Meiosis

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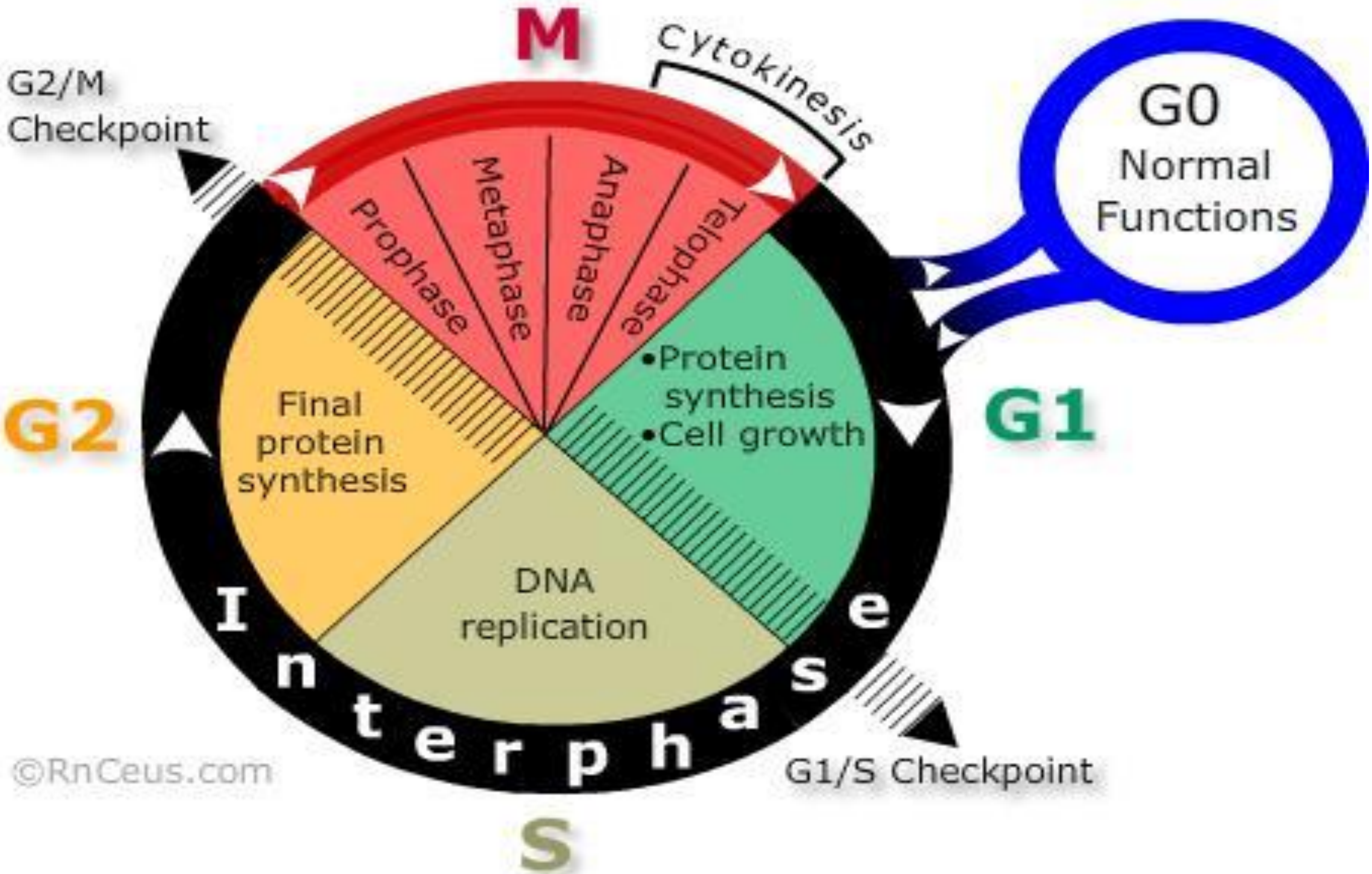
Cell Cycle (Replicating)



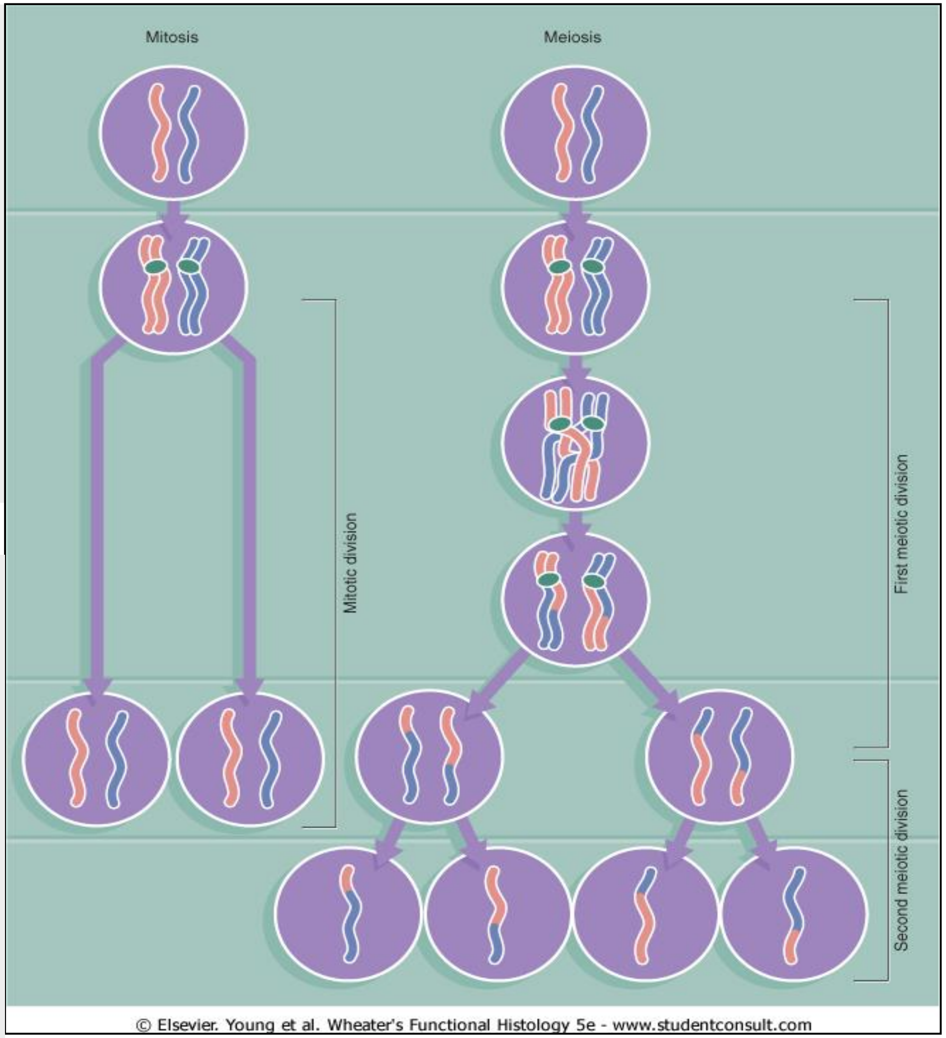
Cell Division

I-Mitosis: in somatic cells

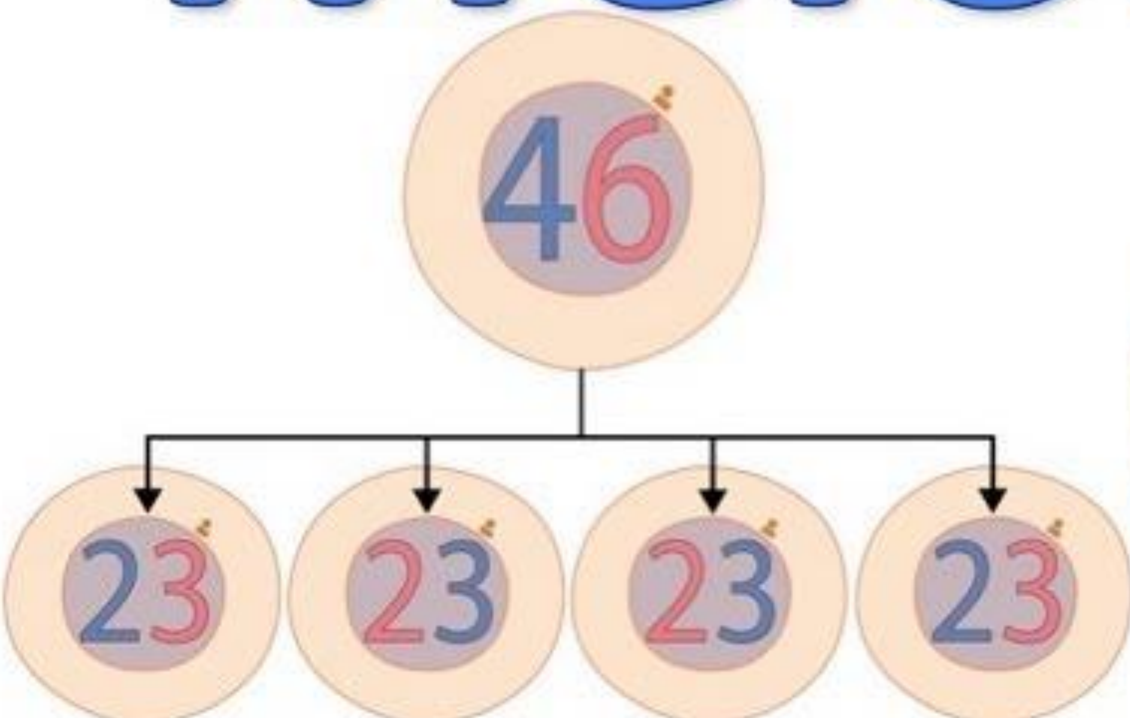
→ giving **two** daughter cells with the **same** number of chromosomes & **same** amount of DNA as parent cell.

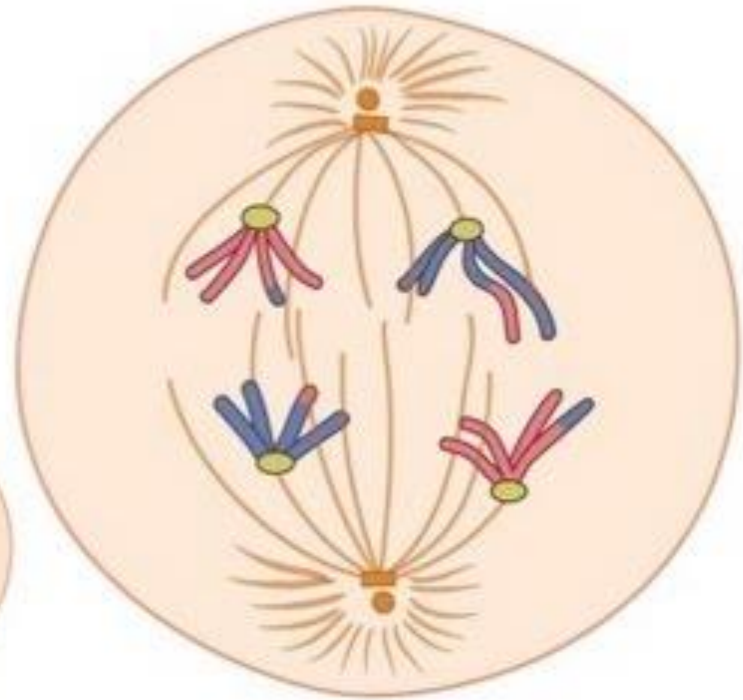
II-Meiosis: in germ cells

→ giving **four** daughter cells with **half** number of chromosomes & **half** amount of DNA (gametes).



Meiosis!





Definition :It is a special form of cell division in which the chromosomes number is reduced from diploid (2n) to haploid (1n).

The DNA content of the original diploid cell is duplicated during the S-phase of the cell cycle before starting meiosis.The cell at the start of meiosis contains diploid number (46 d) & double amount of DNA (4n).

Gives rise to four daughter cells: haploid number (23s) & half the amount of DNA (1n).

It occurs only in the germinal cells of the testis & ovary to produce gametes; (ova & spermatozoa) so, called gametogenesis.

Phases of Meiosis:

It consists of two division:

1. Meiosis I: The cell with 46d chromosomes divides giving rise to two daughter cells each has 23 d-chromosomes and the amount of DNA is 2n. Each chromosome is formed of 2 chromatids.

2.Meiosis II: In this division there is no s-phase. The two chromatids of each chromosome are separated, as in mitosis, leading to the formation of two daughter cells each has 23s-chromosome (haploid number of chromosomes and the amount of DNA is 1n).

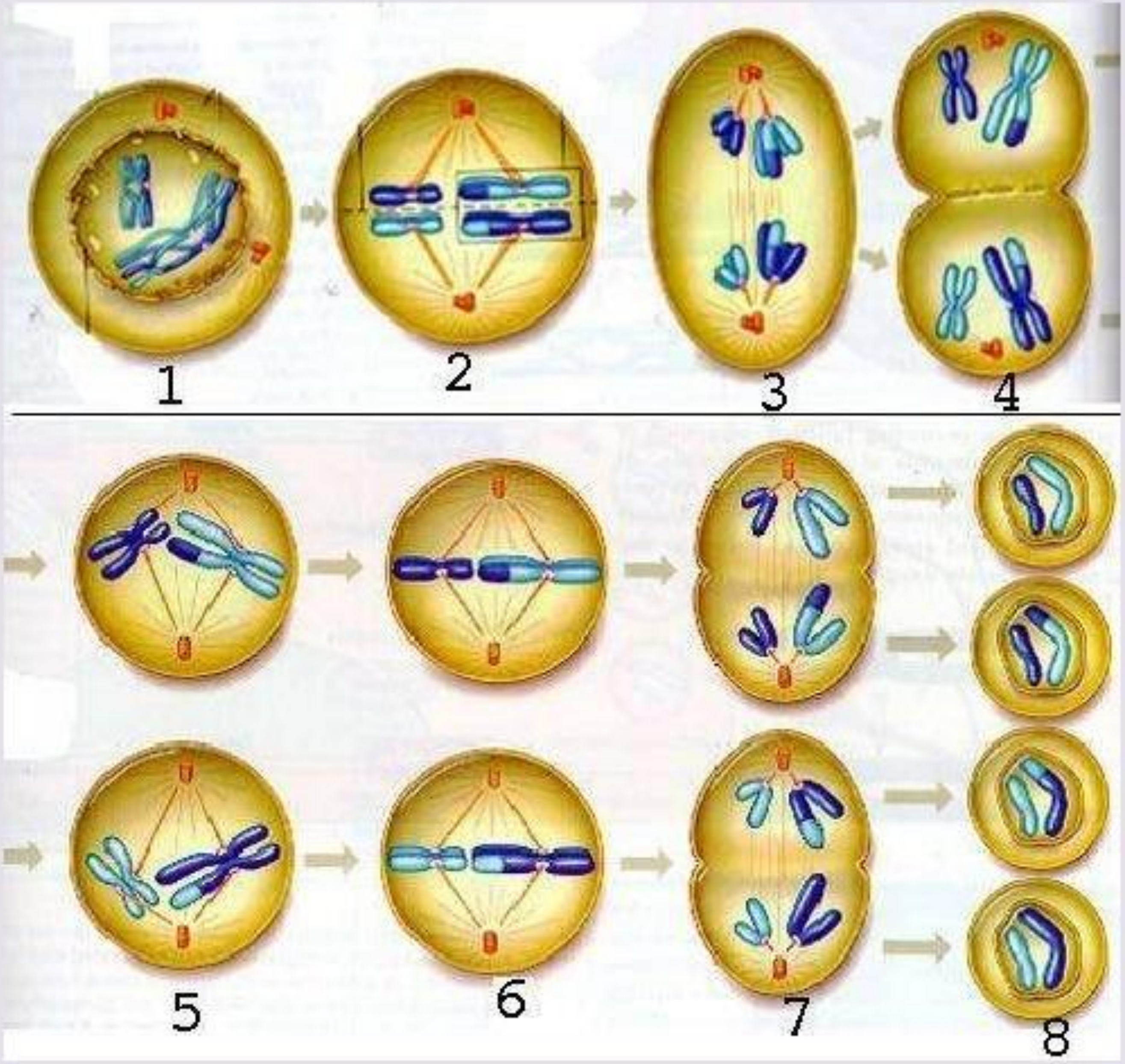
STAGES OF MEIOSIS:

MEIOSIS I

1. Prophase I
2. Metaphase I
3. Anaphase I
4. Telophase I

MEIOSIS II

5. Prophase II
6. Metaphase II
7. Anaphase II
8. Telophase II



Meiosis I

Prophase I:

There are 5 stages, each named based on the morphology of the chromosomes.

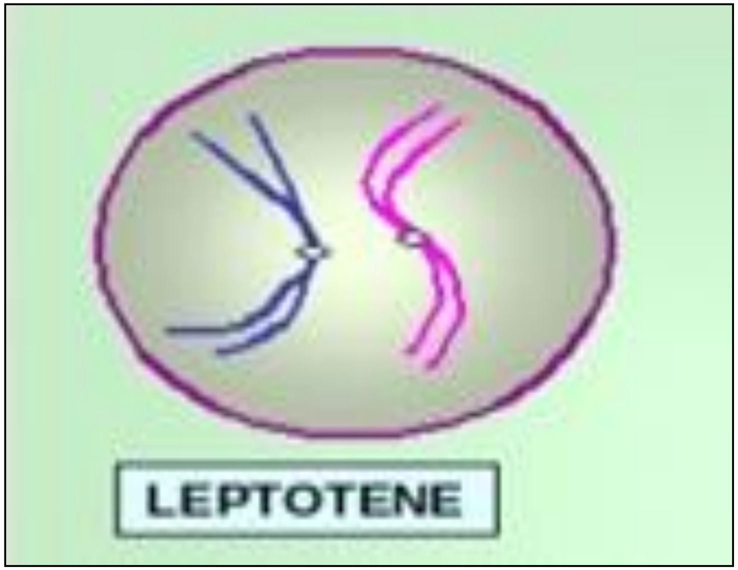
1-**Leptotene** (thin thread)

2-**Zygotene (**paired thread)

3-**Pachytene** (thick thread)

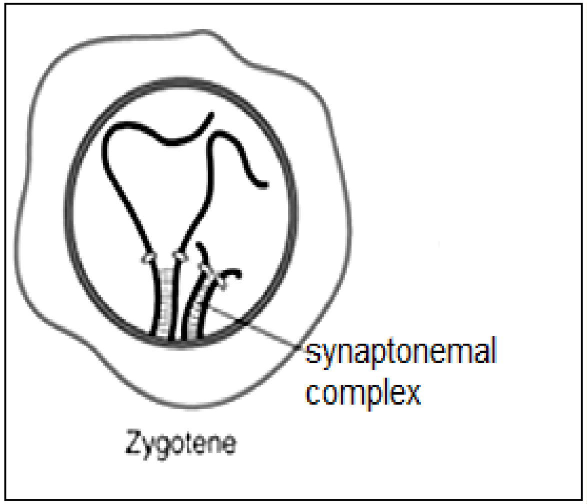
4-**Diplotene** (two thread)

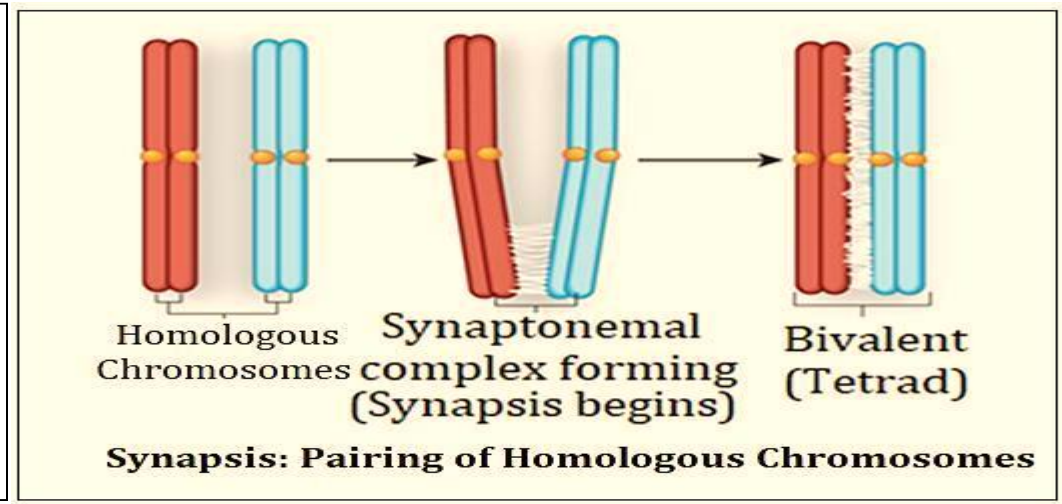
5-Diakinesis(moving through)



1-Leptotene (thin thread):

- The 46 d-chromosomes are visible & appear as long strands.
- Each consists of two chromatids attached by centromere.



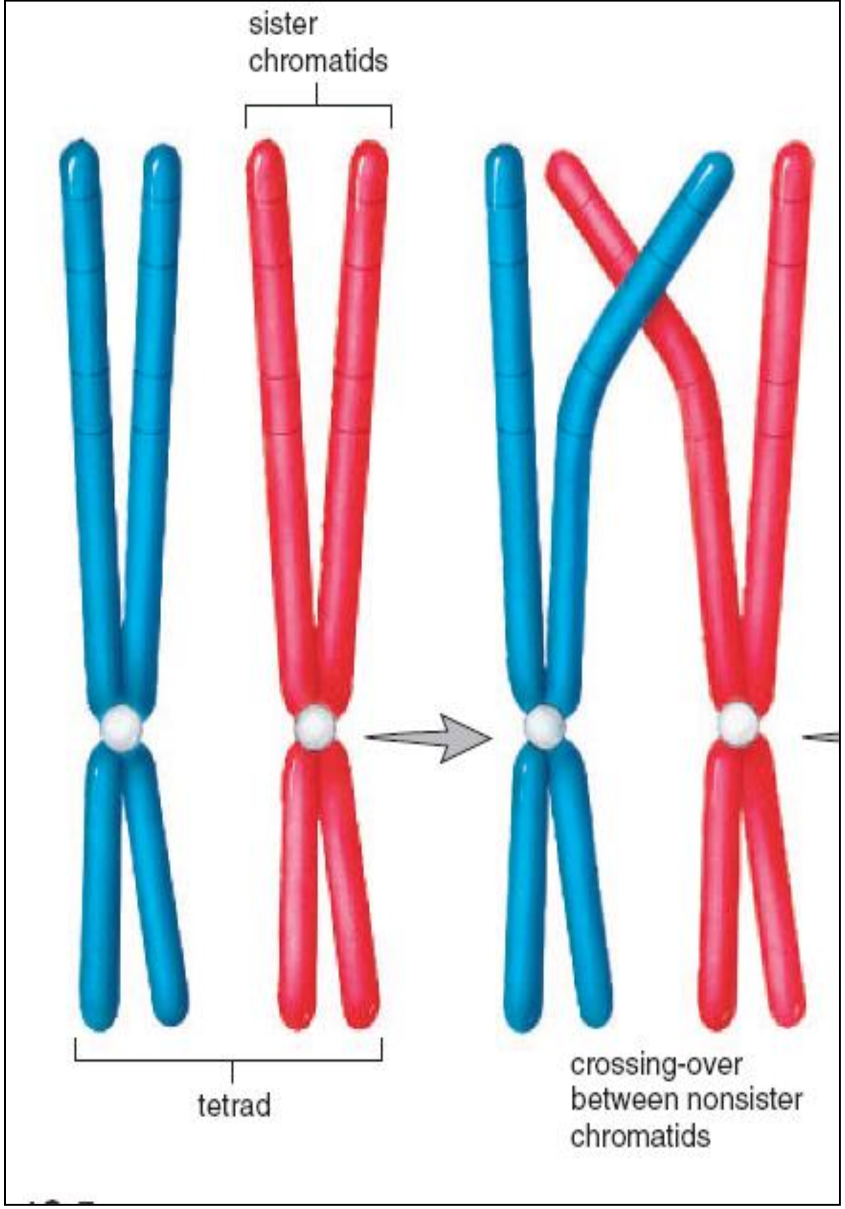


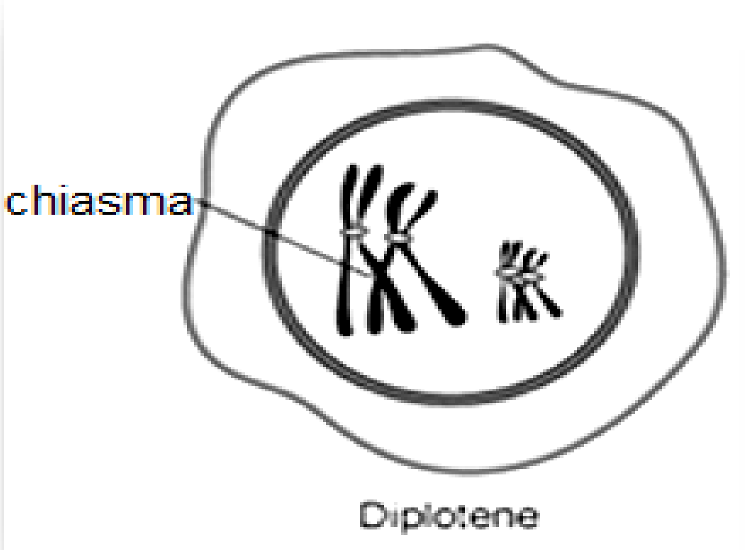
2-Zygotene (**paired threads**):

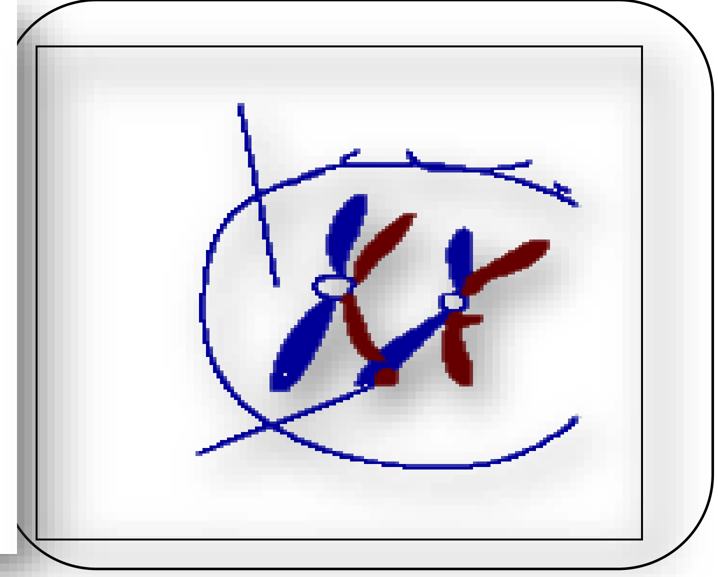
- **During this stage, homologous chromosomes (maternal & paternal) begin to synapse (unite) with each other by synaptonemal complex through a mechanism called (zipper like pairing).**
- **The paired homologous chromosomes are called bivalents. Each bivalent is formed of four chromatids (tetrad).**

3. Pachytene (thick threads):

- The chromosomes become shorter & thicker.
- Crossing over between non-sister homologous chromatids takes place through **chiasmata** (site of exchange of genetic material).

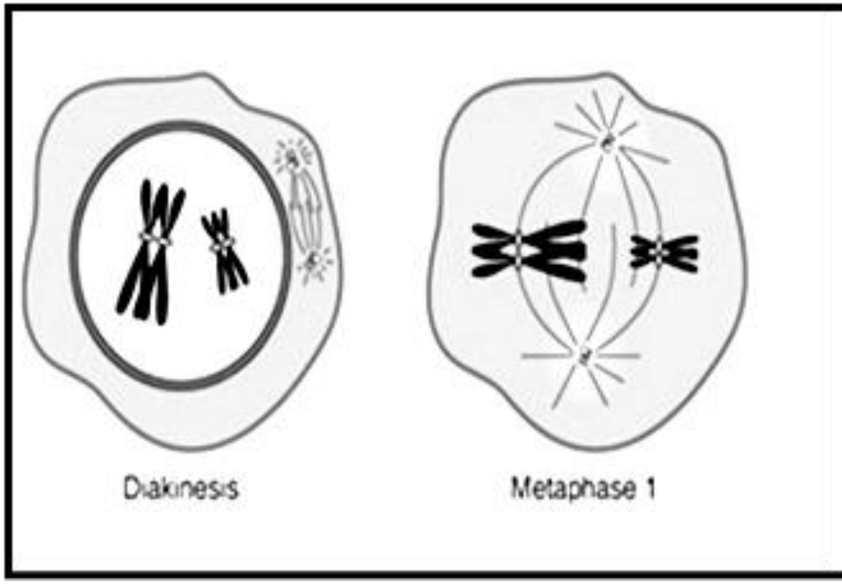


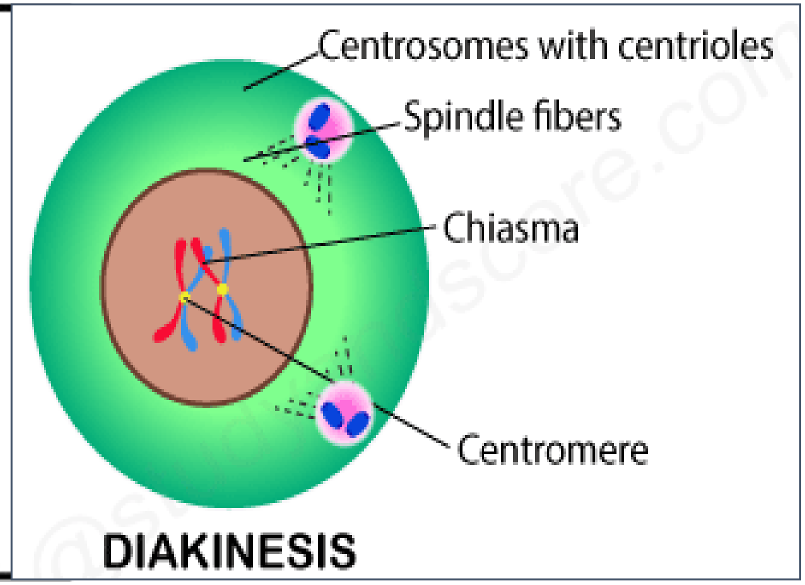




4. **Diplotene (two threads):**

- **Longitudinal separation & more condensation of the two homologous chromosomes except at the chiasmata.**
- **The crossed area or chiasmata makes attachments between the chromosomes holding each bivalent (tetrad) together until metaphase.**





5. Diakinesis (moving through):

- Maximum condensation of chromosomes (the d-chromosome becomes thicker & shorter).

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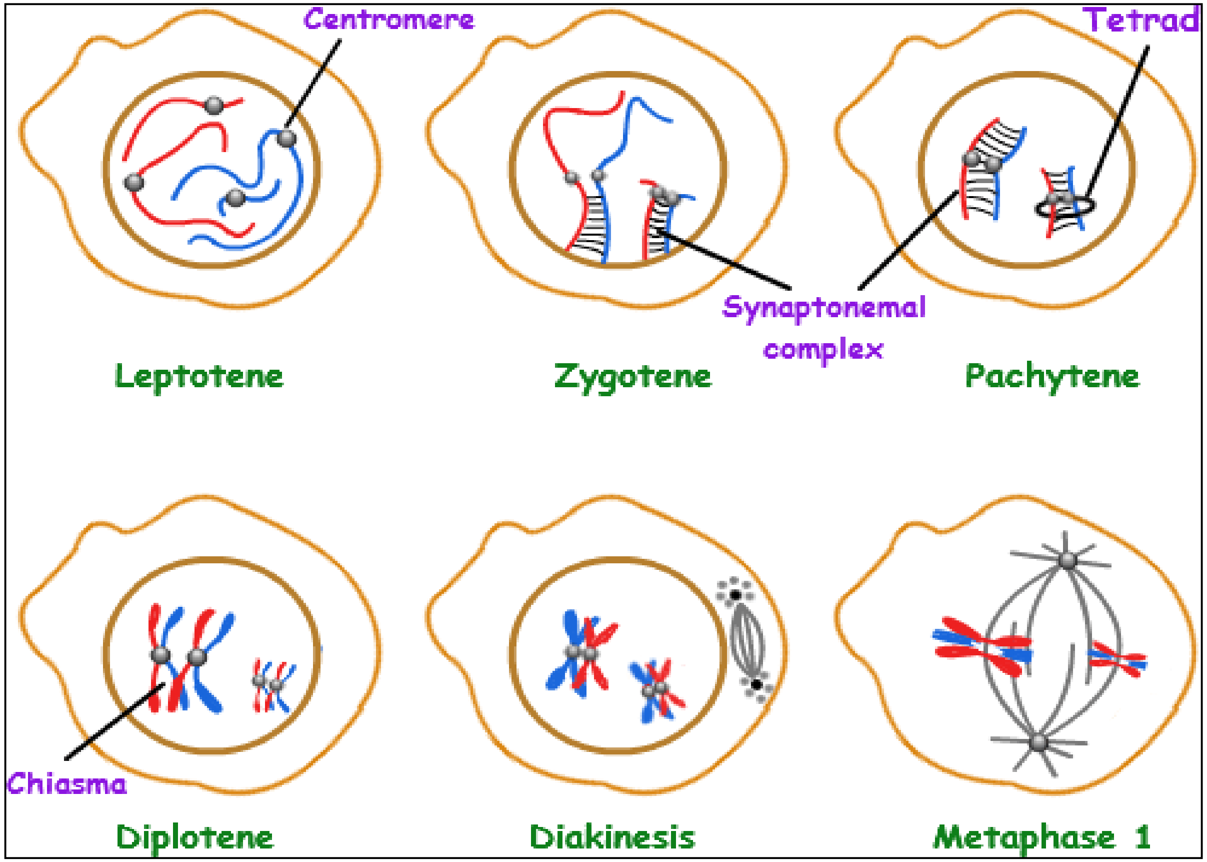
-Disappearance of the nucleolus & nuclear envelope

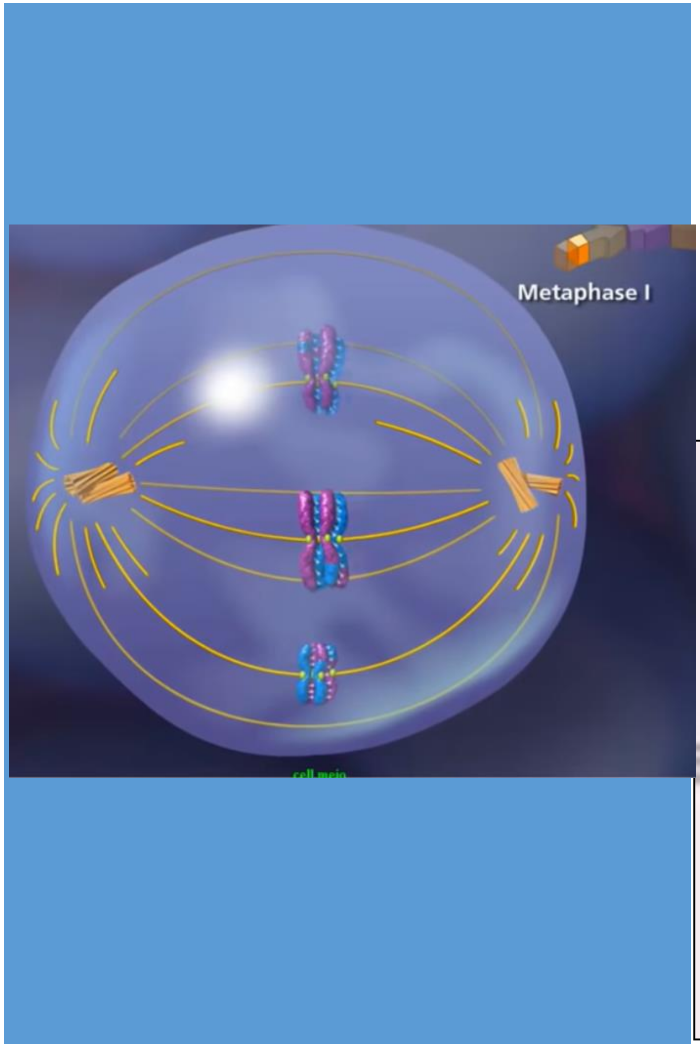
-The chromosomes become free in the cytoplasm & the cell proceed to metaphase.

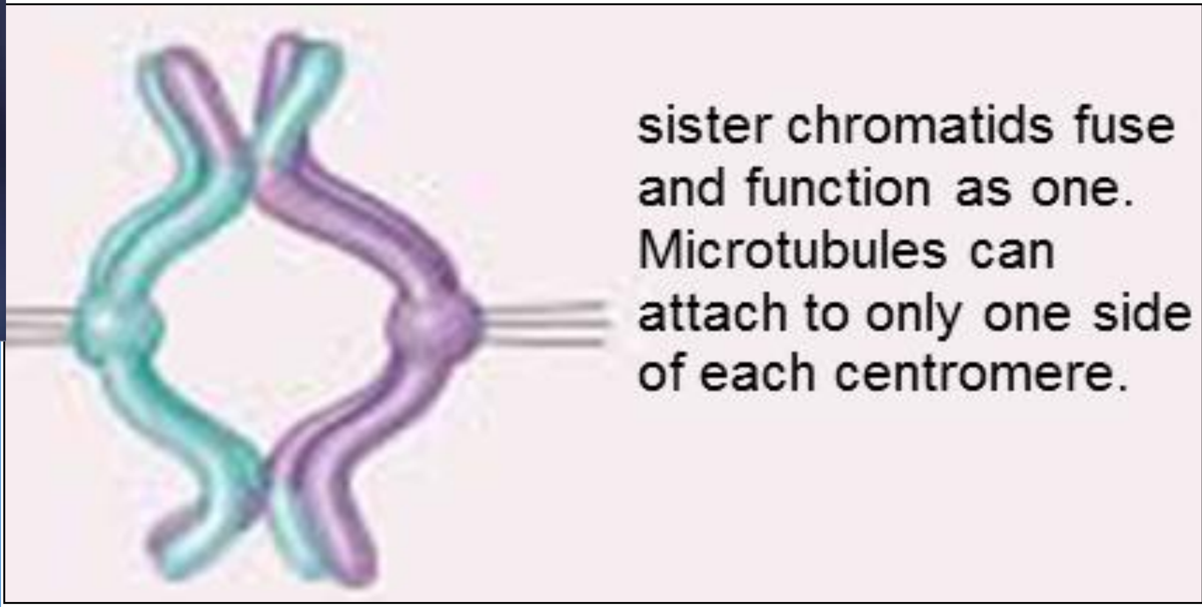


Metaphase I:

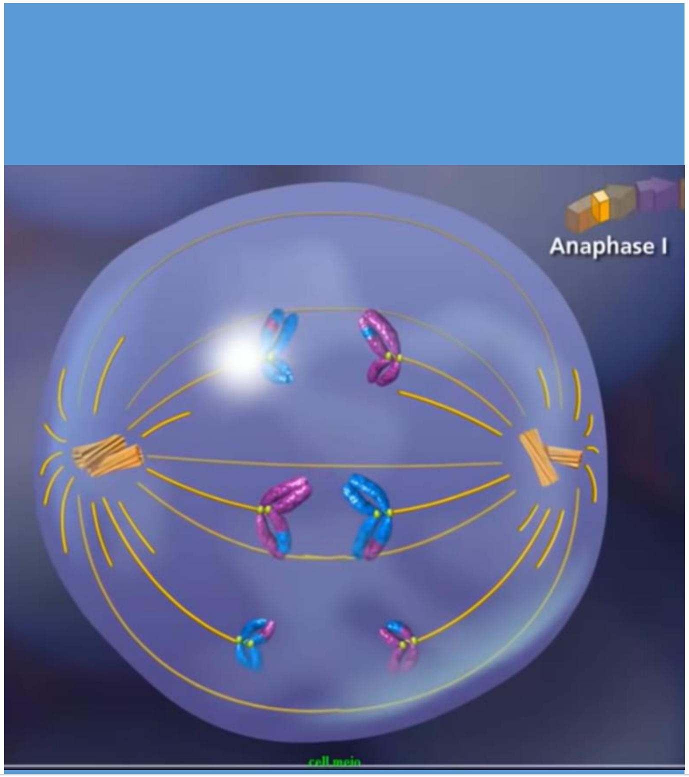
-Shortest phase

-The homologous chromosomes (bivalents) or tetrads are arranged in equatorial plane.



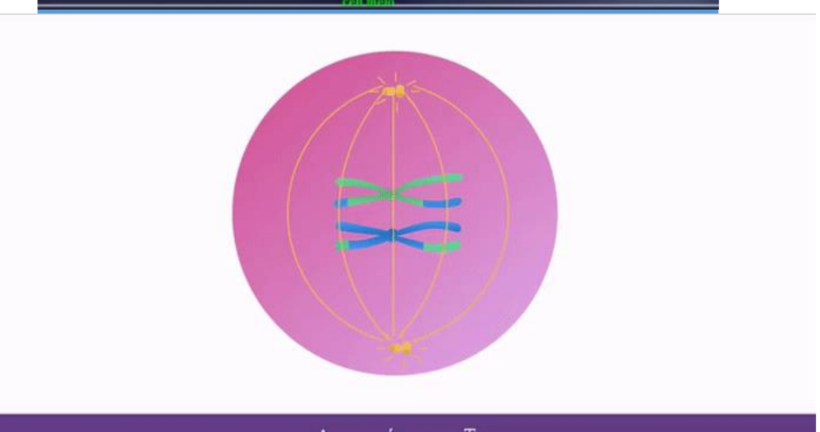


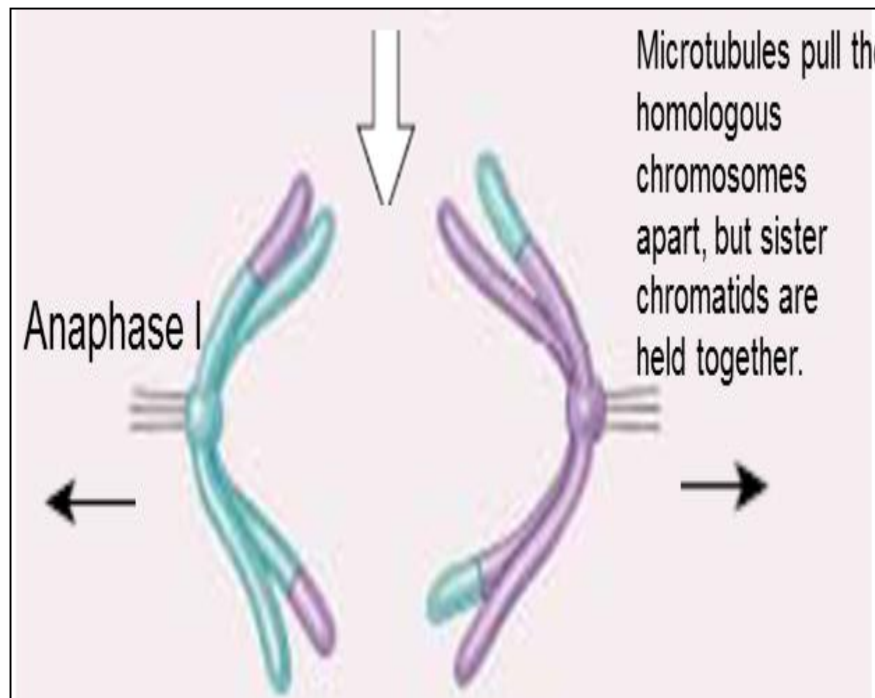
Anaphase I:



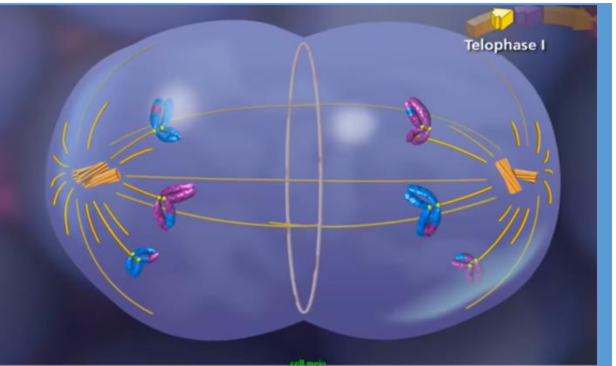
-Homologous chromosomes migrate away from each other, going to opposite poles.

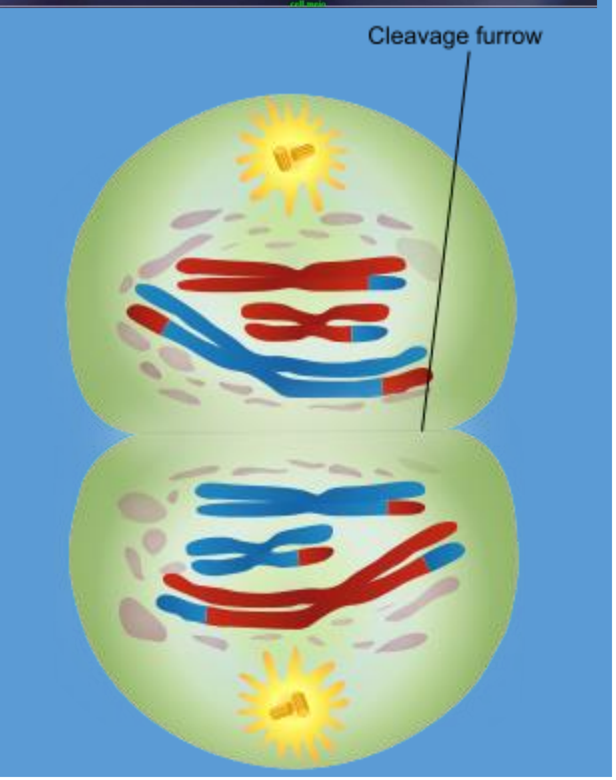
-Each chromosome still consists of two chromatids.





Telophase I:





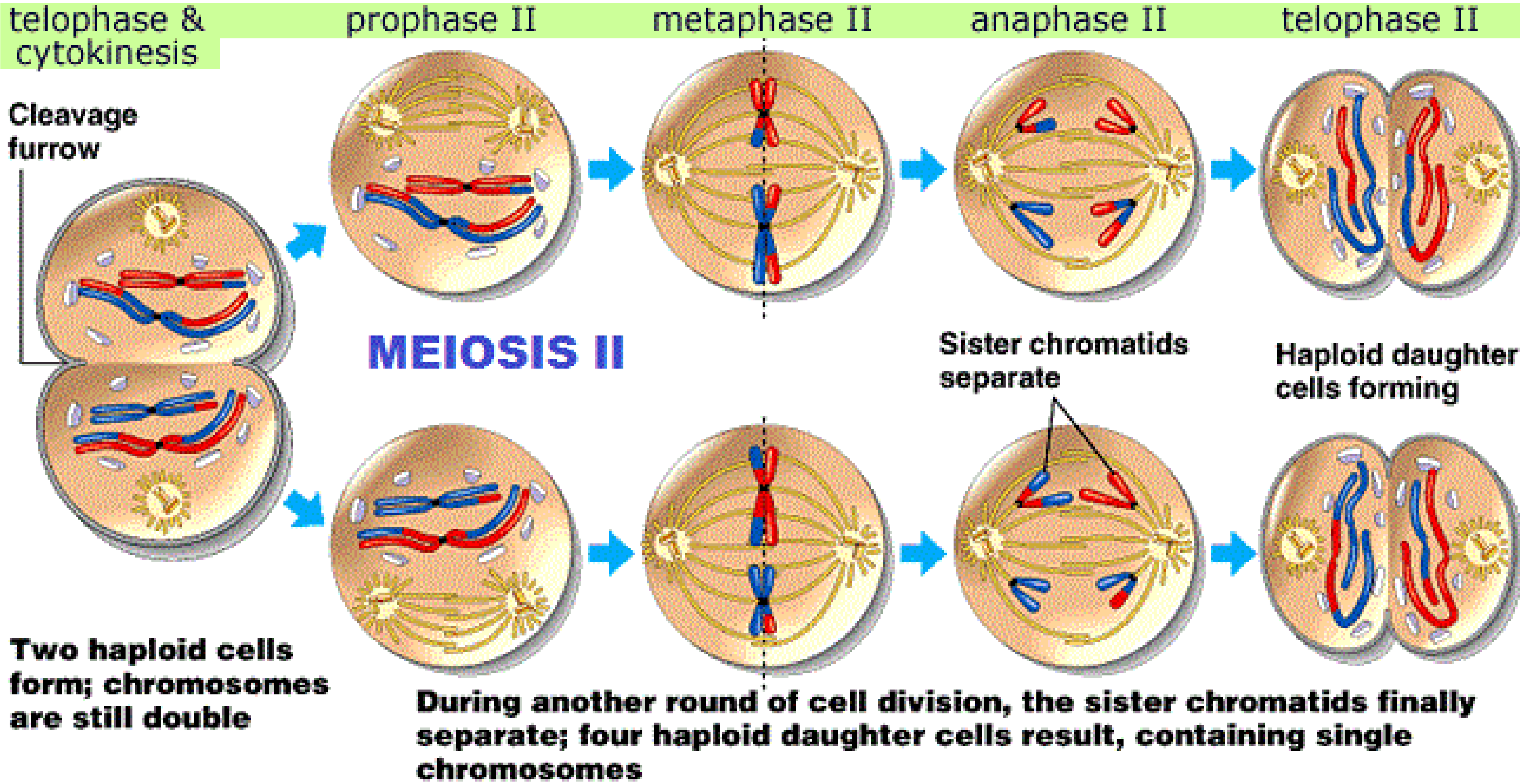
-The chromosomes reach the opposing poles, nuclei are reformed.

-Cytokinesis occurs giving rise to two daughter cells each cell contains 23d chromosomes (haploid number of chromosomes)

-The amount of DNA is (2n) as each chromosome consists of two chromatids.

II- Meiosis II

- It is **like mitosis** without prior DNA replication (**no S stage , no interphase**)



II- Meiosis II

- **The chromosomes** arranged in equatorial plane & kinetochores attach to microtubules of mitotic spindle followed by migration of the chromatids to opposite poles

- **Cytokinesis** divides each of the two cells giving a total of **four** daughter cells.
- Each of the four cells contains 23 s-chromosomes (haploid number of chromosomes) & (1n) amount of DNA.

***Major Phases of Meiosis*:**

- **Meiosis 1: (S stage of interphase I)**
- **Meiosis 2: (NO S stage interphase 2)**

46 s-chromosomes + 2n DNA

S- Phase of cell cycle ↓

46 d-chromosomes + 4n DNA

Meiosis I ↓

23 d-chromosomes + 2n DNA Two daughter cells

Meiosis II ↓

23 s-chromosomes + 1n DNA, Four germ cells, which may be ova or sperm

Mitosis Vs meiosis?

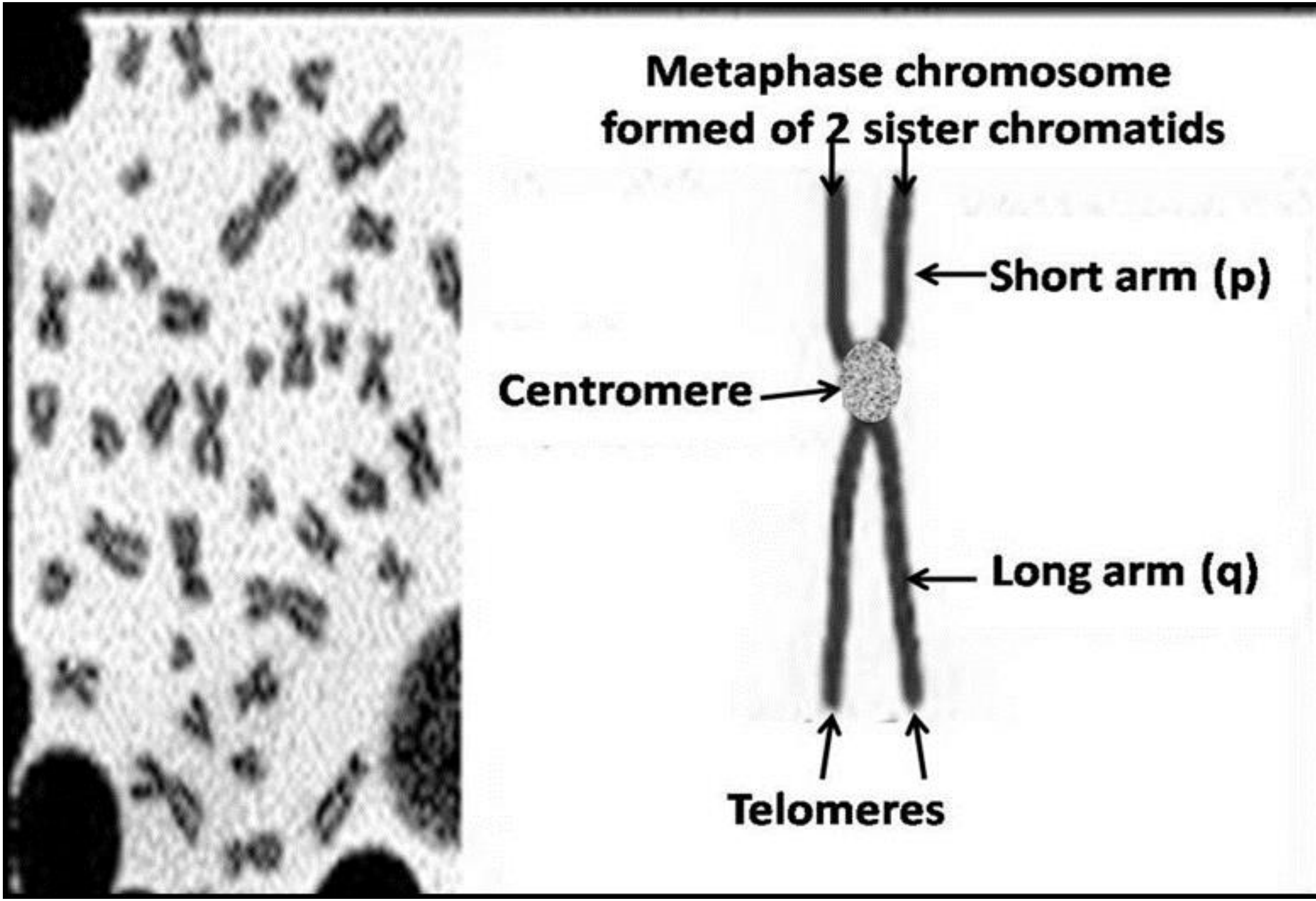
	Mitosis	**Meiosis**
Cell type	Somatic	Gametes
# of divisions	1	2
S- phase	Present	No s-phase between the two division
Chromosome #	Same as parent	Half of parent
# of daughter cells	2	4
Genetically identical?	Yes	No
Crossing over	Absent	In prophase I
When	Throughout life	At sexual maturity
Aim	Growth and repair	Sexual reproduction

Structure of human chromosome

Chemically: Chromosome consists of a continuous molecule of DNA double helix associated with proteins; histones and non-histones.

Microcopically: Each metaphase chromosome (d-chromosome) consists of two sister chromatids. Each one of the sister chromatid is formed of the followings:

- Short upper arm (p).
- Long lower arm (q).
- Centromere is a primary constriction connects the two chromatids together.
- Telomeres are the terminal regions at both ends of the chromosome. Telomere protects chromosome ends from degradation and prevent end to end fusion with other chromosomes


Metaphase chromosome
formed of 2 sister chromatids
Short arm (p)
Centromere
Long arm (q)
Telomeres

Number:

1- Somatic cell:

In humans, the normal cell nucleus contains 46chromosomes or 23 pairs (diploid number). One of each chromosome is paternal in origin (from father) and the other is maternal in origin (from mother). These pairs are divided into:

- 22 pairs called autosomes.
- One pair called sex chromosome.

A male has 44 autosomes and XY sex chromosomes. A female has 44 autosomes and XX sex chromosomes. In female, one X chromosome is an inactive which is called Barr body or sex chromatin.

2- Germ cell (gamete cells) (ova and sperms) contains 23 s-chromosomes (haploid number). All the ova contain one type of sex chromosome (X), while half of the sperms contains X and the other half contains Y chromosomes.

Sex chromatin or Barr body

Definition: It is dark staining heterochromatic mass lying against the inner surface of the nuclear membrane of interphase female cells only.

Barr body is believed to represent the inactivated X chromosome. All of the X chromosomes except one in a cell are inactivated early in development.

Number: The number of barr bodies in the female cell is equal to the number of X chromosomes present in the cell minus one. A female with chromosome number 47, XXX has two barr bodies, and a male with 49, XXXXY has three Barr bodies.

Chromosome Classification

:

There are seven groups of chromosomes

A: 1-3, B: 4-5, C: 6-12+X, D:13-15
E: 16-18, F: 19-20 G: 21-22+Y

Chromosomes are classified according to

1. Length of chromosome:

- Chromosomes are divided into 7 groups according to their length:

- Group A contains chromosome numbers 1- 3(the longest one).
- Group D contains acrocentric chromosomes, number 13-15 (medium-sized),
- Group G contains acrocentric chromosomes, (21 and 22) and Y chromosome (the shortest chromosomes).

2. Position of centromere

- Chromosomes are classified according to centromere position into three groups:

a. Metacentric chromosomes:

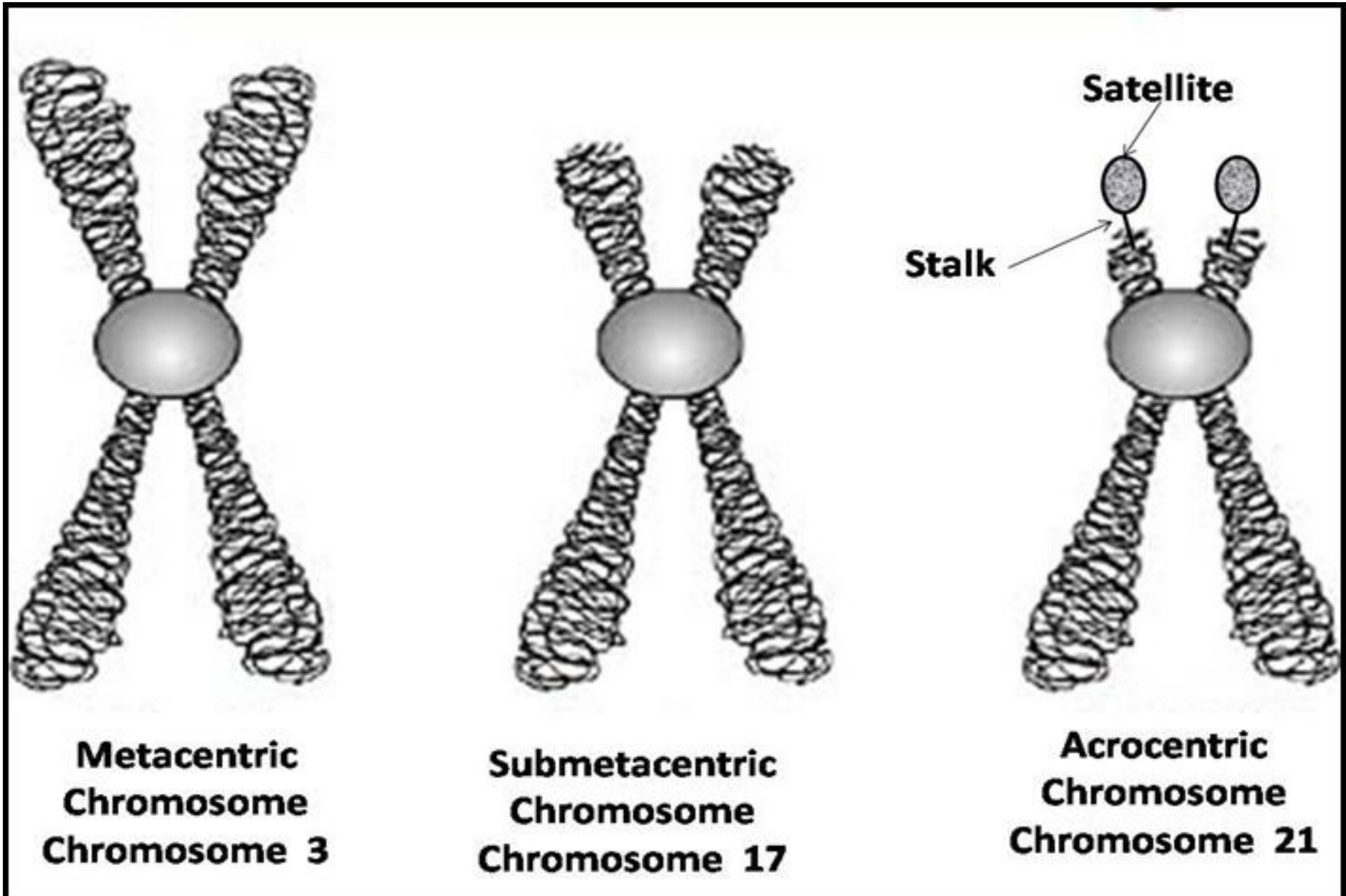
- The centromere lies near the middle of the chromosome where p = q, such as number 1, 3, 16, 19 and 20.

b. Submetacentric chromosome:

- The centromere lies closer to one end than the other.
- P arm is shorter than q arm such as number 2, 4, 12, 17, 18 and X chromosomes.

c. Acrocentric chromosome:

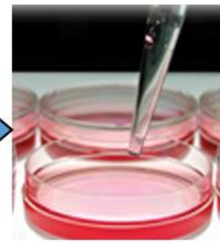
- The short arm p is very small, and the centromere lies near one end such as chromosome number 13, 14, 15, 21, 22 and Y chromosome.
- These chromosomes except the Y have small chromatin masses known as satellites attached to their short arms by narrow stalk and contain genes for rRNA formation.


Satellite
Stalk
Metacentric Chromosome Chromosome 3
Submetacentric Chromosome Chromosome 17
Acrocentric Chromosome Chromosome 21

Karyotyping& Chromosome banding

- **Karyotyping:** Study of the number, type & arrangement of chromosome.
- **Karyotype:** systemic arrangement of the chromosomal set of the cell
- Depends on length of chromosomes & position of centromere.
- Arrangement first autosomes & lastly the sex chromosomes (XX female or XY male)

Blood sample is taken



Incubate 3-4 days

Add chemical to stop mitosis in metaphase

treated with hypotonic solution

Swollen cells are fixed, dropped in a glass slide, dried and stained

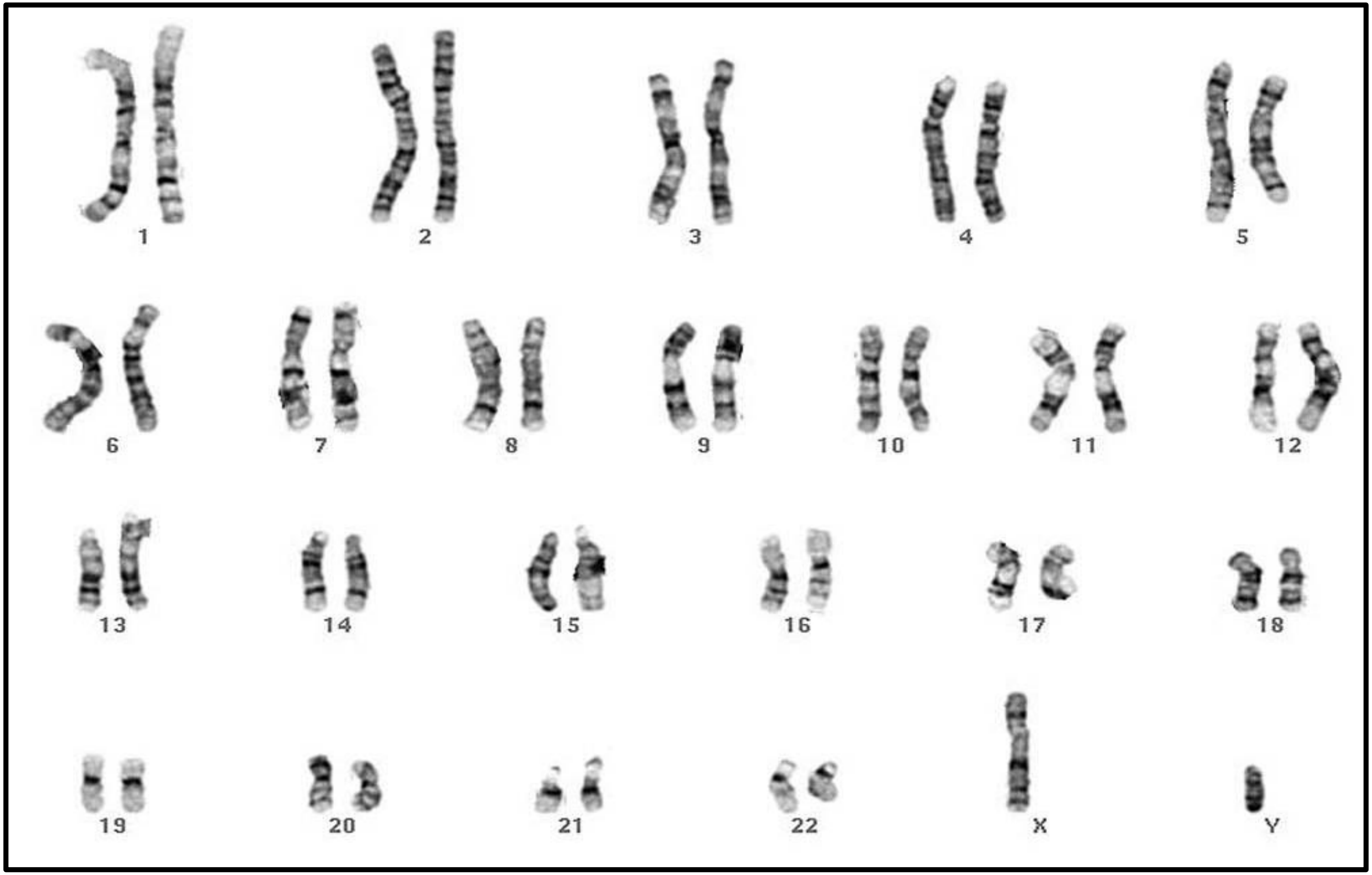
Examine with the microscope & photograph the chromosomes

Cut out the chromosomes and arrange into a karyotype

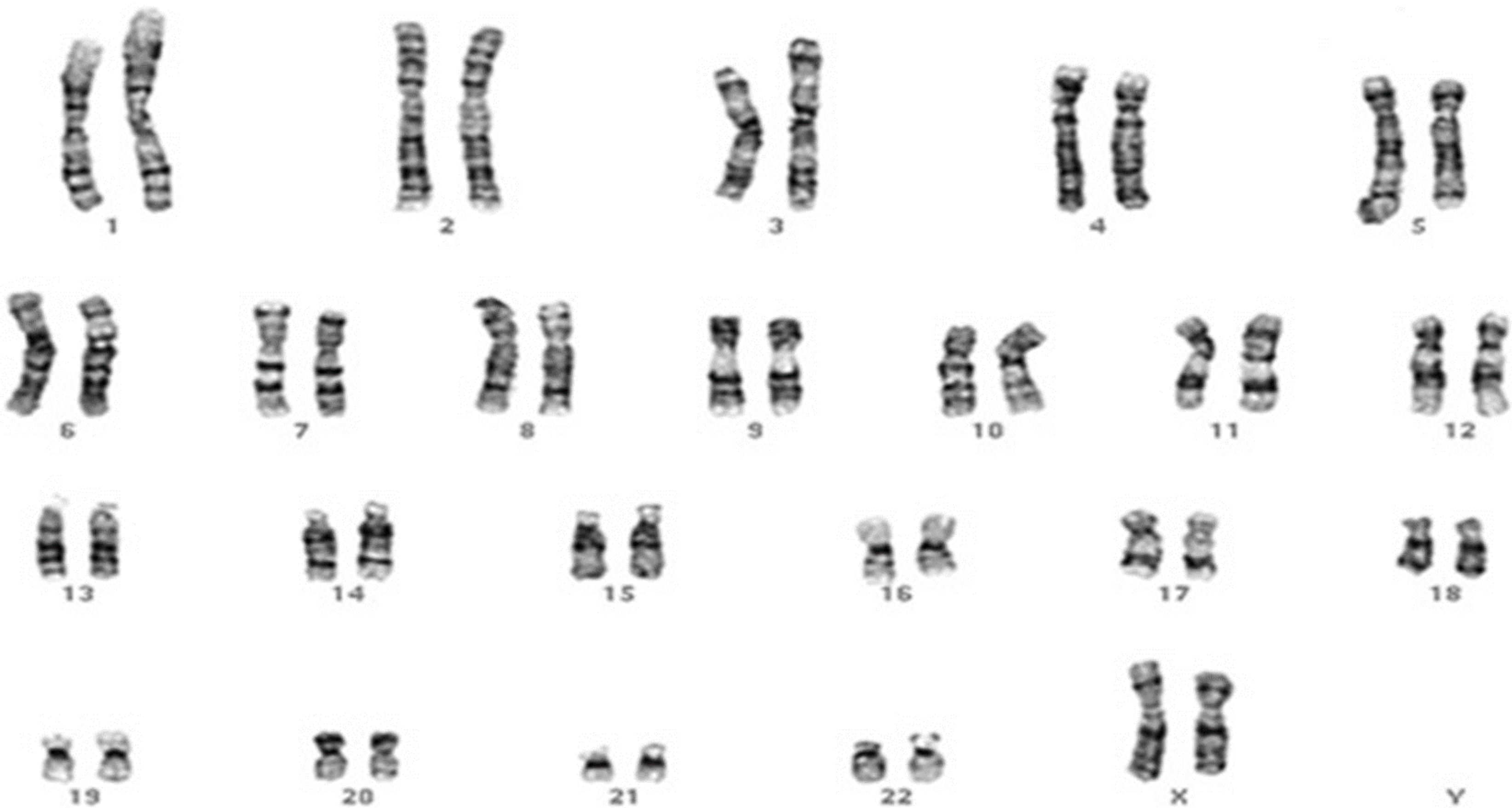
Steps of preparation:

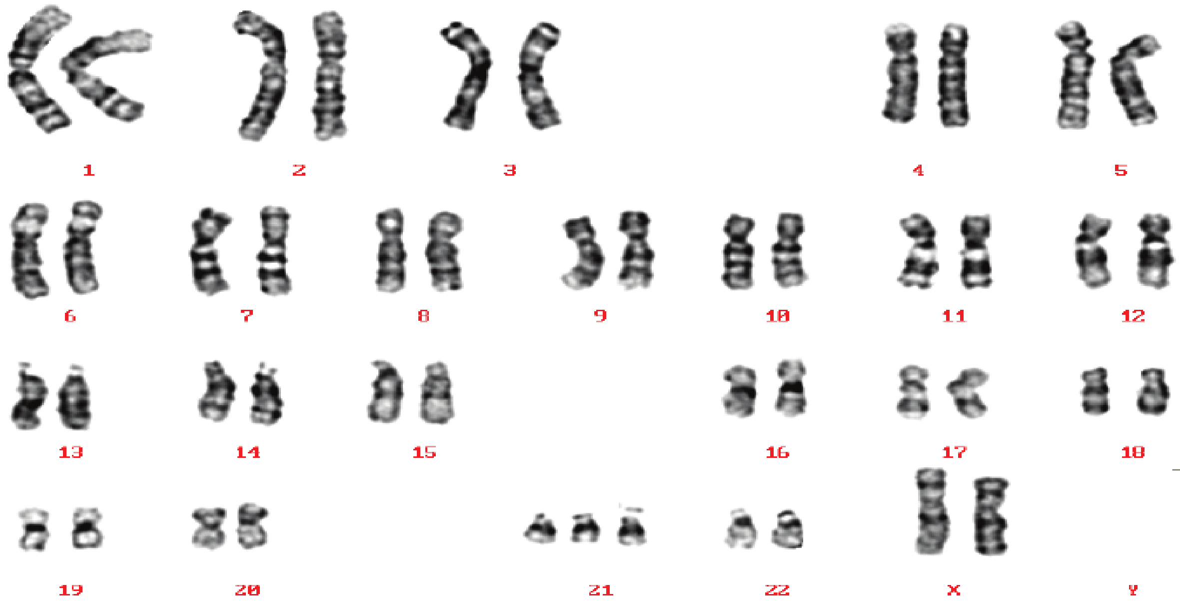
- Culture of living cells in suitable medium
- Add **phytohemagglutinin** to stimulate division
- Add **colchicine** to arrest cells in metaphase
- Add **hypotonic** salt solution to swell the cells
- Spread on glass slides & Staining
- Photographing
- Cut chromosome individually
- Arrange by matching every two pairs in groups
- Seven groups **(A, B, C, D, E, F, G)** according to length and position of centromere
- Now by software of computer

Normal male karyotyping (22+XY)

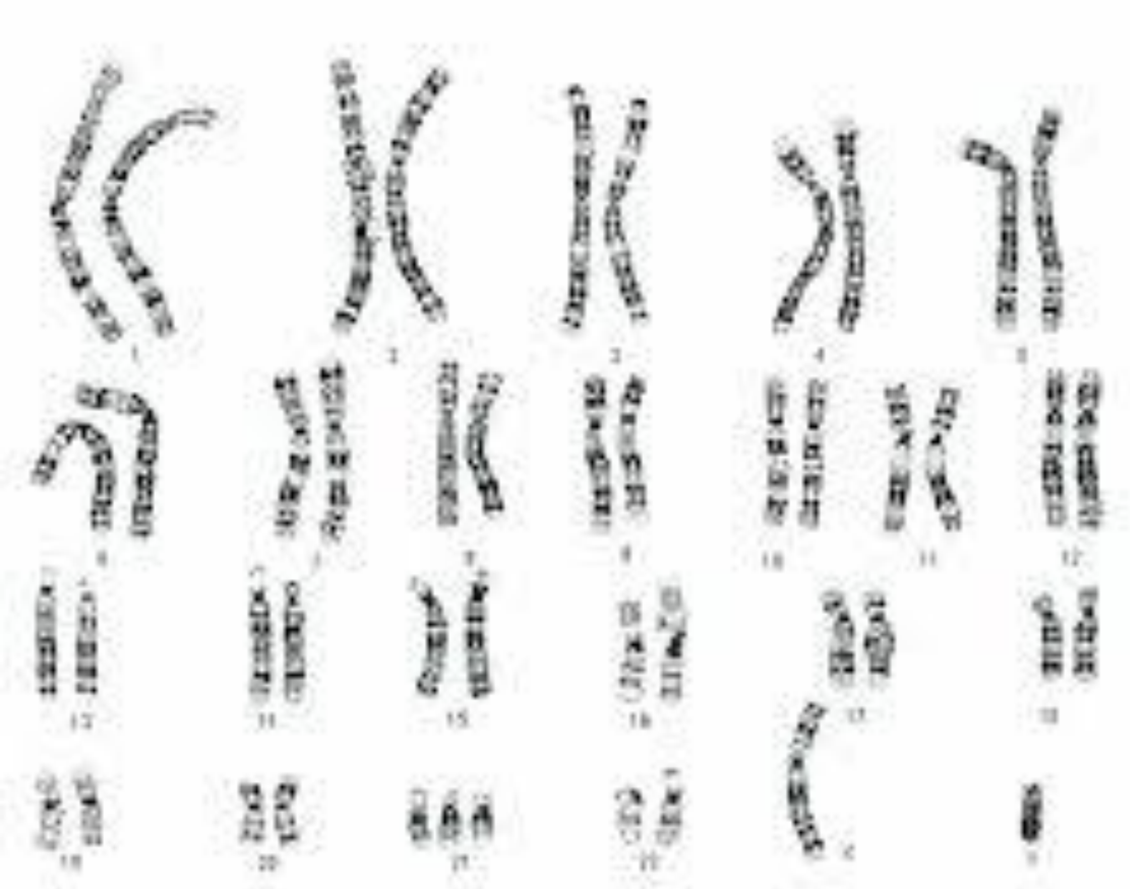


Normal female karyotyping (22+XX)



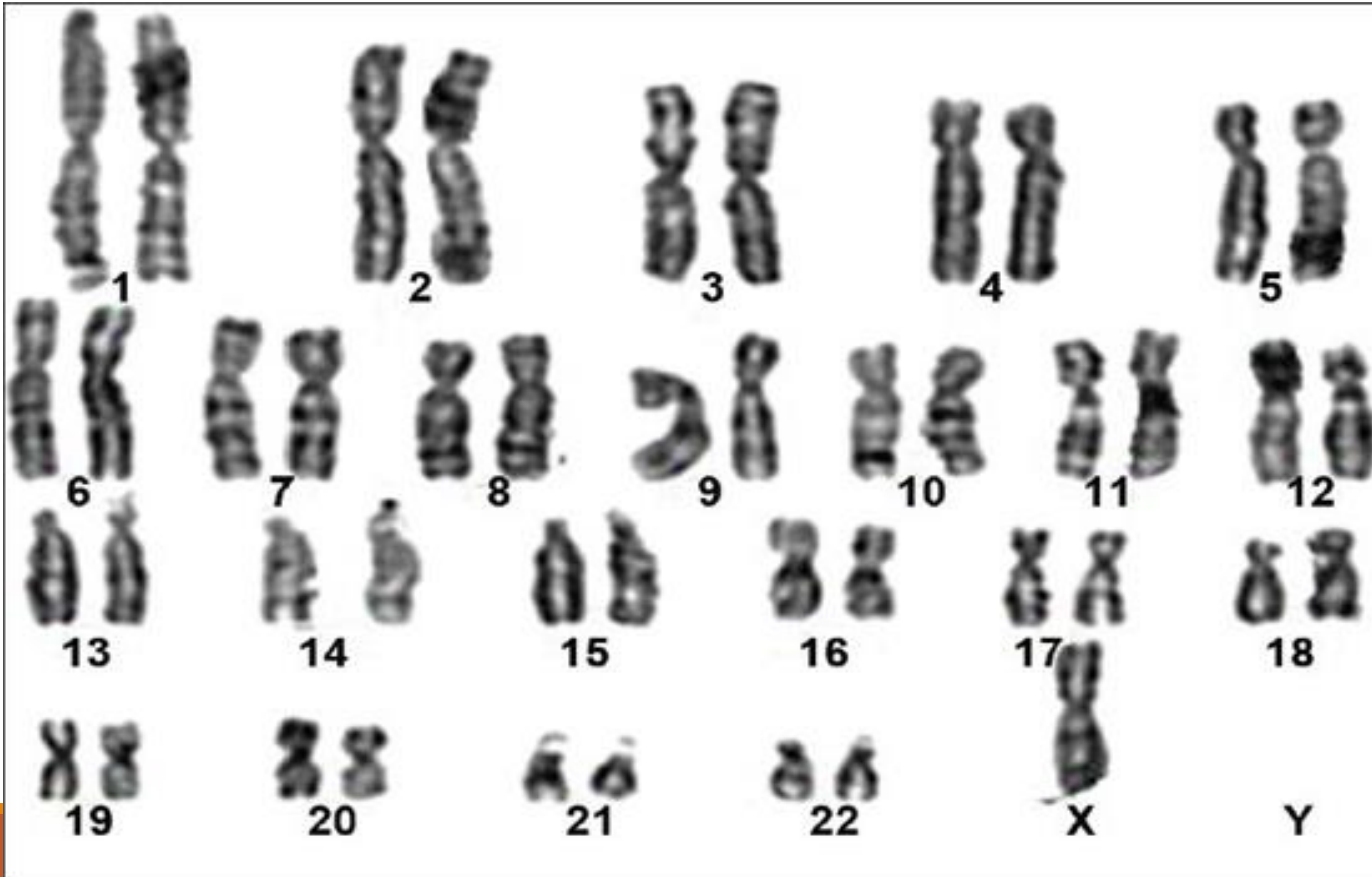


Down female



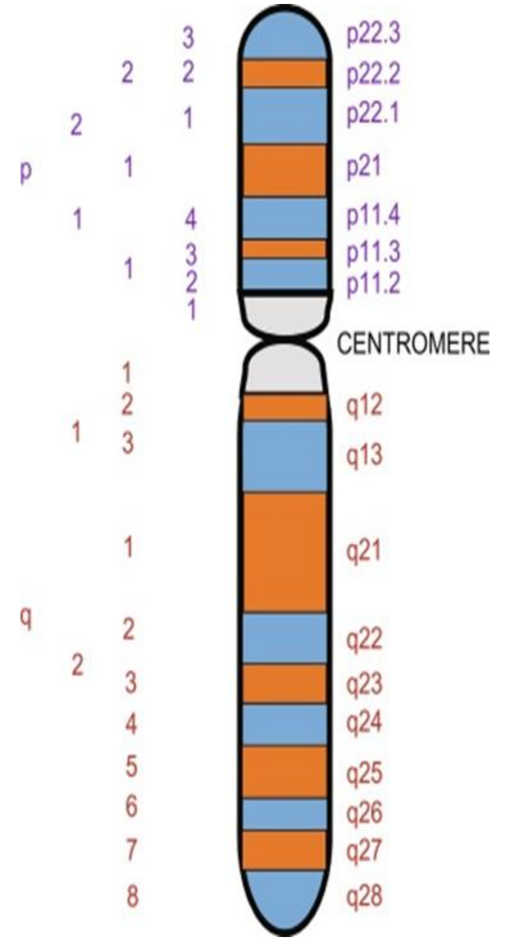
Down male

Turner syndrome



Chromosome banding:

Banding patterns are chromosomal patterns of bright and dark transverse bands. These bands identify where genes are located on a chromosome. The bright and dark bands are visible when the chromosome is stained with a chemical solution and examined under a microscope.



Chromosome Banding Pattern

Chromosome banding patterns are available in various forms, such as:

G-banding or Giemsa Staining,

C-banding,

Q-banding,

R-banding

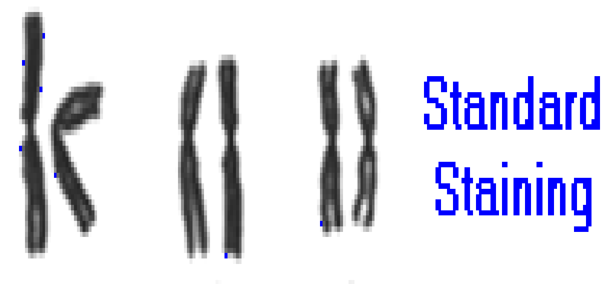
G-banding or Giemsa Staining

This is the most basic chromosomal banding technique. Because the whole complement of chromosomes is photographed, it can be used to detect genetic disorders.

Giemsa = thiazine-eosin compound.

Positive G-bands

The darkly stained bands are positive G-bands. These areas are hydrophobic and facilitate the precipitation of the thiazine-eosin compound. They constitute the late replicating heterochromatin.



Negative G-bands

Negative G-bands are light-stained bands. These are less condensed early replicating euchromatin. Base pairs from GC are abundant in these areas. These areas are less hydrophobic and less conducive to the precipitation of thiazine-eosin.