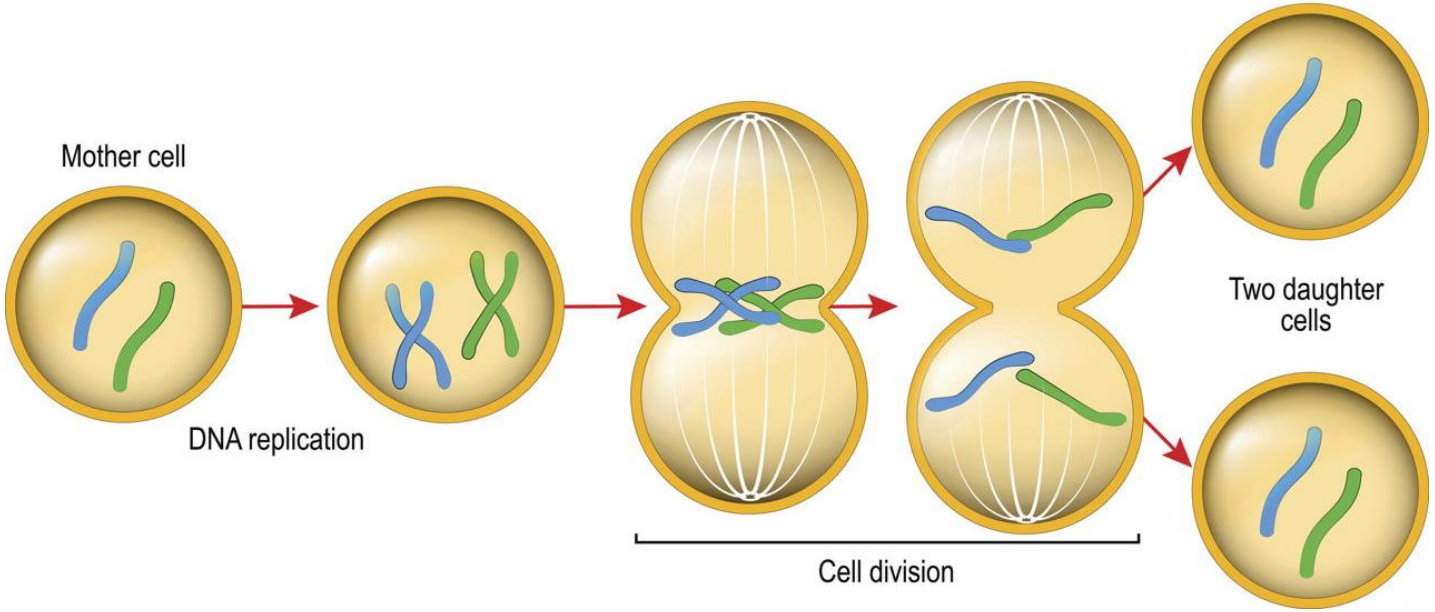
Principles of Genetics (Zoo-352)

Lecture 4

Mitosis

Department of Zoology, 1438-1439 H



Mitosis

- Mitosis is a part of the cell cycle process by which chromosomes in a cell nucleus are separated into two identical sets of chromosomes, each in its own nucleus.
- In general, karyokinesis (division of the nucleus) is followed by cytokinesis (division of the cytoplasm).
- The sister chromatids are held together at a specific region of the chromosome called the centromere**.**
- Mitosis is a continuous process and occurs only in eukaryotic cells particularly in non-sex cells (somatic cells).
- Prokaryotic cells divide by a different process called binary fission.
- Mitosis is divided into four stages: prophase, metaphase, anaphase and telophase (Greek: pro-, before; meta-, mid; ana-, back; telo-, end).
- Replication (duplication) of the genetic material occurs during the S phase of the cell cycle.
- The timing of the four stages varies from species to species and from organ to organ.

The phases of Mitotic division

1. Prophase:

- The first stage of mitosis begins with the shorting and thickening of the chromosomes.
- Each chromosome is composed of two sister chromatids, which are identical double-stranded DNA molecules.
- The nuclear membrane breaks down and the nucleolus disappears (Figure 1).

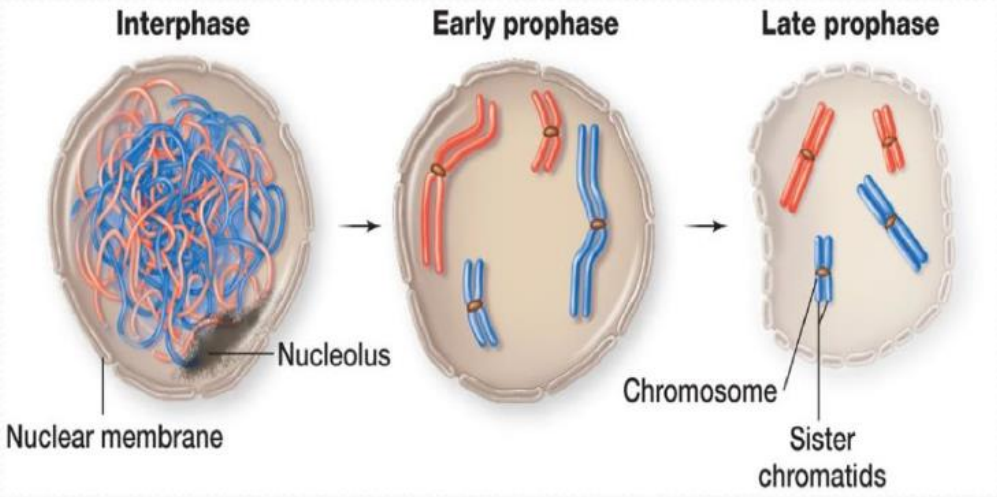


Figure 1: Nuclear events during interphase and prophase of mitosis

The phases of Mitotic division

- The centrosome divides and moves to opposite poles of the cell, around the nucleus (Figure 2).
- The newly divided centrosomes radiate microtubules, which are called spindle fibers.
- Microtubules also spread out from the centrosome in the opposite direction from the spindle itself, forming an aster microtubule (Figure 2).
- The second microtubules that attach to a kinetochore on a sister chromatid are called kinetochore microtubules (Figure 2).

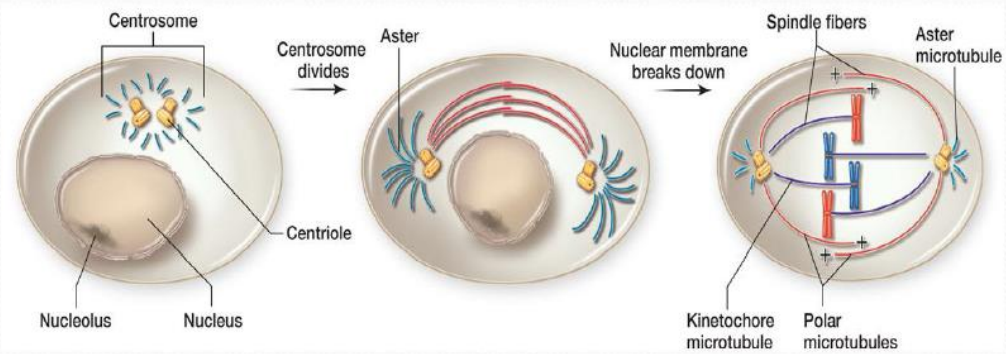


Figure 2: The centrosome divides in prophase, and separate halves move to opposite poles of the cell

The phases of Mitotic division

- The third class of microtubules fail to attach to kinetochore are called polar microtubules.
- The sister chromatids are held together by a complex called cohesin, made up of at least four different proteins.
- Cohesin complexes connect the arms and centromere of sister chromatids at the early prophase.
- At the end of prophase (late prophase), the cohesin complexes holding the arms are released; however, the sister chromatids remain connects only at the centromere.

The phases of Mitotic division

2. Metaphase:

- The spindle fibers are form and each centromere attached to a kinetochore microtubule from each centrosome.
- The two centrosomes begin pulling the chromosomes towards opposite ends of the cell.
- The resulting tension causes the chromosomes to align along the metaphase plate (Figure 3).

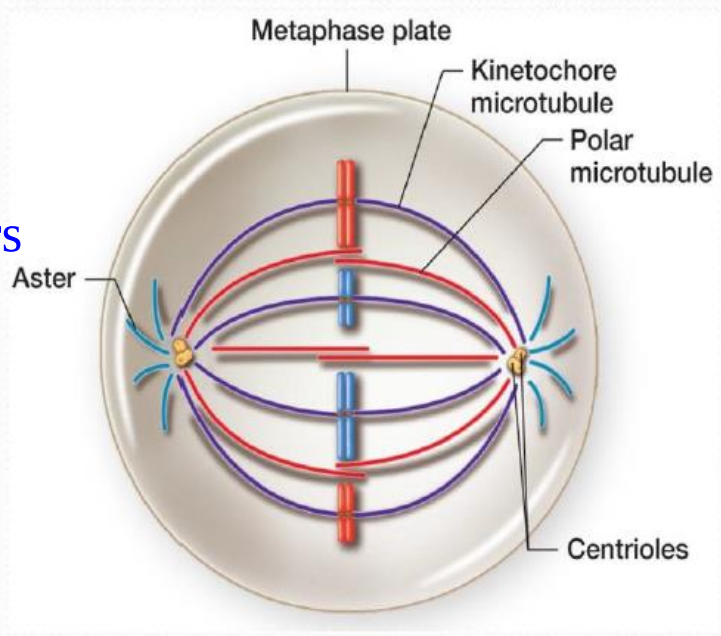


Figure 3: The mitotic spindle fibers during metaphase

The phases of Mitotic division

3. Anaphase:

- Anaphase begins with the two sister chromatids separating and moving toward opposite poles on the spindle fibers (Figure 4).
- The sister chromatids are joined together by cohesins.
- The degradation of cohesin at the centromere allowing the sister chromatids to separate (Figure 5).

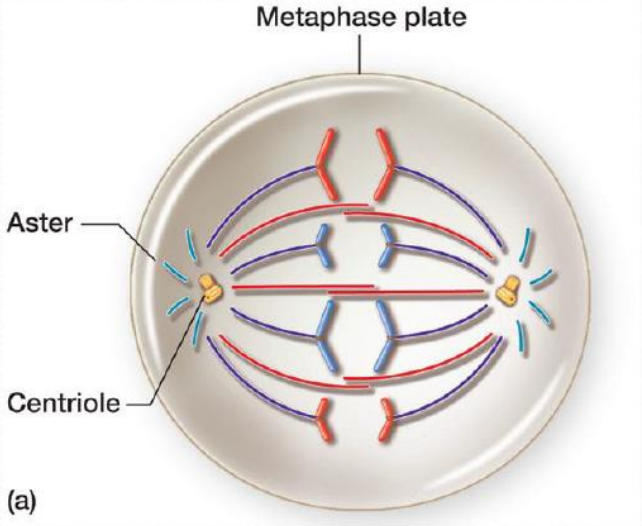


Figure 4: the mitotic spindle fibers during anaphase

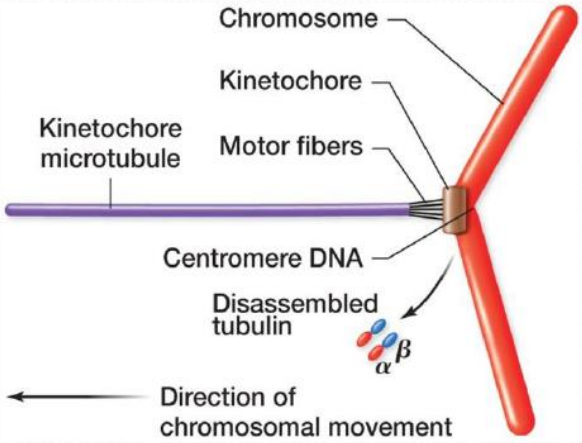


Figure 5: The kinetochore

The phases of Mitotic division

4. Telophase:

- In telophase, the cell reverses the steps of prophase to return to the interphase stage.
- The nuclear membrane reforms around each set of chromosomes and the nucleolus forms again.
- Cytokinesis takes place.
- In animals, cytokinesis is first apparent by constriction between the two poles (Figure 6).
- In plants, a cell plate grows in the approximate location of the metaphase plate.
- After completing cytokinesis, the daughter cells enter the G1 phase of the cell cycle.

The phases of Mitotic division

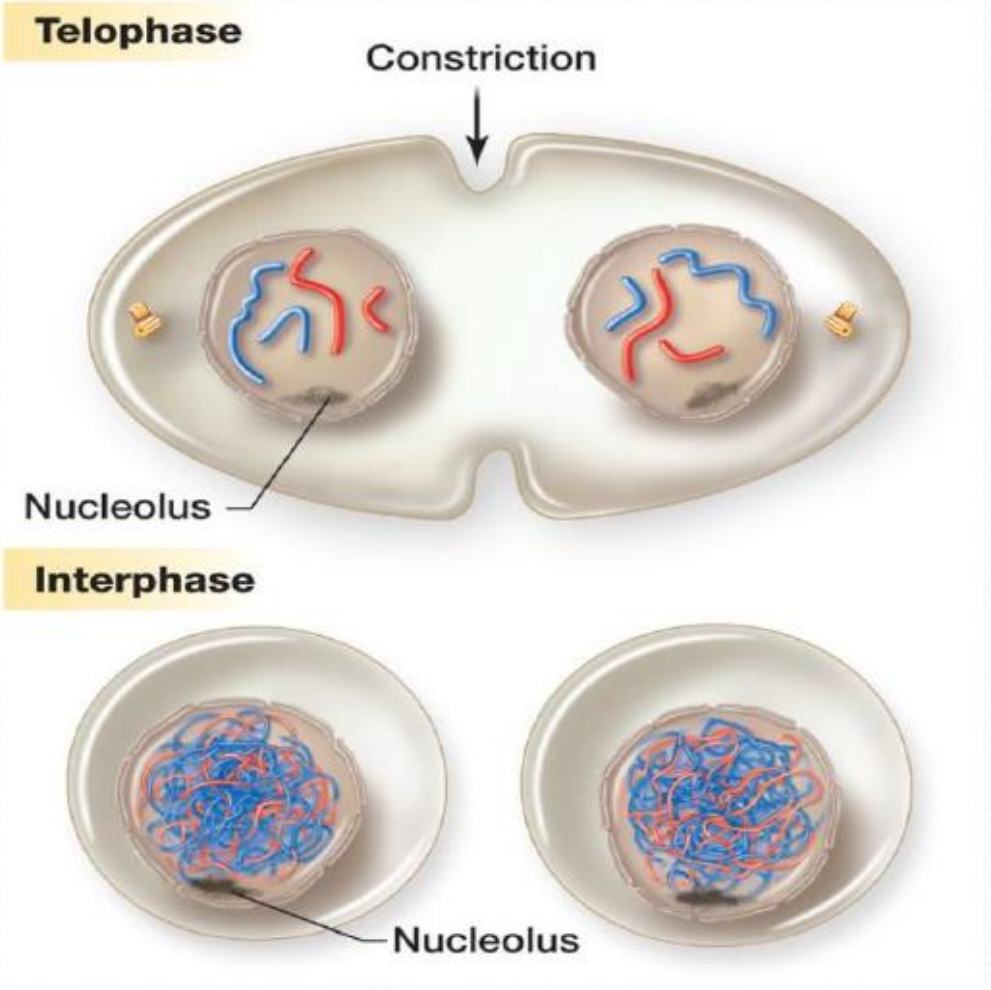


Figure 6: Telophase and interphase of mitosis

The phases of Mitotic division

- The phases of mitosis in onion root tip cells are summarized in Figure 7.

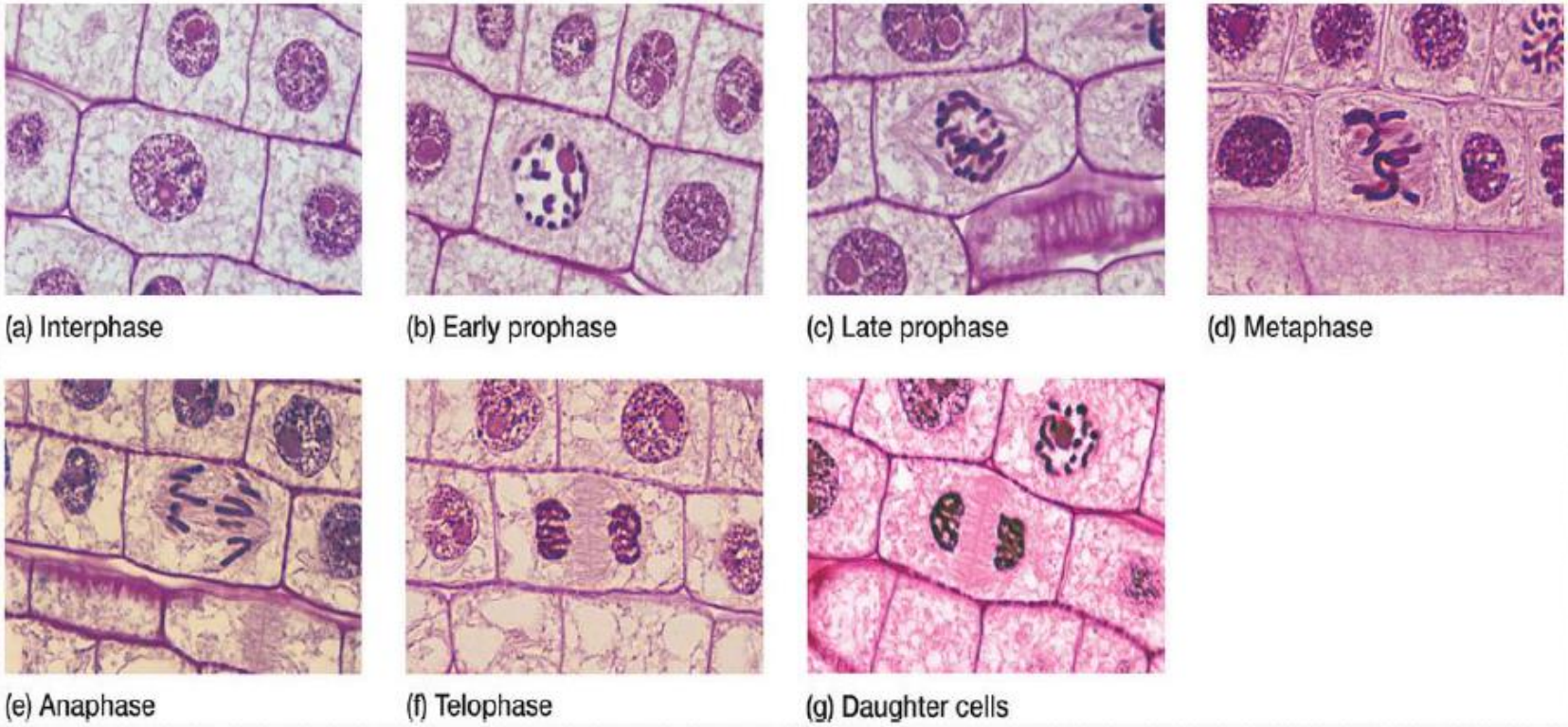


Figure 7: Cells in interphase and in various stages of mitosis in the onion root tip

Significance of mitosis:

1) In multicellular organisms:

- Mitosis produces more cells for growth and repair.

2) In unicellular organisms:

- Mitosis is a type of asexual reproduction.

Videos

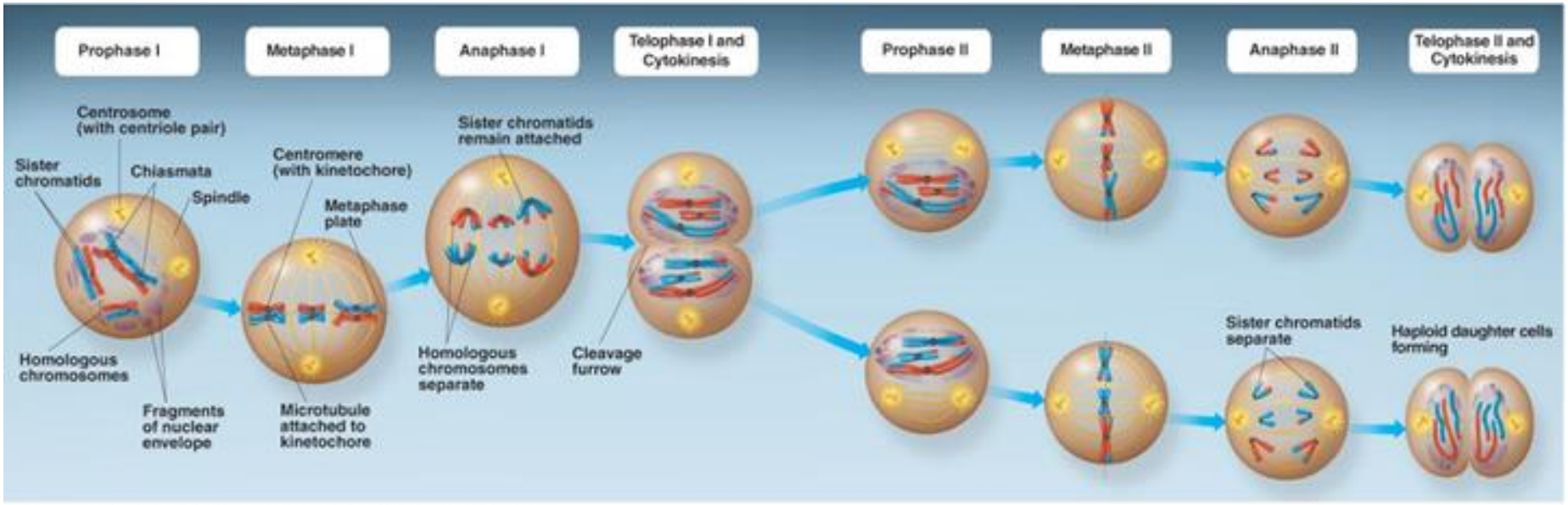
http://highered.mheducation.com/sites/007298760x/student_view0/chapter3/mitosis_and_cytokinesis.html
http://highered.mheducation.com/sites/007298760x/student_view0/chapter3/the_function_of_cohesin.html

Principles of Genetics (Zoo-352)

Lecture 5

Meiosis

Department of Zoology, 1438-1439 H



Overview of meiosis

- In the sexual reproduction process, two gametes fuse during fertilization to produce a zygote.
- Meiosis is a specialized type of cell division which **reduces** the chromosome number by **half**.
- This process occurs in animals and plants (only in **germ cells**).
- **Mitosis** can occur in either **haploid** or **diploid** cells, but **meiosis** is restricted to **diploid** cells.
- Meiosis takes place solely in the **testes (males)** and **ovaries (females)** to produce haploid sex cells or gametes.
- Meiosis is a **two division process** that produces **four haploid cells** from each diploid parental cell.
- These two divisions are known as **meiosis I (a reductional division)** and **meiosis II (an equational division)**.

The first meiotic division, meiosis I

- Meiosis I is divided into four phases:

  1) Prophase I **2) Metaphase I**
  3) Anaphase I **4) Telophase I**

- Prior to meiosis, chromosome duplication occurs during the **S** of the interphase stage in order to **double the sister** chromatid pairs.
- The sister chromatids remain associated at the centromeres; consequently, each set of chromosomes is composed of two identical sister chromatids.
- Prophase I can be sub-classified into five stages (figure 1): **1) leptotene 2) zygotene 3) pachytene 4) diplotene 5) diakinesis.**

The stages of prophase I

1) Leptotene:

•The duplicated sister chromatids start to condense and coil.

•The chromosomes become shorter and thicker.

2) Zygotene:

•The homologous chromosomes draw close to each other by a special structure called the **synaptonemal complex**, which begins to form between paired homologous chromosomes in a process termed **synapsis**.

•As a result, the pairs of chromosomes consist of **four chromatids**, with **one** chromosome coming from each parent.

•Each pair of homologous chromosomes is known as a **bivalent (Tetrad).**

The stages of prophase I

3) Pachytene:

•Synapsis is complete and the paired chromosomes are held together tightly with the aid of the synaptonemal complex and structures termed chiasma (plural: chiasmata).

•The chiasma is the physical link between nonsister chromatids.

•Crossing over between homologous chromosomes occurs and DNA is exchanged between the bivalents in a process called homologous recombination.

•One consequence of crossing over is the generation of a new combination of genetic material in the gametes.

The two chromatids in a single chromosome are sister chromatids, but chromatids from each of the homologous chromosomes are called nonsister chromatids (Figure 2).

The stages of prophase I

4) Diplotene:

•The homologous chromosomes begin to separate in a process called **desynapsis**, but remain connected through sister chromatid cohesion and chiasmata until anaphase I.

5) Diakinesis:

•The synaptonemal complex has completely dissociated, the chromosomes continue to condense further.

•The nuclear membrane breaks down.

•The duplicated centrosomes are at opposite poles.

The stages of prophase I

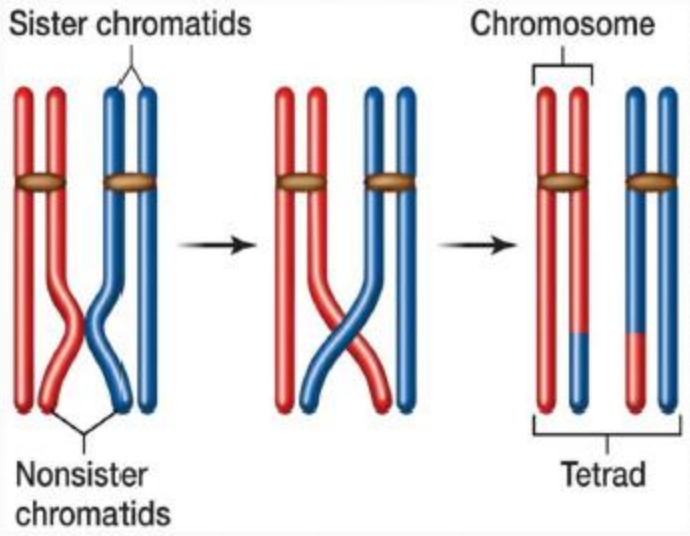


Figure 2: Crossing over in a tetrad during prophase of meiosis I

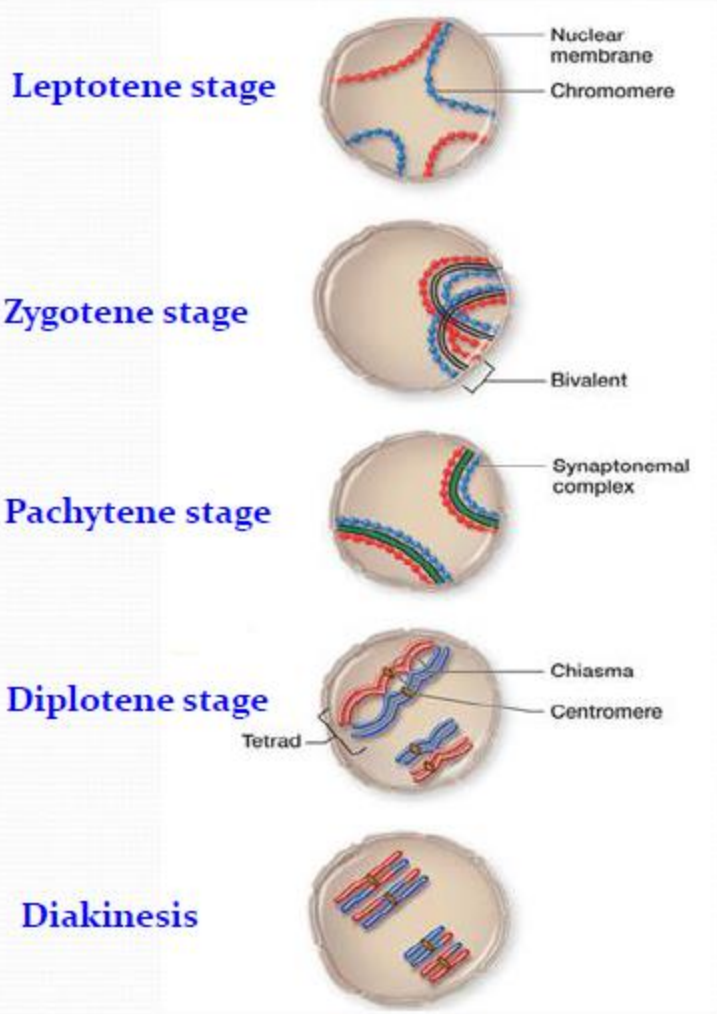


Figure 1: Prophase I of meiosis

The phases of Meiosis I :Metaphase I

- Sister chromatids are attached to kinetochore microtubules from the same centrosome or pole.
- The **tetrads** are aligned in a **double row** along the **metaphase plate** of the cell (figure 3).

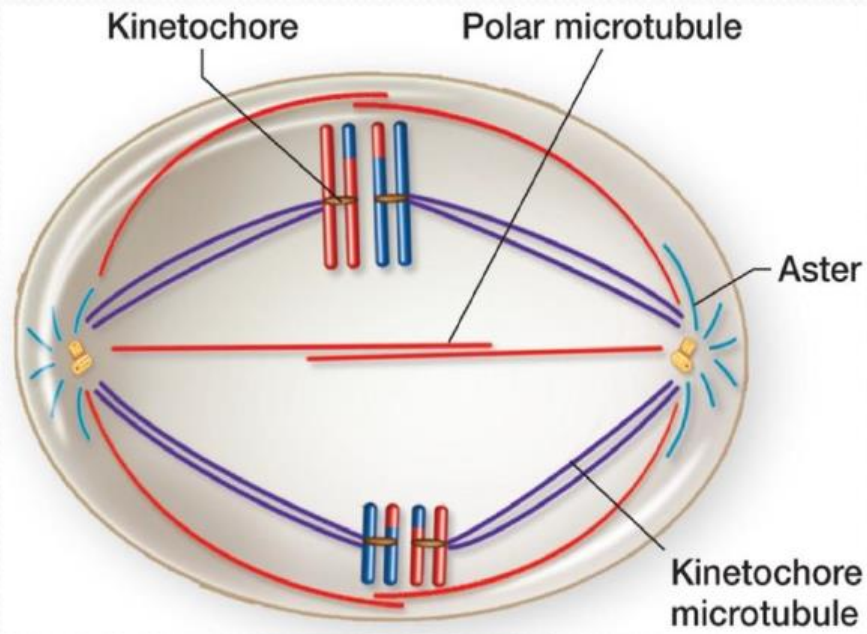


Figure 3: Metaphase of meiosis I

The phases of Meiosis I : Anaphase I

- The chiasmata between homologous chromosomes are separated.
- Sister chromatid cohesion along the chromosome arms is resolved, but the sister chromatids remain bound to each other at the centromeres until the beginning of anaphase II (figure 4).
- The microtubules pull one set of homologous chromosomes toward the opposite poles of the cell.
- This meiotic division is called a reductional division because it reduces the number of chromosomes (2n) by half in each daughter cell (n).

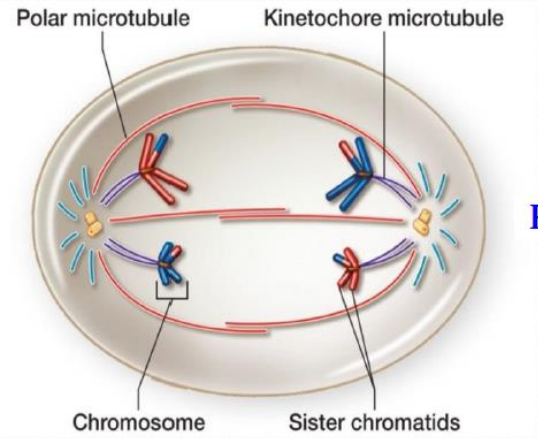
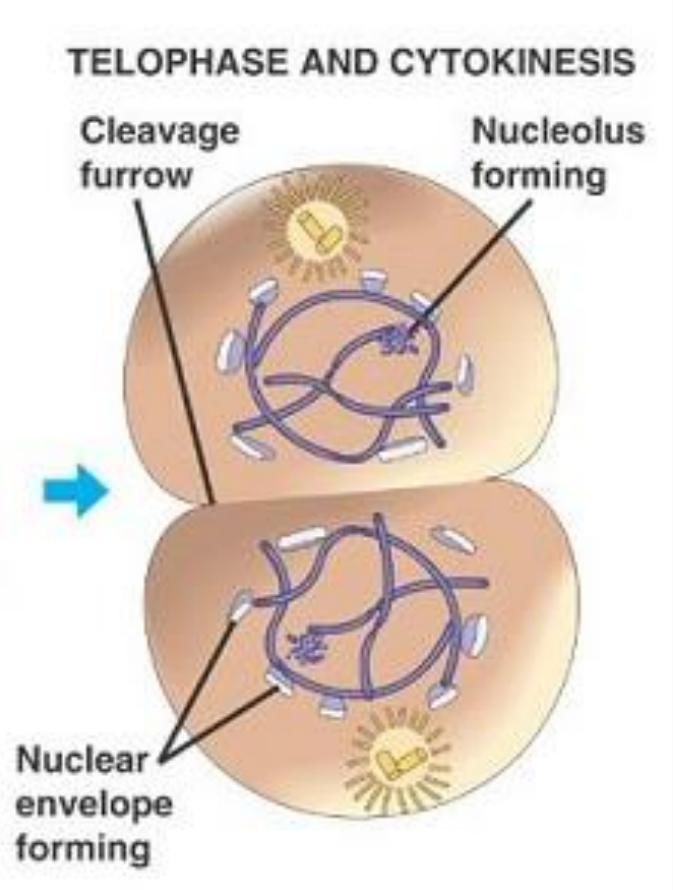


Figure 4: Anaphase of meiosis I

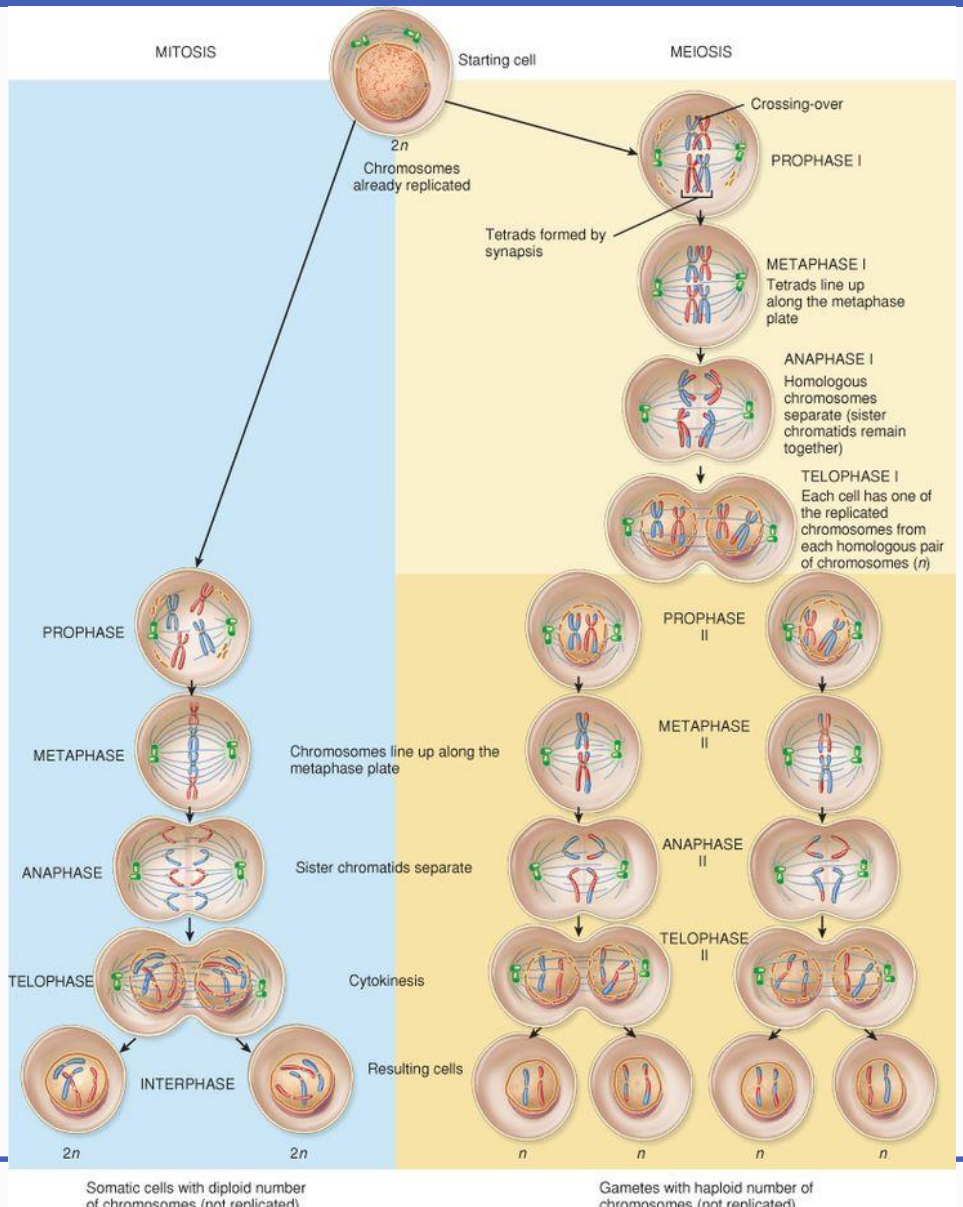
The phases of Meiosis I : Telophase I

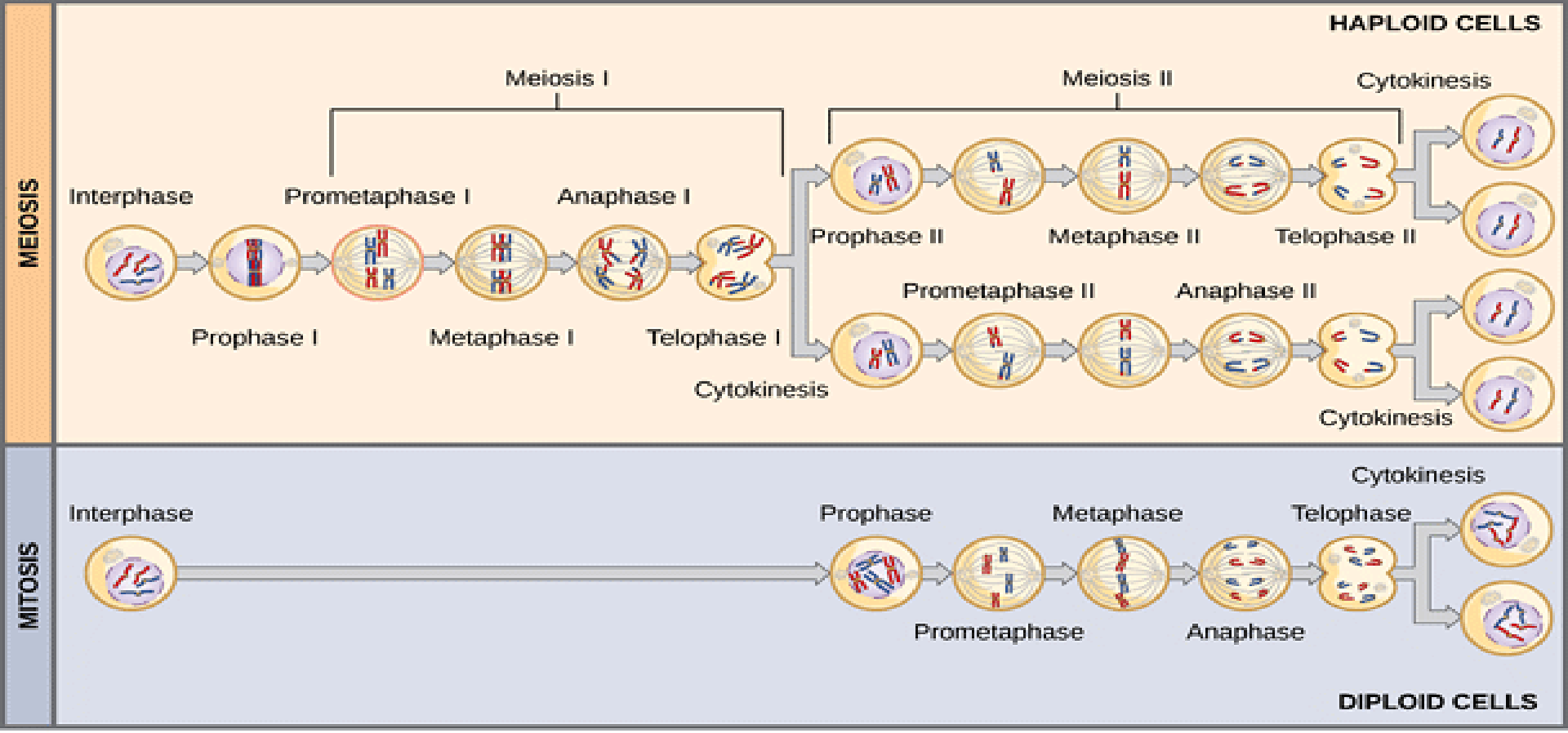
- The nuclear membrane **reforms** around the chromosomes.
- **cytokinesis** takes place.



The second meiotic division, meiosis II

- Meiosis II is basically a mitotic-like division.
- It is called the equational division because the **chromosome number remains the same** in each cell before and after the second division.
- Meiosis II does not further reduce the chromosome number.
- Meiosis II reduces the amount of genetic material per cell by half through separation of the sister chromatids.
- It is shorter than meiosis I, although it consists of four phases: **prophase II, metaphase II, anaphase II, and telophase II**.
- It occurs without further DNA replication.


MITOSIS
Starting cell
MEIOSIS
2n
Chromosomes already replicated
Crossing-over
PROPHASE I
Tetrads formed by synapsis
METAPHASE I
Tetrads line up along the metaphase plate
ANAPHASE I
Homologous chromosomes separate (sister chromatids remain together)
TELOPHASE I
Each cell has one of the replicated chromosomes from each homologous pair of chromosomes (n)
PROPHASE
METAPHASE
Chromosomes line up along the metaphase plate
ANAPHASE
Sister chromatids separate
TELOPHASE
Cytokinesis
INTERPHASE
Resulting cells
2n
2n
PROPHASE II
METAPHASE II
ANAPHASE II
TELOPHASE II
n
n
n
n
Somatic cells with diploid number of chromosomes (not replicated)
Gametes with haploid number of chromosomes (not replicated)



						OUTCOME
PROCESS	DNA synthesis	Synapsis of homologous chromosomes	Crossover	Homologous chromosomes line up at metaphase plate	Sister chromatids line up at metaphase plate	Number and genetic composition of daughter cells
MEIOSIS	Occurs in S phase of interphase	During prophase I	During prophase I	During metaphase I	During metaphase II	Four haploid cells at the end of meiosis II
MITOSIS	Occurs in S phase of interphase	Does not occur in mitosis	Does not occur in mitosis	Does not occur in mitosis	During metaphase	Two diploid cells at the end of mitosis

Comparison between mitosis and meiosis

Mitosis	Meiosis
Occurs in haploid or diploid cells.	Occurs in diploid cells.
Occurs in somatic cells.	Occurs in sex (reproductive) cells.
Consists of one round of cell division.	Consists of two rounds of cell division.
Results in two identical daughter cells.	Results in four daughter cells, which are not identical.
The resulting (daughter) cells have the same number of chromosomes as in the parent (original) cells.	The resulting cells have half the number of chromosomes as in the parent cells.
Prophase is short and does not comprise any phase.	Prophase I is very long and comprises five phases.
There is no pairing of chromosome, synapsis, or crossing over during prophase.	Pairing, synapsis and crossing over before homologous chromosomes occurs during prophase I.
Synaptonemal complex is not found.	Synaptonemal complex is found during the zygotene of prophase I.
Anaphase involves the separation of the two sister chromatids of each chromosome.	During anaphase I, the homologous chromosome separate, while the sister chromatids remain attached at their centromere. During anaphase II, the sister chromatids separate as a result of the separation of the centromere.
Necessary for repair and growth of a cell.	Necessary for sexual reproduction.

Significance of meiosis

1) Meiosis produces haploid gamete required for sexual reproduction from diploid cells.

2) It reduces the diploid number of chromosomes by half.

3) Meiosis produces genetic diversity.

Videos

http://highered.mheducation.com/sites/007298760x/student_view0/chapter3/stages_of_meiosis.html

http://highered.mheducation.com/sites/007298760x/student_view0/chapter3/meiosis_with_crossing_over.html

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http://highered.mheducation.com/sites/007298760x/student_view0/chapter3/how_meiosis_works.html

http://highered.mheducation.com/novella/MixQuizProcessingServlet

http://highered.mheducation.com/sites/007298760x/student_view0/chapter3/comparison_of_meiosis_and_mitosis__quiz_1_.html