Cell Division

Lecture 2

Sexual Reproduction

- During the many rounds of cell division within an embryo, most cells either grow and divide via the mitotic cell cycle just described
  - Somatic cells whose descendants continue to make up the vast majority of each organism's tissues throughout the lifetime of the individual.
- Sexual reproduction is the most common way for eukaryotic organisms to produce offspring
  - Germ cells are precursors to gametes
  - Become incorporated into reproductive organs (ovaries and testes in animals)
  - where they ultimately undergo meiosis

Meiosis

- The special two-part cell division that produces gametes (eggs and sperm)
- Meiosis produces haploid cells (containing half the number of chromosomes) from a cell that was originally diploid
- Like mitosis, meiosis begins after a cell has progressed through interphase (G1, S, and G2) of the cell cycle
  - Chromosomes duplicate once

Meiosis

- Unlike mitosis, meiosis involves two successive divisions
  - Meiosis I (reductional division): homologs pair up and separate, resulting in two haploid daughter cells with replicated chromosomes
  - Meiosis II (equational division) sister chromatids separate
- The result is four haploid daughter cells with unreplicated chromosomes

Figure 13.7-1

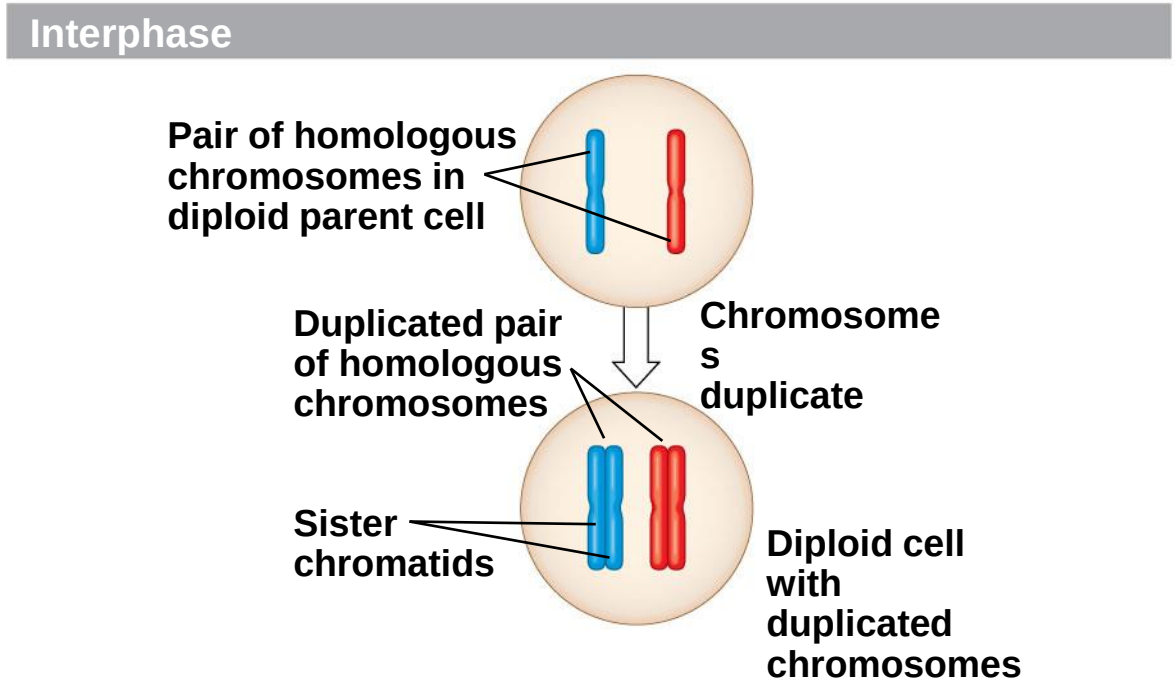

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Figure 13.7-2

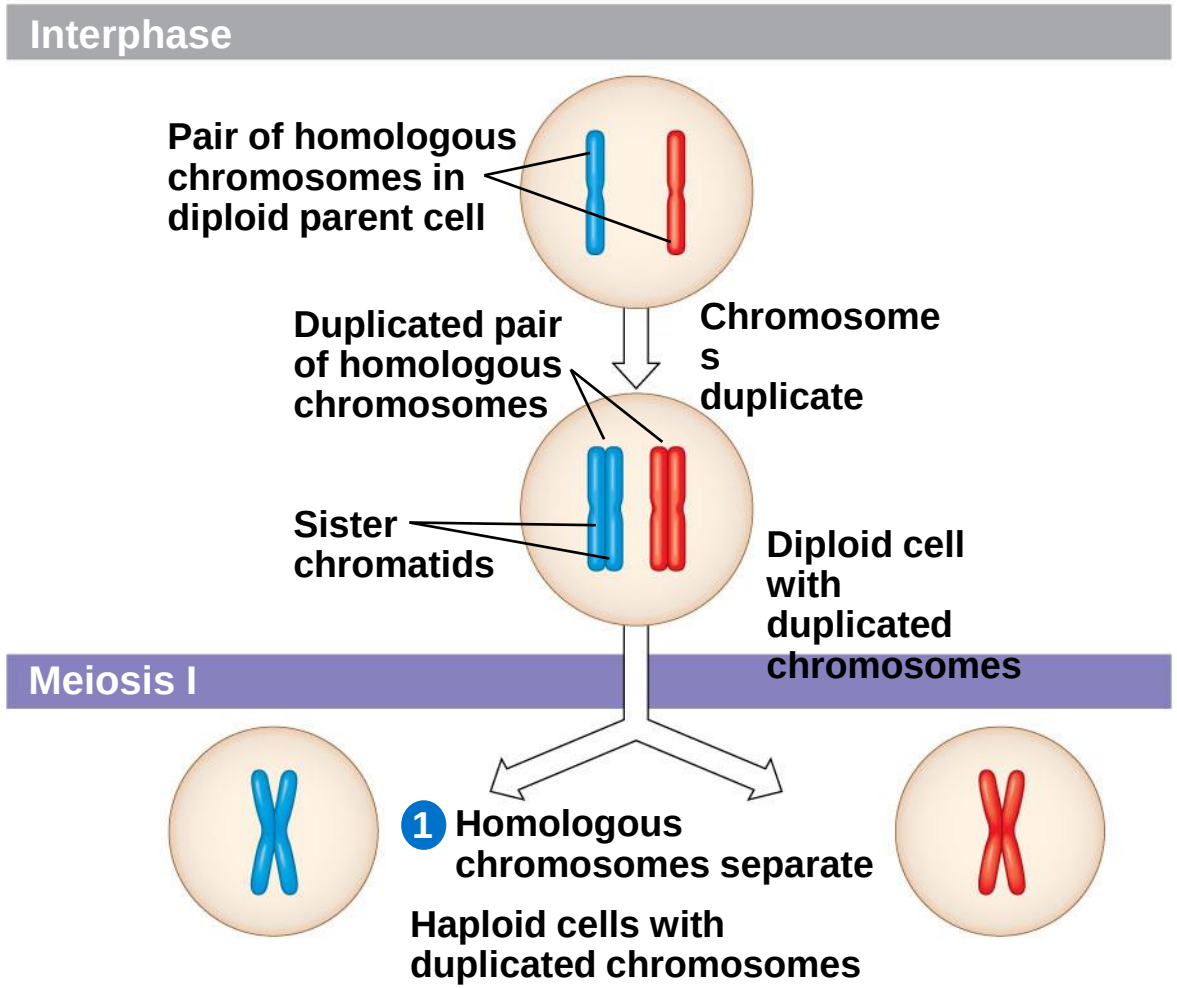

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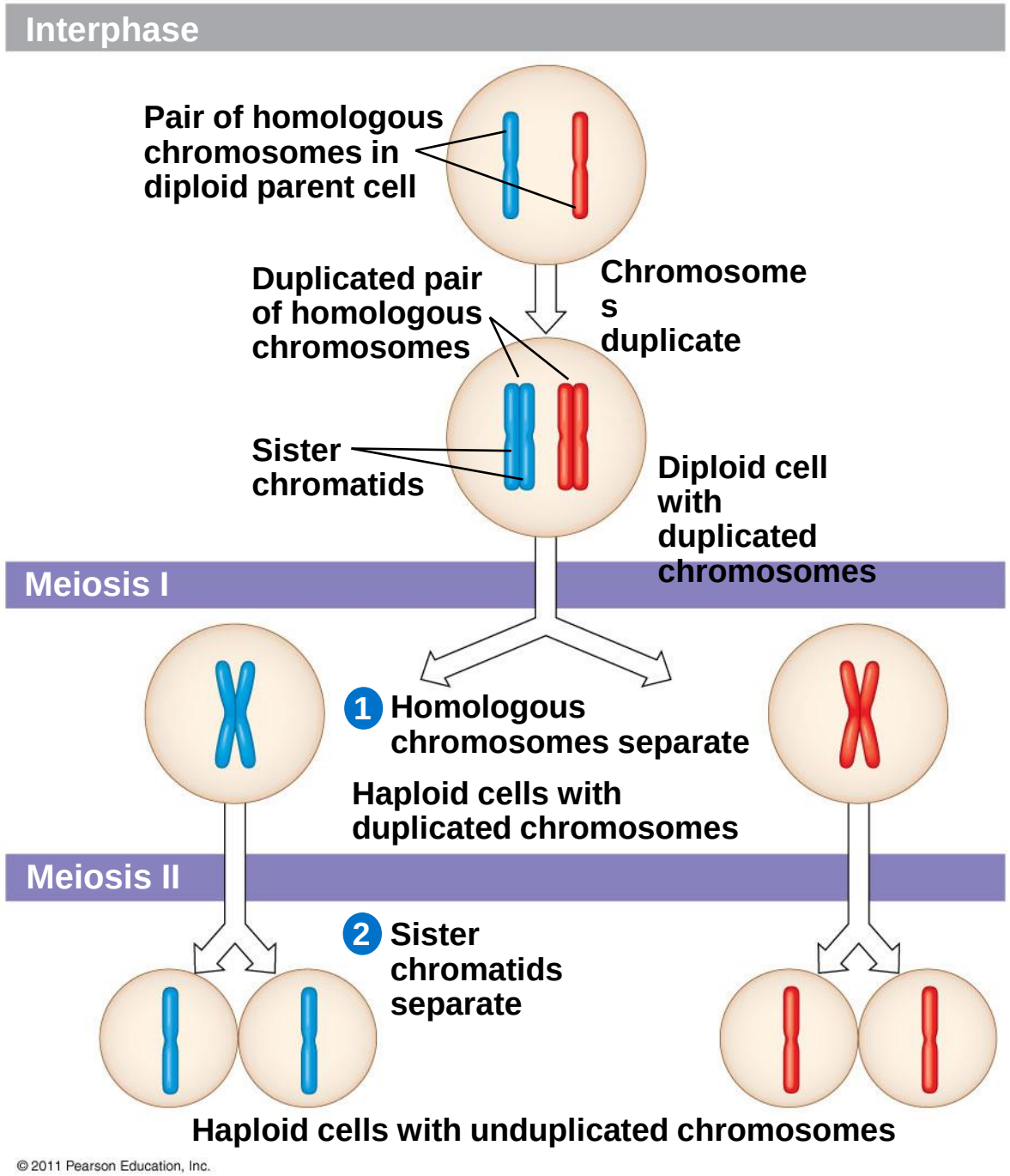
Figure 13.7-3



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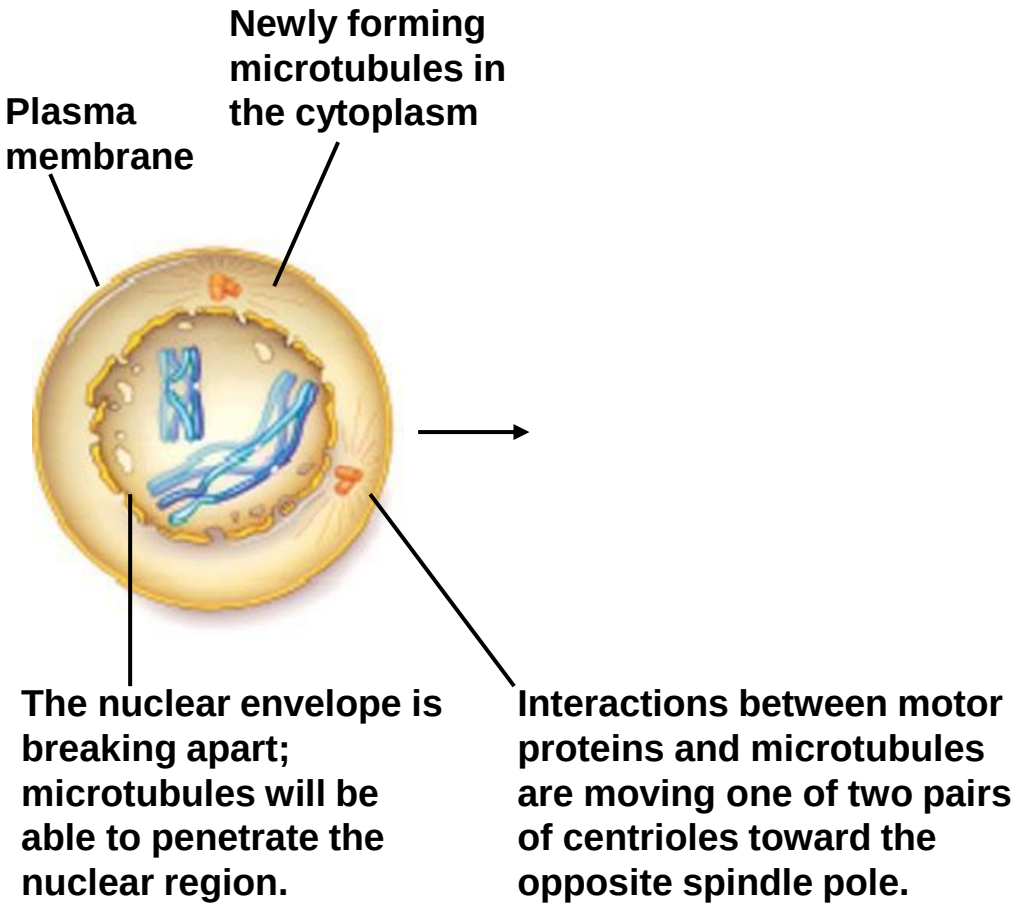
Meiosis

- Prophase I is further subdivided into periods known as
  - Leptotena
  - Zygotena
  - Pachytena
  - Diplotena
  - Diakinesis

Meiosis I



(a) Prophase I

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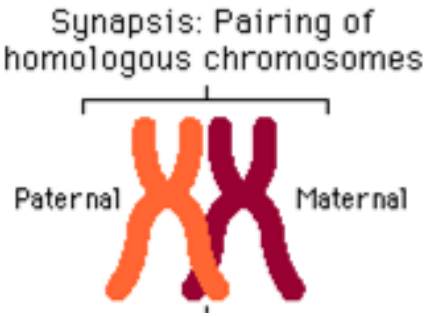
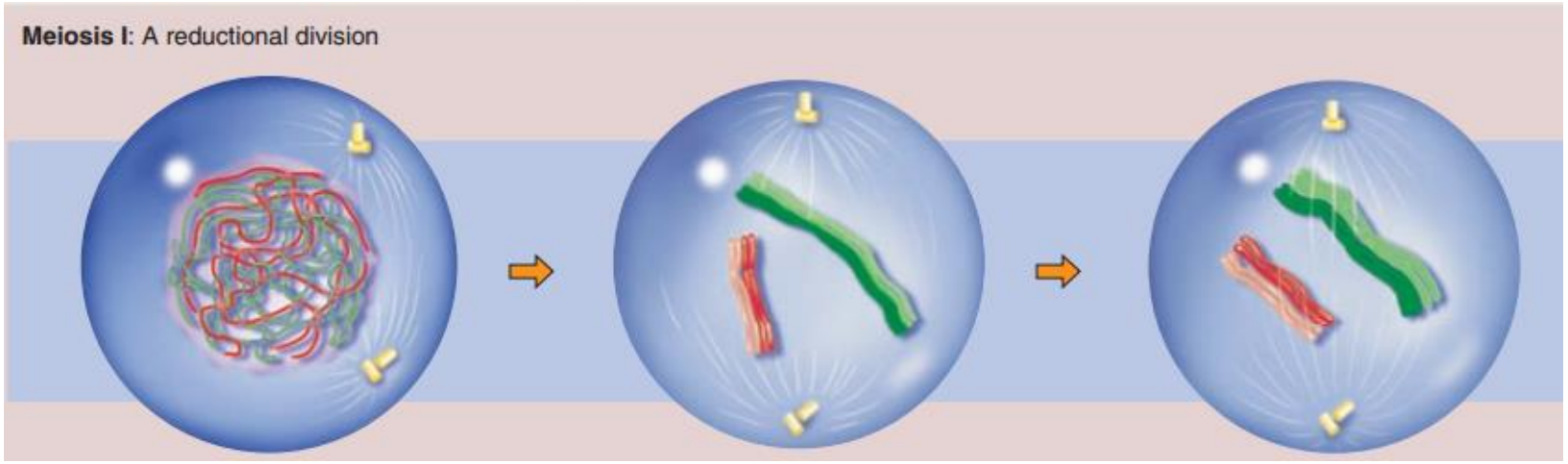
The first three substages of prophase I: Leptotene, zygotene, and pachytene

- Condensation of chromatin, the pairing of homologous chromosomes, and the reciprocal exchange of genetic information between these paired homologs.





Prophase I: **Leptotene**
(from the Greek for “thin” and “delicate”)
1. Chromosomes thicken and become visible, but the chromatids remain invisible.
2. Centrosomes begin to move toward opposite poles.

Prophase I: **Zygotene**
(from the Greek for conjugation)
1. Homologous chromosomes enter synapsis.
2. The synaptonemal complex forms.

Prophase I: **Pachytene**
(from the Greek for “thick” or “fat”)
1. Synapsis is complete.
2. Crossing-over, genetic exchange between nonsister chromatids of a homologous pair, occurs.

Fig. 4.13

Pachytene

- During pachytene: each synapsed chromosome pair is known as a bivalent (because it encompasses two chromosomes), or a tetrad (because it contains four chromatids).
- Structures called recombination nodules (chiasmata) begin to appear along the synaptonemal complex, and an exchange of parts between nonsister (that is, between maternal and paternal) chromatids occurs at these nodules

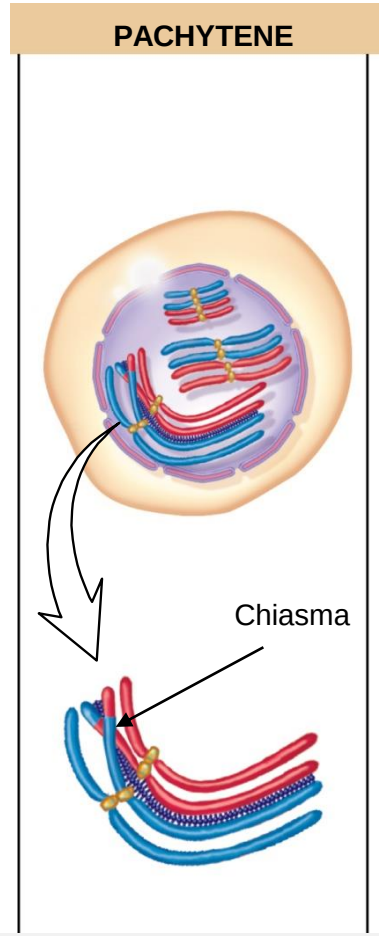


Figure 3.10

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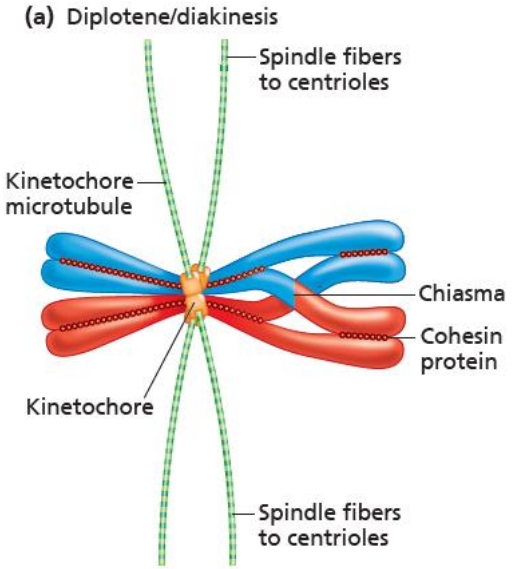
Diplotene and Diakinesis



- **Diplotene**
- Synaptonemal complex dissolves.
- A tetrad of four chromatids is visible.
- Nonsister chromatids appears to pull apart slightly but remains connected at chiasmata.
- Meiotic arrest occurs at this time in many species

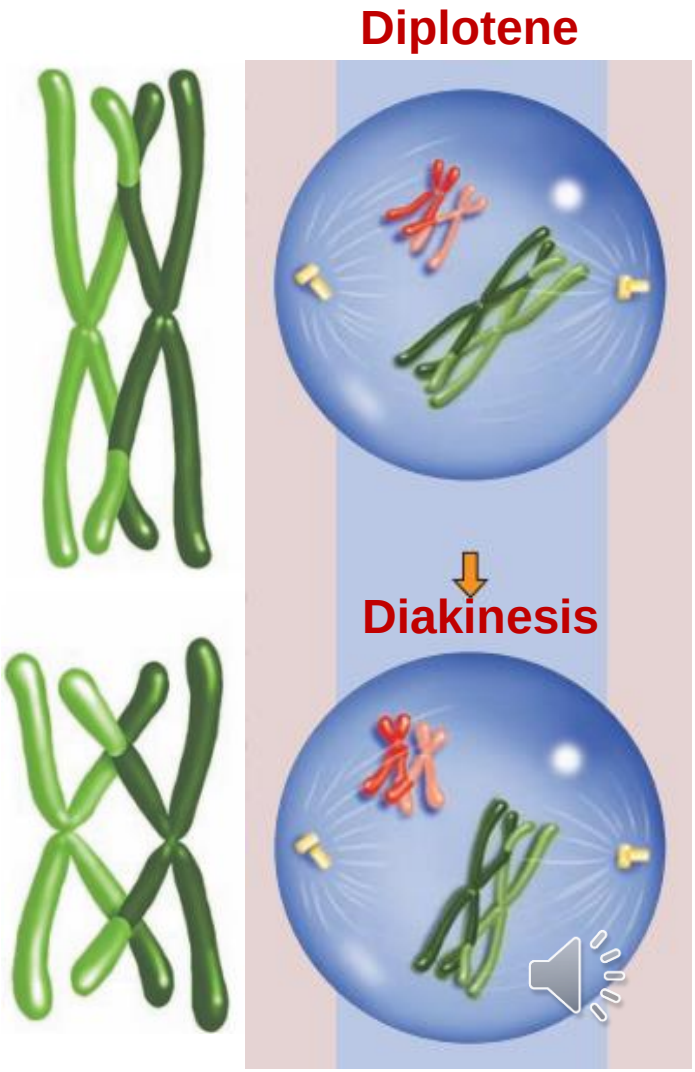


Figure 3.10

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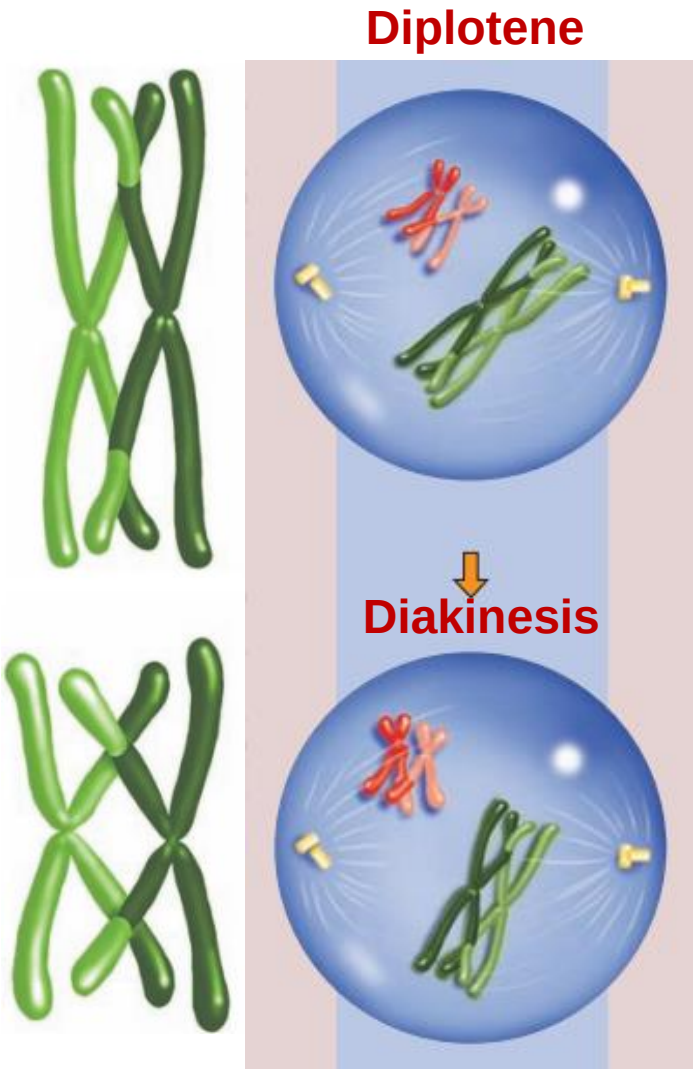
Diplotene and Diakinesis

- **Diakinesis**
- Further condensation of chromatids.
  - Chromatids thicken and shorten
- Nonsister chromatids remain closely associated at chiasmata.
- The end of diakinesis is analogous to the prometaphase of mitosis:
  - The nuclear envelope breaks down, and the microtubules of the spindle apparatus.
- These processes can take many days, months, or even years to complete.
  - For example, in the human females germ cells, meiosis is suspended at prophase I until ovulation



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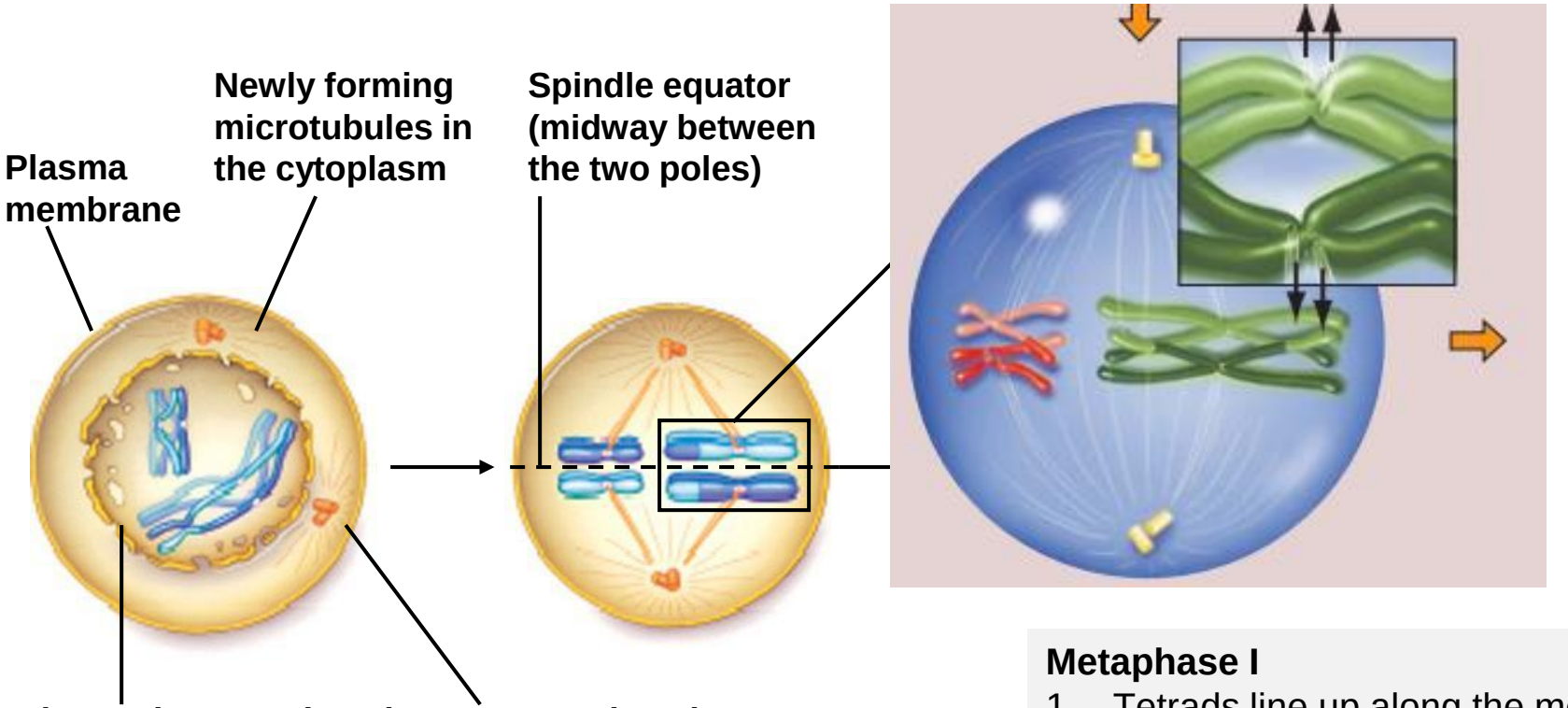
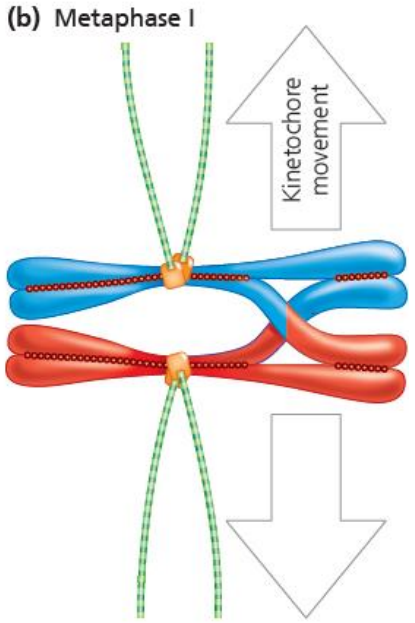
Meiosis I



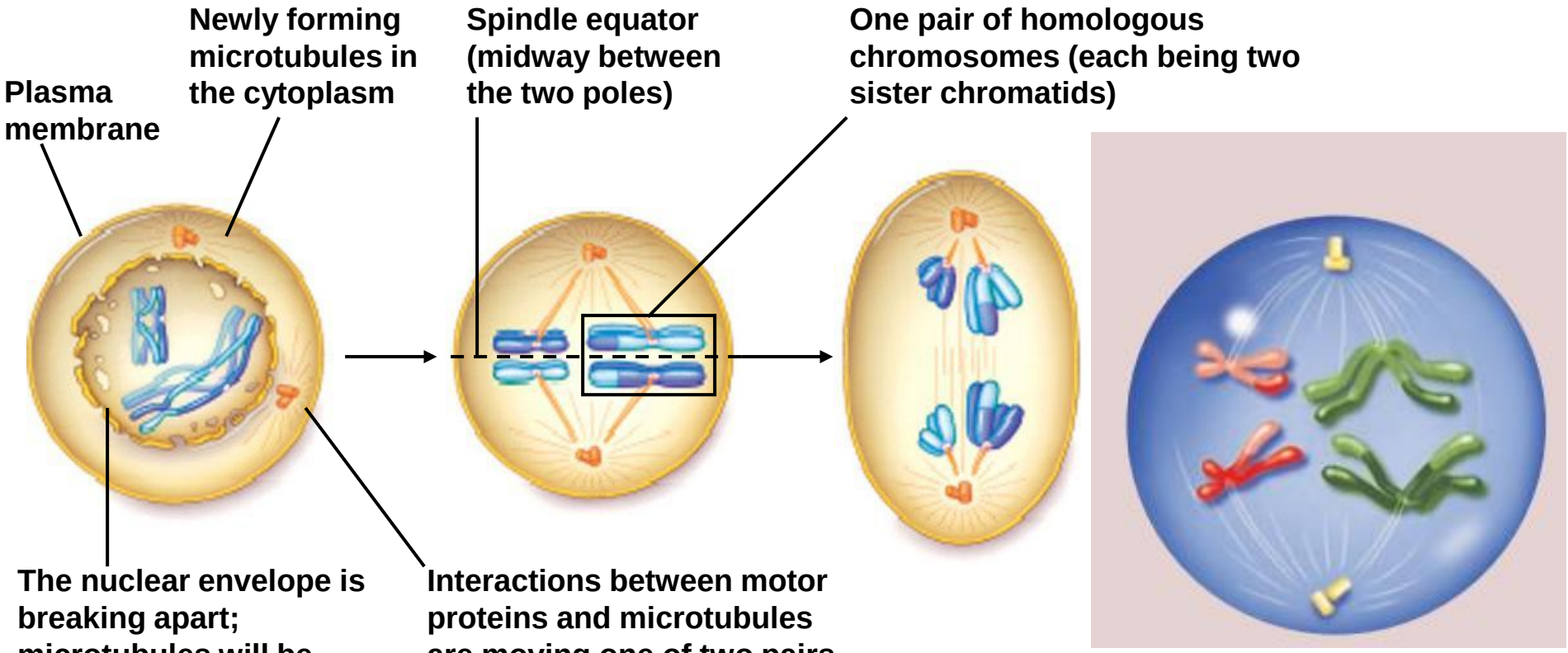


Metaphase I

1. Tetrads line up along the metaphase plate.
2. Each chromosome of a homologous pair attaches to fibers from opposite poles.
3. Sister chromatids attach to fibers from the same pole.

Stepped Art

Meiosis I



Anaphase I

1. The centromere does not divide and sister chromatids are not separated
2. The chiasmata migrate off chromatid ends.
3. Homologous chromosomes move to opposite poles.

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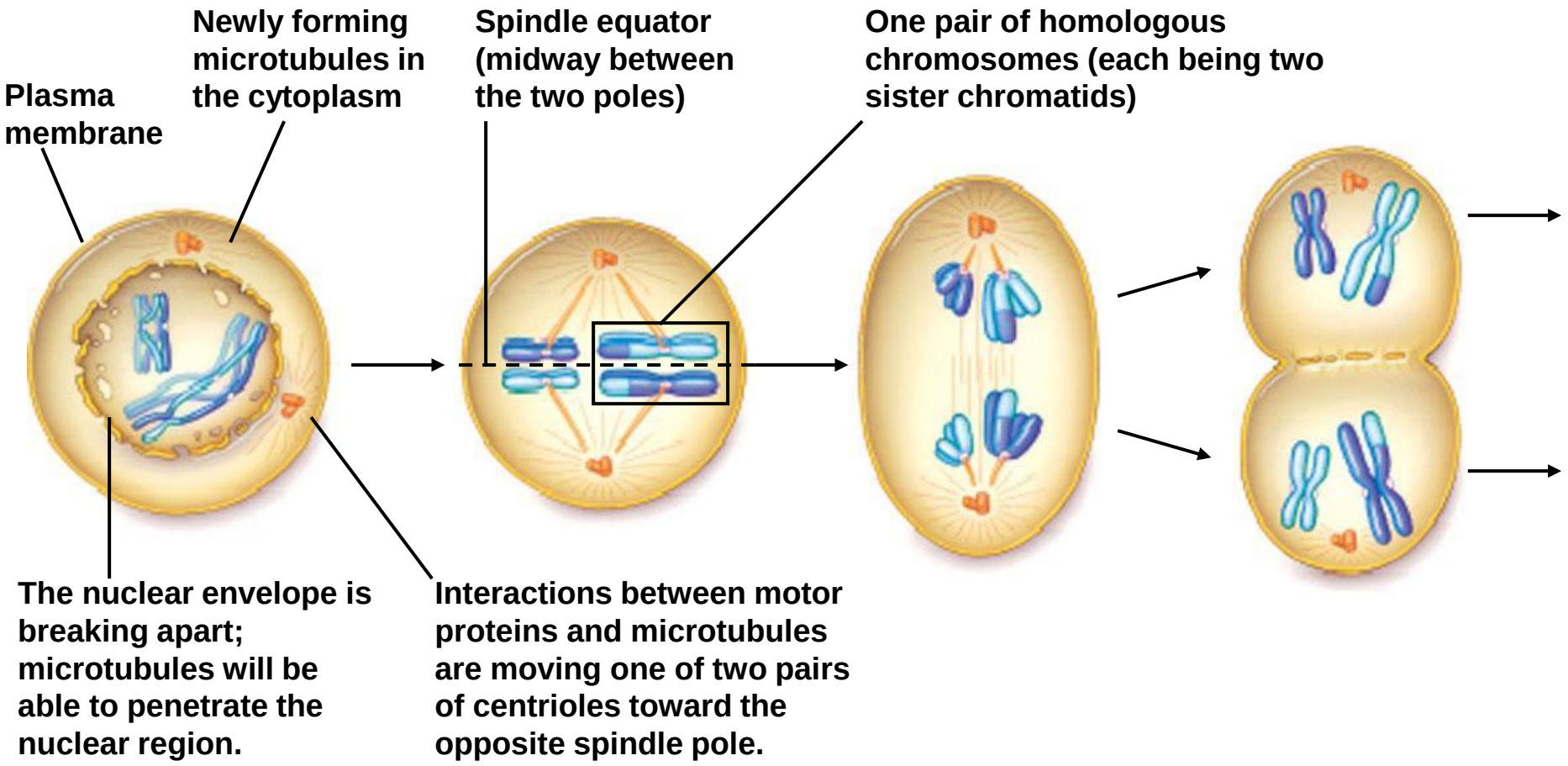
Meiosis I



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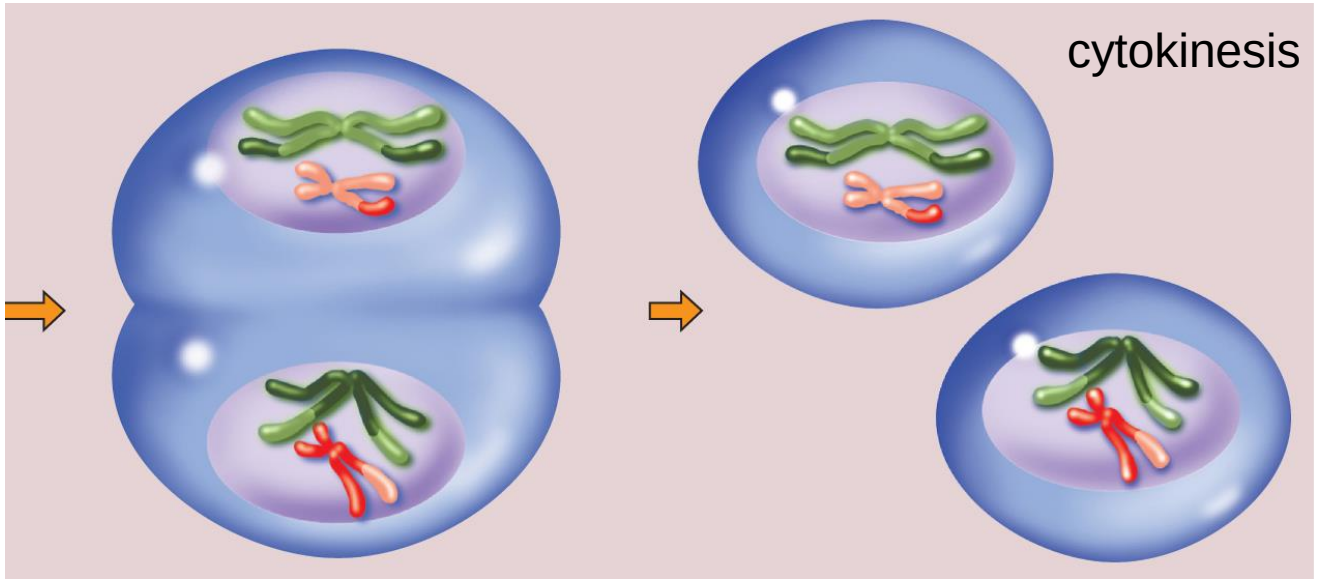
Meiosis I is a reductional division

Fig. 4.13



Telophase I

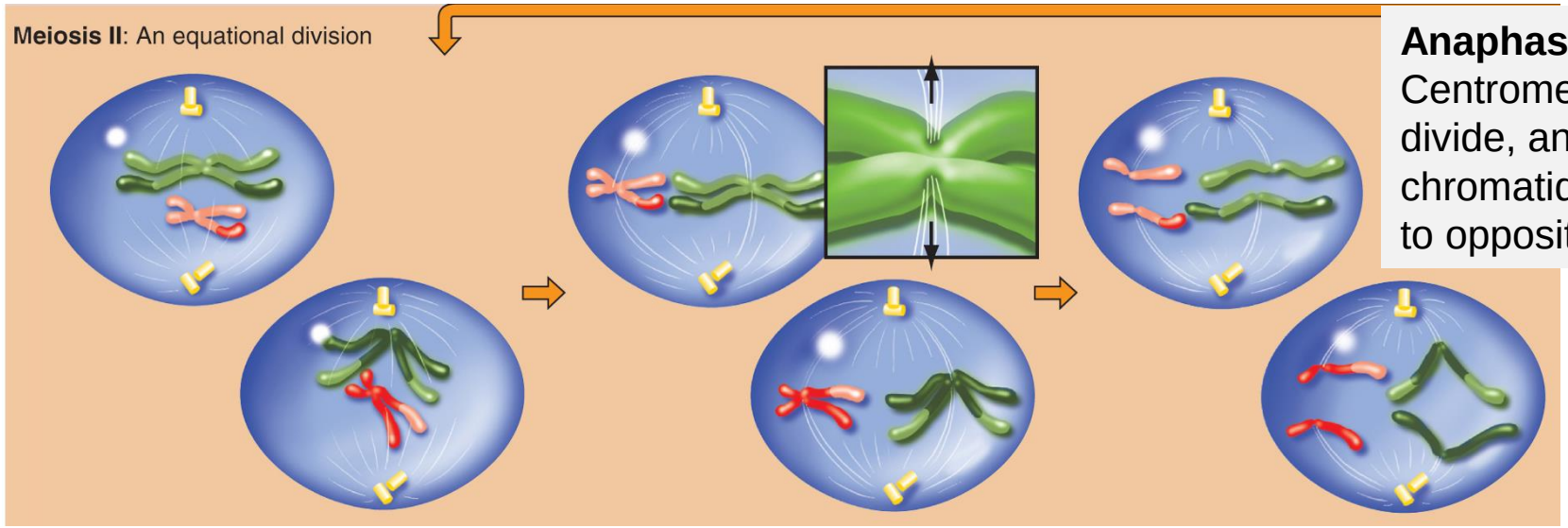
1. The nuclear envelope re-forms.
2. Resultant cells have half the number of chromosomes, each consisting of two sister chromatids.

There is no DNA replication between the two nuclear divisions.

Meiosis I is followed by cytokinesis and then meiosis II

During meiosis II, sister chromatids separate and move to opposite poles

- The sorting events that occur during meiosis II are similar to those that occur during mitosis



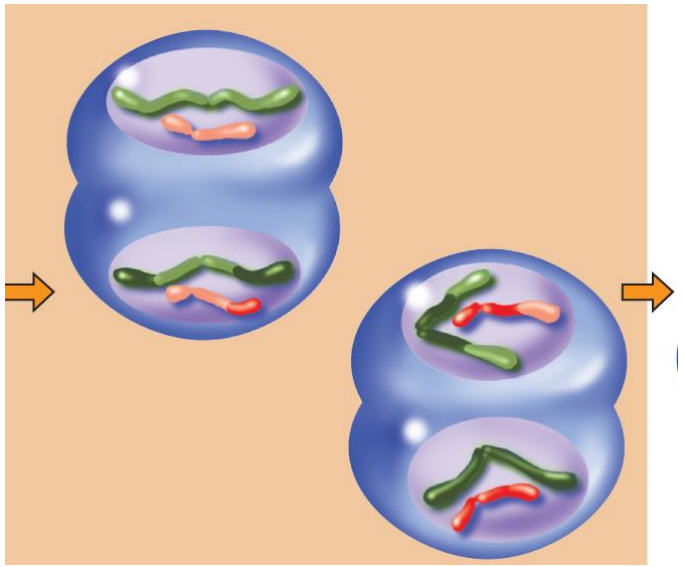
Anaphase II
Centromeres divide, and sister chromatids move to opposite poles.

Prophase II
1. Chromosomes condense.
2. Centrioles move toward the poles.
3. The nuclear envelope breaks down at the end of prophase II (not shown).

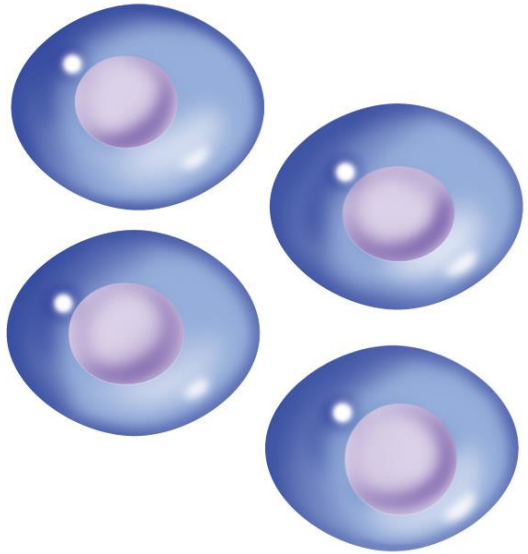
Metaphase II
1. Chromosomes align at the metaphase plate.
2. Sister chromatids attach to spindle fibers from opposite poles.

Fig. 4.13

Meiosis II is an equational division



Telophase II
1. Chromosomes begin to uncoil.
2. Nuclear envelopes and nucleoli (not shown) re-form.

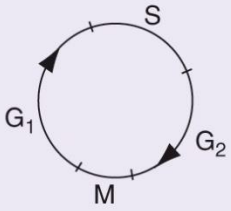
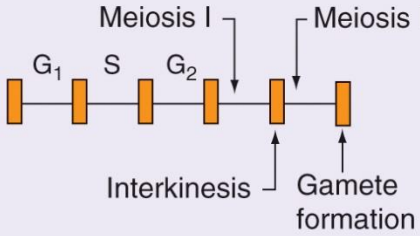
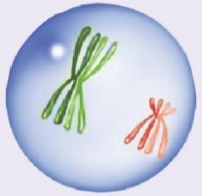
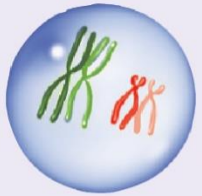


Cytokinesis
The cytoplasm divides, forming four new haploid cells.

- Each daughter cell (gamete) has the same Ch.# as the parental cell present at the beginning of this division.
- For this reason, meiosis II is termed an equational division

Figure. 4.13

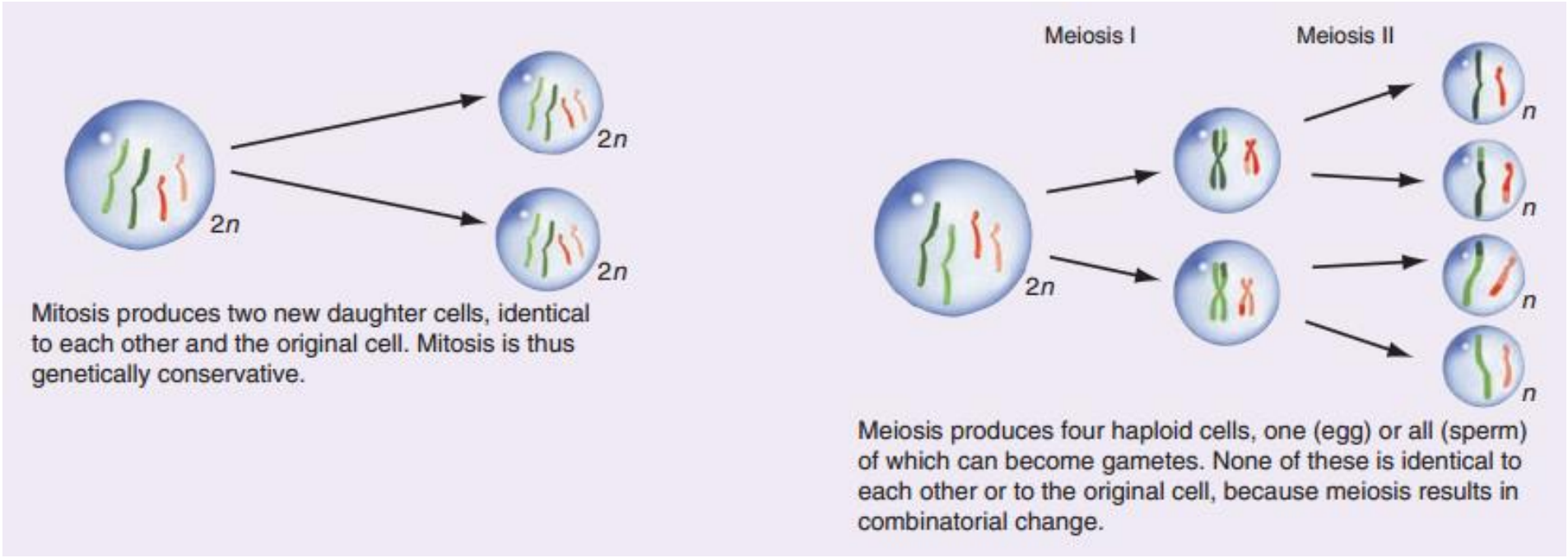
Comparison of mitosis and meiosis

Mitosis	Meiosis
Occurs in somatic cells Haploid and diploid cells can undergo mitosis One round of division	Occurs in germ cells as part of the sexual cycle Two rounds of division, meiosis I and meiosis II Only diploid cells undergo meiosis
 Mitosis is preceded by S phase (chromosome duplication).	 Chromosomes duplicate prior to meiosis I but not before meiosis II.
 Homologous chromosomes do not pair.	 During prophase of meiosis I, homologous chromosomes pair (synapse) along their length.
Genetic exchange between homologous chromosomes is very rare.	 Crossing-over occurs between homologous chromosomes during prophase of meiosis I.

Comparison of mitosis and meiosis

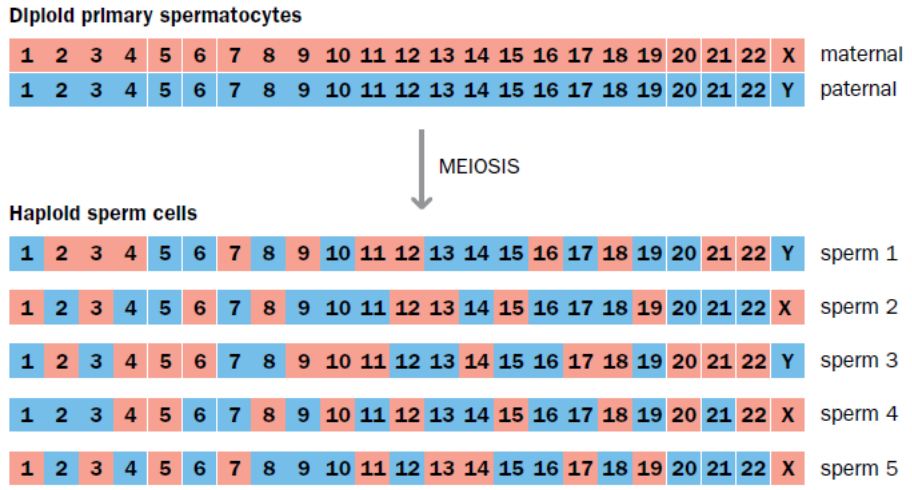
Mitosis	Meiosis
 Sister chromatids attach to spindle fibers from opposite poles during metaphase.	 Homologous chromosomes (not sister chromatids) attach to spindle fibers from opposite poles during metaphase I.
 The centromere splits at the beginning of anaphase.	 The centromere does not split during meiosis I.
	 Sister chromatids attach to spindle fibers from opposite poles during metaphase II.
	 The centromere splits at the beginning of anaphase II.

Comparison of mitosis and meiosis



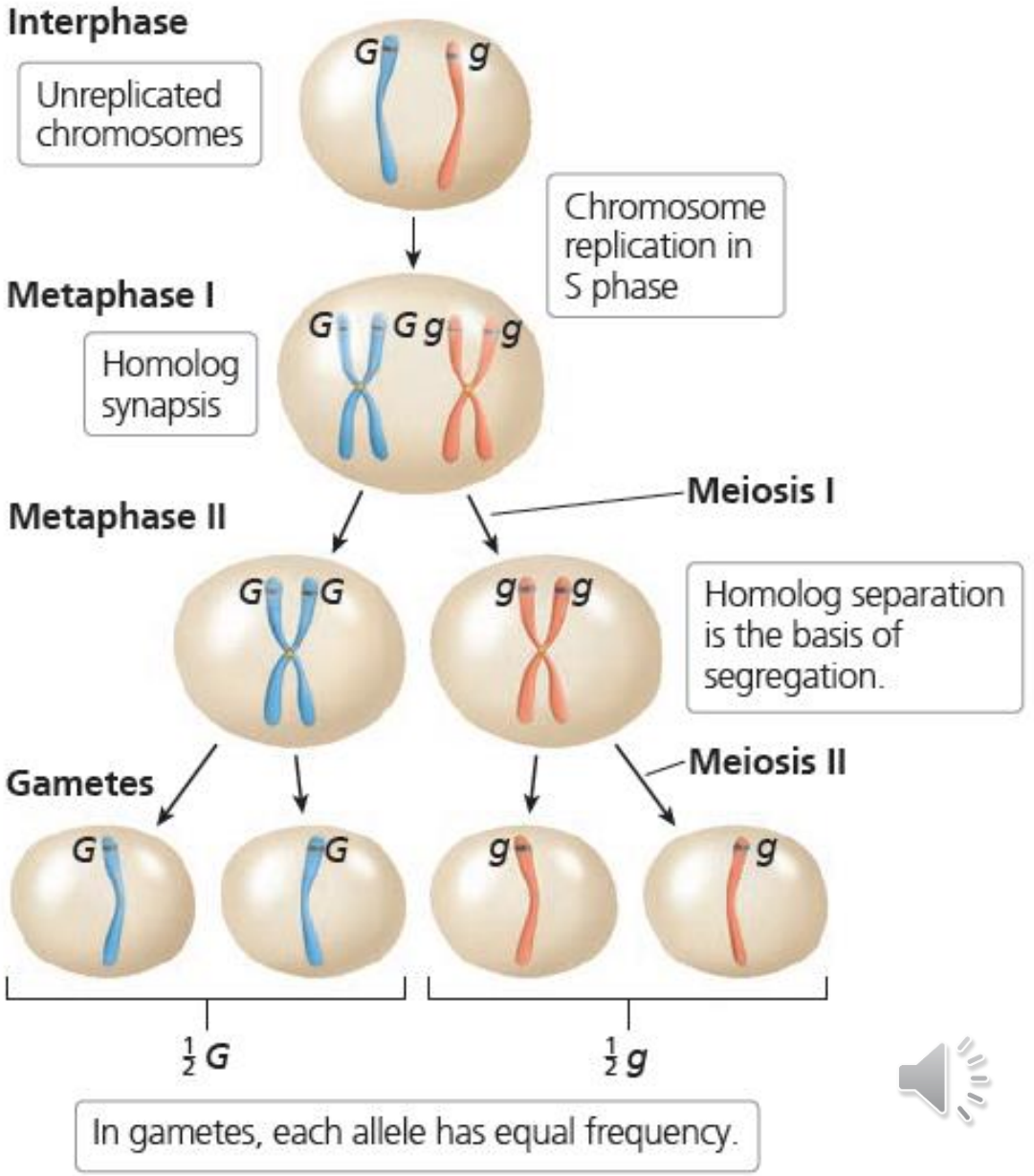
Consequences of meiosis

- Reduction of chromosome number
- Diploid to haploid (essential for gametes)
- Random assortment of maternal and paternal chromosomes
  - Number of possible chromosomal combinations = 2^{23} or 8,388,608
  - Recombination between chromosome pairs increases the possible combinations
- Segregation of alleles
- Recombination/crossing-over
  - Allows new combinations of genes to be produced
  - Important for normal chromosome disjunction
  - Ensures genetic diversity

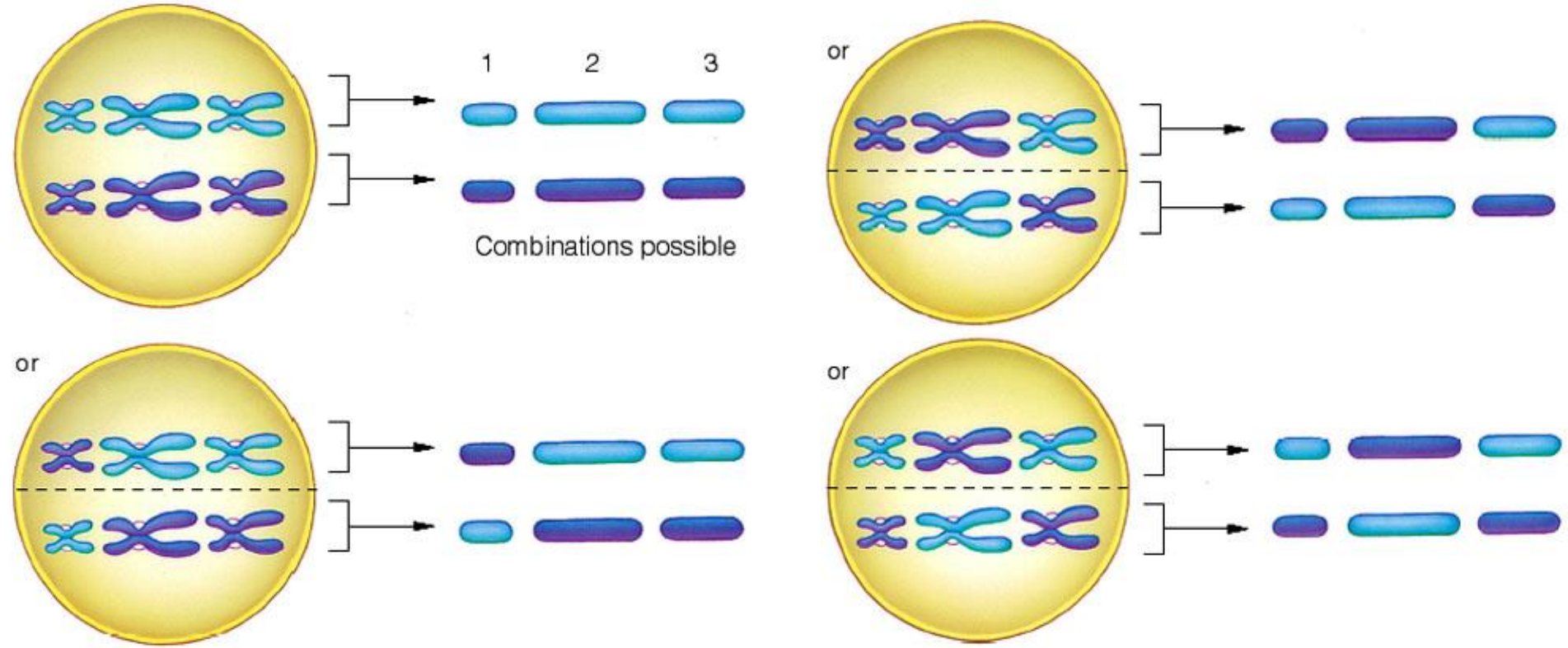


independent assortment of the genes that they carry. Independent assortment means that the fate of a gene on one chromosome is not influenced by a gene on a different chromosome

Law of Segregation



Chromosome combinations: independent assortment



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