Cell Division

Cell division increases the number of *somatic* (body) *cells*, and consists of:

Mitosis (division of nucleus)
Cytokinesis (division of cytoplasm)

Apoptosis (cell death) decreases the number of cells.

Both cell division and apoptosis occur during normal development and growth.

The Cell Cycle

The *cell cycle* is an orderly sequence of events that occurs from the time when a cell is first formed until it divides into two new cells.

Most of the cell cycle is spent in *interphase*.

Following interphase, the *mitotic stage* of cell division occurs.

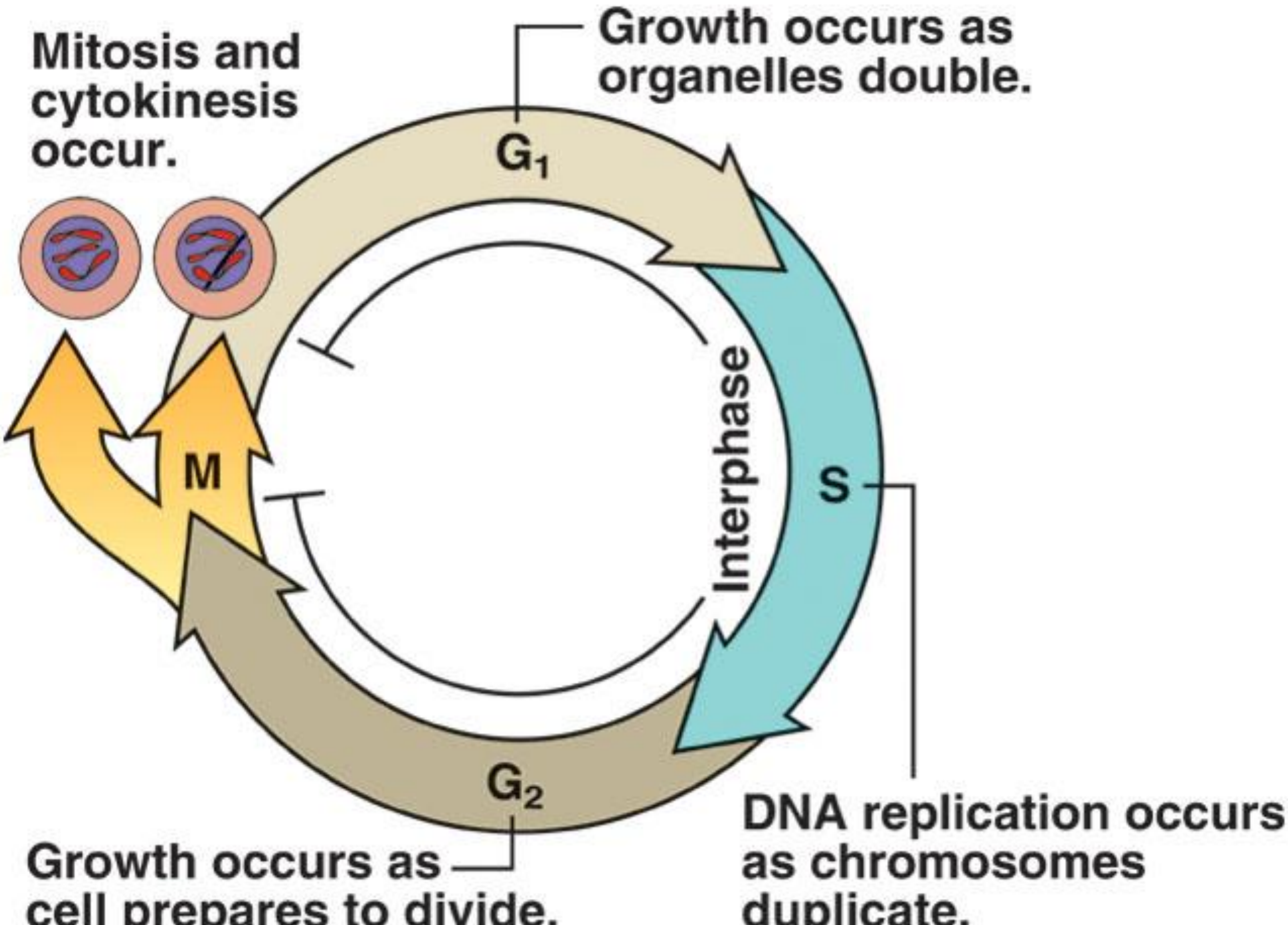
The stages of interphase

G1 stage – cell growth, cell doubles its organelles, accumulates materials for DNA synthesis.

S stage – DNA synthesis occurs, and DNA replication results in duplicated chromosomes.

G2 stage – cell synthesizes proteins needed for cell division

The cell cycle



The Mitotic Stage

Following interphase is the *M stage*, including mitosis and cytokinesis.

During mitosis, *sister chromatids* of each chromosome separate, and become the nuclei of the two daughter cells.

The cell cycle ends when cytokinesis, the cleaving of the cytoplasm, is complete.

Maintaining the Chromosome Number

When a eukaryotic cell is not dividing, the DNA and associated proteins is a tangled mass of thin threads called *chromatin*.

At the time of cell division, the chromatin condenses to form highly compacted structures called *chromosomes*.

Each species has a characteristic number of chromosomes.

Overview of Mitosis

The *diploid number* of chromosomes is found in the somatic (non-sex) cells.

The *diploid (2n) number* of chromosomes contains two chromosomes of each kind.

The *haploid (n) number* of chromosomes contains one chromosome of each kind.

In the life cycle of many animals, only *sperm* and *eggs* have the *haploid* number of chromosomes.

The nuclei of somatic cells undergo *mitosis,* a nuclear division in which the number of chromosomes stays constant.

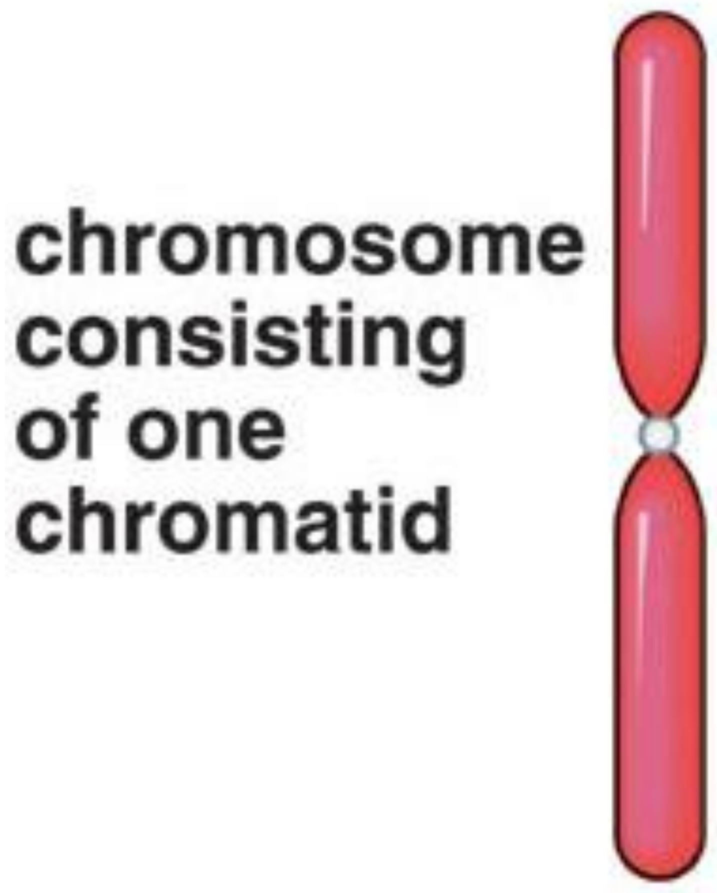
Before nuclear division occurs, *DNA replication* takes place, duplicating the chromosomes.

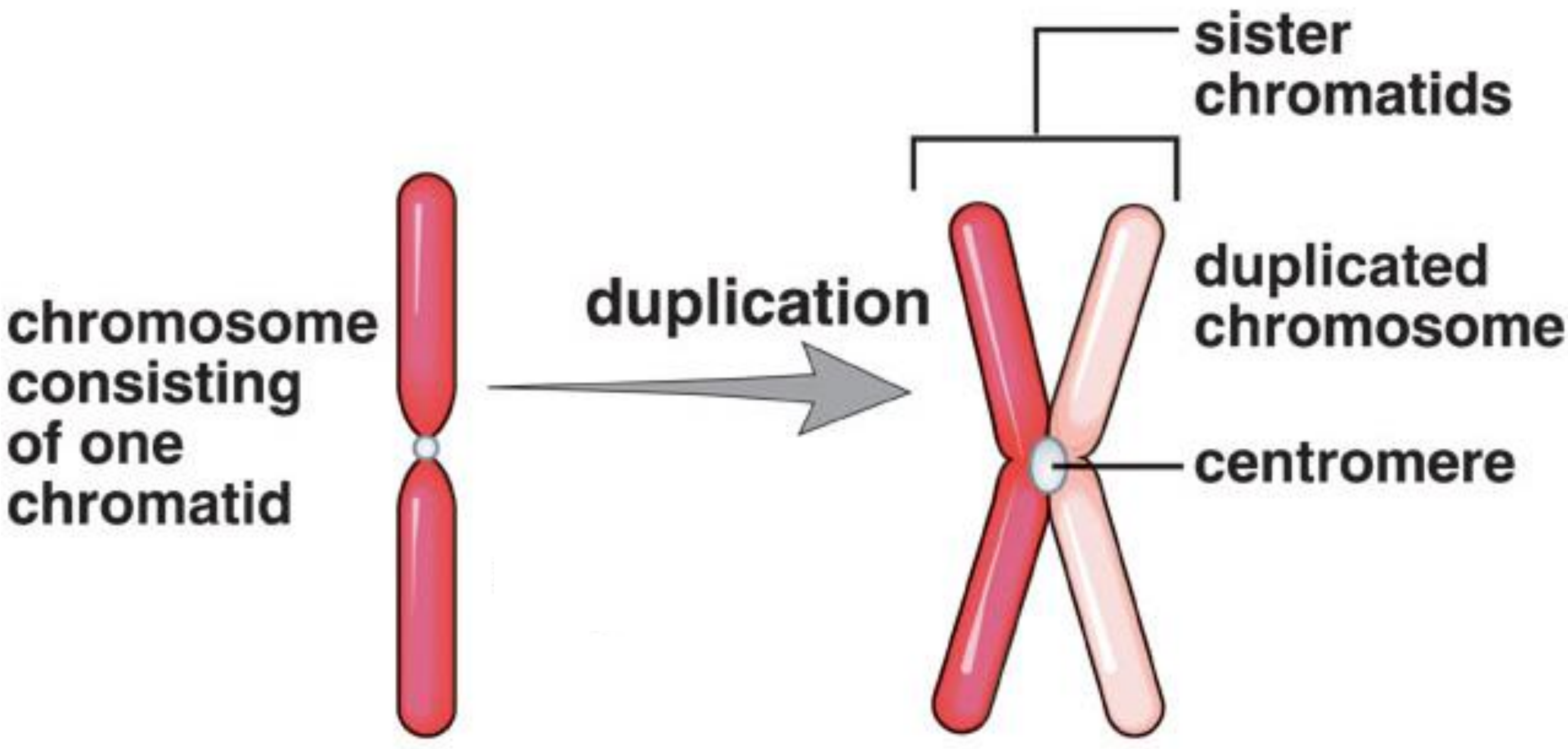
A duplicated chromosome is made of two *sister chromatids* held together in a region called the *centromere*.

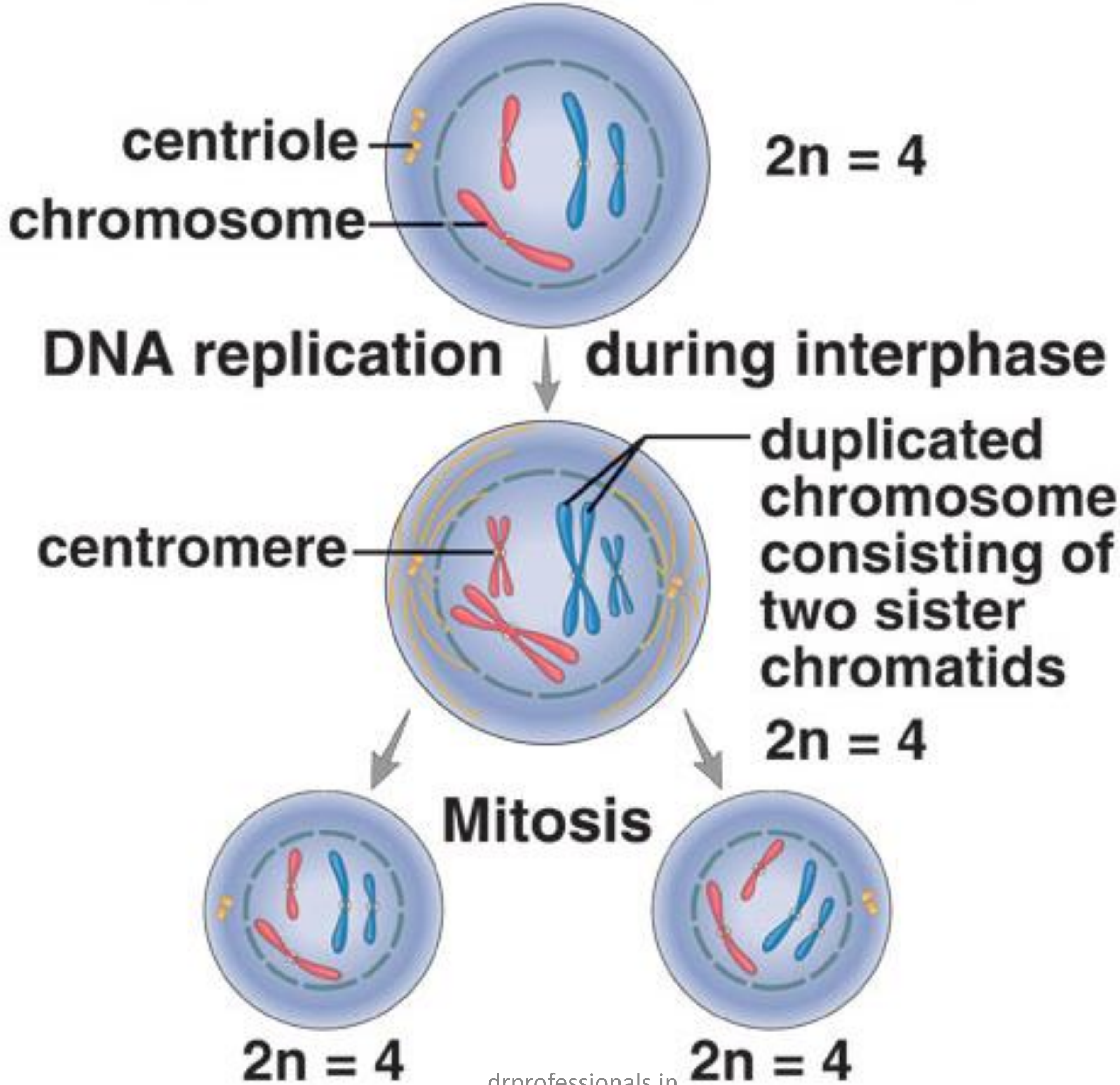
Sister chromatids are *genetically identical*.

At the end of mitosis, each chromosome consists of a single chromatid.

During mitosis, the centromeres divide and then the sister chromatids separate, becoming *daughter chromosomes*.


chromosome
consisting
of one
chromatid


sister
chromatids
duplication
chromosome
consisting
of one
chromatid
duplicated
chromosome
centromere


centriole
chromosome
2n = 4
DNA replication
during interphase
duplicated chromosome consisting of two sister chromatids
centromere
2n = 4
Mitosis
2n = 4
2n = 4

Following mitosis, a 2n parental cell gives rise to two 2n daughter cells, or *2n → 2n*.

Mitosis occurs when *tissues grow* or when *repair* occurs.

Following fertilization, the *zygote* divides mitotically, and mitosis continues throughout the lifespan of the organism.

Mitosis in Detail

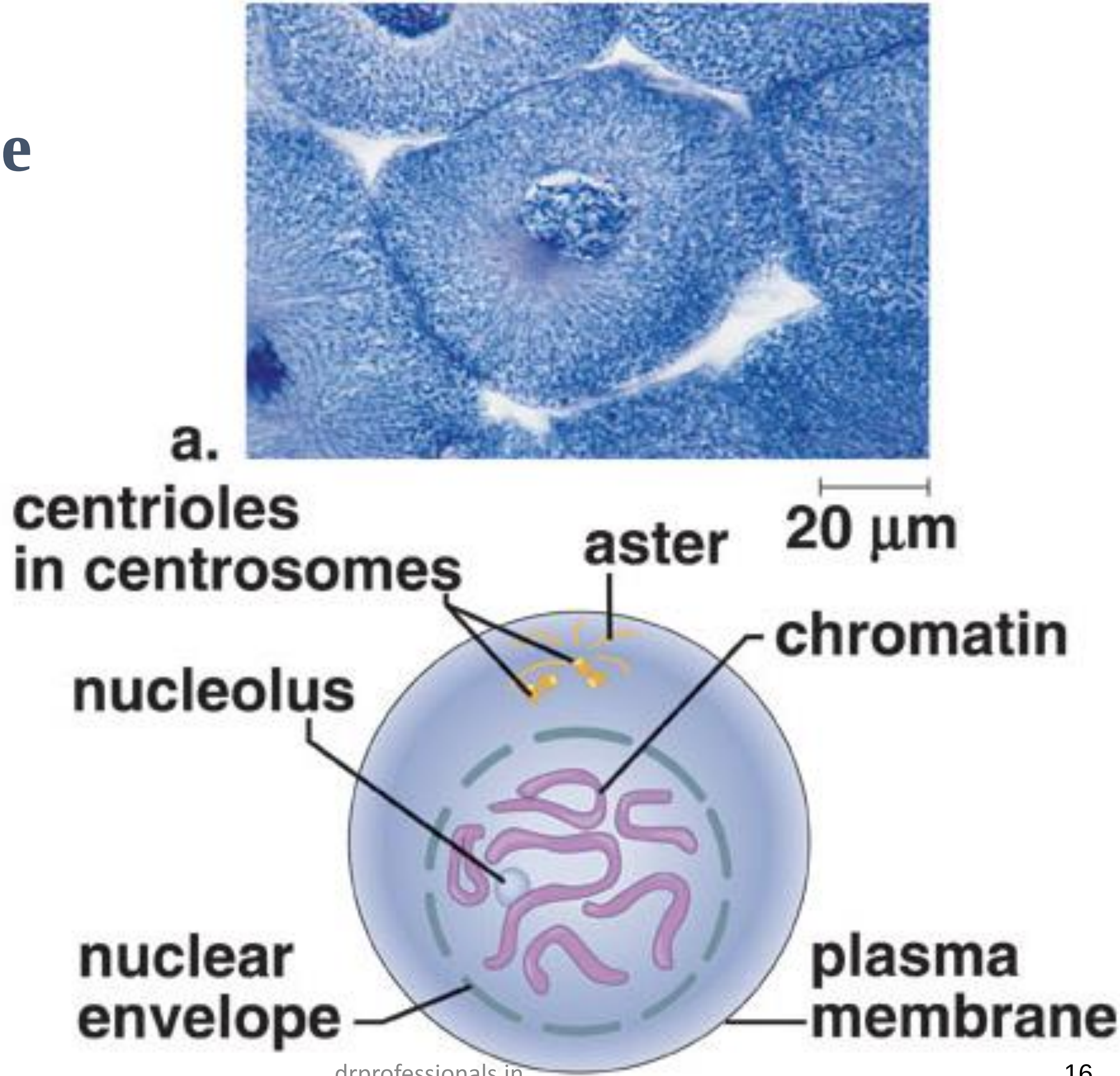
During mitosis, the *spindle* distributes the chromosomes to each daughter cell.

The spindle contains fibers made of *microtubules* that disassemble and assemble.

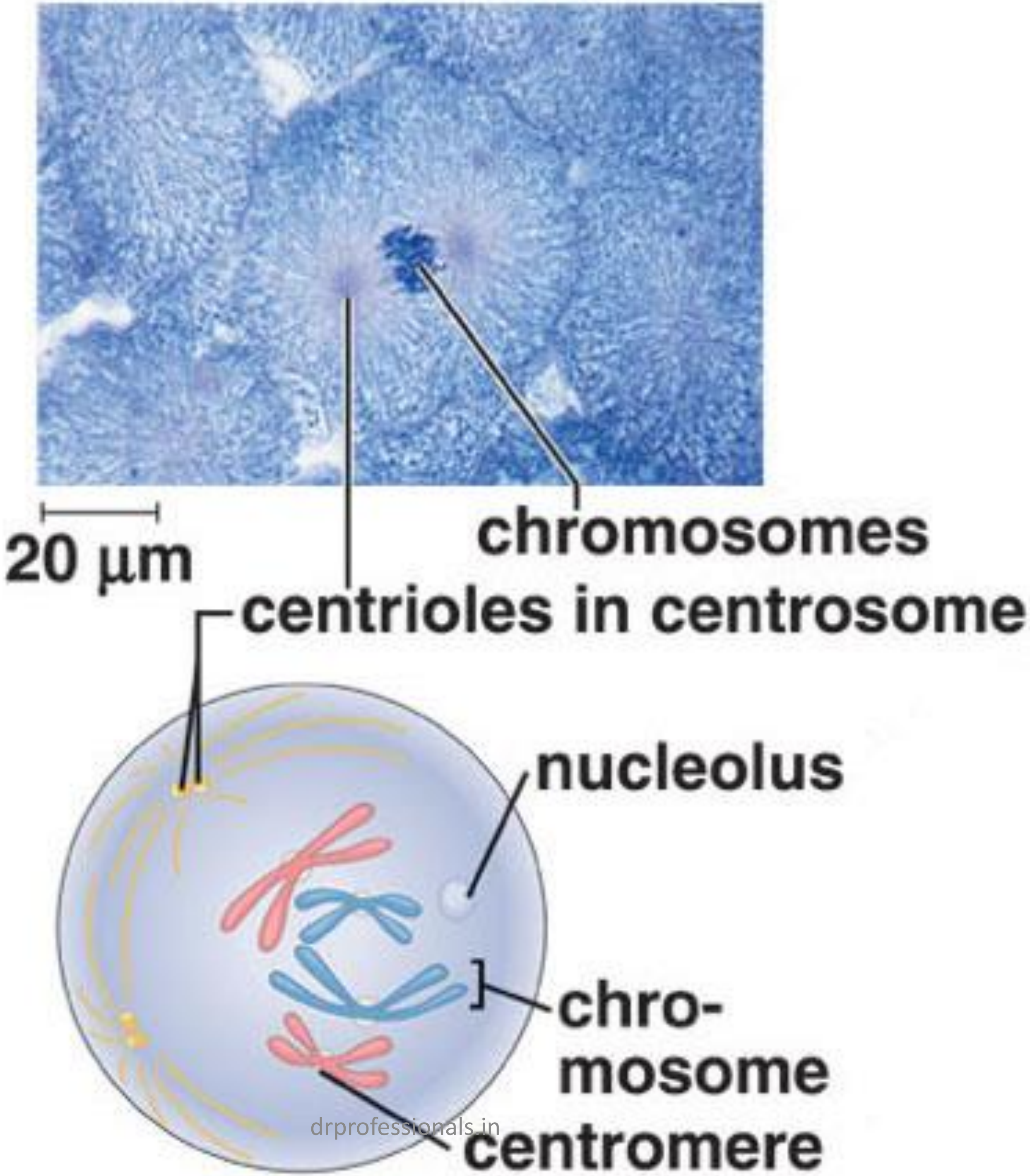
Chromosomes attach to the spindle fibers through their *centrosomes*.

Mitosis has four phases: *prophase*, *metaphase*, *anaphase*, and *telophase*.

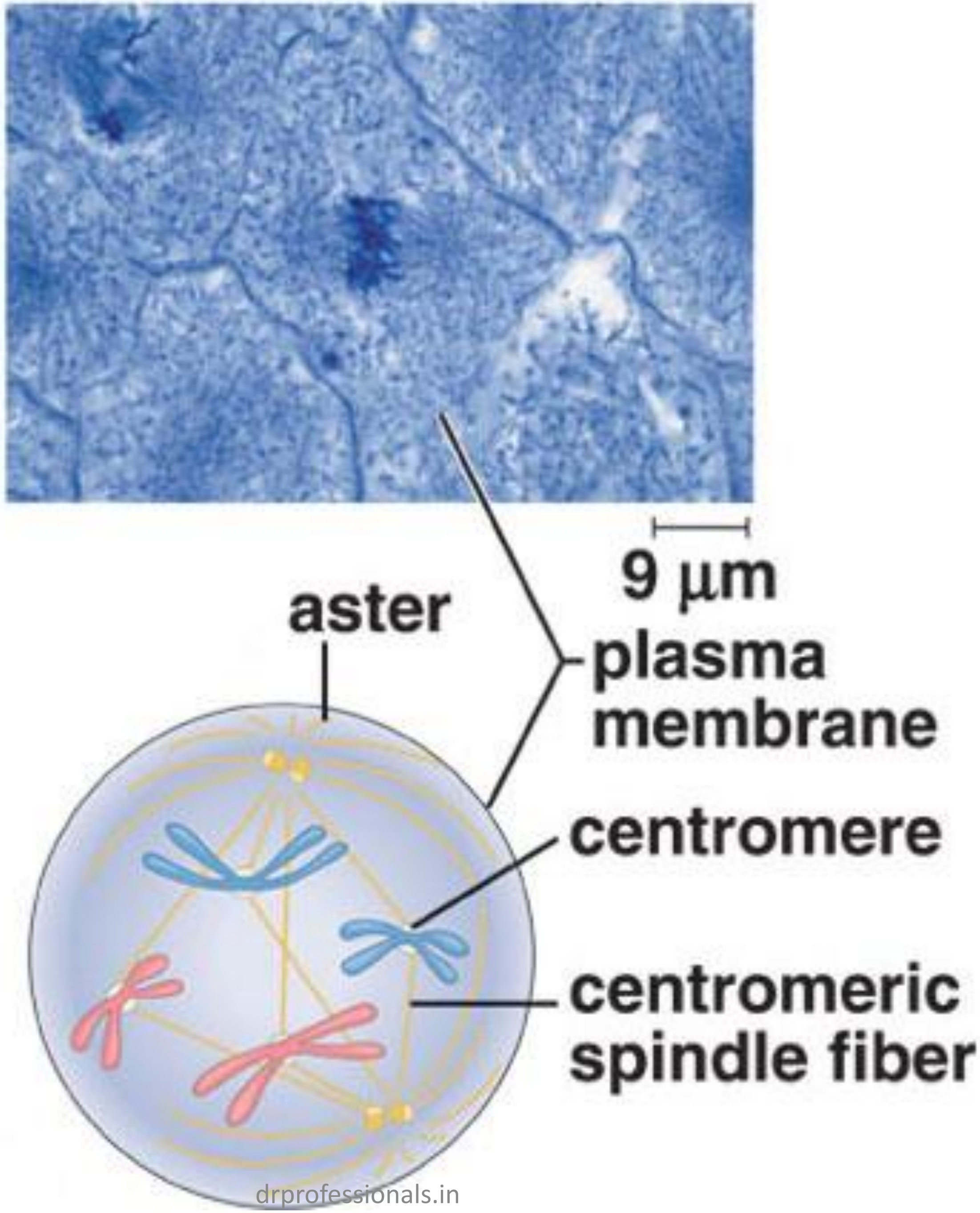
Late Interphase



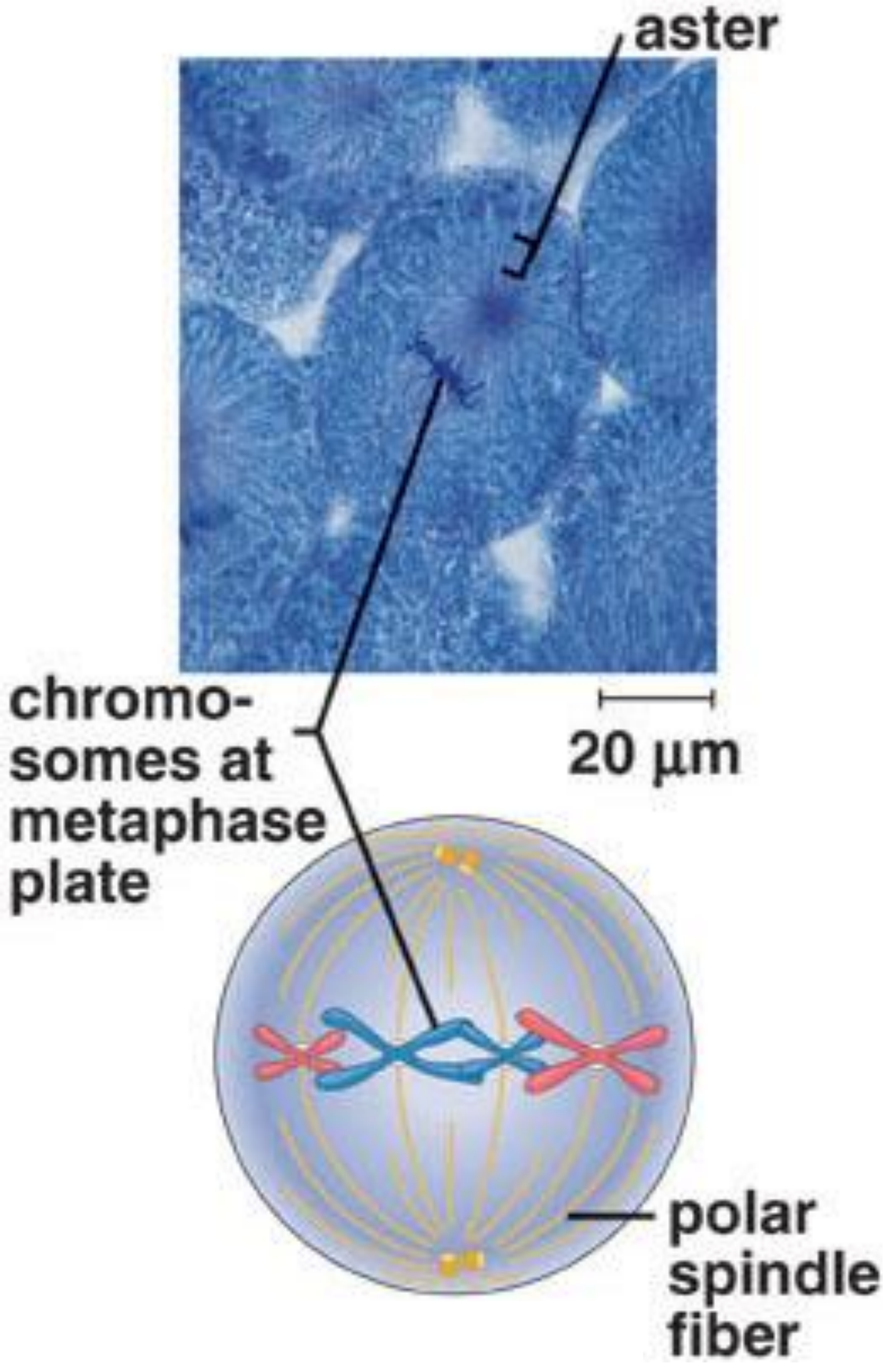
Early Prophase



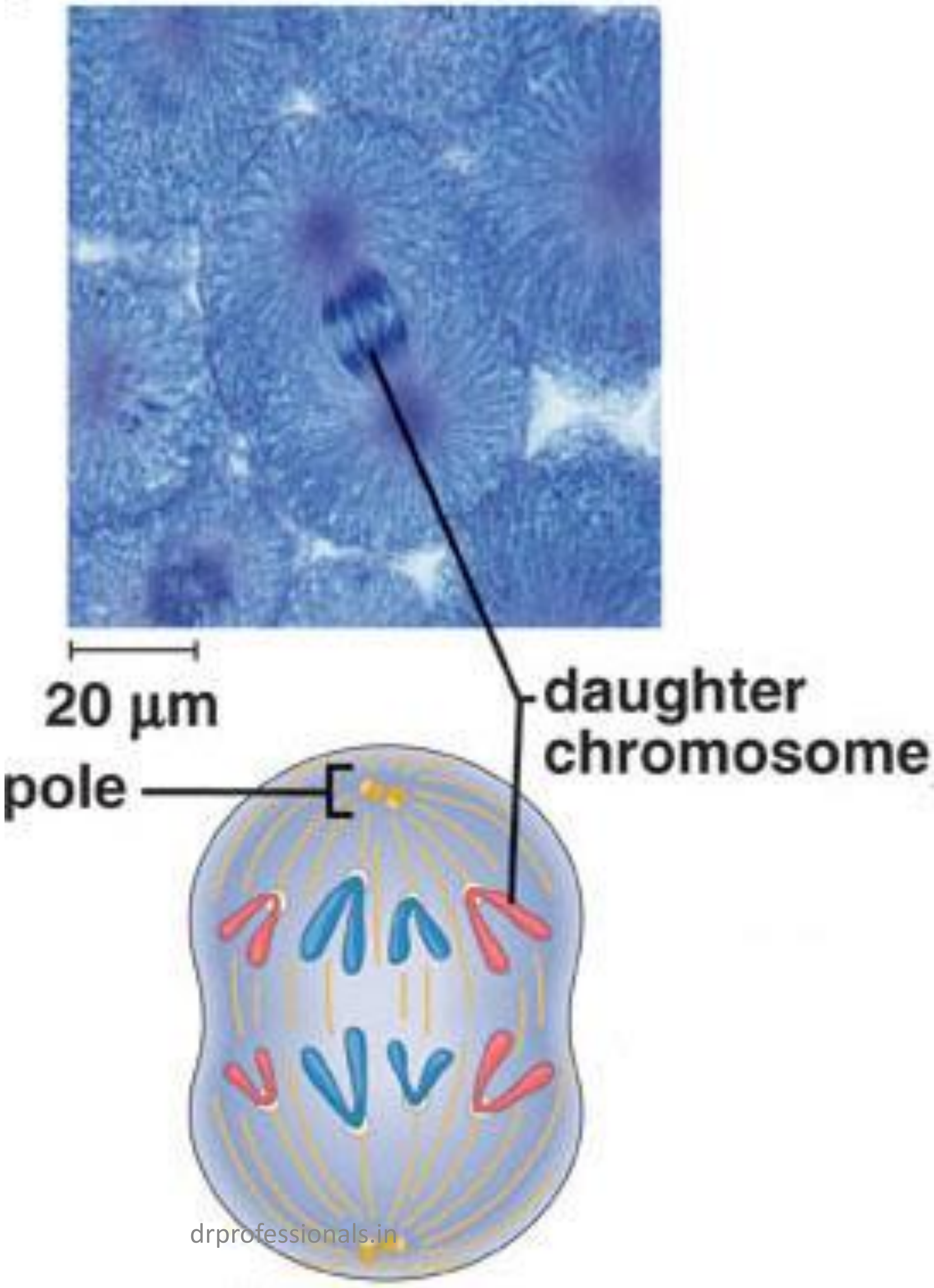
Late Prophase



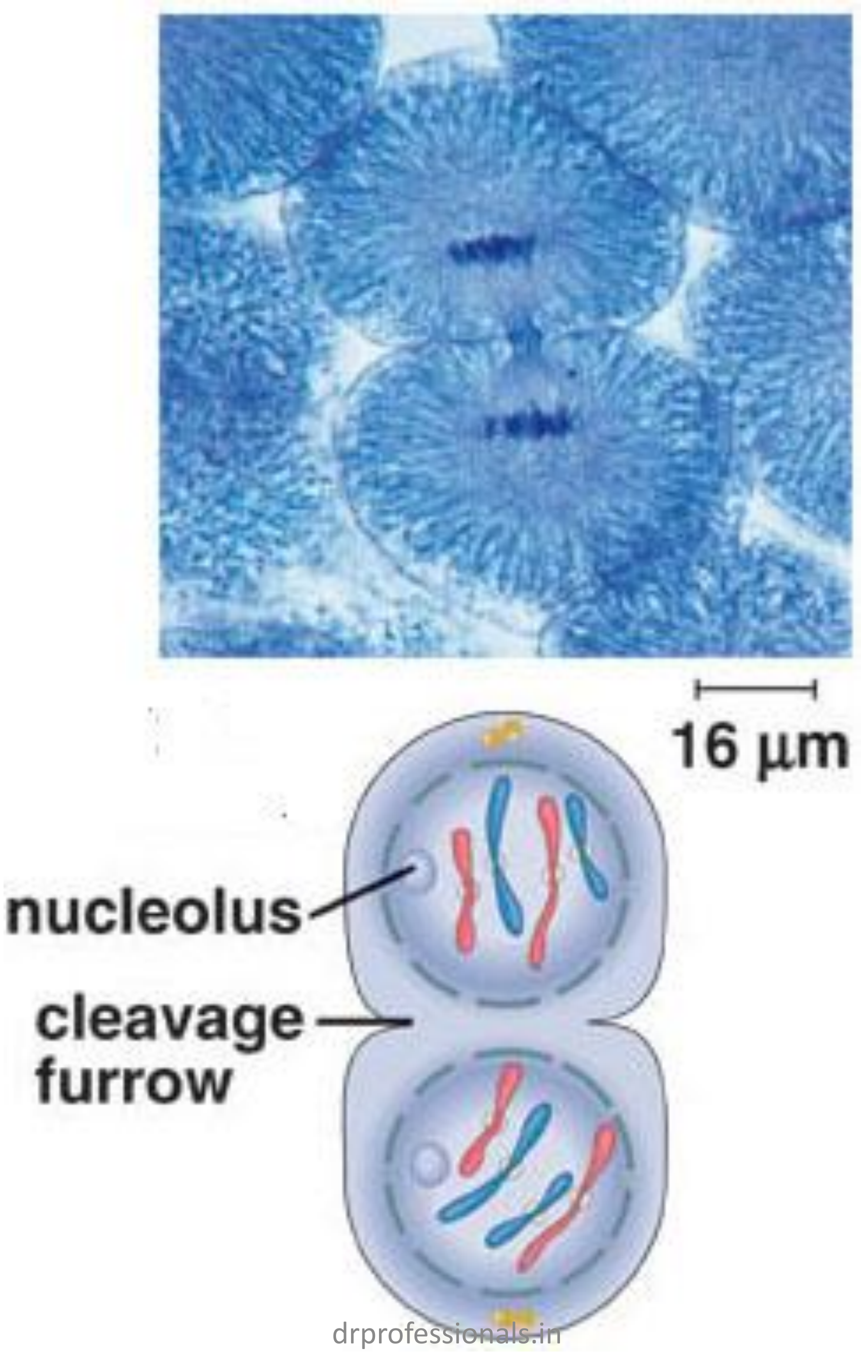
Metaphase


aster
chromo-
somes at
metaphase
plate
20 µm
polar
spindle
fiber

Anaphase



Telophase



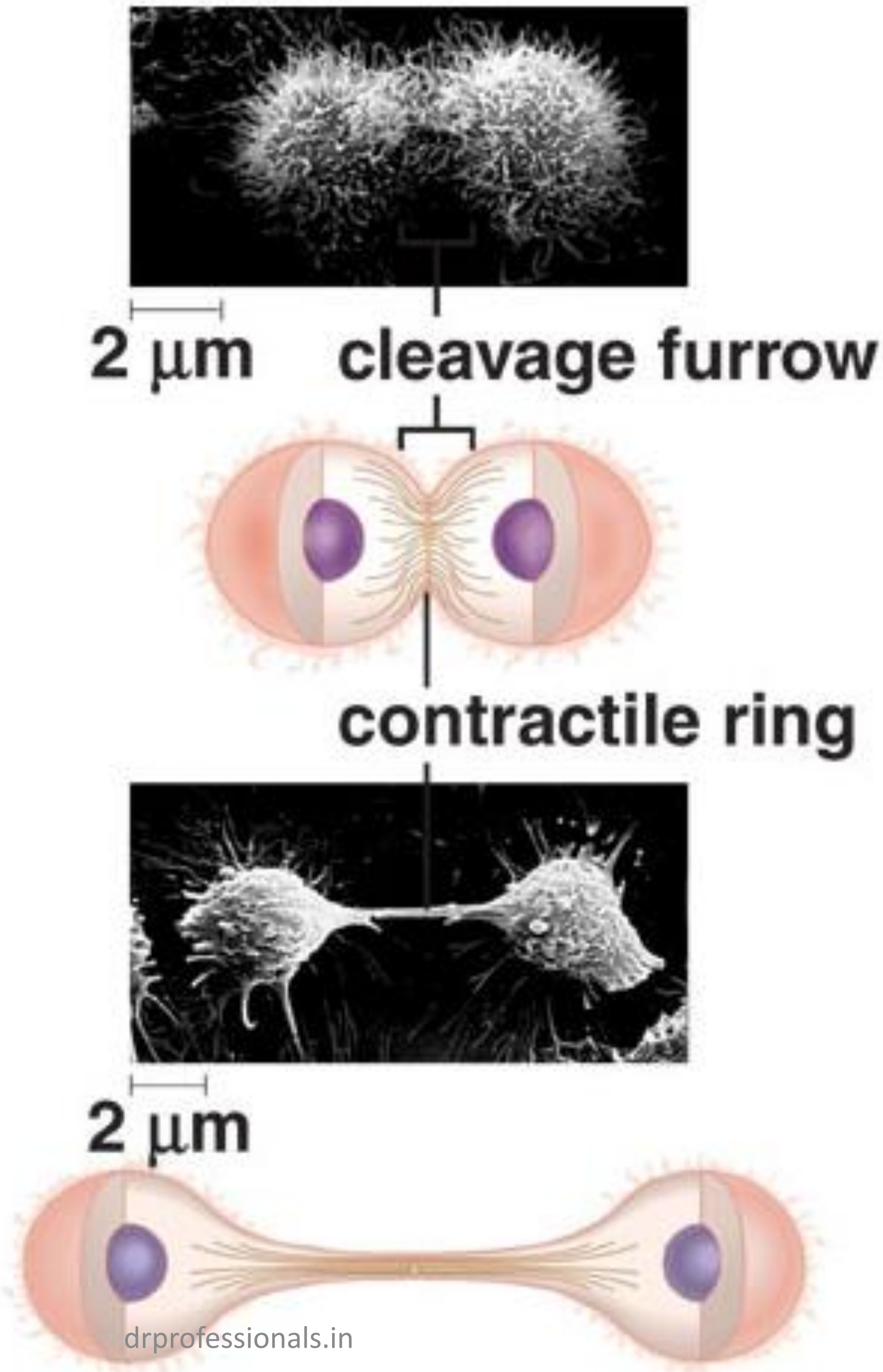
Cytokinesis

Cytokinesis, or cytoplasmic cleavage, accompanies mitosis.

Cleavage of the cytoplasm begins in anaphase, but is not completed until just before the next interphase.

Newly-formed cells receive a share of cytoplasmic organelles duplicated during the previous interphase.

Cytokinesis

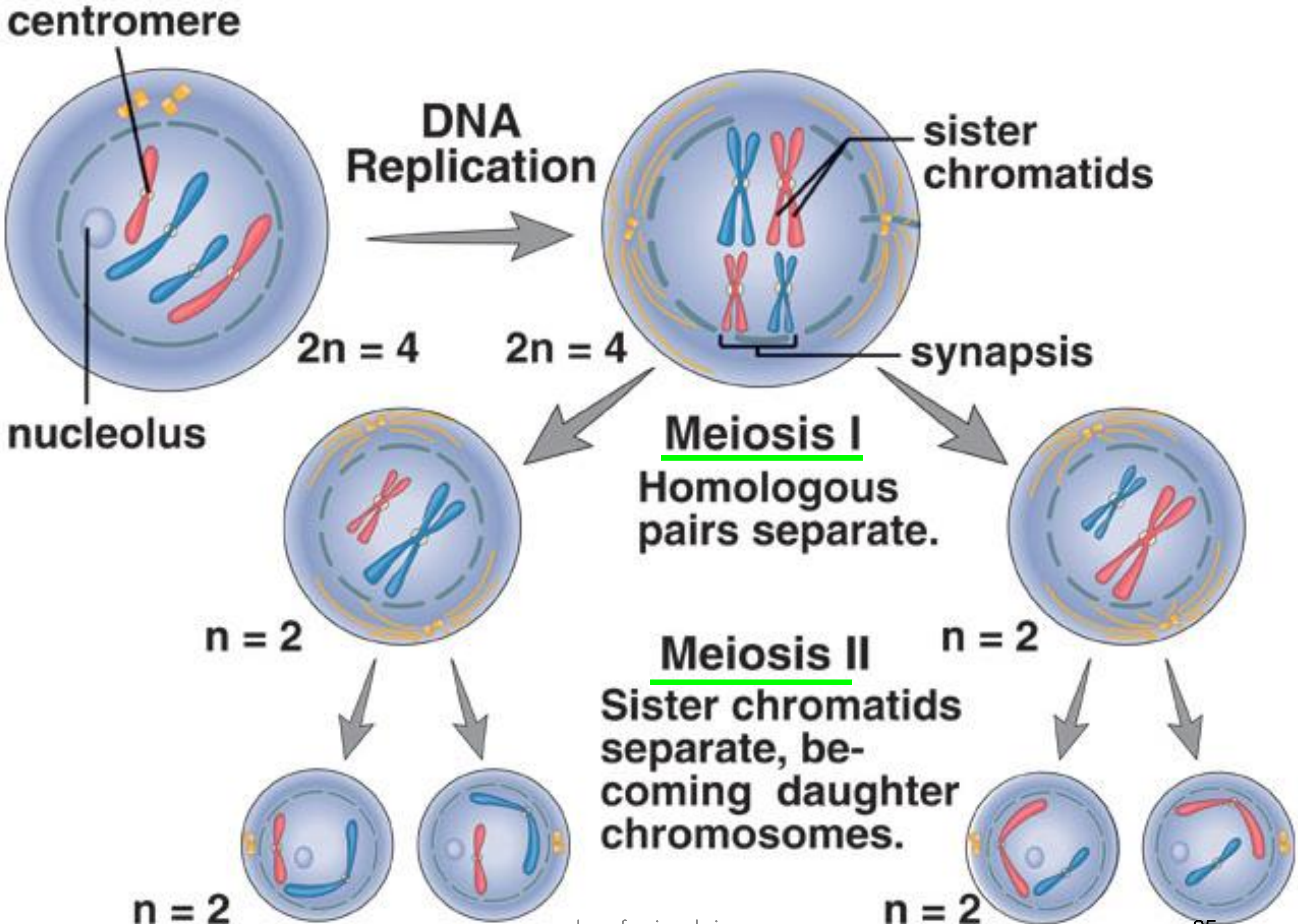


MEIOSIS: Reducing the Chromosome Number

Meiosis reduces the chromosome number such that each daughter cell has only one of each kind of chromosome.

The process of meiosis ensures that the next generation will have:

1. the diploid number of chromosomes
2. a combination of traits that differs from that of either parent.


centromere
DNA
Replication
sister
chromatids
nucleolus
2n = 4
2n = 4
synapsis
Meiosis I
Homologous
pairs separate.
n = 2
Meiosis II
n = 2
Sister chromatids
separate, be-
coming daughter
chromosomes.
n = 2
n = 2

Meiosis I separates homologous pairs of chromosomes.

Daughter cells are haploid, but chromosomes are still in duplicated condition.

Synapsis occurs during meiosis I

Meiosis II separates sister chromatids.

The completely haploid daughter cells mature into *gametes*.

Fertilization restores the diploid number of chromosomes during sexual reproduction.

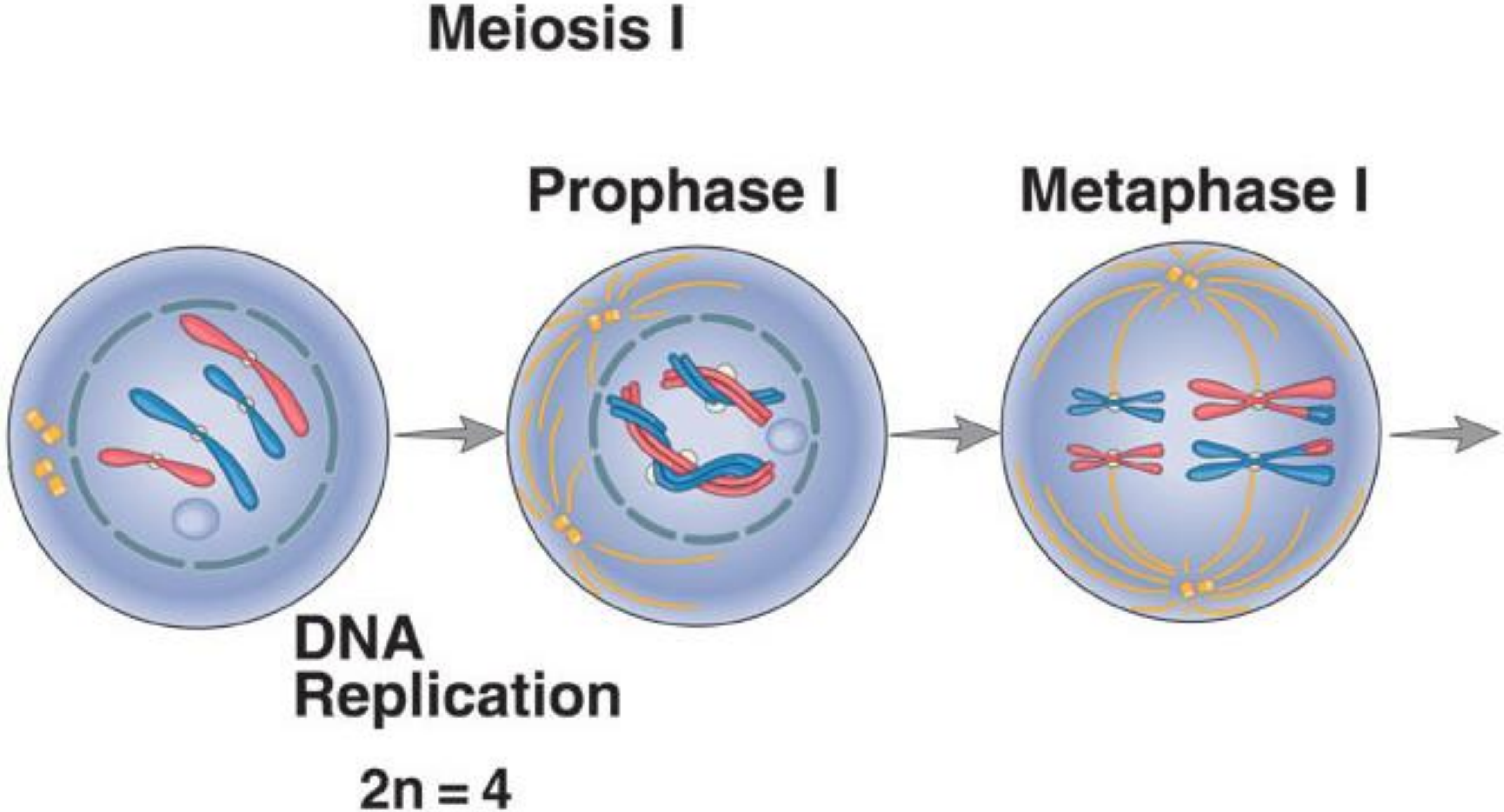
Meiosis in Detail

Meiosis involves the same four phases seen in mitosis *prophase*
metaphase
anaphase
telophase

The occur during both meiosis I and meiosis II.

The period of time between meiosis I and meiosis II is called *interkinesis*.

No replication of DNA occurs during interkinesis because the DNA is already duplicated.


Meiosis I
Prophase I
Metaphase I
DNA
Replication
2n = 4

Leptonema

It means thin thread like

Chromosome appear as long single threads, unassociated with one another.

Centriole moves towards the opposite pole of cell.

Orientation & polarization of chromosome towards the centriole take place.

Bead like structure are often visible.

<u>Bouquet configuration-</u> Chromosome remain attached with one their ends by a portion of nuclear membrane

Zygonema

- Two Chromosome one from paternal & one from maternal form a pair & are homologous to each other.
- Synapsis – pairing of homologous Chromosome
- Bivalant – each is pair of homologous Chromosome
- The pairing starts at one or more points & prigress in a *zipper like fashion* till completion

Pachynema

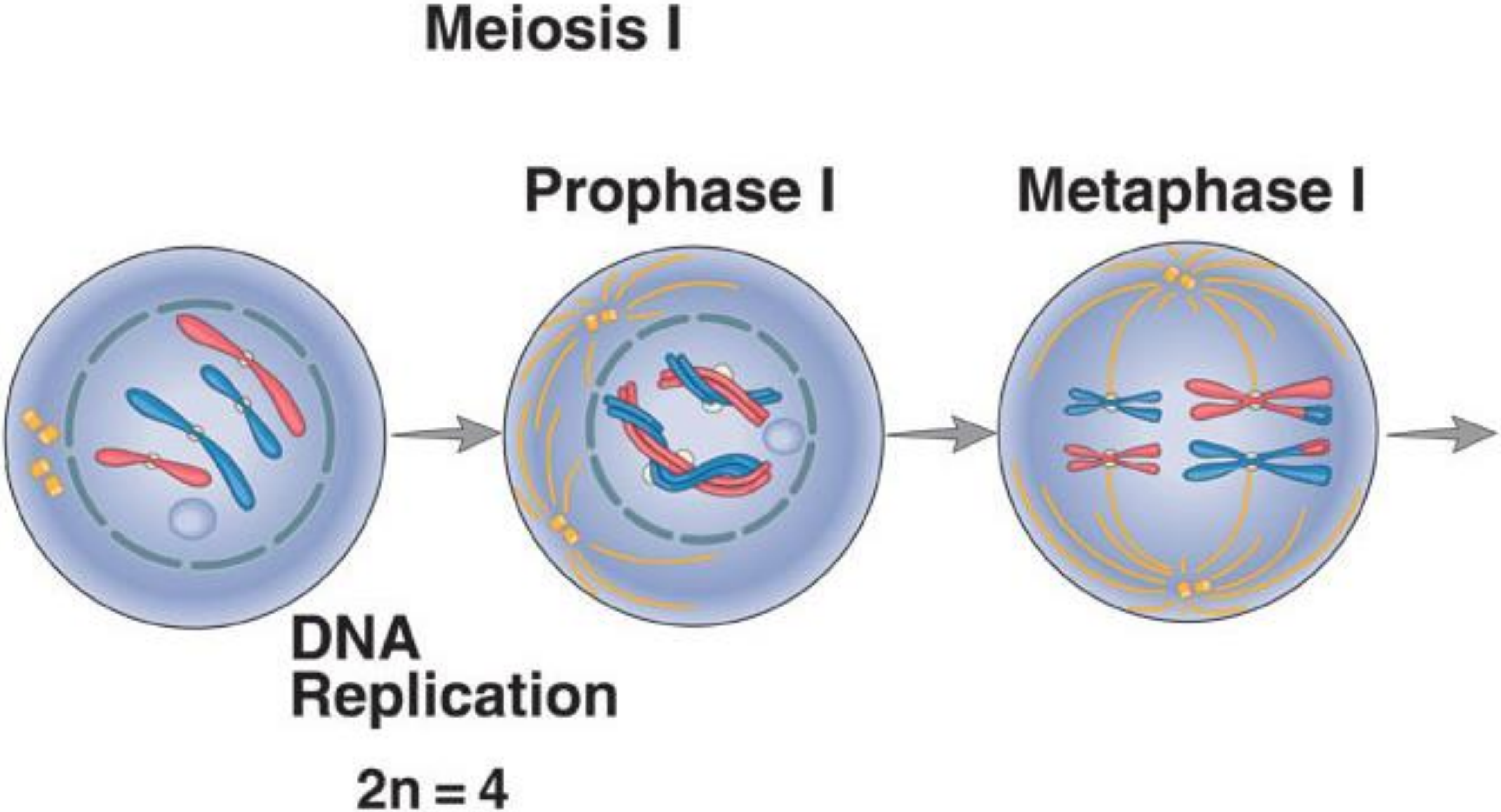
- Stable stage of pairing
- Bivalants become thicker in appearance
- Nucleolus is prominent & remain attached to particular Chromosome
- At later stage each bivalant is divides into two chromatids
- Exchange of genetic material between homologous but non-sister chromatids take place by the end of this stage.
- This phenomenon is called ***crossing over & lead to genetic recombination***

Diplonema

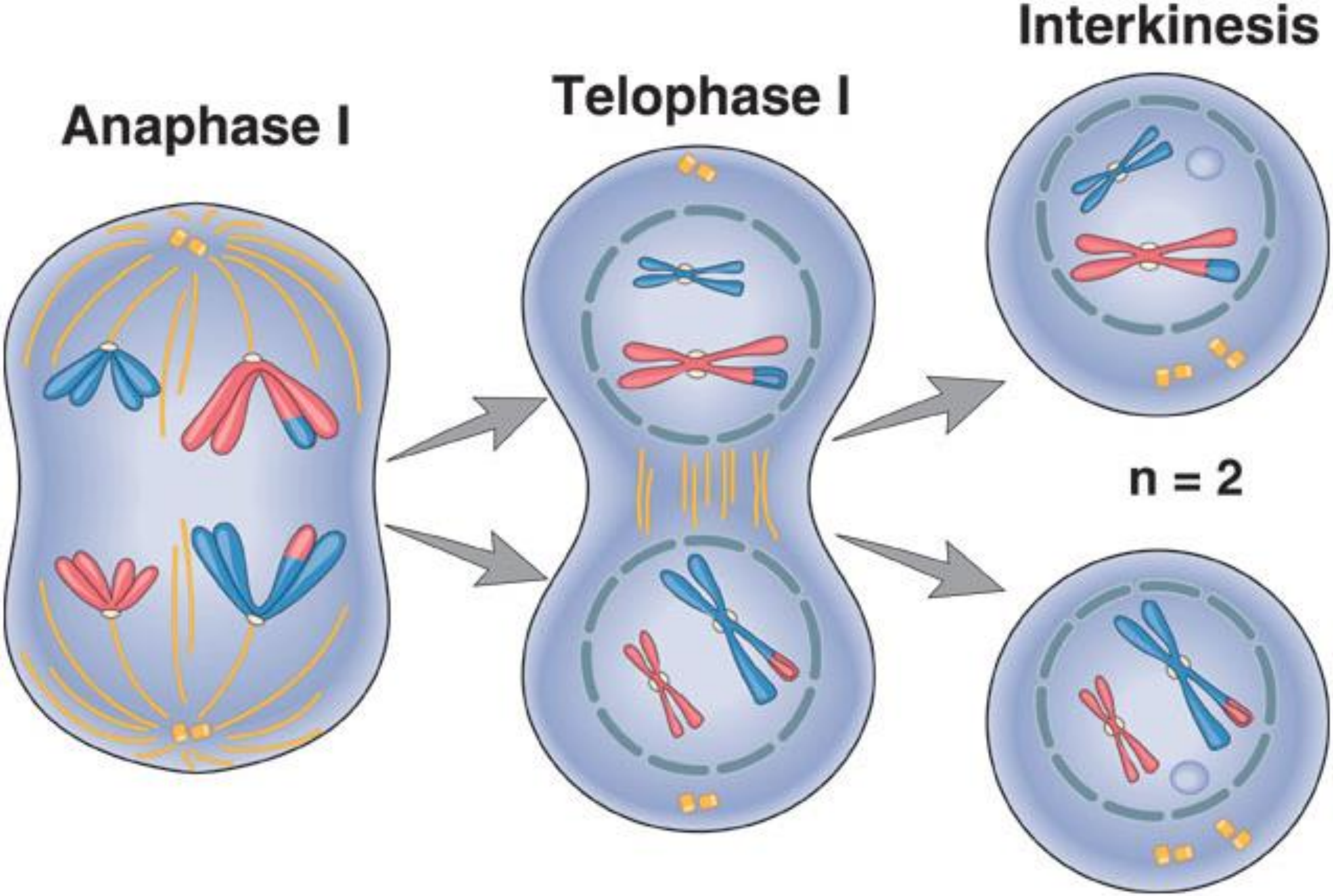
- During this stage homologous Chromosome of bivalant starts separating
- But it is not complete b.coz chromatids are held together at certain points marked as chiasmata
- Longer chromosome have more chiasmata
- Chiasmata move towards the end of bivalent & this is called as ***Terminalization***

Diakinesis

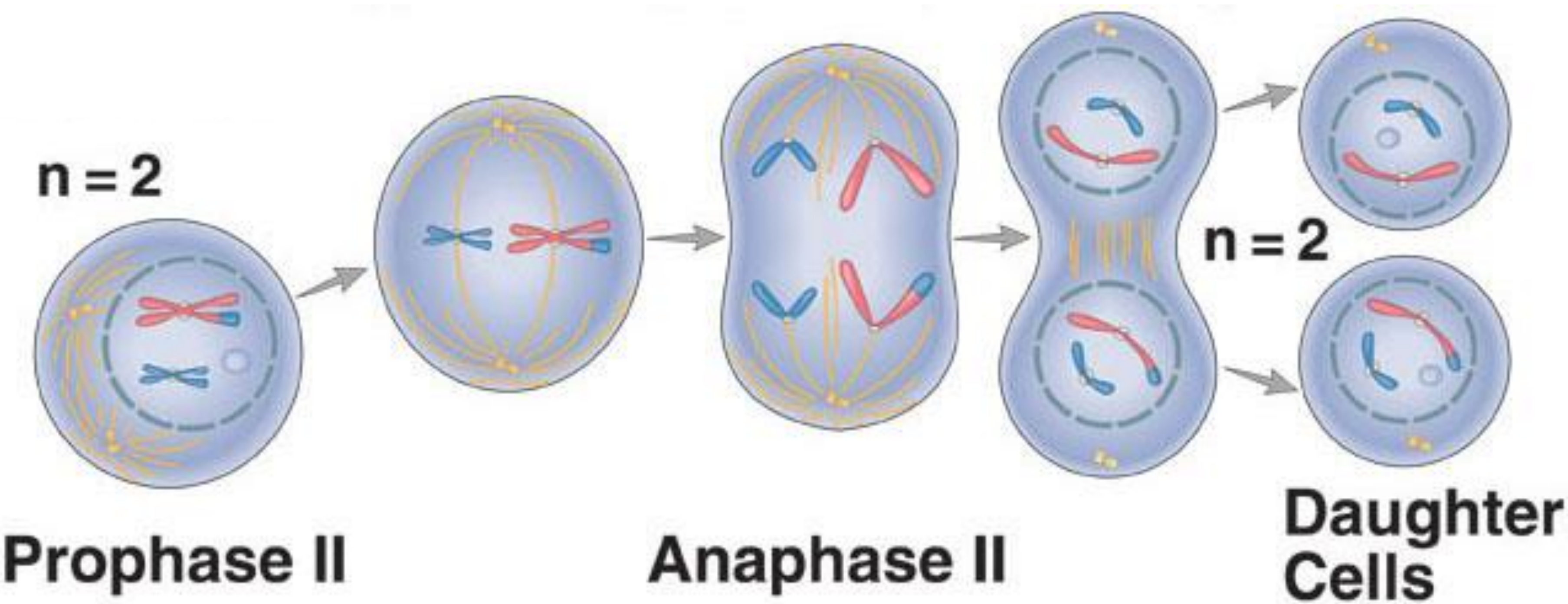
- Chromosome begin to coil & so become shorter & thicker
- Terminalization is completed
- Nucleolus disapper
- Nuclear envelope starts to degenerate & spindle formation is well under the way

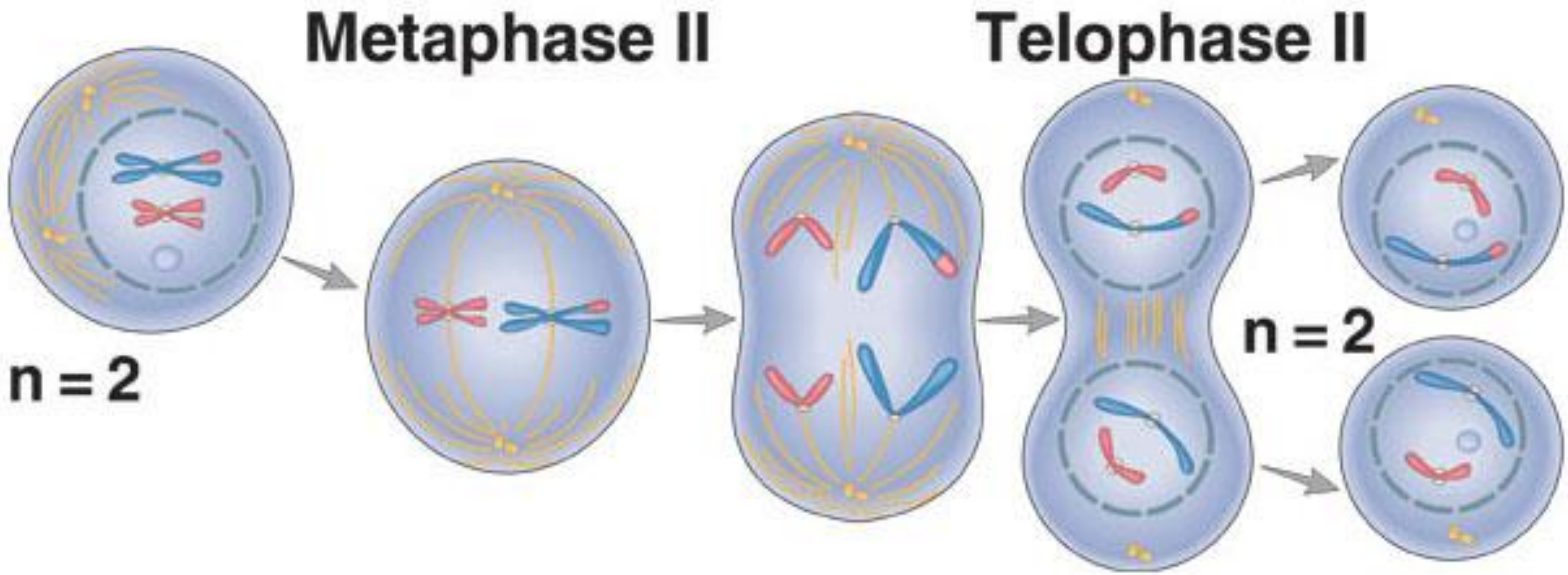

Meiosis I
Prophase I
Metaphase I
DNA
Replication
2n = 4

Meiosis I continued



Meiosis II (similar to mitosis)




Metaphase II
Telophase II
n = 2
n = 2

Genetic Recombination

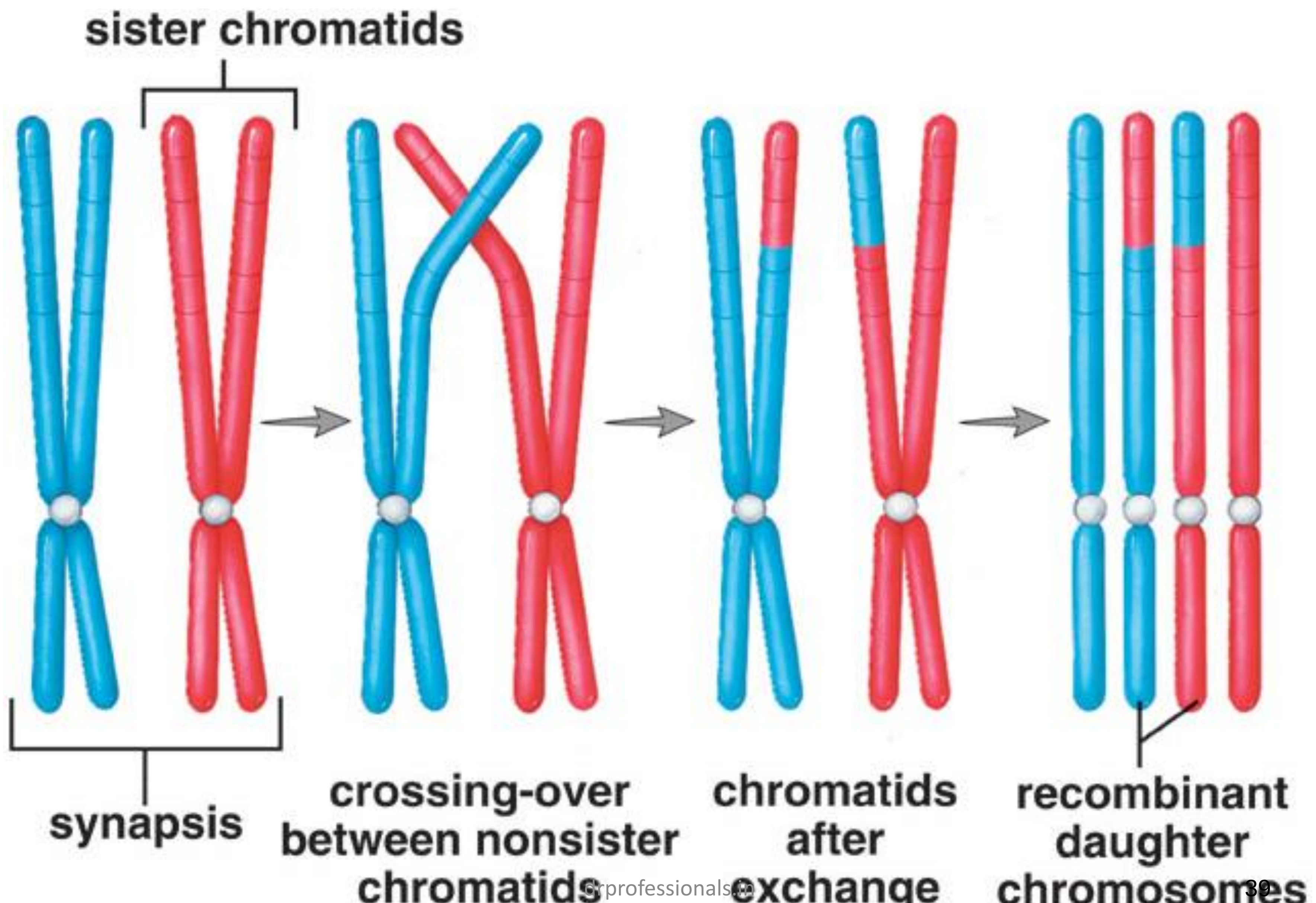
There are two sources of *genetic recombination* during meiosis:

1. Crossing-over.
Non-sister chromatids of a chromosome pair exchange their genetic material.

2. Independent assortment.
Homologous chromosomes are distributed to daughter cells randomly.

Both events assure new genetic combinations in the offspring.

Synapsis and crossing-over



Fertilization between haploid gametes results in a third source of genetic recombination because there is the combining of chromosomes from different individuals (parents).

The three source of genetic recombination are:

1. Independent alignment of paired chromosomes along the metaphase I plate
2. Crossing-over during prophase I
3. Combining of chromosomes of genetically different gametes

Comparison of Meiosis with Mitosis

Before mitosis and meiosis, DNA replication occurs ***only once*** during the interphase prior to cell division.

Mitosis requires one division
Meiosis requires two divisions.

Two diploid daughter cells result from mitosis
Four haploid daughter cells result from meiosis.

Comparison of Meiosis with Mitosis (cont)

Daughter cells from mitosis are genetically identical to parental cells

Daughter cells from meiosis are not genetically identical to parental cells.

Mitosis occurs in all somatic cells for growth and repair.

Meiosis occurs only in the reproductive organs for the production of gametes.

Comparison of Meiosis I to Mitosis

- Meiosis I:
- Prophase I - pairing of homologous chromosomes
- Metaphase I – homologous pairs line up at metaphase plate
- Anaphase I – homologous chromosomes separate
- Telophase I – daughter cells are haploid

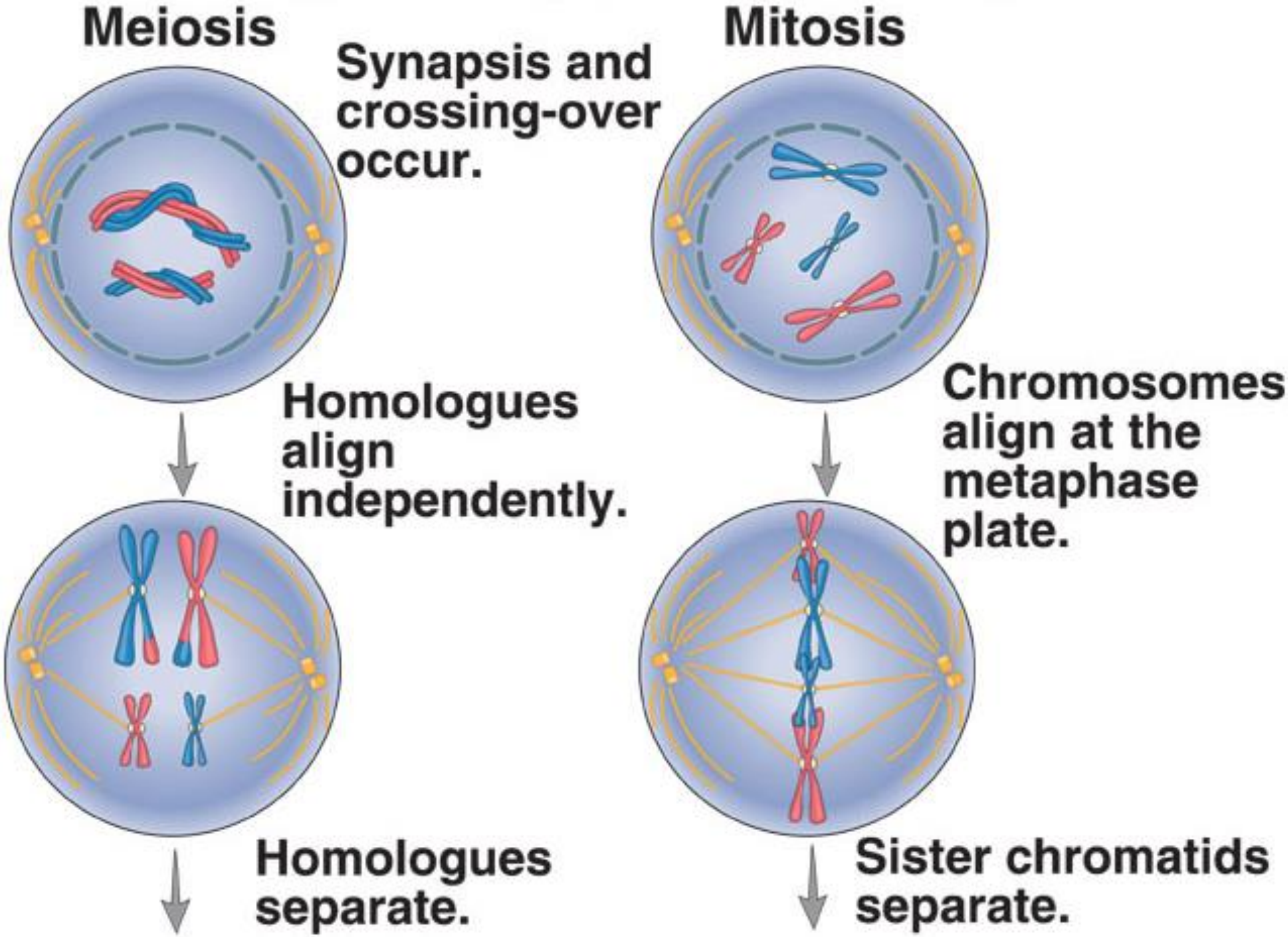
- Mitosis:
- Prophase has no such pairing
- Metaphase – chromosomes align at metaphase plate
- Anaphase – sister chromatids separate
- Telophase – diploid cells

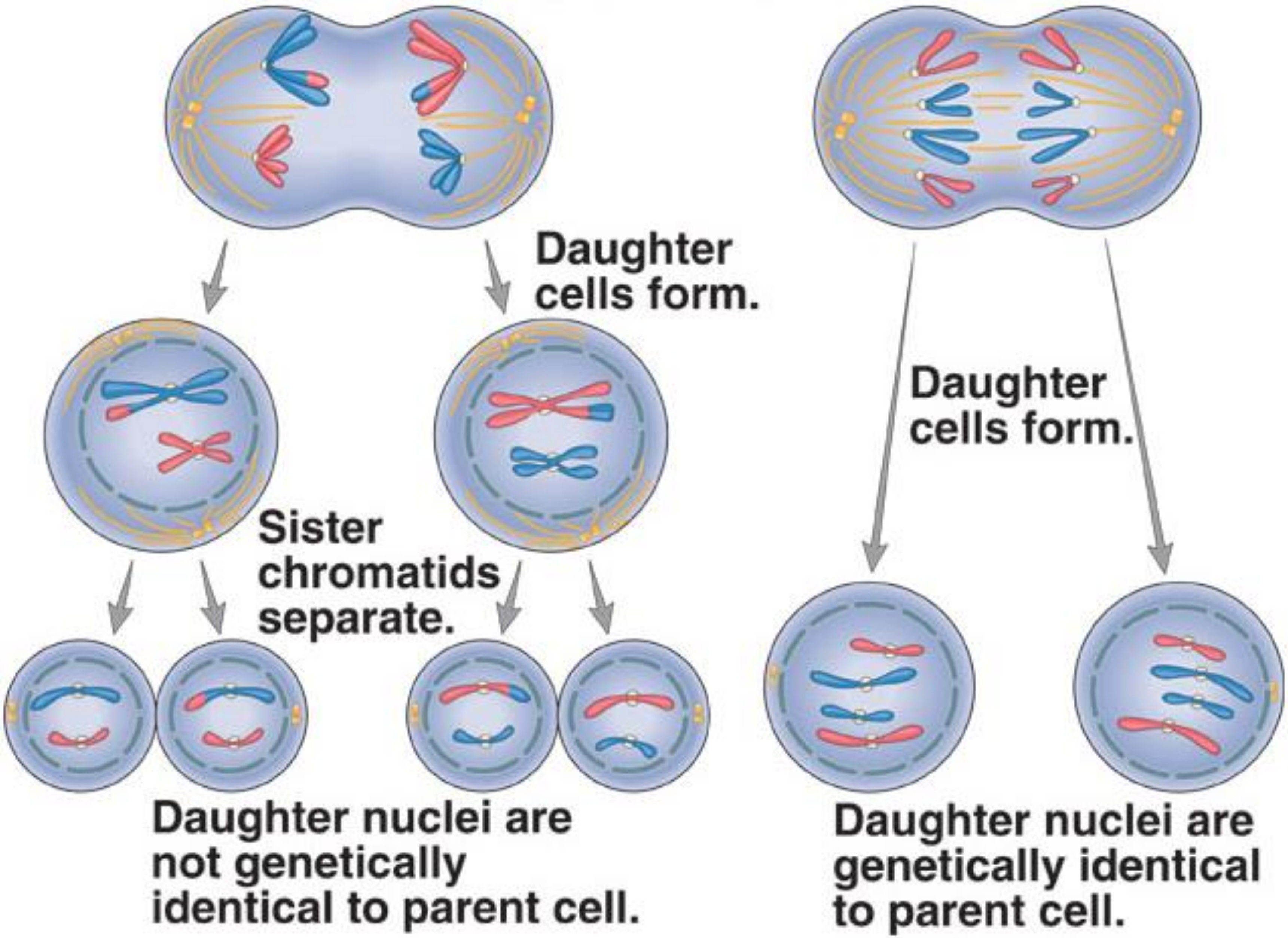
Comparison of Meiosis II to Mitosis

The events of meiosis II are like those of mitosis except in meiosis II, the nuclei contain the haploid number of chromosomes.

At the end of telophase II of meiosis II, there are four haploid daughter cells that are not genetically identical.

At the end of mitosis, there are two diploid daughter cells that are identical.


Meiosis
Synapsis and crossing-over occur.
Homologues align independently.
Homologues separate.
Mitosis
Chromosomes align at the metaphase plate.
Sister chromatids separate.


Daughter
cells form.
Sister
chromatids
separate.
Daughter nuclei are
not genetically
identical to parent cell.
Daughter
cells form.
Daughter nuclei are
genetically identical
to parent cell.

The human life cycle requires both mitosis and meiosis.

In males, meiosis occurs as *spermatogenesis* and produces sperm.

In females, meiosis occurs as *oogenesis* and produces egg cells.

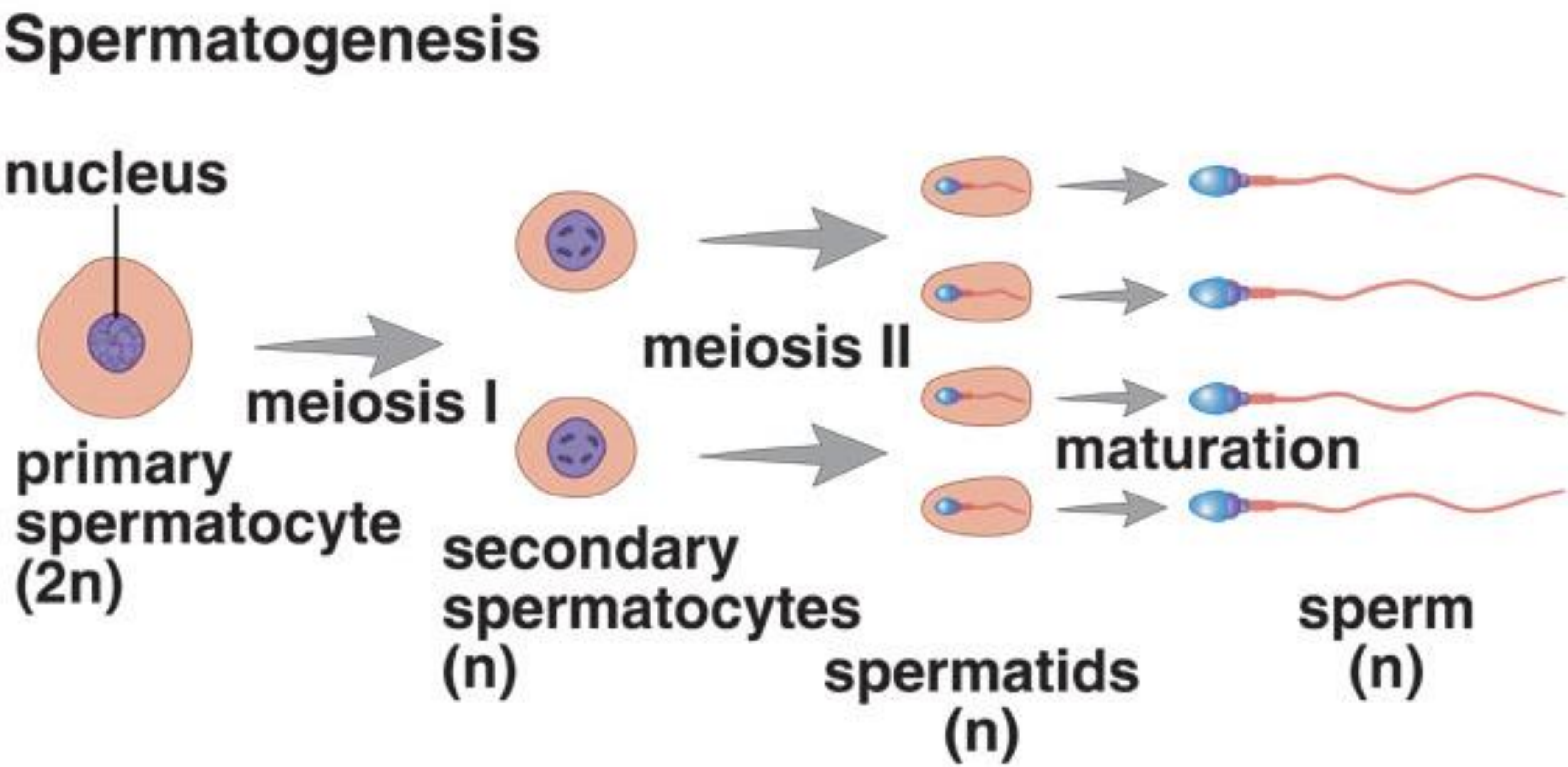
Mitosis is involved in the growth of a child and repair of tissues during life.

Spermatogenesis in human males produces four viable haploid *sperm*.

Diploid *primary spermatocytes* undergo meiosis I to produce haploid *secondary spermatocytes*.

Secondary spermatocytes divide by meiosis II to produce haploid *spermatids*.

Spermatids mature into sperm with 23 chromosomes.


Spermatogenesis
nucleus
meiosis I
primary
spermatocyte
(2n)
meiosis II
secondary
spermatocytes
(n)
spermatids
(n)
maturation
sperm
(n)

During oogenesis, a diploid *primary oocyte* undergoes meiosis I to produce one haploid *secondary oocyte* and one haploid *polar body*.

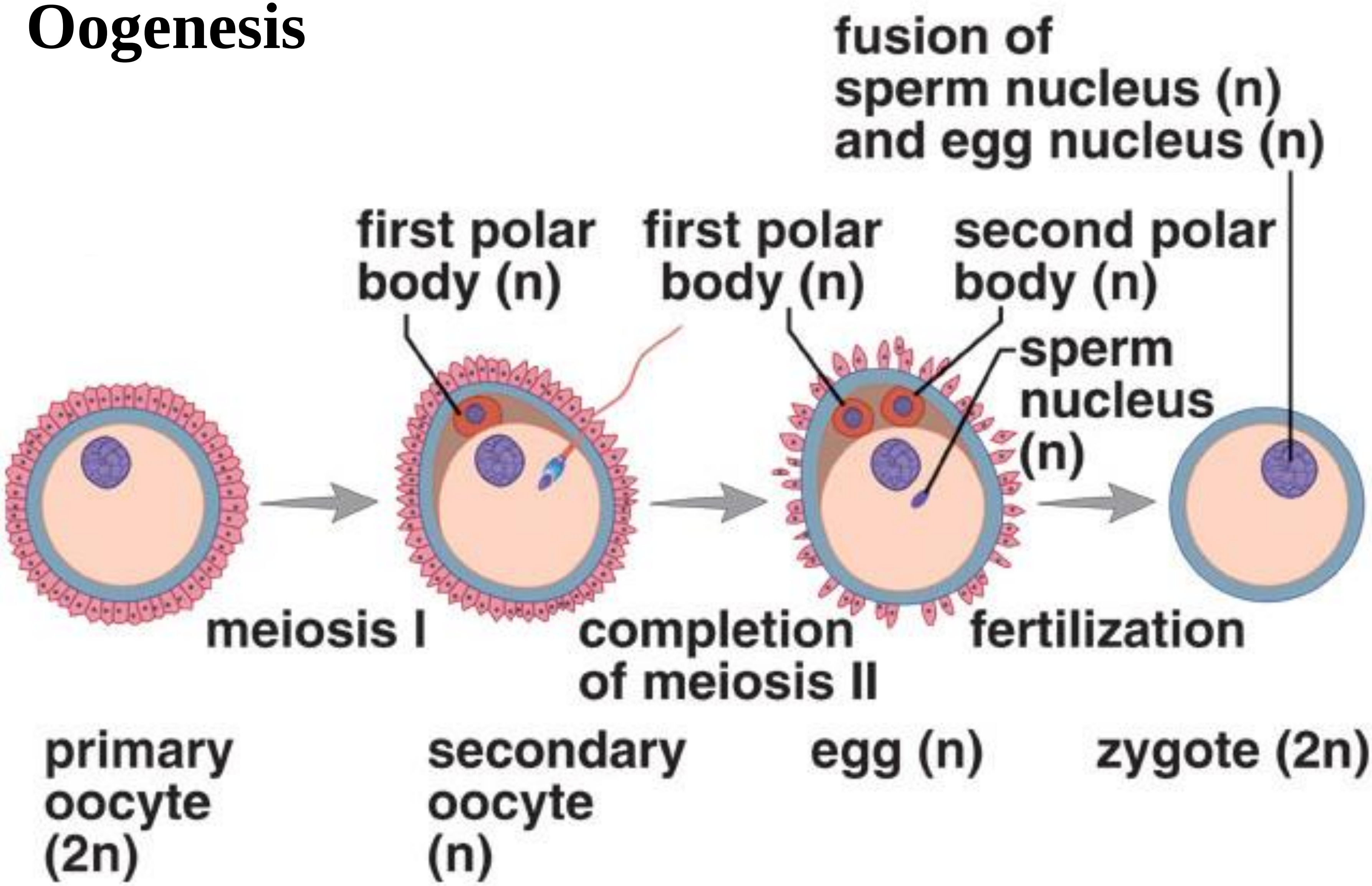
The secondary oocyte begins meiosis II but stops at metaphase II and is released at this stage from the ovary.

Meiosis II will be completed only if sperm are present.

Following meiosis II, there is one haploid egg cell with 23 chromosomes and up to three polar bodies.

Polar bodies serve as a dumping ground for extra chromosomes.

Oogenesis


fusion of
sperm nucleus (n)
and egg nucleus (n)
first polar
body (n)
first polar
body (n)
second polar
body (n)
sperm
nucleus
(n)
meiosis I
completion
of meiosis II
fertilization
primary
oocyte
(2n)
secondary
oocyte
(n)
egg (n)
zygote (2n)

In humans, both sperm cells and the egg cell have 23 chromosomes each.

Following fertilization of the egg cell by a single sperm, the *zygote* has 46 chromosomes, the diploid number found in human somatic cells.

The 46 chromosomes represent 23 pairs of homologous chromosomes.

Genetic Recombination in Humans

There are three ways in which meiosis and fertilization ensure that a child has a different combination of genes from that of either parent:

1. Independent assortment of chromosomes during metaphase I
2. Crossing-over during prophase I
3. Upon fertilization, recombination of chromosomes from different individuals (via their gametes) occurs.

These are the same three we talked about previously.

Summary

Cell division increases the number of body cells;
Apoptosis decreases cell number.

Cells goes through a cell cycle.

Each species has a characteristic number of chromosomes.

Mitosis

1. produces daughter cells that are identical to the parental cell.
2. has four phases designed to maintain the chromosome number.
3. is used for growth and repair of tissues.

Summary continued

Meiosis

1. reduces the chromosome number.
2. includes two nuclear divisions.
3. results in non-identical haploid gametes.

The human life cycle includes both mitosis and meiosis.

The process of meiosis and fertilization in humans and other sexually reproducing organisms result in offspring with new genetic combination.