Lesson - 2

29-06-2024

Cell Cycle and Cell Division

- The process of formation of new cells of their own kind by division of pre-existing cells is called cell division or cell reproduction
- Growth and reproduction are characters of all cells of all living organisms
- Cell division is a fundamental and intrensic property of cell. It is not only essential for growth of the organisms but it is necessary for continuity of life.
- New cells are arrised because of division of pre-existing cells. This was suggested by Rudolf Virchow in 1855 as "omnis Cellula E-Cellula" which means every cells are derived from pre-existing cells.
- The cells which undergo division is called mother cell while newly formed cells are derived as daughter cells.
- Cell division takes place when it has grown to certain maximum size ther the nucleo-cytoplasmic ratio gets disturbed.
- Cell division consists of 2 seperate processes namely:-

1 Karyokinesis

- The division of nucleas is Karyokinesis
- During Karyokinesis the chromosomes of parent cell are duplicated into 2 equal groups that is division of nucleas.

2 Cytokinesis

- Division of cytoplasm is cytokinesis.
- During cytokinesis division of cytoplasm takes place results in the division of cytoplasmic components approximately into 2 halves.

Significane of Cell Division

- Helps in growth, differentiation, reproduction and repair takes place through the cell division
- There are 2 types of cell division :-

1 Mitosis

2 Meiosis

Cell Cycle

- The series of events that takes place in life cycle of the cell is called cell cycle.
- The sequence of coordinated genetically controlled events by which cell duplicates ~~ints~~ genome and synthesis of other cells components and eventually divide into 2 daughter cells is called cell cycle
- During cell cycles the events like :-

1 DNA replication

2 Cell Growth takes place

- The cell growth and DNA synthesis differ in following ways
- Cell growth in terms of cytoplasmic increase in a continuos process.
- DNA synthesis occurs only during one specific stage that is S-phase of the cell cycle.

Significance of Cell Cycle

i Replication of DNA

ii Ensuring the exact distribution of chromosomes and cell content to daughter cell.

- The duration of cell cycle can vary from organism to organism and also cell type to cell type

Eg:-

- Human cell in culture divide once in approximately every 24 hours.
- Yeast cell divide approximately once in 90 minutes

Phase of Cell Cycle

- The Cell is divided into 2 phases:-

i Interphase :-

- It represent the phase between 2 sucessive M phases.
- It is the first phase and non diving phase of the cell cycle.
- The period between 2 mitotic phase is called as Interphase
- It is metabolically very active stage and takes about 95% of total duration of cell cycle.
- It is also called preperatory or resting phase
- During this phase both cell growth and DNA replication occurs in an orderly manner.

ii mitotic Phase :-

- It represents the phase when actual mitosis of cell cycle occurs.
- Cell division proper (M Phase) last only for about an hour in 24 hour of average duration of cell cycle in human cell.
- The Interphase last more than 95% of the duration of cell cycle.

- Interphase has 3 sub phase

i **G_1 Phase (Gap / Growth one phase):-**

- It is the first phase in the Interphase.
- It corresponds to the interval between mitosis and initiation of DNA replication.
- It is also called post mitotic gap phase and takes place at the end of the cell division.
- During this phase cell is metabollicaly active and continously grows but does not replicate its DNA

NEET During this phase synthesis of RNA and proteins take place

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ii **S - Phase (synthesis phase):-**

- It is the second phase of Interphase.

NEET. In this phase DNA synthesis or DNA replication takes place.

- The amount of DNA per cell doubles but chromosomes number remains same. Hence two chromatids per chromosome will be present at end of S-phase.
- If the initial amount of DNA is denoted as 2C then it increases to 4C but there is no increase in the chromosome number if the cell has diploid chromosomes at G_1 even after S phase the number of chromosomes remains same after S phase ie:- 2n

In animal cells during S phase:-

i DNA replication begins in the nucleas.

ii Duplication of centriole in the cytoplasm.

iii **G_2 Phase (Gap-two phase / Growth two phase)**

- It is the last phase of Interphase
- It is also called pre-mitotic Gap phase
- The cell growth continous.

- Synthesis of RNA, proteins and enzymes continue in this phase
- The synthesis of energy rich compounds that provides energy for mitosis also takes place.
- The cell prepares itself to go into mitotic phase

Characters of Interphase :-

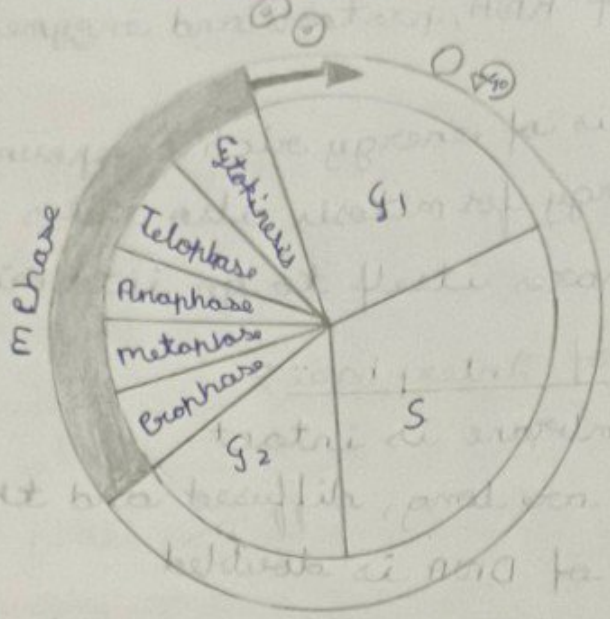
- Nuclear membrane is intact
- Chromosomes are long, diffused and thread like
- The amount of DNA is doubled
- The nuclear volume increases due to accumulation of all RNA and proteins
- It takes longer duration of cell cycle
- It is a non-dividing phase
- It is a period of great activity
- It is the preparatory stage of cell division
- Nucleolus is clearly visible

Quiscent stage (Go Phase)

NEET
- In this stage cells do not divide further and exit G_1 phase to enter an inactive state.
- Cells in this stage remain metabolically active but no longer proliferate unless on to do so depending on requirment of organisms

Eg :- Heart cells which is present in Go phase

- Some cells in the adult animals do not show division (Heart cells) and other cells divide only occasionally
- When there is cell death or loss of cell due to injury, the cells in the Go phase passes to the cell cycle and show division.



Diagrammatic View of Cell cycle

II M-Phase (mitotic phase) :-

- It is the 2nd phase and it represents the actual dividing phase of the cell cycle
- M phase takes place immediately after the Interphase.
- It last for a short period when compared to interphase
- During M phase two important phase occurs :-

i Karyokinesis :- The division of nuclei to form 2 daughter nuclei

ii Cytokinesis :- The division of cytoplasm

- After M phase cell may enter into interphase to repeat the cell cycle or G_0 phase to arrest the cell cycle. The cell in G_0 phase may grow in size and get differentiated

Mitosis :-

- It occurs mainly in somatic cells or body cells, hence it is called somatic cell division
- During mitosis daughter cell receives equal no. of chromosomes to that of parent cell so it is called equational division.

1 mark • It is the type of equational cell division occurs in somatic cells to form 2 diploid daughter cells is called mitosis.

Occurence :-

- In animal cells mitotic cell division is seen only in diploid somatic cells. However there are few exceptions to this, where haploid cells divide by mitosis
  Eg :- male honeybee
- In plant cells mitotic cell division seen in both haploid & diploid cells

Site of mitosis :-

- In animals mitosis occurs in epidermis of skin, bone marrow, embryoes etc
- In plants it occurs in meristematic tissue.
  Eg :- Root tip, shoot tip, embryo etc
- It includes two phases :-

1 Karyokinesis
2 Cytokinesis

1 Karyokinesis :- Involves division of nucleus

- It includes 4 phases :-

1 Prophase
2 metaphase
3 Anaphase
4 Telophase

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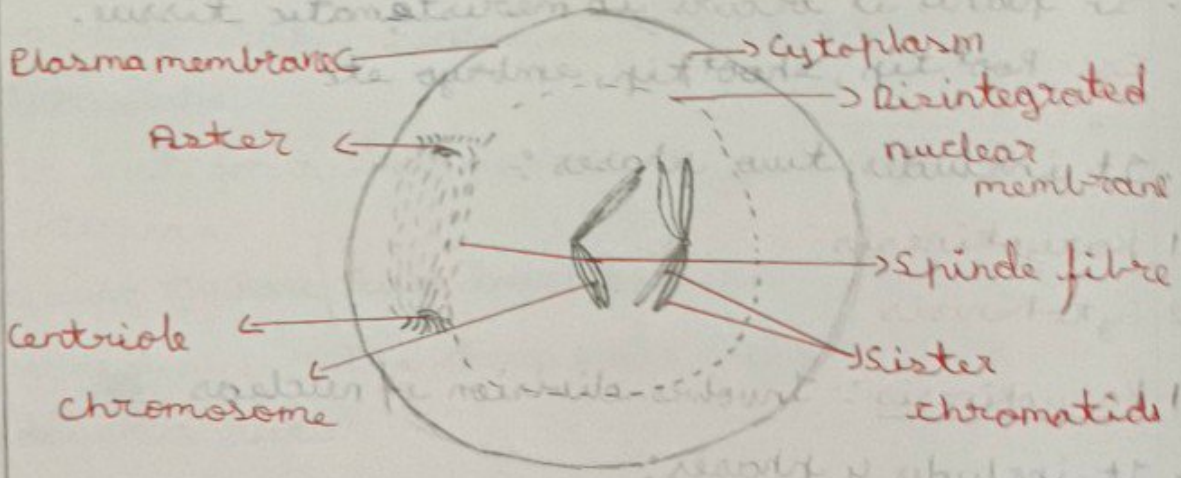
1 Prophase :-

NEET • It is the first stage of Karyokinesis of mitosis follows the S and G_2 phase

- It is the longest phase of mitosis
- The duplicated chromatin network become thicker and shorter due to coiling and condensation to form distinct chromosome.

- Each chromosome consist of 2 chromatids called sister chromatids attached together at centromere.
- Chromosomes are likely visible
- In animal cell already duplicated centriole begans to move towards the opposite pole
- Asters and spindle fibre start to develop.
- The spindle fibres are formed from one centriole to other
- Golgi complex and Endoplasmic reticulum also disappear.
- Disintegration of nucleolus takes place
- nuclear envelope disappear and chromosome release to cytoplasm



Prophase

2 metaphase:-

- It is the 2nd phase of mitosis
- Complete disintegration of nuclear envelope marks the start of 2nd phase of mitosis ie metaphase
- Coiling and condensation of chromosome completed hence chromosomes are more thick and can observed clearly under microscope.
- NEET. morphology of chromosomes is studied at metaphase.
- metaphase chromosome made up of 2 sister

chromatids which are held together by a centromere.

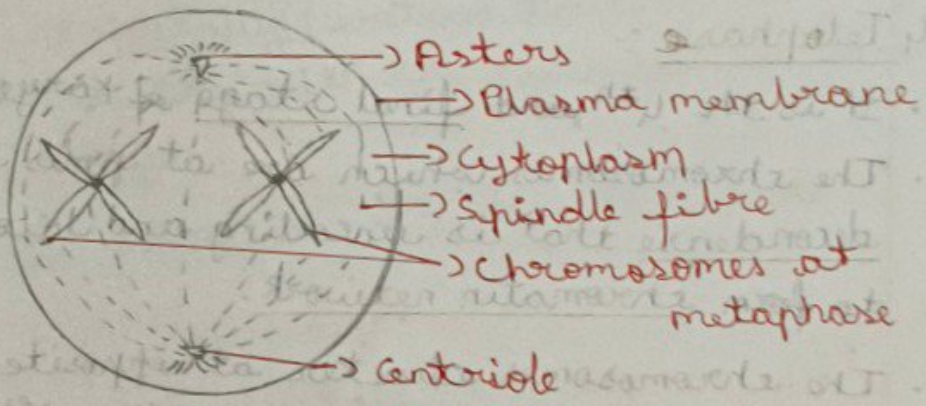
- Centrioles reaches to opposite pole.

Spindle fibres are completely developed and attached to chromatids by their kinetochore from opposite pole.

- The chromosomes are arranged at the centre of the cell called equitorial plane/metaphase plate.
- Centromeres lie at centre ~~that~~ and arms are directed towards plane

metaphase plate :-

- The plane of alignment of chromosomes at the metaphase is reffered to as metaphase plate
- Spindle fibres are made up of microtubles, they guide chromosomes as to seperate and becomes distributed to new daughter cells.



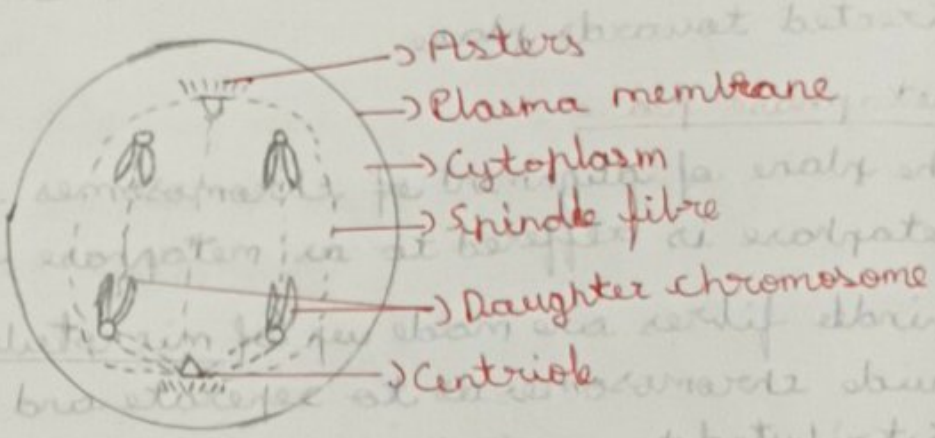
Metaphase

3 Anaphase :-

- The 2 chromatids of each chromosomes seperates (split) at centromere to form daughter chromatids, nolw reffered as daughter chromosome
- The daughter chromosomes moves towards opposite poles due to contraction of spindle ~~s~~ fibre
- The centromere of each chromosome remains directed

towards pole and, while the arms of the chromosomes trailing behind.

- During anaphase nuclear material divide into 2 equal similar halves so called equational division
- At the end of the anaphase daughter chromosomes reaches to opposite pole.
- The daughter chromosome appear V, J, L & i shape



Anaphase

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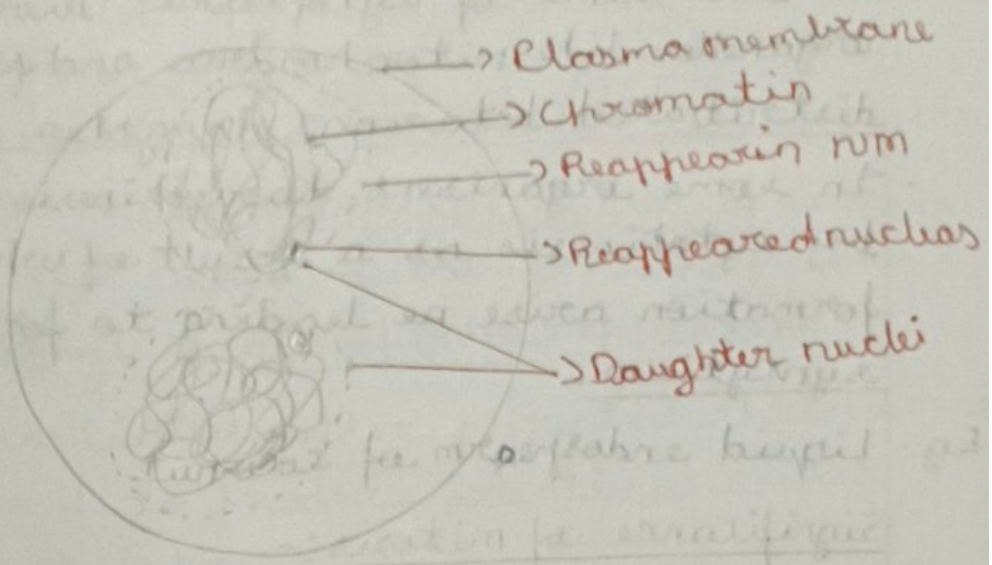
4 Telophase :-

- It is the 4th and final stage of Karyokinesis
- The chromosomes which are at poles begins to decondense that is uncoiling and become threadlike to form chromatin network.
- The chromosomes cluster at opposite spindle poles and their identity is lost as discrete elements
- The spindle fibres disintegrate and disappear
- The nucleolus, ER, Golgi complex get reappeared.
- Nuclear membrane develops around the chromosome to form 2 daughter nuclei
- All the events takes place exactly opposite to prophase phase



Telophase

Cytokinesis :-

- Division of cytoplasm is called cytokinesis.

i **In animal cell :-**

- In animal cell cytokinesis occurs by appearance of "cleavage furrow". The cleavage furrow starts at the sides in the middle of the cell.
- It deepens centripetally (extend towards centre), joints at the centre till the cytoplasm is divided into 2 equal parts.
- It results in formation of 2 daughter cells

ii **In plant cells :-**

- In plant cell, cytokinesis take place by

i Phragmoplast

ii Cell plate

- During cytokinesis vesicles of ER and GC are arranged at the centre of the cell and fused to form phragmoplast.
- It extend centrifugally (from centre to peripheral part of the cell) to the margin of the cell to form cell plate

- The cell plate later forms middle lamella
- At the time of cytoplasmic division cell organelles like mitochondria and plastids get distributed between 2 daughter cells.
- In some organisms karyokinesis is not followed by cytokinesis as a result of which multinucleated formation arise as leading to formation of syncytium.

Eg:- Liquid endosperm of coconut.

Significance of mitosis:-

- It helps in equal distribution of chromosomes to the daughter cell.
- It helps in growth of multicellular organisms.
- It helps in cell repair mechanism.
- In plants meristamatic tissues helps in cell division leads to continues growth in plant throughout their life.

Eg:- Apical & lateral cambium

Meiosis:-

- It is a type of cell division occurs in gametic cells to form four aploid daughter cell.
- It is a type of cell division in which chromosome number is reduced to half in daughter cells compared to parent cells, hence it is called reductional cell division.
- meiosis ensures the production of haploid face in the life cycle of sexually reproducing organisms, whereas fertilization restores the diploid phase.

Imp. The cell which undergo meiosis is called meiocyte.

- meiosis occurs during gametogenesis in plants and animals this leads to formation of haploid gamete

Key features of meiosis

- It takes place in diploid germinal epithilium which is found in gonads ie male gonad (testis), female gonad (ovary) and spore mother cell of plants
- meiosis involves two sequencial cycles of nuclear and cell division called meiosis one and meiosis 2 but only a single cycle of DNA replication.
- meiosis I is initiated after parental chromosomes have replicated to produce identical sister chromatids at S phase.
- meiosis involves pairing of homologus chromosomes and recombination between ~~them~~ ~~bet~~ non-sister chromatids of homologus chromosomes.
- Four haploid daughter cell are formed at the end of the meiosis two.

I meiosis -I	II meiosis -II
1 Prophase -I	1) Prophase -II
2 metaphase -I	2) metaphase - II
3 Prophase -I	3) Prophase - II
4 Telophase -I	4) Telophase - II
cytokinesis -I	cytokinesis -II

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I Meiosis I :-

- It is a reductional division in which diploid parent cell produces 2 haploid daughter cells in which each chromosome will have a pair of chromatids
- meiosis I is divided into 4 phases :-

1 Prophase -I
2 metaphase -I
3 Prophase -I
4 Telophase -I

- Before meiotic phase-I the cell is in the interphase stage where duplication of DNA takes place in S-phase and synthesis of RNA and protein takes place in G_1 and G_2 phase

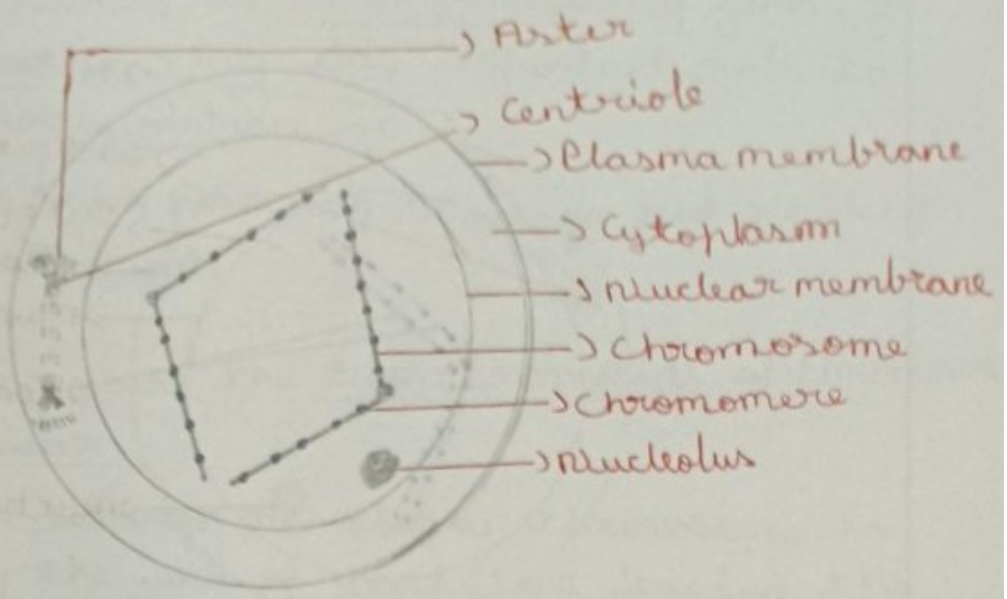
1 Prophase-I :-

- It is the longest ~~pair~~ phase it includes 5 sub stages :-

i Leptotene
ii Zygotene
iii Pachytene
iv Diplotene
v Diakinesis

i Leptotene :-

- The volume of nucleas increases.
- The chromatin undergoes coiling and condensation to form chromosomes.
- They are thin and lightly visible under light microscope.
- At some regions of chromosomes (chromatid) may undergo more coiling to form beaded like appearance called "chromomeres".
- Each chromosomes consisting of 2 chromatids held together by a centromere but it is not distinct
- Already duplicated centrioles move towards opposite poles and asters are found.
- Some times in animal cells chromosomes are arranged in a specific orientation that is bouquet structure. Hence this stage is also called as bouquet stage.



Leptotene

ii2 Zygotene :-

- Due to further coiling and condensation of chromatin, chromosomes became shorter & thicker.

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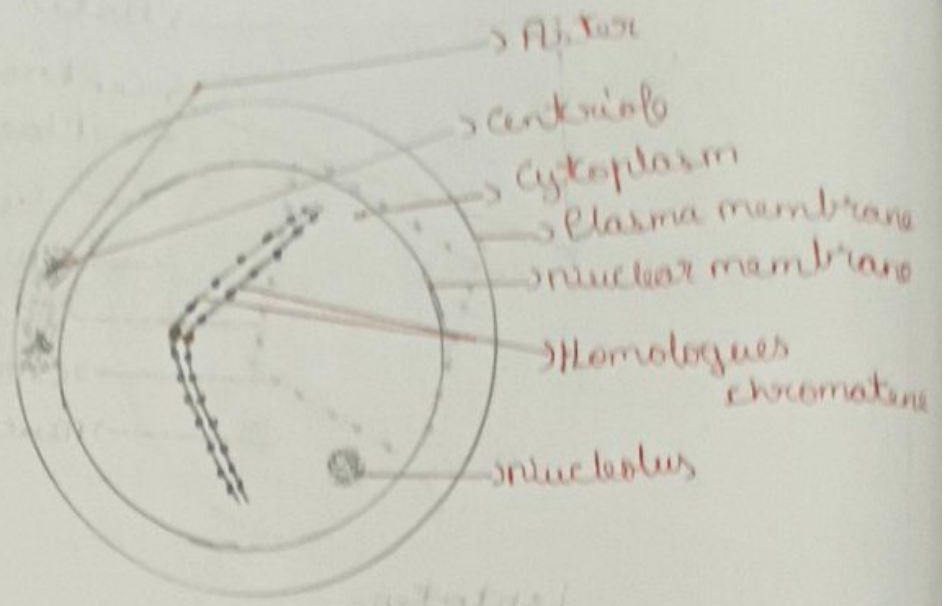
- The pairing of homologes chromosome take place this process is called synapsis.
- The pairing may occur in ~~zip~~ zipper manner hence this stage is also ~~call~~ called zipper stage.
- This leads to synaptonemal complex.
- The complex formed by pairing of synapsed homologous chromosome is called 'bivalent' [tetrad, however these are clearly visible at the next stage called pachytene]
- The paired units consisting of homologous chromosome of which one is paternal and other one is maternal
- The first 2 phases of ~~a~~ prophase one are relatively short lived when compared to pachytene

PTO →



Zygotene

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iii) Pachytene:

- It is relatively longest phase when compared to leptotene and zygotene.
- The bivalent chromosomes become more thicker and shorter due to condensation.
- The chromatids of bivalents became clear. Now each chromosome shows 2 chromatids, so the bivalents shows four chromatids and two centromeres they are called as tetrads. ie the synaptic pair has four chromatids ie tetrads.

IMP The genetic crossing over takes place between non-sister chromatids of homologous chromosomes. leads to recombination of Genes

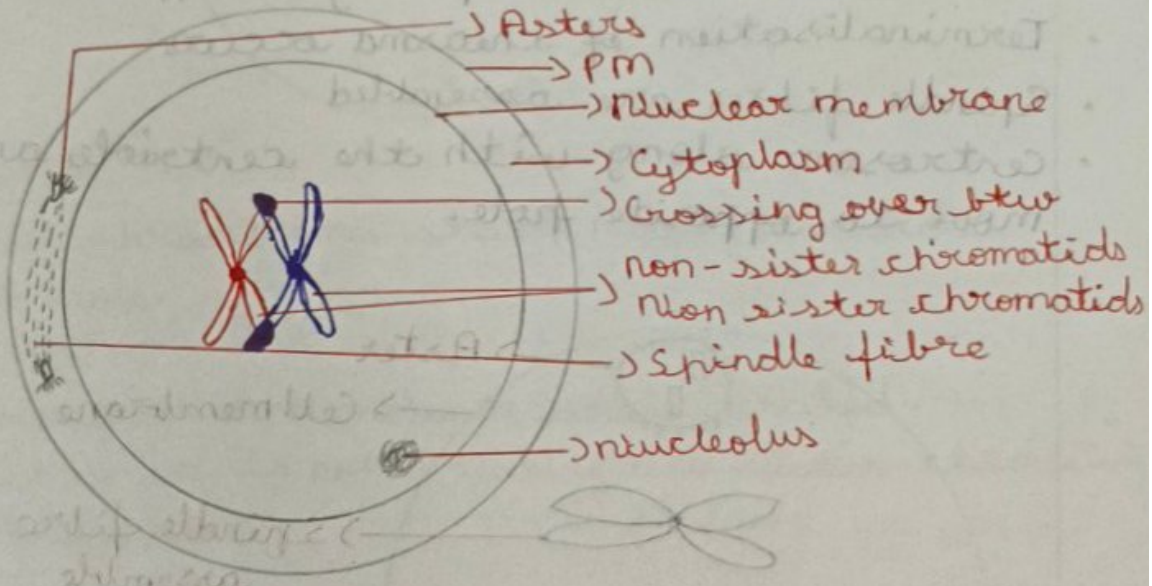
Crossing over:

IMP
- The exchange of chromosomal segment or genetic material between non sister chromatids of homologous chromosome during pachytene with the help of recombinase enzymes.
- Crossing over takes places at recombinase nodules, the site at which crossing over occurs between non-sister chromatids of homologous chromosoma with the help of recombinase enzymes

- Crossing over leads to recombination of genes. It produces variation they play important role in ~~variation.~~ also evolution.
- Crossing over takes place by breakage and re-union of chromatid segment.

Note:-

- After crossing over the two chromatids of chromosome become dissimilar.
- Recombination between homologus chromosome is completed by the end of pachytene leaving the chromosome linked at the sites of crossover.



Pachytene

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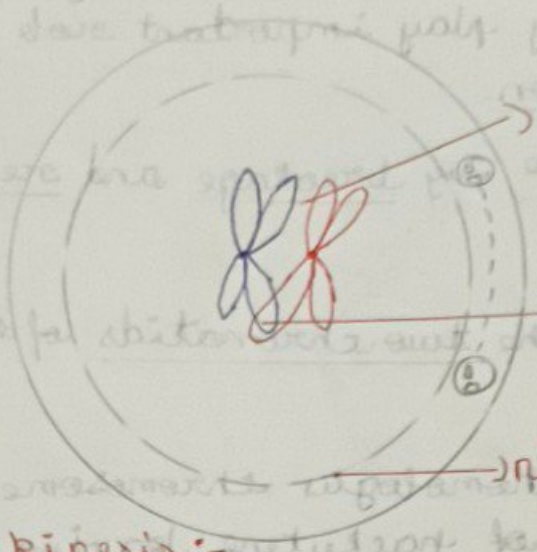
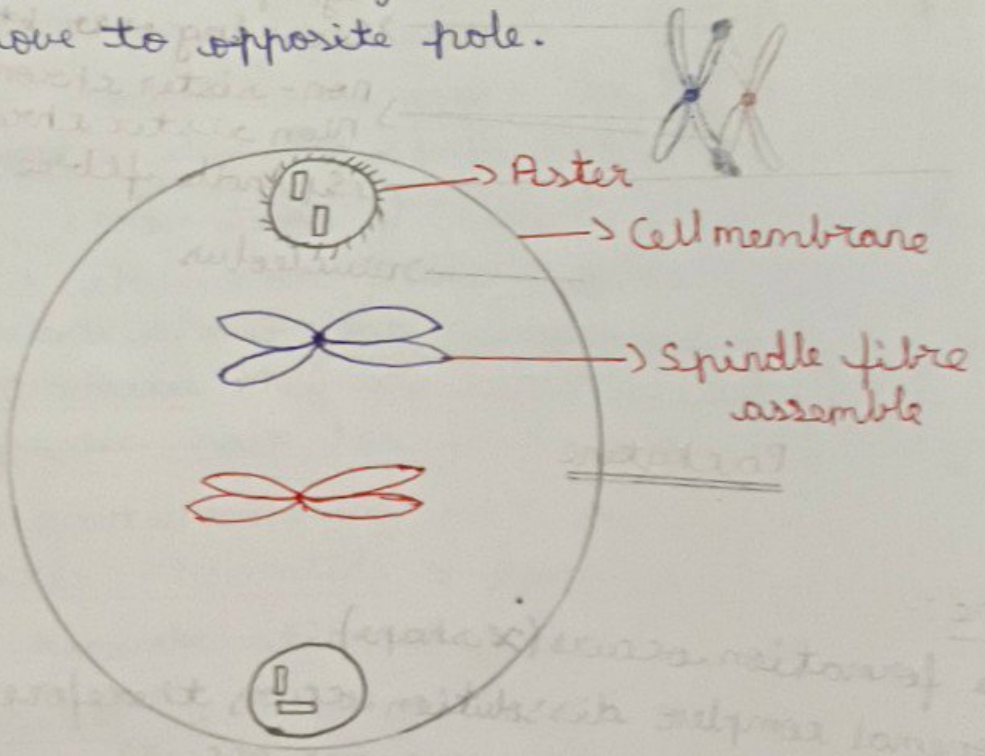
iv Diplotene:-

- Chaisma formation occurs (x shape)
- Synaptonemal complex dissolution occurs therefore, seperation of homologous chromosomes occurs
- Nuclear membrane starts disappearing
- This diplotene stage is suspended for sometime in the oocytes of some vertebrates



Diakinesis :-

- Nuclear membrane completely disappear
- Terminalisation of chiasma occurs
- Spindle fibres are assembled
- Centrosome along with the centriole and Aster move to opposite pole.

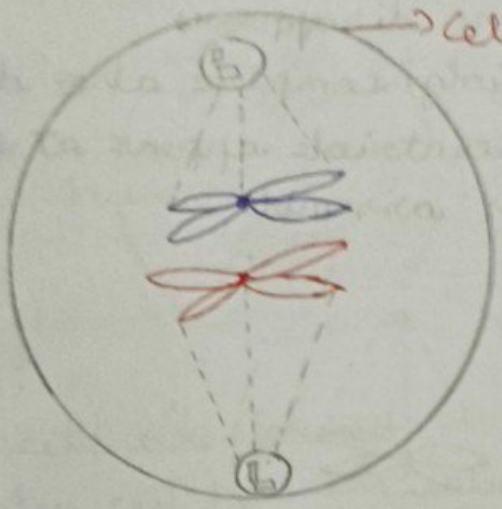


Important Points

- Bivalent or Tetrad formation occurs in Zygotene
- Bivalent or Tetrad can seen very clearly in pachytene
- Crossing over or recombination occur in pachytene
- ~~Chiasma~~ Chiasma formation happen in diplotene.
- Synaptonemal complex formation occur in zygotene whereas its dissolution happen in diplotene
- Chiasma terminilation will happen

Metaphase I :-

- Spindle fibre attach to the kinetochores of centromere.
- Two bivalents allign on the equitorial pho plane.

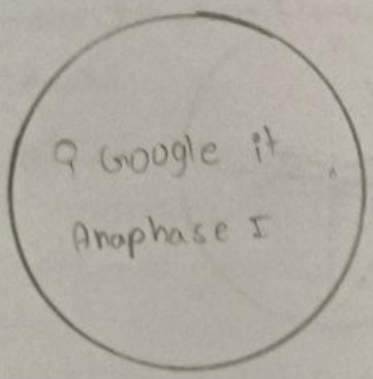


Anaphase I :-

- In this chromosomes starts moving towards opposite pole

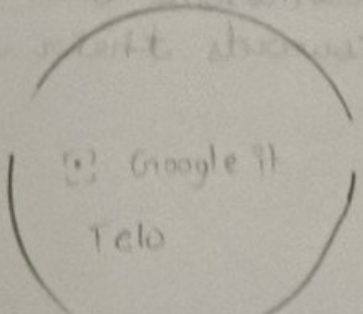
Note:-

- The homologues chromosomes are seperated.
- But centromere is not breaking and sister chromatids are not seperating



Telophase I :-

- nuclear membrane reappears.
- Spindle fibres disappear



Cytokinesis I :-

- Parent cell is divided into 2 daughter cell.
- Each cell will be with the single chromosome of with two chromatids

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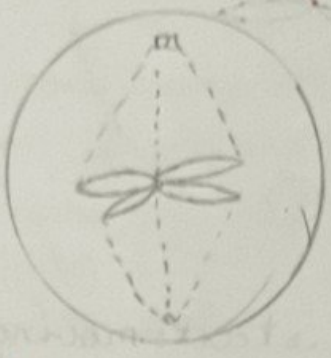
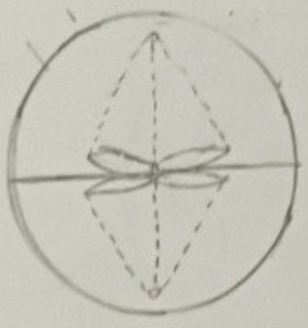
Prophase II :-

- Nuclear membrane disappears
- Nucleolus, ER, Golgi complex also disappears
- Centrosome and centriole appear at poles
- Spindle fibres assemble



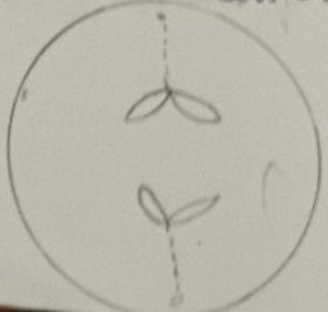
Metaphase II :-

- Homologous chromosome be on the equitorial plate
- Spidle fibres attach to the kinetochore of centromere.
- only one bivalent chromosome is seen as equitorial plate.



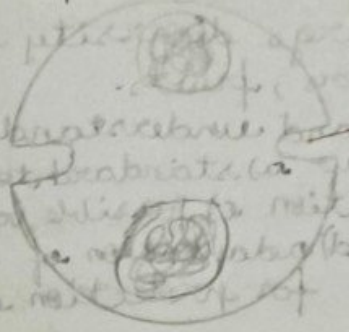
Anaphase -II :-

- Here centromere breaks breaks and sister chromatids will get seperated.
- Each chromosome with simple chromatids starts moving towards their poles.



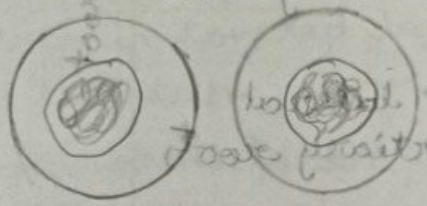
Telophase II :-

- Chromosome starts decondensation into chromatids
- Nuclear envelope, nucleolus, ER, Golgicomplex will reappear.
- Furrow formation takes place
- Spindle fibre disappear.



Cytokinesis II :-

- 2 daughter cells are formed
- Each daughter cell has its own chromatin



Importance of meiosis

- Formation of meiosis which means,
- maintenance of same number of chromosome from one generation to another generation
- Variation occurs
- Gamete formation occurs