XI
10

CELL CYCLE AND CELL DIVISION

SYLLABUS

Cell division: Cell cycle, mitosis, meiosis and their significance.

KEY CONCEPTS

INTRODUCTION

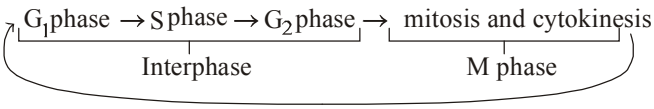
* All cells reproduce by dividing into two, with each parental cell giving rise to two daughter cells each time they divide. These newly formed daughter cells can themselves grow and divide, giving rise to a new cell population that is formed by the growth and division of a single parental cell and its progeny.
* Prevost and Dumans (1824) first to study cell division during the cleavage of zygote of frog. Nagelli (1846) first to propose that new cells are formed by the division of pre-existing cells.

CELL CYCLE

* When cells reach a certain size, they usually either stop growing or divide. Not all cells divide; some, such as skeletal muscle and red blood cells, do not normally divide once they are mature. Other cells undergo a sequence of activities required for growth and cell division.
* The stages through which a cell passes from one cell division to the next are collectively referred to as the cell cycle.
* Timing of the cell cycle varies widely, but in actively growing plant and animal cells, it is about 8 to 20 hours.
* The cell cycle consists of two main phases, interphase and M phase, both of which can be distinguished under a light microscope.

Phases of Cell Cycle

* The cell cycle is divided into two basic phases:
  – Interphase
  – M Phase (Mitosis phase)
* Most of a cell's life is spent in interphase, the time when no cell division is occurring. A cell is metabolically active during interphase, synthesizing needed materials (proteins, lipids, and other biologically important molecules) and growing.
* The sequence of interphase and M phase in the eukaryotic cell cycle:



* The M Phase represents the phase when the actual cell division or mitosis occurs and the interphase represents the phase between two successive M phases.
* It is significant to note that in the 24 hour average duration of cell cycle of a human cell, cell division proper lasts for only about an hour.
* The interphase lasts more than 95% of the duration of cell cycle.
* The M Phase starts with the nuclear division, corresponding to the separation of daughter chromosomes (karyokinesis) and usually ends with division of cytoplasm (cytokinesis).

* The interphase, though called the resting phase, is the time during which the cell is preparing for division by undergoing both cell growth and DNA replication in an orderly manner.

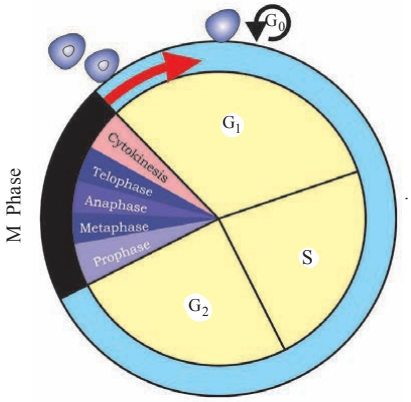


Figure : A diagrammatic view of cell cycle indicating formation of two cells from one cell

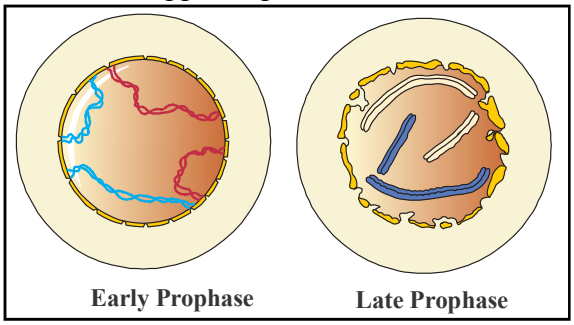
* The interphase is divided into three further phases:
  • G_1 phase (Gap 1) • S phase (Synthesis)
  • G_2 phase (Gap 2)
* G_1 phase corresponds to the interval between mitosis and initiation of DNA replication.
* During G_1 phase the cell is metabolically active and continuously grows but does not replicate its DNA.
* S or synthesis phase marks the period during which DNA synthesis or replication takes place.
* During this time the amount of DNA per cell doubles.
* If the initial amount of DNA is denoted as 2C then it increases to 4C. However, there is no increase in the chromosome number; if the cell had diploid or 2n number of chromosomes at G_1, even after S phase the number of chromosomes remains the same, i.e., 2n.
* In animal cells, during the S phase, DNA replication begins in the nucleus, and the centriole duplicates in the cytoplasm.
* During the G_2 phase, proteins are synthesised in preparation for mitosis while cell growth continues.
* Some cells in the adult animals do not appear to exhibit division (e.g., heart cells) and many other cells divide only occasionally, as needed to replace cells that have been lost because of injury or cell death.
* These cells that do not divide further exit G_1 phase to enter an inactive stage called **quiescent stage (G_0)** of the cell cycle.
* Cells in this stage remain metabolically active but no longer proliferate unless called on to do so depending on the requirement of the organism.
* In animals, mitotic cell division is only seen in the diploid somatic cells. Against this, the plants can show mitotic divisions in both haploid and diploid cells.

M-PHASE

* M phase involves two main processes, mitosis and cytokinesis.
* Mitosis, the nuclear division that produces two nuclei containing chromosomes identical to the parental nucleus, begins at the end of the G_2 phase.
* Cytokinesis, which generally begins before mitosis is complete, is the division of the cell cytoplasm to form two cells.
* Since the number of chromosomes in the parent and progeny cells is the same, mitosis is also called as equational division.
* Mitosis is divided into the following four stages:
  – Prophase – Metaphase
  – Anaphase – Telophase

Prophase

* Prophase which is the first stage of karyokinesis of mitosis follows the S and G_2 phases of interphase.
* In the S and G_2 phases the new DNA molecules formed are not distinct but interwined.
* Prophase is marked by the initiation of condensation of chromosomal material.
* The chromosomal material becomes untangled during the process of chromatin condensation.
* The centriole, which had undergone duplication during S phase of interphase, now begins to move towards opposite poles of the cell.



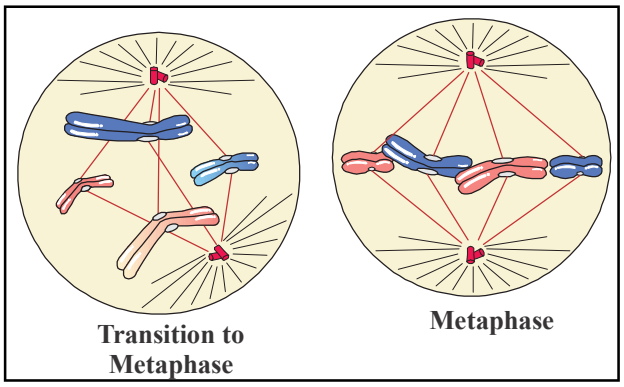
Early Prophase **Late Prophase**

* The completion of prophase can thus be marked by the following characteristic events:
  - Chromosomal material condenses to form compact mitotic chromosomes. Chromosomes are seen to be composed of two chattached together at the centromere.
  - Centrosome which had undergone duplication during interphase, begins to move towards opposite poles of the cell. Each centrosome radiates out microtubules called asters. The two asters together with spindle fibres forms mitotic apparatus.

  Cells at the end of prophase, when viewed under the microscope, do not show golgi complexes, endoplasmic reticulum, nucleolus and the nuclear envelope.

Metaphase

* The complete disintegration of the nuclear envelope marks the start of the second phase of mitosis, hence the chromosomes are spread through the cytoplasm of the cell.
* By this stage, condensation of chromosomes is completed and they can be observed clearly under the microscope. This then, is the stage at which morphology of chromosomes is most easily studied.
* At this stage, metaphase chromosome is made up of two sister chromatids, which are held together by the **centromere.**



* Small disc-shaped structures at the surface of the centromeres are called **kinetochores.** These structures serve as the sites of attachment of spindle fibres (formed by the spindle fibres) to the chromosomes that are moved into position at the centre of the cell.
* The metaphase is characterised by all the chromosomes coming to lie at the equator with one chromatid of each chromosome connected by its kinetochore to spindle fibres from one pole and its sister chromatid connected by its kinetochore to spindle fibres from the opposite pole.
* The plane of alignment of the chromosomes at metaphase is referred to as the metaphase plate.
* When chromosomes duplicate, sister chromatids are initially linked to one another by protein complexes called cohesins. Cohesin linkages are particularly concentrated in the vicinity of the centromere.

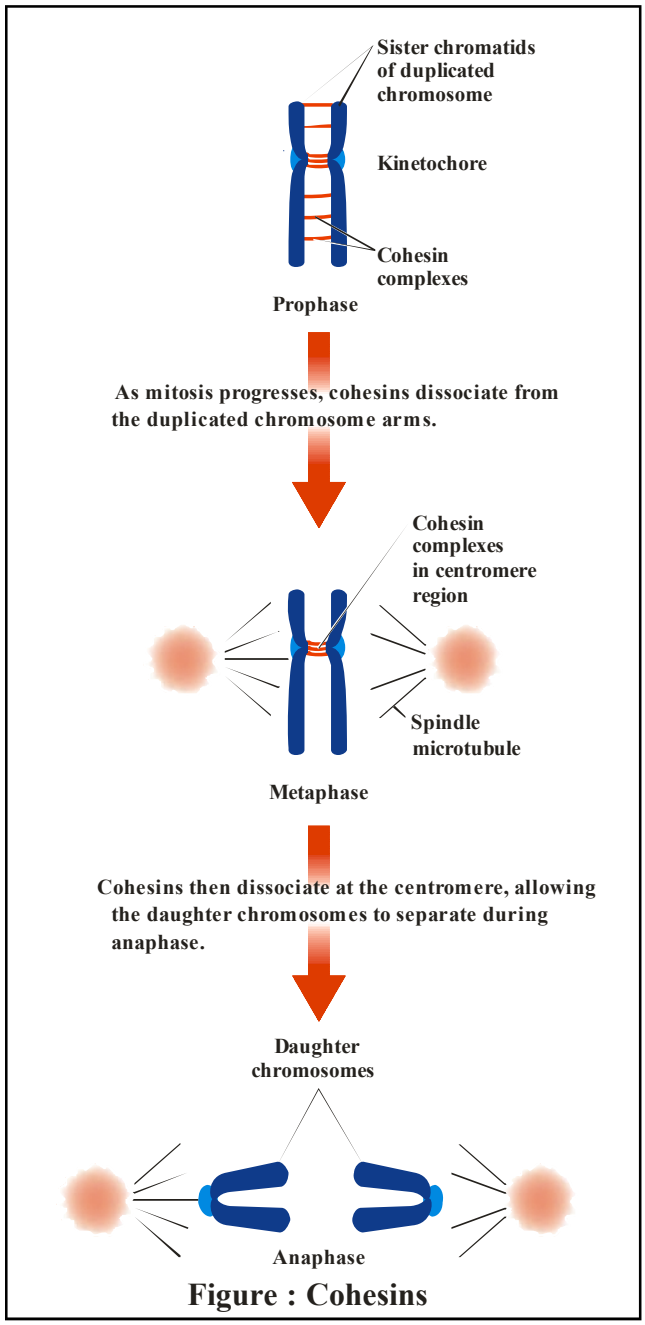
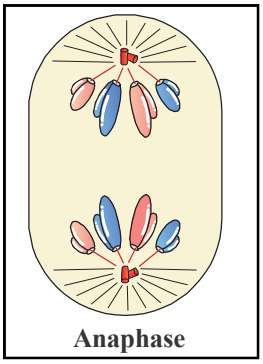


Figure : Cohesins

Anaphase

* At the onset of anaphase, each chromosome arranged at the metaphase plate is split simultaneously and the two daughter chromatids, now referred to as chromosomes of the future daughter nuclei, begin their migration towards the two opposite poles.

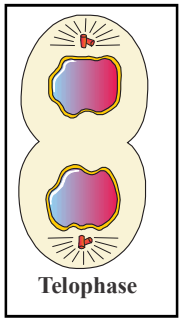


Anaphase

As each chromosome moves away from the equatorial plate, the centromere of each chromosome is towards the pole and hence at the leading edge, with the arms of the chromosome trailing behind.

Telophase

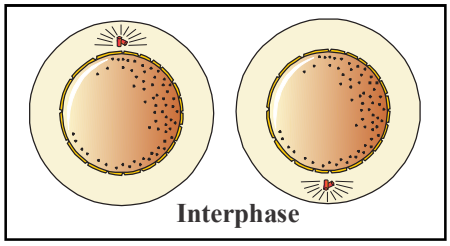
* At the beginning of the final stage of karyokinesis, i.e., telophase, the chromosomes that have reached their respective poles decondense and lose their individuality. The individual chromosomes can no longer be seen and each set of chromatin material tends to collect at each of the two poles.
* This is the stage which shows the following key events:
  - Chromosomes cluster at opposite spindle poles and their identity is lost as discrete elements.
  - Nuclear envelope develops around the chromosome clusters at each pole forming two daughter nuclei.
  - Nucleolus, golgi complex and ER reform.



Telophase

Cytokinesis

* Mitosis accomplishes not only the segregation of duplicated chromosomes into daughter nuclei (karyokinesis), but the cell itself is divided into two daughter cells by the separation of cytoplasm called cytokinesis at the end of which cell division gets completed



Interphase

* In plant cells, wall formation starts in the centre of the cell and grows outward to meet the existing lateral walls. The formation of the new cell wall begins with the formation of a simple precursor, called the cell-plate that represents the middle lamella between the walls of two adjacent cells.

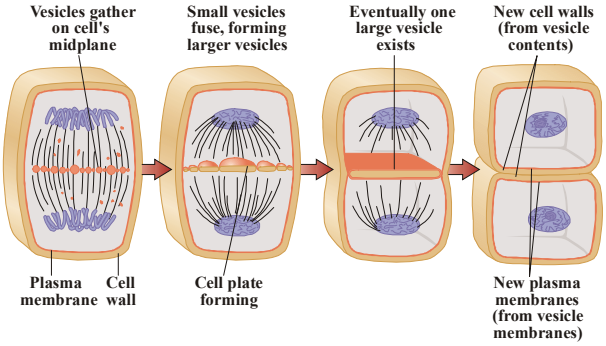


Figure : Cell plate formation during cytokinesis in a plant cell.

* At the time of cytoplasmic division, organelles like mitochondria and plastids get distributed between the two daughter cells. In some organisms karyokinesis is not followed by cytokinesis as a result of which multinucleate condition arises leading to the formation of syncytium (e.g., liquid endosperm in coconut).

S.N.	Cytokinesis in plant cell	Cytokinesis in animal cell
1.	The division of the cytoplasm (cytokinesis) occurs by formation of cell plate.	The division of the cytoplasm occurs by formation of furrow.
2.	Cell plate formation starts at the centre of the cell and grows outward, towards the lateral walls, dividing the cell into two halves.	Furrow starts at the periphery and then moves inward, dividing the cell into two halves.

Types of Mitosis

(i) **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.

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

(iii) **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.

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

Significance of Mitosis

* Mitosis or the equational division is usually restricted to the diploid cells only. However, in some lower plants and in some social insects haploid cells also divide by mitosis.
* It is very essential to understand the significance of this division in the life of an organism.
* Mitosis results in the production of diploid daughter cells with identical genetic complement usually.
* The growth of multicellular organisms is due to mitosis.
* Cell growth results in disturbing the ratio between the nucleus and the cytoplasm.
* It therefore becomes essential for the cell to divide to restore the nucleo-cytoplasmic ratio.
* A very significant contribution of mitosis is cell repair.
* The cells of the upper layer of the epidermis, cells of the lining of the gut, and blood cells are being constantly replaced.
* Mitotic divisions in the meristematic tissues – the apical and the lateral cambium, result in a continuous growth of plants throughout their life.

MEIOSIS

* **Sexual reproduction** involves the union of two sex cells, or **gametes**, to form a single cell called a **zygote**. Usually two different parents contribute the gametes, but in some cases a single parent furnishes both gametes.
* In the case of animals and plants, the egg and sperm cells are the gametes, and the fertilized egg is the zygote.
* If a cell or nucleus contains two sets of chromosomes, it is said to have a **diploid** chromosome number. If it has only a single set of chromosomes, it has the **haploid** number.
* In humans, the diploid chromosome number is 46 and the haploid number is 23. When a sperm and egg fuse at fertilization, each gamete is haploid, contributing one set of chromosomes; the diploid number is thereby restored in the fertilized egg (zygote).
* When the zygote divides by mitosis to form the first two cells of the embryo, each daughter cell receives the diploid number of chromosomes, and subsequent mitotic divisions repeat this. Thus, somatic cells are diploid.
* An individual whose cells have three or more sets of chromosomes is **polyploid**. Polyploidy is relatively rare among animals but common among plants.
* In fact, polyploidy has been an important mechanism of plant evolution. As many as 80% of all flowering plants are polyploid. Polyploid plants are often larger and hardier than diploid members of the same group.
* Many commercially important plants, such as wheat and cotton, are polyploid.
* The chromosome number found in the gametes of a particular species is represented as n, and the zygotic chromosome number is represented as 2n. If the organism is not polyploid, the haploid chromosome number is equal to n, and the diploid number is equal to 2n; thus, in humans, n = 23 and 2n = 46.
* A cell division that reduces chromosome number is called **meiosis.**
* The term meiosis means "to make smaller," and the chromosome number is reduced by one-half.

* In meiosis a diploid cell undergoes two cell divisions, potentially yielding four haploid cells.
* It is important to note that haploid cells do not contain just any combination of chromosomes, but one member of each homologous pair.
* The events of meiosis are similar to the events of mitosis, with four important differences:

1. Meiosis involves two successive nuclear and cytoplasmic divisions, producing up to four cells.
2. Despite two successive nuclear divisions, the DNA and other chromosome components duplicate only once—during the interphase preceding the first meiotic division.
3. Each of the four cells produced by meiosis contains the haploid chromosome number, that is, only one chromosome set containing only one representative of each homologous pair.
4. During meiosis, each homologous chromosome pair is shuffled, so the resulting haploid cells each have a virtually unique combination of genes.

* Meiosis ensures the production of haploid phase in the life cycle of sexually reproducing organisms whereas fertilisation restores the diploid phase. We come across meiosis during gametogenesis in plants and animals. This leads to the formation of haploid gametes.
* Meiosis involves two sequential cycles of nuclear and cell division called meiosis I and meiosis II but only a single cycle of DNA replication.
* Meiosis I is initiated after the parental chromosomes have replicated to produce identical sister chromatids at the S phase.
* Meiosis involves pairing of homologous chromosomes and recombination between non-sister chromatids of homologous chromosomes.
* Four haploid cells are formed at the end of meiosis II.
* Meiotic events can be grouped under the following phases:

Meiosis I	Meiosis II
Prophase I	Prophase II
Metaphase I	Metaphase II
Anaphase I	Anaphase II
Telophase I	Telophase II

MEIOSIS I

* **Prophase I :** Prophase of the first meiotic division is typically longer and more complex when compared to prophase of mitosis.
* It has been further subdivided into the following five phases based on chromosomal behaviour, i.e., Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.
* During leptotene stage the chromosomes become gradually visible under the light microscope.
* The compaction of chromosomes continues throughout leptotene. This is followed by the second stage of prophase I called **zygotene.**
* During this stage chromosomes start pairing together and this process of association is called **synapsis.**
* Such paired chromosomes are called **homologous chromosomes.**
* Electron micrographs of this stage indicate that chromosome synapsis is accompanied by the formation of complex structure called **synaptonemal complex.**

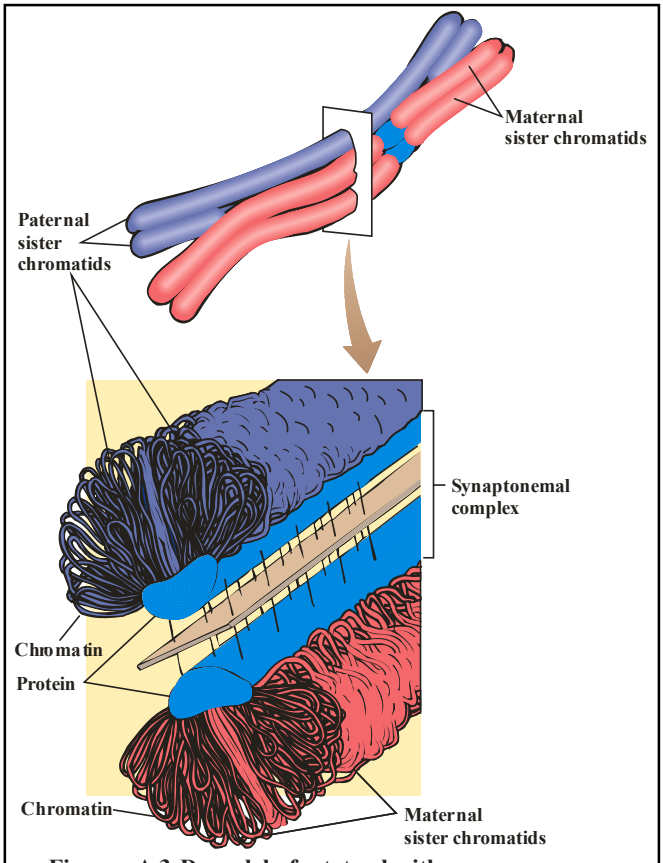


Figure : A 3-D model of a tetrad with a complete synaptonemal complex.

* The complex formed by a pair of synapsed homologous chromosomes is called a **bivalent or a tetrad**. However, these are more clearly visible at the next stage.
* The first two stages of prophase I are relatively short-lived compared to the next stage that is pachytene.
* During this stage, the four chromatids of each bivalent chromosomes becomes distinct and clearly appears as tetrads. This stage is characterised by the appearance of recombination nodules, the sites at which crossing over occurs between non-sister chromatids of the homologous chromosomes.
* Crossing over is the exchange of genetic material between two homologous chromosomes.
* Crossing over is also an enzyme-mediated process and the enzyme involved is called **recombinase**.
* Crossing over leads to recombination of genetic material on the two chromosomes.
* Recombination between homologous chromosomes is completed by the end of pachytene, leaving the chromosomes linked at the sites of crossing over.
* The beginning of diplotene is recognised by the dissolution of the synaptonemal complex and the tendency of the recombined homologous chromosomes of the bivalents to separate from each other except at the sites of crossovers.
* These X-shaped structures, are called **chiasmata**.
* Each chiasma originates at a crossing-over site, that is, a site at which homologous chromatids exchanged genetic material and rejoined, producing an X-shaped configuration.

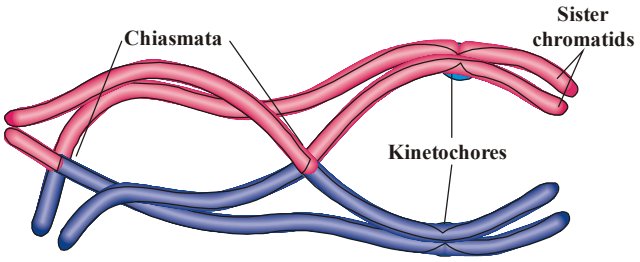


Figure : A meiotic tetrad with two chiasmata

* In oocytes of some vertebrates, diplotene can last for months or years.
* The final stage of meiotic prophase I is diakinesis.
* This is marked by terminalisation of chiasmata.
* During this phase the chromosomes are fully condensed and the meiotic spindle is assembled to prepare the homologous chromosomes for separation.
* By the end of diakinesis, the nucleolus disappears and the nuclear envelope also breaks down.
* Diakinesis represents transition to metaphase.
* **Metaphase I :** The bivalent chromosomes align on the equatorial plate. The microtubules from the opposite poles of the spindle attach to the pair of homologous chromosomes.
* **Anaphase I :** The homologous chromosomes separate, while sister chromatids remain associated at their centromeres.

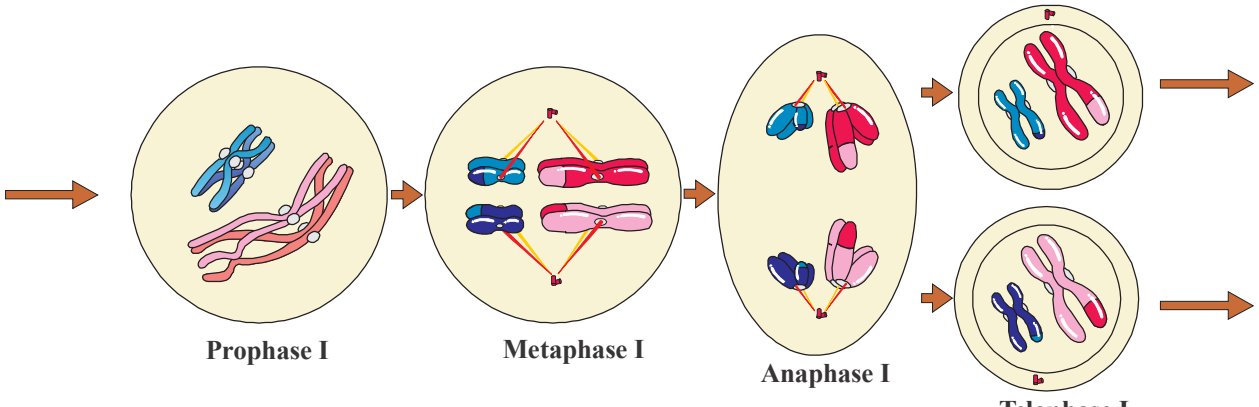


Figure : Stages of Meiosis I

* **Telophase I :** The nuclear membrane and nucleolus reappear, cytokinesis follows and this is called as diad of cells.
* Although in many cases the chromosomes do undergo some dispersion, they do not reach the extremely extended state of the interphase nucleus.
* The stage between the two meiotic divisions is called interkinesis and is generally short lived.There is no replication of DNA during interkinesis.

Interkinesis is followed by prophase II, a much simpler prophase than prophase I.

MEIOSIS II

* **Prophase II:** Meiosis II is initiated immediately after cytokinesis, usually before the chromosomes have fully elongated. In contrast to meiosis I, meiosis II resembles a normal mitosis. The nuclear membrane disappears by the end of prophase II. The chromosomes again become compact.
* **Metaphase II:** At this stage the chromosomes align at the equator and the microtubules from opposite poles of the spindle get attached to the kinetochores of sister chromatids.
* **Anaphase II:** It begins with the simultaneous splitting of the centromere of each chromosome (which was holding the sister chromatids together), allowing them to move toward opposite poles of the cell by shortening of microtubules attached to kinetochores.A
* **Telophase II:** Meiosis ends with telophase II, in which the two groups of chromosomes once again get enclosed by a nuclear envelope; cytokinesis follows resulting in the formation of tetrad of cells i.e., four haploid daughter cells.

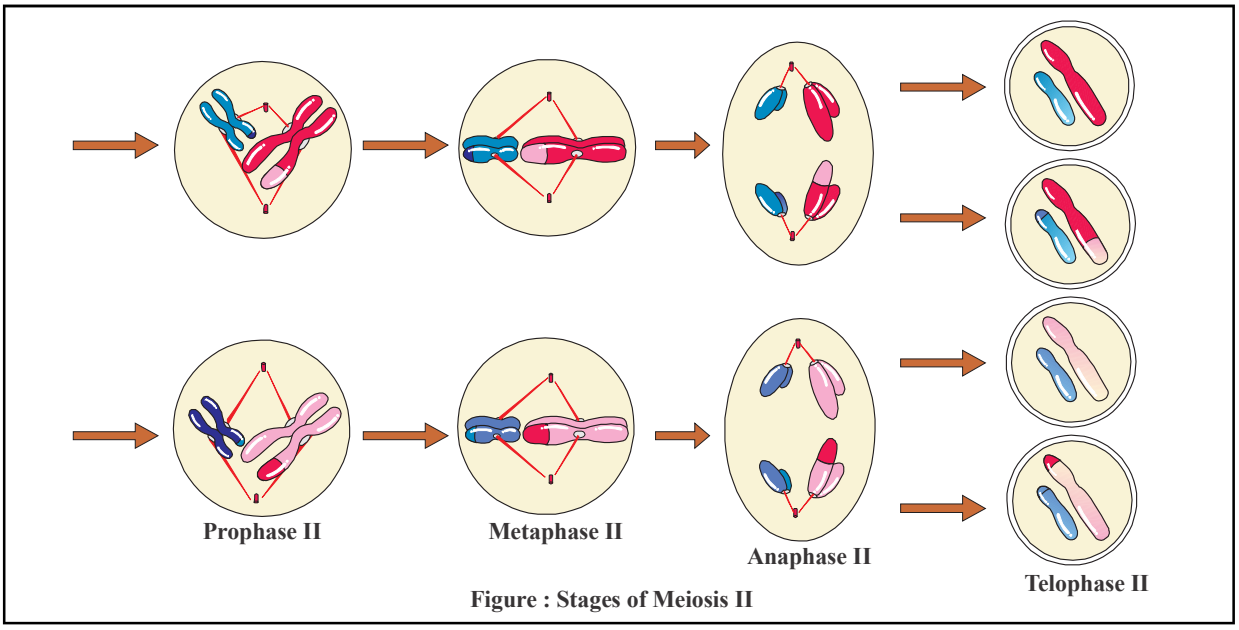


Figure : Stages of Meiosis II

Types of Meiosis

(i) 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.

(ii) 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.

(iii) Sporogenetic / Intermediate meiosis

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

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

(c) 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.

Significance of Meiosis

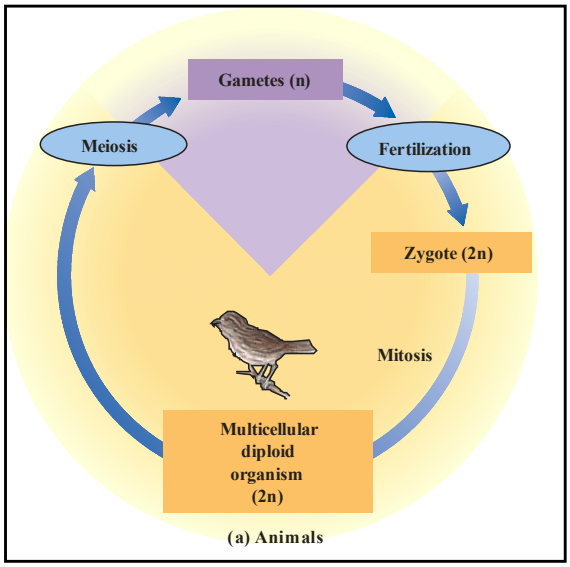
1. **Formation of gametes :** Meiosis produces gametes for sexual reproduction. Gametes are essential for sexual reproduction because in sexual reproduction an organism is formed by the fusion of two gametes.
2. **Maintenance of chromosome number :** Meiosis reduces the chromosome number to half in the gametes, so that fertilization restores the original diploid number in the zygote.
3. **Introduction of variations :** Meiosis provides a chance for the formation of new combinations of chromosomes. This brings out variations.

* **Table : Some Major Differences between Mitosis and Meiosis**

S.N.	Mitosis	Meiosis
1.	Karyokinesis and DNA replication occur once.	Karyokinesis occurs twice, but DNA replicates once only.
Prophase :		
2.	Prophase is short and is **without sub-stages.**	Prophase I is prolonged with **5 different sub-stages.**
3.	There is **no pairing** of homologous chromosomes (synapsis) using synaptonemal complex and hence, **no chance of crossing over** and **chiasmata formation.**	Homologous chromosomes pair using synaptonemal complex during **zygotene substage** of prophase I and often **undergo crossing over**, hence **forming chiasmata.**
4.	Prophase chromosomes appear double from the very beginning.	The chromosomes appear as single thread initially.
Metaphase :		
5.	All chromosomes form a single plate in metaphase.	Chromosomes form 2 parallel plates in metaphase I and one plate in metaphase II.
6.	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 :		
7.	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 :		
8.	Telophase occurs in all cases.	In some cases, telophase I is omitted.
9.	Daughter cells have same number of chromosomes as parent cell.	At the end of telophase I, chromosome number is reduced to half.
Cytokinesis:		
10.	**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:		
11.	Mitosis is responsible for growth, repair and healing.	Meiosis is responsible for maintaining chromosome number constant from generation to generation, forms gametes or spores and also produces variations due to crossing over.

SEXUAL LIFE CYCLES

* In animals and a few other organisms, meiosis leads directly to gamete production (figure a). An organism's somatic cells multiply by mitosis and are diploid; the only haploid cells produced are the gametes. Gametes develop when **germ line cells,** which give rise to the next generation, undergo meiosis.
* The formation of gametes is known as **gametogenesis.** Male gametogenesis, termed **spermatogenesis,** forms four haploid sperm cells for each cell that enters meiosis.
* In contrast, female gametogenesis, called **oogenesis,** forms a single egg cell, or *ovum,* for every cell that enters meiosis. In this process, most of the cytoplasm goes to only one of the two cells produced during each meiotic division.
* At the end of meiosis I, one nucleus is retained and the other, called the first *polar body,* oft en degenerates. Similarly, at the end of meiosis II, one nucleus becomes another polar body and the other nucleus survives.
* In this way, one haploid nucleus receives most of the accumulated cytoplasm and nutrients from the original meiotic cell.
* Although meiosis occurs at some point in a sexual life cycle, it does not always *immediately* precede gamete formation. Many eukaryotes, including most fungi and many protists, remain haploid (their cells dividing mitotically) throughout most of their life cycles, with individuals being unicellular or multicellular.



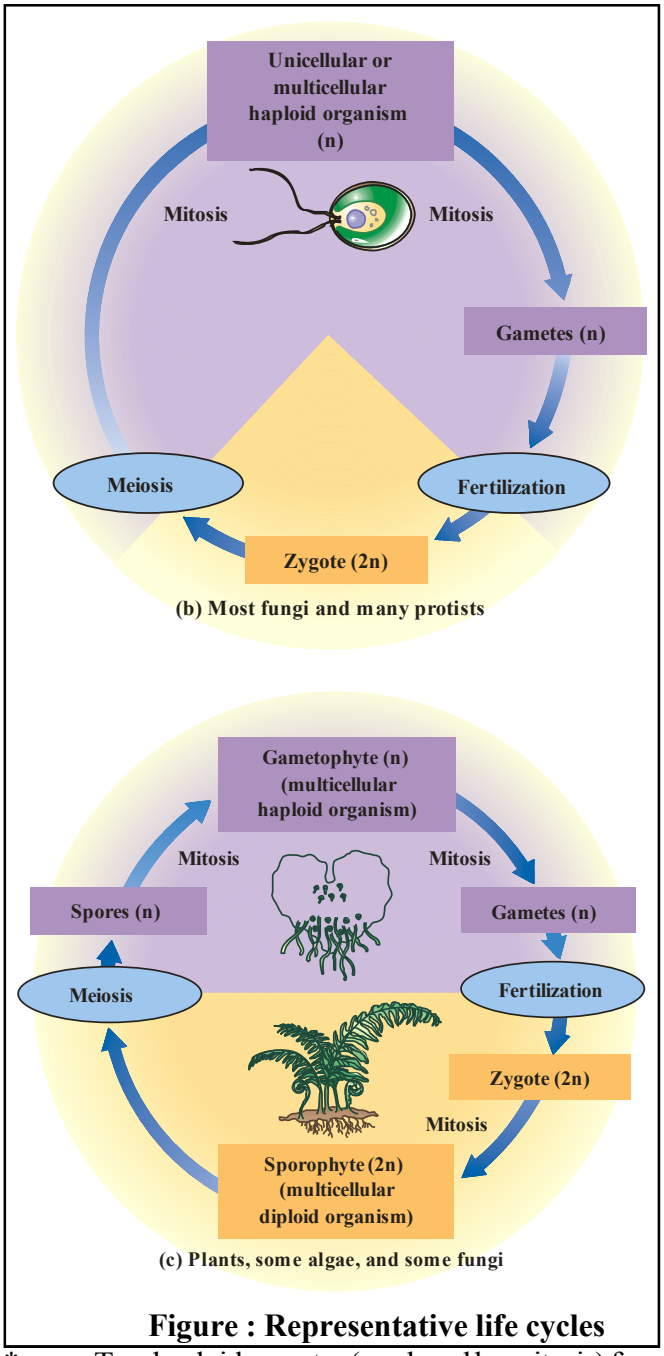


Figure : Representative life cycles

* Two haploid gametes (produced by mitosis) fuse to form a diploid zygote that undergoes meiosis to restore the haploid state(fig b)
* Plants and some algae and fungi have complicated life cycles (fig. c). These life cycles, characterized by an **alternation of generations,** consist of a multicellular diploid stage, the **sporophyte generation,** and a multicellular haploid stage, the **gametophyte generation.**
* Sporophyte cells undergo meiosis to form haploid spores, each of which may divide mitotically to produce a multicellular haploid gametophyte.

* Gametophytes produce gametes by mitosis. Th e female and male gametes (egg and sperm cells) fuse to form a diploid zygote that divides mitotically to form a multicellular sporophyte.

CONCEPT REVIEW

* The eukaryotic **cell cycle** is the period from the beginning of one division to the beginning of the next. The cell cycle consists of interphase and M phase.
* **Interphase** consists of the first gap phase (G_1), the synthesis phase (S), and the second gap phase (G_2). During the **G_1 phase**, the cell grows and prepares for the **S phase**. During the S phase, DNA and the chromosomal proteins are synthesized, and chromosome duplication occurs. During the **G_2 phase**, protein synthesis increases in preparation for cell division.
* **M phase** consists of **mitosis**, the nuclear division that produces two nuclei identical to the parental nucleus, and **cytokinesis**, the division of the cytoplasm to yield two daughter cells.
* A duplicated chromosome consists of a pair of **sister chromatids**, which contain identical DNA sequences. Each chromatid includes a constricted region called the **centromere**. Sister chromatids are tightly associated in the region of their centromeres. Attached to each centromere is a **kinetochore**, a structure formed from proteins to which micro tubules can bind.
* In mitosis, identical chromosomes are distributed to each pole of the cell, and a nuclear envelope forms around each set.
* During **prophase**, duplicated chromosomes, each composed of a pair of sister chromatids, become visible with the microscope. The nucleolus disappears, the nuclear envelope breaks down, and the **mitotic spindle** begins to form.
* During **metaphase**, the chromosomes are aligned on the **metaphase plate** of the cell; the mitotic spindle is complete and the kinetochores of the sister chromatids are attached by microtubules to opposite poles of the cell.
* During **anaphase**, the sister chromatids separate and move to opposite poles. Each former chromatid is now a chromosome.
* During **telophase**, a nuclear envelope re-forms around each set of chromosomes, nucleoli become apparent, the chromosomes uncoil, and the spindle disappears. Cytokinesis generally begins in telophase.
* In **sexual reproduction**, two haploid sex cells, or **gametes**, fuse to form a single diploid **zygote**. In a sexual life cycle, **meiosis** must occur before gametes can be produced.
* A **diploid** cell has a characteristic number of chromosome pairs per cell. The members of each pair, called **homologous chromosomes**, are similar in length, shape, and other features and carry genes affecting the same kinds of attributes of the organism.
* A **haploid** cell contains only one member of each homologous chromosome pair.
* A diploid cell undergoing **meiosis** completes two successive cell divisions, yielding four haploid cells.
* **Meiosis I** begins with **prophase I**, in which the members of a homologous pair of chromosomes physically join by the process of **synapsis**. **Crossing-over** is a process of **genetic recombination** during which homologous (nonsister) chromatids exchange segments of DNA strands.
* At **metaphase I, tetrads**-each consisting of a pair of homologous chromosomes held together by one or more **chiasmata** line up on the **metaphase plate**. The members of each pair of homologous chromosomes separate during meiotic anaphase I and are distributed to different nuclei. Each nucleus contains the haploid number of chromosomes; each chromosome consists of two chromatids.
* During **meiosis II**, the two chromatids of each chromosome separate, and one is distributed to each daughter cell. Each former chromatid is now a chromosome.
* Mitosis involves a single nuclear division in which the two daughter cells formed are genetically identical to each other and to the original cell. Synapsis of homologous chromosomes does not occur during mitosis.

* Meiosis involves two successive nuclear divisions and forms four haploid cells. Synapsis of homologous chromosomes occurs during prophase I of meiosis.

IMPORTANT POINTS

* Prophase is characteristic by
(a) Chromosomal material condenses to form compact mitotic chromosomes. Chromosomes are seen to be composed of two chromatids attached together at the centromere.
(b) Initiation of the assembly of mitotic spindle, the microtubules, the proteinaceous components of the cell cytoplasm help in the process. Cells at the end of prophase, when viewed under the microscope, do not show golgi complexes, endoplasmic reticulum, nucleolus and the nuclear envelope.
* Features of metaphase are:
(a) Spindle fibres attach to kinetochores of chromosomes.
(b) Chromosomes are moved to spindle equator and get aligned along metaphase plate through spindle fibres to both poles.
* Characteristics of anaphase are :
(a) Centromeres split and chromatids separate.
(b) Chromatids move to opposite poles.
* Characteristics of Telophase are :
(a) Chromosomes cluster at opposite spindle poles and their identity is lost as discrete elements.
(b) Nuclear envelope assembles around the chromosome clusters.
(c) Nucleolus, golgi complex and ER reform.
* **KaryoPlasmic Index :** $KI = \frac{V_n}{V_c - V_n}$

V_n = Volume of nucleus, V_c = Volume of cell
$V_c - V_n$ = Volume of cytoplasm
Karyoplasmic index of small cell is high as they have less cytoplasm. Nucleus efficiently controls the activity of cytoplasm in small cells.
* Surface-volume ratio of a cell plays an important role in starting cell division. A cell draws all the materials needed for its maintenance & growth from its surface. When a cell grows in size its volumes increases more than its surface. So a stage will reach when the surface area becomes insufficient to draw the material. At such critical stage, division of cell started.
* Histone protein synthesis occurs during S-phase.
* Shape of chromosome can be best observed during Metaphase.
* Haploid complement of chromosome of an organism is genome.
* During meiosis I, the number of chromosomes is halved.
* Meiosis II performs separation of chromatids.
* In anaphase of mitosis, the chromosomes separate and move towards poles.
* The proper sequence in mitosis:
Prophase, metaphase, anaphase and telophase.
* Zygotic meiosis occurs in *Chalmydomonas*.
* In mitosis, chromosome duplication occurs during interphase.
* DNA synthesis occurs during interphase.
* Nuclear envelope disappears during late prophase.
* The phase active in most cytogenic functions is interphase.
* In meiosis, centromere divides during Anaphase II.
* During metaphase I, the centromeres do not divide.
* Meiosis occurs in megaspore mother cell.
* In metaphse I chromosomes are in tetrad stage.
* Stage connecting meiosis I and meiosis II is interkinesis.
* In diploid zygote, chromosome number is 40.
Chromosome number in a gamete will be 20.
* Astral rays are formed of microtubules.
* DNA polymerase is synthesized in G1-phase.
* In G_2-phase, DNA content is 4n.
* Displacement of chiasmata occurs in diakinesis.
* Initiation of spindle fibres = Zygotene.
Synthesis of RNA and protein = G_1 phase
Action of endonuclease = Pachytene.
Movement of chromatids towards opposite poles = Anaphase II.
* Chromosomes appear beaded during leptotene.
* Number of mitotic divisions for the formation of n number of cells = n – 1
Example: For getting 100 cells 99 mitotic divisions are required.
* Number of generations (n) of mitosis for producing 'x' cells, $x = 2^n$
* Number of meiosis for the formation of 'n' seeds/ grains/fruits = $n + \frac{n}{4}$.

QUESTION BANK

EXERCISE - 1 (LEVEL-1) [NCERT EXTRACT]

SECTION - 1 (VOCABULARY BUILDER)

Choose one correct response for each question.
For Q.1-Q.3
Match the column I with column II.

Q.1

	Column I	Column II
a	Separation of daughter chromosomes	i. Interphase
b.	Divisionof cytoplasm	ii. Karyokinesis
c.	Phase between two successive M-phases	iii. S-phase
d.	Synthesis phase	iv. Cytokinesis

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

Q.2

	Column I		Column II
a.	G_1 phase	i.	State of cellular arrest, growth occurs, but no additional nuclear division.
b.	S phase	ii.	Sister chromatids are apparent for the first time; spindle begins to develop.
c.	G_2 phase	iii.	Sister chromatids are moving towards the middle of the developing spindle.
d.	G_0 phase	iv.	DNA replicates.
e.	Prophase	v.	Cell has twice the amount of DNA as G_1 phase
f.	Prometaphase	vi.	Phase of cell growth after cytokinesis.

Codes
(A) a-vi, b-iv, c-v, d-i, e-ii, f-iii
(B) a-vi, b-i, c-iv, d-ii, e-iii, f-v
(C) a-iii, b-i, c-vi, d-v, e-ii, f-iv
(D) a-iii, b-i, c-iv, d-vi, e-ii, f-v

Q.3

	Column I	Column II
a.	DNA replication of meiosis occurs during the S phase prior to this division.	i. Meiosis I
b.	Recombination of alleles	ii. Meiosis II
c.	4 daughter cells are produced	
d.	Homologous pairs line up and undergo synapses	
e.	Sister chromatids separate	
f.	Homologous pairs separate	

Codes
(A) a-i, b-i, c-ii, d-i, e-ii, f-i
(B) a-ii, b-ii, c-i, d-i, e-i, f-ii
(C) a-ii, b-i, c-ii, d-i, e-i, f-ii
(D) a-i, b-ii, c-ii, d-ii, e-i, f-i

SECTION - 2 (BASIC CONCEPTS BUILDER)

For Q.4 to Q.13 :
Choose one word for the given statement from the list.

S-phase, Anaphase, Chromatin, G_1, Periphery, Quiescent stage (G_0), Centre, Prophase-I, Prophase, Interphase, Cyclins, Metaphase.

Q.4 It is observed that heart cells do not exhibit cell division. Such cells do not divide further and exit ____ phase to enter an inactive stage called _____ of cell cycle.

Q.5 In the process of mitotic division during interphase, chromosome material remains in the form of very loosely coiled threads called ____.

Q.6 Longest phase of meiosis is ____.

Q.7 Chromatid formation takes place in ____.

Q.8 The phase between two succesive M-phase is called ____.

Q.9 _____ of cell cycle initiation of condensation of chromosome takes place.

Q.10 ____ are proteins that activate kinases to regulate eukaryotic cell cycle.

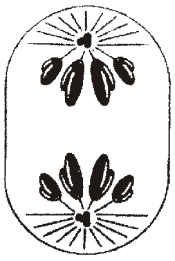
Q.11 The morphology of chromosome is best studied in ____ .

Q.12 Shortest stage of mitosis (M-phase) is _____ .

Q.13 Cell plate is first laid down in ____ and then proceeds towards ___

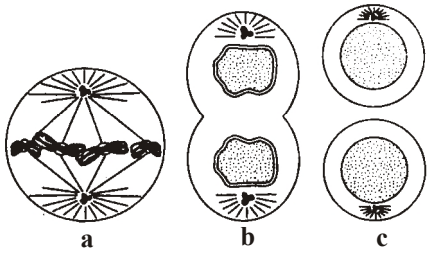
SECTION - 3 (ENHANCE DIAGRAM SKILLS)

Q.14 Given diagram indicates which of the following phase of mitosis? Choose the correct option.



(A) Interphase (B) Prophase
(C) Metaphase (D) Anaphase

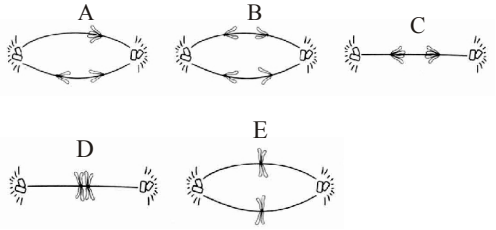
Q.15 See the diagrams carefully and identify the different stages of mitosis (a-c) by choosing appropriate options given below.



(A) a-Metaphase; b-Telophase; c-Interphase
(B) a-Telophase; b-Metaphase; c-Prophase
(C) a-Anaphase; b-Telophase; c-Interphase
(D) a-Telophase; b-Anaphase; c-Prophase

For Q.16-Q.18

Match the event of meiosis with the stages shown below.



Q.16 Identify metaphase I of meiosis.
(A) A (B) B
(C) C (D) D

Q.17 Identify metaphase II of meiosis.
(A) A (B) B
(C) C (D) E

Q.18 Identify anaphase II.
(A) A (B) B
(C) C (D) D

SECTION - 4 (ENHANCE PROBLEM SOLVING SKILLS)

Choose one correct response for each question.

PART - 1 : CELL CYCLE

Q.19 What is the approximate percentage duration of cell cycle that comes under interphase in humans?
(A) 99% (B) 95%
(C) 25% (D) 5%

Q.20 Which of the following is most important point in the regulation of cell cycle during which it must decide whether the cell will start a new cycle or will become arrested in G_0 phase?
(A) S-phase (B) G_1-phase
(C) G_2-phase (D) Interphase

Q.21 G_0-phase of cell denotes
(A) Exit of cell from cell cycle.
(B) Check point before entering the next phase.
(C) Death of cell
(D) Temporary pause.

Q.22 In G_1-phase of cell cycle, what would be the change in DNA content of the cell?
(A) DNA content increases to double.
(B) DNA content gets reduced.
(C) Four fold increase of DNA content.
(D) No change in DNA content.

Q.23 If mitotic division is restricted in G_1 phase of cell, the condition is knows as
(A) G_2-phase (B) S-phase
(C) G_0-phase (D) M-phase

Q.24 Which of the following phase of the cell cycle is not a part of interphase?
(A) S (B) M
(C) G_0 (D) G_1

Q.25 Which is synthesised in G_1-phase of cell cycle?
(A) DNA polymerase (B) Histones
(C) Nuclear DNA (D) Tubulin protein

Q.26 During cell cycle DNA replicates –
(A) Once (B) Twice
(C) Many times (D) Not at all

Q.27 What would be the change in the chromosome number, during S-phase?
(A) No change.
(B) The number of chromosome doubles.
(C) The number of chromosome doubles only in case of diploid cell.
(D) The number of chromosome doubles only in the case of haploid cell.

Q.28 Histone protein synthesis occurs during
(A) G_0-phase (B) G_2-phase
(C) S-phase (D) Prophase

Q.29 Which of the following phase of cell cycle is also known as the resting phase?
(A) G_1-phase (B) M-phase
(C) S-Phase (D) Interphase

Q.30 Phase of cell cycle when DNA polymerase is active
(A) G_1 (B) S
(C) G_2 (D) M

Q.31 Which of the following stage of cell cycle is known as quiescent stage?
(A) G_1-phase (B) S-phase
(C) G_0-phase (D) G_2-phase

Q.32 The stage of cell cycle when cell has undergone differentiation is –
(A) G_0 (B) G_1
(C) G_2 (D) S

Q.33 G_0-phase is –
(A) the phase after G_2-phase, in which nucleus divides.
(B) the phase after M-phase, in which daughter cell enters the new cell cycle.
(C) the phase of arrest of cell cycle and the onset of differentiation.
(D) All of the above

Q.34 The sequence of cell cycle is
(A) S, M, G_1 and G_2 (B) G_1, G_2, S and M
(C) M, G_1, G_2 and S (D) G_1, S, G_2 and M

Q.35 When dividing cells are examined under a light microscope, chromosomes become visible in
(A) interphase (B) S-phase
(C) prophase (D) G_1-phase

Q.36 The synthesis of spindle proteins occur during
(A) G_1-phase (B) S-phase
(C) G_2-Phase (D) M-phase

Q.37 In which of the following phase of cell cycle, mitotic division got arrested?
(A) G_2-phase (B) G_0 phase
(C) S-phase (D) M-phase

Q.38 Condensation of chromosome with visible centromere occurs during
(A) G_1-phase (B) S-phase
(C) G_2-phase (D) M-phase

Q.39 In which phase of the cell cycle, DNA content gets doubled?
(A) Interphase (B) Anaphase
(C) Prophase (D) Telophase

PART - 2 : M-PHASE

Q.40 In a cell cycle, which structures serves as the site of attachment of spindle fibres?
(A) Chromosome (B) Histone
(C) Chromonemeta (D) Kinetochore

Q.41 Which of the following materials you will select to study mitosis?
(A) Anthers (B) Onion root tips
(C) Flower bud (D) Pollen

Q.42 Which of the following stage of mitosis follows the S and G_2-phases of interphase?
(A) Prophase (B) Metaphase
(C) Anaphase (D) Telophase

Q.43 Mitosis is found in
(A) Lower animals (B) Higher animals
(C) All plants (D) All living organisms

Q.44 What is not seen during mitosis in somatic cells?
(A) Spindle fibres
(B) Chromosome movement
(C) Disappearance of nucleolus
(D) Synapsis

Q.45 Mitosis in animal cell is –
(A) Anastral (B) Amphiastral
(C) Pre-mitosis, acentric (D) Eumitosis, acentric

Q.46 Mitosis usually results in the –
(A) production of diploid daughter cells.
(B) growth of multicellular organisms.
(C) cell repair.
(D) All of the above

Q.47 Which of the following is proper sequence of stages in mitosis?
(A) Metaphase, telophase, prophase and anaphase
(B) Prophase, metaphase, anaphase and telophase
(C) Anaphase, metaphase, telophase and prophase
(D) Telophase, anaphase, metaphase and prophase

Q.48 What type of cell division takes place in the functional megaspore initially in angiosperms?
(A) Haemotypic without cytokinesis
(B) Reductional without cytokinesis
(C) Somatic followed by cytokinesis
(D) Meiotic followed by cytokinesis

Q.49 Nuclear envelope disappears at
(A) Metaphase (B) Anaphase
(C) Early prophase (D) Late prophase

Q.50 Which type of cell division helps in regeneration of cells?
(A) Mitosis (B) Amitosis
(C) Meiosis (D) Karyokinesis

Q.51 The chromosome morphology is best studied during –
(A) Prophase
(B) Metaphase, as the chromosomes are most condensed.
(C) Anaphase, as the chromosomes are most condensed.
(D) Telophase

Q.52 Chromosome reaches their respective poles in which of the following stages of mitosis?
(A) Cytokinesis (B) Interphase
(C) S-phase (D) Telophase

Q.53 Karyokinesis refers to the division of –
(A) the cytoplasm
(B) the nucleus
(C) cytoplasm and nucleus
(D) all constituents of the cell

Q.54 The two daughter cells formed during mitosis contains
(A) The same amount of DNA but a set of chromosomes different from those of parental cells.
(B) The same amount of DNA and the same set of chromosomes as those of the parent cell.
(C) Half the amount of DNA and the same set of chromosomes as those of the parent cell.
(D) Double the amount of DNA and a set of chromosomes different from those of the parent cell.

Q.55 The morphology of chromosomes can be studied most easily in
(A) prophase (B) metaphase
(C) anaphase (D) telophase

Q.56 Which of the following phases are longest and shortest in mitosis?
(A) Metaphase, Anaphase
(B) Prophase, Anaphase
(C) Telophase, Anaphase
(D) Prophase, Telophase

Q.57 In which of the following stage of the cell cycle, the attachment of spindle fibres to kinetochores of chromosomes occurs?
(A) Prophase (B) Metaphase
(C) Anaphase (D) Telophase

PART - 3 : MEIOSIS

Q.58 In meiosis, the chromosome number
(A) reduces by half
(B) increase by twice
(C) increase by four times
(D) reduces by one-fourth

Q.59 Meiosis is evolutionarily significant, because it results in
(A) Recombinations
(B) Eggs and sperms
(C) Four daughter cells
(D) Genetically similar daughter cells

Q.60 Arrange the following events of meiosis in a correct sequence and choose the correct option.
I. Terminalisation II. Crossing over
III. Synapsis IV. Disjunction of genomes
(A) IV, III, II and I (B) III, II, I and I
(C) II, I, IV and III (D) I, IV, III and II

Q.61 In oocytes, which of the following phase can last for months or years, since it is at this stage the chromosomes decondense and engage in RNA synthesis?
(A) Diakinesis (B) Diplotene
(C) Pachytene (D) Leptotene

Q.62 When paternal and maternal chromosomes change their material with each other in cell division, this event is called –
(A) bivalent forming (B) crossing over
(C) synapsis (D) dyad forming

Q.63 In the meiotic cell division, 56 daughter cells are produced by two successive divisions in which
(A) First division is equational, second is reductional.
(B) First division is reductional, and second is equational.
(C) Both divisions are reductional.
(D) Both divisions are equational.

Q.64 Stages in proper sequence of prophase-I are –
(A) Zygotene, Leptotene, Pachytene, Diakinesis and Diplotene.
(B) Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.
(C) Leptotene, Zygotene, Pachytene, Diakinesis and Diplotene.
(D) Leptotene, Pachytene, Zygotene, Diakinesis and Diplotene.

Q.65 At the end of meiosis-II, number of haploid cells formed are –
(A) two (B) four
(C) eight (D) None of these

Q.66 All are the essential stages that take place during meiosis, except
(A) Two successive divisions without any DNA replication occuring between them.
(B) Formation of chiasmata and crossing over.
(C) Segregation of homologous chromosomes.
(D) Number of chromosomes in daughter cells after meiosis II is reduced to half but the amount of DNA remains the same.

Q.67 In which of the following stages of the cell cycle chromosome number becomes half?
(A) Metaphase-I (B) Anaphase-I
(C) Prophase-I (D) Metaphase-II

Q.68 Meiosis involves
(A) One nuclear division and one chromosome division.
(B) Two nuclear divisions and one chromosome division.
(C) One nuclear division and two chromosome divisions.
(D) Two nuclear divisions and two chromosome divisions.

Q.69 Crossing over occurs during
(A) Pachytene (B) Diplotene
(C) Diakinesis (D) Zygotene

Q.70 Meiosis can be observed in –
(A) tapetal cells (B) megaspores
(C) micropores (D) spore mother cells

Q.71 Nuclear membrane and nucleoli can be distinctly seen in
(A) Prophase (B) Metaphase
(C) Anaphase (D) Interphase

EXERCISE - 2 (LEVEL-2)

Choose one correct response for each question.

Q.1 During anaphase-II
(A) homologues separate and migrate towards opposite poles.
(B) sister chromatids separate and migrate towards opposite poles.
(C) nuclei reform
(D) chromosomes line up in a single row.

Q.2 The reappearance of nucleolus towards the end of mitosis is attributed to –
(A) nuclear envelope
(B) the specific region of satellite chromosome
(C) the reassemblage of some macromolecules of nucleolus, lost during prophase
(D) the rearrangement of histones present in the nucleus.

Q.3 Which occurs during meiosis but not during mitosis?
(A) Chromosomes align at the metaphase plate.
(B) Chromosomes condense.
(C) Chromosomes migrate to opposite poles.
(D) Synapsis.

Q.4 Mature nerve cells are incapable of cell division. These cell are probably considered in –
(A) G-2 phase (B) S-phase
(C) Mitosis (D) G_0-phase.

Q.5 Which is not a function of mitotic cell division?
(A) Production of gametes
(B) Asexual reproduction
(C) Growth
(D) None of the above

Q.6 Prophase-I of meiosis is different from prophase of mitosis because in prophase-I
(A) nuclear membrane breaks down.
(B) chromosomes become visible.
(C) homologous chromosomes pair up.
(D) spindle forms.

Q.7 Centrioles separate during
(A) cytokinesis
(B) prophase-I and prophase-II
(C) metaphase-I and metaphase-II
(D) anaphase-I and anaphase-II.

Q.8 What is the nature of cells formed at the end of meiosis-II?
(A) Haploid (B) Diploid
(C) Tetrad (D) None of these

Q.9 Assume that no errors occur in DNA replication. Mitosis produces two daughter cells that are genetically.
(A) unique to each other
(B) identical to the parental cell
(C) accurate but unique from the parental cell
(D) unique from the parental cell

Q.10 Which of the following does NOT occur by mitosis?
(A) growth
(B) production of gametes
(C) repair
(D) development in the embryo

Q.11 Which of the following phases is the most variable with respect to length?
(A) G_1 of interphase (B) G_2 of interphase
(C) S phase of interphase (D) mitosis

Q.12 A diploid nucleus at early mitotic prophase has ___ set(s) of chromosomes; a diploid nucleus at mitotic telophase has __ set(s) of chromosomes.
(A) 1; 1 (B) 1; 2
(C) 2; 2 (D) 2; 1

Q.13 The life cycle of a sexually reproducing organism includes
(A) mitosis (B) meiosis
(C) fusion of sex cells (D) A, B, and C

Q.14 Which of the following are genetically identical?
(A) 2 cells resulting from meiosis I
(B) 2 cells resulting from meiosis II
(C) 4 cells resulting from meiosis I followed by meiosis II
(D) 2 cells resulting from a mitotic division.

Q.15 You would expect to find a synaptonemal complex in a cell
(A) mitotic prophase (B) meiotic prophase I
(C) meiotic prophase II (D) meiotic anaphase I

Q.16 A chiasma links a pair of –
(A) homologous chromosomes at prophase II.
(B) homologous chromosomes at late prophase I.
(C) sister chromatids at metaphase II.
(D) sister chromatids at mitotic metaphase.

Q.17 Acc. to Russell, when does the nuclear envelope breakdown
(A) prophase (B) G_2 of interphase
(C) telophase (D) prometaphase

Q.18 Chromatin fibers include
(A) DNA and structural polysaccharides
(B) RNA and phospholipids
(C) protein and carbohydrate
(D) DNA and protein

Q.19 A nucleosome consists of –
(A) DNA and scaffolding proteins.
(B) Scaffolding proteins and histones.
(C) DNA and histones
(D) DNA, histones, and scaffolding proteins.

Q.20 The term S phase refers to –
(A) DNA synthesis during interphase.
(B) synthesis of chromosomal proteins during prophase.
(C) gametogenesis in animal cells.
(D) synapsis of homologous chromosomes.

Q.21 Which of the following structures are visible during cell division?
(A) Golgi body
(B) Spindle fibres
(C) Rough endoplasmic reticulum
(D) Ribosomes

Q.22 Mature red blood cells lack a nucleus. Which phase of the cell cycle would you expect to find this cell?
(A) G_1 of interphase (B) G_2 of interphase
(C) G_0 of interphase (D) S phase of interphase

Q.23 Which of the following is FALSE with respect to pair of sister chromatids?
(A) They are genetically identical.
(B) They will end up in different daughter cells.
(C) They are held together by a single kinetochore.
(D) Once separated are called daughter chromosomes.

Q.24 Choose the correct statements regarding cell cycle.
I. Interphase is called the resting phase.
II. Interphase is the time during which the cell is preparing for division.
III. The interphase is divided into three phases, i.e., G_1, S and G_2-phase.
IV- Interphase represents the phase between the two successive M-phases.
The option with correct statements is
(A) I and IV (B) II and III
(C) I and III (D) I, II, III and IV

Q.25 Which of the following shows diplotene stage of cell cycle?
(A) Separation of synapsed homologous chromosomes except at the site of cross overs
(B) degeneration of nucleolus
(C) Chiasmata shift towards chromosome ends
(D) All of the above

Q.26 In which stage of the life of a cell is the nucleolus always visible?
(A) prophase (B) anaphase
(C) telophase (D) interphase

Q.27 'XX' is a phase of mitosis, in which the chromatin condenses into discrete chromosomes. During 'XX' phase, nuclear envelope breaks down and spindles forms at opposite ends of the cell. Identify 'XX'.
(A) Interphase (B) Anaphase
(C) Telophase (D) Prophase

Q.28 Which of the following is NOT found in plant cells?
(A) cell plate
(B) actin and myosin filaments
(C) microtubule organizing center
(D) cleavage furrow

Q.29 If a cell has 24 chromosomes at the beginning of meiosis, how many chromosomes will it have at the end of meiosis?
(A) 6 (B) 12
(C) 24 (D) 48

Q.30 If a cell has 24 chromosomes, how many will it have at the end of mitosis?
(A) 6 (B) 12
(C) 24 (D) 48

Q.31 All of the following are true of meiosis EXCEPT
(A) crossover occurs during prophase I.
(B) there is no replication of chromosomes between meiosis I and meiosis II.
(C) in plants, spindle fibers are attached to the Centriole.
(D) synapsis occurs during prophase I.

Q.32 In a cell at ___ each chromosome consists of a pair of attached chromatids.
(A) mitotic prophase (B) meiotic prophase II
(C) meiotic prophase I (D) all of the preceding

Q.33 In an animal cell at mitotic metaphase, you would expect to find –
(A) two pairs of centrioles located on the metaphase plate.
(B) a pair of centrioles inside the nucleus.
(C) a pair of centrioles within each microtubule-organizing center.
(D) a centriole within each centromere.

Q.34 Cell plate formation usually begins during –
(A) telophase in a plant cell.
(B) telophase in an animal cell.
(C) G_2 in a plant cell.
(D) G_2 in an animal cell.

Q.35 The synaptonemal complex forms during
(A) anaphase I of meiosis
(B) interphase of any cell
(C) anaphase II of meiosis
(D) prophase I of meiosis

Q.36 Homologous chromosomes separate during
(A) prophase I (B) prophase II
(C) anaphase of mitosis (D) anaphase I

Q.37 Chiasmata are most closely related to which of the following?
(A) mitotic cell division (B) fertilization
(C) cytokinesis (D) crossing-over

Q.38 If you wanted to block the cell from going from G_2 to the M phase, which would accomplish that goal?
(A) increase the amount of cyclin B.
(B) increase the amount of phosphate.
(C) increase the amount of CDK1.
(D) decrease phosphatase

Q.39 Which of the following cells divide by mitosis?
(A) Sperm cell (B) Egg cell
(C) Kidney cell (D) Gamete cell

Q.40 If contact inhibition were blocked, predict a likely response.
(A) A tumor might develop.
(B) Wounds would never heal.
(C) The cell would go into G_0 phase.
(D) Both B and C are possible.

Q.41 Which type of Chromosome will appear L-shaped during anaphase –
(A) Telocentric (B) Acrocentric
(C) Metacentric (D) Submetacentric

Q.42 A contractile mid body forms during cytokinesis in –
(A) Animals (B) Higher plants
(C) Fungi (D) Algae

Q.43 Which element helps in spindle formation :
(A) Mn (B) Co
(C) Pb (D) Ag

Q.44 Which division is characteristic of cartilage cells, mega nucleus of Paramecium and foetal membranes –
(A) Mitosis (B) Meiosis
(C) Cryptomitosis (D) Amitosis

Q.45 Which part of plant is suitable for the study of meiosis :
(A) Root apex (B) Ovary
(C) Anther (D) Shoot apex

Q.46 Colchicine, a mitotic poison, arrests the cell division in :
(A) G_1 - phase (B) G_2 - phase
(C) Anaphase (D) Metaphase

Q.47 Amitosis is characteristic of –
(A) Higher plants (B) Higher animals
(C) Bryophyta (D) Lower organisms

Q.48 Reason of chromosomal movement in Anaphase
(A) Astral rays
(B) Centrioles
(C) Kinetochore
(D) Kinetochore and spindle fibres

Q.49 Nuclear envelope reappears at –
(A) Metaphase (B) Prophase
(C) Anaphase (D) Telophase

Q.50 Slipping of chiasmata towards the ends of bivalent is called –
(A) Terminalisation (B) Diakinesis
(C) Interkinesis (D) Heteropycnosis

Q.51 Duplication of chromosomes without the division of nucleus is called –
(A) Cytokinesis (B) Plasmotomy
(C) Endomitosis (D) Dino-mitosis

Q.52 Which division maintains genetic similarity –
(A) Mitosis (B) Meiosis
(C) Amitosis (D) Reduction division

Q.53 Which does not occurs in prophase –
(A) Hydration of chromatin
(B) Dehydration of chromatin
(C) Appearance of chromosome
(D) Disappearance of nuclear membrane and nucleolus.

Q.54 During cell cycle, RNA and protein synthesis takes
(A) G_1 and G_2 - phase (B) S - phase
(C) M - phase (D) Cytokinesis

Q.55 In which stage of cell division, number of chromosomes best counted –
(A) Prophase (B) Metaphase
(C) Telophase (D) Interphase

Q.56 The cellular structure which disappear during mitosis is –
(A) Plasma membrane
(B) Nuclear membrane
(C) Mitochondria
(D) Nuclear membrane and nucleolus

Q.57 Cell division in blue green algae similar to that in
(A) Bacteria (B) Brown algae
(C) Green algae (D) Higher plants

Q.58 Meiosis takes place in –
(A) Apical meristem (B) Inter calary meristem
(C) Reproductive cells (D) Vegetative cells

Q.59 Replication of DNA in meiosis occur during –
(A) S - phase
(B) S - phase and leptotene
(C) S - phase and zygotene
(D) All of these

Q.60 The synaptonemal complex was first observed by –
(A) Moore (1905)
(B) Farmer & moore (1905)
(C) Mosses (1956)
(D) Hemming (1882)

Q.61 Which chromosome may lost during cell division
(A) Giant chromosome
(B) Acentric chromosome
(C) Polycentric chromosome
(D) Telocentric chromosome

Q.62 In which order, cytokinesis occurs in plants :
(A) Centripetal (B) Centrifugal
(C) Oblique (D) Equatorial

Q.63 Meiosis not occurs in –
(A) Ovule (B) Anther
(C) Microsporangia (D) Shoot tip

Q.64 Which of the two events restore the normal number of chromosomes in life cycle :
(A) Mitosis and Meiosis
(B) Meiosis & fertilisation
(C) Fertilisation and mitosis
(D) Only meiosis

Q.65 Division of nucleus is indirect in –
(A) Mitosis (B) Meiosis
(C) Amitosis (D) (A) and (B) both

Q.66 Number of meiosis required to produce 100 ovules in angiosperms :
(A) 125 (B) 100
(C) 25 (D) 75

Q.67 Constancy of the chromosome number in sexually producing generation is brought by the process of –
(A) Meiosis (B) Mitosis
(C) Amitosis (D) None

Q.68 A cell is bound to divide, if it has entered –
(A) G_2 - phase (B) G_1 - phase
(C) Prophase (D) S - phase

Q.69 How many chromosome shall be present in a diploid cell at mitotic anaphase if its egg cell has ten chromosome –
(A) 10 (Ten) (B) 20 (Twenty)
(C) 30 (Thirty) (D) 40 (Forty)

Q.70 If crossing-over occur at two strand stage then percentage of crossing over is –
(A) 50% (B) 60%
(C)70% (D) 100%

Q.71 Meiosis which occur at the time of spore formation is called–
(A) Zygotic meiosis (B) Haplontic meiosis
(C) Terminal meiosis (D) Intermediate meiosis

Q.72 Most fastest type of cell division is –
(A) Mitosis (B) Meiosis
(C) Amitosis (D) Endomitosis

Q.73 Chromosome exhibit high level of coiling at which phase of karyokinesis –
(A) Prophase (B) Metaphase
(C) Telophase (D) Interphase

Q.74 "Bouquet-stage" occur in which sub stages of prophase I
(A) Leptotene (B) Zygotene
(C) Pachytene (D) Diplotene

Q.75 Which reorganises the nucleolus during telophase
(A) Secondary constriction -I
(B) Secondary constriction - II
(C) Primary constriction
(D) Pore - complex

Q.76 Each chromosome composed of one chromatid in:
(A) Anaphase - I (B) Anaphase - II
(C) Metaphase - I (D) Metaphase - II

Q.77 If the number of bivalents are 8 in metaphase - I, what shall be the number of chromosomes in daughter cells after meiosis - I and meiosis - II respectively –
(A) 8 and 4 (B) 4 and 4
(C) 8 and 8 (D) 16 and 8

Q.78 Arrangement of ascospores in ascus of Neurospora is 2 + 2 + 2 + 2. The number of recombinant type of ascospores
(A) 2 (B) 4
(C) 6 (D) 8

Q.79 Which of the following not occurs in AnaphaseI
(A) Segregation of homologous chromosomes.
(B) Contraction in spindle.
(C) Poleward movement of chromosomes.
(D) Division of centromere.

Q.80 Homologous chromosomes shows maximum attraction during :
(A) Leptotene (B) Zygotene
(C) Pachytene (D) Diplotene

Q.81 In meiosis –
(A) Division of nucleus twice but replication of DNA only once.
(B) Division of nucleus twice and replication of DNA twice.
(C) Division of nucleus once and replication of DNA is also once.
(D) Division of nucleus once and DNA-replication is twice.

Q.82 After meiosis - I, the two chromatids of a chromosome
(A) Genetically similar
(B) Genetically different
(C) There occurs only one chromatid in each chromosome
(D) None of the above

Q.83 Ribonuclease, a mitotic poison, inhibits cell cycle in –
(A) Interphase (B) Prophase
(C) Metaphase (D) Anaphase

Q.84 The most primitive type of mitosis is :
(A) Amitosis (B) Cryptomitosis
(C) Endomitosis (D) Zygotic mitosis

Q.85 Dinomitosis occurs in –
(A) Prokaryotes (B) Mesokaryotes
(C) Eucaryotes (D) Akaryotes

Q.86 Genetic information is transferred from zygote to all body
(A) Meiosis (B) Amitosis
(C) Endomitosis (D) Mitosis

Q.87 Division of cell without recognizable chromosomes is –
(A) Amitosis (B) Mitosis
(C) Meiosis - I (D) Meiosis - II

Q.88 In plants, active mitosis occurs in –
(A) Cambium (B) Leaf tip
(C) Root base (D) Mid vein

Q.89 Stain for cell division –
(A) Saffranin (B) Aniline blue
(C) PAS (D) Acetocarmine

Q.90 Terminal meiosis occurs in –
(A) Sporocyte (B) Gametocyte
(C) Zygote (D) Gamete

Q.91 How many midrospore mother cells are required to produce 80 male gametes in angiosperms
(A) 10 (B) 20
(C) 40 (D) 80

Q.92 Gap between meiosis - I and II is called :
(A) Interphase (B) Interkinesis
(C) Diakinesis (D) Metakinesis

Q.93 In animals, cytokinesis is –
(A) Centrifugal (B) Centripetal
(C) Random (D) Collateral

Q.94 In the somatic cell cycle –
(A) DNA replication takes place in S-phase.
(B) A short interphase is followed by a long mitotic phase.
(C) G_2 phase follows mitotic phase.
(D) In G_1 phase DNA content is double the amount of DNA present in the original cell.

Q.95 In which stage of meiosis the chromosome number reduces to half:
(A) Anaphase-I (B) Anaphase-II
(C) Telophase-I (D) Telophase-II

Q.96 Chiasmata are formed as a result of –
(A) Exchange of parts of paired homologous chromosome.
(B) Exchange of part of unpaired non-homologous chromosome.
(C) Duplication of parts of paired homologous chromosome.
(D) Loss of parts of unpaired non-homolog us chromosome.

Q.97 When synapsis is complete all along the chromosome, the cell is said to have entered a stage called –
(A) Zygotene (B) Pachytene
(C) Diplotene (D) Diakinesis

Q.98 Many cells function properly and divide mitotically through they do not have –
(A) Plasma membrane (B) Cytoskeleton
(C) Mitochondria (D) Plastids

Q.99 Centromere is required for –
(A) Movement of chromosomes towards poles
(B) Cytoplasmic cleavage
(C) Crossing over
(D) Transcription

Q.100 At what stage of the cell cycle are histone proteins synthesized in a eukaryotic cell –
(A) During telophase
(B) During S-phase
(C) During G_2-stage of prophase
(D) During entire prophase

Q.101 If the n =16 in plant cell then how is possible in metaphase - I of meiosis –
(A) 32 Bivalents (B) 16 Tetravalents
(C) 16 Bivalents (D) 32 Bivalents

Q.102 If you are provided with root-tips of onion in your class and are asked to count the chromosomes which of the following stages can you most conveniently look into –
(A) Telophase (B) Anaphase
(C) Prophase (D) Metaphase

Q.103 At anaphase-II of meiosis each chromosome contains –
(A) 4 DNA (B) 3 - DNA
(C) 2 - DNA (D) 1 - DNA

Q.104 Kinetin (Cytokinin) increase the rate of mitosis by reducing the duration of –
(A) Interphase (B) Metaphase
(C) Anaphase (D) Telophase

Q.105 Select the incorrect statement regarding S phase of interphase.
(A) Occurs between G_1 and G_2.
(B) DNA replicates in the nucleus.
(C) Centrioles duplicate in the cytoplasm.
(D) As DNA is doubled, number of chromosomes also doubles.

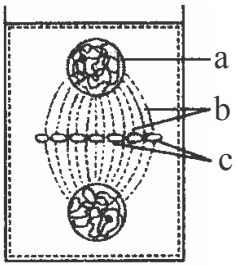
Q.106 During cell division, the spindle fibres get attached to condensing chromosome at a highly differentiated region, this region is called as
(A) chromomere (B) chromocentre
(C) centriole (D) kinetochore

Q.107 Synthesis of histone proteins occurs in
(A) G_1 phase (B) S phase
(C) anaphase (D) G_0 phase

Q.108 At what phase of meiosis are there two cells, each with separated sister chromatids that have been moved to opposite spindle poles?
(A) Anaphase - II (B) Anaphase - I
(C) Telophase - II (D) Telophase - I

Q.109 The cells that do not divide further, exit G_1 phase to enter an inactive stage called__of the cell cycle.
(A) G_1 stage (B) G_2 stage
(C) S stage (D) G_0 stage

Q.110 The given diagram depicts cell plate method of cytokinesis in plant cells. Identify a, b and c.



(A) a-Daughter nucleus, b-Phragmoplast, c-Vesicles
(B) a-Daughter nucleus, b-Vesicles, c-Phragmoplast
(C) a-Parent nucleus, b-Vesicles, c-Phragmoplast
(D) a-Parent nucleus, b-Phragmoplast, c-Vesicles

Q.111 The members of a homologous pair of chromosomes
(A) are identical in size and appearance
(B) contain identical genetic information
(C) separate and move to opposite poles of the cell during mitosis
(D) are found only in haploid cells.

Q.112 At which stage of mitosis, the two daughter chromatids separate from each other, migrate towards the opposite poles and are now referred to as chromosomes of the future daughter nuclei?

(A) Prophase (B) Metaphase
(C) Anaphase (D) Telophase

Q.113 Crossing over in diploid organisms is responsible for

(A) dominance of genes
(B) linkage between genes
(C) segregation of alleles
(D) recombination of alleles

Q.114 Read the following statements and select the correct option.

I. M-phase represents the phase when the actual cell division or mitosis occurs.
II. Interphase represents the phase between two successive M-phases.
III. In the 24 hrs average duration of cell cycle of a human cell, cell division proper lasts for only about an hour.
IV. The M-phase lasts more than 95% of the duration of cell cycle.

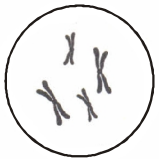
(A) I, II and III (B) II and IV
(C) II, III and IV (D) I and IV

EXERCISE - 3 (LEVEL-3)

Choose one correct response for each question.

For Q.1-Q.2

Refer to the sketch of a cell containing chromosomes.



Q.1 How many chromosomes are in this cell?

(A) 2 (B) 4
(C) 8 (D) 16

Q.2 How many chromatids are in this cell?

(A) 2 (B) 4
(C) 8 (D) 16

Q.3 A particular plant species has a diploid chromosome number of 20. A haploid cell of that species at mitotic prophase contains a total of ___ chromosomes and ____ chromatids.

(A) 20; 20 (B) 20; 40
(C) 10; 10 (D) 10; 20

Q.4 Match the column

	Column I	Column II
a.	Terminalization of chiasmata	1. Pachytene
b.	Exchange of segments of chromatids	2. Zygotene
c.	Synapsis of homologous chromosomes	3. Diakinesis
d.	Appearance of chiasmata	4. Leptotene
		5. Diplotene

(A) a-4, b-2, c-3, d-1
(B) a-3, b-1, c-2, d-5
(C) a-2, b-5, c-1, d-3
(D) a-2, b-4, c-3, d-1

Q.5 When the number of chromosomes is already reduced to half in the first reductional division of meiosis, what is the necessity of second meiotic division?

(A) The division is required for the formation of four gametes.
(B) Division ensures equal distribution of haploid chromosomes.
(C) Division ensures equal distribution of genes on chromosomes.
(D) Division is required for the segregation of replicated chromosomes.

Q.6 Which of the following statements are correct for cell cycle?

I. Cell Cycle is the sequence of events involving growth and division of a cell from the time of its formation to its own division into daughter cells.
II. Cell growth (in terms of cytoplasmic increase) is a continuous process.
III. DNA synthesis occurs only during one specific stage in the cell cycle.
IV. The replicated chromosomes (DNA) are distributed to daughter nuclei during cell division.

(A) I and III (B) I and II
(C) III and IV (D) I, II, III & IV.

Q.7 For a somatic cell with 2n = 4, which of the following is true? (Note G_1 - growth phase 1, G_2 - growth phase 2, M - metaphase, P-prophase and T-telophase)

(A) (Number of chromatids) $G_2 = 4$; (Number of chromosomes) $G_1 = 4$
(B) (Number of chromatids) $G_1 = 2$; (Number of sister chromatids) T = 8
(C) (Number of chromatids) P = 8 (Number of chromosomes) $G_2 = 4$
(D) (Number of chromatids) $G_2 = 4$; (Number of chromosomes) M = 8.

Q.8 Which is NOT a source of genetic variation?

(A) independent assortment of chromosomes
(B) crossover
(C) random fertilization
(D) mitosis

Q.9 Which of the following cells are permanently arrested in the G_0 phase?

(A) bone marrow (B) liver cells
(C) cancer cells (D) nerve cells

Q.10 Which is TRUE of the cell cycle?
(A) The timing of cell division is controlled by cyclins & CDKs.
(B) A characteristic of cancer cells is density-dependent inhibition.
(C) The cell cycle is controlled solely by signals external to the cell.
(D) The cell cycle is controlled soley by internal signals.

Q.11 A cell that passes the restriction point will most likely
(A) stop dividing
(B) divide
(C) show density-dependent inhibition
(D) die

Q.12 Arrange the following events of meiosis in a proper sequence and select the correct option.
I. Terminalization II. Crossing over
III. Synapsis IV. Disjunction of genome
(A) IV, III, II and I (B) III, II, I and IV
(C) II, I, IV and III (D) I, IV, III and II

Q.13 Which statements are correct for meiosis?
I. Meiosis is a double division. It gives rise to four cells.
II. The cells undergoing meiosis may be haploid or diploid.
III. No bouquet stage is recorded.
IV. Pairing or synapsis of homologous chromosomes takes place during zygotene of prophase-I & continues upto metaphase-I.
(A) I Only (B) I and IV
(C) II and III (D) All of these

Q.14 At which of the following stages do human skin cell nuclei have the same DNA content?
(A) early mitotic prophase; late mitotic telophase
(B) G_1; G_2
(C) G_1; early mitotic prophase
(D) G_2; late mitotic telophase

Q.15 A primary difference between mitosis in eukaryotic cells and binary fission is
(A) binary fission lacks cytokinesis
(B) binary fission has few to no checkpoints
(C) mitosis requires the presence of centrioles
(D) DNA replication only occurs in mitosis

Q.16 Which of the following statement about cells that undergo mitosis is FALSE?
(A) DNA replication starts at a specific region, the origin of replication.
(B) G_2 phase has twice as much DNA as G_1 phase.
(C) Chromatids move to opposite poles of the cell.
(D) Checkpoints ensure that one phase is complete before the next phase is initiated.

Note (Q.17-Q.21) :
(A) Statement- 1 is True, Statement-2 is True, Statement-2 is a correct explanation for Statement -1
(B) Statement-1 is True, Statement-2 is True ; Statement-2 is NOT a correct explanation for Statement - 1
(C) Statement - 1 is True, Statement- 2 is False
(D) Statement -1 is False, Statement -2 is False

Q.17 **Statememt 1 :** Interphase is resting stage.
Statememt 2: The interphase cell is metabolically inactive.

Q.18 **Statememt 1 :** Mitosis maintains the genetic similarity of somatic cells.
Statememt 2: Chromosomes do not undergo crossing over.

Q.19 **Statememt 1 :** Chiasmata is formed during diplotene.
Statememt 2 : Chiasmata are formed due to deposition of nucleoproteins.

Q.20 **Statememt 1 :** During zygotene, chromosomes show bivalent stage.
Statememt 2 : Bivalent is half the number of chromosomes.

Q.21 **Statememt 1 :** Meiosis takes place in pollen mother cells.
Statememt 2 : Each pollen mother cell produce 4 haploid pollen grains.

Q.22 The DNA content of individual cells and the number of cells in each phase of a "cell cycle" can be determined using flow cytometry. Which of the following combinations of "phase of a cell cycle and its corresponding DNA content" can be considered normal?

(i) Diploid cells found in the G_0 or G_1 phase.
(ii) Cells with twice the normal DNA content in the early M phase.
(iii) Cells with intermediate amounts of DNA in the S phase.
(iv) Cells with twice the normal DNA content in the G_2 phase.

(A) (i) and (ii) (B) (ii) and (iii)
(C) (iii) and (iv) (D) (i), (ii), (iii) and (iv)

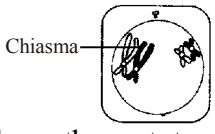
Q.23 The separation of two chromatids of each chromosome at early anaphase is initiated by

(A) the interaction of centromere with the chromosomal fibres.
(B) the elongation of metaphasic spindle
(C) the force of repulsion between the divided kinetochores
(D) all of these

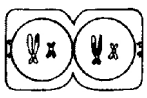
Q.24 What is true about telophase stage?

(A) Chromosomes lose their identity as discrete elements.
(B) Chromosomes cluster at opposite spindle poles.
(C) Nuclear envelope, nucleolus, Golgi complex and ER reform.
(D) All of these.

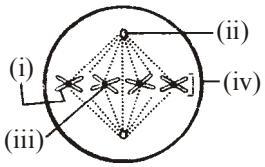
Q.25 The figure shows a cell undergoing meiosis.



Which of the options below shows the next stage in the process?

(A) 
(B) 
(C) 
(D) 

Q.26 Identify the structures indicated by labels (i), (ii), (iii) and (iv) and select the correct option.



(A) (i)-Chromatid, (ii)-Centriole, (iii)-Centromere, (iv)-Chromosome
(B) (i)-Chromosome, (ii)-Centriole, (iii)-Centromere, (iv)-Chromatid
(C) (i)-Chromatid, (ii)-Centromere, (iii)-Centriole, (iv)-Chromosome
(D) (i)-Chromosome, (ii)-Centromere, (iii)-Centriole, (iv)-Chromatid

Q.27 An anther has 1200 pollen grains. How many PMCs must have been there to produce them?

(A) 1200 (B) 300
(C) 150 (D) 2400

Q.28 The process of crossing over is assisted by which of the following enzymes?

(A) Endonuclease (B) Polymerase
(C) Ligase (D) Both (A) and (C)

Q.29 Which of the following statement(s) is/are not correct about meiosis?

I. Meiosis involves pairing of homologous chromosomes and recombination between them.
II. Two diploid cells are formed at the end of meiosis-II.
III. Meiosis involves two sequential cycles of nuclear and cell division called meiosis-I and meiosis-II, but only a single cycle of DNA replication.
IV. Meiosis-I is initiated after the parental chromosome replication which produce identical sister chromatids at the S-phase.

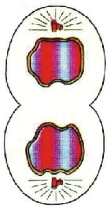
The correct option is

(A) I and III (B) II Only
(C) II and III (D) I, II, III and IV

EXERCISE - 4 (PREVIOUS YEARS AIPMT/NEET EXAM QUESTIONS)

Choose one correct response for each question.

Q.1 A stage in cell division is shown in the figure. Select the answer which gives correct identification of the stage with its characterstics. **[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.

Q.2 The complex formed by a pair of synapsed homologous chromosomes is called **[NEET 2013]**

(A) Axoneme (B) Equatorial plate
(C) Kinetochore (D) Bivalent

Q.3 In which phase(s) of cell cycle, amount of DNA in a cell remains at 4C level if the initial amount is denoted as 2C? **[AIPMT 2014]**

(A) G_0 and G_1 (B) G_1 and S
(C) Only G_2 (D) G_2 and M

Q.4 In 'S' phase of the cell cycle **[AIPMT 2014]**

(A) Amount of DNA doubles in each cell.
(B) Amount of DNA remains same in each cell.
(C) Chromosome number is increased.
(D) Amount of DNA is reduced to half in each cell.

Q.5 The enzyme recombinase is required at which stage of meiosis? **[AIPMT 2014]**

(A) Pachytene (B) Zygotene
(C) Diplotene (D) Diakinesis

Q.6 Select correct option **[AIPMT 2015]**

(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) Pachytene-I (v) Pachytene

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

Q.7 A somatic cell that has just completed the S-phase of its cell cycle, as compared to gamete of the same species, has **[AIPMT 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.

Q.8 Spindle fibres attach on to – **[NEET 2016 PHASE 1]**

(A) Telomere of the chromosome
(B) Kinetochore of the chromosome
(C) Centromere of the chromosome
(D) Kinetosome of the chromosome

Q.9 In meiosis crossing over is initiated at – **[NEET 2016 PHASE 1]**

(A) Pachytene (B) Leptotene
(C) Zygotene (D) Diplotene

Q.10 Which of the following is not a characteristic feature during mitosis in somatic cells? **[NEET 2016 PHASE 1]**

(A) Spindle fibres
(B) Disappearance of nucleolus
(C) Chromosome movement
(D) Synapsis

Q.11 A cell at telophase stage is observed by a student in a plant brought from the field. He tells his teacher that this cell is not like other cells at telophase stage. There is no formation of cell plate and thus the cell is containing more number of chromosomes as compared to other dividing cells. This would result in **[NEET 2016 PHASE 1]**

(A) Aneuploidy (B) Polyploidy
(C) Somaclonal variation (D) Polyteny

Q.12 During cell growth, DNA synthesis takes place in **[NEET 2016 PHASE 2]**

(A) S phase (B) G_1 phase
(C) G_2 phase (D) M phase

Q.13 Match the stages of meiosis of Column-I to their characteristic features in Column-II and select the correct option using the codes given **[NEET 2016 PHASE 2]**

	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

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

Q.14 When cell has stalled DNA replication fork, which checkpoint should be predominantly activated? **[NEET 2016 PHASE 2]**

(A) G_1/ S (B) G_2/ M
(C) M (D) Both G_2/ M and M

Q.15 Which of the following options gives the correct sequence of events during – **[NEET 2017]**

(A) codensation → 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

Q.16 DNA replication in bacteria occurs – **[NEET 2017]**

(A) During s-phase
(B) Within nucleolus
(C) Prior to fission
(D) Just before transcription

Q.17 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.

Q.18 The stage during which separation of the paired homologous chromosomes begins is **[NEET 2018]**

(A) Diakinesis (B) Diplotene
(C) Pachytene (D) Zygotene

Q.19 The correct sequence of phases of cell cycle is **[NEET 2019]**

(A) M → G_1 → G_2 → S
(B) G_1 → G_2 → S → M
(C) S → G_1 → G_2 → M
(D) G_1 → S → G_2 → M

Q.20 Cell in G_0 phase : **[NEET 2019]**

(A) exit the cell cycle
(B) enter the cell cycle
(C) suspend the cell cycle
(D) terminate the cell cycle

ANSWER KEY

EXERCISE-1 (SECTION-1&2)

(1) (C) **(2)** (A) **(3)** (A)
(4) G_1, quiescent stage (G_0)
(5) Chromatin **(6)** Prophase-I
(7) S-phase **(8)** Interphase
(9) Prophase **(10)** Cyclins
(11) Metaphase **(12)** Anaphase
(13) Centre, periphery

EXERCISE - 1 [SECTION-3 & 4]

Q	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
A	D	A	D	D	B	B	B	A	D	C	B	A	A	A	C	D	B	C	A	C	D	C	C	B	D
Q	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
A	A	D	B	A	D	D	B	D	B	A	D	A	B	D	B	B	B	B	B	A	A	B	B	B	B
Q	64	65	66	67	68	69	70	71																	
A	B	B	D	B	B	A	D	D																	

EXERCISE - 2

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	B	B	D	D	A	C	B	A	B	B	A	C	D	D	B	B	D	D	C	A	B	C	C	D	D
Q	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
A	D	D	D	B	C	C	D	C	A	D	D	D	D	C	A	D	A	A	D	C	D	D	D	D	A
Q	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
A	C	A	A	A	B	D	A	C	C	C	B	B	D	B	D	B	B	D	D	D	D	C	B	A	A
Q	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
A	B	C	B	D	C	A	B	A	B	B	D	A	A	D	B	A	B	B	A	A	A	B	D	A	B
Q	101	102	103	104	105	106	107	108	109	110	111	112	113	114											
A	C	D	D	A	D	D	B	A	D	A	A	C	D	A											

EXERCISE - 3

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	B	C	D	B	D	D	C	D	D	A	B	B	B	D	B	A	C	A	C	B	A	D	C	D	B
Q	26	27	28	29																					
A	A	B	D	D																					

EXERCISE - 4

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	B	D	C	A	A	A	B	B	A	D	B	A	A	A	B	C	C	B	D	A

SOLUTIONS

EXERCISE-1

(1) (C) **(2)** (A) **(3)** (A)

(4) G_1, quiescent stage (G_0),

(5) **Chromatin.** During interphase, the chromosome material (DNA of chromosome) replicates and becomes doubled. Chromosome material in the form of very loosely coiled . threads is called chromatin.

(6) **Prophase-I** is the longest phase of meiosis, consuming 90% of the time for the two divisions.

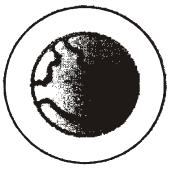
(7) **S-phase.** Interphase of cell cycle is composed of G_1-phase, S-phase and G_2-phase. During S-phase, DNA replicates in semiconservative manner so, each chromosome is formed of two chromatids joined at centromere.

(8) **Interphase.** The phase between two successive M-phases is called interphase.

(9) **Prophase.** Prophase is marked by the initiation of condensation of chromosomal material. The chromosomal material becomes untangled during the process of chromatin condensation. The completion of prophase can thus be marked by the following characteristic events

(i) Chromosomal material condenses to form compact mitotic chromosomes.
Chromosomes are seen to be composed of two chromatids attached together at the centromere.

(ii) Initiation of the assembly of mitotic spindle, the microtubules, the proteinaceous components of the cell cytoplasm help in the process.



Early prophase

Late prophase

(10) Cyclins **(11)** Metaphase

(12) Anaphase **(13)** Centre, periphery

(14) **(D).** At the onset of anaphase, each chromosome arranged at the metaphase plate is split simultaneously and the two daughter chromatids, now referred to as chromosomes of the future daughter nuclei, begin their migration towards the two opposite poles. As each chromosome moves away from the equatorial plate, the centromere of each chromosome is towards the pole and hence at the leading edge, with the arms of the chromosome trailing behind. Thus, anaphase stage is characterised by the following key events

- Centromeres split and chromatids separate.
- Chromatids move to opposite poles.

(15) **(A).**

a. **Metaphase:** Spindle fibres attaches to kinetochores of chromosomes.
Chromosomes are moved to spindle equator and get aligned along metaphase plate through spindle fibres of both poles.

b. **Telophase:** Chromosomes cluster at opposite spindle poles and their identity is lost as discrete elements.
Nuclear envelope assembles around the chromosome clusters.
Nucleolus, Golgi complex and ER reform.

c. **Interphase :** It is the duration which is a variable depending on the function of cell.
Just before nuclear division, the DNA of chromosome replicates thus, it becomes doubled.
During this phase, chromosome material is in the form of very loosely coiled threads called chromatin.

(16) **(D).** During metaphase I of meiosis, homologous pairs line up on the metaphase plate in double file.

(17) **(D).** During metaphase II of meiosis, single chromosomes line up on the metaphase plate in preparation for division. During meiosis II, sister chromatids separate.

(18) **(B).** During anaphase II, sister chromatids are separating.

(19) **(B).** The interphase takes approximate 75-95% of the entire generation time.

(20) (B) **(21)** (A)

(22) **(D).** G_1-phase corresponds to the interval between mitosis and initiation of DNA replication. During G_1-phase, the cell is metabolically active and continuously grows but do not replicate its DNA.

(23) (C)

(24) **(B).** The cell cycle is divided into two basic phases. Interphase and M-phase (mitosic phase). Interphase further divides into three phases: G_1-phase, S-phase and G_2-phase.

(25) **(A).** G_1-phase is the longest phase of cell cycle and is also called as presynthetic or post-mitotic phase. During this phase, the synthesis of biochemicals like RNAs, proteins, enzymes like DNA polymerase for DNA synthesis, amino acids for histone formation, nucleotide and ATP takes place.

(26) (A)

(27) **(A).** During S-phase, there is no increase in the chromosomes number. If the cell has diploid or 2n number of chromosomes at G_1, even after S-phase the number of chromosomes remains the same, i.e., 2n.

(28) (C)

(29) **(D).** The interphase is also called the resting phase. It is the time during which the cell gets prepared for division by undergoing both cell growth and DNA replication in an orderly manner.

(30) (B)

(31) **(C).** Some cells that do not divide further, exit G_1-phase and enter an inactive stage called quiescent stage (G_0) of the cell cycle. Cells in this stage remains metabolically active but no longer proliferate unless called on to do so depending on the requirement of the organism.

(32) (A)

(33) **(C).** After M-phase, daughter cells may enter G_0-phase, which is a stage of arrest of cell cycle, stoppage of cell division and onset of differentiation.

(34) (D)

(35) **(C).** The S and G_2-phases of interphase are followed by prophase. Prophase is marked by the initiation of condensation of chromosomal material. The chromosomal material become untangled during the process of chromatin condensation. Centriole, now begins to move towards opposite poles of the cell. Therefore, when dividing cells are examined under a light microscope, in prophase only the chromosomes become visible.

(36) (C) **(37)** (B) **(38)** (D)

(39) **(A).** Interphase is divided into G_1, S and G_2-phase, out of which in S-phase duplication of chromosomal material occurs.

(40) **(D).** Small disc-shaped structure at the surface of the centromeres are called kinetochores. These structures serve as the sites of attachment of spindle fibres (formed by the spindle fibres) to the chromosomes that are moved into position at the centre of the cell. Hence, the metaphase is characterised by all the chromosomes coming to lie at the equator with one chromatid of each chromosome connected by its kinetochore to spindle fibres from one pole and its sister chromatid connected by its kinetochore to spindle fibres from the opposite pole.

(41) (B)

(42) **(A).** In the S and G_2-phases of interphase, the new DNA molecules formed are not distinct but interwined. Prophase, is the first stage of mitosis which follows the S and G_2-phases of interphase.

(43) (D)

(44) **(D).** Synapsis is the pairing of homologous chromosomes during the zygotene stage of meiosis. Each pair is called bivalent. One chromosome of the pair comes from the male parent and other from the female parent. Each member of the pair is of the same length, their centromeres are in the same position and they usually have the same number of genes arranged in the same order.

(45) (B)

(46) **(D).** Mitosis usually results in the production of diploid daughter cells with identical genetic complement. The growth of multicellular organisms is due to mitosis.

Cell growth results in disturbing the ratio between the nucleus and the cytoplasm. It therefore, becomes essential for the cell to divide to restore the nucleo-cytoplsmic ratio. A very significant contribution of mitosis is cell repair.

The cells of the upper layer of the epidermis, cells of the lining of the gut and blood cells are being constantly replaced. Mitotic divisions in the meristematic tissues - the apical and the lateral cambium, result in a continuous growth of plants throughout their life.

(47) (B)

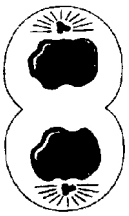
(48) **(A).** Initially, hoemeotypic cell division takes place in the functional megaspore without cytokinesis.

(49) (D)

(50) **(A).** Mitosis is one of the types of cell division. which helps in regeneration. Because it keeps all the somatic cells of an organism genetically similar, so that they are able to regenerate a part or whole of the organism.

(51) (B)

(52) **(D).** At the beginning of the final stage of mitosis, i.e., telophase, the chromosomes that have reached their respective poles, decondense and lose their individuality. The individual chromosomes can no longer be seen and chromatin material tends to collect in a mass in the two poles (Fig.).



Telophase

(53) **(B).** There are two main ways of cell division i.e., mitosis and meiosis. In each case, division of the nucleus, called karyokinesis, occurs before the division of the cytoplasm, termed as cytokinesis.

(54) (B)

(55) **(B).** During metaphase, the nuclear envelope disintegrates and the chromosomes are spread through the cytoplasm of the cell. Condensation of chromosomes is completed and it can be observed under the microscope. At this stage, the morphology as well as the number of chromosomes can be easily studied.

(56) (B)

(57) **(B).** Metaphase plate is the plane of alignment of the chromosomes at metaphase.

During metaphase, spindle fibres attach to kinetochores of chromosomes.

Chromosome are moved to spindle equator and get aligned along metaphase plate through spindle fibres to both poles.

(58) **(A).** After meiosis, the chromosomes get reduce by half, producing haploid cells. The sperm and the egg are haploid cells and when they fuse during fertilisation, they produce original diploid cell.

(59) (A)

(60) **(B).** The correct sequence is

Synapsis → crossing over → terminalisation → disjunction of genomes.

(61) (B)

(62) **(B).** Chromosomal crossing over is the exchange of genetic material between homologous chromosomes that results in the recombinant chromosomes. It occurs during prophase-I of meiosis.

(63) (B) **(64)** (B)

(65) **(B).** Meiosis start with one diploid cell containing copies of chromosome, one from mother and one from father. The cell divides twice, producing up to four haploid cells containing one copy of each chromosome.

(66) (D)

(67) **(B).** In anaphase-I chromosome become half in number. Chromosomes split and move to opposite ends of the cell, both in anaphase-I and anaphase-II. The difference is that in anaphase-I, homologous pairs of chromosomes are split and in anaphase-II, sister chromatids are split.

(68) (B) **(69)** (A)

(70) **(D).** Meiosis can be observed in spore mother cells. Spore mother cell undergoes meiosis and usually produces four spores.

(71) (D)

EXERCISE-2

(1) (B) **(2)** (B) **(3)** (D) **(4)** (D)
(5) (A) **(6)** (C) **(7)** (B) **(8)** (A)

(9) **(B).** Assuming mistakes don't occur, mitosis results in two daughter cells that are genetically identical to the parent cell.

(10) **(B).** The production of gametes, sperm, and eggs occurs by meiosis, where the chromosome no. gets cut in half.

(11) **(A).** G_1 phase is the most variable and could lead to cell arrest. All other phases of interphase and mitosis are uniform in length for a given species.

(12) (C) **(13)** (D) **(14)** (D)
(15) (B) **(16)** (B)

(17) **(D).** Breakdown of the nuclear envelope is primary indicator of prometaphase.

(18) (D) **(19)** (C) **(20)** (A) **(21)** (B)

(22) **(C).** Cells lacking a nucleus is unable to undergo cell division, the cell would be in the arrest phase or G_0 phase.

(23) **(C).** All statements except (C) are correct, there is a separate kinetochore for each sister chromatid.

(24) **(D).** The interphase, as called the resting phase, is the time during which the cell is preparing for division by undergoing both cell growth and DNA replication. It is the phase between two successive M-phases.
The interphase is divided into three further classes
G_1-phase (Gap 1), S-phase (synthesis) and G_2-phase (Gap 2).

(25) **(D).** The beginning of diplotene stage is marked by chiasma formation. The chiasma formation is the indication of crossing over and the beginning of separation of chromosomes.
The chiasma formation is associated with the process of terminalisation.

(26) **(D).** Most of the life of the cell is spent in interphase when the chromosomes are threadlike and not visible under a light microscope. When the cell divides, chromosomes must be condensed. When supercoiled or condensed, chromosomes appear like the Xs and Ys we commonly see them as. The nucleolus is not a real structure but threadlike chromosomes organized in a way that form a sphere.

(27) **(D).** Prophase is generally identified by the initiation of condensation of chromosomal material. The chromosomal material condenses to form chromosomes. The nuclear envelope breaks down and spindles start to assemble at opposite ends of the cell.

(28) **(D).** A cleavage furrow is a shallow groove in the cell surface in animal cells where cytokinesis is taking place. The cell plate is seen in dividing plant cells.The middle lamella is a layer between two adjacent plant cells.

(29) **(B).** Meiosis cuts the chromosome number in half, from 2n to n. This occurs so that after fertilization, when two gametes fuse, the embryo will have the correct chromosome number, 2n.

(30) **(C).** The cells that result from mitotic cell division have the same number of chromosomes as the parent cell.

(31) **(C).** Plants do not have centrioles, they have only microtubule organizing centers.

(32) (D) **(33)** (C) **(34)** (A)

(35) **(D).** The synaptonemal complex forms during prophase I and holds the two replicated chromosomes tightly together as a bivalent or tetrad so that crossing-over can occur without error.

(36) **(D).** Homologous chromosomes separate during anaphase I of meiosis.

(37) **(D).** Chiasmata are the microscopically visible regions of homologous chromatids where crossing-over has occurred.

(38) **(D).** at the checkpoint prior to mitosis, many of the proteins are phosphorylated, a phosphatase must remove the inhibitory phosphate in order for CDK to become active. Decreasing the level of phosphatase would prevent the cell from undergoing mitosis.

(39) (C)

(40) **(A).** Contact inhibition occurs when cell surface receptors are in contact with adjacent cells or extracellular matrix. If blocked, cells would continue to undergo division and a tumor or mass of cells would develop.

(41)	(D)	**(42)**	(A)	**(43)**	(A)	**(44)**	(D)
(45)	(C)	**(46)**	(D)	**(47)**	(D)	**(48)**	(D)
(49)	(D)	**(50)**	(A)	**(51)**	(C)	**(52)**	(A)
(53)	(A)	**(54)**	(A)	**(55)**	(B)	**(56)**	(D)
(57)	(A)	**(58)**	(C)	**(59)**	(C)	**(60)**	(C)
(61)	(B)	**(62)**	(B)	**(63)**	(D)	**(64)**	(B)
(65)	(D)	**(66)**	(B)	**(67)**	(B)	**(68)**	(D)
(69)	(D)	**(70)**	(D)	**(71)**	(D)	**(72)**	(C)
(73)	(B)	**(74)**	(A)	**(75)**	(A)	**(76)**	(B)
(77)	(C)	**(78)**	(B)	**(79)**	(D)	**(80)**	(C)
(81)	(A)	**(82)**	(B)	**(83)**	(A)	**(84)**	(B)
(85)	(B)	**(86)**	(D)	**(87)**	(A)	**(88)**	(A)
(89)	(D)	**(90)**	(B)	**(91)**	(A)	**(92)**	(B)
(93)	(B)	**(94)**	(A)	**(95)**	(A)	**(96)**	(A)
(97)	(B)	**(98)**	(D)	**(99)**	(A)	**(100)**	(B)
(101)	(C)	**(102)**	(D)	**(103)**	(D)	**(104)**	(A)

(105) **(D).** S or synthesis phase marks the period during which DNA synthesis or replication takes place. During this time the amount of DNA per cell doubles. If the initial amount of DNA is denoted as 2C then it increases to 4C. However, there is no increase in the chromosome number; if the cell had diploid or 2n number of chromosomes at G_1, even after S phase the number of chomosomes remains the same, i.e., 2n.

(106) **(D).** The key feature of metaphase is the attachment of spindle fibres to kinetochores of chromosomes. Kinetochores are disc-shaped structures at the surface of the centromeres. These structures serve as the sites of attachment of spindle fibres to the chromosomes that are moved toward poles.

(107) **(B).** Replication of DNA along with the synthesis of nuclear proteins such as the histones occur during S phase of interphase.

(108) **(A).** Anaphase II, where the centromeres are cleaved, allows the kinetochores to pull the sister chromatids apart. The sister chromatids by convention are now called sister chromosomes, and they are pulled towards opposite poles.

(109) **(D).** The phase in which cells fail to divide further (do not undergo S- phase after G_1 -phase) and undergo differentiation is known as G_0 phase or quiescent stage. It occurs due to non-availability of mitogen and energy rich compounds. The cells remain metabolically active, grow in size and differentiate for particular function after attaining a particular shape.

(110) **(A).**

(111) **(A).** Homologous chromosomes are chromosomes having same structural features. In diploid nuclei, pairs of homologous chromosomes can be identified at the start of meiosis. One member of each pair comes from the female parent and other from the male. Homologous chromosomes have the same pattern of genes along the chromosome but the nature of the genes may differ.

(112) **(C).** In anaphase, the centromeres of chromosomes start to divide into two, forming daughter chromosomes with centromere in each. Daughter chromosomes are repulsive, so they migrate towards opposite poles. Spindle fibres attached to the centromeres shorten and pull the chromosomes to the poles.

(113) **(D).** Crossing over is a process of exchange of genetic material between non-sister chromatids of two homologous chromosomes and leads to recombination of genes. It is an enzyme mediated process.

(114) **(A).** The M-phase represents the phase when the actual cell division or mitosis occurs and the interphase represents the phase between two successive M-phases. It is significant to note that in the 24 hour average duration of cell cycle of a human cell, cell division proper lasts for only about an hour. The interphase lasts more than 95% of the duration of cell cycle.

EXERCISE-3

(1) **(B).** There are 4 replicated chromosomes in this cell but 8 chromatids. The number of chromosomes is determined by the number of centromeres, 1 per chromosome.

(2) (C) **(3)** (D) **(4)** (B)

(5) (D) **(6)** (D) **(7)** (C)

(8) **(D).** The daughter cells resulting from mitotic cell division are genetically identical to each other and to the mother cell. Sources of variation are independent assortment of chromosomes, crossover, random fertilization, and recombinant chromosomes.

(9) **(D).** A cell arrested in the G_0 phase is not dividing. Most human body cells are not actively dividing. Highly specialized cells such as nerve and musele cells never divide. Liver cells can be induced to divide when necessary, and human skin and bone marrow cells are always dividing. Also, cancer cells are always rapidly dividing.

(10) **(A).** The timing of the cell cyele responds to external and internal cues and to fluctuations in levels of cyelins and cyclin-dependent kinases (CDKs). Normal cells stop dividing when crowded. This phenomenon is called contact inhibition or density-dependent inhibition. Cancer cells are characterized by uncontrolled growth.

(11) **(B).** In mammalian cells, the G_1 checkpoint is known as the restriction point. If the cell receives the go-ahead signal at the G_1 checkpoint, it will usually complete the cyele and divide. In contrast, if the cell is not stimulated to pass the restriction point, it will switch into a nondividing mode known as G_0.

(12) (B) **(13)** (B) **(14)** (D)

(15) **(B).** Of the given selections, (B), or lacking checkpoints is the primary difference.

(16) **(A).** Only cells that undergo binary fission have an origin of replication site, these cells typically have 1 circular DNA molecule.

(17) (C) **(18)** (A) **(19)** (C) **(20)** (B)

(21) (A) **(22)** (D)

(23) **(C).** Kinetochore is a plate-like structure by which microtubules of the spindle attach to the centromere of a chromosome during nuclear division. The centromere of each chromosome divides into two, so that each chromatid comes to have its own centromere. The two chromatids now start repelling each other and separate completely to become daughter chromosomes. The daughter or new chromosomes move towards the poles of spindle along the path of their chromosomes fibres or tractile fibrils.

(24) **(D).** During telophase, the individual chromosomes are no longer seen and chromatin material tends to coiled in a mass at the two poles. Chromosomes cluster at opposite spindle poles and their identity is lost as discrete elements. Nuclear envelope assembles around the chromosome clusters. Nucleolus, Golgi complex and ER reform.

(25) **(B).** The given figure is showing diplotene stage of prophase I of meiosis I. Next stage would be metaphase I.

(26) **(A).**

(27) **(B).** Meiosis of one Pollen Mother Cell (PMC) produces 4 haploid pollen grains. Thus, for producing 1200 pollen grains, 1200/4 = 300 PMCs are required.

(28) **(D).** Crossing over (recombination) occurs during pachytene. Recombination involves mutual exchange of the corresponding segments of non-sister chromatids of homologous chromosomes. It takes place by breakage and reunion of chromatid segments. Breakage, called nicking, is assisted by an enzyme endonuclease and reunion, termed annealing, is aided by an enzyme ligase.

(29) **(D).** During meiosis, four haploid cells are produced by reductional division from a single diploid cell. Parent cell contains replicated chromosomes, but the daughter cells contains unreplicated chromosomes.

EXERCISE-4

(1) **(B).** Telophase is reverse of prophase.

(2) **(D).** After synapsis in meiosis two homologous chromosomes are called Bivalent.

(3) **(C).** In M-phase, both 4C and 2C of DNA are present in different stages.

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

(5) **(A).** Crossing over is an enzyme-mediated process and the enzyme involved is called recombinase.

(6) **(A).**

(7) **(B).** Gamete is haploid while somatic cell is diploidAfter S-phase it will contain twice the number of chromosomes and four times the amount of DNA.

(8) **(B).** Spindle fibres attach to kinetochores of chromosomes

(9) **(A).** Leptotene - Condensation of chromatin
Zygotene - Synapsis of homologous chromosomes
Pachytene - Crossing over
Diplotene - Dissolution of synaptonemal complex and appearance of chiasmata
Diakinesis - Terminalisation of chiasmata

(10) **(D).** Synapsis is pairing of homologous chromosomes. It occurs during zygotene stage of meiosis.

(11) **(B).** Polyploidy cells have a chromosome number that is more than double the haploid number.

(12) **(A).** DNA replication occurs in S-phase of cell cycle.

(13) **(A).** Pachytene - Stage of crossing over
Metaphase-I - Chromosome align at equatorial plate
Diakinesis - Terminalisation of chiasmata
Zygotene-Pairing of homologous chromosome

(14) **(A).** G_1/ S check point of cell cycle is a major check point.

(15) **(B).** The correct sequence of events during mitosis would be as follows:
(i) Condensation of DNA so that chromosomes become visible occurs during early to mid-prophase.
(ii) Nuclear membrane disassembly begins at late prophase or transition to metaphase.
(iii) Arrangement of chromosomes at equator occurs during metaphase, called congression.
(iv) Centromere division or splitting occurs during anaphase forming daughter chromosomes.
(v) Segregation also occurs during anaphase as daughter chromosomes separate and move to opposite poles.
(vi) Telophase leads to formation of two daughter nuclei.

(16) **(C).** DNA replication in bacteria occurs prior to fission. Prokaryotes do not show well marked S-phase due to their primitive nature.

(17) **(C).** Anaphase Promoting Complex (APC) is a protein necessary for separation of daughter chromosomes during anaphase. If APC is defective then the chromosomes will fail to segregate during anaphase.

(18) **(B).** Synaptonemal complex disintegrates. Terminalisation begins at diplotene stage i.e. chiasmata start to shift towards end.

(19) **(D).** The correct sequence of phases of cell cycle is $G_1 \rightarrow S \rightarrow G_2 \rightarrow M$.

(20) **(A).** Cells in G_0 phase are said to exit cell cycle. These are at quiescent stage and do not proliferate unless called upon to do so.