Cell Division: Fundamental Pathway of Growth and Development

Nidhi Dubey[1] and Harshal Avinashe[2]

[1&2]Assistant Professor, Dept. of Genetics and Plant Breeding, Lovely Professional University, Phagwara (Punjab), India.

Abstract

Cell is the architectural and functional component of life in all the living creatures. The hereditary determinants are located on chromosomes which act as the physical basis of heredity. In plants, microspore and megaspore are formed through meiosis from anther and ovaries respectively followed by formation of microgamete and megamete through mitotic cell division. So, both these cell division is important for proper growth and development of an individual.

Keywords: Cell, mitosis, meiosis, heredity, gamete.

Cell Division

Cell is the architectural and functional component of life in all the living creatures. Cells exhibit large variation in number and shape among the organisms. Mainly there are two types of cells i.e. eukaryotic cell with a well defined nucleus and other cell organelles and prokaryotic cell without well defined nucleus and cell organelles (Fig. 1). Both plant and animal cells possess hereditary determinants carrying information for transmission of characters from one generation to other are located on nuclear structures called chromosomes. A Chromosome play important role in individual cell division and also take part in reproduction of the organisms. Body frame of all multicellular organisms are formed from unicellular zygotes via repetitive division of the zygote. Cell division can be defined as division of chromosomes and cytoplasm of the cell into two daughter cells. The cell which is being divided is known as 'mother cell or nucleus' and the new cells which are formed are known as 'daughter cells or nuclei'. Cell division majorly functions for proper growth and development of somatic tissues of individuals followed by repair of damaged parts, development of new organs and formation of zygote. Furthermore, it helps in maintaining cell size in a prescribed range and through evolution of new forms leads to continuity of life.

Cell division is majorly of two types i.e. mitosis and meiosis followed by division of nucleus (karyokinesis) and division of cytoplasm (cytokinesis). Growth requires an increase in cell mass, a duplication of genetic material and a division in which each progeny cell receives an equal complement of the genetic material to ensure perpetuation of the cell line.

Mitosis

A detail of cell reproduction was described in the late 19th century by Walther Flemming in animal cells and by Edward Strausberger in plant cell. It is mainly responsible for development of zygote into adult organisms. In case of plants mitosis occurs in root tip, leaf base and stem tip. Since the daughter cells produced are identical in shape, size and chromosome complement therefore it is also known as equational or homotypic division. One cell cycle of mitotic cell division consists of five stages i.e. Interphase, prophase, metaphase, anaphase and Telophase followed by karyokinesis and cytokinesis (Singh, B.D. 1990).

1. Interphase: Consists of three sub stages-

✓ G_1 phase is known as pre-DNA synthesis phase where RNA and protein synthesis takes place.

✓ S phase is known as synthesis phase in which complete DNA synthesis and replication occurs.

✓ G_2 phase is known as post-DNA synthesis phase where RNA and protein synthesis takes place (fig.1).

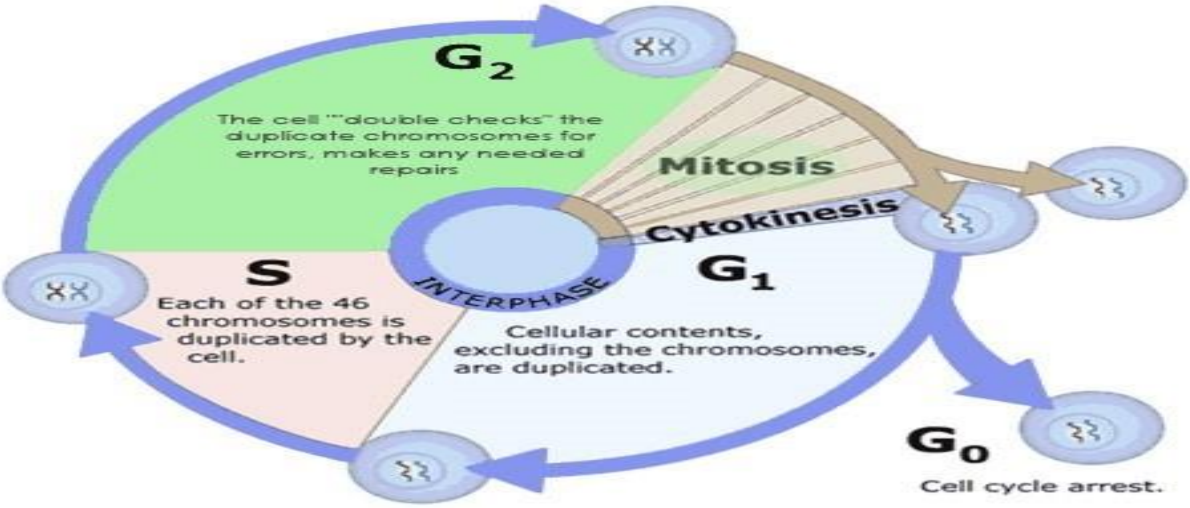

Fig. 1. Interphase

2. Prophase:

✓ In early prophase, chromosomes look like thin thread like structures uncoiled.

✓ In mid prophase, chromosomes become condensed and thicker and in late prophase, longitudinally double chromosomes become visible.

✓ Nucleolus and nuclear membrane disappears (fig.2).

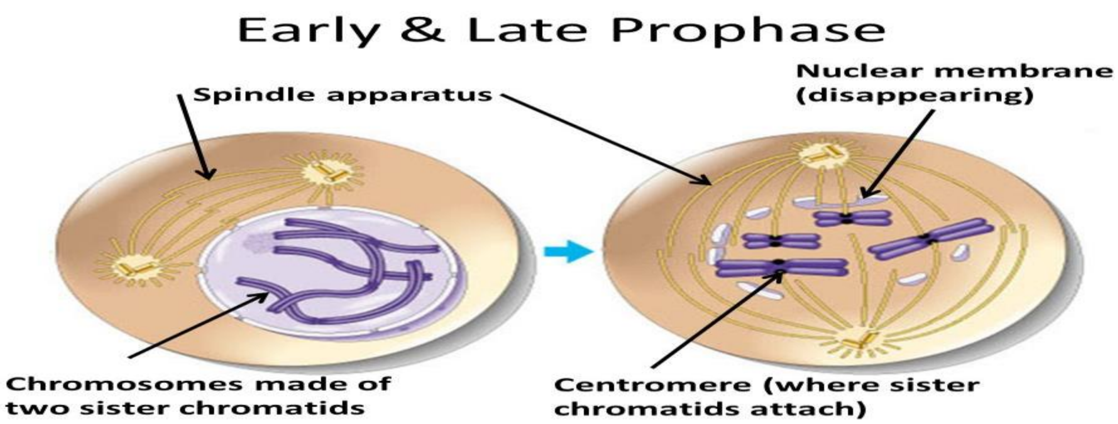

Fig.2. Prophase

3. Metaphase:

✓ In prometaphase, Centrioles start moving to opposite poles and spindle apparatus formation starts.

✓ In metaphase the chromosomes are aligned on the equatorial plate with the help of spindle fibres attached to the centromere keeping the arms free (fig.3).

4. Anaphase:

✓ Spindle apparatus degeneration starts in early anaphase.

✓ In late anaphase centromere divides longitudinally and the chromatids start moving to the opposite poles (fig.4).

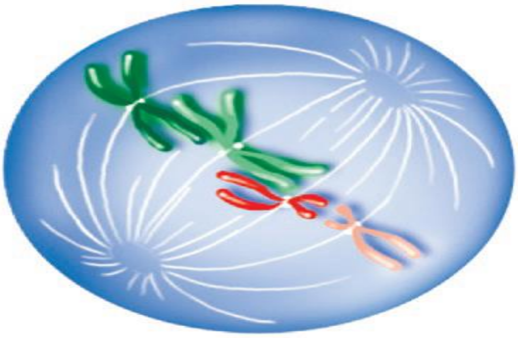

Fig.3. Metaphase

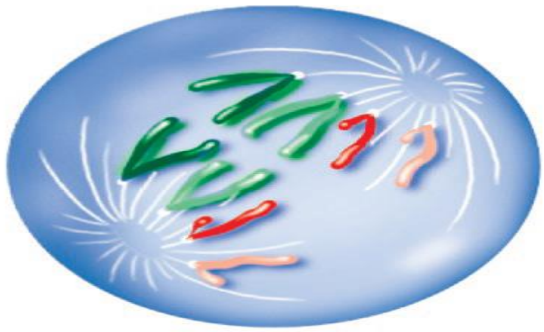

Fig.4. Anaphase

5. Telophase:

✓ Spindle Apparatus degeneration is complete.

✓ Chromatids reach to the end of opposite poles and become uncoiled thin thread like structures (Zimmerman and Forer 1981).

✓ Nucleolus and nuclear membrane reappears (fig.5).

After the completion of telophase stage the division of nucleus occurs i.e. karyokinesis followed by division of cytoplasm i.e. cytokinesis leading to the formation of two identical daughter cells (fig.6).

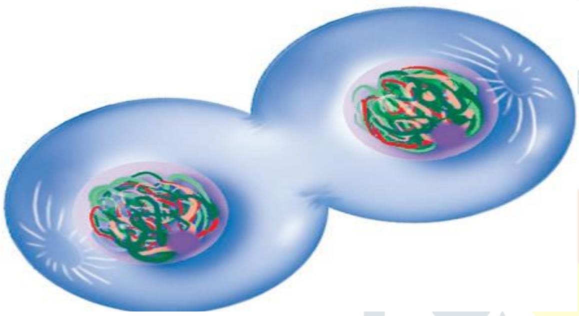

Fig.5. Telophase

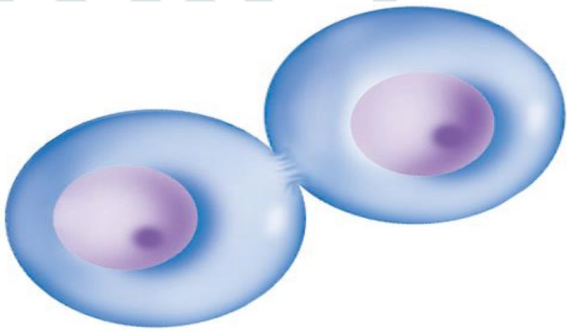

Fig.6. Cytokinesis

Meiosis

The mechanism in which chromosome number from diploid i.e. 2n is reduced to haploid i.e. n in mature reproductive cells is known as meiosis. In plants it occurs in anthers and ovaries leading to the formation of microspore and megaspore. Since the daughter cells produced have half the chromosome complement as of the mother cell therefore it is also known as reductional division. Meiosis is mainly responsible for formation of zygote putting forward a platform for evolution due to segregation and recombination. It consists of two phases i.e. meiosis phase I and meiosis phase II each having five sub stages (Strickberger, M. 1985).

Meiosis Phase I (Reductional division)

1. Interphase I:

✓ G_1 phase in which RNA and protein synthesis takes place.

✓ S phase in which 99.7% DNA synthesis occurs followed by DNA and chromosome replication.

✓ G_2 phase in which RNA and protein synthesis takes place.

2. Prophase I: divided into five sub stages:-

a. Leptotene

✓ Chromosomes look like thin thread like structure coiled with each other giving the appearance of ball of wool.

✓ RNA and protein synthesis takes place (fig.7).

b. Zygotene

✓ Homologous chromosomes start pairing with each other with the formation of synaptonemal complex (Westergaard and Wettstein 1972).

✓ Remaining 0.3% DNA synthesis also takes place (fig.8).

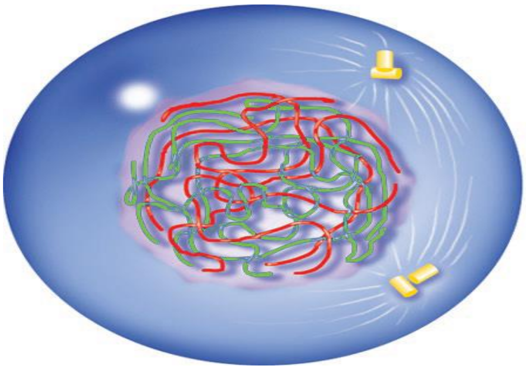

Fig. 7. Leptotene

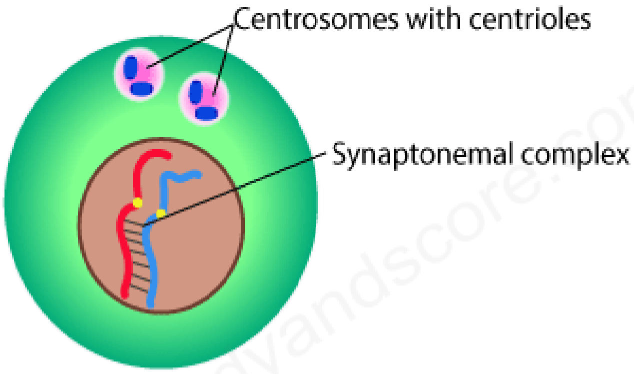

Fig. 8. Zygotene

c. Pachytene

✓ Formation of chaisma takes place.

✓ Crossing over takes place in the tetrad stage (fig.9).

d. Diplotene

✓ Homologous chromosomes start separating from each other and are attached to each other at some pints called as Chaismata.

✓ At the end of diplotene stage chaismata terminalization starts (fig.10).

e. Diakinesis

✓ Chaismata terminalization completes.

✓ Bivalents bearing a portion of non sister chromatid as a result of crossing over are visible.

✓ Nucleolus and nuclear membrane disappears (fig.11).

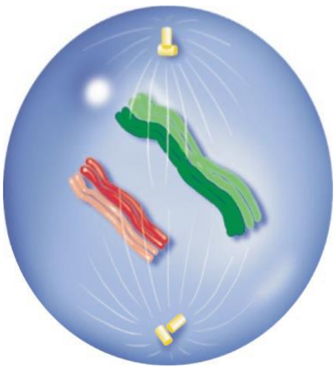

Fig. 9. Pachytene

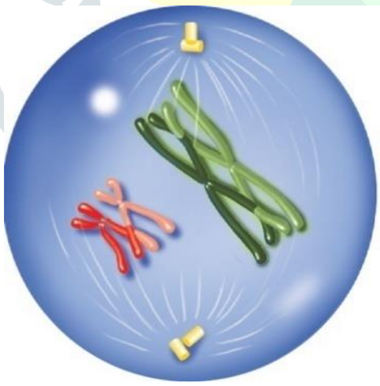

Fig. 10. Diplotene

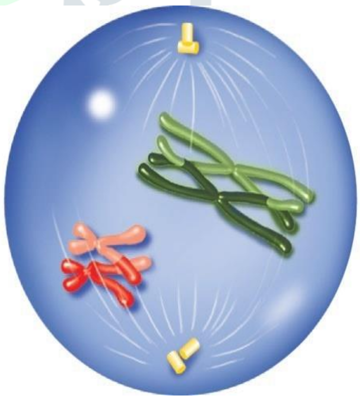

Fig. 11. Diakinesis

3. Metaphase I

✓ Spindle apparatus is completed.

✓ Homologous chromosomes are arranged on equatorial plate with the help of spindle fibres (fig.12).

4. Anaphase I

✓ Spindle fibre degeneration starts.

✓ Each chromosome from the homologous pair starts moving to the opposite poles (fig.13).

5. Telophase I

✓ Chromosomes reach to the end of opposite poles and become uncoiled.

✓ Nucleolus and nuclear membrane reappears (fig.14).

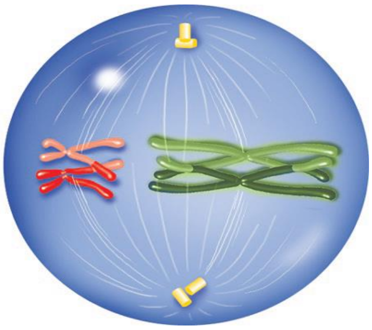

Fig.12. Metaphase I

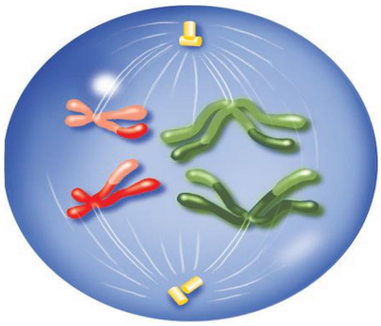

Fig.13. Anaphase I

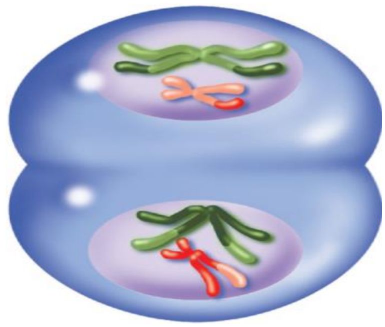

Fig.14.Telophase I

Meiosis Phase II

In this there is no S phase in interphase II as the cell entering meiosis phase II already possess bivalent chromosomes and DNA synthesis is also completed in the previous interphase stage (Singh, P. 2009).

1. Interphase II
✓ G_1 phase in which RNA and protein synthesis takes place.
✓ G_2 phase in which RNA and protein synthesis takes place.
2. Prophase II
✓ In early prophase, chromosomes look like thin thread like structures uncoiled.
✓ In mid prophase, chromosomes become condensed and thicker and in late prophase, longitudinally double chromosomes become visible.
✓ Nucleolus and nuclear membrane disappears (fig.15).
3. Metaphase II
✓ The chromosomes are aligned on the equatorial plate with the help of spindle fibres attached to the centromere keeping the arms free (fig.16).
4. Anaphase II
✓ Spindle apparatus degeneration starts in early anaphase.
✓ In late anaphase centromere divides longitudinally and the chromatids start moving to the opposite poles (fig.17).

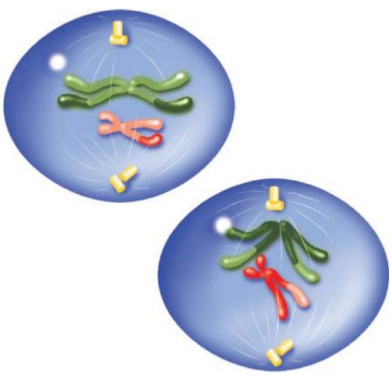

Fig.15. Prophase II

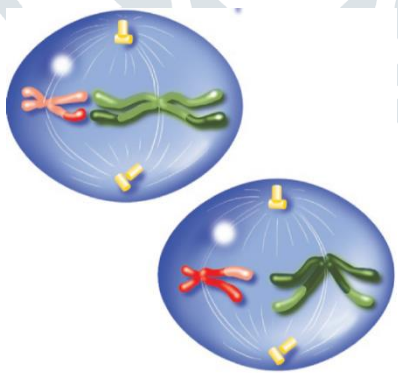

Fig.16.Metaphase II

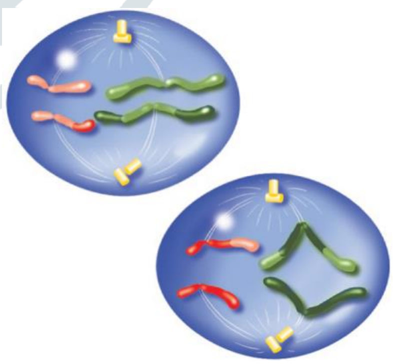

Fig.17. Anaphase II

5. Telophase II
✓ Spindle Apparatus degeneration is complete.
✓ Chromatids reach to the end of opposite poles and become uncoiled thin thread like structures.
✓ Nucleolus and nuclear membrane reappears (fig.18).

Since meiosis phase II is same as mitotic division therefore it is also known as equational division.

Furthermore, through mitosis from one parent cell two daughter cells are formed while through meiosis from one parent cell four haploid daughter cells are formed (fig.19). Hence, it can be said that in all sexually reproducing species, male and female gametes form the zygote through meiosis and further the zygote is developed into an adult through mitosis. So, both these cell division is important for proper growth and development of an individual.

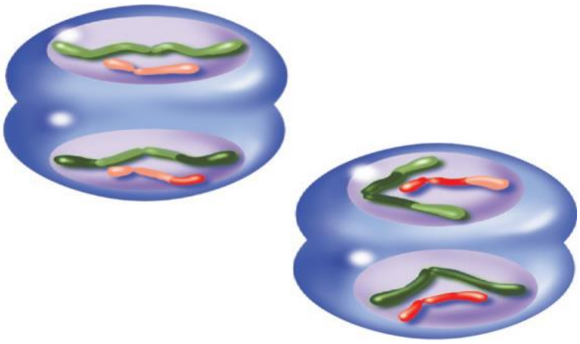

Fig.18.Telophase II

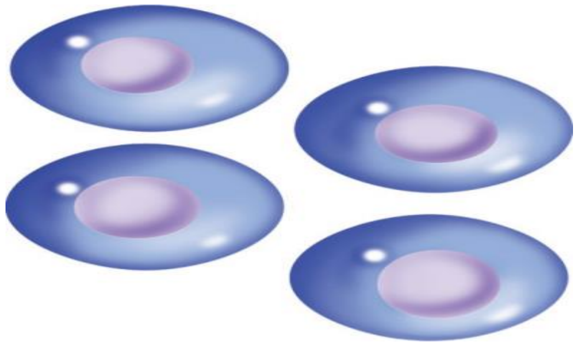

Fig.19.Cytokinesis

References

Singh, B.D. (1990). Fundamentals of genetics. Kalyani Publ. Ludhiana.

Singh, P. (2009). Genetics (3rd ed). Kalyani Publ. Ludhiana.

Strickberger, M. (1985). Genetics (3rd ed) Macmillan Publ. Co., New York, London.

Westergaard, M. and Von Wettstein, D. (1972). The synaptonemal complex. *Ann. Rev. Genet.* 6: 71-110.

Zimmerman, A. and Forer, A. (1981). Mitosis/cytokinesis. Academic press. New York.