CELL CYCLE AND CELL DIVISION

- All multicellular organism start life as a single cell, the fertilized egg and grow by addition of new cells. The phenomenon of production of daughter cell from parent cell is known as **cell division** or **cell replication.**
- Cell reproduction has three major parts - first, involves replication of parental DNA; second, separation of duplicated DNA into two equally sized groups of chromosomes and third, division of entire cell.

CELL CYCLE

- The sequence of events by which a cell duplicates its genome, synthesizes other cell contents and eventually divides into two daughter cell is tenned as **cell cycle.** All the events of cell cycle occurs in a co-ordinated manner and are under genetic control.
- A typical eukaryotic somatic cell has two main stages : a long undividing stage called **interphase (I-phase)** and a shorter nucleus dividing stage called **mitotic (M-phase) phase.** These two main phases are followed by a still shorter phase of cytoplasmic division called **cytokinesis (C-phase).**
- Interphase is the metabolically **active stage** and is a period of **intense synthesis** and **growth.** This phase is divided into three periods - first gap phase **(G_1-phase),** synthesis phase **(S-phase)** and second gap/growth phase **(G_2-phase).**
- **G_1 phase** is a stage of initial growth of a newly formed cell in which the cell carries on active metabolic activities in preparation for DNA replication. In G_1-phase, a cell has three options : to continue cell cycle and enter S-phase, stop cell cycle and enter **G_0 phase** for undergoing differentiation and get arrested in G_1-phase when it may enter G_0 phase or re-enter cell cycle.
- Some cells such as **nerve cells** and **erythrocytes** that do not divide further exit G_1 phase to enter an inactive stage called quiescent stage (G_0) of the cell cycle. They remain metabolically active but no longer proliferate unless called on to do so.
- **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.** In animal cells, during the S phase, DNA replication begins in the nucleus, and the centriole duplicates in the cytoplasm.
- **G_2 phase** is a stage of further growth of the cell and preparation for its division. During this stage, synthesis of RNAs and proteins continue.
- The **M-phase** is itself composed of two tightly coupled processes ; **karyokinesis** in which the cell's chromosomes are divided between the two daughter cells and **cytokinesis,** in which the cells' cytoplasm divides in half forming distinct cells.
- Activation of each phase is dependent on the proper progression and completion of the previous one. Thus the correct sequence of these phases in cell cycle is $G_1 \rightarrow S \rightarrow G_2 \rightarrow M$.

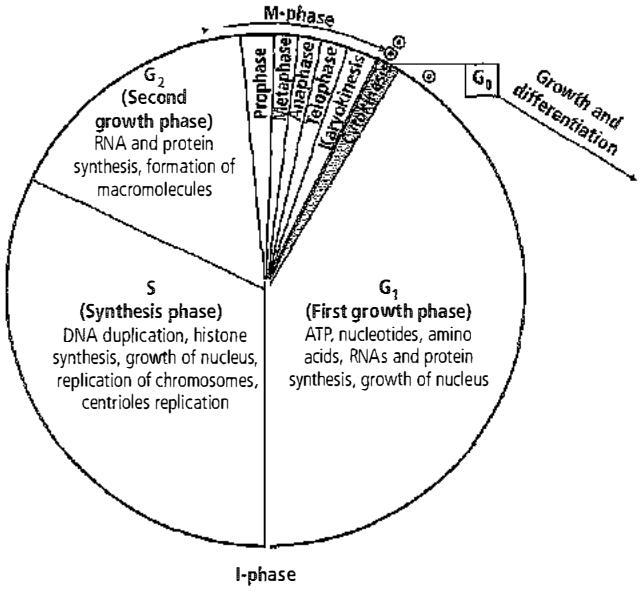


Fig.: Cell cycle

MITOSIS

- Mitosis involves the exact replication of parent cell followed by its division into two daughter cells which are identical and contain the same number of chromosomes as in parent cells.
- It was first observed by **Strassburger** (1870) in plant cells and **Fleming** (1882) in animal cells. Flemming used the term mitosis (Gk. *mitos* = thread).
- In plants mitosis occurs in the meristematic cells of root or shoot tip.
- Mitosis is divided into four stages as given in the flow chart

Significance of mitosis

- Production of diploid daughter cells with identical genetic complement.
- Cell division helps to restore the nucleo-cytoplasmic ratio.
- Old or worn out cells are replaced by new cells formed through mitosis.
- Helps to increase the number of cells within an organism.

What is colchicine ?

- It is an alkaloid widely used in plant breeding for doubling the chromosome number. Colchicine is extracted from the corms of autumn crocus (*Colchicum autumnale*). The alkaloid does not allow the formation of spindle because it prevents assembly of microtubules. It is, therefore, called **'mitotic poison'.**
- Colchicine holds the cells in metaphase. The enzyme ribonuclease is prophase poison.
- Colchicine does not inhibit chromosome replication. As a result the colchicine treated meristematic cells show doubling of chromosomes. This property of increasing the number of chromosome sets or genomes is called polyploidy.

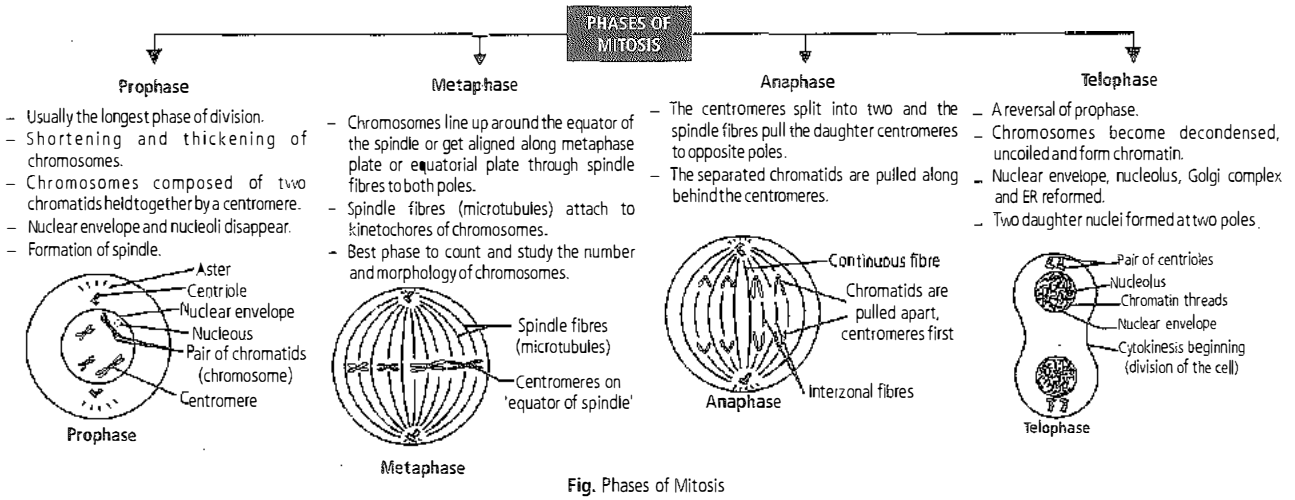
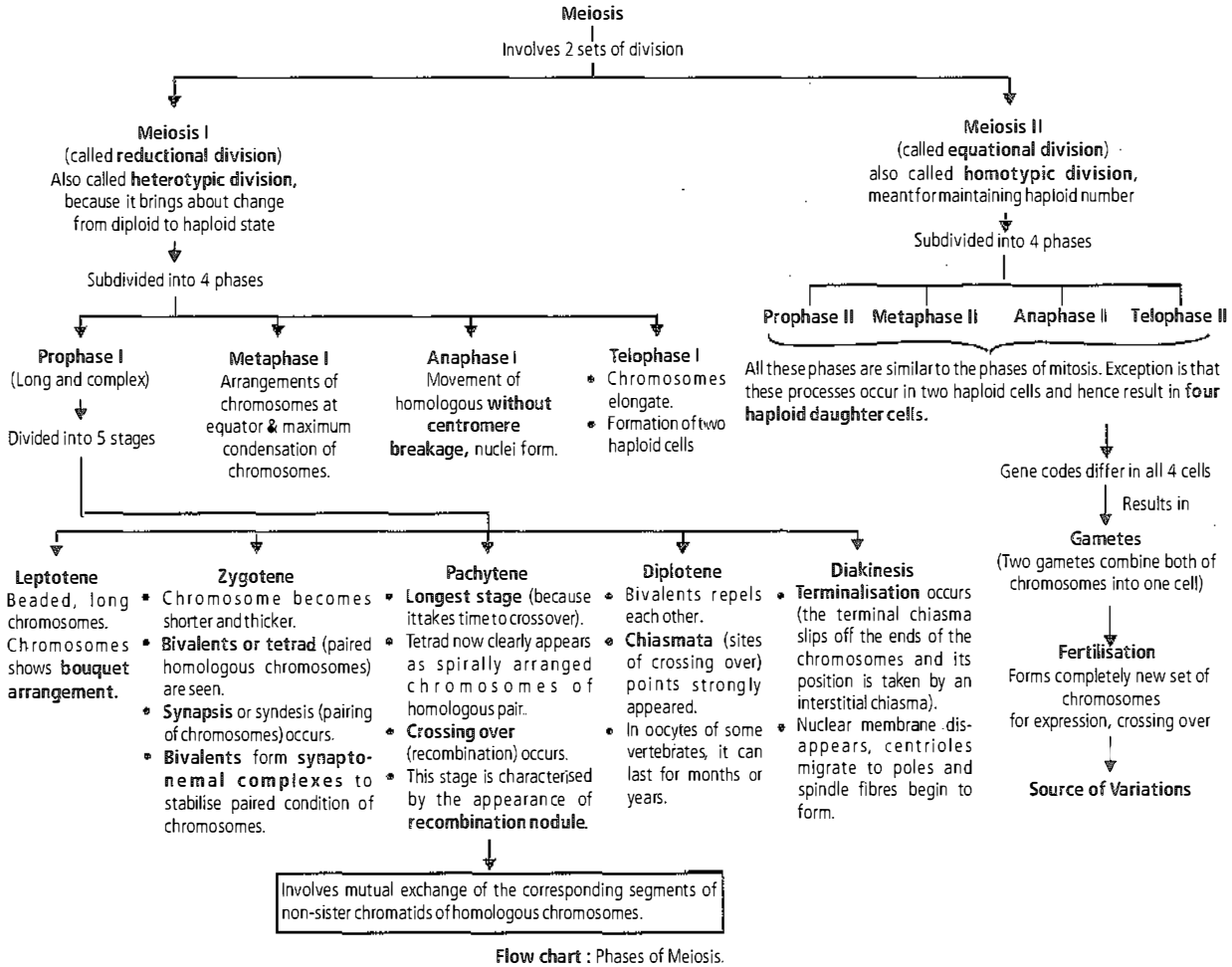


Fig. Phases of Mitosis

MEIOSIS

- Meiosis is a specialised kind of cell division that reduces the **chromosome number by half** which results in the production of **haploid daughter cells.** It ensures the production of haploid phase in the life cycle of sexually reproducing organisms whereas fertilisation restores the diploid phase. Meiotic events can be grouped into different phases as given in the flow chart. 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 have only a single cycle of DNA replication.



Flow chart : Phases of Meiosis.

- 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 them.
- **Four halpoid cells** are formed at the end of meiosis II.

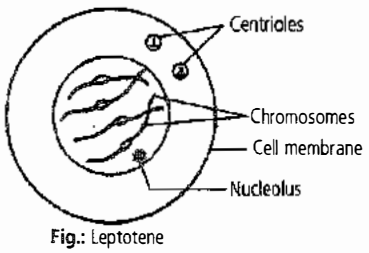


Fig.: Leptotene

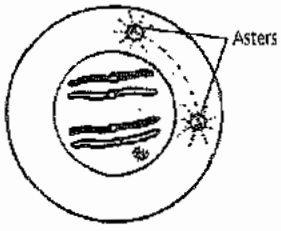


Fig.: Zygotene

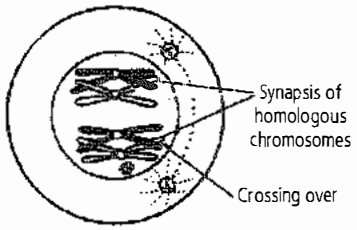


Fig.: Pachytene

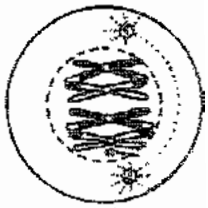


Fig.: Diplotene

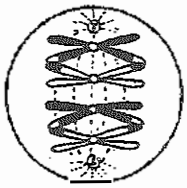


Fig.: Diakinesis


Fig.: Metaphase I

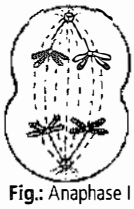


Fig.: Anaphase I

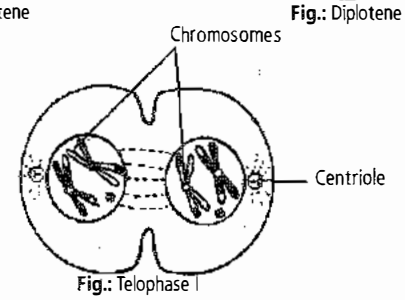


Fig.: Telophase I

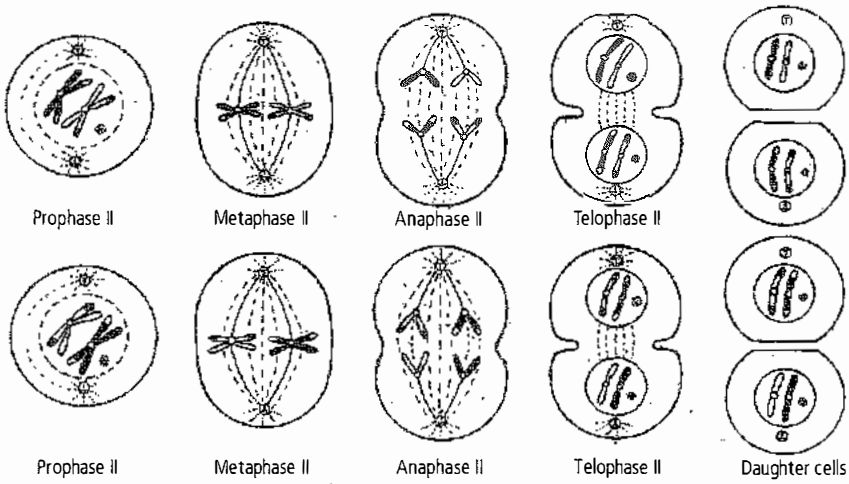


Fig.: Different stages of meiosis in animal cell

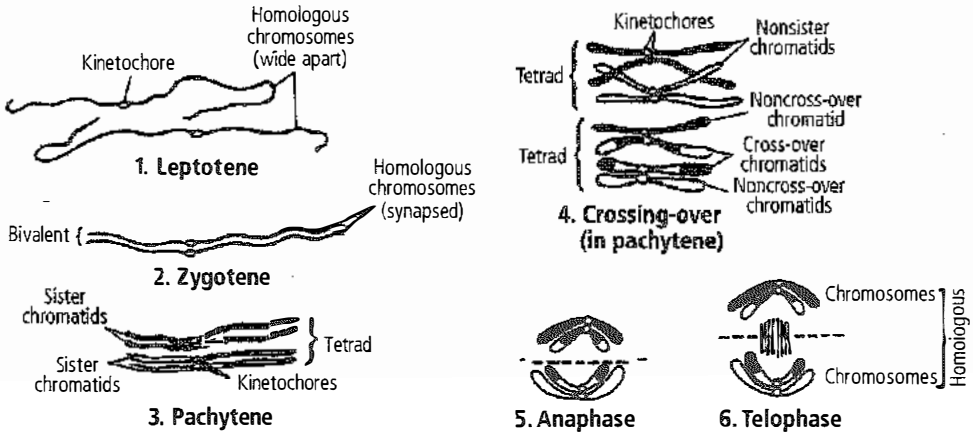


Fig.: Behaviour of chromosomes in meiosis I including crossing over

Table : Differences between mitosis and meiosis

	Mitosis	Meiosis
1.	The cell divides only once.	There are two cell divisions, the first and the second meiotic divisions.
2.	Mitosis takes place in the somatic cells of the body.	Meiosis takes place in the germ cells.
3.	DNA replication takes place during interphase I.	DNA replication takes place during interphase I but not during interphase II.
4.	The duration of prophase is short, usually of a few hours.	Prophase is comparatively longer and may take days.
5.	There is no synapsis.	Synapsis of homologous chromosomes takes place during prophase.
6.	The two chromatids of a chromosome do not exchange segments during prophase.	Chromatids of two homologous chromosomes exchange segments during crossing over.
7.	A synaptonemal complex is absent.	Synapsed homologous chromosomes develop a synaptonemal complex.
8.	Crossing over is absent.	Crossing over or exchange of similar segments between nonsister chromatids of homologous chromosomes usually takes place during pachytene stage.
9.	Chiasmata are absent.	Chiasmata or visible connections between homologous chromosomes of bivalent are observed during diplotene, diakinesis (prophase I) and metaphase I.
10.	Division of the centromeres takes place during anaphase.	There is no centromeric division during anaphase I. Centromeres divide only during anaphase II.
11.	Anaphasic chromosomes are single stranded.	Chromosomes are double stranded in anaphase I but single stranded in anaphase II.
12.	The chromosome number remains constant at the end of mitosis.	The chromosome number is reduced from the diploid to the haploid.
13.	The genetic constitution of the daughter cells is identical to that of parent cells.	The genetic constitution of the daughter cells differs from that of the parent cell. The chromosomes of daughter cells usually contain a mixture of maternal and paternal genes.
14.	Mitosis helps in multiplication of cells.	Multiplication of cells is not involved.
15.	Mitosis takes part in healing and repair.	Meiosis takes part in the formation of meiospores or gametes and maintenance of chromosome number of the race.

Significance of meiosis

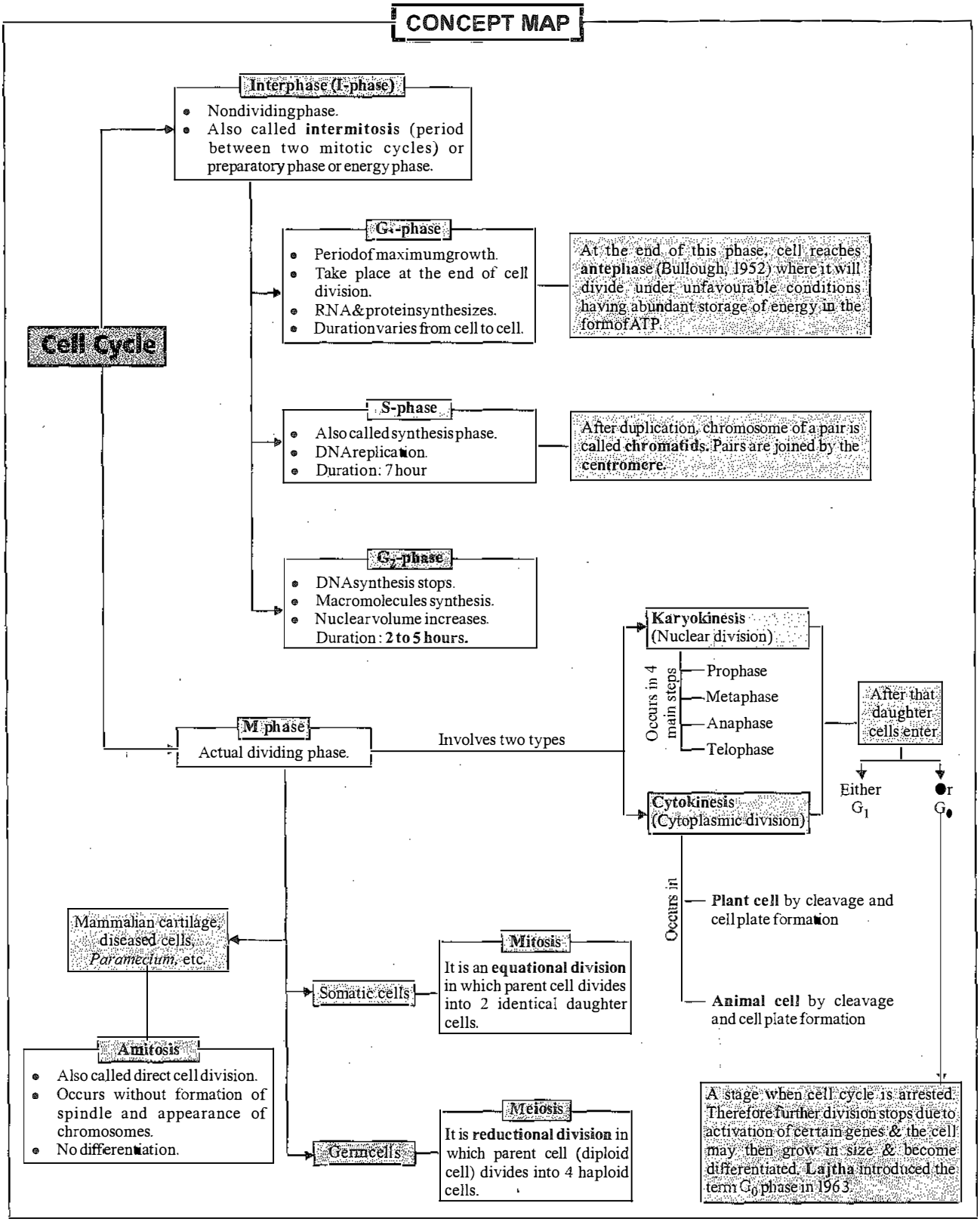
- Leads to the formation of sex cells or gametes capable of engaging in fertilisation.
- Provides opportunities for new combination of genes to occur in the gametes by two ways – independent assortment of chromosomes and crossing over.
- Switches on the genetic information for the development of gametes and switches off the sporophytic informations.
- Chromosomal and gene mutations can take place by irregularities of meiotic divisions.

Disjunction leads to normal development while non-disjunction to abnormalities. Why?

The normal separation of chromosomes in meiosis I or sister chromatids in meiosis II is termed **disjunction**. As it causes normal separation of homologous chromosomes so leads to normal number of chromosomes in daughter cells. Therefore it is essential for normal development. On the contrary when the separation is not normal, it is called non-disjunction. This results in the production of gametes which have either more or less of the usual amount of genetic material, and is a common mechanism for trisomy or monosomy. Non-disjunction can occur in the meiosis I or meiosis II phases of cellular reproduction, or during mitosis. This is a cause of several medical conditions in humans, including :

- **Down's-syndrome :** trisomy of chromosome 21.
- **Patau's syndrome :** trisomy of chromosome 13.
- **Edward's-syndrome :** trisomy of chromosome 18.
- **Klinefelter's syndrome :** an extra X chromosome in males.
- **Turner's-syndrome :** only one X chromosome present in females.
- **XYY syndrome :** an extra Y chromosome in males.
- **Triple X syndrome :** an extra X chromosome in females.

CONCEPT MAP


Cell Cycle
Interphase (I-phase)
Nondividing phase.
Also called intermitosis (period between two mitotic cycles) or preparatory phase or energy phase.
G1-phase
Period of maximum growth.
Take place at the end of cell division.
RNA & protein synthesizes.
Duration varies from cell to cell.
At the end of this phase, cell reaches antephase (Bullough, 1952) where it will divide under unfavourable conditions having abundant storage of energy in the form of ATP.
S-phase
Also called synthesis phase.
DNA replication.
Duration: 7 hour
After duplication, chromosome of a pair is called chromatids. Pairs are joined by the centromere.
G2-phase
DNA synthesis stops.
Macromolecules synthesis.
Nuclear volume increases.
Duration: 2 to 5 hours.
M phase
Actual dividing phase.
Involves two types
Karyokinesis (Nuclear division)
Occurs in 4 main steps
Prophase
Metaphase
Anaphase
Telophase
Cytokinesis (Cytoplasmic division)
After that daughter cells enter
Either G1
or G0
Occurs in
Plant cell by cleavage and cell plate formation
Animal cell by cleavage and cell plate formation
A stage when cell cycle is arrested. Therefore further division stops due to activation of certain genes & the cell may then grow in size & become differentiated. Lajtha introduced the term G0 phase in 1963.
Somatic cells
Mitosis
It is an equational division in which parent cell divides into 2 identical daughter cells.
Germ cells
Meiosis
It is reductional division in which parent cell (diploid cell) divides into 4 haploid cells.
Mammalian cartilage, diseased cells, Paramecium, etc.
Amitosis
Also called direct cell division.
Occurs without formation of spindle and appearance of chromosomes.
No differentiation.