Cell Cycle and Cell Division

10

INTRODUCTION

* **Rudolf Virchow** stated that new cell develops from the division of pre-existing cell.
* **Van Beneden and Flemming** discovered mitosis in animal cell. The term **'Mitosis' coined by Flemming**.
* The term **meiosis** coined by **Farmer and moore**.
* Some substances stimulate cell division these are called **mitogen - Eg: Cytokinins, Epidermal growth Factor or EGF, Platelet Derived Growth Factor or PDGF, Lymphokines**.
* Some substances inhibit cell division these are called mitotic poison **Eg: Cyanides, Azides, Chalones, Colchicine.**

CELL CYCLE (HOWARD & PELC 1953) :

* It involves programmed cyclic changes in the cell that leads to change in cellular components and ultimately cell divides to form two cells. This process is genetically controlled. The duration between two cell cycles is generation time.

CELL CYCLE INVOLVES TWO STAGES :

(1) Interphase or I-phase or Intermitosis or Nondividing phase or Energy phase.

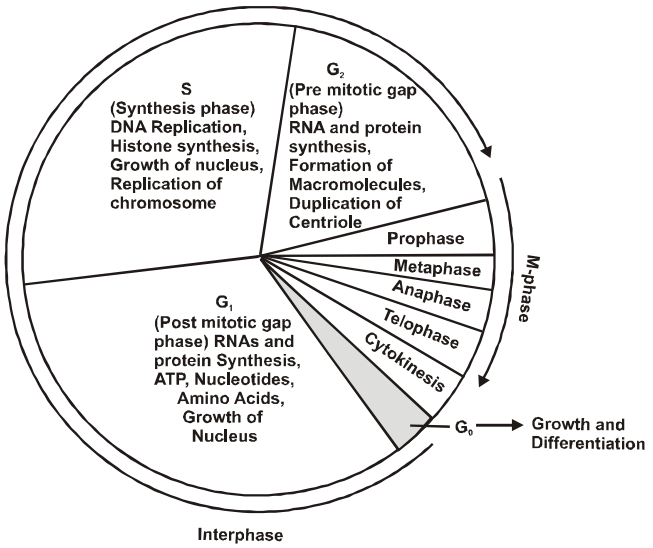


Fig:- Cell Cycle.

It is longest phase. It is differentiated into three stages.

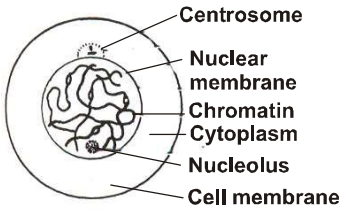
(A) G_1-phase or first gap phase or first Growth phase or pre synthetic phase or post mitotic phase

* Its duration is **42%** of total time of cell division.
* In this phase some changes occur like synthesis of RNA, proteins, Enzymes for DNA synthesis, Amino acids for Histone formation.
* Some time, G_1-phase arrest at the middle and cell undergoes differentiation it is called **G_0 phase**.
  The Deciding factors are energy producing substances and mitogens this point is called chack point.
* Once a cell is passed from check point this stage is called **Antephase (Bullough)** Now cell will divide even in unfavourable conditions.
* **Size of cell and Nucleus becomes doubled in G_1 phase.**

(B) S-phase (Synthetic phase) :

It is invisible phase of Mitosis. Its duration is **33%** of total time. **Replication of DNA** of chromosome takes place in S-phase **Histone protein synthesizes** in this phase.

Replication of centrioles (centrosome) starts in S- phase.



(i)

Fig:- Interphase

(C) G_2-phase (Second Gap phase or second Growth phase or postsynthetic phase or pre-mitotic phase) :

* Synthesis of RNA and proteins takes place. **Replication of centrioles (centrosome) completed in G_2 - phase. Tubulin protein** is **formed**. Its duration is **21%** of total time.
* **Cyclin protein : Cyclin dependent protein Kinases (CDK) regulate the cell cycle.**

(2) M-Phase (Mitotic phase) :

Its duration is **4%** of total time. It divides into two stages

(A) Karyokinesis **(B) Cytokinesis**

MITOSIS :

(A) Karyokinesis (Schneider 1887) :

It can be divided into four stages for sake of convinience

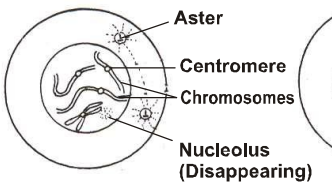
(I) Prophase **(II) Metaphase**
(III) Anaphase **(IV) Telophase**

(I) Prophase : It is longest phase. Its duration is 2·1% of total time. It involves three phases.

(a) Early prophase :

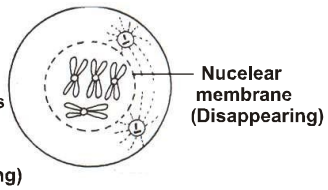
Chromatin undergoes dehydration to form long thin & coiled chromosomes that are called spiralization and their ends are indistinct they look like a boll of wool this stage is called **spireme stage**.

Centrosomes move away to each other and move towards opposite poles.



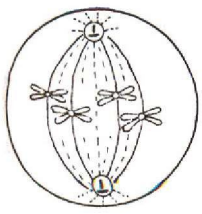
(ii)

Fig:- Early prophase



(iii)

Fig:- Middle prophase



(iv)

Fig :- Late prophase

(b) Mid prophase :

Chromosomes are thickened and shifted in the peripheral part of nucleus.

Formation of Astral rays starts. Nuclear membrane starts breakdown. Nucleolus reduces in size.

(c) Late prophase :

Chromosome are comparatively thickened. Centrosomes are reached to the opposite poles.

In this phase nuclear membrane is disappeared. Nucleolus & ER are also disappeared.

Aster is formed at each pole by a pair of centrioles and astral rays. Centrioles start formation of spindle fibres. Centrosome helps in the initiation of cell division in animal cells by forming spindle. In plant cells centrosome is absent. The spindle fibre arise from tubulin protein by gelation in the cytoplasm thus in plant cell centriole and asters have no role in the formation of spindle apparatus. The middle broad part of spindle apparatus is called equator.

(II) Metaphase :

* Its duration is **0·4%.** Chromosomes are thick, shorten and distinct.
* **The shape, size and structure of chromosomes can be studied in the metaphase stage.**
* The tightening of chromosomal fibres brings chromosomes at the equator. This process is called **congression or metakinesis**.
* The centromeres of all the chromosomes arrange in linear sequence at the equator to form **single metaphase plate.**
* Kinetochore of chromosomes connect chromosomes to the spindle fibre. Each chromosomes has two distinct chromatids. The arms of each chromosome lie in different direction and the centromere lie on equator.

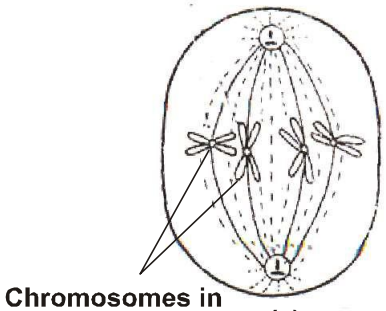


Fig:- Metaphase

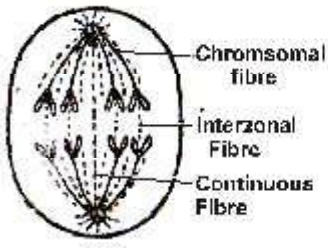


Fig:- Early anaphase

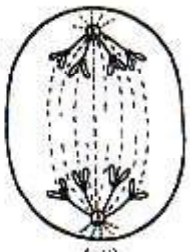


Fig:- Late anaphase

(III) Anaphase :

* Its duration is 0·3%. Anaphase promoting complex or APC becomes activated. It causes equatorial division in each chromosome as a result the no. of chromosomes becomes doubled.
* Now half chromosomes move towards one pole and remaining half chromosomes move towards opposite pole by the constriction of chromosomal fibre. It is called **Anaphasic movement**.
* At this time centromere of each chromosome lies towards poles and its arms behind it.
* 20–25 ATP are consumed by a chromosome during anaphasic movement.
* Each chromosome has **single chromatid** & it is **V-shaped / L-shaped / J-shaped / I-shaped.**

(IV) Telophase :

It is reverse of prophase. Chromosomes are reached on the opposite poles and now they become uncoiled and converted into long thin chromatin network. Nuclear membranes is reappeared NOR forms Nucleolus. Thus each pole has a nucleus in telophase stage. Spindle fibres are disappeared.

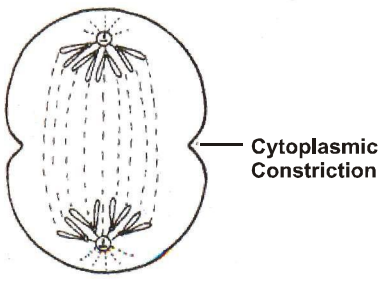
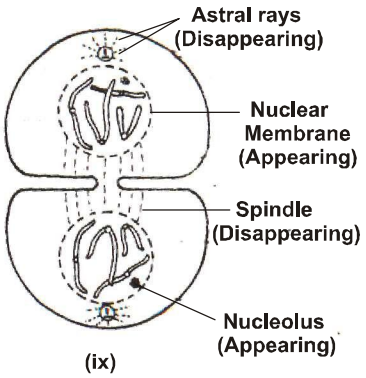
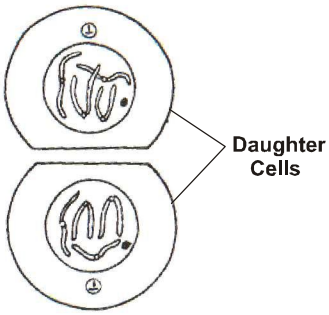


Fig:- Early Telophase



(ix)

Fig:- Late Telophase



(x)

(B) Cytokinesis (Whitemen) :

It is a division of cytoplasm. It starts in late anaphase & Completed at the end of telophase.

Cytokinesis comprises two types.

(i) Cell furrow or cell cleavage method :

A viscous fibrous dense **Mid body** is formed in the centre. Constriction of peripheral microfilaments takes place toward centre **(Centripetal)** and finally both sides meet and two daughter cells are formed **Ex: Animal cell.**

(ii) Cell plate method :

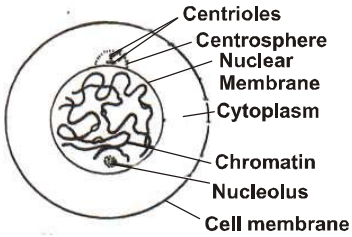
In case of plant cell, some spindle fibres exist that form **phragmoplast**.

Golgi vesicles and some ER vesicles deposite in the central part of phragmoplast and their deposition proceeds towards peripheral part **(centrifugal)** and finally a cell plate is formed followed by the formation of middle lamella.

Now Primary wall deposites at each side of middle lamella and ultimately both cells get seperated to form two daugther plant cells.

MEIOSIS :

It is essential for sexual reproduction. It involves meiosis-I and meiosis-II. Interphase involves - G_1, S, G_2 Phase. Out of them G_2 phase is short. Centrosome replicates in this stage.



Interphase

Meiosis-I :

M-phase-It involves karyokinesis & cytokinesis.

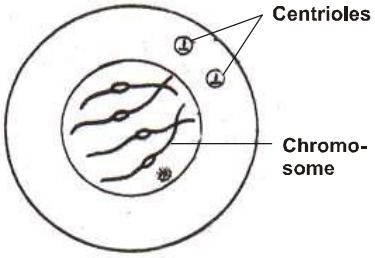
Karyokinesis : It involves prophase-I, Metaphase-I, Anaphase-I, Telophase-I.

(A) Prophase-I :

It is longest phase. It can be differentiated into five stages.

Laptotene : Chromatin is condensed to form chromosomes. All the chromosomes converge towards a common point near centrosome and form basket like arrangement this stage is called **boquet stage**.

The chromatids of chromosomes are not distinct due to nucleoprotein.

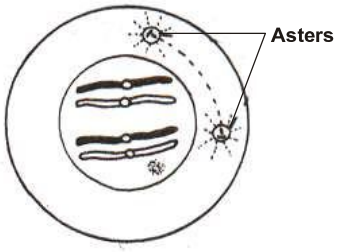


Leptotene

Zygotene :

Chromosomes are comparatively small & thick. Homologous chromosomes perform pairing. One homolgous

chromosome is maternal and second is paternal. This pairing of two homolgous chromosomes is called **synapsis / Syndesis (Mont Gomery 1901).** It forms Bivalent.

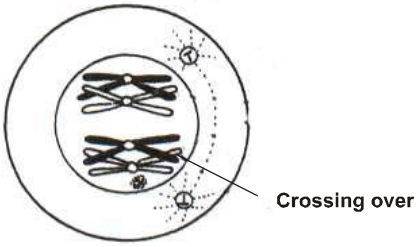


Zygotene

Pachytene :

In this stage Recombination nodule **(Zinkler-1977)** is formed between two nonsister chromatids.

The exchange of segments of nonsister chromatids between two homolgous chromosomes of a Bivalent is called **crossing over (Morgan)**. **Recombinase** enzyme catalyzes this process.Syneptinemal complex starts dissolving.



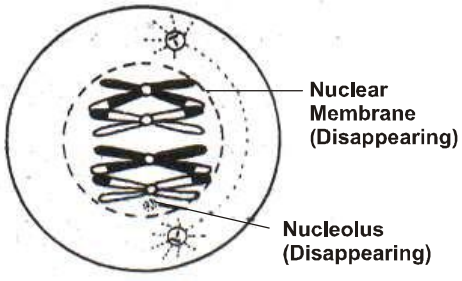
Pachytene

Diplotene :

Syneptonemal complex is completely dissolved and chromatids of bivalents are distinct.

Each Bivalent has four chromatids and two centromeres.

Homologous chromosomes of each Bivalent start seperation. They are connected at certain points these are called **chiasmata (janssen 1909)** and the Bivalents are now called tetrad. Chiasmata are the results of Crossing over. Nuclear membrane starts disintigration. Nucleolus decreases in size.

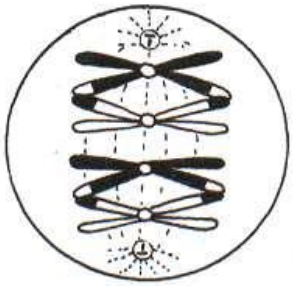


Diplotene

Diakinesis :

Separation of Homologous chromosomes proceeds towards terminal part (terminalization) by the shifting of chiasmata towards chromsomal ends.

Centrioles are reached on opposite poles and form aster with astral rays spindle is formed that is amphiastral in animal cell and anastral in plant cell.



Diakinesis

(B) Metaphase-I :

Bivalents arrange in two raws on equator to form **Double metaphasic plate.**

The arms of homologous chromosomes lies parallel to the equator and their centromeres are projected outwardly towards poles.

Each chromosome in a bivalent is connected to the spindle pole of its side by a single kinetochore microtubule (chromosomal tractile fibre) instead of two as in metaphase of mitosis.

(C) Anaphase-I :

In this stage reduction division takes place & segregation of Mendelian factors occurs. The chromosome no. becomes half (2n–n). Maternal and paternal chromosomes of each bivalent are completely seperated it is called **disjunction**.

They move in opposite direction towards opposite poles due to constriction of chromosomal fibres. It is called anaphasic movement. Thus Bivalents are converted in univalents. Each univalent has divergent two chromatids.

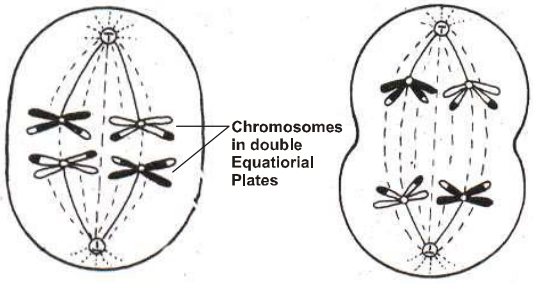
At the end of this phase chromosomes are reached at opposite poles.

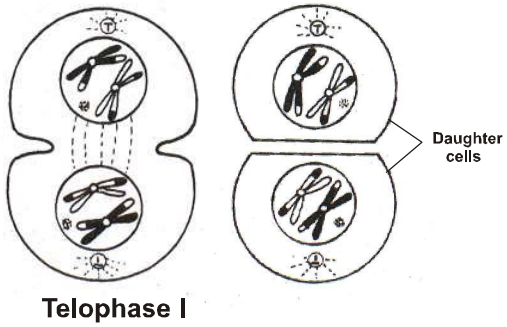
(D) Telophase-I :

Regrouping of Dyad chromosomes occur at each pole

Chromosomes undergo despirilization, become thin & elongated. Nucleolus is rarely formed. Nuclear membrane reappears and each pole has a haploid nucleus.

Cytokinesis may or may not occur after meiosis-I



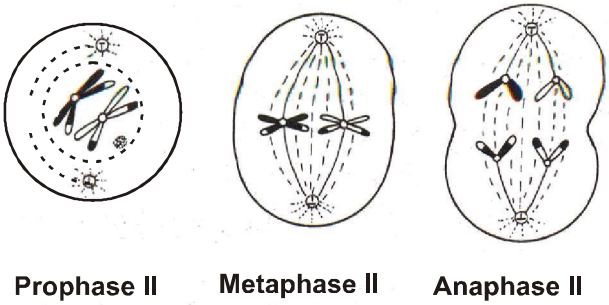


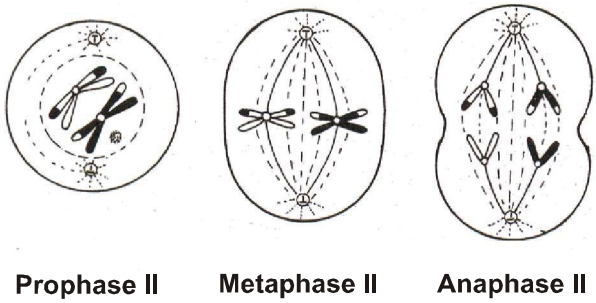
Interkinesis :

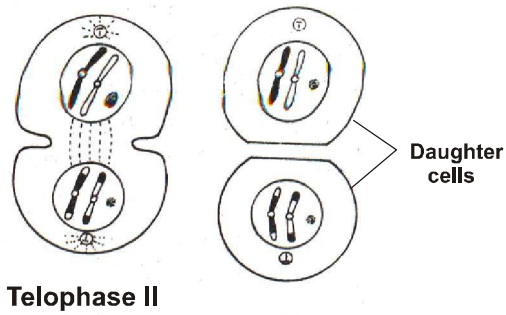
It is called intrameiotic interphase. In this phase some deficient substance form but synthesis of DNA does not occur.

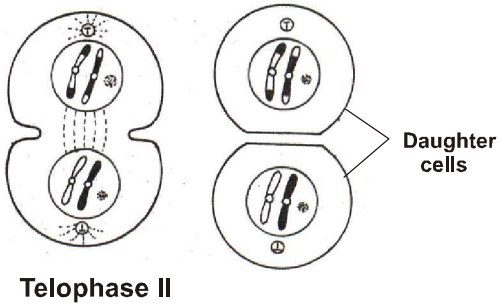
Meiosis-II :

It is also called homotypic or Homoeotypic or equational division. It is just like mitosis but occurs in halpoid nuclei.









At the end of meiosis-II four haploid cells are formed that are genetically different.

Significance of meiosis :

(a) Variations :

(i) Independent assortment of chromosomes

(ii) Crossing over

(iii) Irregular disjunction

(iv) Gene mutation during replication & nicking for crossing over.

(b) Polyploidy : Failure of chromosomes to separate during anaphase-I leads to polyploidy.

(c) Maintenance of chromosome number

(d) Sexual reproduction

Mitosis takes place in the somatic cells		
S.No.	**Mitosis**	**Meiosis**
1.	Mitosis takes place in the somatic cells.	It occurs either in the reproductive cells or at the time of germination of zygote or zygospore.
2.	The cells undergoing mitosis may be haploid or diploid.	The cells undergoing meiosis are always diploid.
3.	It is a single division which produces two cells.	Meiosis is a double division. It gives rise to four cells.
4.	Subsequent mitotic divisions are similar to one is the earlier ones.	The two divisions of meiosis are not similar. The first heterotypic or reductional while the second one is homotypic or equational like mitosis.
5.	Each chromosome replicates in the interphase before every division.	The chromosomes replicate only once, prior to meiosis.
6.	The number of chromosomes remains the same after mitosis.	The number of chromosomes is reduced to one half after mitosis.
Prophase		
7.	Prophase is of shorter duration.	Prophase I is of longer duration while prophase II is very brief.
8.	Each chromosome has two distinct chromatids.	Chromosomes of prophase I do not show distinct chromatids.
9.	No bouquet stage is recorded.	Chromosomes of animals and some plants show con vergence towards one side during early prophase I. It is known as bouquet stage.
10.	Pairing of chromosomes does not occur in mitosis	Pairing or synapsis of homologous chromosomes takes place during zygotene of prophase I and continues upto metaphase I.
11.	A synaptinemal complex is absent.	Synapsed homologous chromosome develop a synaptinemal complex.
12.	Crossing over is absent.	Crossing over or exchange of similar segments between nonsister chromatids of homologous chromosomes usually takes place during pachytene stage.
13.	Chiasmata are absent.	Chiasmata or visible connections between homologous chromosomes of bivalents are observed during diplotene, diakinesis

Metaphase		
14.	Centromeres produce a single metaphasic plate.	A double metaphasic plate is formed by cen tromeres in metaphase I but only one in metaphase II.
15.	Only the centromeres lie at the equator. The limbs of chromosomes are oriented in various directions.	Limbs of the chromosomes mostly lie at the equator while the centromeres project towards the poles in metaphase I.
16.	A centromere is connected with both the spindle poles.	A centromere is connected to one spindle pole in metaphase I but both in metaphase II.
17.	Two chromatids of a chromosome are genetically similar.	The two chromatids of a chromosome are often genetically dissimilar due to crossing over.
Anaphase		
18.	A centromere splits length-wise to form two centromeres in the beginning of anaphase.	Centromeres do not divide during anaphase I but do so in anaphase II.
19.	Anaphasic chromosomes are single stranded.	Chromosomes are double stranded in anaphase I but single stranded in anaphase II.
Telophase		
20	Telophase is longer and produces interphase nuclei.	Telophase I is shorter and nuclei never enter the interphase.
Cytokinesis		
21.	Cytokinesis follows every mitosis. It produces two cells.	Cytokinesis often does not occur after the first or reductional division. It is then simultaneous after second division to result in four new cells.