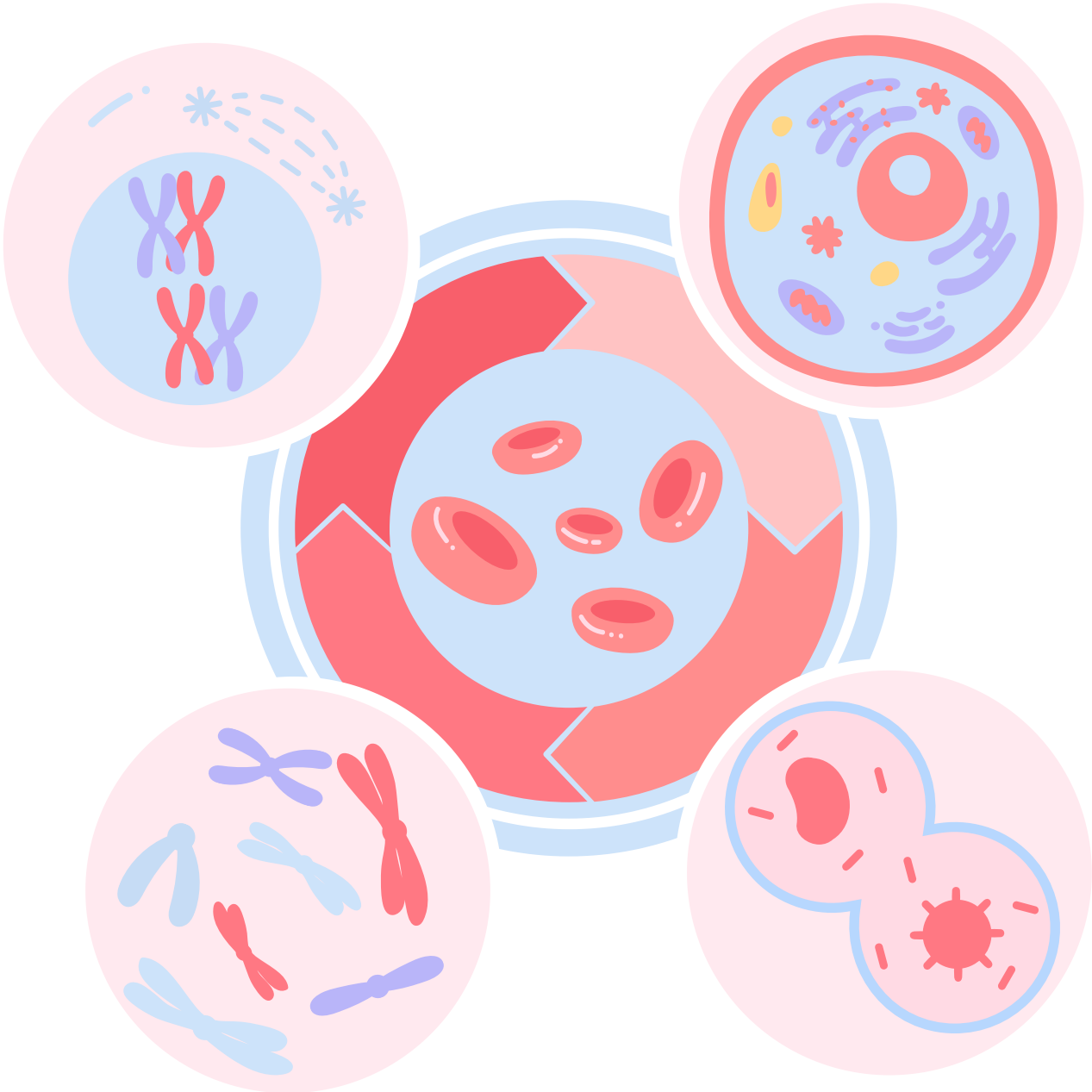
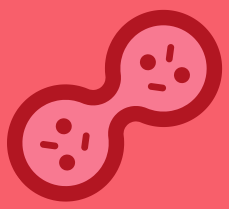
PreMed.PK

# CELL CYCLE



High Yield Notes



# NOTES
# CELL CYCLE

## Indroduction To Cell Cycle

CELL cycle involves:

- Period of growth
- Replication of DNA
- CELL division

There are two phases of CELL cycle:

1. INTERPHASE: (misleadingly called resting phase)
   - period of non-apparent division
   - period of CELL CYCLE between two consecutive divisions.
   - A period of great biochemical activity.
2. MITOTIC PHASE:
   - period of division

NOTES

# INTERPHASE

INTERPHASE is further divided into three phases:

- G1( gap 1) phase: "period of extensive metabolic activity "
  - CELL grows in size
  - Specific enzymes are made
  - DNA base units are accumulated for DNA synthesis.
  - (~remember these three points as SEDa( S for size, E for enzymes, Da for DNA accumulation)
- S( SYNTHESIS) PHASE:
  - DNA is synthesized
  - Chromosome number is doubled.
  - (~ remember as DsCd ( Ds for DNA synthesis, Cd for chromosomes duplication)
- G2 (GAP 2) PHASE: " pre mitotic phase"
  - It prepares the CELL for division.
  - Energy storage for chromosome movements.
  - Mitosis specific protein e.g kinase are synthesized
  - RNA and microtubule subunits(for spindle fibers ) are synthesized.
  - (~ remember these points as EPR (E for energy storage, P for protein synthesis, R for RNA synthesis)
- G0( G NOT) PHASE: " CELL can leave the cell cycle during G1 entering a phase called G0"
  - CELL may remain in this phase for days, weeks or even years or in some cases (e.g nerve cells and cells of the eye lens) even the lifetime of the organism without dividing further.

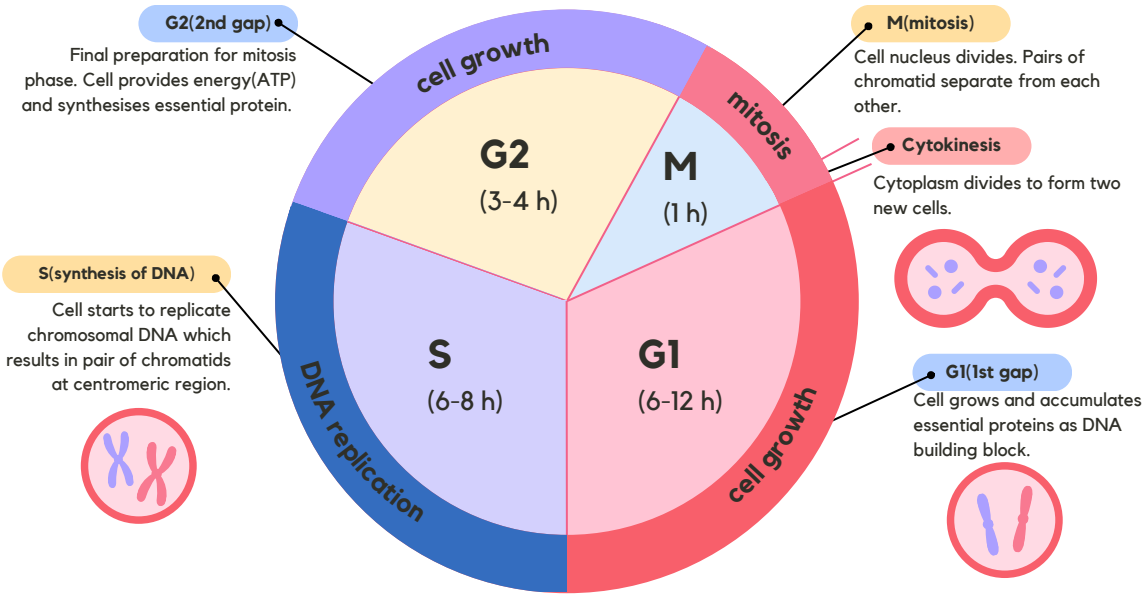
## CONTROL OF CELL CYCLE:

- At each stage, there are specific checkpoints which determine the fate of each cell according to the cell's internal make up.

## LENGTH OF EACH PHASE:

"It is variable"

- Average cell cycle is 24 hours.
- Mitosis takes 30 minutes.
- G1 takes 9 hours
- S phase takes 10 hours
- G2 takes 4.5 hours.
- Full cell cycle in yeast is only 90 minutes.

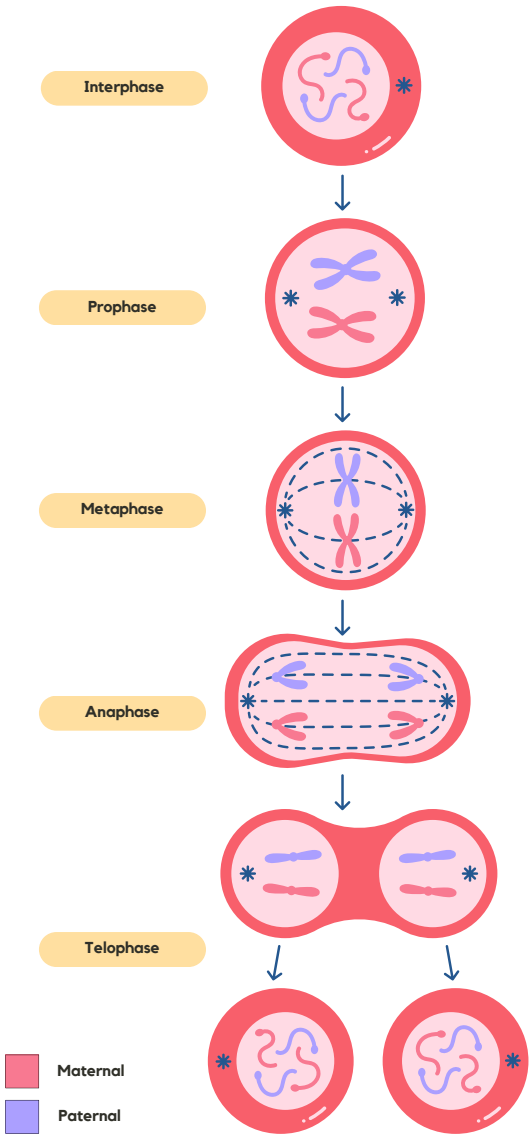


NOTES

# MITOSIS

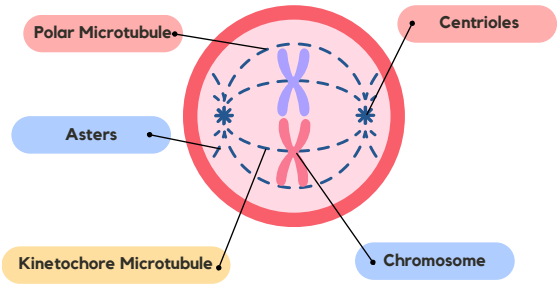
"a type of cell division which ensures the same number of chromosomes in the daughter cells as that are in the parent cells."

- Takes place in haploid as well as diploid cells
- Takes place in nearly all parts of the body when and if required.
- A continuous process.
- Mitosis is further divided into **two phases:**
  - karyokinesis involves division of nucleus
  - cytokinesis refers to division of the whole cell.




## KARYOKINESIS:

- Partition of the centrioles( the two pairs of centrioles separate and migrate towards opposite sides of the nucleus)
- Three sets of microtubules originate from each set of centrioles.
  - one set the astral microtubule radiate outward and form aster
  - the other two sets of microtubule compose the spindles.( the kinetochore microtubule attach to chromosomes at kinetochore whereas the polar microtubule do not interact the chromosomes but instead interdigitate with polar microtubule from the opposite poles.)



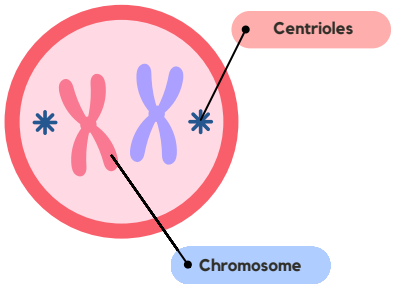

**The microtubules are composed of tubular protein and traces of RNA.**

- "The specialized microtubule structure including asters and spindle is called mitotic apparatus."
- It is larger than the nucleus
- It's designed to attack and capture the chromosomes, aligning them and finally separating them
- It ensures equal distribution of chromosomes.

NOTES

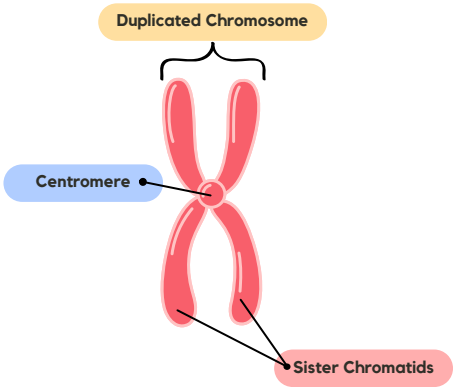
KARYOKINESIS is further divided into four phases:

- Prophase:
  - Chromatin material ( a network of very fine threads of DNA visible only during the interphase/non-dividing phase of the cell cycle is called chromatin) is condensed by folding into chromosomes.
  - (* chromosomes appear as thin threads 0.25 micrometers to 50 micrometers in length at the beginning of prophase).
  - Nuclear envelope disappears
  - Nuclear material is released in the cytoplasm.
  - Nucleoli disappear.
  - Mitotic apparatus is organized
  - Cytoplasm becomes more viscous.

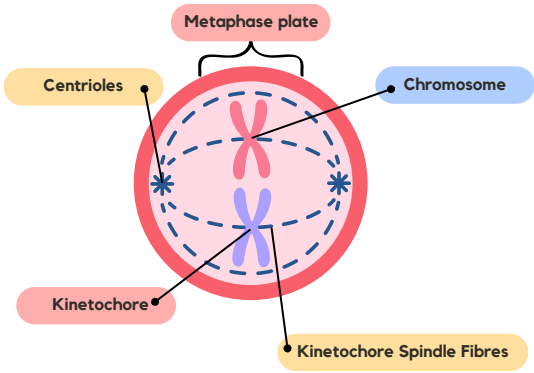



- Metaphase:

(* each metaphase chromosome is a duplicated structure which consists of two sister chromatids attached at a point called centromere. )



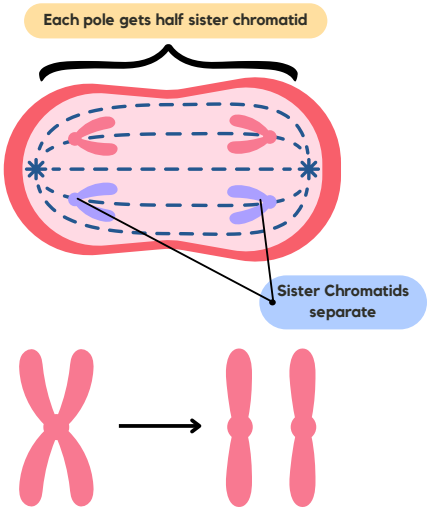

  - Kinetochore spindle fibers attach to the kinetochore region ( specialist area with specific base arrangements and specific proteins )of chromosomes.
  - Chromosomes are aligned at the equator/center of the spindle forming equatorial plate or metaphase plate.




- Anaphase:

" the most critical phase of mitosis"

  - Ensures equal distribution of chromatids in the daughter cells
  - Kinetochore spindle fibers contract towards their respective poles.
  - Polar microtubule elongates
  - Sister chromatids are separated from centromeres.
  - Hence, half sister chromatids travel towards each pole.

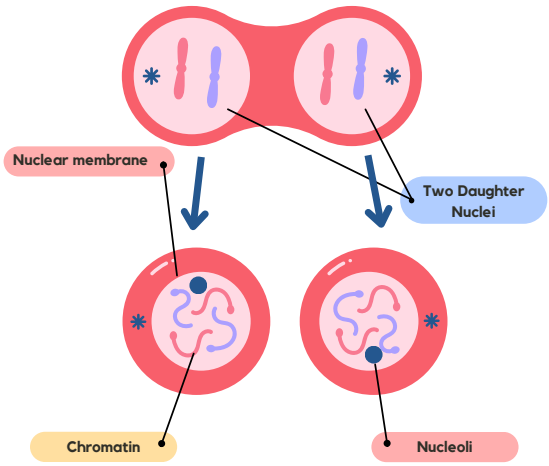


NOTES

- **Telophase**

"Reverse of prophase"

  - The chromosomes decondense and disappear into chromatin due to unfolding
  - Mitotic apparatus disorganized
  - Nuclear membrane and nucleoli reorganize.
  - Result is two nuclei at two poles of the cell.




## CYTOKINESIS

In Animals:

- During late telephone, the astral microtubule sends signals to the equatorial region of the cell, where actin and myosin are activated.
- The contractile ring is formed followed by a cleavage furrow which deepens towards the center of the cell. This divides the cell into two daughter cells.

In plants:

- higher plants lack centrioles
- Instead they have **analogous regions** from which the spindle microtubules radiate.
- the shape of the plant cell does not change greatly compared with an animal cell due to the **rigid cell wall.**
- Instead of contractile rings, a membrane structure called **phragmoplast** is formed from vesicles coming from **Golgi apparatus.**
- The membrane of vesicles becomes the plasma membrane of daughter cells.
- These vesicles also contain materials for **future cell walls** such as **precursors of cellulose and pectin.**

| Significance of mitosis | Significance of meiosis |
|---|---|
| As there is no crossing over or recombination, the genetic information remains unchanged generation after generation and hereditary material is equally distributed in each daughter cell. | Crossing over allows the exchange of parental chromosome segments resulting in a large number of recombinations. |
| Regeneration, healing of wounds, asexual reproduction, and replacement of older cells are all gifts of mitosis. | During anaphase of meiosis, the separation of homologous chromosomes takes place randomly which gives a very wide range of variety of gametes. |

| | |
|---|---|
| Development and growth of multicellular organisms depends on mitosis. | It causes variations and modifications in the genome. It forms basis of evolution. It makes every individual specific, particular and unique in its characteristics |
| Tissue culture and cloning | Maintains chromosome number constant generation after generation. |

NOTES

## Cancer:

## Caused by:

- Mutation in somatic cells
- Results from the accumulation of few as three to as many as twenty mutations in gene that regulate cell division

## Metastasis:

- The spreading of tumor cells and establishment of secondary growth areas.
- E.g malignant tumors invade surrounding tissues, get into the body's circulatory system, and set up an area of proliferation away from the site of the original appearance.

## Characteristics of cancerous cells:

- Less differentiated than normal cells
- Rapidly growing cells
- High nucleus-to-cytoplasm ratio
- Prominent nucleoli
- Many mitoses
- The presence of invading cells

## Difference between benign and malignant tumor:

| Benign tumor | Malignant tumor |
|---|---|
| Localised | Delocalised |
| Small | Large |
| Behave like normal cells | Get into body's circulatory system |
| These cells have little deleterious effects. | These cells have great deleterious effects. |

## Tumor:

'A mass of unwanted cells of cells that have proliferated in an uncontrolled fashion.

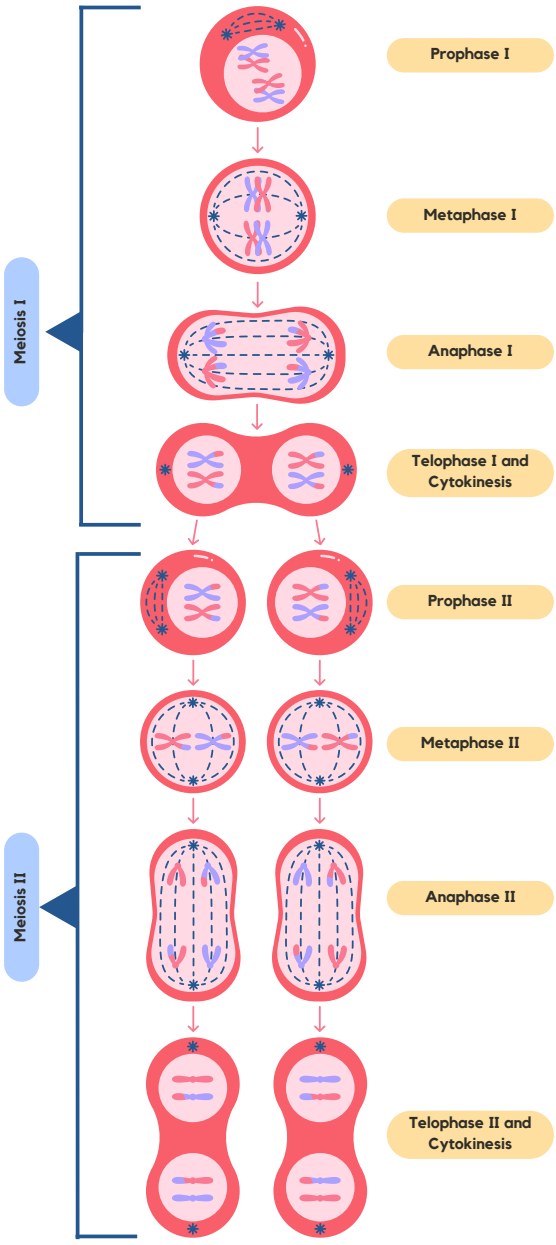
- Clonal in origin which is why they arise from a single cell.
- Arises frequently, especially in older animals and humans.

NOTES

# MEIOSIS

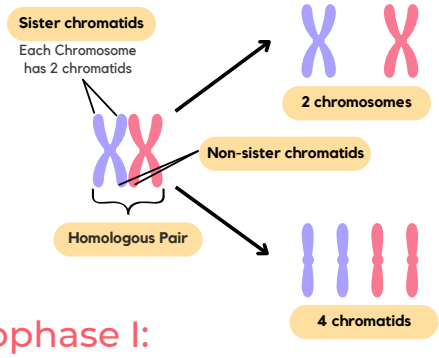
"A SPECIAL type of cell division in which the number of chromosomes in daughter cells is reduced to half as compared to the parent cell"

- Only takes place in diploid organisms
- Each diploid cell after meiosis produces four haploid cells.
- Involves two consecutive divisions [ meiosis 1 and meiosis 2]
- Meiosis 1 is the reduction division
- Meiosis 2 is just like mitosis.



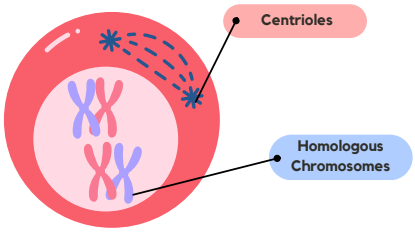

Note:

- The interphase of meiosis lacks the G2 stage.
- The similar [ means that each chromosome has two chromatids] but not necessarily identical [ means there are two chromosomes in the homologous pair , one from the male parent and the other from the female parent ] are called homologous chromosomes.



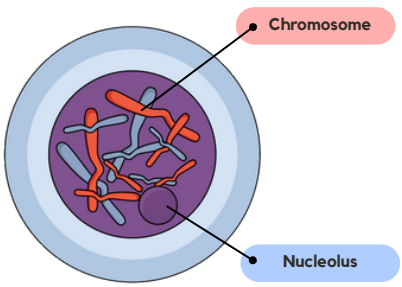

## Prophase I:

- Very prolonged phase
- Chromosomes behave as homologous pairs




### Stages of Prophase I

- Leptotene
  - The chromosomes become visible, shorten and thick.
  - The size of the nucleus increases
  - Homologous chromosomes start getting closer to each other

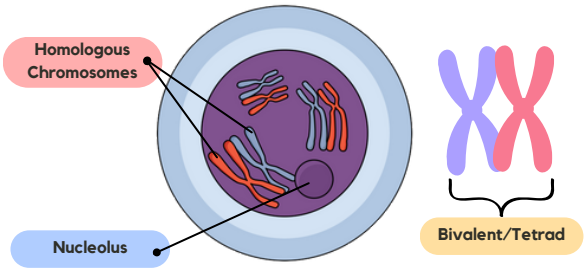


NOTES

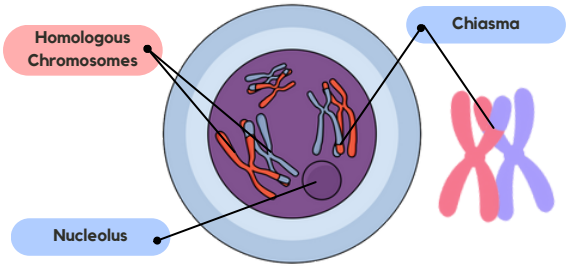
- Zygotene

First essential phenomenon of meiosis

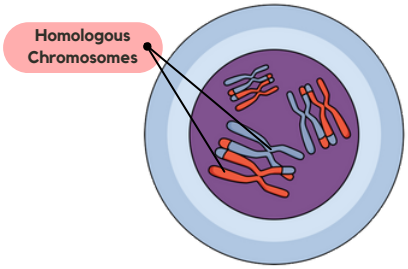
  - Pairing of homologous chromosomes called synapsis starts.
  - This pairing is highly specific and exactly pointed, but with no definite starting point(s).
  - Each paired but not fused, complex structure is called bivalent or tetrad.



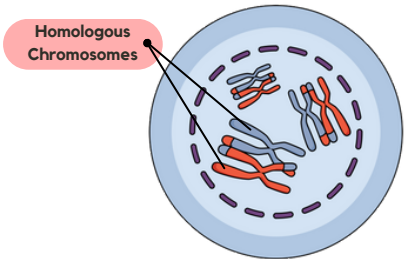

- Pachytene
  - The pairing of homologous chromosomes is completed.
  - Chromosomes become thicker and thicker.
  - Each bivalent has four chromatids, which wrap around each other.
  - **Non-sister chromatids of homologous chromosomes exchange their segments due to chiasmata formation, during the process called crossing over.**
  - In this way reshuffling of genetic material occurs which produces recombinations.
  - Pachytene may last **for days, weeks, or even years,**
  - Leptotene and Zygotene can last only for few hours.




- Diplotene
  - The paired chromosomes repel each other and begin to separate.
  - Separation however, is not complete, because homologous chromosomes remain united by their point of interchange (chiasmata)



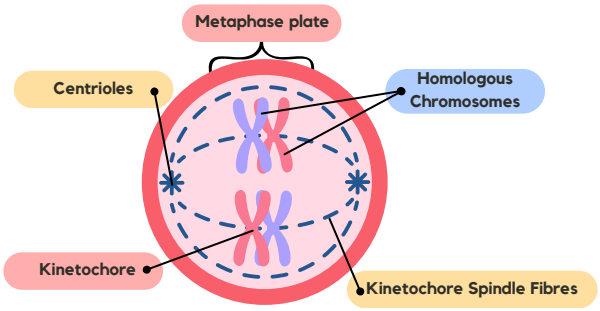

- Diakinesis
  - During this phase the condensation of chromosomes reaches its maximum.
  - At the same time separation of the homologous chromosomes (started during diplotene) is completed, but still they are united at one point, more often at ends.
  - Nucleoli disappear.




Metaphase I

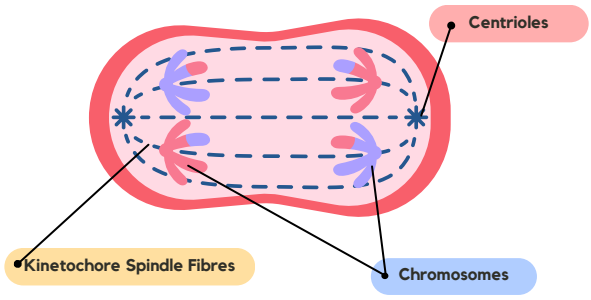
- Nuclear membrane disorganized
- Spindle fibers and kinetochore fibers attach to the kinetochore of homologous chromosomes from each pole and arrange bivalents at the equator.
- The sister chromatids of individual chromosomes in bivalent behave as a unit.

NOTES



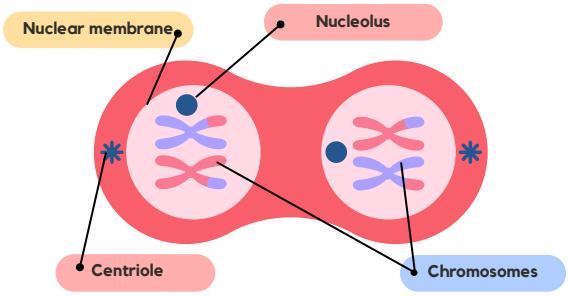

Anaphase I

- Kinetochore fibers contract and spindle fibers elongate
- Pull the individual chromosomes [each having two chromatids] towards the poles.
- Sister chromatids are not separated
- A reduction phase
- Each pole receives half of the total number of chromosomes.




Telophase I

- Kinetochore fibers contract and spindle fibers elongate
- Pull the individual chromosomes [each having two chromatids] towards the poles.
- Sister chromatids are not separated
- A reduction phase
- Each pole receives half of the total number of chromosomes.




## Meiosis II:

After telophase I two daughter cells experience small interphase, but in contrast to interphase of mitosis there is no replication of chromosomes.

- Prophase II, metaphase II, anaphase II and telophase II are just like the respective phases of mitosis during which
- The chromosomes, condense,
- Mitotic apparatus forms,
- Chromosomes arrange at the equator
- Individual/sister chromatids move apart
- And ultimately four nuclei at the respective poles of two daughter cells (formed after meiosis I) are formed.
- Cytokinesis takes place and four haploid cells, with half of the number of chromosomes (chromatids) are formed.

NOTES

# MEIOTIC ERRORS

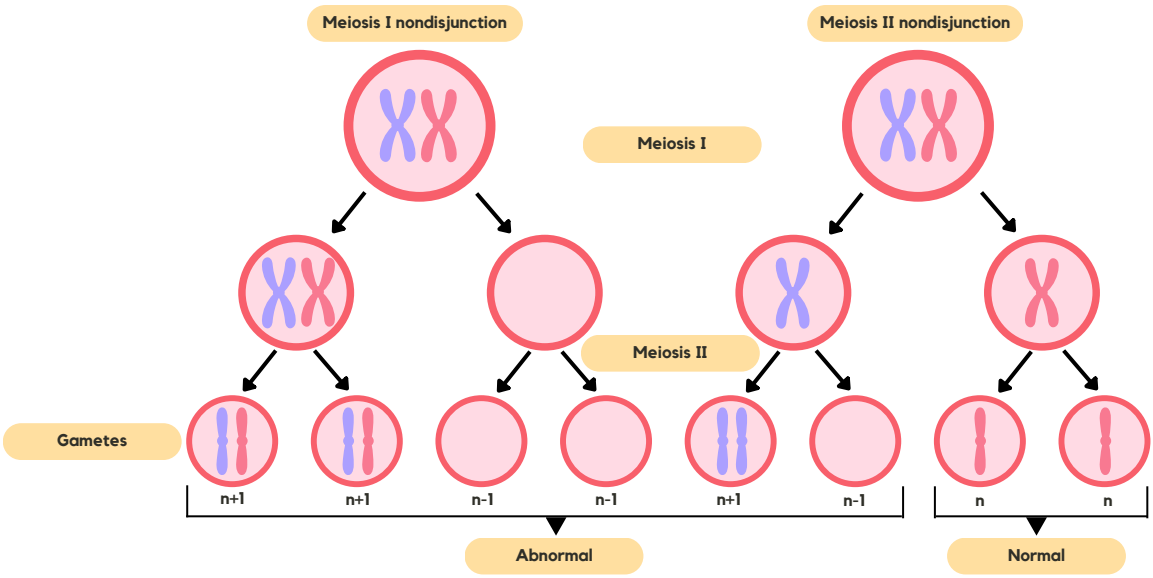
## Meiotic errors/ Nondisjunction:

- The pairing of homologous chromosomes is completed.
- Chromosomes become thicker and thicker.
- Each bivalent has four chromatids, which wrap around each other.
- **Non-sister chromatids of homologous chromosomes exchange their segments due to chiasmata formation, during the process called crossing over.**
- In this way reshuffling of genetic material occurs which produces recombinations.
- Pachytene may last **for days, weeks, or even years,**
- Leptotene and Zygotene can last only for few hours.

## Chromosome nondisjunction:

'chromosomes fail to segregate during anaphase and telophase and do not finish with equal distribution of chromosomes among all the daughter nuclei.'

- This results in either an increase or decrease in the number of chromosomes, causing serious physical, social and mental disorders.
- This nondisjunction may be in autosomes or in the sex chromosome.



NOTES

| Down's Syndrome | Klinefelter's Syndrome | Turner's Syndrome |
|---|---|---|
| • Consequence of autosomal nondisjunction<br>• The 21st pair of chromosomes fails to segregate, resulting in gamete with 24 chromosomes.<br>• When this gamete fertilizes normal gamete the new individual will have 47 (2n + 1) chromosomes.<br>• Non-disjunction appears to occur in the ova and is related to the age of the mother.<br>• The chances of teenage mother having Down's syndrome child is one in many thousands,<br>• forty years old mother, one in hundred chances<br>• and by forty-five the risk is three times greater.<br>**Symptoms:**<br>1. have flat, broad face,<br>2. squint eyes<br>3. with the skin fold in the inner corner,<br>4. protruding tongue,<br>5. mental retardation,<br>6. defective development of central nervous system. | • These individuals have additional sex chromosomes e.g., 47 chromosomes (44 .autosome + XXY).<br>• Males with 48 chromosomes (44 autosomes + XXXY), with 49 chromosomes (44 autosomes + XXXXY) and with 47 chromosomes (44 autosomes + XYY) are also observed<br>**Symptoms:**<br>1. They are phenotypically male<br>2. frequently enlarged breasts,<br>3. tendency to tallness, obesity,<br>4. small testes with no sperms at ejaculation<br>5. underdeveloped secondary sex characters. | • These affected individuals have one missing X chromosome with only 45 chromosomes (44 autosomes + X).<br>• Individuals with this condition often do not survive pregnancy and are aborted.<br>**Symptoms:**<br>1. Those who survive have female appearance<br>2. with short stature,<br>3. webbed neck,<br>4. without ovaries<br>5. complete absence of germ cell |

★Autosomal nondisjunction may occur in other than 21st chromosome which usually results in abortion, or death in a very early age.

NOTES

| Apoptosis | Necrosis |
| --- | --- |
| Programmed cell death | Accidental death of a cell |
| Involves sequence of morphological changes according to internal program. | Does not involve a sequence of morphological changes. |
| Cell commits suicide | Cell swell and burst |
| Intracellular( within the cell) constituents do no damage neighboring cells | Cell releases intracellular contents which damage neighbouring cells. |