10

Cell Cycle and Cell Division

A sea urchin begin it's life as a single cell that divides to form two cells. After four rounds of cell division, there are 16 cells. Individuals develop into complex, multicellular organisms after many rounds of cell division, as seen in this mature sea urchin.

Topic Notes

- *Phases of Cell Cycle and its Significance*

PHASES OF CELL CYCLE AND ITS SIGNIFICANCE 1

TOPIC 1

CELL CYCLE AND ITS PHASES

Cell Division

Cell division is the process where a mature cell divides into two nearly equal daughter cells that share most characteristics with the parental cell. In multicellular organisms, cell division is the development of new individuals from a single cell while in unicellular organisms, it is the division of a cell (parent cell) into two or more new cells (daughter cells.) Cell division is necessary for the survival of a species.

Important

➥ *Rudolf Virchow proposed that new cells are formed by the division of pre-existing cells. (Omnis-cellula-e-cellula).*

Cell Cycle

The cell cycle is the orderly and sequential changes by which a cell duplicates its genome, synthesises other constituents, grows and divides into two daughter cells. All these events occur in a coordinated manner and are genetically controlled.

Phases of Cell Cycle

The time interval between two cell cycles is called generation time. Generation time varies from a few minutes to a few days depending upon the type of cell and its environmental conditions. For example, Yeast cells divide once in 90 minutes. Human cells divide once approximately every 24 hours. Bacterial cell divides in 20 minutes.

Cell cycle consists of two basic phases, stages or periods. There is a long non-dividing growing, I phase, *i.e.* Interphase and a short dividing phase, M phase, also called as Mitosis phase.

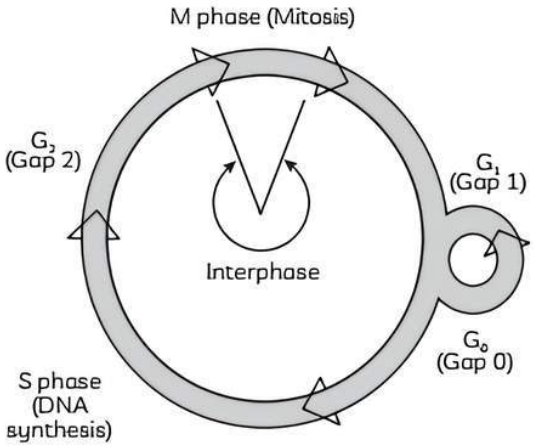
Important

➥ *In all living organisms, cell division is a very important and necessary process. DNA replication and cell growth occur simultaneously during cell division.*

Interphase

It is the phase between two M phases. It is a series of changes that takes place in a newly formed cell and its nucleus before it becomes capable to divide again. The interphase lasts more than 95% of the duration of cell cycle. Earlier it was known as the resting stage because there is no apparent activity related to cell division. Although during this stage, cell becomes metabolically very active. During this phase, cells prepare for cell division.

Interphase of a dividing cell has three phases—G_1 phase, S phase and G_2 phase.



Interphase and its phases

The interphase lasts for more than 95% of the total cell cycle span (around 23 hours) whereas about 5% of the total span (around 1 hour) is required for the cell division, *i.e.* M-phase. The table below depicts the different phases of cell cycle and their average time duration for the better understanding.

Phases	Time duration (in hours)
G_1	about 11 hours
S	about 8 hours
G_2	about 4 hours
M	about 1 hour

Example 1.1: What is the average cell cycle span for a mammalian cell? [NCERT]

Ans. The average cell cycle span for a mammalian cell is 24 hours.

G_1 phase

Also known as Post mitotic, Pre-DNA synthetic phase or gap I. It is the longest phase of interphase.

During this phase, cell size increases and cell synthesises all required elements including rRNA, mRNA, ribosomes and proteins. Carbohydrates, proteins and lipids are also synthesised in this phase.

This phase also synthesise amino acids, enzymes, nucleotides, and other compounds, however, there is no change in the DNA amount. Due to synthesis of all these components, the cell is metabolically active and grows continuously.

Nucleus, however, grows only to a small extent. RNA and proteins are synthesised. A large number of nucleotides, amino acids for histone synthesis and energy-rich compounds are formed. Cell organelles also increase in number.

When the cell is in G_1 phase, it has 3 options, and they are:

(1) To continue cell cycle and move to S phase of the cell cycle.

(2) Get arrested in G_1 phase cycle and then, enter G_0 phase for undergoing differentiation.

(3) Get arrested in G_1 phase when it may enter G_0 phase or re-enter cell cycle.

The factors that decide the above three situations are availability of mitogens and storage of energy rich compounds at the deciding point called checkpoint.

S phase

Also known as Synthetic phase. In this phase, DNA amount becomes double due to DNA replication. Along with DNA synthesis of histone proteins and NHC (non-histone chromosomal proteins) takes place.

Each chromosome bears two chromatids and euchromatin replicates earlier than heterochromatin. Centriole duplication also occurs in this phase. In this phase, the DNA content doubles, *i.e.* 1C to 2C for haploid cells and 2C to 4C for diploid cells. But the number of chromosomes remains same.

It is also called the invisible phase of M phase. Since it is in this phase that the chromosomes prepare themselves for equal distribution later on. Subunits of kinetochores are synthesised.

G_2 phase

Also known as Pre-mitotic, Post synthetic phase, or gap-II. In this phase, the synthesis of DNA stops.

The formation of RNAs and proteins continues. They are required for duplication of cell organelles (like mitochondria, plastid, etc.), spindle formation and cell growth.

It prepares the cell to undergo division. The synthesis of tubulin protein occuring in this phase and the damaged DNA is also repaired in this phase.

Important

➥ ***G_0 phase (Quiescent stage):*** *G_0 phase is the stage of inactivation of cell cycle due to non-availability of mitogens and energy-rich compounds. After the cell has finished division, it enters this phase. When an organism needs to grow, cells exit the G_0 phase and enter mitosis.*
Cell undergoes differentiation to perform a particular function. Cell in this stage remain metabolically active but no longer proliferate unless called on to do so depending upon the requirement of the organisms.

Example 1.2: Do all cells in a plant divide all the time? Can you tell the name and the location of tissues having cells that divide all their life in higher plants? [NCERT]

Ans. No, every cell does not divide all of the time. There are specialised cells on the apex of the plant, *i.e.* Root apex and shoot apex that divides continuously. These cells are known as meristematic cells. These cells divide, resulting in undifferentiated cells that eventually specialise into specific organs.

TOPIC 2

MITOSIS

M phase

Mitotic phase is also known as the dividing phase/ M phase. It is also known as equational division, somatic cell division, or indirect cell division. In this case, mature cells multiply in a way that the number of chromosomes in daughter cells remains the same as in the parent cell. Thus, it is known as equational division. The most typical mechanism of cell division is mitosis. M phase represents the phase of actual division. Prior to it (in Interphase), the cell components have undergone replication. Therefore, the M phase is a stage of separation of already duplicated components. Mitosis takes place in somatic cells. Mitosis occurs in meristematic cells in plants, such as the root apex and shoot apex.

Mitosis is further divided into two stages—Karyokinesis and Cytokinesis.

Karyokinesis

Karyokinesis is simply the division of the nucleus. Prophase, Metaphase, Anaphase and Telophase are four different phases of karyokinesis.

Prophase (Longest phase of karyokinesis)

(1) In the early prophase, condensation of chromosomal material starts and chromosomal material becomes untangled during this process. Chromatin fibres get thicker and shorter, forming chromosomes that may overlap and resemble a ball of wool.

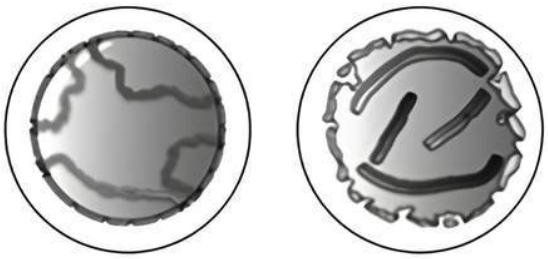
(2) Each chromosome contains two chromatids that remain connected to the centromere.

(3) In the late prophase, the nuclear membrane along with nucleolus begins to dissolve.

(4) Duplicated centrosomes begin to move towards opposite poles of the cell.

(5) Both the centriole pair and centrosome radiate out fine microtubular fibrils called astral rays.

(6) Each group of astral rays along with its centriole pair is called an aster.



Early prophase Late prophase

Prophase

Metaphase

(1) Begins with the complete disappearance of the nuclear membrane.

(2) No differentiation between cytoplasm and nucleoplasm.

(3) In this phase, condensation of a chromosome is completed. Chromosomes are composed of two sister chromatids connected by kinetochores. (Kinetochores are little disc-shaped structures on the surface of centromeres.)

(4) Each chromosome is attached to both the spindle poles by distinct chromosome fibres, one for each chromatid.

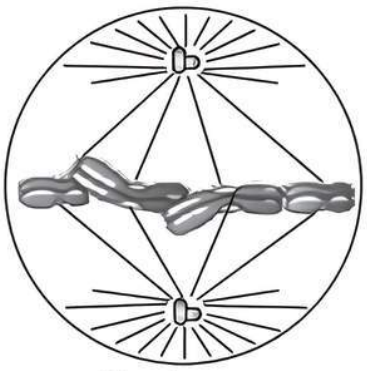
(5) Kinetochores are the sites of attachment of spindle fibres to the chromosome. Chrosomosal fibres (spindle fibres) tighten. This tightening brings the chromosomes on the equator of the spindle. The phenomenon of bringing the chromosomes on the equator of the spindle is called congression.

(6) Metaphasic plate or equatorial plate (the plane on which chromosomes align themselves during metaphase) is formed at the centre.

(7) It is the best stage to count the number and study the chromosome morphology.

Important

Colchicine, which inhibits the assembly of microtubules and stops cell division during metaphase, is widely used in plant breeding for doubling the number of chromosomes. This is called polyploidy.



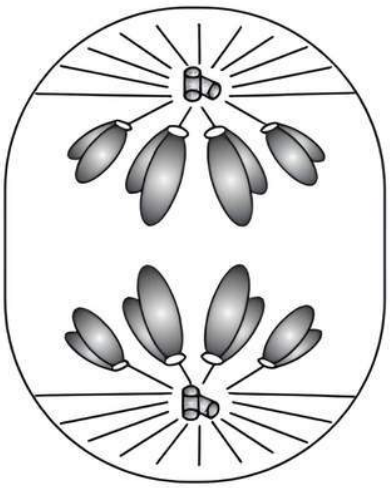
Metaphase

Anaphase

(1) During anaphase, the centromere of each chromosome divides into two so that each chromatid comes to have its own centromere.

(2) Due to a repulsive force known as anaphasic movement, both chromatids travel towards opposite poles.

(3) As the result, the anaphase chromosomes appear in different shapes like V, L, J and I. The shapes are formed respectively in metacentric, submetacentric, acrocentric and telocentric.



Anaphase

(4) Microtubule contraction is involved in the chromosomes' formation by separating chromatids. Each separated chromatid is known as the daughter chromosome.

(5) Centromere of the daughter chromosome faces towards their poles and their arms trailing behind.

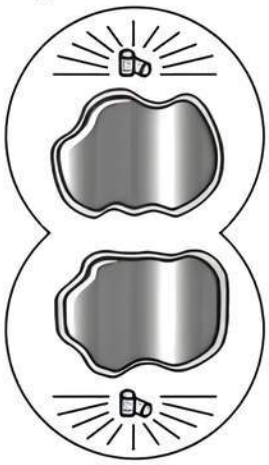
(6) Anaphase is the best phase to study the shapes of chromosomes.

Telophase

(1) It is the reverse of prophase.

(2) The mitotic spindle disappears, the chromosomes arrive at the poles of the cell, and vesicles containing fragments of the earlier nuclear membrane gather around the two sets of chromosomes

(3) New nuclear membrane is formed around each chromosomal group.
(4) Chromosomes decondensed and lost their identity.
(5) Two daughter nuclei are formed.
(6) Nucleolus, Endoplasmic reticulum and Golgi complex are reappeared.



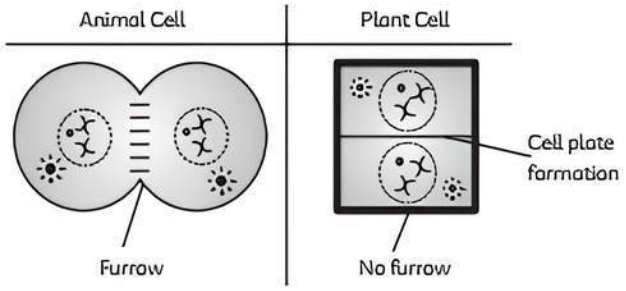
Telophase

Cytokinesis

(1) It is the division of protoplast of a cell into two daughter cells after the nuclear division or karyokinesis, so that each daughter cell can have its own nucleus.
(2) Cell organelles (mitochondria, plastids, Golgi bodies, lysosomes, endoplasmic reticulum, ribosomes) are distributed between the two daughter cells.
(3) Mitochondria, plastids undergo division by cleavage or fission mode.
(4) In some organisms, karyokinesis is not followed by cytokinesis due to which a multinucleated condition arises called coenocyte or syncytium. *E.g.* Liquid endosperm in coconut.
(5) Cytokinesis is different in animal and plant cells.

Difference between Plant and Animal Cytokinesis:

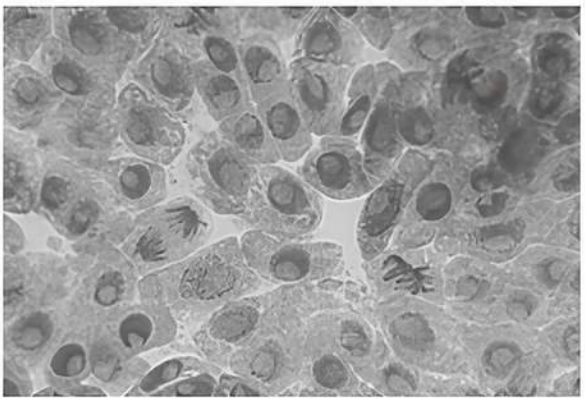
S. No.	Plant Cytokinesis	Animal Cytokinesis
(1)	It usually occurs by the cell plate method.	It takes place by cell furrow method.
(2)	Central part of spindle grows in size and forms an interdigitated complex called phragmoplast.	A mid body of dense fibrous and vesicular material is formed in the middle.
(3)	Cell plate grows centrifugally.	The cleavage or furrow formation progresses centripetally.
(4)	The new cell membrane is derived from vesicle of Golgi apparatus.	The new cell membrane is usually derived from endoplasmic reticulum.



Cell furrow method *Cell plate method*

Example 1.3: **Case Based:**

In a practical class, students were told to bring an onion root tip with them to observe the root under a microscope. Students saw the image as shown here. Students observed some activities, i.e. cell stages under the microscope. Students were asked to answer the following questions on the study of a given diagram and cell division of onion root tip.



(A) What is the number of chromosomes in onion root tip cells?
(a) 20 (b) 14
(c) 16 (d) 46

(B) How many chromosomes are present in the G_1, S and G_2 phases of onion root tip?
(a) 16 in each phase
(b) 16 in G_1, 32 in S and G_2 phase
(c) 16 in G_1, 32 in S and 16 in G_2 phase
(d) Both (c) and (d) are correct

(C) Which phases can be seen by students under a microscope?

(D) How will you describe mitotic cell division?

(E) Assertion (A): Synthesis of DNA occurs in S phase.
Reason (R): The DNA content doubles in the G_1 and G_2 phase of cell cycle.

(a) **Both A and R are true and R is the correct explanation of A.**

(b) **Both A and R are true and R is not the correct explanation of A.**

(c) **A is true but R is false.**

(d) **A is false but R is true.**

Ans. (A) *(c) 16*

Explanation: Onion root tip has 16 chromosomes. The onion root tip is a vegetative cell of onion and it is diploid as well. So, it has a total 16 number of chromosome present in it.

(B) *(a) 16 in each phase*

Explanation: In G_1, S and G_2 phase, the cell prepares for the mitotic division and in mitosis, chromosome number remains constant at all stages.

(C) All four phases of Mitosis, *i.e.* prophase, metaphase, anaphase and telophase can be observed by the students.

(D) Mitotic cell division: The mitotic phase of a cell cycle is a set of stages in which DNA content and other cell components are duplicated twice. The cell divides into two daughter cells, each of which receives a copy of the doubled material.

(E) *(c) A is true but R is false.*

Explanation: DNA synthesis occurs solely during the S phase of interphase, which is preceded and followed by two "gap" periods of interphase (G_1 and G_2) during which no DNA synthesis occur. The time between the end of mitosis I and the preparation of DNA synthesis occur in G_1. S phase represents the DNA synthesis, and G_2 phase is for the time between both the termination of DNA synthesis and the beginning of mitosis. During the S phase, a cell contains twice (4C) the amount of DNA as compared to what is found in the diploid cell during G_1 (2C).

Significance of Mitosis

(1) It is essential for growth and development of multicellular organisms. For example, all organisms developed from a zygote which is a single cell. The zygote forms a multicellular organism by undergoing repeated mitosis. Plants are able to grow throughout their life due to mitotic divisions in their apical and lateral meristem.

(2) Mitosis usually results in the production of diploid daughter cells with identical genetic complements.

(3) It generates new cells to aid in the repair and regeneration of damaged body parts as well as wound healing.

(4) Asexual reproduction such as fragmentation, budding and stem cutting is done by mitosis.

(5) Somatic variations can play a major role in speciation when they are maintained by vegetative propagation.

(6) Plants develop continuously due to meristematic division (mitotic) in the apical and lateral cambium.

(7) Mitosis is essential to maintain nucleo-cytoplasmic ratio.

(8) The cells of the upper layer of the epidermis, cells of the lining of the gut, and blood cells are being constantly replaced by mitosis.

Important

➥ *There are so many significances of mitosis but there is also a drawback or hazardous effect of uncontrolled mitosis, i.e. Cancer. As we all know, uncontrolled mitotic division can lead to cancer.*

Example 1.4: Can there be mitosis without DNA replication in S phase? [NCERT]

Ans. No, there cannot be any mitotic division without DNA replication in S phase.

TOPIC 3
MEIOSIS

The term meiosis was coined by Farmer and Moore in the year 1905.

Meiosis is slower than mitosis. In meiosis, a mature diploid reproductive cell undergoes a double division in which the nucleus divides twice but the chromosome (DNA) replicates only once, resulting in four haploid cells with half the number of chromosomes as the parent cell. It is also called reductional division because it reduces the number of chromosomes. It has been found in diploid germ cells (reproductive cells) of sex organs (*e.g.* Spermatozoa and ova in animals)

Interphase occurs prior to meiosis. It is generally similar to interphase of mitosis except that S phase is prolonged. DNA replication occurs during S phase. A distinct G_2 phase is either short or absent. At this time, each chromosome comes to have two chromatids. Chromosome replication

occurs once but meiosis has two M-phases each with its own Karyokinesis and Cytokinesis. As a result, chromosome number is halved. The transition period between M phase I (meiosis I) and M phase II (meiosis II) is short without DNA replication. It is called interkinesis.

Following are the details about the two stages of meiosis:

Meiosis I

In meiosis I, the number of chromosomes is reduced to half. As a result, it is also known as heterotypic division or reductional division. It produces two haploid cells from a diploid cell.

It is the process of nucleus division. Prophase I, metaphase I, anaphase I, and telophase I are the four phases of Meiosis I.

Prophase I

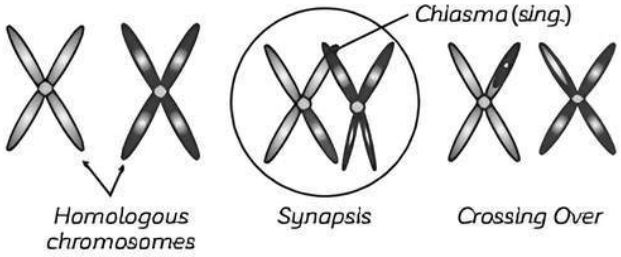
It is the longest phase of meiosis I. It is further divided into five sub-phases.

Table: Events of Prophase

Subphase of prophase I	Events taking place
Leptotene	Chromosomal compacting continues and the chromosomes become gradually visible under the light microscope.
Zygotene	Pairing of homologous chromosomes called synapsis. Synapsis is accompanied by the formation of a complex structure called synaptonemal complex Homologous chromosomes are called bivalent or tetrad. The number of bivalent chromosomes is half the number of the total chromosomes.
Pachytene	Four chromatids of each bivalent are clearly visible and appear as tetrad. Formation of recombination nodules at which crossing over occurs. *i.e.*, exchange of genetic material.
Diplotene	Dissolution of synaptonemal complexes. Homologous chromosomes separate from each other except at the site of crossover. The X-shaped structure formed is called Chiasmata. In oocytes of some vertebrates, diplotene can last for months or years.
Diakinesis	Movement of chiasmata towards the chromosomal end. Chrosomoses are fully condensed. Meiotic spindle is assembled to prepare the homologous chromosomes for separation. By the end of this phase, nucleolus disappears and nuclear membrane disintegrates. Diakinesis represents the transition to metaphase.

Important

- ***Synapsis:*** *The steady pairing of homologous chromosomes is known as synapsis.*
- ***Crossing over:*** *The exchange of genetic material between two homologous chromosomes is called crossing over.*
- ***Chiasmata:*** *The chiasmata is a structure that arises between two homologous chromosomes by crossing over, recombination and physical links between them.*



Metaphase I

On the equatorial plate of the spindle fibre, homologous pairs of chromosomes align and form a metaphase plate.

Each chromosome of bivalent gets attached to the spindle pole of its side by means of a chromosomal fibre or tractile fibril which arises in the region of the centromere.

Two metaphasic plates are formed.

Anaphase I

The homologous chromosome pairs separate and move to the spindle's opposite poles. But their sister chromatids remain associated at their centromere. The process of separation of homologous pairs is called a disjunction.

The separate chromosomes or univalents are also called dyads (dyads - two) because each of them consists of two chromatids which lie at an angle to each other.

Every tetrad has two daughter dyads.

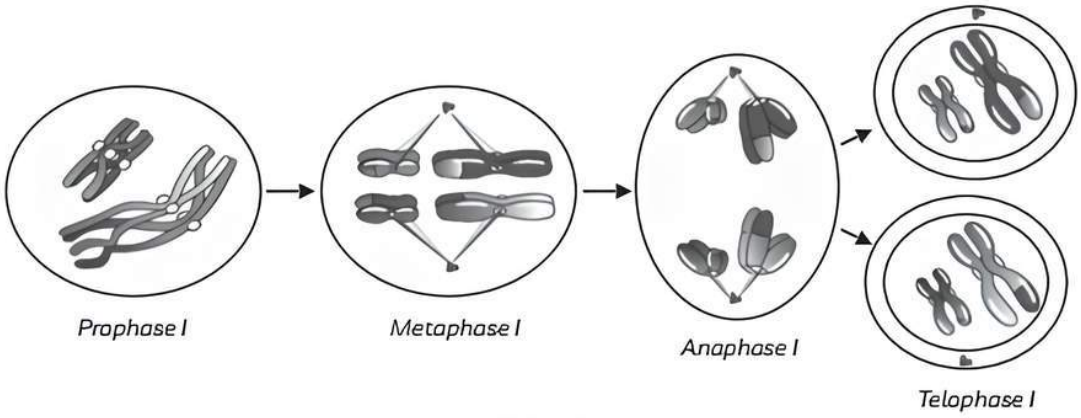
Telophase I

Each daughter cell has the same number of haploid chromosomes as the mother cell.

Genetic material is redistributed as a result of cross-over.

Nuclear membrane and nucleolus reappear.

Like long chromatin fibres, chromosomes decondensed into the thread.



Meiosis I

Interkinesis or Intermeiotic Phase

It is a metabolic stage between telophase of meiosis I and prophase of meiosis II. Chromosomes are elongated but chromatin reticulum is not formed. Protein and RNA synthesis may occur. Centrosomes or centriole pairs undergo replication in animal cells. However, there is no DNA synthesis. It is important for bringing true haploidy (haploidy of DNA) in the daughter cell.

Meiosis II

It is also known as equational division/ homotypic division. Meiosis II is similar to mitosis but it is shorter than mitosis. Though the meiosis II is similar to mitosis but meiosis II is not mitosis because it always occurs in haploid cells. It is not preceded by DNA replication. The two chromatids of the chromosome are often dissimilar. The daughter cell formed after meiosis II is neither similar to each other nor similar to parent cell. After meiosis I each daughter cell enters prophase II of meiosis II.

Prophase II

The chromosomes which were decondensed in telophase I are then re-condensed.

The spindle is fully formed and the nuclear envelope gets totally broken down.

Metaphase II

Chromosomes align in the equatorial plane of the spindle to form a metaphase plate.

The microtubules from opposite poles of the spindle get attached to the kinetochores of sister chromatids.

Anaphase II

The centromere divides and the chromatids migrate to opposite poles of the spindle to forming new chromosomes.

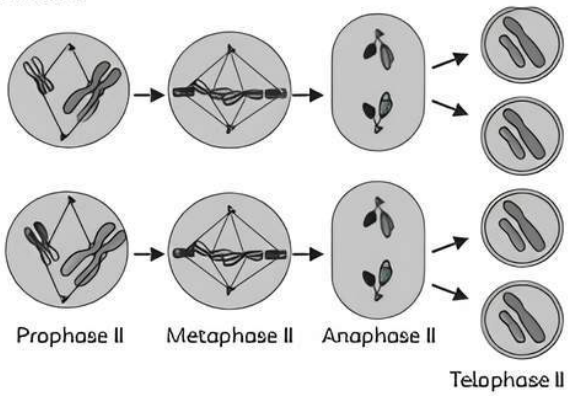
At the end of anaphase II, four groups of chromosomes are produced, each group having a haploid number.

Telophase II

The four groups of chromosomes arrange themselves into haploid nuclei. For this, chromosomes elongated very much to form chromatin.

A nucleolus is also produced followed by the formation of nucleoplasm and a nuclear envelope.

The spindle fibres usually degenerate during telophase II.



Meiosis II

Significance of Meiosis

(1) **Formation of gametes:** Meiosis forms gametes that are essential for sexual reproduction.

(2) **Genetic information:** It switches on the genetic information for the development of gametes or gametophytes and switches off the sporophytic information.

(3) **Maintenance of chromosome numbers:** Meiosis maintains the fixed number of chromosomes in sexually reproducing organisms by halving the same. It is essential since the chromosomes number becomes double after fertilisation.

(4) **Assortment of chromosomes:** In meiosis, parental and maternal chromosomes assort independently. It causes reshuffling of chromosomes and the trait controlled by them. The variation helps the breeder in improving the races of useful plants and animals.

(5) **Crossing over:** It introduces new combination of traits or variation.

(6) **Mutations:** Chromosomal and genomatic mutations can take place by irregularities of meiotic division. Some of these mutations are useful to the organism and are perpetuated by natural selection.

(7) **Evidence of Phylogenetic Relationship:** Details of meiosis are essentially similar in the majority of organisms showing their basic similarity and relationship.

Example 1.5: Find examples where the four daughter cells from meiosis are equal in size and where they are found unequal in size. [NCERT]

Ans. The four daughter cells formed during meiosis during the generation of male gametes (*i.e.* spermatozoa) in a normal mammal (*i.e.* human being) are equal in size. While the four daughter cells are formed of a female gamete (*i.e.* ovum) in a normal mammal (*i.e.* human being) are uneven in size.

Types of Meiosis

The cells in which meiosis takes place is called meiocytes. Depending upon the stage when meiosis occurs, it is of three types:

(1) **Gametic meiosis:** Meiosis in most of animal takes place during the formation of gametes, *i.e.* during gametogenesis that's why termed as gametic meiosis. When two gametes fuse in fertilisation, a diploid zygote is formed. Gametic meiosis result in diplontic life cycle.

(2) **Zygotic meiosis:** In some lower plants, meiosis takes place in the zygote and the resulting organisms are haploid. It is called zygotic meiosis. Organism have zygotic meiosis have haplontic life cycle.

(3) **Sporic meiosis:** In plants, meiosis generally occurs at the time of sporogenesis (formation of spores or microspores and megaspores). It is called sporic or intermediate meiosis. Spores produce a new gametophytic phase in the life cycle. Gametes are formed by gametophytes. Because of the presence of two distinct multicellular phases, diploid and haploid, life cycle of plants is diplohaplontic.

Important

➥ ***Need for meiosis:*** *Meiosis is essential for all sexually reproducing organisms. It occurs in reproductive cells so that the gametes formed are haploid or have half no. of chromosomes of those cells, which are directly formed from zygote. Meiosis by halving the number of chromosomes maintains a fixed number of chromosomes of a species.*

Example 1.6: Case Based:

Rattus norvegicus, is widely used as a laboratory animal in many kinds of scientific field, such as biochemical, biomedical, and pharmacological studies. Rats offer some advantages over mice in some transplantation, behaviour, and pharmacokinetic studies, because the larger size and greater intelligence of rats compared to mice enables ease of surgical operation, a large-volume of blood sampling, and assessment of high-level learning.

Some researchers studied two generations of wistar rats for a project. The stem cells of these rats have 21 pairs of chromosomes. They continuously observed the stem cells, reproductive cells and their changes of the first generation. After the birth they found the offspring had some mutations.

(A) **Number of chromosomes in a germ cell of Wistar rats are:**

(a) 22 (b) 21
(c) 13 (d) 8

(B) **Describe the process through which the paternal and maternal chromosomes exchange material takes place during cell division.**

(a) Dyad forming (b) Crossing over
(c) Bivalent forming (d) Synapsis

(C) **Why mutations are found in the offspring of the Wistar rats?**

(D) **What stages can be observed in meiotic cell division?**

(E) **Assertion (A):** Meiosis is referred to as reduction division, while mitosis is referred to as equational division.

Reason (R): Exchange of genetic information and cross-over between non-sister chromatids of homologous chromosomes occur during meiosis. This step is skipped during the process of mitosis.

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true and R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

Ans. (A) *(b) 21*

Explanation: The stem cells of Wistar rats have 42 chromosomes *i.e.*, 21 pairs. All the germ cells are haploid in number thus, the total number of chromosomes in a germ cell of a rat is 21.

(B) *(b) Crossing over*

Explanation: Crossing over is the exchange of genetic material between non-sister chromatids of two homologous chromosomes during sexual reproduction, resulting in recombinant chromosomes.

Dyad formation: A dyad is a double chromosome formed when a tetrad (a quadruple chromosome) splits during meiosis (germ cell formation).

Bivalent forming: Bivalent is formed in the zygotene stage of prophase I.

Synapsis: It is the initiation of the pairing of the homologous chromosomes.

(C) Prior to meiosis, mutations develop during DNA replication. During metaphase I, alleles from various homologous are mixed together to form new combinations. As a result eggs or sperm have a mix of maternal and paternal chromosomes when meiosis is completed, this may lead to mutations in the offspring.

(D) In meiotic cell division, following stages are observed:

In meiosis I: Prophase I, metaphase I, anaphase I and telophase I.

In prophase I: Leptotene, zygotene, pachytene, diplotene and diakinesis.

In meiosis II: Prophase II, metaphase II, anaphase II and telophase II.

(E) *(b) Both A and R are true but R is not the correct explanation of A.*

Explanation: Meiosis is a phase of cell division that develops in sexually reproducing organisms' reproductive cells. This reduces the number of chromosomes by half, resulting in haploid daughter cells. Meiosis is also known as reduction division because the daughter cells receive only half of the parent cell's chromosomes from each parent. During prophase I, the non-sister chromatids of homologous chromosomes crossover and exchange genetic information, which is one of the hallmarks of meiosis I. Meiosis results in recombination of the genetic material.

OBJECTIVE Type Questions

[1 mark]

Multiple Choice Questions

1. In plant cells, cytokinesis is completed by:

(a) Equatorial plate (b) Aster

(c) Cell plate (d) Membrane furrow

Ans. *(c) Cell plate*

Explanation: Cytokinesis is a process in which the cytoplasm is divided by the formation of a new cell plate in higher plant cells whereas by membrane furrow in animals.

2. Meiosis in diploid organisms such as humans and animals results in:

(a) Production of gametes

(b) Reduction in the number of chromosomes

(c) Introduction of variations

(d) All of the above [NCERT Exemplar]

Ans. *(d) All of the above*

Explanation: In diploid species, meiosis results in the formation of gametes, a reduction in chromosome number, and the introduction of variations.

3. Which of the following phases can you effectively look into if you are given onion root tips in class and asked to count the chromosomes?

(a) Anaphase (b) Prophase

(c) Metaphase (d) Telophase

Ans. *(c) Metaphase*

Explanation: In metaphase, chromosomes align themselves in a plane to form a metaphase plate which is formed at the centre. This stage is considered the most convenient for the study of chromosome number and morphology.

4. In mitosis, at which phase nuclear envelope and nucleolus disappear:

(a) Anaphase (b) Prophase

(c) Metaphase (d) Telophase

Ans. *(b) Prophase*

Explanation: Prophase is the first phase of mitosis where each chromosome is divided into two chromatids that remain connected to the centromere and in late prophase, the nuclear membrane along with nucleolus begins to dissolve.

5. **Statement A: The chromosomes become short and thin in prophase.**

Statement B: It is easier for short, compact chromosomes to move through cytoplasm than for very long, twisted interphase chromosome.

(a) Both A and B are correct.
(b) Both A and B are incorrect.
(c) Only A is correct.
(d) Only B is correct.

Ans. *(d) Only B is correct.*

Explanation: The chromosome appears as a thin, uncoiled thread in the early prophase stage. The chromosome becomes coiled and short, as well as more distinct, during mid-prophase. The chromosome will appear thicker, shorter, and more conspicuous in late prophase, as well as double longitudinally.

6. **During anaphase I of meiosis:**

(a) Homologous chromosomes separate.
(b) Non-homologous chromosomes separate.
(c) Sister chromatids chromosomes separate.
(d) Non-sister chromatids chromosomes separate. **[NCERT Exemplar]**

Ans. *(a) Homologous chromosomes separate.*

Explanation: During anaphase I, from each tetrad, two chromatids of a chromosome move as a unit (dyad) to one pole of a spindle, and the remaining two chromatids of its homologous migrate to the opposite pole. Thus, the homologous chromosomes of each pair, rather than the chromatids of a chromosome, are separated. As a result, half of the chromosomes, which appear in early prophase, go to each pole. It is here in the anaphase I that the real reduction in the number of chromosomes occurs.

7. **Which of the following is incorrect with respect to the significance of meiosis division?**

(a) New recombination of genes.
(b) Number of chromosomes reduced to half.
(c) Number of chromosomes remains same.
(d) Formation of spores and gametes.

Ans. *(c) Number of chromosomes remains same.*

Explanation: In meiosis, the number of chromosomes does not remain the same but they are reduced to half. As crossing over takes place, new recombination of genes occurs. Meiotic division occurs in germ cells and it introduces gametes and spore formation.

8. **Select the correct statement about G_1 phase.**

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

Ans. *(b) DNA in the cell does not replicate.*

Explanation: The cell is metabolically active and expands continually throughout the G_1 phase, but it does not replicate its DNA; instead, proteins and RNA are synthesised.

9. **Statement A: The interphase is considered as the most active stage of cell cycle.**

Statement B: Interphase is a period of least synthesis and growth.

(a) Both A and B are correct.
(b) Both A and B are incorrect.
(c) Only A is correct.
(d) Only B is correct.

Ans. *(c) Only A is correct.*

Explanation: The cell cycle is the time frame in which a cell completes one cycle of cell division. Interphase and Mitotic phase are the two distinct phases of the cell cycle. Nuclear division takes place during the mitotic phase, while DNA synthesis takes place during the interphase. The length of the cell cycle varies depending on the species. So, Interphase is a period of intense synthesis and growth.

10. **In human female, meiosis occurs in:**

(a) Kidney **(b) Liver**
(c) Ovary **(d) Pancreas**

Ans. *(c) Ovary*

Explanation: Meiosis is a reductional division which occurs in germ cells of organisms. In humans, the female ovary has a haploid set of chromosomes and reproductive cells.

11. **The key event that occurs during mitosis' anaphase, which results in the equal distribution of chromosomes, is:**

(a) splitting of the centromeres
(b) condensation of the chromatin
(c) splitting of the chromatids
(d) replication of the genetic material

Ans. *(a) splitting of the centromeres*

Explanation: In this phase the centromere divides in the middle, separating two chromatids. Due to a repulsive force known as anaphasic movement, both chromatids travel towards opposing poles.

12. **In which stage do the chromosomes become visible for the first time?**

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

Ans. *(c) Prophase*

Explanation: Prophase is the first and longest phase of mitosis. The nuclear envelope (the membrane that surrounds the nucleus) breaks down during prophase, and chromatin condenses into chromosomes and becomes visible.

Caution

- *Students do not focus on the word 'first time observed' and select the option metaphase, as it is said that the chromosome can be perfectly seen in metaphase but it becomes visible first time in prophase.*

13. **In which phase, Lampbrush chromosomes are observed?**

(a) Mitotic metaphase
(b) Meiotic prophase
(c) Meiotic metaphase
(d) Mitotic prophase

Ans. *(b) Meiotic prophase*

Explanation: Lampbrush chromosomes are called diplotene chromosomes because they originate during the diplotene stage of prophase I of meiosis I cell division when many genes are actively transcribed. They are a unique form of chromosome found in most animals' maturing oocytes (except mammals).

14. **The meristematic cells of a plant were studied. The meristematic cells are developed cells that are incompletely differentiated. The essential structure of the plant body is provided by the division of meristematic cells, which produces new cells for tissue development and differentiation, as well as the initiation of new organs. Meristematic cells divide by:**

(a) Meiosis **(b) Mitosis**
(c) Endomitosis **(d) Amitosis**

Ans. *(b) Mitosis*

Explanation: The meristematic cells divide mitotically. These cells have the ability to continuously divide unless they lose their ability to divide.

Related Theory

- ***Meiosis:*** *Meiosis is a process in which a single cell divides repeatedly to produce four cells with half the amount of genetic material as the original cell.*
- ***Endomitosis:*** *It is a chromosomal division that is not followed by nuclear division, resulting in an increase in the number of chromosomes in the cell.*
- ***Amitosis:*** *It is the division of the nucleus and cytoplasm without spindle formation or the development of chromosomes. Amitosis results in a random distribution of chromosomes in the daughter cells.*

15. **Statement A: In anaphase, the number of chromosomes gets doubled.**

Statement B: During anaphase, each chromosome split simultaneously and two daughter chromatids now referred to as chromosomes.

(a) Both A and B are correct.
(b) Both A and B are incorrect.
(c) Only A is correct.
(d) Only B is correct.

Ans. *(a) Both A and B are correct.*

Explanation: The number of chromosomes doubles during anaphase. Each chromosome split into two daughter chromatids, which are now known as chromosomes, simultaneously during anaphase.

The division of the sister chromatids marks the start of anaphase. The chromosomes of the daughter nuclei are formed from these sister chromatids. The chromosomes are then drawn toward the pole by the fibres that are connected to their kinetochores. The arms of each chromosome trail behind the centromere at the periphery.

16. **Statement A: Cytokinesis is similar in plant and animal cells.**

Statement B: In both plants and animals, the cell division takes place via formation of cell furrows.

(a) Both A and B are correct.
(b) Both A and B are incorrect.
(c) Only A is correct.
(d) Only B is correct.

Ans. *(c) Only A is correct.*

Explanation: Cytokinesis is quite different in plant and animal cells. In animals, the cell division takes place via formation of cell furrow and in plant cells, the cell plate or phragmoplast is formed.

17. **Which of the following options gives the correct sequence of events during mitosis?**

(a) Condensation → Nuclear membrane disassembly → Arrangement at equator → Centromere division → Segregation → Telophase
(b) Condensation → Crossing over → Nuclear membrane disassembly → Segregation → Telophase
(c) Condensation → Arrangement at equator → Centromere division → Segregation → Telophase
(d) Condensation → Nuclear membrane disassembly → Crossing over → Segregation → Telophase

Ans. *(a) Condensation → Nuclear membrane disassembly → Arrangement at equator → Centromere division → Segregation → Telophase*

Explanation: During prophase, the chromosomes condense, the nucleolus disappears, and the nuclear envelope breaks down. And the chromosomes align at the metaphase plate, the centromeres divide and during telophase, the chromosomes segregate and move to opposite ends of the cell and two nuclei are formed.

Caution

Students make a lot of mistakes in such types of questions as they are not clear with the concept. In order to identify the correct sequence, it is necessary to know the correct stepwise process.

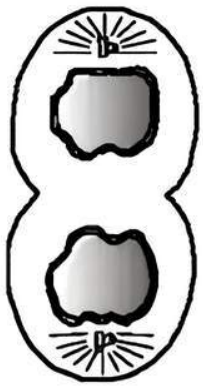
18. Select the incorrect pair.

(a) G_1 phase - DNA replication
(b) M phase - Metaphase
(c) Diplotene - Meiosis I
(d) Meiosis - Chromosome number remains same

Ans. *(a) S phase - DNA replication*

Explanation: Interphase and division phase make up a cell cycle. The longest phase of the cell cycle is the interphase. It consists of the S phase, the first growth phase, and the second growth phase. DNA replication happens during the synthesis phase or S phase.

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



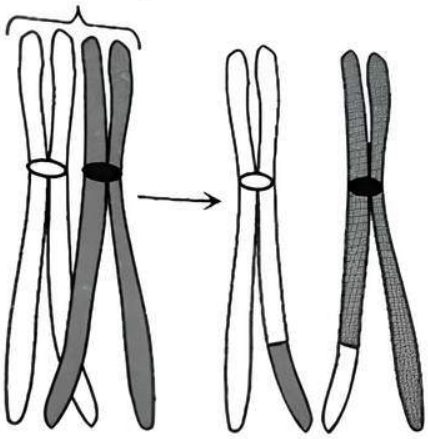
(a) Cytokinesis – Cell plate formed, mitochondria distributed between two daughter cells.
(b) Telophase – Endoplasmic reticulum and nucleolus not reformed yet.
(c) Telophase – Nuclear envelope re-forms, Golgi complex reforms.
(d) Late Anaphase – Chromosomes move away from the equatorial plate, Golgi complex not present.

Ans. *(c) Telophase – Nuclear envelope re-forms, Golgi complex reforms.*

Explanation: The figure shows a stage of mitotic cell division called telophase stage. The individual chromosomes are no longer seen and chromatin material tends to collect in a mass at the poles. This is the stage which shows the following key events:

(1) Chromosomes cluster at opposite spindle poles and their identity is lost as discrete elements.
(2) Nuclear envelope assembles around the chromosome clusters.
(3) Nucleolus, Golgi complex and ER reform.

20. The given figure shows a certain event at a particular stage of a type of cell division. Which is this stage?



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

Ans. *(a) Prophase – I during meiosis.*

Explanation: The given figure shows crossing over which shows the exchange of segments between two homologous chromosomes. Crossing over is characteristic of the meiosis phase of cell division that occurs during the pachytene stage of prophase I.

Assertion-Reason (A-R)

Given below are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below:

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true and R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

21. **Assertion (A):** **Synthesis of DNA occurs in S phase of cell cycle.**

Reason (R): **While the synthesis of DNA completed in the G_1 and G_2 stages of cell cycle.**

Ans. *(c) A is true but R is false.*

Explanation: DNA synthesis is done only in the S phase of interphase, which is followed by two "gap" periods of interphase (G_1 and G_2) during which no DNA synthesis occurs. The time between the end of mitosis and the beginning of DNA synthesis is known as G_1. S stands for DNA synthesis, while G_2 stands for the period between the completion of DNA synthesis and the beginning of mitosis. In S phase, a cell contains double the amount of DNA as compared to what is found in the diploid cell during G_1.

22. **Assertion (A):** **The ratio between the nucleus and the cytoplasm is disrupted as a result of cell growth.**

Reason (R): **Mitosis aids in the restoration of the nucleo-cytoplasmic ratio in the cell.**

Ans. *(a) Both A and R are true and R is the correct explanation of A.*

Explanation: Mitosis is the process by which a multicellular organism grows. The cell's functions are controlled by the nucleus. During cell growth, the nucleus does not vary in size, but the cytoplasm does. The nucleo–cytoplasmic ratio is disrupted as the size of the cell increases. Through cell division, this ratio is restored to an efficient level.

23. **Assertion (A):** **Mitosis is also known as indirect division.**

Reason (R): **Mitosis is the process through which a parent cell divides into two daughter cells.**

Ans. *(b) Both A and R are true and R is not the correct explanation of A.*

Explanation: Mitosis is frequently referred to as an indirect division. It is a process for dividing nuclei into equal parts. It is a complicated procedure that involves a number of significant changes in both the nucleus and the cytoplasm. As a result, it is known as the indirect way of division.

24. **Assertion (A):** **Daughter somatic cells formed by mitosis are genetically similar to the parental cell.**

Reason (R): **Chromosomes do not undergo crossing over in mitosis.** **[Delhi Gov. QB 2022]**

Ans. *(a) Both A and R are true and R is the correct explanation of A.*

Explanation: In the process of mitosis, one cell divides into two, with each receiving the same quantity of DNA as the original cell. During mitosis, homologous chromosome pairing does not take place. However, during meiosis, homologous chromosomes couple up and exchange chromosomal segments at their locations of intersection.

Related Theory

Genetic diversity is possible in sexually reproducing organisms because gametes are formed as a result of meiosis because of this interchange of chromosomal segments. On the other side, mitosis preserves the genetic similarities of somatic cells.

25. **Assertion (A):** **Meiosis II is similar to mitosis.**

Reason (R): **Meiosis I cannot occur in haploid cells.**

[Delhi Gov. QB 2022]

Ans. *(b) Both A and R are true and R is not the correct explanation of A.*

Explanation: (1) Despite the similarities between meiosis II and mitosis, meiosis II is not mitosis because it always takes place in haploid cells.

(2) DNA replication is not performed prior to meiosis II.

(3) The two chromatids of a chromosome are frequently dissimilar.

(4) The daughter cells produced following meiosis II are neither similar to the parent cell nor to each other.

CASE BASED Questions (CBQs)

[**4** & **5** marks]

Read the following passages and answer the questions that follow:

26. *In a poster-making competition a group of students got the topic of meiotic cell division in human germ cells.*

M phase has its role to play in the body of the organism. The meiotic cell division of human germ cells was studied by the group and all visible changes in meiosis I and meiosis II were observed. Students made notes of what they observed. They came across various events and understood cell cycle to its depth.

(A) Write the meiosis events in the correct sequence.

(I) Disjunction of genomes

(II) Crossing over

(III) Terminalisation of chiasmata

(IV) Synapsis

(B) What is the number of chromosomes in metaphase II of meiosis in a human germ cell?

(C) Meiosis occurs in which tissues of animals and plants?

Ans. (A) The correct sequence is (IV) Synapsis → (II) Crossing Over → (III) Terminalisation of chiasmata → (I) Disjunction of genomes.

(B) The meiosis II is similar to mitosis where chromosome number does not get reduced. Thus, in meiosis II the total number of chromosomes is 23.

Caution

Students may write 46, as it is said that mitosis is similar to meiosis II and there is no reduction in chromosome number. In meiosis I the diploid cell becomes haploid where the chromosome is reduced to half.

(C) Only the tissues that form gametes go through meiosis. Meiosis occurs in animals within the reproductive cells, which include the testes and ovaries. In plants, androecium (male reproductive) and gynoecium (female reproductive) portions of the plant undergo meiosis.

27. *The sequence of events by which a cell duplicates its genome synthesises the other constituents of the cell and eventually divides into two daughter cells is termed cell cycle. Cell cycle is divided into interphase and M phase. In the interphase, though called the resting phase, cell is preparing for division by undergoing both cell growth and DNA replication. Interphase is divided into three phases— G_1 phase, S phase and G_2 phase. In G_1 phase, cell prepares proteins and enzymes. In S phase, DNA replication and centriole duplication take place. After S phase, chromosome number of the cell does not change but the amount of DNA becomes double (4C). In G_2 phase, synthesis of protein especially tubulin, which is used in the formation of spindle fibres, occurs.*

During M phase, cell division occurs through karyokinesis and cytokinesis.

[Delhi Gov. QB 2022]

(A) How many chromosomes and DNA content will the onion cell have in G_1 phase, after completing S phase and after M phase respectively, if onion plant possesses 14 chromosomes initially?

(a) 14 / 2C, 28 / 4C and 14 / 4C

(b) 14 / 2C, 14 / 4C and 14 / 2C

(c) 14 / 2C, 14 / 2C and 14 / 2C

(d) 28 / 4C, 28 / 4C and 14 / 2C

(B) Choose the correct option for a human cell before it enters prophase?

	Number of Chromatids	Number of Chromosomes
(a)	46	92
(b)	46	46
(c)	92	46
(d)	92	92

(C) Non-dividing cells like muscles and neurons are in ..... phase

(a) G_1 **(b) G_2**

(c) G_0 **(d) M**

(D) How many mitotic divisions are required to form 128 cells from a single onion root tip cell (mitosis)?

(a) 14 **(b) 21**

(c) 6 **(d) 7**

(E) Assertion (A): Interphase is called resting stage.

Reason (R): In interphase, the cell is metabolically inactive.

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true and R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false but R is true.

Ans. (A) *(b) 14 / 2C, 14 / 4C and 14 / 2C*

Explanation: Replication of DNA takes place at the S phase of the cell cycle.

At G_1, phase it will have 14 chromosomes.

At S phase also, it will have 14 chromosomes.

G_2 phase also has 14 chromosomes.

After M phase, 7 chromosomes were there.

The content will be 2C at G_1 phase and it will be 4C at G_2 and S phase.

(B)

	Number of Chromatids	*Number of Chromosomes*
(c)	*92*	*46*

Explanation: There are a total of 92 sister chromatids present in 46 chromosomes. Each chromosome has a pair of identical sister chromatids attached together in the centromere, giving the chromosome its distinctive X-shaped structures.

(C) *(c) G_0 phase*

Explanation: Cells that do not divide further exit G_1 and enter the quiescent stage (G_0) of the cell cycle, which is an inactive state. The cells at this stage are still metabolically active, but they no longer multiply unless they are triggered by an appropriate single based on the organism's needs.

Caution

During the process of cytokinesis, the cell's cytoplasm divides into two, creating two new cells. The start of cytokinesis typically coincides with the end of mitosis with some overlap. Importantly, cytokinesis happens in different ways in plant and animal cells. When the cell is ready to divide, it is in the G_1 stage. The cell goes into the S phase, where it duplicates all of the DNA, to do this.

(D) *(d) 7*

Explanation: In mitosis, each cell divides into two. So starting from a single cell, the increase in a number of cells will occur as per the following progression: 1->2->4->8->16->32->64->128.

Thus a total of 7 divisions is required to produce 128 cells starting from a single cell or 2n times the division.

(E) *(c) A is true but R is false.*

Explanation: Three subphases make up the interphase (G_1, G_2 and S). S phase is when DNA synthesis takes place. Between the end of mitosis and the beginning of S phase lies the growth phase known as G_1. Between S phase and the beginning of mitosis is G_2. We can infer that the interphase is metabolically active because DNA synthesis happens in S phase and the cell actively synthesised chemicals needed for division during the growth phases (G_1 and G_2).

Caution

Students usually don't know that as there is no obvious activity associated with cell division during interphase, it was previously referred to as the resting state. Later research demonstrated how metabolically active a cell's interphase is.

VERY SHORT ANSWER Type Questions (VSA)

[1 mark]

28. State the phase of cell division where crossing over takes place.

Ans. Pachytene stage of Prophase I of Meiosis I.

29. Homologous chromosomes have a structure 'chiasmata'. What is it?

Ans. The X-shaped structure generated by the connecting point between paired chromatids during meiosis is known as chiasmata. It is the point at which homologous chromosomes are linked together to form a crossover and exchange of genetic material occurs.

30. Which of the phases of the cell cycle is of longest duration? [NCERT Exemplar]

Ans. Interphase.

31. Why is meiosis referred to as reductional division?

Ans. Meiosis is also known as "reductional division" as it reduces the number of chromosomes to half the original number so that the embryo has the correct number when sperm and egg fuse.

32. Name a stain commonly used to colour chromosomes.

[NCERT Exemplar]

Ans. Basic fuchsin and acetocarmine are mainly used to stain chromosomes.

Related Theory

Acetocarmine stain is a DNA-specific dye that is used to investigate distinct mitotic phases. To stain chromosomes, carmine is used to make acetocarmine dye. Carmine is a basic dye made from the progeny of an insect.

33. ..... is an equational division.

Ans. Mitosis

34. ..... and ..... are the two phases of the cell cycle.

Ans. Interphase and M phase.

35. **Anaphase Promoting Complex (APC) is a protein degradation machinery necessary for proper mitosis of animal cells. What will be the consequences if APC is defective in a human cell?**

Ans. During anaphase, the protein known as the Anaphase Promoting Complex (APC) is essential for daughter chromosome separation. If APC is defective then the chromosomes will fail to segregate during anaphase.

36. **Which meiotic phases (or prophase I substages) might you anticipate to see DNA replication and bivalents present, respectively?**

Ans. The homologous chromosomes are placed in pairs during the meiotic process of chromosomal bivalent creation. Synapsis, as the phenomenon is known, takes place at the zygotene stage. Synthetic phase, the second phase of interphase, is when DNA replication takes place.

37. **Arrange in correct sequence: (I) Pachytene (ii) Zygotene (III) Leptotene (IV) Diakinesis (V) Diplotene**

Ans. The correct sequence is (III) Leptotene → (II) Zygotene → (I) Pachytene → (V) Diplotene → (IV) Diakinesis.

SHORT ANSWER Type-I Questions (SA-I)

[**2** marks]

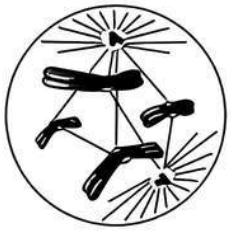
38. **(A) Define kinetochore.**
(B) At what stage of cell cycle does DNA synthesis take place? [NCERT Exemplar]

Ans. (A) The centromeres' surface has a tiny disc-shaped proteinaceous structure called a kinetochore.
(B) During the S phase of interphase DNA is synthesised.

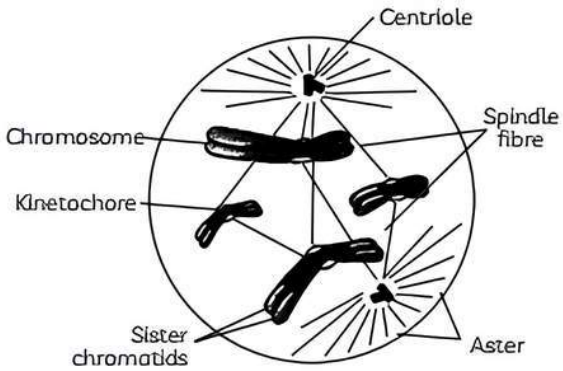
39. **An anther has 1200 pollen grains. How many pollen mother cells (PMC) must have been there to produce them? [NCERT Exemplar]**

Ans. 1 pollen mother cell produces 4 pollen grains. Thus, 1200 pollen grains are produced by 300 pollen mother cells.

40. **Label the diagram and also determine the stage at which this structure is visible. [NCERT Exemplar]**



Ans. The diagram shows transition to metaphase.



41. **Give specific terms for the following.**
(A) The period between 2 successive mitotic divisions.
(B) Cell division in which chromosome number is halved.
(C) Phase in cell cycle where DNA is synthesised.
(D) Division of nuclear material.
[Delhi Gov. QB 2022]

Ans. (A) Interphase
(B) Melosis
(C) S phase
(D) Karyokinesis

SHORT ANSWER Type-II Questions (SA-II)

[**3** marks]

42. **Comment on the statement – Telophase is the reverse of prophase. [NCERT Exemplar]**

Ans. The beginning of chromosomal material condensation is characterised in prophase.

During the chromatin condensation process, the chromosomes are clearly visible as thickened thread pairs connected at the centromere. The chromosomes that have reached their respective poles decondensed and lose their identity at the start of the final stage of mitosis, telophase.

Under the microscope, cells at the end of prophase lack golgi complexes, endoplasmic reticulum, nucleolus, and the nuclear envelope. The nuclear envelope forms around the chromosomal clusters during the telophase stage. Endoplasmic reticulum, Golgi complex and nucleolus again formed in the telophase stage.

43. (A) Mitochondria and plastids have their own DNA (genetic material). What is known about their fate during nuclear division like mitosis?

(B) What role does chromosomal replication play during interphase?

(C) Name the pathological condition when uncontrolled cell division occurs.

[NCERT Exemplar]

Ans. (A) Organelles such as mitochondria and plastids have their own DNA. This DNA is called extrachromosomal DNA. They are independent of the nuclear division of nuclear DNA. Hence, there is no effect of mitosis on extrachromosomal DNA.

(B) Interphase is a period of time between cell division. It is termed as the resting stage of a nucleus since it shows no morphological changes; but, physiologically, it is an active stage in the life of a cell as the cell prepares for division and other biochemical changes.

(C) Cancer is the pathological condition when uncontrolled cell division occurs.

Related Theory

Cancer is a term used to describe a group of diseases that are characterised by uncontrolled cell proliferation. When a single cell mutates, the normal regulatory processes that keep cell division in check are disrupted which results in cancer. The cancerous cell does not follow contact inhibition.

44. Prophase I is a multi-step process. Which is the fourth phase and what are its features?

Ans. Diplotene is the fourth phase of prophase I of meiosis I (a five-stage process).

Desynapsis and chiasmata formation are the characteristic features of this stage. The synaptonemal complex created during zygotene dissolves in the diplotene stage, and desynapsis of the homologous chromosome begins. Homologous chromosomes separate from each other except the chiasmata where crossing occurs. The chiasmata are formed like an X. At this point, chromatids open up and fast RNA production starts.

45. Mitosis and meiosis are two common phenomena which you observe around you. Write a few points to differentiate them.

Ans.

Mitosis	Meiosis
It occurs in somatic cells/vegetative cells.	It occurs in germ cells /reproductive cells.
Synapsis does not take place.	Synapsis takes place in prophase I.
Crossing over absent.	Crossing over present.
Two diploid cells are produced.	Four haploid cells are produced.
No variations occur.	Variation occur.

46. Differentiate between Prophase and Telophase.

Ans.

Prophase	Telophase
First phase of karyokinesis.	Last phase of karyokinesis.
Disappearance of nuclear membrane takes place.	Formation of nuclear membrane takes place.
Nucleolus starts to disappear.	Nucleolus formation occurs in this stage.
Arrangement of chromosomes is random.	Chromosomes are arranged on opposite poles.

47. Sheela's biology teacher told her that mitosis is very beneficial for many organisms. Justify this by giving importance of mitosis.

Ans. (1) It ensures that genetic stability is maintained over generations.

(2) It aids multicellular organisms in their growth.

(3) Mitosis, or asexual reproduction, is used by many plants and animals to regenerate the entire organism.

(4) It aids in the regeneration of lost bodily parts in animals.

LONG ANSWER Type Questions (LA)

[4 & 5 marks]

48. Meiosis occurs in two stages I and II. Write a note on phases of stage II.

Ans. (1) **Prophase II:** Prophase II of meiosis-II begins after cytokinesis, usually before the chromosomes have fully extended. By the end of prophase II, the nuclear membrane has disintegrated. The chromosomes are compacted once more.

(2) **Metaphase II:** The chromosomes are arranged in a plane at the equator at this point, microtubules from opposing poles of the spindle bind to the sister chromatids' kinetochores.

(3) **Anaphase II:** It initiates with the centromeres of each chromosome splitting at the same time, allowing them to move to opposite poles of the cell.

(4) **Telophase II:** After telophase-II, in which two groups of chromosomes are once again contained by the nuclear membrane, cytokinesis occurs, leading in the tetrad formation of haploid daughter cells.

49. During meiosis, what happens to homologous chromosomes?

Ans. Homologous chromosomes are characterised as pairs of chromosomes that share genes that control the same set of features.

The chromosomes in leptotene are thread-shaped and coiled during heterotypic division of meiosis. Homologous chromosomes begin to pair during zygotene. Chromosomes get thicker while also shortening in pachytene.

The absence of attraction force between the two homologous chromosomes characterises diplotene. The uncoiling of homologous chromosomes separates them, although they remain linked at the chiasmata. The homologous chromosome is completely separated during diakinesis.

It is possible for portions to be exchanged across chromatids of homologous chromosomes. Following the dissociation of the centromere, centromeres of homologous bivalent compounds resist each other during Anaphase I.

In telophase I, homologous chromosomes begin to move apart, as chromosomes reach poles and shorten.

50. (A) Between a prokaryote and a eukaryotic, which cell has a shorter cell division time?

(B) When paired homologous chromosomes are shortened and thickened during cell division, what is the name of the stage?

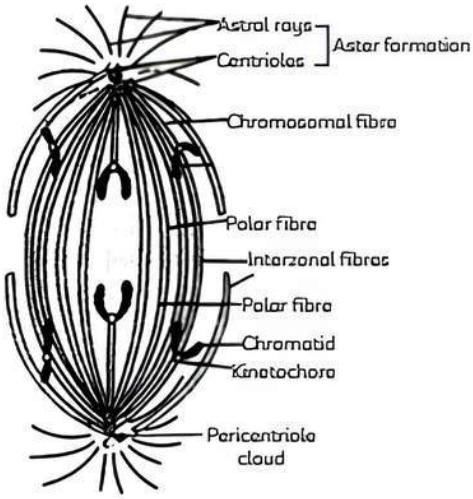
(C) Draw a labelled diagram of Anaphase.

[NCERT Exemplar]

Ans. (A) Cell division in prokaryotic cells is faster than in eukaryotic cells. Human cells in culture exhibit a typical eukaryotic cell cycle. These cells divide once every 24 hours on average. The cell cycle in bacteria *(E.coli)* lasts 20 minutes per cell. Thus, the shorter cell division time is of prokaryotes.

(B) Pachytene is a stage of cell division during which paired homologous chromosomes become shorter and thicker.

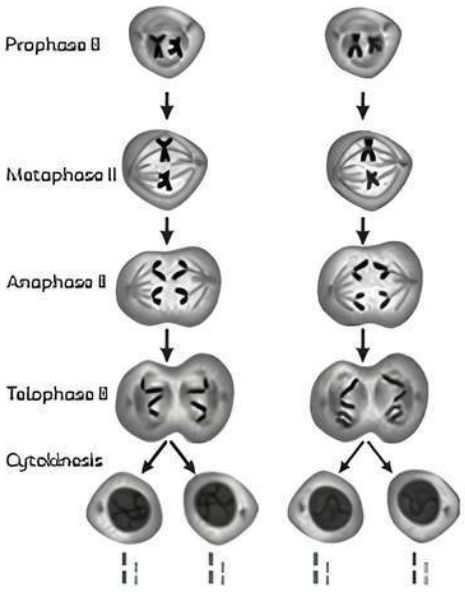
(C)



Anaphase

51. An organism has two pairs of chromosomes (*i.e.* chromosome number = 4). Diagrammatically represent the chromosomal arrangement during different phases of meiosis II. [NCERT Exemplar]

Ans.



Meiosis II

52. With the help of labelled diagrams, explain various stages of mitosis cell division.

[Delhi Gov. QB 2022]

Ans.