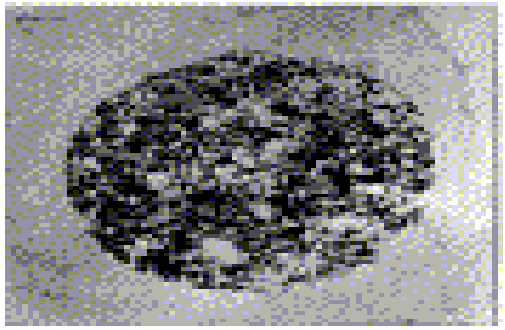
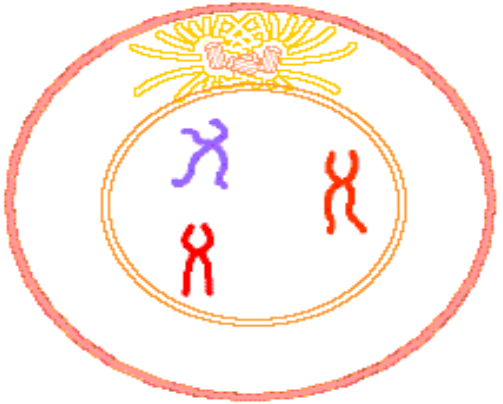
Lecture 7.Cell division – mitosis, meiosis and their significance, cell cycle; zygote formation and embryo development - identical and fraternal twins





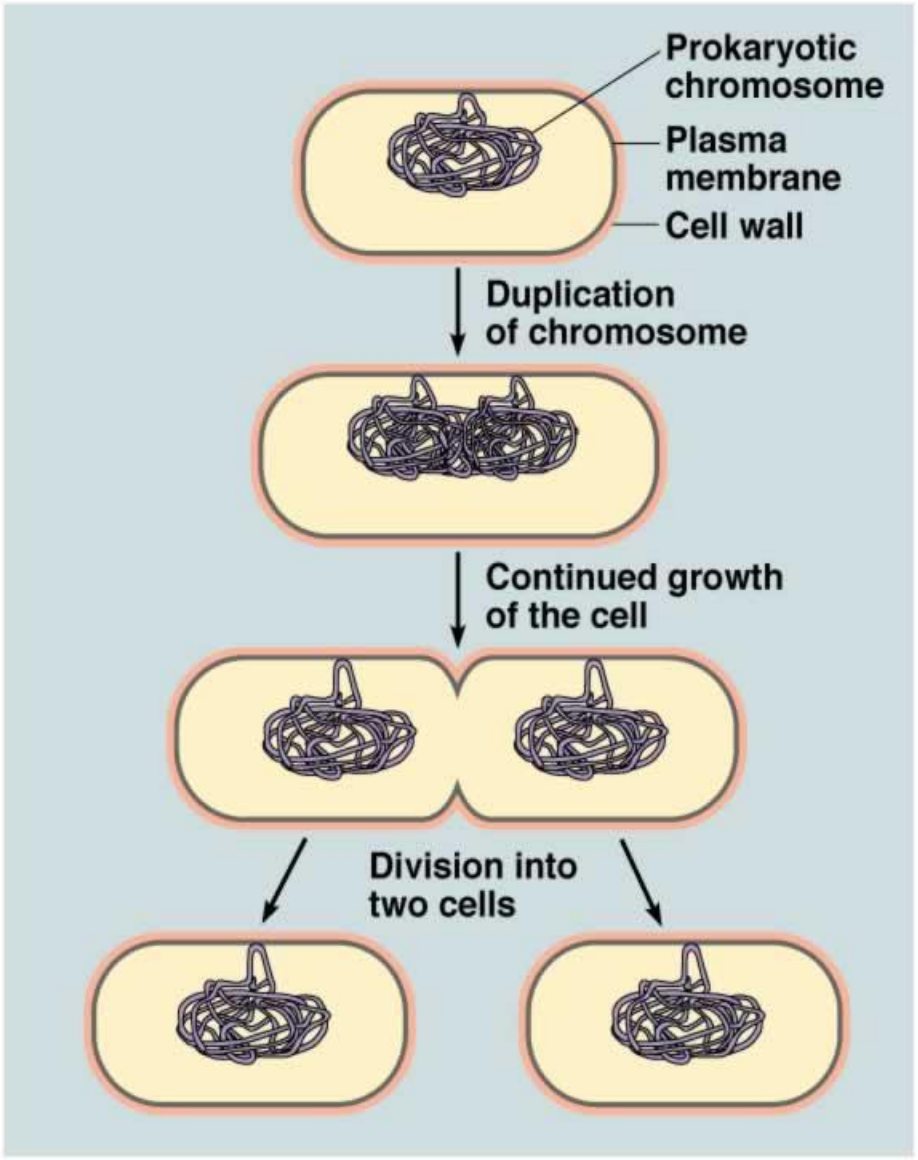
- Cell is the basic unit of structure and function in all living systems.
- The process of reproduction or formation of new cells from the pre- existing cells is referred to as cell division.
- The cell which undergoes division is called mother cell and the new cells which are formed by the process of cell division are termed as daughter cells.
- Cell Division is of 2 types
    - Direct cell division / Amitosis
    - Indirect cell division

1. Direct cell division / Amitosis / Nuclear fission

Cytoplasm and nucleus of a pre existing cell divides directly by constriction and form two daughter cells.

Amitotic division is seen in cells which lack distinct nuclei and chromosome.

Eg: bacterial cells.



2. Indirect cell division

This type of cell division takes place in a specialized manner in higher organisms.

It is of 2 types

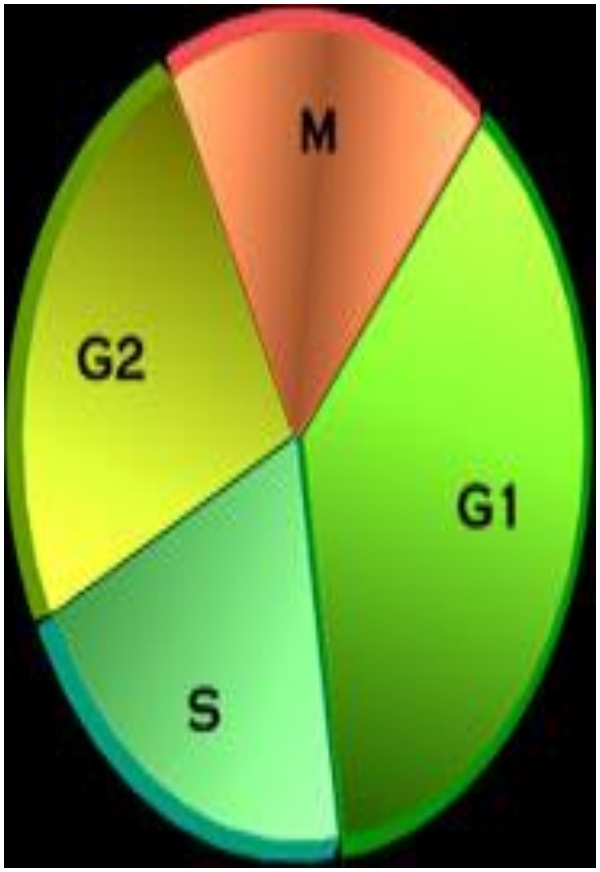
- Mitosis – does not involve reduction in chromosome number.
- Meiosis – involves reduction in chromosome number.

Cell cycle

The period in which **one cycle of cell division is completed** is called cell cycle.

A cell cycle consists of two phases

1. **Interphase**
2. **Mitotic phase**



Interphase

- Also Known as DNA synthesis phase.
- It consists of 3 sub phases
  1. **G1 phase**
  2. **S phase**
  3. **G2 phases**

G1 phase

- It is the Pre DNA replication phase, also called resting phase
- This is phase between telophase and S phase.
- It is the longest phase eg: In *Vicia faba,* it takes 12 hours.
- Protein and RNA synthesis takes phase.

S phase (DNA synthesis phase)

- Called as DNA replication phase
- Chromosome and DNA replication takes place.
- Takes less time when compared to G1 phase.

  Eg: *Vicia faba* – 6 hours.

G2 phase

- Resting phase after DNA replication, also called Post DNA replication phase.
- Protein and RNA synthesis take place.
- This phase takes 12 hours in *Vicia faba*

Mitosis

- Flemming (1882), a German biologist coined the term Mitosis and he was the first to study cell division.
- The nucleus of a dividing somatic cell undergo series of changes called Mitosis.
- It leads to separation of replicated DNA into 2 daughter nucleus without any recombination.
- Thus, the daughter nucleus have the same chromosome combination as that of parent nucleus.

  Thus Mitosis refers to only Karyokinesis.
- Since equal division of nucleus followed by equal division of Cytoplasm – it is also called equational division.
- Root tips / shoot tips - suitable materials for studying Mitosis
- In Mitosis – 2 distinct successive process taken place.
  1. Division of nucleus - Karyokinesis
  2. Division of cytoplasm – Cytokinesis

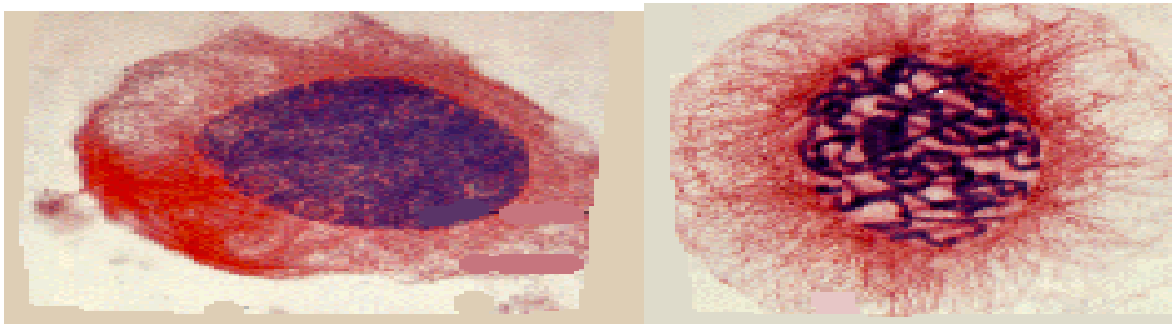
I. Karyokinesis

- Division of nucleus takes place
- This is a continuous of process.
- But, divided into four successive steps.

a) Prophase
b) Metaphase
c) Anaphase
d) Telophase.

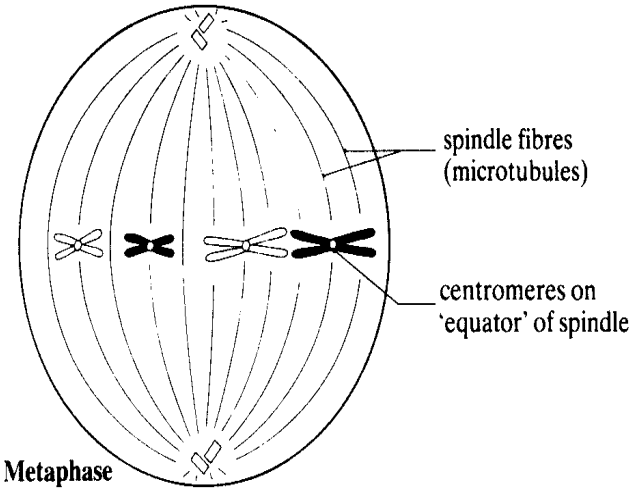
1. Prophase

- It is the first visible step in nuclear division.
- Series of changes takes place in this division
- The nuclear reticulam and nucleoli becomes clear due to dehydration of nuclear sap.
- The chromatin network (woollen ball) dissociates and chromosomes become distinct and become still shorter and thicker due to increased condensation.
- By the middle of prophase the two chromatids of each chromosomes becomes visible.
- In the beginning, the chromatids of the chromosomes are spirally coiled called plectonemic coiling but uncoiling takes place at the end of prophase.
- Each chromatids contain many deeply staining bodies called chromonema.
- At the end of prophase, the chromatids become shorter and thicker and the nucleolus and nuclear membrane disappear.



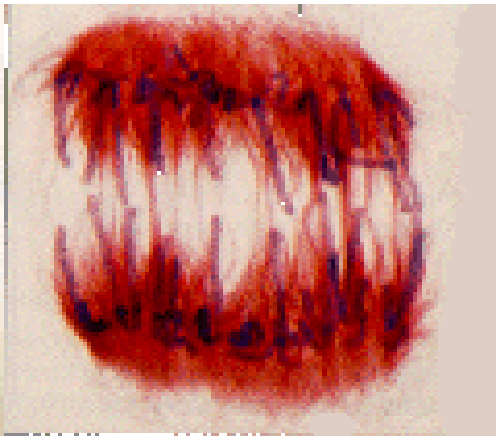
2. Metaphase

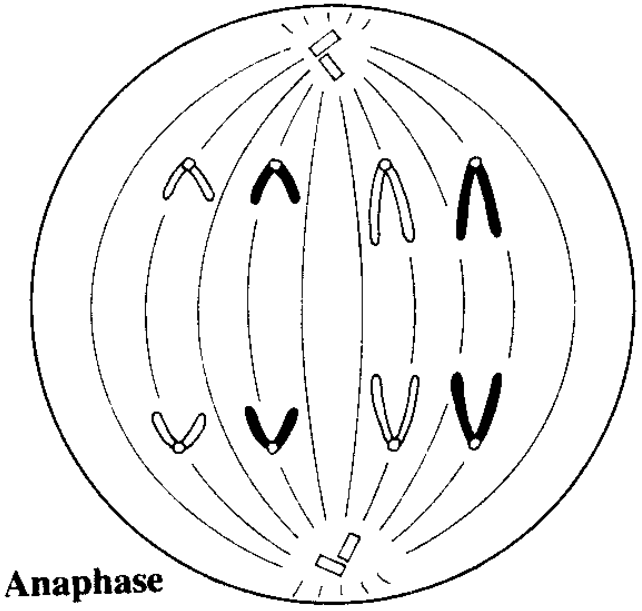
- With the disappearance of nuclear membrane,
- Metaphase begins with appearance of spindle fibres.
- The **movement of chromosomes to the middle and their orientation on the equatorial plate** is termed as metakinesis.
- **In this stage the chromosomes can be easily counted and their size and shape can be determined**.
- Spindle fibres are responsible for equal distribution of the chromosomes to the two daughter cells.
- The spindle fibres that gets connected with the centromeres are called chromosomal fibres.
- Other spindle fibres that run between poles without any interruption called continuous fibres.
- The spindle attachment region determines the future shape of the chromosomes whether rod / J shaped / Ring shaped.



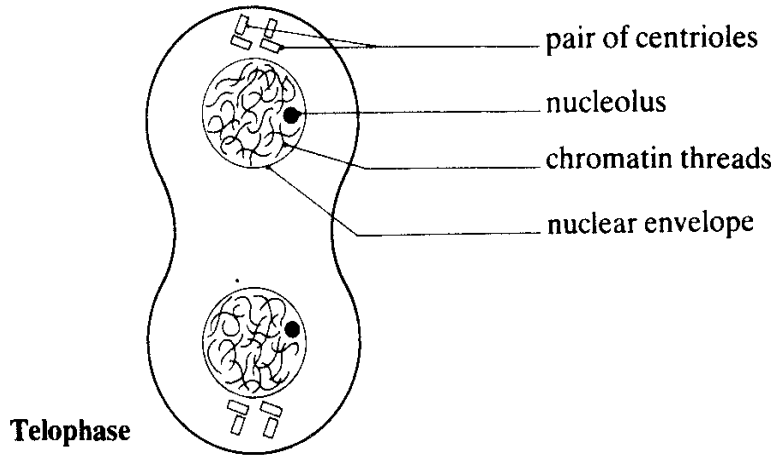
3. Anaphase

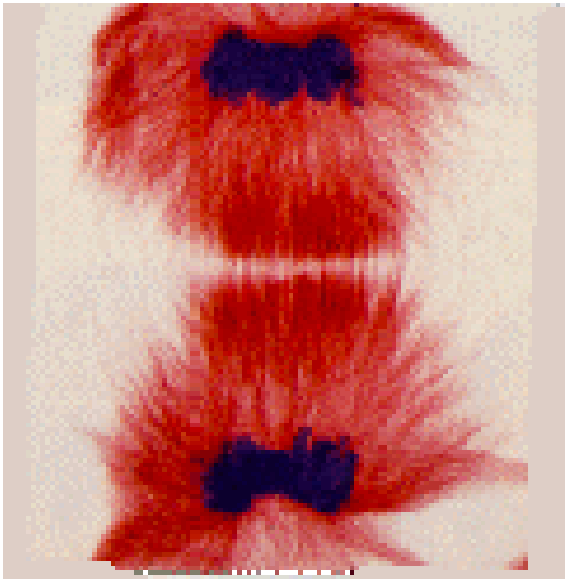
- The centromere of each chromosome divides longitudinally and the **two sister chromatids** become completely free from each other and **migrate towards the opposite poles**
- Centromere is the first portion of the chromosome that begins to move towards the poles.
- Here, the chromosome gets more condensed when compared to metaphase stage and the spindle fibres attached with the centromere contracts the **chromatids towards the poles** and finally disappears.



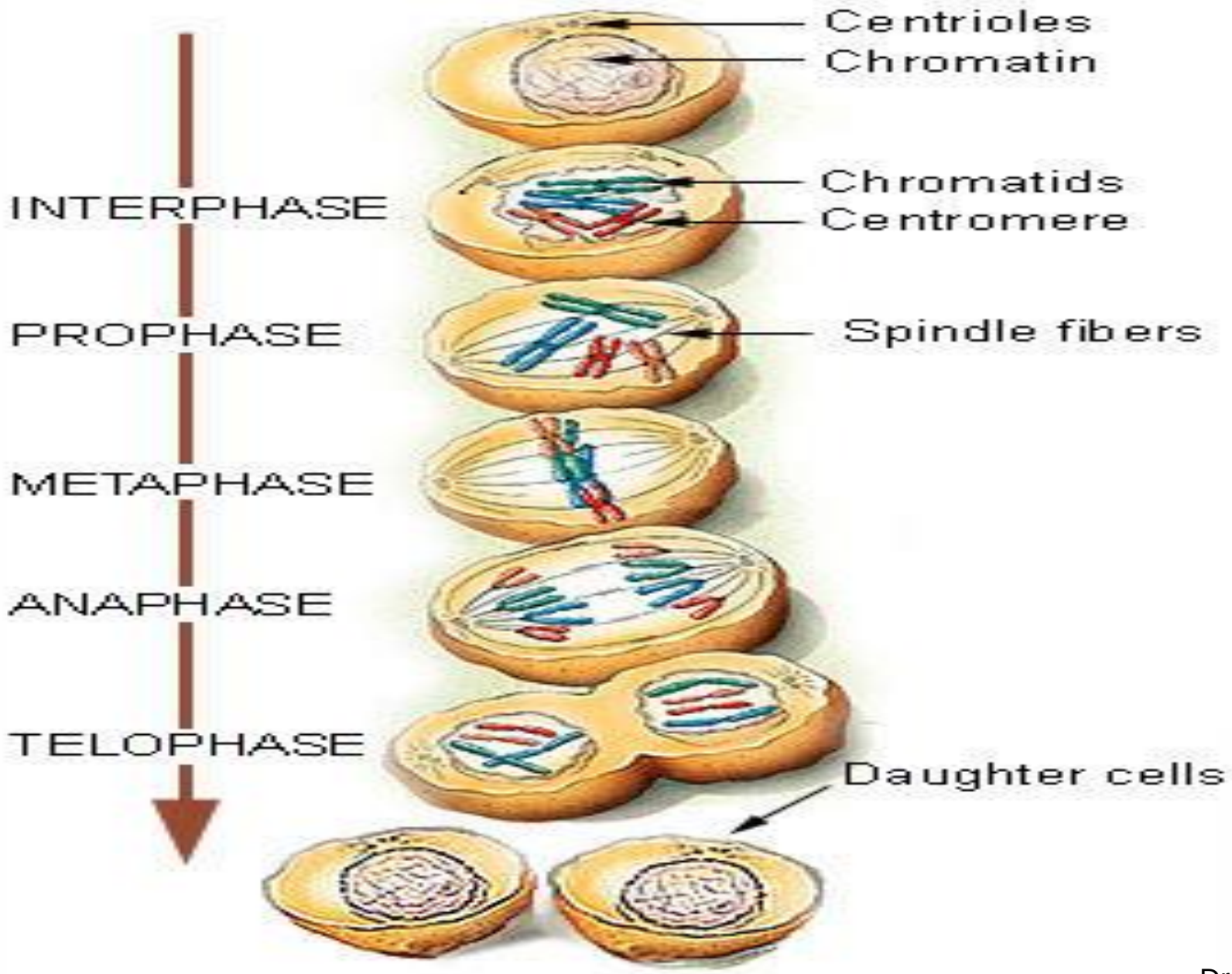


- **4. <u>Telophase:</u>**
- Last visible stage of nuclear division.
- This stage begins when the sister chromatids of all the chromosome of the cell reaches the opposite pole.
- The chromosome begin to uncoil, become very long and thin with the appearance like a coiled thin thread.
- Nucleolus reappears.
- Nuclear membarane gets reorganized around each group of chromosomes in the poles.
- At the end of telophase, two daughter nuclei are completely organised from the two sets of daughter chromosomes.





Mitosis



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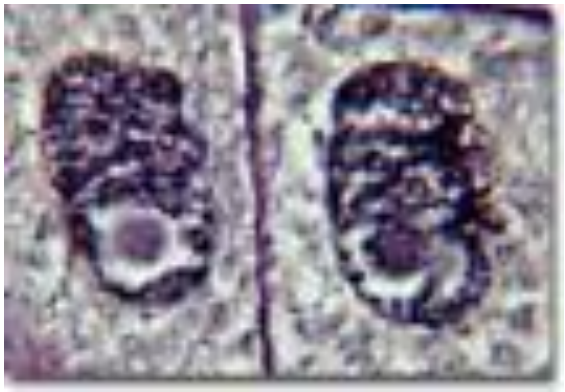
II. Cytokinesis / Division of Cytoplasm

- Cytokinesis is the division of extra nuclear protoplast
- This happens either through formation of cell plate in between the two newly formed daughter nucleus.
- This cell plate divides the protoplast into two, resulting in two daughter cells which later enlarges in size.
- The two daughter cells, thus contain one nucleus each and each nucleus having same number of as that of the parent cell.



In terms of duration

Prophase is the longest stage of cell division.

Anaphase is the shortest.

Metaphase and Telophase are considerably longer than Anaphase.

Genetic control of Mitosis

- **Mitosis play an important role in the life of living organisms**
- During mitosis, the chromosomes split longitudinally and the chromatids of the chromosome separate into two equal groups and finally form two daughter nuclei.
- So, the same genetic constitution is maintained qualitatively as well as quantitatively in the chromosomes of the two daughter nuclei.

Significance of Mitosis

- After fusion of male and female gametes the zygotes are formed. So, Mitosis is responsible for development of zygote into adult organism.
- it is essential for normal growth and development of living organism. It gives shape to a specific organism.
- Mitosis, in plants leads to formation of new parts – roots, leaves, stem branches. It helps in repairing of damaged parts.
- Mitosis, leads to production of identical progenies in vegetatively propagated crops.
- It is useful in maintaining purity of types because it leads to production of identical daughter cells and does not allow segregation and recombination to occur.
- In animals, it helps in continuous replacement of old tissues. Eg. Blood cells.

Meiosis

- Meiosis Is the mechanism, where reduction in chromosome number takes place during cell division.
- It takes place before / after reproduction in the reproductive cells.
- Weisman (1887) was the first to point out the reduction of chromosome number in the reproductive cells (Young anthers)
- During meiosis, a diploid cell undergoes 2 successive divisions finally producing 4 haploid cells.
- According to Darlington (1956), in Meiosis, single chromosome doubling takes place followed by 2 nuclear divisions namely

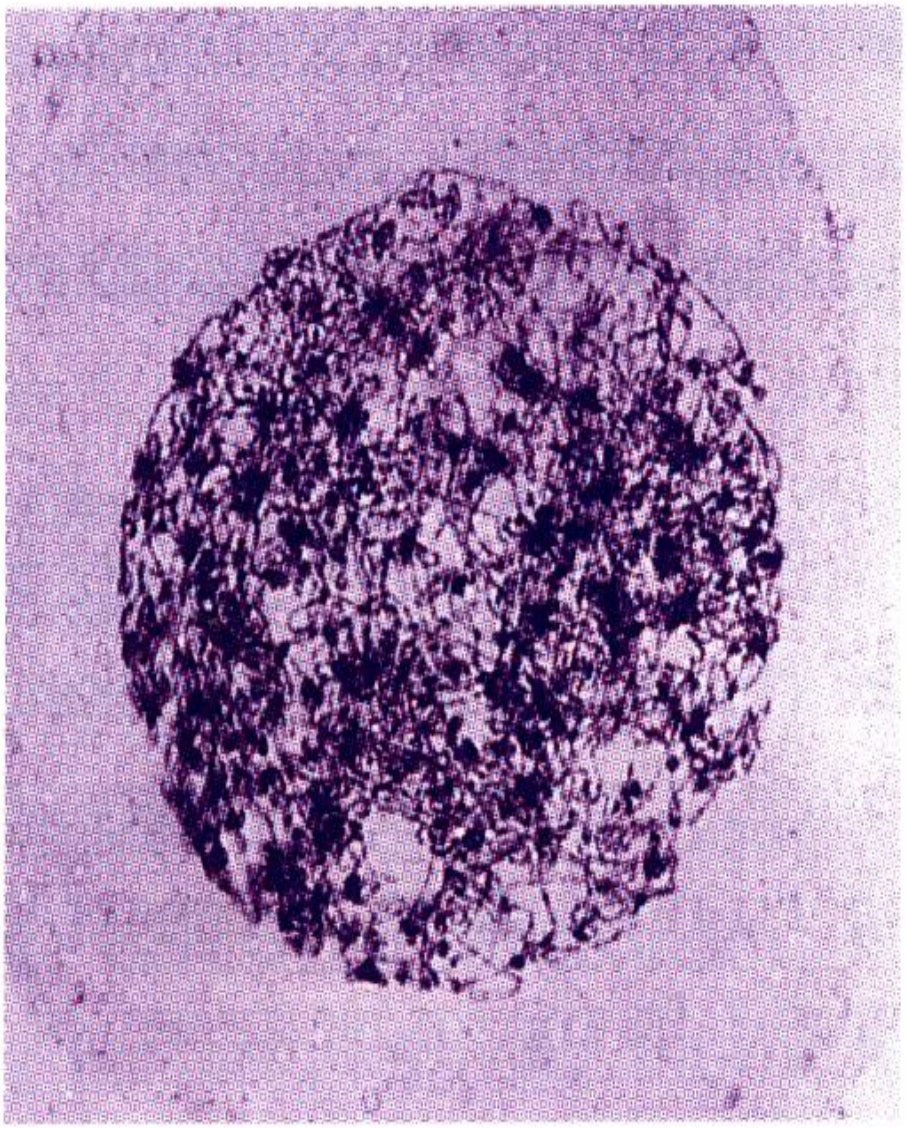
    1. Meiosis I
    2. Meiosis II

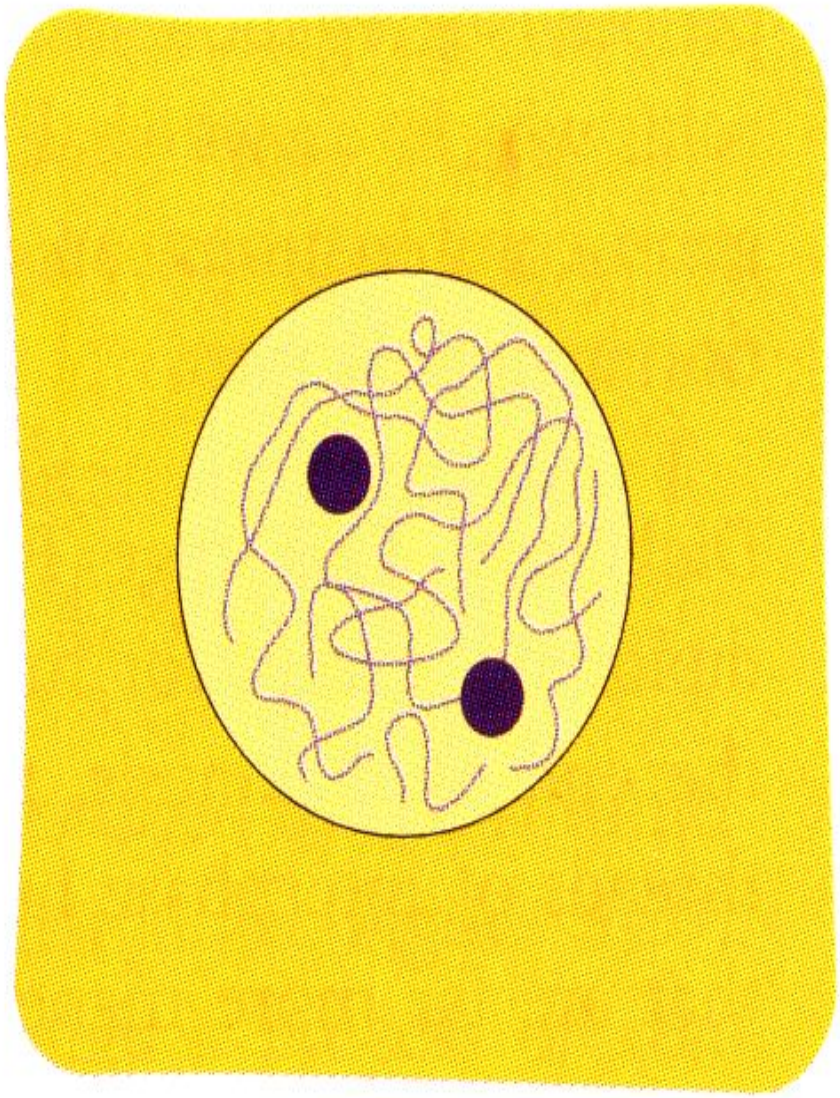
- **Premeiotic Interphase**
- Important stage prior to the entry of the cell to cell division.
- Consists of there phases G1, S and G2 phase, like Mitosis.
- In meiosis, G2 phase is of very short duration.
- S phase occurs only once in the entire process of Meiosis.
- About 99.7% of the total DNA in the nucleus is synthesized during S phase and the remaining 0.3 % DNA synthesis takes place during zygotene stage.

- **Meiosis - I**
- Meiosis I results in reduction in chromosome number in each new cell to half of the mother cell, referred to as reductional division.
- It consists of 4 different phases.
    - Prophase I
    - Metaphase I
    - Anaphase I
    - Telophase I

Prophase I

- After Interphase, first prophase starts and it is of maximum duration.
- It consists of 5 sub stages
    - Leptotene,
    - Zygotene,
    - Pachytene,
    - Diplotene
    - Diakinesis.





Leptotene

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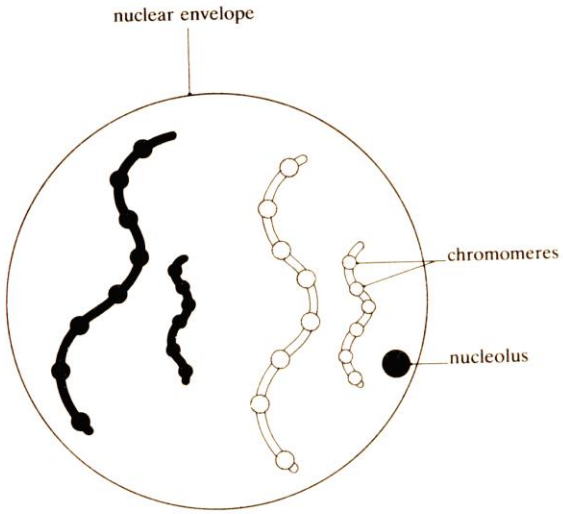
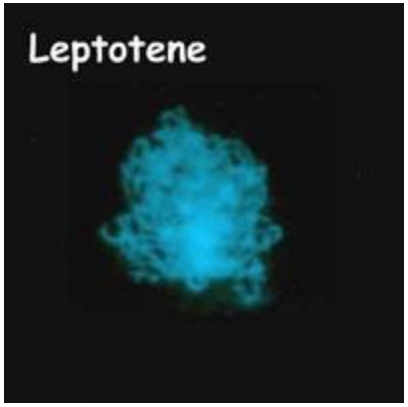
Leptotene ***(Leptonema)-*** thin thread stage



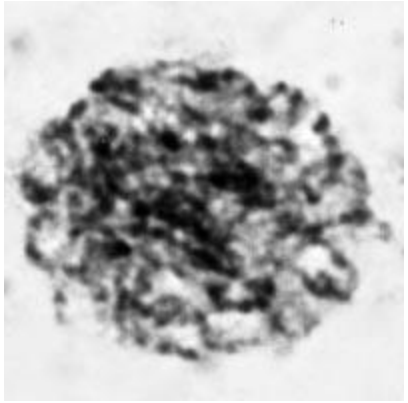


Petunia hybrida

- The chromosomes are longer and thinner and bead like structures called *chromomeres* are appearing along the entire length of chromosomes

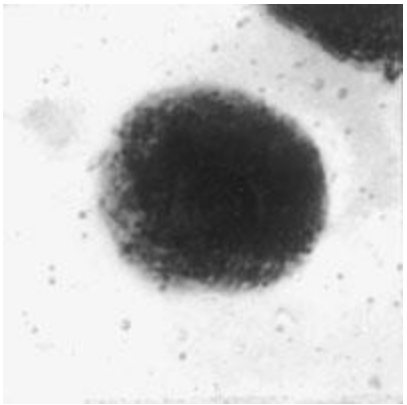
Chromomeres : These are the regions of chromatin threads (*Chromonemata*) that are tightly coiled than inter chromosomal regions

Leptotene--- The nucleus increases in size and it has been related to RNA and protein synthesis.



***Locusta sp*.**

The nucleus has now the diploid number of chromosomes.



Lilium grandiflorum

Hence the nucleus has therefore pairs of similar or homologous chromosomes.

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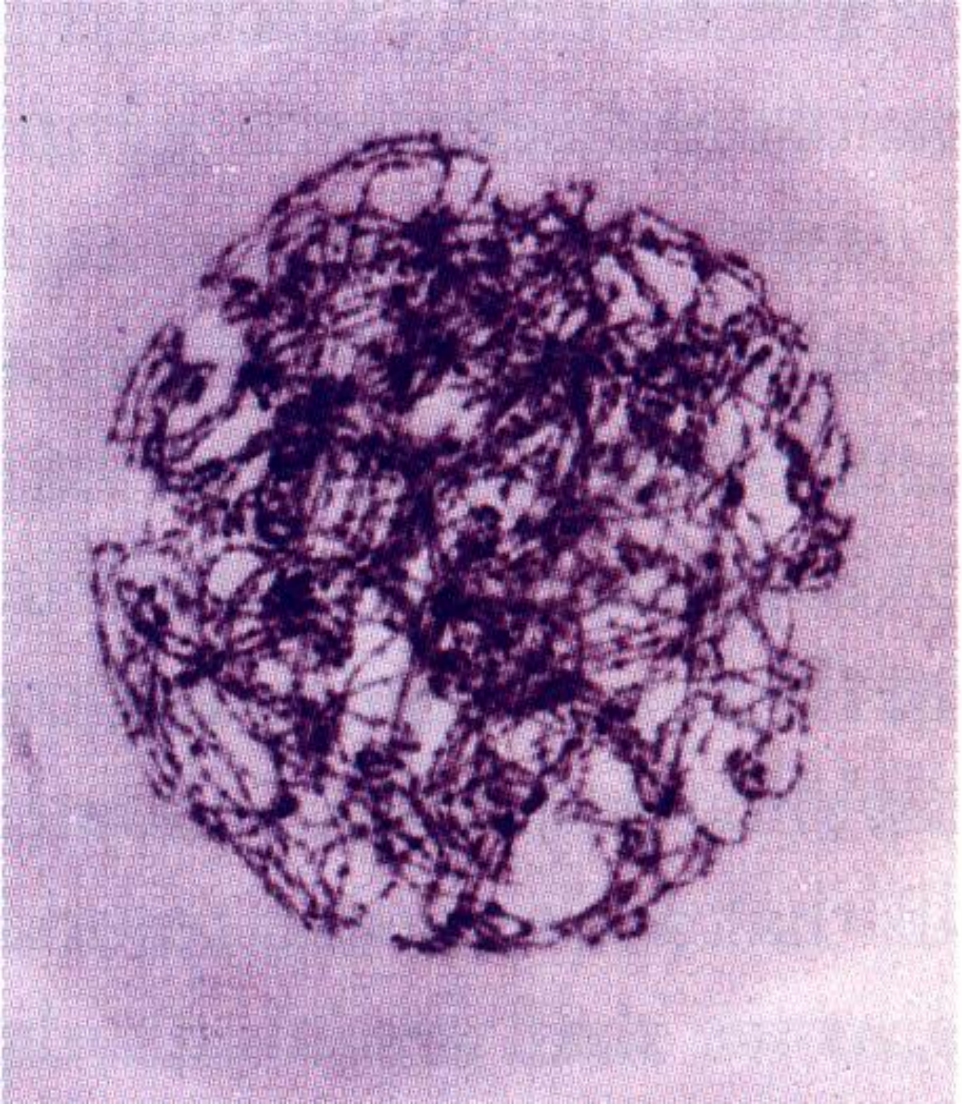
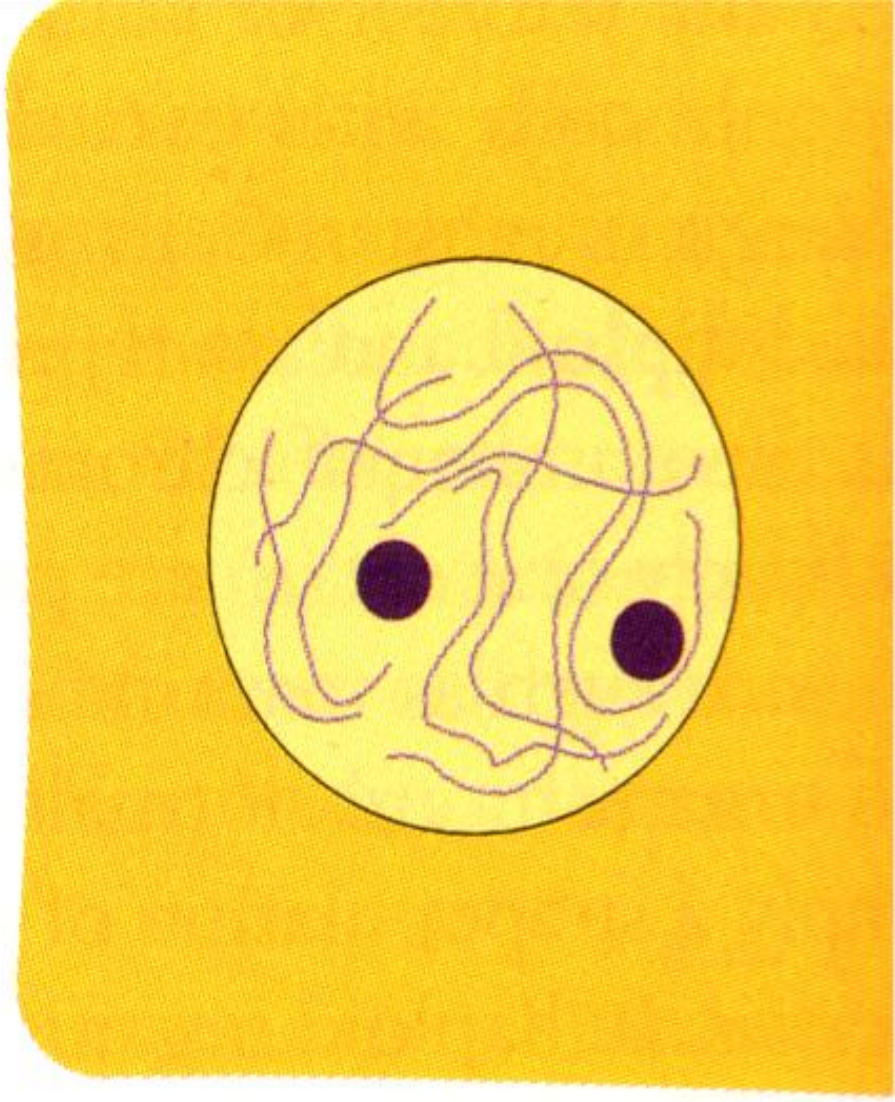
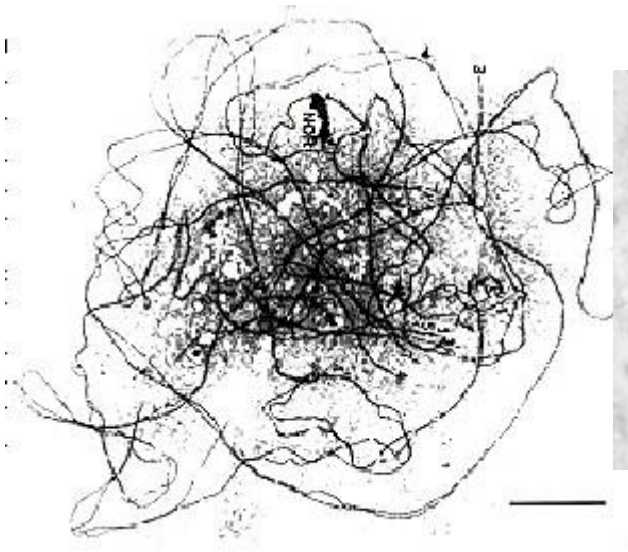




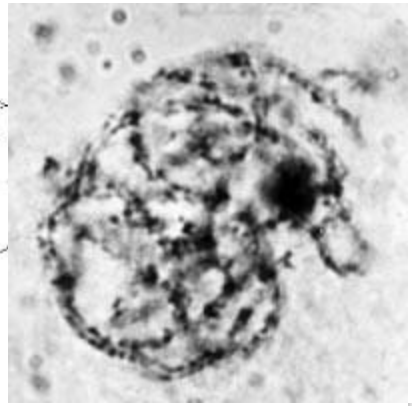
Zygotene

Zygotene *(Zygonema)-* jointed thread stage

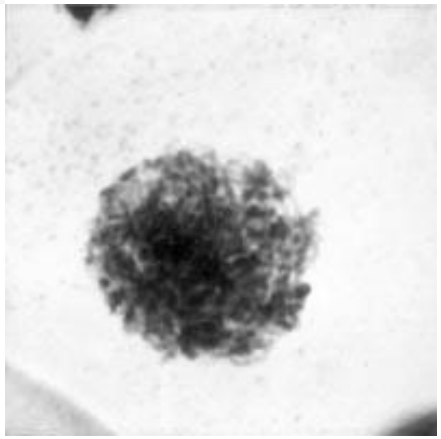


Bivalents in zygotene stage

Locusta sp.



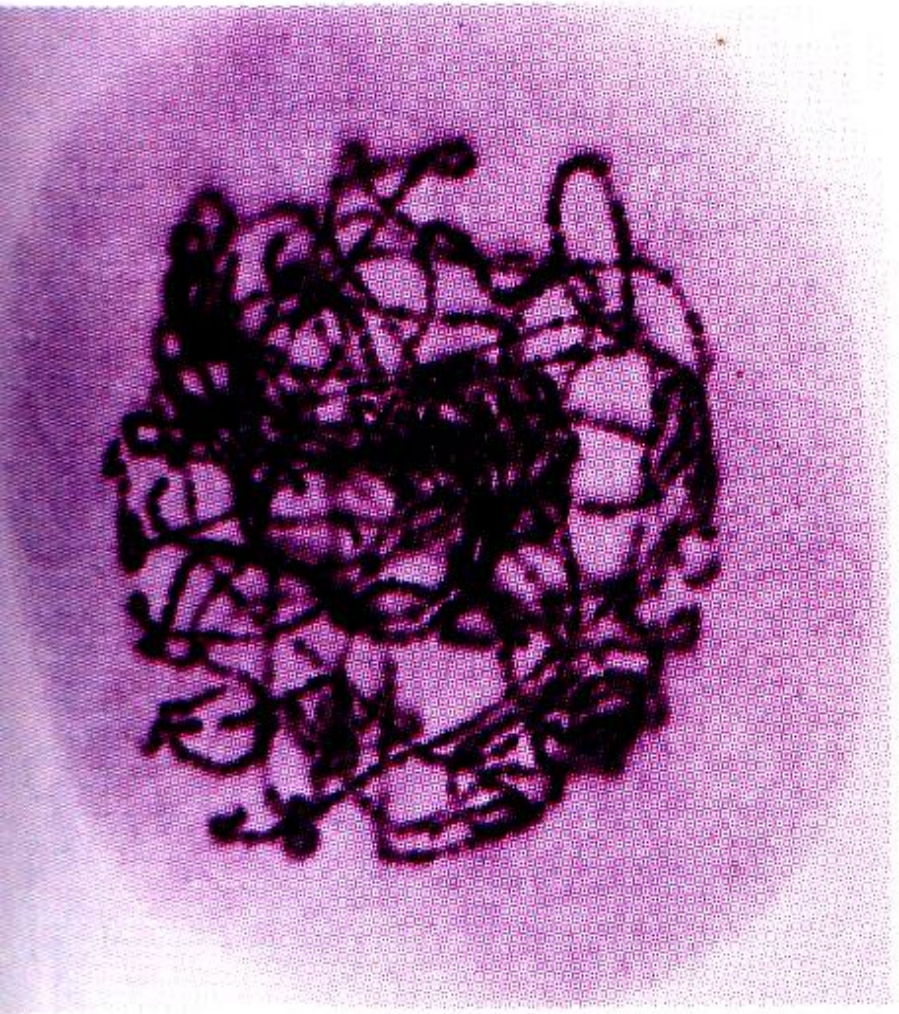
The chromosomes gradually become shorter in length and wider in diameter as a result of **progressive coiling**.

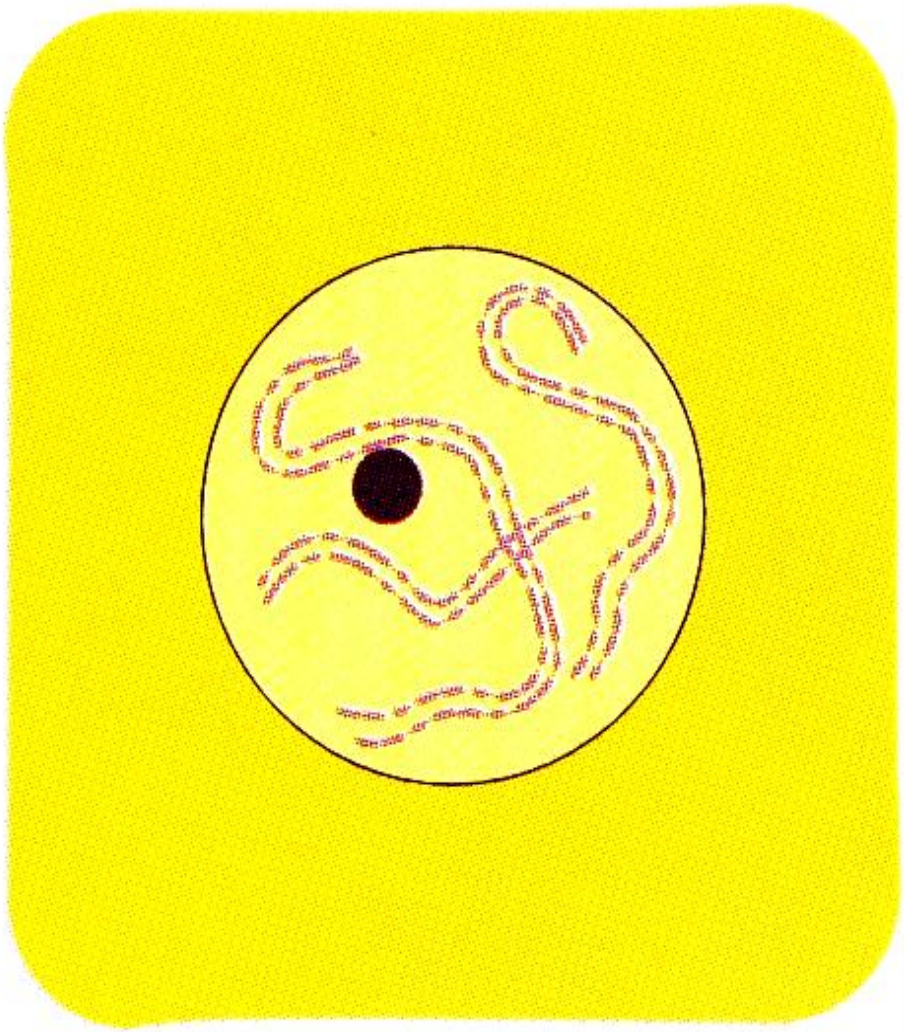


Lilium grandiflorum

It is stage of pairing of homologous in several 'contact points' in zipper like fashion precise and specific. This phenomenon of chromosome pairing is called **synapsis.**

Petunia hybrida

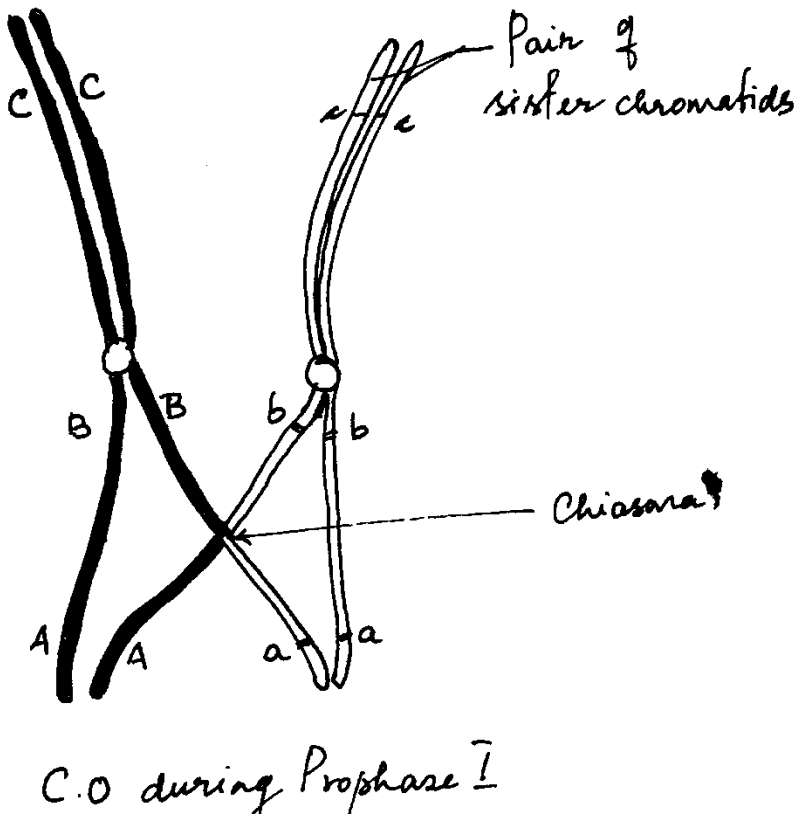




(c) Pachytene

Pachytene *(Pachynema)-* thick-thread stage

Pairing of homologous chromosomes completed.



C.O during Prophase I

There are now four chromosomatids (each chromosome with **two sister chromatids**) called **tetrad** chromosome.

This is also called **bivalents** referring to the two homologous chromosomes. Each locus represented **four times.**

There is a reciprocal exchange of segments between homologous non sister chromatids called **crossing over** takes place.

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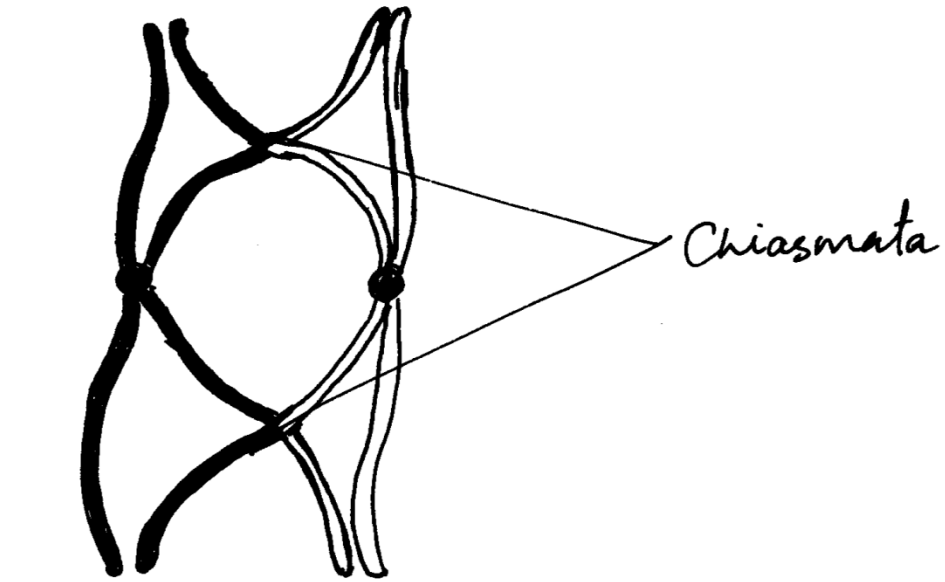
Bivalents may also be called tetrad (4 chromatids)



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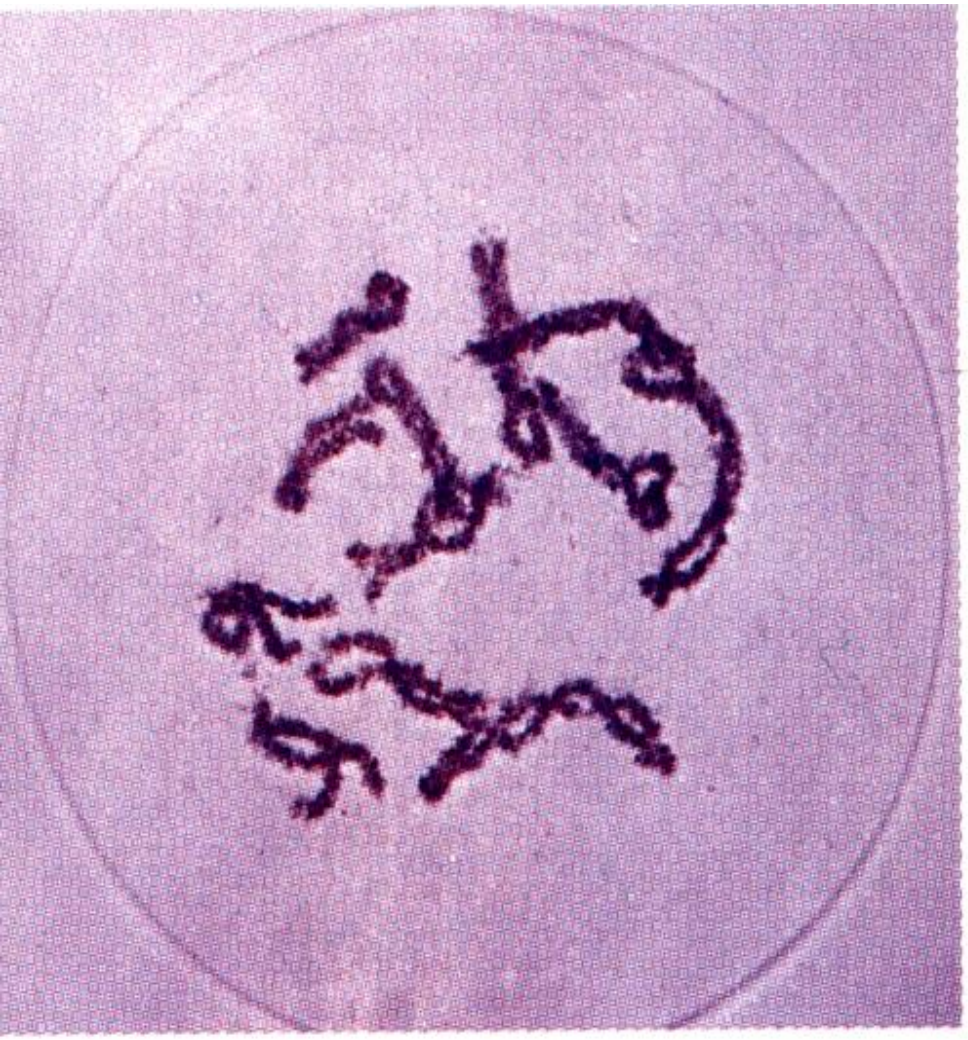
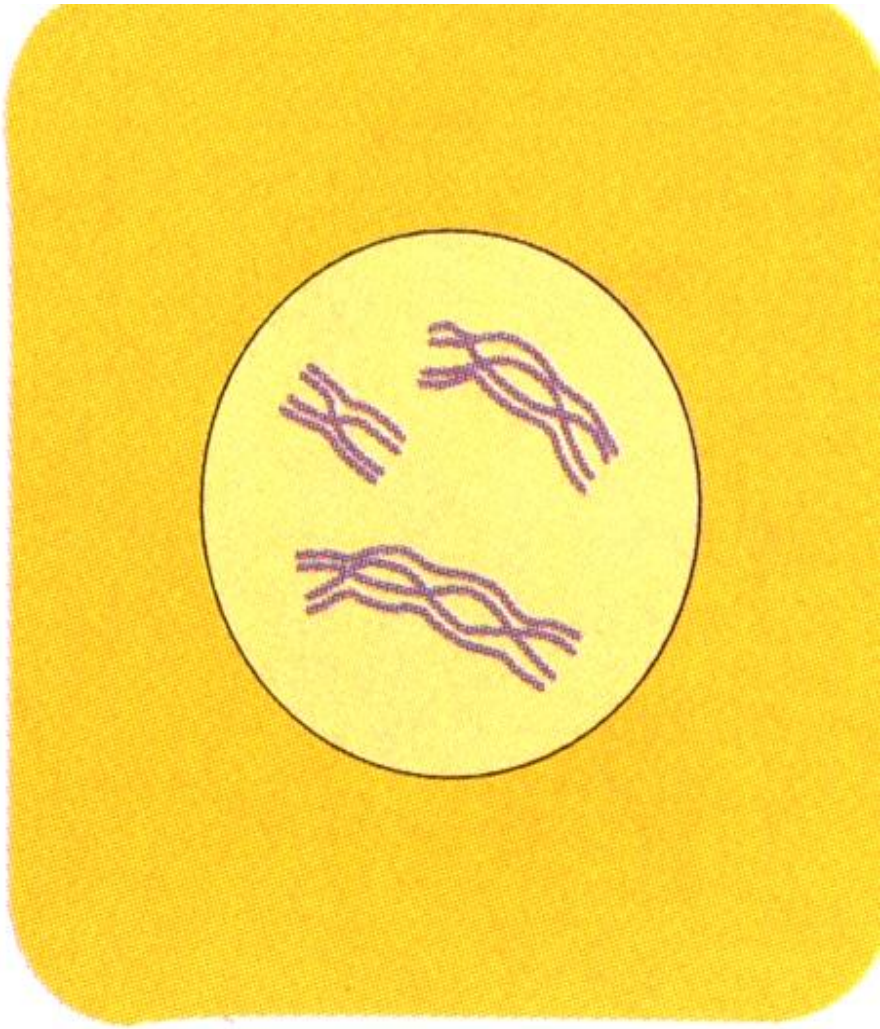




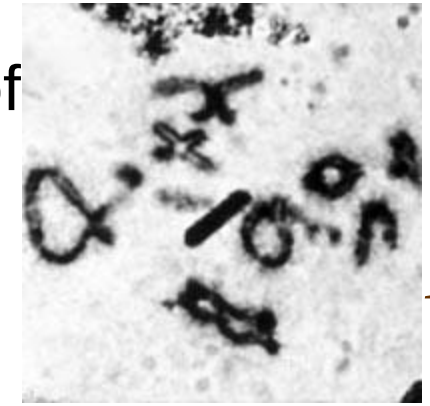
(d) Diplotene

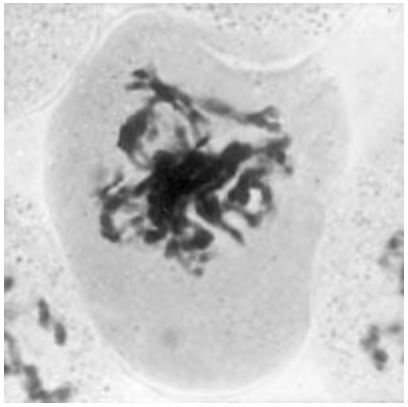
Diplotene ***(Diplonema)*** **–** double thread stage

The chromosomes further contract and thickens
The chiasma becomes clearly visible
The homologous chromosomes move apart in repulsion.

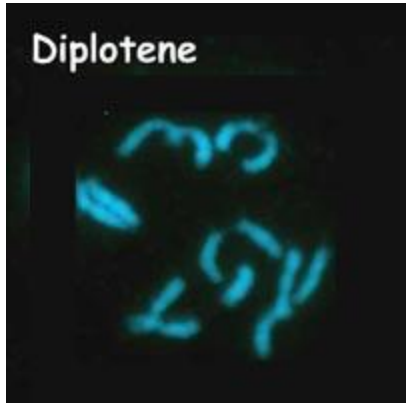
The number of chiasma per homologous chromosomes is depend upon the species and length of chromosomes.
Longer the chromosome more the chiasma.

Locusta sp.



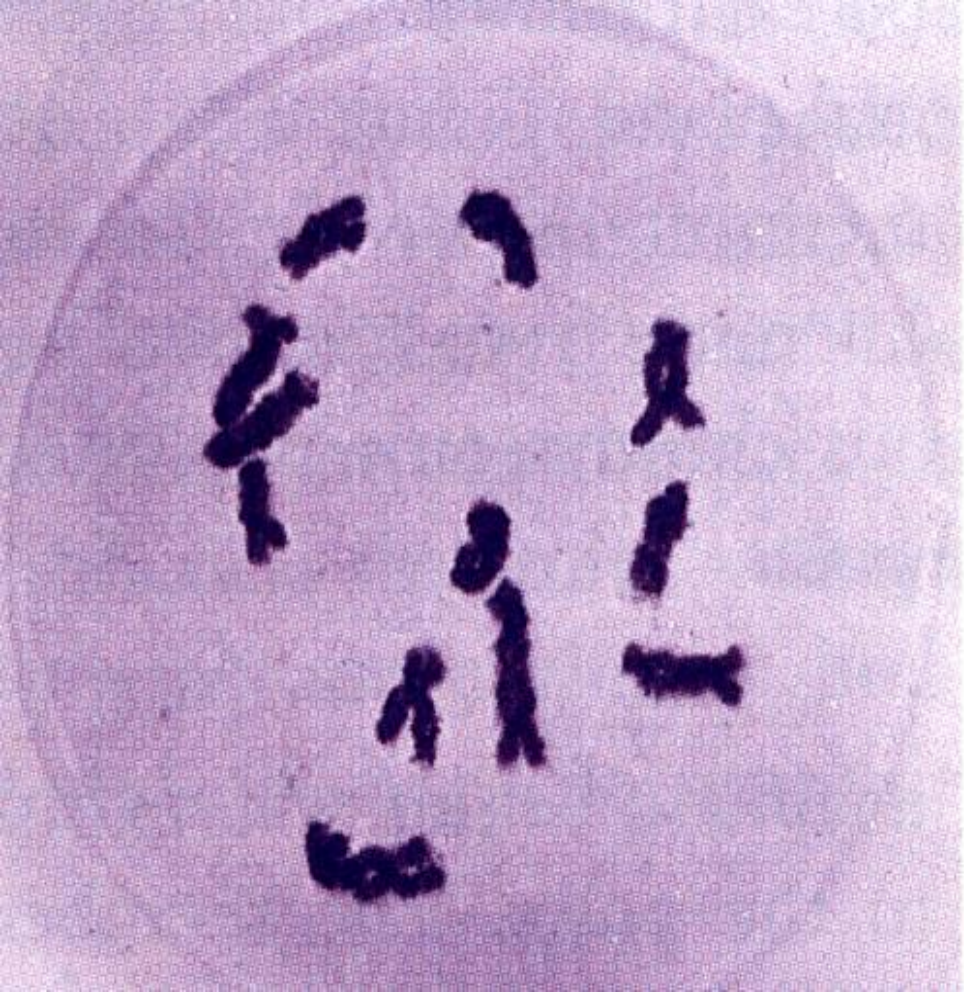


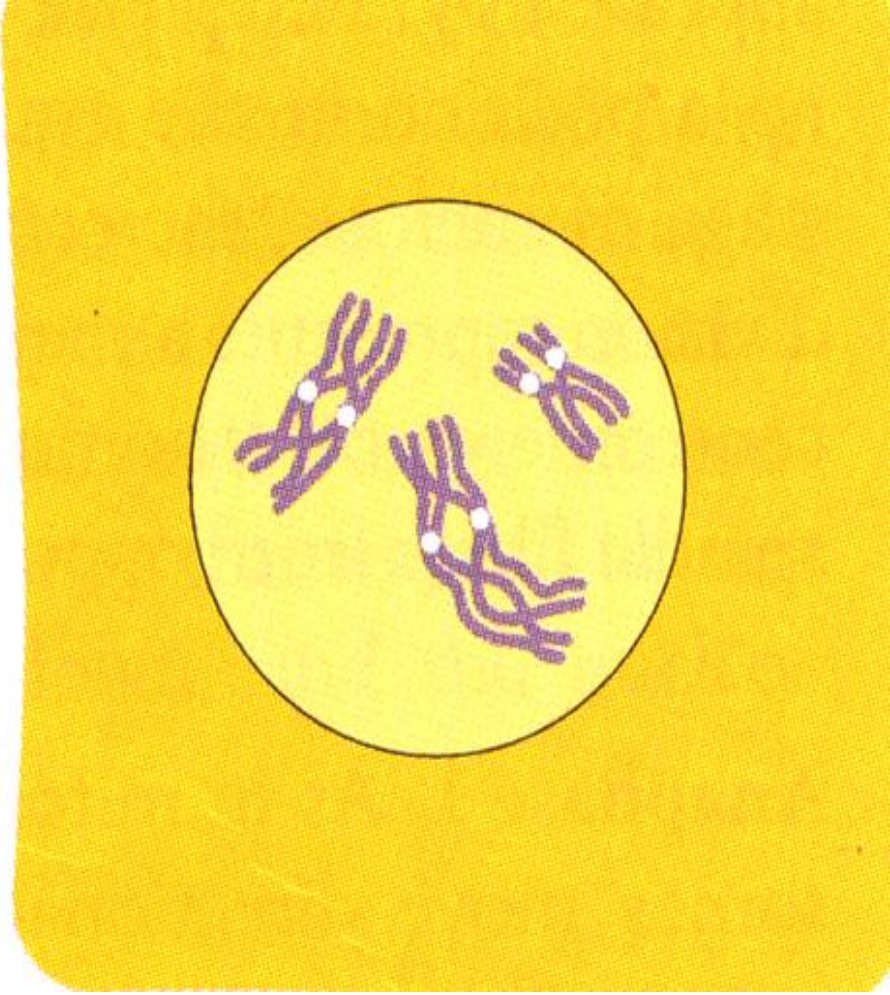
Lilium grandiflorum



Petunia hybrida

As diplotene proceeds the chiasmata seems to move away from the centromore and diminish in number. This is called chiasma **terminalisation**.



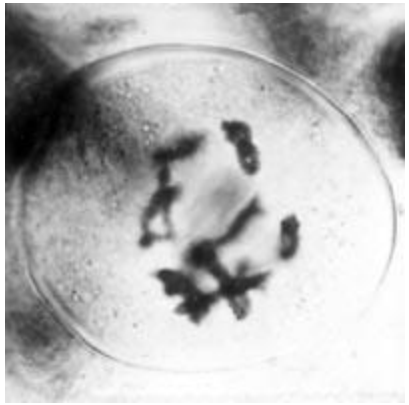


Diakinesis

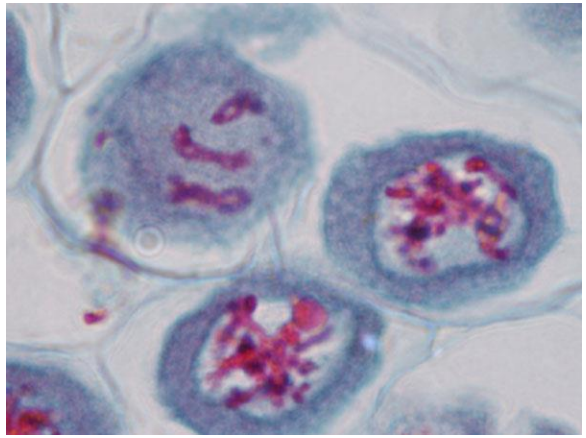
Diakinesis

Maximum condensation, nucleoli and nuclear membrane disappear, spindle apparatus begins to form.

Locusta sp.



Lilium grandiflorum



The bivalents are in greater contraction stage and easily countable. They may be shaped as rods, ring, 8 or open etc.

Metaphase I

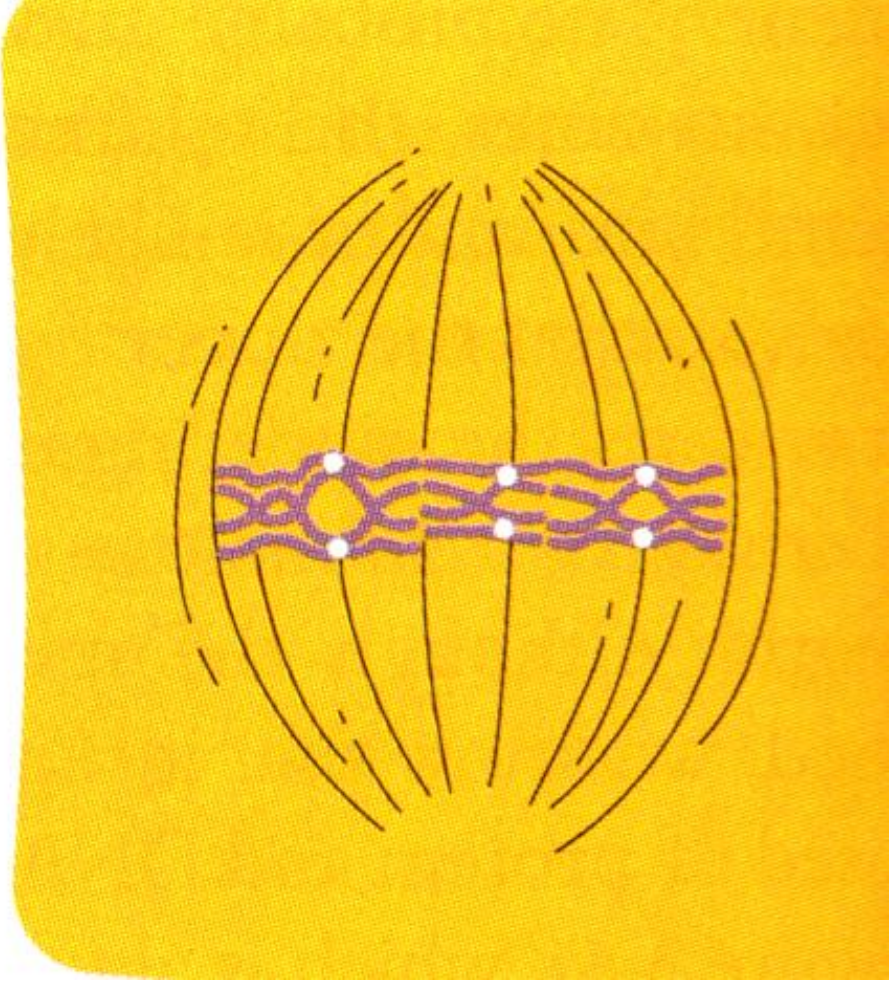
- The spindle fibre gradually organizes.
- Bivalents are arranged on the equatorial plate.
- The centromere of each chromosome starts dividing longitudinally.

Anaphase I

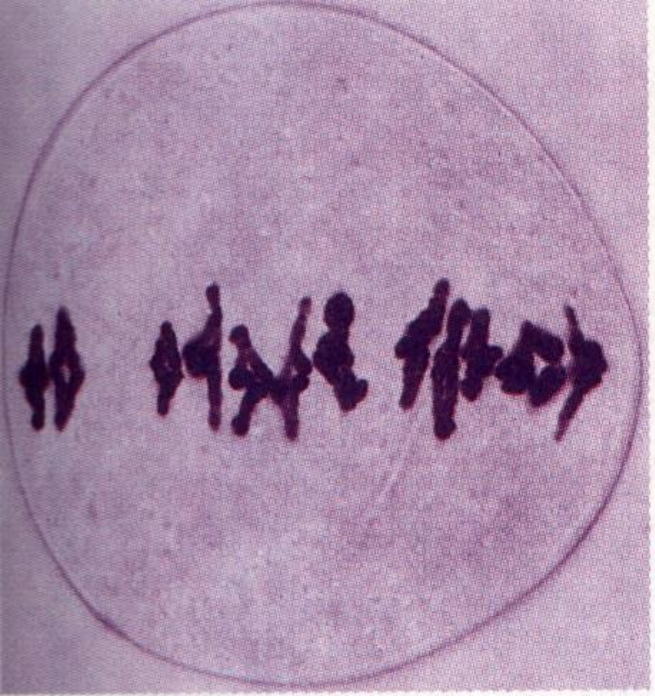
- As a result of longitudinal division, from each bivalent, one chromosome move towards one pole and the other towards opposite pole.
- The sister chromatids are seen attached to the centromere.
- The homologous chromosome reach the poles, at the end of this phase.

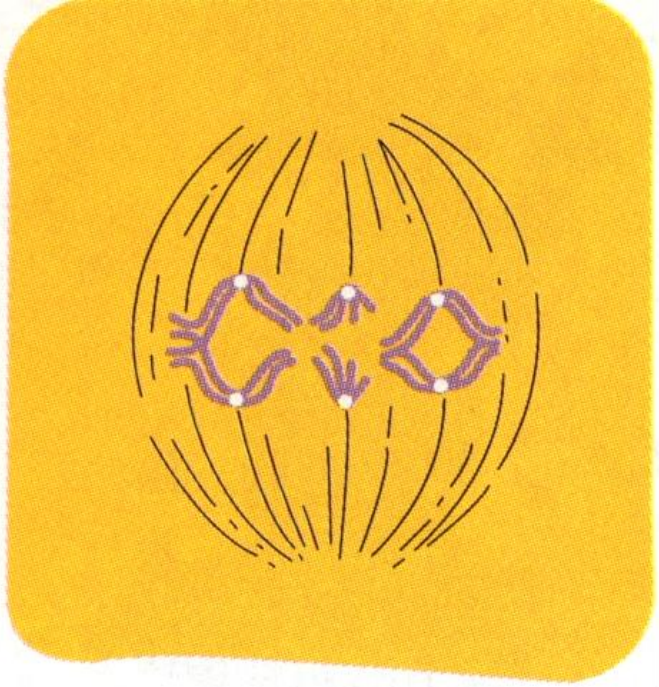
Telophase - I

- Chromosome uncoil and regrouping of chromosome occurs.
- Nucleolus and Nuclear membrane reappear.
- Two haploid daughter nuclei are formed.

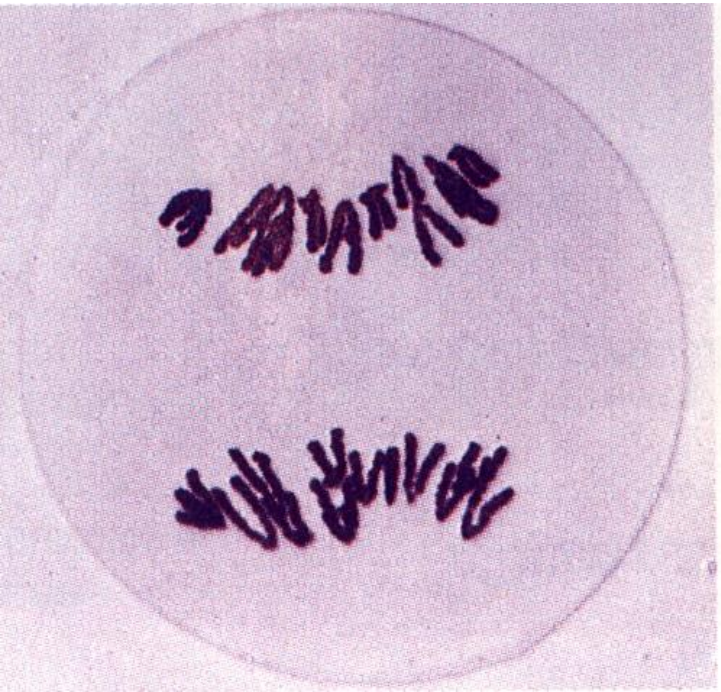


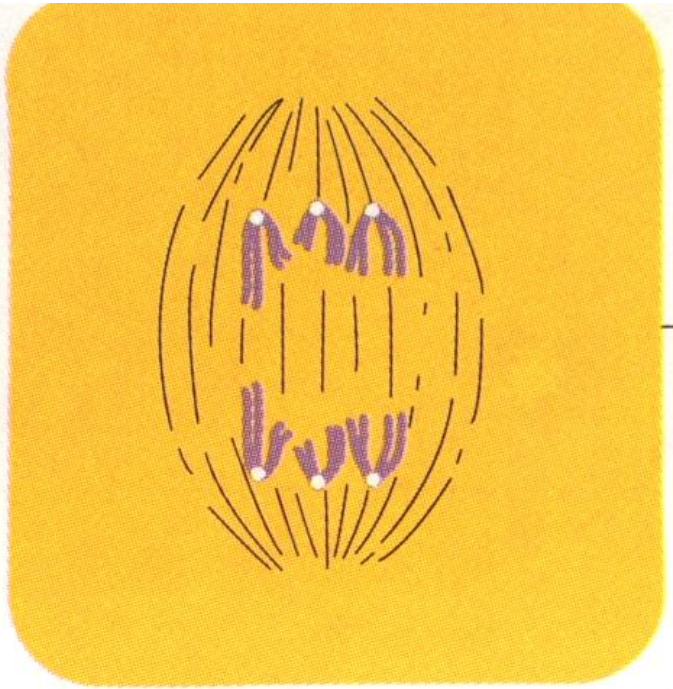
Metaphase I



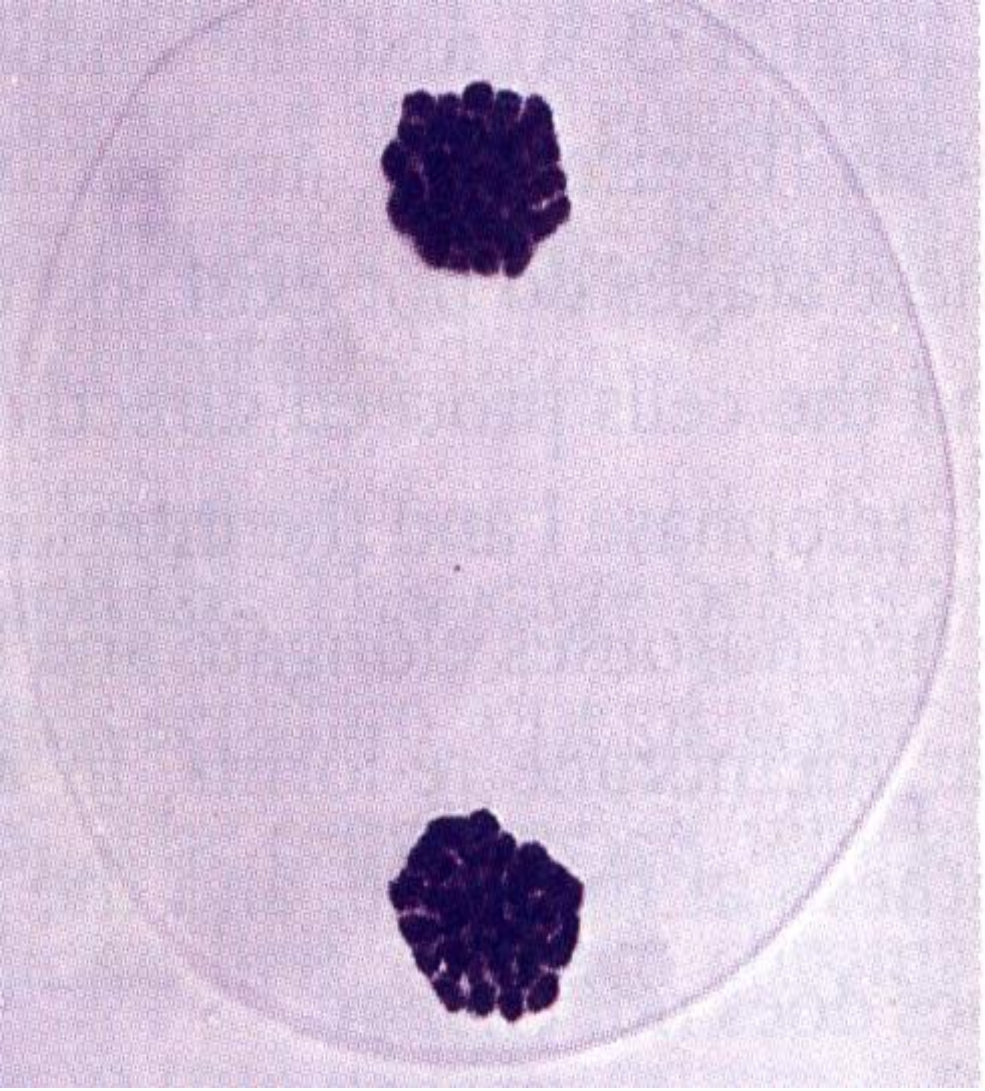


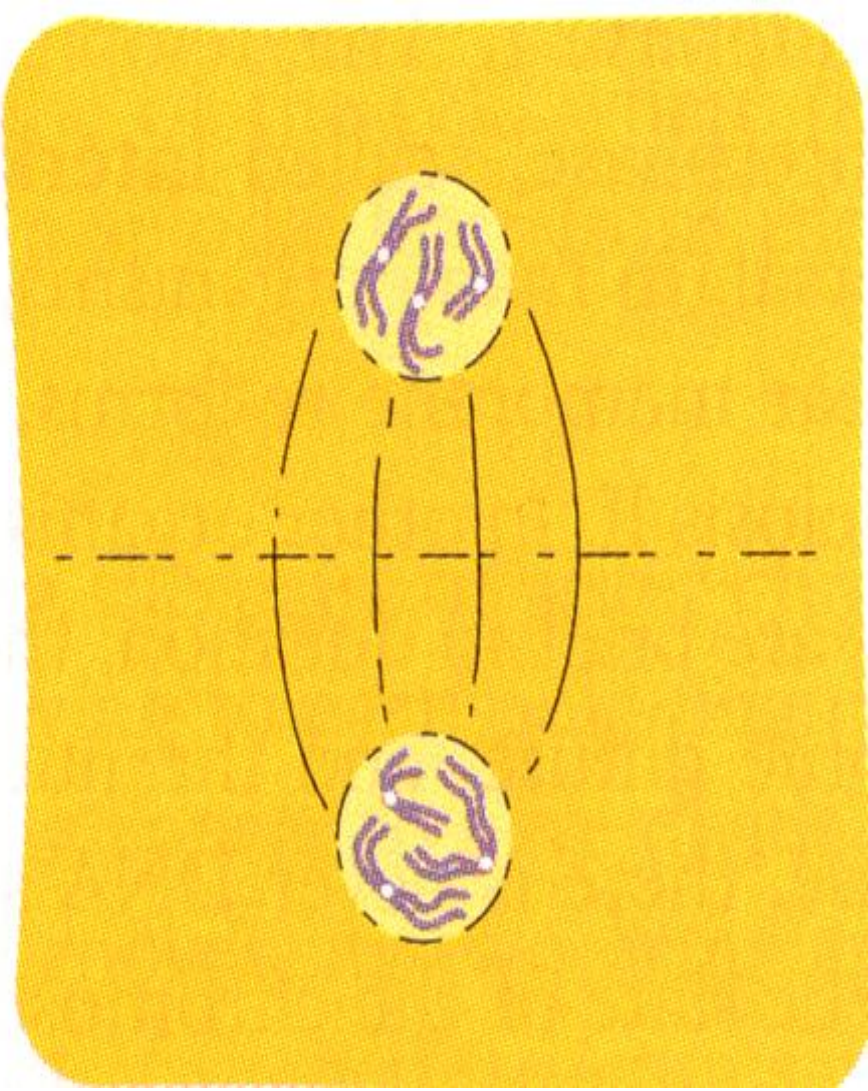
Early Anaphase I





Late Anaphase I

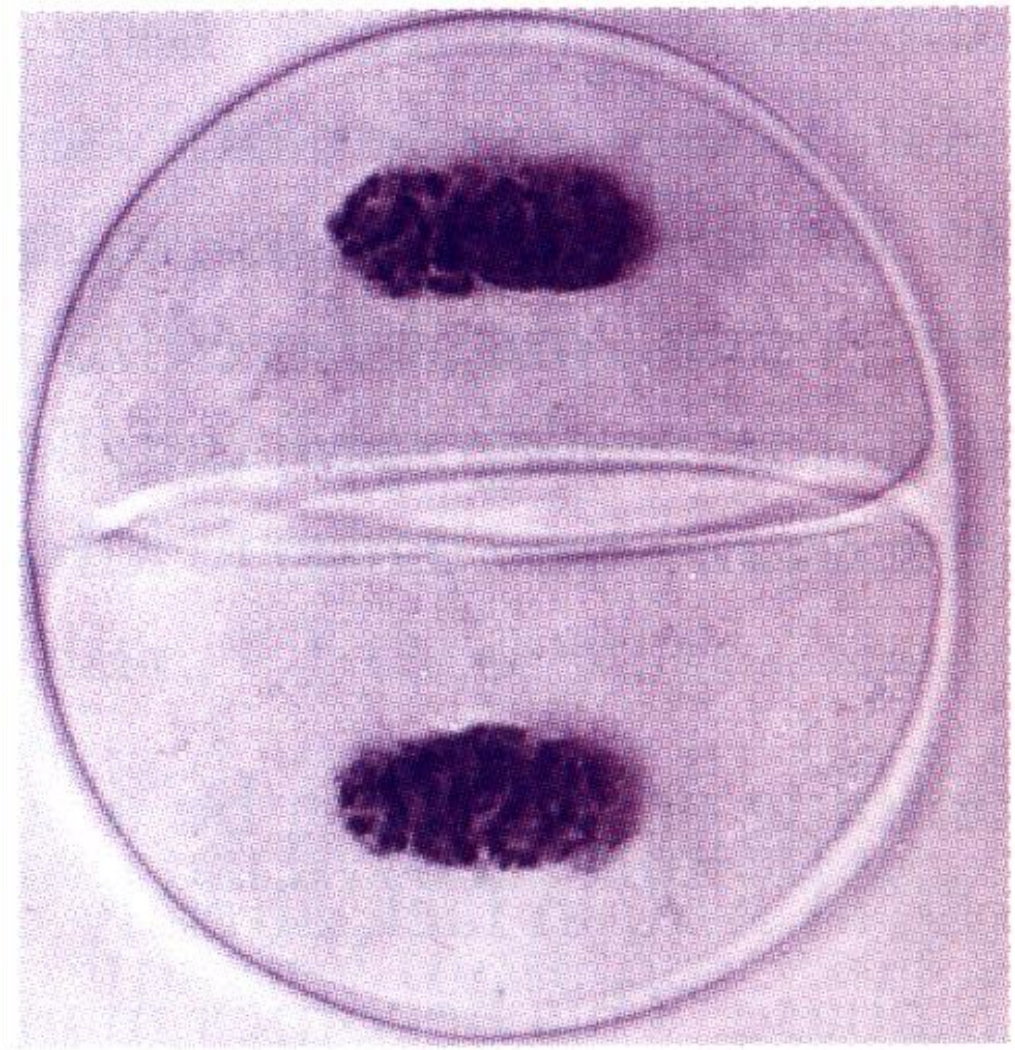




Telophase I

Interkinesis or Interphase

- The two daughter nuclei undergo resting period. Sometimes, this interkinesis is absent and the two daughter nuclei will enter Prohase II of Meiosis II



Interphase

- **Meiosis - II**
- The first nuclear division (Meiosis - I) results in reduction of chromosome number from diploid to haploid.
- The second nuclear division (Meiosis - II) is required to reduce the nuclear of chromatids per chromosome.

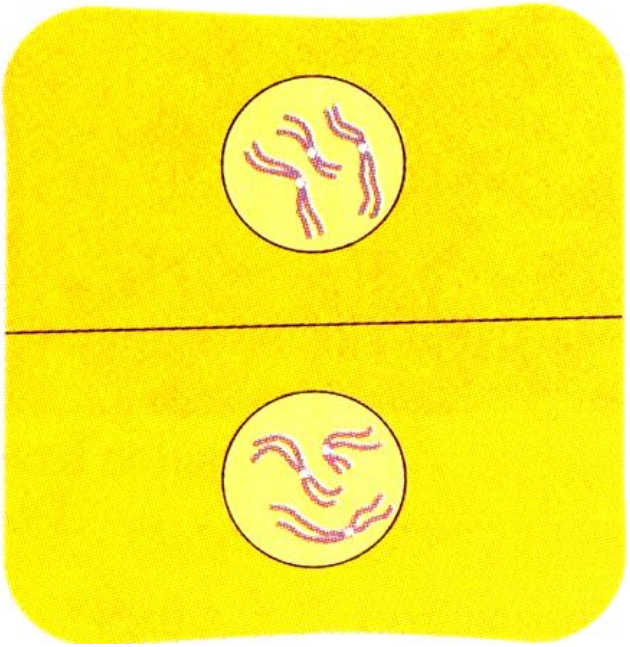
Meiosis – II differs from Mitosis in three aspects

- The interphase prior to Meiosis – II is very short. It does not have 'S' period – because each chromosome already contains 2 chromatids.
- The 2 chromatids in each chromosome are not sister's thro out.

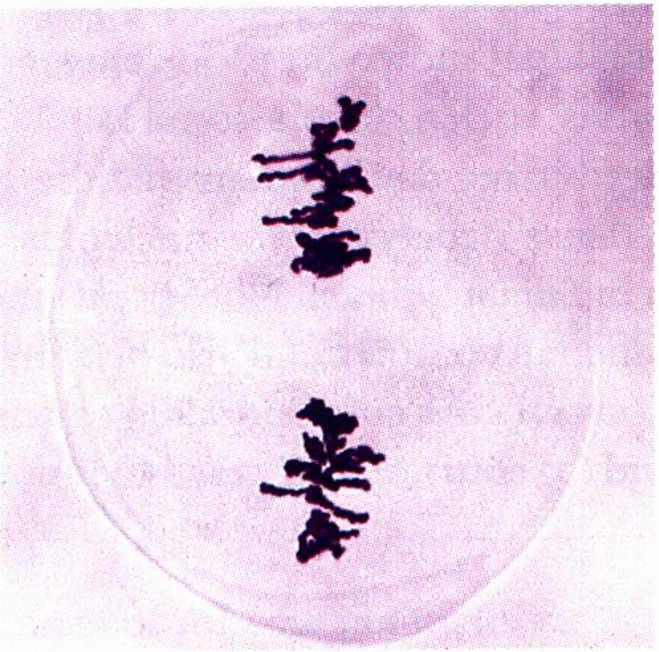
  ie., it may have some alternative segments due to recombination (Crossing over) between non sister chromatids.
- In Meiosis II (ie., in Meiotic Mitosis), division is with respect to haploid chromosome number whereas in normal mitosis it is with respect to diploid chromosome number.
- Except for this three aspects, Meiotic mitosis ie., Meiosis II is similar to normal Mitosis and contains all 4 stages followed by Cytokinesis.

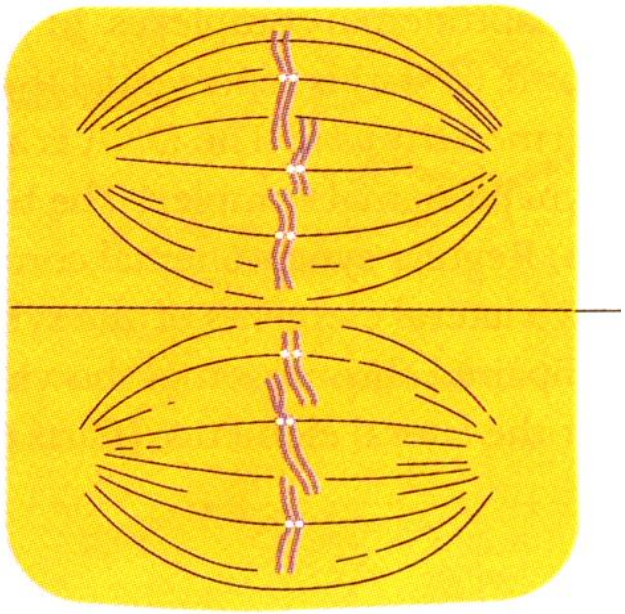
Cytokinesis

- Takes place after meiosis I and Meiosis II separately or sometimes it may even take place at the end of Meiosis –II
- Eg: In Maize after meiosis I and Meiosis II
- In Trillium after Meiosis II only.



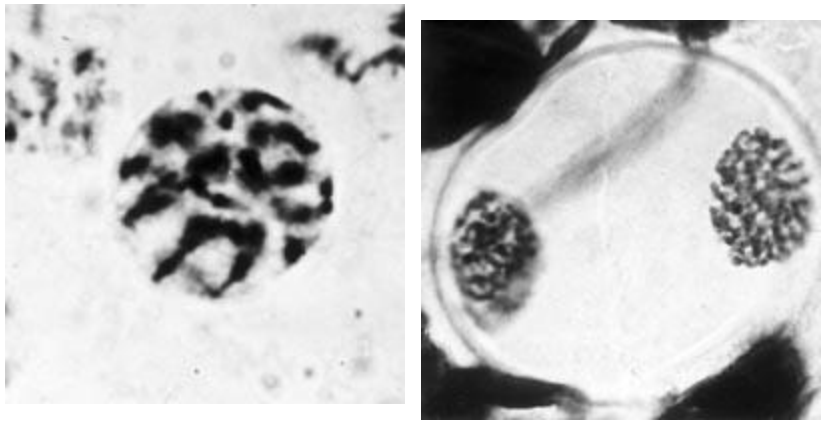
Prophase II



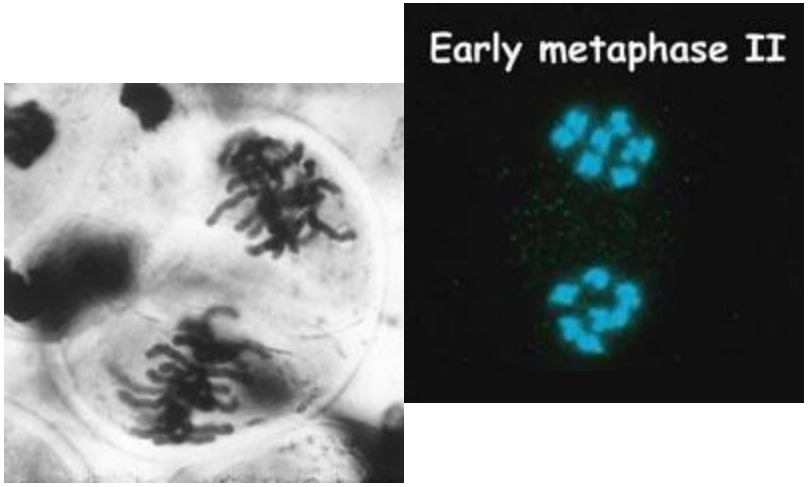


Metaphase II

Meiosis II

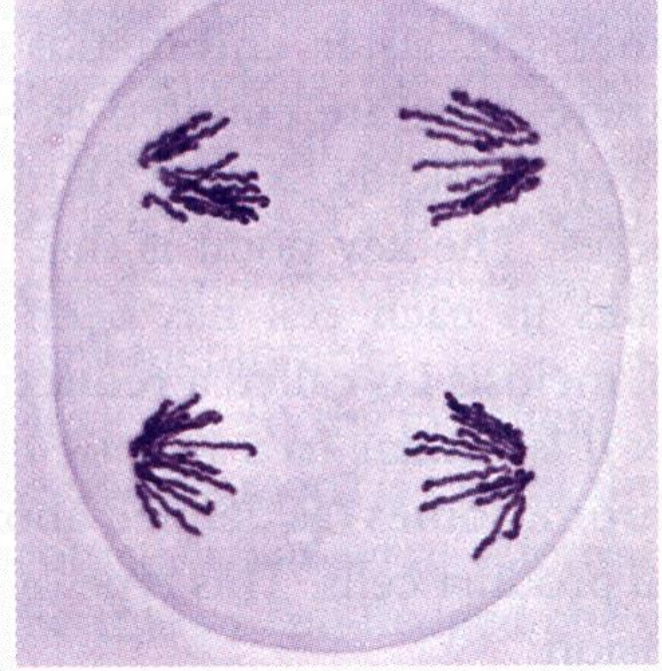


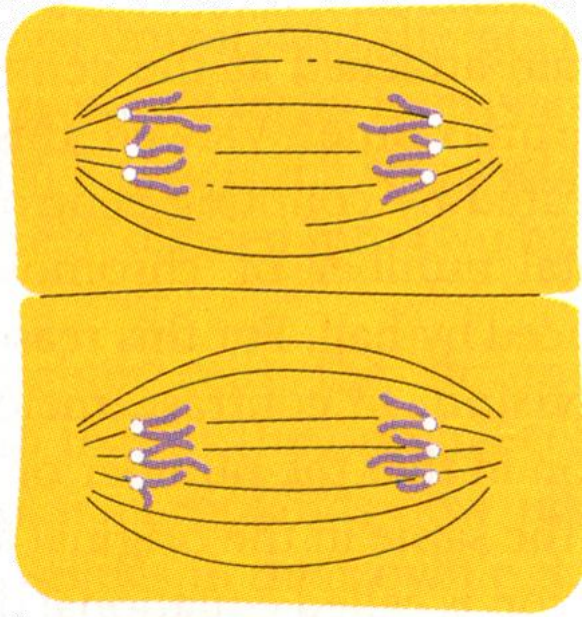
Prophase II



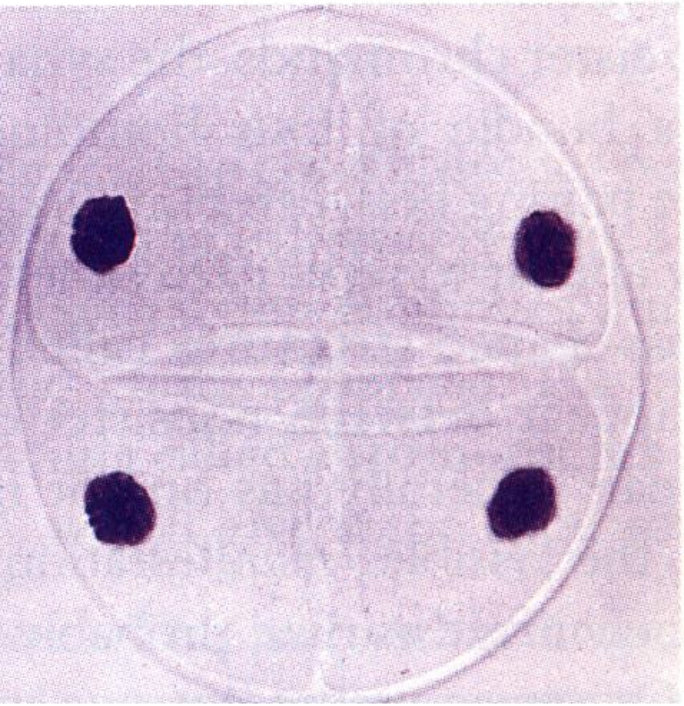
Metaphase II

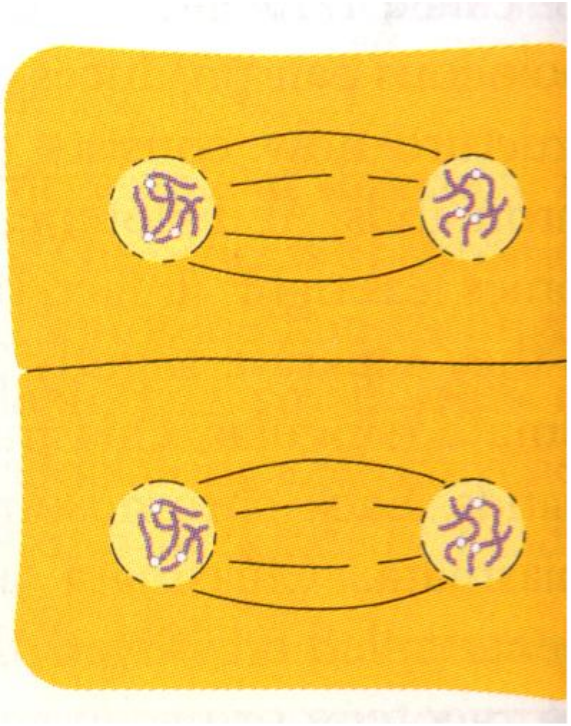
As in Mitosis, Second division of meiosis serves to separate the chromatids of each chromosomes by undergoing prophase- II, Metaphase - II, Anaphase - II, and Telophase - II to form 4 daughter cells called *tetrad*.



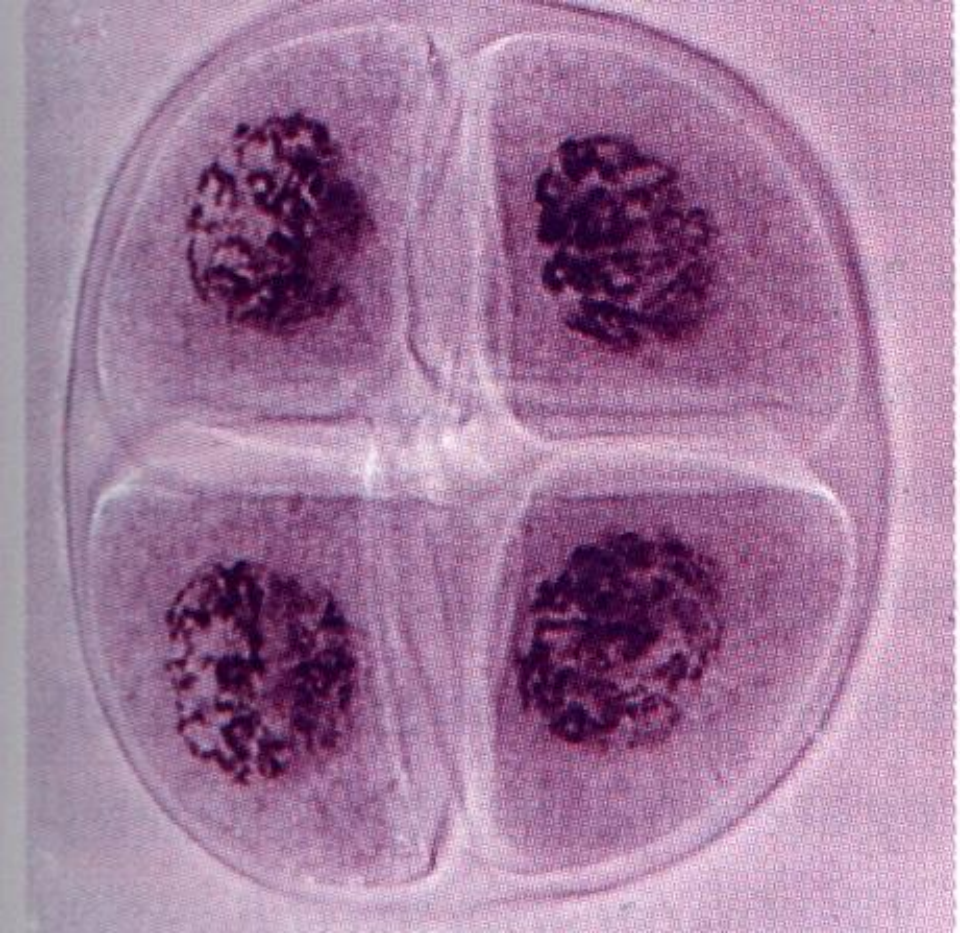


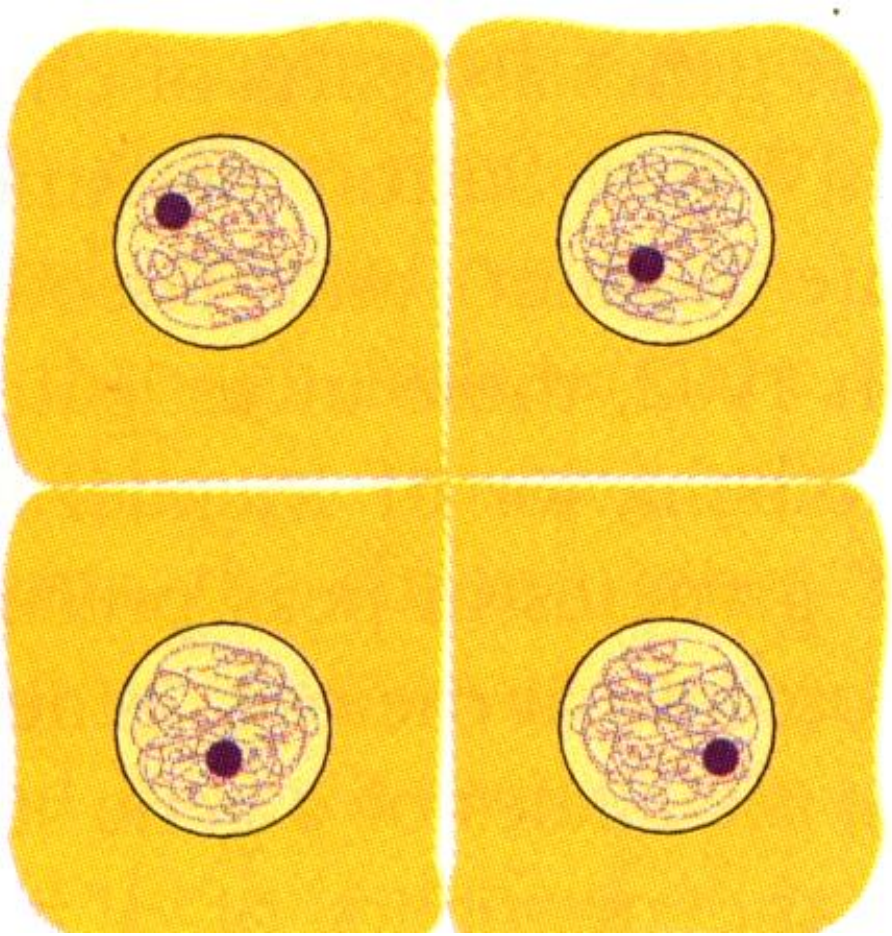
Anaphase II





Telophase II





Tetrad

Significance of Meiosis

- Meiosis play an important role in all living organisms
- It helps in maintaining the chromosome number constant in a species.
- Meiosis results in production of gametes with haploid chromosome number.
- Union of female and male leads to formation of Zygote which receives ½ chromosome number from female and ½ chromosome number from male, thus the original somatic chromosome number is restored.
- Meiosis facilitates segregation of independent assortment of chromosome and genes.
- Recombination of genes results in Creation of Variability which is essential for evolution of new crop plants.
- In sexually reproduction crops Meiosis helps for continuity of generation.

Mitosis	Meiosis
One nuclear division	Two nuclear division
Production of 2 daughter nuclei	Production of 4 daughter nuclei
Chromosome number is the same (2n)	Chromosome No. is reduced to half (n)
Daughter cells identical in structure and chromosome composition	Different from mother cell in chromosome No. and composition
Occurs in somatic cells.	Occurs in Reproductive tissues.
Total DNA replicates during S phase	99.7 % of DNA replicates during S phase and 0.3 % during zygotene
No paring between homologous chromosome	Homologous chromosome pair during pachytene.
Segregation and Recombination do not occurs there by maintaining purity	Crossing over takes place during pachytene thereby creates variability
Chromosomes are in the form of dyad at metaphase.	Chromosomes are in the form of tetrad at metaphase.
One member of sister chromatids move to opposite pole during Anaphase.	One member of homologous chromosomes move to opposite pole during Anaphase I.

Zygote formation and embryo development

- The development of the embryo is called embryogenesis.
- In organisms that reproduce sexually, once a sperm fertilizes an egg cell, the resultant cell is called as zygote that has half of the DNA of each of two parents.
- In plants, animals, and some protists, the zygote will begin to divide by mitosis to produce a multicellular organism. The result of this process is an embryo.
- **Plant embryogenesis** is the process that produces a plant embryo from a fertilized ovule by asymmetric cell division and the differentiation of undifferentiated cells into tissues and organs.
- It occurs during seed development, when the single-celled zygote undergoes a programmed pattern of cell division resulting in a mature embryo.

Identical and fraternal twins

- A **twin** is one of two offspring produced in the same pregnancy
- Identical twins (*monozygotic)* : They develop from one zygote that splits and forms two embryos
- Fraternal twins (*dizygotic*) : They develop from two separate eggs that are fertilized by two separate sperm