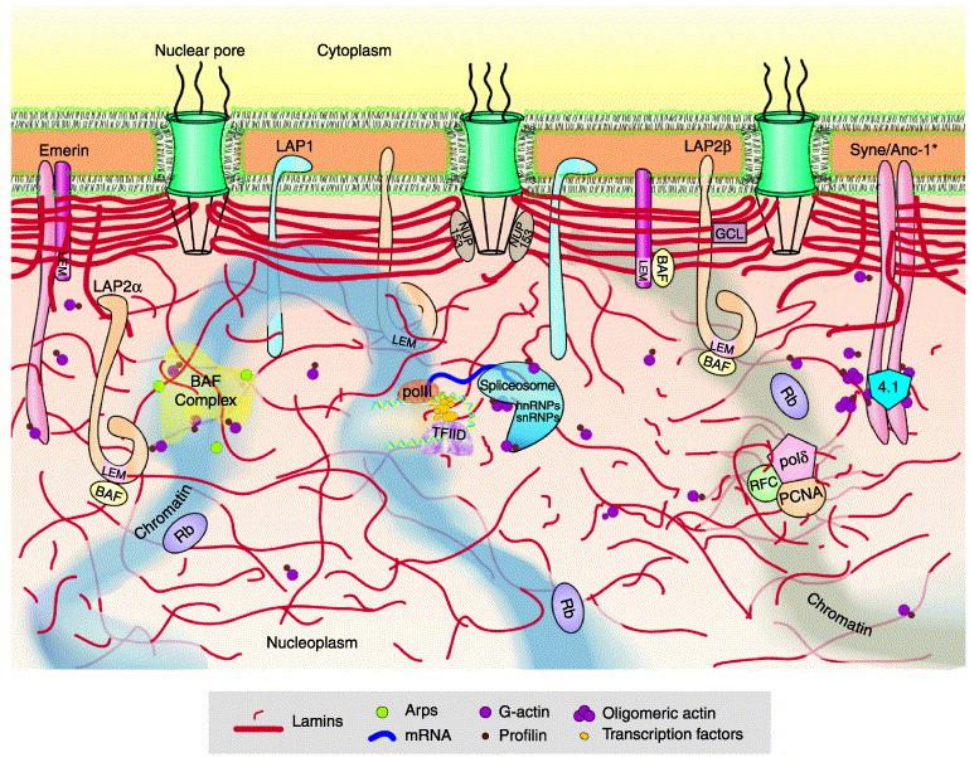
Nuclear lamina:

A thin and dense network of highly insoluble proteins, attached to the nucleoplasmic side of the inner membrane of the nuclear envelope.

Nuclear matrix:

An extensive fibrous and granular insoluble matrix that seems to form a nucleoskeleton, which helps maintain the shape of the nucleus.





- Within the nuclear matrix, we can distinguish:
- A **peripheral fibrous layer**, close to the lamina.
- An **endonuclear fibrillar network**, distributed throughout the nucleoplasm.
- A **nucleolar spongy matrix**, which contributes to the internal structure of the nucleolus.

NUCLEOSKELETON: Nuclear Matrix and Nuclear Lamina

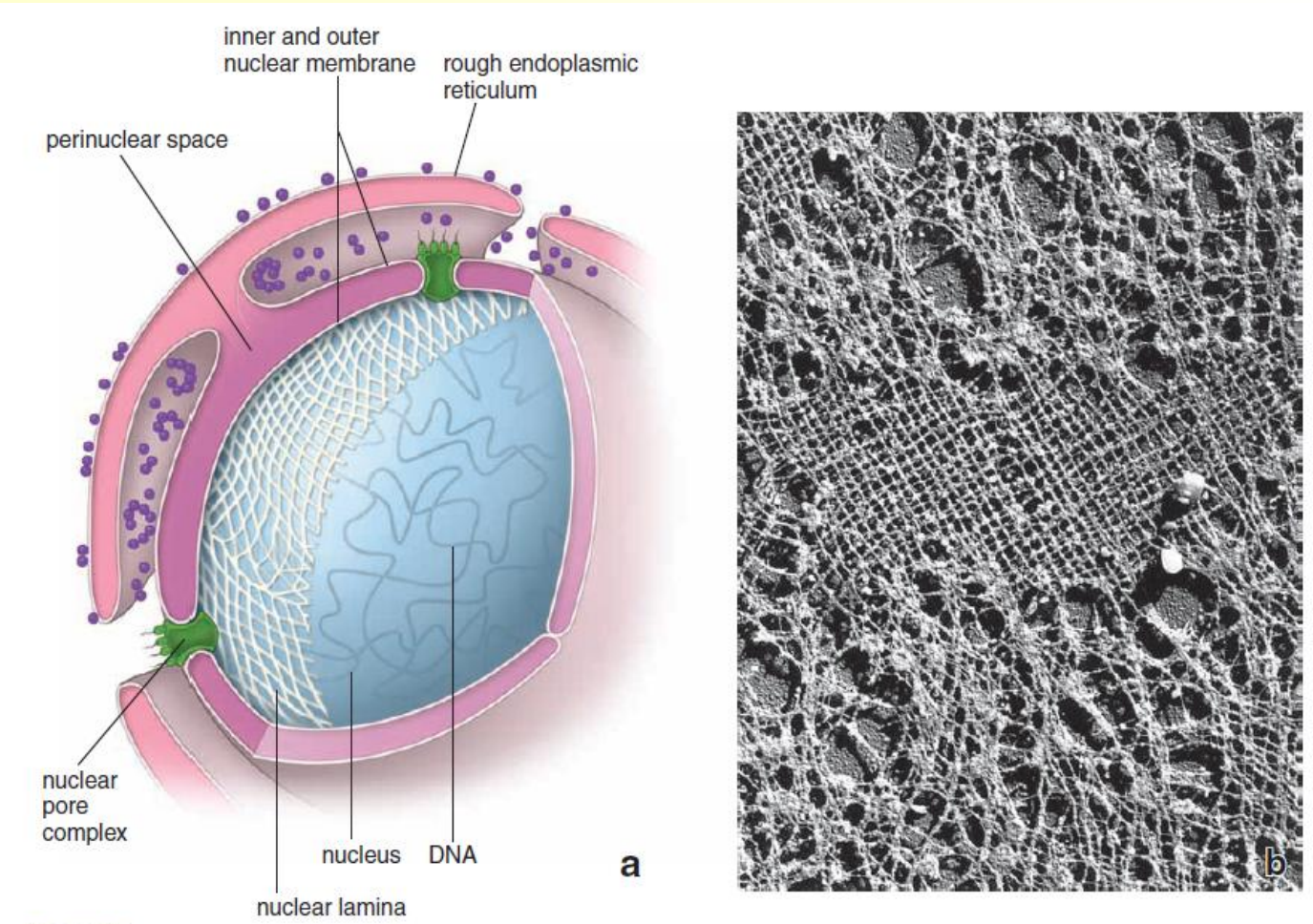


FIGURE 3.6 ▲ Structure of the nuclear lamina. a. This schematic drawing shows the structure of the nuclear lamina adjacent to the inner nuclear membrane. The cut window in the nuclear lamina shows the DNA within the nucleus. Note that the nuclear envelope is pierced by nuclear pore complexes, which allow for selective bidirectional transport of molecules between nucleus and cytoplasm. **b.** Electron micrograph of a portion of the nuclear lamina from a *Xenopus* oocyte. It is formed by intermediate filaments (lamins) that are arranged in a square lattice. ×43,000. (Adapted from Aebi U, Cohn J, Buhle L, Gerace L. The nuclear lamina is a meshwork of intermediate-type filaments. Nature 1986;323:560–564.)

NUCLEUS: structure

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1. Nuclear membrane or nuclear envelope

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4. Nucleolus

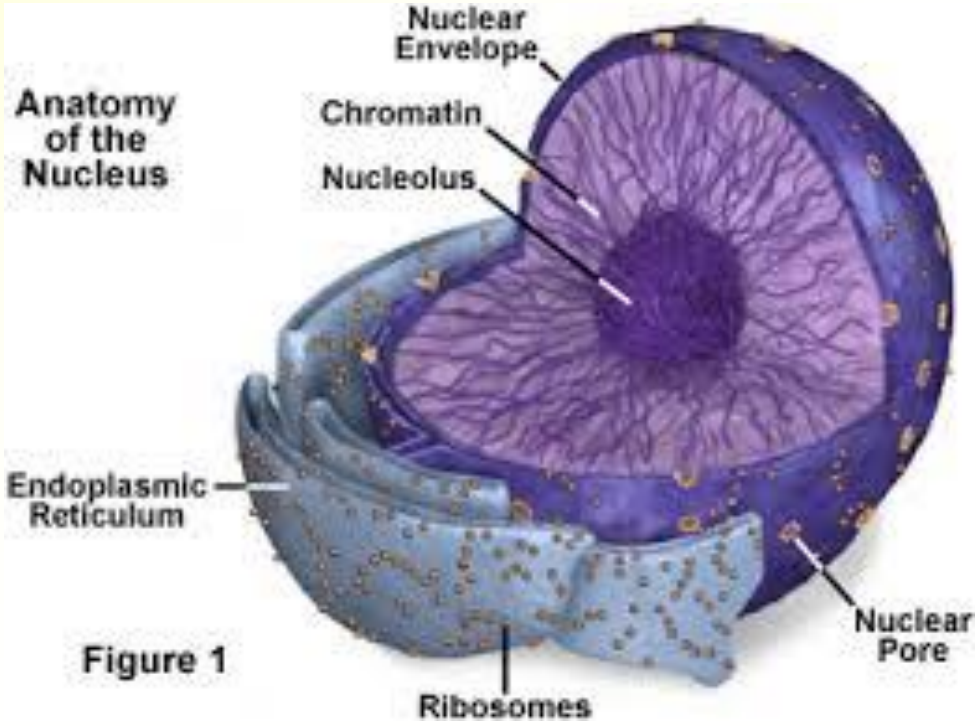
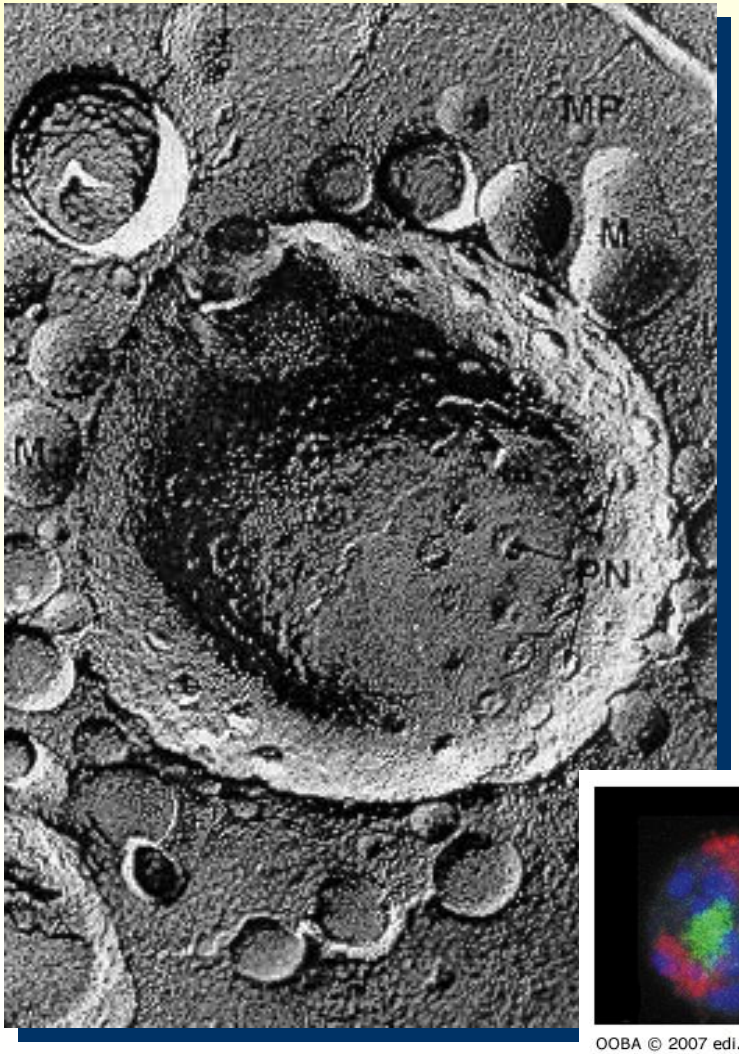


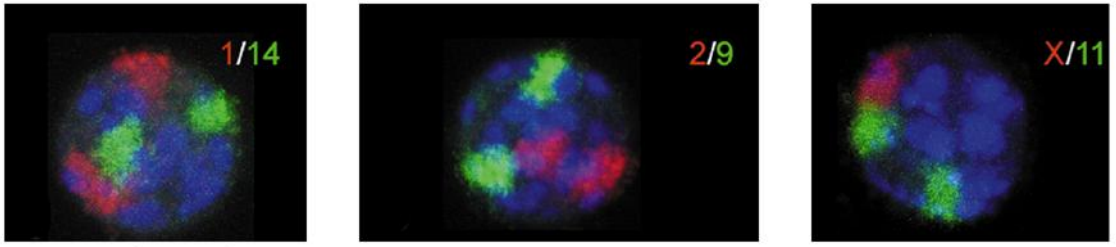
Figure 1

NUCLEUS: Function



Within the nucleus, several precisely regulated processes take place, such as:

- **Genome duplication**
- **Transcription and RNA processing**
- **Temporal control of gene expression**
- **DNA repair**
- **Ribosome synthesis**

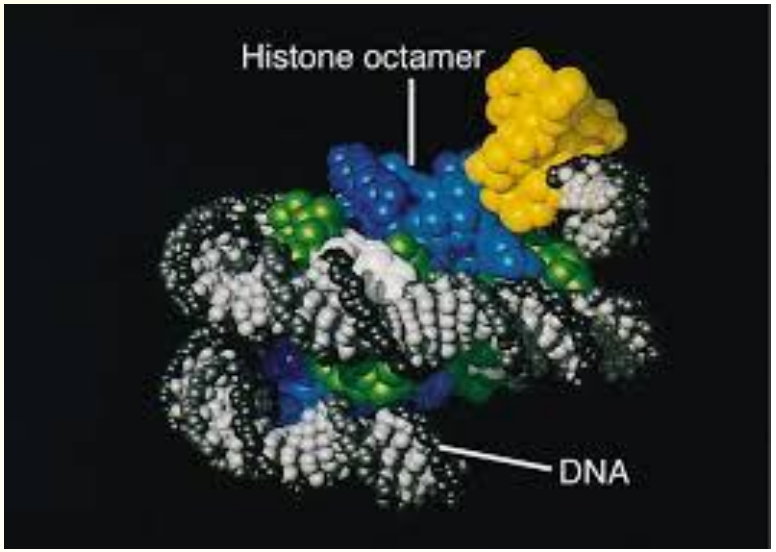


Colored nuclei obtained using the Fluorescent In Situ Hybridization (FISH) technique.

NUCLEUS: Function

Contain:

1) 30 % of DNA
2) 15 % of RNA
3) nucleoproteins: histones and non-histone proteins

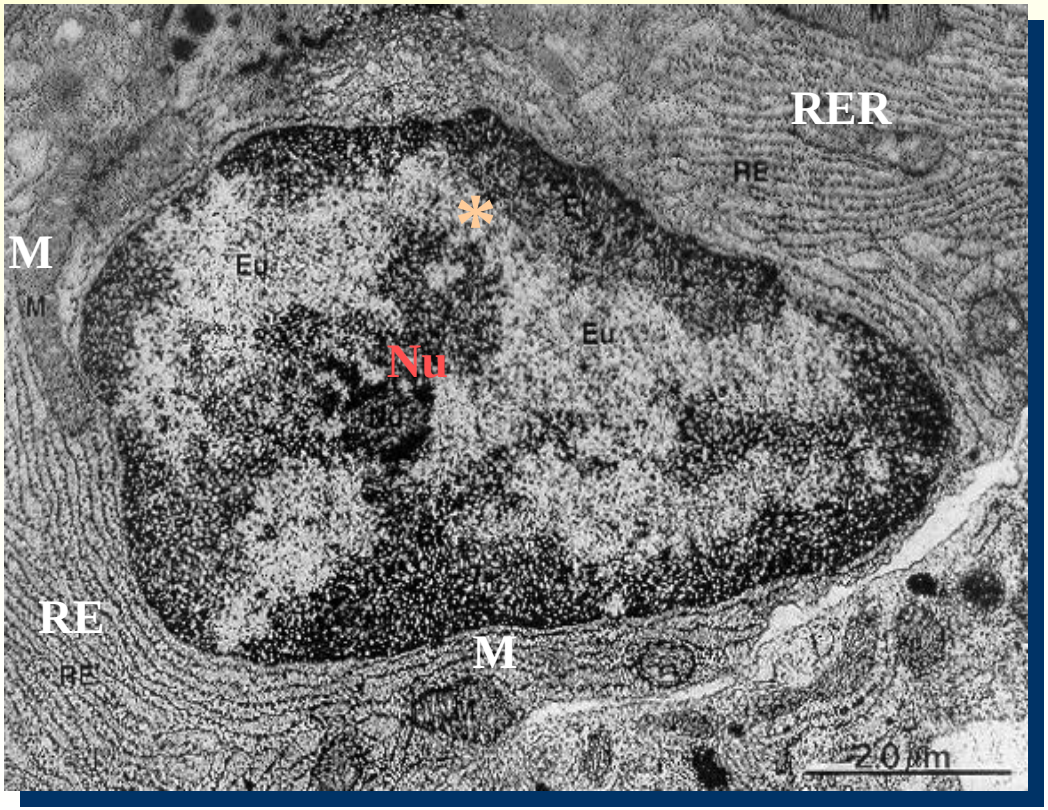


Histones: basic proteins that bind to DNA, forming ***nucleosomes*** and contributing to chromatin structure and compaction.

Non-histone proteins: a diverse group of nuclear proteins involved in regulating DNA replication, transcription, repair, and chromatin organization.

NUCLEUS: Chromatin

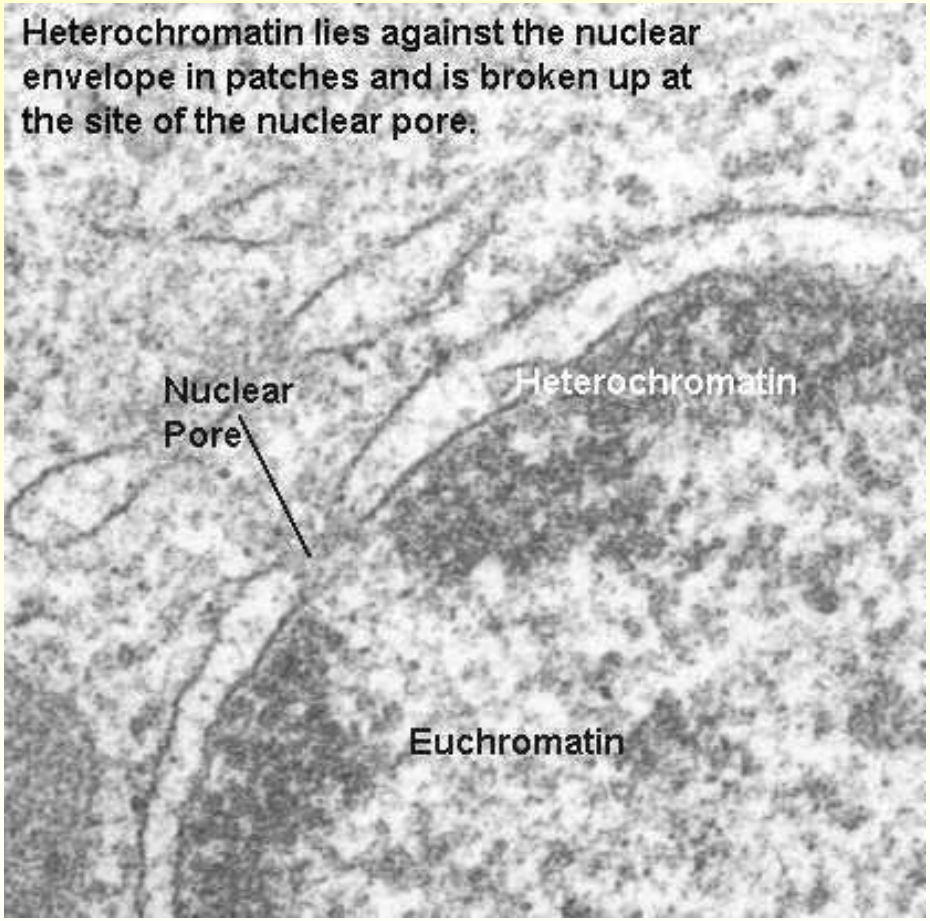
Chromatin, a complex of DNA and proteins, is responsible for the characteristic basophilia of the nucleus.



Chromatin :
DNA + Proteins

Chromosomes:
folding of chromatin that which occurs during mitosis

NUCLEUS: Chromatin

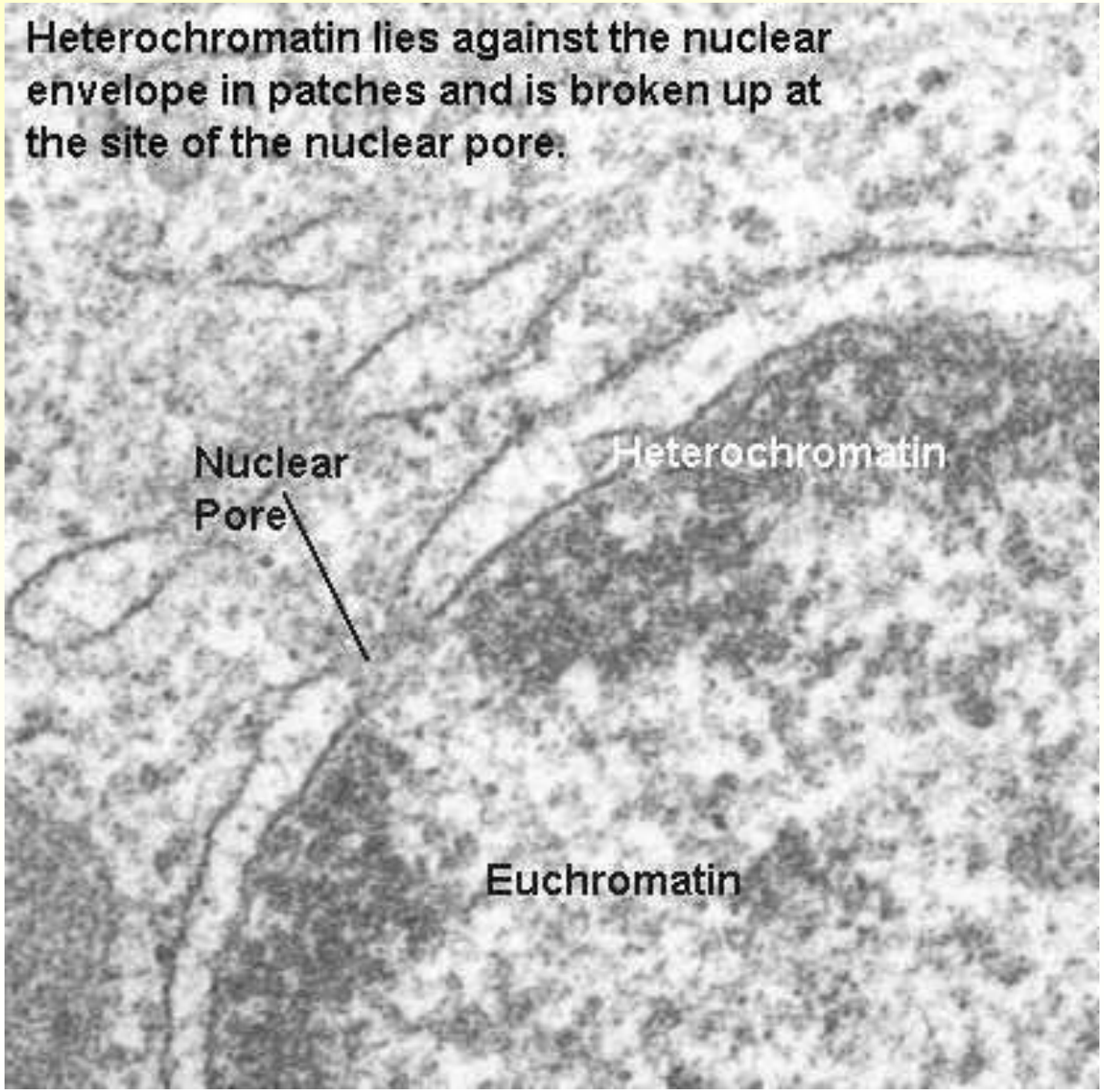


two forms of chromatin are found in the nucleus:

- **a condensed form called *heterochromatin (inactive form)***

- **and a dispersed form called *euchromatin* (*active form*)**

NUCLEUS: Chromatin



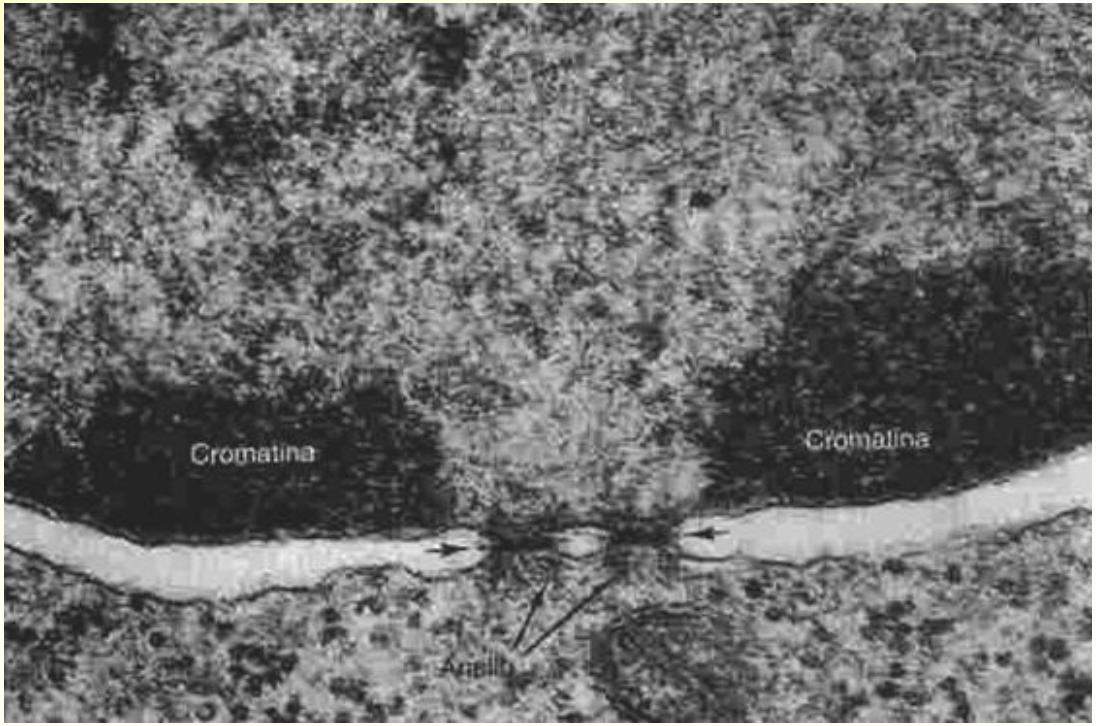
Heterochromatin is disposed in three locations :

• **Marginal chromatin** is found at the periphery of the nucleus (the structure light microscopists formerly referred to as the nuclear membrane actually consists largely of marginal chromatin).

• **Karyosomes** are discrete bodies of chromatin irregular in size and shape that are found throughout the nucleus.

• **Nucleolar-associated chromatin** is chromatin found in association with the nucleolus.

NUCLEUS: Chromatin



Chromatin is absent in front of the pores, revealing the so-called **interchromatin channels**

NUCLEUS: Chromatin

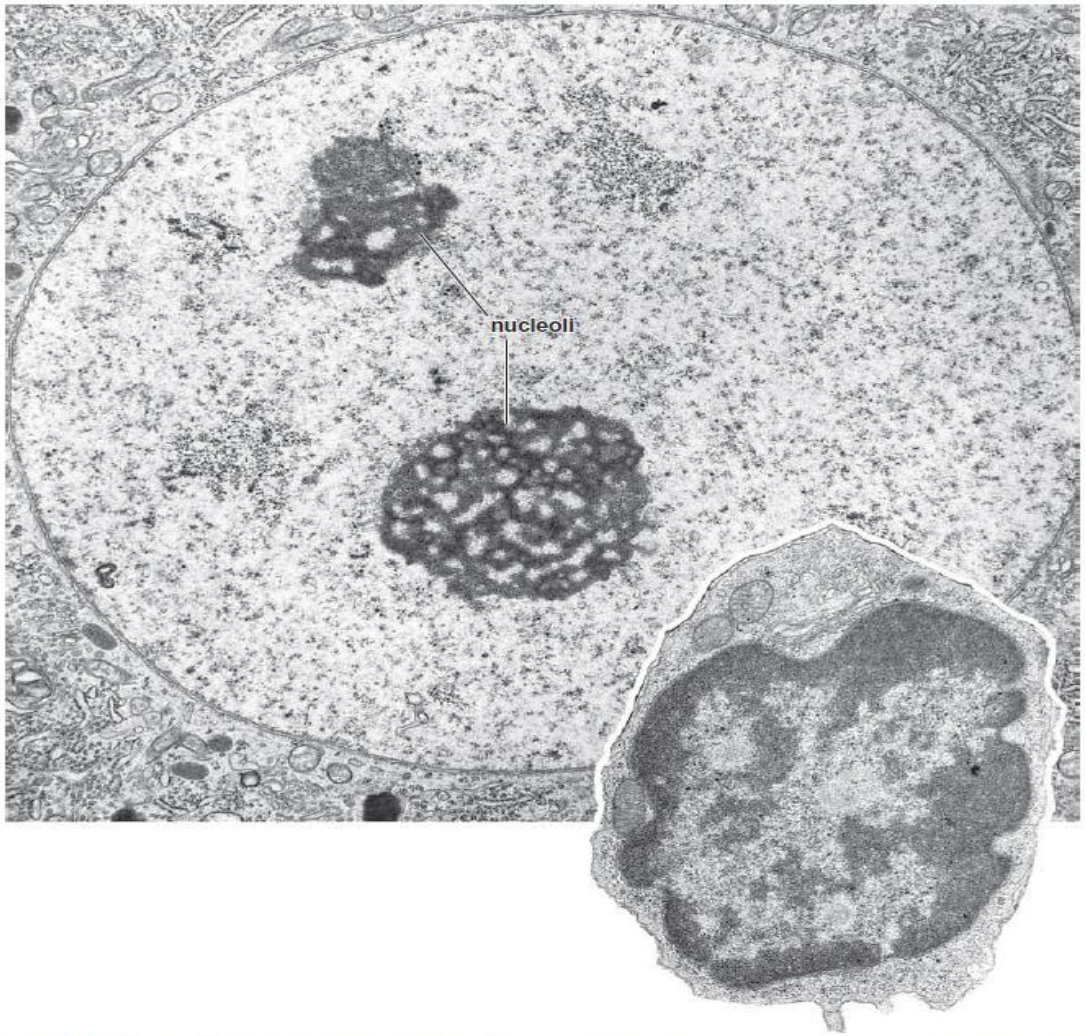
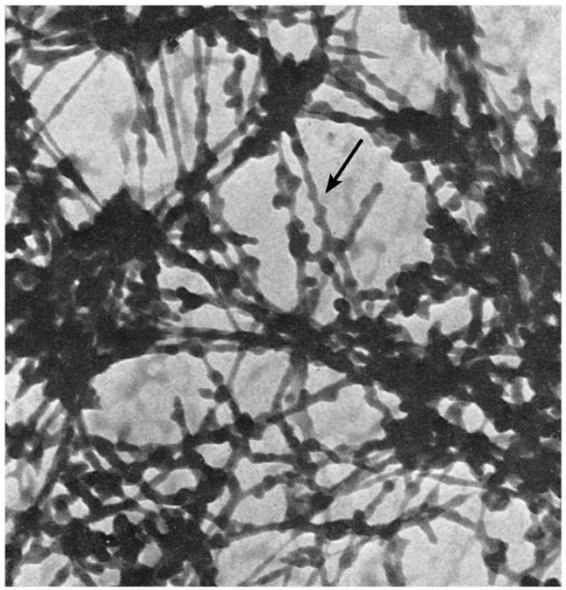
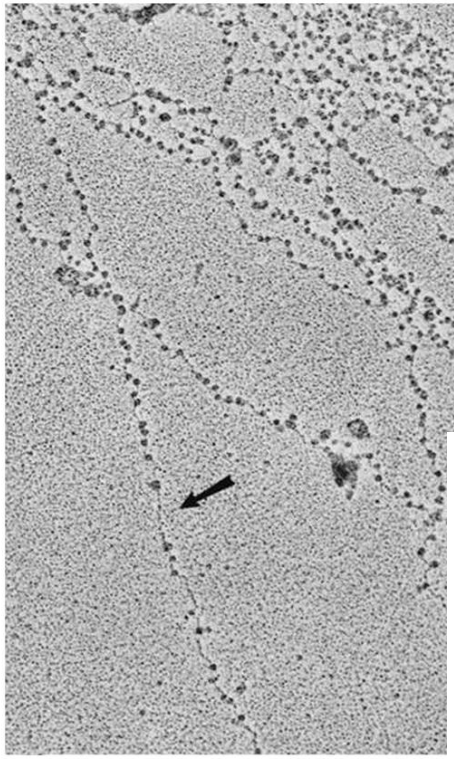


FIGURE 3.2 ▲ Electron micrographs of nuclei from two different cell types. The large electron micrograph shows the nucleus of a nerve cell. Two nucleoli are included in the plane of section. The nucleus of this active cell, exclusive of the nucleoli, comprises almost entirely extended chromatin or euchromatin. ×10,000. **Inset.** The smaller nucleus belongs to a circulating lymphocyte (the entire cell is shown in the micrograph). It is a relatively inactive cell. Note the paucity of cytoplasm and cytoplasmic organelles. The chromatin in the nucleus is largely condensed (heterochromatin). The lighter areas represent euchromatin. ×13,000.

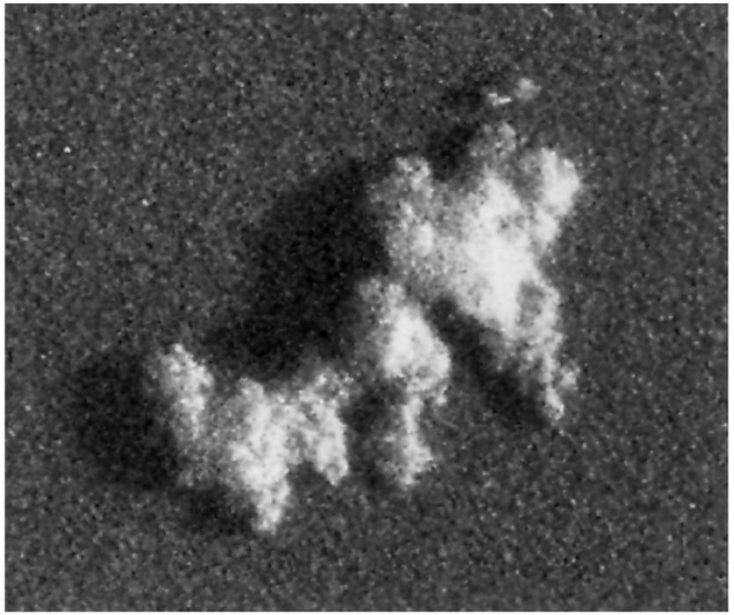
Struttura della cromatina



During ME observation, Euchromatin appears in the form of strands (30 nm).

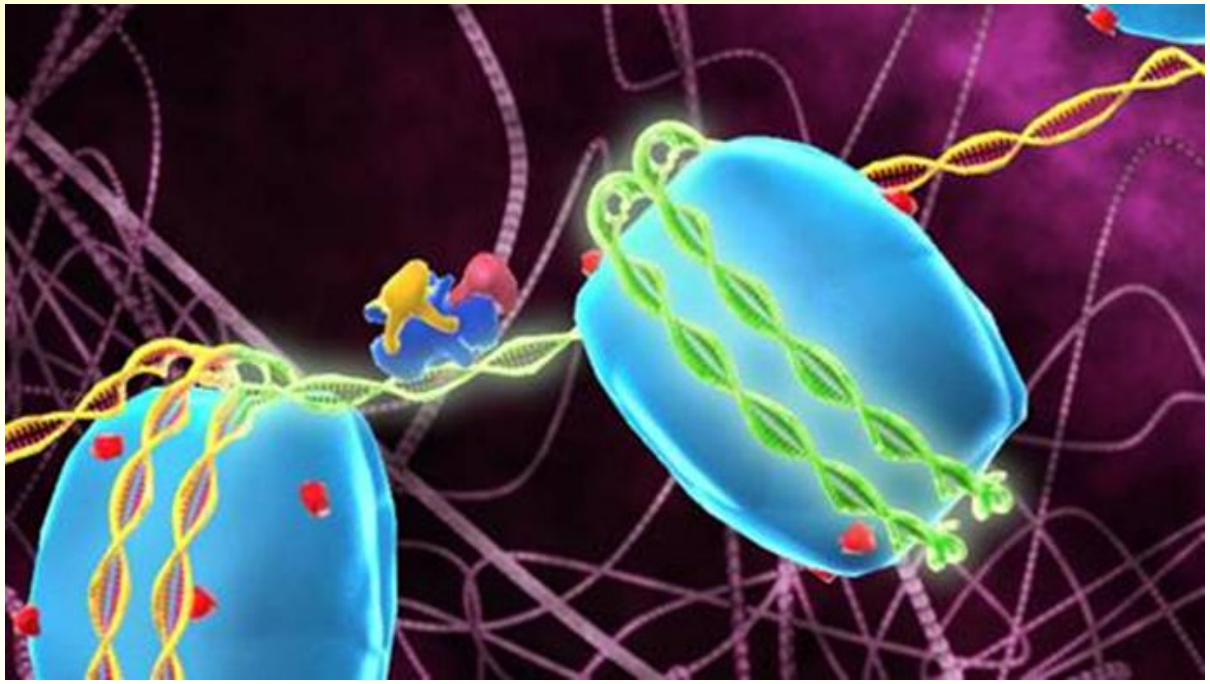


At high magnification, it can be seen that these strands can be unraveled , they look like threads and beads of a rosary (11 nm).



NUCLEUS: Chromatin structure

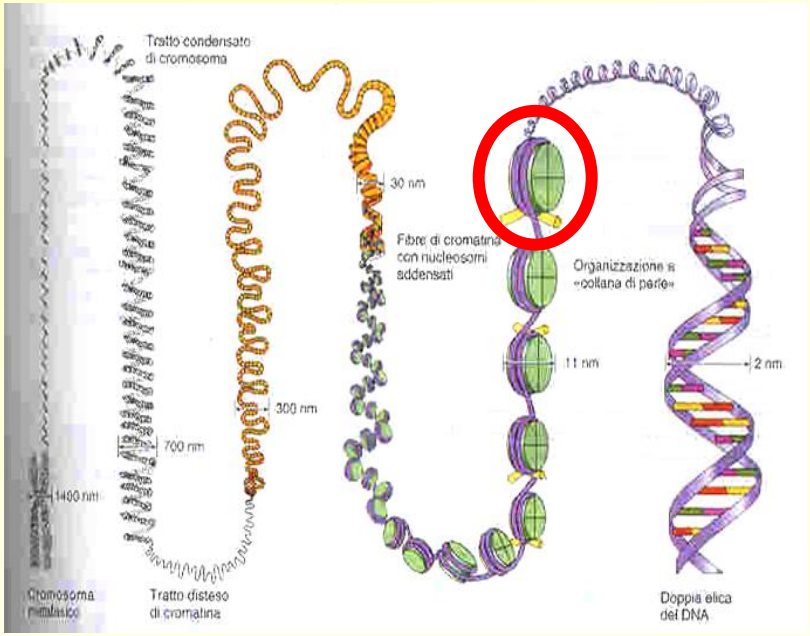
The **smallest units of chromatin structure are** macromolecular **complexes of DNA and histones** called **nucleosomes**.

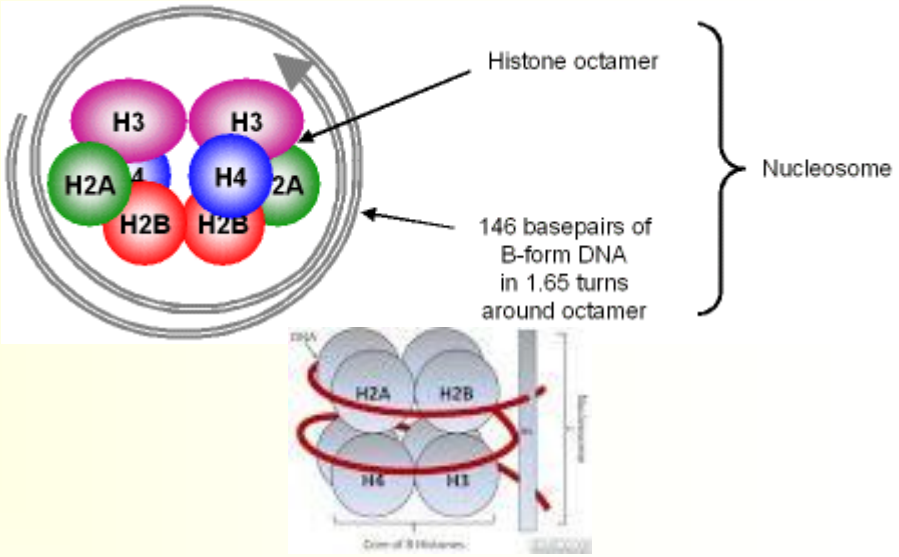


nucleosomes

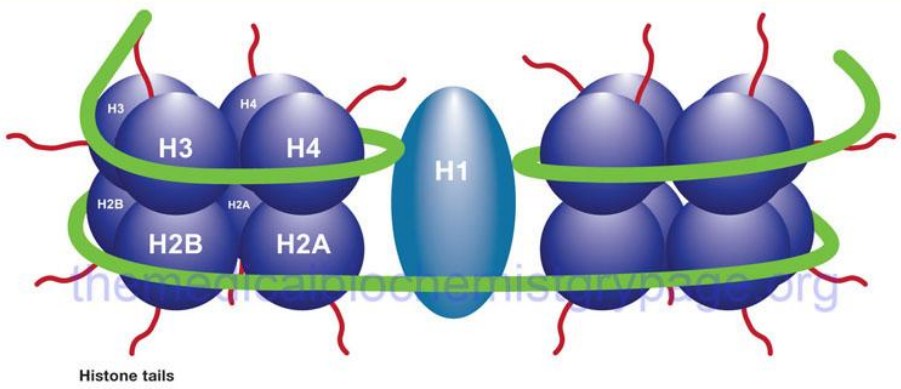
Adjacent nucleosomes are linked by linear stretches of DNA strands, **DNA linkers**.

NUCLEUS: Chromatin structure

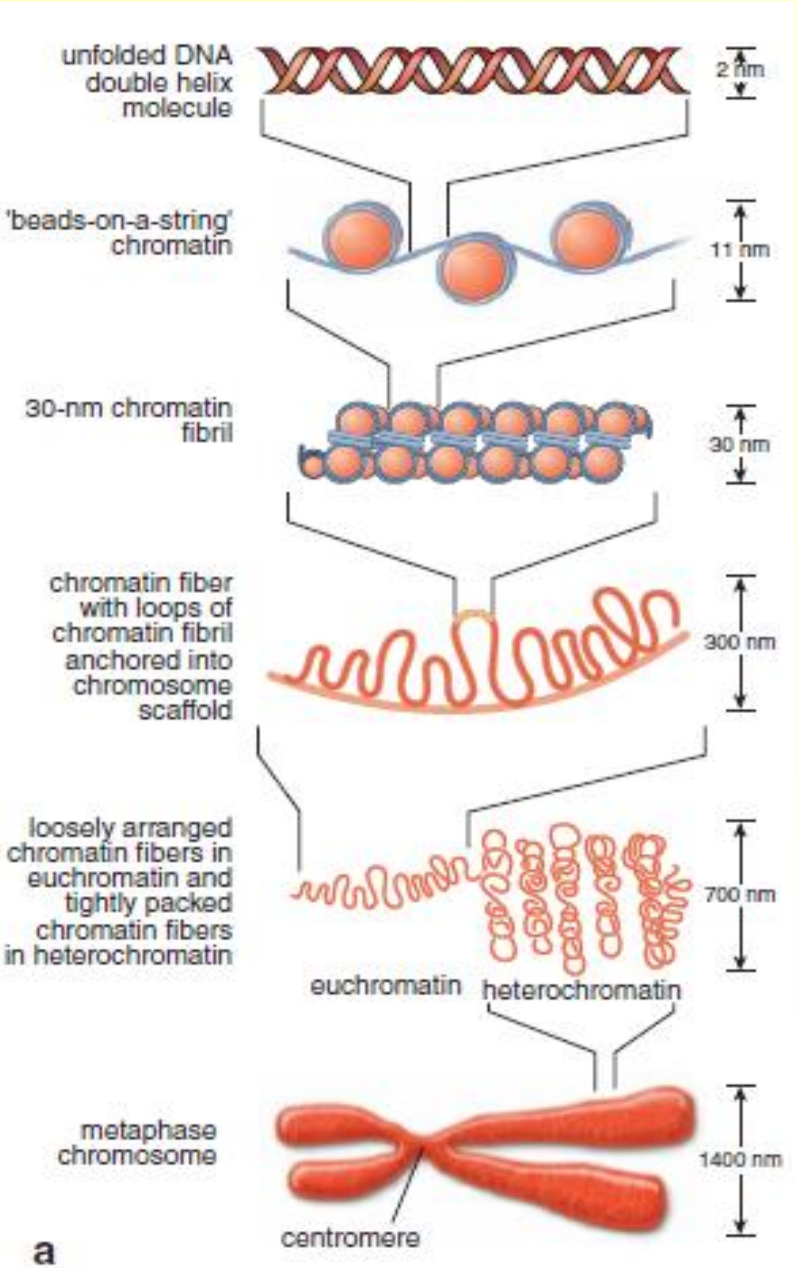


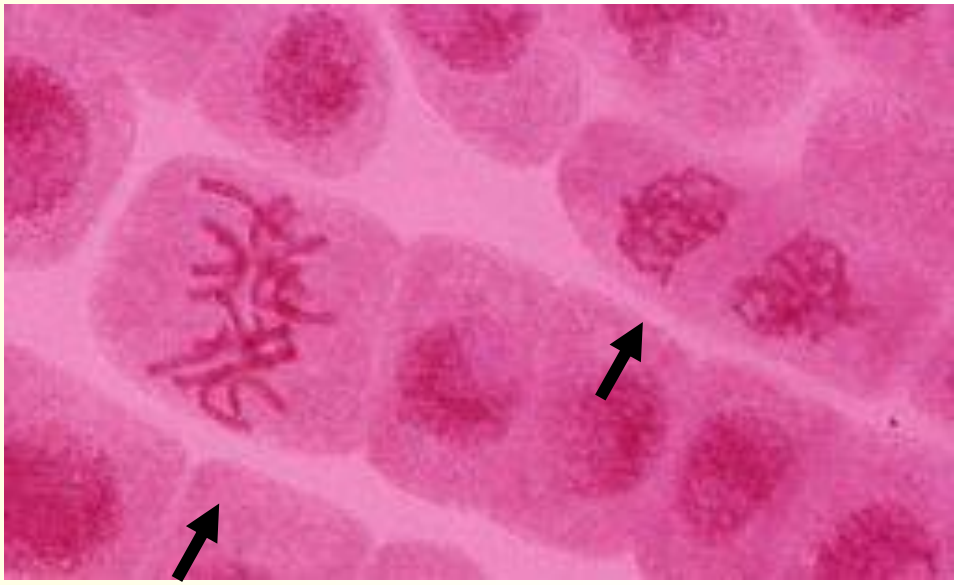


The nucleosome consists of an octamer formed by four different histone proteins (H1, H2A, H2B, H3, H4) present in pairs. The nucleosome is wrapped in a double turn of DNA strand that continues from one nucleosome to another with the linker DNA.

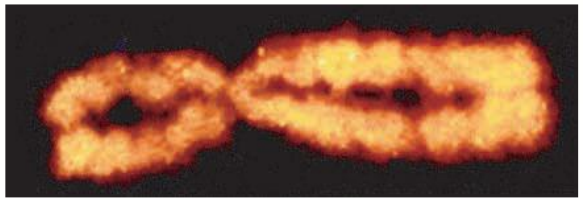


NUCLEUS: Chromatin structure

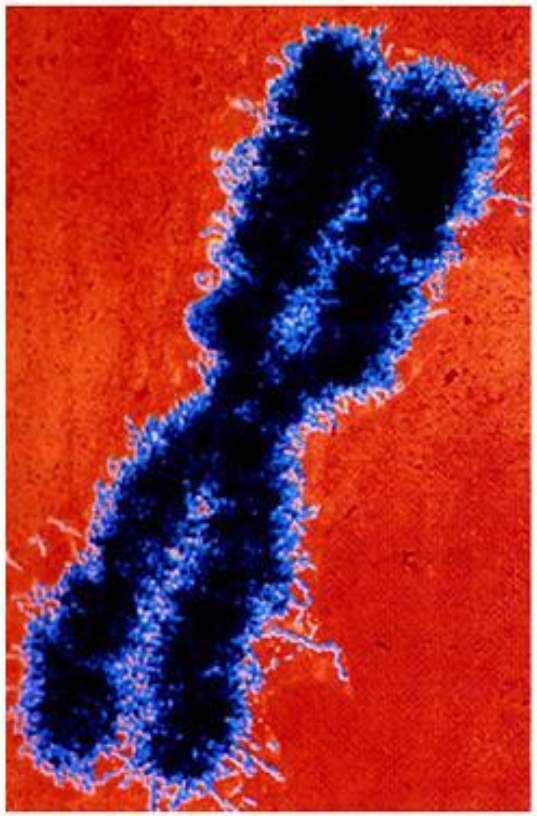




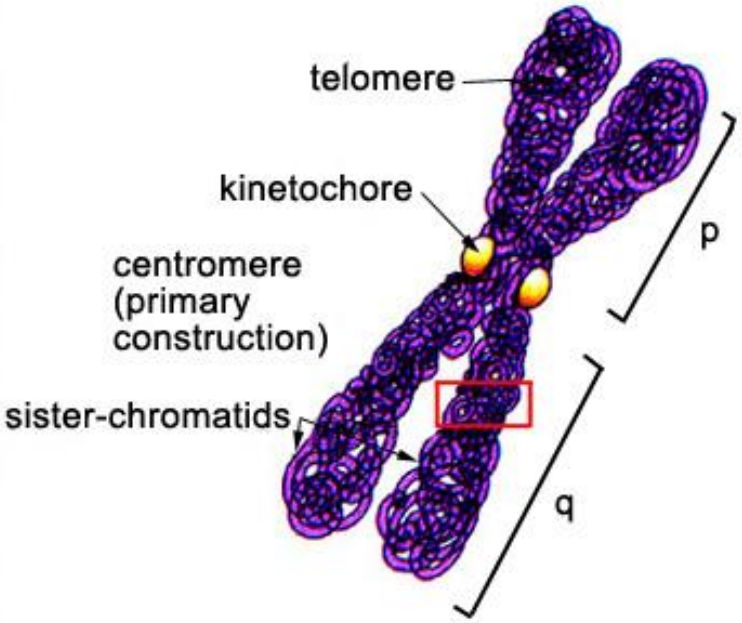
In dividing cells, chromatin is condensed and organized into discrete bodies called **chromosomes** visible under the optical microscope

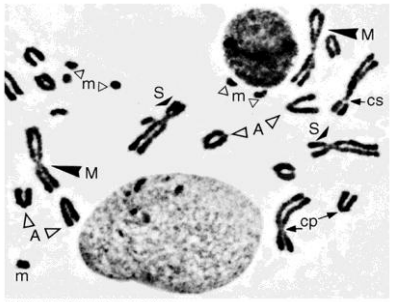


NUCLEUS: Chromatin structure

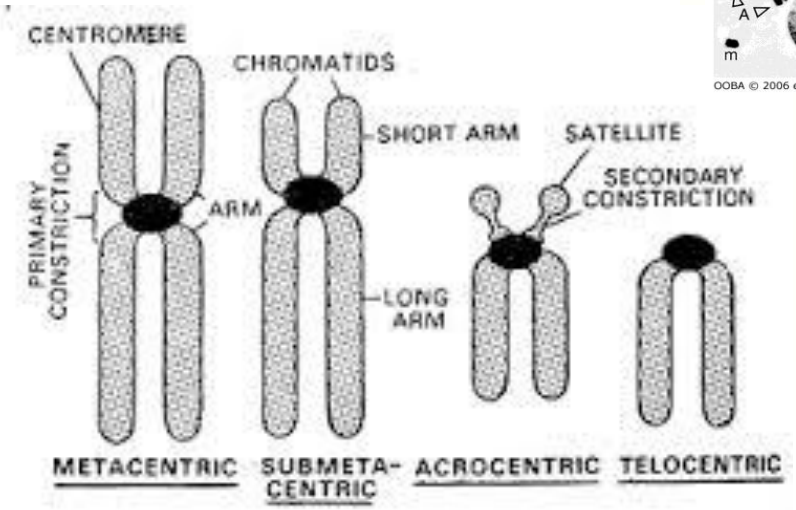


Chromosomes





Morphological classification
of Chromosomes

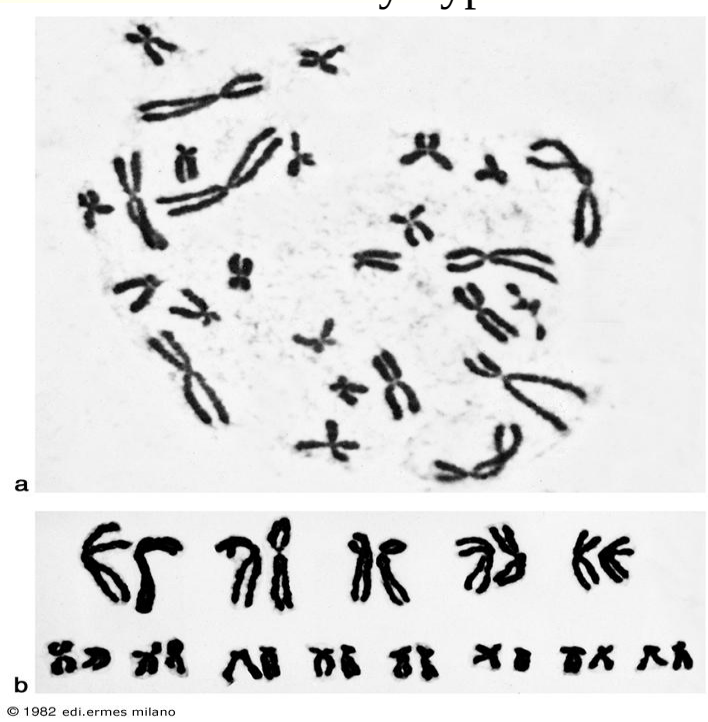


NUCLEUS: Chromatin structure

Chromosomes

The number of chromosomes in somatic cells is fixed for a species and constitutes the GENOME.

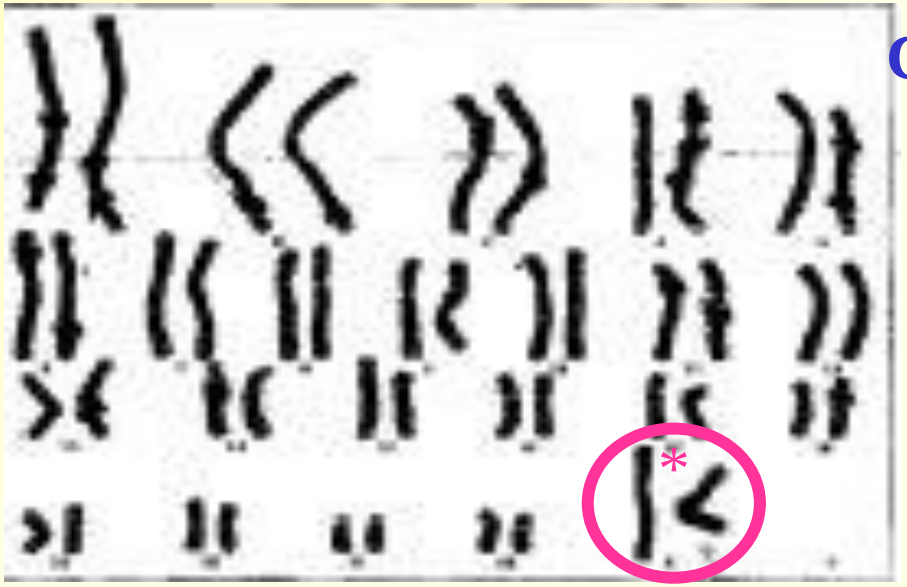
karyotype



Humansomatic cells contain **46 chromosomes** organized as **23 homologous pairs**

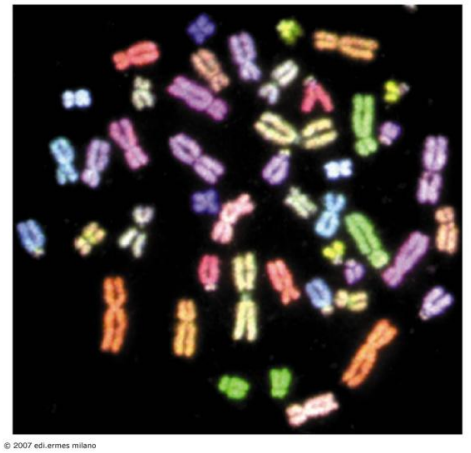
In a karyotype, chromosome pairs are sorted according to their size, shape, and emitted fluorescent color

NUCLEUS: Chromatin structure



Chromosomes

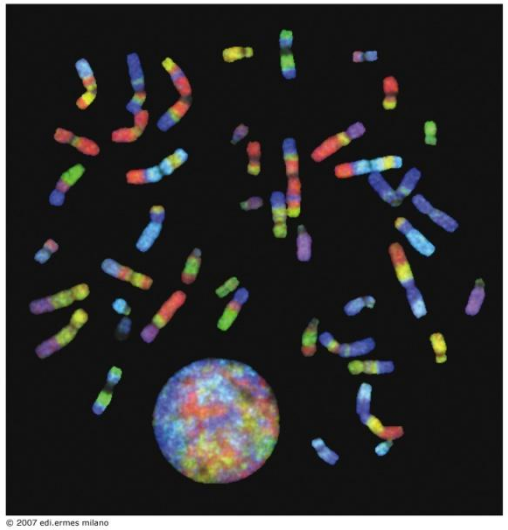
Stained human chromosome slide
DNA-FISH technique



Human
23 Pairs

22 pairs
AUTOSOMES

*
SEX
CHROMOSOMES
(XX
XY)



Human chromosome array stained using the Harlequin-FISH method

NUCLEUS: Chromatin structure

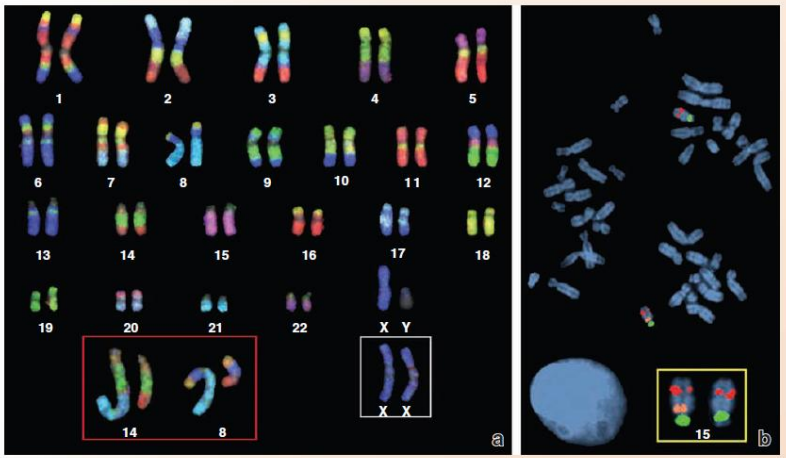
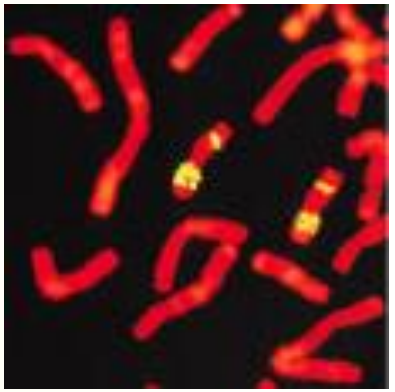


FIGURE F3.1.1 ▲ **Karyotypes obtained with the FISH technique. a.** Karyotype of a normal male. The *white box inset* shows the XX chromosome pair of a normal female. The *red box inset* reveals an abnormality in chromosomes 14 and 8. (Courtesy of the Applied Imaging International Ltd., Newcastle upon Tyne, United Kingdom.) **b.** A metaphase spread from a patient with Prader-Willi/Angelman syndrome. The *yellow box inset* shows the enlarged pair of chromosome 15. (Courtesy of Dr. Robert B. Jenkins.)

Chromosomes



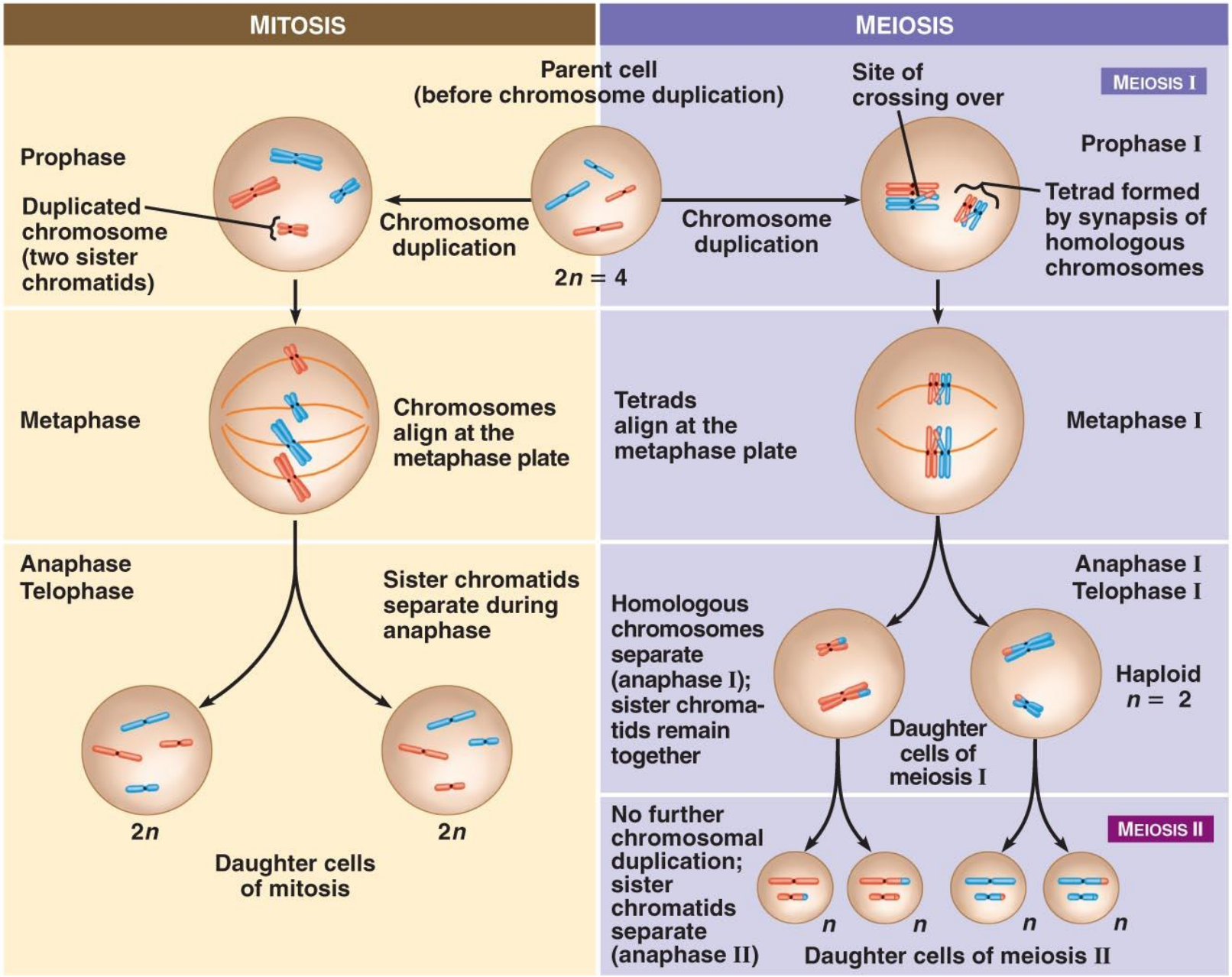
Cells

contain the entire chromosome set (somatic cells)

Diploid (2n)

contain one of the two homologous chromosomes of the pair (germ cells)

Aploid (n)



Number of Chromosomes

Species	Number of Chromosomes
Chimpanzee	48
Horse	64
Donkey	62
Dog	78
Cat	38
Mouse	40
Chicken	78
Frog	26
Fly	12
Fruit fly (*Drosophila*)	8
Oak	24
Cherry tree	32
Pea	14
Tomato	24

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4. Nucleolus

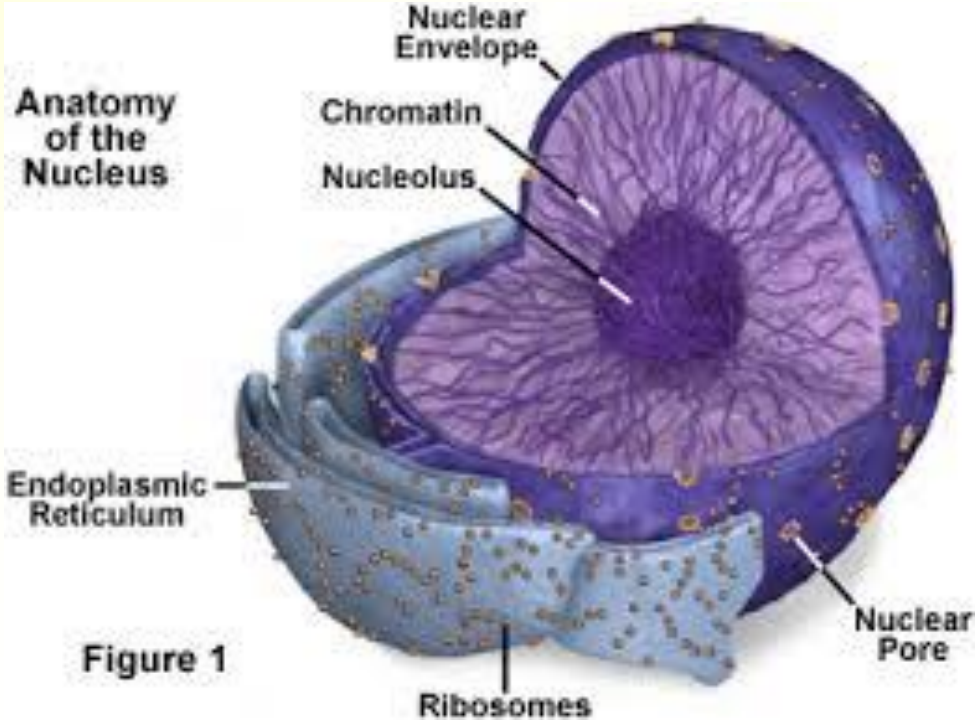
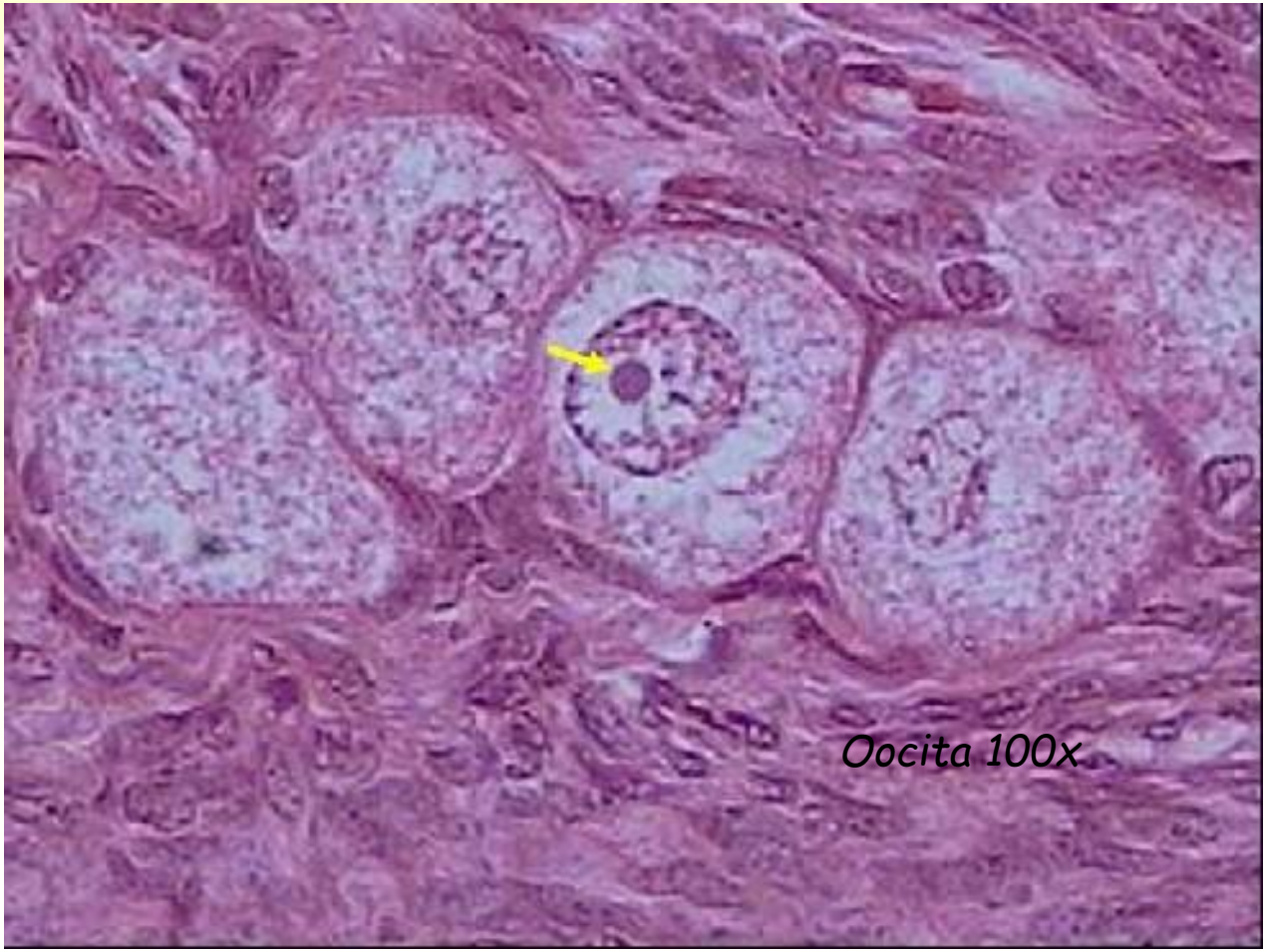


Figure 1

NUCLEUS: Nucleulus

The nucleolus in MO appears as a spherical corpuscle located eccentrically in the nucleus.



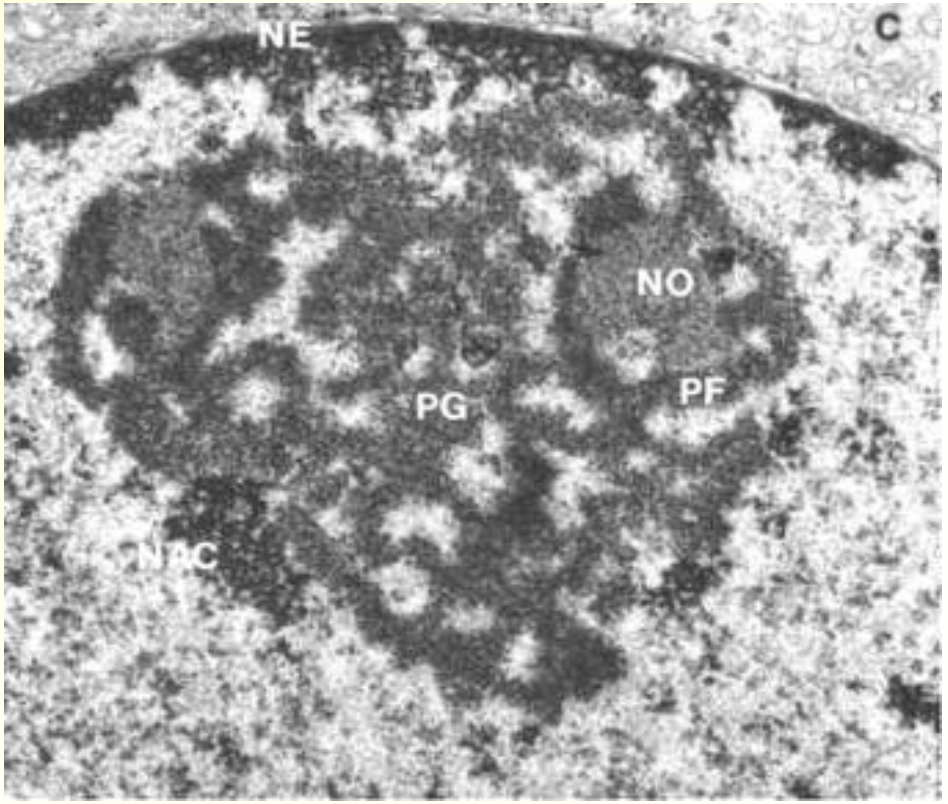
NUCLEUS: Nucleulus

NUCLEOLUS HAS THREE MORPHOLOGICALLY DISTINCT REGIONS:

Fibrillar centers contain DNA loops of fi ve different chromosomes that contain rRNA genes, RNA polymerase I, and transcription factors.

Fibrillar material (pars fibrosa) contains ribosomal genes that are actively undergoing transcription and large amounts of rRNA.

Granular material (pars granulosa) represents the site of initial ribosomal assembly and contains densely packed preribosomal particles



The nucleolus forms around nucleolus organizer regions (NORs), which consist of rDNA repeat clusters typically distributed across multiple chromosomes.

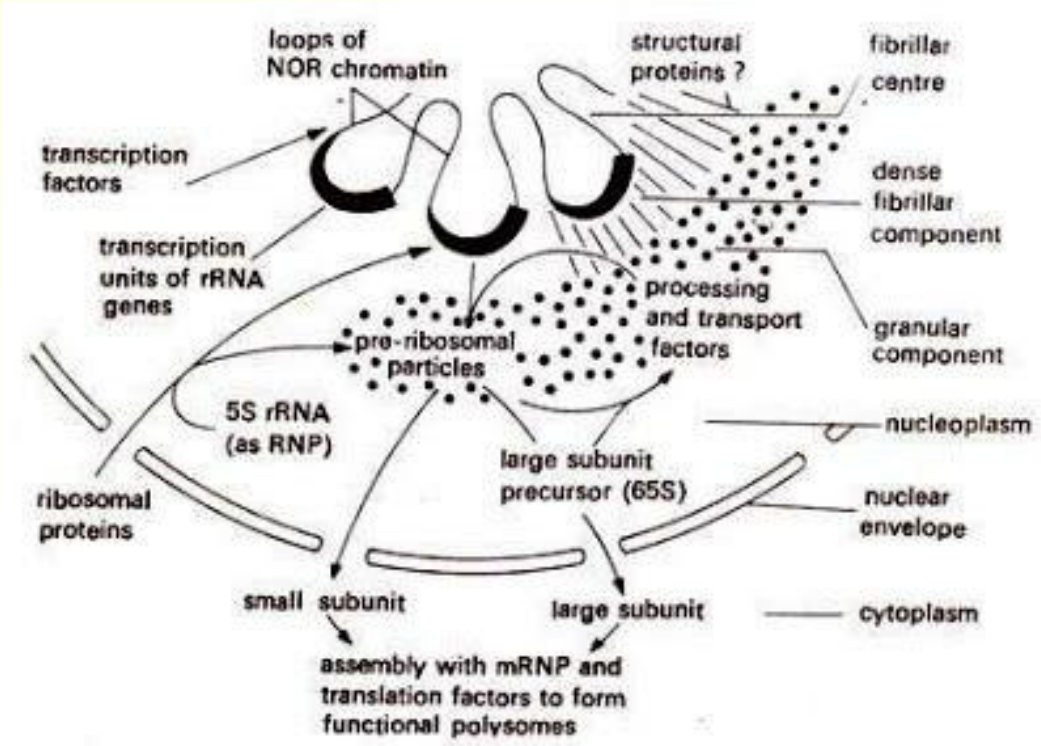
NUCLEUS: Nucleulus

A specialized structure that includes:

1.A group of **genes** carrying the information for ribosomal RNA (rRNA).
2.The corresponding **RNA transcripts**.
3.Newly synthesized ribosomes.
It contains ribosomal particles at various stages of assembly.

Biogenesis of Ribosomes in the Nucleolus:

After their assembly, ribosomal subunits are exported into the cytoplasm through the nuclear pores.



DNA Structure and Genetic Information

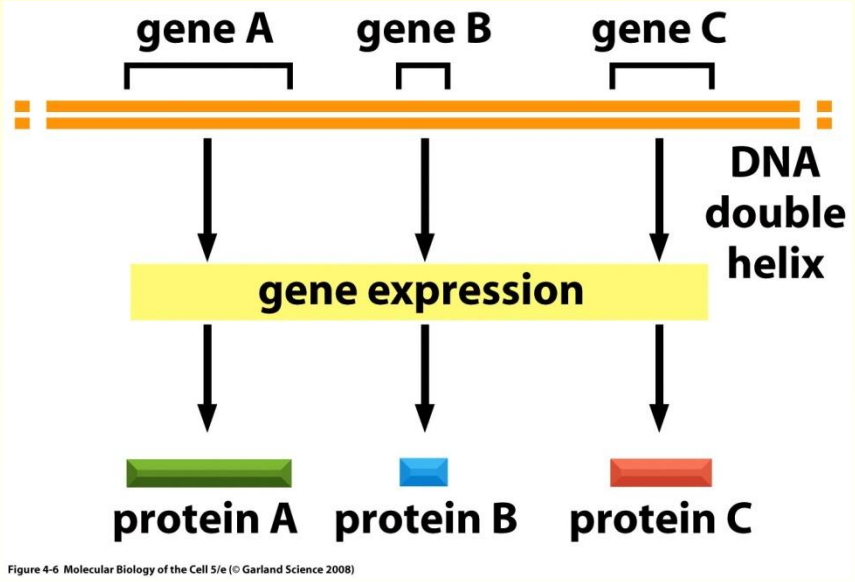
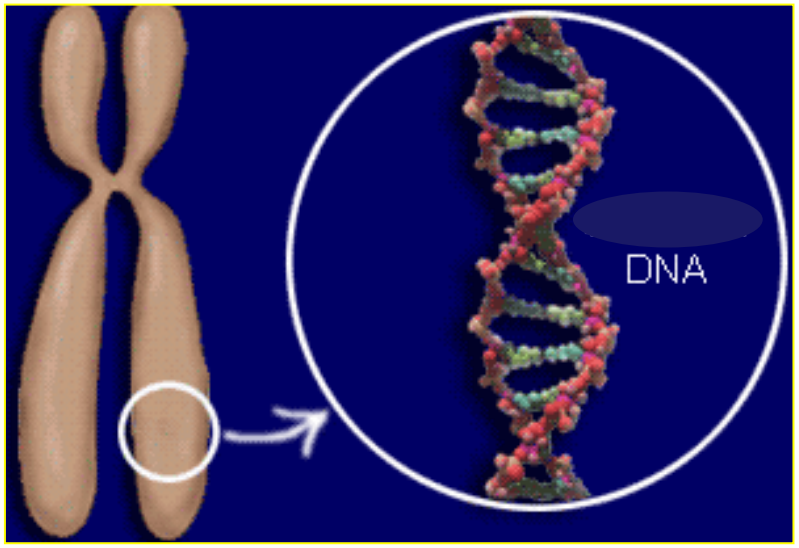


Figure 4-6 Molecular Biology of the Cell 5/e (© Garland Science 2008)



DNA carries the hereditary information of the cell

DNA Structure and Genetic Information

A DNA Molecule Consists of Two Complementary Chains of Nucleotides

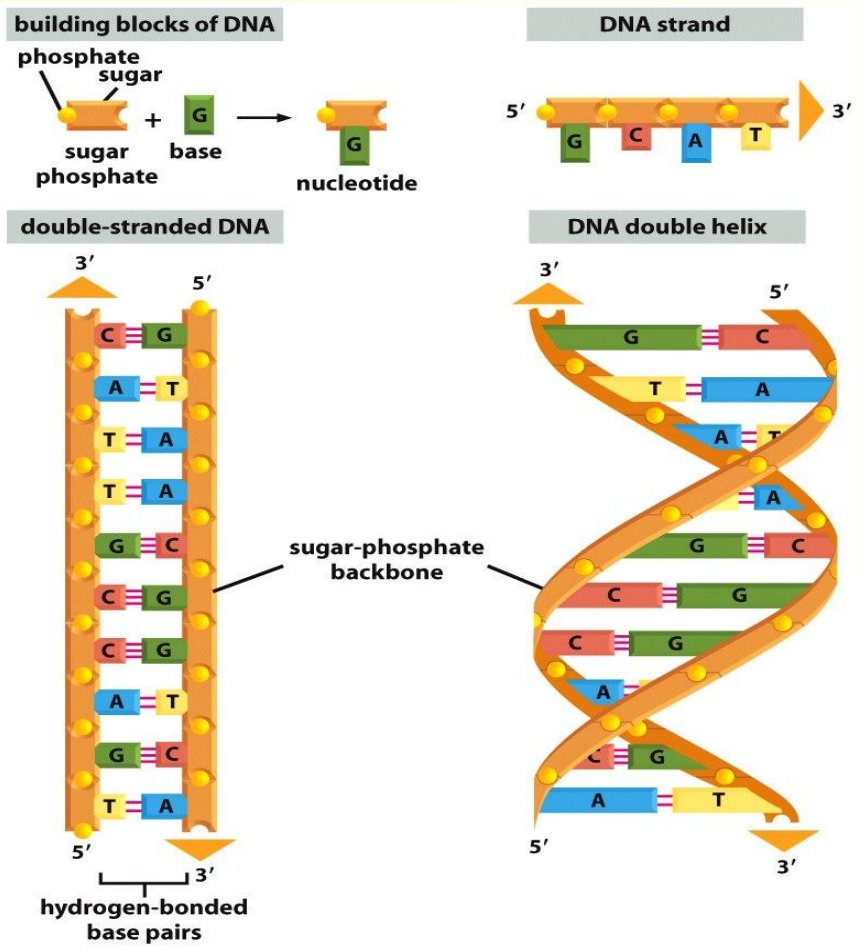


Figure 4-3 Molecular Biology of the Cell 5/e (© Garland Science 2008)

The bases pairs Complementary:
A always pairs with T,
and G always pairs with C

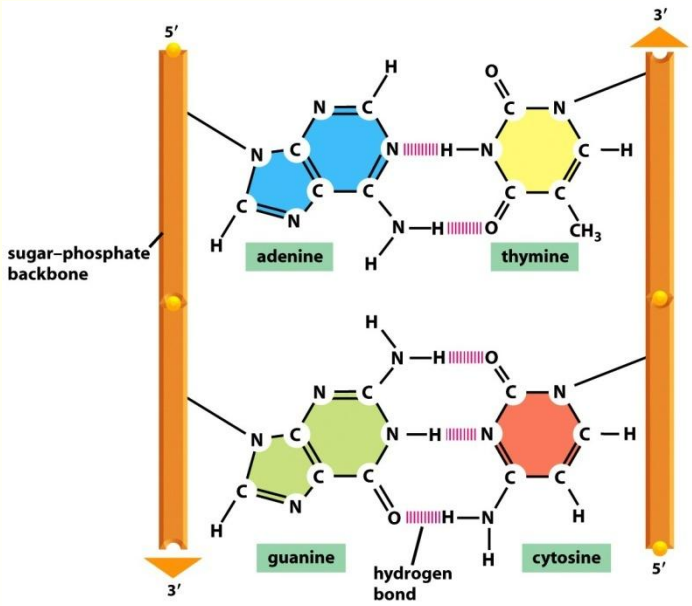


Figure 4-4 Molecular Biology of the Cell 5/e (© Garland Science 2008)

Information is encoded in the order, or sequence, of the nucleotides along each DNA strand.

Each base—A, C, T, or G—can be considered a letter in a four-letter alphabet that is used to spell out biological messages

Semiconservative DNA replication

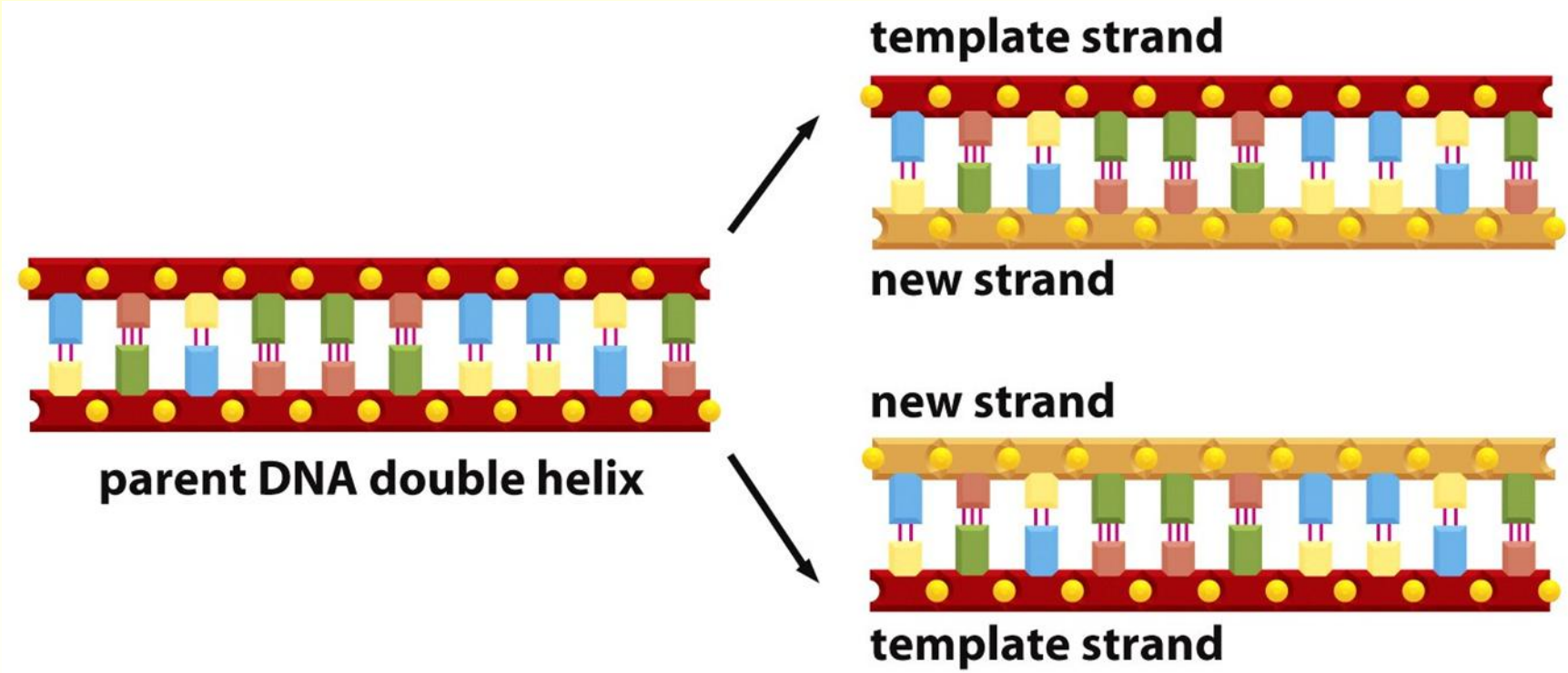
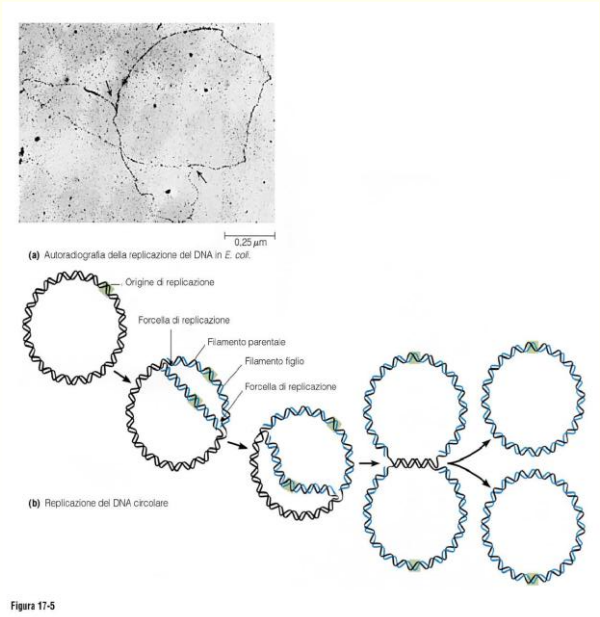


Figure 1-3 Molecular Biology of the Cell 5/e (© Garland Science 2008)

DNA replication process in prokaryotes and eukaryotes, the main structural and functional differences

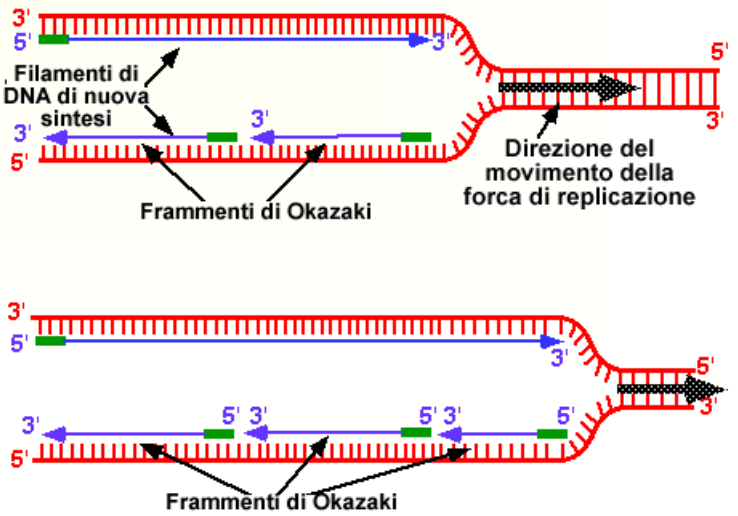
prokaryotes

•**Chromosome structure**: the chromosome is **circular**.
•**Origin of replication**: there is **a single starting point** (oriC) where replication begins.
•**Location of the process**: replication takes place **in the cytoplasm**, since prokaryotes **lack a nucleus**.



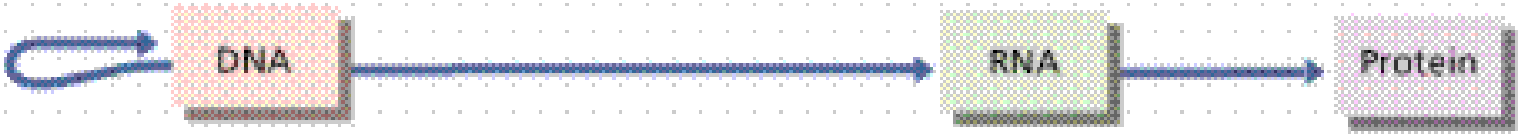
eukaryotes

•**Chromosome structure and length**: chromosomes are **linear** and **very long**.
•**Origins of replication**: there are **multiple origins** along each chromosome, allowing replication to occur more efficiently.
•**Okazaki fragments**: formed on the **lagging strand** during discontinuous DNA synthesis.
•**Location of the process**: replication occurs **inside the nucleus**, where the genetic material is located.

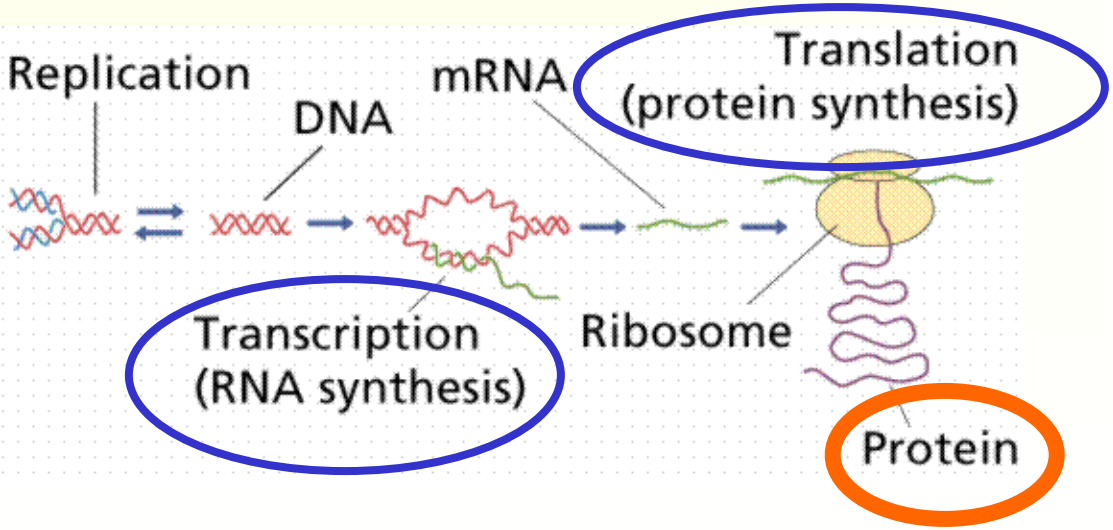


GENE

set of all nucleotides (DNA segment) involved in the production of a protein (and its isoforms)



For gene expression to occur, *transcription* and subsequent *translation* must take place.



From DNA to RNA

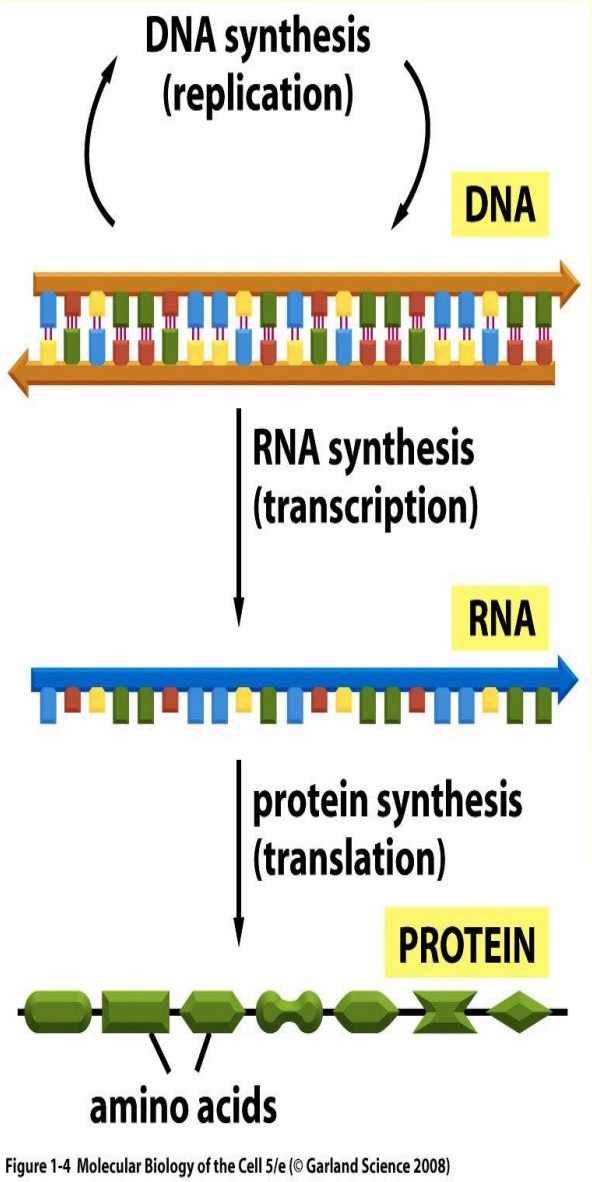
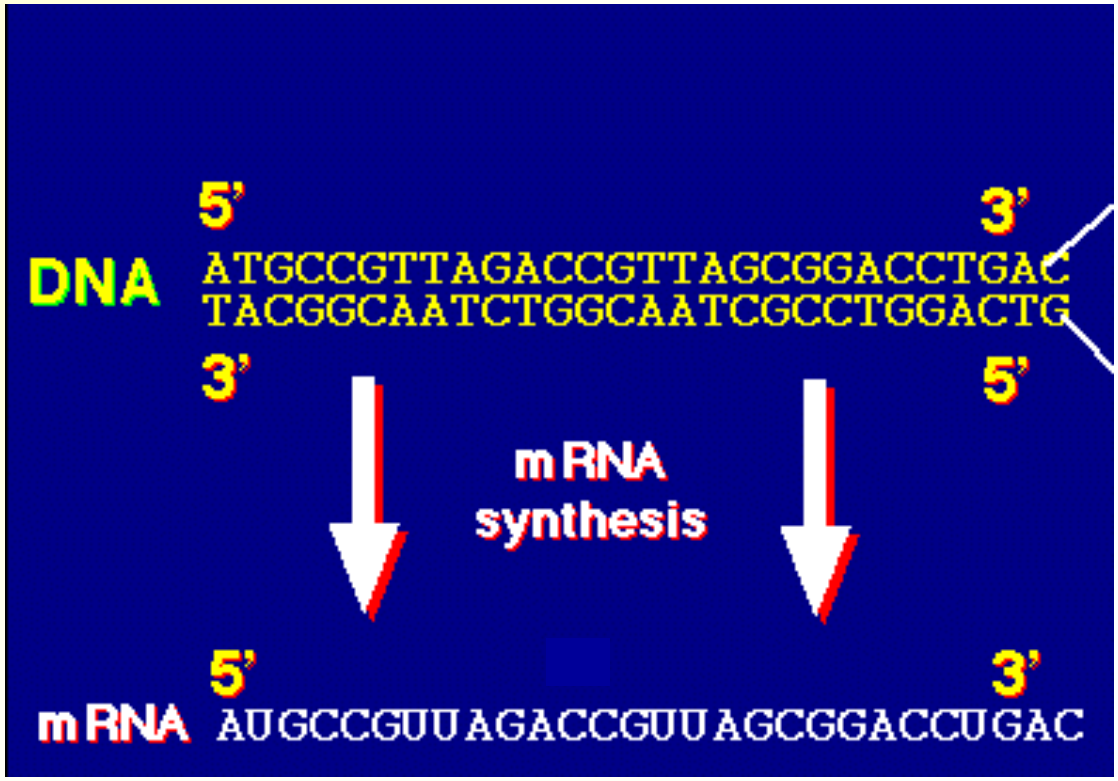


Figure 1-4 Molecular Biology of the Cell 5/e (© Garland Science 2008)



Each DNA strand acts as a template for the formation of a complementary RNA chain (**transcription**).

RNA chemical structure

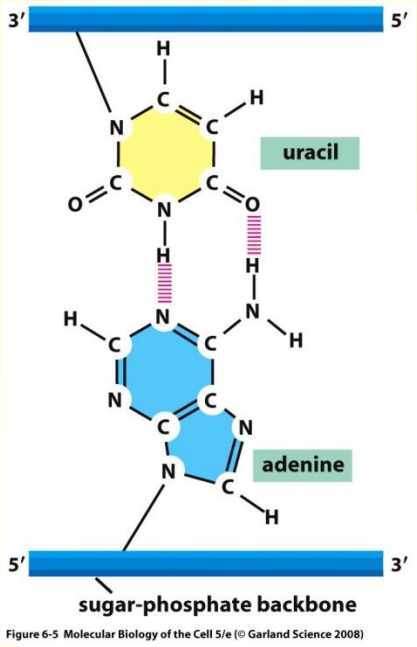
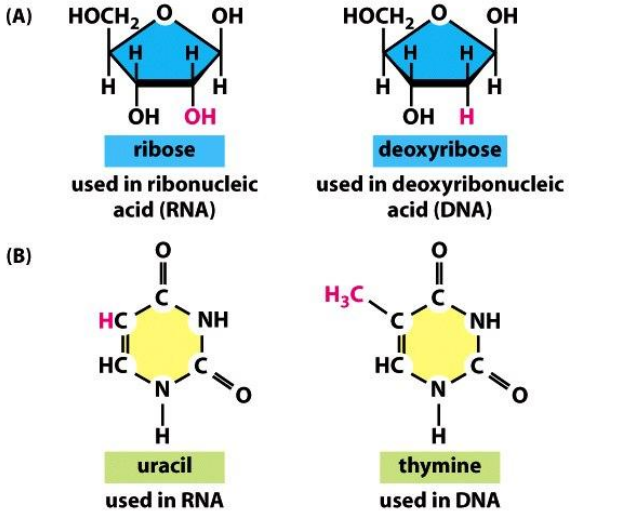


Figure 6-5 Molecular Biology of the Cell 5/e (© Garland Science 2008)



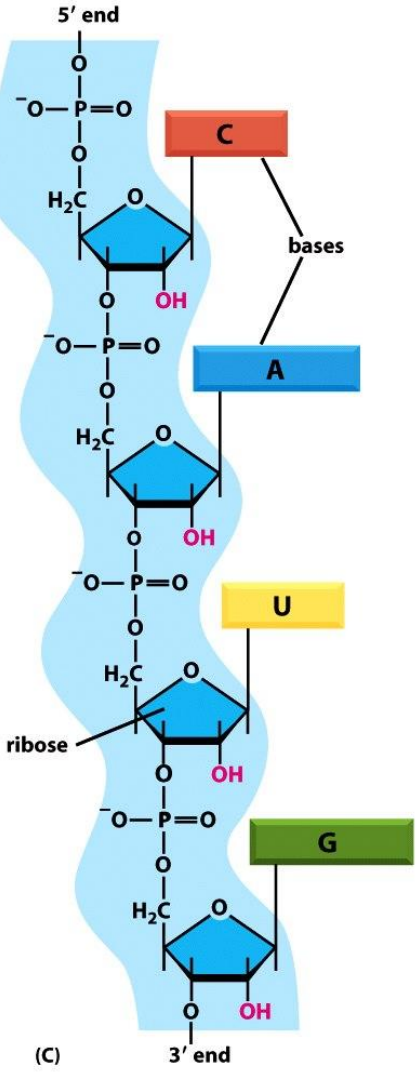


Figure 6-4 Molecular Biology of the Cell 5/e (© Garland Science 2008)

It consists of a single strand. It is made up of monomers (nucleotides) formed by nitrogenous bases (purines and pyrimidines), linked to C1 of the sugar, ribose, and a phosphate group (in position 5'). Unlike DNA, it contains uracil instead of thymine.RNA is synthesized in the nucleus but functions in the cytoplasm.

The three classes of RNA

- RNA messenger (m-RNA)
- RNA ribosomal (r-RNA)
- RNA transfer (t-RNA)

mRNA: its sequences can be “translated”into polypeptide chains

r-RNA: small strands of ribonucleic acid that are inserted with a structural function in ribosomes

tRNA:small RNA molecules able to transport aminoacids during protein synthesis

mRNA e Splicing

In Eukaryotes, Protein-Coding Genes Are Interrupted by Noncoding Sequences Called **Introns (**in yellow**)** that will be removed in a process called **Splicing**

The translated sequences are called **exons** (E) and will be spliced together to form mature RNA.

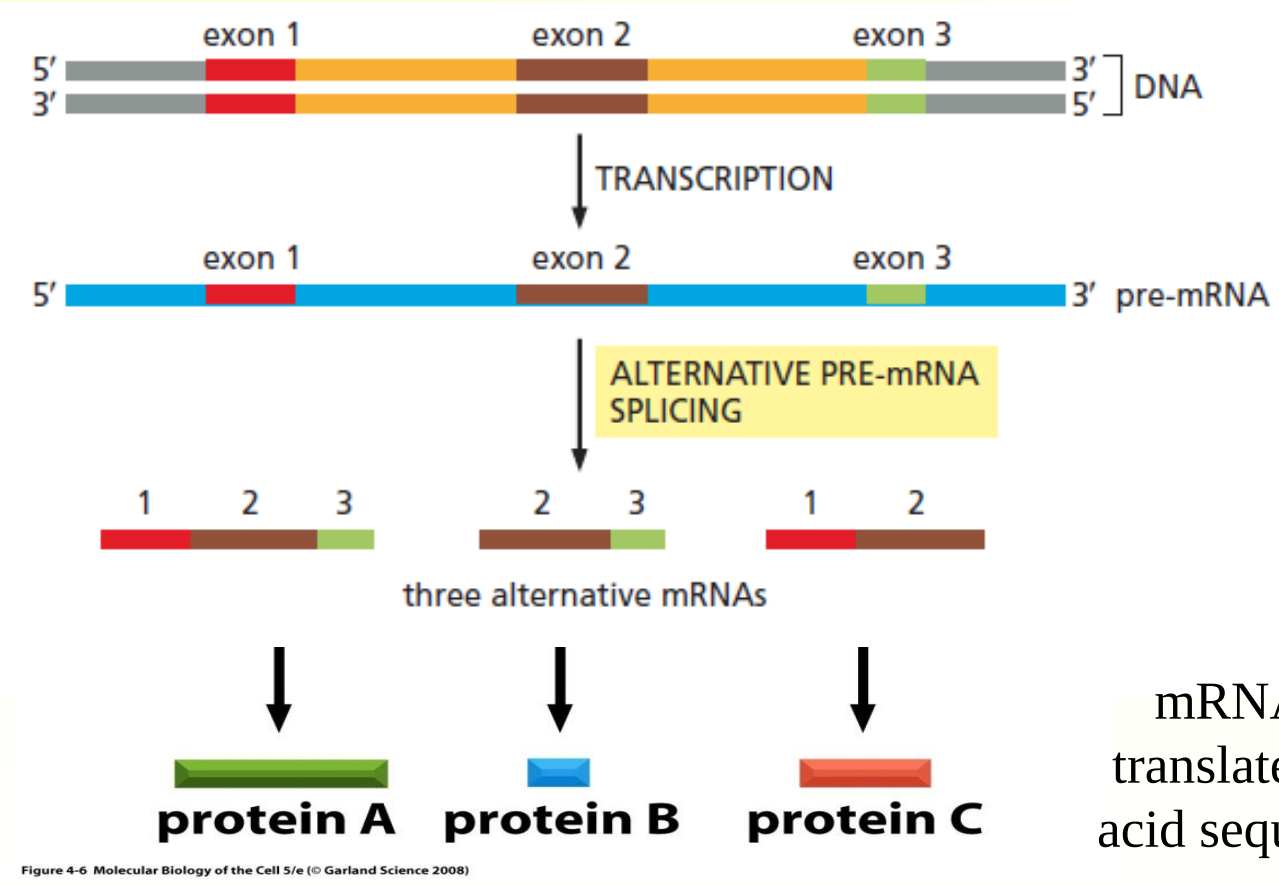


Figure 4-6 Molecular Biology of the Cell 5/e (© Garland Science 2008)

mRNA molecules, is translated into the amino acid sequence of a protein