Cell Cycle and Cell Division

Introduction

- Growth and reproduction are characteristics of cells, indeed of all living organisms.
- 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.
- In other words, such cycles of growth and division allow a single cell to form a structure consisting of millions of cells.

Cell Cycle

- Cell division is a very important process in all living organisms. During the division of a cell, DNA replication and cell growth also take place.
- All these processes, i.e., cell division, DNA replication, and cell growth, hence, have to take place in a coordinated way to ensure correct division and formation of progeny cells containing intact genomes.
- 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 growth (in terms of cytoplasmic increase) is a continuous process but DNA synthesis occurs only during one specific stage in the cell cycle.
- The replicated chromosomes (DNA) are then distributed to daughter nuclei by a complex series of events during cell division. These events are themselves under genetic control.

Phases of Cell Cycle :

- A typical eukaryotic cell cycle is illustrated by human cells in culture. These cells divide once in approximately every 24 hours.
- The time period of cell cycle is varied from organism to organism and also from cell type to cell type eg. :- Yeast can progress through the cell cycle in only about 90 minutes..

Cell cycle involves **two stages** :-

Interphase

Division Phase/M-Phase

Interphase :- This is phase between two successive M-phase. In interphase cell grows in size and prepares itself for next division.

Interphase is **most active phase** of cell cycle.

The interphase last more than 95% of the duration of cell cycle.

- A series of metabolic changes occurs during interphase in cell. These changes were not visible under microscope, so some scientist termed interphase as **resting phase**. It is the time during which cell is preparing for division by undergoing both cell growth and DNA replication in an orderly manner.

- **Howard and Pelc** classified interphase into three sub stages :-

G_1 – Phase (I^{st} Gap Phase) or Pre DNA Synthesis Phase or Post Mitosis Gap Phase :-

- 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.
- During G_1-most of cell organelles increases in cell and cell rapidly synthesizes different types of RNA and proteins. Due to availability of protein, synthesis of new protoplasm takes place in cell and it starts growing in size. Cell grows maximum in G_1 stage.

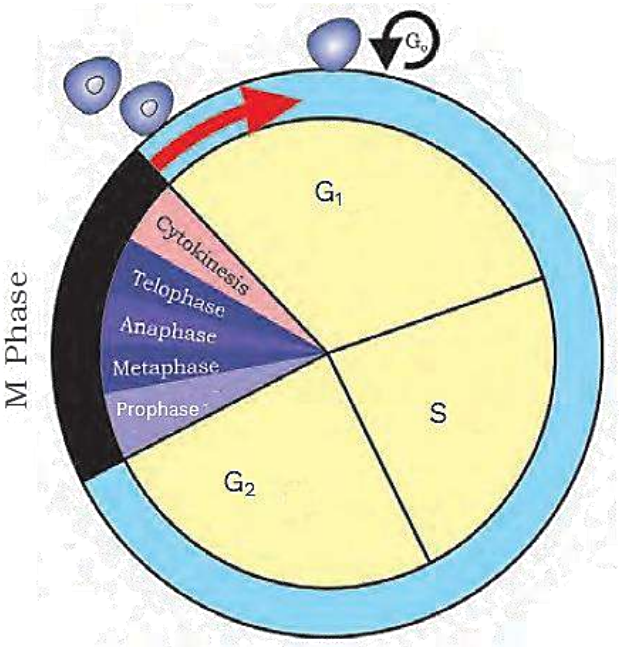


Figure : A diagrammatic view of cell cycle indicating formation of two cells from one cell

S – Phase (DNA Synthesis Phase) :

- Replication of nuclear DNA and synthesis of histone protein takes place in s-phase. Replication of cytoplasmic DNA may occur in any stage of cell cycle.
- 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.
- S-phase marks the phase of DNA replication and chromosome duplication (DNA content in a chromosome become double).
- In animal cells, during the S phase, DNA replication begins in the nucleus, and the centriole duplicates in the cytoplasm.

G_2 – phase (2^{nd} Gap Phase) or Post DNA Synthesis Phase or Pre Mitosis Gap Phase :-

- Final preparation of M-phase occurs during this phase. Special proteins required for M-phase are synthesized in G_2 phase. eg. Tubulin protein. (Required for formation of spindle fibres). Cell growth continues.

G_0-Phase

- 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 (divide) unless called on to do so depending on the requirement of the organism.

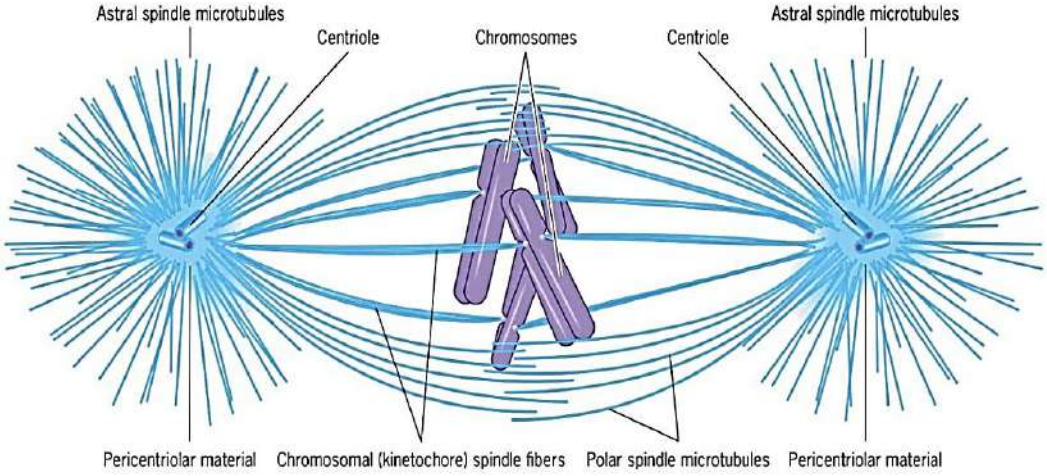
Mitosis Phase (M-Phase)

- **Division Phase** or **M–Phase** or mitosis phase lasts for only about an hour in the 24 hour duration of cell cycle of a human cell.
- The M-phase represents the phase when the actual cell division or mitosis occurs.
- In animals, mitosis or **equational cell division** is restricted or only seen in diploid somatic cell except in some social insects for example-male honey bee etc. Against this, the plants can show mitotic division in both haploid and diploid cells.
- This is the **most dramatic period** of the cell cycle, involving a major reorganisation of virtually all components of the cell. Since the number of chromosomes in the parent and progeny cells is the same, it is also called as **equational division**.
- Though for convenience mitosis has been divided into four stages of nuclear division, it is very essential to understand that cell division is a progressive process and very clear-cut lines cannot be drawn between various stages.
- The M-phase start with nuclear division, corresponding to the separation of daughter chromosome (Karyokinesis) and usually ends with division of cytoplasm (cytokinesis).
- Karyokinesis is divided into the following four stages :-

  (1) Prophase (2) Metaphase (3) Anaphase (4) Telophase

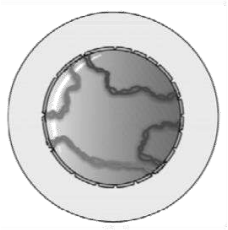
  (1) Prophase :
  - Prophase which is the first stage of karyokinesis of mitosis follows the S and G_2 phases of interphase.
  - In the S and G_2 phases the new DNA molecules formed are not distinct but intertwined.
  - Prophase is marked by the initiation of condensation of chromosomal material. The chromosomal material becomes untangled during the process of chromatin condensation.

> **Anastral and Amphiastral Mitosis :** In plants, centrioles are absent and no asters are formed. Mitosis without asters is known as **anastral mitosis**. In animals, the asters are present and the mitosis is described as **amphiastral** or **astral mitosis**.



  - 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 chromatids attached 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 aster. The two asters together with spindle fibres forms mitotic apparatus.
- Cell at the end of prophase when viewed under the microscope, do not show golgi complexes, endoplasmic reticulum, nucleolus and nuclear envelope.

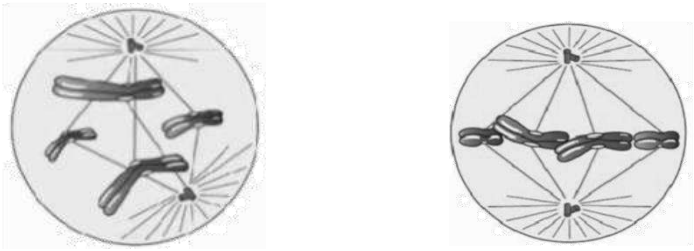


Early Prophase

Late Prophase

(2) 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 microtubules) to the chromosomes that are moved into position at the centre of the cell.**



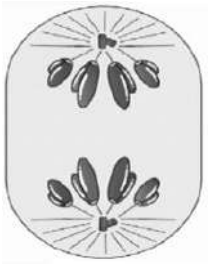
Transation to metaphase

- 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. The plane of alignment of the chromosomes at metaphase is referred to as the **metaphase plate**.
- Chromosomal fibres (discontinuous/kinetochore fibres which run from pole to centromere) and supporting fibres (continuous/non-kinetochore fibres which run from pole to pole) arrange in cell.
- Centromere lies at equator and arms of chromosomes remain directed towards poles.
- The key features of metaphase are:
  - Spindle fibres attach to kinetochores of chromosomes.
  - Chromosomes are moved to spindle equator and get aligned along metaphase plate through spindle fibres to both poles.

(3) Anaphase :

- Centromere of each chromosome splits simultaneously lengthwise **(division of centromere)**. Sister chromatids separate from each other and separated each chromatid is now referred to as individual chromosome.
- **Number of chromosome become double** in cell.
- **The two new daughter chromosomes begin moving toward opposite ends of the cell as their spindle fibres shorten due to depolymerisation of tubulin protein towards kinetochoric end.**
- 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.

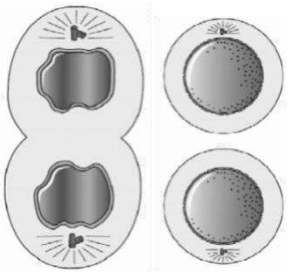
  Anaphase stage is characterised by the following key events:
  - Centromeres split and chromatids separate.
  - Chromatids (now reffered as chromosomes) move to opposite poles.



Anaphase

(4) Telophase or Reverse Prophase :

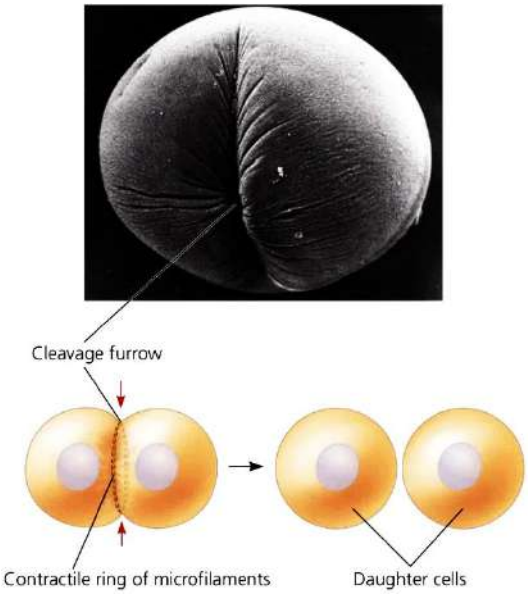
- At the beginning of the final stage of karyokinesis, i.e., telophase, the chromosomes that have reached their respective poles decondense and lose their individuality. The individual chromosomes can no longer be seen and chromatin material tends to collect at each of the two poles. This is the stage 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.



Telopha Interpha

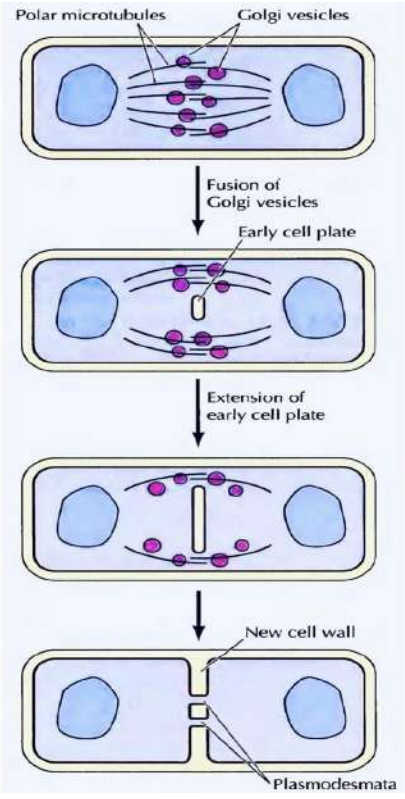
(5) Cytokinesis :

- Mitosis accomplishes not only the segregation of duplicated chromosome 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.
- In animals cytokinesis occurs by constriction & furrow formation. At the periphery of the equator a contractile ring is formed that is made up of actin and myosin protein. Due to interaction between actin and myosin, ring contract, thus a furrow forms from outside to inside in cell. Furrow deepens continuously and ultimately a cell divides into two daughter cells. In animals cytokinesis occurs in centripetal order.



- **Cytokinesis in Plants** takes place by **cell plate formation** because constriction is not possible due to presence of the rigid cell wall. Many golgi vesicles and spindle microtubules arrange themselves on equator to form **phragmoplast**. Fragments of ER may also deposit in phragmoplast. Membranes of golgi vesicles fuse to form a plate like structure called **cell plate**.

  Golgi vesicles secret calcium and magnesium pectate due to which cell plate is modified into middle lamella. In plants, cytokinesis occurs in **centrifugal order** (cell plate formation is from center to periphery).
- 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**).



Significance of Mitosis

1. **Development of an organism occurs by mitosis. Every organism starts its life from a single cell i.e. zygote. Repeated mitosis in zygote leads to the formation of the whole body.**
2. The growth of multicellular organisms is due to mitosis.
3. 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.
4. 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.
5. Mitotic divisions in the meristematic tissues – the apical and the lateral cambium, result in a continuous growth of plants throughout their life.

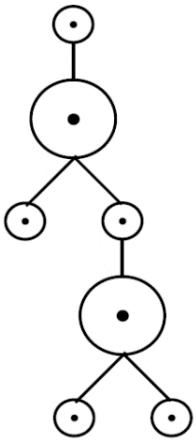
Golden Key Points

- During the division of a cell, DNA replication and cell growth also take place.
- The sequence of events by which a cell duplicates its genome, synthesise the other constituents of the cell and eventually divides into two daughter cells is termed cell cycle.
- The interphase lasts more than 95% of the duration of cell cycle.
- S phase marks the phase of DNA replication and chromosome duplication.
- In prophase, chromosomal material (Chromatin) condenses to form compact mitotic chromosomes.
- In metaphase, spindle fibres attach to kinetochores of chromosomes.
- In anaphase, centromeres split and chromatids separate.
- **In animal cell cytokinesis occurs by furrow formation and in plant cell it occurs by cell plate method.**
- A very significant contribution of mitosis is cell repair.

(1) Cause of Mitosis :

(A) Kern Plasm Theory :

- **Hertwig** proposed kern plasm theory. According to this theory mitosis occurs due to disturbance in Karyoplasmic Index (KI) or **Nucleocytoplasmic ratio** of cell.



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.
- In a large cell nucleus fail to control the activity of cytoplasm efficiently. To attain the control of nucleus on cytoplasm a large cell divides into two cells.

(B) Surface-Volume Ratio :

- Surface-volume ratio is also considered as a cause of cell division. When a cell grows in size its volumes increases more than its surface. So a stage will reach when the surface area of cell becomes insufficient to draw the materials from surrounding. At such critical stage, cell increases its surface volume ratio by division.

Concept Builder

1. The Interphase lasts more than _____ of the duration of cell cycle:-
(1) 80% (2) 5 % (3) 95 % (4) 98 %

2. In animal cells, during the S-phase:-
(1) DNA Replication begins (2) Centriole duplication
(3) Histone protein synthesis (4) All of these

3. In animals, mitotic cell division is only seen in the:
(1) Haploid cell (2) Haploid and diploid cell
(3) Diploid cell (4) None

4. Small disc-shaped structure at the surface of centromeres are called:-
(1) Heterochromatin (2) Euchromatin
(3) Kinetochores (4) Secondary constriction

5. Select the odd one about telophase:-
(1) Nuclear envelop assembles around the chromosome
(2) Nucleolus, golgi complex and E.R. reform
(3) Chromatids move to opposite poles.
(4) Chromosome identity is lost as discrete element

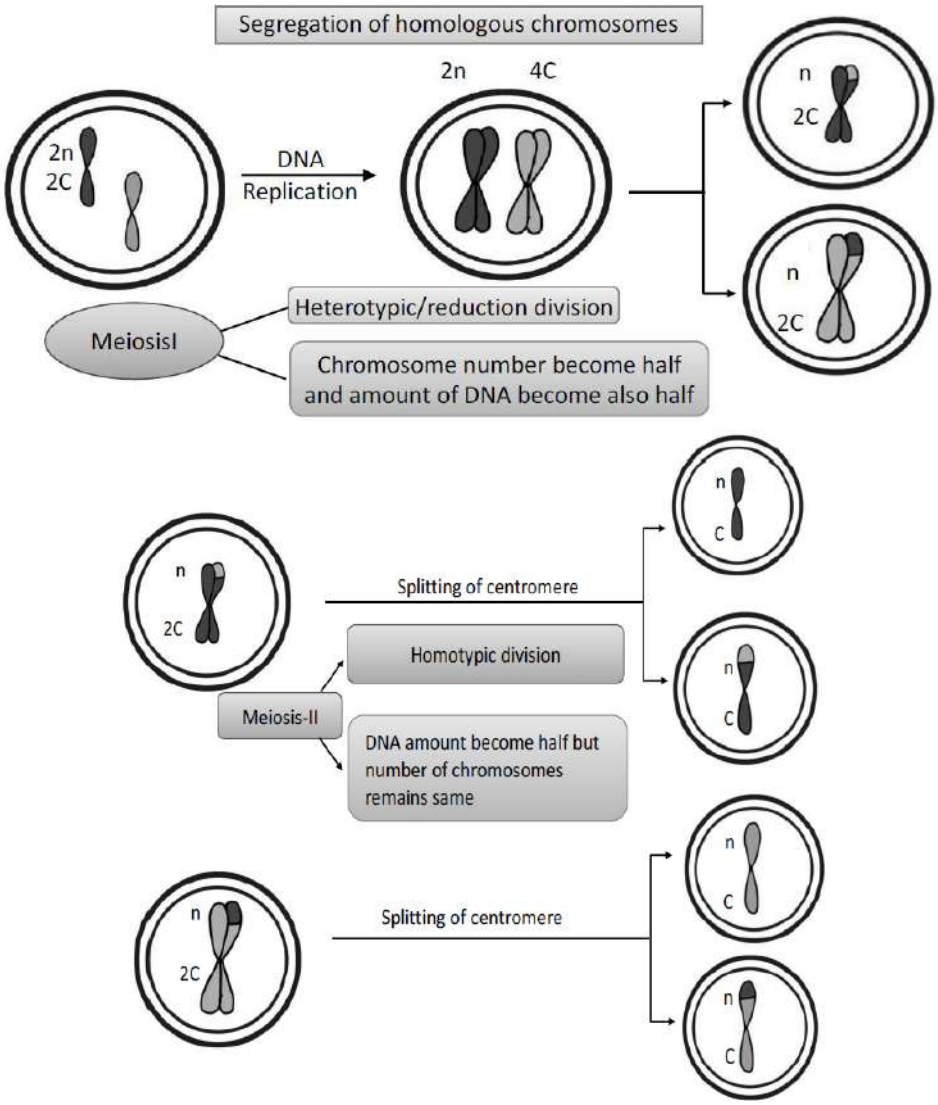
Concept Builder (Answer–Key)					
Que.	**1**	**2**	**3**	**4**	**5**
Ans.	3	4	3	3	3

Meiosis

- The specialised kind of cell division that reduces the chromosome number by half results in the production of haploid daughter cells. This kind of division is called meiosis.
- Meiosis ensures the production of haploid phase in the life cycle of sexually reproducing organisms whereas fertilisation restores the diploid phase. Meiosis occurs during gametogenesis, leads to the formation of haploid gametes.

The Key Features of Meiosis are as Follows :

- Meiosis involves two sequential cycles of nuclear and cell division called meiosis-I and meiosis-II but only a single cycle of DNA replication.



(1) Meiosis I :

- Heterotypic division or **reduction division**. It leads to reduction in chromosome numbers. **Division of chromosomes does not occur** in meiosis-I, only **segregation of homologous chromosomes** takes place.
- Meiosis I is initiated after the parental chromosomes have replicated to produce identical sister chromatids at the S phase.
- Meiosis I involves pairing of homologous chromosomes and **recombination** between their non sister chromatids.

(2) Meiosis II :

- This is a homotypic division because it does not leads to any change in chromosome number.
- **Division of chromosome** or centromere occurs during meiosis II.
- Four haploid cells are formed at the end of meiosis II. All the four **daughter cells** produced by meiosis are **genetically different** from each other and also differ from the mother cell.
- In meiosis, division of nucleus takes place twice but division of chromosome occurs only once in anaphase 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

- **Interphase – Same as in Mitosis**

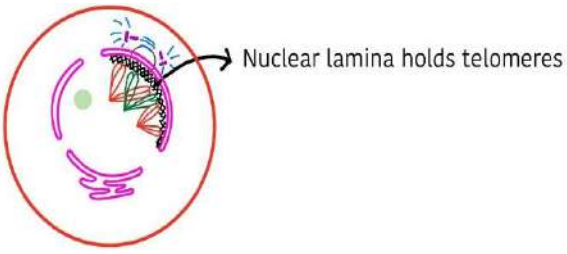
(1) Meiosis-I

(A) Prophase – I :

- Typically longer and more complex when compared to prophase of mitosis**. Prophase I is classified in five substages based on chromosomal behaviour :**

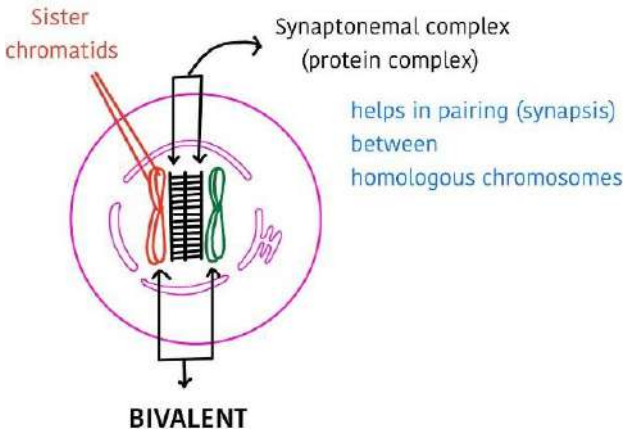
(i) Leptotene ⇒ Chromatin threads condense to form chromosomes. Chromosomes are **longest & thinest**. Chromosomes become gradually visible under the light microscope.

- All the chromosomes in nucleus remain directed towards centrioles, so group of chromosomes in nucleus appears like a bouquet. **(Bouquet Stage)**



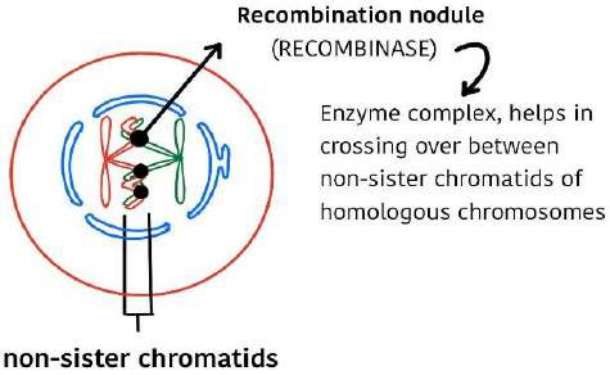
(ii) Zygotene or Synaptotene : Zygotene is characterized by pairing of homologous chromosomes **(Synapsis)**. Pairs of homologous chromosomes are called **Bivalents** or **tetrads**. However these are more clearly visible at next stage (pachytene) A structure develops in between homologous chromosomes, which is termed as ***synaptonemal complex***.

- The 1st two stages of prophase I is relatively short lived compared to the pachytene.



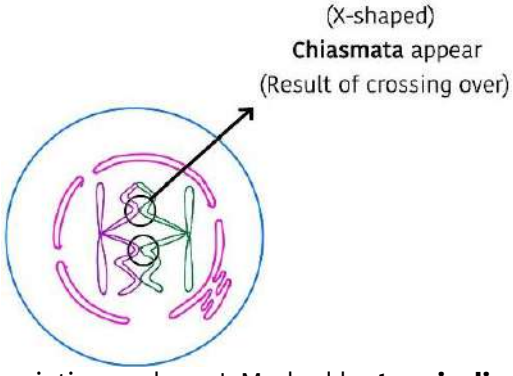
(iii) Pachytene (Thick Thread) :

- During this stage, the four chromatids of each bivalent chromosome become distinct and clearly appear as tetrad.
- Recombination nodules between non-sister chromatids of homologous pair develop and these non-sister chromatid exchange their parts i.e. crossing over.
- Crossing over leads to recombination of genetic material on the two chromosomes.
- Crossing over is an enzyme mediated process and the enzyme involved is called recombinase (Endonuclease + ligase)
- Recombination between homologous chromosomes is completed by the end of pachytene, leaving the chromosomes linked at the sites of crossing over.



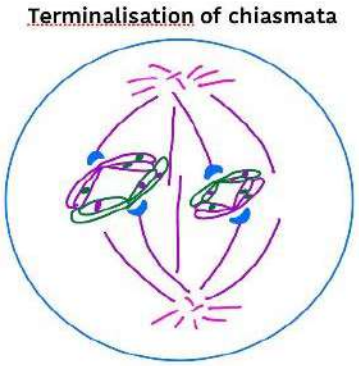
(iv) Diplotene : The beginning of diplotene is recognised by dissolution of synaptonemal complex. Homologous chromosomes start repulsing each other so X-shape structures appear called **chiasmata**.

- Diplotene may last long up to months or years in oocytes of some vertebrates.



(v) Diakinesis: It is final stage of meiotic prophase I. Marked by **terminalization** of chiasmata (Chiasmata open in zip like manner).

- Chromosome are fully condensed and meiotic spindle is assembled to prepare the homologous chromosomes for separation.
- Centrioles move towards the opposite poles.
- By the end of diakinesis nucleolus disappear and the nuclear envelop also breaks down.
- Diakinesis represents transition to metaphase.



(B) Metaphase I :

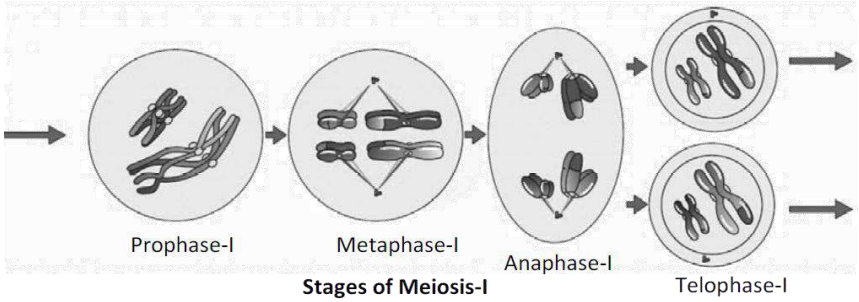
- Bivalents arrange on equator (congression) of cell to form metaphase plate. The microtubules (spindle fibres) from the opposite poles of the spindle attach to the pair of homologous chromosome with one kinetochore of each chromosome.
- Two types of spindle fibres appear in the cell :-
  (i) Chromosomal / Kinetochore Spindle fibres
  (ii) Supporting / Continuous / non-kinetochore Spindle fibres

(C) Anaphase I :

- Due to shortening of kinetochore/chromosomal fibres homologous chromosomes segregate from each other and move towards the opposite poles. Sister chromatids remain associated at their centromeres (i.e. chromosomes remain in double chromatid stage)
- Anaphase I is characterised by **segregation** or **disjunction** of chromosomes. **Division of centromere is absent.**

(D) Telophase I :

- The nuclear membrane and nucleolus reappear. Although in many case the chromosomes do undergo some dispersion, but they do not reach the extremely extended state of the interphase nucleus.
- Cytokinesis follows telophase-I and a diploid (2n) cell divides into two haploid (n) daugther cells. This is called as **dyad of cells**.



Stages of Meiosis-I

Figure

- Gap between meiosis I and meiosis II is called **Interkinesis**. Preparations of meiosis II occur during interkinesis. It is like interphase of mitosis but **replication of DNA is absent** in interkinesis.
- Interkinesis is generally short lived. Interkinesis is followed by prophase-II, a much simpler prophase than prophase-I.

(2) Meiosis-II

(A) 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.

(B) Metaphase II :

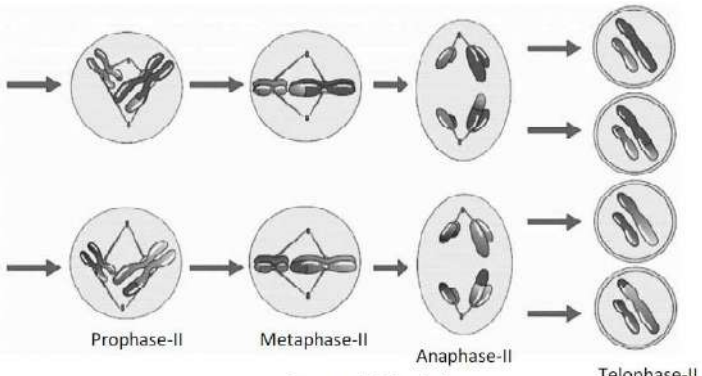
- At this stage the chromosomes align at the equator and the microtubules from opposite poles of the spindle get attached to the kinetochores of sister chromatids.

(C) 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.

(D) 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.



Stages of Meiosis-II

Figure

Significance of Meiosis

(1) Meiosis is the mechanism by which **conservation of specific chromosome number** of each species is achieved across generations in sexually reproducing organisms, even though the process (per se paradoxically) results in reduction of chromosome number by half.

(2) It also **increases the genetic variability** in the population of organisms from one generation to the next. **Variations are very important for the process of evolution.**

Golden Key Points

- Prophase-I further subdivide into five phases based on the chromosomes behaviour.
- Meiosis ensures the production of haploid phase in the life cycle of sexually reproducing organisms.
- Meiosis involves pairing of homologous chromosomes and recombination between them.
- Chiasmata formation is the result of crossing over.
- Meiosis increases the genetic variability in the population from one generation to next.

Concept Builder :

1. Meiosis involves two sequential cycles of :-
(1) Nuclear division and DNA Replication (2) Cell division and DNA Replication
(3) Nuclear division and cell division (4) Not possible

2. Formation of synaptonemal complex and chiasmata occurs in:-
(1) Leptotene and zygotene (2) zygotene and pachytene
(3) Pachytene and diplotene (4) zygotene and diplotene

3. Bivalent chromosomes align on the equatorial plate is characteristic of:
(1) Metaphase II (2) Metaphase I
(3) Anaphase I (4) Anaphase II

4. The stage between the two meiotic division is called _____ and is generally _____ lived.:
(1) Interphase, long (2) Inter kinesis, short
(3) Inter Kinesis, long (4) Inter phase, short

5. Meiosis ensures the production of _____ in the life cycle of sexually reproducing organism, whereas fertilisation restore the _____ .
(1) Diploid phase, Haploid phase (2) Haploid phase, Diploid phase
(3) Diploid phase, Diploid phase (4) Haploid phase, Haploid phase

Concept Builder (Answer–Key)					
Que.	**1**	**2**	**3**	**4**	**5**
Ans.	3	4	2	2	2

Exercise - I

1. The sequence of events by which cells duplicate their genome, synthesize the other components of cell which eventually distribute into two daughter cells is called :
(1) Quiescent stage
(2) Generation time
(3) Cell cycle
(4) Kinetochore

2. Interphase is called the resting phase because :
(1) It is the most active phase of the cell cycle
(2) There is no apparent activity related to cell division
(3) It does not prepare cell for cell division
(4) It is the phase where cell rests before entering into mitosis

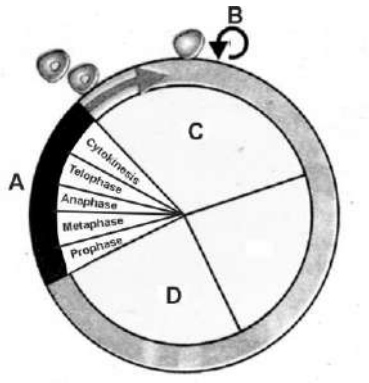
3. Read the following statements :
(a) Complete disintegration of the nuclear envelope marks the start of the second phase of mitosis.
(b) Metaphase chromosome is made up of one sister chromatid.
(1) Only (b) is correct
(2) Both (a) and (b) are incorrect
(3) Only (a) is correct
(4) Both (a) and (b) are correct

4. Select the incorrect statement w.r.t. cell cycle :
(1) Duplication of genes occurs twice in meiosis
(2) Karyokinesis occurs twice during meiotic division
(3) Cyclins are proteins that activate protein kinases to regulate the cell cycle
(4) After telophase-I, chromosome number is reduced to half

5. Cyclin Dependent Kinases (CDKs) :
(1) Act as mitotic poisons
(2) Cause disassembly of the microtubules
(3) Control various phases of cell cycle
(4) Arrest cell division due to non-formation of spindle

6. What is **not** true about cell cycle ?
a. During G_1 phase is active synthesis of RNA and proteins but no change in its DNA content
b. In synthesis or S phase, each chromosome carries a duplicate set of genes
c. During G_2 phase, a cell contains double the amount (4C) of DNA present in the original diploid cell (2C)
d. In S-phase a cell doubles the original diploid (2n) chromosome number
(1) c and d
(2) b and c
(3) d only
(4) b, c and d

7. Identify the mismatched pair :



(1) A – Starts with karyokinesis and ends with cytokinesis
(2) B – Stage where cells are inactive metabolically
(3) C – Cell grows and carries out normal metabolism
(4) D – Period of cytoplasmic growth

8. Chromatin fibres duplication, Genetic material –4C, Histone protein synthesis, Membranous Organelle duplication, DNA replication, centriole duplication.
How many of the above features are associated with synthesis phase of cell cycle ?
(1) Three (2) Five
(3) Four (4) Six

9. The two daughter cells formed during mitosis contains :
(1) The same amount of DNA but a set of chromosomes different from those of parental cells
(2) The same amount of DNA and the same set of chromosomes as those of the parent cell
(3) Half the amount of DNA and the same set of chromosomes as those of the parent cell
(4) Double the amount of DNA and a set of chromosomes different from those of the parent cell

10. Which one of the following is correct for mitosis in most of the plants member ?
(1) Amphiastral, anastral and eumitosis
(2) Anastral, acentric and premitosis
(3) Anastral, acentric and eumitosis
(4) Astral, centric and eumitosis

11. Select an **incorrect** statement w.r.t. metaphase :
(1) Spindle fibres are attached to small disc shaped structure at the surface of centromeres called kinetochores
(2) The plane of alignment of the homologous pair of chromosomes at metaphase is referred to as the metaphasic plate
(3) Chromosome appears to be made up of two sister chromatids
(4) The size of chromosomes can be studied in this phase

12. All are the essential stages that take place during meiosis, **except** :
(1) Two successive divisions without any DNA replication occurring between them
(2) Formation of chiasmata and crossing over
(3) Segregation of homologous chromosomes
(4) Number of chromosomes in daughter cells after meiosis II is reduced to half but the amount of DNA remains the same

13. Diplotene phase of meiosis is also characterised by :
a. Desynapsis
b. Complete terminalisation of chiasmata
c. Dictyotene stage
d. Complete disappearance of nuclear membrane and nucleoli
e. Complete development of astral rays and aster
f. Longest phase of prophase-I
(1) a, b, c and e (2) b, d, e and f
(3) a, c and f (4) b, d and f

14. The paradox of meiosis is :
(1) Conservation of specific chromosome number from generation to generation
(2) Produces four haploid cells after meiosis II
(3) It is a double division
(4) Does not involve DNA replication

15. Best stages to study morphology and shape of chromosomes are respectively :
(1) Metaphase, Telophase
(2) Prophase, Anaphase
(3) Telophase, Anaphase
(4) Metaphase, Anaphase

16. Most active stage of cell cycle is :
(1) Prophase (2) Metaphase
(3) Telophase (4) Interphase

17. Which of the following is the method of cytokinesis in plant cell :
(1) By cell plate formation
(2) By constriction
(3) By furrow formation
(4) (1) and (3) both

18. What happens in interkinesis :
(1) DNA - replication
(2) Chromosome duplication
(3) Preparation of second meiotic division
(4) Resting stage

19. Minimum number of meiotic div. required to produce 62 pollen grains :
(1) 15 (2) 31
(3) 62 (4) 16

20. In cell cycle, changes of which stage are not visible under microscope :
(1) Interphase (2) Prophase
(3) Metaphase (4) Anaphase

21. Which type of division leads to polyploidy?
(1) Crypto mitosis (2) Meiosis
(3) Endomitosis (4) Amitosis

22. Which of the following does not occur in Anaphase–I but occurs in Anaphase–II?
(1) Condensation of chromosomes
(2) Poleward movement of chromosome
(3) Contraction of spindle fibres
(4) Splitting of centromere

23. During G_2 - phase a diploid cell contains the amount of DNA equal to a :
(1) Diploid cell
(2) Tetraploid cell
(3) Haploid cell
(4) Nothing can be said

24. Crossing over takes place in :
(1) Zygotene (2) Pachytene
(3) Diplotene (4) Diakinesis

25. A contractile mid body forms during cytokinesis in :
(1) Animals (2) Higher plants
(3) Fungi (4) Algae

26. In which order, cytokinesis occurs in plants :
(1) Centripetal (2) Centrifugal
(3) Oblique (4) Equatorial

27. Which of the two events restore the normal number of chromosomes in life cycle ?
(1) Mitosis and Meiosis
(2) Meiosis and fertilisation
(3) Fertilisation and mitosis
(4) Only meiosis

28. Number of meiosis required to produce 100 functional megaspore in angiosperms :
(1) 125 (2) 100
(3) 25 (4) 75

29. Constancy of the chromosome number in sexually producing generation is brought by the process of :
(1) Meiosis (2) Mitosis
(3) Amitosis (4) None

30. Match the column–I with column–II and select the correct answer :

Column–I		Column–II	
(A)	Pachytene	(i)	Synizesis
(B)	Zygotene	(ii)	Chiasma visible
(C)	Diplotene	(iii)	Terminalisation
(D)	Leptotene	(iv)	Gene exchange
(E)	Diakinesis	(v)	Synapsis

(1) A–i, B–ii, C–iii, D–iv, E–v
(2) A–iv, B–v, C–ii, D–i, E–iii
(3) A–iii, B–iv, C–v, D–ii, E–i
(4) A–ii, B–iii, C–iv, D–i, E–v

31. Which division is characteristic of cartilage cells, meganucleus of ***Paramaecium*** and foetal membranes?
(1) Mitosis (2) Meiosis
(3) Cryptomitosis (4) Amitosis

32. Colchicine, a mitotic poison, arrests the cell division in :
(1) G_1 - phase (2) G_2 - phase
(3) Anaphase (4) Metaphase

33. Amitosis is characteristic of :
(1) Higher plants
(2) Higher animals
(3) Bryophyta
(4) Lower organisms

34. Reason of chromosomal movement in anaphase:
(1) Astral rays
(2) Centrioles
(3) Kinetochore
(4) Kinetochore and spindle fibres

35. Slipping of chiasmata towards the ends of bivalent is called :
(1) Terminalisation
(2) Diakinesis
(3) Interkinesis
(4) Heteropycnosis

36. Duplication of chromosomes without the division of nucleus is called :
(1) Cytokinesis (2) Plasmotomy
(3) Endomitosis (4) Dino-mitosis

37. Which does not occurs in prophase ?
(1) Hydration of chromatin
(2) Dehydration of chromatin
(3) Appearance of chromosome
(4) Disappearance of nuclear membrane and nucleolus

38. During cell cycle, RNA and protein synthesis takes place in :
(1) G_1 and G_2 - phase only
(2) S - phase only
(3) M – phase
(4) Interphase

39. The cellular structure which disappear during mitosis is :
(1) Plasma membrane
(2) Nuclear membrane
(3) Mitochondria
(4) Nuclear membrane and nucleolus

40. A cell is bound to divide, if it has entered:
(1) G_2 - phase (2) G_1 - phase
(3) Prophase (4) S - phase

41. How many chromosome shall be present in a diploid cell at mitotic anaphase if its egg cell has ten chromosome?
(1) 10 (Ten) (2) 20 (Twenty)
(3) 30 (Thirty) (4) 40 (Forty)

42. "Bouquet-stage" occur in which sub stages of prophase - I :
(1) Leptotene (2) Zygotene
(3) Pachytene (4) Diplotene

43. The synaptonemal complex appears :
(1) Between homologous chromosomes
(2) In zygotene stage
(3) Composed of DNA + protein
(4) All the above

44. The phragmoplast is organised :
(1) At the beginning of anaphase
(2) At the end of anaphase
(3) At the beginning of telophase
(4) At the end of telophase

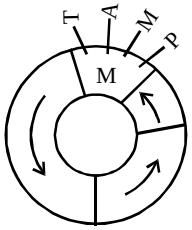
45. At anaphase-II of meiosis each chromosome contains :
(1) 4 DNA (2) 3 - DNA
(3) 2 - DNA (4) 1 - DNA

46. Kinetin (Cytokinin) increase the rate of mitosis by reducing the duration of :
(1) Interphase (2) Metaphase
(3) Anaphase (4) Telophase

47. Which of the following statement is correct ?
(1) DNA is synthesized through out the cell-cycle
(2) Cell division is inhibited by cytokinin
(3) Chromosome are condensed at S - stage
(4) Only extra chromosomal DNA is replicated at any stage of cell cycle

48. During cell division chromosome move towards different poles due to :
(1) Centriole
(2) Vacuole formation
(3) Microtubules
(4) Cytokinesis

49. Observe the following scheme. Which stage of cell division occurs after G_2 phase?



(1) Prophase (2) Metaphase
(3) Anaphase (4) Diakinesis

50. In which stage of mitosis, the chromosomes are bivalent i.e. composed of two chromatids :
(1) Prophase and metaphase
(2) Anaphase and telophase
(3) Prophase and telophase
(4) Metaphase and anaphase

51. In meiosis, nuclear membrane and nucleolus disappear during :
(1) Zygotene (2) Pachytene
(3) Diakinesis (4) Metaphase - I

52. Which of the following are mitotic poisons ?
(1) Colchicine
(2) Mustard gas and Azides
(3) Cyanides
(4) All the above

53. In cell cycle, which stage is misnomerly called resting phase :
(1) S–phase (2) Telophase
(3) Cytokinesis (4) Interphase

54. Spindle fibres which extend from pole to kinetochores are :
(1) Chromosomal or tractile fibres
(2) Interzonal fibres
(3) Supporting fibres
(4) Astral rays

55. Separation of homologous chromosomes during Anaphase - I is called :
(1) Synapsis (2) Disjunction
(3) Nondisjunction (4) Crossing over

56. During cell division, spindle fibres attach to which part of chromosome :
(1) Primary constriction
(2) Sec. Constriction
(3) Chromomere
(4) Chromatid

57. Persistent nuclear membrane and intranuclear spindle are characteristic of:
(1) Crypto mitosis (2) Endomitosis
(3) Free nuclear div. (4) Mitosis

58. If a meristematic cell is placed in a medium containing radio active thymidine, radioactivity will be first observed in :
(1) Euchromatin
(2) Hetero chromatin
(3) Both simultaneously
(4) None of the above

59. Karyoplasmic index (K.I.) is :
(1) $\frac{V_n}{V_n - V_c}$ (2) $\frac{V_n}{V_c - V_n}$
(3) $\frac{V_c}{V_n}$ (4) $\frac{V_n}{V_c + V_n}$

60. What happens during growth of a cell ?
(1) K.I. decreases
(2) K.I. increases
(3) K. I. fluctuates
(4) K. I. remains constant

61. Synthesis of cycline protein occurs in :
(1) Permanent tissue
(2) Meristem
(3) Lignified cells
(4) All the types of cells

62. Which of the following reorganises the nucleolus during telophase ?
(1) Sec. constriction -I
(2) Centromere
(3) Primary constriction
(4) Pore - complex

63. 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 :

(1) 8 and 4 (2) 4 and 4

(3) 8 and 8 (4) 16 and 8

64. Which one of the following statements is correct?

(1) Cell divided by cytokinesis only in mitosis

(2) DNA is replicated before the start of meiosis only

(3) Spindles consisting of microtubule form only in mitosis

(4) Exchange of genetic materials occurs only in meiosis

65. Which of the following not occurs in Anaphase –I?

(1) Segregation of homologous chromosomes

(2) Shortening in spindle

(3) Poleward movement of chromosomes

(4) Division of centromere

66. In meiosis :

(1) Division of nucleus twice but replication of DNA only once

(2) Division of nucleus twice and replication of DNA twice

(3) Division of nucleus once and replication of DNA is also once

(4) Division of nucleus once and DNA - replication is twice

67. After meiosis - I, the two chromatids of a chromosome are :

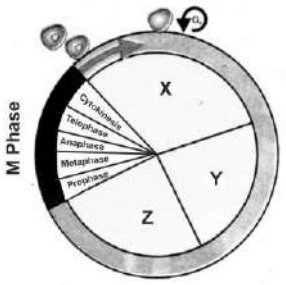
(1) Genetically similar

(2) Genetically different

(3) There occurs only one chromatid in each chromosome

(4) None of the above

68. The following diagram refers to a typical cell cycle.



Identify the parts marked as X, Y and Z :

(1) Y–S, Z–G_2

(2) X–G_2, Y–S, Z–G_1

(3) X–G_0, Y–S, Z–G_2

(4) X–G_1, Y–G_2, Z–G_0

69. Dinomitosis occurs in :

(1) Prokaryotes (2) Mesokaryotes

(3) Eukaryotes (4) Akaryotes

70. What happens in synthesis phase during cell cycle?

(1) DNA synthesis

(2) Chromosome number becomes double

(3) Formation of two nuclei

(4) Synthesis of proteins & RNA

71. Reappearance of nuclear membrane & nucleolus along with thinning & elongation in chromosomes are diagnostic characters for the phase :

(1) Anaphase (2) Metaphase

(3) Interphase (4) Telophase

72. Synthesis and storage of ATP molecules required for cell div. takes place in :

(1) Prophase (2) G_1–phase

(3) Anaphase (4) G_2–phase

73. A parent cell has 16 chromosomes and 28 picogram DNA content. What must be the chromosome number and DNA content respectively in anaphase-II ?

(1) 8, 14 (2) 16, 14

(3) 8, 28 (4) 16, 28

74. Cell plate which appears during cytokinesis, ultimately transforms in :
(1) Middle lamella
(2) Primary wall
(3) Sec. wall
(4) Plasma membrane

75. Colchicine which prevents spindle formation is chemically a :
(1) Protein (2) Amino acid
(3) Alkaloid (4) Glycolipid

76. Chromosomal morphology (Structure) is best observed at :
(1) Prophase (2) Metaphase
(3) Interphase (4) Anaphase

77. Direct or incipient cell division is :
(1) Crypto mitosis
(2) Dinomitosis
(3) Amitosis
(4) Mitosis and Meiosis

78. Bead like thickened portions of leptotene chromosomes are :
(1) Centromeres (2) Chromomeres
(3) Centrioles (4) Chromocenters

79. Which stage of cell cycle is characterised by DNA - replication, synthesis of Histones and formation of new nucleosomes?
(1) S-phase (2) G_1-phase
(3) G_2-phase (4) M-phase

80. In which stage the centromere lie at equator and arms are directed towards poles :
(1) Metaphase of mitosis
(2) Metaphase -I
(3) Metaphase -II
(4) 1 and 3 both

81. What type of division lead to coenocytic condition^:
(1) Cryptomitosis (2) Endomitosis
(3) Free nuclear div. (4) Dino-mitosis

82. In anaphase, a metacentric chromosome appears :
(1) i shaped (2) J - shaped
(3) V - shaped (4) L - shaped

83. Pairing of homologous chromosomes is called:-
(1) Disjunction (2) Synapsis
(3) Segregation (4) Polyteny

84. During cytokinesis in plants, which of the following secretes the middle lamella :
(1) Golgi body
(2) SER
(3) RER
(4) Lysosomes

85. Crossing over takes place on :
(1) Two stranded stage
(2) Three stranded stage
(3) One stranded stage
(4) Four stranded stage

86. DNA replication is found in :
(1) Mitosis and meiosis–I
(2) Mitosis and meiosis–I and meiosis–II
(3) Meiosis only
(4) Mitosis only

87. How many divisions will occur in an isolated tip cell to form 128 cells.
(1) 128 (2) 127
(3) 32 (4) 7

88. In which stage the Chromosomes combine and begin to separate from each other during meiosis cell division :
(1) Pachytene (2) Diplotene
(3) Zygotene (4) Diakinesis

89. Number of spore mother cells required to produce 64 spores :
(1) 16 (2) 32
(3) 64 (4) 128

90. The significance of Meiosis is that it :
(1) Produce four cells having chromosomal number equal to mother cell
(2) Occurs in all types of cells
(3) Maintains the constant Chromosomes number to a particular species
(4) Growth of animal body organs.

91. Which statement is true for mitosis :
(1) Daughter cells exhibit division of labour i.e. perform different functions
(2) Daughter cells are exactly similar in all respect
(3) Daughter cells have half the number of chromosomes as compared to mother cell
(4) Daughter cells have differences in genetic characters

92. Cell Cycle of an ordinary animal cell :
(1) $2n \xrightarrow{\text{Mitosis}} n \xrightarrow{\text{Fertilization}}$
$2n \xrightarrow{\text{Meiosis}} 2n$
(2) $n \xrightarrow{\text{Meiosis}} 2n \xrightarrow{\text{Fertilization}}$
$2n \xrightarrow{\text{Mitosis}} n$
(3) $2n \xrightarrow{\text{Meiosis}} n \xrightarrow{\text{Fertilization}}$
$2n \xrightarrow{\text{Mitosis}} 2n$
(4) $2n \xrightarrow{\text{Fertilization}} (n) \xrightarrow{\text{Mitosis}}$
$2n \xrightarrow{\text{Meiosis}} n$

93. Best material for the study of mitosis in laboratory :
(1) Anther (2) Root tip
(3) Leaf tip (4) Ovary

94. Mitosis occurs in :
(1) Haploid individuals
(2) Diploid individuals
(3) Both (1) and (2)
(4) In bacteria only

95. Which is correct for meiotic metaphase–I :
(1) Bivalents are arranged at equator
(2) Univalents are arranged at equator
(3) Non-homologous chromosomes forms pair
(4) Spindle fibres are attache at chromomere

96. Crossing over that results in genetic recombination in higher organisms occurs between :
(1) Non-sister chromatids of a bivalent
(2) Two daughter nuclei
(3) Two different bivalents
(4) Sister chromatids of a bivalents

97. In the somatic cell cycle :
(1) DNA replication takes place in S–phase
(2) A short interphase is followed by a long mitotic phase
(3) G_2 phase follows mitotic phase
(4) In G_1 phase DNA content is double the amount of DNA present in the original cell

98. In which stage of meiosis the chromosome number reduces to half :
(1) Anaphase–I (2) Anaphase–II
(3) Telophase–I (4) Telophase–II

99. Chiasmata are formed as a result of :
(1) Exchange of parts of paired homologues chromosome
(2) Exchange of part of unpaired non– homologous chromosome
(3) Duplication of parts of paired homologues chromosome
(4) Loss of parts of unpaired non–homologous chromosome

100. When synapsis is complete all along the chromosome, the cell is said to have entered a stage called :
(1) Zygotene (2) Pachytene
(3) Diplotene (4) Diakinesis

101. Many cells function properly and divide mitotically even though they do not have:
(1) Plasma membrane
(2) Cytoskeleton
(3) Mitochondria
(4) Plastids

102. Centromere is required for :
(1) Movement of chromosomes towards poles
(2) Cytoplasmic cleavage
(3) Crossing over
(4) Transcription

103. At what stage of the cell cycle are histone proteins synthesized in a eukaryotic cell :
(1) During telophase
(2) During S–phase
(3) During G_2–stage of prophase
(4) During entire prophase

104. If the n=16 in plant cell then which one is possible in metaphase - I of meiosis:
(1) 32 Bivalents (2) 16 Tetravalents
(3) 16 Bivalents (4) 32 Bivalents

105. Which of the following statement is true?
(1) Cell plate represents the middle lamella between the walls of two adjacent cells
(2) At the time of cytokinesis, organelles like mitochondria and plastids get distributed between the daughter cells.
(3) Cytokinesis in plant cell is centrifugal and takes place by cell plate formation while animal cells by furrowing and is centripetal.
(4) All of these

106. In which phase of the cell cycle are sister chromatids available as template for repair?
(1) G_1 (2) G_2 (3) S (4) M

ANSWER KEY

Que.	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
Ans.	3	2	3	1	3	3	2	2	2	3	2	4	3	1	4	4	1	3	4	1	3	4	2	2	1
Que.	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
Ans.	2	2	2	1	2	4	4	4	4	1	3	1	4	4	4	4	1	4	2	4	1	4	3	1	1
Que.	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
Ans.	3	4	4	1	2	1	1	1	2	1	2	1	3	4	4	1	2	1	2	1	4	4	4	1	3
Que.	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
Ans.	2	3	2	1	4	3	3	2	1	4	1	2	2	1	3	2	3	2	3	1	1	1	1	1	2
Que.	101	102	103	104	105	106																			
Ans.	4	1	2	3	4	3																			

Exercise – II

1. Which one is correct for G_0 stage?

I. It is a quiescent stage.
II. In this phase cell cycle is stopped
III. G_0 cells do not grow or proliferate but metabolically active
IV. G_0 cells may divide in response to some stimulus

(1) All are correct
(2) I, II, III are correct
(3) I, II are correct
(4) Only I and IV are correct

2. Which of the following is not correctly matches a phase of the cell cycle with its function?

	Column–I	Column–II
1	Second gap phase	Period of cytoplasmic growth
2	First gap phase	Most of the organelle duplication
3	Interphase	Phase of preparation for cell division
3	DNA synthesis phase	Doubling of number of chromosome in cell

3. In a diploid cell after S phase quantity of DNA is 20 pg (pico gram), after Telophase–II situation will be, in each daughter nucleus :

(1) Diploid, 10 pg DNA
(2) Haploid, 10 pg DNA
(3) Haploid, 5 pg DNA
(4) Diploid, 5 pg DNA

4. Mark incorrect statements:

(A) Meiosis involves only a single cycle of DNA replication
(B) Four haploid cells are formed at the end of meiosis–I
(C) Mitosis restricted to diploid cells only
(D) In yeast, cell cycle takes about 90 minutes.

(1) A and B
(2) A and C
(3) B and C
(4) All are correct

5. Interval between mitosis and initiation of DNA replication is called:

(1) G_2 – Phase (2) G_1 – phase
(3) Karyokinesis (4) s–phase

6. Recombinase enzyme is involved in which phase of meiosis:

(1) Pachytene (2) Diplotene
(3) Diakinesis (4) Zygotene

7. Diploid cell in human, where cell division does not occur:

(a) Heart cell
(b) Muscle cell
(c) Nerve cell

(1) Only c (2) b and c
(3) a and c (4) a, b and c

8. In yeast, duration of cell cycle is about:

(1) 80 minutes (2) 99 minutes
(3) 1.30 hrs. (4) 60 minutes

9. In which phase of the cell cycle centriole move towards opposite poles of the cell.

(1) Anaphase (2) Metaphase
(3) Telophase (4) Prophase

10. The M-phase starts with the :

(1) G_1 (2) Karyokinesis
(3) Cytokinesis (4) Telophase

11. It is said that the one cycle of cell division in human cells takes 24 hours. Which phase of the cycle, do you think occupies the maximum part of cell cycle?

(1) Prophase (2) Interphase
(3) Anaphase (4) Metaphase

12. In which phase of meiosis the chromosomes do undergo some dispersion but they do not reach the extremely extended state of the interphase nucleus?

(1) Prophase-I (2) Metaphase-I
(3) Telophase-I (4) Prophase-II

13. Following are the events occurs during meiosis:

(A) Appearance of chiasmata

(B) Synapsis

(C) Terminalisation of Chiasmata

(D) Use of recombinase enzyme

Choose the correct sequence :-

(1) A → B → C → D (2) B → D → A → C

(3) D → C → B → A (4) B → C → A → D

14. Which stage of cell cycle is marked by initiation of condensation of chromosomal material ?

(1) Prophase (2) Metaphase

(3) G_2–phase (4) S–phase

15. Match the columns

	Column–I		**Column–II**
A.	Leptotene	(i)	Condensation of chromatin start
B.	Zygotene	(ii)	Recombination nodule formation
C.	Pachytene	(iii)	Synapsis
D.	Diplotene	(iv)	Terminalisation of Chiasmata
E.	Diakinesis	(v)	Dissolution of Synaptonemal complex

(1) A–i, B–iii, C–ii, D–v, E –iv

(2) A–i, B–ii, C–iii, D–v, E–iv

(3) A–v, B–iii, C–ii, D–i, E–iv

(4) A–iii, B–ii, C–v, D–iv, E–i

16. In which phase of mitosis, chromosomes lose their individuality?

(1) Prophase (2) Metaphase

(3) Anaphase (4) Telophase

17. Which of the following events does not occur during meiosis-I?

(1) Pairing of homologous chromosomes

(2) Separation of homologous chromosomes

(3) Crossing over between homologous chromosomes.

(4) Splitting of centromere.

18. What is evolutionary advantage provided by meiosis?

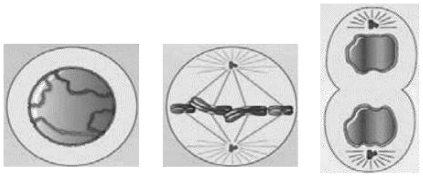
(1) Increases the genetic variability

(2) Increases the complexity of organisms

(3) Increases the chromosome's size

(4) Increases the chromosomal number

19. The figures below show three stages (A, B, C) of mitotic division. Select the option giving correct identification together with what it represents?



A B C

Options :-

(1) B–Individual chromosomes can no longer be seen

(2) A–Initiation of condensation of chromosomal material

(3) C–Initiation of assembly of mitotic spindle

(4) B–Chromosomes consist of one chromatid

20. Which of the following is/are correct with respect to reduction division?

(A) Diakinesis is marked by appearance of chiasmata

(B) Duplication of centrioles occur in anaphase-I

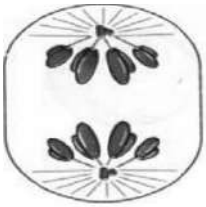
(C) Sister chromatids of homologous chromosomes exhibit crossing over

(D) Interkinesis is short lived phase which is followed by prophase-II, a much simpler phase than prophase-I

(1) A, B (2) B, D

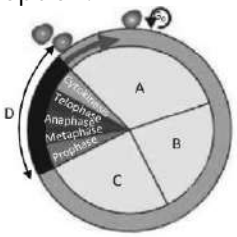
(3) A, C (4) Only D

21. What is correct about following stage of mitotic division ?



(1) Crossing over has been occurred between homologous chromosomes
(2) Centrioles divide and move to opposite poles
(3) Each chromosome consists of two chromatids
(4) Daughter chromosomes move to opposite poles.

22. Identify A,B,C and D in the given diagram depicting cell cycle and select the correct option:-



	A	B	C	D
(1)	G_0	G_1	S	G_2
(2)	G_1	S	G_2	M
(3)	G_1	G_0	S	M
(4)	S	G_0	G_1	G_2

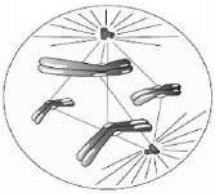
(1) P (2) M (3) G (4) S

23. Select the correct option :-

	I		II
(a)	Synapsis aligns homologous chromosomes	(i)	Anaphase-I
(b)	Synthesis of tubulin protein	(ii)	Zygotene
(c)	Action of enzyme recombinase	(iii)	G_2-phase
(d)	Centromeres split and chromatids move towards opposite poles	(iv)	Anaphase-II
		(v)	Pachytene

	(a)	(b)	(c)	(d)
(1)	(ii)	(iii)	(v)	(iv)
(2)	(i)	(ii)	(v)	(iii)
(3)	(ii)	(iii)	(iv)	(i)
(4)	(ii)	(i)	(iii)	(iv)

24. Identify the following diagram :-



(1) Transition to Metaphase
(2) Transition to Anaphase-II
(3) Transition to Metaphase-I
(4) Transition to Anaphase

25. Leptotene, zygotene, pachytene, diplotene and diakinesis are 5 phases of prophase–I.
Which one is the longest in human oogenesis?
(1) Zygotene (2) Leptotene
(3) Diplotene (4) Diakinesis

26. In which phase of mitosis, cell does not have nucleolus ?
(1) Interphase (2) Telophase
(3) Late prophase (4) All of these

27. "X-shaped structures" occurs during which phase of meiotic division ?
(1) Prophase I (2) Metaphase I
(3) Anaphase II (4) Telophase I

28. Which phase is marked by terminalization of chiasmata?
(1) Diakinesis (2) Pachytene
(3) Diplotene (4) Zygotene

29. Cell cycle involves -
(1) Duplication of genome
(2) Synthesis of cell constituents
(3) Division of cell
(4) All the above

30. During poleward movement of chromosomes in anaphase, centromere of each daughter chromosome remains directed towards -
(1) Pole
(2) Equatorial plate
(3) Lateral wall
(4) Pole sometimes and towards equatorial plate sometimes

ANSWER KEY

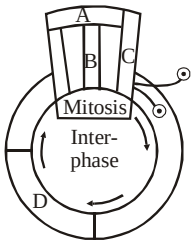
Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Ans.	1	4	3	3	2	1	4	3	4	2	2	3	2	1	1	4	4	1	2	4	4	2	1	1	3
Que.	26	27	28	29	30																				
Ans.	3	1	1	4	1																				

Exercise – III (Previous Year Questions)

[AIPMT - 2009]

1. Synapsis occurs between :
(1) Two homologous chromosomes
(2) A male and a female gamete
(3) mRNA and ribosomes
(4) Spindle fibres and centromere

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

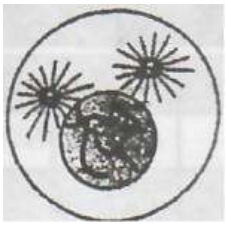


Which one of the following is the correct indication of the stage/phase in the cell cycle :
(1) A – Cytokinesis
(2) B – Metaphase
(3) C – Karyokinesis
(4) D – Synthetic phase

[AIPMT Pre. - 2010]

3. During mitosis ER and nucleolus being to disappear at :
(1) Early prophase (2) Late prophase
(3) Early metaphase (4) Late metaphase

4. Which stage of cell division do the following figures A and B represent respectively?



(A) (B)
(1) Prophase - Anaphase
(2) Metaphase - Telophase
(3) Telophase - Metaphase
(4) Late Anaphase - Prophase

[AIPMT Pre. - 2011]

5. Select the correct option with respect to mitosis
(1) Chromatids separate but remain in the centre of the cell in anaphase.
(2) Chromatids start moving towards opposite poles in telophase.
(3) Golgi complex and endoplasmic reticulum are still visible at the end of prophase.
(4) Chromosomes move to the spindle equator and get aligned along equatorial plate in metaphase

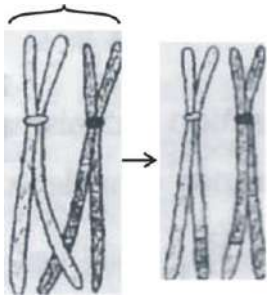
[AIPMT Mains - 2011]

6. At metaphase, chromosomes are attached to the
spindle fibres by their :-
(1) Centromere
(2) Satellites
(3) Secondary constrictions
(4) Kinetochores

[AIPMT Pre. - 2012]

7. During gamete formation, the enzyme recombinase participates during :-
(1) Prophase-I (2) Prophase-II
(3) Metaphase-I (4) Anaphase-II

8. Given below is the representation of a certain event at a particular stage of a type of cell division. Which is this stage?



(1) Prophase of mitosis
(2) Both prophase and metaphase of mitosis
(3) Prophase I during meiosis
(4) Prophase II during meiosis

[AIPMT Mains - 2012]

9. Identify the meiotic stage in which the homologous chromosomes separate while the sister chromatids remain associated at their centromeres -

(1) Anaphase I (2) Anaphase II

(3) Metaphase I (4) Metaphase II

[NEET - UG 2013]

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

1	Telophase	Endoplasmic reticulum and nucleolus not reformed yet
2	Telophase	Nuclear envelop reforms, golgi complex reforms
3	Late anaphase	Chromosomes move away from equatorial plate, golgi complex not present
4	Cytokinesis	Cell plate formed, mitochondria distributed between two daughter cells

11. The complex formed by a pair of synapsed homologous chromosomes is called :

(1) Axoneme

(2) Equatorial plate

(3) Kinetochore

(4) Bivalent

[AIPMT – 2014]

12. During which phase(s) of cell cycle, amount of DNA in a cell remains at 4C level if the initial amount is denoted as 2C?

(1) G_0 and G_1 (2) G_1 and S

(3) Only G_2 (4) G_2 and M

13. In 'S' phase of the cell cycle :

(1) Amount of DNA doubles in each cell.

(2) Amount of DNA remains same in each cell.

(3) Chromosome number is increased.

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

14. The enzyme recombinase is required at which stage of meiosis :

(1) Pachytene (2) Zygotene

(3) Diplotene (4) Diakinesis

[AIPMT – 2015]

15. A somatic cell that has just completed the S phase of its cell cycle, as compared to gamete of the same species, has :

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

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

(3) Four times the number of chromosomes and twice the amount of DNA

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

[Re-AIPMT – 2015]

16. Arrange the following events of meiosis in correct sequence :

(a) Crossing over

(b) Synapsis

(c) Terminalisation of chiasmata

(d) Disappearance of nucleolus

(1) (b), (c), (d), (a) (2) (b), (a), (d), (c)

(3) (b), (a), (c), (d) (4) (a), (b), (c), (d)

[NEET - I – 2016]

17. Spindle fibres attach on to :-

(1) Telomere of the chromosome

(2) Kinetochore of the chromosome

(3) Centromere of the chromosome

(4) Kinetosome of the chromosome

18. In meiosis crossing over is initiated at :
(1) Pachytene (2) Leptotene
(3) Zygotene (4) Diplotene

[NEET - II – 2016]

19. During cell growth, DNA synthesis takes place in :-
(1) G_2 phase (2) M phase
(3) S phase (4) G_1 phase

20. Match the stages of meiosis in Column-I to their characteristic features in Column–II and select the correct option using the codes given below :

	Column-I		Column-II
a	Pachytene	i	Pairing of homologous Chromosomes
b	Metaphase-I	ii	Terminalization of Chiasmata
c	Diakinesis	iii	Crossing over takes Place
d	Zygotene	iv	Chromosomes align at equatorial plate

Codes :

	a	b	c	d
(1)	ii	iv	iii	i
(2)	iv	iii	ii	i
(3)	iii	iv	ii	i
(4)	i	iv	ii	iii

[NEET – 2017]

21. Which of the following options gives the correct sequence of events during mitosis?
(1) Condensation → nuclear membrane disassembly → crossing over → segregation → telophase
(2) Condensation → nuclear membrane → disassembly → arrangement at equator → centromere division → segregation → telophase
(3) Condensation → crossing over → nuclear membrane disassembly → segregation → telophase
(4) Condensation → arrangement at equator → centromere division → segregation → telophase

[NEET – 2018]

22. The stage during which separation of the paired homologous chromosomes begins is :
(1) Zygotene (2) Pachytene
(3) Diakinesis (4) Diplotene

[NEET - 2019]

23. The correct sequence of phases cell cycle is :
(1) $M \rightarrow G_1 \rightarrow G_2 \rightarrow S$
(2) $G_1 \rightarrow G_2 \rightarrow S \rightarrow M$
(3) $S \rightarrow G_1 \rightarrow G_2 \rightarrow M$
(4) $G_1 \rightarrow S \rightarrow G_2 \rightarrow M$

24. Cells in G_0 phase :
(1) exit the cell cycle
(2) enter the cell cycle
(3) suspend the cell cycle
(4) terminate the cell cycle

[NEET – 2019 (Odisha)]

25. After meiosis-I, the resultant daughter cells have:-
(1) Same amount of DNA as in the parent cell in S phase
(2) Twice the amount of DNA in comparison to haploid gamete.
(3) Same amount of DNA in comparison to haploid gamete
(4) Four times the amount of DNA in comparison to haploid gamete

26. Crossing over takes place between which chromatids and in which stage of the cell cycle ?
(1) Non-sister chromatids of nonhomologous chromosomes at Zygotene stage of prophase I.
(2) Non-sister chromatids of homologous chromosomes at Pachytene stage of prophase I.
(3) Non-sister chromatids of homologous chromosomes at Zygotene stage of prophase I.
(4) Non-sister chromatids of nonhomologous chromosomes at Pachytene stage of prophase I.

[NEET – 2020]

27. Match the following with respect to meiosis:

(a) Zygotene	(i) Terminalization
(b) Pachytene	(ii) Chiasmata
(c) Diplotene	(iii) Crossing over
(d) Diakinesis	(iv) Synapsis

Select the correct option from the following:

	(a)	(b)	(c)	(d)
(1)	(ii)	(iv)	(iii)	(i)
(2)	(iii)	(iv)	(i)	(ii)
(3)	(iv)	(iii)	(ii)	(i)
(4)	(i)	(ii)	(iv)	(iii)

28. Identify the correct statement with regard to G_1 phase (Gap 1) of interphase.

(1) Nuclear Division takes place.
(2) DNA synthesis or replication takes place.
(3) Reorganisation of all cell components takes place.
(4) Cell is metabolically active, grows but does not replicate its DNA.

29. Some dividing cells exit the cell cycle and enter vegetative inactive stage. This is called quiescent stage (G_0). This process occurs at the end of :

(1) G2 phase (2) M phase
(3) G1 phase (4) S phase

30. Dissolution of the synaptonemal complex occurs during :

(1) Leptotene (2) Pachytene
(3) Zygotene (4) Diplotene

[NEET – 2020 (Covid-19)]

31. Attachment of spindle fibres to kinetochores of chromosomes becomes evident in :

(1) Anaphase (2) Telophase
(3) Prophase (4) Metaphase

32. In a mitotic cycle, the correct sequence of phases is

(1) S, G_1, G2, M (2) G_1, S, G_2, M
(3) M, G_1, G_2, S (4) G_1, G_2, S, M

33. During Meiosis-I, in which stage synapsis takes place?

(1) Pachytene (2) Zygotene
(3) Diplotene (4) Leptotene

34. Match the following events that occur in their respective phases of cell cycle and select the correct option:

(a) G_1 phase	(i) Cell grows and organelle duplication
(b) S phase	(ii) DNA replication and chromosome duplication
(c) G_2 phase	(iii) Cytoplasmic growth
(d) Metaphase in M-phase	(iv) Alignment of chromosomes

(1) (a)-(ii), (b)-(iii), (c)-(iv), (d)-(i)
(2) (a)-(iii), (b)-(iv), (c)-(i), (d)-(ii)
(3) (a)-(iv), (b)-(i), (c)-(ii), (d)-(iii)
(4) (a)-(i), (b)-(ii), (c)-(iii), (d)-(iv)

[NEET – 2021]

35. Which of the following stages of meiosis involves division of centromere?

(1) Metaphase I
(2) Metaphase II
(3) Anaphase II
(4) Telophase II

36. Match List-I with List – II

	List-I		List-II
a	S phase	i	Proteins are synthesized
b	G_2 phase	ii	Inactive phase
c	Quiescent stage	iii	Interval between mitosis and initiation of DNA replication
d	G_1 phase	iv	DNA replication

Choose the correct answer from the options given below.

	(a)	(b)	(c)	(d)
(1)	(iii)	(ii)	(i)	(iv)
(2)	(iv)	(ii)	(iii)	(i)
(3)	(iv)	(i)	(ii)	(iii)
(4)	(ii)	(iv)	(iii)	(i)

37. The fruit fly has 8 chromosomes (2n) in each cell. During interphase of Mitosis if the number of chromosomes at G_1 phase is 8, what would be the number of chromosomes after S phase?
(1) 8 (2) 16 (3) 4 (4) 32

38. The centriole undergoes duplication during:
(1) S-phase (2) Prophase
(3) Metaphase (4) G_2 phase

39. Which stage of meiotic prophase shows terminalisation of chiasmata as its distinctive feature?
(1) Leptotene (2) Zygotene
(3) Diakinesis (4) Pachytene

[NEET – 2022]

40. Regarding Meiosis, which of the statements is **incorrect**?
(1) There are two stages in Meiosis, Meiosis–I and II
(2) DNA replication occurs is S phase of Meiosis–II
(3) Pairing of homologous chromosomes and recombination occurs in Meiosis–I
(4) Four haploid cells are formed at the end of Meiosis–II

41. Select the **incorrect** statement with reference to mitosis:
(1) All the chromosomes lie at the equator at metaphase.
(2) Spindle fibres attach to centromere of chromosomes.
(3) Chromosomes decondense at telophase.
(4) Splitting of centromere occurs at anaphase.

[Re NEET – 2022]

42. Which stage of meiosis can last for months or years in the oocytes of some verterbrates ?
(1) Leptotene (2) Pachytene
(3) Diplotene (4) Diakinesis

43. In meiosis, crossing over and exchange of genetic material between homologous chromosomes are catalyzed by the enzyme.
(1) Phosphorylase (2) Recombinase
(3) Transferase (4) Polymerase

44. Identify the correct sequence of events during Prophase I of meiosis :
(a) Synapsis of homologous chromosomes
(b) Chromosomes become gradually visible under microscope
(c) Crossing over between non-sister chromatids of homologous chromosomes
(d) Terminalisation of chiasmata
(e) Dissolution of synaptonemal complex
Choose the correct answer from the options given below :
(1) (a), (b), (c), (d), (e)
(2) (b), (c), (d), (e), (a)
(3) (b), (a), (c), (e), (d)
(4) (a), (c), (d), (e), (b)

45. Bivalent or Tetrad formation is a characteristic feature observed during :
(1) Synaptonemal complex in zygotene stage
(2) Chiasmata in Diplotene stage
(3) Synaptonemal complex in Pachytene stage
(4) Chiasmata in zygotene stage

46. With respect to metaphase, which of the following statements is incorrect ?
(1) Complete disintegration of nuclear envelope takes place
(2) Chromosomes are highly condensed
(3) Metaphase chromosomes are made up of four sister chromatids held together by centromere
(4) Chromosomes lie at the equator of the cell

ANSWER KEY

Que.	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
Ans.	1	4	2	4	4	4	1	3	1	2	4	4	1	1	2	3	2	1	3	3	1	2	4	3	2
Que.	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46				
Ans.	2	3	4	3	4	4	2	2	4	3	3	1	1	3	2	2	3	2	3	1	3				