



Chapter # 21

Cell Cycle



Q.1. What is cell cycle? Explain the different stages of interphase stage.

Ans. CELL CYCLE:

“The sequence of changes in cell involving period of growth replication of DNA, followed by cell division is called cell cycle”.

In other words life of a cell is often described as a cell cycle.

PHASES OF CELL CYCLE:

Cell cycle is divided into two phases.

Inter Phase:

It is period between two cell divisions and is period of non-apparent division.

Mitosis:

It is Period of division.

INTER PHASE

“The period of life cycle of cell (cell cycle) between two consecutive divisions is called inter phase”.

This Phase is also called resting phase which is not true. It is actually a period of biochemical activity which is further divided as follows.

(1) G_1 (2) S (3) G_2

At each stage there are specific points which determine the fate of new phase according to cells internal make up. Length of each phase is variable In humans it is of 24 hours mitosis is 30 minutes G_1 , 9 hours, S phase 10 hours and G_2 4.5 hours. In yeast cell cycle completes in 90 minutes.

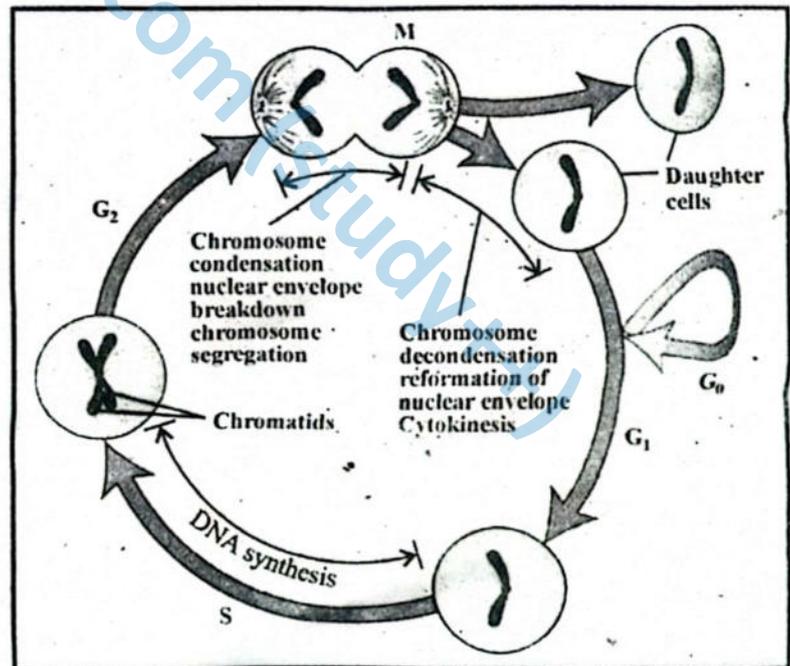


Fig. The fate of a single parental chromosome throughout the eukaryotic cell cycle .



G₁ (Gap 1):

The first part of the inter phase is G₁. During this time cell grows about twice its original size due to extensive metabolic activity. Growth includes protein synthesis. DNA base unit are accumulated for DNA synthesis. This lasts for about 8 hours.

Go stage:

Some times post-mitotic cell can exit in the cell cycle during G₁ entering a phase called G₀ and remain for days, weeks or in some cases like nerve cells and cells of eye lens remain for life time with out proliferating further.

S phase (Synthesis Phase)

After the G₁ phase S phase takes places. In this phase DNA is synthesize and chromosome number get doubled which initiates G₂ phase.

G₂ phase (Gap 2, Pre-mitotic phase)

In. this phase energy is stored for chromosome movements, mitosis specific proteins RNA and microtubule subunits are synthesized.

Q.2. Define is mitosis. Explain in detail the karyokinesis and cytokinesis phases of mitotic division. Write the importance of mitosis.

Ans: Mitosis:

It is a process of nuclear and cell division in which the number of chromosomes in daughter cells are same as that of parent cell.

Mitosis of plant and animal cell is same with only few differences.

Phases of mitosis:

Mitosis is a continuous process which has two phases.

1. Karyokinesis.
2. Cytokinesis

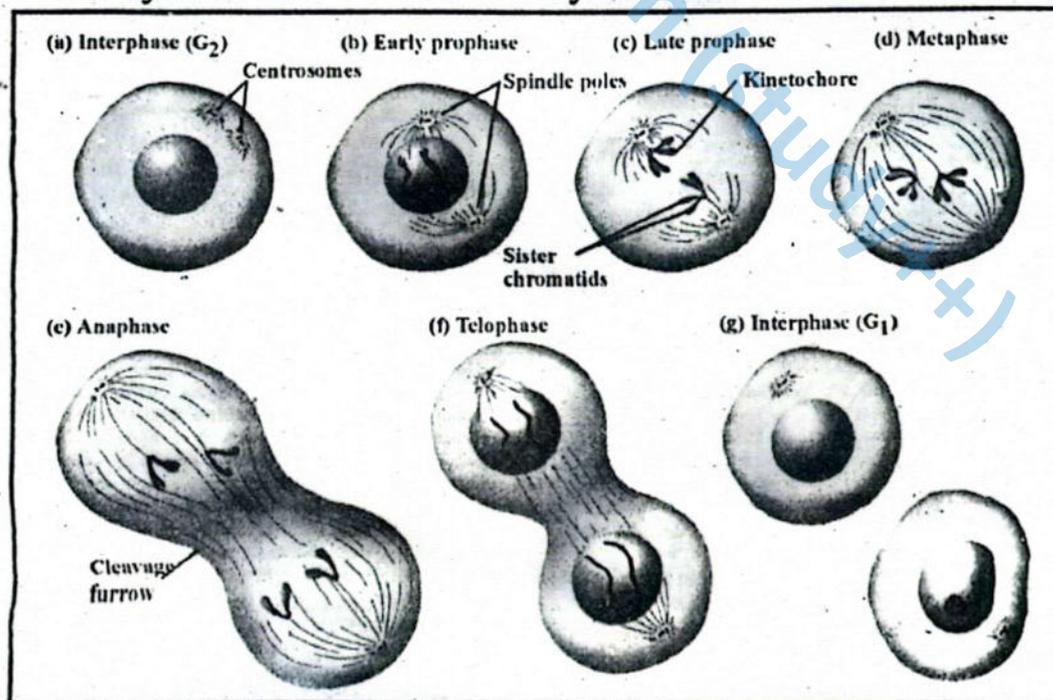


Fig. The stages of mitosis and cytokinesis in an animal cell.

1. KARYOKINESIS:

This phase involves the nuclear division. Animal cell has a special structure for cell division called centriole. At the start of mitosis centriole is divided into two pairs. Each pair migrate to the opposite side of the nucleus thus forming two poles of the dividing cell.

Mitotic apparatus:

The microtubules including aster and spindle are called mitotic apparatus. Their size is larger than nucleus. The function of the mitotic apparatus is to attach and capture chromosomes, align them correctly and separate them so that equal distribution of chromosomes should take place.

Types of Microtubules

The microtubule are sets of fiber which are three in number. They originate from each pair of centrioles. One set of microtubule is called astral microtubules which form asters outward. The other two sets form the spindle in which one is kinetochore microtubules and other is polar microtubules. The kinetochore microtubules are attached to the chromosomes at kinetochore. Polar microtubules do not interact the chromosomes but interdigitate with polar microtubules from opposite pole.

The microtubules are composed of protein tubulin and traces of RNA.

STAGES OF KARYOKINESIS:

Karyokinesis is further divided into four stages.

- | | |
|----------------|----------------|
| (i) Prophase | (ii) Metaphase |
| (iii) Anaphase | (iv) Telophase |

(i) Prophase (pro-first, phage - stage : first stage)

Chromosomes can not be seen in the inter phase stage even by using electron microscopy. However by using some special stains chromatin network of fine threads can be seen which is called chromatin. The following events take place in prophase.

1. Nuclear envelope along with nucleoli disappears.
2. Centrioles completely migrate towards their pole.
3. Mitotic apparatus is organized.
4. Cytoplasm becomes more viscous.
5. The chromatin material get condensed by folding and chromosome appear as thin threads and eventually become thick consisting of two chromatids attached with centromere.

(ii) Metaphase (meta - middle : attachment of chromosomes in the middle)

At metaphase chromosomes have become completely thick consisting of chromatid. These chromatids are attached to centromere. The centromere has special area the **kinetochore** where kinetochore fibres of mitotic apparatus be attach. The kinetochore fibers of spindle attach to kinetochore region of chromosome and align them *at the equator* of the spindle forming equatorial plate or meta phase plate. Each kineto chore get two fibers each from opposite poles.



(iii) Anaphase (upward movement)

It is very important phase of mitosis. The kinetochore fibers of spindle contract towards their respective pole, exert force which separates the two chromatids from centromere. In this way two sister chromatids are formed. Half of them moves to one pole and other half towards other pole.

(iv) Telophase (Tail - last)

As the chromosomes reach to their respective pole telophase starts. The chromosomes starts unfolding and become chromatin material. Mitotic apparatus starts disappearing while nucleus and nucleoli appears and thus two nucleoli are formed at each pole of the cell.

2. CYTOKINESIS:

"The division of whole cell is called cytokinesis"

Cytokinesis is a phase of the mitosis in which whole cell of the divides. At this phase (in late telophase) the astral microtubules send signals to equatorial region of cell which activate actin and myosin to form contractile ring. This contractile ring form cleavage furrow in the center of cells which get deepens gradually and ultimately divide the parent cell into two daughter cells.

DIFFERENCE OF MITOSIS IN PLANT AND ANIMAL CELLS:

Most of the events of mitosis is same in plant and animal cells but there are some differences which are as follows.

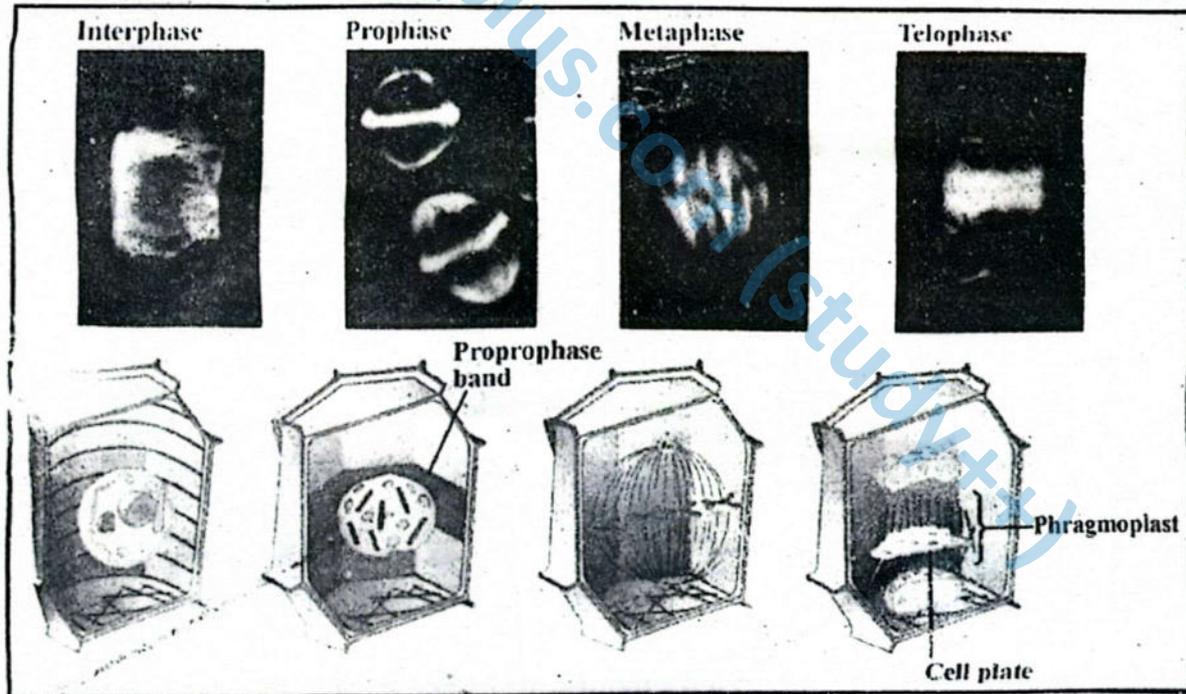


Fig. Mitosis in a higher plant cell

- (i) Higher plants do not have centrioles. They have analogous region instead of that from which spindle microtubule radiates.
- (ii) The shape of plant cell do not change as much as that of animal cell. This is due to presence of cell wall.

(iii) At cytokinesis, animal cell forms contractile ring but plant cell do not form such ring. Instead they form phragmoplast which is membranous structure which is formed from the vesicles of golgi complex.

At metaphase these vesicles are linked in the center and fuse to form phragmoplast at end of telophase. These vesicles have precursors of cellulose and pectin which is future material of cell wall.

IMPORTANCE OF MITOSIS:

Mitosis play an important role in life of cell which is as follows.

Equal Distribution of Hereditary Material

1. Equal distribution of hereditary material:

Due to mitosis number of chromosomes remain same as that in parent cell because hereditary material is equally distributed.

2. Genetic information remains unchanged:

No genetic variation occur because crossing over does not take place thus genetic information remains unchanged generation after generation.

3. Many types of reproduction:

Mitosis is a source of many types of reproduction such as regeneration, healing of wounds and replacement of older cells.

4. Development and growth:

Development and growth of multicellular organism depends upon orderly mitosis.

5. Tissue culturing and cloning:

Mitosis is helpful in cloning and tissue culture.

Q.3. What is cancer? Write the relationship of cancer with that of cell cycle?

Ans. CANCER (uncontrolled cell division)

It is a lethal disease in which cells begin to grow and divide in unregulated fashion without body's need.

We can say:

"Any malignant growth or tumor from an abnormal and uncontrolled division of body cells is known as cancer".

TUMORS:

When cells continue to grow then they produce tumor which are mostly found in older animals. Tumors are of two types.

1. Benign tumor
2. Malignant tumor

1. Benign tumor:

Benign tumor is of small size and does not transfer to other parts of body i.e. they are localized this tumor has not very destructive effect.

2. Malignant Tumor:

The cells of malignant tumor divide very rapidly and spread on surrounding tissues. They also enter blood circulatory system and set up areas of proliferation away from their site of original appearance. This tumor cause cancer and show many dangerous results.



The spread of tumor cells as establishment of secondary areas of growth is called metastasis.

Recognition of cancerous cells:

The cancerous cells are little bit different from normal cells. They have high nucleus to cytoplasm ratio, prominent nucleoli and many mitosis. The presence of such cells is the sign of malignancy.

Causes of cancer:

There are two causes of cancer.

- (i) Mutations in somatic cells.
- (ii) Secondly the cancer results from the accumulation of as few as three to as many as twenty mutations, in genes that regulate cell division.

Changes in Cancerous Cells due to Mutation

The mutation bring two basic changes.

- (a) The metastatic cells break their contact with other cells and overcome the restrictions on cell movement provided by basal lamina and other barriers ultimately metastatic cells can invade other parts of body.
- (b) They proliferate unlimitedly without considering the checks or programmes of the body.

Q.4. Write a detail account on meiosis emphasizing on the stages of prophase I.

Ans: MEIOSIS:

Definition:

Meiosis is a special type of cell division in which the number of chromosomes in daughter cells are reduced to half as compared to parent cell.

Occurrence:

In animals it occurs in diploid cells at gamete formation while in plants it takes place at spore formation.

TYPES OF DIVISION:

Two divisions take place in meiosis meiosis I and meiosis II. The first meiotic division is reduction division and second meiotic divisions is like that of mitosis. After two division diploid cell produce four haploid cells.

Interphase

The interphase of meiosis

MEIOSIS I:

Meiosis I is further divided into four sub-stages as follows:

1. Prophase I :

Prophase I is a very long phase. The chromosomes in this phase behave like the homologous pairs which is different as that from mitosis. The similar chromosomes are called **homologous chromosomes**. Each chromosome has two chromatids because chromosomes have been replicated during interphase. Prophase I is further divided as.



(i) Leptotene:

At this time chromosomes are seen which have become thick and short. The size of the nucleus increase and homologous chromosomes become closer. The time duration is few hours.

(ii) Zygotene:

The homologous chromosomes get paired to form tetrad or bivalent. This pairing is specific with no definite starting point. The synapsis also start at this point. It lasts for few hours. At his phase nuclei also disappears. Each paired but not fused complex structure is called bivalent or tetrad.

(iii) Pachytene:

In pachytene stage very important event occurs which is called *crossing over*. As the pairing of homologous chromosomes completed chromosomes become very thick. Each bivalent has four chromatids chiasmata is formed and non-sister chromatids of homologous chromosomes exchange their segments. This is called crossing over. Crossing over is helpful in reshuffling genetic material. The time for pachytene stage is not fixed. It may prolong from days to week even to years.

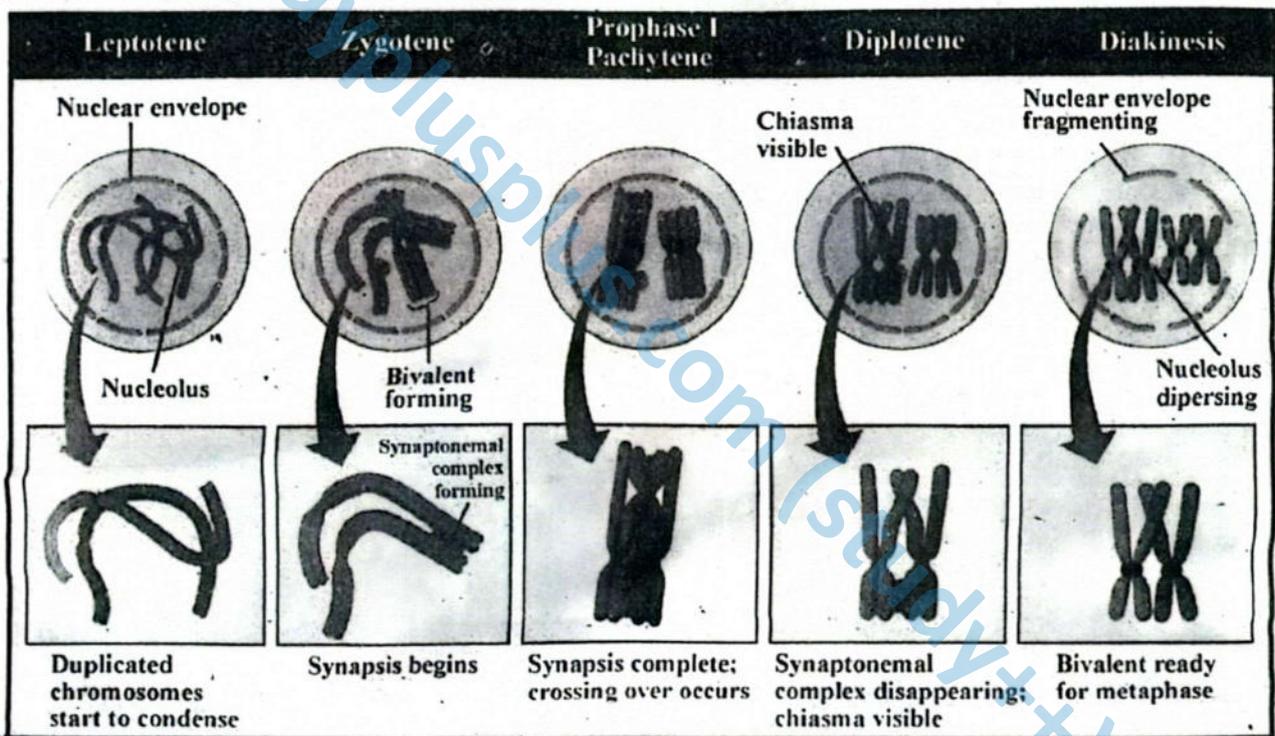


Fig. Chiasmata formation

(iv) Diplotene:

After the crossing over the paired chromosomes start separating from one another however they do not get separated completely as they remain united at chiasmata. Each bivalent has united points.

(v) Diakinesis:

Chromosomes reach to condensation at maximum at this phase. Homologous chromosomes get separated but attached at one point more of tenly at ends. Nucleoli disappear point of.

2. Metaphase I:

At the beginning of this phase nuclear membrane start dis-organizing. Spindle fibers originate and the kinetochore fibers attach to the kinetochore of homologous chromosome from each pole and arrange bivalents at equator. The sister chromatids of individual chromosome in bivalent behave as a unit.

4. Telephase I:

At this stage nuclear membrane reorganizes around each set at two poles, nucleoli also appears. Thus in this way two nuclei each with half number of chromosomes are formed, each on to plasma divides. The first meiotic, division finishes at this point.

Meiosis II:

A short period of interphase takes place in two daughter cells after telophase I. Here no replication of chromosomes occur.

All the phases prophase II metaphase II anaphase II and telophase II all are like mitosis. During these phases mitosis apparatus appear, chromosomes condense and arrange themselves at equator sister chromatid separates and at last four nuclei at respective poles of two daughter cells are formed. Cytokinesis takes place and four haploid cells are formed which have half number of chromosomes.

Importance of Meiosis

1. Variation

Two significant processes take place during meiosis. These are

* Crossing Over

The parental chromosomes exchange segments with each other during crossing recombinations.

* Random assortment of chromosomes

The separation of homologous chromosomes in random during anaphase. It gives a large variety of gametes.

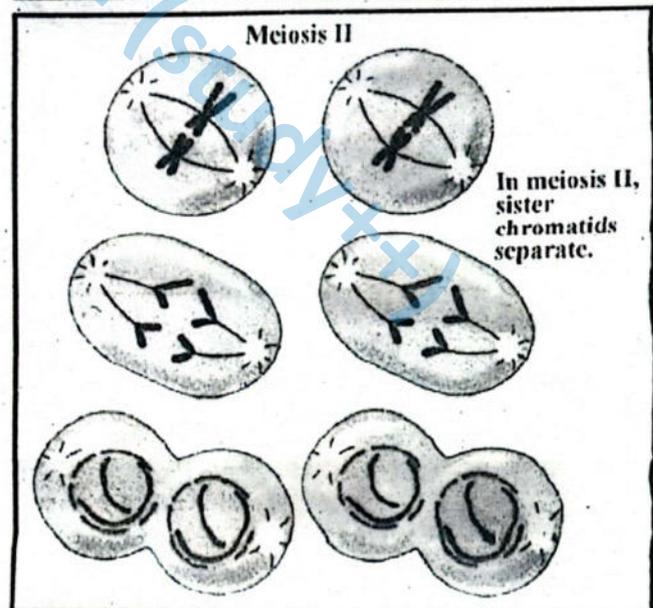
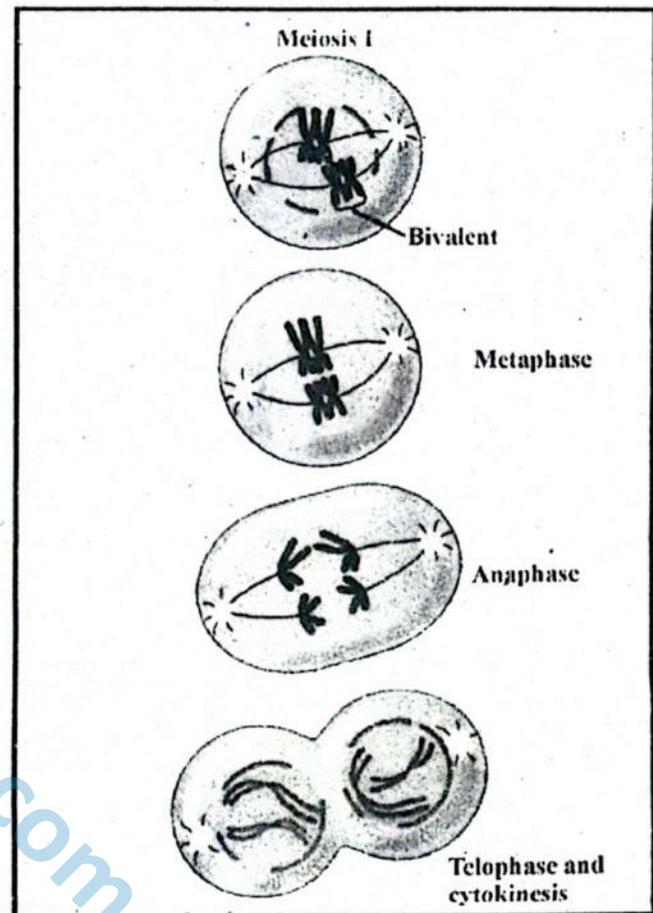


Fig. Result of meiosis, four haploid cells, each with half as many chromosomes as the original cells

Both these phenomenon cause variation and modification in the genome. These variations are the bases of evolution. These variations also make every individual specific particular and unique in his characteristics. Each the progeny of very same parent i.e., brothers and sisters are not identical to each other.

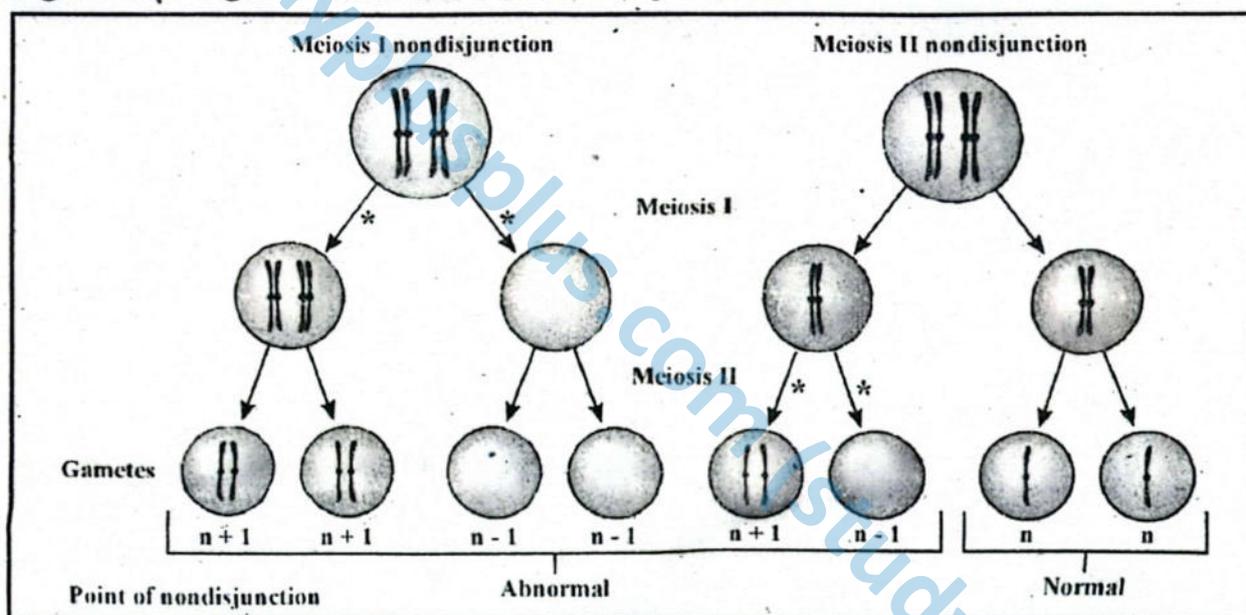
2. Constant Number of Chromosomes in each Generation

During the gamete formation meiosis takes place which gives half number of chromosomes. When these gametes fuse or fertilize then the number of chromosomes is restore and thus it remains constant generation after generation e.g. Drosophila has total 8 chromosomes, gametes have 4 chromosomes when these 4 + 4 (male and female) fuse the number of chromosomes in zygote revisions constant.

Q.5. What is non disjunction? Describe different types of nondisjunction.

Ans: **NON-DISJUNCTION:**

The abnormality in which during meiosis chromosomes fail to segregate during anaphase and telophase and does not finish with equal distribution of chromosomes among all the daughter nuclei is called non disjunction.



Syndrome	Sex	Chromosomes	Frequency	
			Abortuses	Births
Down	M or F	Trisomy 31	1/40	1/700
Patau	M or F	Trisomy 13	1/33	1/15,000
Edward	M or F	Trisomy 18	1/200	1/6,000
Turner	F	XO	1/18	1/6,000
Metafemale	F	XXX (or XXXX)	0	1/1,500
Klinefelter	M	XXY (or XXXY)	0	1/1,500
Jacobs	M	XYY	?	1/1,000

Fig. Non-disjunction of autosomes (a) Non disjunction occurring during meiosis I and meiosis II, gametes (asterisks mark points of non-disjunction). (b) Frequency of syndromes

Non-disjunction is actually a meiotic disorder which may cause decrease or increase of the number of chromosomes. The result may be serious physical, social or mental disorders.

Types of Non-disjunctions:

Non-disjunction may be in autosome or in sex chromosome. There are three types of non-disjunction.

1. Down's syndrome
2. Kline felter's syndrome
3. Turner's syndrome

1. DOWN'S SYNDROME MONGOLISM:

This non-disjunction occur in autosomes of man. During the gamete formation 21st chromosome fails to segregate and gamete with 24 chromosomes is produced. When this gamete fertilizes with normal gamete then the individual with 47 (2n+1) chromosomes will produce. Some autosomal non-disjunction may occur in other than 21st chromosome which results in abortion or death in very early stage.

Chances of Down's syndrome:

The chances of child having downs syndrome is one in many thousand if mother is teenage while of forty years old mother it is one in hundred. The risk is increased three times in forty five years old mother.

Effects:

The affected individuals have flat, broad face, squint eyes with skin fold in inner corner, protruding tongue, mental retardation and defective development of central nervous system.

2. Kline filter's syndrome:

In this type of syndrome the individuals have additional sex chromosome e.g. 47 chromosome (44 autosome +xxy). Variations have been seen in this non disjunction where males with 48 chromosomes (44 autosome+xxxxy) and 49 chromosomes (autosomes +xxxxxy) are also observed.

Effects:

Such individuals are phenotypically male but have enlarged breasts tendency to tallness, obesity, small testis with no sperms and poorly developed secondary sexual characters.

3. Turner's syndrome:

The individuals affected by Turner's syndrome have one missing X chromosome with only 45 chromosomes (44 autosomes +y).

Effects:

Such individuals mostly do not survive long but those who survive have female appearance with short stature webbed neck, no ovaries and germ cells.



Q.6. Write a note on necrosis and apoptosis.

Ans: APOPTOSIS:

Necrosis and apoptosis are the two ways of cell death (Greek word falling off, dropping off).

Apoptosis

Internal program of events and sequence of morphological changes by which cell commit suicide is collectively called as apoptosis.

Effects:

The dying cell shrink and get condense which ultimately split up and release a small membrane founded **apoptotic body** which phagocytose other cells.

Programming in cells:

The cells are already programmed for different activities like cell division, pattern formation, differentiation etc. Each cell is predestined to its fate i.e. what responsibility it has to take in which way. Even the death of cell is programmed.

Advantages of the programming:

Cell death programming of the cell helps a lot. It helps in deletion of whole structures like the tail of developing embryo in humans or part of structure like digits. Cell death controls the number of neurons because most of the neurons in the human body die during development.

NECROSIS:

The cell death due to tissue damage is called necrosis.

Effects:

The resulting cell swells and bursts releasing intracellular contents and cause inflammation.

Causes:

- (i) Habitations in Somatic cells: The main reason of cancer is mutations in somatic cells.
- (ii) Mutations in Genes: The genes which regulate the cell division are affected by mutations which cause cancer. Such kind of mutations results in two kind of changes in cancerous cells. Firstly the metastasis cells spread in the body and secondly they start dividing uncontrolled and unlimited.

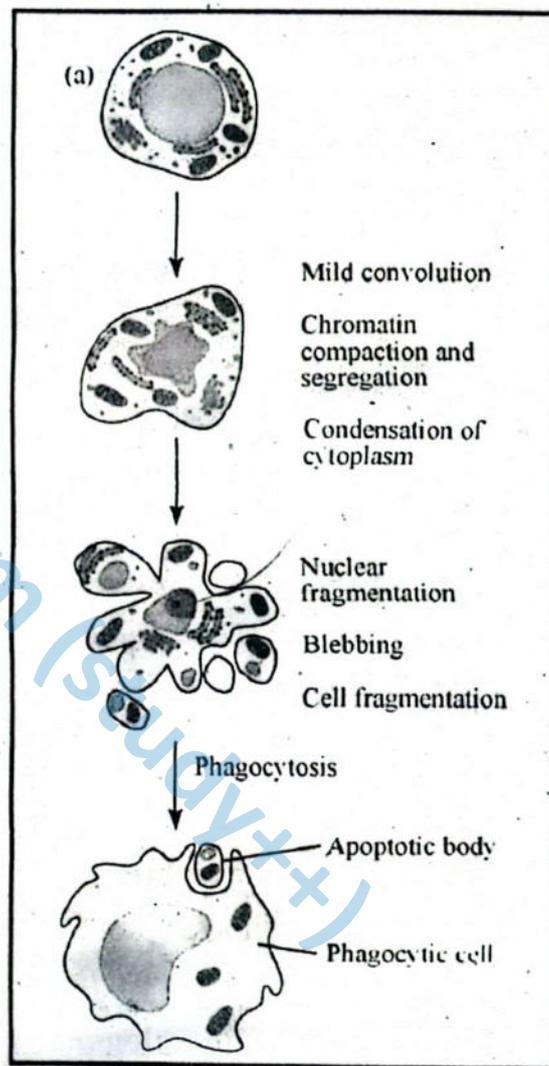


Fig. Ultrastructural features of cell death by apoptosis

◀ SOLVED EXERCISE ▶

Q.1: Fill in the blank with appropriate words.

- (i) Mongolism is also known as _____.
- (ii) During _____ homologous chromosomes get close to each other.
- (iii) _____ phase precedes G_2 phase.
- (iv) Polar microtubules _____ during anaphase.
- (v) Mitotic apparatus is formed during _____ of cell division.
- (vi) The chromosome number (44+1) denotes _____ syndrome.
- (vii) Intracellular contents are released during the type of cell death called _____.

Ans.

- | | |
|---------------------|----------------|
| (i) Down's Syndrome | (ii) meiosis |
| (iii) S-phase | (iv) elongates |
| (v) prophase | (vi) Turner's |
| (vii) necrosis | |

Q.2. Each question has four option. Encircle the correct answer.

- (i) **In klinefilter's syndrome**
 - (a) one x chromosome is missing
 - (b) additional sex chromosome is present
 - (c) sex chromosome fails to segregate
 - (d) none of these
- (ii) **Mitosis is divided into**
 - (a) karyokinesis
 - (b) cytokinesis
 - (c) interphase
 - (d) both a and b
- (iii) **Separation of homologous chromosomes occur during**
 - (a) prophase
 - (b) metaphase
 - (c) telophase
 - (d) anaphase

Ans.

- (i) (b) (ii) (d) (iii) (d)



Q.3. Write whether the statement is 'true' or 'false' and write the correct statement if it is false.

- (i) **Meiosis occurs in haploid cells only.** **False**
True: Meiosis occurs in diploid cells only.
- (ii) **Cell cycle is comprised of two phases i.e. karyokinesis and cytokinesis.** **False**
True: Cell cycle is comprised of two phases i.e. interphase and mitosis.
- (iii) **A point where non sister chromatids cross each other is called kinetochore.** **False**
True: A point where non sister chromatids cross each other is called chiasmata.
- (iv) **G₀ stands for no gap.** **False**
True: G₀ stands for gap.
- (v) **Full life cycle of yeast cells require 90 seconds to be completed.** **False**
True: Full life cycle of yeast cells require 90 minutes to be completed.
- (vi) **Crossing over takes place during metaphase I.** **False**
True: Crossing over takes place during prophase I.
- (vii) **Autosomal non disjunction may occur in other than 21st chromosome.** **True**
- (viii) **Benign tumors are always non localized.** **False**
True: Benign tumors are always localized.
- (ix) **Cancer is caused mainly by mutations in germ cells.** **False**
True: Cancer is caused mainly by mutations in genes.
- (x) **Genetic informations remain unchanged during mitosis.** **True**
- (xi) **Homologous chromosomes are necessarily identical.** **True**
- (xii) **The cells are kept alive due to trophic factors.**
- (xiii) **Cytokinesis involves the division of cytochromes.** **False**
True: Cytokinesis involves the division of cytoplasm.
- (xiv) **Phragmoplast is a type of fragmentation.** **False**
True: Phragmoplast is a contractile ring which is formed during the mitosis of plants.

Q.4 Short Questions

(i) **Differentiate between necrosis and apoptosis.**

Ans. The cell death due to tissue damage is called necrosis. While internal program of events and sequence of morphological changes by which cell commit suicide is collectively called as apoptosis.



(ii) **What are the functions of mitotic apparatus?**

Ans. The functions of the mitotic apparatus is to attach and capture chromosomes, align them correctly and separate them.

(iii) **How can you identify the cancer cells?**

Ans. The cancerous cells are little bit different from normal cells. They have high nucleus to cytoplasm ratio, prominent nucleoli and many mitosis. The pressure of such cells is the sign of malignancy.

(iv) **Give importance and significance of meiosis?**

Ans. 1. During the gamete formation meiosis takes place which gives half number of chromosomes. When these gametes fuse or fertilize then the number of chromosomes is restore and thus it remains constant generation after generation.
2. In meiosis crossing over takes place which gives genetic variability to the individuals.

(v) **Define chromosomal non disjunction.**

Ans. The abnormality in which during meiosis chromosomes fail to segregate during anaphase and telophase and does not finish with equal distribution of chromosomes among all the daughter nuclei is called non disjunction.

(vi) **What are symptoms of turner's syndrome?**

Ans. Such individuals mostly do not survive long but those who survive have female appearance with short stature webbed neck, no ovaries and germ cells.

(vii) **Define cell cycle. Highlight its importance and significance.**

Ans. Life of a cell is often described as a cell cycle. It is important because it includes growth period replication of DNA, followed by cell division.

(viii) **Is inter phase a resting phase? Why?**

Ans. No, inter phase is misleadingly called resting phase. It is the period of great biochemical activity.

(ix) **In what respect mitosis in plant cells differ from that of in animal cells?**

Answer

Mitosis in Animals	Mitosis in Plants
1. Mitotic apparatus of animals is composed of centrioles, spindle, tubules and esters.	1. The mitotic apparatus of plants lacks centrioles and ester. So it is composed of only spindle tubules.
2. The shape of the animal cell change greatly during mitosis.	2. The shape of the plant cell do not greatly changed during mitosis because cell is surrounded by thick wall.
3. The cytokinesis takes place by cleavage furrow formation.	3. The cytokinesis takes place by phragmoplast formation.



Q.5 Extensive Questions

(i) How cytokinesis occurs in animal cells? In which way does it differ from that in plant cell?

Ans. Please see Q. No. 2.

(ii) Why and how do the chromosomes get separated during anaphase of mitosis?

Ans. It is very important phase of mitosis. The kinetochore fibers of spindle contract towards their respective pole, exert force which separates the two chromatids from centromere. In this way two sister chromatids are formed. Half of them moves to one pole and other half towards other pole.

(iii) What is role of centriole in an animal cell? How this function is carried out in plant cell?

Ans. Centriole is a place for formation of mitotic apparatus in animals while in plants in place of centriole they have analogous region from which the spindle micro tubules radiate.

(iv) In what respect cell death be regarded beneficial.

Ans. Cell death controls the number of neurons because most of the neurons in the human body die during development.

(v) Compare mitosis with meiosis and describe their importance.

Ans.

MITOSIS	MEIOSIS
1. It is a process of nuclear and cell division in which the number of chromosomes in daughter cells are same as that of parent cell.	1. Meiosis is a special type of cell division in which the number of chromosomes in daughter cells are reduced to half as compared to parent cell.
2. In mitosis no crossing over takes place.	2. In meiosis crossing over takes place which can bring the genetic variability.
3. Mitosis can take place both in haploid and diploid cell.	3. Meiosis occurs in diploid cells only.
Importance: 1. Due to mitosis number of chromosomes remain same as that in parent cell because hereditary material is equally distributed.	Importance: 1. During the gamete formation meiosis takes place which gives half number of chromosomes. When these gametes fuse or



2. No genetic variation occur because crossing over does not take place thus genetic information remains unchanged generation after generation.

3. Mitosis is a source of many types of reproduction such as regeneration, healing of wounds and replacement of older cells.

4. Development and growth of multicellular organism depends upon orderly mitosis.

5. Mitosis is helpful in cloning and tissue culture.

fertilize then the number of chromosomes is restore and thus it remains constant generation after generation e.g. Drosophila has total 8 chromosomes, gametes have 4 chromosomes when these 4 + 4 (male and female) fuse the number of chromosomes in zygote revisions constant.

2. In meiosis crossing over takes place which gives genetic variability to the individuals.

(vi) Define disjunction and discuss its effect?

Ans. Please see Q. No. 5

(vii) Describe meiosis and explain significance.

Ans. Please see Q. No. 4

