UNIT 2 | CHROMOSOMIC BASIS OF INHERITANCE

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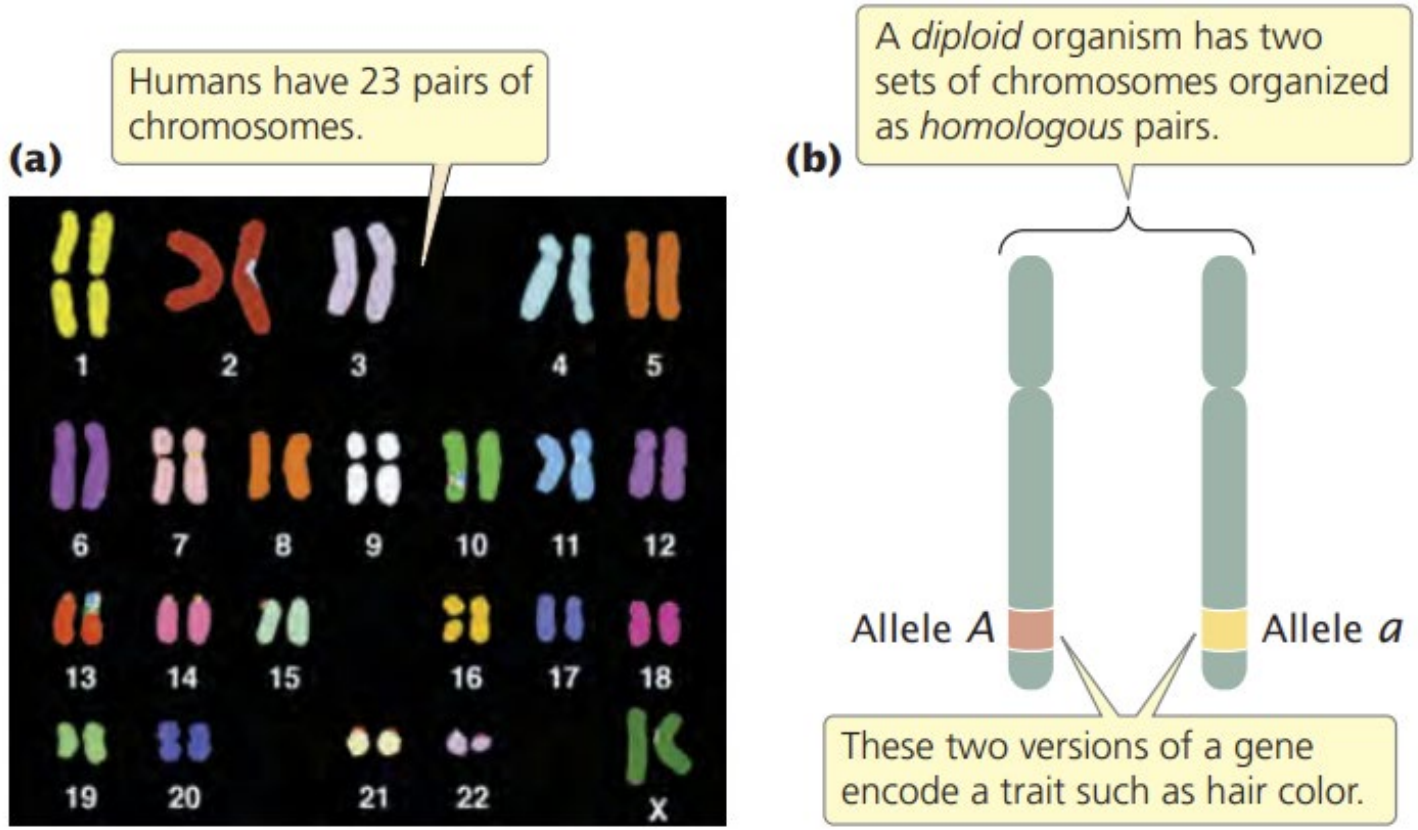
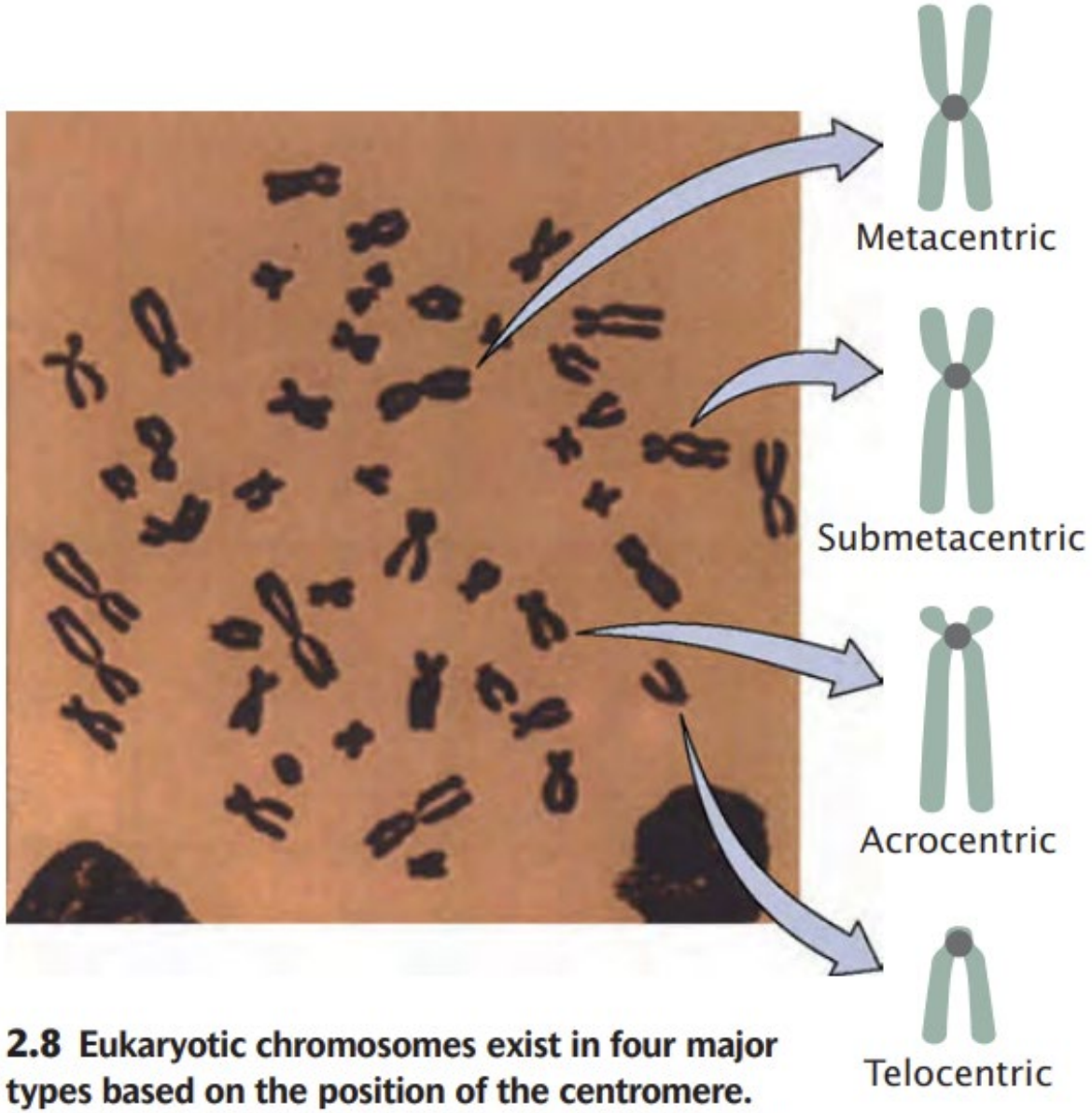
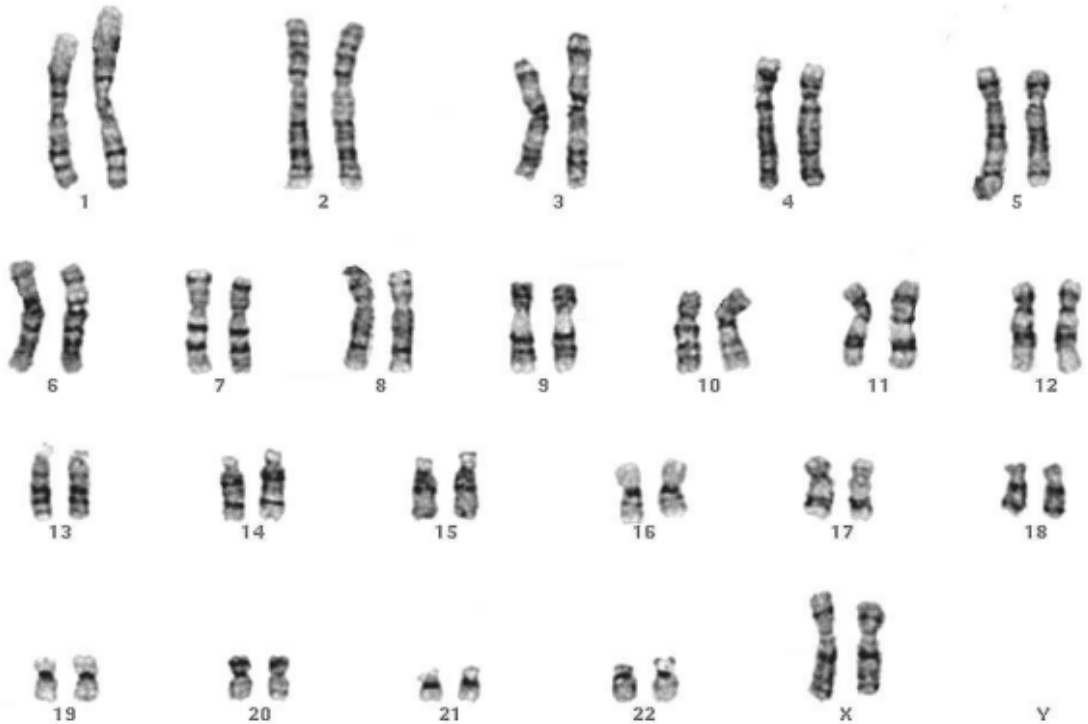
Source: Tijo & Levan, 1956 & exploratorium.edu


(a)
Humans have 23 pairs of chromosomes.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
X
(b)
A *diploid* organism has two sets of chromosomes organized as *homologous* pairs.
Allele *A*
Allele *a*
These two versions of a gene encode a trait such as hair color.

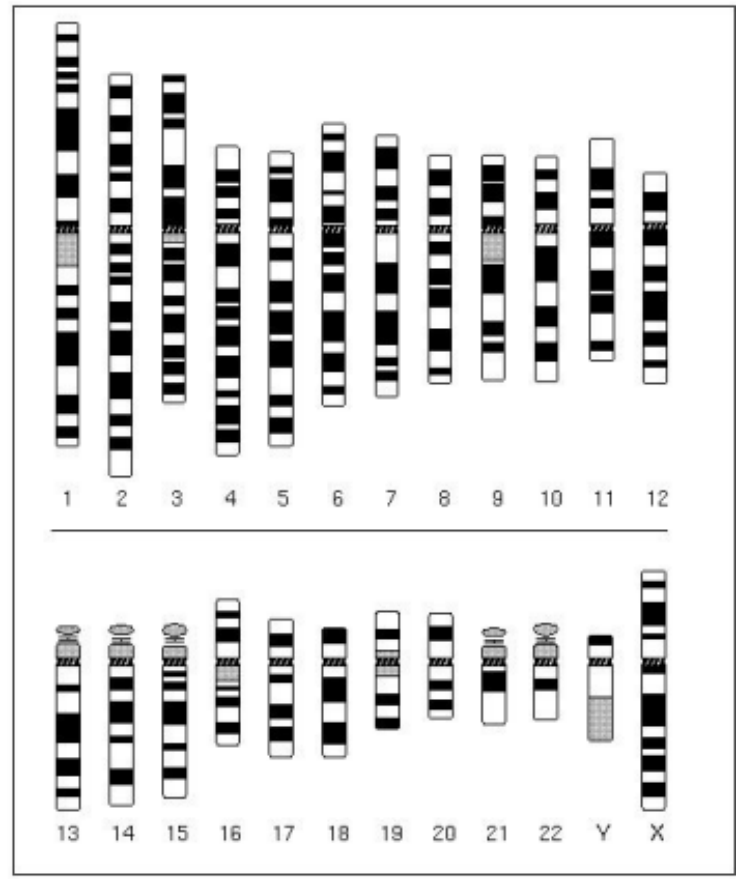


2.8 Eukaryotic chromosomes exist in four major types based on the position of the centromere.
[Micrograph by L. Lisco, D. W. Fawcett/Visuals Unlimited.]

Chromosome morphology
Size and relative position of centromeres



Karyotpye

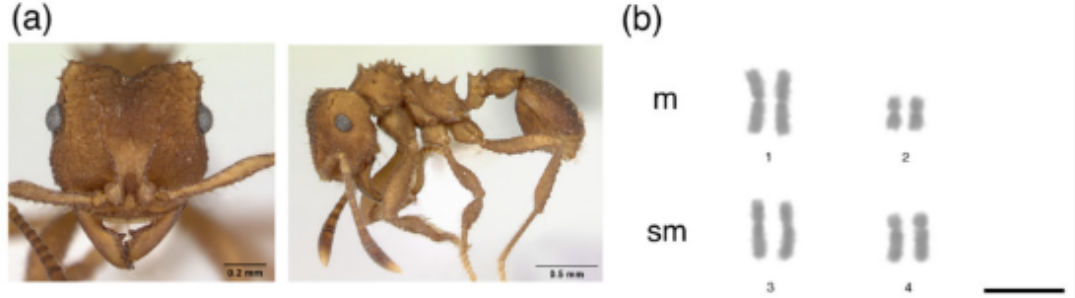


Idiogram

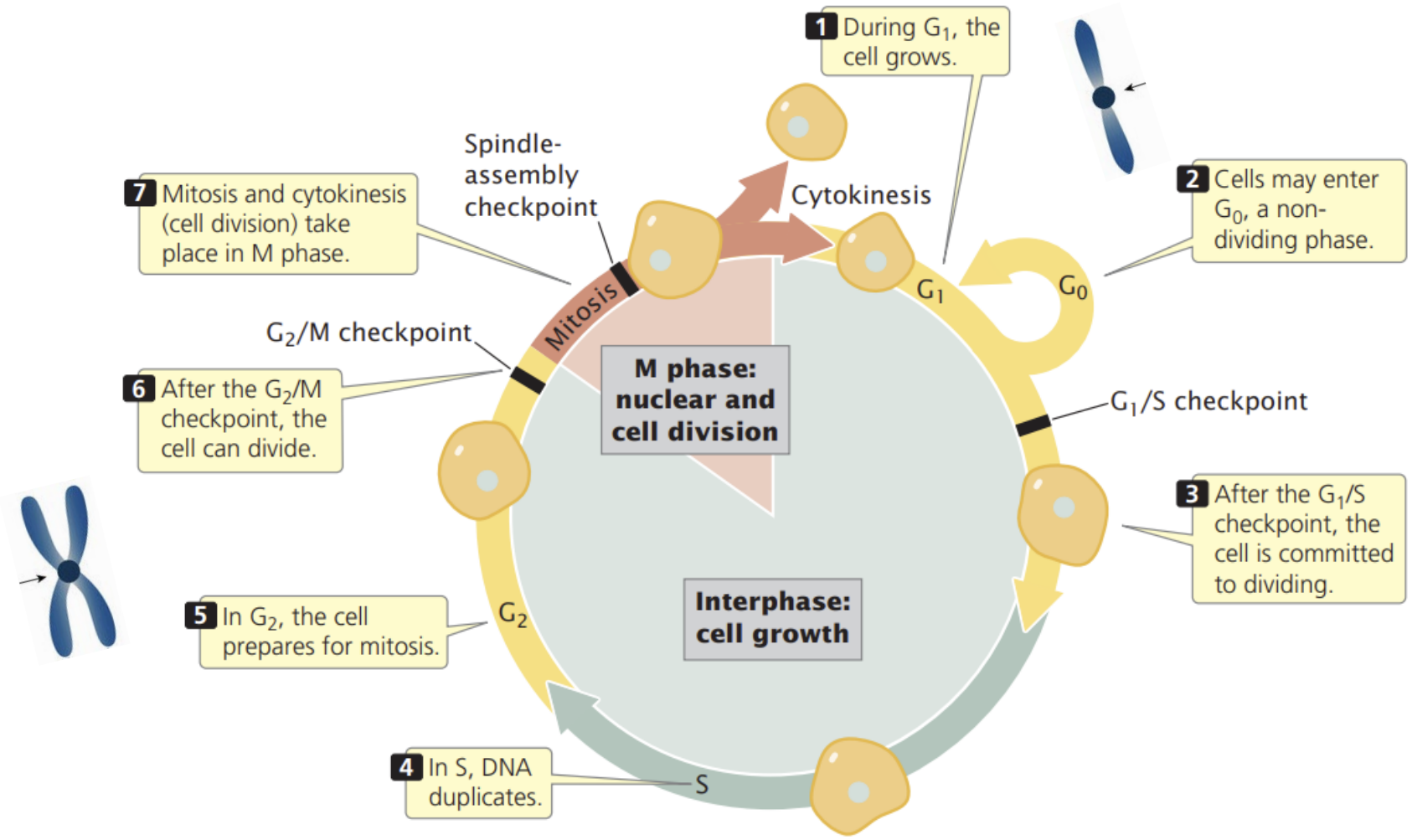
Chromosome diversity and evolution

Mitotic chromosomes of strugeon (2n=274?)

Figure 1. Mitotic chromosomes of *Mycocepurus goeldii* stained with Giemsa. Species (**a**) images and (**b**) diploid karyotype of *Mycocepurus goeldii* with 2*n* = 8 chromosomes. m = metacentric, sm = submetacentric. Scale bar = 5 µm. Ant image from AntWeb (**www.antweb.org**, accessed on 13 June 2021): *Mycocepurus goeldii* (CASENT0173988, photo by: A. Nobile).

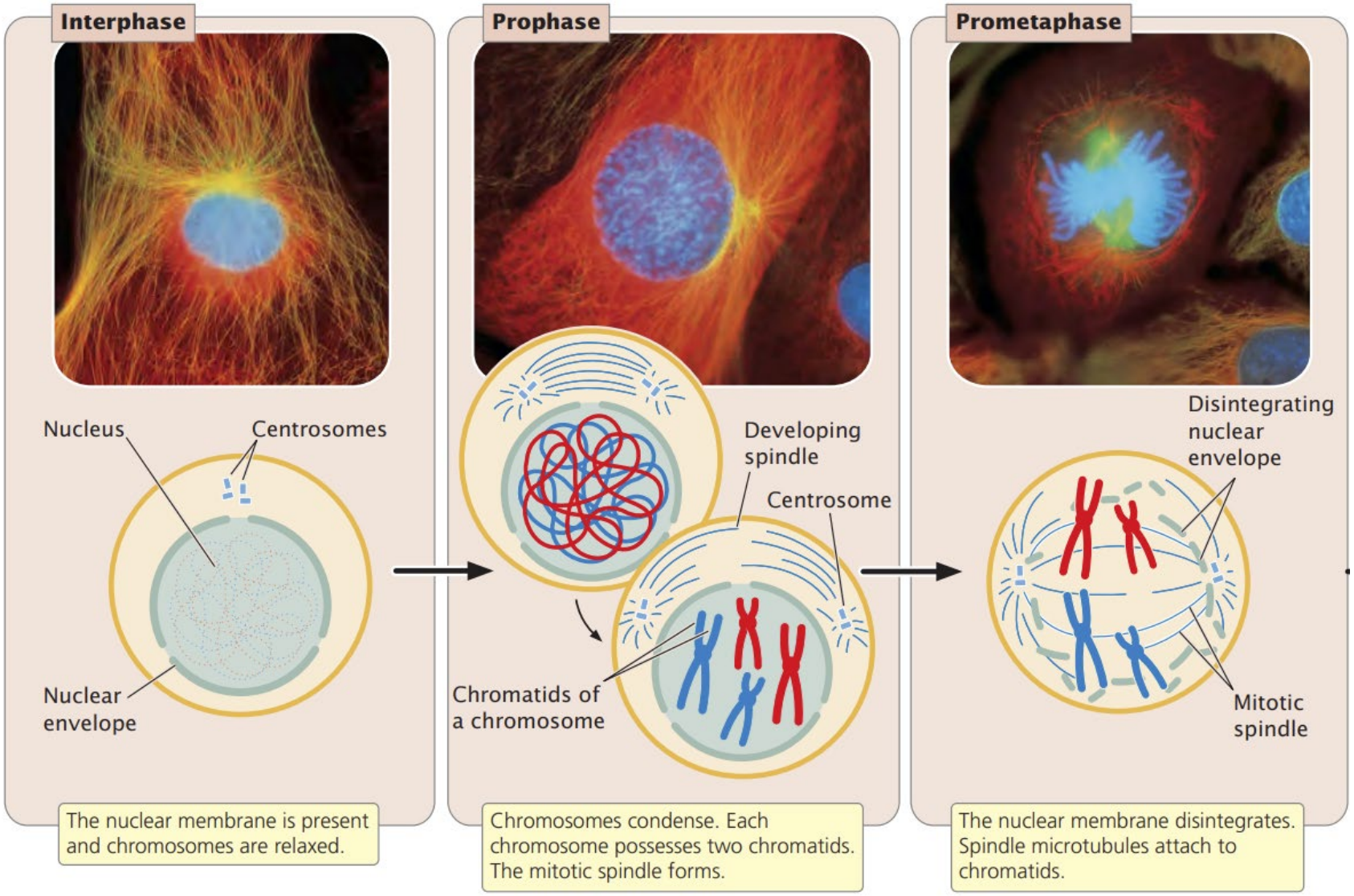


Cell cycle

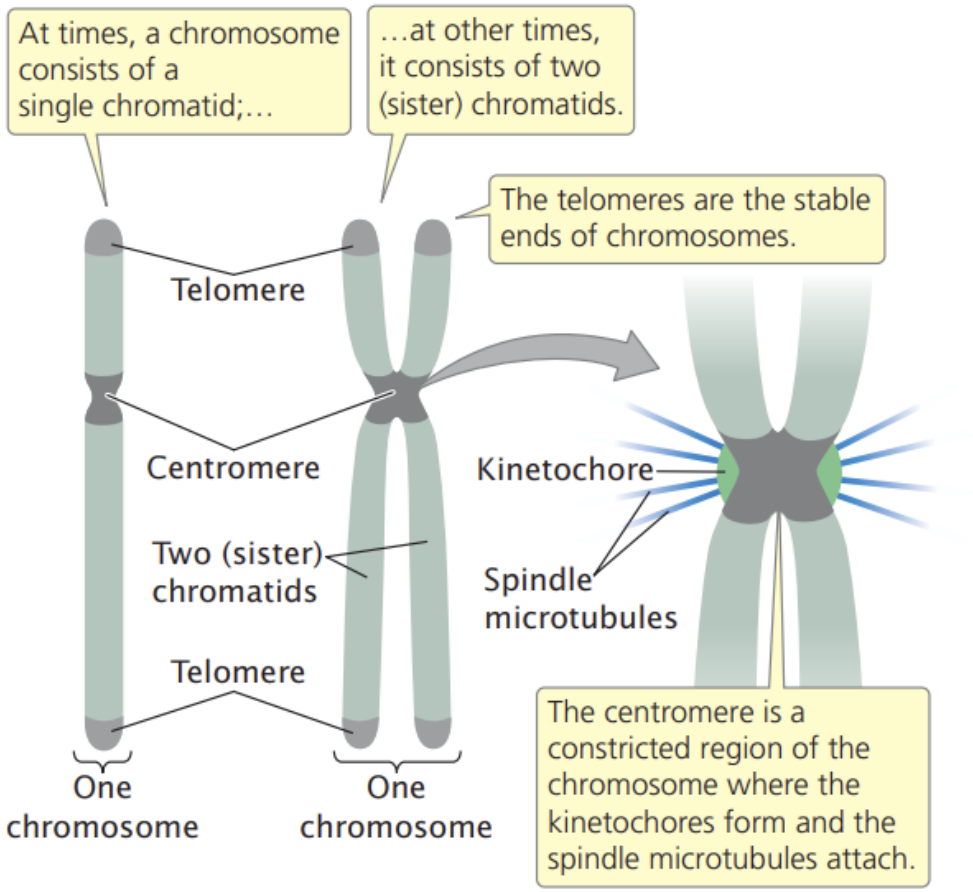


2.9 The cell cycle consists of interphase and M phase.

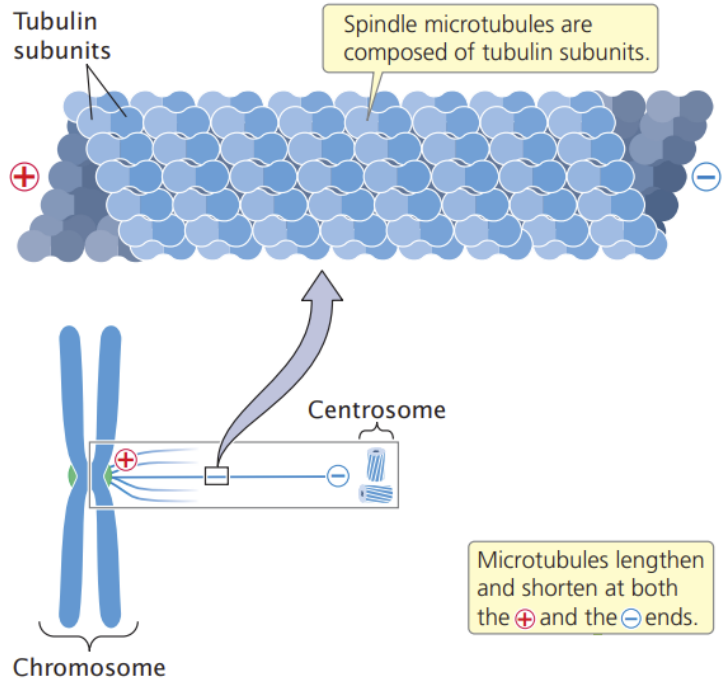
Mitosis


Interphase
Nucleus
Centrosomes
Nuclear envelope
The nuclear membrane is present and chromosomes are relaxed.
Prophase
Developing spindle
Centrosome
Chromatids of a chromosome
Chromosomes condense. Each chromosome possesses two chromatids. The mitotic spindle forms.
Prometaphase
Disintegrating nuclear envelope
Mitotic spindle
The nuclear membrane disintegrates. Spindle microtubules attach to chromatids.

Mitosis

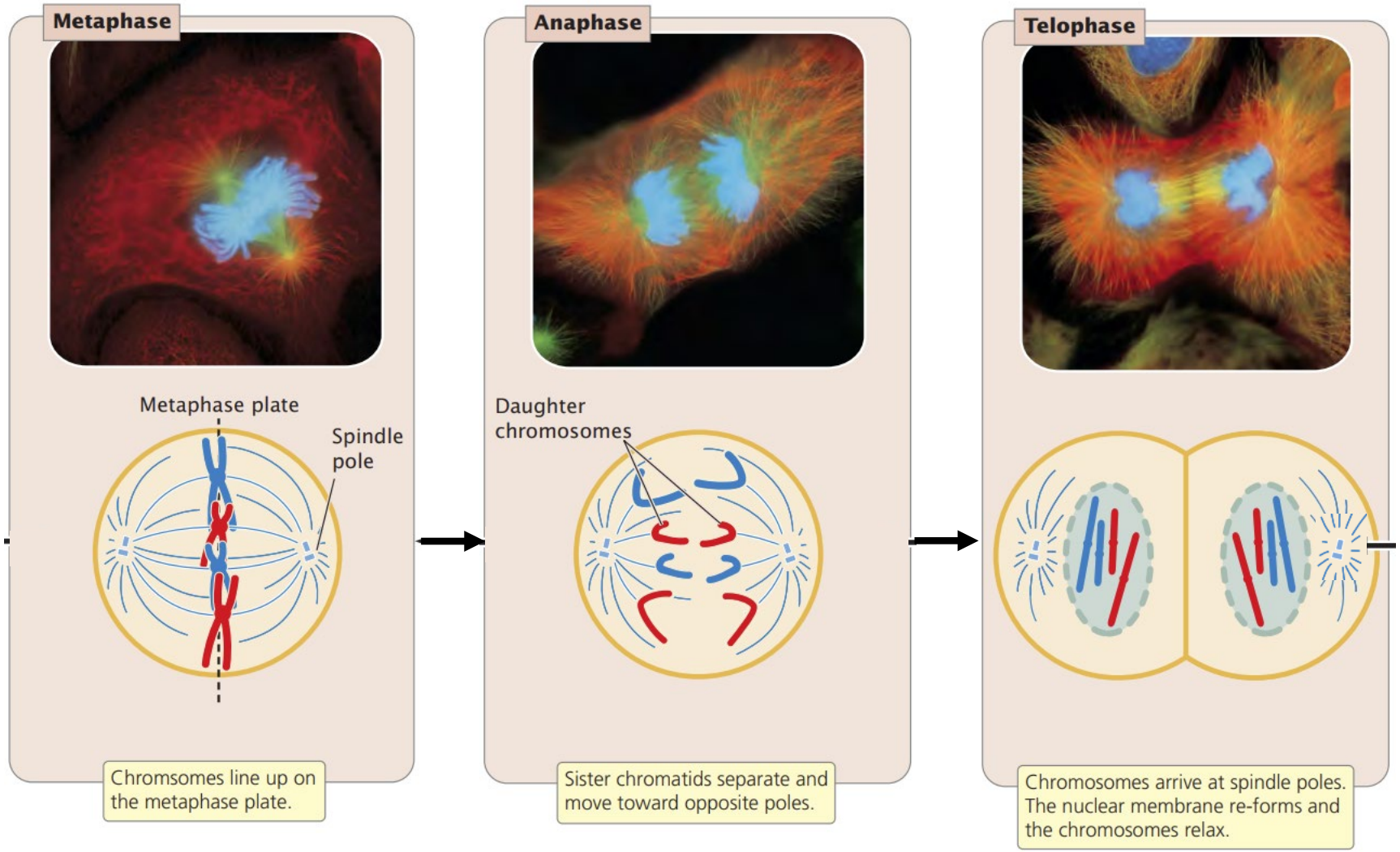


2.7 Each eukaryotic chromosome has a centromere and telomeres.



2.11 Microtubules are composed of tubulin subunits. Each microtubule has its plus (+) end at the kinetochore and its negative (−) end at the centrosome.

Mitosis


Metaphase
Metaphase plate
Spindle pole
Chromsomes line up on the metaphase plate.
Anaphase
Daughter chromosomes
Sister chromatids separate and move toward opposite poles.
Telophase
Chromosomes arrive at spindle poles. The nuclear membrane re-forms and the chromosomes relax.

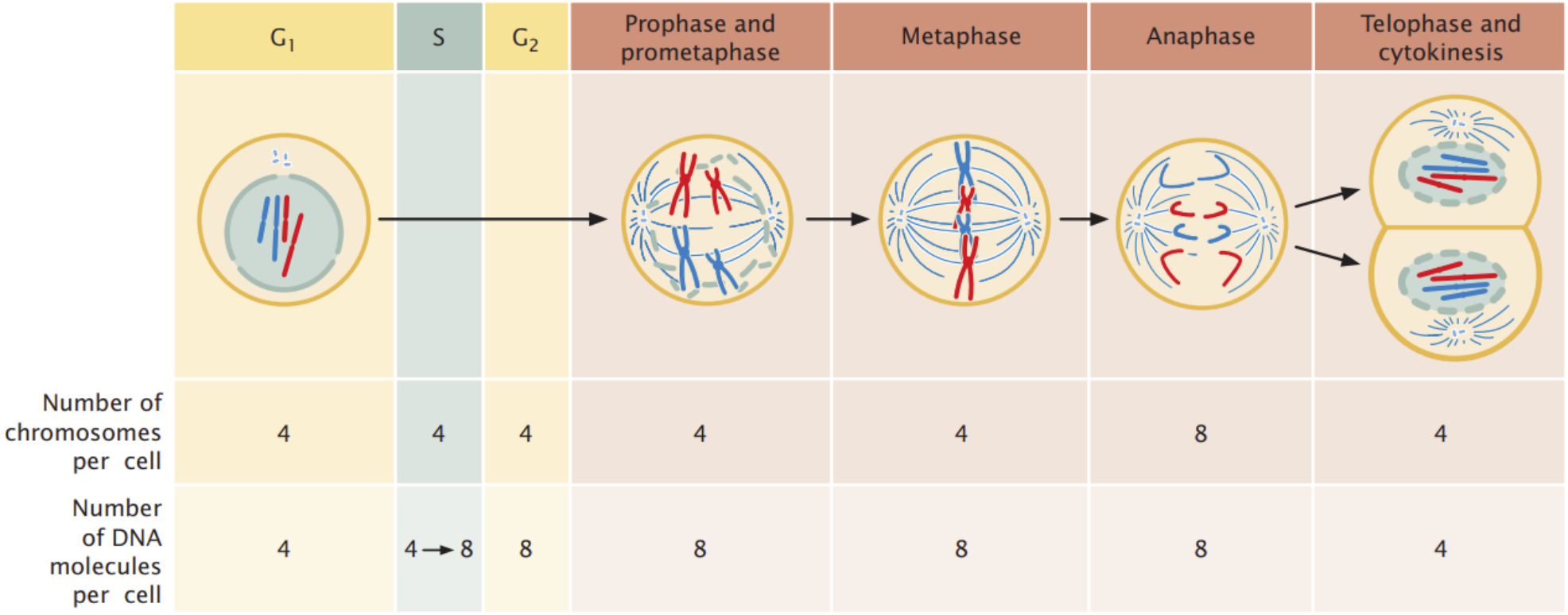
Biological Significance of Mitosis

- Somatic cells.
- Two identical sister cells from a mother cell.
- Growth, replacement of old cells, regeneration and asexual division.
- Level of ploidy is constant.

Table 2.1 Features of the cell cycle

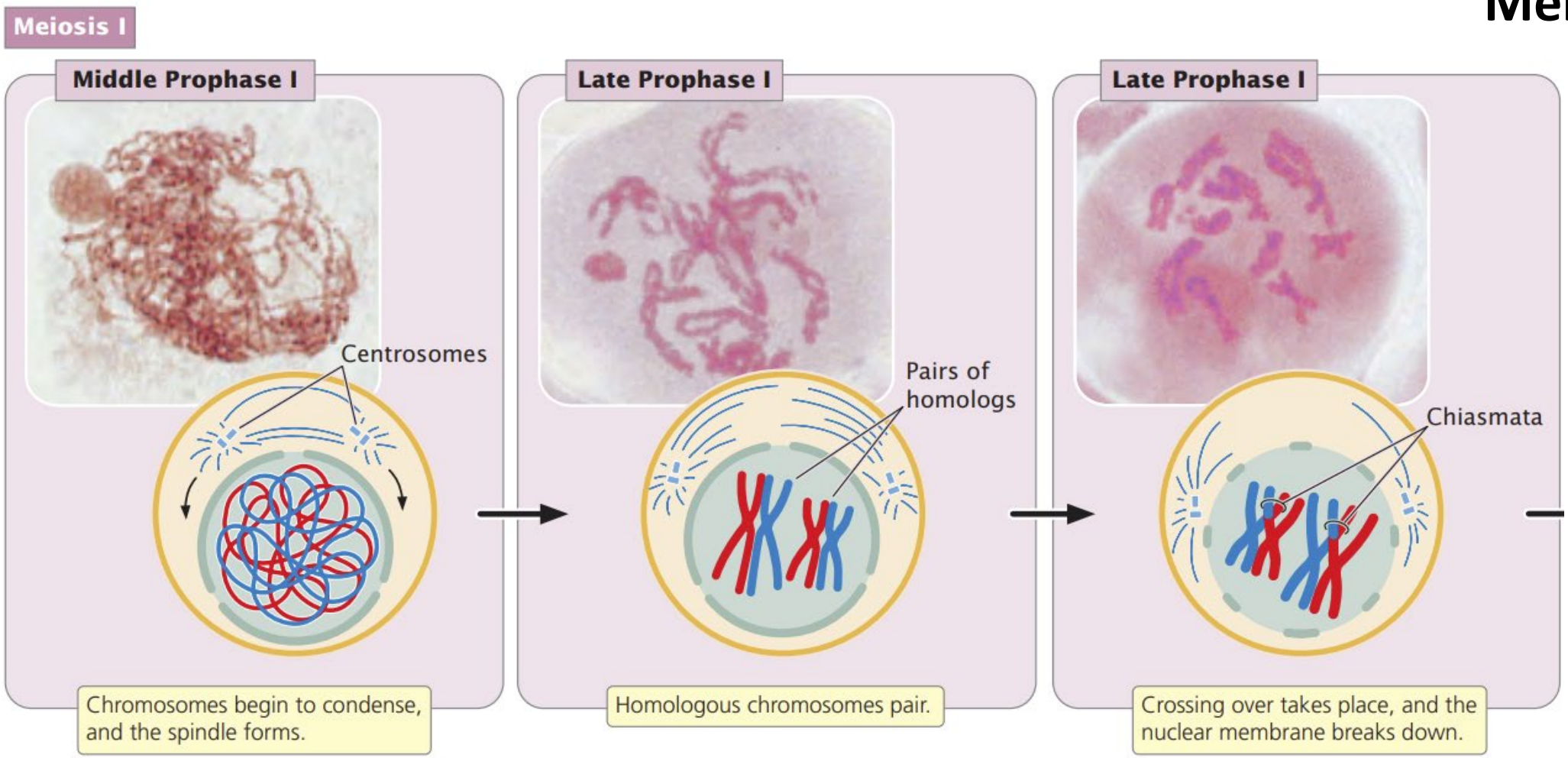
Stage	Major Features
G_0 phase	Stable, nondividing period of variable length.
Interphase	
G_1 phase	Growth and development of the cell; G_1/S checkpoint.
S phase	Synthesis of DNA.
G_2 phase	Preparation for division; G_2/M checkpoint.
M phase	
Prophase	Chromosomes condense and mitotic spindle forms.
Prometaphase	Nuclear envelope disintegrates, and spindle microtubules anchor to kinetochores.
Metaphase	Chromosomes align on the metaphase plate; spindle-assembly checkpoint.
Anaphase	Sister chromatids separate, becoming individual chromosomes that migrate toward spindle poles.
Telophase	Chromosomes arrive at spindle poles, the nuclear envelope re-forms, and the condensed chromosomes relax.
Cytokinesis	Cytoplasm divides; cell wall forms in plant cells.

Mitosis

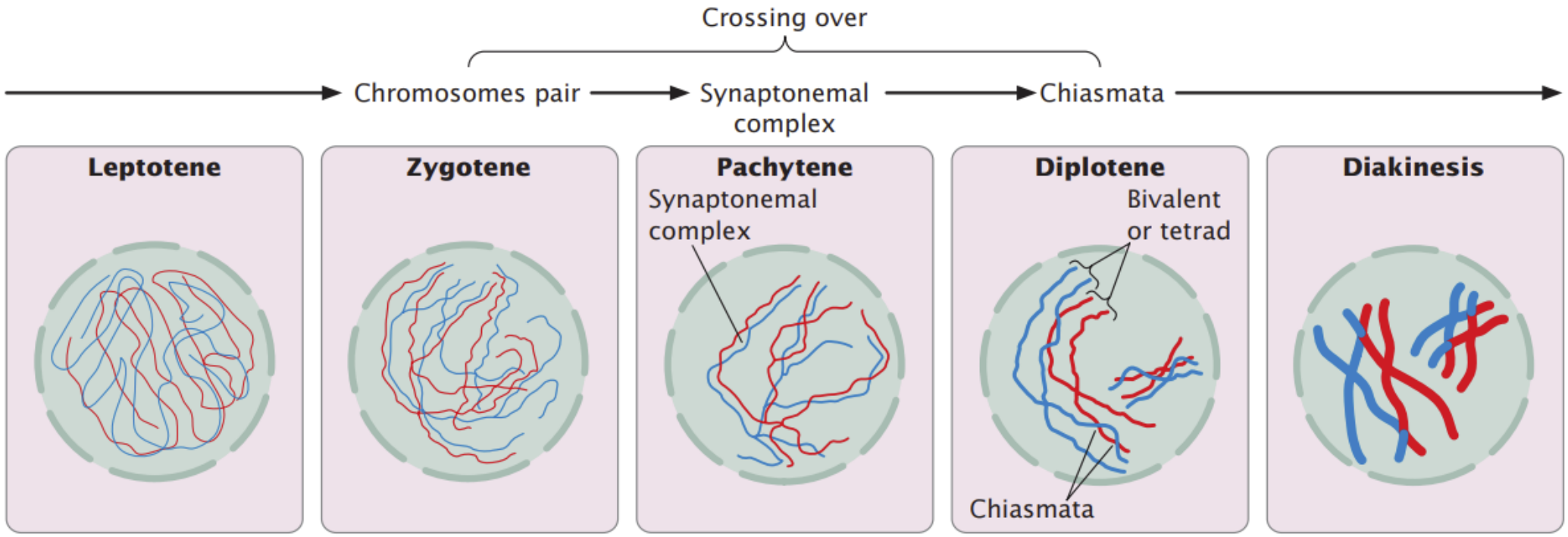


2.12 The number of chromosomes and the number of DNA molecules change in the course of the cell cycle.
The number of chromosomes per cell equals the number of functional centromeres. The number of DNA molecules per cell equals the number of chromosomes when the chromosomes are unreplicated (no sister chromatids present) and twice the number of chromosomes when sister chromosomes *are* present.

Meiosis


Meiosis I
Middle Prophase I
Centrosomes
Chromosomes begin to condense, and the spindle forms.
Late Prophase I
Pairs of homologs
Homologous chromosomes pair.
Late Prophase I
Chiasmata
Crossing over takes place, and the nuclear membrane breaks down.

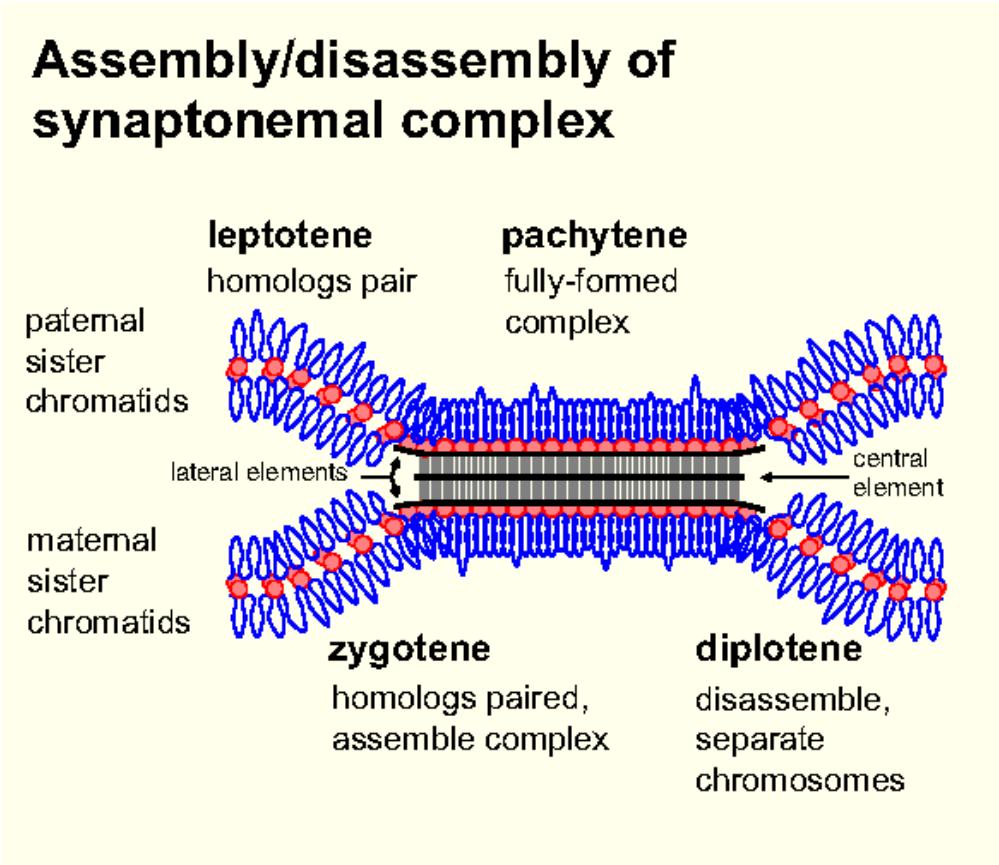
Prophase I

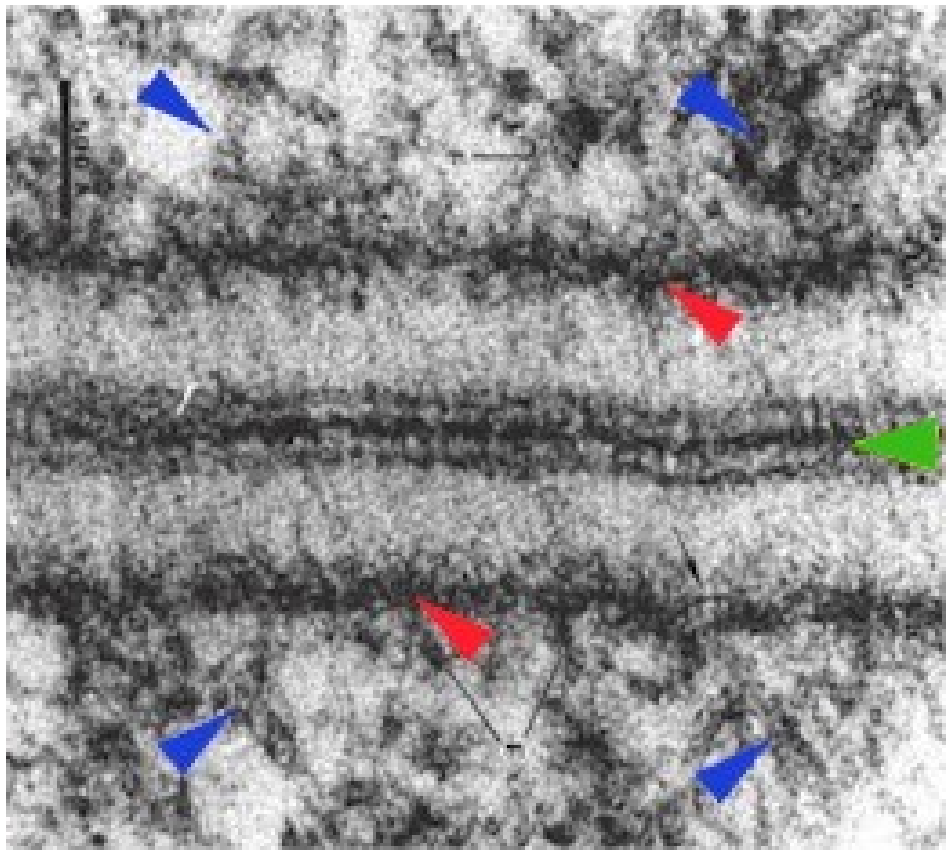


2.14 Crossing over takes place in prophase I.

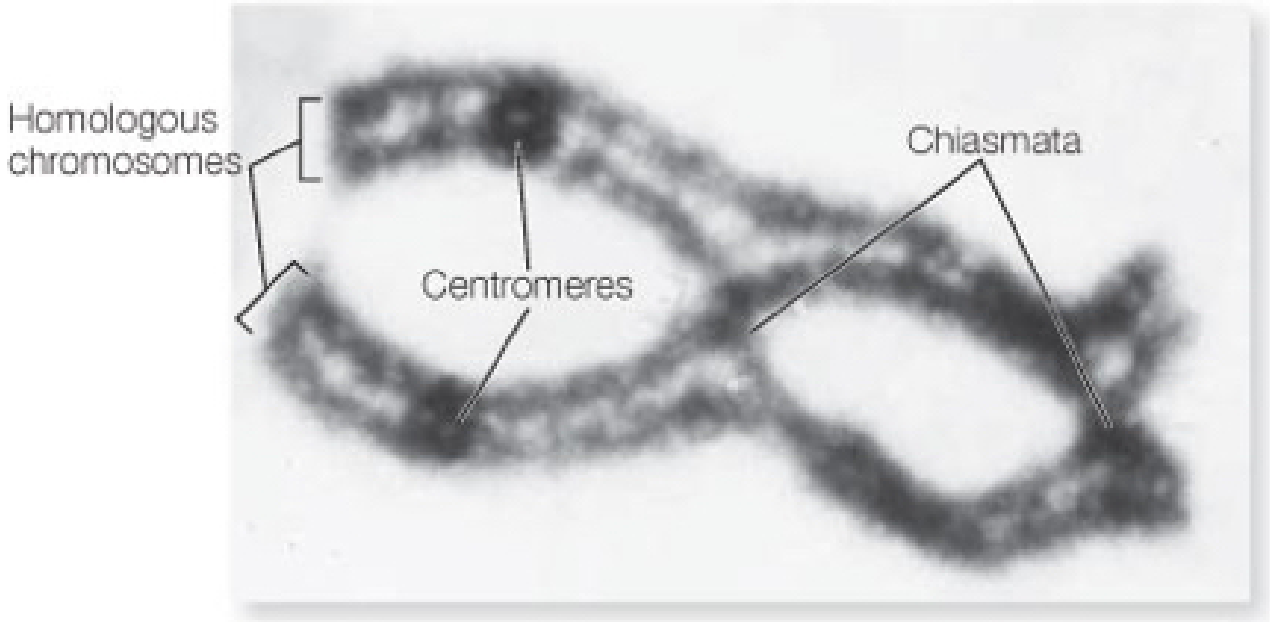
Prophase I

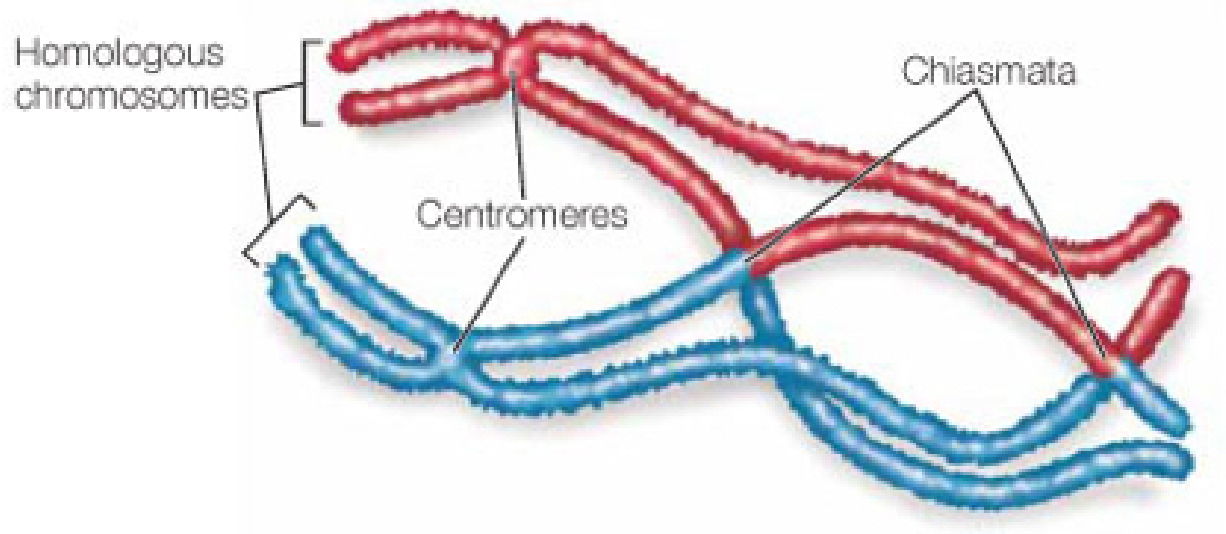
Synaptonemal complex





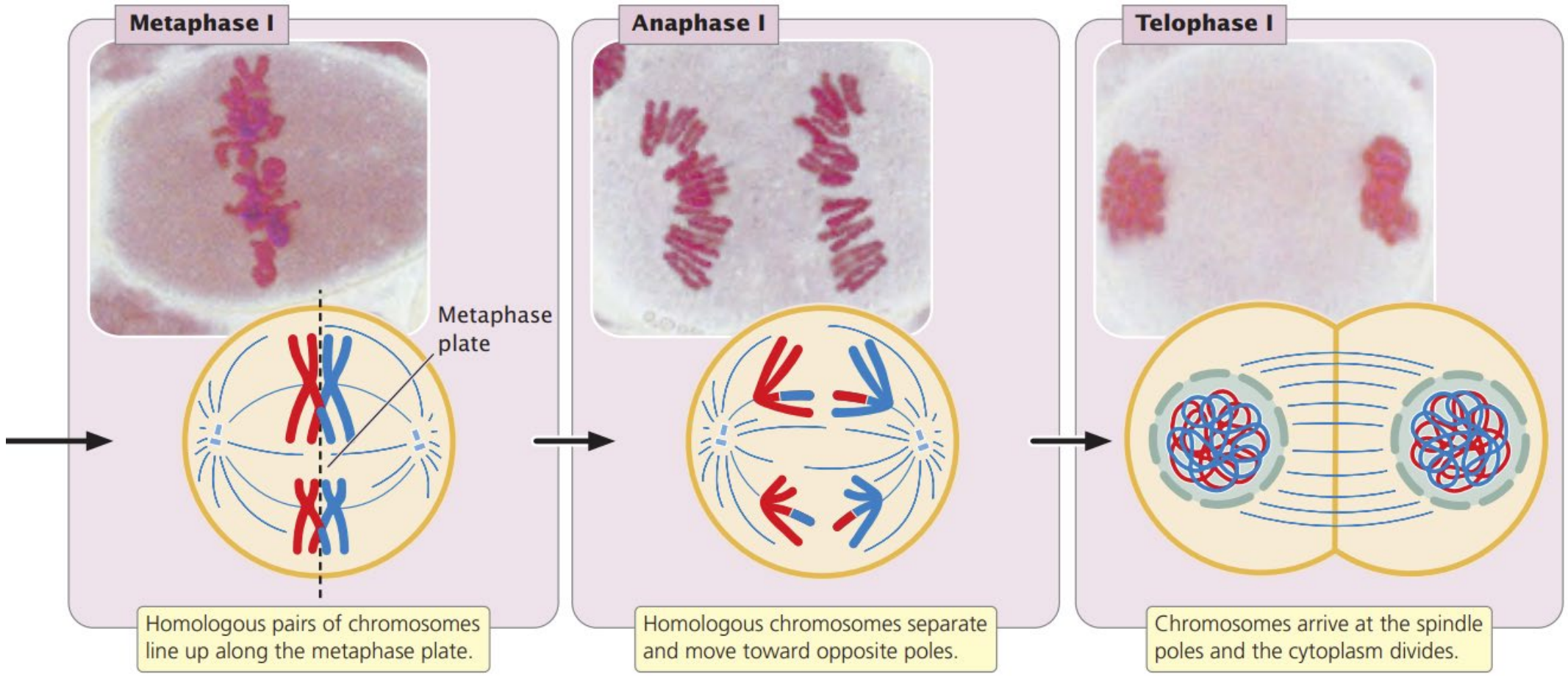
Prophase I



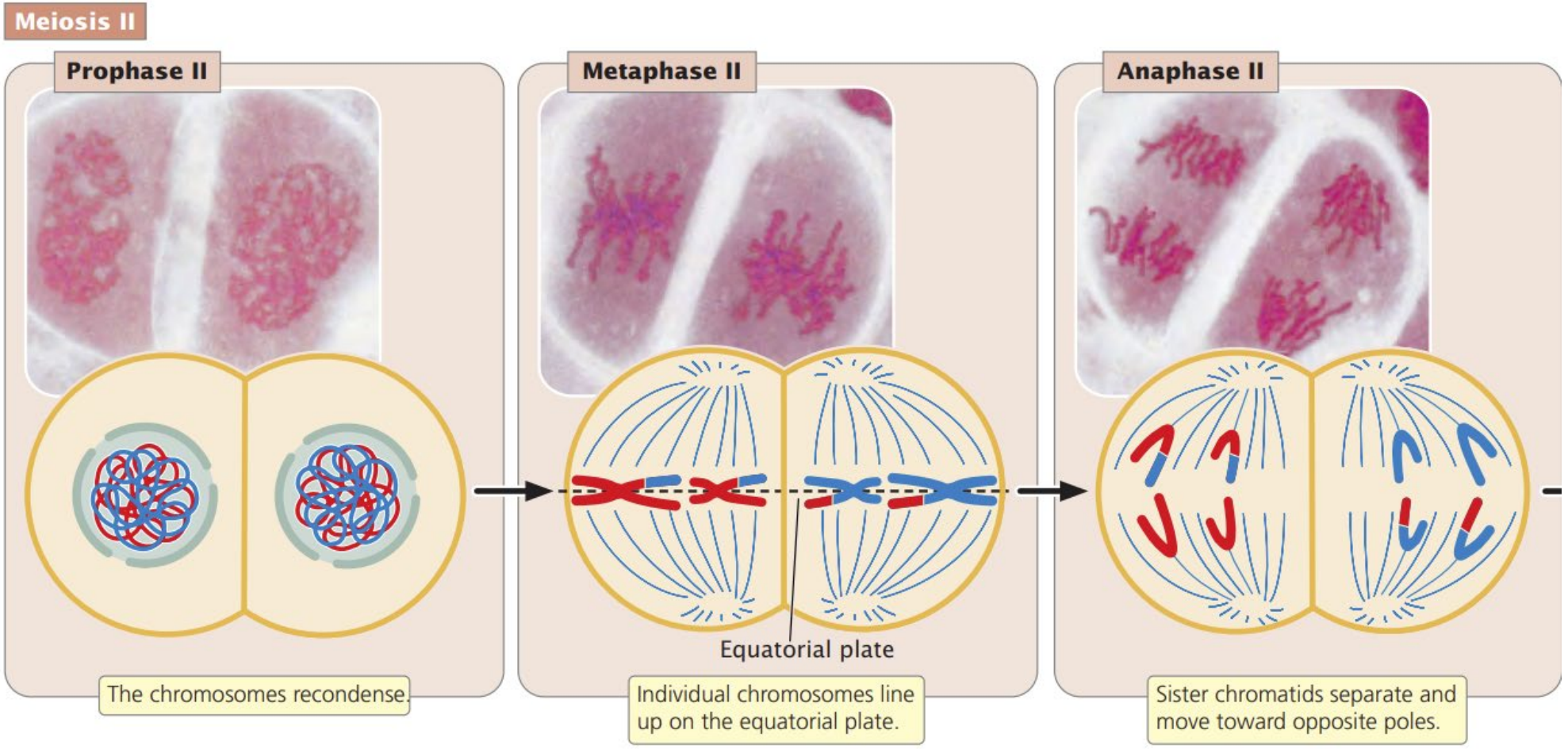


Crossing over

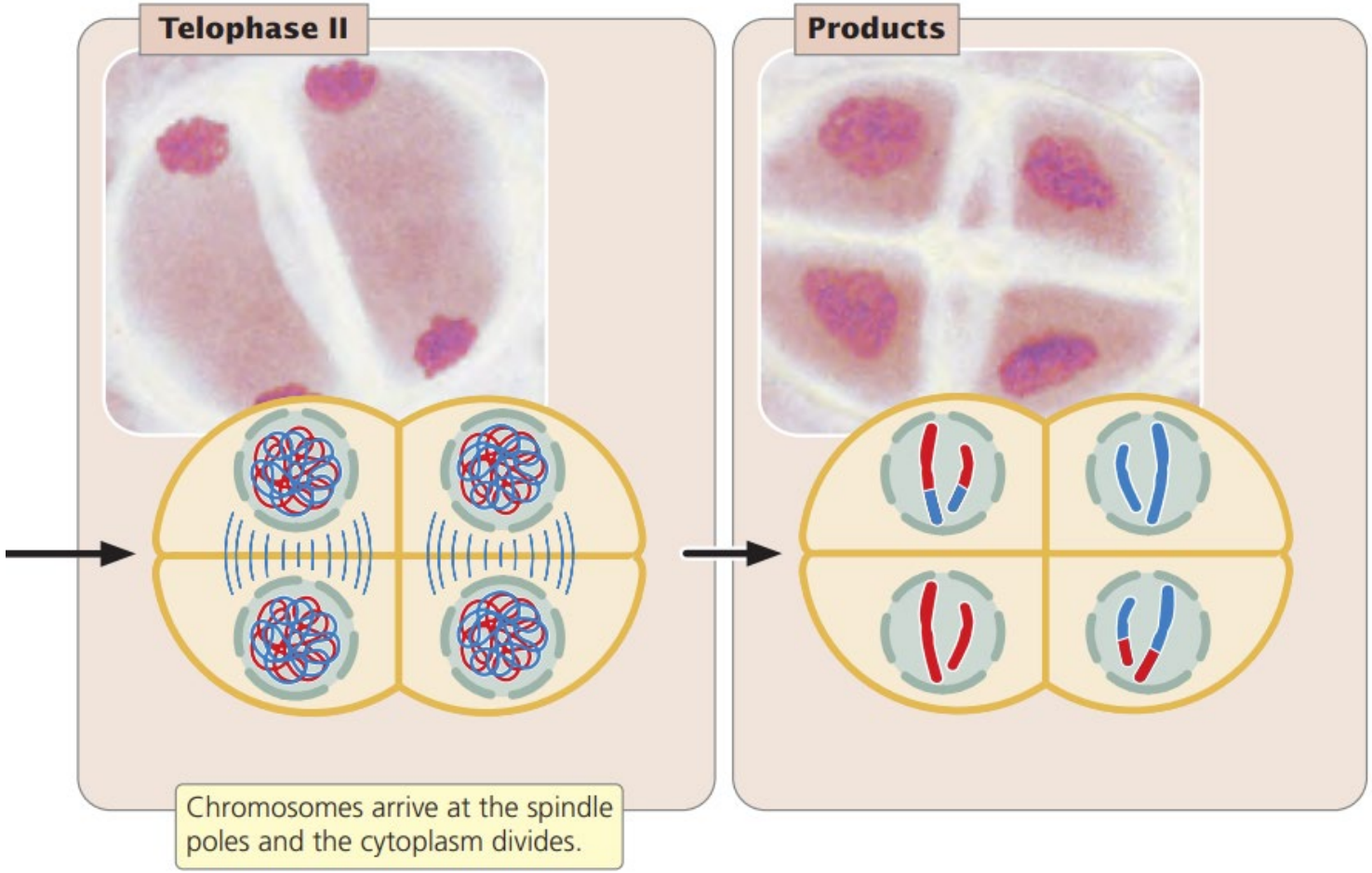
Meiosis


Metaphase I
Metaphase plate
Homologous pairs of chromosomes line up along the metaphase plate.
Anaphase I
Homologous chromosomes separate and move toward opposite poles.
Telophase I
Chromosomes arrive at the spindle poles and the cytoplasm divides.

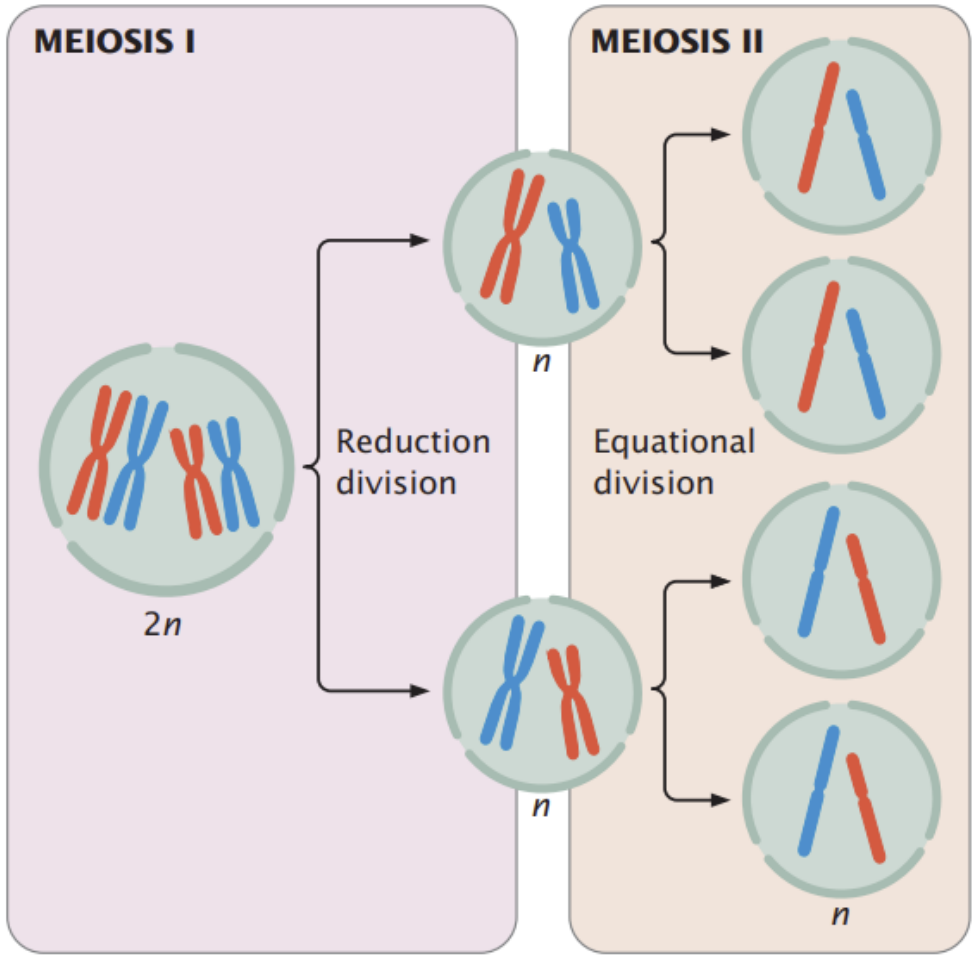
Meiosis


Meiosis II
Prophase II
Metaphase II
Anaphase II
Equatorial plate
The chromosomes recondense.
Individual chromosomes line up on the equatorial plate.
Sister chromatids separate and move toward opposite poles.

Meiosis


Telophase II
Products
Chromosomes arrive at the spindle poles and the cytoplasm divides.

Meiosis summary



2.13 Meiosis includes two cell divisions. In this illustration, the original cell is $2n = 4$. After two meiotic divisions, each resulting cell is $1n = 2$.

Biological Significance of Meiosis

- Germ cells.
- Produces variability. Four different haploid cells from a diploid mother cell.
- Formation of gametes for reproduction.
- Level of ploidy is constant through generations.

Table 2.2 Major events in each stage of meiosis

Stage	Major Events
Meiosis I	
Prophase I	Chromosomes condense, homologous chromosomes synapse, crossing over takes place, the nuclear envelope breaks down, and the mitotic spindle forms.
Metaphase I	Homologous pairs of chromosomes line up on the metaphase plate.
Anaphase I	The two chromosomes (each with two chromatids) of each homologous pair separate and move toward opposite poles.
Telophase I	Chromosomes arrive at the spindle poles.
Cytokinesis	The cytoplasm divides to produce two cells, each having half the original number of chromosomes.
Interkinesis	In some types of cells, the spindle breaks down, chromosomes relax, and a nuclear envelope re-forms, but no DNA synthesis takes place.
Meiosis II	
Prophase II*	Chromosomes condense, the spindle forms, and the nuclear envelope disintegrates.
Metaphase II	Individual chromosomes line up on the metaphase plate.
Anaphase II	Sister chromatids separate and move as individual chromosomes toward the spindle poles.
Telophase II	Chromosomes arrive at the spindle poles; the spindle breaks down and a nuclear envelope re-forms.
Cytokinesis	The cytoplasm divides.

*Only in cells in which the spindle has broken down, chromosomes have relaxed, and the nuclear envelope has re-formed in telophase I. Other types of cells proceed directly to metaphase II after cytokinesis.

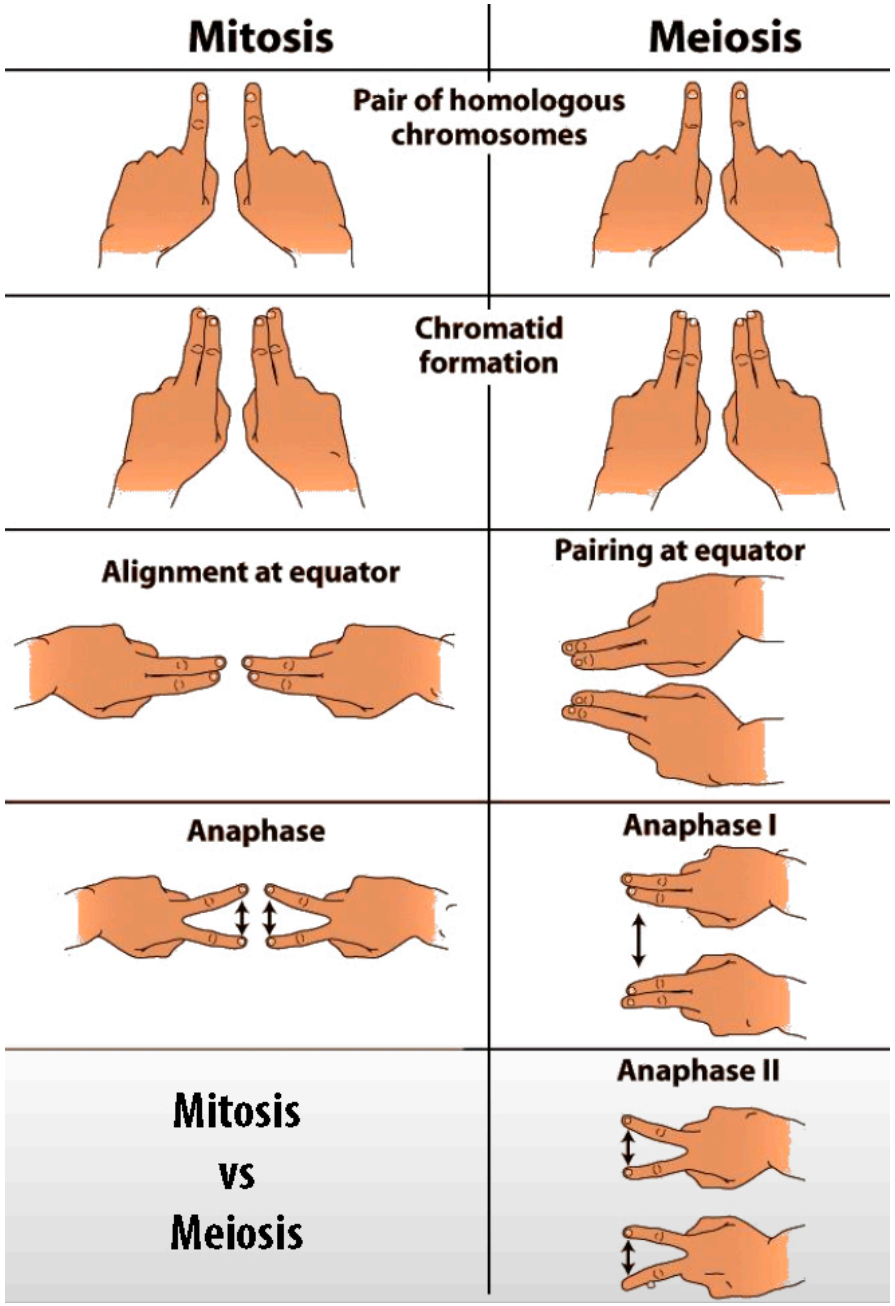
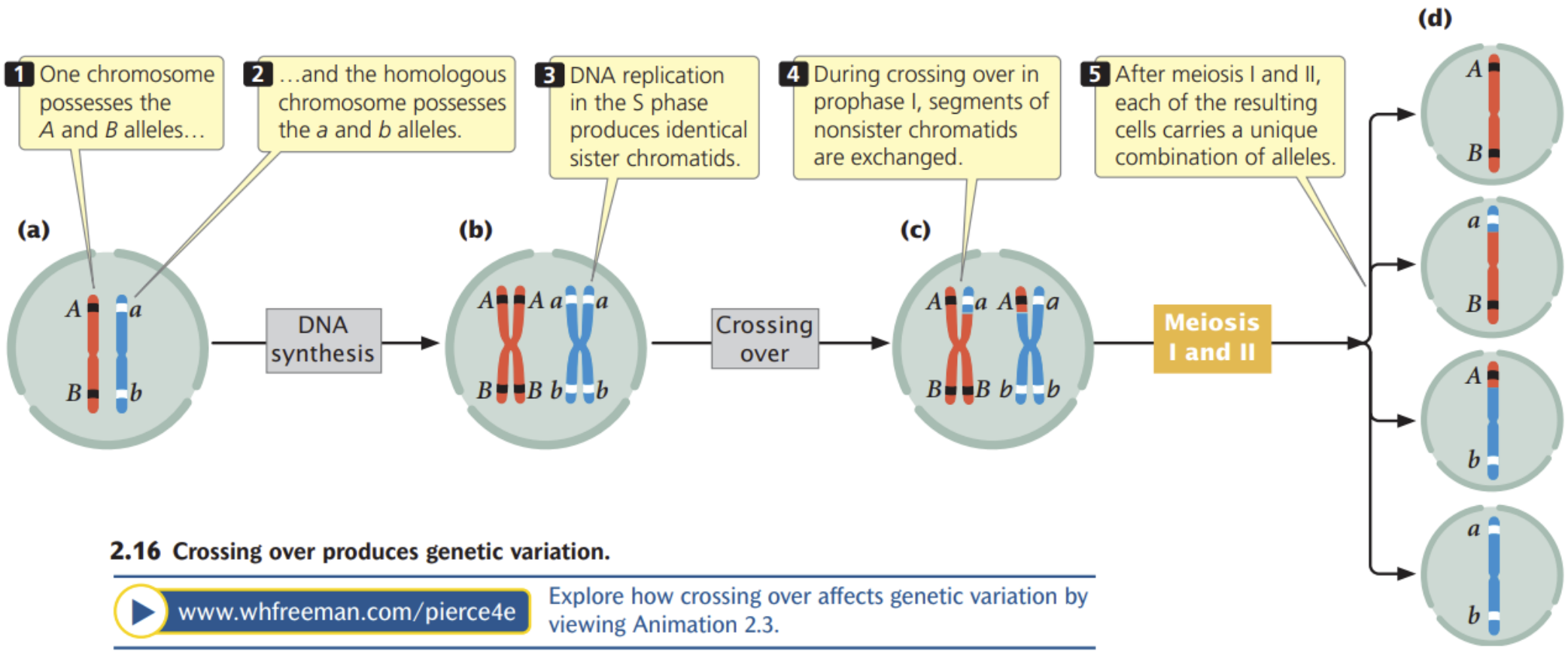


Table 2.3 Comparison of Mitosis, Meiosis I, and Meiosis II

Event	Mitosis	Meiosis I	Meiosis II
Cell division	Yes	Yes	Yes
Chromosome reduction	No	Yes	No
Genetic variation produced	No	Yes	No
Crossing over	No	Yes	No
Random distribution of maternal and paternal chromosomes	No	Yes	No
Metaphase	Individual chromosomes line up	Homologous pairs line up	Individual chromosomes line up
Anaphase	Chromatids separate	Homologous chromosomes separate	Chromatids separate

Meiosis: two sources of variability | RECOMBINATION



2.16 Crossing over produces genetic variation.

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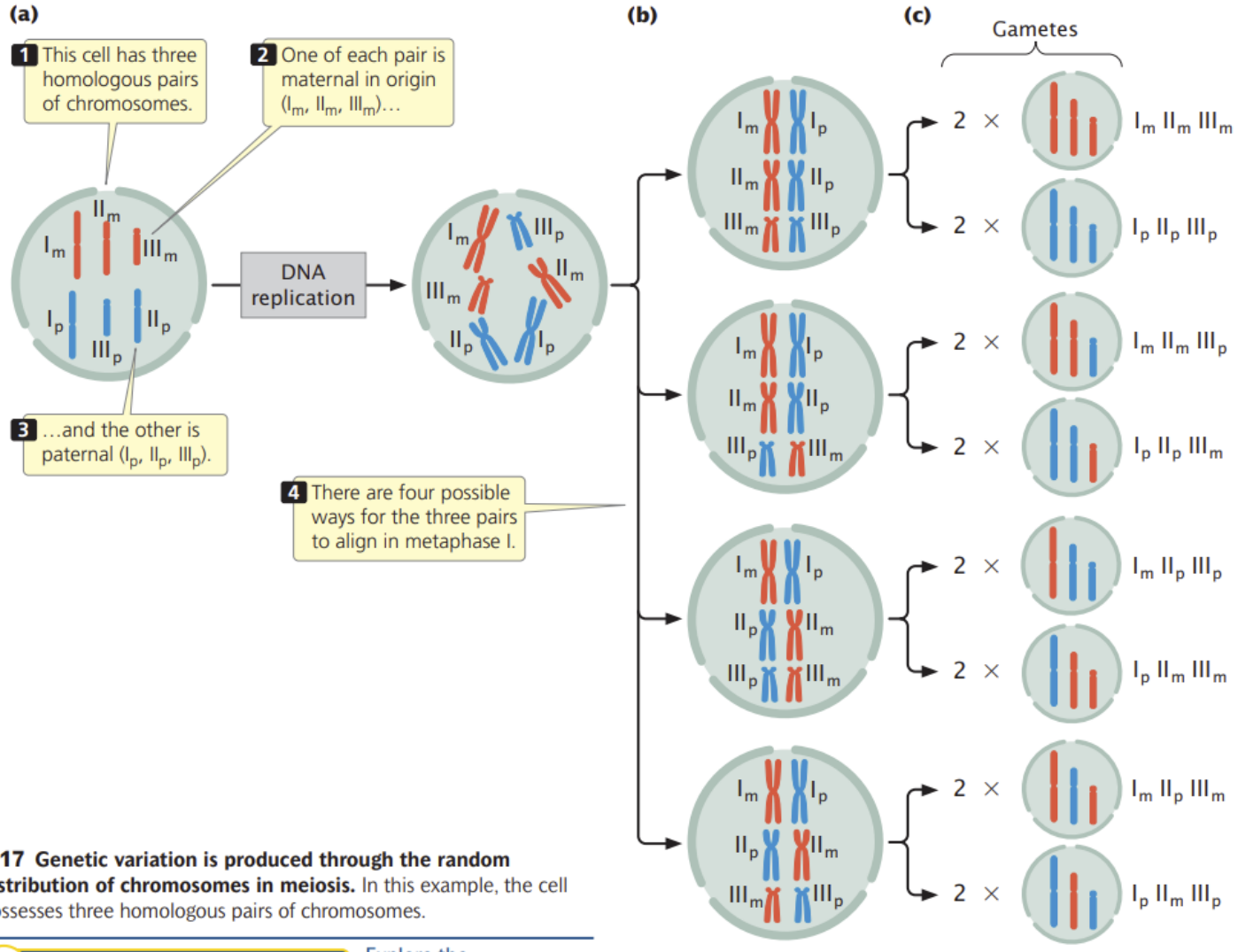
Explore how crossing over affects genetic variation by viewing Animation 2.3.

Meiosis: two sources of variability | CHROMOSOMES RANDOM DISTRIBUTION



2.17 Genetic variation is produced through the random distribution of chromosomes in meiosis. In this example, the cell possesses three homologous pairs of chromosomes.

www.whfreeman.com/pierce4e Explore the random distribution of chromosomes by viewing Animation 2.3.

Morgan's Experiment | Sex linkage and Chromosome Theory of Inheritance