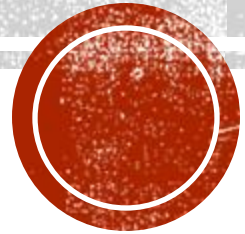
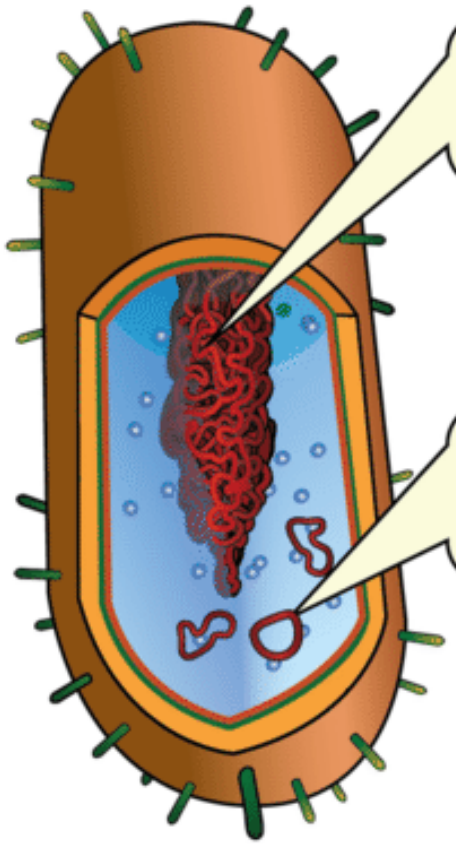
CELL CYCLE AND SEXUAL REPRODUCTION

Benilda Ramos-Butron



WHERE ARE THE GENES?

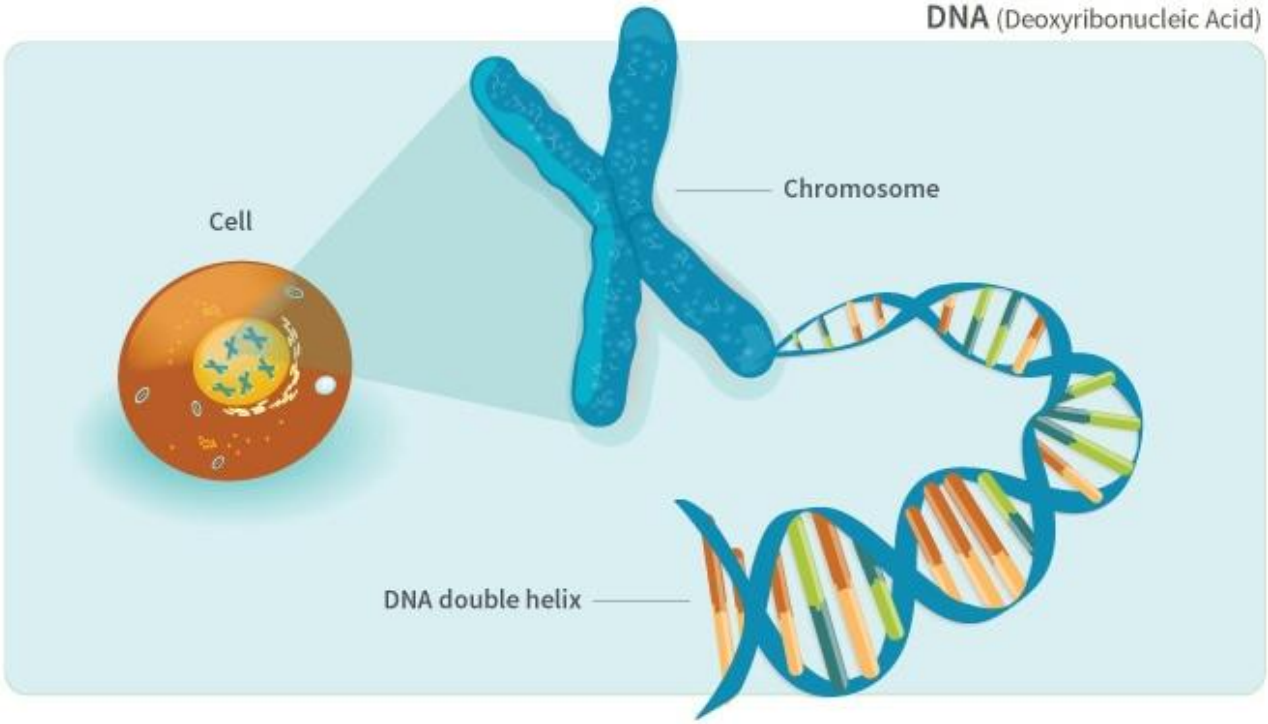


Nucleoid
chromosomal DNA

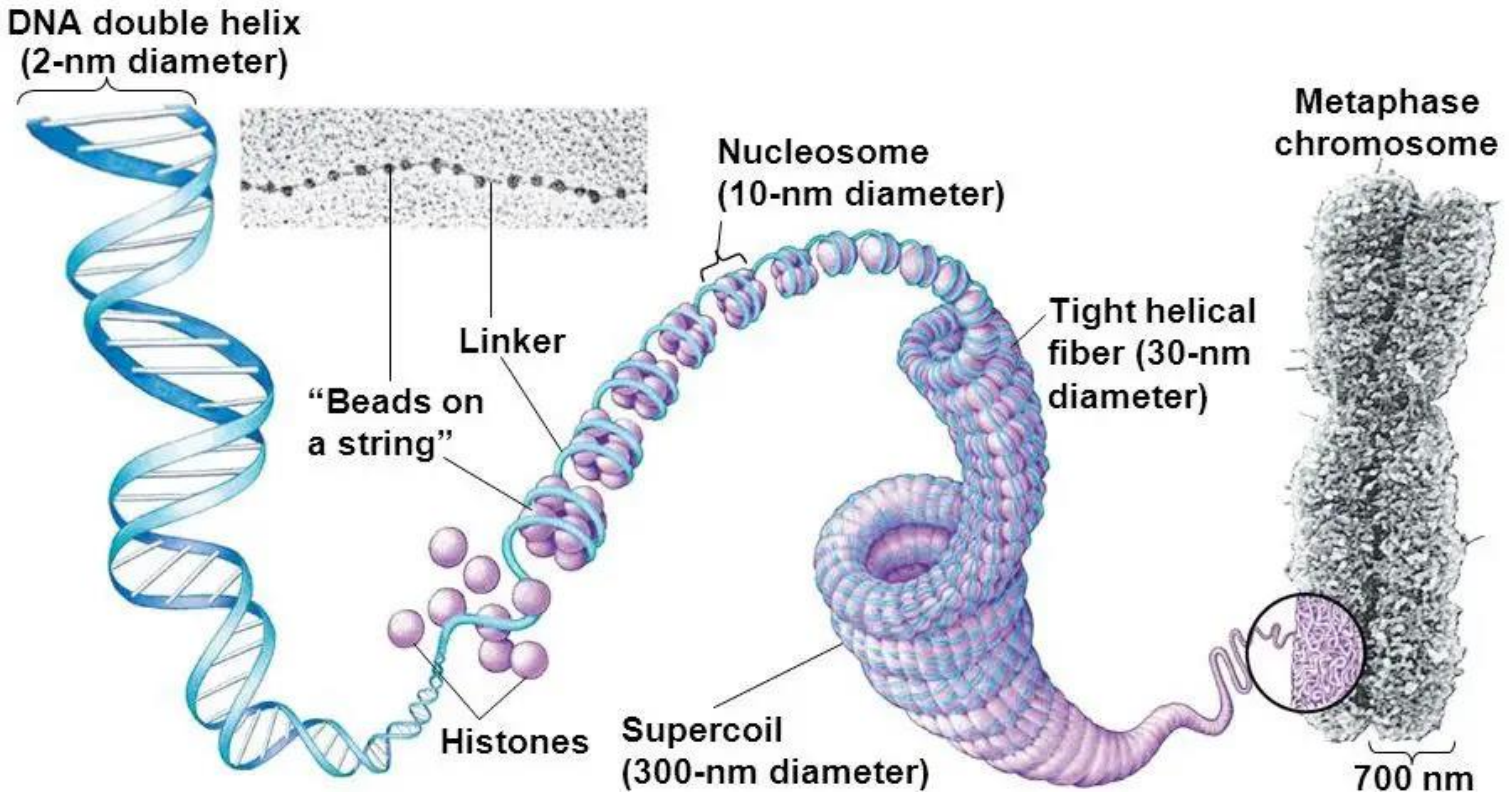
Circular, double-stranded piece of DNA, not surrounded by a nuclear membrane.

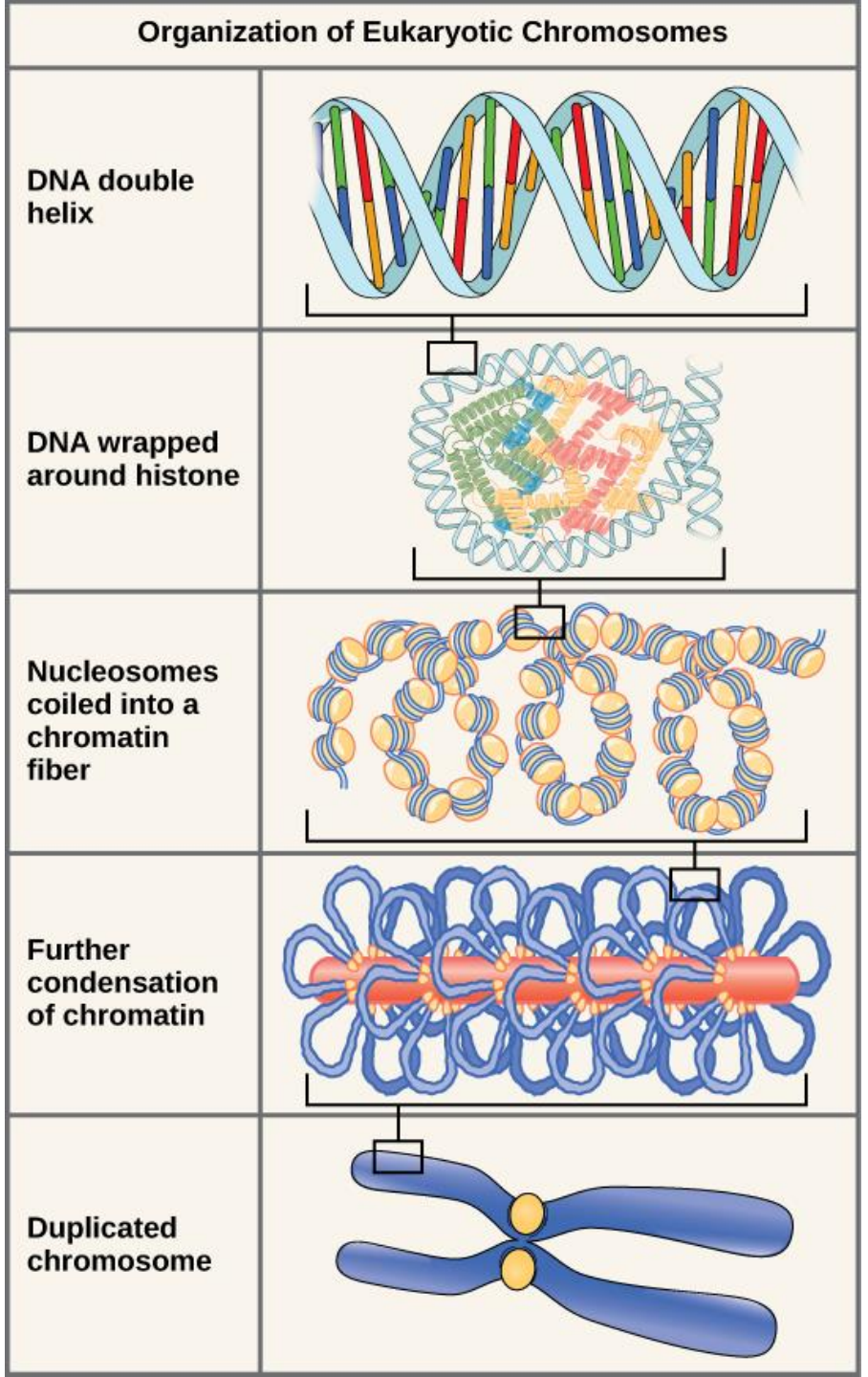
Plasmid
independent DNA molecule

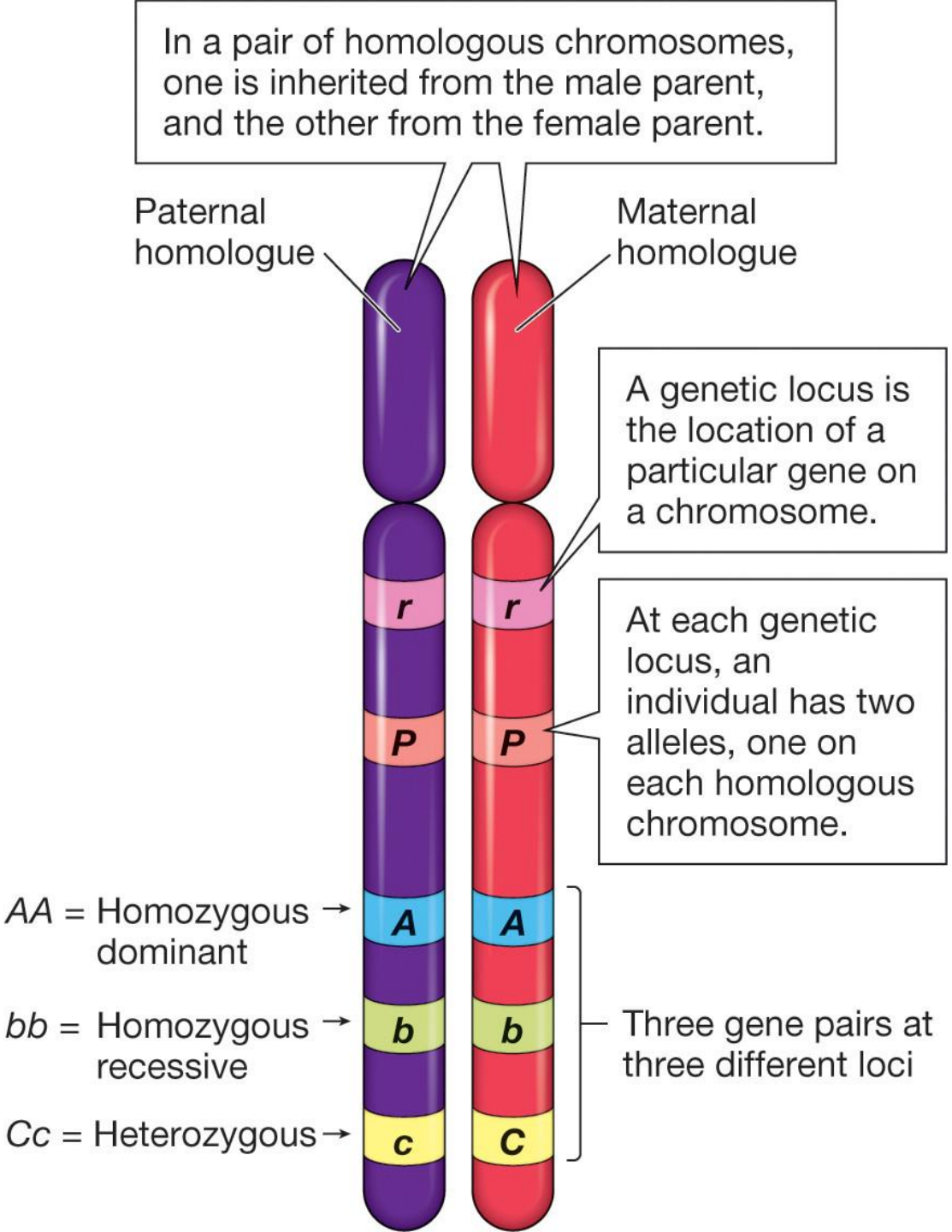
Small circular, independent double-stranded DNA molecule. Plasmids can frequently be transmitted from one bacterium to another.



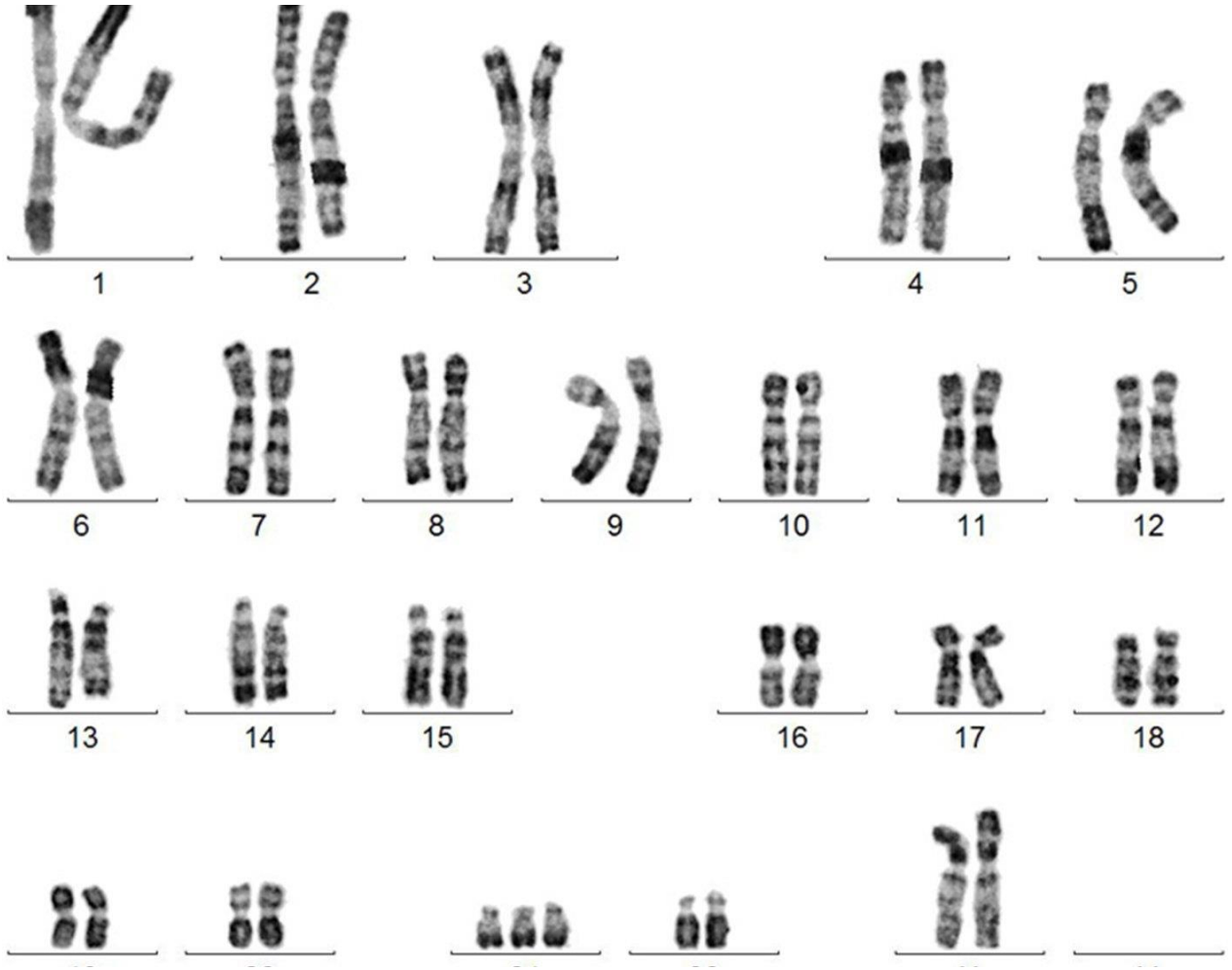
DNA to Chromosome






In a pair of homologous chromosomes, one is inherited from the male parent, and the other from the female parent.
Paternal homologue
Maternal homologue
A genetic locus is the location of a particular gene on a chromosome.
At each genetic locus, an individual has two alleles, one on each homologous chromosome.
r
P
A
b
c
r
P
A
b
C
AA = Homozygous dominant
bb = Homozygous recessive
Cc = Heterozygous
Three gene pairs at three different loci

Human Karyotype



Chromosome numbers in animals and plants

Indian muntjac
(6)

Fruit fly
(8)

Earthworm
(36)

Cat
(38)

Mouse
(40)

Human
(46)

Snail
(54)

Elephant
(56)

Cow
(60)

Dog
(78)

Hedgehog
(90)

Goldfish
(100)

Rye
(14, diploid)

Pasta wheat
(28, tetraploid)

Bread wheat
(42, hexaploid)

Adder's tongue fern
(~1200, polyploid)

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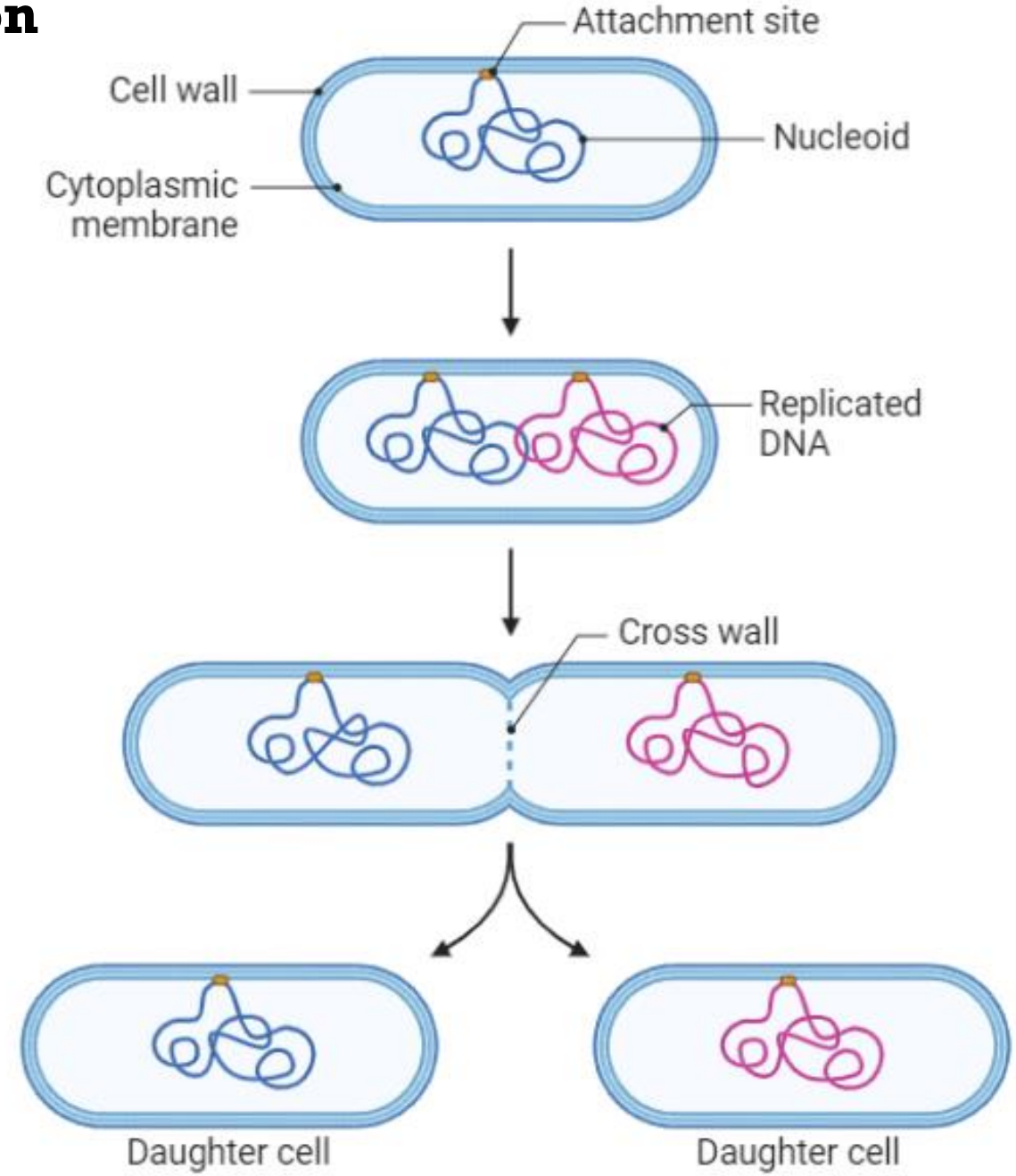
CELL DIVISION

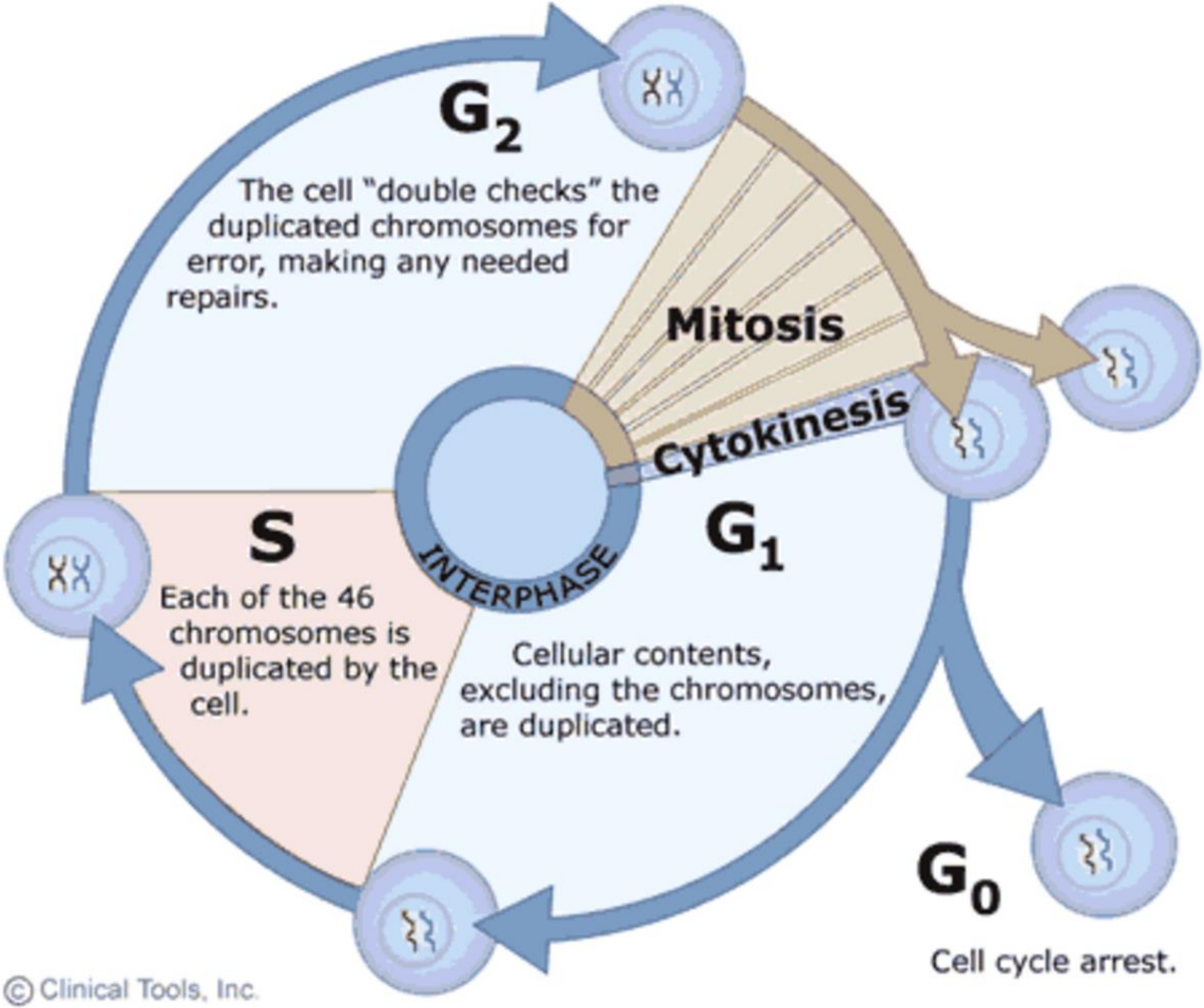
PURPOSE OF CELL DIVISION

1. Asexual reproduction
2. Multicellularity

Binary Fission



1. Prokaryotic parent cell initiates replication
2. A copy of the cell's DNA is created
3. Cell elongates and cross wall forms
4. Cross wall forms completely and daughter cells separate


G2
The cell "double checks" the duplicated chromosomes for error, making any needed repairs.
Mitosis
Cytokinesis
INTERPHASE
G1
S
Each of the 46 chromosomes is duplicated by the cell.
Cellular contents, excluding the chromosomes, are duplicated.
G0
Cell cycle arrest.
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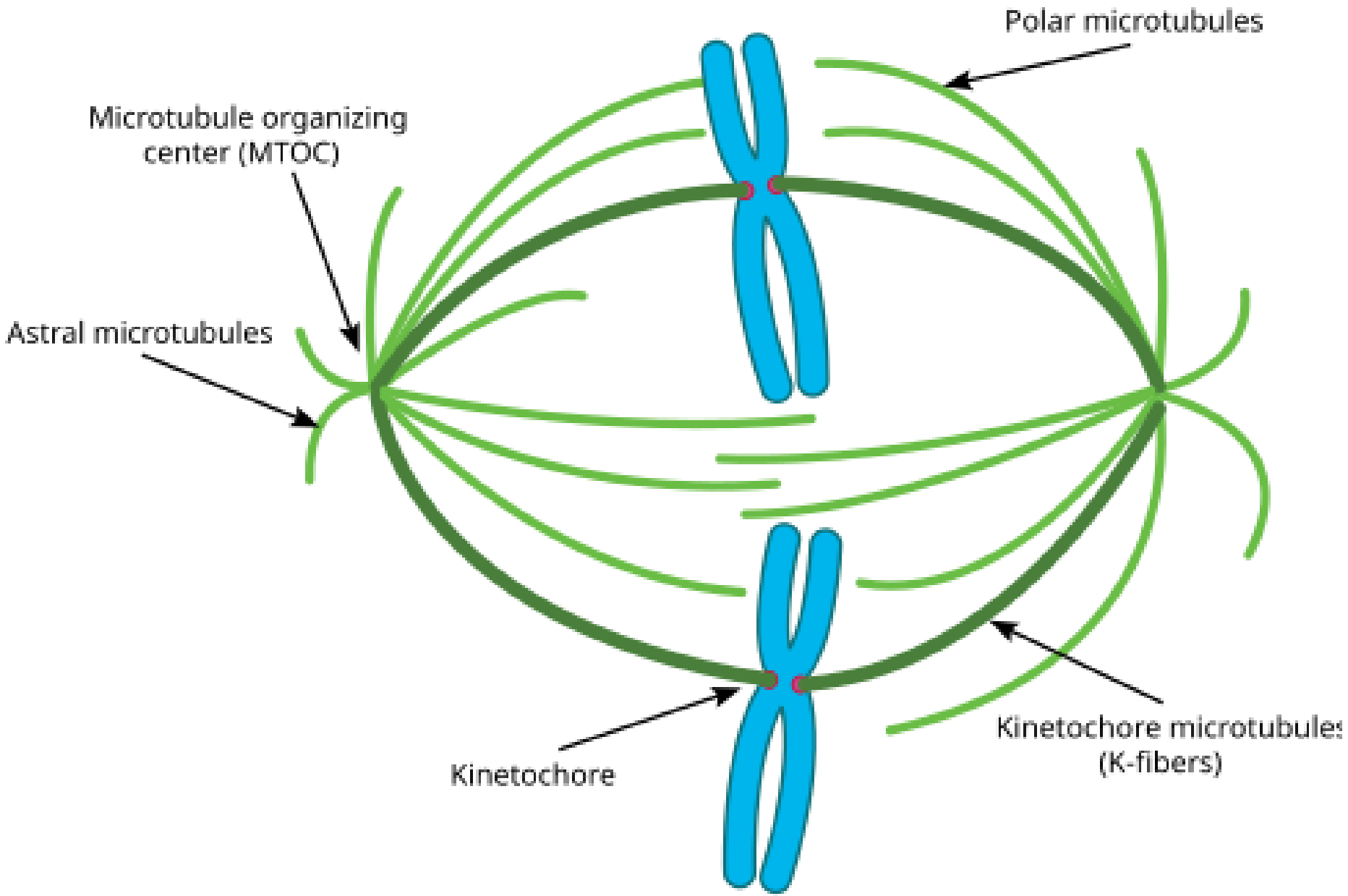
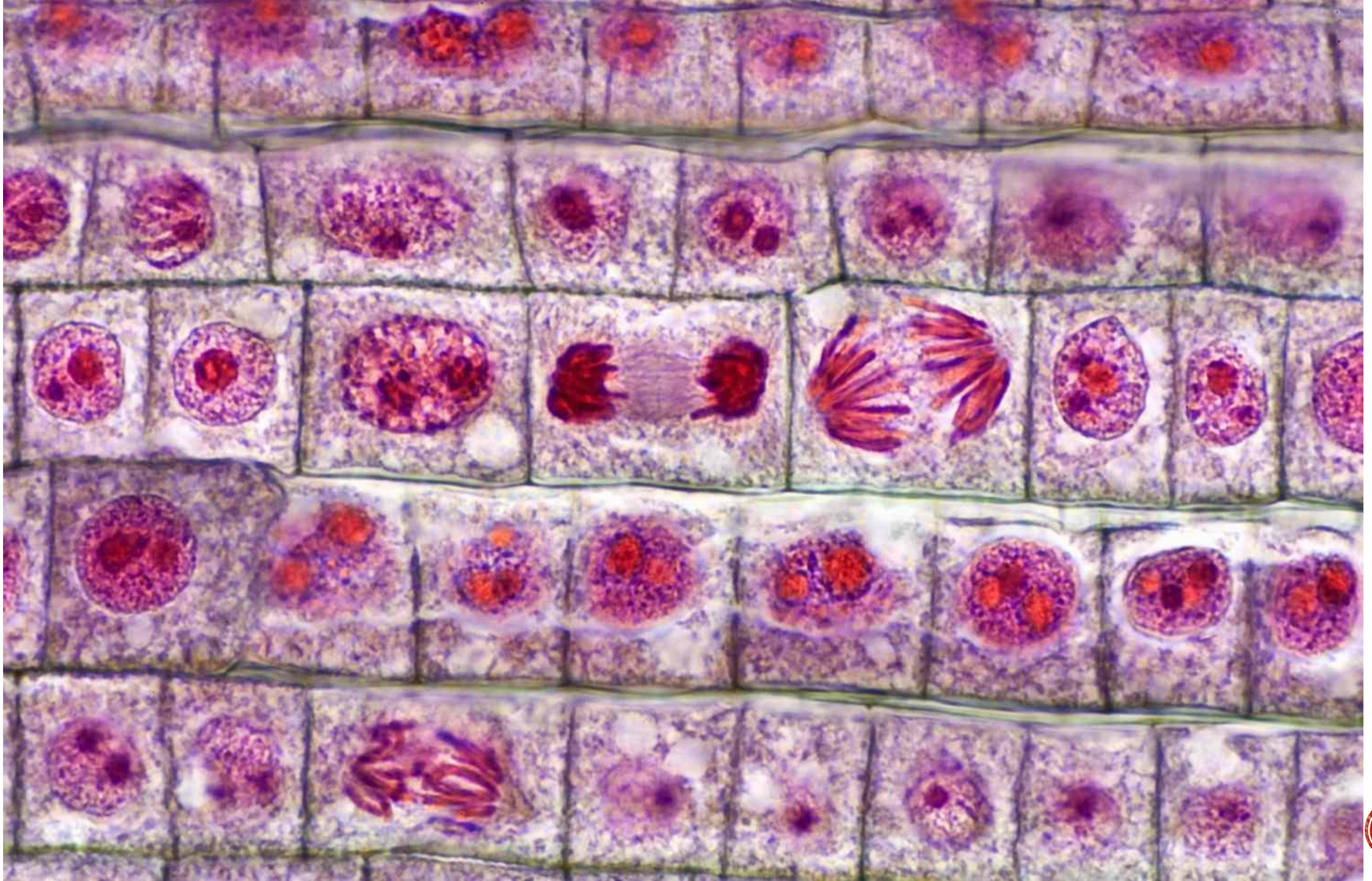
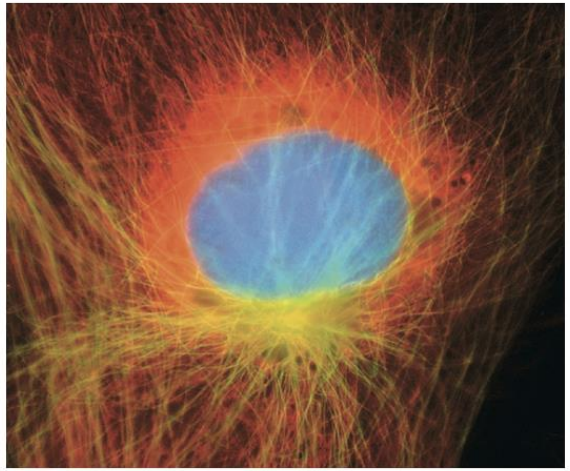
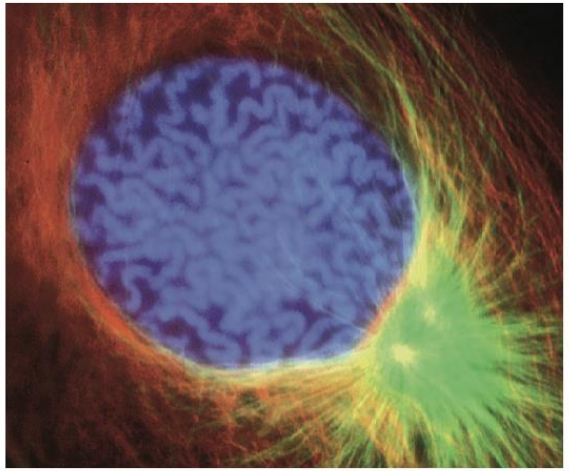
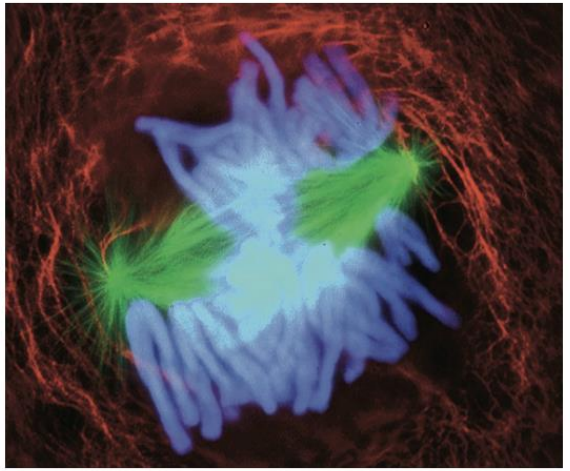
MITOSIS AND CYTOKINESIS

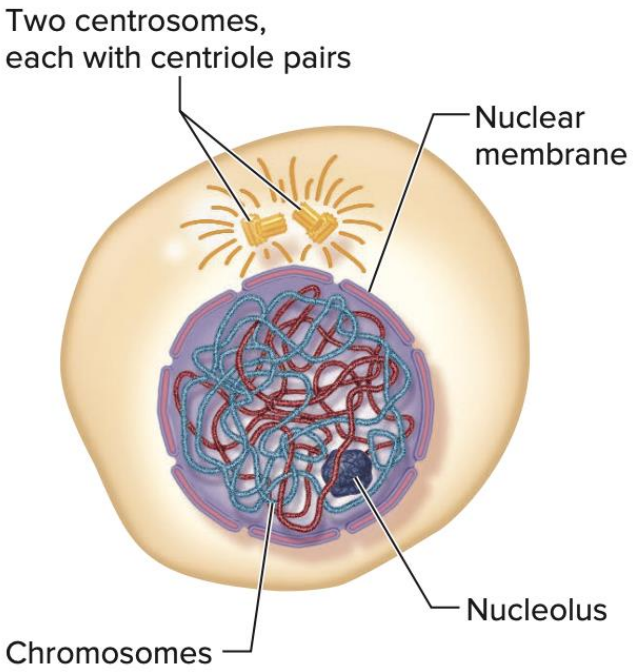

Polar microtubules
Microtubule organizing center (MTOC)
Astral microtubules
Kinetochore
Kinetochore microtubules (K-fibers)



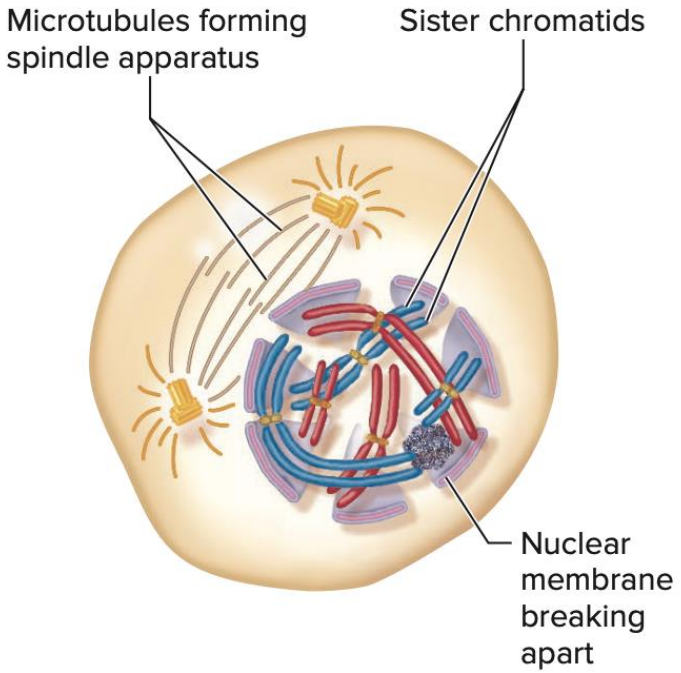




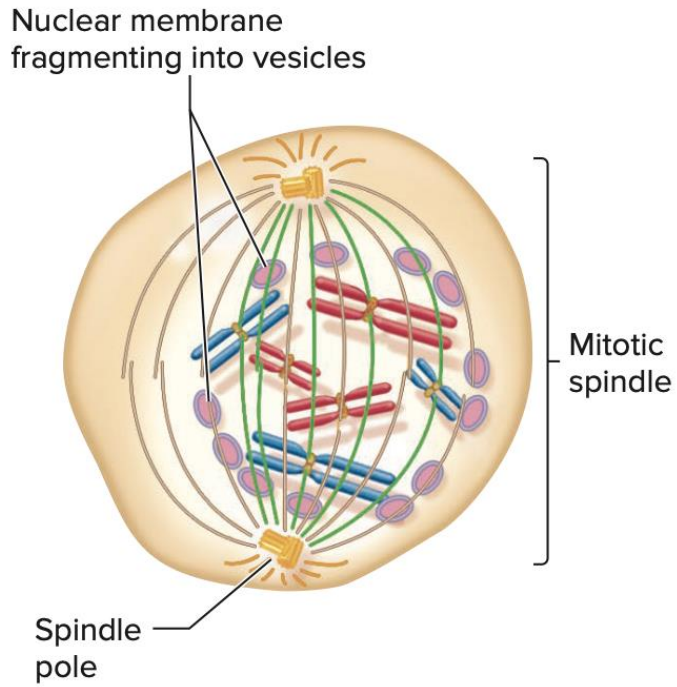




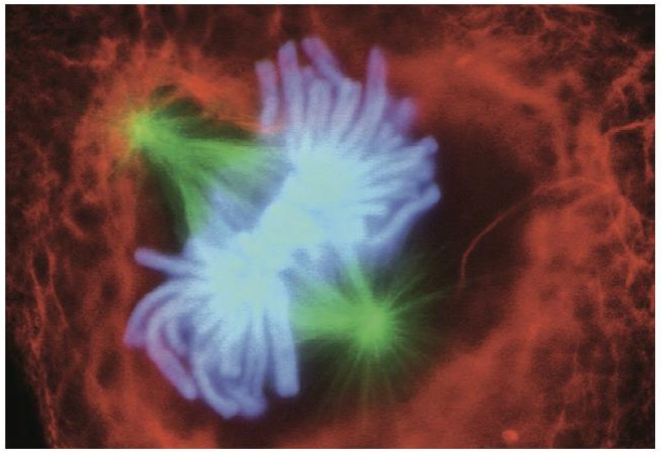
(a) **INTERPHASE**

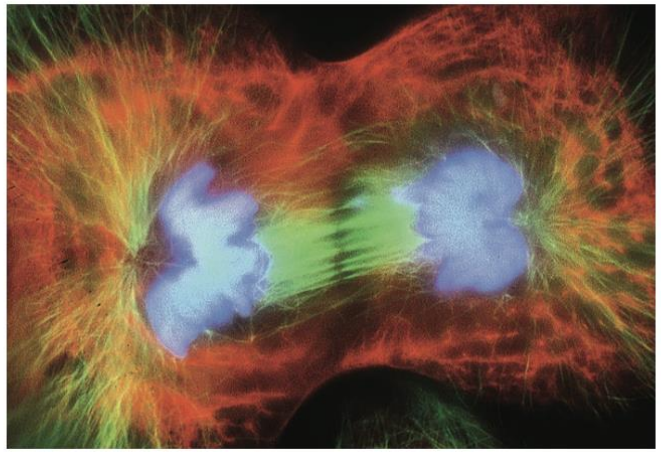


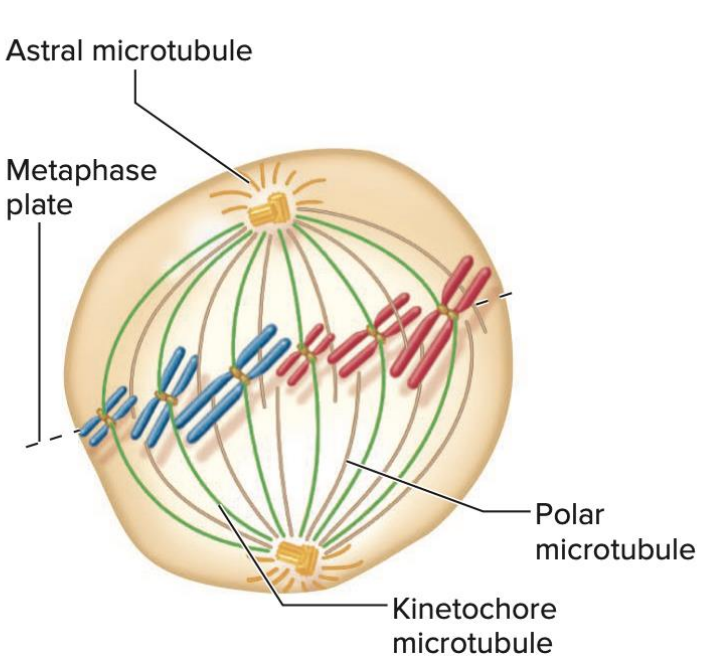
(b) **PROPHASE**



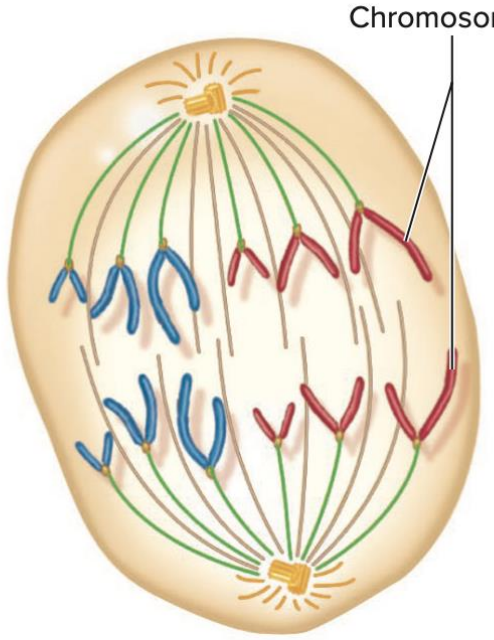
(c) **PROMETAPHASE**



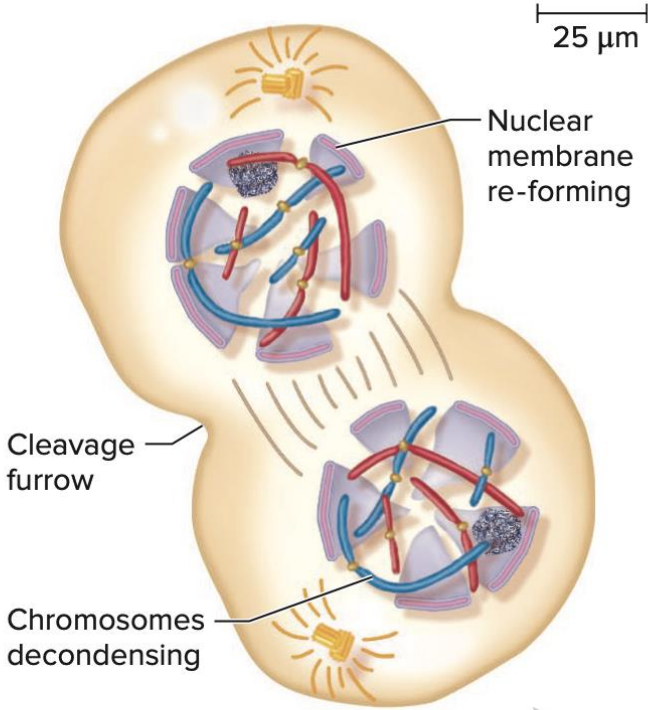




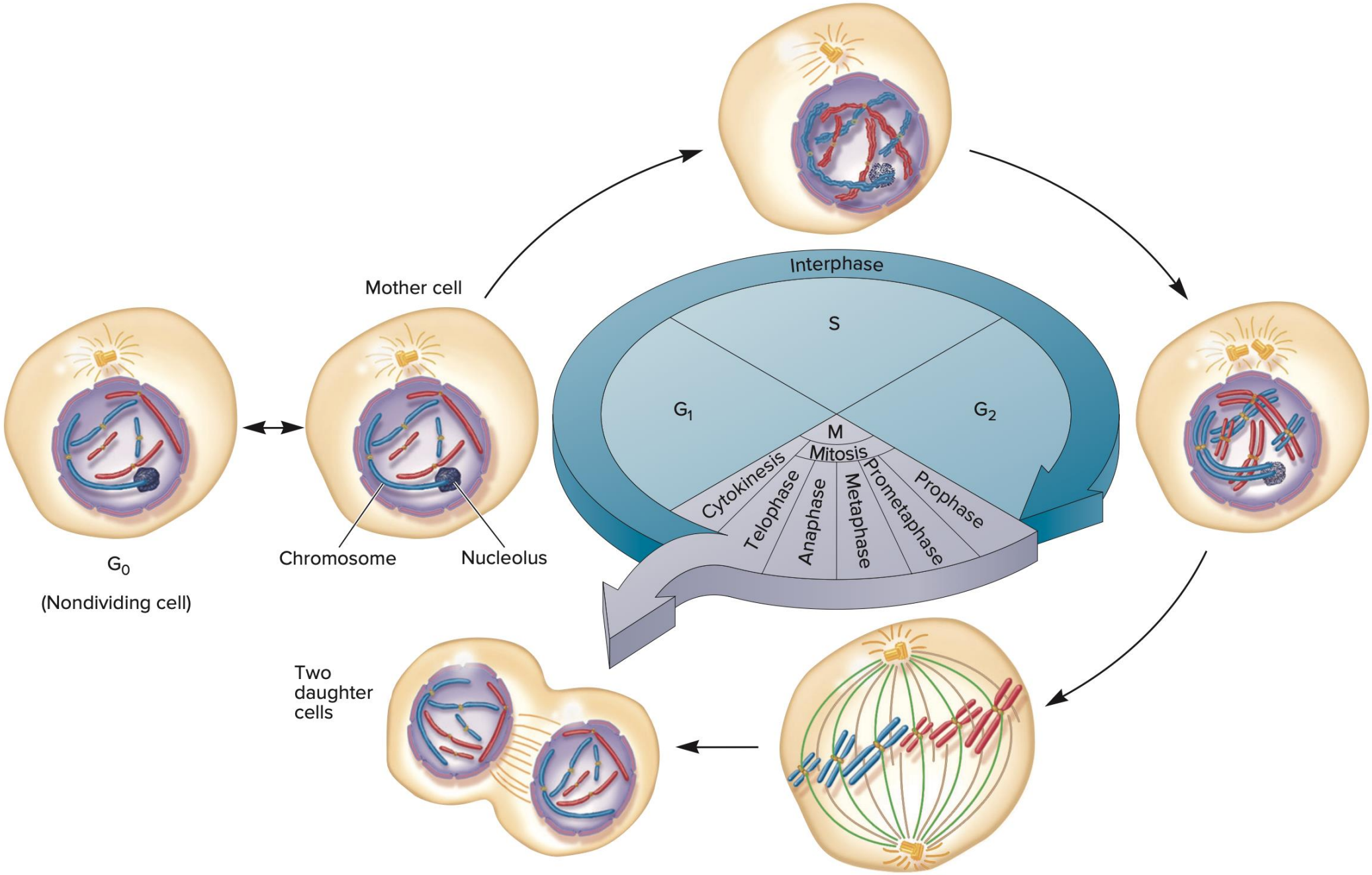
(d) METAPHASE



(e) ANAPHASE



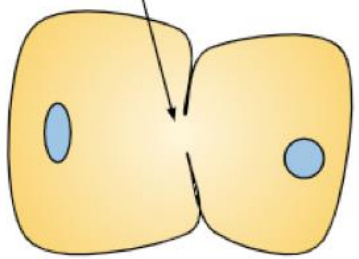
(f) TELOPHASE AND CYTOKINESIS


Mother cell
Interphase
S
G1
G2
M
Mitosis
Cytokinesis
Telophase
Anaphase
Metaphase
Prometaphase
Prophase
G0
(Nondividing cell)
Chromosome
Nucleolus
Two daughter cells

Cytokinesis in an animal cell:

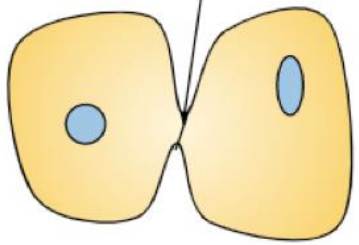
Cleavage furrow

A cleavage furrow is created using a ring of contractile protein, actin and myosin

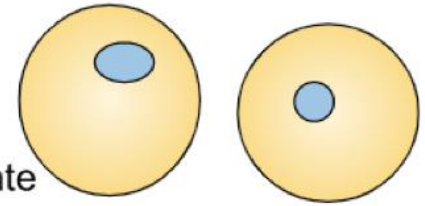


Center

The cleavage furrow reaches the center



The cells are pinched apart into two, separate daughter cells

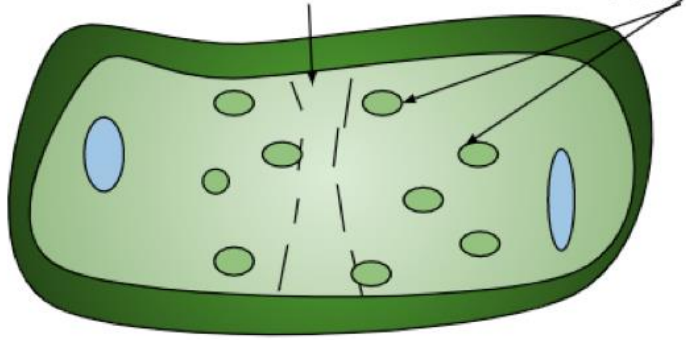


Cytokinesis in a plant cell:

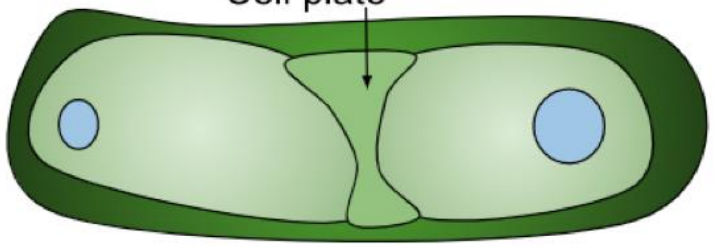
Equator

Vesicles

Vesicles moved to the equator where thev fuse

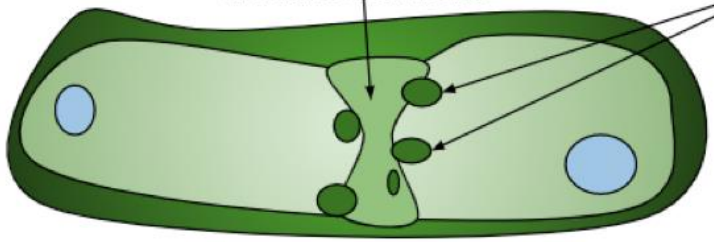


Cell plate



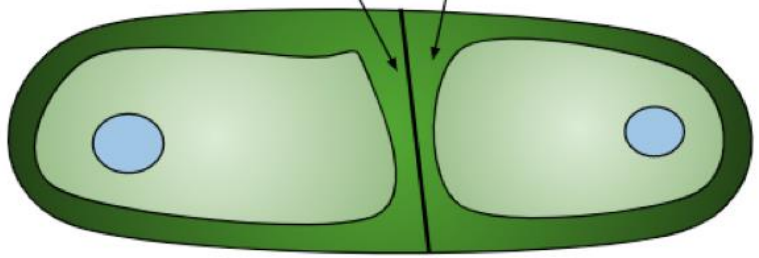
Middle Lamella

Vesicles



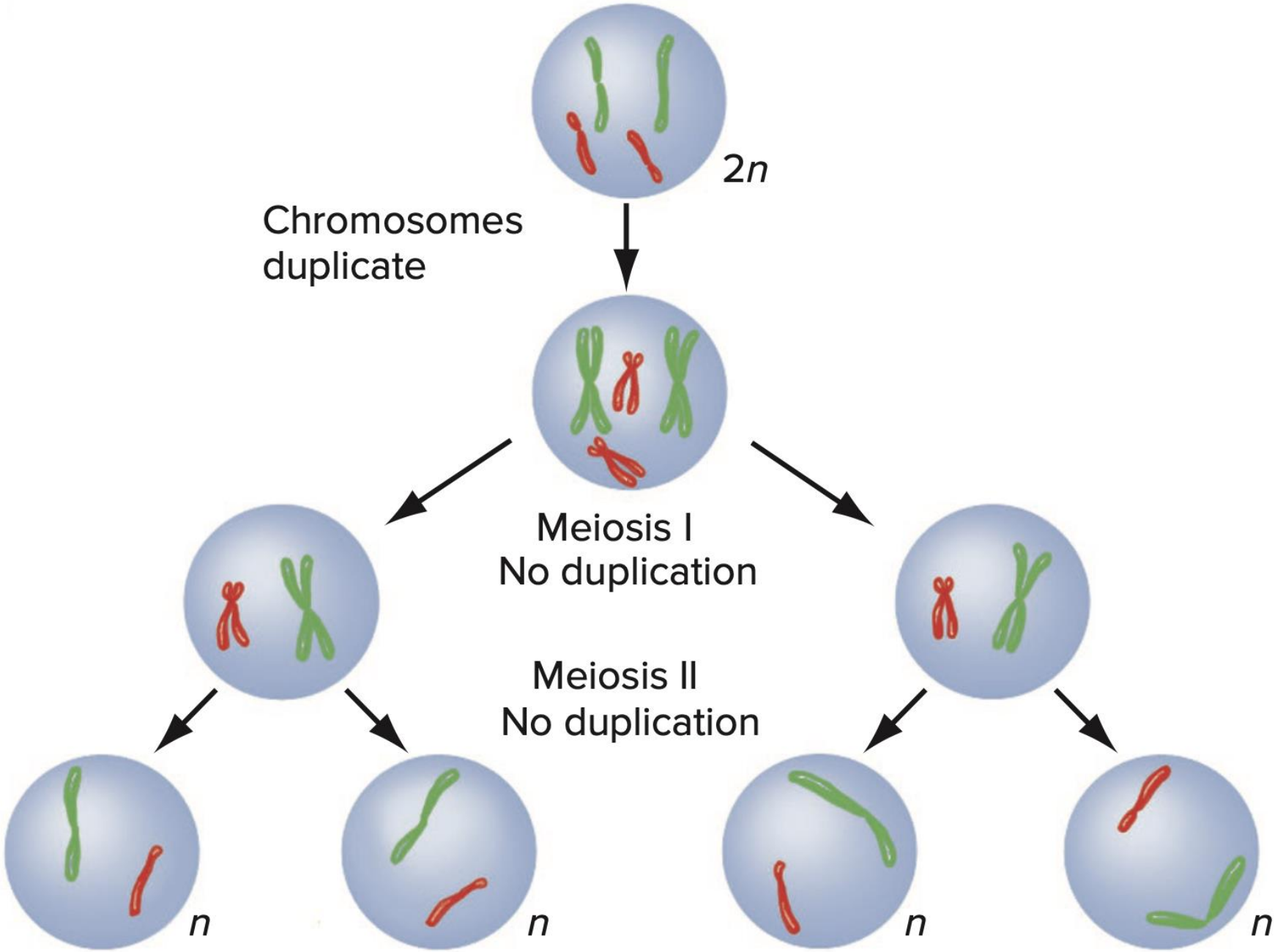
Cell Walls

Cell walls are formed adjacent to the equator



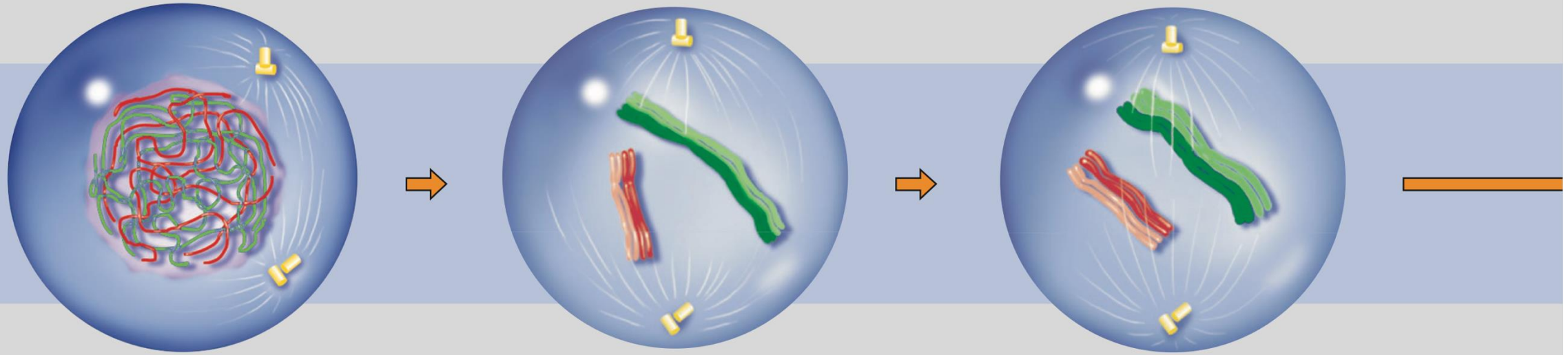
MEIOSIS

Overview


2n
Chromosomes duplicate
Meiosis I
No duplication
Meiosis II
No duplication
n
n
n
n

Prophase I

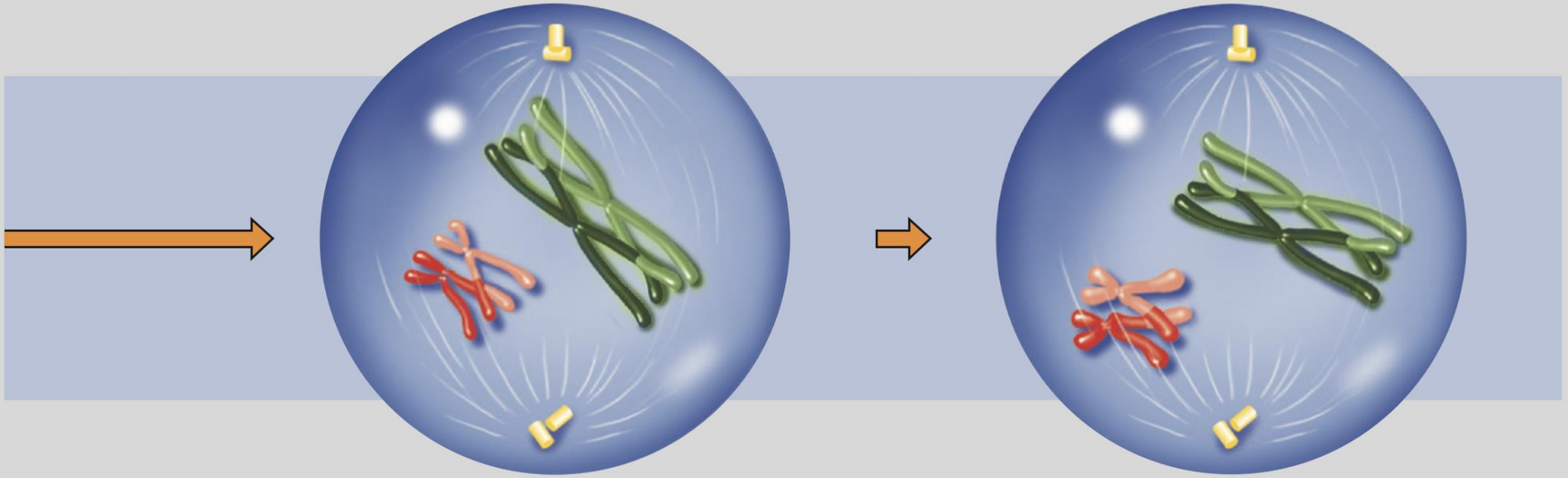
Meiosis I: A reductional division



Prophase I: Leptotene
1. Chromosomes begin to condense.
2. Centrosomes begin to move toward opposite poles.

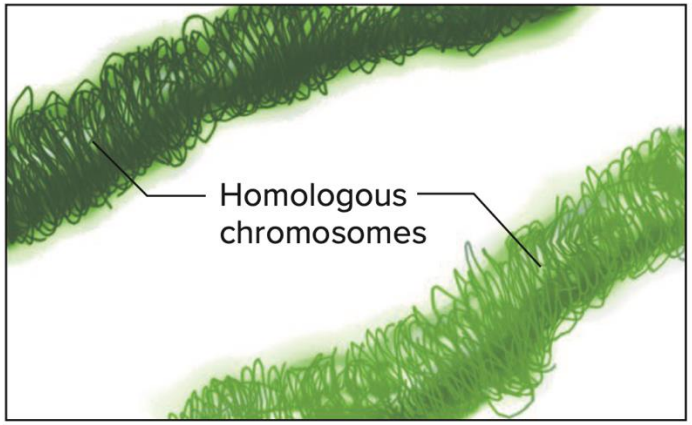
Prophase I: Zygotene
1. Homologous chromosomes enter *synapsis*.
2. The *synaptonemal complex* forms.

Prophase I: Pachytene
1. Synapsis is complete.
2. *Crossing-over*, genetic exchange between nonsister chromatids of a homologous pair, occurs.

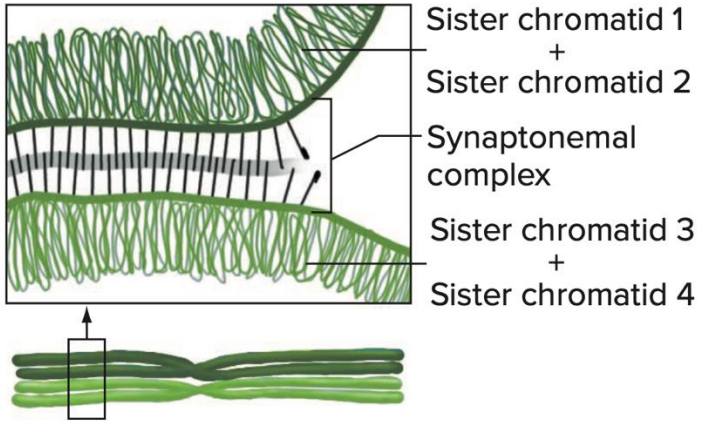


Prophase I: Diplotene
1. Synaptonemal complex dissolves.
2. A *tetrad* of four chromatids is visible.
3. Crossover points appear as *chiasmata*, holding nonsister chromatids together.
4. Meiotic arrest occurs at this time in many species.

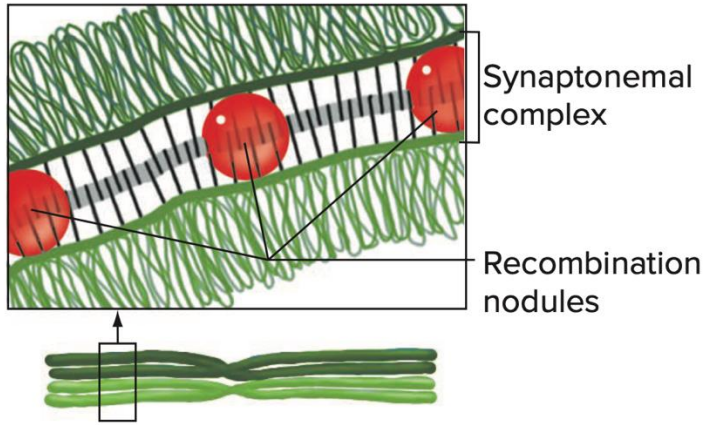
Prophase I: Diakinesis
1. Chromatids thicken and shorten.
2. At the end of prophase I, the nuclear membrane (*not shown earlier*) breaks down, and the spindle begins to form.



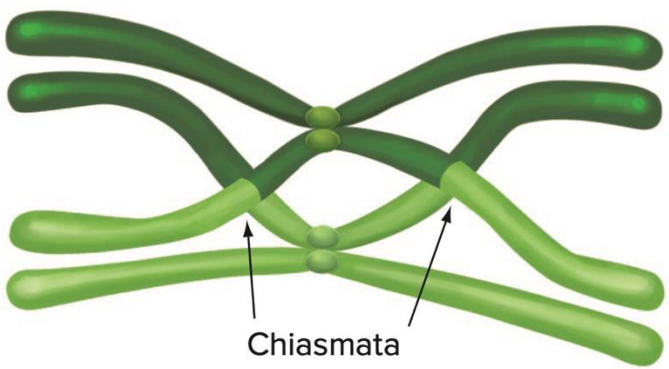
(a) **Leptotene:** Threadlike chromosomes begin to condense, becoming visible as discrete structures, although the sister chromatids cannot yet be distinguished.



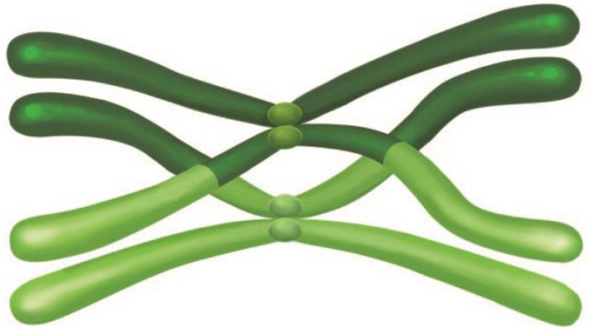
(b) **Zygotene:** Chromosomes are clearly visible and begin pairing with homologous chromosomes along the synaptonemal complex to form a bivalent, or tetrad.



(c) **Pachytene:** The homologs synapse fully. Recombination nodules appear along the synaptonemal complex.

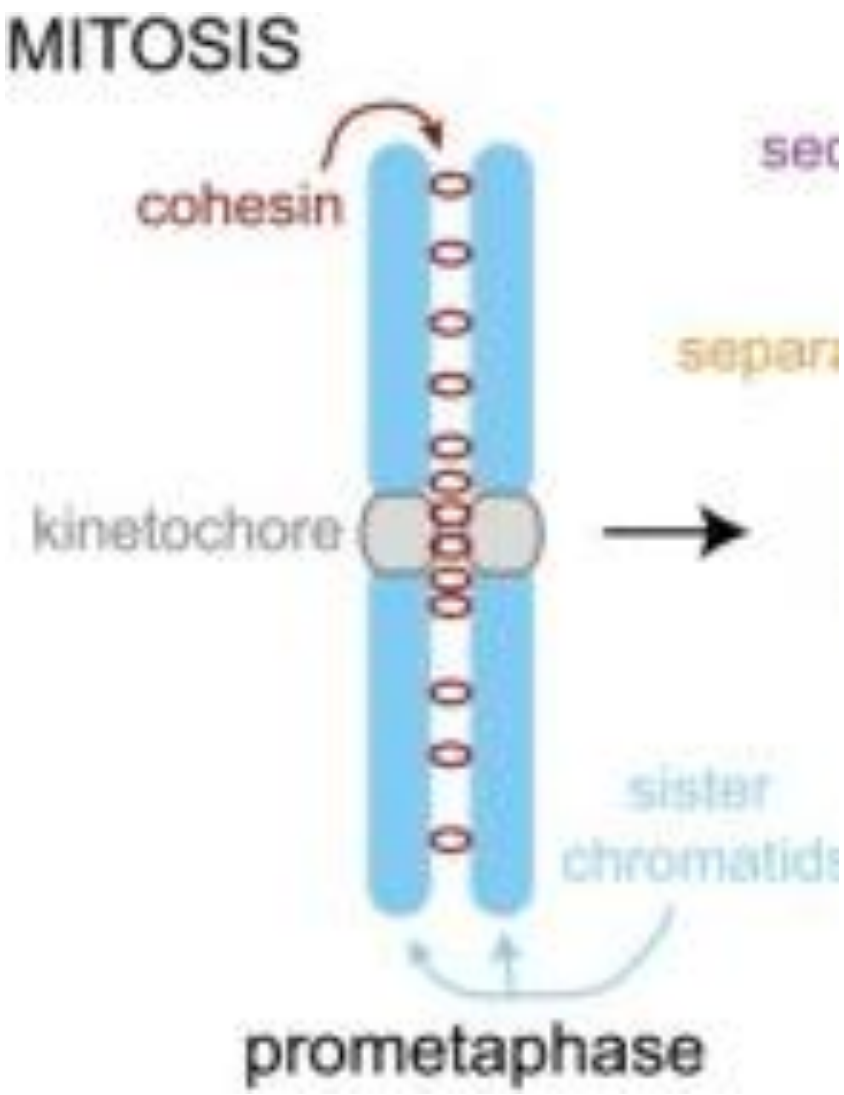


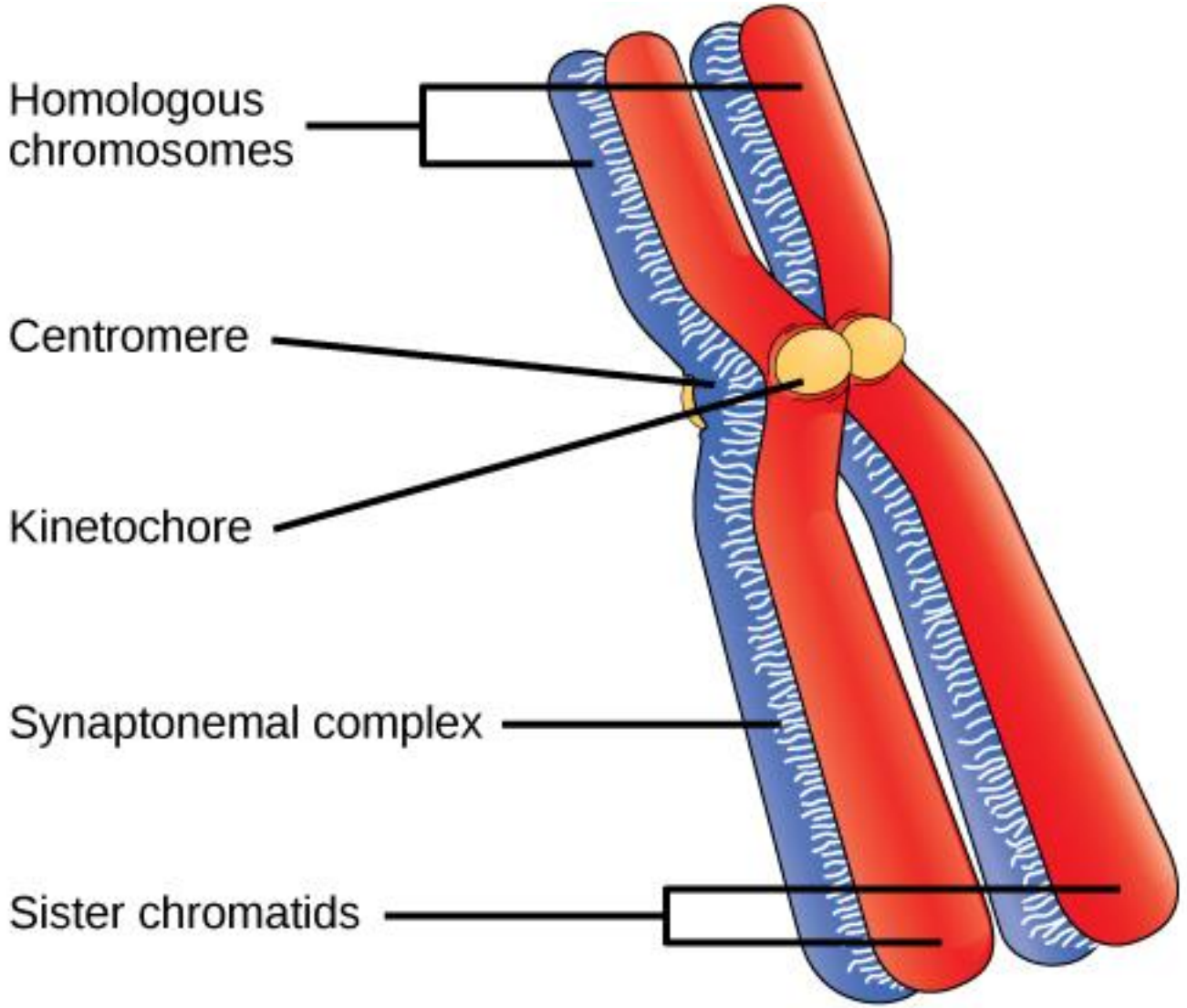
(d) **Diplotene:** The bivalent pulls apart slightly, but homologous chromosomes remain connected due to recombination at crossover sites (chiasmata).

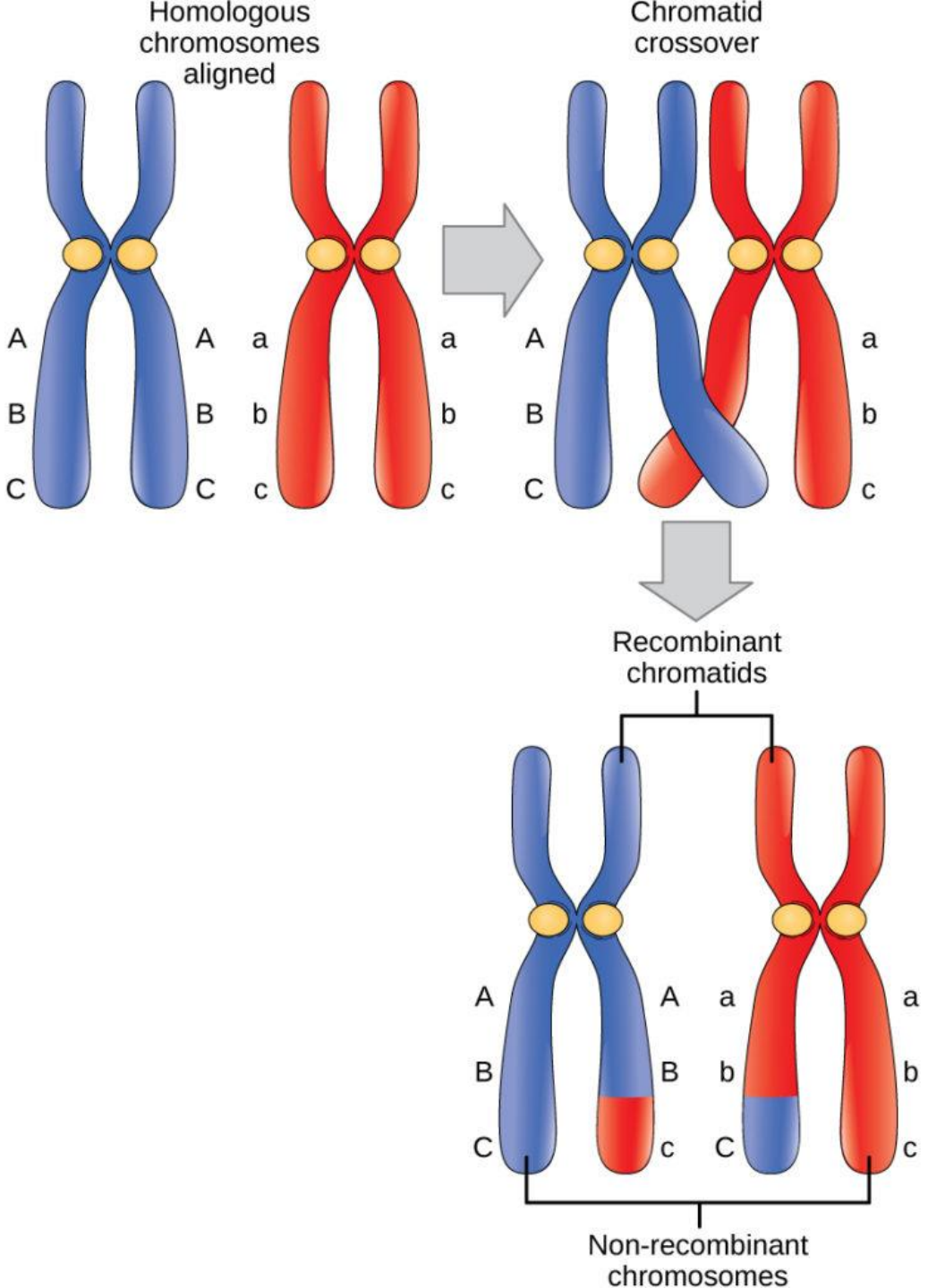


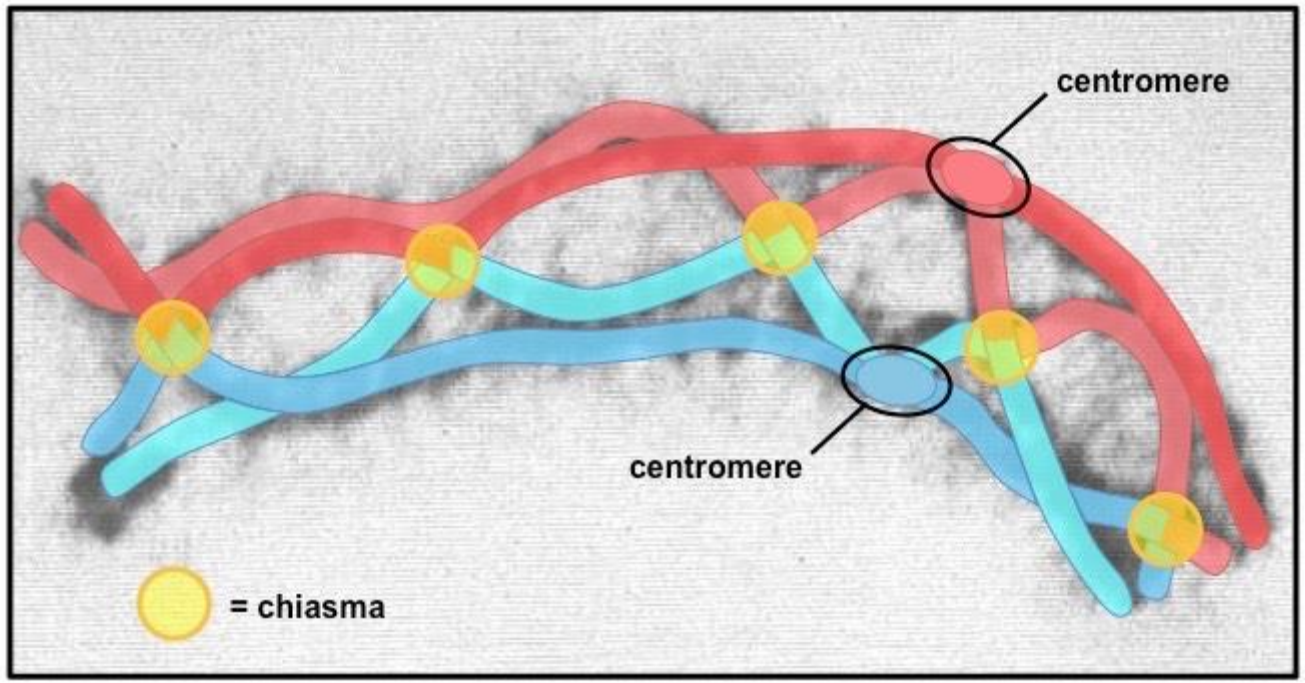
(e) **Diakinesis:** The bivalent condenses further.

Prophase I

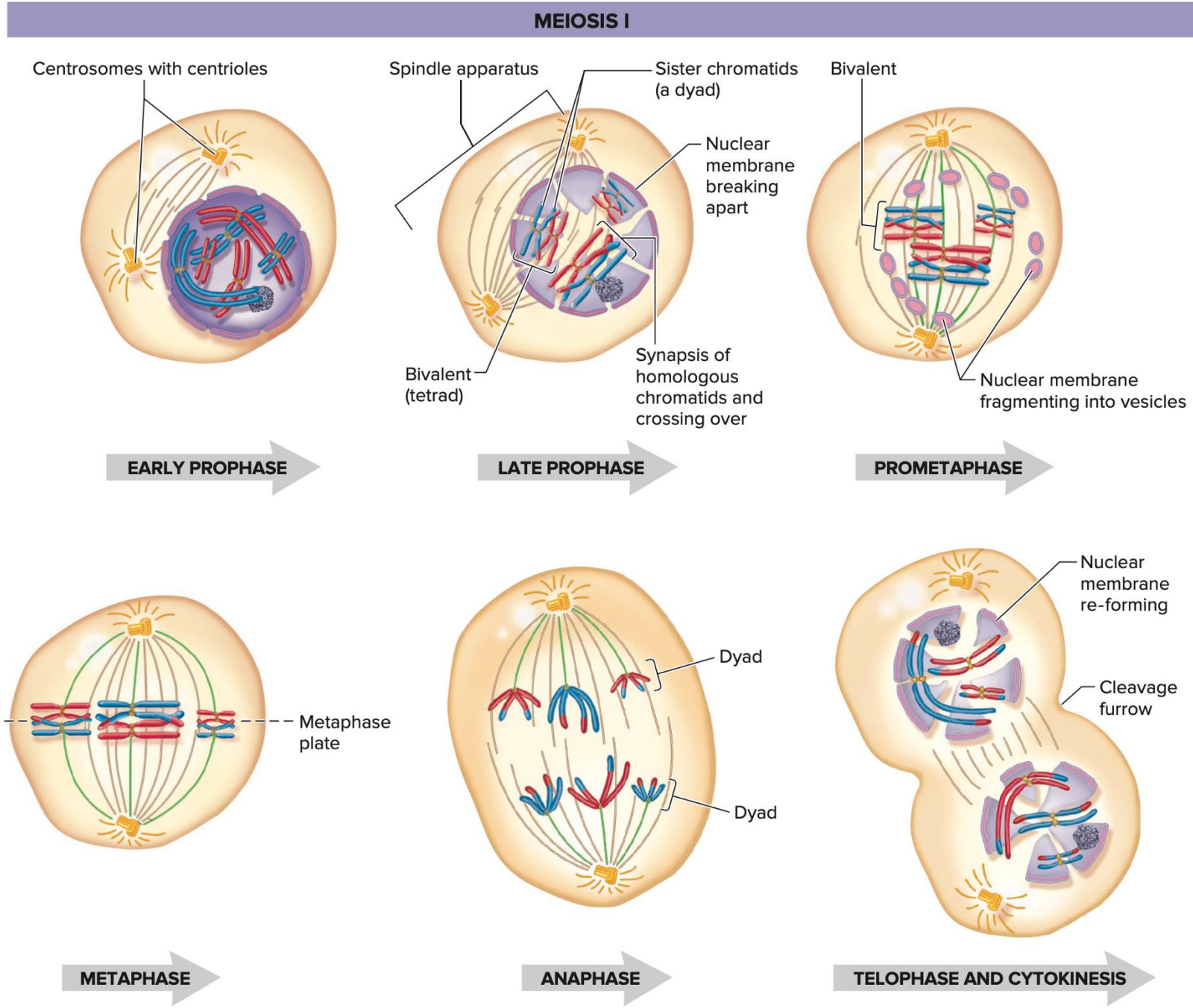

MITOSIS
cohesin
kinetochore
sister
chromatids
prometaphase


Homologous chromosomes
Centromere
Kinetochore
Synaptonemal complex
Sister chromatids

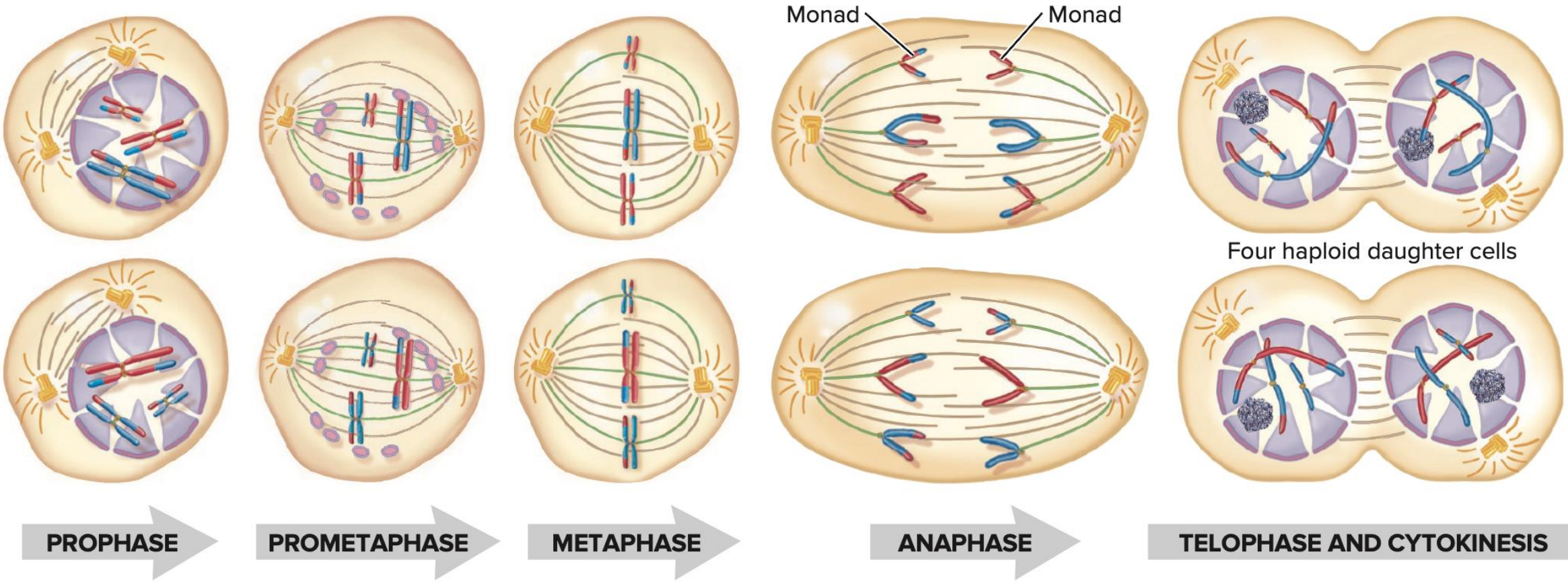




Answer: There are **5** chiasmata present between these homologous chromosomes


MEIOSIS I
Centrosomes with centrioles
EARLY PROPHASE
Spindle apparatus
Sister chromatids (a dyad)
Nuclear membrane breaking apart
Bivalent (tetrad)
Synapsis of homologous chromatids and crossing over
LATE PROPHASE
Bivalent
Nuclear membrane fragmenting into vesicles
PROMETAPHASE
Metaphase plate
METAPHASE
Dyad
Dyad
ANAPHASE
Nuclear membrane re-forming
Cleavage furrow
TELOPHASE AND CYTOKINESIS

MEIOSIS II


Monad
Monad
Four haploid daughter cells
PROPHASE
PROMETAPHASE
METAPHASE
ANAPHASE
TELOPHASE AND CYTOKINESIS

How meiosis contributes to genetic diversity based on the figure below?

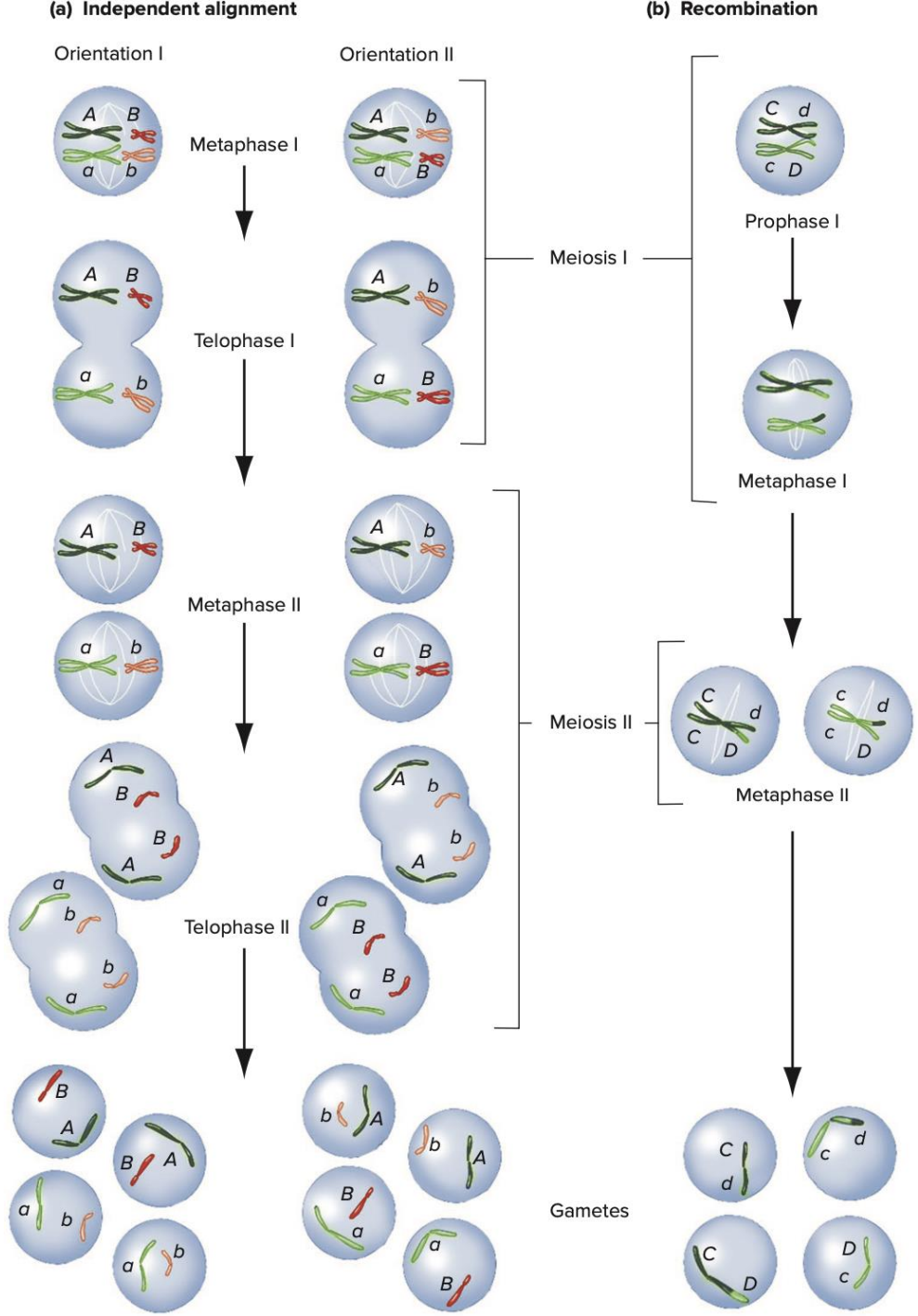
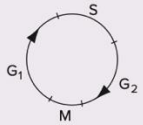
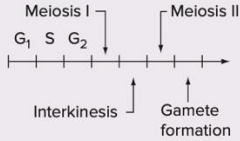
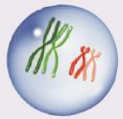
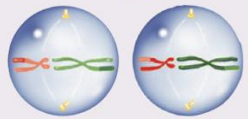
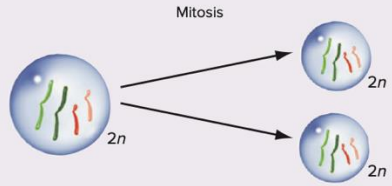
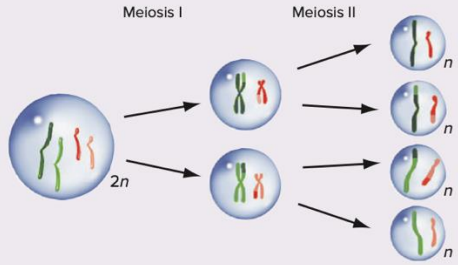
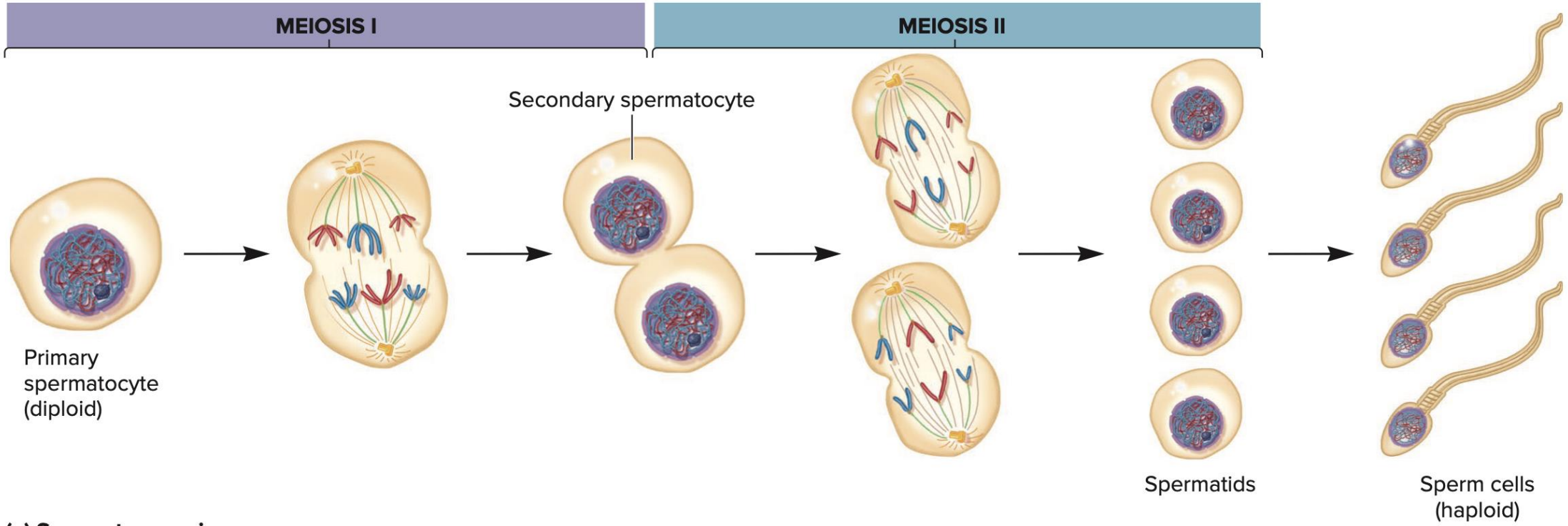


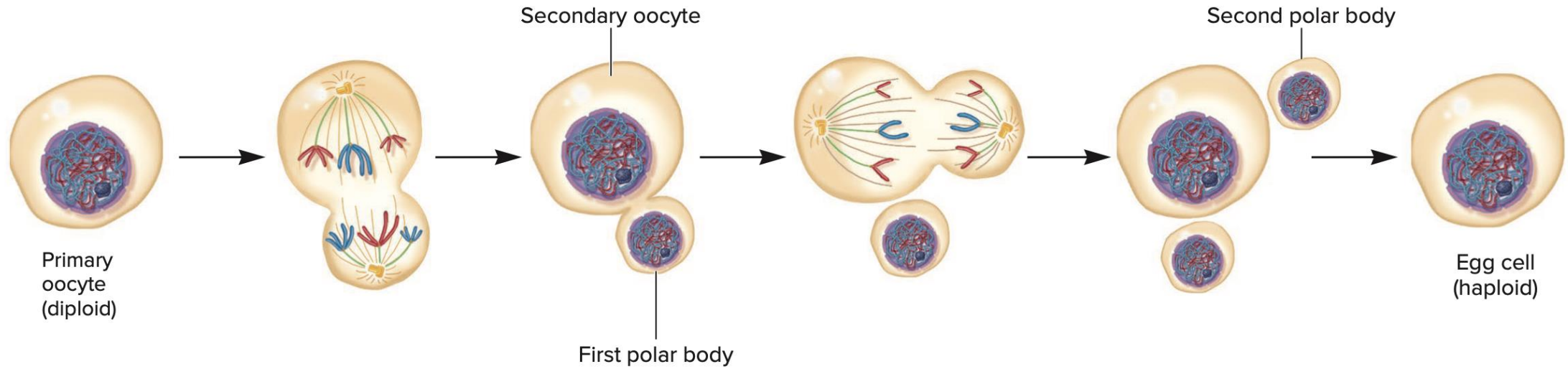
TABLE 3.1 Comparing Mitosis and Meiosis

Mitosis	Meiosis
Occurs in somatic cells and germ-line precursor 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.
 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 centromeres of the sister chromatids separate at the beginning of anaphase.	 The centromeres of the sister chromatids remain tightly attached during meiosis I.
	 Sister chromatids attach to spindle fibers from opposite poles during metaphase II.
	 The centromeres of the sister chromatids separate at the beginning of anaphase II.
 Mitosis produces two new daughter cells, identical to each other and the original cell. Mitosis is thus genetically conservative.	 Meiosis produces four haploid cells, one (egg) or all (sperm) of which can become gametes. None of these is identical to each other or to the original cell, because meiosis results in combinatorial change.

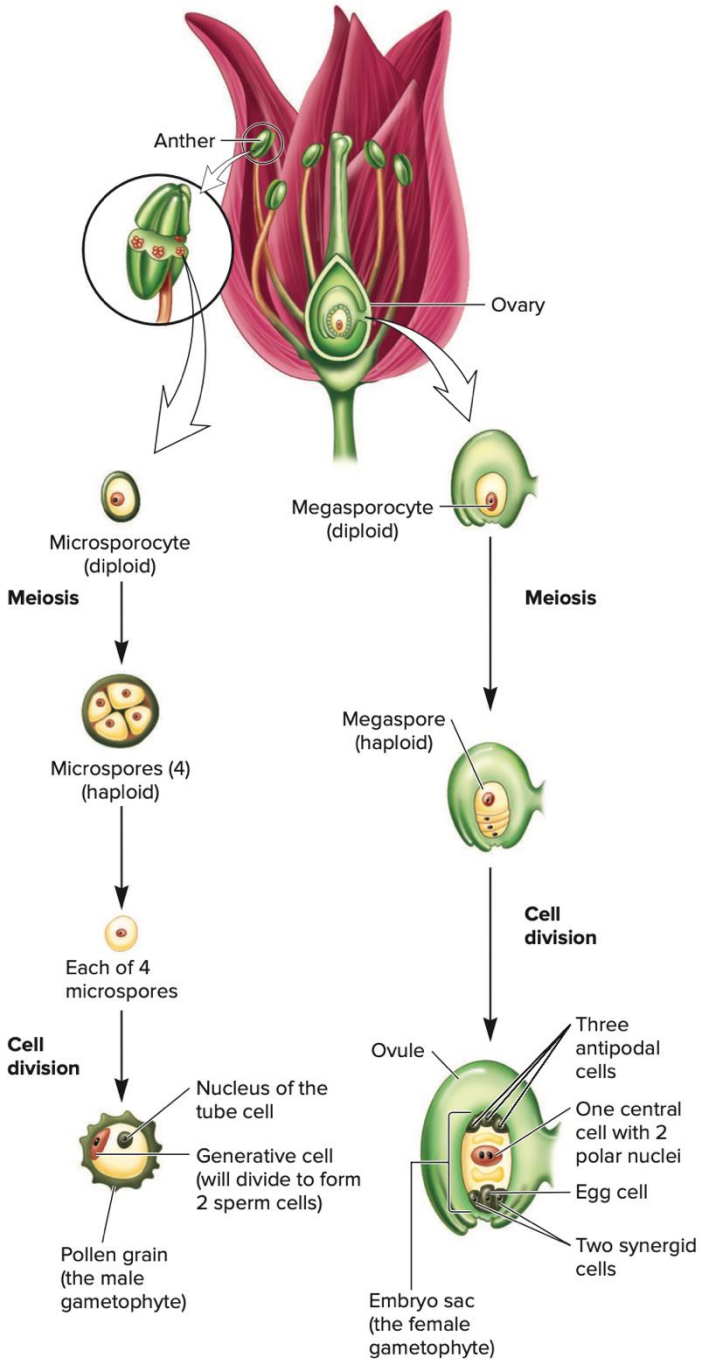
SEXUAL REPRODUCTION

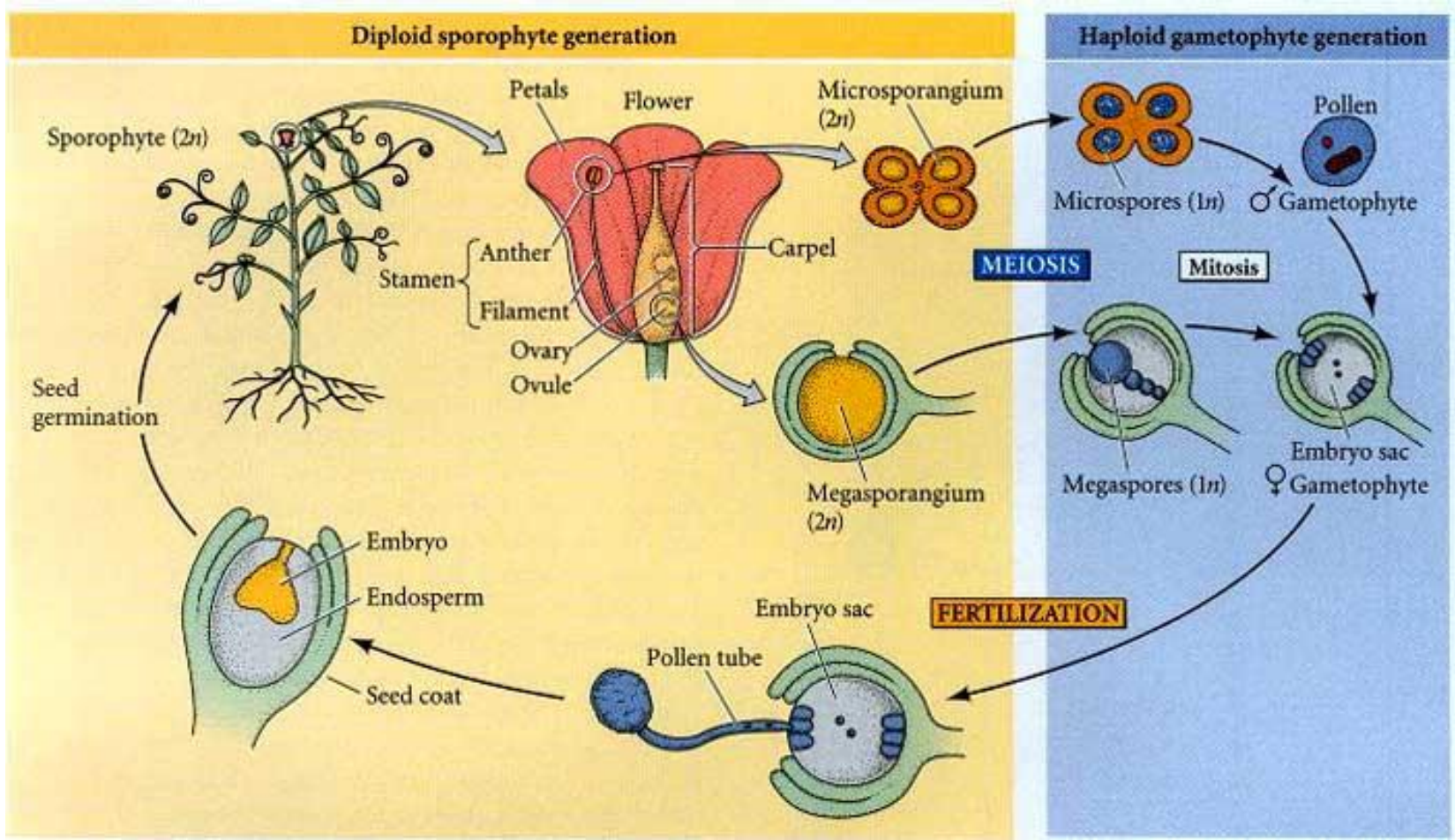


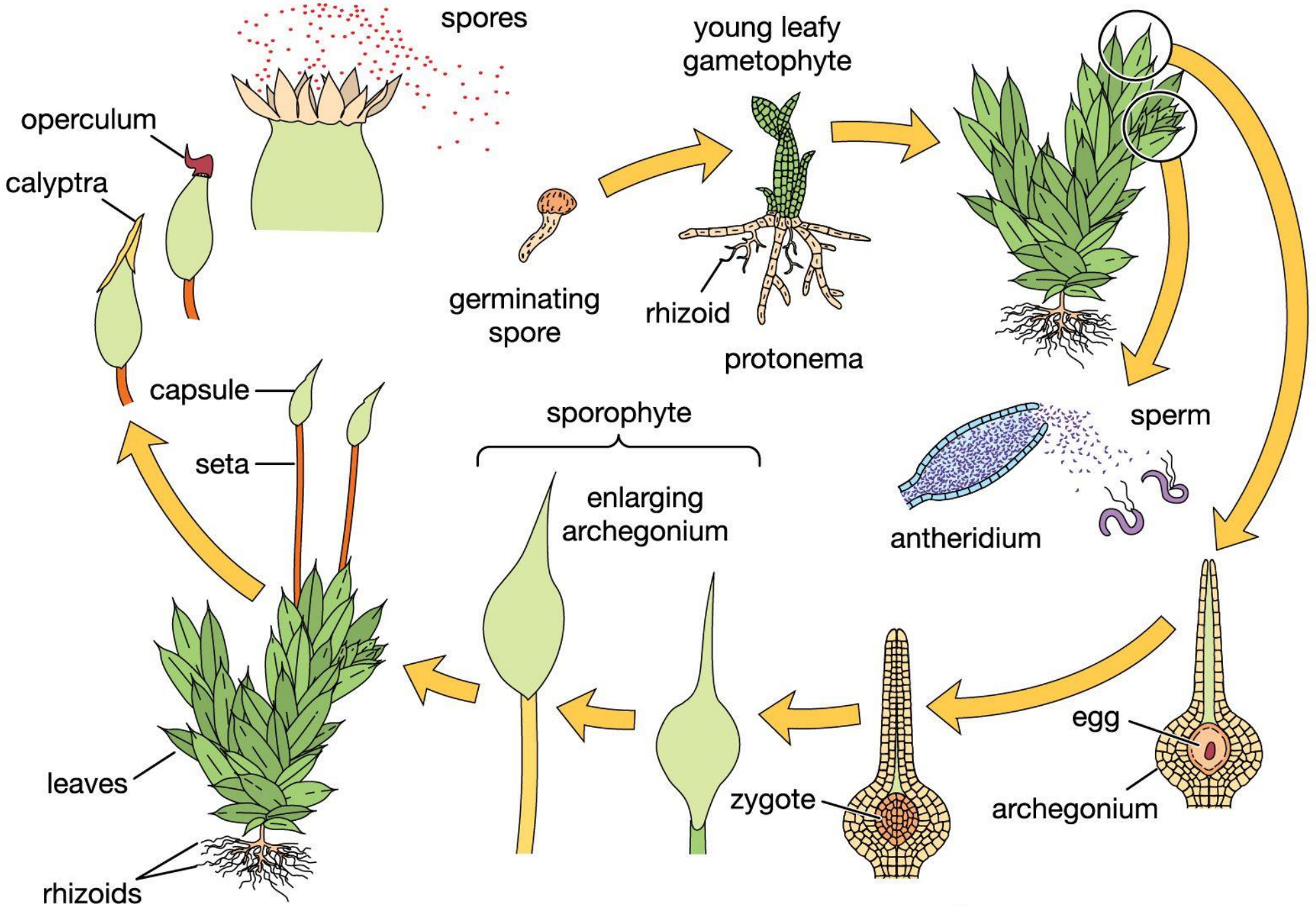
(a) Spermatogenesis



(b) Oogenesis


Anther
Ovary
Microsporocyte (diploid)
Meiosis
Microspores (4) (haploid)
Each of 4 microspores
Cell division
Nucleus of the tube cell
Generative cell (will divide to form 2 sperm cells)
Pollen grain (the male gametophyte)
Megasporocyte (diploid)
Meiosis
Megaspore (haploid)
Cell division
Ovule
Three antipodal cells
One central cell with 2 polar nuclei
Egg cell
Two synergid cells
Embryo sac (the female gametophyte)


Diploid sporophyte generation
Haploid gametophyte generation
Sporophyte (2n)
Petals
Flower
Microsporangium (2n)
Pollen
Microspores (1n)
Gametophyte
Stamen
Anther
Filament
Carpel
Ovary
Ovule
MEIOSIS
Mitosis
Seed germination
Megasporangium (2n)
Megaspores (1n)
Embryo sac
Gametophyte
Embryo
Endosperm
Seed coat
Embryo sac
FERTILIZATION
Pollen tube



ANIMAL PRODUCED GAMETES BY MEIOSIS WHILE PLANTS PRODUCE GAMETES BY MITOSIS.

SEX CHROMOSOME AND SEX DETERMINATION

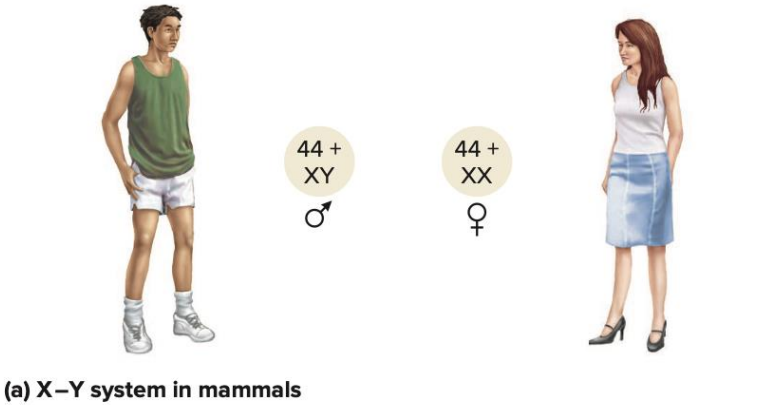


FIGURE 2.15 **Different mechanisms of sex determination in animals.** See the text for a description.

X-Y System:
The male has one X chromosome and one Y chromosome.
Females are homogametic. Males are heterogametic.

X-0 System (Insects)
X0 insect is male; XX insect is female
The ratio between X chromosomes and the number of autosomal sets determine sex

1:2 ratio is male **2:2 ratio is female**

Z-W System (Birds and Fish)

ZZ is male	ZW is female
Homogametic	Heterogametic

Haplodiploid System (Bees)
Males – produced from unfertilized eggs
Females – worker bees and queen bees – produced from fertilized eggs

SEX DIFFERENCE MAY DEPEND ON THE ENVIRONMENT

SEX IS CONTROLLED BY

1. **Temperature (i.e. American alligator)**
   - 7 to 12 days
   - < 30 degrees C produce all female offspring
   - >34 degrees C produce all male offspring
   - TRPV 4 (thermosensitive protein)
2. **Behavior**
   - Clownfish are protandrous hermaphrodites

PROBLEM:

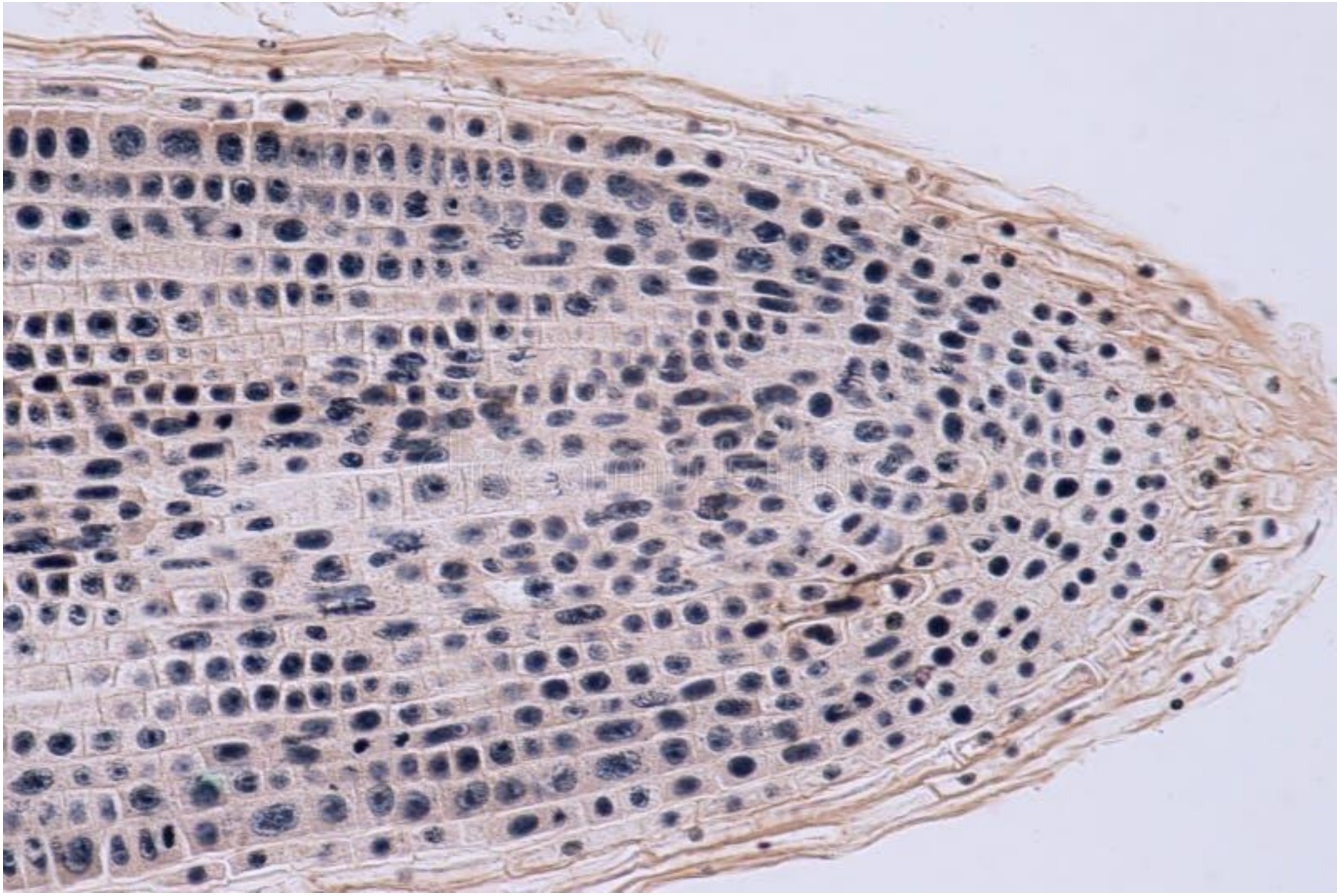
Some organisms, for example some kinds of salmon, are naturally tetraploid; their somatic cells contain four sets of chromosomes and thus four copies of each homolog. During meiosis I in germ cells, the four homologs form two pairs (bivalents) randomly, and thus two random homologs segregate into each daughter cell. Suppose a tetraploid salmon has 100 chromosomes in each of its somatic cells.

a. How many different types of chromosomes are present in this species?

b. How many chromosomes will each germ cell contain after meiosis I? How many chromatids?

c. How many chromosomes are in the gametes of this organism? (What is n?)

d. If no crossing-over were to take place, how many genetically different eggs could a female salmon produce, assuming (correctly) that each chromosome in each set of four differ in the alleles of some genes?

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