BIOLOGY

CLASS-XI NEET

MODULE-02

Cell Cycle & Cell Division

| Structural Organisation in Animals |Cell Unit of Life |
Transport in plants| Biomolecules |

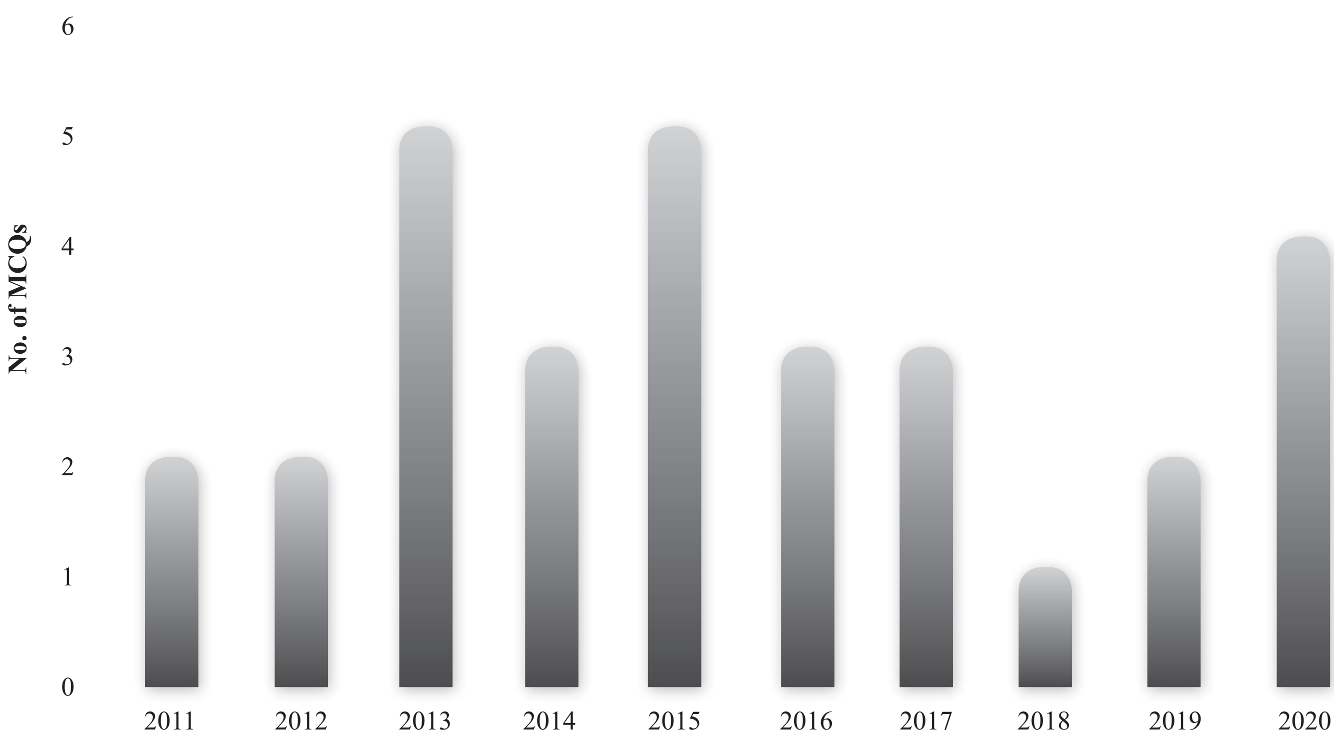
Physics Wallah

10 CHAPTER

Cell Cycle and Cell Division

Scan for Video Solution

Past Year NEET Trend



Investigation Report

TARGET EXAM	PREDICTED NO. OF MCQs	CRITICAL CONCEPTS
NEET	2-3	• Phases of cell cycle • Regulation of cell cycle

Perfect Practice Plan

TOPIC-WISE MCQs	NCERT BASED MCQs	MULTI-CONCEPT MCQs	NEET PAST 10 YEAR QUESTIONS	TOTAL MCQs
114	36	22	34	206

INTRODUCTION

☺ All sexually reproducing organisms, start their life from a single celled zygote which undergoes to divition and differentiation to form the whole organism.

☺ **Rudolf Virchow** (1855) observed that new cells always develop from pre-existing cells. **(cell lineage theory** or **law of cell lineage)**

☺ **Cell division** is a very important process by which a mature cell divides and forms two or 4 daughter cells

☺ The cell which undergoes division is called **mother cell or parent cell**. The newly formed cells are known as **daughter cells**.

☺ Cell division is a **biological process** in all living organisms.

☺ Growth and reproduction are characteristics of cells, indeed of all living organisms. Both growth and reproduction are **not well-defined features of living organisms** as some non-living things do show growth by the accumulation of matter or **accretion** (such as sand dunes, mountains, etc.) and some living organisms are exception for reproduction (mules, sterile worker bees, infertile human couples).

CELL CYCLE

☺ The sequence of events by which a cell duplicates its genome (replication), synthesizes the other constituents of the cell (since the cell is going to divide into 2 equal parts, all the cell constituents must be duplicated for their equal distribution) and eventually divides into two daughter cells is termed **cell cycle**.

☺ During the division of a cell, DNA replication (occur in **S-phase only**), cell growth (growth in terms of cytoplasmic increase is a continuous process) etc. takes place in a **coordinated way** to ensure correct division and formation of progeny cells containing intact genomes (replication occurs with high fidelity so that there must be no error and the same intact genome will be passed to the daughter cells- for this our cell have various proofreading and error correcting proteins).

☺ 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:

☺ The duration of cell cycle can vary from organism to organism and from cell type to cell type. The duration between 2 cell cycles is called as **generation time**.

Table: Cells and their cell cycle duration

Type of Cell	Duration of Cell Cycle
Human cells in culture	Divide once in approximately every 24 hours
Yeast	90 minutes
E.coli	20 minutes (**in ideal conditions**)

☺ The cell cycle is divided into **two basic phases:**

1. Interphase
2. M-phase

1. Interphase

☺ Represents the phase between two successive M phases.

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

☺ The interphase is called the **resting phase** (as no division process occurs in this phase) but the cell is metabolically active at this stage. It is the time during which the cell is preparing for division by undergoing both cell growth, organelle duplication and DNA replication in an orderly manner.

☺ The interphase is divided into three further phases:

(i) **Gap-1 phase** (G_1 phase):

(ii) **Synthesis** (S-phase)

(iii) **Gap-2 phase** (G_2 phase)

(iv) G_0 or **quiescent** phase is also present in some cells

Table: Events occurred in Interphase

Phase	Events Occurred
Gap-1 or **post-mitotic** or **pre-DNA synthetic phase**	◆ It is the **period** between mitosis and initiation of DNA replication (S-phase) ◆ Cell is metabolically active, cell **continuously grows** and synthesises many **biomolecules** (proteins, RNA, ATP, **amino acids** for the synthesis of histone in later stages etc.) needed for S-phase ◆ Many **organelles duplicate** in this phase ◆ The embryonic cells divide at a faster rate as they have **shorter G_1 phase** so the cell division takes quite less time. ◆ It is called as the **decision making phase** as S-phase is quite energy requiring process and the cell cannot waste so much energy without commitment. So if the decision is made in G_1 phase for division, the cell will continue the division even in unfavorable conditions (lack of nutrients etc.)

Phase	Events Occurred
G_0/ quiescent stage	◆ Some cells in the adult animals do not divide (**heart cells, neurons**) and some divide occasionally only when cells are lost due to injury or cell death (**lining of stomach** is replaced twice a week as it is excoriated and damaged by highly acidic HCl). ◆ These cells that do not divide further **exit G_1** phase to enter an inactive stage called G_0 (cells remain **metabolically active** in this stage but can no longer proliferate unless stimulated by a signal depending upon need of organism)
S-phase	◆ **DNA synthesis** or replication takes place only (therefore the amount of DNA per cell doubles, i.e., from **2C to 4C**) ◆ There is **no increase in the chromosome number** (will be same as that of G_1) ◆ **Histone** protein formation occurs in this phase ◆ **Centriole** duplicates in the cytoplasm with DNA in nucleus (this happens in animals as centrioles are not present in plant cells) ◆ Due to the presence of centriole, the division is called **astral** (star shaped) in animal cells (**amphiastral** term is also used for animals as 2 stars are formed at opposite poles) and anastral in plants (centriole absent)
Gap-2 or **pre-mitotic** or **post-synthetic phase**	◆ It is the **duration** between S and M phase ◆ **Some organelles duplicates** in this phase such as mitochondria and chloroplast ◆ **Tubulin** protein that forms the spindle fibres are synthesised during this phase (helps to move the chromatids to opposite poles) ◆ **Proteins, RNA** are synthesized in preparation for mitosis while cell growth continues

2. M Phase (Mitotic phase/ actual cell division).

☺ This is the **most dramatic** period of the cell cycle where virtually all components of the cell are reorganized.

☺ In the 24 hour average duration of cell cycle of a human cell, cell division proper lasts for only about an hour (less than **5%** duration).

☺ Components of a cell already duplicated in interphase are now distributed to the daughter cells in M-phase.

☺ In **animals**, mitotic cell division is **only** seen in the **diploid somatic cells** (in diploid germ cells, meiosis is responsible for the formation of gametes). Against this, the plants can show mitotic divisions in both diploid and haploid (meiosis in sporophyte produces haploid spores in case of bryophytes after which, the spores divide by mitotic divisions to form the gametophyte) cells.

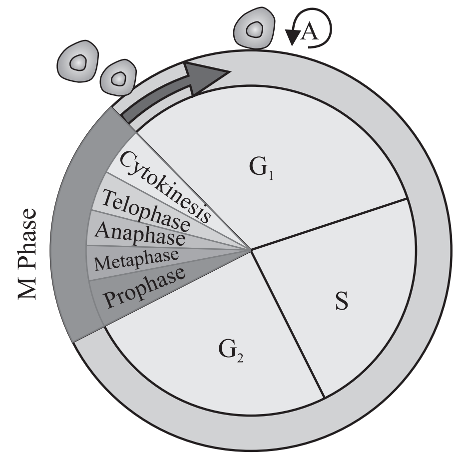


Fig.: A diagrammatic view of cell cycle indicating formation of two cells from one cell

☺ It is of three types - **amitosis**, **mitosis** and **meiosis**.

Amitosis

☺ **Amitosis** is also called as direct cell division.

☺ In this division, there is **no differentiation of chromosomes** and spindle. The nuclear envelope does not degenerate. The nucleus elongates and constricts in the middle to form two daughter nuclei. This is followed by a centripetal constriction of the cytoplasm to form two daughter cells.

Examples: Prokaryotes, protozoans, yeasts, foetal membrane of mammals, cartilage of mammals, etc.

Mitosis

☺ Mitosis is called as **equational** division (no change in number of chromosomes in parent cell and daughter cell).

☺ Cell division is a progressive process and very clear-cut lines cannot be drawn between various stages but there are some changes occurring in cell that will tell us about the phase in which a cell is present.

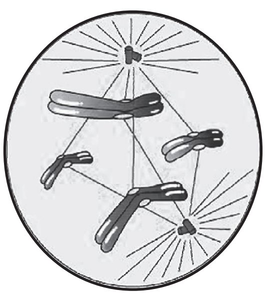
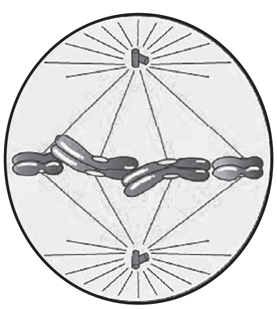
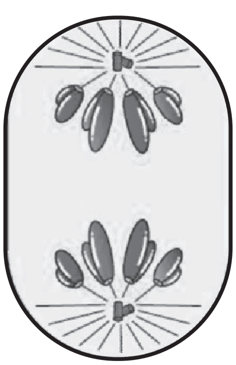
☺ 2 major processes occur during M-phase:

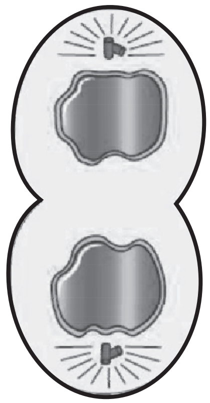
A. Karyokinesis: M Phase starts with the nuclear division, corresponding to the separation of daughter chromosomes.

B. Cytokinesis: M Phase usually ends with division of cytoplasm.

A. Karyokinesis

● Mitosis has been divided into **four stages** of nuclear division (Karyokinesis) for convenience: namely prophase, metaphase, anaphase and telophase.

Phase	Events
Prophase  **Fig.:** Early prophase  **Fig.:** Late prophase	◆ Follows the S and G_2 phases of interphase (**first step of karyokinesis**) ◆ 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 (it is like a **woolen ball** at **spireme stage**) ◆ The centriole begins to move towards opposite poles of the cell. ◆ The completion of prophase can thus be marked by the following **characteristic events**: a. Chromosomal material condenses to form **compact mitotic chromosomes**. Chromosomes are seen to be composed of **two chromatids** attached together at the centromere (called primary constriction). b. Centrosomes which have undergone duplication during interphase **begin to move** towards the opposite poles of the cell. Each centrosome radiates out microtubules called asters. The two asters together with spindle fibres form mitotic apparatus. c. At the end of prophase, cell when viewed under the microscope, do **not show** golgi complexes (GC), endoplasmic reticulum (ER), **nucleolus and the nuclear envelope**.
Metaphase  **Fig.:** Transition to metaphase  **Fig.:** Metaphase	◆ **Second phas**e of mitosis which is started after complete disintegration of the nuclear envelope, hence the **chromosomes** are **spread** through the cytoplasm of the cell (since no boundary is there to hold the chromosomes) ◆ By this stage, condensation of chromosomes is completed and they can be observed clearly under the microscope (this stage is the best stage to study the **morphology** of chromosomes). ◆ Metaphase chromosome is made up of **two sister chromatids**, which are held together by the centromere. ◆ There is a **proteinaceous small disc** that covers the centromere on its surface called **kinetochore**. Kinetochores serve as the sites of attachment of spindle fibres (formed by the spindle fibres) to the chromosomes that are moved into position at the centre of the cell. ◆ **Metaphasic plate formation:** Metaphase is characterised by all the chromosomes coming to lie at the **equator** (called **congression or metakinesis**) 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. ◆ Metaphasic plate is **single** here but **double** metaphasic plates are formed during **Meiosis-I**. ◆ The **key features** of metaphase are: a. Spindle fibres attach to kinetochores of chromosomes b. Chromosomes are moved to spindle equator and get aligned along metaphasic plate through spindle fibres to both poles.
Anaphase  **Fig.:** Anaphase	◆ In beginning of anaphase, the chromosomes arranged at the metaphasic plate is **split** (so doubles in number) simultaneously and the two daughter chromatids (now referred to as chromosomes of the future daughter nuclei) begin their **migration** towards the two **opposite poles** by the virtue of spindle fibers. ◆ As each chromosome moves away from the equatorial plate (known as **anaphasic movement that requires ATP**) the **centromere** of each chromosome is towards the pole and hence at the **leading** edge, with the **arms** of the chromosome **trailing behind** (at this time, the shape of chromosome can be easily studied as the moving chromosomes make some patterns such as **I, J, V and L** which represents the shape of chromosomes). ◆ Anaphase stage is **characterised by:** a. Centromere split and chromatids separate b. Chromatids move to opposite poles.

Phase	Events
Telophase  **Fig.:** Telophase	◆ Final stage of karyokinesis which is also referred as **reverse of prophase** ◆ The chromosomes that have reached their respective poles **decondense** and **lose their individuality.** ◆ The individual chromosomes can no longer be seen and each set of chromatin material tends to collect at each of the two poles ◆ Mitotic **spindle disappears** ◆ This stage shows the following **key events:** a. Chromosomes cluster at opposite spindle poles and their identity is lost as discrete elements b. Nuclear envelope develops around the chromosome clusters at each pole forming 2 daughter nuclei. c. Nucleolus, golgi complex and ER reform ◆ 2 daughter cells will be formed after cytokinesis (division of cytoplasm)

B. Cytokinesis

- Cell division is completed after the division of parent cell into 2 daughter cells by cytokinesis which takes place after karyokinesis.
- **Furrow formation:** In an **animal** cell, this is achieved by furrow formation in the plasma membrane. The furrow gradually **deepens** (from periphery to centre i.e. **centripetal**) and ultimately joins in the centre dividing the cell cytoplasm into two parts.
- **Phragmoplast/ cell plate formation:** Plant cells are enclosed by a relatively inextensible cell wall, so they undergo cytokinesis in a different manner. The wall formation starts in the centre of the cell and grows outward (i.e., **centrifugal**) to meet the existing lateral walls. The formation of the new cell wall begins with the formation of a simple precursor (like very small residual parts of **GC and ER**), called the cell-plate that represents the middle lamella between the walls of two adjacent cells.
- At the time of cytoplasmic division, **organelles** like mitochondria and plastids get **distributed** between the two daughter cells so that both the daughter cells can function well and that's why these organelles are duplicated in interphase.
- 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).

Sometimes the septa or cross wall is not present between cells due to which they appear to be multinucleated, this condition can be referred as **coenocytic condition**.

Significance of Mitosis:

☺ Mitosis is usually restricted to the **diploid cells only**. In some lower plants and in some social insects haploid cells also divide by mitosis.

☺ **Cell growth:** The **growth** of multicellular organisms is due to mitosis (from single celled zygote to an adult).
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.
Low nucleo-cytoplasmic ratio stimulates cell division in a cell.
Mitotic divisions in the **meristematic** tissues-the apical and the lateral cambium, result in a continuous growth of plants throughout their life. It also occurs in parts of a plant such as **leaves, fruits,** etc.,

☺ **Cell repair:** Lost cells in case of injury and trauma can be replaced by mitosis.
The cells of the upper layer of the epidermis, cells of the **lining of the gut** (twice a week), and blood cells (e.g., **RBC** has a life span of 120 days) are being constantly replaced.

☺ **Reproduction:** For simpler organisms (**unicellular eukaryotic** organisms), mitosis serve as a mode of **reproduction.**

Meiosis

- Sexual reproduction involves the formation and fusion of haploid (containing only single set of chromosomes) gametes from diploid cells (spermatogonium and oogonium in case of animals).
- Since we need to make a haploid cell from diploid cell, so we have to decrease the chromosome number by half. For this we need meiosis which is called as **reductional division** as it decreases the chromosome number by half.
- Meiosis ensures the production of haploid phase in the life cycle of sexually reproducing organisms whereas fertilisation restores the diploid phase (2 gametes fuses to form diploid zygote).
- Meiosis plays a vital role during **gametogenesis** in plants and animals.

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 (only during meiosis-I).
- Meiosis-I is initiated after the parental chromosomes have replicated to produce identical sister chromatids at the S phase.

- Meiosis involves pairing of homologous chromosomes and recombination between them.
- **Four haploid cells** are formed at the end of meiosis-II.

Meiosis-I

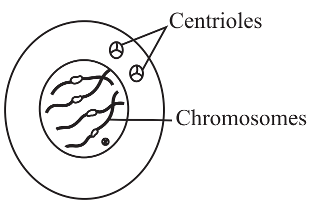
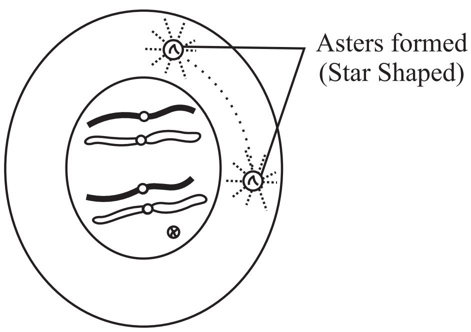
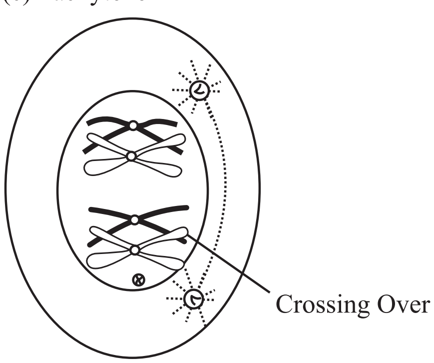
☺ Meiosis-I is the first stage in meiosis which is comprised of prophase-I, metaphase-I, anaphase-I and telophase-I. After this, meiosis-II will occur which is comprised of prophase-II, metaphase-II, anaphase-II and telophase-II.

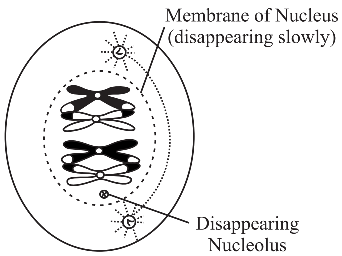
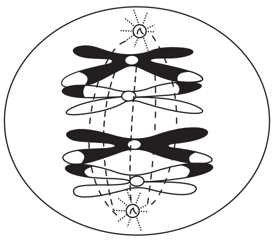
— KEY NOTE —

Meiosis-I is called as **reductional** division (chromosome number is reduced to half) and **meiosis-II** is called **equational** division which is just like mitosis.

☺ Prophase-I of meiosis I is quite complex and it will have **5 phases** namely: Leptotene, zygotene, pachytene, diplotene and diakinesis.

Table: Meiosis-I (Reductional Division)

Phase of Meiosis-I	Events
Prophase-I	◆ It is typically **longer** and more complex as compared to prophase of mitosis. ◆ It is further divided into Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.
(a) Leptotene  	◆ The **compaction** of **chromosomes** continues throughout Leptotene and chromosomes become gradually **visible** under the light microscope. ◆ It is called flower **bouquet stage** as in this stage, the chromosomes forms a basket like arrangement by **converging their telomeres** (end portions) towards a common point near centrosomes.
(b) Zygotene  	◆ Chromosomes start pairing together (this side by side association is called **synapsis**) ◆ Such paired chromosomes are called **homologous chromosomes** (same in size, form and have same arrangement of genes). Out of the 2 homologous chromosomes, **one is paternal and one is maternal.** ◆ Electron micrographs of this stage indicate that chromosome synapsis is accompanied by the formation of complex structure called **syneptonemal complex** which provides stability. ◆ The complex formed by a pair of synapsed homologous chromosomes is called a **bivalent** (bi means two as two homologous chromosomes combines) or a **tetrad** (tetra means four as there are four chromatids).
(c) Pachytene  	◆ Pachytene phase is quite longer as compared to leptotene and zygotene. ◆ 4 chromatids of each bivalent chromosomes now become distinct and **clearly appear as tetrads**. ◆ This stage is characterized by the appearance of **recombination nodules** the sites at which crossing over occurs between **non-sister chromatids** of the two different homologous chromosomes. ◆ Sister chromatids are the chromatids of same chromosome. ◆ Crossing over is the exchange of genetic material between two homologous chromosomes. ◆ Crossing over is also an **enzyme-mediated** process and the **enzyme** involved is called **recombinase**. ◆ Crossing over leads to recombination of genetic material on the two chromosomes by **breakage** and **rejoining** of DNA fragments. ◆ Recombination between homologous chromosomes is completed by the end of pachytene, leaving the chromosomes linked at the sites of crossing over.

Phase of Meiosis-I	Events
(d) Diplotene 	◆ The beginning of diplotene is recognized by the **dissolution** of the **syneptonemal complex** and the tendency of the recombined homologous chromosomes of the bivalents to separate from each other except at the sites of crossovers. ◆ These **X-shaped** structures which are the point of attachment of homologous chromosomes after dissolution are called **chiasmata** (become visible in this phase). ◆ In **oocytes** of some **vertebrates**, **diplotene can last for months or years** termed **dictyotene**.
(e) Diakinesis 	◆ The final stage of meiotic prophase-I ◆ **Terminalisation of chiasmata** occurs where chiasmata is **shifted** toward chromosomal ends and **slipped off**. ◆ During this phase the chromosomes are **fully condensed** and the **meiotic spindle is assembled** to prepare the homologous chromosomes for separation. ◆ By the end of diakinesis, the **nucleolus disappears** and the **nuclear envelope** also **breaks down**. ◆ Diakinesis represents transition to metaphase.
Metaphase-I	◆ The bivalent chromosomes comes to cytoplasm and align on the equatorial plate (**double metaphasic plate** formed due to chromosomes lying in parallel fashion) ◆ The microtubules from the opposite poles of the spindle attach to the pair of homologous chromosomes.
Anaphase-I	◆ The homologous chromosomes **separate** (number of chromosomes reduces as only one pair of chromosome will reach at each pole), while sister chromatids remain associated at their centromeres. ◆ Chromosomes start moving to opposite poles (disjunction) by the virtue of spindle fibers. ◆ Now the chromosomes are **monovalent** with 2 chromatids (after separation).
Telophase-I	◆ The **nuclear membrane and nucleolus reappear**; spindle disappears ◆ Cytokinesis follows and this is called as dyad of cells (2 cells are formed with half number of chromosomes as each daughter cell will have one chromosome out of the homologous pair).

Interkinesis

☺ The stage between the two meiotic divisions is called **interkinesis** and is generally short lived. There can be **centriole** duplication or **RNA/protein** synthesis during this phase but no DNA replication at all.

☺ Although in many cases the chromosomes do undergo some dispersion, they do not reach the extremely extended state of the interphase nucleus.

Meiosis-II

☺ Interkinesis is followed by prophase-II, a much simpler prophase than prophase-I as there are no phases in prophase-II of meiosis-II.

Table: Meiosis-II (Equational Division)

Prophase-II	◆ In contrast to meiosis I, meiosis II resembles a normal mitosis ◆ The **nuclear membrane and nucleolus disappears** by the end of prophase-II ◆ The chromosomes again become **compact**
Metaphase-II	◆ At this stage the chromosomes align at the **equator** and the microtubules from opposite poles of the spindle get attached to the kinetochores of sister chromatids
Anaphase-II	◆ It begins with the simultaneous **splitting** of the centromere of each chromosome (which was holding the sister chromatids together), allowing them to move toward opposite poles of the cell

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

Significance of Meiosis

☺ 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.

☺ 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.

☺ Thus 4 haploid cells are formed at the end of meiosis.

Table: Types of Meiosis

Type of Meiosis	Features
Gametic or terminal meiosis	Diploid organisms form haploid gametes. e.g., **Animals**
Zygotic meiosis	Haploid organisms use to form haploid gametes by **mitosis**. These gametes fuse to form diploid **zygote** which undergoes **meiosis** which is followed by **mitosis again** to form haploid adult. e.g., **Algae and fungi**
Sporic meiosis	Diploid sporocytes undergo **meiosis** which generates haploid **spores**. This haploid spore **germinates** and forms **haploid gametophyte** that generates haploid **gametes by mitosis**. These haploid gametes again fuse to form **diploid zygote**. e.g., **Bryophytes, pteridophytes**

Diagrammatic representation of meiosis-I and meiosis-II

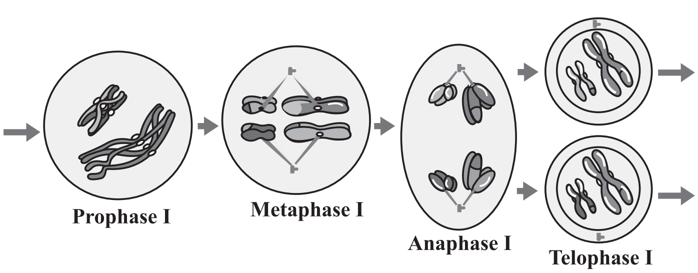


Fig.: Stages of Meiosis-I

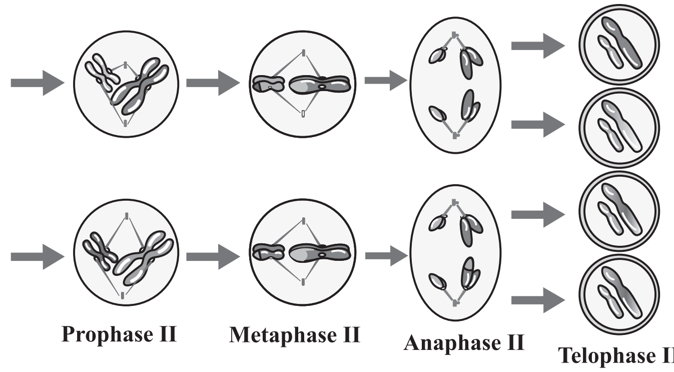


Fig.: Stages of Meiosis-II

☺ **Inhibitors of mitosis/ Mitotic poisons:** Cyanides, Azides, Ribonuclease (all 3 are **inhibitors of prophase**), Colchicine (inhibits **spindle formation** and **induces polyploidy**), Chalones, Mustard gas, Paclitaxel, Docentaxel etc. Since mitotic poisons are used to stop the cell division, they can be used to stop the **tumor** promoting/ cancerous cells.

☺ **Mitosis stimulators/ Mitogens:** Cytokinins, Auxin, Gibberlin, Epidermal growth Factor, Platelet Derived Growth Factor, Lymphokines.

Table: Types of Spindle Fibres

Spindle Fibres	Location
Continuous	As the name suggests, it will connect one pole of cell to the other
Discontinuous	As the name suggests, it will arise from one pole but don't reach to the another one
Chromosomal	Connect chromosomes to poles
Interzonal	Interconnect separating chromosomes during **anaphase**

Need To Know:

◆ If a cup is filled with bacteria in 10 minutes, how much time will it take to fill half cup if the bacteria divide once in 1 minute?

If bacteria divide once in 1 minute, we can say that their **number will be doubled every minute.** So if a cup is fully filled with bacteria in 10 minutes, it will be half filled in 9 minutes (not in 5 minutes).

◆ What is the number of generations required to form 64 cells by mitosis?

Now one cell divides to form 2 cells. 2 cells divides to form 4 cells, then 8, then 16, then 32, then 64 and so on.

To simplify this we can write it as 2^n. Therefore,

$64 = 2^6$ (so 6 generations are required).

◆ How many meiotic divisions will be required to form 100 zygotes/seeds/grains/fruits?

We know very well that the fusion of male and female gametes is required to form zygote and these gametes are in fact formed by meiosis. One meiotic division will form **4 eggs (3 degenerates and only one will become egg cell)** and one meiotic division in male forms **4 pollen grains**. So we need 100 eggs (100 meiosis)+100 pollens (25 meiosis)= 125 meiotic divisions to form 100 zygotes/ seeds/ grains/ fruits.

A general formula which we can use is **'1.25x'** where **'x' is the number of zygotes** to be formed and **1.25x is the number of meiotic divisions** occurred.

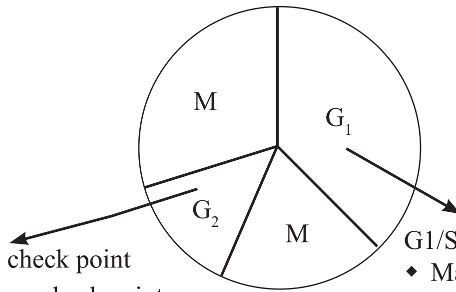
Regulation Of Cell Cycle

☺ Cell cycle take place in a very **regulated** manner and many **check points** are present over there which ensures the **correct replication** of DNA and **distribution** of cell constituents in daughter cells.

☺ One checkpoint that we have talked about is in **G_1 phase** (**commitment** phase) which ensures the division once the cell enters S-phase. If the cell is not in a condition to divide, then it enters the quiescent phase.

☺ Other checkpoints are also present when the cell does transition from **G_2 to M** phase.

☺ There are some proteins that regulate and check the cell cycle progression. These proteins are termed as **Cdk (cyclin dependent kinases).** As the name indicates, these proteins require some other proteins for activation which are called cyclins. **Kinases** are enzymes (proteins) which are involved in the transfer of phosphate group.



G_2/M check point
- Minor check point
- By MPF (maturation promoting factor)

↓

Mitotic cyclin + cdc2.

G1/S check point
- Major check point
- By G_1 cyclin – co

Fig.: Various cell cycle checkpoints are shown in the figure

ABOUT PHYSICS WALLAH

Alakh Pandey is one of the most renowned faculty in NEET & JEE domain's Physics. On his YouTube channel, Physics Wallah, he teaches the Science courses of 11th and 12th standard to the students aiming to appear for the engineering and medical entrance exams.

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