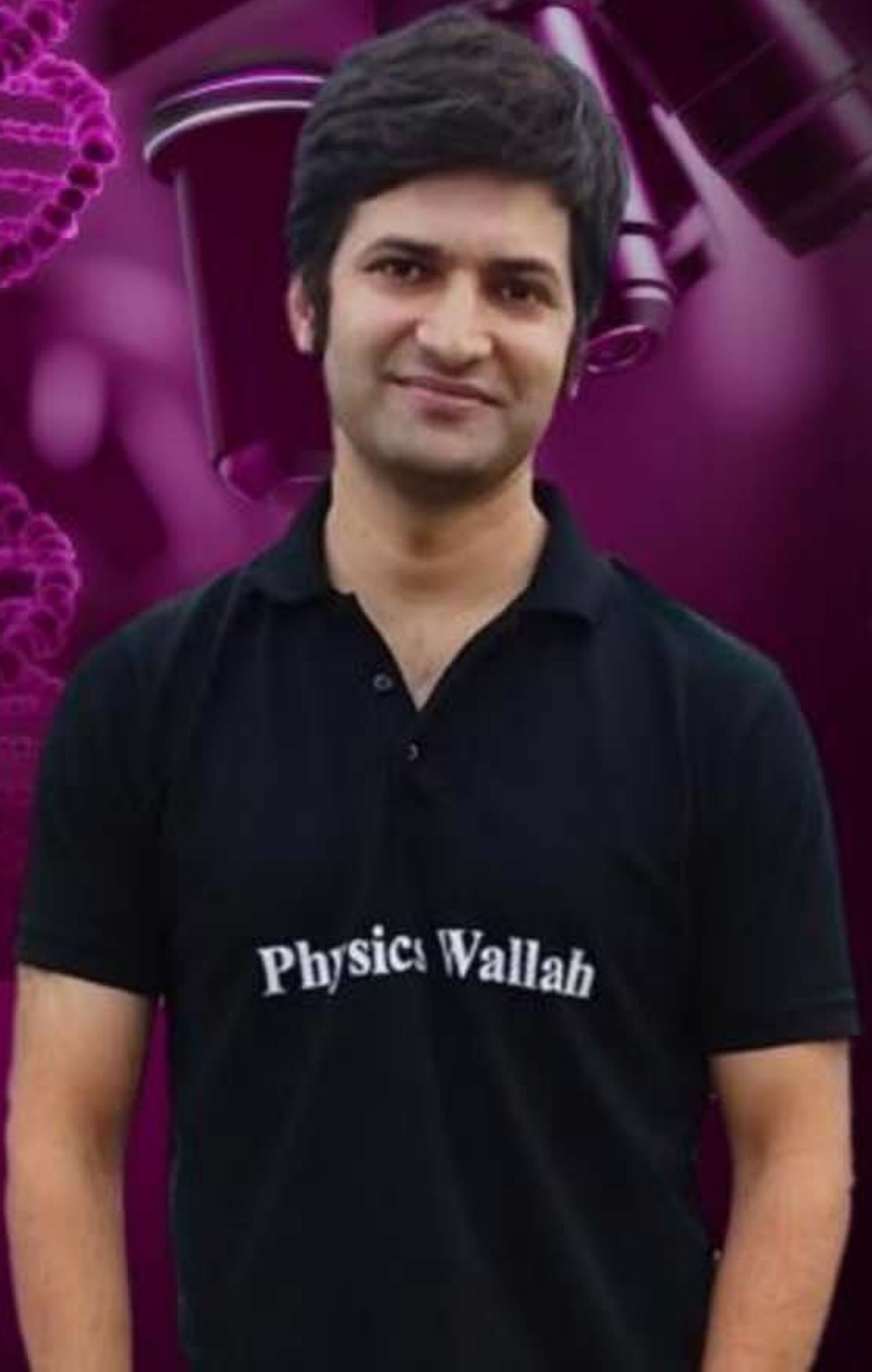
PRACHAND NEET

ONE SHOT

Botany

Cell Cycle and Cell Division

Rupesh Chaudhary Sir



Topics *to be covered*

1. Cell Cycle and Cell Division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RUPESH SIR
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Physics Wallah
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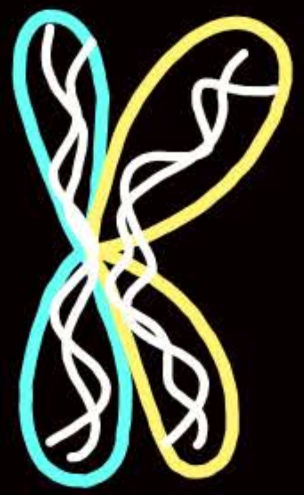
Chromatin & Chromosome

DNA → Chromatin → Chromosome

Chromatin	Chromosome
less Folded DNA	MORE FOLDED DNA
less packaging	more Packaging
Long	Short
Thin	Thick
less condensed (less visibility)	more condensed (more visibility)

Chromosome

a)



b)

	a)	b)
Chromosome:	1	1
Chromatid	1	2
DNA amount	x	$2x$

CELL CYCLE

Papa/parent cell
(2n)

PROPERTY DOUBLE (DNA & CELL ORGANELLE SYNTHESIS)

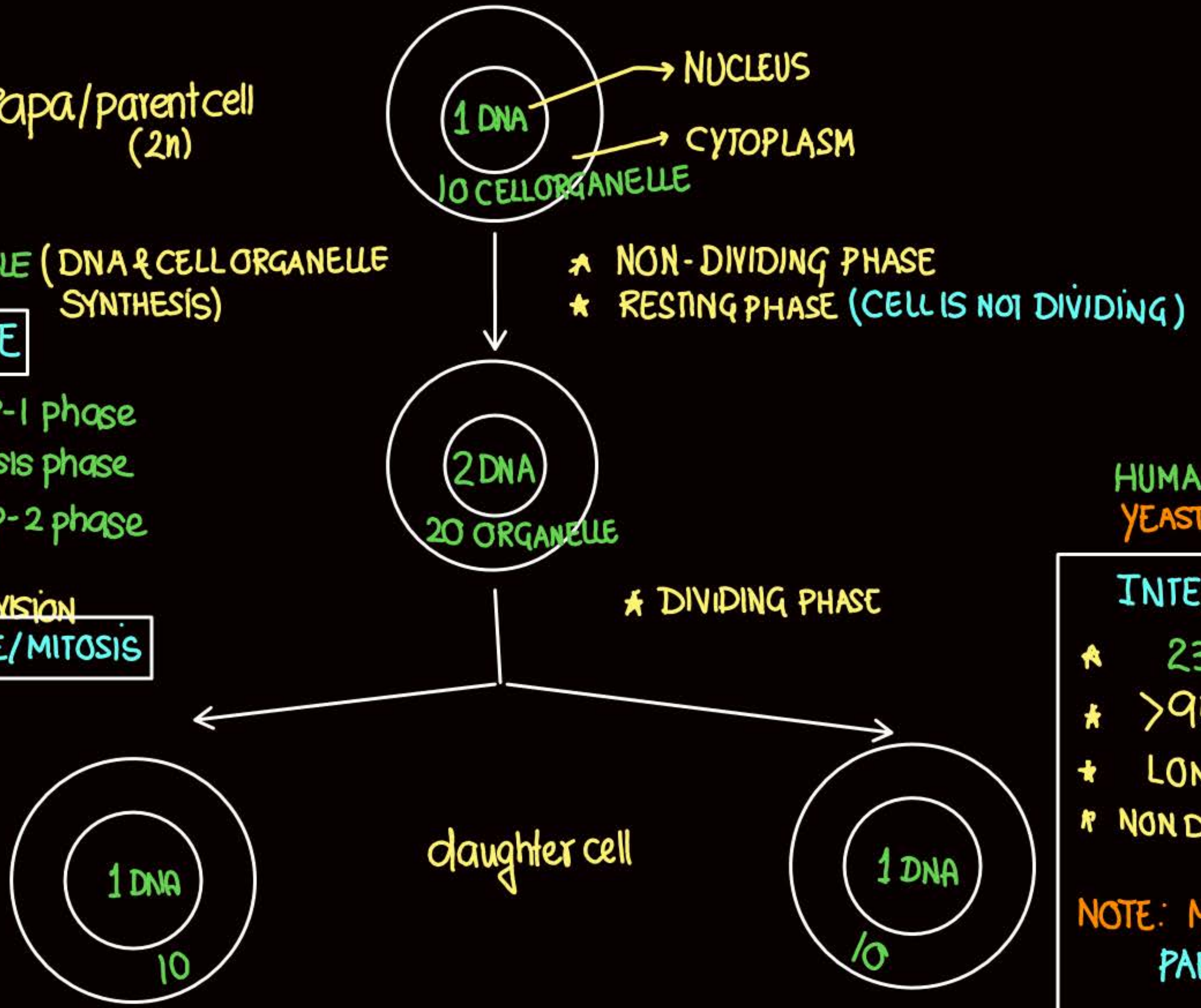
① INTERPHASE

a) G_1 / GAP-1 phase
b) S ynthesis phase
c) G_2 / Gap-2 phase

PROPERTY DIVISION

② M PHASE/ MITOSIS

a) KARYOKINESIS
b) CYTOKINESIS



duration vary from cell to cell / organism to organism

HUMAN: 24 HOURS
YEAST: 90 minutes

INTERPHASE	+ M PHASE = CELL CYCLE
★ 23 hour	1 HOUR
★ >95	<5%
★ LONG	SHORT
★ NON DIVIDING	DIVIDING PHASE

NOTE: MITOSIS / EQUATIONAL DIVISION:
PARENT & DAUGHTER CELL
CHROMOSOME NUMBER: SAME.

Definition of cell cycle

The sequence of events by which cell duplicates its genome / DNA (NUCLEUS) → DNA
and
Other constituent of cell. (cytoplasm) → CELL ORGANELLE

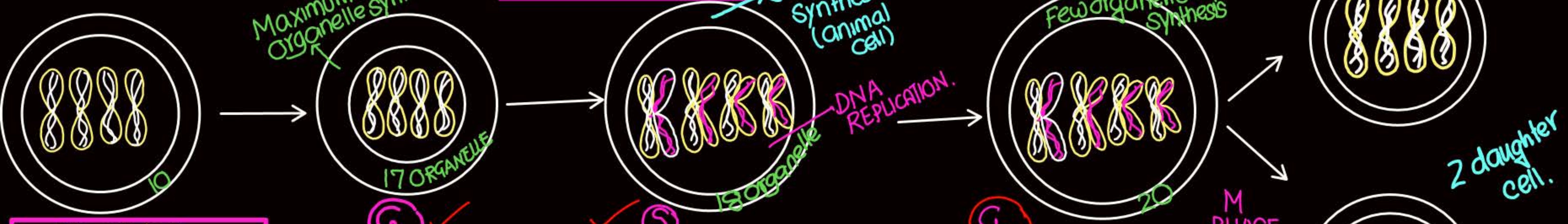
[INTERPHASE]

Equal distobution in TWO DAUGHTER CELL → M PHASE / MITOSIS

All events: ORDER / SEQUENCE

UNDER CONTROL OF GENE (PART OF DNA).

DETAIL OF CELL CYCLE



	G_1	S	G_2
2n =	4	4	4
	1 growth	2 growth	2 growth.
	2C = 20	4C = 40	4C = 40

PARENT (2N)

Chromosome : 4

Chromatid : 1

DNA amount : 2C = 20

INTERPHASE

SOME PROTEIN SYNTHESIS

2n = 4 chromosome
1 chromatid
DNA amount : 2C
20

Q Parent (2n) : 10 chromosome

G_1 : 10, 2n
S : 10, 2n
G_2 : 10, 2n
M PHASE : 10, 2n

Q Parent Cell (2C)

G_1 : 2C
S : 4C
G_2 : 4C
M : 2C

Q PARENT CELL : 20Pg DNA

G_1 : 20 / 2C
S : 40 / 4C
G_2 : 40 / 4C
M : 20 / 2C

CYTOPLASM CONTENT
NUCLEUS CONTENT
INCREASE → CONTINUOUS

growth.

NOTE IN MITOSIS:
NO CHANGE IN CHROMOSOME: TRUE ✓

Q: G_1: 4 Chromosome, 4 chromatid — 1 chrom : 1 chromatid

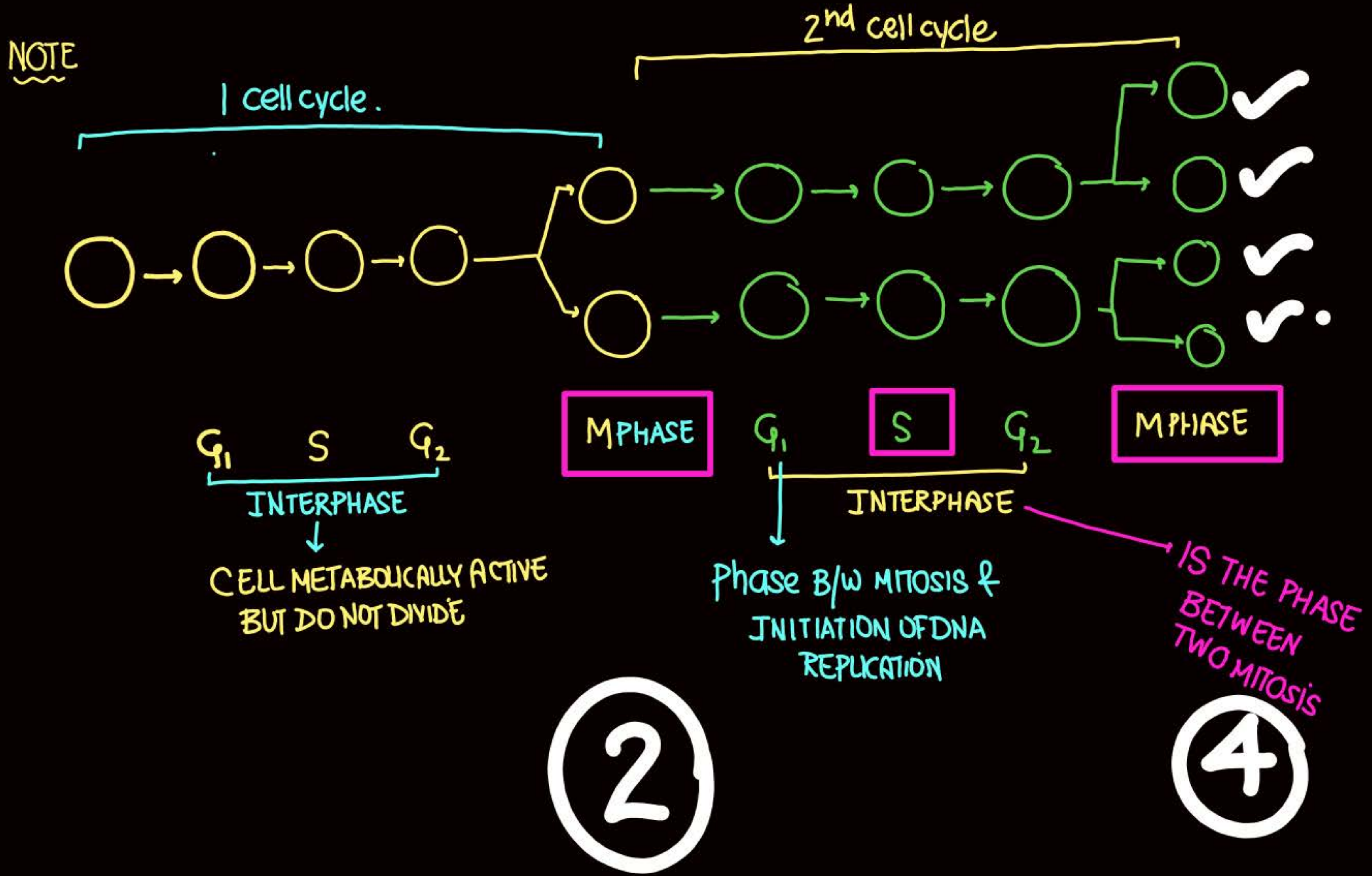
Q S: 4 chromosome, 8 chromatid. — 1 chrom : 2 chromatid (DNA REPLICATION)

Q S phase
Total chromatid: 20
Chromosome: 10

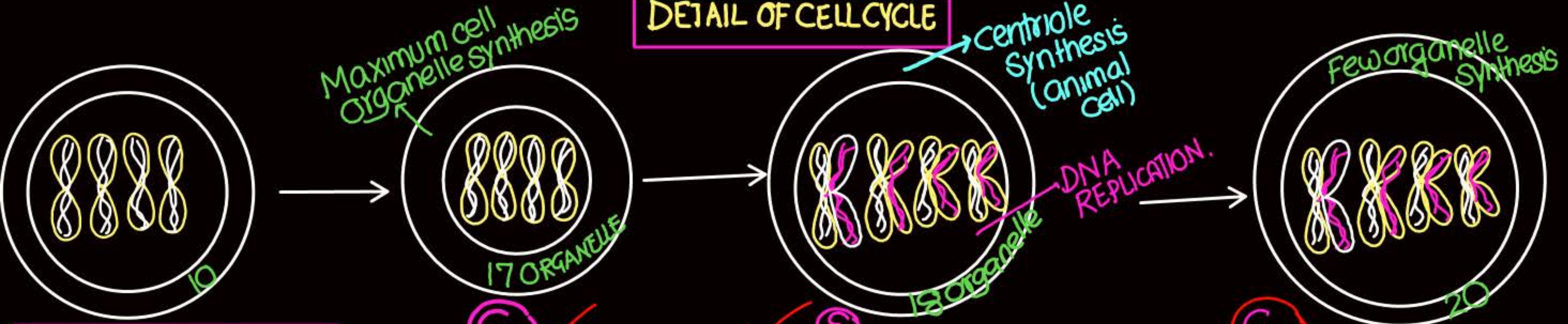
Q G_1 phase
40 chromatid
Chromosome: 40

CELL CYCLE: INTERPHASE + M PHASE
- Karyokinesis (NUCLEAR DIVⁿ)
  - PROPHASE
  - METAPHASE
  - ANAPHASE
  - TELOPHASE
  - [Complex series of events]
- Cytokinesis
  - CYTOPLASM DIVⁿ

NOTE: S PHASE:
DUPLICATION OF CHROMOSOME / REPLICATED CHROMOSOME
[DNA]


NOTE
1 cell cycle.
2nd cell cycle
G_1 S G_2
INTERPHASE
CELL METABOLICALLY ACTIVE
BUT DO NOT DIVIDE
M PHASE
G_1 S G_2
INTERPHASE
Phase B/W MITOSIS &
INITIATION OF DNA
REPLICATION
M PHASE
IS THE PHASE
BETWEEN
TWO MITOSIS
2
4

DETAIL OF CELL CYCLE



	PARENT (2N)	G_1	S	G_2
Chromosome :	4	4	4	4
Chromatid :	1	1	2	2
DNA amount :	2C =	2C	4C	4C

MITOSIS

a) KARYOKINESIS

1. PROPHASE
2. METAPHASE
3. ANAPHASE
4. TELOPHASE

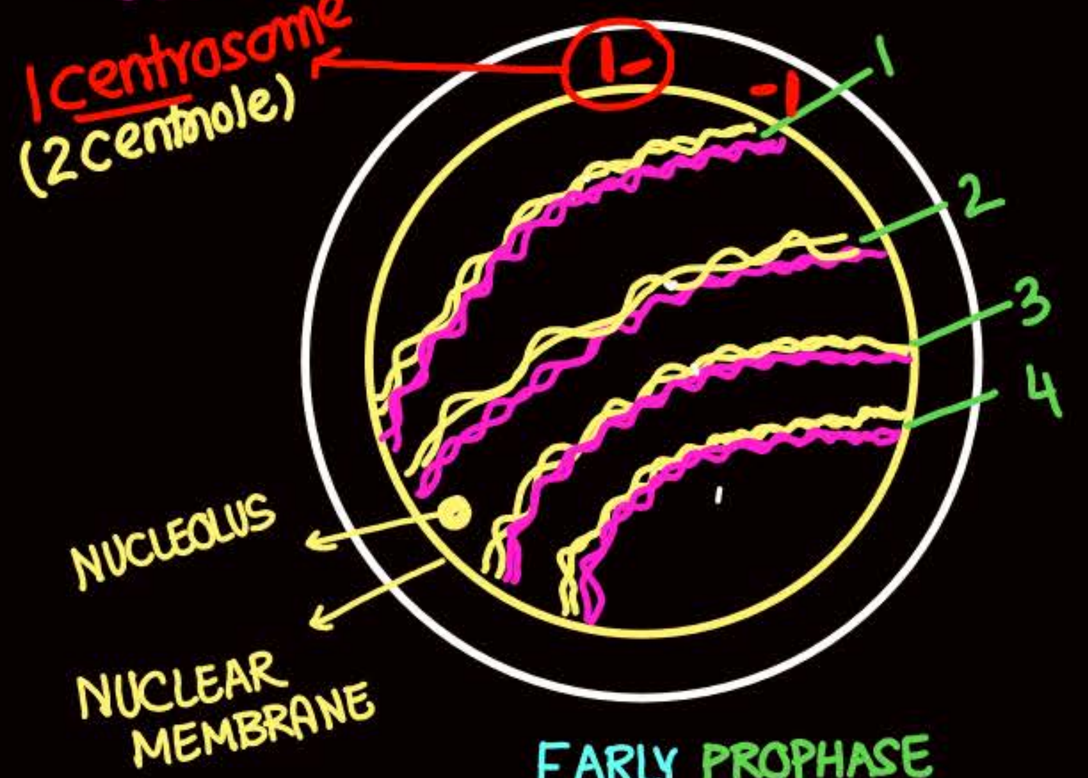
DECONDENSED FORM OF CHROMOSOME

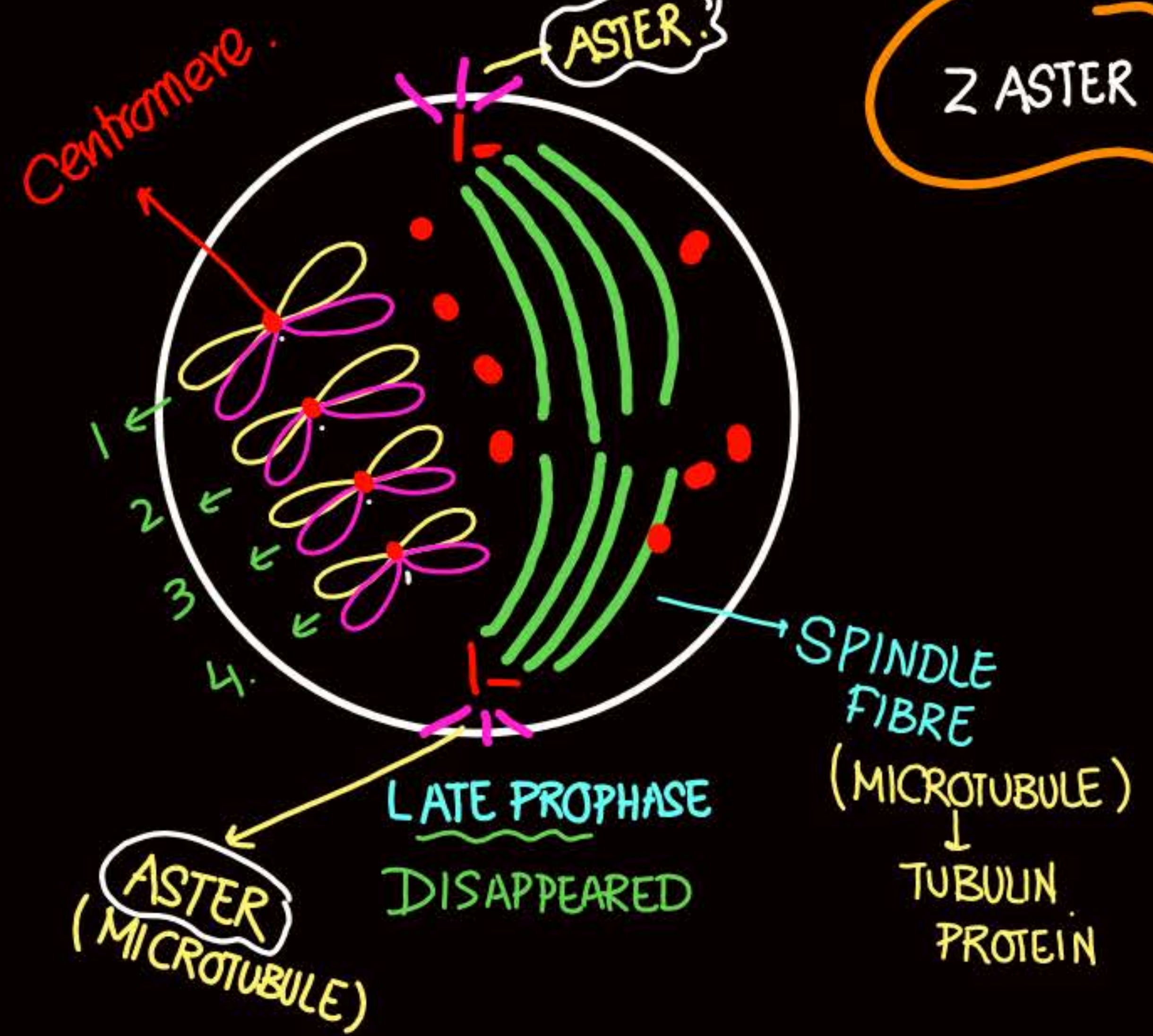
CHROMATIN

	Chromosome	DNA amount
parent cell	4	2C
G_1	4	2C
S	4	4C
G_2	4	4C
PROPHASE	4	4C
METAPHASE	4	4C
ANAPHASE	8	4C
TELOPHASE	4	2C

Equational Division

PROPHASE



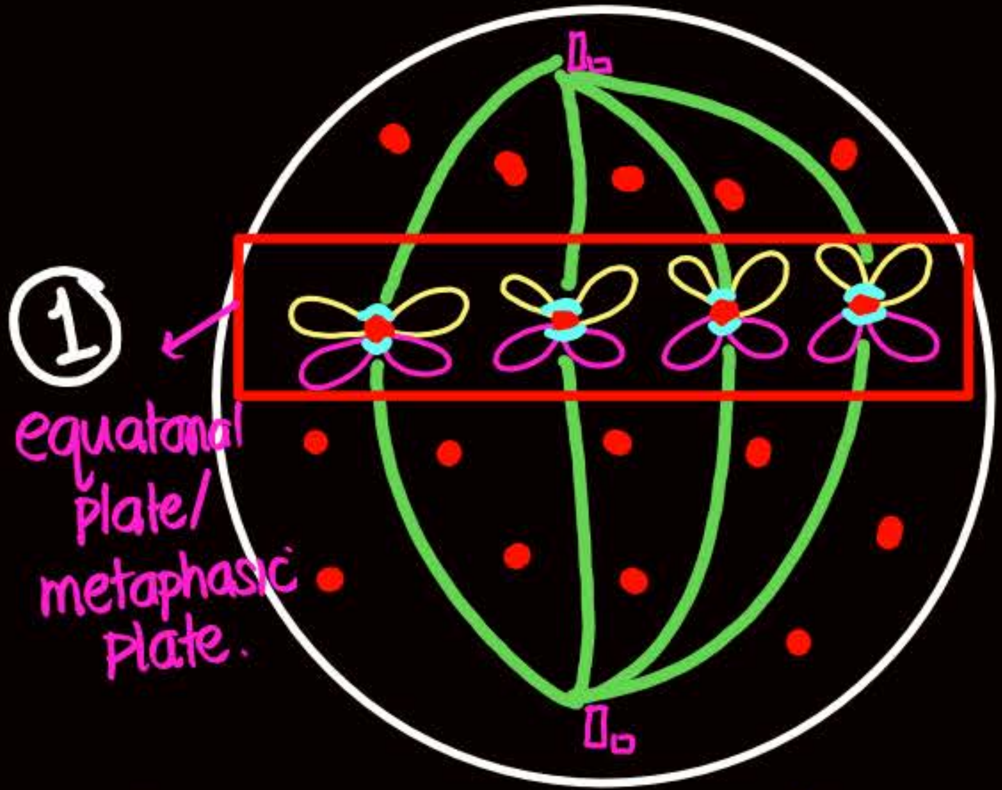


	EARLY PROPHASE	LATE PROPHASE
NUCLEOLUS, NM.	Starts disappearing	DISAPPEARED
Chromosome	decondensed form (Chromatin)	Condensed
Centriole	Starts moving Towards opposite pole	Reached at opposite pole.
DNA	TANGLED (VISIBILITY LOW)	UNTANGLED (VISIBILITY HIGH)

2 ASTER + SPINDLE FIBRE ~~~ MITOTIC APPARATUS.

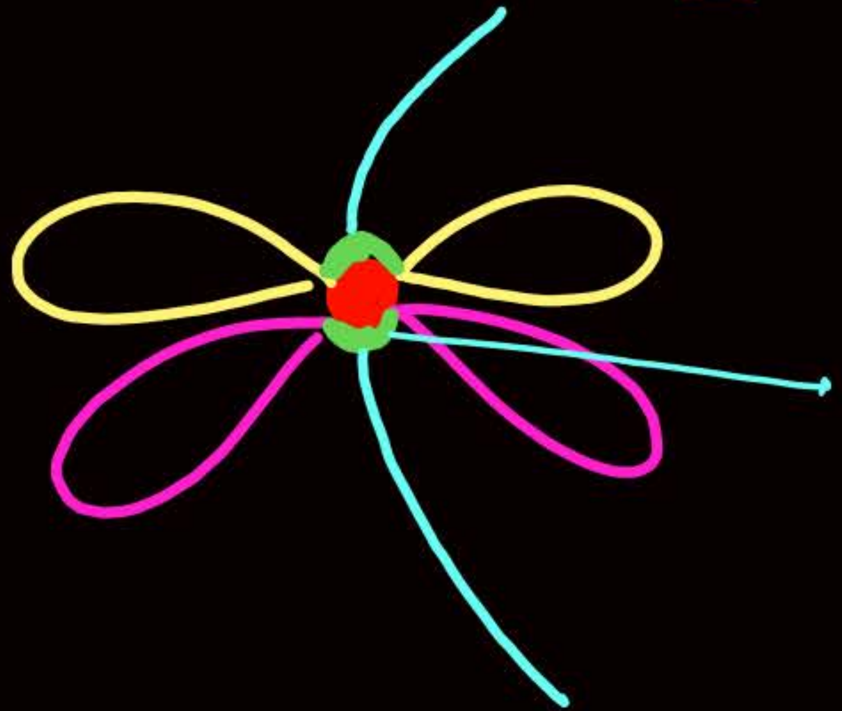
- ⇒ Chromosomal material (DNA) OR CHROMATION → CONDENSATION.
- ⇒ CHROMATIN CONDENSED TO FORM CHROMOSOME.
- ⇒ BY END OF PROPHASE, NUCLEOLUS, NUCLEAR MEMBRANE, golgi BODY, ER: DISAPPEARED.
- ⇒ BOTH CHROMATID OF CHROMOSOME ATTACH AT CENTROMERE
- ⇒ CHROMOSOMAL MATERIAL (DNA) BECOME UNTANGLED.
- ⇒ CHROMOSOME NOT PRESENT ON SPINDLE FIBRE

METAPHASE



- DISINTEGRATION OF 'N' & 'NM' IS BEGINING OF METAPHASE
- All chromosome arrange on centre/ equator
- Condensation of chromosome Completed (Maximum)
  VISIBILITY : Very HIGH.

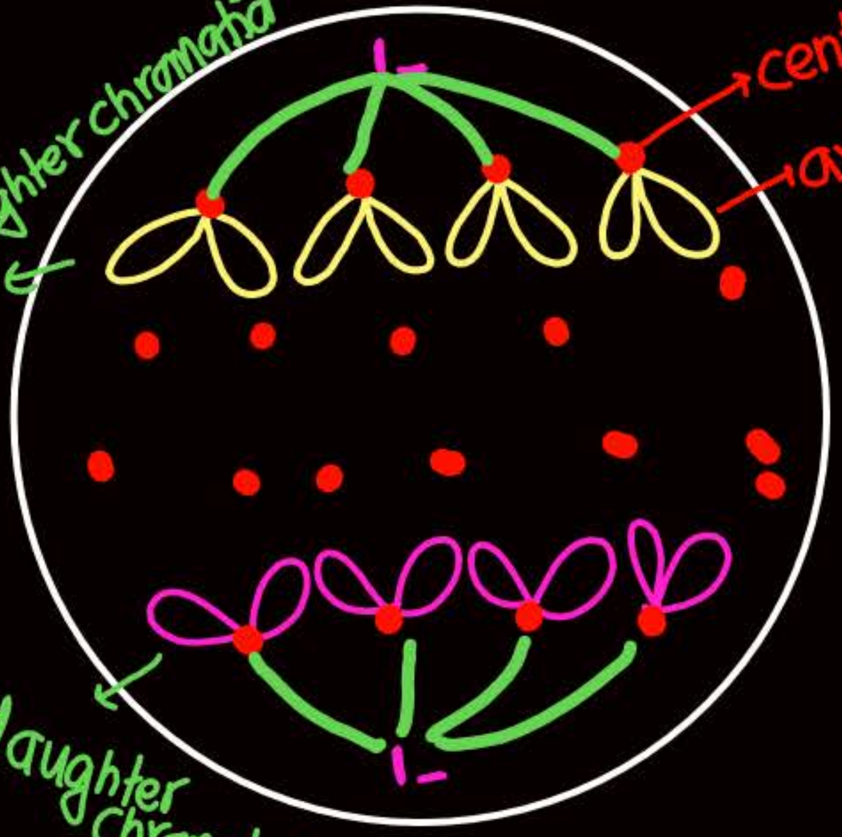
- MORPHOLOGY (SIZE, NUMBER) : STUDY



Small protein disc (kinetochore) → Provide attachment site to SPINDLE FIBRE/ MICROTUBULE.
↓
PRESENT ON CENTROMERE

* Plane of alignment of Chromosome : METAPHASIC PLATE.
↓
PRESENT IN CYTOPLASM.

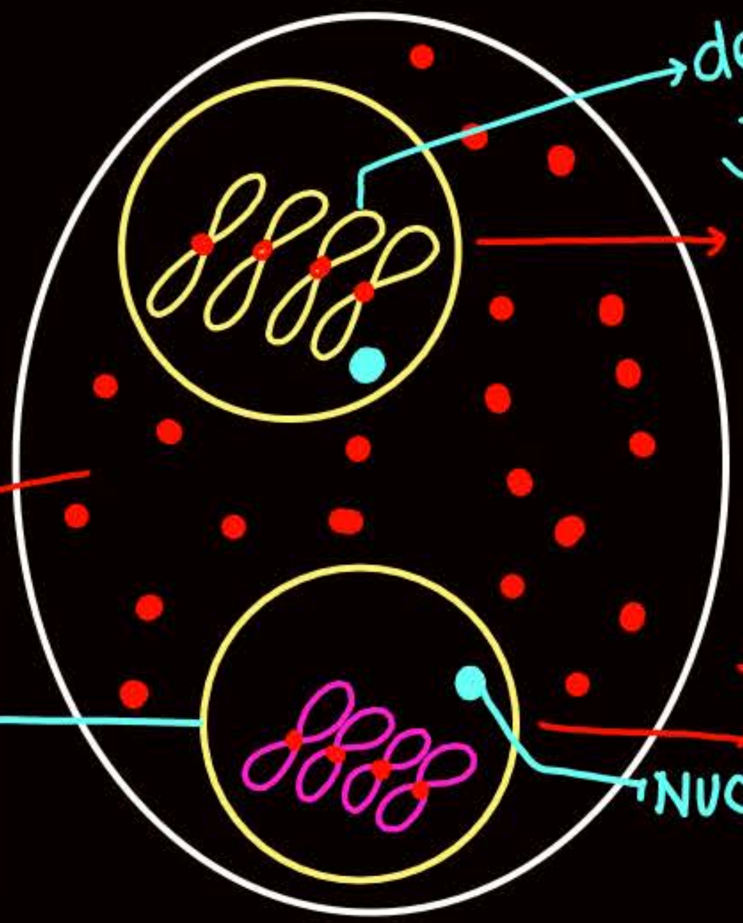
ANAPHASE



- Chromosome/Centromere: splitting
- daughter chromatid of each chromosome moves towards opposite pole

⇒ NOW EACH DAUGHTER CHROMATID CALLED DAUGHTER CHROMOSOME.

TELOPHASE



Spindle fibre disappear

Visibility of chromosome: गायब

⇒ Karyokinesis completed.

⇒ NM, NUCLEOLUS REAPPEAR.

⇒ Chromosome ⟶ chromatin (decondensation)

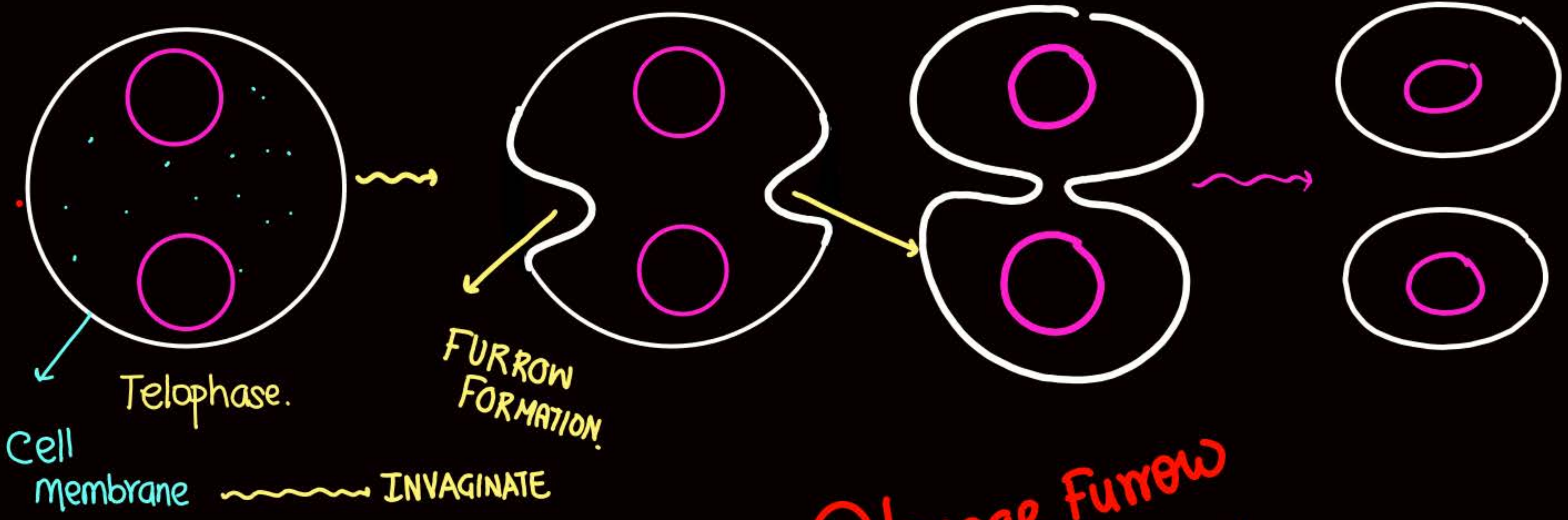
after karyokinesis cytokinesis

CHROMOSOME: IDENTITY LOST.

Two cells are formed

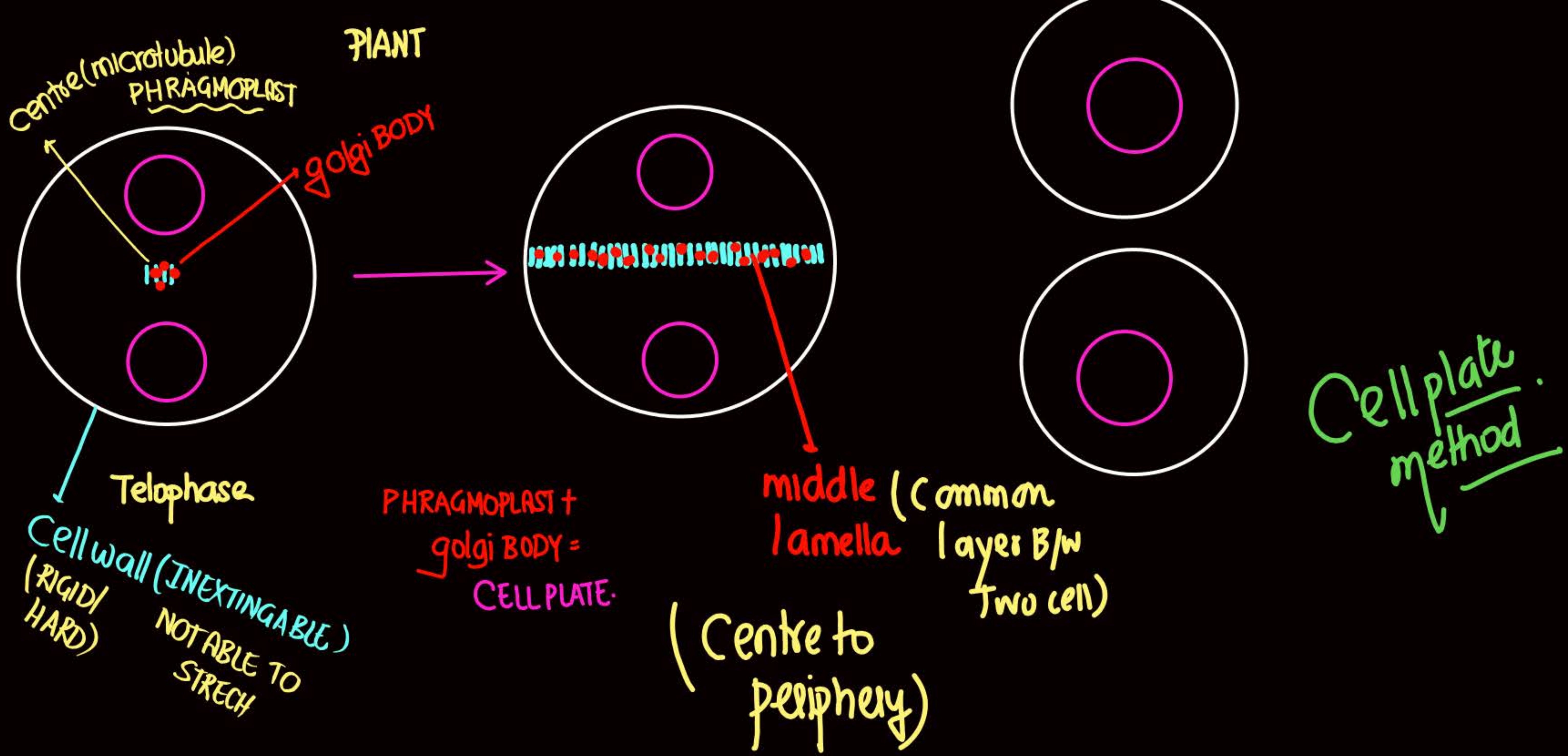
CYTOKINESIS

ANIMAL.

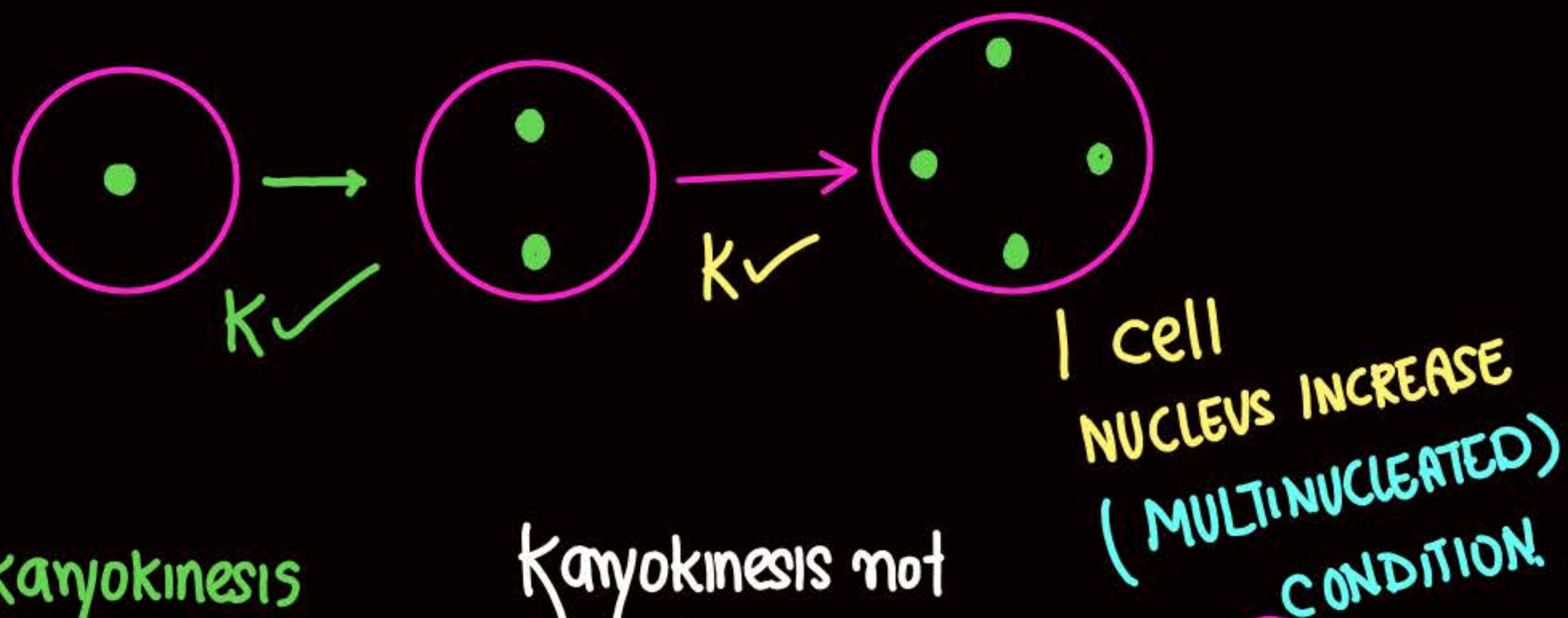


Clevage Furrow method

(outer/periphery to centre).


PlANT
Centre (microtubule)
PHRAGMOPLAST
golgi BODY
Telophase
Cellwall (INEXTINGABLE)
(RIGID/ HARD)
NOT ABLE TO STRECH
PHRAGMOPLAST + golgi BODY = CELL PLATE.
middle lamella (Common layer B/w two cell)
(Centre to periphery)
Cellplate method.

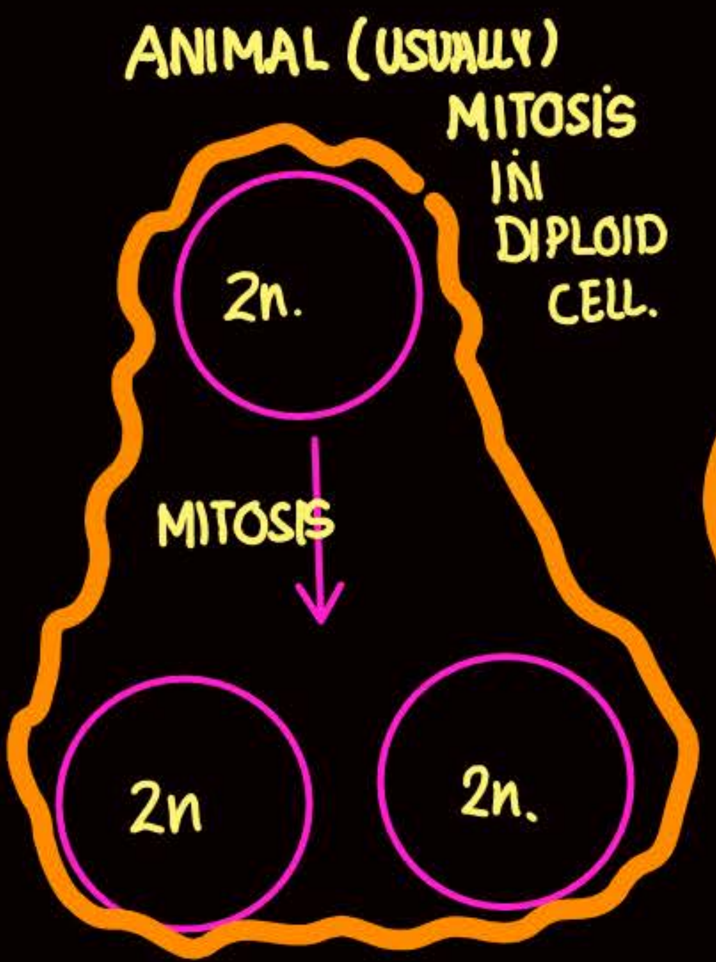
NOTE :



K : karyokinesis
C : cytokinesis

Karyokinesis not Followed By cytokinesis

Syncytium → COCONUT : Liquid (Endosperm).
1000 nucleus.



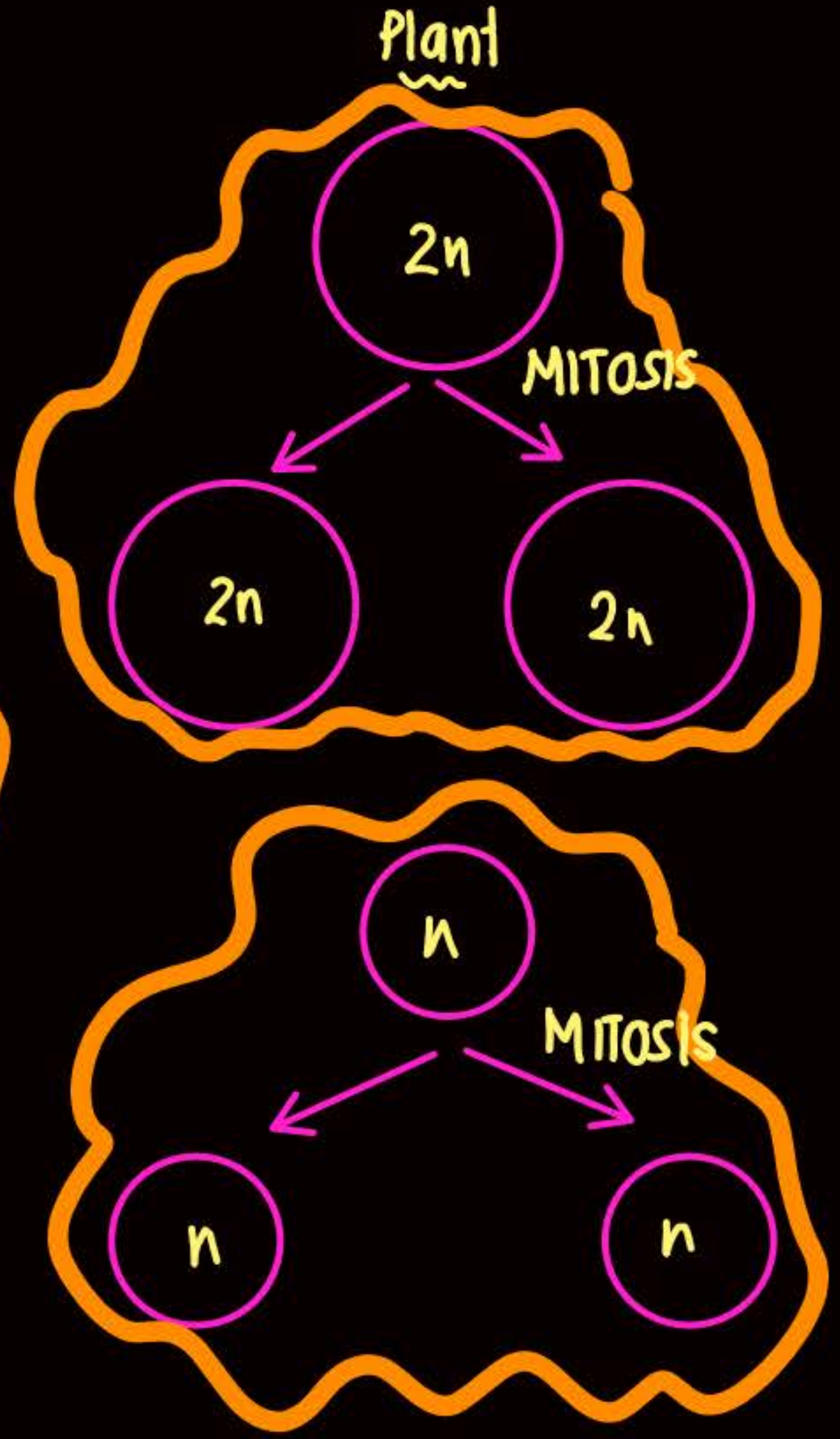
exception

Honey Bee

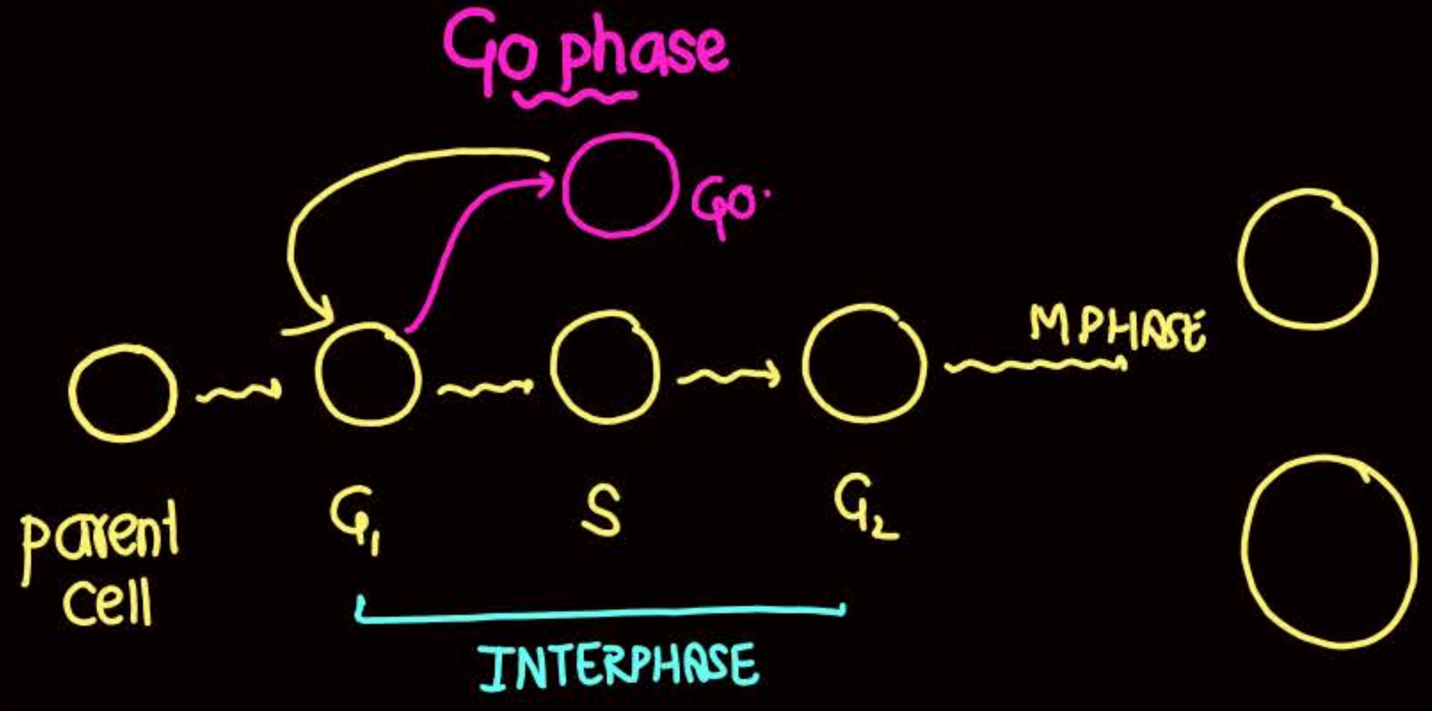
Queen (2n) → Female

Male/DRONE (n) → mitosis

SOCIAL INSECT



Go phase



⇒ Go: NOT A PART OF INTERPHASE / CELL CYCLE.

⇒ Go: EXIT THE CELL CYCLE.
: NOT DIVIDE / INACTIVE STAGE / QUIESCENT STAGE

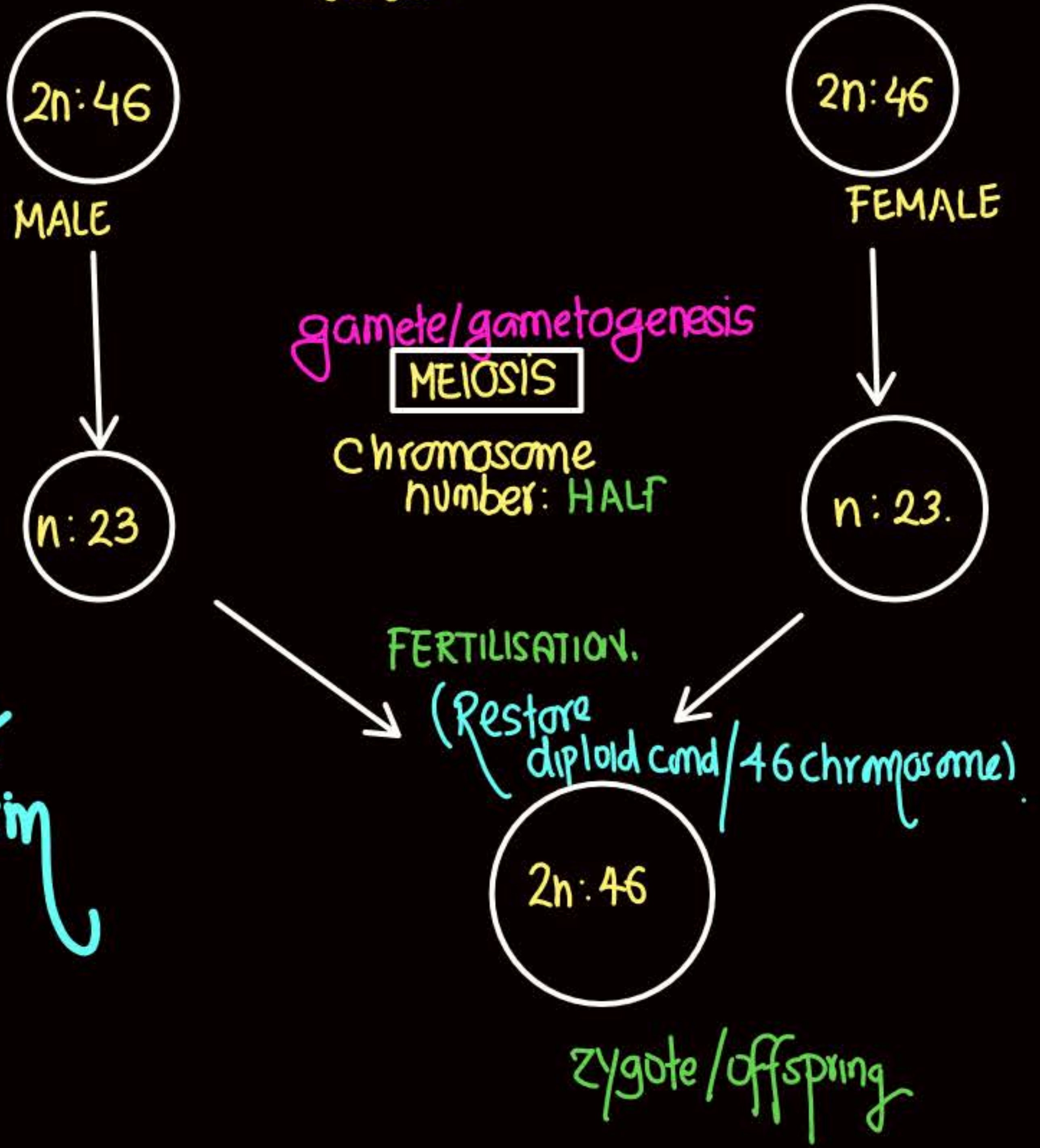
⇒ Go: cell: metabolically active

- Permanent: cell never ever Back to G1
  NEVER DIVIDE (HEART CELL / NERVE CELL)
- Temporary: Can back to G1
  & then follow normal path.

(depend upon Requirement)

MEIOSIS

MEIOSIS & FERTILISATION



Sexual Reproducing organisim

CONCEPT: ② MEIOSIS: MEIOSIS-I & MEIOSIS-II

2n:30 2C DNA.

INTERPHASE: DNA REPLICATION, CENTRIOLE DUPLICATION

2n:30 4C

MEIOSIS-I : OCCUR IN DIPLOID CELL
CHROMOSOME NO REDUCED TO HAIF
TWO CELLS FORMED.

Karyokinesis
cytokinesis

REDUCTIONAL DIVISION

n:15 2C — n:15 2C

INTERKINESIS/SHORT PHASE
CENTRIOLE DUPLICATION

n:15 , 2C — n:15 , 2C

Karyokinesis
cytokinesis

MEIOSIS-II (EQUATIONAL DIVISION)
(similar to mitosis)

n:15 1C — n:15 1C — n:15 1C — n:15 1C

DNA REPLICATION : ①
CENTRIOLE DUPLICATION : ②
NUCLEAR DIVISION/KARYOKINESIS : ②
CYTOKINESIS : ②

⇒ OCCUR IN HAPLOID CELL
⇒ 4 Haploid cells formed
⇒ No change in, chromosome number.

INTERPHASE
MEIOSIS-I → PROPHASE-I
INTERKINESIS
MEIOSIS-II

INTERPHASE

PROPHASE-I
METAPHASE-I
ANAPHASE-I
TELOPHASE-I

→ MEIOSIS-I

INTERKINESIS

PROPHASE-II
METAPHASE-II
ANAPHASE-II
TELOPHASE-II

→ MEIOSIS-II

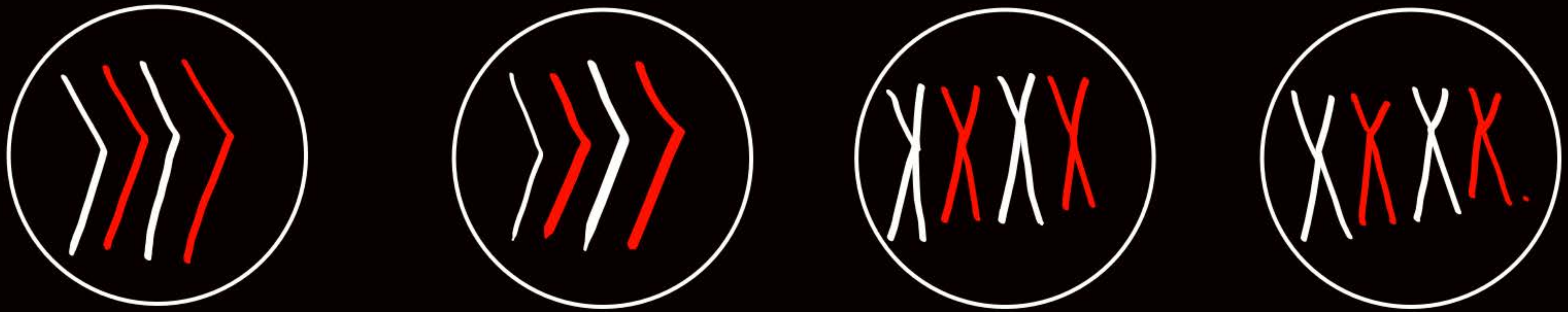
MEIOSIS-I

PROPHASE-I
↓
DIVIDED INTO 5 STAGES.

1. Leptotene
2. Zygotene
3. Pachytene
4. diplotene
5. Diakinesis

MITOSIS < MEIOSIS-I
↓
PROPHASE-I
LONG,
COMPLEX.

INTERPHASE



PARENT CELL (2n) | G_1 | S | G_2

Chromosome: (4)

DNA amount: (2C)

1 chromosome: 1 chromatid

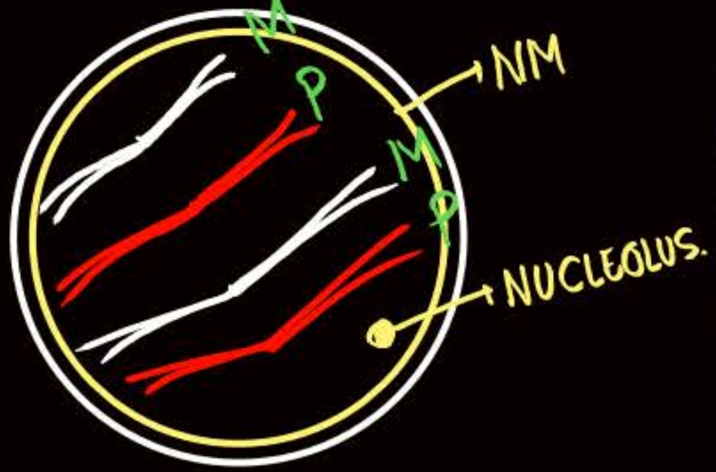
G_1: (4), (2C), (1)

S: (4), (4C), 2 chromatid.

G_2: (4), (4C), 2 chromatid → MEIOSIS-I (PROPHASE-I)

decondensed form of chromosome (chromatin)

4
4C



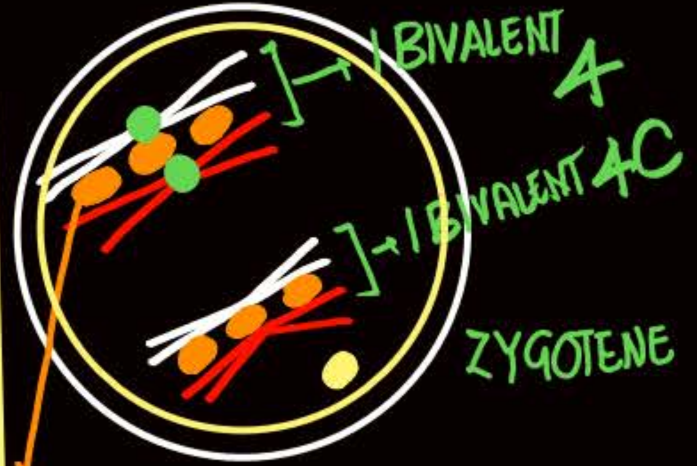
LEPTOTENE

* COMPACTION / CONDENSATION OF CHROMOSOME
* CHROMOSOME VISIBLE IN LIGHT MICROSCOPE
* M: Maternal
* P: Paternal

Sister Chromatid [

] NON-SISTER CHROMATID

Sister Chrom. [



4
4C

ZYGOTENE

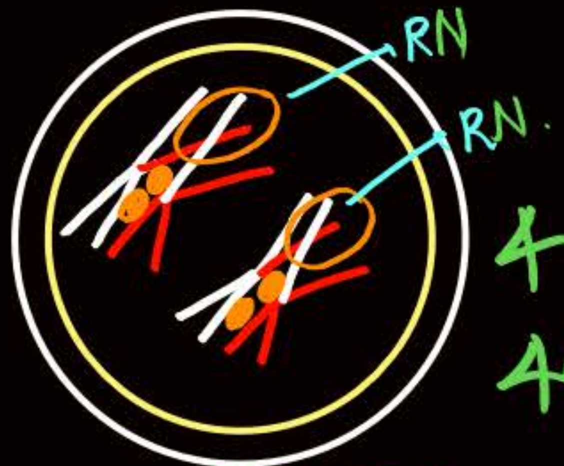
* SYNAPTONEMAL COMPLEX (PROTEIN) HOLD 'M' & 'P' CHROMOSOME
* PAIRING OF HOMOLOGOUS CHROMOSOME: SYNAPSIS
* BIVALENT FORMED / TETRAD.
* 1 BIVALENT: 2 CHROMOSOME: 4 CHROMATID
* ALL 4 CHROMATID OF ONE BIVALENT CLEARLY VISIBLE AT PACHYTENE STAGE
* SO TETRAD BETTER TO USE IN PACHYTENE.

Q Parent cell: 40 chromosome

Zygotene: BIVALENT: 20

CHROMATID: 40x2

⇒ 80.



4
4C

PACHYTENE

* EXCHANGE DNA OF NON-SISTER CHROMATID OF HOMOLOGOUS CHROMOSOME CROSSING OVER / RECOMBINATION.
* RECOMBINASE ENZYME.
* RECOMBINATION (RN) NODULE: SITE WHERE CROSSING OVER.

4
4C

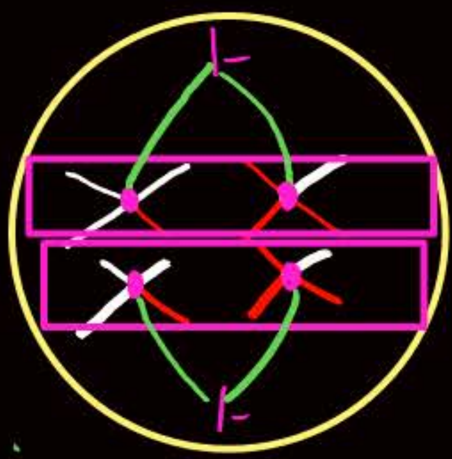
DIPLOTENE (LONGEST)

* Synaptonemal Complex Begins to dissappear.
* Homologous Chromosome Begins to seperate except at the Region where CROSSING OVE OCCUR CALLED CHIASMATA. CROSS LIKE STRUCTURE
* This stage SUSPEND FOR MONTH / YEAR IN OOCYTE OF VERTEBRAE.

DIAKINESIS

* NUCLEOLUS, NM DISAPPEAR.
* TRANSITION TO METAPHASE
* TERMINALISATION OF CHIASMATA.
* SPINDLE FORMATION
* CHROMOSOME CONDENSED

4
4C.



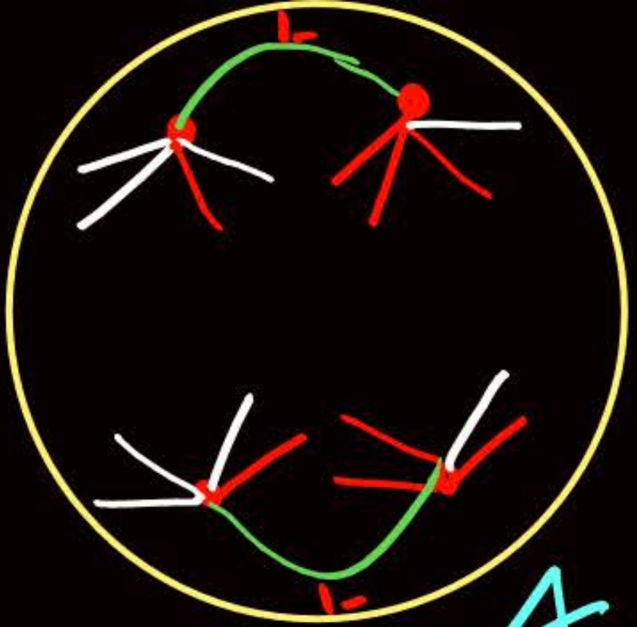
2 equ. plate

METAPHASE-I

⇒ BIVALENT ON EQUATORIAL PLATE.

4

4C



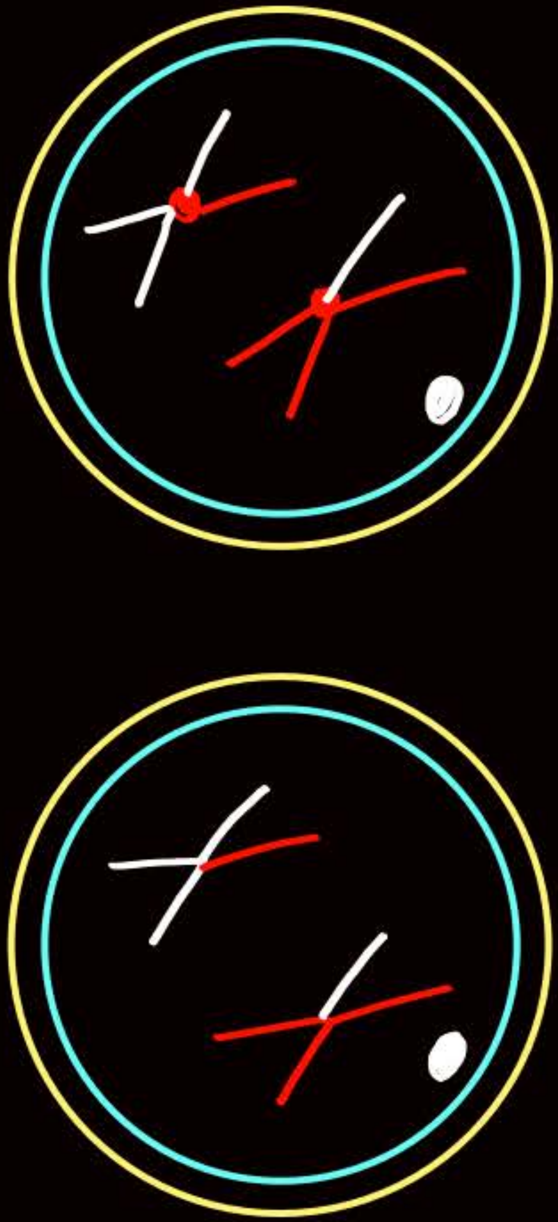
ANAP-I

4

4C

⇒ SEPERATION / SEGREGATION OF HOMOLOGOUS CHROMOSOME

⇒ HOMOLOGOUS CHROMOSOME MOVE OPPOSITE POLE



Telop-I

2 chromosome

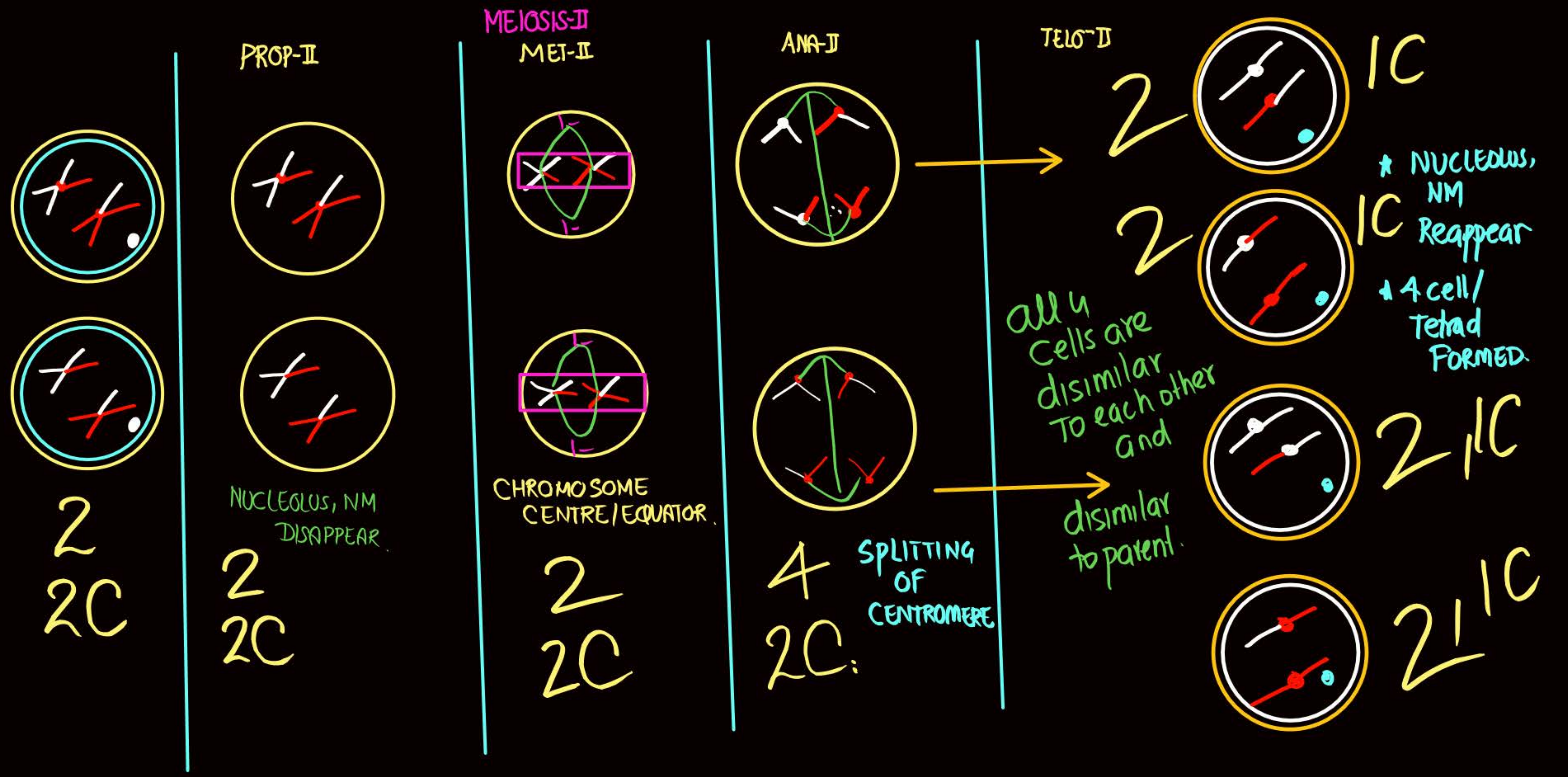
2C DNA.

⇒ dyad of cells Formed

⇒ NUCLEOLUS, NM REAPPEAR.

2 chromo

2C DNA


MEIOSIS-II
PROP-II
MET-II
ANA-II
TELO-II
2
2C
NUCLEOLUS, NM DISAPPEAR
2
2C
CHROMOSOME CENTRE/EQUATOR.
2
2C
4
2C.
SPLITTING OF CENTROMERE
all 4 cells are disimilar To each other and disimilar to parent.
2 1C
2 1C
2 1C
2 1C
* NUCLEOLUS, NM Reappear
* 4 cell/ Tetrad FORMED.

MEIOSIS-II

	Chromosome	DNA amount
Parent cell	4	2C/60
G_1	4	2C/60
S	4	4C/120
G_2	4	4C/120
LEPTOTENE (PROPHASE-I)	4	4C/120
ZYGOTENE (PROPHASE-I)	4	4C/120
PACHYTENE (PROPHASE-I)	4	4C/120
DIPLOTENE (PROPHASE-I)	4	4C/120
DIAKINESIS (PROPHASE-I)	4	4C/120
METAPHASE-I	4	4C/120
ANAPHASE-I	4	4C/120
TELOPHASE-I/MEIOSIS-I	2 ⇒ 2 chromatid (Half)	2C/60 (Half)
PROPHASE-II	2	2C
METAPHASE-II	2	2C
ANAPHASE-II	4	2C
TELOPHASE-II/MEIOSIS-II	2 ⇒ 1 chromatid	1C (Half)

Chromosome DOUBLE नहीं होता

Q: Parent cell: 60 Pg DNA

Meiosis-I ⇒ 60

Meiosis-II ⇒ 30

DOUBLE करके दो बार Half करता है

G_1 : 80
S : 160
G_2 : 160
M-I : 80
M-II : 40

Q Parent : 100 chromosome

M-I : 50

M-II : 50

Double नहीं करता

BUS EK बार Half करता

Q Meiosis-II :
In each cell : 60 chromosome.

Parent cell : G_1 = ? (120)

Q Meiosis-II
DNA : 40 Pg
G_1 =

NCERT

Introduction

Are you aware that all organisms, even the largest, start their life from a single cell? You may wonder how a single cell then goes on to form such large organisms. Growth and reproduction are characteristics of cells, indeed of all living organisms. All cells reproduce by dividing into two, with each parental cell giving rise to two daughter cells each time they divide. These newly formed daughter cells can themselves grow and divide, giving rise to a new cell population that is formed by the growth and division of a single parental cell and its progeny. In other words, such cycles of growth and division allow a single cell to form a structure consisting of millions of cells.

Cell Cycle

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

1. Phases of Cell Cycle

A typical eukaryotic cell cycle is illustrated by

human cells in culture. These cells divide once in approximately every 24 hours (Figure 10.1). However, this duration of cell cycle can vary from organism to organism and also from cell type to cell type. Yeast for example, can progress through the cell cycle in only about 90 minutes. The cell cycle is divided into two basic phases:

- **Interphase**
- **M Phase (Mitosis phase)**

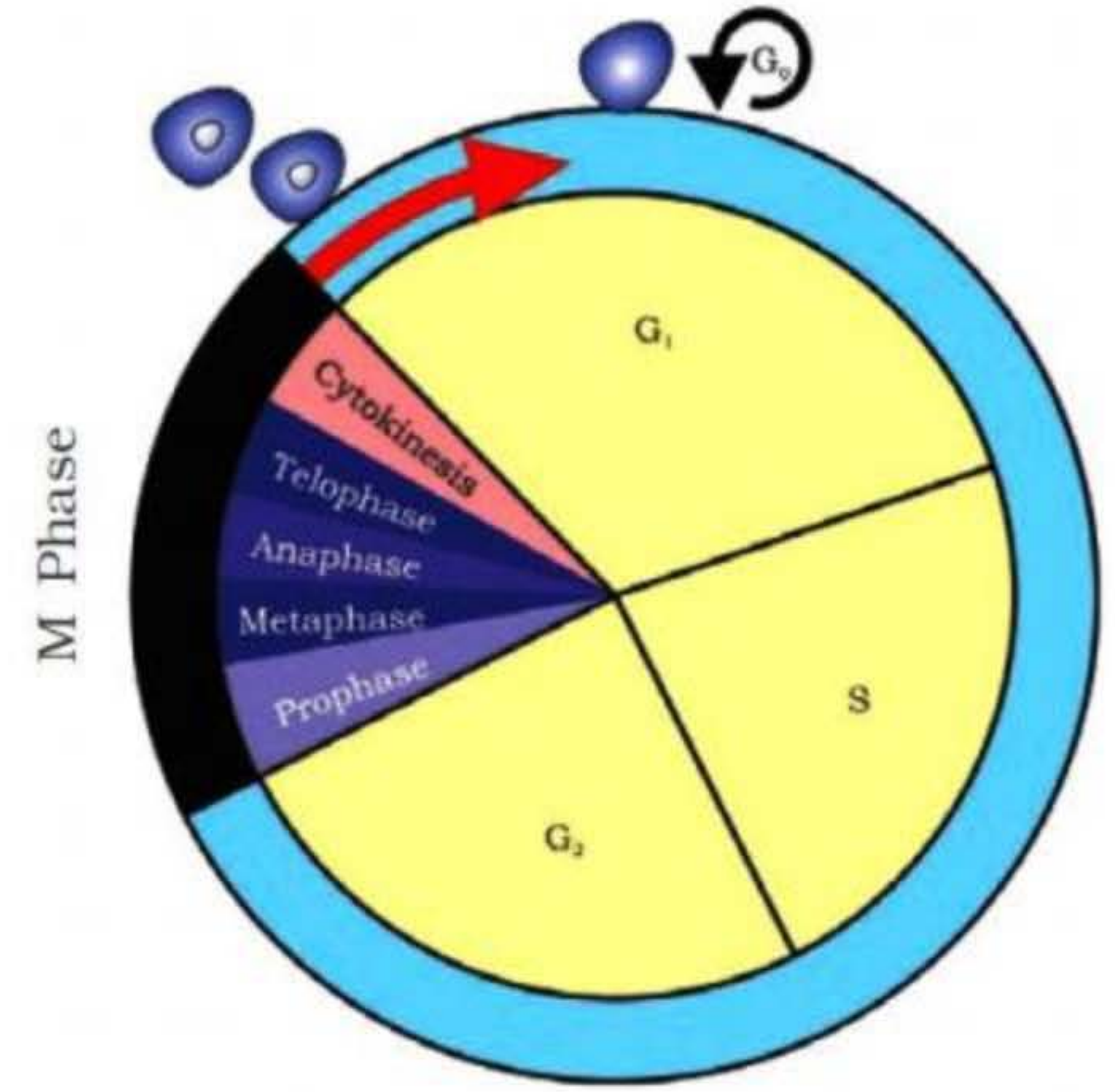


Figure 10.1 A diagrammatic view of cell cycle indicating formation of two cells from one cell

The M Phase represents the phase when the actual cell division or mitosis occurs and the interphase represents the phase between two successive M phases. It is significant to note that in the 24 hour average duration of cell cycle of a human cell, cell division proper lasts for only about an hour. The interphase lasts more than 95% of the duration of cell cycle.

The M Phase starts with the nuclear division, corresponding to the separation of daughter chromosomes **(karyokinesis)** and usually ends with division of cytoplasm **(cytokinesis)**. The interphase, though called the resting phase, is the time during which the cell is preparing for division by undergoing both cell growth and DNA replication in an orderly manner.

The interphase is divided into three further phases:

- **G_1 phase (Gap 1)**
- **S phase (Synthesis)**
- **G_2 phase (Gap 2)**

G_1 phase corresponds to the interval between mitosis and initiation of DNA replication. During G_1 phase the cell is metabolically active and continuously grows but does not replicate its DNA. S or **synthesis** phase marks the period during which DNA synthesis or replication takes place. During this time the amount of DNA per cell doubles. If the initial amount of DNA is denoted as 2C then it increases to 4C. However, there is no increase in the chromosome number; if the cell had diploid or 2n number of chromosomes at G_1, even after S phase the number of chromosomes remains the same, i.e., 2n.

In animal cells, during the S phase, DNA replication begins in the nucleus, and the centriole duplicates in the cytoplasm. During the G_2 phase, proteins are synthesised in preparation for mitosis while cell growth continues.

How do plants and animals continue to grow all their lives? Do all cells in a plant divide all the time? Do you think all cells continue to divide in all plants and animals? Can you tell the name and the location of tissues having cells that divide all their life in higher plants? Do animals have similar meristematic tissues?

You have studied mitosis in onion root tip cells. It has 16 chromosomes in each cell. Can you tell how many chromosomes will the cell have at G_1 phase, after S phase, and after M phase? Also, what will be the DNA content of the cells at G_1, after S and at G_2, if the content after M phase is 2C?

Some cells in the adult animals do not appear to exhibit division (e.g., heart cells) and many other cells divide only occasionally, as needed to replace cells that have been lost because of injury or cell death. These cells that do not divide further exit G_1 phase to enter an inactive stage called ***quiescent stage* (**G_0**))** of the cell cycle. Cells in this stage remain metabolically active but no longer proliferate unless called on to do so depending on the requirement of the organism.

In animals, mitotic cell division is only seen in the diploid somatic cells. However, there are few exceptions to this where haploid cells divide by mitosis, for example, male honey bees. Against this, the plants can show mitotic divisions in both haploid and diploid cells. From your recollection of examples of alternation of generations in plants (Chapter 3) identify plant species and stages at which mitosis is seen in haploid cells.

M Phase

This is the most dramatic period of the cell cycle, involving a major reorganisation of virtually all components of the cell. Since the number of chromosomes in the parent and progeny cells is the same, it is also called as ***equational division***.

Though for convenience mitosis has been divided into four stages of nuclear division (karyokinesis), it is very essential to understand that cell division is a progressive process and very clear-cut lines cannot be drawn between various stages. Karyokinesis involves following four stages:

- **Prophase**
- **Metaphase**
- **Anaphase**
- **Telophase**

1. Prophase

Prophase which is the first stage of karyokinesis of mitosis follows the S and G_2 phases of interphase. In the S and G_2 phases the new DNA molecules formed are not distinct but intertwined. Prophase is marked by the initiation of condensation of chromosomal material. The chromosomal material becomes untangled during the process of chromatin condensation (Figure 10.2 a). The centrosome, which had undergone duplication during S phase of interphase, now begins to move towards opposite poles of the cell. The completion of prophase can thus be marked by the following characteristic events:

- Chromosomal material condenses to form compact mitotic chromosomes. Chromosomes are seen to be composed of two chromatids attached together at the centromere.
- Centrosome which had undergone duplication during interphase, begins to move towards opposite poles of the cell. Each centrosome radiates out microtubules called asters. The two asters together with spindle fibres forms mitotic apparatus.

Cells at the end of prophase, when viewed under the microscope, do not show golgi complexes, endoplasmic reticulum, nucleolus and the nuclear envelope.

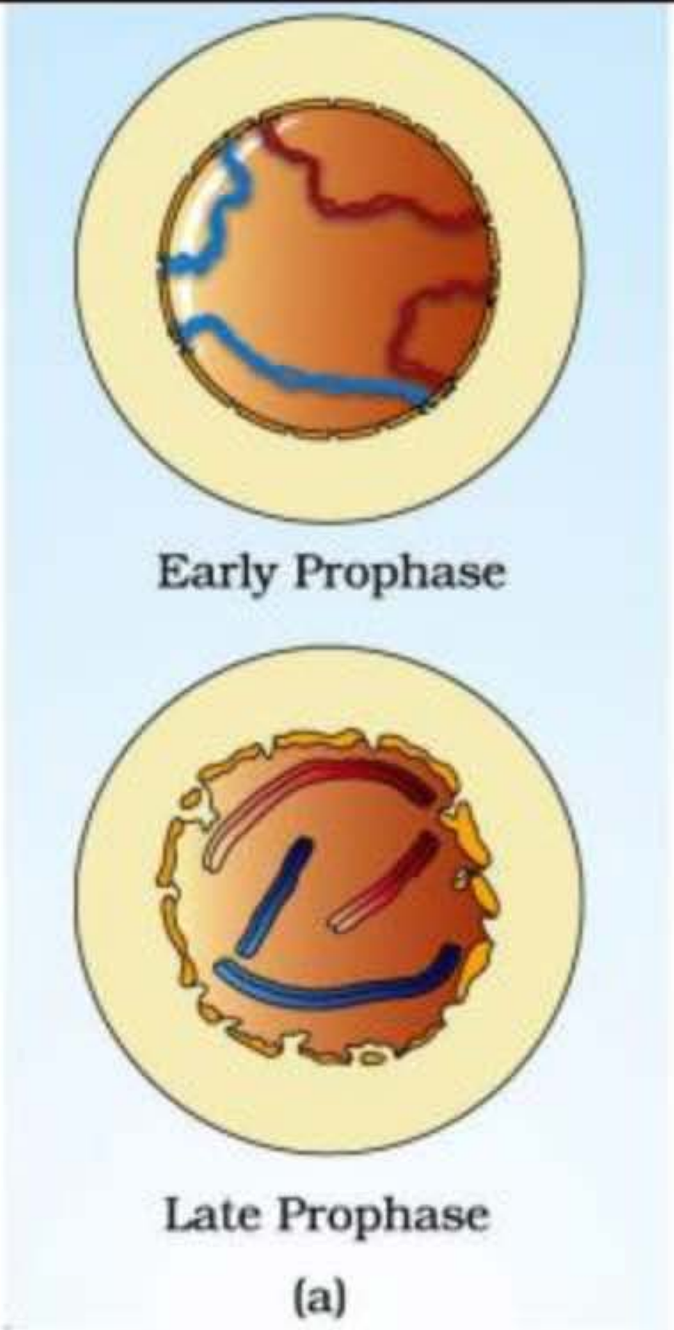


Figure 10.2 a and b : A diagrammatic view of stages in mitosis

2. Metaphase

The complete disintegration of the nuclear envelope marks the start of the second phase of mitosis, hence the chromosomes are spread through the cytoplasm of the cell. By this stage, condensation of chromosomes is completed and they can be observed clearly under the microscope. This then, is the stage at which morphology of chromosomes is most easily studied. At this stage, metaphase chromosome is made up of two sister chromatids, which are held together by the centromere (Figure 10.2 b). Small disc-shaped structures at the surface of the centromeres are called kinetochores. These structures serve as the sites of attachment of spindle fibres (formed by the spindle fibres) to the chromosomes that are moved into position at the centre of the cell.

Hence, the metaphase is characterised by all the chromosomes coming to lie at the equator with one chromatid of each chromosome connected by its kinetochore to spindle fibres from one pole and its sister chromatid connected by its kinetochore to spindle fibres from the opposite pole (Figure 10.2 b). The plane of alignment of the chromosomes at metaphase is referred to as the **metaphase plate**. The key features of metaphase are:

- Spindle fibres attach to kinetochores of chromosomes.
- Chromosomes are moved to spindle equator and get aligned along metaphase plate through spindle fibres to both poles.

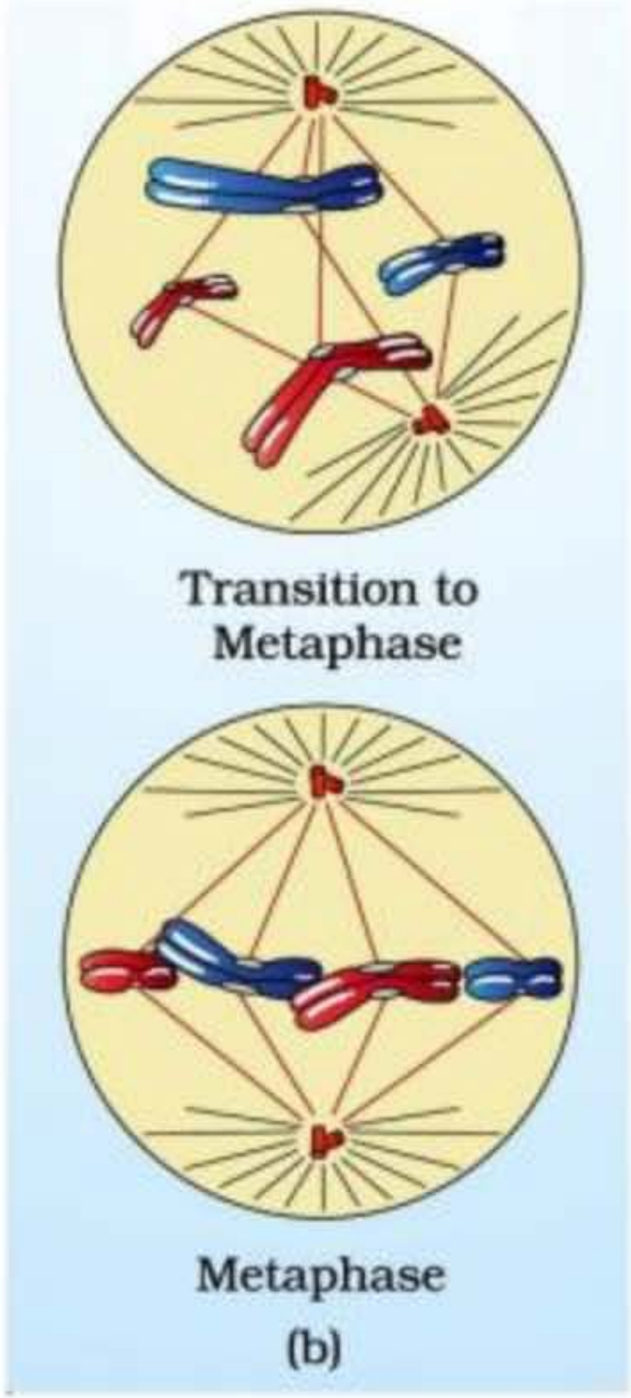


Figure 10.2 a and b : A diagrammatic view of stages in mitosis

3. Anaphase

At the onset of anaphase, each chromosome arranged at the metaphase plate is split simultaneously and the two daughter chromatids, now referred to as daughter chromosomes of the future daughter nuclei, begin their migration towards the two opposite poles. As each chromosome moves away from the equatorial plate, the centromere of each chromosome remains directed towards the pole and hence at the leading edge, with the arms of the chromosome trailing behind (Figure 10.2 c). Thus, anaphase stage is characterised by the following key events:

- Centromeres split and chromatids separate.
- Chromatids move to opposite poles.

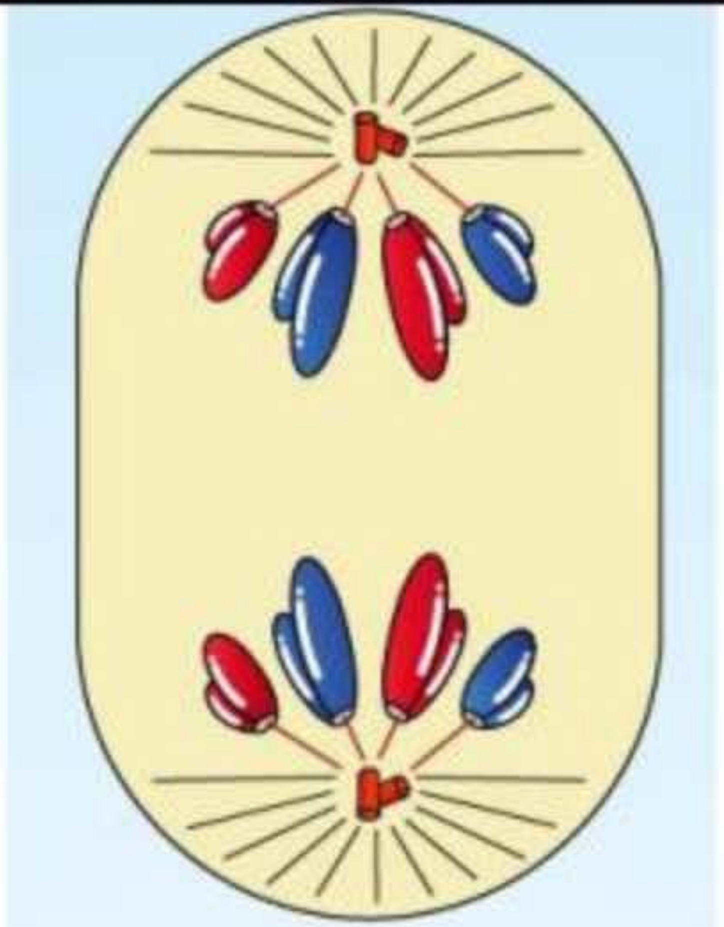
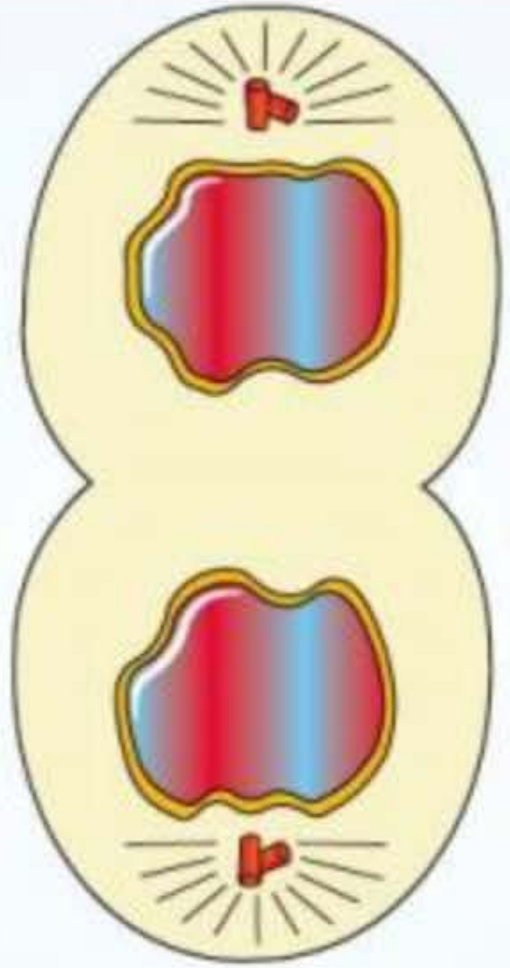


Figure 10.2 c to e : A diagrammatic view of stages in Mitosis

4. Telophase

At the beginning of the final stage of karyokinesis, i.e., telophase, the chromosomes that have reached their respective poles decondense and lose their individuality. The individual chromosomes can no longer be seen and each set of chromatin material tends to collect at each of the two poles (Figure 10.2 d). This is the stage which shows the following key events:

- Chromosomes cluster at opposite spindle poles and their identity is lost as discrete elements.
- Nuclear envelope develops around the chromosome clusters at each pole forming two daughter nuclei.
- Nucleolus, golgi complex and ER reform.



Telophase

(d)

Figure 10.2 c to e : A diagrammatic view of stages in Mitosis

5. Cytokinesis

Mitosis accomplishes not only the segregation of duplicated chromosomes into daughter nuclei (karyokinesis), but the cell itself is divided into two daughter cells by the separation of cytoplasm called cytokinesis at the end of which cell division gets completed (Figure 10.2 e). In an animal cell, this is achieved by the appearance of a furrow in the plasma membrane. The furrow gradually deepens and ultimately joins in the centre dividing the cell cytoplasm into two. Plant cells however, are enclosed by a relatively inextensible cell wall, thererfore they undergo cytokinesis by a different mechanism. In plant cells, wall formation starts in the centre of the cell and grows outward to meet the existing lateral walls.

The formation of the new cell wall begins with the formation of a simple precursor, 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. 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).

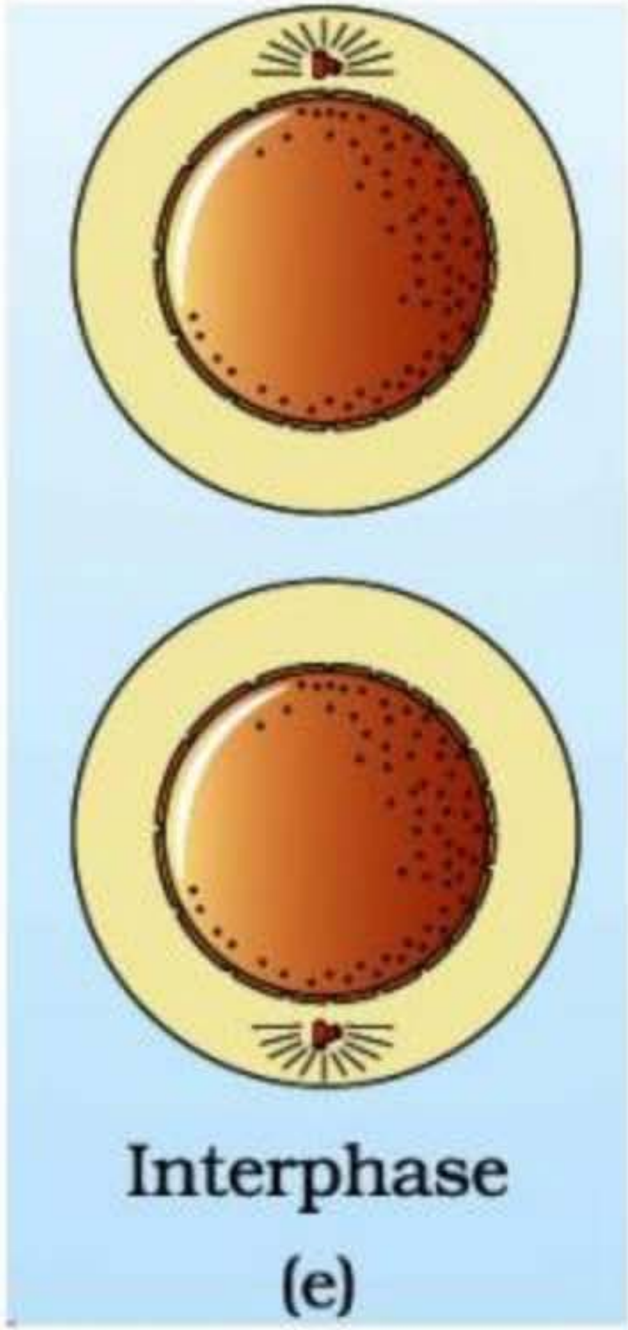


Figure 10.2 c to e : A diagrammatic view of stages in Mitosis

Significance of Mitosis

Mitosis or the equational division is usually restricted to the diploid cells only. However, in some lower plants and in some social insects haploid cells also divide by mitosis. It is very essential to understand the significance of this division in the life of an organism. Are you aware of some examples where you have studied about haploid and diploid insects?

Mitosis usually results in the production of diploid daughter cells with identical genetic complement. The growth of multicellular organisms is due to mitosis. 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. A very significant contribution of mitosis is cell repair. The cells of the upper layer of the epidermis, cells of the lining of the gut, and blood cells are being constantly replaced. Mitotic divisions in the meristematic tissues – the apical and the lateral cambium, result in a continuous growth of plants throughout their life.

Meiosis

The production of offspring by sexual reproduction includes the fusion of two gametes, each with a complete haploid set of chromosomes. Gametes are formed from specialised diploid cells. This specialised kind of cell division that reduces the chromosome number by half results in the production of haploid daughter cells. This kind of division is called **meiosis**. Meiosis ensures the production of haploid phase in the life cycle of sexually reproducing organisms whereas fertilisation restores the diploid phase. We come across meiosis during gametogenesis in plants and animals. This leads to the formation of haploid gametes. The key features of meiosis are as follows:

- Meiosis involves two sequential cycles of nuclear and cell division called **meiosis I** and **meiosis II** but only a single cycle of DNA replication.
- 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 non-sister chromatids of homologous chromosomes.
- Four haploid cells are formed at the end of meiosis II.

Meiotic events can be grouped under the following phases:

Meiosis I	**Meiosis II**
Prophase I	Prophase II
Metaphase I	Metaphase II
Anaphase I	Anaphase II
Telophase I	Telophase II

1. Meiosis I

Prophase I: Prophase of the first meiotic division is typically longer and more complex when compared to prophase of mitosis. It has been further subdivided into the following five phases based on chromosomal behaviour, i.e., Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.

During **leptotene** stage the chromosomes become gradually visible under the light microscope. The compaction of chromosomes continues throughout leptotene. This is followed by the second stage of prophase I called **zygotene**. During this stage chromosomes start pairing together and this process of association is called synapsis. Such paired chromosomes are called homologous chromosomes. Electron micrographs of this stage indicate that chromosome synapsis is accompanied by the formation of complex structure called **synaptonemal complex**.

The complex formed by a pair of synapsed homologous chromosomes is called a **bivalent** or a tetrad. However, these are more clearly visible at the next stage. The first two stages of prophase I are relatively short-lived compared to the next stage that is **pachytene**. During this stage, the four chromatids of each bivalent chromosomes becomes distinct and clearly appears as tetrads. This stage is characterised by the appearance of recombination nodules, the sites at which crossing over occurs between non-sister chromatids of the homologous chromosomes. Crossing over is the exchange of genetic material between two homologous chromosomes. 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. Recombination between homologous chromosomes is completed by the end of pachytene, leaving the chromosomes linked at the sites of crossing over.

The beginning of **diplotene** is recognised by the dissolution of the synaptonemal 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, are called **chiasmata**. In oocytes of some vertebrates, diplotene can last for months or years.

The final stage of meiotic prophase I is **diakinesis**. This is marked by terminalisation of chiasmata. 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 align on the equatorial plate (Figure 10.3). The microtubules from the opposite poles of the spindle attach to the kinetochore of homologous chromosomes.

Anaphase I: The homologous chromosomes separate, while sister chromatids remain associated at their centromeres (Figure 10.3).

Telophase I: The nuclear membrane and nucleolus reappear, cytokinesis follows and this is called as dyad of cells (Figure 10.3). Although in many cases the chromosomes do undergo some dispersion, they do not reach the extremely extended state of the interphase nucleus. The stage between the two meiotic divisions is called interkinesis and is generally short lived. There is no replication of DNA during interkinesis. Interkinesis is followed by prophase II, a much simpler prophase than prophase I.

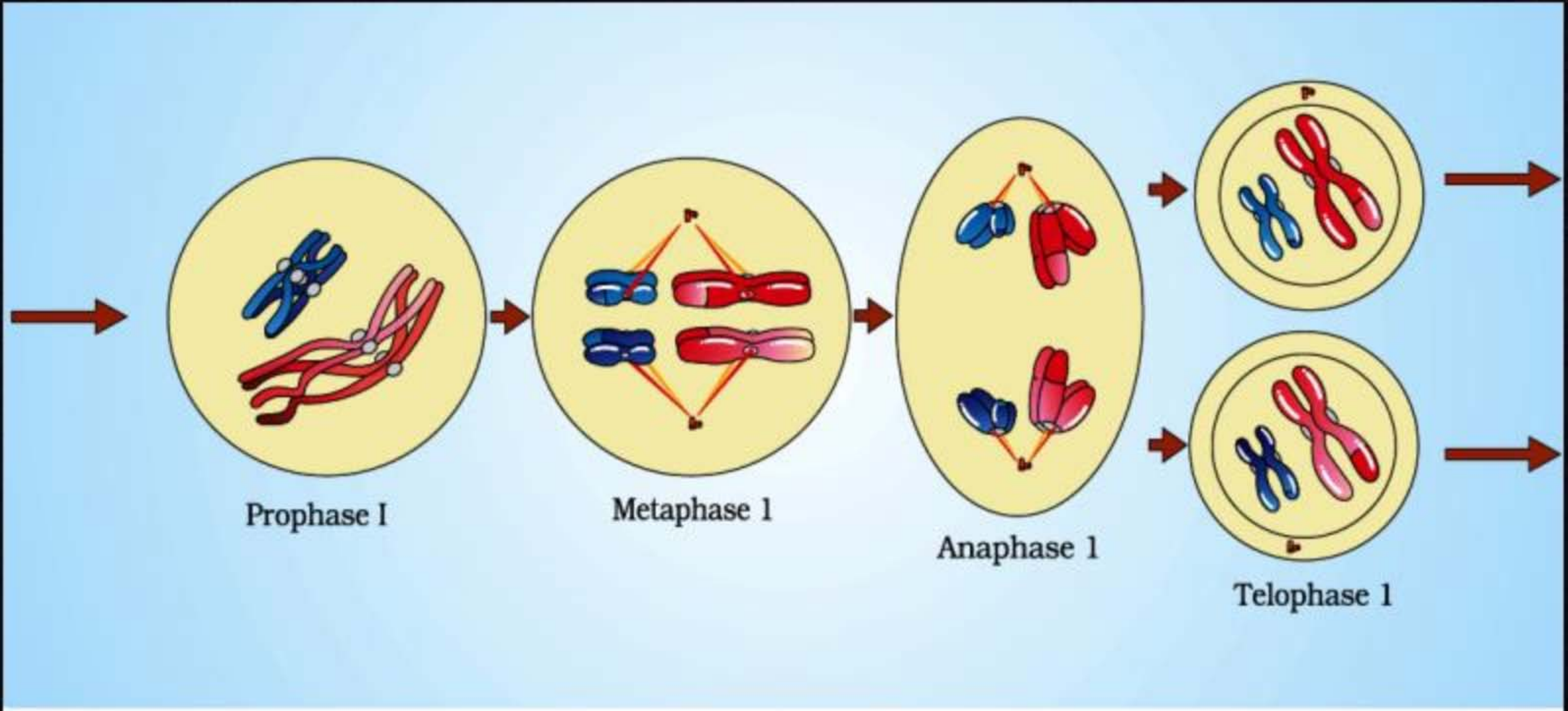


Figure 10.3 Stages of Meiosis I

2. Meiosis II

Prophase II: Meiosis II is initiated immediately after cytokinesis, usually before the chromosomes have fully elongated. In contrast to meiosis I, meiosis II resembles a normal mitosis. The nuclear membrane disappears by the end of prophase II (Figure 10.4). 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 (Figure 10.4) 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 (Figure 10.4) by shortening of microtubules attached to kinetochores.

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 (Figure 10.4).

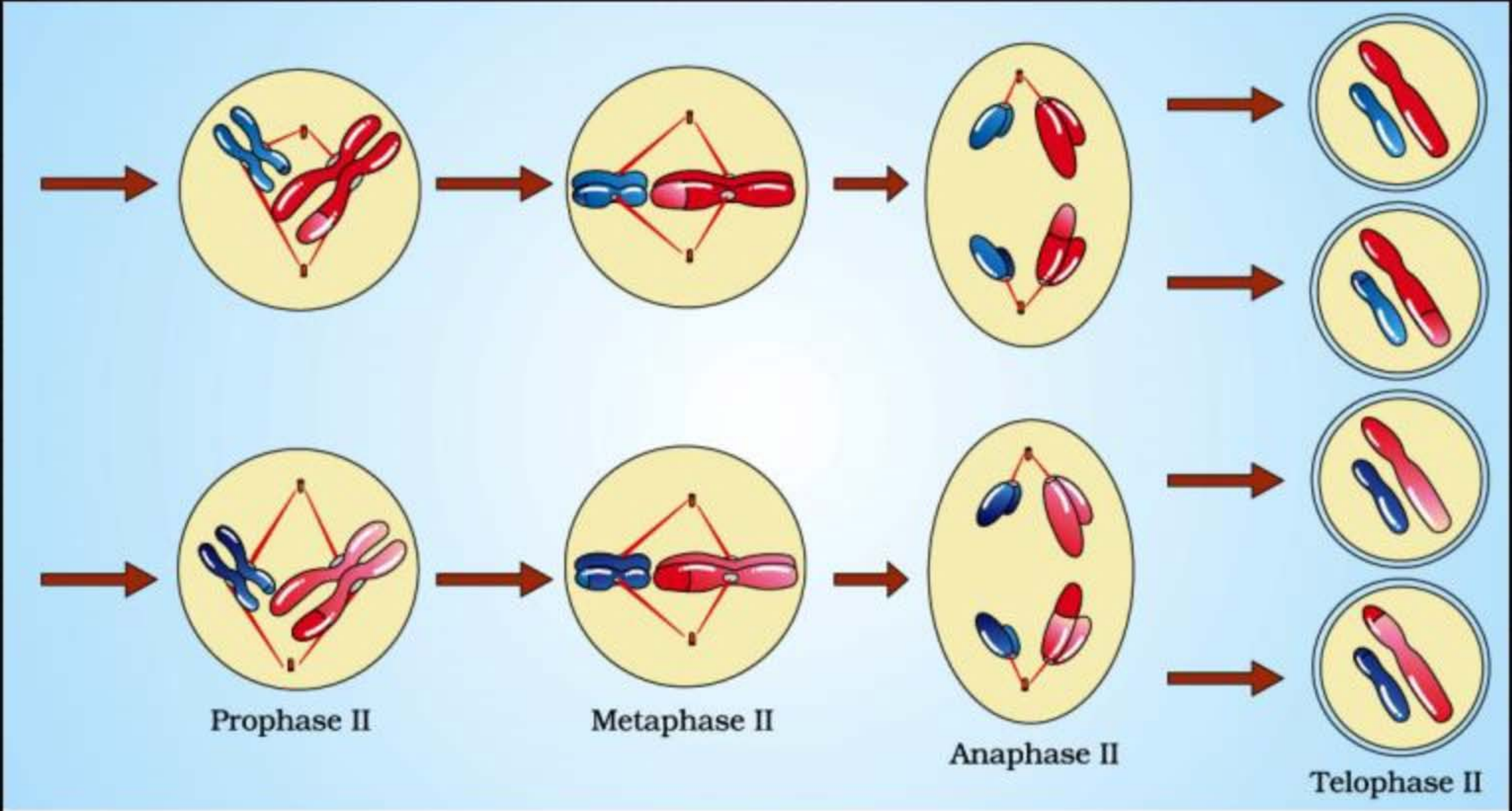


Figure 10.4 Stages of Meiosis II

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.

QUESTION

Following are the stages of cell division :

A. Gap 2 phase

B. Cytokinesis

C. Synthesis phase

D. Karyokinesis

E. Gap 1 phase

Choose the correct sequence of stages from the options given below : (2024)

1. C-E-D-A-B
2. E-B-D-A-C
3. B-D-E-A-C
4. E-C-A-D-B

QUESTION

Among eukaryotes, replication of DNA takes place in : (2023)

1. S phase ✓
2. G_1 phase
3. G_2 phase
4. M phase

PROKARYOTE

INTERPHASE
CELL CYCLE = ABSENT

G_1, S, G_2, MITOSIS ✗

Before Binary fission : DNA Replication

QUESTION

Match List - I with List – II

Choose the correct answer from the options given below. (2023)

List-I		List-II	
A.	M phase	(i)	Proteins are synthesized
B.	G_2 phase	(ii)	Inactive phase
C.	Quiescent stage	(iii)	Interval between mitosis and initiation of DNA replication
D.	G_1 phase	(iv)	Equational division

1. A-(iv); B-(ii); C-(i); D-(iii)
2. A-(iv); B-(i); C-(ii); D-(iii)
3. A-(ii); B-(iv); C-(i); D-(iii)
4. A-(iii); B-(ii); C-(iv); D-(i)

QUESTION

Match List - 1 with List – 2

Choose the correct answer from the options given below. (2021)

1. A-(iv); B-(ii); C-(iii); D-(i)
2. A-(iv); B-(i); C-(ii); D-(iii)
3. A-(ii); B-(iv); C-(iii); D-(i)
4. A-(iii); B-(ii); C-(i); D-(iv)

List-1		List-2	
A.	S phase	(i)	Proteins are synthesized
B.	G_2 phase	(ii)	Inactive phase
C.	Quiescent stage	(iii)	Interval between mitosis and initiation of DNA replication
D.	G_1 phase	(iv)	DNA replication

QUESTION

The centriole undergoes duplication during: (2021)

1. Prophase
2. Metaphase
3. G_2 phase
4. S-phase

QUESTION

Some dividing cells exit the cell cycle and enter vegetative inactive stage. This is called quiescent stage (G_0). This process occurs at the end of: (2020)

1. G_1 phase
2. S phase
3. G_2 phase
4. M phase

QUESTION

In a mitotic cycle, the correct sequence of phases is (2020 - Covid)

1. G_1, S, G_2, M
2. M, G_1, G_2, S
3. G_1, G_2, S, M
4. S, G_1, G_2, M

QUESTION

Match the following events that occur in their respective phases of cell cycle and select the correct option: (2020 - Covid)

	(1)	(2)	(3)	(4)
1	(iii)	(iv)	(i)	(ii)
2	(iv)	(i)	(ii)	(iii)
3	(i)	(ii)	(iii)	(iv)
4	(ii)	(iii)	(iv)	(i)

1.	G_1 phase	(i)	Cell grows and organelle duplication
2.	S phase	(ii)	DNA replication and chromosome duplication
3.	G_2 phase	(iii)	Cytoplasmic growth (cell organelle synthesis)
4.	Metaphase in M-phase	(iv)	Alignment of chromosomes

QUESTION

The correct sequence of phases of cell cycle is (2019)

1. $M \rightarrow G_1 \rightarrow G_2 \rightarrow S$
2. $G_1 \rightarrow G_2 \rightarrow S \rightarrow M$
3. $S \rightarrow G_1 \rightarrow G_2 \rightarrow M$
4. $G_1 \rightarrow S \rightarrow G_2 \rightarrow M$

QUESTION

Cell in G_0 phase (2019)

1. Exit the cell cycle
2. Enter the cell cycle
3. Suspend the cell cycle
4. Terminate the cell cycle

QUESTION

DNA replication in bacteria occurs: (2017 - Delhi)

1. During S-phase
2. Within nucleolus
3. Prior to fission
4. Just before transcription

QUESTION

$G_1: 2C$
$S: 4C$
$G_2: 4C$ $M: 2C$

Which of the following statements is correct with respect to cell cycle? (2017 - Gujarat)

1. DNA content of cell remains ~~constant~~ NOT constant during entire cell cycle ✗
2. A cell in G_1 (2C) phase has ~~double~~ half the amount of DNA than a cell in G_2 (4C) phase ✗
3. Each chromosome has ~~two~~ one chromatids in G_1 phase
4. Nerve cells in adult human are in G_0 state ✓

QUESTION

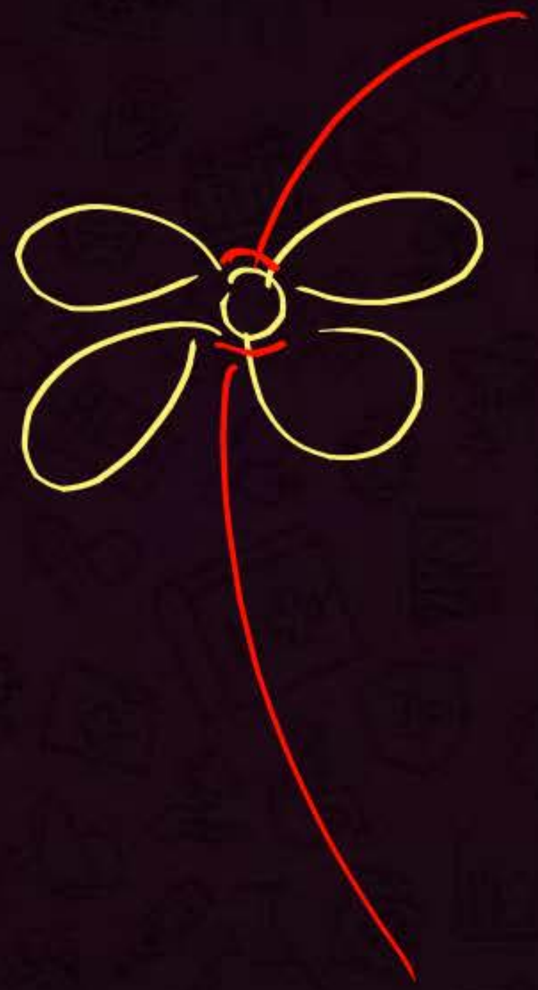
During cell growth, DNA synthesis takes place in: (2016 - II)

1. G_2 phase
2. M phase
3. S phase ✓
4. G_1 phase

QUESTION

Spindle fibers attach to kinetochores of chromosomes during (2024)

1. Prophase
2. Metaphase
3. Anaphase
4. Telophase



QUESTION

Attachment of spindle fibers to kinetochores of chromosomes becomes evident in :

(2020 - Covid)

Chrom: morphology

1. Telophase
2. Prophase
3. Metaphase
4. Anaphase

QUESTION

Which of the following is not a characteristic feature during mitosis in somatic cells?

(2016 - I)

1. Spindle fibres ✓
2. Disappearance of nucleolus ✓
3. Chromosome movement (anaphase)
4. Synapsis (zygotene - meiosis-I)

QUESTION

Given below are two statements :

Statement-I : Chromosomes become gradually visible under light microscope during leptotene stage.

Statement-II : The begining of diplotene stage is recognized by dissolution of synaptonemal complex.

In the light of the above statements, choose the correct answer from the options given below : (2024)

1. Both Statement-I and Statement-II are true
2. Both Statement-I and Statement-II are false
3. Statement-I is true but Statement-II is false
4. Statement-I is false but Statement-II is true

QUESTION

Match List I with List-II :

Choose the correct answer from the options given below : (2024)

1. A-IV, B-II, C-III, D-I
2. A-I, B-II, C-IV, D-III
3. A-II, B-IV, C-I, D-III
4. A-IV, B-III, C-II, D-I

	List-I (Sub Phases of Prophase I)		List-II (Specific characters)
A.	Diakinesis	I.	Synaptonemal complex formation
B.	Pachytene	II.	Completion of terminalisation of chiasmata
C.	Zygotene	III.	Chromosomes look like thin threads
D.	Leptotene	IV.	Appearance of recombination nodules

QUESTION

The process of appearance of recombination nodules occurs at which sub stage of prophase I in meiosis? (2023)

1. Pachytene
2. Diplotene
3. Diakinesis
4. Zygoten

CR. OVER

QUESTION

The appearance of recombination nodules on homologous chromosomes during meiosis characterizes : (2022)

1. Terminalization
2. Synaptonemal complex
3. Bivalent
4. Sites at which crossing over occurs

QUESTION

Which one of the following never occurs during mitotic cell division? (2022)

1. Coiling and condensation of the chromatids
2. Spindle fibres attach to kinetochores of chromosomes
3. Movement of centrioles towards opposite poles
4. Pairing of homologous chromosomes

QUESTION

Which stage of meiotic prophase shows terminalisation of chiasmata as its distinctive feature? (2021)

1. Zygotene
2. Diakinesis
3. Pachytene
4. Leptotene

QUESTION

Match the following with respect to meiosis:

Select the correct option from the following: (2020)

	Column - I		Column - II
1.	Zygotene	(i)	Terminalization
2.	Pachytene	(ii)	Chiasmata
3.	Diplotene	(iii)	Crossing over
4.	Diakinesis	(iv)	Synapsis

	(1)	(2)	(3)	(4)
1	(iv)	(iii)	(ii)	(i)
2	(i)	(ii)	(iv)	(iii)
3	(ii)	(iv)	(iii)	(i)
4	(iii)	(iv)	(i)	(ii)

QUESTION

During Meiosis I, in which stage synapsis takes place? (2020 - Covid)

1. Zygotene
2. Diplotene
3. Leptotene
4. Pachytene

QUESTION

Dissolution of the synaptonemal complex occurs during: (2020)

1. Zygotene
2. Diplotene
3. Leptotene
4. Pachytene

QUESTION

The stage during which separation of the paired homologous chromosomes begins is

(2018)

1. Pachytene
2. Diplotene
3. Diakinesis
4. Zygotene

synap. complex
dissolve

QUESTION

At what phase of meiosis homologous chromosomes are separated? (2017 - Gujarat)

1. Anaphase II X : splitting of centromere
2. Prophase I
3. Prophase II
4. Anaphase I

Bivalent seperate

QUESTION

Match the stages of meiosis in Column-I to their characteristic features in Column-II and select the correct option using the codes given below: (2016 - II)

1. A-(ii); B-(iv); C-(iii); D-(i)
2. A-(iv); B-(iii); C-(ii); D-(i)
3. A-(iii); B-(iv); C-(ii); D-(i)
4. A-(i); B-(iv); C-(ii); D-(iii)

	Column - I		Column - II
A.	Pachytene	(i)	Pairing of homologous chromosomes
B.	Metaphase-I	(ii)	Terminalisation of chiasmata
C.	Diakinesis	(iii)	Crossing over takes place
D.	Zygotene	(iv)	Chromosomes align at equatorial plate

QUESTION

In meiosis, crossing over is initiated at: (2016 - I)

1. Pachytene
2. Leptotene
3. Zygotene
4. Diplotene

QUESTION

Which of the following stages of meiosis involves division of centromere? (2023)

1. Metaphase II
2. Anaphase II
3. Telophase
4. Metaphase I

QUESTION

Regarding Meiosis, which of the statements is incorrect? (2022)

1. Four haploid cells are formed at the end of Meiosis-II C
2. There are two stages in Meiosis, Meiosis-I and II C
3. DNA replication occurs in S phase of ~~Meiosis-II~~ Interphase
4. Pairing of homologous chromosomes and recombination occurs in Meiosis-I C

QUESTION

Select the incorrect statement with reference to mitosis: (2022)

1. Splitting of centromere occurs at anaphase C
2. All the chromosomes lie at the equator at metaphase C
3. Spindle fibres attach to ~~centromere~~ Kinetochore of chromosomes ✓
4. Chromosomes decondense at telophase C

QUESTION

Which of the following stages of meiosis involves division of centromere? (2021)

1. Metaphase II
2. Anaphase II
3. Telophase II
4. Metaphase I

QUESTION

How many meiotic divisions are required to produce 101 seeds in a typical dicot plant?

(2021)

1. 16
2. 4
3. 32
4. 8

QUESTION

Identify the correct statement with regard to G_1 phase (Gap 1) of interphase. (2020)

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

QUESTION

Anaphase promoting complex (APC) is a protein degradation machinery necessary for proper mitosis of animal cells. If APC is defective in a human cell, which of the following is expected to occur? (2017 – Delhi)

1. Chromosomes will not condense
2. Chromosomes will be fragmented
3. Chromosomes will not segregate
4. Recombination of chromosome arms will occur

QUESTION

Which of the following options gives the correct sequence of events during mitosis?

(2017 – Delhi)

1. Condensation → Nuclear membrane disassembly → Crossing over → Segregation → Telophase
2. Condensation → Nuclear membrane disassembly → Arrangement at equator → Centromere division → Segregation → Telophase
3. Condensation → Crossing over → Nuclear membrane disassembly → Segregation → Telophase
4. Condensation → Arrangement at equator → Centromere division → Segregation → Telophase

QUESTION

When cell has stalled DNA replication fork, which checkpoint should be predominantly activated? (2016 - II)

1. M
2. Both G_2 / M and M
3. G_1 / S
4. G_2 / M

Summary

Homework


THANK YOU