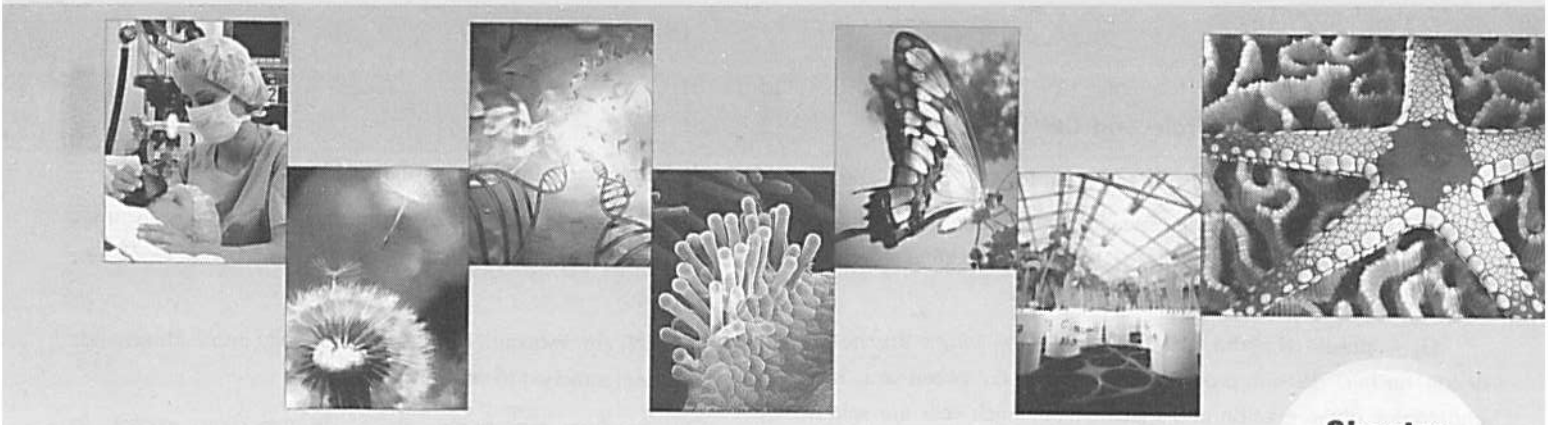


Chapter

3.3

Cell Cycle and Cell Division

Cell division / Cell reproduction / Cell cycle

It is the process by which a mature cell divides and f+orms two nearly equal daughter cells which resemble the parental cell in a number of characters.

In unicellular organisms, cell division is the means of reproduction by which the mother cell produces two or more new cells. In multicellular organism also, new individual develop from a single cell. Cell division is central to life of all cell and is essential for the perpetuation of the species.

Discovery : Prevost and Dumans (1824) first to study cell division during the cleavage of zygote of frog. Nageli (1846) first to propose that new cells are formed by the division of pre-existing cells.

Rudolf Virchow (1859) proposed "omnis cellula e cellula" and "cell lineage theory".

A cell divides when it has grown to a certain maximum size which disturb the karyoplasmic index (KI)/Nucleoplasmic ratio (NP)/Kernplasm connection.

Cell cycle : *Howard* and *Pelc* (1953) first time described it. The sequence of events which occur during cell growth and cell division are collectively called cell cycle. Cell cycle completes in two steps:

(1) Interphase, (2) *M*-phase/Dividing phase

(1) **Interphase :** It is the period between the end of one cell division to the beginning of next cell division. It is also called resting phase or not dividing phase. But, it is actually highly metabolically active phase, in which cell prepares itself for next cell division. In case of human beings it will take approx 25 hours. Interphase is completed into three successive stages.

G_1 phase/Post mitotic/Pre-DNA synthetic phase/gap Ist : In which following events take place.

(i) Intensive cellular synthesis.

(ii) Synthesis of rRNA, mRNA ribosomes and proteins.

(iii) Metabolic rate is high.

(iv) Cells become differentiated.

(v) Synthesis of enzymes and ATP storage.

(vi) Cell size increases.

(vii) Decision for a division in a cell occurs.

(viii) Substances of G stimulates the onset of next S – phase.

(ix) Synthesis of NHC protein, carbohydrates, proteins, lipids.

(x) Synthesis of enzyme, amino acids, nucleotides etc. but there is no change in DNA amount.

***S*-phase/Synthetic phase**

(i) DNA replicates and its amount becomes double (2C - 4C).

(ii) Synthesis of histone proteins and NHC (non-histone chromosomal proteins).

(iii) Euchromatin replicates earlier than heterochromatin.

G_2-phase/Pre mitotic/Post synthetic phase/gap-IInd

(i) Mitotic spindle protein (tubulin) synthesis begins.

(ii) Chromosome condensation factor appears.

(iii) Synthesis of 3 types of RNA, NHC proteins, and ATP molecule.

(iv) Duplication of mitochondria, plastids and other cellular macromolecular complements.

(v) Damaged DNA repair occur.

(2) ***M*-phase/Dividing phase/Mitotic phase :** It is divided into two phases, karyokinesis and cytokinesis.

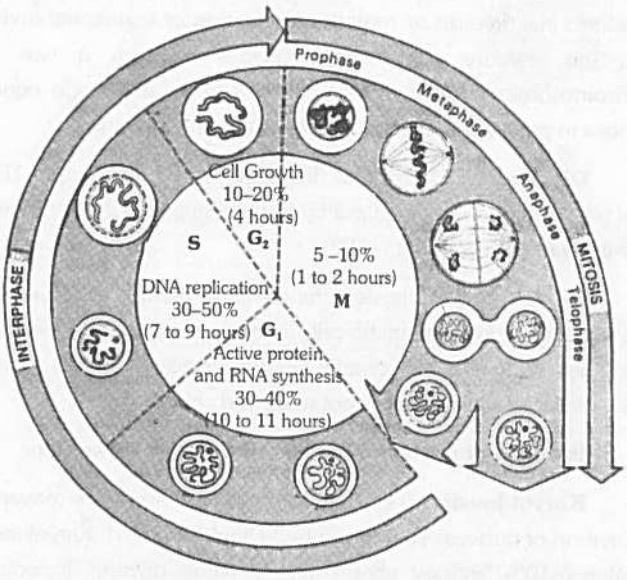


Fig : 3.3-1 Different stages of cell cycle (Mitotic cycle)

Duration of cell cycle : Time period for G_1, S, G_2 and M-phase is species specific under specific environmental conditions. *e.g.*, 20 minutes for bacterial cell, 8-10 hours for intestinal epithelial cell, and onion root tip cells may take 20 hours.

G_0 – phase (Lajtha, 1963) : The cells, which are not to divide further, do not proceed beyond the G_1 phase and start undergoing differentiation into specific type. Such cells are said to be in G_0 phase.

Types of cell division : It is of three types, Amitosis, Mitosis and Meiosis.

Amitosis

Amitosis (Gk. *Amitos* = without thread; osis = state). It is also called as direct cell division. It was discovered by Remak (1855) in RBC of chick embryo. In this division there is no differentiation of chromosomes and spindle. The nuclear envelope does not degenerate.The nucleus elongates and constricts in the middle to form two daughter nuclei. This is followed by a centripetal constriction of the cytoplasm to form two daughter cells. It is primitive type of division occuring in prokaryotes, protozoans, yeasts, foetal membrane of mammals, cartilage of mammals etc.

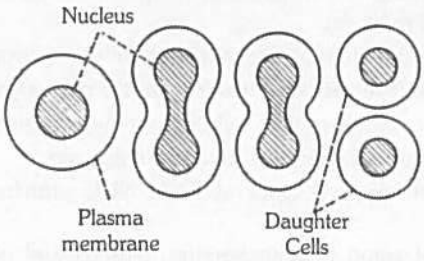


Fig : 3.3-2 Amitosis division

Mitosis

Mitosis (Gk. *Mitos* = thread; *osis* = state). It is also called indirect cell division or somatic cell division or equational division. In this, mature somatic cell divides in such a way that chromosomes number is kept constant in daughter cells equal to those in parent cell. So it is called equational division.

Discovery : Mitosis was first observed by *Strasburger* (1875) in plant cell and in animal cell by *W.flemming* (1879). Term mitosis was given by Flemming (1882).

Occurrence : Mitosis is the common method of cell division. It takes place in the somatic cells in the animals and plants. Hence, it is also known as the somatic division. In plants mitosis occurs in the meristematic cells *e.g.*, root apex and shoot apex.

Process of mitosis : Mitosis is completed in two steps.

Karyokinesis : (Gk. *Karyon* = nucleus; *kinesis* = movement) Division of nucleus. Term given by *Schneider* (1887). Karyokinesis it takes 5-10% (shortest phase) time of whole division. It comprises four phases *i.e.*, Prophase, Metaphase, Anaphase, Telophase.

(1) **Prophase :** It is longest phase of karyokinesis.

(i) Chromatin fibres thicken and shorten to form chromosomes which may overlap each other and appears like a ball of wool. *i.e.*, Spireme stage.

(ii) Each chromosome divides longitudinally into 2 chromatids which remain attached to centromere.

(iii) Nuclear membrane starts disintegrating except in dinoflagellates.

(iv) Nucleolus starts disintegrating.

(v) Cells become viscous, refractive and oval in outline.

(vi) Spindle formation begins.

(vii) Cell cytoskeleton, golgi complex, ER, etc. disappear.

(viii) In animal cells, centrioles move towards opposite sides.

(ix) Lampbrush chromosomes can be studied well.

(x) Small globular structure (beaded) on the chromosome are called chromomeres.

(xi) Spindle is formed from centriole (in animal cells) or MTOC (microtubule organising centre) in plant cells successively called astral and anastral spindle.

(2) **Metaphase**

(i) Chromosomes become maximally distinct *i.e.*, size can be measured.

(ii) A colourless, fibrous, bipolar spindle appears.

(iii) Spindle fibre are made up of 97% tubulin protein and 3% RNA.

(iv) Chromosomes move towards equatorial plane of spindles called congression and become arranged with their arms directed towards pole and centromere towards equator.

(v) Spindle fibres attach to kinetochores.

(vi) Metaphase is the best stage for studying chromosome morphology (structure, size, number).

(vii) Spindle has two type of fibres :

(a) Continous fibre (run from pole to pole).

(b) Discontinous fibre (between pole to centromeres).

(3) **Anaphase**

(i) Centromere splits from the middle and two chromatids gets separated.

(ii) Both the chromatids move towards opposite poles due to repulsive force called anaphasic movement.

(iii) Anaphasic movement is brought about by the repolymerisation of continuous fibres and depolymerisation of chromosomal fibres. Formation and expansion of interzonal fibres.

(iv) Different shape of chromosomes (V, J, I or L shapes) become evident during chromosome movement viz. metacentric acrocentric etc.

(v) The centromere faces towards equator.

(vi) The chromatids are moved towards the pole at a speed of 1 *μm/minute*. About 30 ATP molecules are used to move one chromosome from equator to pole.

(vii) Shape of chromosome is best studied at anaphase.

(4) **Telophase**

(i) Chromosomes reached on poles by the spindle fibers and form two groups.

(ii) Chromosomes begin to uncoil and form chromatin net.

(iii) The nuclear membrane and nucleolus reappear.

(iv) Two daughter nuclei are formed.

(v) Golgi complex and ER etc., reform.

(vi) This phase is also known as reverse prophase.

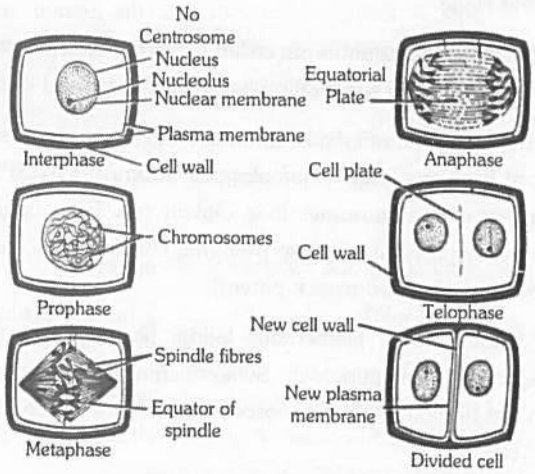


Fig : 3.3-3 Various stages of mitosis

Cytokinesis : (Gk –kitos = cell; kinesis = movement) Division of cytoplasm, Term given by *Whiteman* (1887). Division of cytoplasm into 2 equal parts.

Cytokinesis is by 2 methods :

(1) **Cell furrow method** : This is characteristic of animal cells. Due to absence of rigid cell wall here, the more flexible plasmamembrane forms the outer layer of cell. A **circular constriction** or invagination appears at centre or equator, which deepens gradually and finally two daughter cells are separated.

(2) **Cell plate method** : This is characteristic of plant cells. Here, vesicles provided by Golgi apparatus unite to form phragmoplasts, which join to form cell plate. Cell plate is first laid down in centre and then proceeds towards periphery (*i.e.*, centrifugal plate-formation). Cell wall materials are now laid down on both sides of cell plate and thus forming two daughter cells.

Significance of mitosis

(1) It keeps the chromosome number constant and genetic stability in daughter cells, so the linear heredity of an organism is maintained. All the cells are with similar genetic constituents.

(2) It provides new cells for repair and regeneration of lost parts and healing of the wounds.

(3) It helps in asexual reproduction by fragmentation, budding, stem cutting, etc.

(4) Somatic variations when maintained by vegetative propagation can play important role in speciation.

Types of Mitosis

(1) **Intranuclear or Promitosis** : In this nuclear membrane is not lost and spindle is formed inside the nuclear membrane *e.g.*, Protozoans (*Amoeba*) and yeast. It is so as centriole is present within the nucleus.

(2) **Extranuclear or Eumitosis** : In this nuclear membrane is lost and spindle is formed outside nuclear membrane *e.g.*, in plants and animals.

(3) **Endomitosis** : Chromosomes and their DNA duplicate but fail to separate which lead to polyploidy *e.g.*, in liver of man, both diploid (2N) and polyploid cells (4N) have been reported. It is also called endoduplication and endopolyploidy.

(4) **Dinomitosis** : In which nuclear envelope persists and microtubular spindle is not formed. During movement the chromosomes are attached with nuclear membrane.

Mitotic poision : The agents which inhibit cell division.

(1) **Azides and Cyanides** : Inhibit prophase.

(2) **Colchicine** : Inhibits spindle formation at metaphase.

(3) **Mustard gas** : Agglutinates the chromosomes.

(4) **Chalones** : These were first reported by Laurence and Bullough (1960). They are peptides and glycoproteins secreted by extracellular fluid of healthy cells and inhibit cellular division.

Karyochoriosis : A type of mitosis in fungi in which is intranuclear nucleus divides by furrow formation.

Table : 3.3-1

Difference between animal and plant cells (Mitosis)

Animal cells	Plant cells
Centrioles present at spindle poles.	Centrioles lacking at spindle poles.
Asters are formed (amphiastral).	No asters are formed (anastral).
Cytokinesis by furrowing of cytoplasm.	Cytokinesis mostly by cell plate formation.
Furrow extends centripetally	Cell plate grows centrifugally.

Microfilament ring brings about cleavage.	Microfilaments have no role in cytokinesis.
Occurs nearly in all tissues.	Occurs mainly at meristems.
Cell becomes rounded and its cytoplasm more viscous at the time of mitosis.	Cell does not change form or nature at the time of mitosis.
Midbody is formed at the equator of the spindle.	Equator of the spindle changes into phragmoplast.
Intercellular spaces appear between the daughter cells.	Daughter cells remain adhered together by middle lamella.
Animal mitosis is controlled by certain mitogens.	Plant mitosis is usually controlled by a hormone cytokinin.

Meiosis

Meiosis (Gr. meio – to lessen, *osis* – state). *Meiosis is a much slower process than mitosis*. It is a double division that occurs in a mature diploid reproductive cell (2x) in which nucleus divides twice but chromosome (DNA) replicates only once to form four haploid cells, each having the half the number of chromosomes present in the parent cell. As it causes reduction in the number of chromosomes, it is known as **reduction division**. Meiosis in a cell occurs only once. The so formed haploid cells do not further undergo meiosis because there is no synaptinemal complex in haploid genome.

Discovery : It was first demonstrated by *Van Beneden* (1887) but was described by *Winiwarter* (1900). Term "meiosis" was given by Farmer and Moore (1905). Gregoire used the term meiosis I and II.

Occurrence : It is found in special types and at specific period. It is reported in diploid germ cells of sex organs (*e.g.*, primary spermatocytes of testes to form male gametes called spermotozoa and primary oocytes to form female gametes called ova in animals) and in pollen mother cells (microsporocytes) of anther and megasporocyte of ovule of ovary of flowers in plant to form the haploid spores. The study of meiosis in plants can be done in young flower buds.

Process of meiosis : Meiosis is completed in two steps, meiosis I and meiosis II

Meiosis-I : In which the actual chromosome number is reduced to half. Therefore, meiosis I is also known as reductional division or heterotypic division. It results in the formation of two haploid cells from one diploid cell. It is divided into two parts, karyokinesis I and cytokinesis I.

Karyokinesis-I : It involves division of nucleus. It is divided into four phases *i.e.*, prophase, metaphase, anaphase, telophase.

(1) **Prophase-I :** It is of longest phase of karyokinesis of meiosis. It is again divisible into five subphases *i.e.*, leptotene, zygotene, pachytene, diplotene and diakinesis.

(i) **Leptotene/Leptonema**

(a) Chromosomes are long thread like with chromomeres on it.

(b) Volume of nucleus increases.

(c) Chromatin network has half chromosomes from male and half from female parent.

(d) Chromosome with similar structure are known as homologous chromosomes.

(e) Leptonemal chromosomes have a definite polarization and forms loops whose ends are attached to the nuclear envelope at points near the centrioles, contained within an aster. Such peculiar arrangement is termed as *bouquet stage* (in animals) and *syndet knot* (in plants).

(g) Lampbrush chromosome found in oocyte of amphibians is seen in leptotene.

(ii) **Zygotene/Zygonema**

(a) Pairing or "synapsis" of homologous chromosomes takes place in this stage.

(b) Paired chromosomes are called bivalents, which by furthur molecular packing and spiralization becomes shorter and thicker.

(c) Pairing of homologous chromosomes in a zipper-fashion. Number of bivalents (paired homologous chromosomes) is half to total number of chromosomes in a diploid cell. Each bivalent is formed of one paternal and one maternal chromosome (*i.e.*, one chromosome derived from each parent).

(d) Under EM, a filamentous ladder like nucleoproteinous complex, called synaptinemal. Synaptinemal complex is seen between the homologous chromosomes which was discovered by "*Moses*" (1956).

(iii) **Pachytene/Pachynema**

(a) In the tetrad, two similar chromatids of the same chromosome are called sister chromatids and those of two homologous chromosomes are termed non-sister chromatids.

(b) Crossing over *i.e.*, exchange of segments between non-sister chromatids of homologous chromosome occurs at this stage.

It takes place by breakage and reunion of chromatis segments. Breakage called nicking, is assisted by an enzyme endonuclease and reunion termed annealing is added by an enzyme ligase. Breakage and reunion hypothesis proposed by *Darlington* (1937).

(c) Chromatids of pachytene chromosome are attached with centromere.

(d) A tetrad consists of two sets of homologous chromosomes each with two chromatids. Each tetrad has four kinetochore (two sister and two homologous).

(e) A number of electron dense bodies about 100 *nm* in diameter are seen at irregular intervals within the centre of the synaptonemal complex, known as recombination nodules.

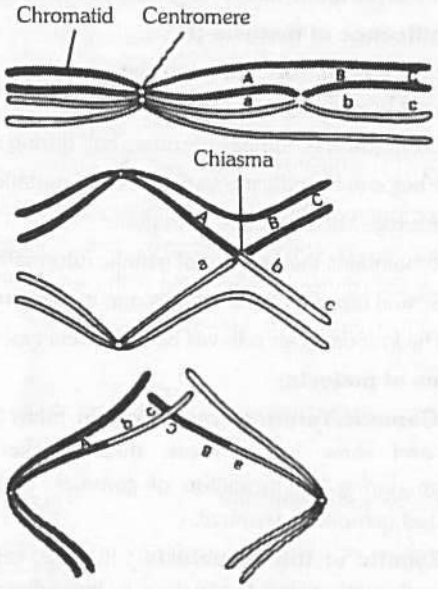


Fig : 3.3-4 Crossing over during meiosis

(f) DNA polymerase is responsible for the repair synthesis.

(iv) **Diplotene/Diplonema**

(a) At this stage the paired chromosomes begin to separate (desynapsis). Terminalisation starts.

(b) Cross is formed at the place of crossing over between non-sister chromatids.

(c) Homologous chromosomes move apart they remain attached to one another at specific points called chiasmata.

(d) At least one chiasma is formed in each bivalent.

(e) Chromosomes are attached only at the place of chiasmata.

(f) Chromatin bridges are formed in place of synaptonemal complex on chiasmata.

(g) This stage remains as such for long time.

(v) **Diakinesis**

(a) Terminalization completes.

(b) Nuclear membrane and nucleolus degenerates.

(c) Chromosome recondense and tetrad moves to the metaphase plate.

(d) Formation of spindle.

(e) Bivalents are irregularly and freely scattered in the nucleocytoplasmic matrix.

When the diakinesis of prophase-I is completed than cell enters into the metaphase-I.

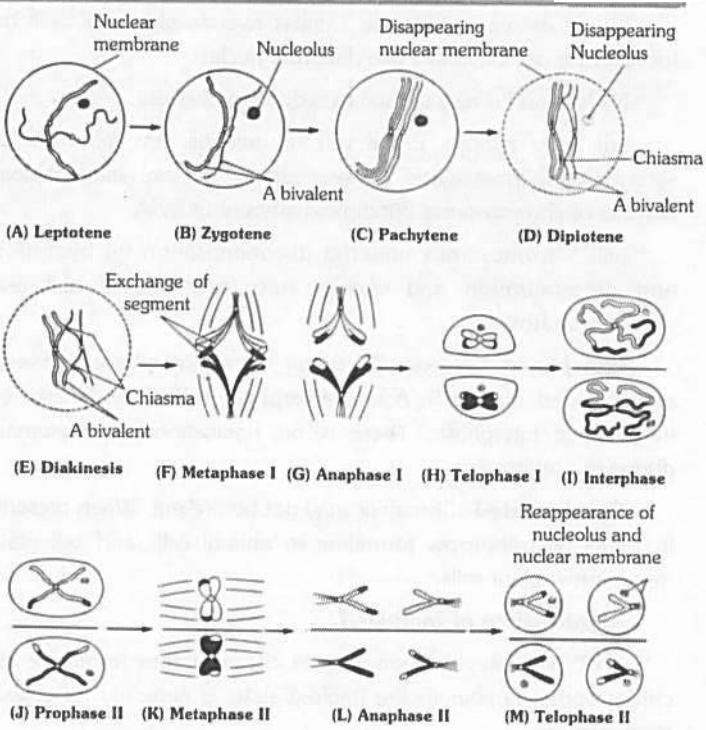


Fig : 3.3-5 Different stages of meiotic cell division (meiosis)

(2) **Metaphase-I**

(i) Chromosome come on the equator.

(ii) Bivalents arrange themselves in two parallel equatorial or metaphase plates. Each equatorial plate has one genome.

(iii) Centromeres of homologous chromosomes lie equidistant from equator and are directed towards the poles while arms generally lie horizontally on the equator.

(iv) Each homologous chromosome has two kinetochores and both the kinetochores of a chromosome are joined to the chromosomal or tractile fibre of same side.

(3) **Anaphase-I**

(i) It involves separartion of homologous chromosomes which start moving opposite poles so each tetrad is divided into two daughter dyads. So anaphase-I involves the reduction of chromosome number, this is called *disjunction*.

(ii) The shape of separating chromosomes may be rod or J or V-shape depending upon the position of centromere.

(iii) Segregation of Mendelian factors or independent assortment of chromosomes take place. In which the paternal and maternal chromosomes of each homologous pair segregate during anaphase-I which introduces genetic variability.

(4) **Telophase-I**

(i) Two daughter nuclei are formed but the chromosome number is half than the chromosome number of mother cell.

(ii) Nuclear membrane reappears.

(iii) After telophase I cytokinesis may or may not occur.

(iv) At the end of Meiosis I either two daughter cells will be formed or a cell may have two daughter nuclei.

(v) Meiosis I is also termed as reduction division.

(vi) After meiosis I, the cells in animals are reformed as secondary spermatocytes or secondary oocytes; with haploid number of chromosomes but diploid amount of DNA.

(vii) Chromosomes undergo decondensation by hydration and despiralization and change into long and thread like chromation fibres.

Interphase : Generally there is no interphase between meiosis-I and meiosis-II. A brief interphase called interkinesis, or intrameiotic interphase. There is no replication chromosomes, during this interphase.

Cytokinesis-I : It may or may not be present. When present, it occurs by cell-furrow formation in animal cells and cell plate formation in plant cells.

Significance of meiosis-I

(1) It separates the homologous chromosomes to reduce the chromosome number to the haploid state, a necessity for sexual reproduction.

(2) It introduces variation by forming new gene combinations through crossing over and random assortment of paternal and maternal chromosomes.

(3) It induces the cells to produce gametes for sexual reproduction or spores for asexual reproduction.

Meiosis-II : It is also called equational or homotypical division because the number of chromosomes remains same as after meiosis-I. It is of shorter duration than even typical mitotic division. It is also divisible into two parts, Karyokinesis-II and Cytokinesis-II.

Karyokinesis-II : It involves the separation of two chromatids of each chromosome and their movement to separate cells. It is divided in four phases *i.e.*, Prophase-II, Metaphase-II. Anaphase-II and Telophase-II.

Almost all the changes of Karyokinesis-II resembles to mitosis which involves.

(1) It starts just after end of telophase I.

(2) Each daughter cell (nucleus) undergoes mitotic division.

(3) It is exactly similar to mitosis.

(4) At the end of process, cytokinesis takes place.

(5) Four daughter cells are formed after completion.

(6) The sister kinetochores of one chromosome are separated.

(7) The four daughter cells receive one chromatid each of the tetravalent.

(8) Centromere split at anaphase II.

(9) Spindle fibres contract at prophase II.

Cytokinesis-II : It is always present and occurs by cell furrow formation in animal cell and cell plate formation in plant cell.

So by meiosis, a diploid parental cell divides twice forming four haploid gametes or sex cells, each having half the DNA amount than that of the parental cell and one-fourth of DNA present in the cell at the time of beginning of meiosis.

Significance of meiosis-II

(1) Constancy of chromosome number in successive generation is brought by process.

(2) Chromosome number becomes half during meiosis.

(3) It helps in introducing variations and mutation.

(4) It brings about gamete formation.

(5) It maintains the amount of genetic informative material.

(6) Sexual reproduction includes one meiosis and fusion.

(7) The four daughter cells will have different types of chromatids.

Types of meiosis

(1) **Gametic/Terminal meiosis :** In many protozoans, all animals and some lower plants, meiosis takes place before fertilization during the formation of gametes. Such a meiosis is described as gametic or terminal.

(2) **Zygotic or Initial meiosis :** In fungi, certain protozoan groups, and some algae fertilization is immediately followed by meiosis in the zygote, and the resulting adult organisms are haploid. Such a meiosis is said to be zygotic or initial. This type of life cycle with haploid adult and zygotic meiosis is termed the haplontic cycle.

(3) **Sporogenetic / Intermediate meiosis**

(i) Diploid sporocytes or spore mother cells of sporophytic plant, undergo meiosis to form the haploid spores in the sporangia.

(ii) Haploid spore germinates to form haploid gametophyte which produces the haploid gametes by mitosis.

(iii) Haploid gametes fuse to form diploid zygote which develops into diploid sporophyte by mitotic divisions. *e.g.*, In higher plants like pteridophytes, gymnosperms and angiosperms.

Table : 3.3-2

Where does meiosis take place in different plant

Plant	Stage at which meiosis occurss
Chlamydomonas (alga)	In zygote
Ulothrix (alga)	In zygospore
Spirogyra (alga)	In zygospore
Rhizopus or Bread mould (fungus)	In zygospore
Saccharomyces or Yeast (fungus)	During formation of ascospores in ascus mother cell or ascus
Riccia, *Marchantia*, *Funaria*, etc. (Bryophytes)	In spore mother cell inside capsule of sporophyte.
Ferns (Pteridophytes)	In spore mother cell inside sporangium
Gymnosperms (*e.g.*, *Cycas*, *Pinus*, etc.)	In microspore mother cells and megaspore mother cells inside
Angiosperms (Wheat, pea, etc.)	Microsporangia and megasporangia during formation of microspores (pollens) and megaspores.

Table : 3.3-3

Differences between Mitosis and Meiosis

Mitosis	Meiosis
General	
This division takes place in all kinds of cells and may continue throughout life.	It usually occurs in reproductive cells just before formation of gametes or spores in the life cycle of a plant
Nucleus undergoes a single division at the completion of division cycle. Similar is the case with chromosomes.	Nucleus undergoes two divisions, first is reductional while second is equational, at the completion of division cycle, while the chromosomes divide only once, *i.e.*, in anaphase II.
Two daughter cells are formed at the end of mitosis	Four daughter cells are formed at end.
The chromosome no. remains constant in daughter cells like parent cell, *i.e.*, daughter cells are **genetically identical** to parent cell.	The chromosome no. is reduced to half in daughter cells as compared to parent cells, *i.e.*, daughter cells are **genetically different** from parent cell.
Mitosis is much shorter.	Meiosis is much longer.
Mitosis may occur in diploid or haploid cells.	Meiosis always occurs in diploid cells (meiocytes).
Prophase	
Prophase is short and is without sub-stages.	Prophase 1 is prolonged with 5 different sub-stages as leptotene, zygotene, pachytene, diplotene and diakinesis.
There is no pairing of homologous chromosomes (synapsis) and hence no chance of **crossing over** and **chiasmata formation.**	Homologous chromosomes pair during **zygotene sub-stage** of prophase 1 and often **undergo crossing over** and hence **forming chiasmata.**
No synaptonemal complex (SC) is formed between chromosomes.	Synaptonemal complex (tripartite protein framework) is formed between pairing homologous chromosomes.
The chromosomes are longitudinally split into two sister chromatids during early prophase, *i.e.*, prophase chromosomes appear double from the very begining.	The chromosomes are **not longitudinally split** but appear as single thread, *i.e.*, prophase I chromosomes do not appear double in the beginning.
Chromosomes do not unfold and there is **no transcription** and **protein synthesis** in prophase.	Chromosomes unfold and there may occur transcription and protein synthesis during **diplotene** sub-stage of prophase I.
Metaphase	
All chromosomes form a single plate in metaphase.	Chromosomes form 2 parallel plates in metaphase I and one plate in metaphase II.
On equatorial plate, chromosomes appear two threaded.	On equatorial plate, chromosomes appear four threaded in metaphase I, while metaphase II is similar to metaphase of mitosis.
Anaphase	
Splitting of centromere of chromosomes and hence separation of 2 chromatids of each chromosome occurs at anaphase.	There is no splitting of centromeres in anaphase I and there is separation of homologous chromosomes in anaphase I. In anaphase II, splitting of centromeres and hence separation of chromatids occurs.
Telophase	
Telophase occurs in all cases.	In some cases, telophase I is omitted.
Daughter cells have same number of chromosomes as parent cell.	At the end of telophase I, chromosome number is reduced to half.
Cytokinesis	
Karyokinesis (division of nucleus) is usually followed by **cytokinesis** (wall formation).	Sometimes cytokinesis does not occur after telophase I or meiosis. I but it **always occurs** after meiosis II or telophase II, thus forming 4 cells simultaneously.
Significance	
Mitosis is responsible for growth, repair and healing.	Meiosis is responsible for maintaining chromosomes number constant from generation to generation, forms gametes or spores and also produces variations due to crossing over.

Tips & Tricks

- Interkinesis : Stage between meiosis I and meiosis II.
- Mitosis index is the ratio of dividing and non-dividing cells.
- Karyochoriosis : A type of mitosis in fungi in which is intranuclear nucleus divides by furrow formation.
- In mitosis, plectonemic coiling takes place, in which sister chromatids are tightly coiled upon each other and are not easily separable. Paranemic coiling found in meiosis.
- Brachymeiosis : Failure of meiosis-II. It is characteristic feature of fungi.
- Chiasmata first observed by Janssens (1909).
- To study mitosis root tips are fixed in 1: 3 acetic acid and methanol.
- Mitotic crossing over takes place in parasexual cycle.
- Cell cycle duration – 20 minutes in bacteria, 20 hours in root tip of onion. 2-3 hrs in yeast, 24- hrs man.

Ordinary Thinking

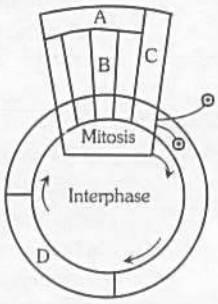
Objective Questions

Cell division

1. The term "meiosis" was coined by
(a) Hertwig and Van Bevedin
(b) Sutton and Boveri
(c) Hofmeister and Waldeyer
(d) Farmer and Moore

2. Coiling of chromatids in mitotic and meiotic division is **[MP PMT 2002]**
(a) Paranemic in both
(b) Plectonemic in both
(c) Paranemic in mitosis and plectonemic in meiosis
(d) Plectonemic in mitosis and paranemic in meiosis

3. Given below is a schematic break-up of the phases/stages of cell cycle



Which one of the following is the correct indication of the stage/phase in the cell cycle **[CBSE PMT 2009]**
(a) B-Metaphase (b) C-Karyokinesis
(c) D-Synthetic phase (d) A-Cytokinesis

4. Condensation of chromosomes occurs in **[AFMC 2002]**
(a) Prophase I (b) Prophase II
(c) Anaphase (d) Metaphase

5. Find the correctly matched pairs and choose the correct option

A. Leptotene	–	The chromosomes become invisible
B. Zygotene	–	Pairing of homologous chromosomes
C. Pachytene	–	Dissolution of the synaptonemal complex takes place
D. Diplotene	–	Bivalent chromosomes appear as tetrads
E. Diakinesis	–	Terminalization of chiasmata takes place

[AFMC 1995; Odisha JEE 2012; Kerala PMT 2012]
(a) A and B are correct (b) B and D are correct
(c) B and E are correct (d) B and C are correct
(e) C and D are correct

6. The role of meiosis **[AFMC 2002]**
(a) Formation of gametes (b) Bringing haplophase
(c) Bringing diplophase (d) Completing life cycle

7. Which of the following events are not characteristic features of telophase
A. Chromosome material condenses to form compact mitotic chromosomes
B. Nucleolus, Golgi complex and ER reform
C. Nuclear envelope assembles around the chromosome clusters
D. Centromeres split and chromatids separate
E. Chromosomes cluster at opposite, spindle poles and their identity as discrete elements is lost **[Kerala PMT 2012]**
(a) A, B and D only (b) A and D only
(c) B and C only (d) C, D and E only
(e) A and B only

8. Which stage connecting link between Meiosis I and Meiosis II **[AFMC 2002; Kerala PMT 2011]**
(a) Interphase I (b) Interphase II
(c) Interkinesis (d) Anaphase I

9. Which of the following stage is affected by colchicum **[BVP 2001; AFMC 2002; Pb. PMT 2004; Odisha JEE 2011]**

Or

Spindle apparatus is formed during which stage of mitosis **[AFMC 1999]**
(a) Metaphase (b) Prophase
(c) Interphase (d) Anaphase

10. "G_0" state of cells in eukaryotic cell cycle denotes **[AIEEE Pharmacy 2003]**
(a) Check point before entering the next phase
(b) Pausing in the middle of a cycle to cope with a temporary delay
(c) Death of a cell
(d) Exit of cells from cell cycle

11. Three copies of chromosome – 21 in a child with Down's syndrome have been formed analysed using molecular biology technology to detect any possible DNA polymorphism with reference to different alleles located on chromosome – 21. Results showed that out of 3 copies 2 of the chromosomes of the child contain the same alleles as one of the mother's alleles. Based on this when did the non-disjunction event most likely occur **[KCET 2015]**
(a) Paternal meiosis – I (b) Maternal meiosis – I
(c) Paternal meiosis – II (d) Maternal meiosis – II

12. Mitosis occurs in **[RPMT 2002]**
(a) Haploid individuals (b) Diploid individuals
(c) Both (a) and (b) (d) In bacteria only

13. Which is not true for anaphase **[Odisha JEE 2004]**
(a) Golgi body and ER are reformed
(b) Chromosomes move to opposite poles
(c) Spindle poles move farther apart
(d) Centromeres split and chromatids separate

14. Cyclin is associated with which one of the following **[BHU 2000]**

Or

Diploid living organism develops from zygote by repeated cell divisions is called **[J & K C CET 2005]**
(a) Glycolysis (b) Cyclosis
(c) Haemolysis (d) Mitosis

15. For viewing diakinesis which one of the following would be a suitable material **[MP PMT 2002]**
(a) Onion root tip (b) Leaf of Dichanthium
(c) Rat tail (d) Flower bud

16. Which is not the character of mitosis **[MP PMT 2000]**
(a) Leptotene (b) Zygotene
(c) Pachytene (d) All of the above

17. Synaptonemal complex is formed during **[CBSE PMT 2001]**
(a) Meiosis (b) Amitosis
(c) Mitosis (d) Cytokinesis

18. Synaptonemal complex was discovered in **[BHU 2000]**
(a) 1956 (b) 1950
(c) 1935 (d) 1980

19. Recombinant nodules are found during which of the following **[BHU 2000]**
(a) Anaphase (b) Prophase
(c) Telophase (d) Metaphase

20. Four daughter cells formed after meiosis are **[MP PMT 2001]**
(a) Genetically similar (b) Genetically different
(c) Anucleate (d) Multinucleate

21. The term synaptonemal complex refers to site of **[BHU 2012]**
(a) Chromatid separation
(b) Spindle attachment
(c) Replication
(d) Chromosome alignment and recombination

22. Repulsion of homologous chromosomes takes place in **[MP PMT 2001]**
(a) Zygotene (b) Leptotene
(c) Diakinesis (d) Diplotene

23. Which cell division is found during cleavage **[RPMT 2001]**
(a) Amitosis (b) Mitosis
(c) Closed mitosis (d) Meiosis

24. A stage in mitosis that starts towards the middle of anaphase and is completed with the telophase is **[AFMC 2012]**

Or

Division of cytoplasm after completion of nuclear division is called **[MP PMT 2012]**
(a) Cytokinesis (b) Karyokinesis
(c) Crossing over (d) Interkinesis

25. How many ATP is required during anaphase to move chromosomes from equator to the poles **[BHU 2000]**
(a) 38 ATP (b) 5 ATP
(c) 30 ATP (d) 76 ATP

26. Mitosis is the process by which eukaryotic cells **[Pune CET 1998; CBSE PMT 2000; BHU 2000]**
(a) Expose the genes for protein synthesis
(b) Become specialized in structure and function
(c) Multiply
(d) Grow

27. In pachytene stage of meiosis the chromosomes appear **[MP PMT 1994; BHU 2002; Kerala PMT 2010]**
(a) Single stranded (b) Double stranded
(c) Three stranded (d) Four stranded

28. Microtubule depolymerizing drug such as colchicine is expected to **[AIIMS 2012]**
(a) Inhibit spindle formation during mitosis
(b) Inhibit cytokinesis
(c) Allow mitosis beyond metaphase
(d) Induce formation of multiple contractile rings

29. Recombination of genes occur at **[J & K CET 2002]**
(a) Prophase in mitosis (b) Prophase I in meiosis
(c) Prophase II in meiosis (d) Metaphase II in meiosis

30. The second division in meiosis is called **[KCET 1998]**
(a) Equational division (b) Reduction division
(c) Multiplied division (d) None of the above

31. Which stages of cell division do the following figures A and B represent respectively **[NCERT; CBSE PMT (Pre.) 2010]**


A


B

(a) Prophase – Anaphase
(b) Metaphase – Telophase
(c) Telophase – Metaphase
(d) Late Anaphase – Prophase

32. Select correct option

	I		I
(A)	Synapsis aligns homologous chromosomes	(i)	Anaphase-II
(B)	Synthesis of RNA and protein	(ii)	Zygotene
(C)	Action of enzyme recombinase	(iii)	G_2-phase
(D)	Centromeres do not separate but chromatids move towards opposite poles	(iv)	Anaphase-I
		(v)	Pachytene

[AIPMT (Cancelled) 2015]

	(A)	(B)	(C)	(D)
(a)	(ii)	(iii)	(v)	(iv)
(b)	(i)	(ii)	(v)	(iv)
(c)	(ii)	(iii)	(iv)	(v)
(d)	(ii)	(i)	(iii)	(iv)

33. Which of the following statements is incorrect about G_0 phase **[AIIMS 2012]**
(a) Mitosis occurs after G_0 phase
(b) Biocatalysts can be used to exit G_0 phase
(c) Cell volume keeps on increasing during this phase
(d) Cell metabolism occurs continuously in G_0 phase

34. A somatic cell that has just completed the S-phase of its cell cycle, as compared to gamete of the same species, has **[AIPMT (Cancelled) 2015]**

(a) Same number of chromosomes but twice the amount of DNA

(b) Twice the number of chromosomes and four times the amount of DNA

(c) Four time the number of chromosomes and twice the amount of DNA

(d) Twice the number of chromosomes and twice the amount of DNA

35. Arrange the following events of meiosis in correct sequence

(A) Crossing over

(B) Synapsis

(C) Terminalisation of chiasmata

(D) Disappearance of nucleolus **[AIPMT 2015]**

(a) (B), (A), (C), (D) (b) (A), (B), (C), (D)

(c) (B), (C), (D), (A) (d) (B), (A), (D), (C)

36. In Which stage of meiosis crossing over takes place **[Odisha JEE 2009]**

(a) Prophase - 1 (b) Prophase

(c) Metaphase (d) Anaphase

37. Beads on string like structures of **A** are seen in **B**, which further condense to form chromosomes in **C** stage of cell division. What are **A, B** and **C** **[AIIMS 2012]**

	A	B	C
(a)	Chromonema	Chromatin	Metaphase
(b)	Chromatin	Chromatid	Metaphase
(c)	Chromonema	Chromosome	Anaphase
(d)	Chromonema	Chromatid	Anaphase

38. The best stage to count the number of chromosomes during mitosis is or structure of chromosomes can be best seen at **[CPMT 2000; BHU 2001; CBSE PMT 2004; J & K CET 2008; MP PMT 2010]**

Or

In which phase of mitosis the chromosomes are arranged around the equator of the spindle **[Manipal MEE 1995; CPMT 1998; Kerala CET 2002; BVP 2002; RPMT 2005; MP PMT 2009]**

(a) Prophase (b) Metaphase

(c) Anaphase (d) Telophase

39. In 'S' phase of the cell cycle **[CBSE PMT 2014]**

(a) Chromosome number is increased

(b) Amount of DNA is reduced to half in each cell

(c) Amount of DNA doubles in each cell

(d) Amount of DNA remains same in each cell

40. Homologous pairing in prophase I of meiosis I is called **[MP PMT 2005]**

(a) Synapsis (b) Linkage

(c) Crossing over (d) Syndesis

41. In meiosis, the centromere divides during **[MP PMT 1996, 97, 2001, 11; CBSE PMT 2000; BVP 2002]**

(a) Prophase-I (b) Metaphase-I

(c) Anaphase-I (d) Anaphase-II

42. During interphase, RNA and proteins are synthesized in **[MP PMT 1997]**

(a) *S* phase

(b) G_1 phase

(c) G_2 phase

(d) In both G_1 and G_2 phases

43. Four chromatids and two centromeres which are homologous occurs in **[CPMT 1995]**

(a) Zygotene (b) Diplotene

(c) Diakinesis (d) Pachytene

44. The number of chromosome groups at the equatorial plate in metaphase–I of meiosis in a plant with $2n = 50$ shall be **[MP PMT 1995, 98]**

(a) 50 (b) 25

(c) 30 (d) 100

45. The significance of meiosis lies in **[NCERT; MP PMT 1995, 98; BVP 2003]**

(a) Reduction of the diploid number of chromosomes to haploid

(b) Maintaining constancy in the number of diploid chromosomes during sexual reproduction

(c) Production of genetic variability in the population of a species

(d) All the above

46. During which phase(s) of cell cycle amount of DNA in a cell remains at 4C level if the initial amount is denoted as 2C **[CBSE PMT 2014]**

(a) Only G_2 (b) G_2 and M

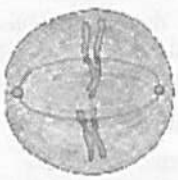
(c) G_0 and G_1 (d) G_1 and S

47. The given figure represent a sequence in cell division

The missing stage in the above sequence is **[NCERT]**

(a) 

(b) 

(c) 

(d) 

48. Identify the meiotic stage in which the homologous chromosomes separate while the sister chromatids remain associated at their centromeres **[NCERT; Odisha JEE 2009; CBSE PMT (Mains) 2012; PET (Pharmacy) 2013]**

Or

In which stage of meiosis homologous chromosomes are segregated **[WB JEE 2016]**

(a) Metaphase I (b) Metaphase II

(c) Anaphase I (d) Anaphase II

49. Which phase comes in between the G_1 and G_2 phase of cell cycle **[WB JEE 2010]**

Or

The formation of chromatid takes place in **[Odisha JEE 2011]**

(a) M-phase (b) G_0 – phase
(c) S-phase (d) Interphase

50. During mitosis ER and nucleolus begin to disappear at **[AFMC 1996; CBSE PMT (Pre.) 2010]**

(a) Early prophase (b) Late prophase
(c) Early metaphase (d) Late metaphase

51. Match List I and List II and select the correct answer using the code given below in the lists :

List I (Phase of meiosis)		List II (Event that occurs)
1.	Prophase I	Crossing over occurs
2.	Metaphase I	Sister chromatids migrate to opposite poles
3.	Anaphase I	Homologous line up at equator in pairs

Code **[MP PMT 1993]**

(a) 1, 2 and 3 are correct
(b) 1 and 2 are correct, 3 is false
(c) 1 is correct, 2 and 3 are false
(d) 1 and 3 are correct, 2 is false

52. Chromosome number is halved in meiosis during **[NCERT; RPMT 2006]**

(a) Metaphase-I (b) Anaphase-I
(c) Metaphase-II (d) Telophase-I

53. Yeast cell can progress through the cell cycle in about **[NCERT; AMU (Med.) 2012]**

(a) 30 minutes (b) 60 minutes
(c) 90 minutes (d) 120 minutes

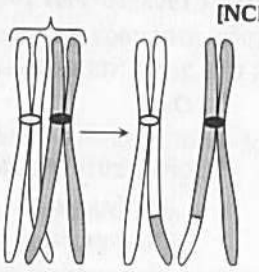
54. Normal cellular activities, such as protein synthesis occur primarily during **[Pune CET 1998]**

Or

Chromosome replicate in which stage of meiosis **[MP PMT 1994; BHU 2002; WB JEE 2008; Odisha JEE 2008]**

(a) Interphase (b) Anaphase
(c) Metaphase (d) Prophase

55. Given below is the representation of a certain event at a particular stage of a type of cell division. Which is this stage **[NCERT; CBSE PMT (Pre.) 2012]**



(a) Prophase I during meiosis
(b) Prophase II during meiosis
(c) Prophase of Mitosis
(d) Both prophase and metaphase of mitosis

56. In mitosis the movement of chromosomes requires **[CPMT 1993]**

(a) Presence of centromere (b) Plasmalemma
(c) Spindle fibres (d) Nucleotides

57. DNA replication occurs during **[MDAT Bihar 1995; MP PMT 2005; Odisha JEE 2010]**

Or

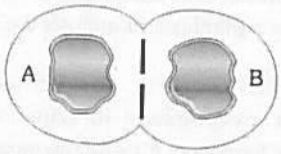
The replication of centrioles occurs during **[MP PMT 1994; BHU 2004; WB JEE 2016]**

Or

G_1, G_2 and S phases are seen in which phase of the cell cycle **[AFMC 2009]**

(a) Prophase (b) Metaphase
(c) Anaphase (d) Interphase
(e) Leptotene

58. The given diagram shows a cell



Which of the following statements related to the image is not correct **[NCERT]**

(a) The nuclear envelope is disappearing
(b) The cell furrow is forming
(c) It is an animal cell
(d) It is in telophase

59. Meiosis is found at **[MP PMT 2005]**

(a) Shoot apex (b) Reproductive part
(c) Leaves bud (d) Vegetative parts

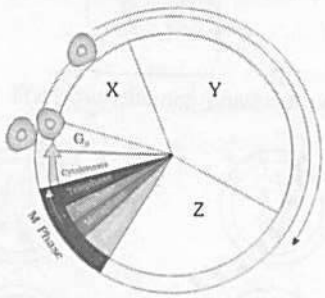
60. During cell division, sometimes there will be failure of separation of sister chromatids. This event is called **[Kerala PMT 2004; WB JEE 2016]**

(a) Interference (b) Complementation
(c) Coincidence (d) Non-disjunction

61. If a cell has a chromosome number after first meiosis equal to 48. The chromosome number in the daughter cells after the completion of meiosis will be **[BHU 2001]**

(a) 48 (b) 24
(c) 12 (d) 36

62. The given diagram is of a typical cell cycle



Identify the parts labelled as X, Y and Z **[NCERT]**

(a) X - G_1; Y - G_2; Z - G_0 (b) X - G_0; Y - S; Z - G_2
(c) X - G_2; Y - S; Z - G_1 (d) X - G_1; Y - S; Z - G_2

63. Chiasmata formation takes place during **[CPMT 1994, 2004; RPMT 1995; MP PMT 2002, 03, 06, 11; AMU (Med.) 2010]**

(a) Prophase I (Diplotene) (b) Metaphase I
(c) Anaphase II (d) Telophase I

64. The given figure represents various stages of cell division. Identify them **[NCERT]**

(a) A - Metaphase I, B - Prophase, C - Anaphase
(b) A - Metaphase I, B - Prophase I, C - Anaphase I
(c) A - Metaphase, B - Prophase I, C - Anaphase I
(d) A - Metaphase, B - Prophase I, C - Anaphase

65. During the first metaphase of meiosis the centromeres **[MP PMT 1994]**

(a) Undergo division (b) Do not divide
(c) Divide but do not separate (d) Are not identical

66. During gamete formation, the enzyme recombinase participates during **[NCERT; CBSE PMT (Pre) 2012; CBSE PMT 2014]**

(a) Metaphase - I (b) Anaphase - II
(c) Prophase – I (Pachytene) (d) Prophase - II

67. Which of the following is unique to mitosis and not a part of meiosis **[DUMET 2009]**

(a) Homologous chromosomes behave independently
(b) Chromatids are separated during anaphase
(c) Homologous chromosomes pair and form bivalents
(d) Homologous chromosomes crossover

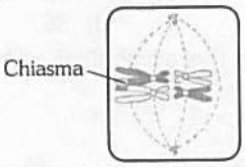
68. The protein for spindle fibre is **[AIIMS 2001; WB JEE 2011; Odisha JEE 2011]**

(a) Myosin (b) Actin
(c) Troponin (d) Myoglobin

69. 56 cells are produced in meiosis in which **[Odisha JEE 2011]**

(a) First division is reductional (b) First division is equational
(c) Second division is reductional (d) None of these

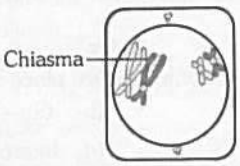
70. The given diagram of a cell undergoing meiosis, indicated that crossing over occurs only at the chiasma



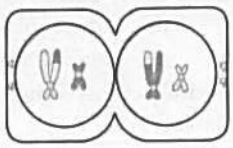
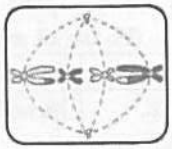
Which of the following gametes will NOT be formed from this cell **[NCERT]**

(a) 
(b) 
(c) 
(d) 

71. The given diagram shows a cell undergoing meiosis



Which diagram shows the next stage in the process **[NCERT]**

(a) 
(b) 
(c) 
(d) 

72. The process of mitosis is divided into 4 phases. Identify the correct order in which these phases appear in mitosis **[MP PMT 1993]**

(a) Anaphase, metaphase, telophase and prophase
(b) Telophase, anaphase, metaphase and prophase
(c) Metaphase, prophase, anaphase and telophase
(d) Prophase, metaphase, anaphase and telophase

73. Meiosis and mitosis differ from each other because in meiosis **[CPMT 1993]**

(a) The four nuclei formed are not similar to parental ones
(b) Homologous chromosomes pair are exchange parts
(c) Number of chromosomes gets halved
(d) All the above

74. Cell division is initiated by **[CBSE PMT 1993]**

(a) Centrosome (b) Centriole
(c) Centromere (d) Chromomere

75. "Endomitosis" refers to

(a) Division of nucleus without chromosomal division
(b) Division of chromosome without nuclear division
(c) Division of cytoplasm
(d) None of the above

76. The homologous chromosomes follow the process of synapsis in the stage **or** Pairing of homologous chromosome takes place in **[DPMT 1995; MP PMT 1996, 99, 2011; RPMT 1997; BHU 2003; Haryana PMT 2005; J & K CET 2010; NEET (Karnataka) 2013]**

Or

During which stage of meiosis, synaptonemal complex is formed **[CPMT 2010; Odisha JEE 2011]**

(a) Leptotene (b) Zygotene
(c) Diplotene (d) Pachytene

77. At metaphase, chromosomes are attached to the spindle fibres by their **[NCERT; Manipal 2005; CBSE PMT (Mains) 2011; NEET (Karnataka) 2013]**

(a) Kinetochores (b) Centromere
(c) Satellites (d) Secondary constrictions

78. The process of mitosis can be studied in **[CPMT 1998, 2009; MHCET 2001; CBSE PMT 2002]**
(a) Onion root tip (b) Garlic root tip
(c) Tendril tip (d) All of the above

79. Exchange of chromosome segments between maternal and paternal chromatids during meiosis is called **[CBSE PMT 2000]**

Or

In meiosis the daughter cells are not similar to that of parent because of **[AFMC 2005]**
(a) Linkage (b) Dominance
(c) Crossing over (d) DNA multiplication

80. Mitotic stages are not observed in **[KCET 2011]**
(a) *Cosmarium* (b) *E.coli*
(c) *Saccharomyces* (d) *Chlorella*

81. Period of active mitosis ranges from
(a) 10 minutes to a few hours (b) A few hours to a one day
(c) One day to a week (d) Less than a minute

82. Which is synthesized in G_1 phase **[CPMT 2004]**
(a) DNA polymerase (b) Histones
(c) Nucleolar DNA (d) Tubulin protein

83. How many meiotic divisions will be necessary to produce two hundred pollen grains **[MP PMT 1999]**
(a) 50 (b) 100
(c) 199 (d) 150

84. Prophase of reduction division is divided into number of stages. The correct chronological sequence is **[CMC Vellore 1993; CPMT 1996, 2000; KCET 1999; Odisha PMT 2002; HP PMT 2005]**
(a) Leptotene — pachytene — zygotene — diplotene — diakinesis
(b) Leptotene — diplotene — pachytene — zygotene — diakinesis
(c) Leptotene — zygotene — diplotene — pachytene — diakinesis
(d) Leptotene — zygotene — pachytene — diplotene — diakinesis

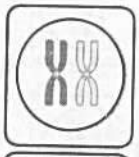
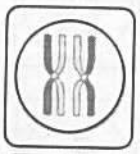
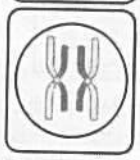
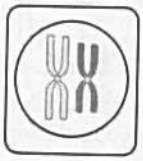
85. What is the correct sequence of the steps given here? Also work out the process depicted in the steps
i. Homologous chromosomes move toward opposite poles of the cell; chromatids do not separate
ii. Chromosomes gather together at the two poles of the cell and the nuclear membranes reform
iii. Homologous chromosomes pair and exchange segments
iv. Homologous chromosomes align on a central plate
v. The haploid cells separate completely **[AIIMS 2009]**
(a) The correct sequence is III → IV → I → II → V and the process is meiosis-I
(b) The correct sequence is II → I → V → IV → III and the process is mitosis
(c) The correct sequence is IV → I → III → II → V and the process is meiosis-I
(d) The correct sequence is II → V → IV → I → II and the process is mitosis

86. Regarding the sequence of cell cycle, which one is correct **[NCERT; MP PMT 1998; AIIMS 1999; CPMT 2002; RPMT 2005; WB JEE 2008, 12]**
(a) G_1, G_2, S and M (b) S, G_1, G_2, and M
(c) G_1, S, G_2 and M (d) G_2, S, G_1, and M

87. If we ignore the effect of crossing over, how many different haploid cells arise by meiosis in a diploid cell having $2n=12$ **[AFMC 2006]**
(a) 8 (b) 16
(c) 32 (d) 64

88. In which of the following stage, the chromosome is thin and like long thread **[NCERT; AFMC 1997; MP PMT 2011; AMU (Med.) 2012]**
(a) Leptotene (b) Zygotene
(c) Pachytene (d) Diakinesis

89. Which figure correctly represents a pair of homologous chromosomes at the start of meiosis **[NCERT]**

(a) 
(b) 
(c) 
(d) 

90. Diploid cells have **[DUMET 2009]**
(a) Two chromosomes
(b) One set of chromosomes
(c) Two pairs of homologous chromosomes
(d) Two sets of chromosomes

91. Calcium dependent kinases can control **[AIIMS 2010]**
(a) Cell cycle activities (b) DNA replication
(c) Cell surface receptors (d) Membrane structure

92. G_2 phase of mitosis takes **[BVP 2003]**
(a) 50% time of cell cycle (b) 25 to 33% time of cell cycle
(c) 12 to 16% time of cell cycle (d) 4% time of cell cycle

93. Study the following lists

List-I		List-II	
(A)	Initiation of spindle fibres	(I)	Anaphase-I
(B)	Synthesis of RNA and protein	(II)	Zygotene
(C)	Action of endonuclease	(III)	G_1 phase
(D)	Movement of sister chromatids towards opposite poles	(IV)	Pachytene
		(V)	Anaphase-II

[NCERT; AFMC 1995; Pb. PMT 2004; BHU 2005; CPMT 2009; EAMCET 2009]

The correct match is

	A	B	C	D
(a)	II	III	IV	V
(b)	III	II	I	V
(c)	I	III	V	IV
(d)	V	III	I	II

94. What is not seen during mitosis in somatic cells **[DPMT 2006; NEET (Phase-I) 2016]**

(a) Spindle fibres
(b) Chromosome movement
(c) Disappearance of nucleolus
(d) Synapsis

95. The given figure shows a cell undergoing in Prophase I

Keeping the diagram in view which of the following diagram is correct for one of the cell at the end of meiosis **[NCERT]**

(a) 
(b) 
(c) 
(d) 

96. The microtubules from opposite poles of the spindle get attached to the kinetochores of sister chromatids in **[AMU (Med.) 2009]**

Or

At what phase of meiosis are there two cells, each with sister chromatids aligned at the spindle equator **[Pune CET 1998; BHU 1999]**

(a) Prophase II (b) Metaphase II
(c) Anaphase II (d) None of these

97. Prophase is longer in **[Manipal MEE 1995; CPMT 2001; MHCET 2001; WB JEE 2011]**

(a) Mitosis (b) Meiosis
(c) Equal in both (d) Amitosis

98. Which of the following characters is related with telophase **[MP PMT 2009]**

(a) Formation of nuclear membrane
(b) Formation of nucleolus
(c) Elongation of chromosome
(d) Formation of two daughter nuclei

99. In which stage of cell division chromosomes are most condensed **[WB JEE 2009; AIIMS 2010]**

(a) Prophase (b) Metaphase
(c) Anaphase (d) Telophase

100. Which of the following event takes place during Diplotene stage of prophase I of meosis **[DUMET 2010]**

(a) Compaction of chromosomes
(b) Formation of synaptonemal complexes
(c) Formation of recombinational nodules
(d) Dissolution of synaptonemal complex

101. The term "mitosis" was proposed by **[MP PMT 2011]**

(a) Flemming (b) Farmer
(c) Moore (d) Boveri

102. Root cells of wheat has $2n = 42$ chromosomes. Which one of the following is the basic chromosome number of wheat **[WB JEE 2010]**

(a) 42 (b) 21
(c) 7 (d) 14

103. Which of the following structure will not be common to mitotic cell of a higher plant **[CBSE PMT 1997]**

(a) Cell plate (b) Centromere
(c) Centriole (d) Spindle fibre

104. How many mitotic divisions are needed for a single cell to make 128 cells **[CBSE PMT 1997; AFMC 1999, 2002; Odisha JEE 2010]**

(a) 7 (b) 14
(c) 28 (d) 32

105. Which one of the following forms the spindle apparatus during cell division **[Kerala CET 2002]**

(a) Chromosome (b) Centrosome
(c) Ribosome (d) Chondriosome

106. During cell division in apical meristem nuclear membrane reappears in **[CBSE PMT 1997]**

(a) Interphase (b) Telophase
(c) Prophase (d) S phase

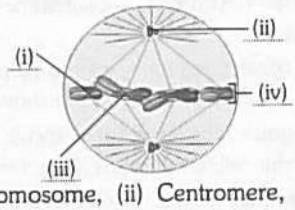
107. Cell in G_0 phase of cell cycle **[WB JEE 2009]**

(a) Exit cell cycle (b) Enter cell cycle
(c) Suspend cell cycle (d) Terminate cell cycle

108. How many reduction divisions are necessary for the formation of 200 grains of wheat **[MHCET 2002]**

(a) 250 (b) 150
(c) 200 (d) 360

109. See the following figure and identify marked lines (i), (ii), (iii) and (iv) **[NCERT]**



(a) (i) Chromosome, (ii) Centromere, (iii) Centriole, (iv) Chromatid
(b) (i) Chromatid, (ii) Centromere, (iii) Centriole, (iv) Chromosome
(c) (i) Chromosome, (ii) Centriole, (iii) Centromere, (iv) Chromatid
(d) (i) Chromatid, (ii) Centriole, (iii) Centromere, (iv) Chromosome

110. The non-sister chromatids twist around and exchange segments with each other during **or** In meiosis crossing over is initiated at **[Kerala PMT 2009; WB JEE 2011; NEET (Phase-I) 2016]**

(a) Diplotene (b) Diakinesis
(c) Leptotene (d) Pachytene
(e) Zygotene

111. During mitosis chromosomes go to their poles in a stage called **[CPMT 1994; MP PMT 2001; DPMT 2003; BHU 2004]**

Or

The shape of chromosome is clearly visible at **[Odisha JEE 2009]**

(a) Prophase (b) Metaphase
(c) Anaphase (d) Telophase

112. The number of mitotic cell division required to produce 256 cells from single cell would be **[KCET 2007]**

(a) 10 (b) 12
(c) 6 (d) 8

113. DNA replication takes place in **[MP PMT 2009; AFMC 2010; WB JEE 2016]**

Or

DNA molecule of each chromosome become double in **[NCERT; CPMT 1996, 2001, 10; MP PMT 1994, 99, 2001, 02, 06, Kashmir MEE 1995; CBSE PMT 1996, 2001; RPMT 1997; Pb. PMT 1999; Kerala PMT 2006]**

Or

DNA and histone proteins are synthesized during the following phase of cell cycle **[DPMT 2004; CBSE PMT 2005; NEET (Phase-II) 2016]**

(a) G_1 phase (b) G_2 phase
(c) S phase (d) Mitotic phase

114. During the meiotic division the **[BHU 2005]**

(a) Homologous chromosomes are separated
(b) The linkage is disturbed
(c) The homologous chromosomes do not segregate
(d) All of the above

115. The number of chromosomes after I phase of meiotic division in reduction division **[CPMT 1994]**

(a) Remain unchanged (b) Become doubled
(c) Become halved (d) None of the above

116. Meiosis can be observed in **[MP PMT 1992, 96; CPMT 1994; WB JEE 2008]**

(a) Root tips (b) Cambium
(c) Anther (PMC) (d) Pollen grains

117. Select the correct match

A.	*S* phase	-	*DNA* replication
B.	Zygotene	-	Synapsis
C.	Diplotene	-	Crossing over
D.	Meiosis	-	Both haploid and diploid cells
E.	Gap 2 phase	-	Quiescent stage

[Kerala PMT 2011]

(a) A and B (b) C and D
(c) C and E (d) A, C and E
(e) A and D

118. During meiosis, the alleles of the parental pair separate or segregate from each other. How many allele(s) are then transmitted to a gamete **[Kerala PMT 2011]**

(a) Four (b) Two
(c) Six (d) One
(e) Eight

119. In meiosis *I*, a bivalent is an association of **[NCERT; Kerala PMT 2007]**

(a) Four chromatids and four centromeres
(b) Two chromatids and two centromeres
(c) Two chromatids and one centromere
(d) Two chromatids and four centromeres
(e) Four chromatids and two centromeres

120. Cell division can not be stopped in which phase of the cell cycle **[WB JEE 2010]**

(a) G_1 – phase (b) G_2 – phase
(c) S – phase (d) Prophase

121. Cell plate is referred as **[MP PMT 1994; MHCET 2001; JIPMER 2002; Odisha JEE 2004]**

(a) Germplast (b) Idioblast
(c) Phragmoplast (d) Middle lamella

122. In which phase proteins for spindle fibre formation are synthesized **[Odisha JEE 2004]**

(a) G_1 phase (b) G_2 phase
(c) S-phase (d) Anaphase

123. Karyokinesis differ from cytokinesis because it involves **[MP PMT 1994, 2003]**

(a) Division of cytoplasm
(b) Division of the nucleus and cytoplasm
(c) Division of the nucleus
(d) Division of the cell

124. Differentiated cell arrests at which stage **[DPMT 2007]**

(a) G_1 (b) H_2
(c) G_0 (d) U

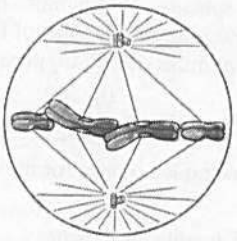
125. The nuclear membrane disappears in **[CPMT 1993; MP PMT 1995, 98; J & K CET 2002]**

(a) Metaphase (b) Early prophase
(c) Late prophase (d) Anaphase

126. Chromonemata start associating into bivalent chromosomes during **[MP PMT 1997; J & K CET 2002]**

(a) Zygotene (b) Leptotene
(c) Pachytene (d) Diplotene

127. Select the correct option with respect to mitosis



[CBSE PMT (Pre.) 2011; NEET (Karnataka) 2013]

(a) Chromosomes move to the spindle equator and get alingned along equatorial plate in metaphase
(b) Chromatids separate but remain in the centre of the cell in anaphase
(c) Chromatids start moving towards opposite poles in telophase
(d) Golgi complex and endoplasmic reticulum are still visible at the end of prophase

128. Which one of the following precedes re-formation of the nuclear envelope during *M* phase of the cell cycle **[NCERT; CBSE PMT 2004; AIIMS 2008]**

(a) Formation of the contractile ring, and formation of the phragmoplast
(b) Formation of the contractile ring, and transcription from chromosomes
(c) Decondensation of chromosomes, and reassembly of the nuclear lamina
(d) Transcription from chromosomes, and ressembly of the nuclear lamina

129. In an organism, if the normal diploid number of chromosomes is 8, how many chromatids are present in each daughter cell at the end of meiosis I **[MP PMT 1993]**

(a) 2 (b) 4
(c) 8 (d) 16

130. In eukaryotic cell cycle, cell fusion experiments show that **[AIEEE Pharmacy 2004]**

(a) When an S-phase cell is fused with a G_1-phase cell, G_1-phase cell is stimulated to synthesize DNA
(b) When an S-phase cell is fused with a G_2-phase cell, DNA synthesis is induced in G_2-phase cell.
(c) When a G_1-phase cell is fused with a G_2-phase cell, DNA synthesis is induced in both G_1 and G_2 phase cells
(d) When a G_1-phase cell is fused with an M-phase cell both G_1 and *M* phase cells are stimulated to synthesise DNA

131. The points at which crossing over has taken place between homologous chromosomes are called **[Pune CET 1998; BHU 2001]**

Or

Visible expression of the genetic phenomenon of crossing over is called **[KCET 2012]**

(a) Protein axis (b) Synaptonemal complexes
(c) Chiasmata (d) Centromeres

132. How many meiotic division would be required to produce 101 female gametophytes in an angiosperm **[Pb. PMT 1997]**

(a) 101 (b) 26
(c) 127 (d) None of these

133. Mitotic spindle have main protein **[BHU 2006; MP PMT 2007]**

(a) Tubulin (b) Myosin
(c) Tropomyocin (d) Dynein

134. Cells of certain species of animals have six pairs of chromosomes. How many molecules of DNA will remain in a nucleus of these animals during G_2 phase **[WB JEE 2016]**

(a) 12 (b) 48
(c) 6 (d) 24

135. Which of the following is not true for meiosis **[WB JEE 2016]**

(a) Production of genetic variability
(b) Maintaining constancy of chromosome number during sexual reproduction
(c) Reduction of chromosome number to one half
(d) Production of diploid cell

136. Which of the following is used as the mitotic spindle poison **[WB JEE 2016]**

(a) Ca^{++} (b) Mg^{++}
(c) Tubulin (d) Colchicine

137. Progression of cell cycle is regulated by the concentration of which type of molecule **[WB JEE 2016]**

(a) Centrosomes (b) Cyclin-dependent kinases
(c) Cyclins (d) Microtubules

138. When cell has stalled DNA replication fork, which checkpoint should be predominantly activated **[NEET (Phase-II) 2016]**

(a) Both G_2/M and M (b) G_1/S
(c) G_2/M (d) M

139. Match the stages of meiosis in **Column-I** to their characteristic features in **Column-II** and select the correct option using the codes given below **[NEET (Phase-II) 2016]**

Column-I	**Column-II**
(A) Pachytene	(i) Pairing of homologous chromosomes
(B) Metaphase I	(ii) Terminalization of chiasmata
(C) Diakinesis	(iii) Crossing-over takes place
(D) Zygotene	(iv) Chromosomes align at equatorial plate

Codes	**(A)**	**(B)**	**(C)**	**(D)**
(a)	(iv)	(iii)	(ii)	(i)
(b)	(iii)	(iv)	(ii)	(i)
(c)	(i)	(iv)	(ii)	(iii)
(d)	(ii)	(iv)	(iii)	(i)

140. Anaphase promoting Complex (APC) is a protein degradation machinery necessary for proper mitosis of animal cells. If APC is defective in a human cell, which of the following is expected to occur **[NEET 2017]**

(a) Chromosomes will not condense
(b) Chromosomes will be fragmented
(c) Chromosomes will not segregate
(d) Recombination of chromosome arms will occur

141. Which of the following options gives the correct sequences of events during mitosis **[NEET 2017]**

(a) Condensation → nuclear membrane disassembly → crossing over → segregation → telophase
(b) Condensation → nuclear membrane disassembly → arrangement at equator → centromere division → segregation → telophase
(c) Condensation → crossing over → nuclear membrane disassembly → segregation → telophase
(d) Condensation → arrangement at equator → centromere division → segregation → telophase

NCERT Exemplar Questions

1. Select the correct statement about G 1 phase **[NCERT]**

(a) Cell is metabolically inactive
(b) DNA in the cell does not replicate
(c) It is not a phase of synthesis of macromolecules
(d) Cell stops growing

2. At which stage of meiosis कबमे the genetic constitution of gametes is finally decided [NCERT]
(a) Metaphase I (b) Anaphase II
(c) Metaphase II (d) Anaphase I

3. Meiosis occurs in organisms during [NCERT]
(a) Sexual reproduction
(b) Vegetative reproduction
(c) Both sexual and vegetative reproduction
(d) None of the above

4. During anaphase-I of meiosis [NCERT]
(a) Homologous chromosomes separate
(b) Non-homologous autosomes separate
(c) Sister chromatids separate
(d) Non-sister chromatids separate

5. Mitosis is characterised by [NCERT]
(a) Reduction division
(b) Equal division
(c) Both reduction and equal division
(d) None of the above

6. Identify the wrong statement about meiosis [NCERT]
(a) Pairing of homologus chromosomes
(b) Four haploid cells are formed
(c) At the end of meiosis the number of chromosomes are reduced to half
(d) Two cycle of DNA replication occurs

7. Cells which are not dividing are likely to be at [NCERT]
(a) G 1 (b) G 2
(c) G o (d) S phase

8. Which of the events listed below is not observed during mitosis [NCERT]
(a) Chromatin condensation
(b) Movement of centrioles to opposite poles
(c) Appearance of chromosomes with two chromatids joined together at the centromere.
(d) Crossing over

CT Critical Thinking

Objective Questions

1. Pick out the correct statements
(A) Mitosis takes place in the somatic cells and meiosis takes place in the germ cells
(B) During mitosis, the DNA replicates once for one cell division and in meiosis the DNA replicates twice for two cell divisions
(C) Mitosis and meiosis occur both in sexually and asexually reproducing organisms [Kerala PMT 2008]
(a) (A) only (b) (B) only
(c) (C) only (d) (A) and (B) only
(e) (B) and (C) only

2. The number of DNA in chromosome at G_2 stage of cell cycle [RPMT 2002]
(a) One (b) Two
(c) Four (d) Eight

3. While working in a lab, a student forgot to add colchicine while karyotyping through blood culture technique, Then what will happen [GUJCET 2014]
(a) Mitosis will be arrested at metaphase
(b) Chromosomal division will continue and each chromosome will have four arms
(c) Chromosomal division will continue
(d) Mitosis will be arrested at telophase

4. Which one of the following pairs is correctly matched [MP PMT 1993]
(a) Anaphase I – Homologous chromosomes are separated
(b) Metaphase I – Pairing of maternal and paternal homologous chromosomes takes place
(c) Interphase – A nuclear envelope encloses each haploid set of chromosomes
(d) Prophase I – Non-homologous chromosomes are separated

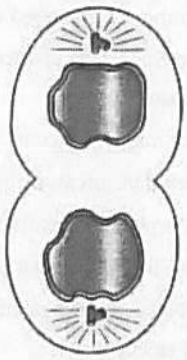
5. Chromosome start separating at which stage of mitosis [AFMC 1996]
(a) Early metaphase (b) Late metaphase
(c) Early anaphase (d) Early telophase

6. The number of chromatids in a chromosome at anaphase is [CBSE PMT 1992; BHU 1994; AFMC 1995]
(a) 2 in mitosis and 1 in meiosis
(b) 1 in mitosis and 2 in meiosis
(c) 2 each in mitosis and meiosis
(d) 2 in mitosis and 4 in meiosis

7. The major event that occurs during the anaphase of mitosis, which brings about the equal distribution of chromosomes, is [KCET 2006]
(a) Replication of the genetic material
(b) Splitting of the chromatids
(c) Splitting of the centromeres
(d) Condensation of the chromatin

8. In the somatic cell cycle [CBSE PMT 2004]
(a) A short interphase is followed by a long mitotic phase
(b) G_2 phase follows mitotic phase
(c) In G_1 phase DNA content is double the amount of DNA present in the original cell
(d) DNA replication takes place in S-phase

9. A stage in cell division is shown in the figure. Select the answer which gives correct identification of the stage with its characteristics



[NEET 2013]

(a)	Telophase	Endoplasmic reticulum and nucleolus not reformed yet
(b)	Telophase	Nuclear envelop reforms, Golgi complex reforms
(c)	Late anaphase	Chromosomes move away from equatorial plate, Golgi complex not present
(d)	Cytokinesis	Cell plate formed, mitochondria distributed between two daughter cells

10. Meiosis takes place in **[NEET 2013]**
(a) Megaspore (b) Meiocyte
(c) Conidia (d) Gemmule

11. The complex formed by a pair of synapsed homologous chromosomes is called **[NEET 2013]**
(a) Axoneme (b) Equatorial plate
(c) Kinetochore (d) Bivalent

12. DNA replication in bacteria occurs **[NEET 2017]**
(a) During S phase (b) Within nucleolus
(c) Prior to fission (d) Just before transcription

AR Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

(a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion
(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion
(c) If the assertion is true but the reason is false
(d) If both the assertion and reason are false
(e) If the assertion is false but reason is true

1. Assertion : Synthesis of DNA takes place in the S-phase of interphase.
Reason : Every chromosome, during metaphase, has two chromatids. **[KCET 2010]**

2. Assertion : Reduction division occurs in anaphase-I. So there is no need of meiosis.
Reason : Meiosis-II occurs to separate homologous chromosomes. **[AIIMS 2009]**

3. Assertion : Karyokinesis occurs in M-phase.
Reason : Cell division stops in M-phase.

4. Assertion : Interphase is resting stage.
Reason : The interphase cell is metabolically inactive.

5. Assertion : DNA synthesis occurs in G_1 and G_2 periods of cell cycle.
Reason : During G_1 and G_2 phase the DNA contents become double.

6. Assertion : Mitosis maintains the genetic similarity of somatic cells.
Reason : Chromosomes do not undergo crossing over.

7. Assertion : Chiasmata is formed during diplotene.
Reason : Chiasmata are formed due to deposition of nucleoproteins.

8. Assertion : During zygotene, chromosomes show bivalent stage.
Reason : Bivalent is half the number of chromosomes.

9. Assertion : Meiosis takes place in pollen mother cells.
Reason : Each pollen mother cell produce 4 haploid pollen grains. **[AIIMS 1996]**

10. Assertion : Meiotic division results in the production of haploid cells.
Reason : Synapsis occurs during zygotene of meiosis. **[AIIMS 1998]**

Answers

Cell division

1	d	2	d	3	c	4	a	5	c
6	b	7	b	8	c	9	a	10	d
11	d	12	c	13	a	14	d	15	d
16	d	17	a	18	a	19	b	20	b
21	d	22	d	23	c	24	a	25	c
26	c	27	d	28	a	29	b	30	a
31	d	32	a	33	a	34	b	35	a
36	a	37	a	38	b	39	c	40	a
41	d	42	d	43	a	44	b	45	d
46	a	47	c	48	c	49	c	50	a
51	c	52	b	53	c	54	a	55	a
56	c	57	d	58	a	59	b	60	d
61	a	62	d	63	a	64	b	65	b
66	c	67	a	68	b	69	a	70	a
71	c	72	d	73	d	74	a	75	b
76	b	77	a	78	d	79	c	80	b
81	a	82	a	83	a	84	d	85	a
86	c	87	d	88	a	89	a	90	d
91	a	92	c	93	a	94	d	95	c
96	b	97	b	98	d	99	b	100	d
101	a	102	c	103	c	104	a	105	b
106	b	107	c	108	a	109	d	110	d
111	c	112	d	113	c	114	a	115	c
116	c	117	a	118	d	119	e	120	c
121	c	122	a	123	c	124	c	125	c
126	a	127	a	128	c	129	c	130	b
131	c	132	a	133	a	134	d	135	d
136	d	137	b	138	b	139	b	140	c
141	b								

NCERT Exemplar Questions

1	b	2	d	3	a	4	a	5	a
6	d	7	c	8	d				

Critical Thinking

1	a	2	b	3	c	4	a	5	c
6	b	7	c	8	d	9	b	10	b
11	d	12	c						

Assertion and Reason

1	a	2	b	3	d	4	c	5	d
6	a	7	c	8	b	9	a	10	a

Answers and Solutions

Cell division

4. (a) Condensation of chromosomes occurs in the prophase-I. After that chromosome moves toward the poles.

6. (b) The most important role of meiosis is to maintain haploid phase.

9. (a) Colchicine is obtained from colchicum autumnale plant, which inhibits the formation of spindle fibers in metaphase.

10. (d) When cells are not to divide after G_1 phase and start undergoing differentiation into specific types of cells such cells are said to be in G_0 phase/G_0 state.

14. (d) Cyclin is a protein, which participates in cell division.

15. (d) Diakinesis is the stage of meiosis. For the study of meiosis young flower bud is the best material.

16. (d) Leptotene, zygotene, pachytene, diplotene and diakinesis all are successive stages of meiosis.

17. (a) Synaptonemal complex is formed during meiotic prophase first.

18. (a) Synaptonemal complex is formed in meiotic prophase-I, which was first observed by Moses in 1956.

19. (b) Knot like structure 'Chromomeres' found in the stage leptotene of prophase first of meiosis.

20. (b) During meiosis, daughter cells has the half number of chromosomes with respect to parent cells. Therefore daughter cell will be genetically different.

22. (d) In meiosis, crossing over takes place in pachytene, after that chromosome get repulsion in diplotene.

23. (c) During cleavage, cell divides mitotically without taking any gap, so that is known as closed mitosis.

27. (d) During the pachytene, chromosomes get crossed with each other and forms a four stranded or tetrad appearance.

29. (b) The crossing over of homologous chromosome occurs in Pachytene of prophase first of meiosis. It is known as recombination.

34. (b) Gamete is haploid while somatic cell is diploid. After S-phase it will contain twice the number of chromosomes and four times the amount of DNA.

35. (a) In prophase I of meiosis I, the correct sequence of events are
B – synapsis in Zygotene
C –crossing over in pachytene in diakinesis
D – disappearance of nucleolus in diakinesis

38. (b) Because in metaphase, chromosomes are present in bivalent form on equator. Chromosomes are much condense and well visible.

39. (c) S or synthesis phase marks the period where DNA synthesis takes place. During this time the amount of DNA per cell doubles.

41. (d) In meiosis II division is equational division; thus centromere divides and chromatid move towards the pole during anaphase-II.

44. (b) One chromosome forms one chromosome group in metaphase-I after splitting of tetravalent condition.

46. (a) In M=phase, both 4C and 2C of DNA are present in different stages.

49. (c) The sequence of interphase (I-Phase) is $G_1 \rightarrow S \rightarrow G_2$.

55. (a) Diagrame first represents crossing over that takes place in pachytene stage of prophase I during meiosis.

56. (c) Because they are thread like structures, which contract to pull the chromosome towards pole.

57. (d) Because interphase is the growth phase of cell. Centrioles replicate in G_2 of interphase of cell cycle but some authors reported this duplication in early prophase.

66. (c) Crossing over is an enzyme-mediated process and the enzyme involved is called recombinase.

73. (d) All the above; four nuclei formed are not similar to parent ones because they are haploid in nature. Homologous chromosome pairs are exchange parts because in crossing over exchange of chromatid arms takes place and number of chromosomes gets halved.

76. (b) In zygotene of prophase of meiosis, chromosomes pairing occurs for crossing over.

83. (a) Because one cell produces 4 daughter cells after meiotic division, thus 50 cells produce $50 \times 4 = 200$ daughter cells.

85. (a) III-Prophase, IV-Metaphase, I-Anaphase (I), II-Telophase (I), V-Telophase (III)

87. (d) The number of different haploid cells arise by meiosis can be calculated by 2^n
n = number of haploid chromosome.

88. (a) Leptotene is a stage in the prophase I of meiosis. In this stage chromosome appears thin and long.

91. (a) Calcium Dependent Kinases (CDKs) have the ability to control cell cycle activities during cell division.

94. (d) Synapsis is the pairing of homologous chromosomes during zygotene stage of prophase I of meiotic division-I. The homologous chromosomes come from the mother and father.

102. (c) For wheat, $2n = 6x = 42$.

$\therefore x = 7$

'x' represents basic or genomic number.

103. (c) Centrioles are organelles important in spindle formation during nuclear division. These are found commonly in most animal cells and some lower plant cells.

104. (a) A single mitotic division results in the production of two cells from a single one.

108. (a) For the formation of 100 grains of wheat 100 pollen grains and 100 megaspores are required. Each microspore mother cell produces 4 microspores (pollen grains) as a result of reduction division. Hence for the formation of 100 pollen grains, $\frac{100}{4} = 25\ PMC$ are needed and each will undergo one reduction division. Each megaspore mother cell will produce 4 megaspores in which one become functional and other three degenerate. Thus each MMC produces one megaspore. So 100 MMC are required to produce 100 megaspores.

Total number of reduction divisions to produce 100 grains is 100 + 25 = 125.

112. (d) Mitotic cells division is equational division where a mother cell divides to form 2 daughter cells. So to produce 256 cells from a single cell, 8 mitotic divisions will occur which can be represented as $1 \rightarrow 2 \rightarrow 4 \rightarrow 8 \rightarrow 16 \rightarrow 32 \rightarrow 64 \rightarrow 128 \rightarrow 256$.

115. (c) Because first phase of meiosis includes reduction division while second phase exhibits mitotic divisions.

116. (c) As a result of it pollen grains formed.

120. (c) The check points are basically present in the interphase.

126. (a) Pairing between the homologous chromosomes takes place in zygotene stage of prophase-I.

129. (c) Because each chromosome bears two chromatids and at the end of meiosis–I chromosome number becomes halved *i.e.*, 4 and number of chromatids are $4 \times 2 = 8$.

134. (d) $G_1 \rightarrow 6$ pairs or 12 chromosomes or 12 chromatids or 12 DNA molecules. After S or $G_2 \rightarrow 6$ pairs or 12 chromosomes or 24 chromatids or 24 DNA molecules.

135. (d) As a result of meiosis only haploid cells are produced.

136. (d) Spindle depolymerization is caused by Colchicine.

138. (b) DNA replication occurs in S-phase of cell cycle.

Critical Thinking

2. (b) The duplication of DNA takes place in 'S' stage of interphase after that cell reaches in G_2 phase. That is why the strand of DNA in G_2 phase will be two.

3. (c) In absence of colchicines mitotic division will be continued in normal way.

8. (d) In the somatic cell cycle S-phase is a stage of replication of each chromosome by synthesis of a new DNA molecule on the template of existing DNA.

Assertion and Reason

1. (a)

2. (b) Anaphase-I involves separation of homologous chromosomes into different daughter cells. So, meiosis I is a reductional division. But each chromosome is still formed of two sister chromatids joined at the common centromers. Anaphase-I results in reduction in number of chromosomes but each chromosome has double amount of DNA, so, meiosis-II occurs, during, which chromatids of each chromosome separate into different cells. Main aim of meiosis II is to separate genetically modified chromatids of each homologous chromosome formed during crossing over in meiosis-I

3. (d) M-phase represents the phase of actual division. It consists of karyokinesis (The division of nucleus) followed by cytokinesis (The division of cytoplasm). Cell divisions stop after M-phase.

4. (c) Previously interphase is called resting stage because there is no apparent activity related to cell division. The interphase cell is metabolically quite active. Interphase consist of three subphases (G_1, G_2 and S). Synthesis of DNA occurs in S phase. G_1 is the period between the end of mitosis and the start of S phase. G_2 is the interval between S phase and start of mitosis. As the synthesis of DNA occurs in S phase so it is considered as metabolically active phase.

5. (d) The synthesis of DNA occurs only in a restricted portion of the interphase during S period, which is preceded and followed by two "gap" periods of interphase (G_1 and G_2) in which there is no DNA synthesis. G_1 is the period between the end of mitosis and the start of DNA synthesis. S is the period of DNA synthesis and G_2, the interval between the end of DNA synthesis and the start of mitosis. During G_2 a cell contains two times (4C) the amount of DNA present in the original diploid cell (2C). Following mitosis the daughter cell again enter the G_1 period and have a DNA content equivalent to 2C.

6. (a) Mitosis keeps all the somatic cells of an organism genetically similar, resembling the fertilized egg. Mitosis involves replication and equitable distribution of all the chromosomes so that all the cells of a multicellular organism have the same number and type of chromosomes. This helps in proper co-ordination among different cells.

7. (c) The points of attachment between the homologous chromosomes after the partial dissolution of nucleoprotein complex are called chiasmata. It occurs during diplotene substage of prophase I.

8. (b) During zygotene, because of the pairing of the homologous, the nucleus contains half the number of chromosomes. Each unit is a bivalent composed of two homologous chromosomes.

9. (a) Meiosis occurs in pollen mother cells. All pollen mother cells are diploid and produce haploid pollen grains after meiosis.

10. (a) Diploid cell produce haploid cell by meiosis. It occurs due to synapsis. A chromosome has two chromatids, hence a bivalent has 4 chromatids.

Cell Cycle and Cell Division

SET Self Evaluation Test

1. Bivalents in meiosis are **[RPMT 2001]**
   (a) Tetrad
   (b) Pairs of non-homologous chromosomes
   (c) Pairs of several chromatids
   (d) Pairs of homozygous chromosomes

2. Which type of cell division occurs in the gonads **[RPMT 2001]**
   (a) Mitosis only (b) Meiosis
   (c) Both (a) and (b) (d) Amitosis and meiosis

3. The spindle fibre contracts in **[KCET 1998]**
   (a) Metaphase I (b) Anaphase II
   (c) Prophase II (d) Telophase II

4. If there were 4 chromosomes present during prophase, how many chromosomes are there in each cell at the end of anaphase II **[Pune CET 1998]**
   (a) 16 (b) 4
   (c) 2 (d) 8

5. Which is not characteristic of meiosis **[AIIMS 2011]**
   (a) Two stages of DNA replication, first before meiosis I and second before meiosis II
   (b) Recombination and crossing over
   (c) Sister chromatids separate during anaphase II
   (d) Nuclear membrane disappears towards end of prophase

6. Cell division in blue-green algae is more or less similar to that in **[MP PMT 1994]**
   (a) Red algae (b) Green algae
   (c) Brown algae (d) Bacteria

7. Which out of the following is not a divisional stage
   (a) Telophase (b) Interphase
   (c) Metaphase (d) Prophase

8. Crossing over is advantageous because it brings about
   (a) Variation (b) Linkage
   (c) Inbreeding (d) Stability

9. Cellular structure always disappears during mitosis is
   (a) Cell wall (b) Cell membrane
   (c) Nucleolus (d) All the above

10. Anastral mitosis is found in **[MHCET 2001]**
    (a) Animals (b) Higher plants
    (c) Bacteria (d) Cyanobacteria

* * *

AS Answers and Solutions

1	a	2	c	3	b	4	c	5	a
6	d	7	b	8	a	9	c	10	b

1. (a) Bivalent formation occurs in pachytene of meiosis, In this stage, two chromatids of homologous chromosome (Bivalent) later on forms a cross and now showing a tetravalent or tetrad stage.

2. (c) Mitosis and meiosis both type of cell division occurs in gonads. Mitosis during growth and development and meiosis during gametogenesis.