Learning Mantras

Biology Handwritten Notes

On

Cell Cycle and Cell Division

. Cell growth to increase cytoplasm occurs throughout the cell cycle but DNA duplication is restricted to ~~of~~ S - phase.

Date ___/___/___

Page _____

Cell Cycle and Cell division

↙

It is an orderly series of changes that occurs in a cell by which it duplicates its genome and divides into daughter cells.

Generation Time: Time required by cell to complete one cell-cycle

e.g Humans : 24 hrs
Yeast : 90 minutes

- Cell cycle
  - Howard and Pele (details of cell cycle given by)

↓ I - phase
Interphase
earlier → resting phase
(i) · preperatory phase
(ii) · non-dividing phase

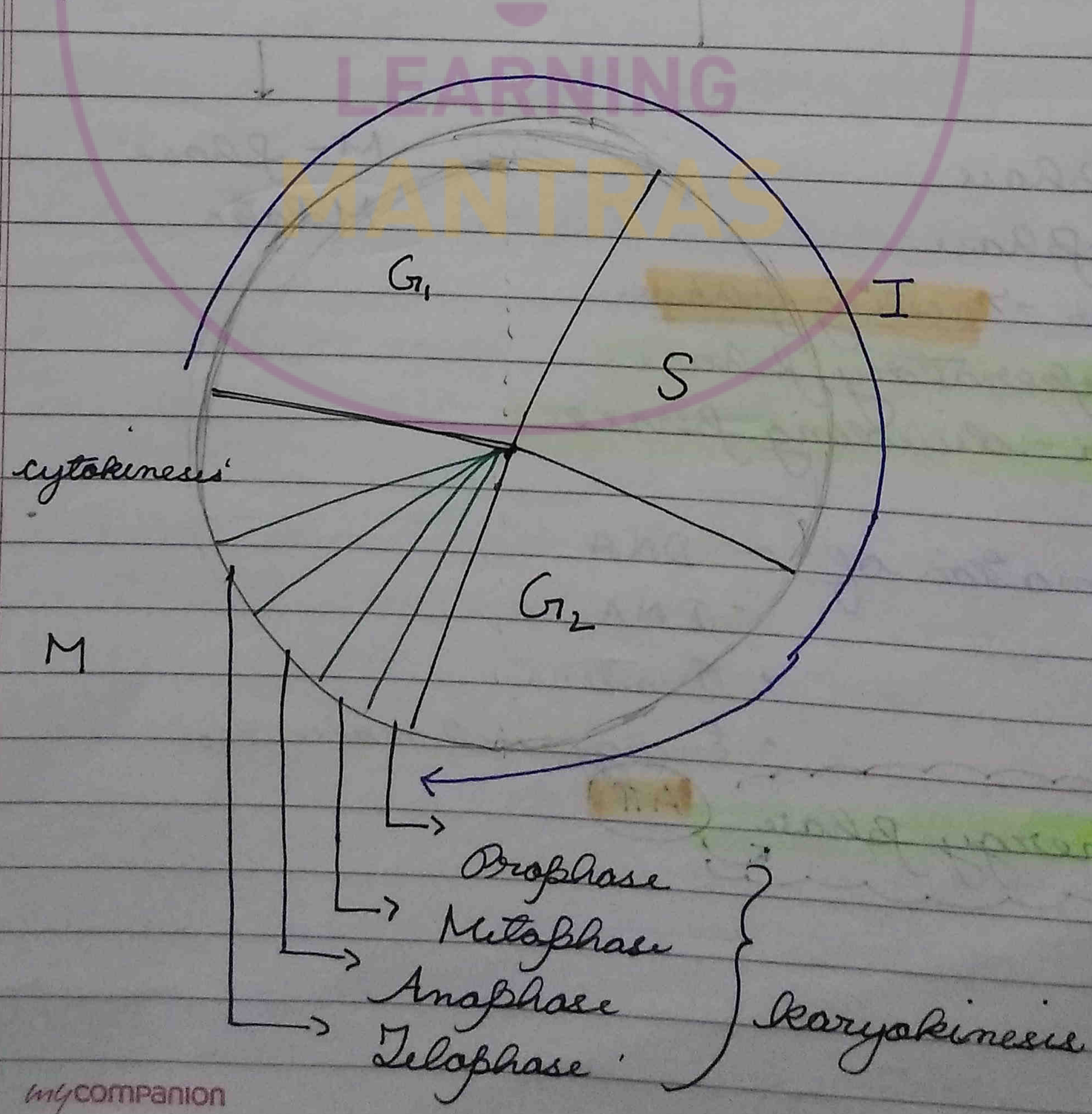
Formation of ~ DNA
· RNA
· Proteins
· Energy rich molecules

(iii) Energy phase ATP

↓ M - phase
Mitotic

- Interphase lies between two successive cell division.

I - phase	M - phase
• Preperation for cell division	cell division occurs
• Longer duration → about 95% duration	shorter duration about 5% ~ cell cycle 1 hr
• Growth and multiplication of cellular structures	Distribution and division of cellular structure in daughter cells.
• Hereditary materials in the form of chromatin fibres	Hereditary material in the form of chromosomes



* In G_0 phase RNA synthesis occurs but DNA synthesis is absent.

Date __/__/__
Page _____

- G_1 Phase → one
  - First growth phase, Gap - I phase
  - Postmitotic phase
  - Pre Synthetic phase
  - Increase in cell size (Max.)
  - Nuclear size increases
  - ✱ It is of longest duration

Substances synthesised
- → Amino acid
- Nucleotides
- ATP
- RNA — RNA Polymerase (RNAP) is active and synthesises → rRNA, mRNA, t-RNA
- Protein synthesis
- ✱✱ Synthesis of amino acids required to make histone.

G_1

↓ $G_1 \longrightarrow S$ committed to cell division

↓ Cell division capacity lost change Differentiation

Exit from G_1 Phase

↓ can be

Temporary — Parenchyma

↓ Dedifferentiation

↓

Cell division capacity ✓
2° Meristem

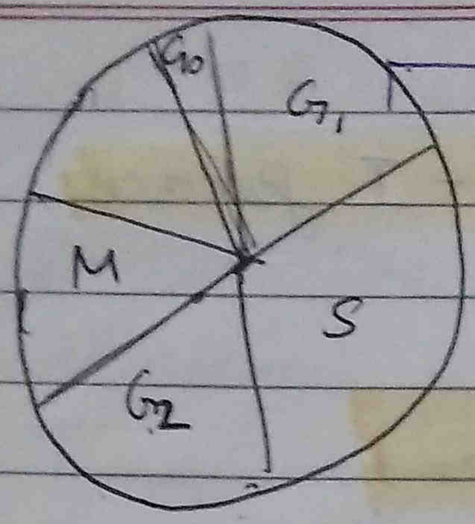
Permanent
- Sclerenchyma

↓

Specific function (Permanent tissue)

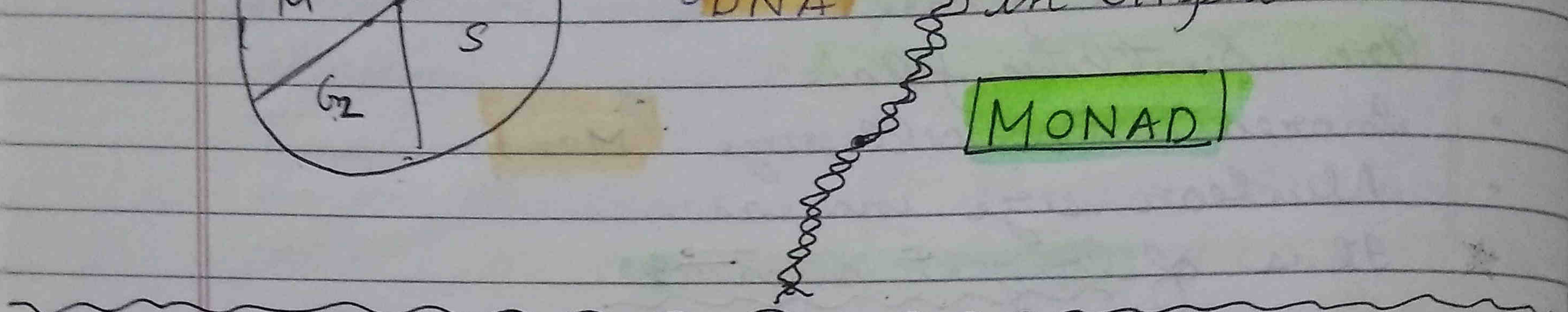
$G_1 \longrightarrow G_0$ (Quiescent)

- G_0 → metabolically active since it performs all other functions.



→ Each chromosome is represented by single double stranded DNA in G_1 phase.

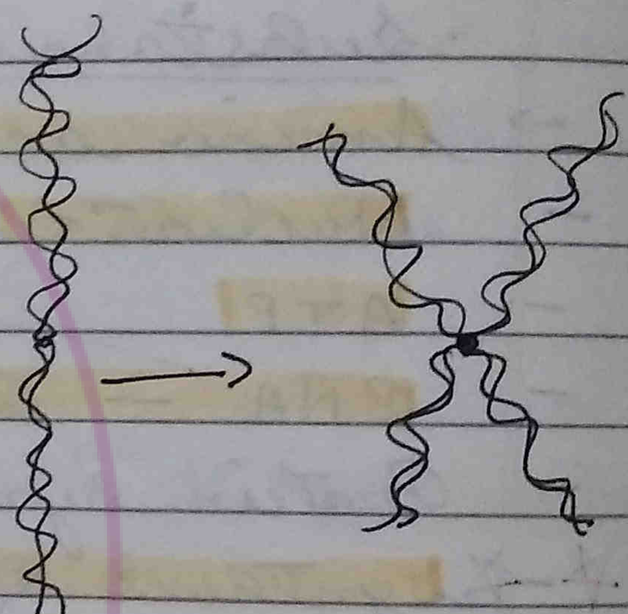
MONAD



S. Phase

In the nucleus. Each chromosome consists of two double stranded DNA.

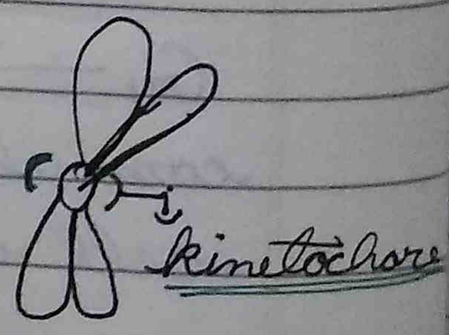
→ DNA duplication occurs - hence DNA polymerase required.



G_1 S

Monad Dyad

- ✡ - Centriole duplication occurs in cytoplasm.
- ✡✡ Histone (protein) formation occurs
- ✡ assembly of subunits of kinetochore occurs



- ✡ Duplicated chromosomes are not visible in this phase hence known as → Invisible phase.

haploid (n) = 1c ⟶ 2c

DNA content

diploid (2n) = 2c ⟶ 4c

$n \longrightarrow n$ (haploid) (haploid)

$2n \longrightarrow 2n$ (diploid) (diploid)

DNA amount increases but chromosome no. remains same.

* Kinases are activated by cyclin protein. Hence called cyclin dependent kinases.

☆ Synthesis of RNA takes place in both G I and G II phase

Date __/__/__

G_2 Phase

- Croft II phase
- Second growth phase
- Post synthetic phase.
- Pre mitotic phase.

- cell size and nuclear size increases

(0.12) RNA synthesis (RNAP active) and protein synthesis occurs

☆ duplication of most cell organelles including Mitochondria and plastids

☆ Biochemicals made for synthesis of spindle fibres during M-Phase.

⇒ | Tubulin - protein synthesis | occurs.

Regulation of Cell Cycle

- Cell cycle is genetically controlled through proteins

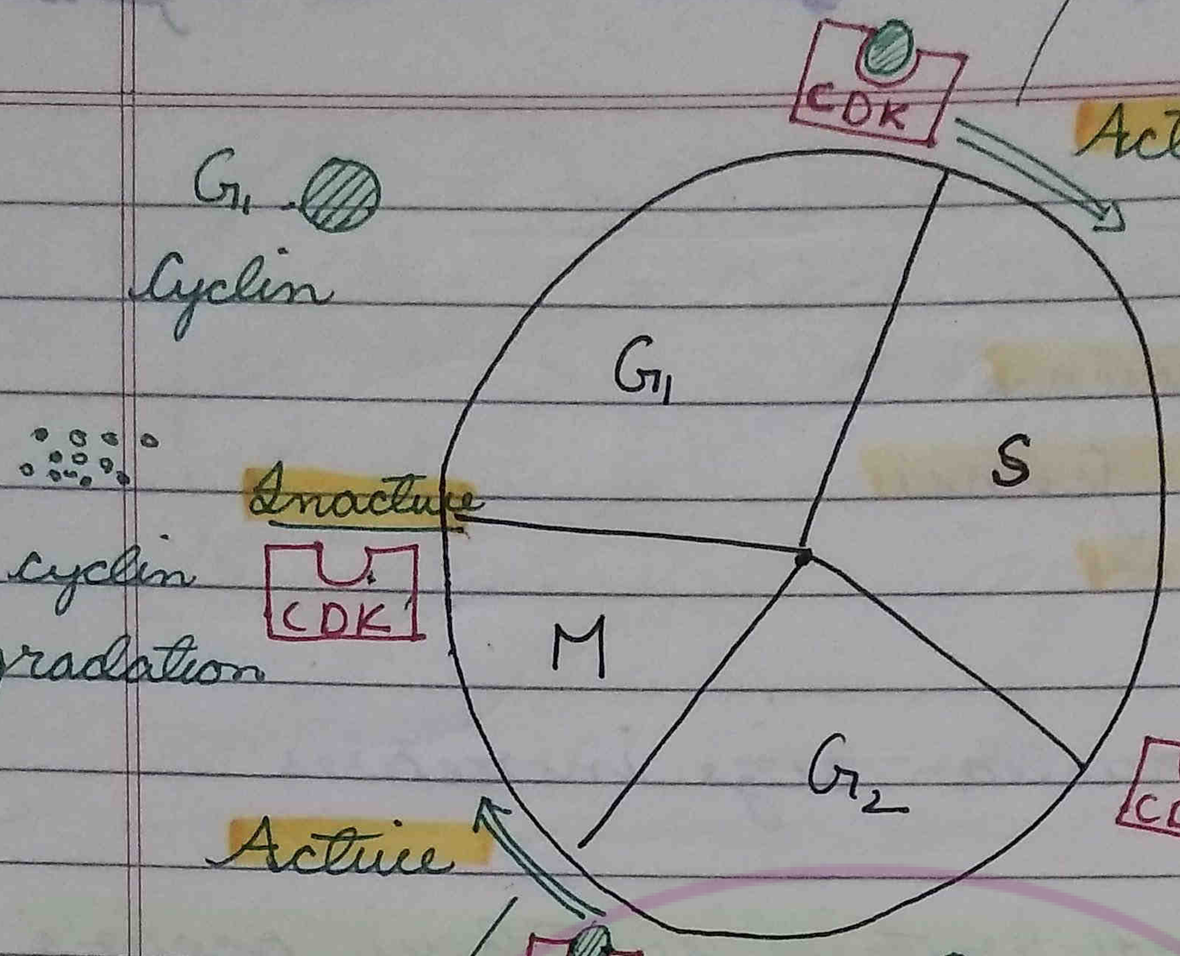
Cyclin proteins

- G_1 cyclin ⇓ Formation in G_1 phase
- M cyclin ⇓ Formation in G_2 phase

- Degradation in S phase
- Degradation in M phase

CDK
Cyclin dependent kinases
(enzyme)

Transition from G_1 to S phase



G_1 cyclin degradation

→ M-cyclin - CDK complex

☆ MPF

Maturation Promoting factor

Help in transition $G_2 \longrightarrow M$

☆ **Anaphase :**

refers to end of G_1 phase, when cell has stored (sufficient) energy.

= So even in ~~cell division~~ (stress) condition cell division occurs because sufficient energy has been stored.

Q Phase in which DNA polymerase is active
G_1, S ✓, G_2, M.

Q Phase in which centriole duplication occurs?
In S phase. centriole duplication occurs in cytoplasm.

Equational division: Because no. of chromosomes and type of chromosom in daughter cell same as that of mother cell.

Date / / Page

Phase

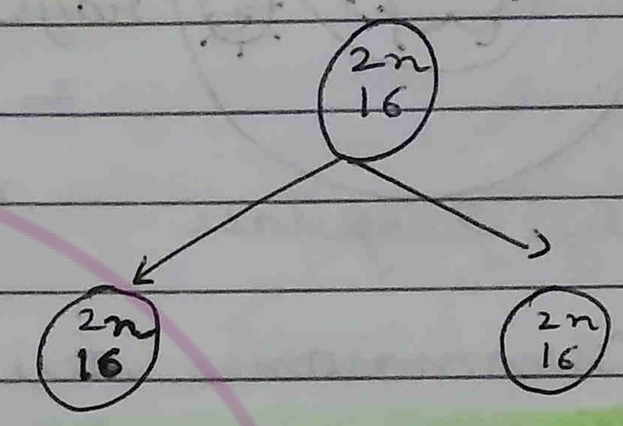
Q In which protein and its amino acids are made required for DNA packaging.

DNA packaging (Histones)

Protein → S phase Amino acid → G1 phase

Mitosis

- Equational division
- Duplication division
- Somatic division



* Mitosis first studied in plant cells by — Strasburger.

* Mitosis first studied by in animal cells by — Bowri and Flemming.

* Onion root tip cells are best materials to study mitosis.

Mitosis

↓ Karyokinesis / M-phase

Indirect Nuclear division:
Nucleus passes through complex stages before formation of daughter cells.

- Prophase → Longest
- Metaphase
- Anaphase → Shortest
- Telophase

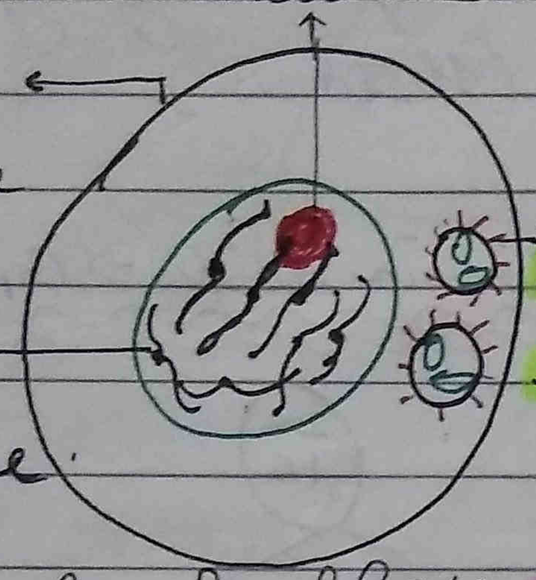
↓ Cytokinesis / C-phase.

- Astral rays + centrosome → star shaped structure (Microtubules) ⇒ Aster

Animals — 2-aster — Amphiastral conn.
Plants — no-aster — Anastral mito

Prophase

nucleolus → Early Prophase



Early Prophase

1 Chromatin fibres undergo condensation to form chromosomes.

2 Ends of chromosomes are not distinguished.

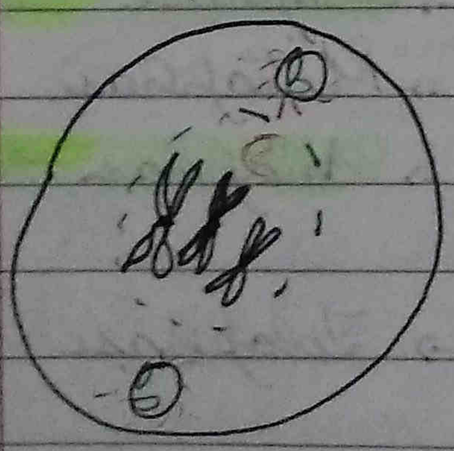
3 ✱ Chromosomes due to overlapping appear as Ball of wool → Spireme Stage.

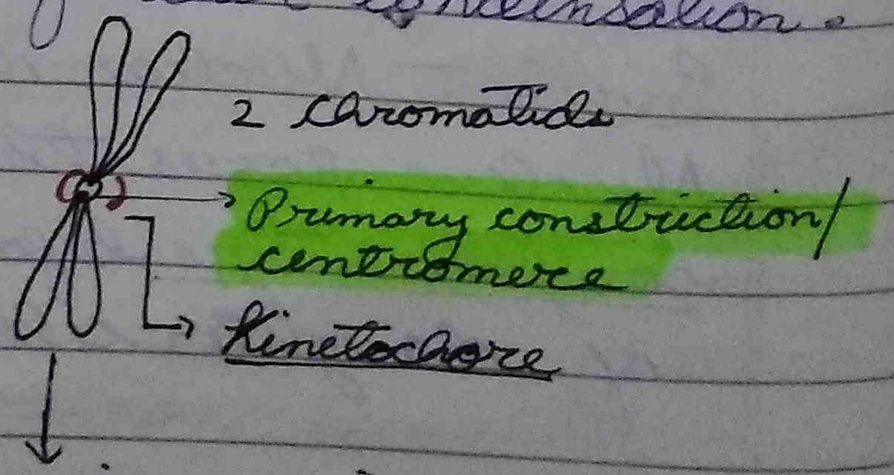
4 Duplicated centrosomes move away from each other.

- Centrosome contains a pair of centrioles around which masses are present which work like MTOC (Microtubule organising centre) and form microtubule fibres which move centrosome away from eachother.

– Late prophase

- chromatin fibres undergo further condensation.





Dyad is a single chromosome having two chromatids.

- Spindle fibre are made up of microtubule which range from 4–20 in no.

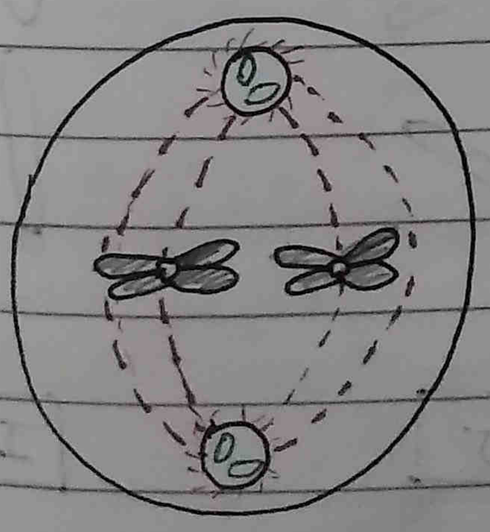
Date __/__/__
Page _____

- In the end of prophase →
  - nuclear membrane degenerates
  - Nucleolus
  - Endoplasmic reticulum
  - Golgi Bodies

  → not in cell

Metaphase

- condensation of chromosomes complete ⇒ highest level of chromosomal coiling in this stage because of which it is the
- ✡ Best stage to study no. and morphology of chromosomes.
- spindle fibre get the joined to the chromosome at the point where kinetochore is present.
- Move chromosomes to centre position in cell.
- ✡ Congression → Movement of chromosome to the equator.



Spindle Fibres

Pole–Pole
- continous spindle fibres

Not reaching other pole
- discontinous spindle fibres
- attach to chromosome
- ★ chromosomal fibres/ tractile fibres.

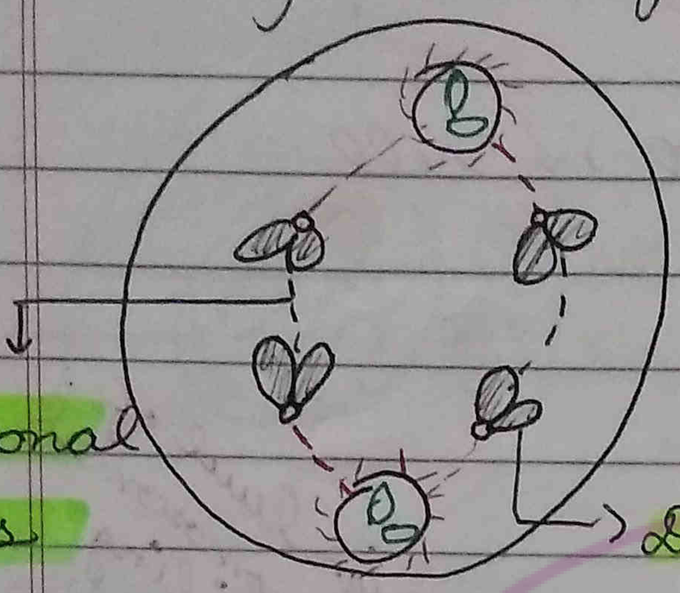
Plane of alignment of chromosome is known as equitorial / Metaphase plate.

Date ___/___/___
Page ___

Anaphase

☆ Here separation of chromatid occurs = Disjunction.

chromatids move towards opposite pole.



- centromere — leading edge
- Arms — trailing behind

Monad

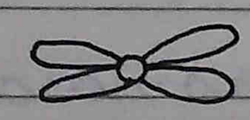
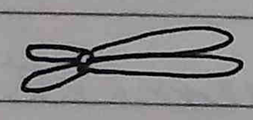
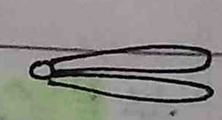
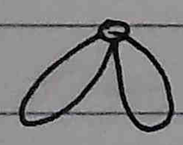
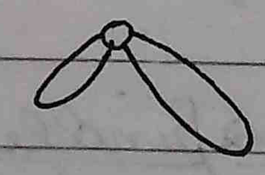
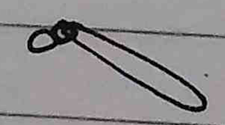
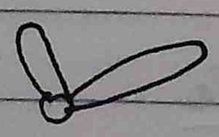
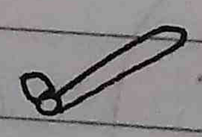
Mechanism of chromatid movement

↓

Expansion of Interzonal fibres

↓

Dissolution of chromosomal / Tractile fibres.

→	Metacentric	Submetacentric	Acrocentric	Telocentric
				
				
				
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∵ Telocentric chromosomes are absent in humans

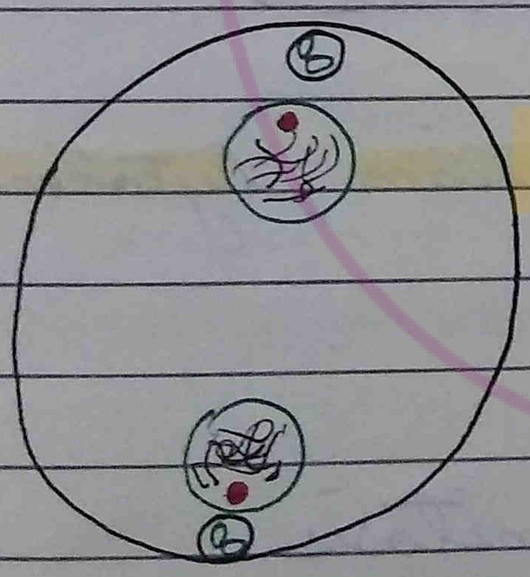
∴ I shape can never appear in humans.

NOR → nucleolar organiser region

- All events in Telophase are opposite of what occurs in prophase Hence telophase is called "Reverse Prophase".

Telophase

- daughter chromosomes have reached opposite poles.
- chromosomes show decondensation and appear as chromatin fibres.
- Reappearance of nucleolus formed by NOR region of SAT chromosome
- reformation of nuclear membrane, endoplasmic reticulum, Golgi bodies.
- Astral rays and spindle fibres disintegrate.



Cytokinesis

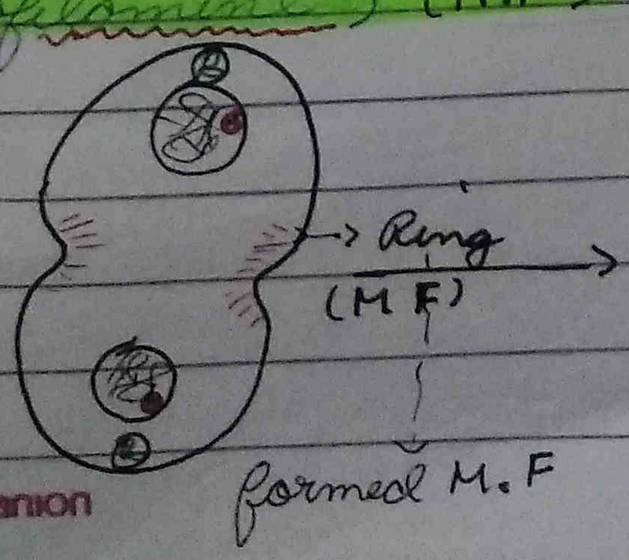
Cytokinesis starts in late anaphase.

↓

Furrow

Animals

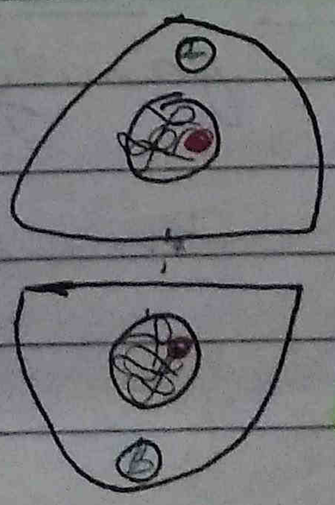
(microfilament) (M.F)



↓

Cell plate

Plants



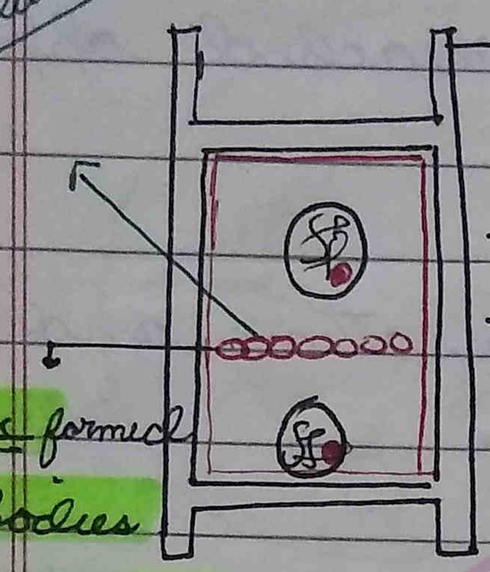
- Division of cytoplasm proceeding centripetally

- Microtubule help in cytokinesis of plants whereas microfilament help in cytokinesis of animals.

Date / /
Page

Cell Plate — Plant cell

Phragmoplast



Vesicles formed by Golgi Bodies

solidification due to Ca^{+2} and Mg^{++} pectate

Thin film formed which is precursor of plasma membrane of daughter cell

- cell plate represent middle lamella
- Primary wall formed by daughter protoplast.

- Growth of cell plate occurs in centrifugal fashion

Mitogens

chemicals that induce mitosis.

- ✡ Plants → Auxin, Gibberellin, Cytokinin
- ✡ Animals → Insulin.

Mitotic poisons :

chemicals that inhibits mitosis.

Azide, Cyanide, Ribonuclease, Mustard gas, Colchicine.

↓

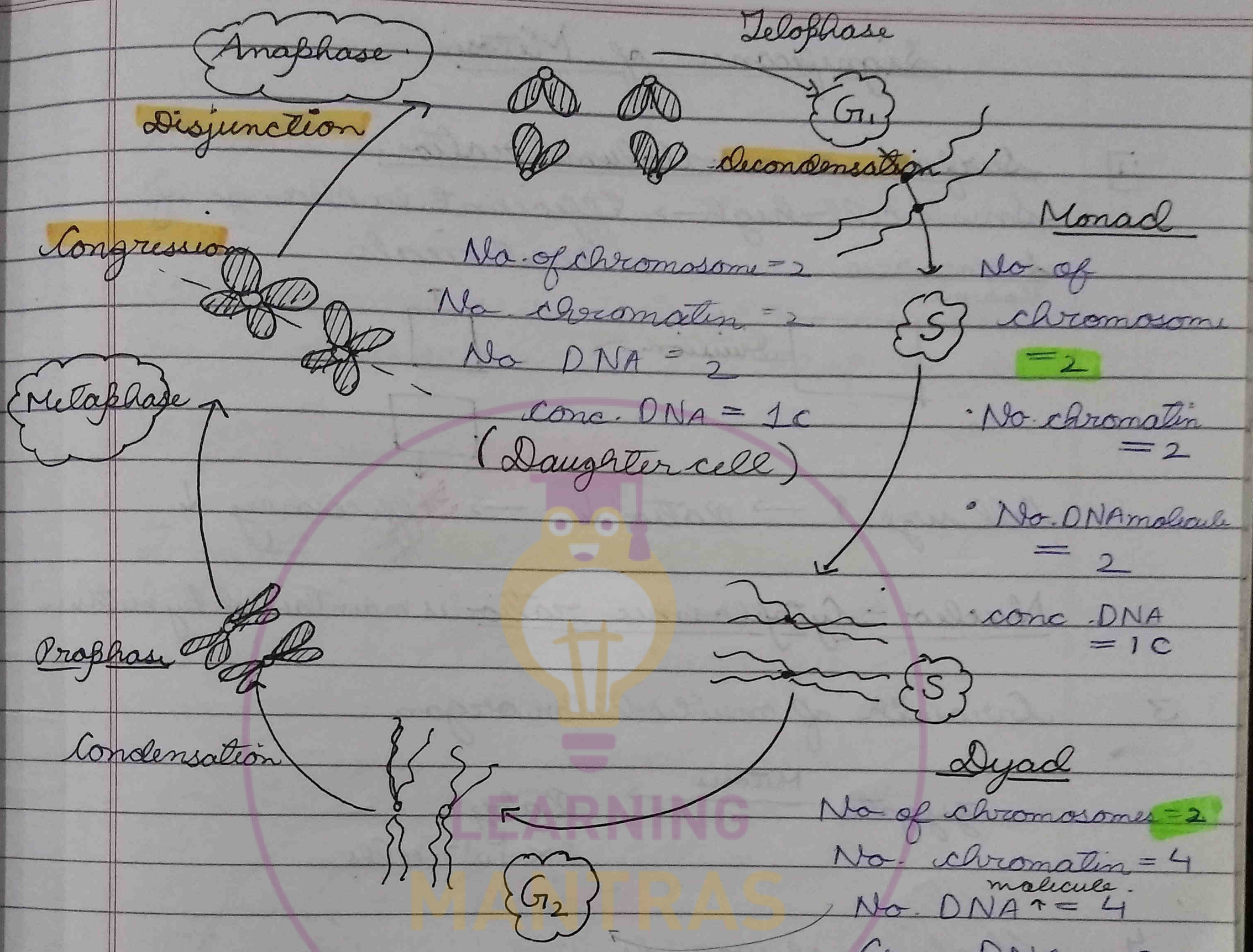
Inhibit spindle fibre formation.

obtained from seed and corm of Colchicum autumnale; obtained from Liliaceae family.

1 chromatin thread = 1 ds DNA = 1 DNA molecule

Behaviour of chromosome in cell cycle

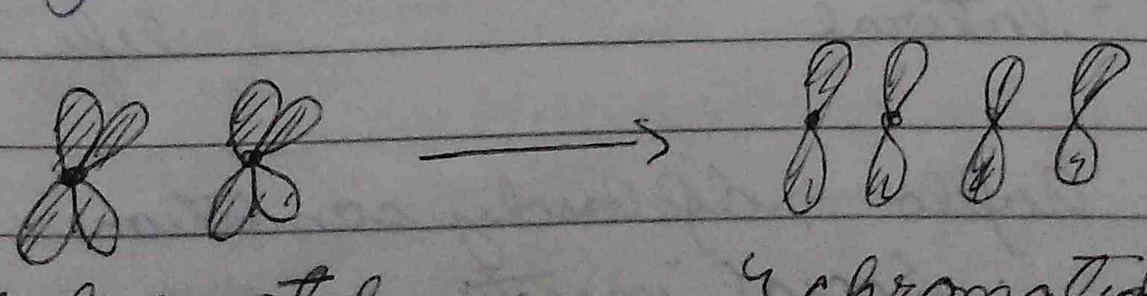
Date __/__/__
Page



Some conditions

Q* In which phase of mitosis, the no. of chromatids are same as parent cell but no. of chromosomes are double of the parent cell.

~ Anaphase.



4 chromatid
2 chromosome

4 chromatid
4 chromosome

- In plants growth is open ended because product meristem cell can take part in diviision and can differentiate ~~into~~ in mature cell.

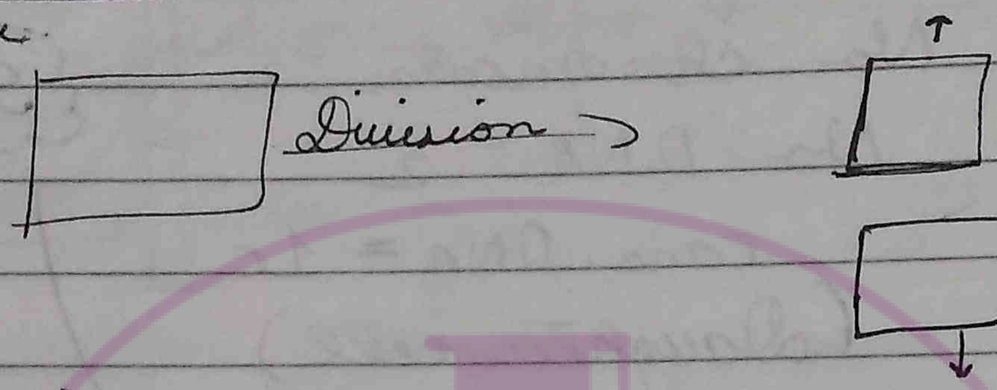
Date __/__/__
Page

Significance of Mitosis

1. **Surface area – Volume ratio**

Small cell – high → Efficient exchange of materials

$\frac{\text{Surface area}}{\text{Volume}}$



Cell size ↑ → Ratio ↓ → Efficiency ↓

2. **Nucleo – Cytoplasmic ratio** is maintained by mitosis.

3. Growth of multicellular organ.

Zygote $\xrightarrow{\text{Mitosis}}$ Baby

6×10^{12} cells

4. Healing of wounds.

5. Replacement of – outer layer of skin
– linning of gut
– WBC, RBC.

6. Meristem – Apical → Growth → Throughout life cycle.
– lateral

7. Maintain haplo – diploidy condition.

Social insects
– Honey bees

↓

Egg (n) ↓ fertilisation – not Mitosis
Male (n)

↓

Egg (n) × Sperm (n)
↓ F ✓
Zygote (2n)
↓ Mitosis

Microspore mother cell also called --- Microcyte
Megaspore mother " " " Megacyte

Date __/__/__
Page _____

Meiosis

- Meiosis a double division
- Occurs in diploid cell
- After division of four daughter cells in which no. of chromosomes is half that of parent cell.
  ~ Reductional division.

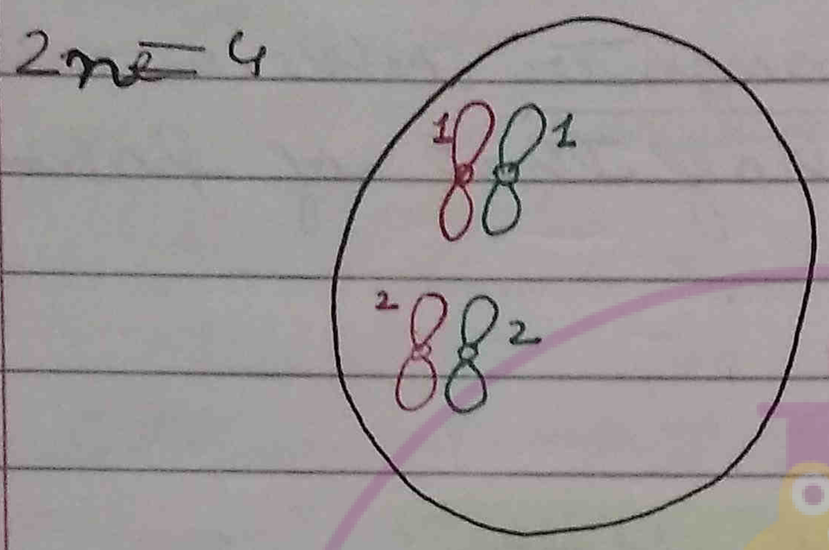
Term "Meiosis" — Farmer and Moore.
Details given by → • Beneden ✓
• Strasburger ✓
• Sutton ✓
• Wilmivater ✓

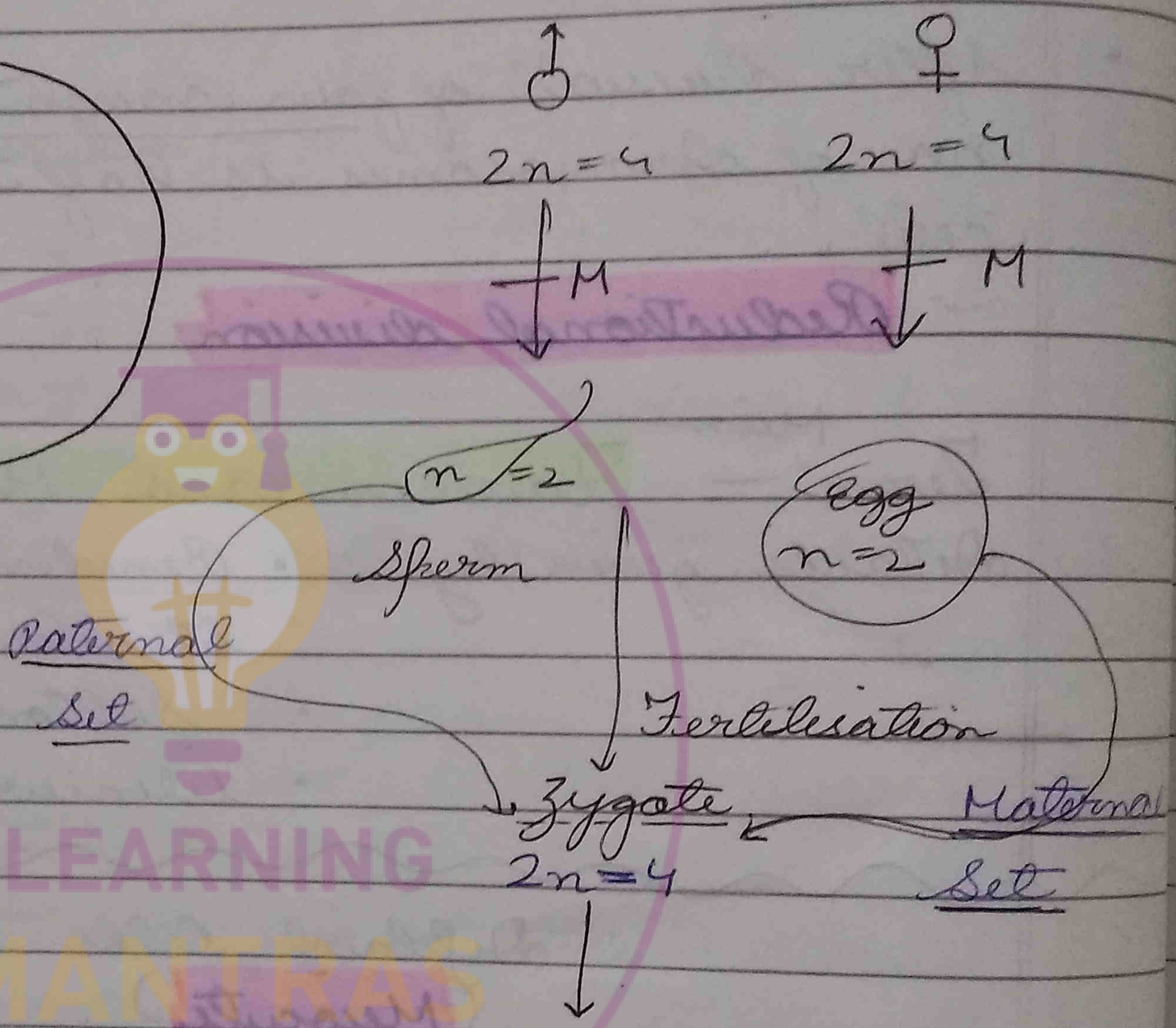
Diploid cells (Meiocyte)

Gonads	Sporangia	Zygote
Gametic meiosis	Sporic meiosis	Zygotic meiosis
at the time of gamete formation	Sporocyte	Zygote (2n)
Testis → Spermatocyte (2n) → M → n → Sperm	Ovary → Oocyte (2n) → M → Egg n	Microspore mother cell (2n) → M → Microspore (n)
		Megaspore mother cell (2n) → M → Megaspore (n)
		M → Haploid organism.

Homologous chromosomes

- Pair of identical chromosomes with size, position of genes and position of centromere.

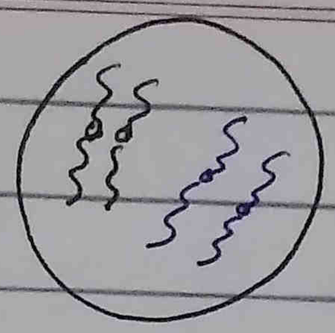




• No. of chromatin thread = No. of DNA molecule.

Meiosis → Brief.

Date __/__/__
Page

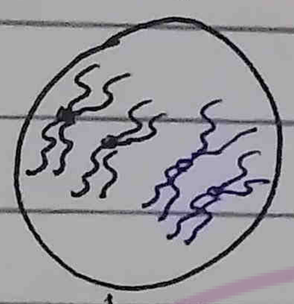


G1

2n=4 Monad

No. of chromosomes = 4
No. chromatin = 4
No. DNA = 4
Amount DNA = 2C

S



No. chromosomes = 4
No chromatin = 8
No. DNA = 8
Amount DNA = 4C

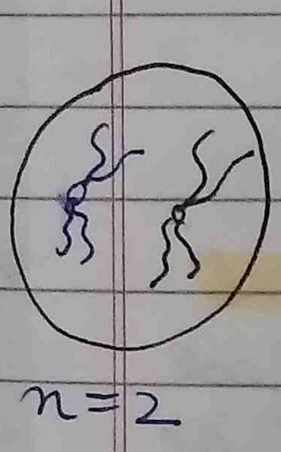
Reductional / Heterotypic division

G_2, Meiosis I — karyokinesis, cytokinesis

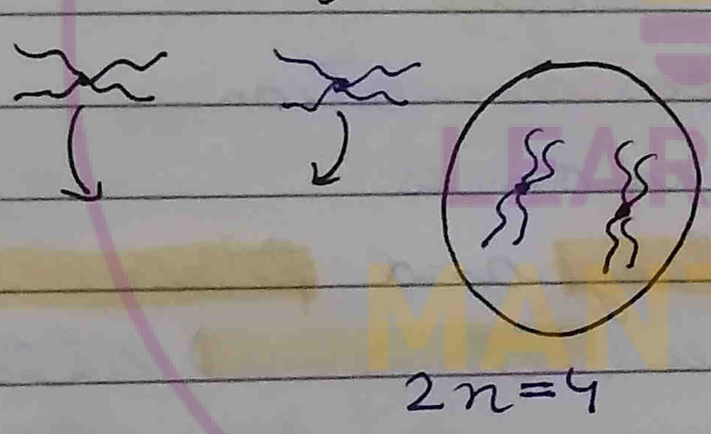
- P-I
- M-I
- A-I
- T-I

No. chromosomes = 2
No. chromatids = 4
No. DNA = 4
DNA amount = 2C

1/2



n=2



2n=4

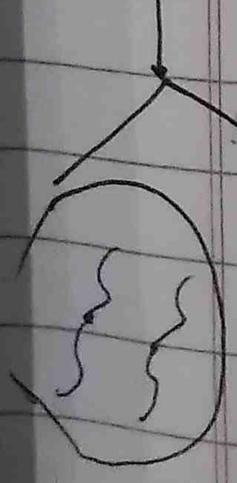
1/4

No. of chromosomes = 2
No. of chromatids = 2
No. DNA = 2
DNA conc. = 1C

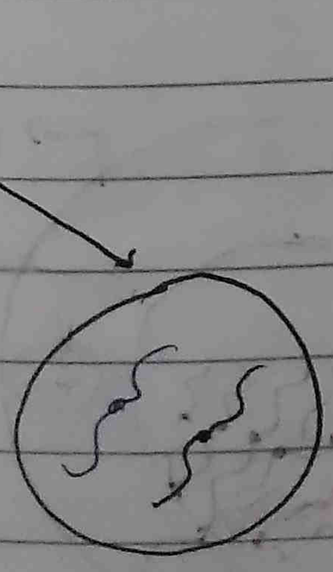
Meiosis - II

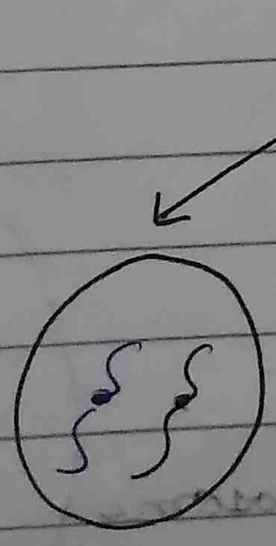
Equational / Homotypic division

- P-II
- M-II
- A-II
- T-II

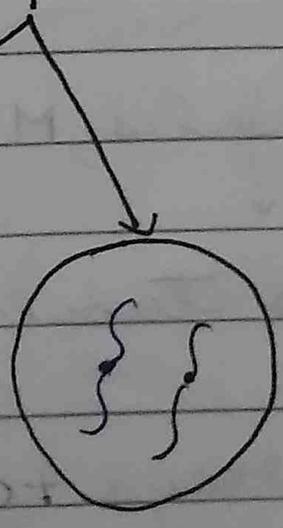


n=2





n=2



Monad

Meiosis I

- Karyokinesis

Prophase I

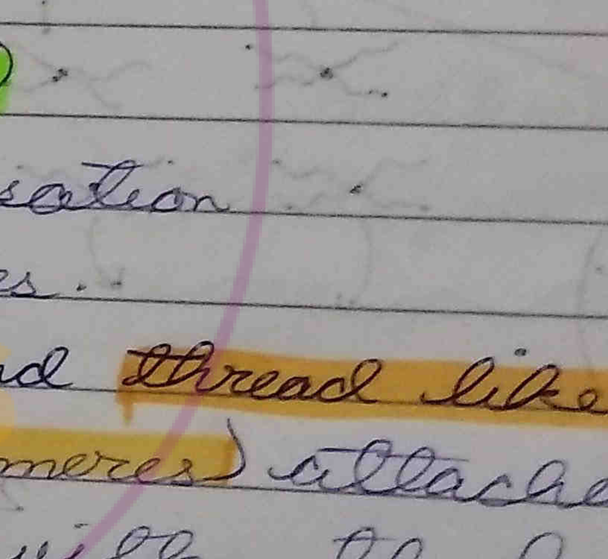
- Longest
  - → Leptotene
  - → Zygotene
  - → Pachytene
  - → Diplotene
  - → Diakinesis

→ **Leptotene** (Bouquet stage)

- Chromatin fibres condensation
- Elongated chromosomes.
- Chromosomes are thin, long and thread like.
- Ends of chromosomes (telomeres) attached to nuclear membrane with the help of attachment plate.

- Duplicated centrosomes move away from each other.

Microtubules, MTOC
↓
Micro tubule
↓
Astral rays + centrosome
||
Aster



☆ A pair of homologous chromosome is called bivalent.

Date __/__/__
Page _____

- Zygotene

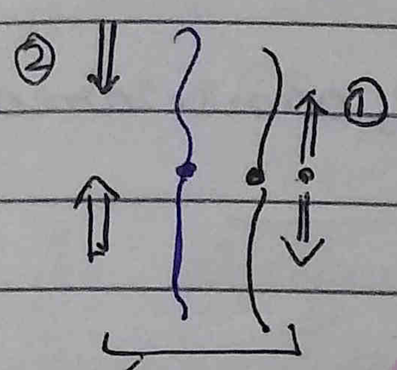
- Pairing of homologous chromosomes

Synapsis | Syndesis

→ ① Procentric
Pairing from centre

→ ② Pro terminal
Pairing from end.

→ Intermediate
Between end and centre



No of Bivalent is half the total no of chromosomes

pair of homologous chromosomes → Bivalent

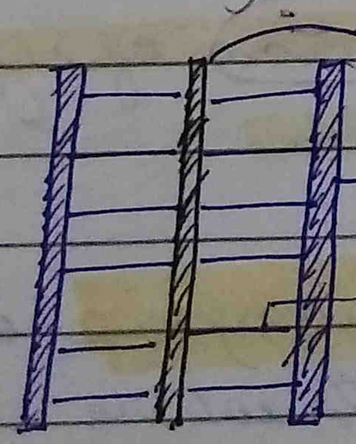
☆ Pairing with the help of Synaptonemal complex.

↓

☆ Contains RNA and protein hence called Ribonucleoprotein complex.

↓

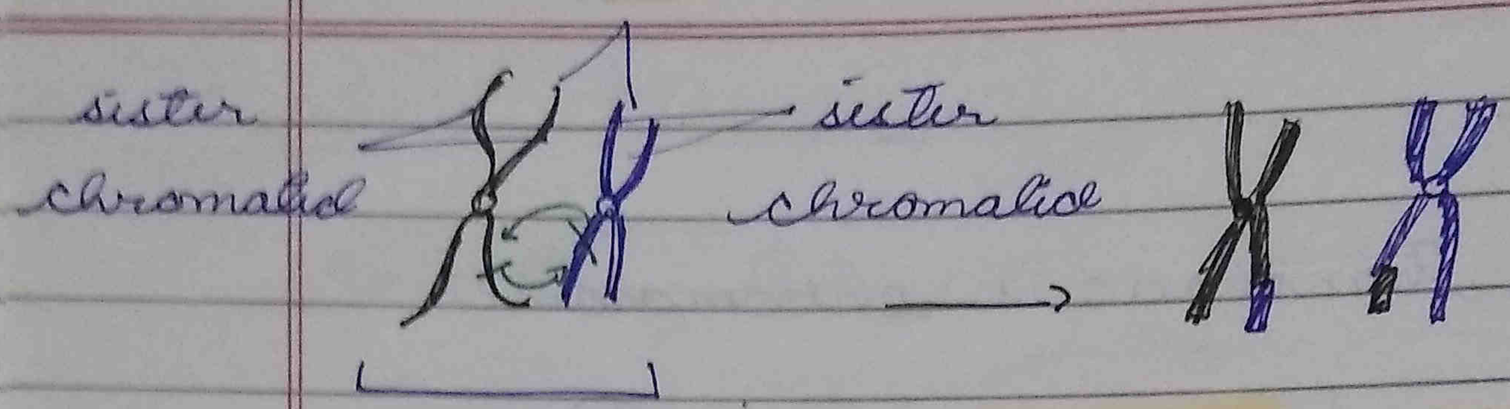
It has tripartite structure



- Pachytene

Thick thread stage.

Further condensation of chromatin fibres. Chromosomes become thick and short in size. Two chromatids of each chromosome are visible.



- Bivalent
- Tetrad stage

Recombination nodules : Dark, dense areas

↓

Site of crossing over

↓

Exchange of genetic material between non-sister chromatids of homologous chromosomes

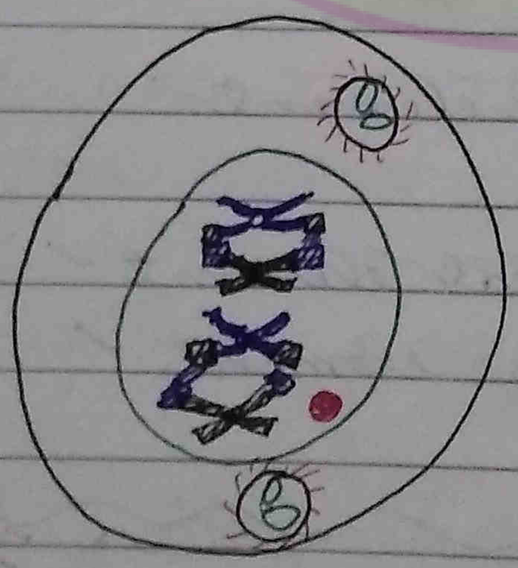
↓

Recombination occurs

↓

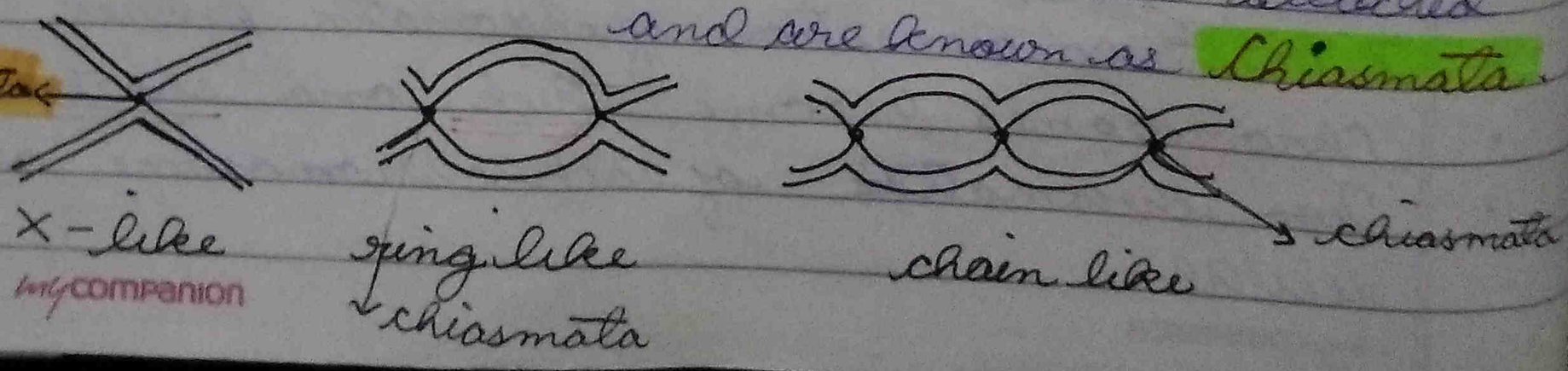
★ Recombinase enzyme - (Multienzyme complex)

- Diplotene



- Dissolution of synaptonemal complex
- Desynapsis - occur except point where crossing over has occured.
- These sites remain attached and are known as Chiasmata.

Chiasmata:



Terminalisation starts in diplotene but ends in diakinesis.

Date __/__/__
Page _____

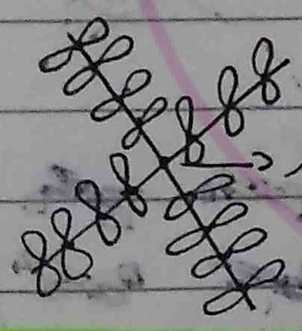
Terminalisation: is shifting of chiasmata towards ends due to dissolution of synaptonemal complex.

* In oocytes of some vertebrates, the diplotene stage can last for months to years. This prolonged diplotene stage ↓ is known as:

Dictyotene Stage

- In dictyotene stage decondensation of chromosome takes place at points where genes are present.

After decondensation, transcription will occur which leads to formation of **rna** and hence **protein**.
↓
which represents yolk in egg and helps in development of embryo.



- Lampbrush chromosomes
- Giant chromosomes.

** In human females, the oocytes the diplotene stage is reached at 5th month of foetus.
↓ stage suspended
Meiosis resumes at time of ovulation (at Puberty)

Bivalents = two homologous chromosomes

Date / /
Page

Diakinesis

- Terminalisation occurs. → completed here

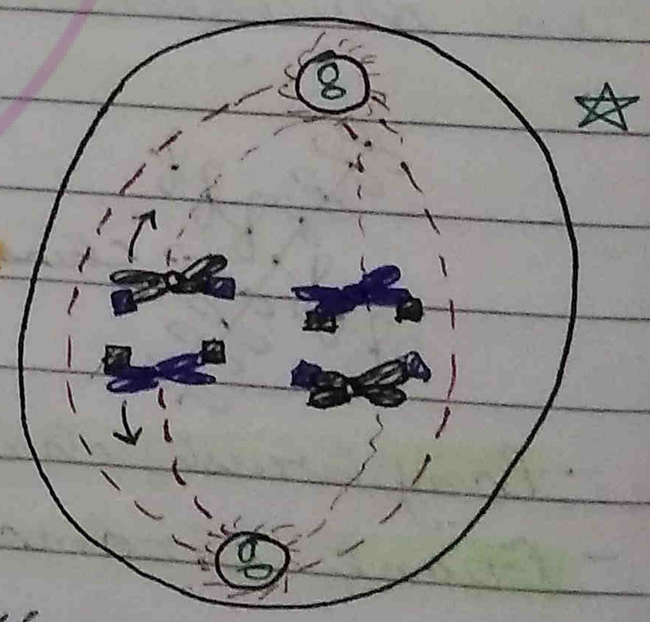
→ Nuclear membrane
- Nucleolus
- Endoplasmic reticulum
} disintegrate.

- ✡ Formation of spinde fibres starts.

Metaphase I

- Bivalents arrange themselves on the equator with the help of spindle fibres.

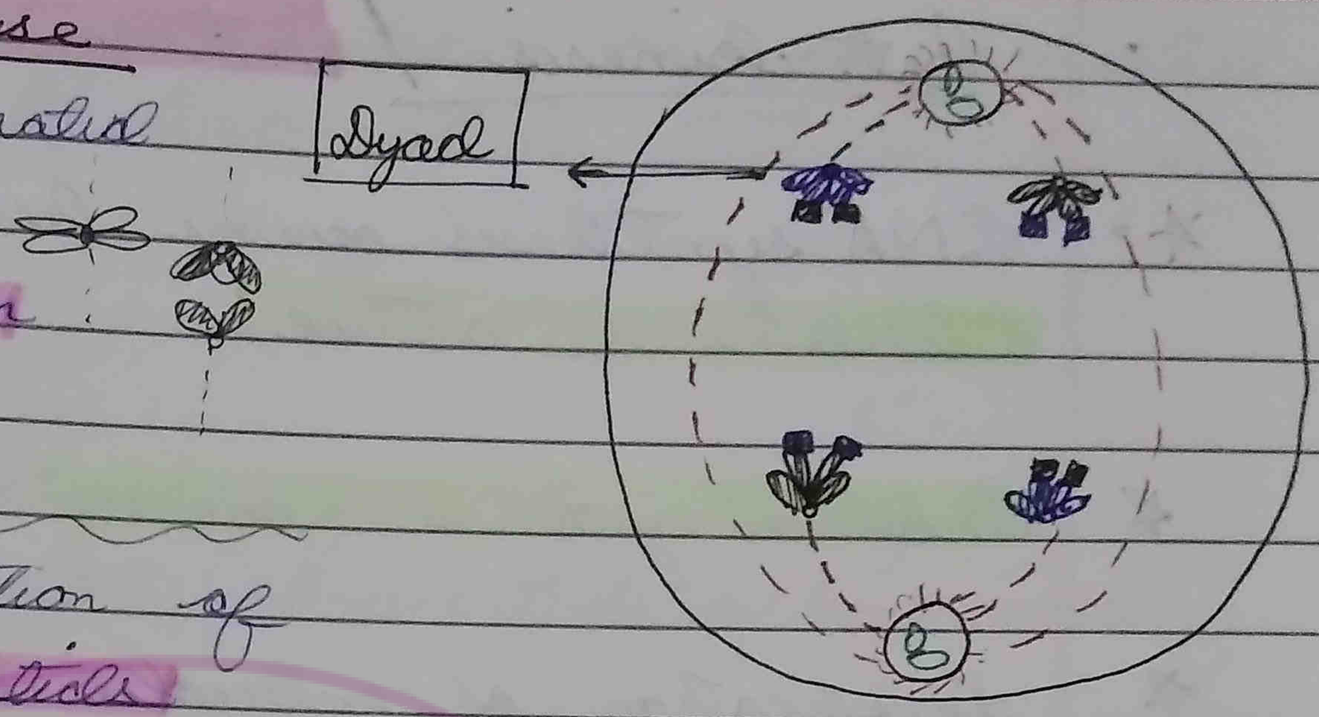
Metaphase I	Metaphase
Double metaphasic plate formed	Single metaphasic plate formed.
One tractile fibre attached to each chromosome	Two tractile fibres attached to each chromosome.



Anaphase I

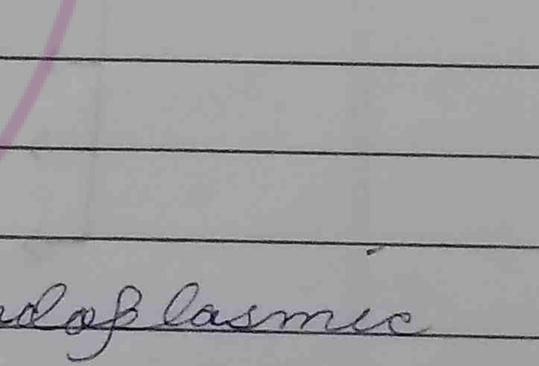
- Homologous chromosomes move towards opposite pole which is known as disjunction.

Anaphase I	Anaphase
• Daughter chromosomes contain 2 chromatids = Dyad condition - Separation of homologous chromosome occur.	1 chromatid = Monad condition Separation of chromatids occur.



Telophase I

- Last phase of karokinesis I
- Chromosomes show decondensation
- Chromatin fibres (network) formed.
- Nuclear membrane, Nucleolus, Endoplasmic Reticulum reform.
- Spindle fibres and astral rays disintegrate



Cytokinesis - I

Two daughter cells formed containing 1/2 half the no. of chromosomes.

• DNA replication present in interphase of mitosis but absent in interkinesis.

Date __/__/__
Page

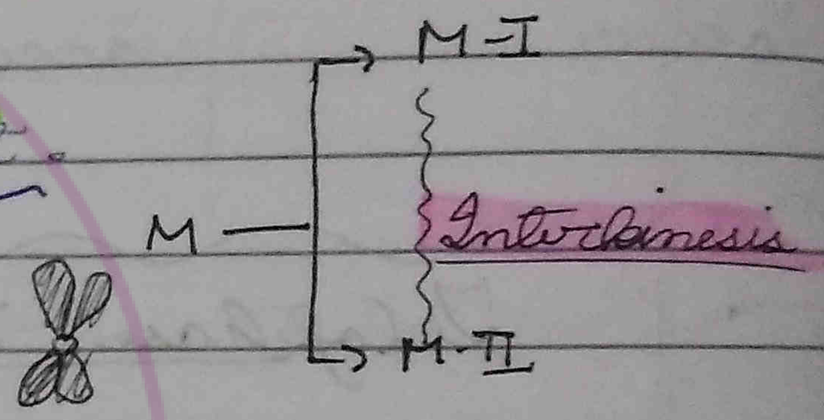
• Interkinesis / Intrameiotic Interphase

☆ RNA synthesis occurs hence RNA Polymerase (RNAP) is active.

☆ Protein synthesis occurs

☆ Duplication of centriole (Animal cell)

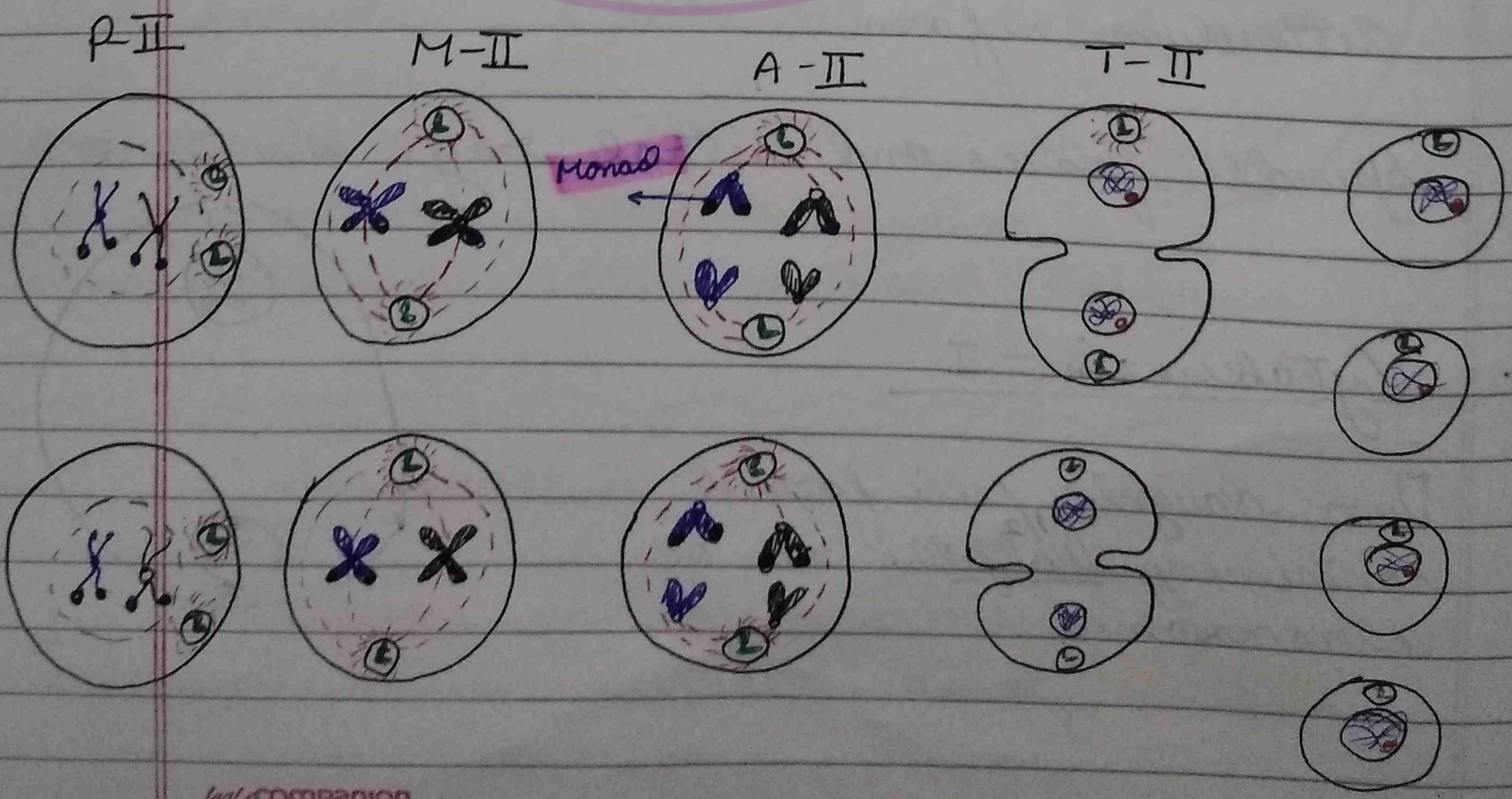
☆ DNA replication is absent.
Because chromosomes are already in dyad condition



• Meiosis – II

Karyokinesis II, Cytokinesis-II

→ Prophase-II
→ Metaphase-II
→ Anaphase-II
→ Telophase-II



Date __/__/__
Page

☆ V-protein and Vmoindase are responsible for separation of chromatids between two gaps.

- R-Protein: responsible for reunion of separated chromatids after crossing over.

- Meiosis involves two nuclear division and one chromosome division

- Small cells are metabollically more active due to high K.I of small cells.