CELL CYCLE AND CELL DIVISION

INTRODUCTION

All cells reproduce by dividing Into two, with each parental cell giving rise to two daughter cells each time they divide.

Growth and reproduction are characteristics of cells, indeed of all living organisms.

Such cycles of growth and division allow single cell to form a structure consisting of millions of cells.

CELL CYCLE

It is sequence of events by which a cell duplicates its genome, synthesises the other constituents of the cell & eventually divides into two daughter cells.

Cell growth results in disturbing the ratio between the nucleus and cytoplasm. It therefore becomes essential for the cell to restore the nucleo-cytoplasmic ratio.

Cell growth (in terms of cytoplasmic increase) is a continuous process.

Duration or cell cycle can vary from organism to organism & also from cell type to cell type
Eg.• Yeast cell cycle duration ~90 minutes;
• Human cell cycle duration ~24 hours.

PHASES OF CELL CYCLE

INTERPHASE

- Called resting phase
- Cell is preparing for division by undergoing both cell growth & DNA replication in an orderly manner.
- It lasts more than 95% of the duration of cell cycle.

M-PHASE

- Actual cell division phase.
- Starts with nuclear division (karyokinesis) & usually ends with division of cytoplasm (cytokinesis).

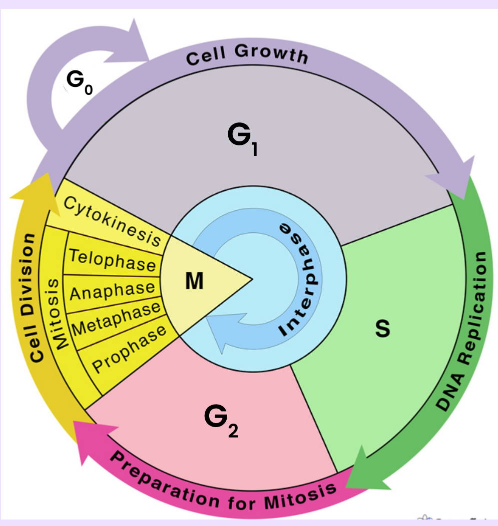
INTERPHASE

Divided further into three phases

(i) G_1-phase (Gap 1)

(ii) S-phase (Synthesis)

(iii) G_2-phase (Gap 2)



- Some cells 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. eg- Heart cells
- **G_1** ⟶Interval between mitosis and initiation of DNA replication.
- Cell is metabolically active and continuously grows but does not replicate its DNA.
- Most of the cell organelles duplicate
- **S** ⟶This phase marks the phase of DNA replication and chromosome duplication.
- Amount of DNA per cell doubles but there is no increase in chromosome number
- In animal cells, centriole duplicates in cytoplasm.
- DNA replication begins in nucleus.
- **G_2**⟶Proteins are synthesised in preparation for mitosis.

In animal cells mitotic division is only seen in diploid somatic cells. Plant can show mitotic division in both haploid and diploid cells.
- Most dramatic period of cell cycle
- Chromosome number in parent and progeny cells is the same hence called equational division

M PHASE (MITOSIS)

KARYOKINESIS

PROPHASE

- First phase, follows the S and G_2 phases of interphase.
- Marked by the initiation of condensation of chromosomal material which becomes untangled.
- Centrosome starts to move towards opposite poles.
- The completion of prophase can be marked by-

(i) Chromosomes condense to form compact mitotic chromosome.

(ii) Each centrosome reach at pole and radiates out microtubules called asters. The two asters together with spindle fibres form mitotic apparatus.

- At the end of prophase cells do not show golgi complex, ER, nucleolus & nuclear envelope.

METAPHASE

- The complete disintegration of the nuclear envelope marks the start of metaphase
- Condensation of chromosomes is completed and can be observed clearly under microscope and morphology of chromosomes is most easily studied
- one chromatid of each chromosome has two sister chromatids which are held together by the centromere.
- All the chromosome coming to lie at equator.
- one chromatid of Each chromosome connected by its kinetochore to spindle fibre from one pole & its sister chromatid connected by its kinetochore to spindle fibre from the opposite pole.
- The plane of alignment of the chromosomes at metaphase is referred to as metaphase plate.

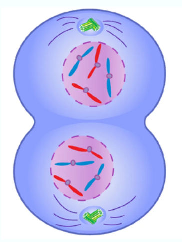
ANAPHASE

- Centromere of each chromosome split simultaneously and chromatids separate
- Two daughter chromatids, now referred to as daughter chromosome begin their migration towards the two opposite poles.
- The centromere of each chromosome remain directed towards the pole and arms trailing behind (leading to different shapes of chromosomes).

TELOPHASE

The chromosomes decondense and lose their individuality.

- Nuclear envelope develops around the chromosome cluster at each pole forming two daughter nuclei.
- Nucleolus, Golgi complex and ER reform.



CYTOKINESIS

- It is division of cytoplasm at the end of which cell division gets completed.
- In animal cells it is achieved by the appearance of a furrow in the plasma membrane.
- In plant cells cytokinesis is achieved by wall formation, which starts in the centre of the cell and grows outward to meet the existing lateral walls.
- The formation of new cell wall begins with the formation of a simple precursor, called the cell plate that represents the middle lamella between the wall of two adjacent cells.
- When karyokinesis is not followed by cytokinesis as a result of which multinucleate condition arises leading to formation of syncytium, eg. liquid endosperm in coconut.

Kinetochore Is disc shaped structure at the surface of centromere, serves as the site of attachment of spindle fibres

SIGNIFICANCE OF MITOSIS

1. Mitosis usually results in identical genetic complement in daughter cells.
2. Growth of multicellular organisms.
3. Cell repair.
4. Mitotic division in apical and lateral meristem results continuous growth of plants throughout their life.
5. In some lower plants and in some social insects haploid cells also divide by mitosis.

MEIOSIS

- Specialised kind of cell division that reduces the chromosome number by half results in the production of haploid daughter cells.
- Meiosis ensures the production of haploid phase in the life cycle of sexually reproducing organisms whereas fertilization restores the diploid phase. Meiosis involves two sequential cycles of nuclear division i.e. meiosis I and meiosis II but only single cycle of DNA replication.
- Meiosis I initiated after parental chromosomes have replicated.
- Four haploid cells are formed at the end of meiosis II.

MEIOSIS I (Reductional Phase)

PROPHASE I

Typically longer and more complex when compared to prophase of mitosis.

Leptotene

- Chromosomes become gradually visible under the light microscope.
- The compaction of chromosomes continues throughout leptotene.

Zygotene

- Homologous chromosomes called synapsis.
- Synapsis is accompanied by formation of complex structure called synaptonemal complex.
- The complex formed by a pair of synapsed homologous chromosomes is called bivalent or a tetrad.
- Leptotene and zygotene are relatively short live compared to the pachytene.

Pachytene

- Four chromatids of each bivalent become distinct and clearly appears as tetrads.
- Appearance of recombination nodule at the sites where crossing over occurs between non sister chromatids of the homologous chromosomes
- Crossing over is exchange of genetic material between two homologous chromosomes. It is an enzyme mediated process, enzyme involved is called recombinase.
- Crossing over leads to recombination of genetic material which is completed by the end of pachytene leaving chromosomes linked at the sites of crossing over.

Diplotene

- Beginning of diplotene is recognised by the dissolution of synaptonemal complex and tendency of the recombined homologous chromosomes of the bivalent to separate from each other except at the site of crossovers
- This X-shaped structures (site of crossing over) are called chiasmata.
- In oocytes of some vertebrates, diplotene can last for months or years (dictyotene).

Diakinesis

- This is marked by terminalisation of chiasmata.
- Chromosomes are fully condensed and meiotic spindle is assembled to prepare the homologous chromosomes for separation.
- By the end of diakinesis, the nucleolus disappears and nuclear envelope also breaks down.
- Diakinesis represents transition to metaphase.

METAPHASE I

- Bivalent chromosomes align on the equatorial plate (Double metaphasic plate).
- Microtubules from the opposite poles of the spindle attach to the kinetochore of homologous chromosomes.

ANAPHASE I

Homologous chromosomes separate, while sister chromatids remain associated at their centromere.

TELOPHASE I

The nuclear membrane and nucleolus reappear cytokinesis follows and this is called as dyad of cells.

INTERKINESIS

It is the stage between the meiotic divisions. It is generally short lived.

No DNA replication

It is followed by prophase II.

MEIOSIS II– (Equational Phase), Resembles a normal mitosis

PROPHASE II

- It is initiated immediately after cytokinesis
- The nuclear membrane disappears by the end of prophase II.
- Chromosomes become compact.

METAPHASE II

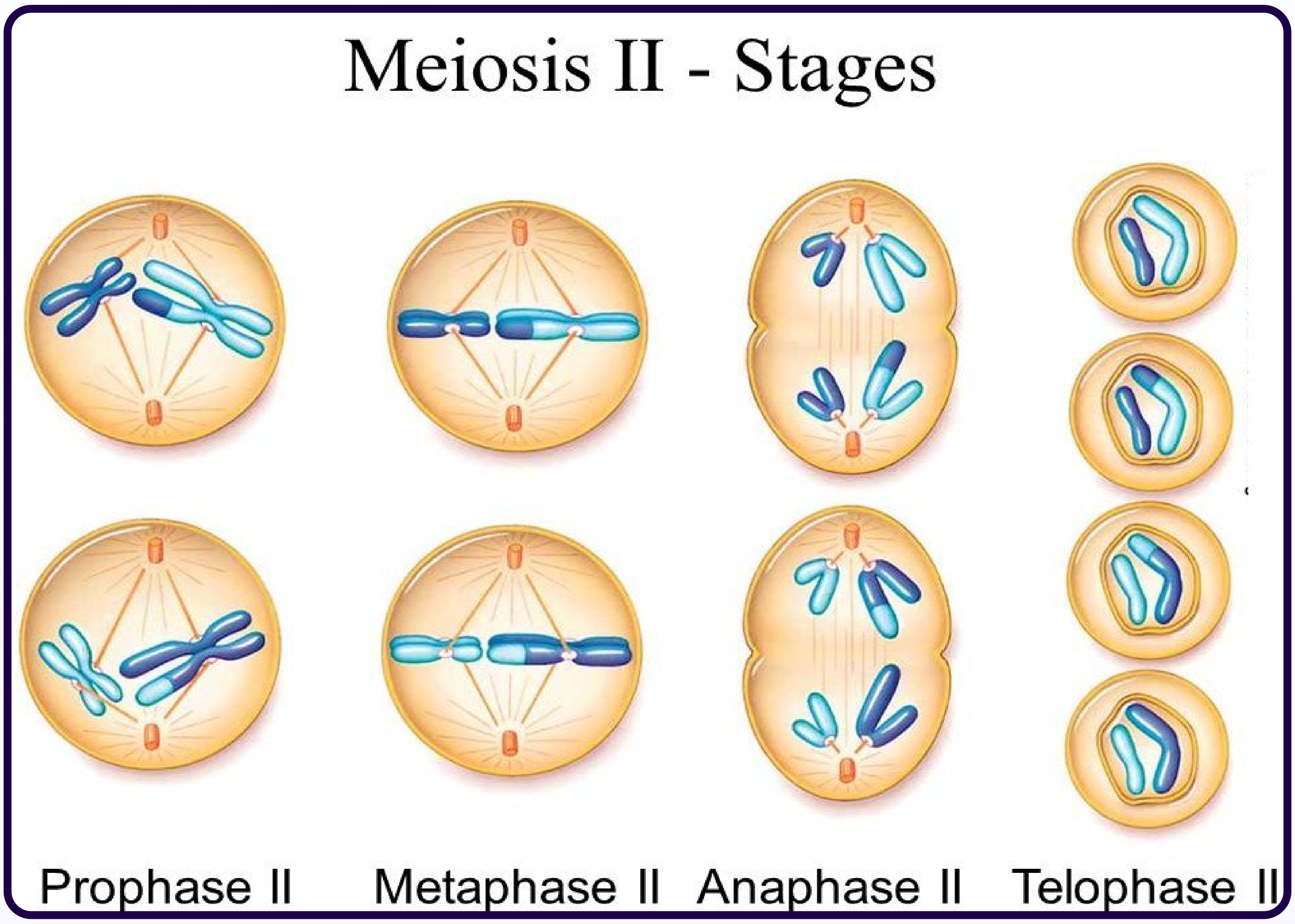
- Chromosomes align at the equator.
- Microtubules from opposite poles of the spindle get attached to the kinetochore of sister chromatids.

ANAPHASE II

- Splitting of centromere allowing chromosomes to move towards opposite poles of the cell by shortening of microtubules attached to the kinetochores.

TELOPHASE II

- Meiosis ends with telophase II.
- Two groups of chromosomes once again get enclosed by a nuclear envelope.
- Cytokinesis follows resulting in the formation of tetrad of cells.



SIGNIFICANCE OF MEIOSIS

Conservation of specific chromosome number of each species is achieved across generation in sexually reproducing organisms, paradoxically results in reduction of chromosome number by half.

Increases genetic variability in the population of organisms which is important for the process of evolution