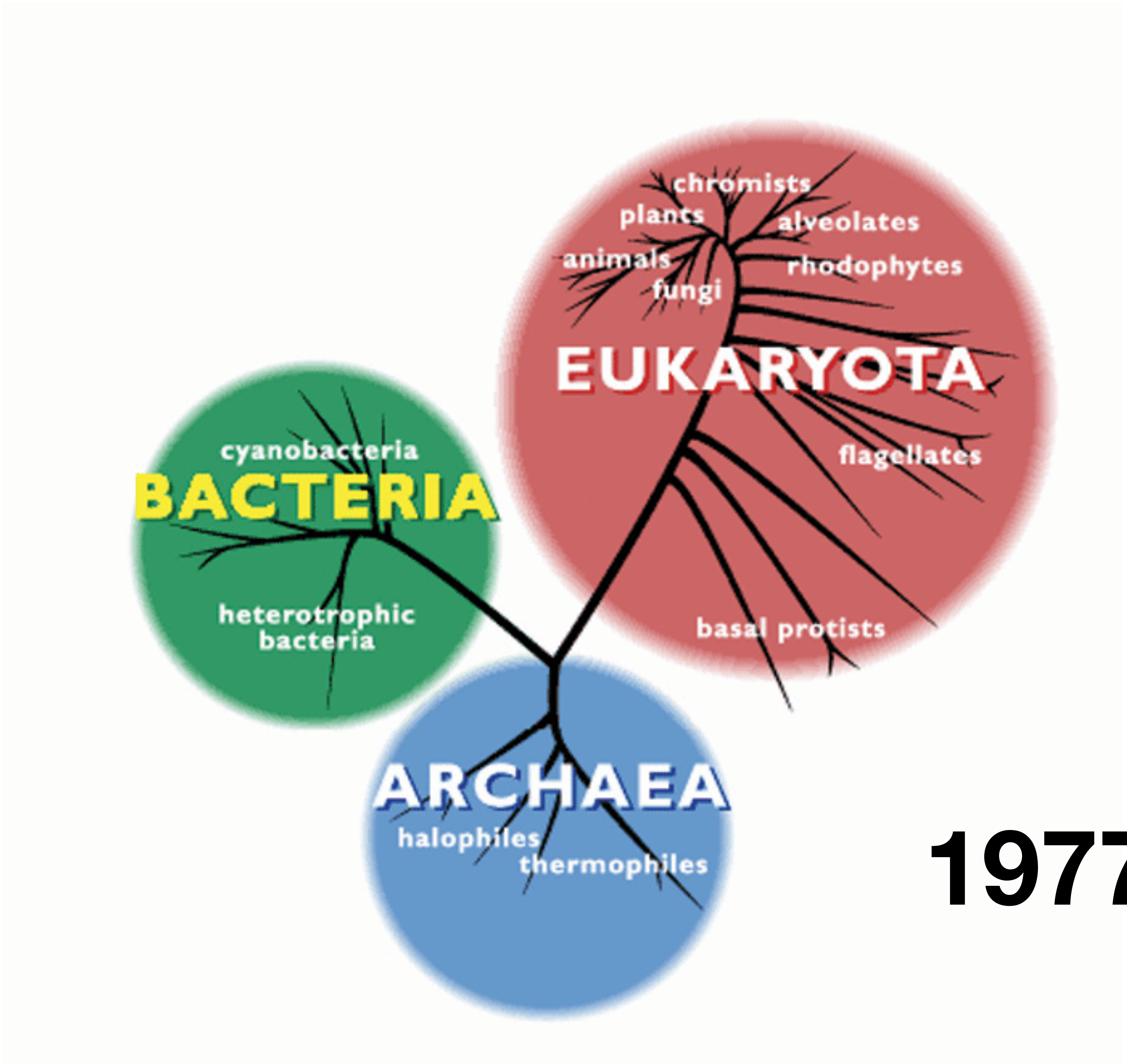
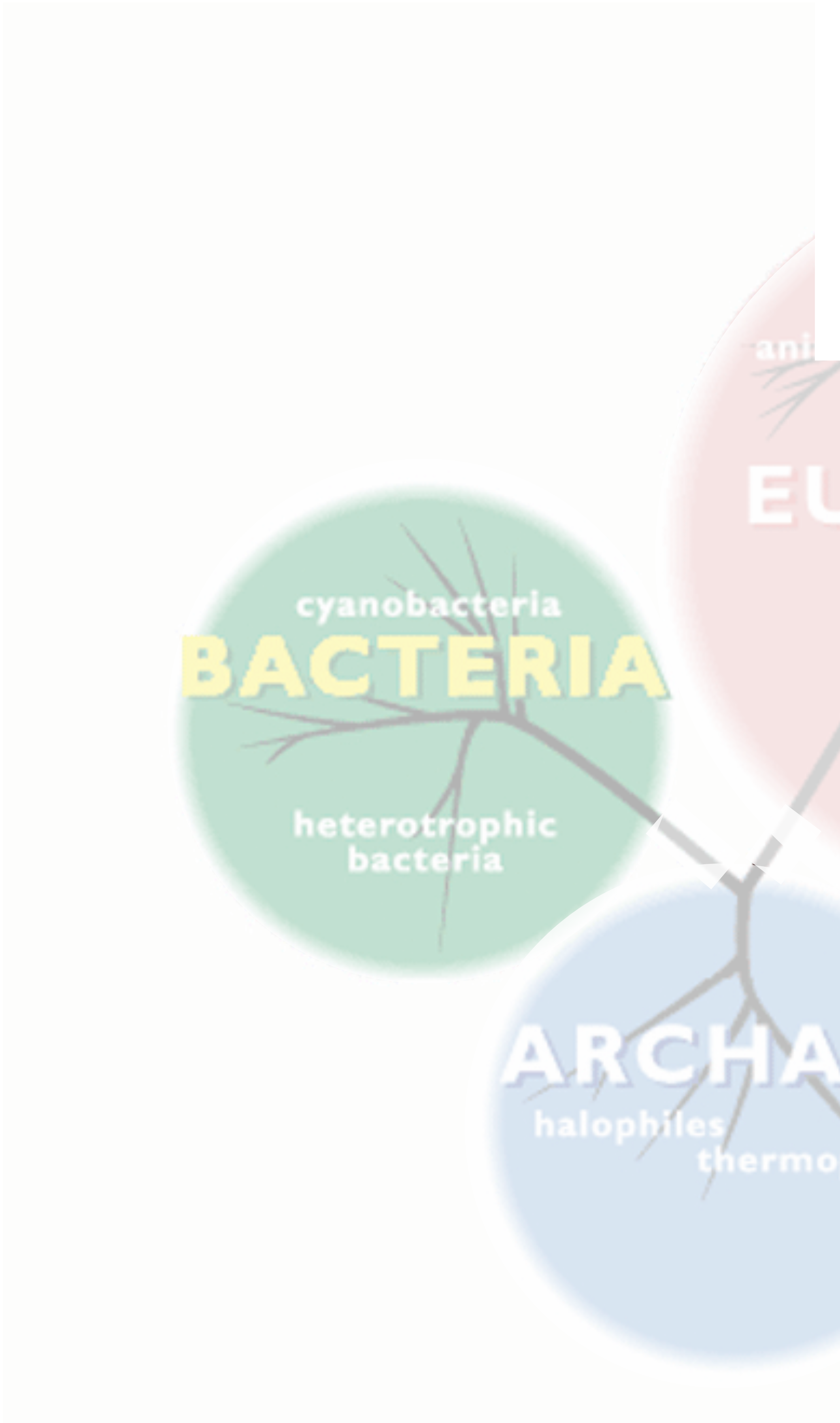
BIOL2107, Fall ’23

Lecture 9: Eukaryotes & Cell Division


chromists
plants
alveolates
animals
rhodophytes
fungi
EUKARYOTA
flagellates
basal protists
cyanobacteria
BACTERIA
heterotrophic
bacteria
ARCHAEA
halophiles
thermophiles

1977



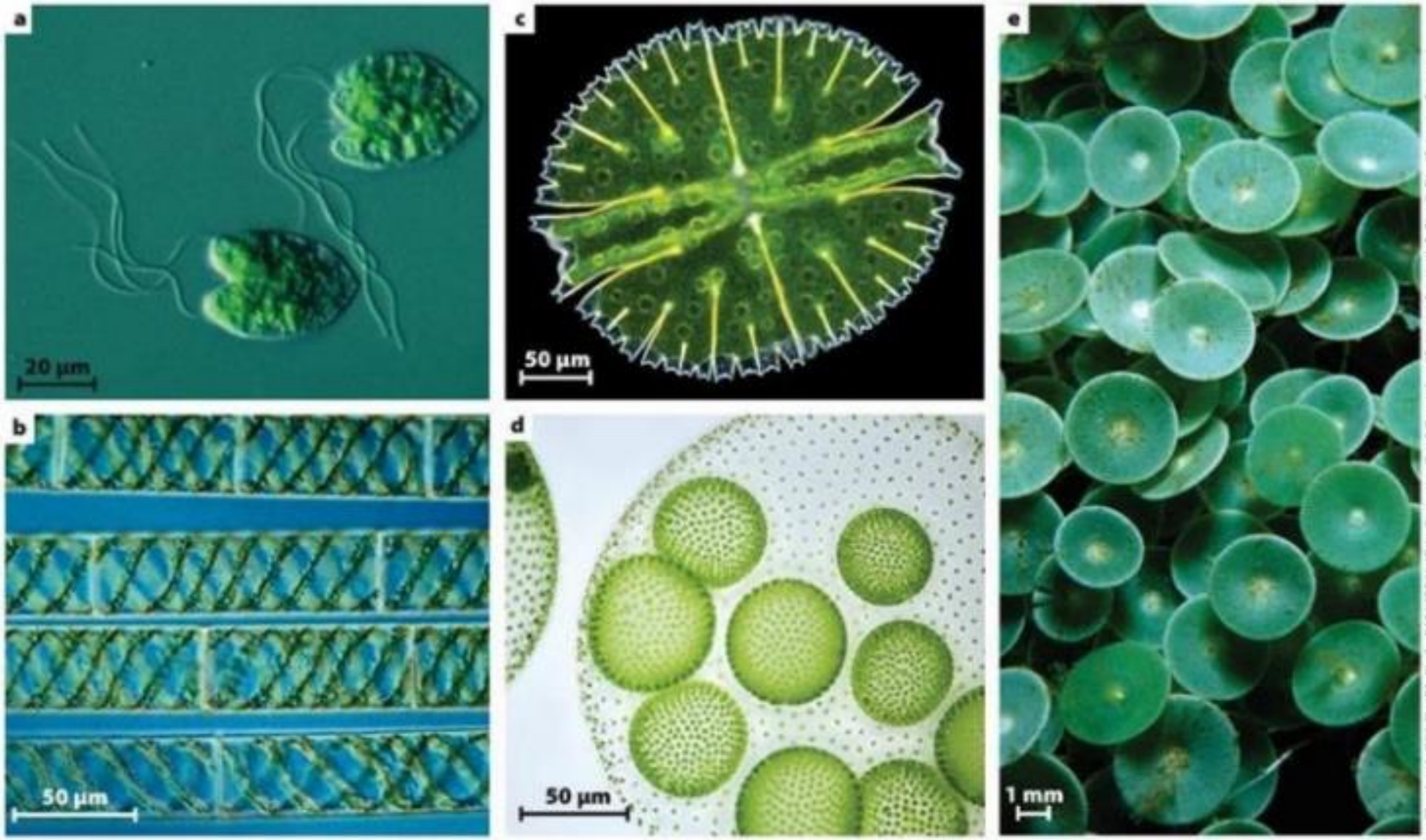
Eukaryote

Temporal range: Orosirian – Present

1850–0 Ma

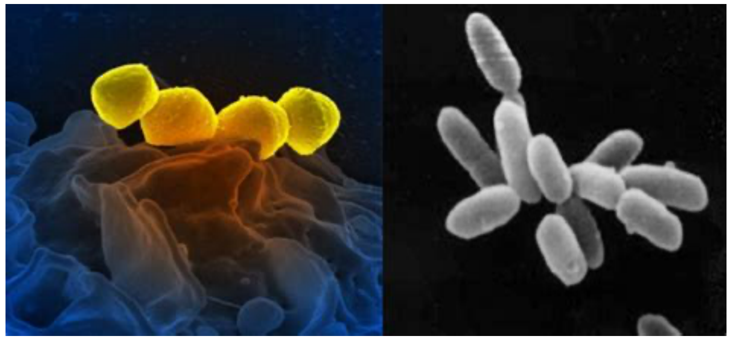
Had'n Archean Proterozoic Pha.

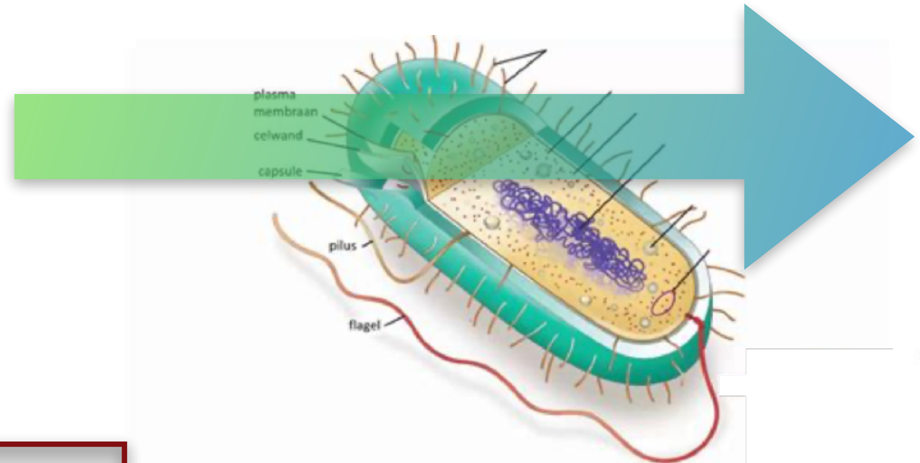
Diversity in Eukaryotes

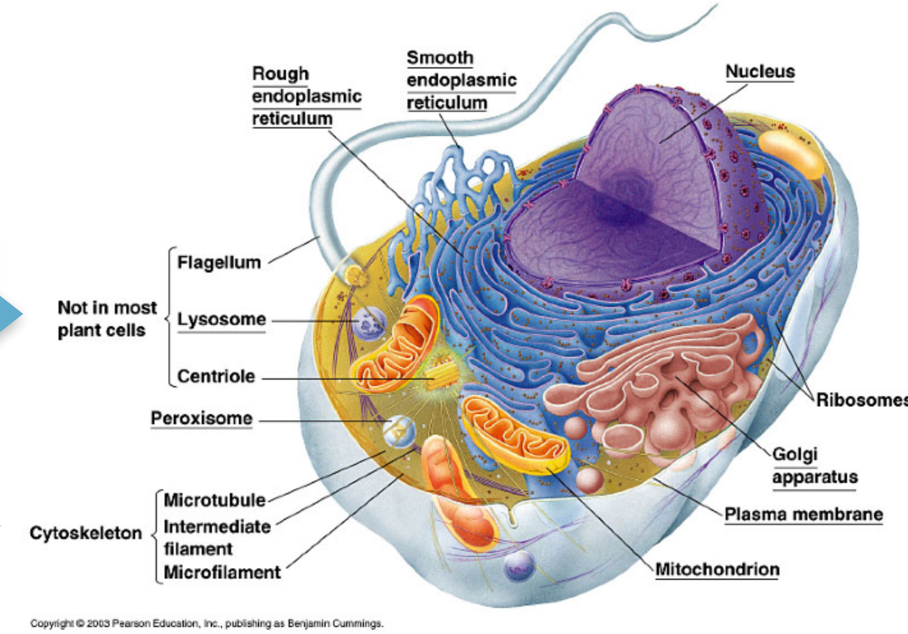


a: Charles J. O'Kelly, Ph.D.; b: DIOMEDIA/Erik Grave; c: Gerd Guenther/Science Source; d: Frank Fox/Science Source; e: Wolfgang Poelzer/Wa/AGE Fotostock

Figure 25.15
Biology: How Life Works, Third Edition






Rough endoplasmic reticulum
Smooth endoplasmic reticulum
Nucleus
Flagellum
Not in most plant cells
Lysosome
Centriole
Peroxisome
Ribosomes
Golgi apparatus
Cytoskeleton
Microtubule
Intermediate filament
Microfilament
Plasma membrane
Mitochondrion
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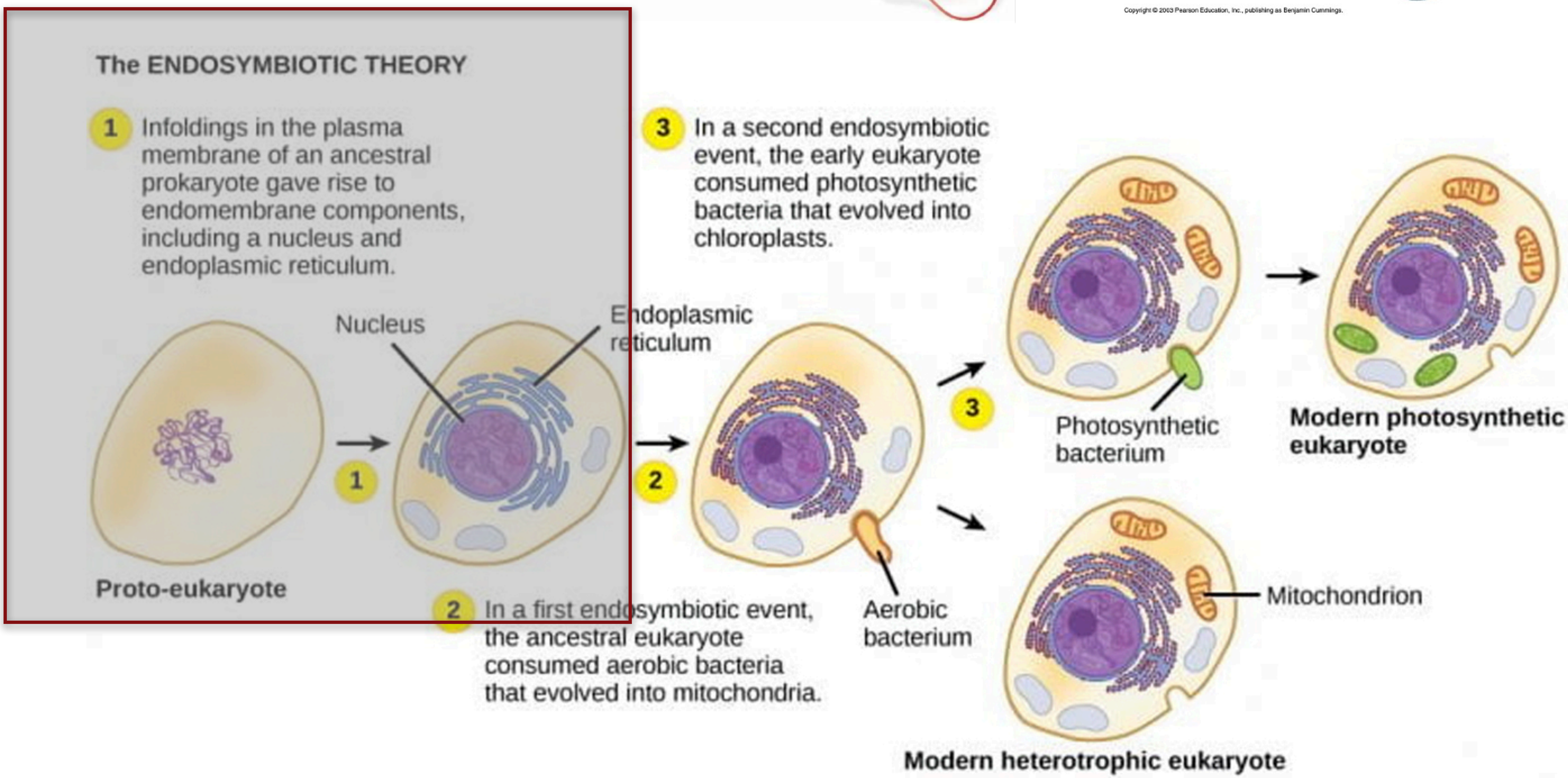
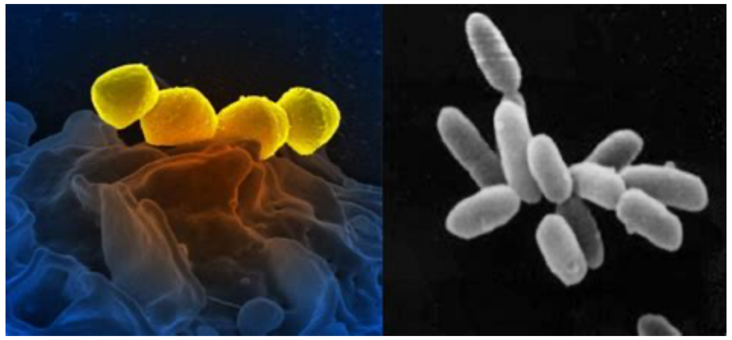
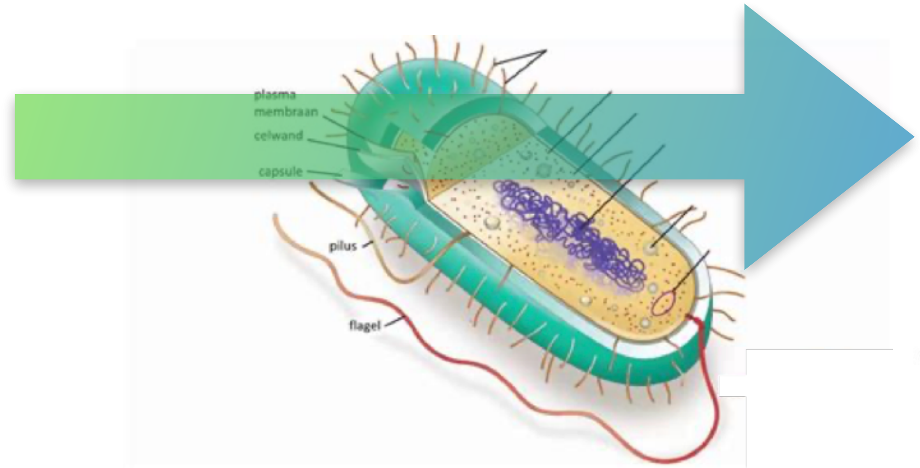
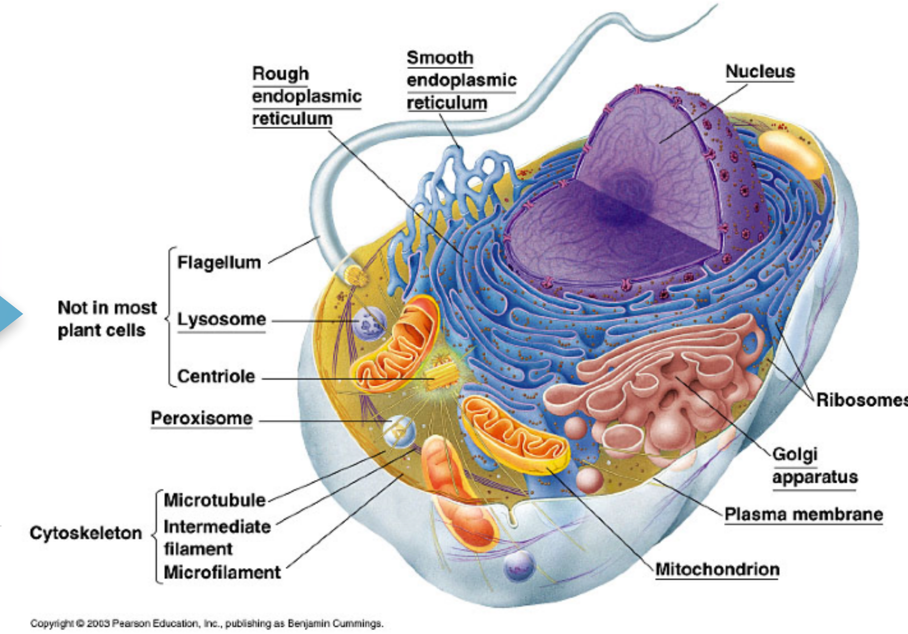

The ENDOSYMBIOTIC THEORY
1 Infoldings in the plasma membrane of an ancestral prokaryote gave rise to endomembrane components, including a nucleus and endoplasmic reticulum.
3 In a second endosymbiotic event, the early eukaryote consumed photosynthetic bacteria that evolved into chloroplasts.
Nucleus
Endoplasmic reticulum
1
2
3
Proto-eukaryote
Photosynthetic bacterium
Modern photosynthetic eukaryote
Aerobic bacterium
Mitochondrion
2 In a first endosymbiotic event, the ancestral eukaryote consumed aerobic bacteria that evolved into mitochondria.
Modern heterotrophic eukaryote




plasma membraan
celwand
capsule
pilus
flagel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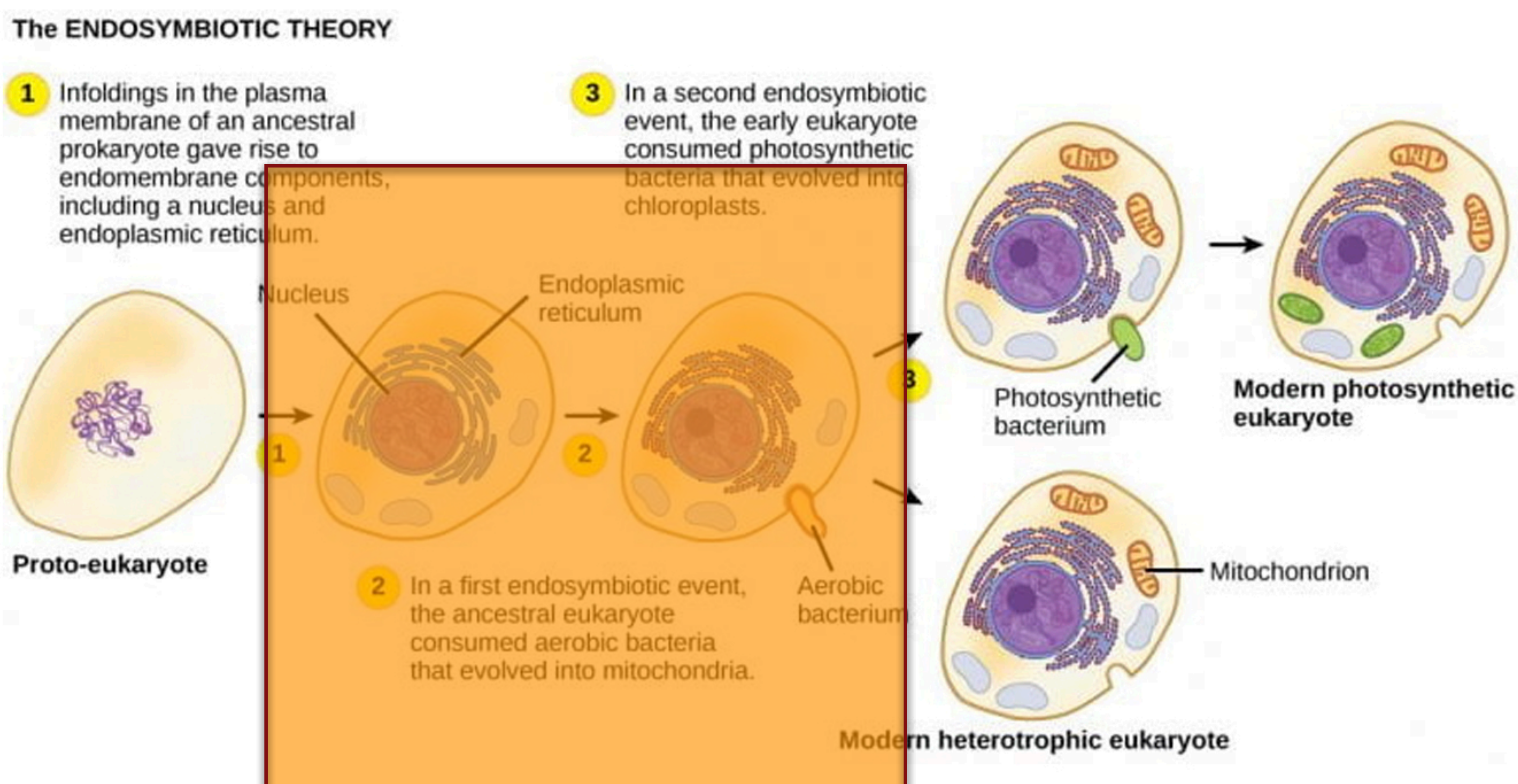
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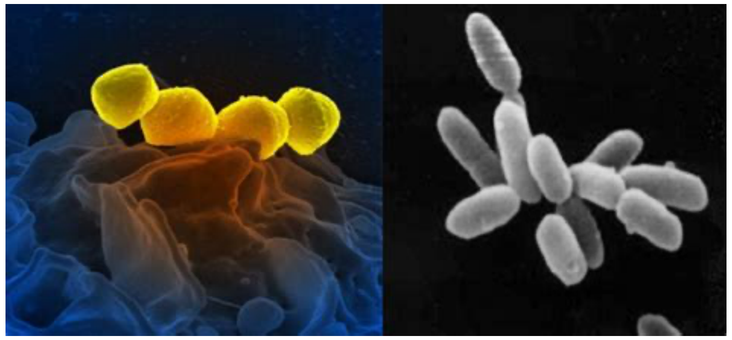

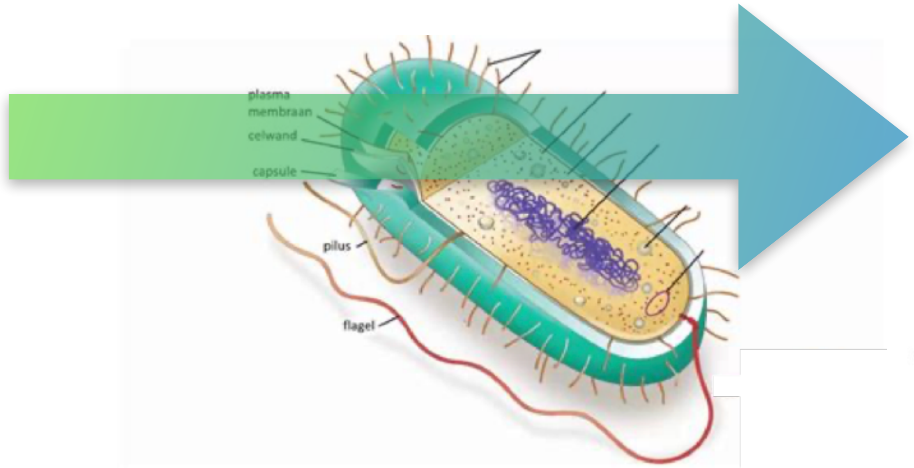
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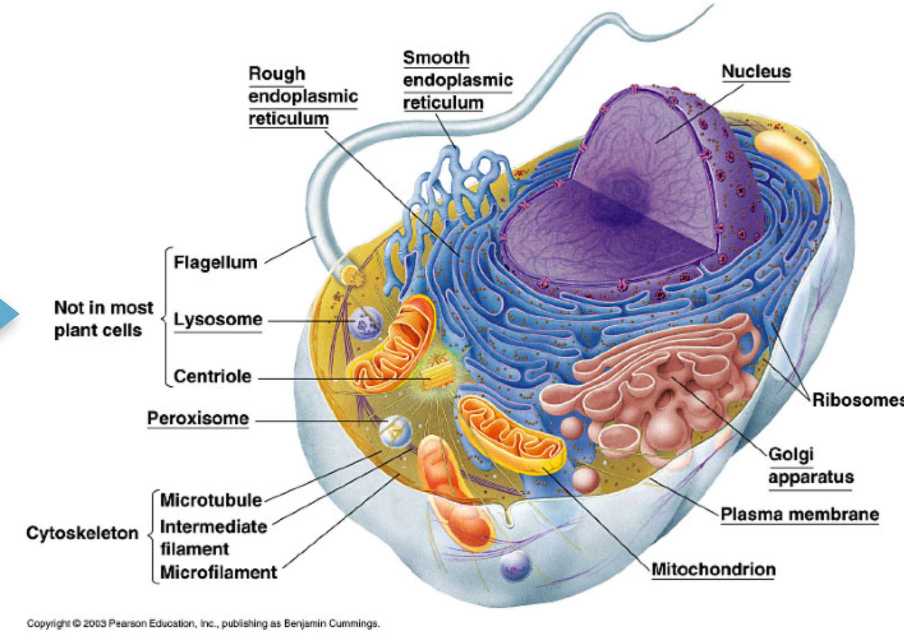
celwand
capsule
pilus
flagel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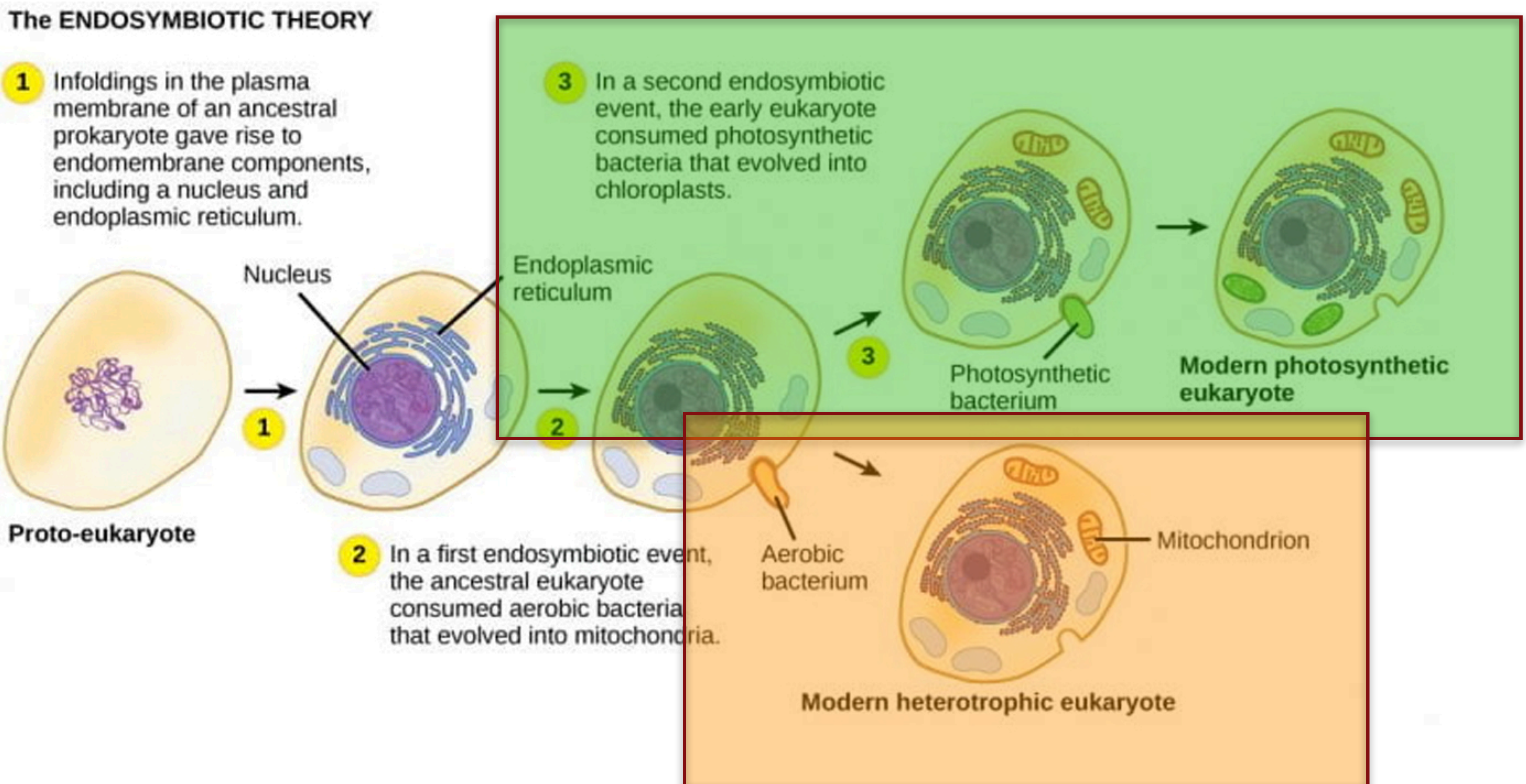
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Aerobic bacterium
Mitochondrion
Modern heterotrophic eukaryote

Prokaryotic Phylogeny

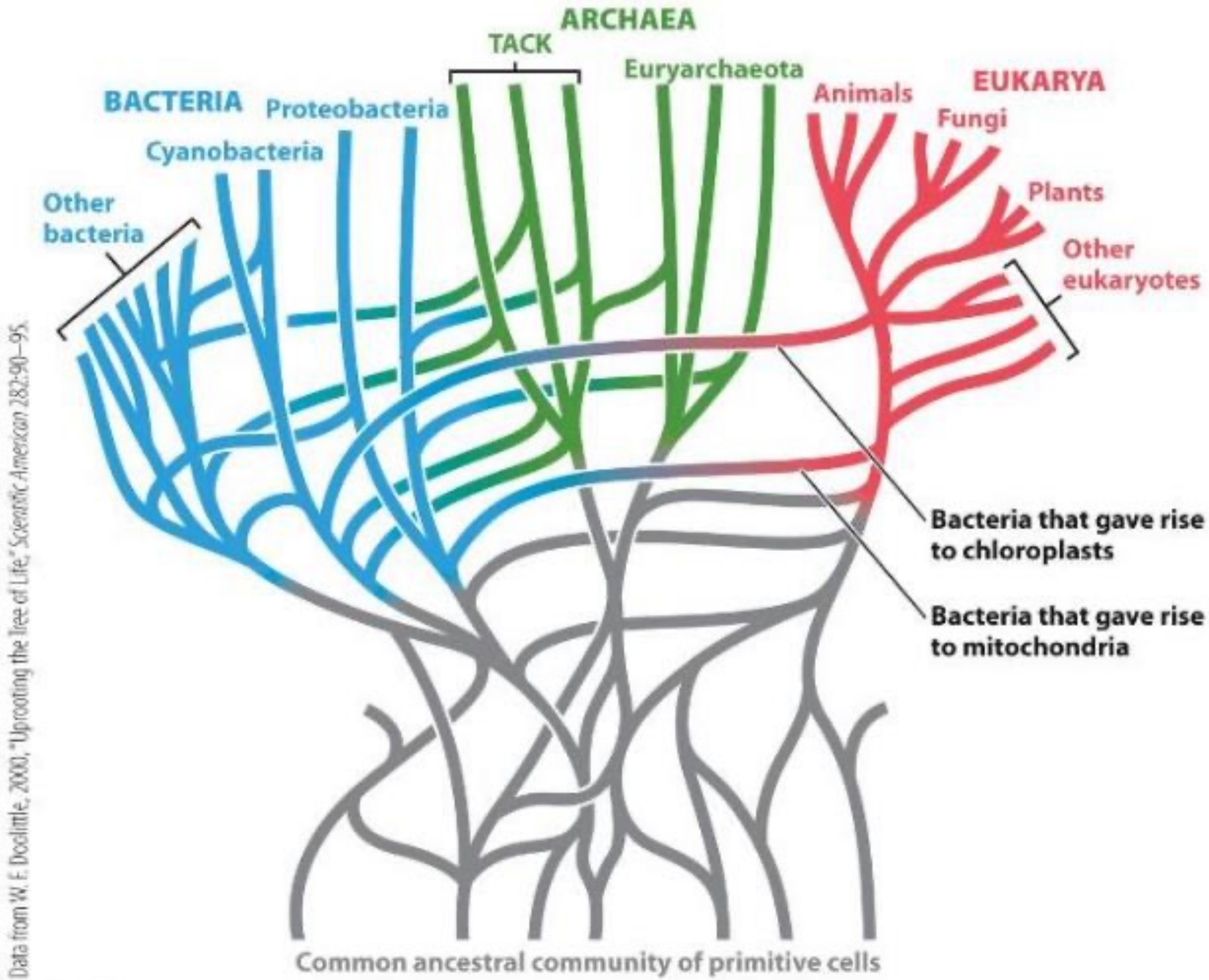


Figure 24.15
Biology: How Life Works, Third Edition

Origins of Eukaryotic Cells

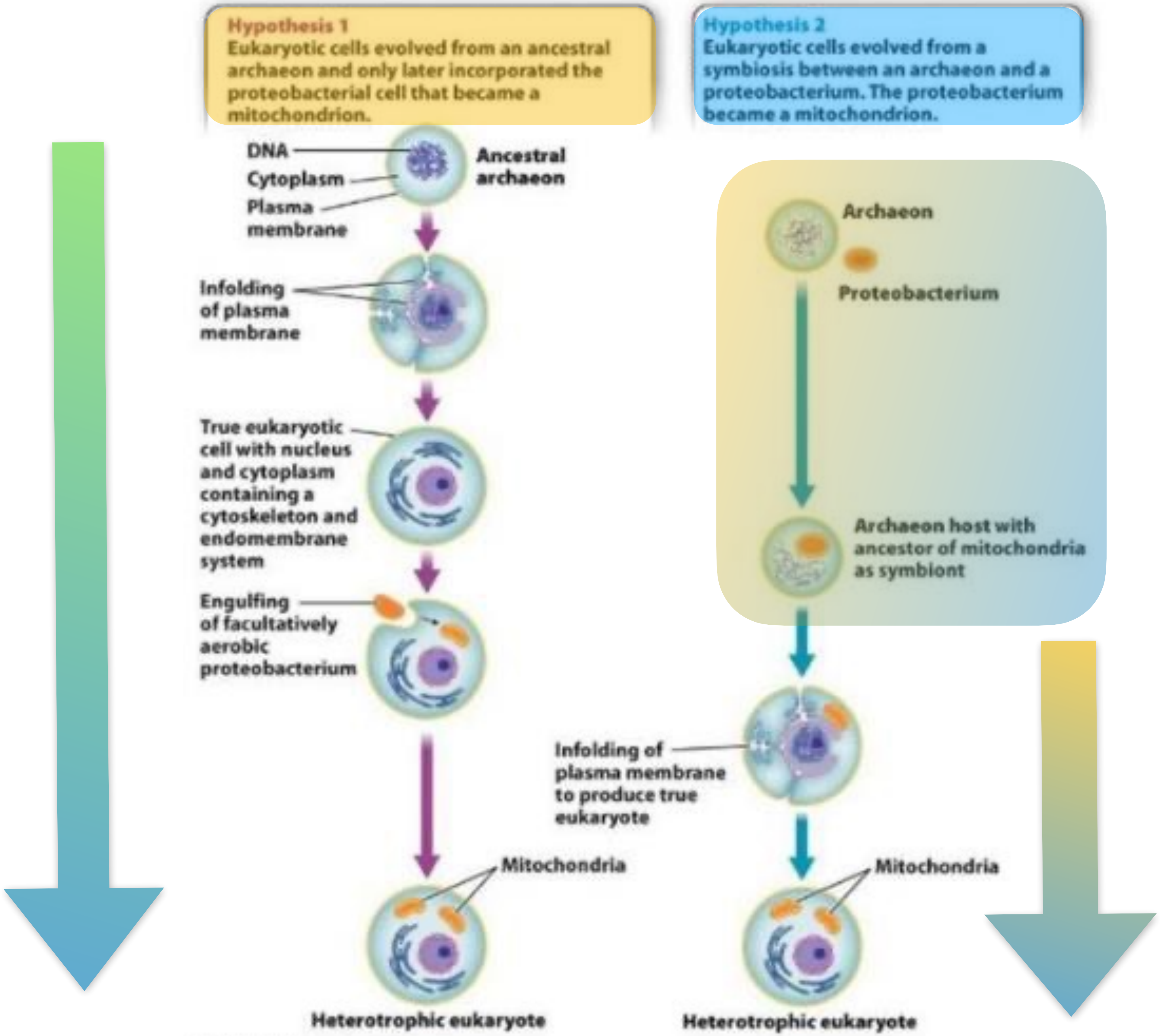
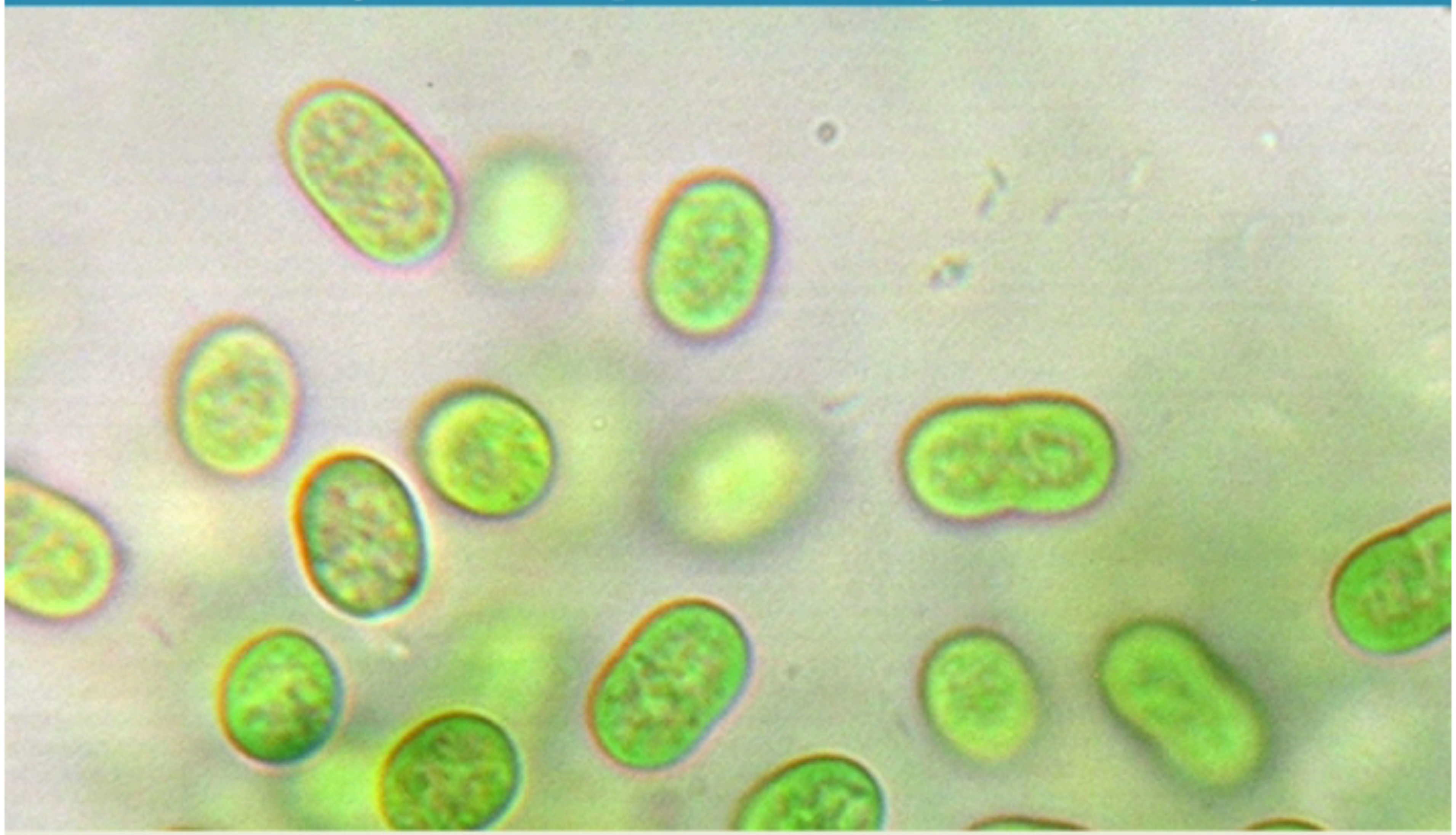


Figure 25.7
Biology: How Life Works, Third Edition

How Photosynthesis spread through the Eukarya

How Photosynthesis Spread through the Eukarya



Photosynthesis did not first evolve in eukaryotic cells. In fact, oxygenic photosynthesis evolved only once, in the common ancestor of living cyanobacteria.

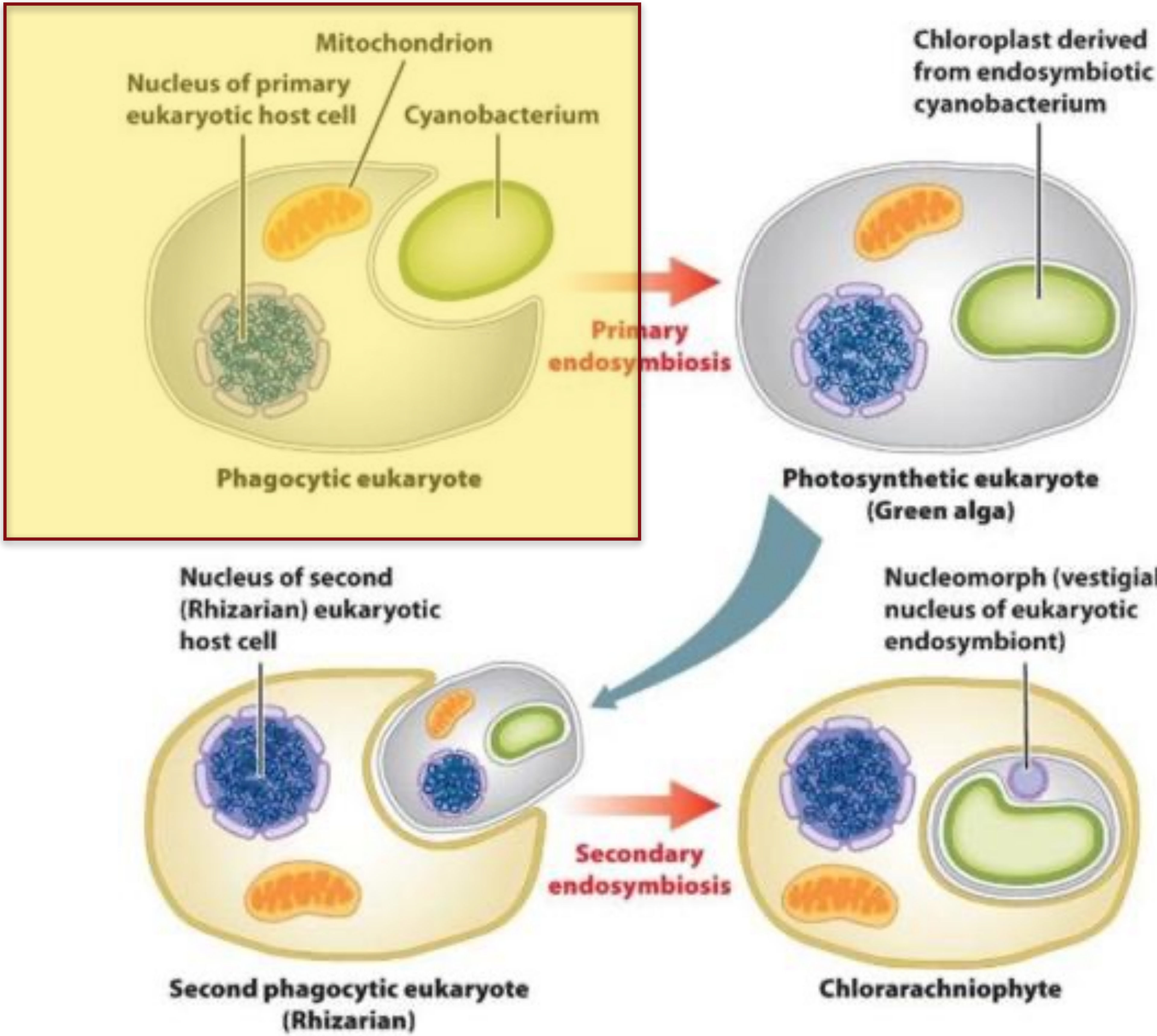


Figure 25.21
Biology: How Life Works, Third Edition

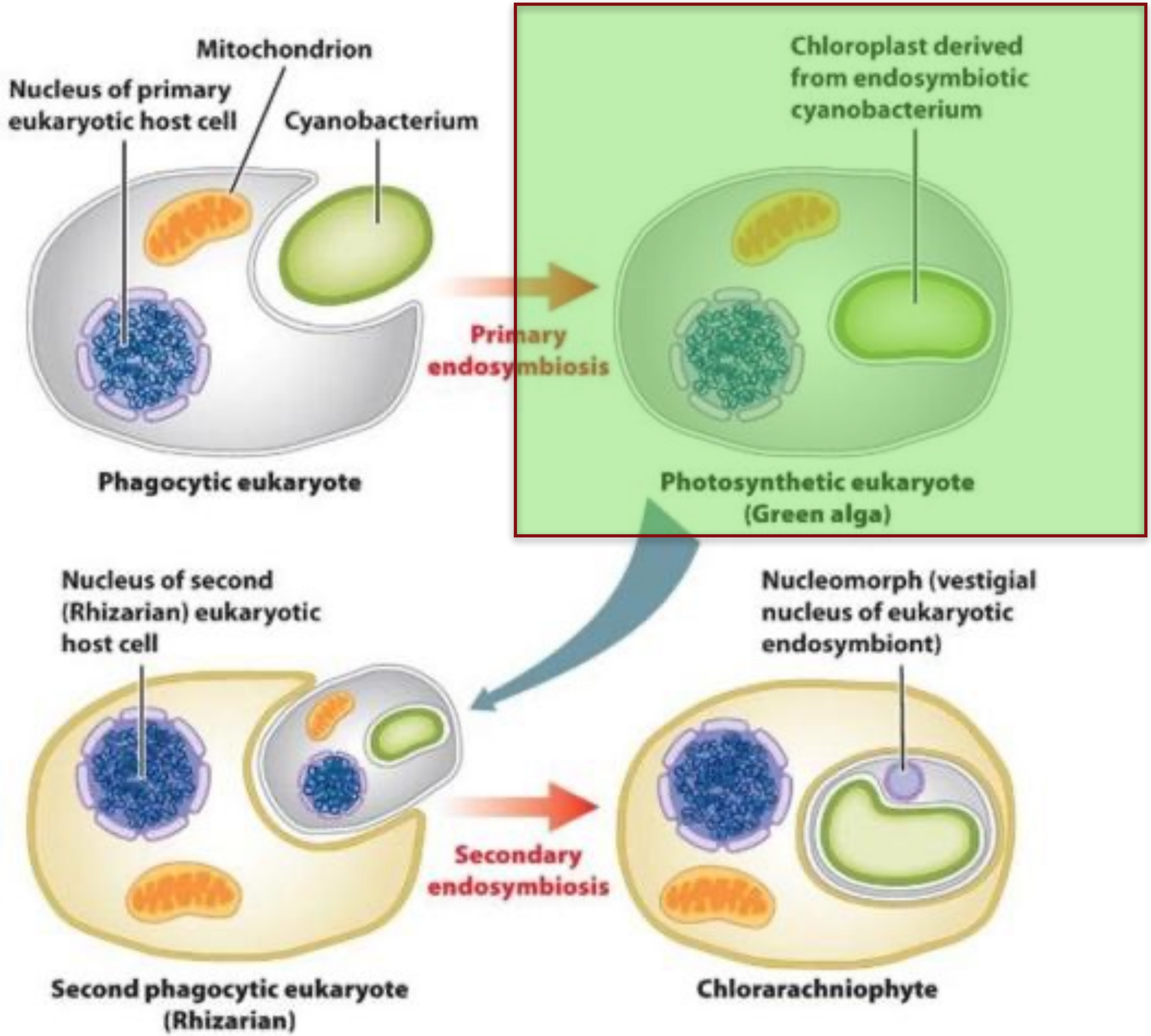


Figure 25.21
Biology: How Life Works, Third Edition

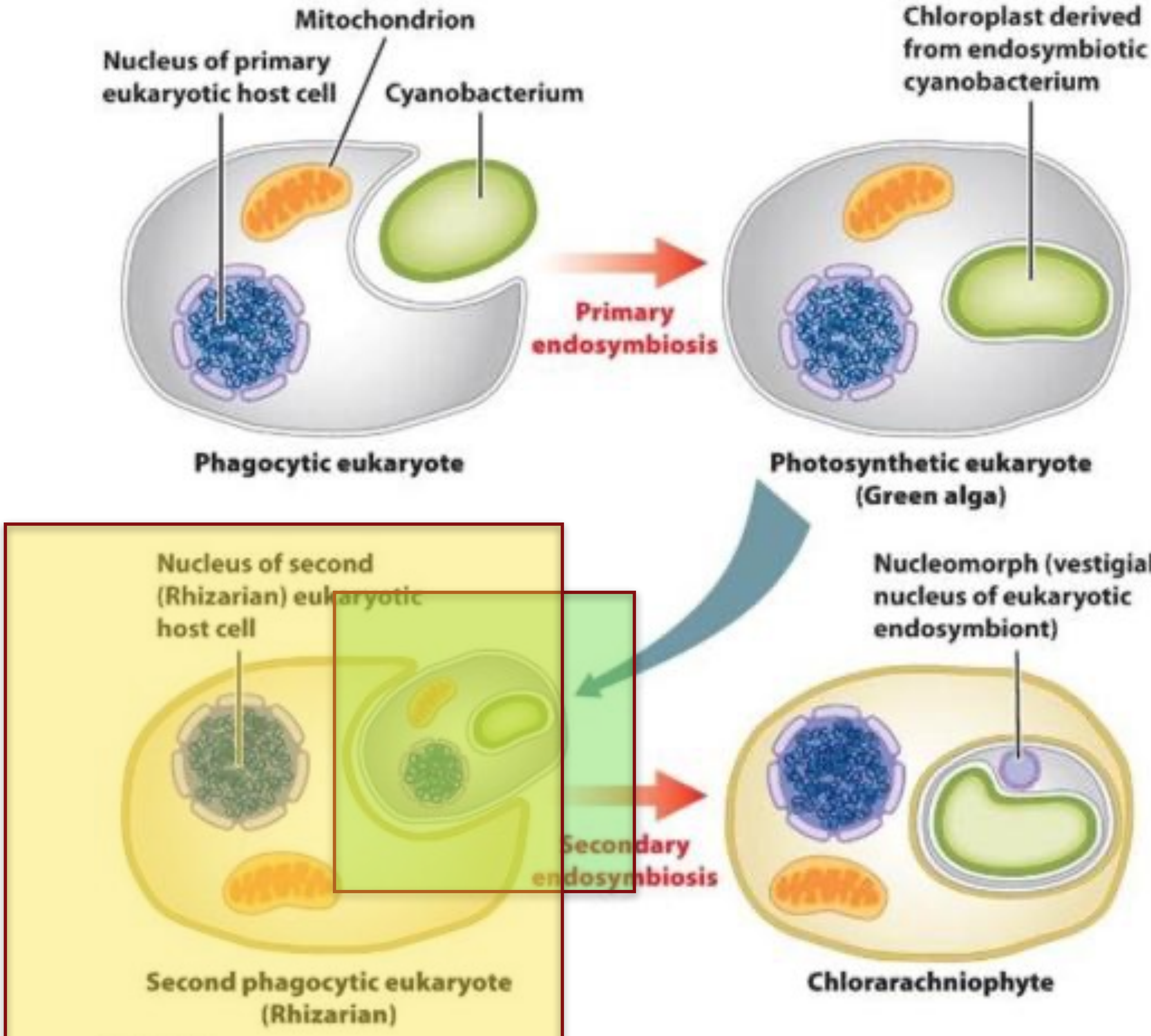


Figure 25.21
Biology: How Life Works, Third Edition

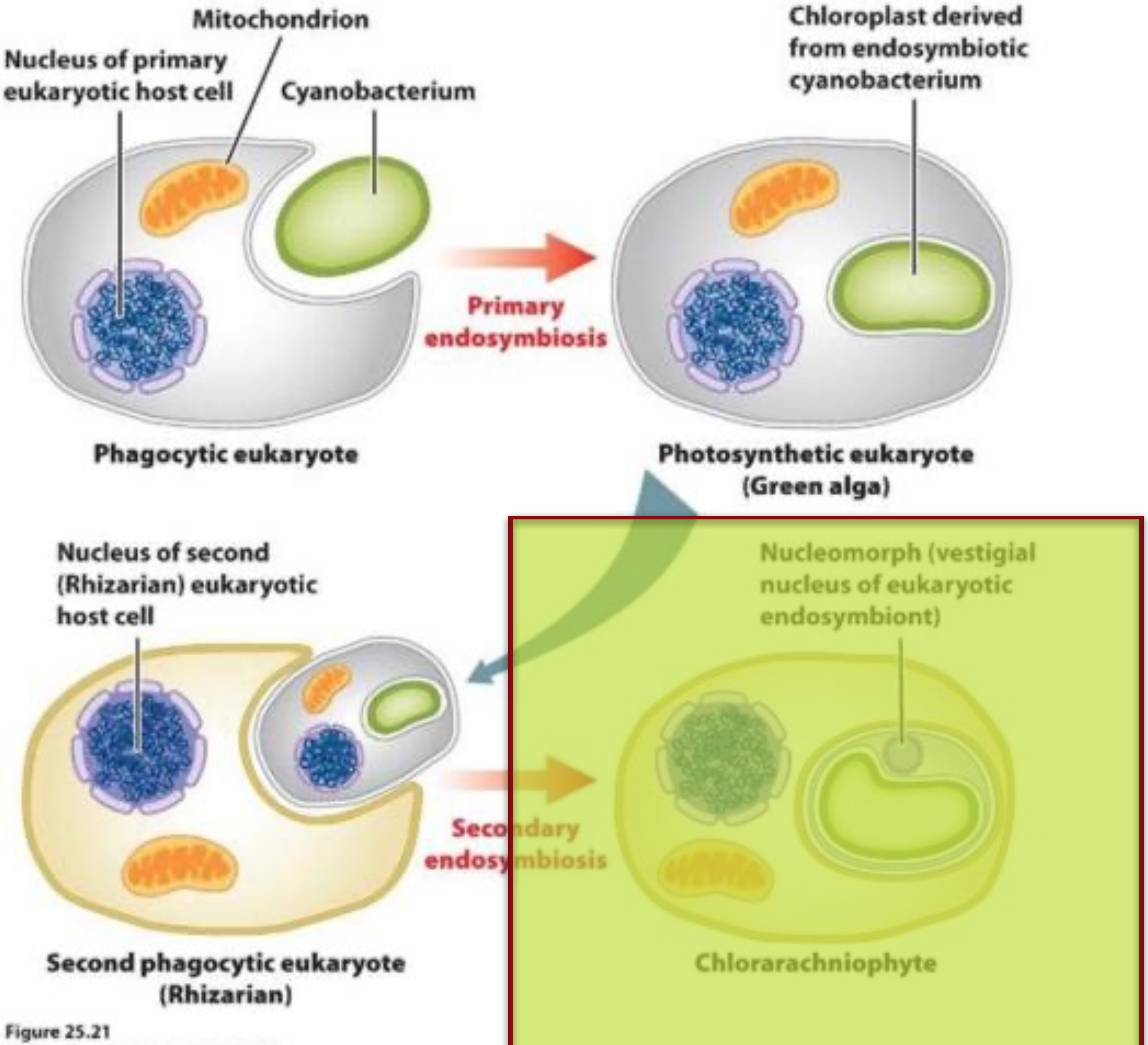
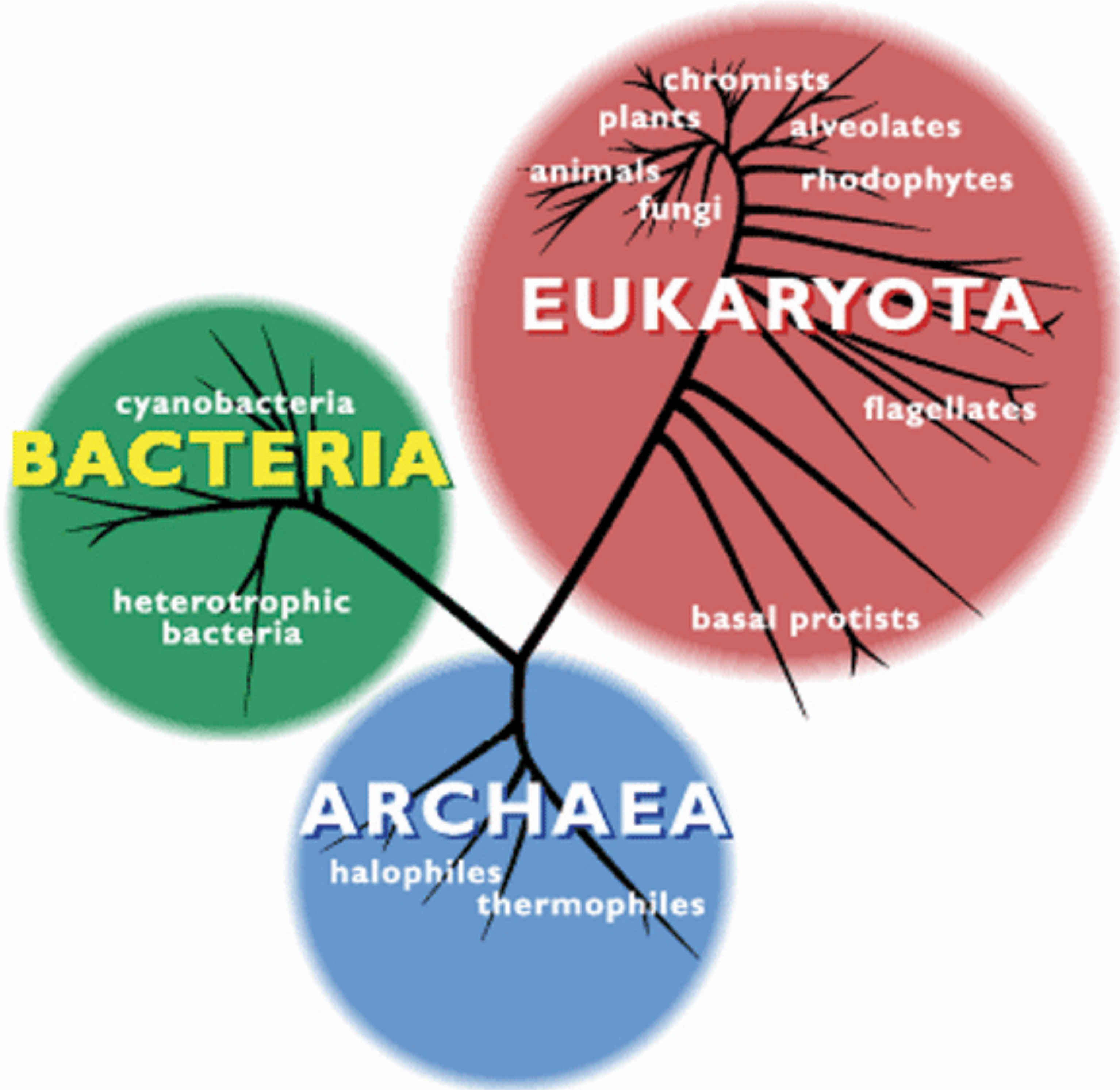
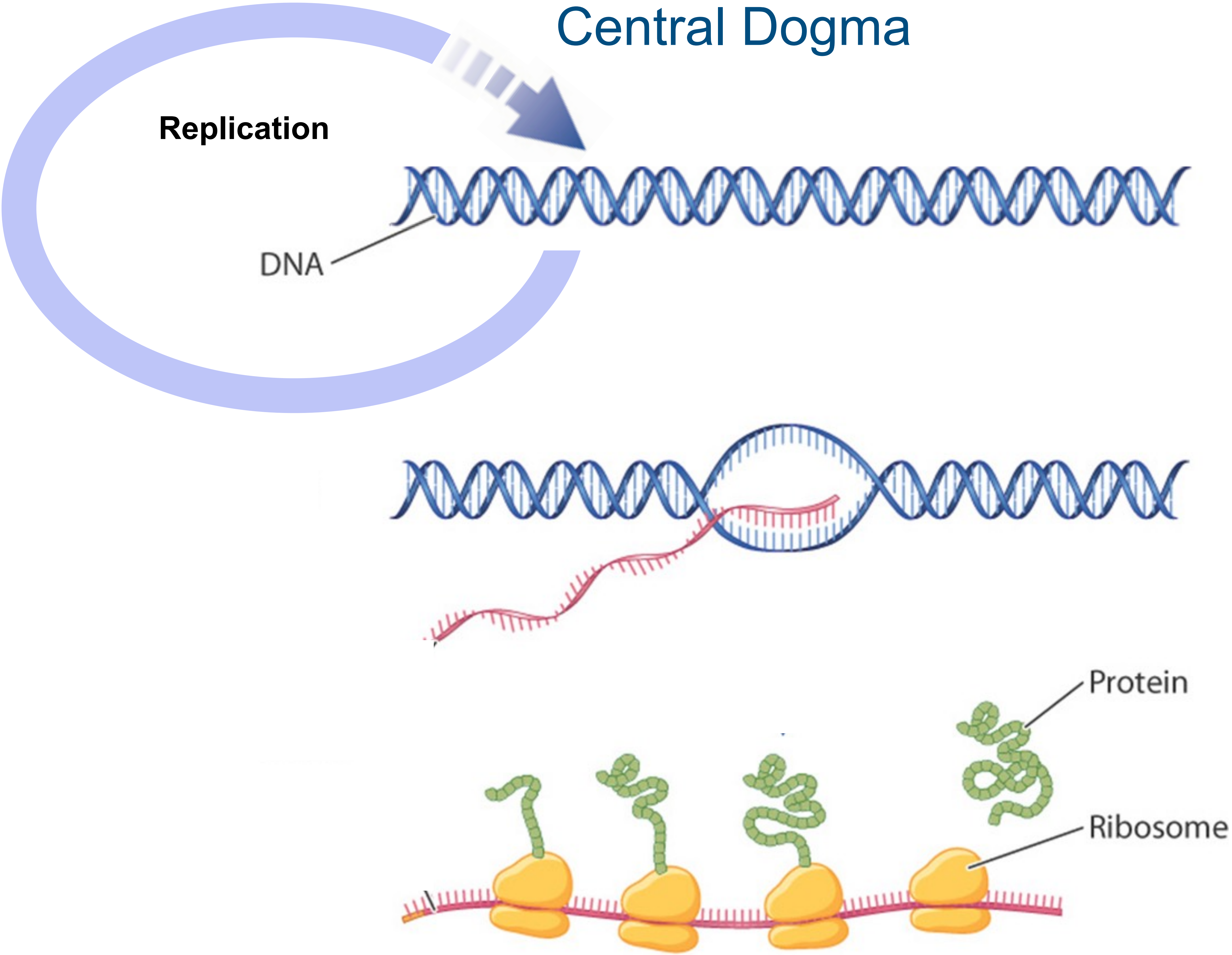


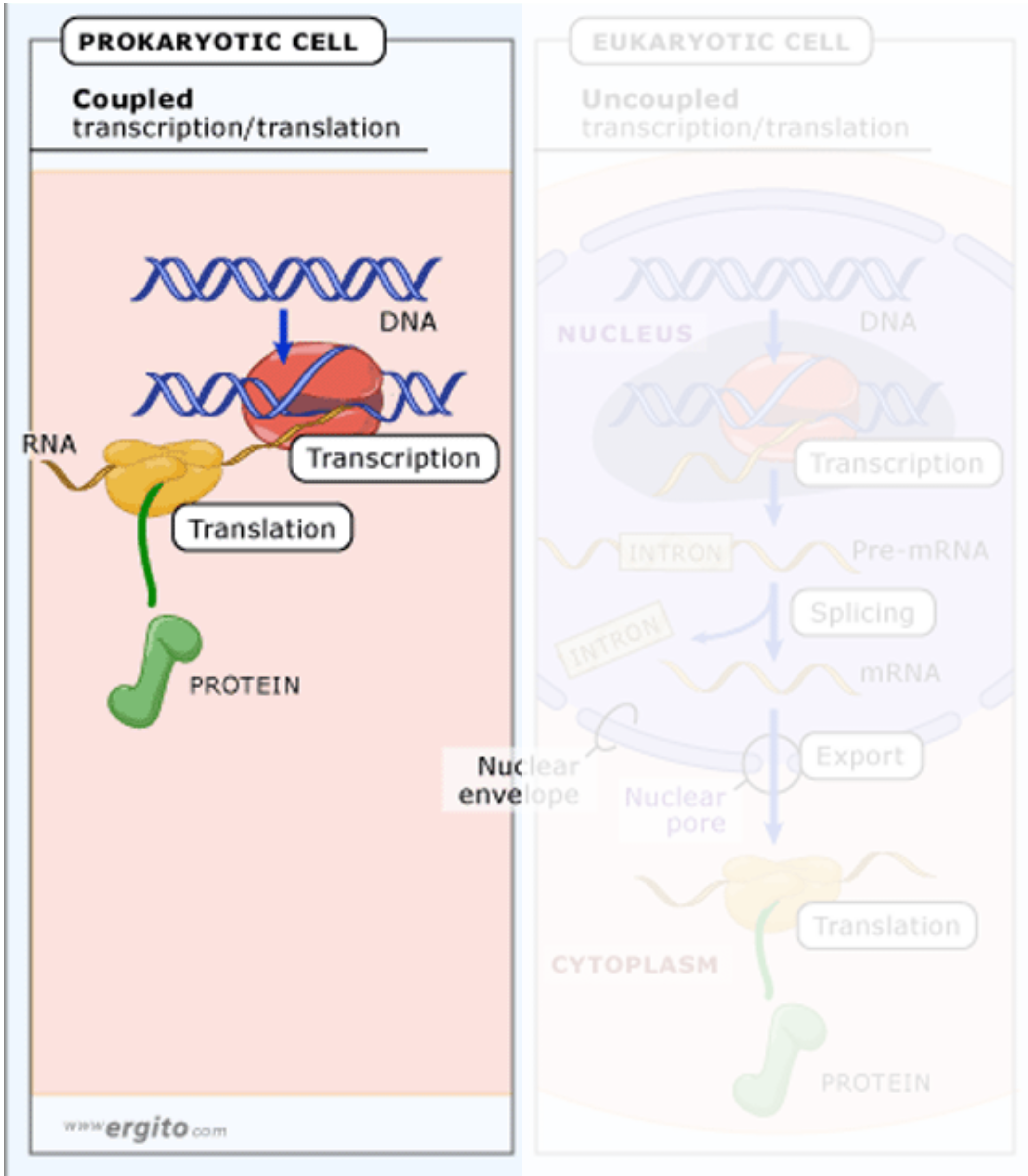
Figure 25.21
Biology: How Life Works, Third Edition

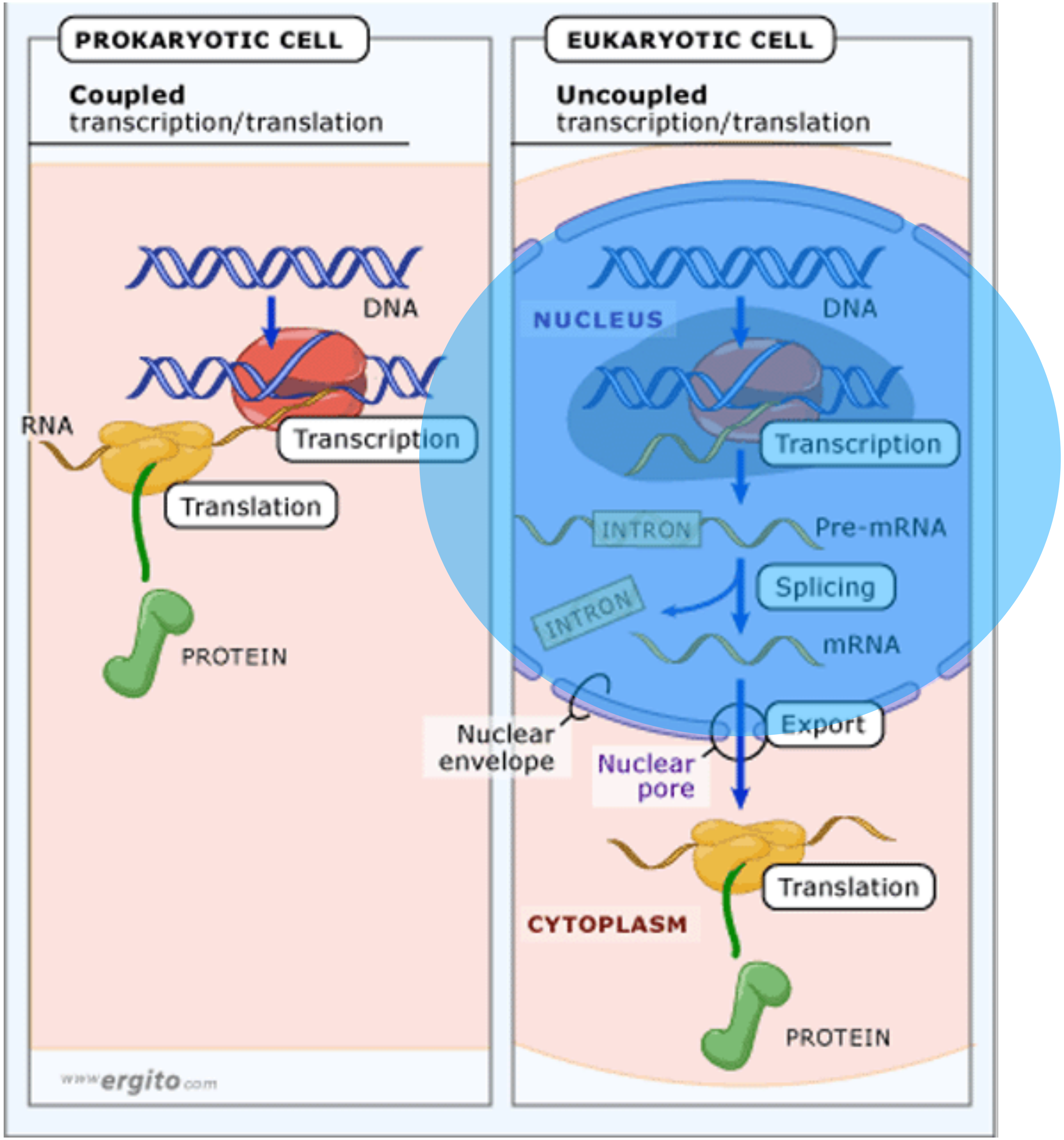


chromists
plants
alveolates
animals
rhodophytes
fungi
EUKARYOTA
cyanobacteria
BACTERIA
flagellates
heterotrophic
bacteria
basal protists
ARCHAEA
halophiles
thermophiles

Central Dogma




PROKARYOTIC CELL
Coupled
transcription/translation
DNA
RNA
Transcription
Translation
PROTEIN
www.ergito.com
EUKARYOTIC CELL
Uncoupled
transcription/translation
NUCLEUS
DNA
Transcription
INTRON
Pre-mRNA
Splicing
INTRON
mRNA
Export
Nuclear
envelope
Nuclear
pore
Translation
CYTOPLASM
PROTEIN



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mRNA
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envelope
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pore
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PROTEIN
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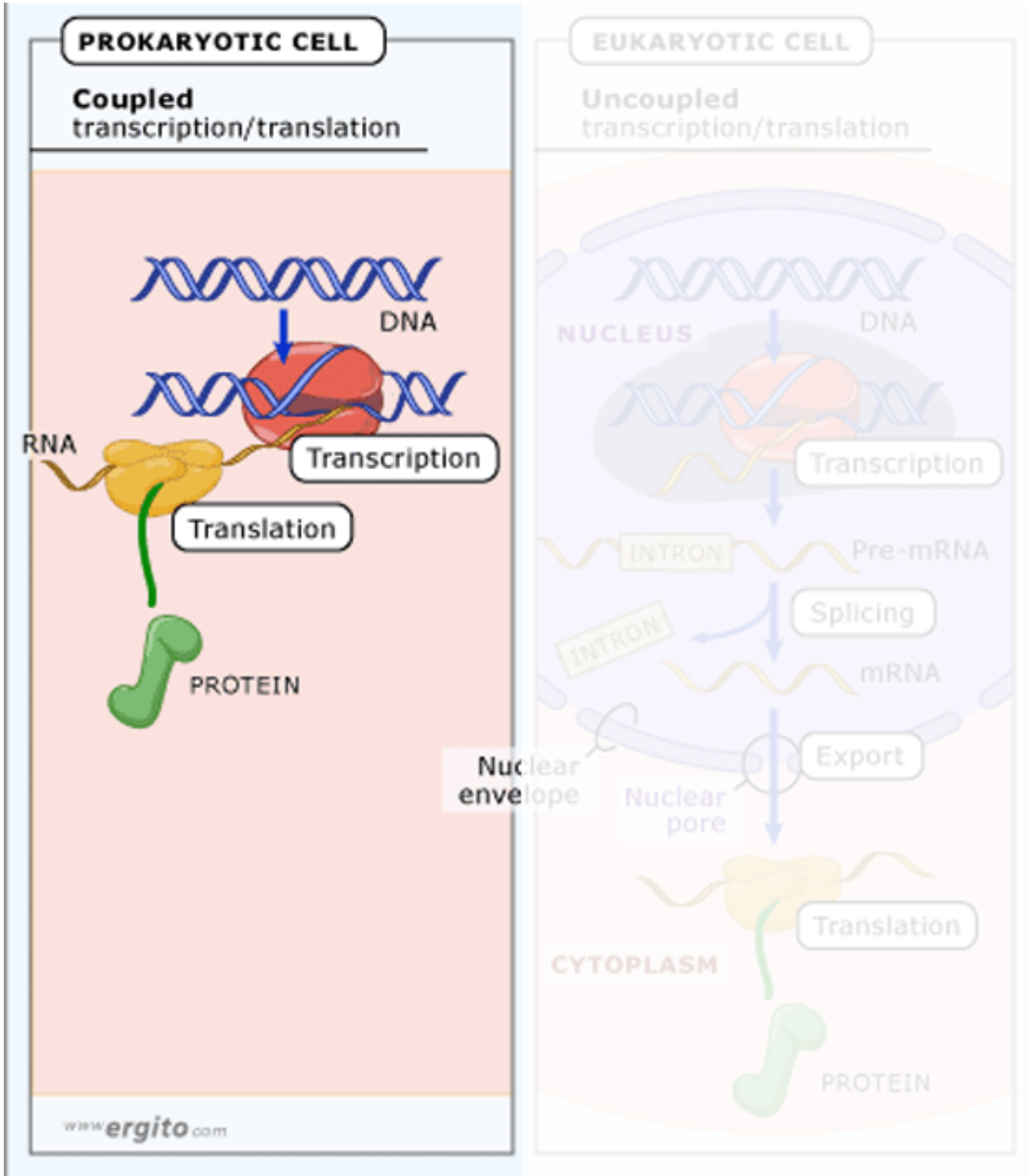
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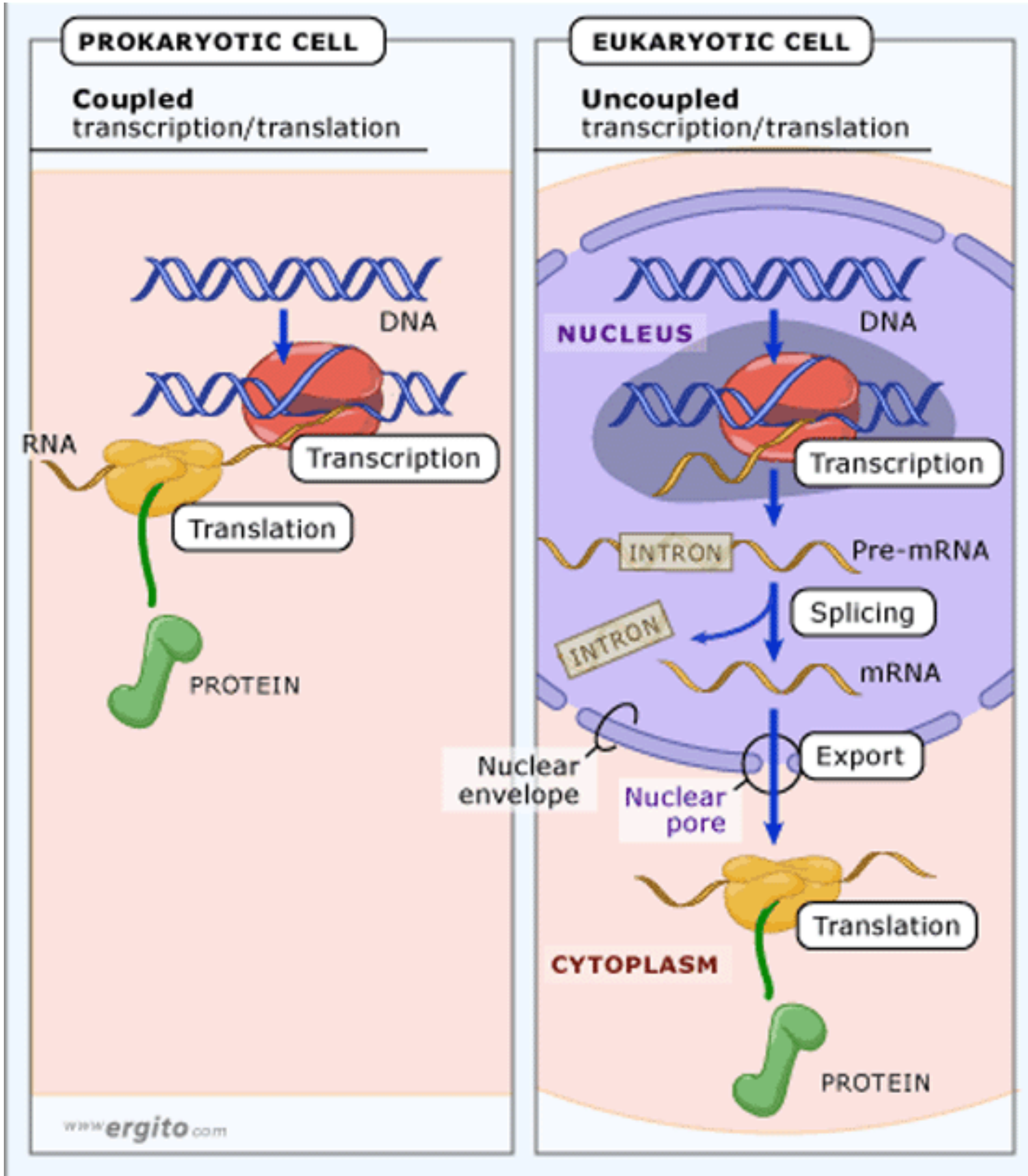

PROKARYOTIC CELL
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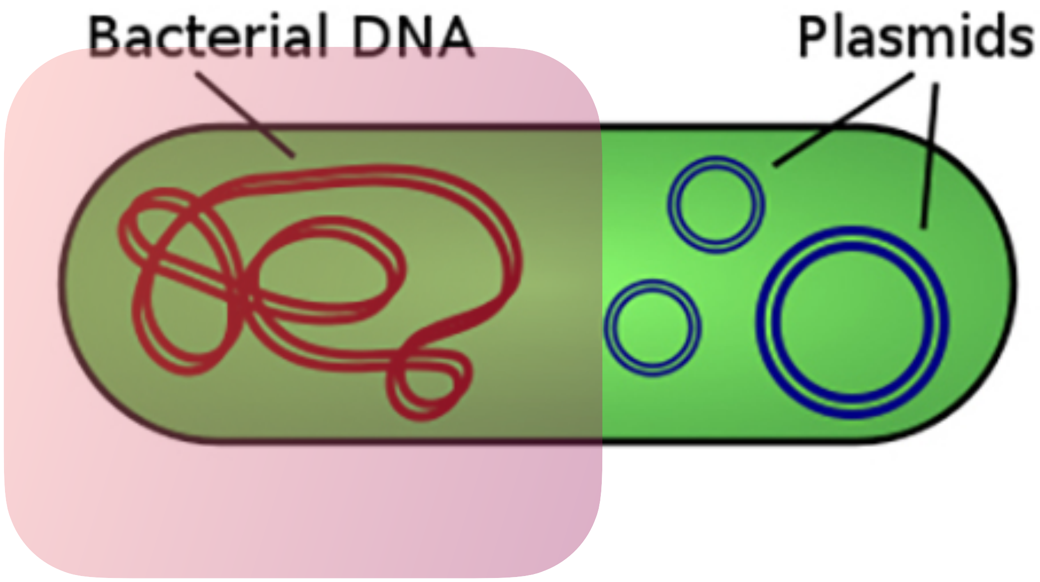
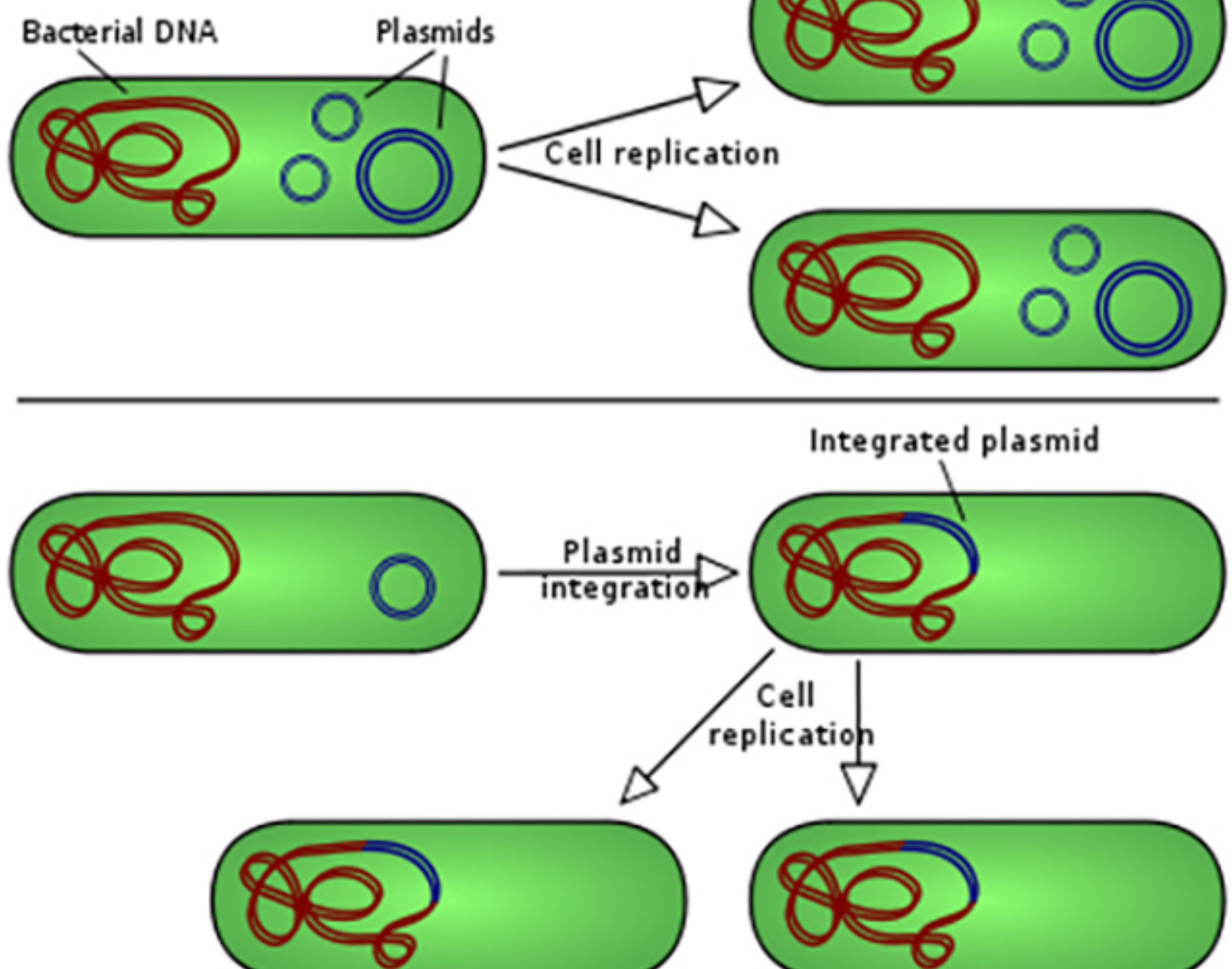

Bacterial DNA
Plasmids


Bacterial DNA
Plasmids
Cell replication
Integrated plasmid
Plasmid integration
Cell replication

1 The circular bacterial DNA molecule is attached by proteins to the inner membrane (red).

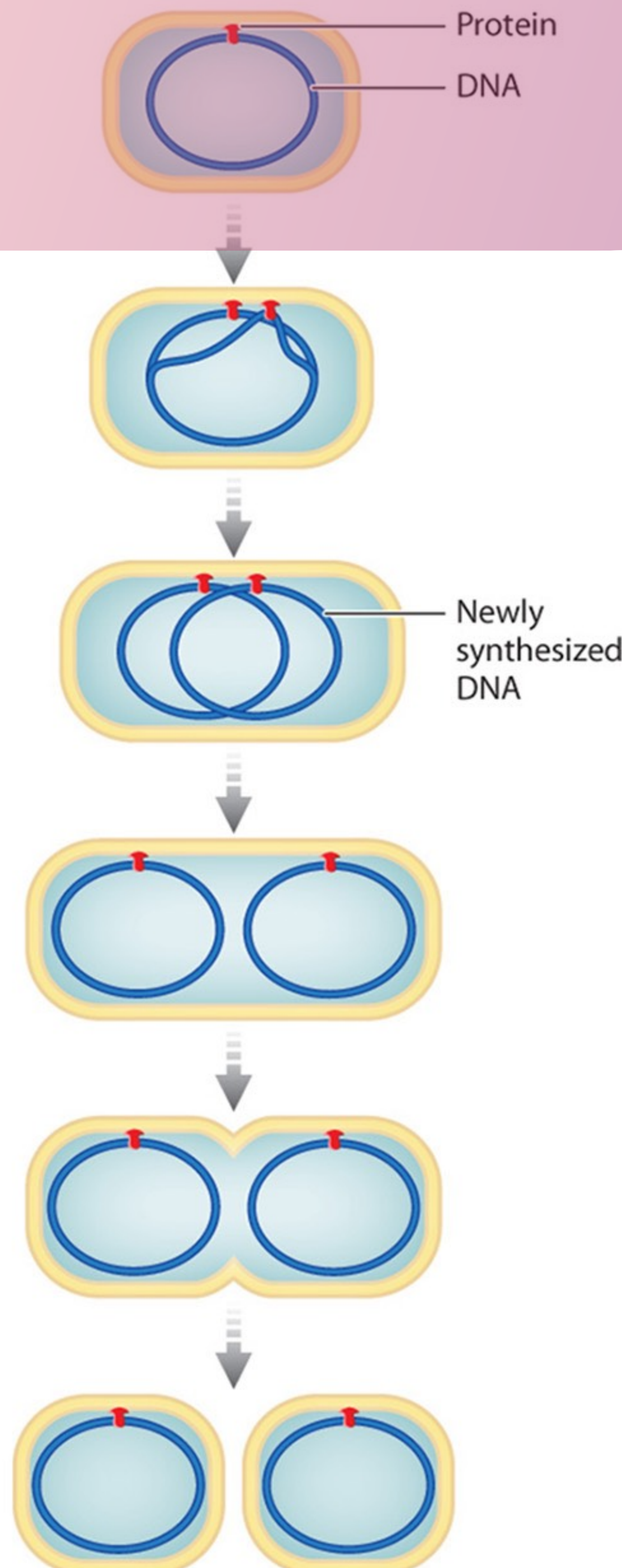
2 DNA replication begins at a specific location and proceeds bidirectionally around the circle.

3 The newly synthesized DNA molecule is also attached to the inner membrane, near the attachment site of the initial molecule.

4 As replication proceeds, the cell elongates symmetrically around the midpoint, separating the DNA attachment sites.

5 Cell division begins with the synthesis of new membrane and wall material at the midpoint.

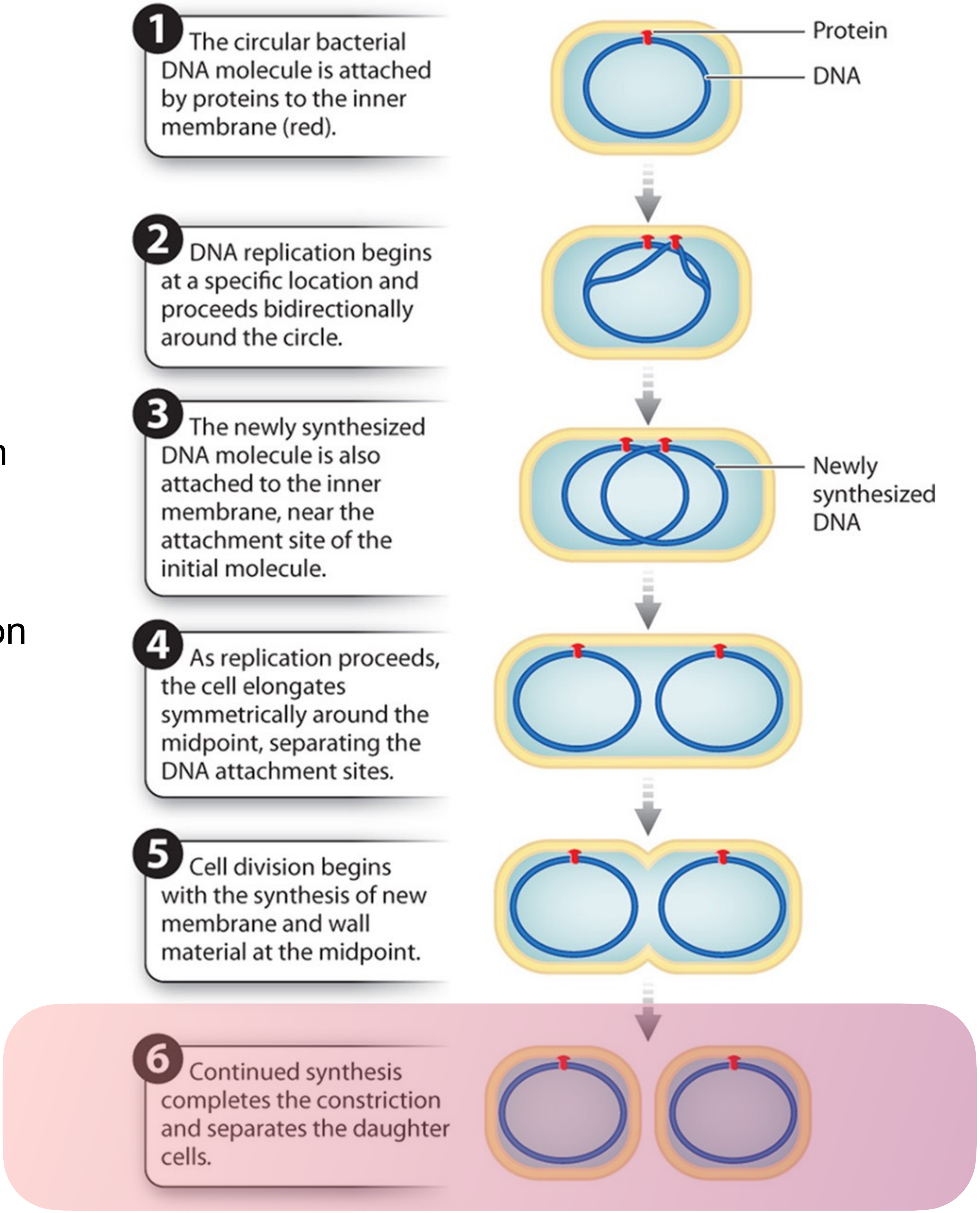
6 Continued synthesis completes the constriction and separates the daughter cells.



Cell Division

by

Simple Fission



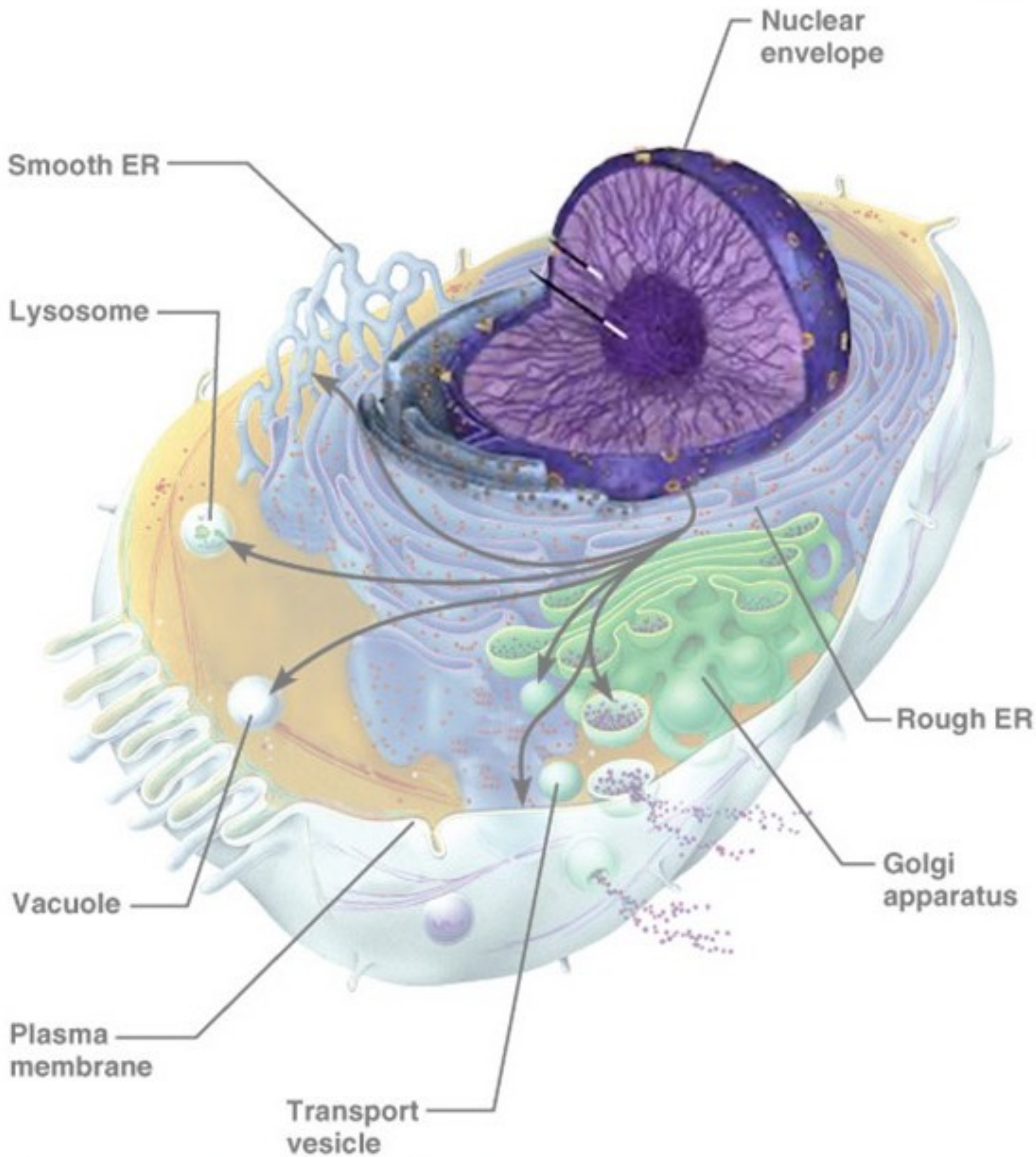

Nuclear envelope
Smooth ER
Lysosome
Rough ER
Golgi apparatus
Vacuole
Plasma membrane
Transport vesicle

Figure 3.23

Systems of Cell Reproduction:

Four events need to occur before any given cell can undertake cell division.

(1) A signal to "reproduce" must be received.

(2) Replication of DNA and duplication (multiplication) of vital cell components must occur.

(3) DNA must be distributed in to the new “daughter” cells.

(4) The cell membrane must begin to separate and ultimately divide, and reform (along with a new cell wall in some organisms (?) into two new daughter cells.

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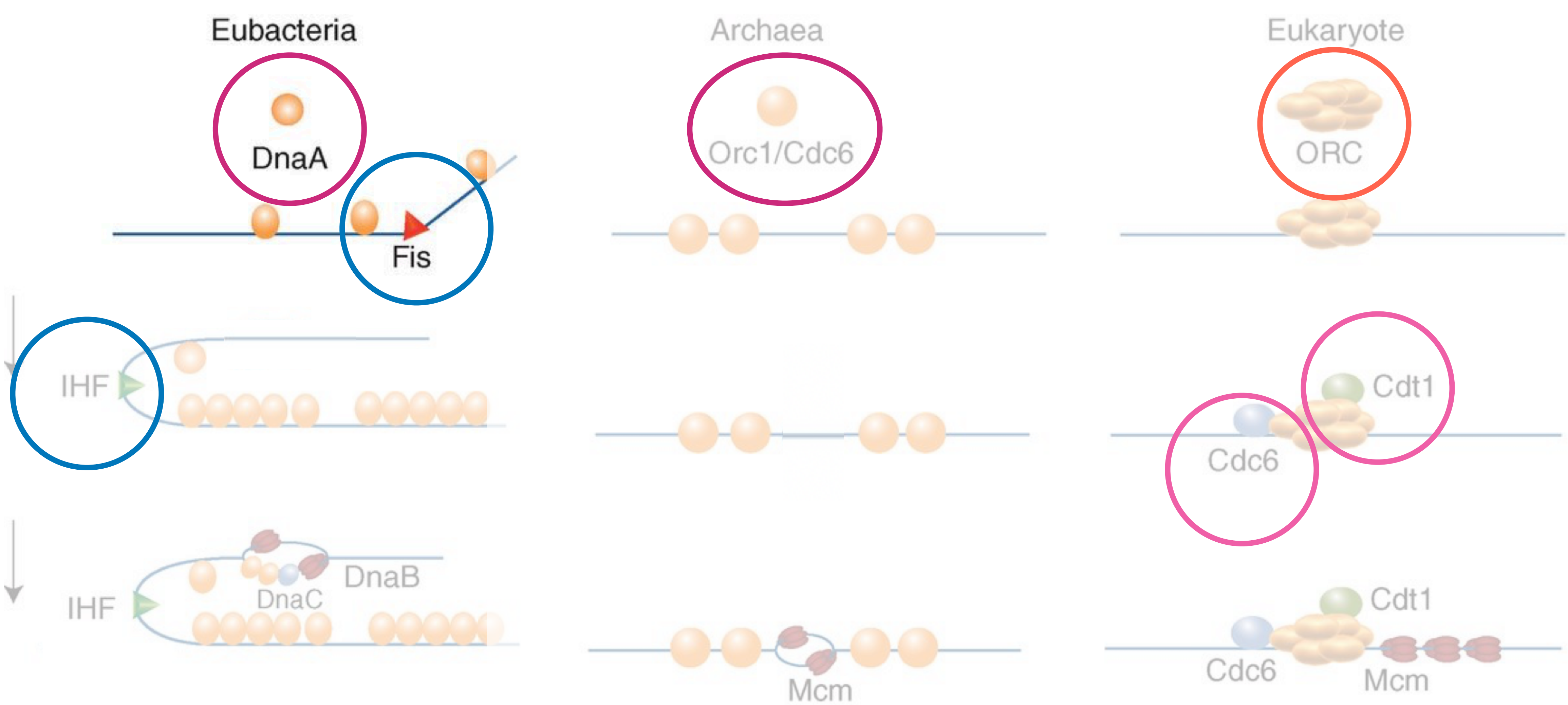
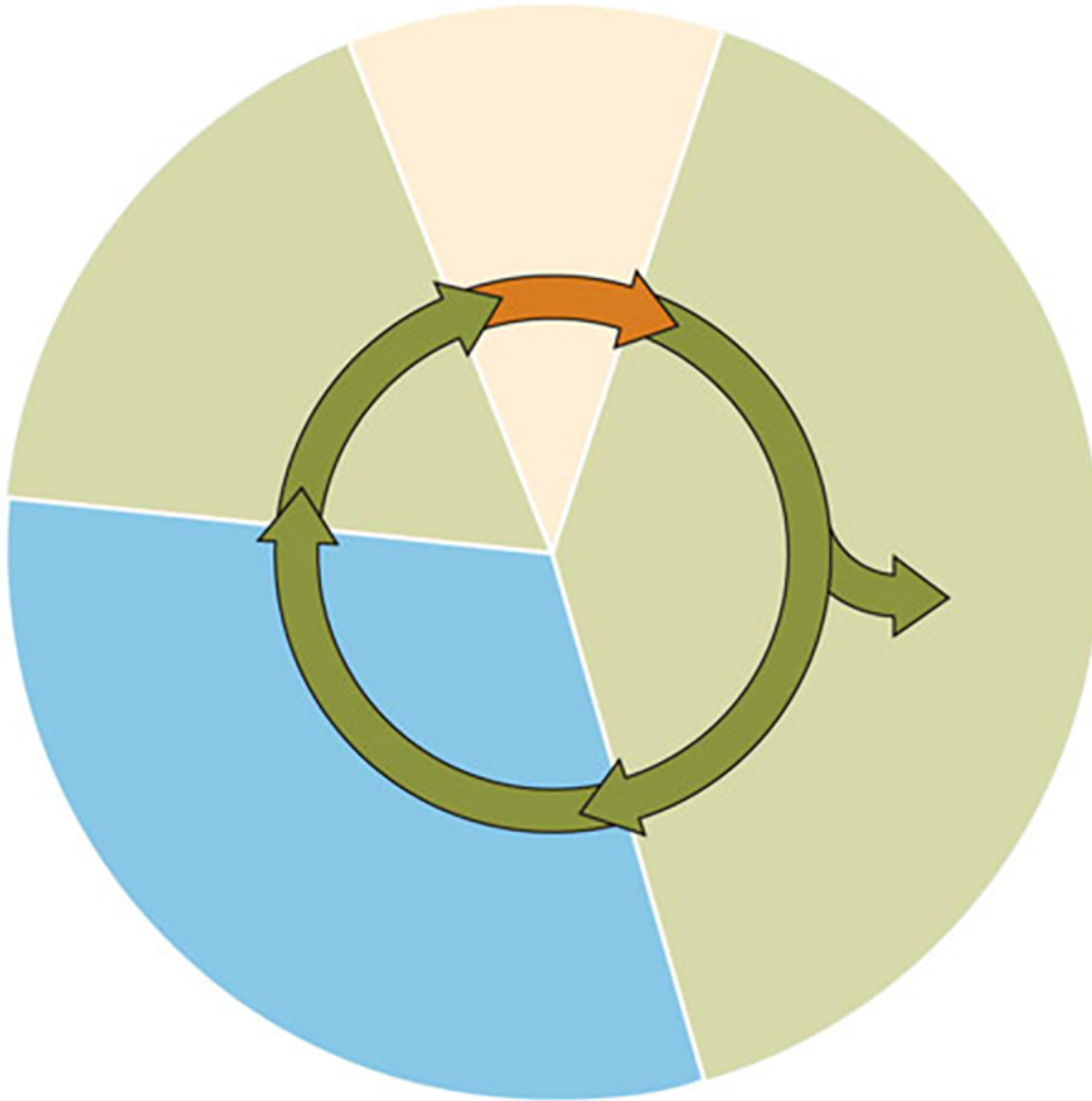
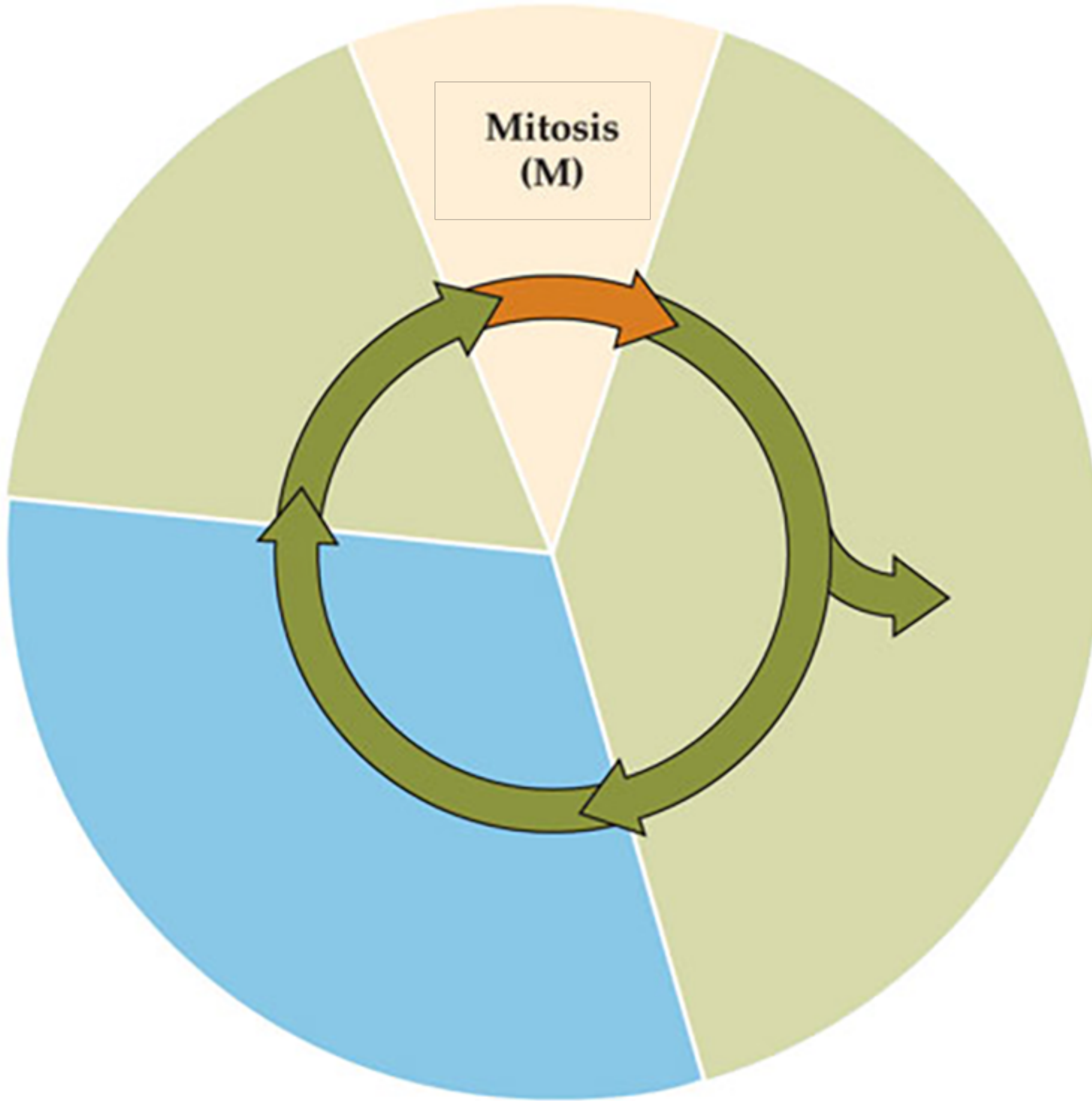
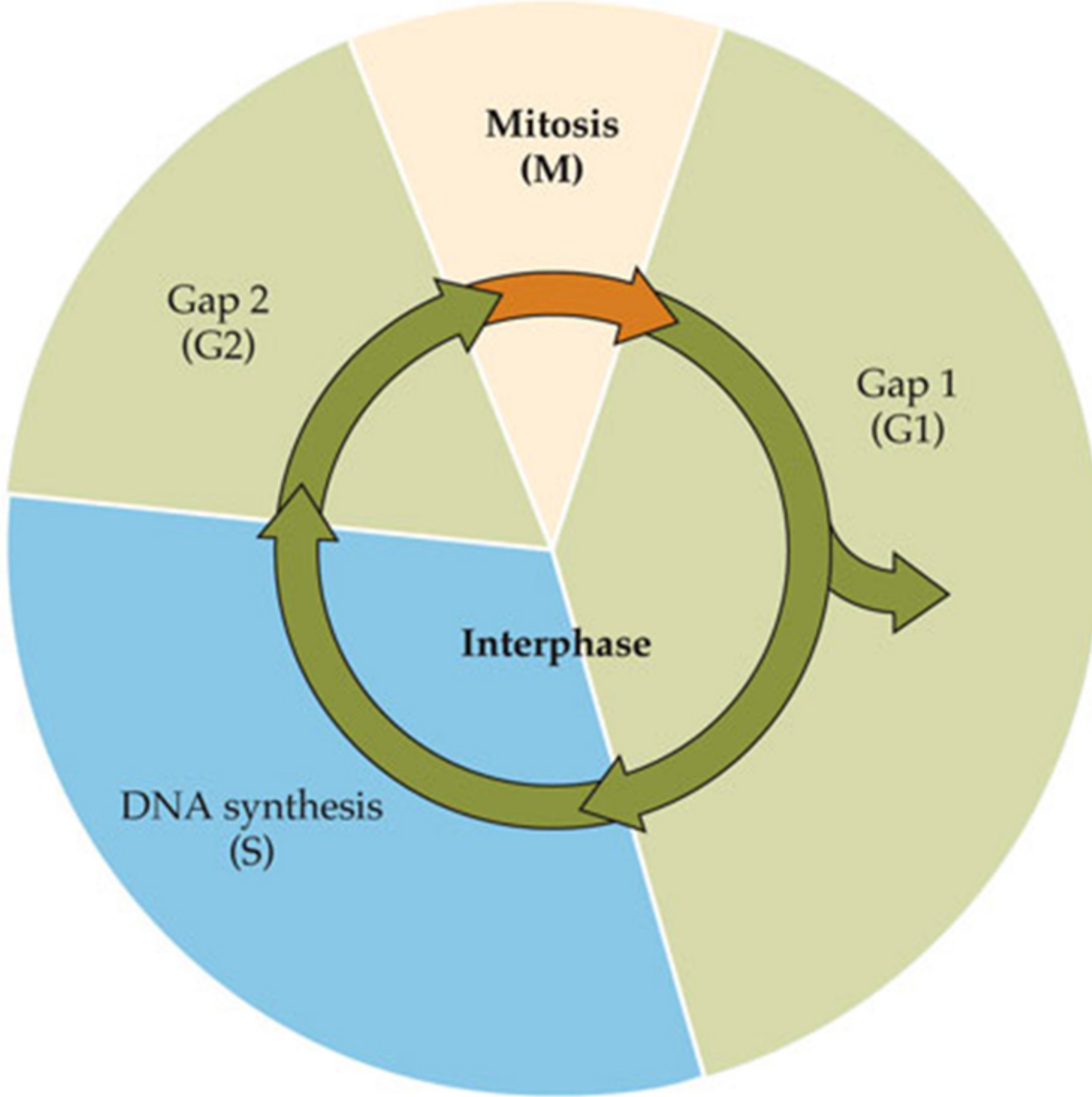


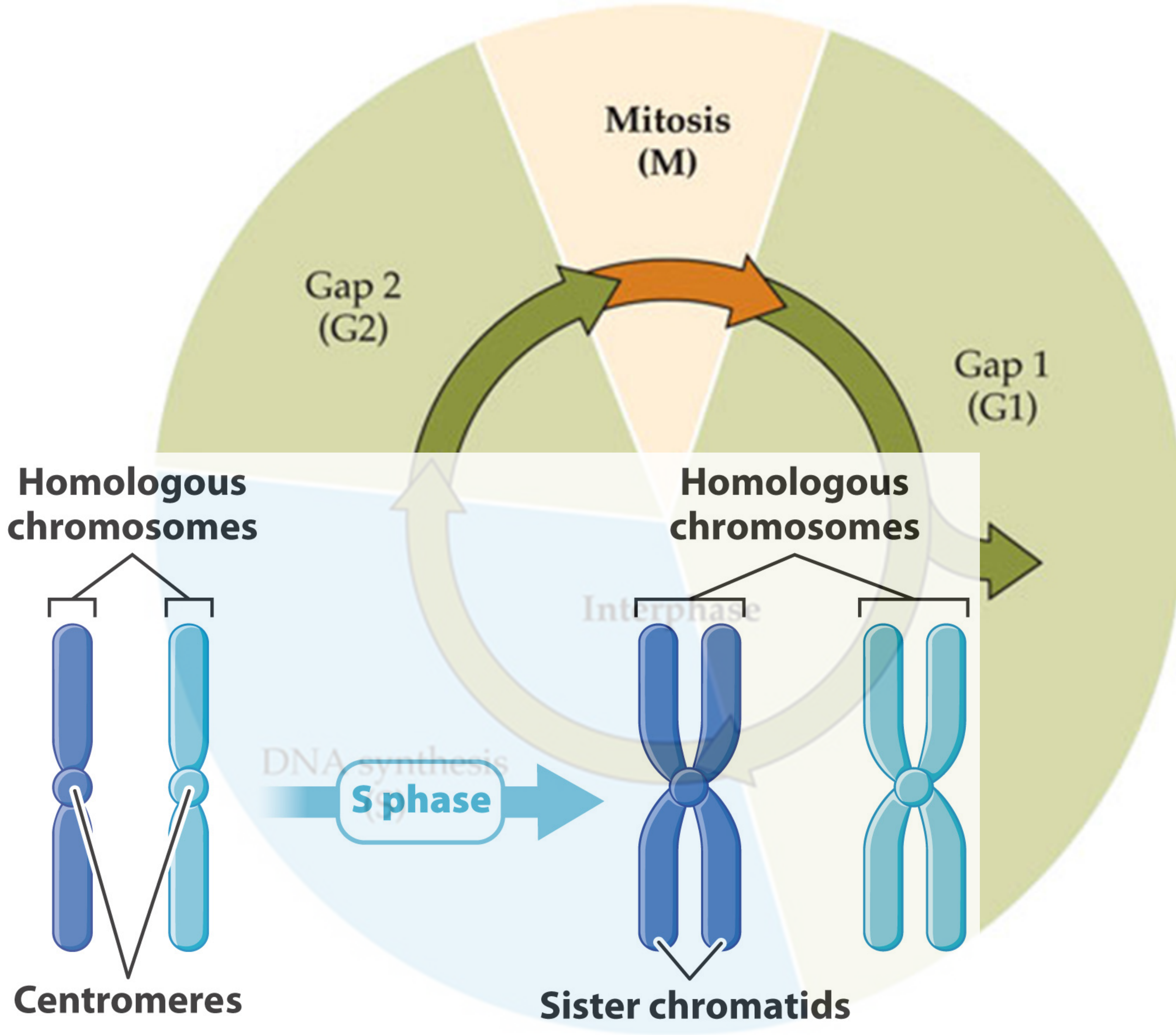
Eubacteria
Archaea
Eukaryote
DnaA
Orc1/Cdc6
ORC
Fis
IHF
Cdt1
Cdc6
DnaB
DnaC
IHF
Cdt1
Mcm
Cdc6
Mcm



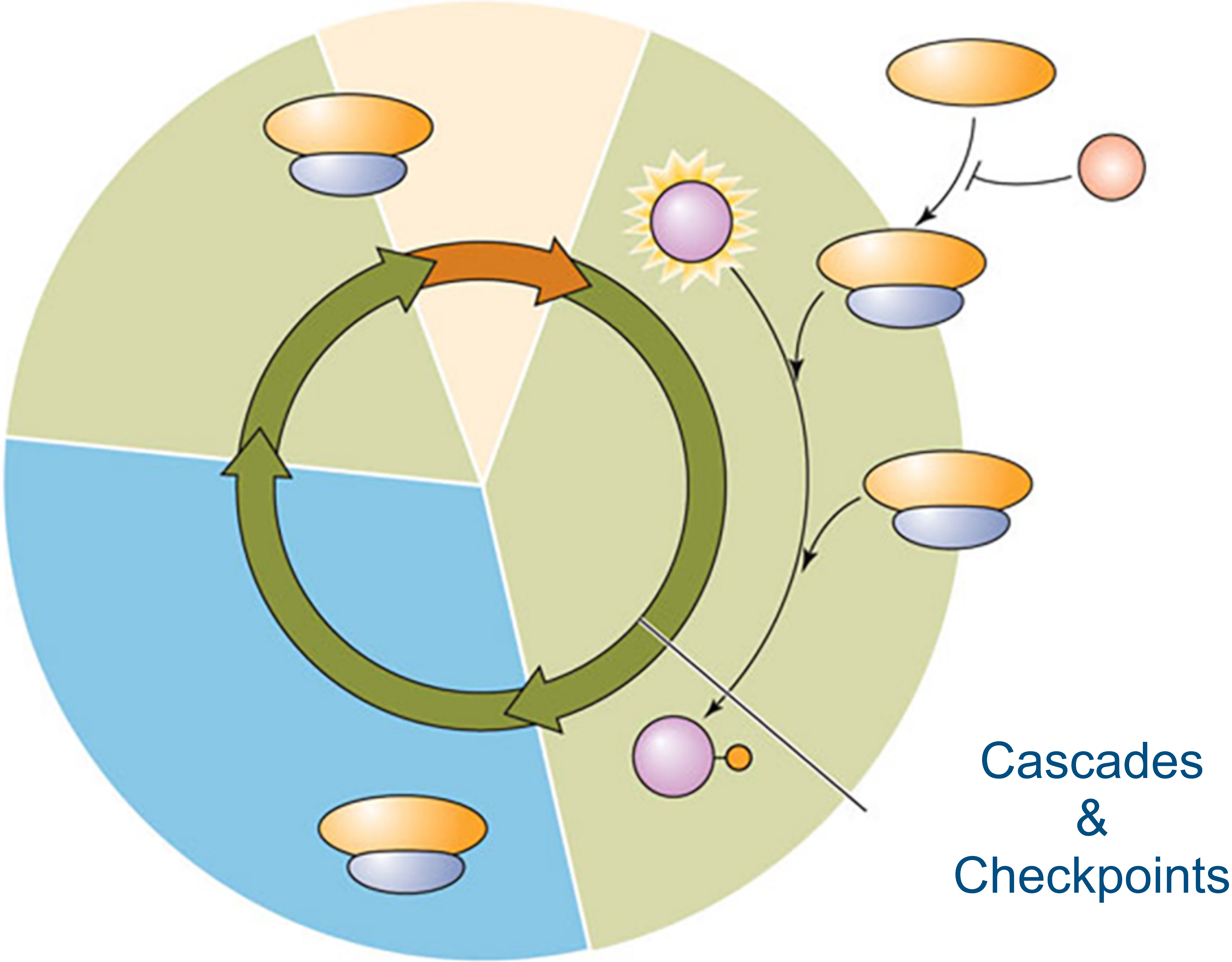

Mitosis
(M)

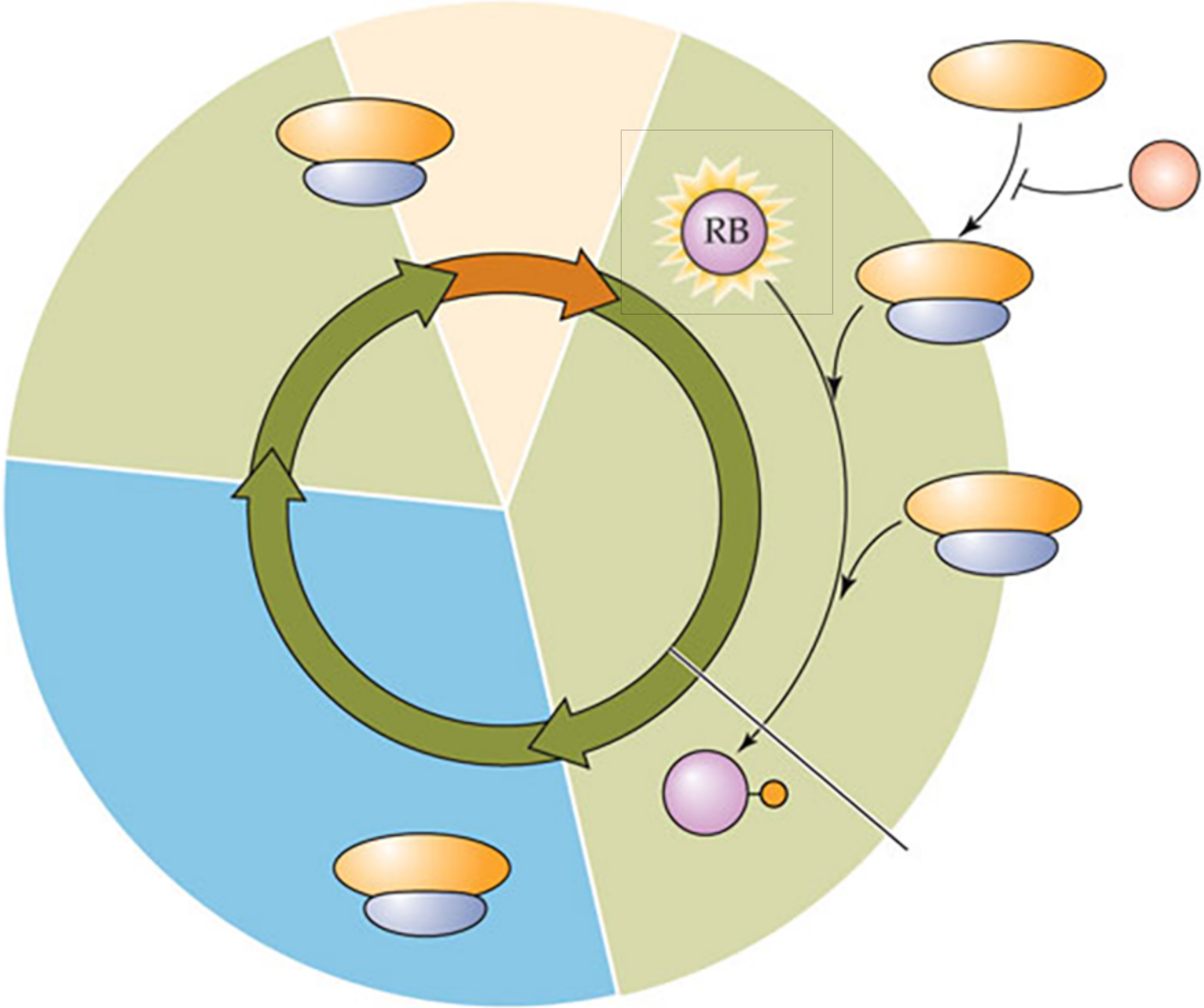


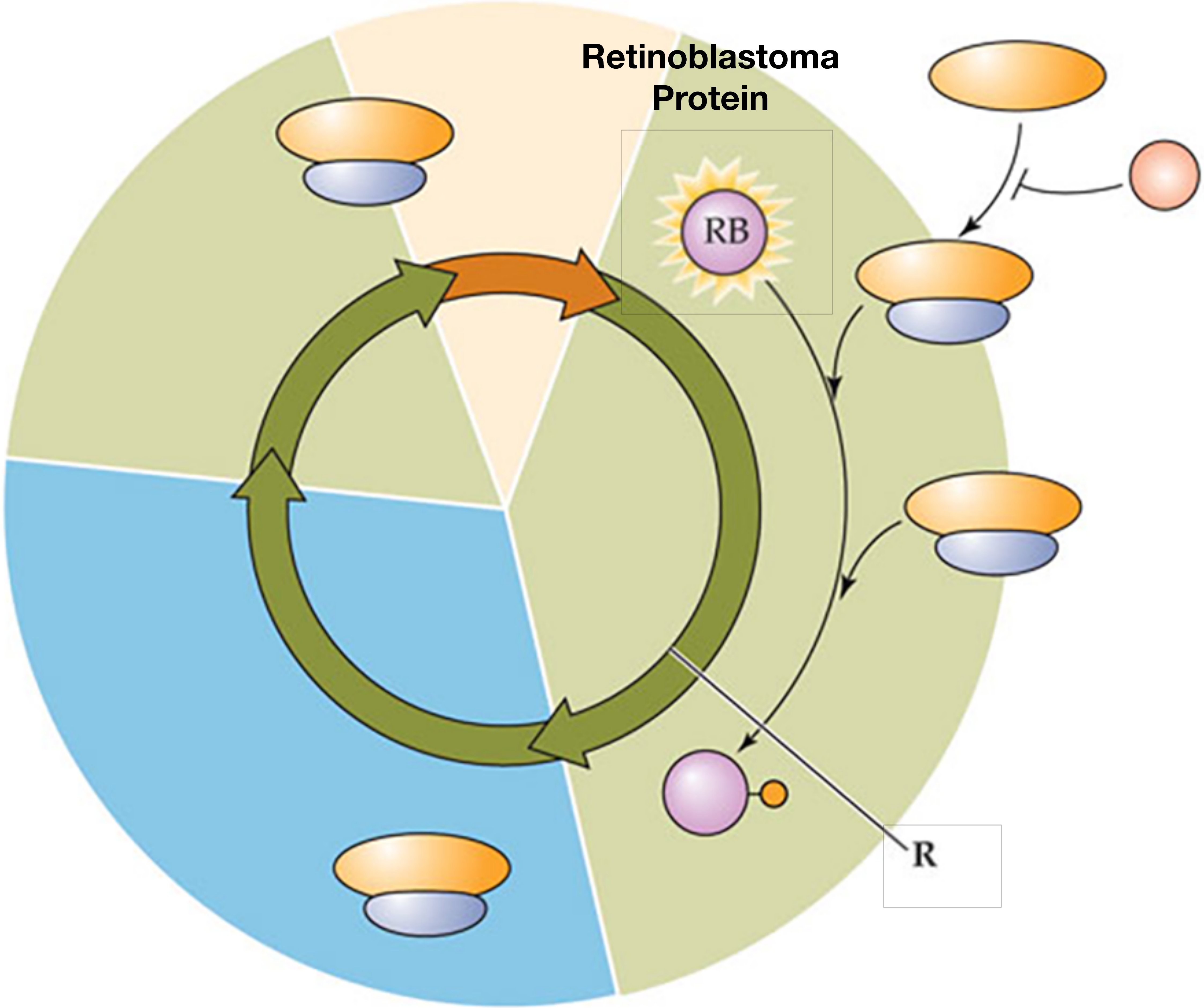
Mitosis
(M)
Gap 2
(G2)
Gap 1
(G1)
Interphase
DNA synthesis
(S)



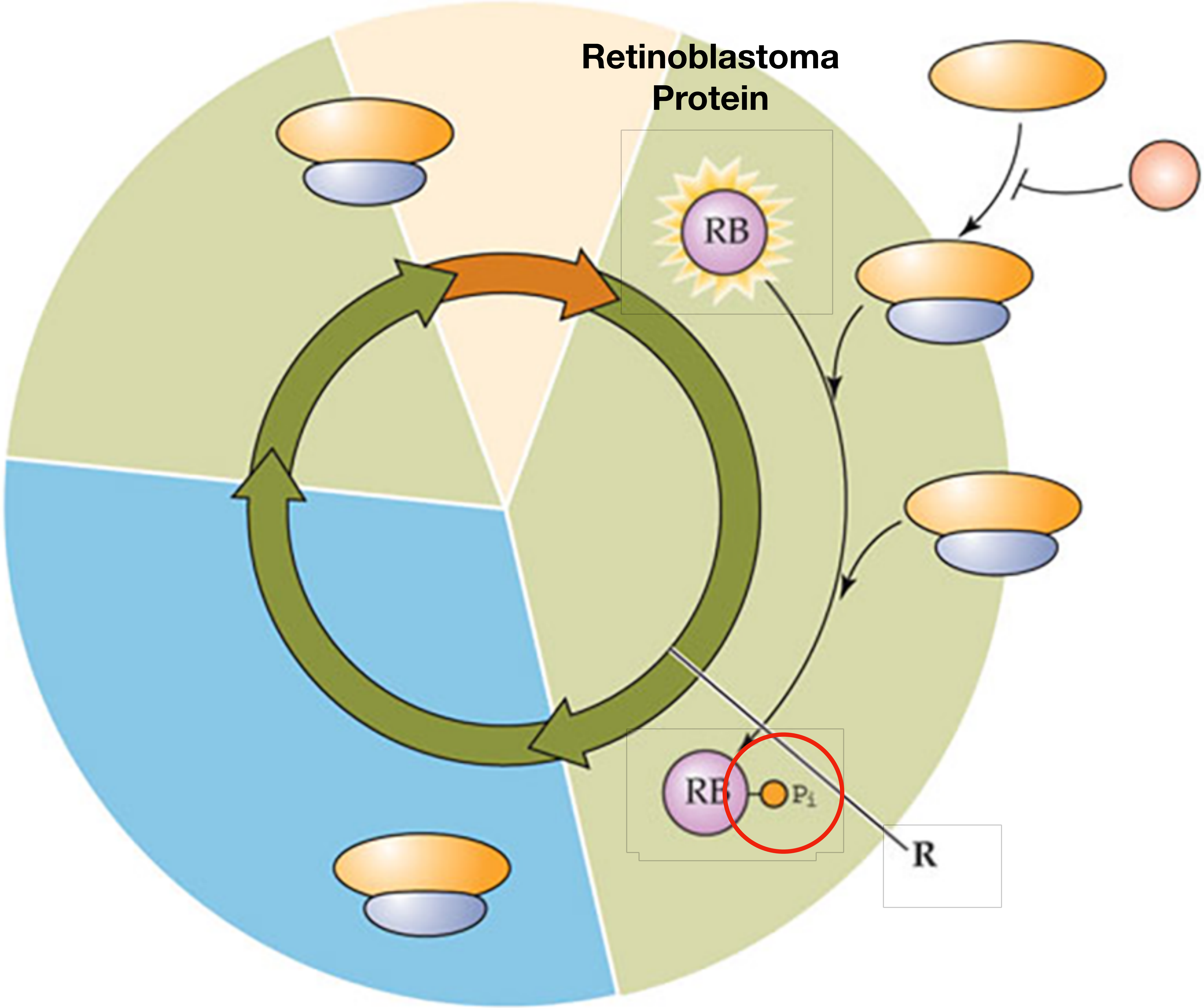
Mitosis
(M)
Gap 2
(G2)
Gap 1
(G1)
Interphase
DNA synthesis
Homologous
chromosomes
Homologous
chromosomes
S phase
Centromeres
Sister chromatids


Cascades
&
Checkpoints

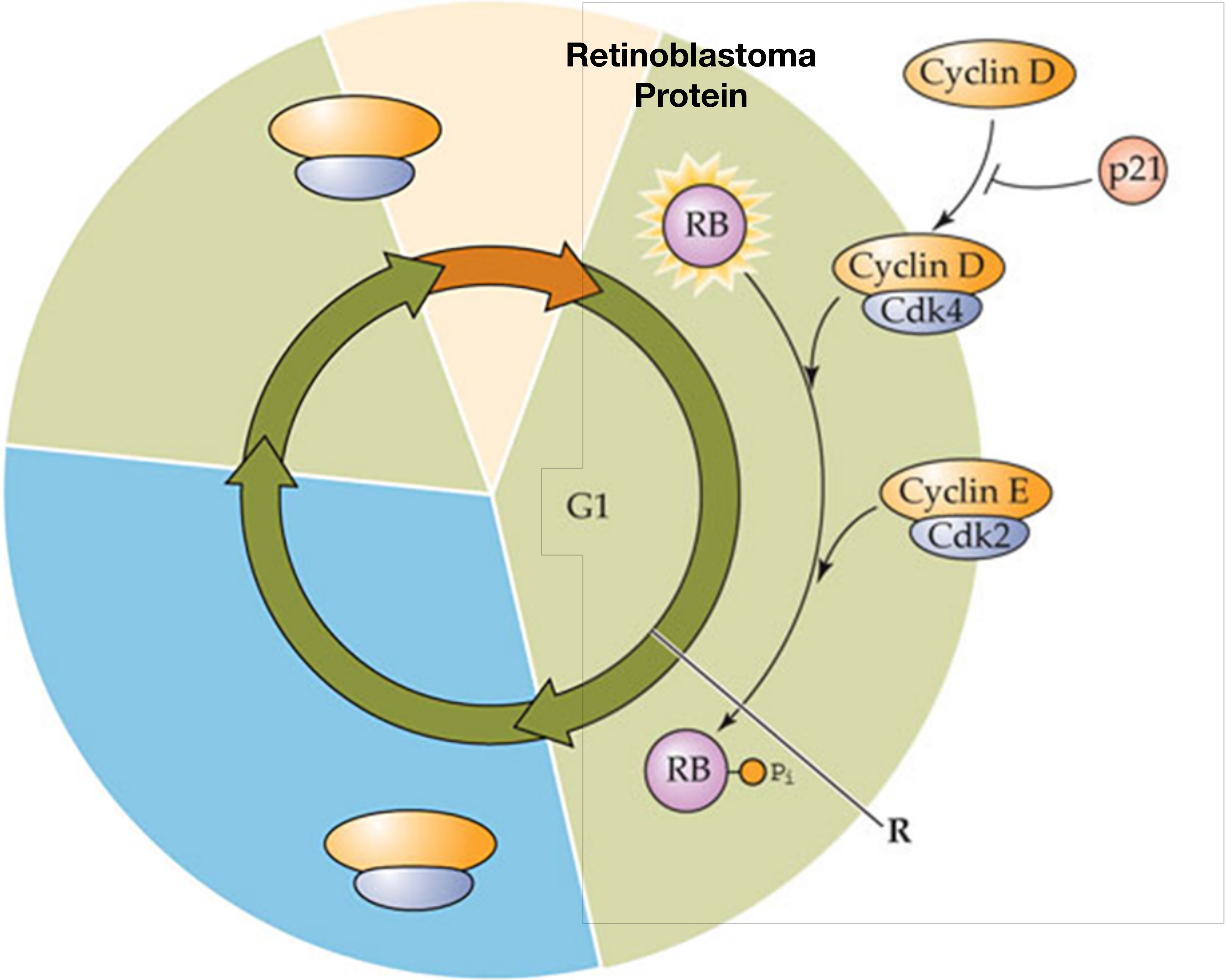

RB

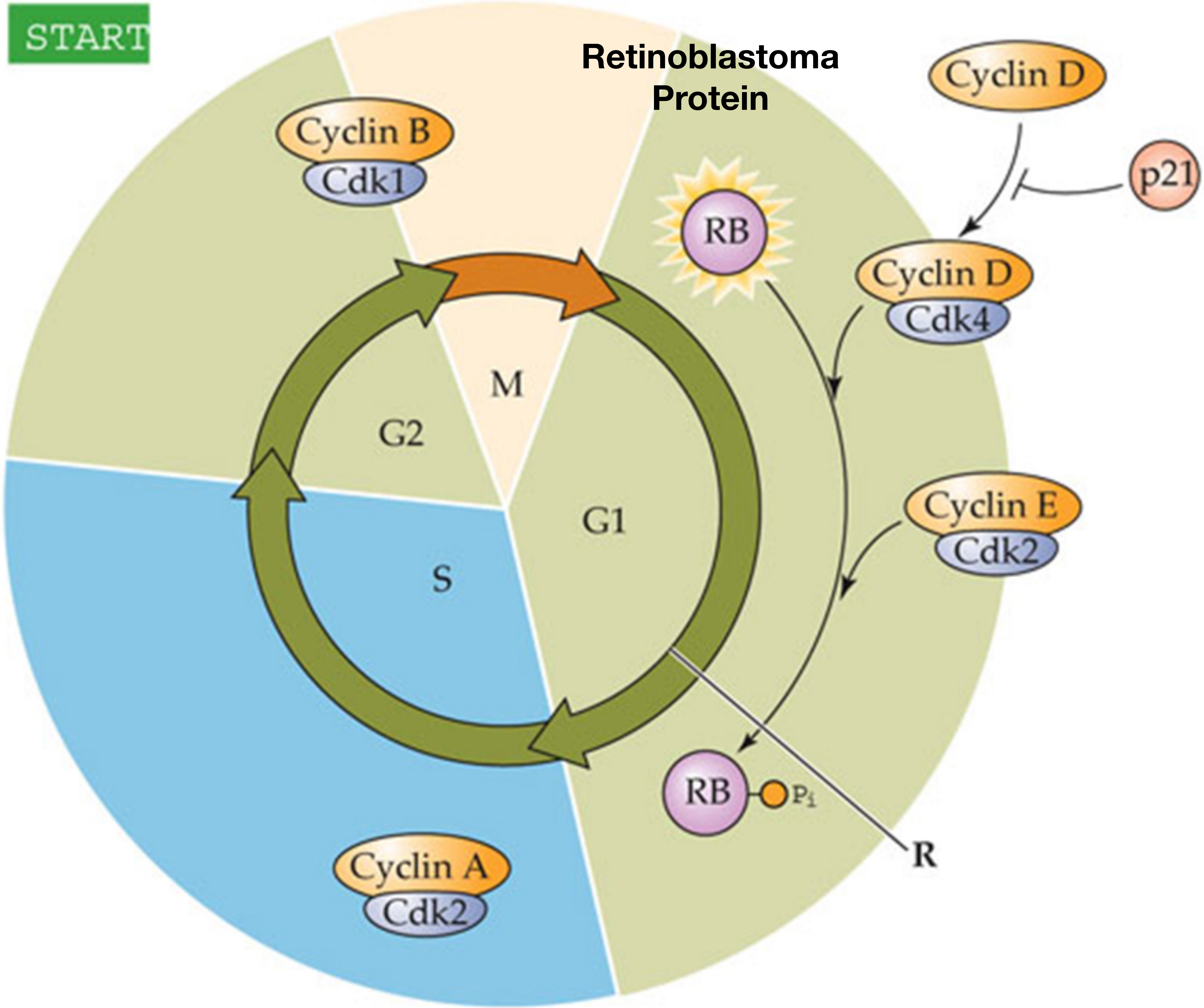


Retinoblastoma Protein
RB
R



Retinoblastoma
Protein
RB
RB
P_i
R


Retinoblastoma
Protein
Cyclin D
p21
RB
Cyclin D
Cdk4
G1
Cyclin E
Cdk2
RB
Pi
R


START
Retinoblastoma
Protein
Cyclin D
p21
Cyclin B
Cdk1
RB
Cyclin D
Cdk4
M
G2
G1
Cyclin E
Cdk2
S
RB
Pi
R
Cyclin A
Cdk2

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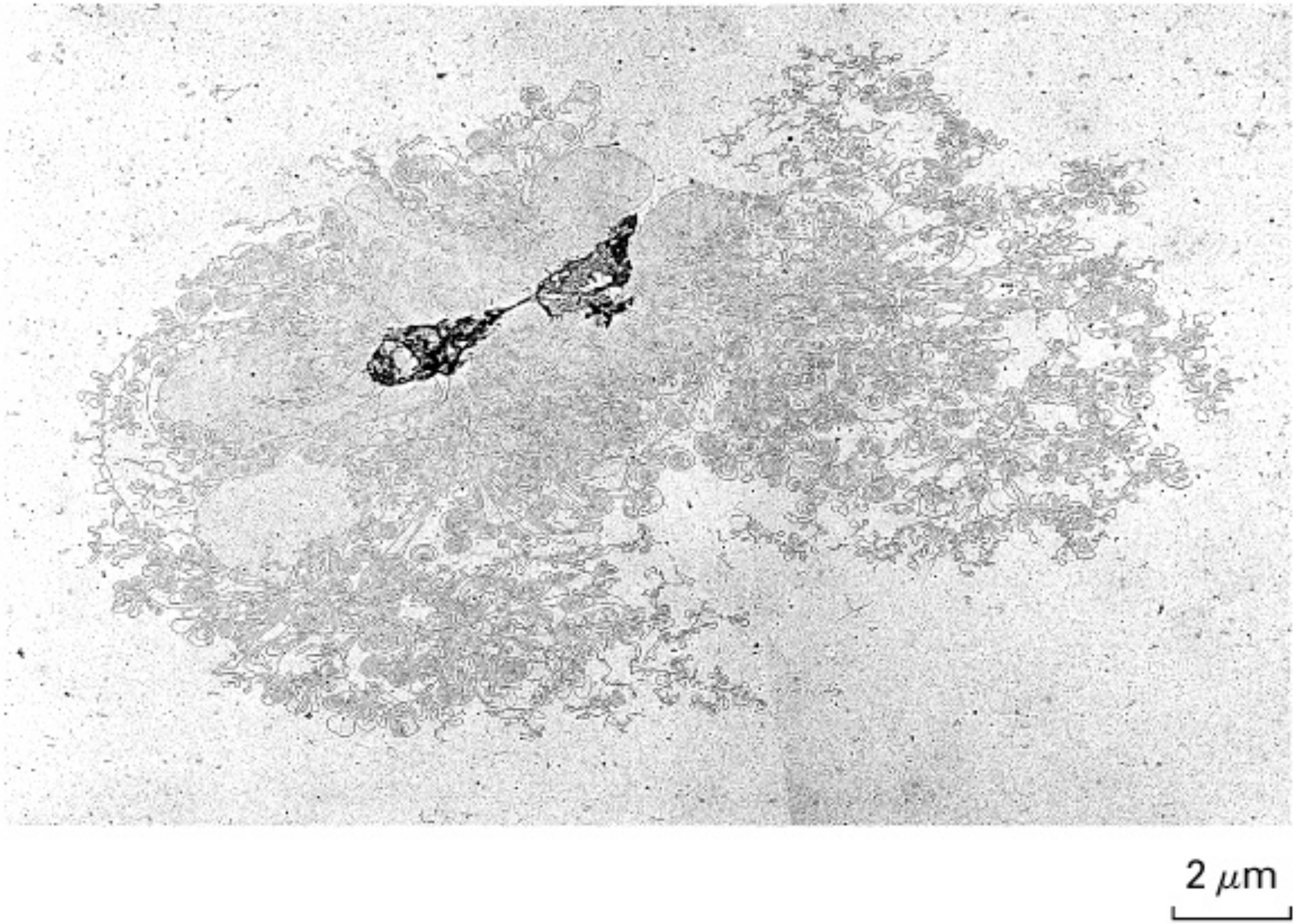
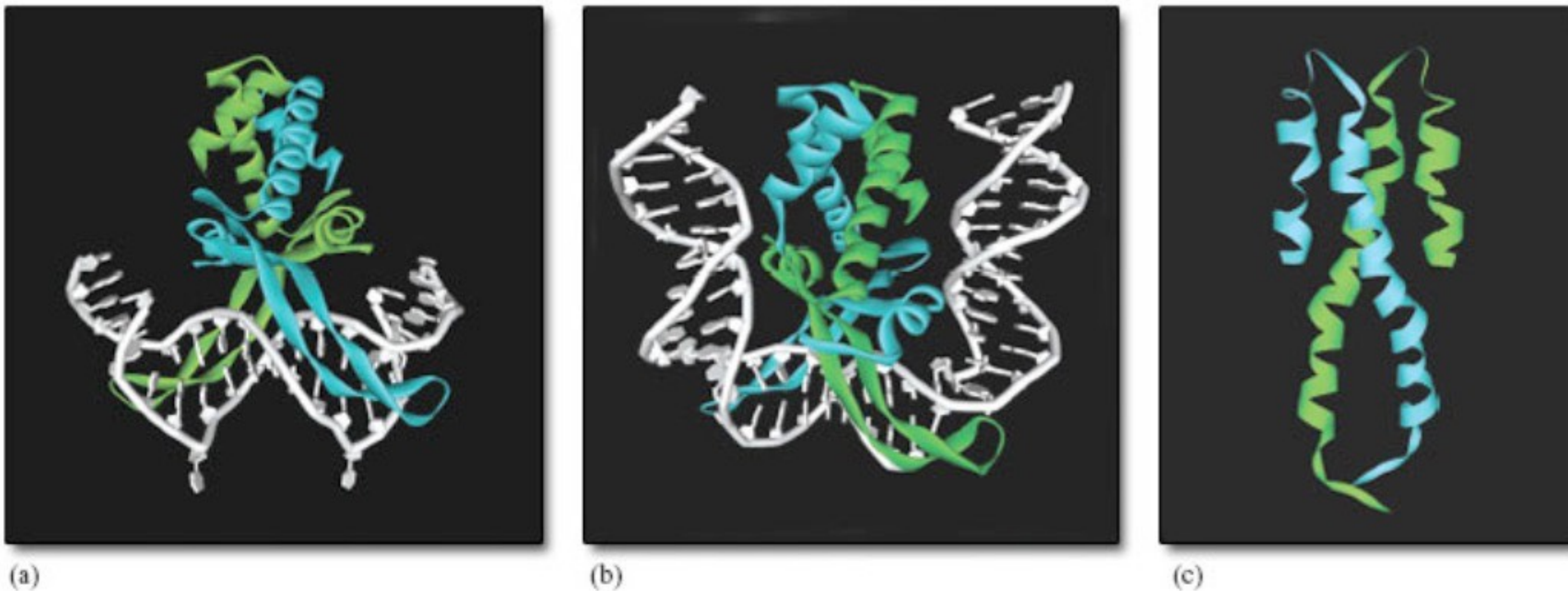
The Bacterial Genome Is Supercoiled

A thin section shows the bacterial nucleoid as a compact mass in the center of the cell

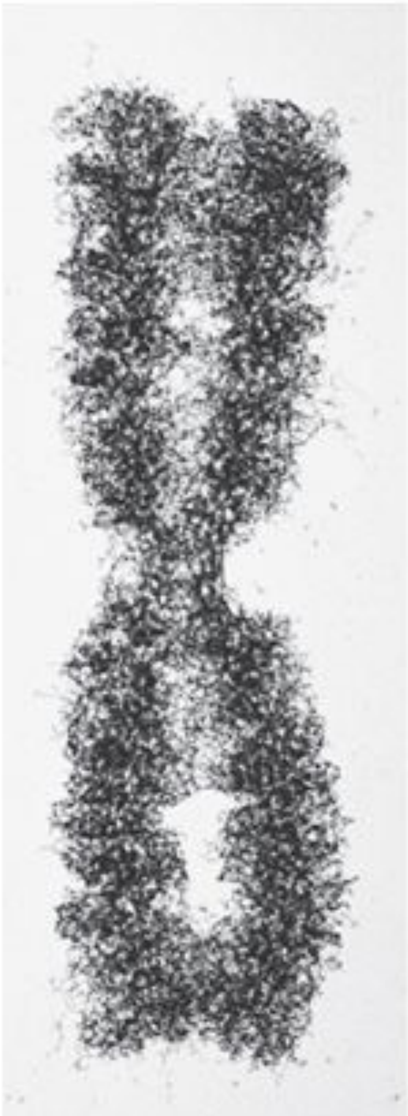




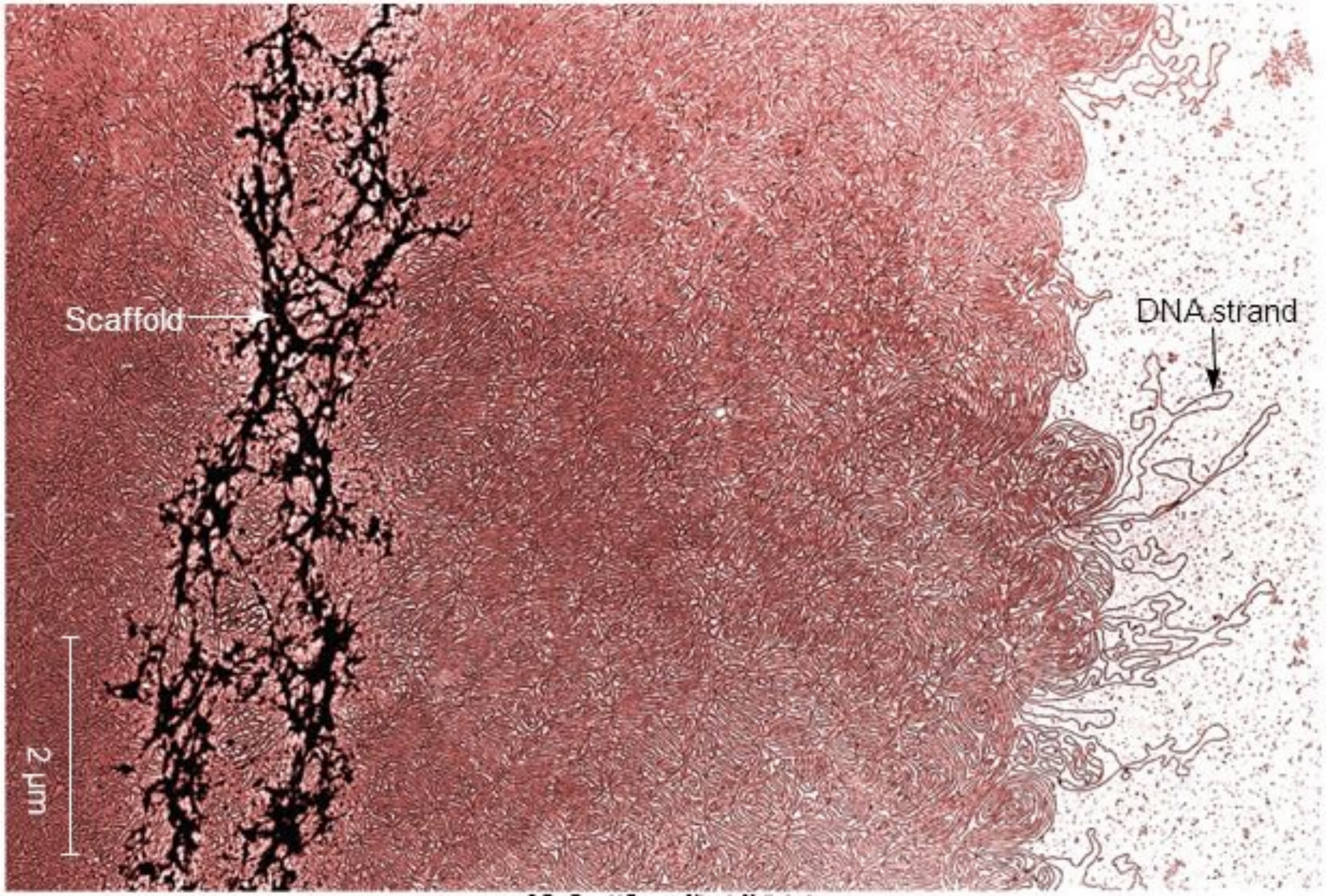
- (a) The HU protein dimer complexed with DNA
- (b) Binding of an *E. coli IHF* dimer to DNA induces a 180° Turn
- (c) Structure of the N-terminal domain of *E. coli* H-NS dimer.

All structures show protein secondary structures and tubular DNA

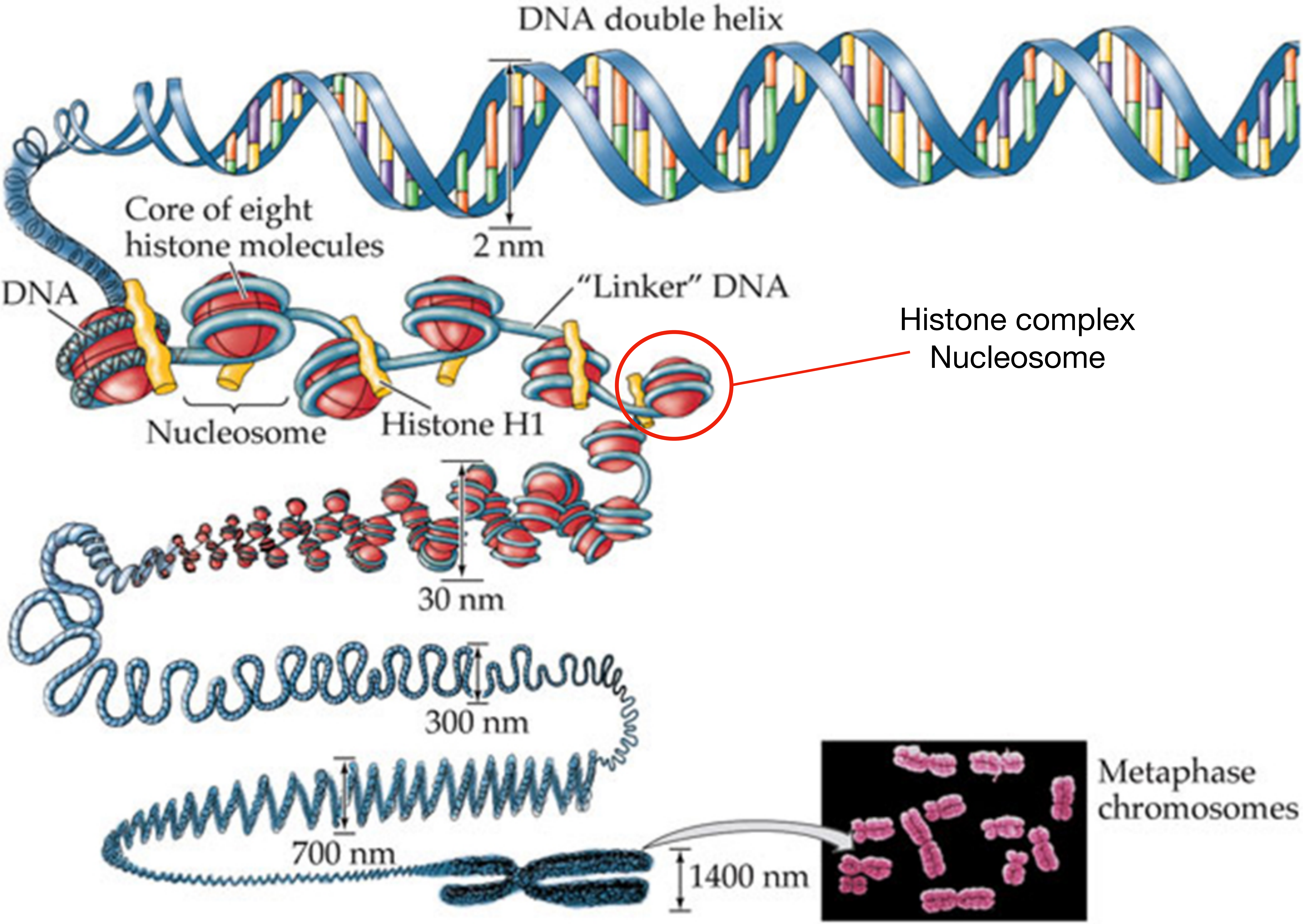
Metaphase Chromosomes



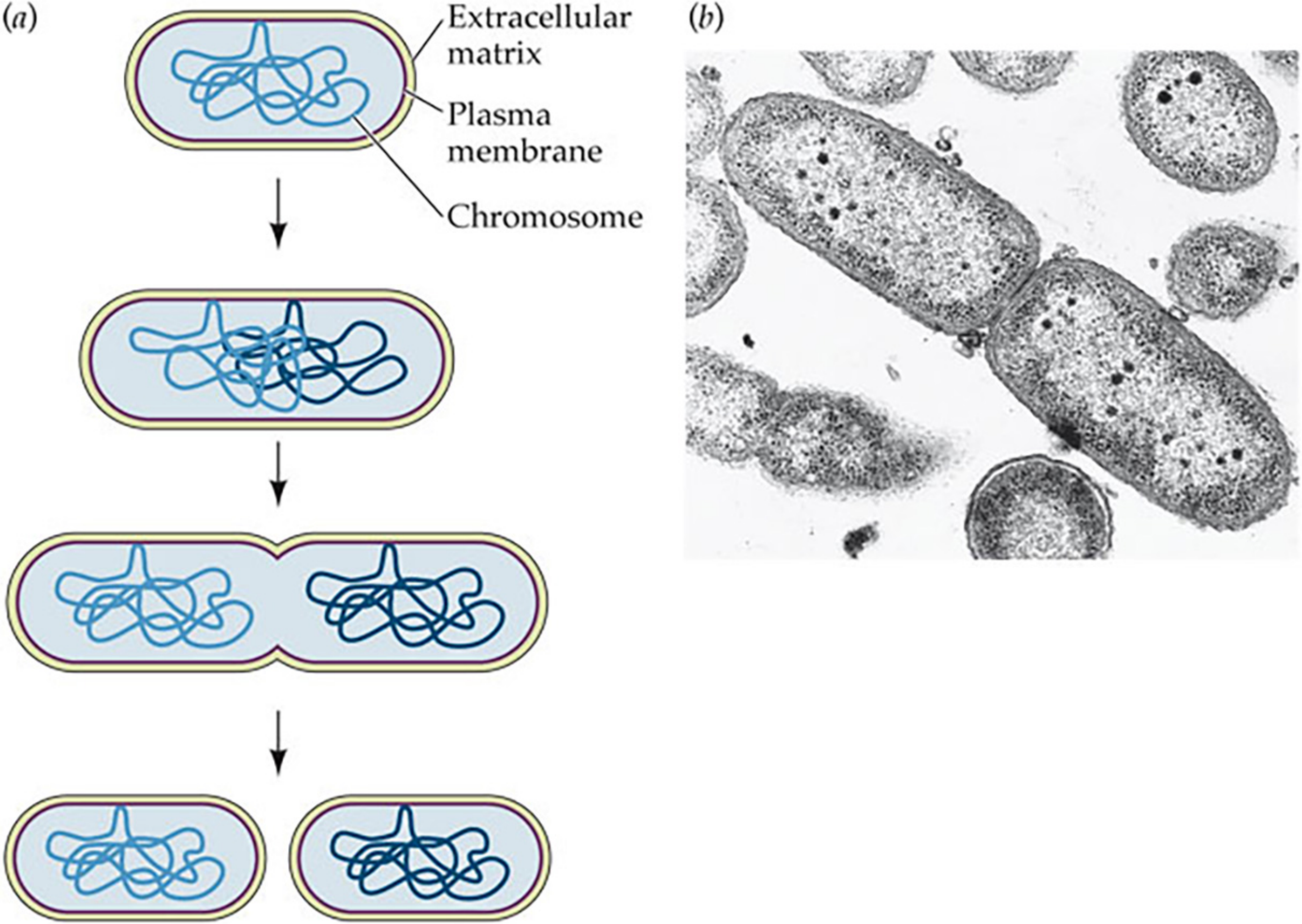
Metaphase chromosome



Metaphase chromosome treated with high salt to remove histone proteins



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 9.6 DNA Packs into a Mitotic Chromosome


(a)
Extracellular matrix
Plasma membrane
Chromosome
(b)

Eukaryotic Life Cycles

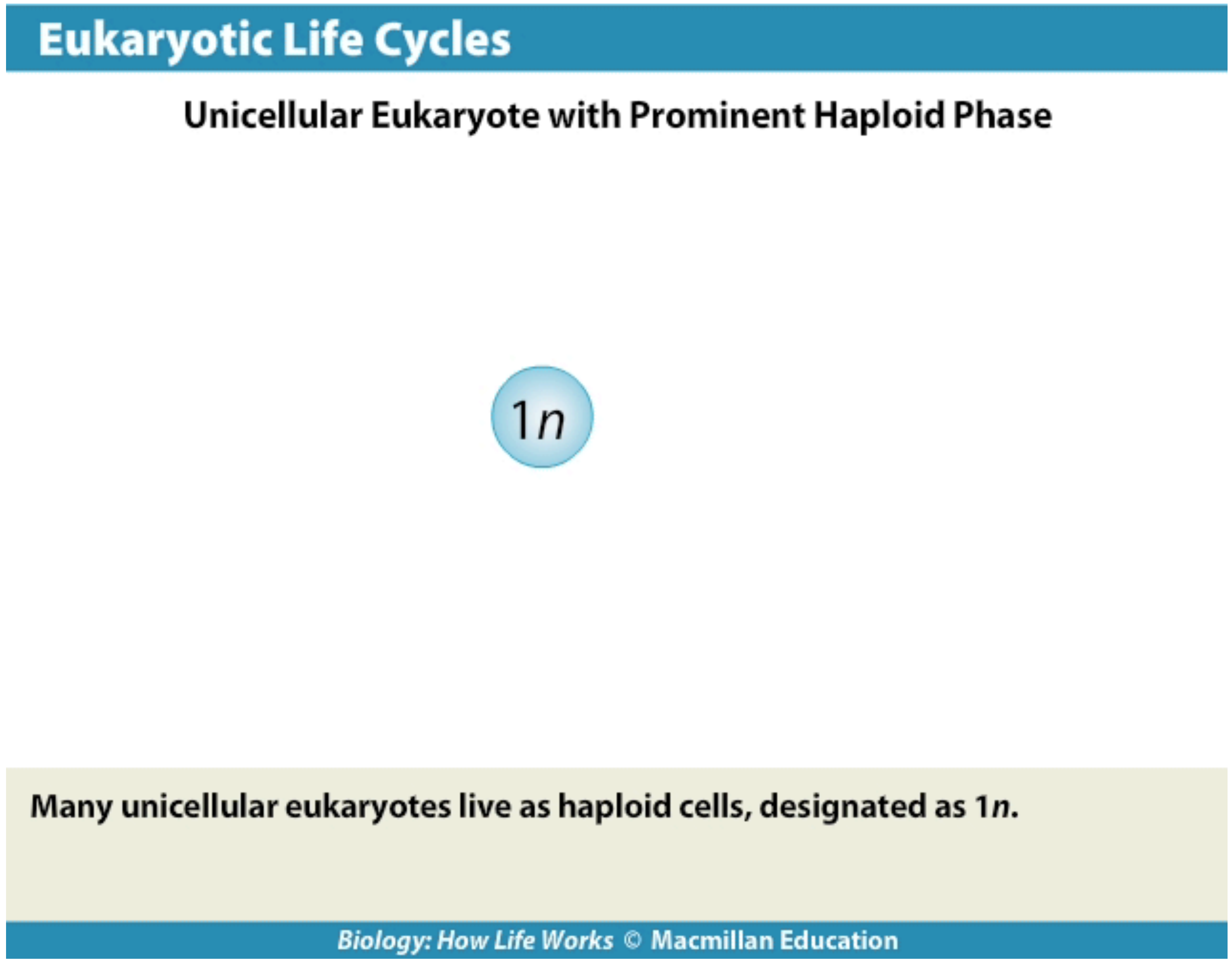
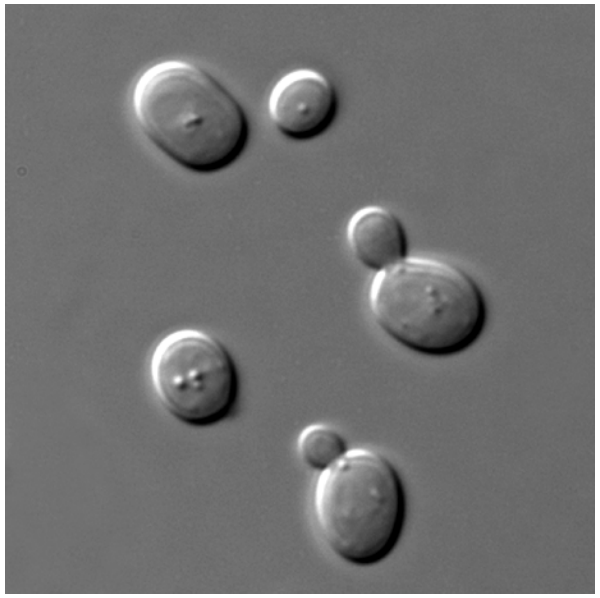
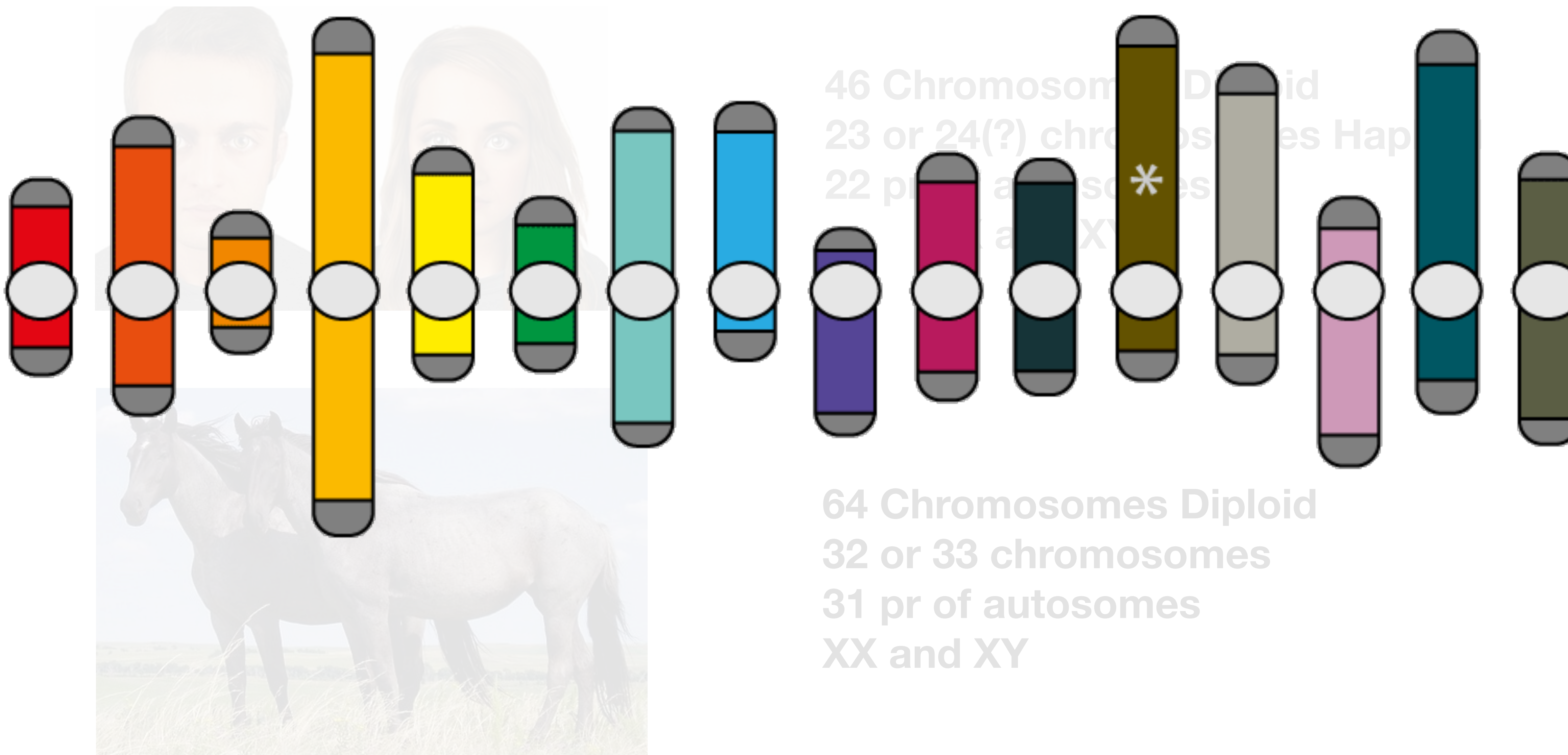


Photo credits: Chlamydomonas: Andrew Syred/Science Source; Diatom: Steve Gschmeissner/Science Source

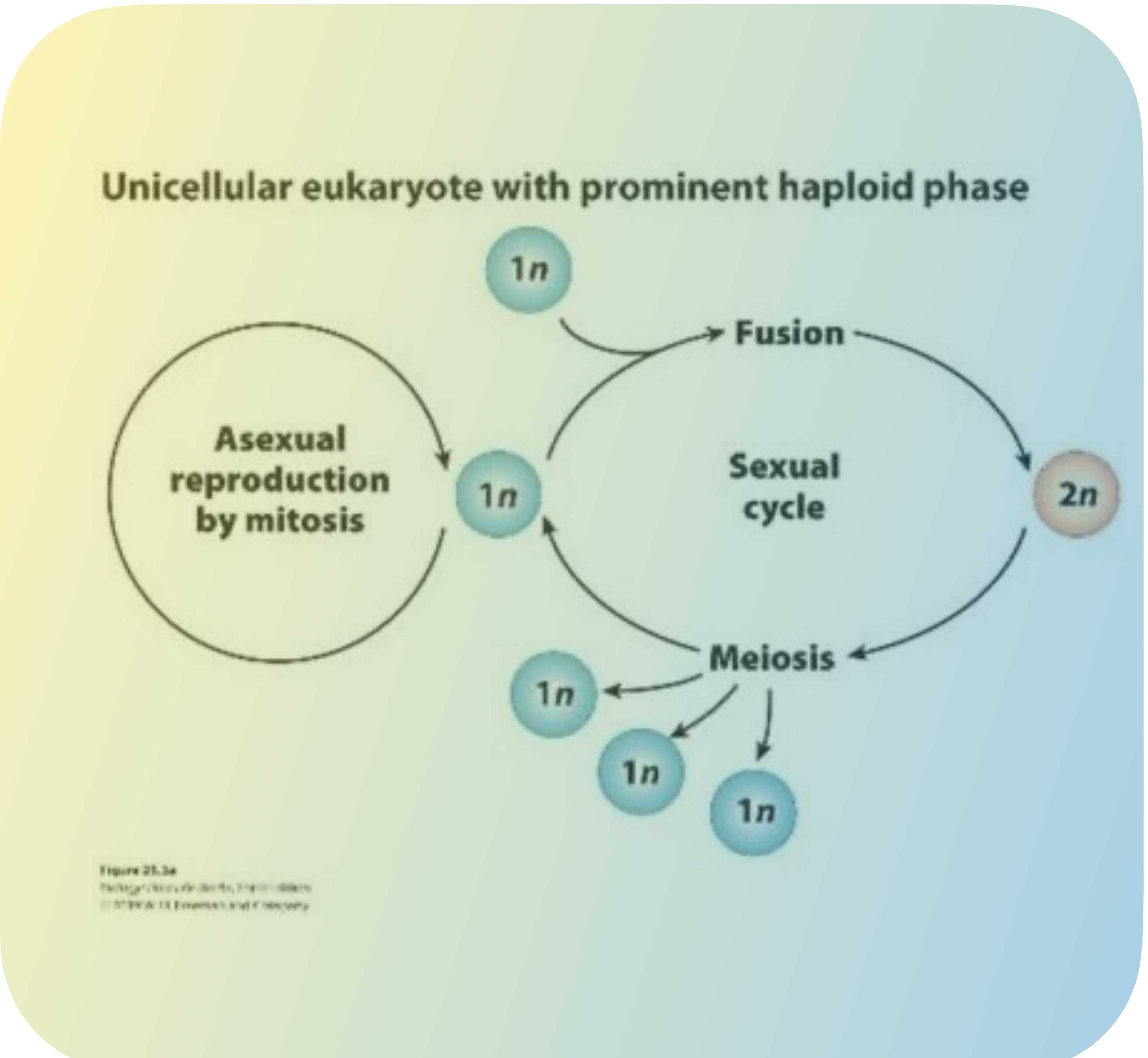


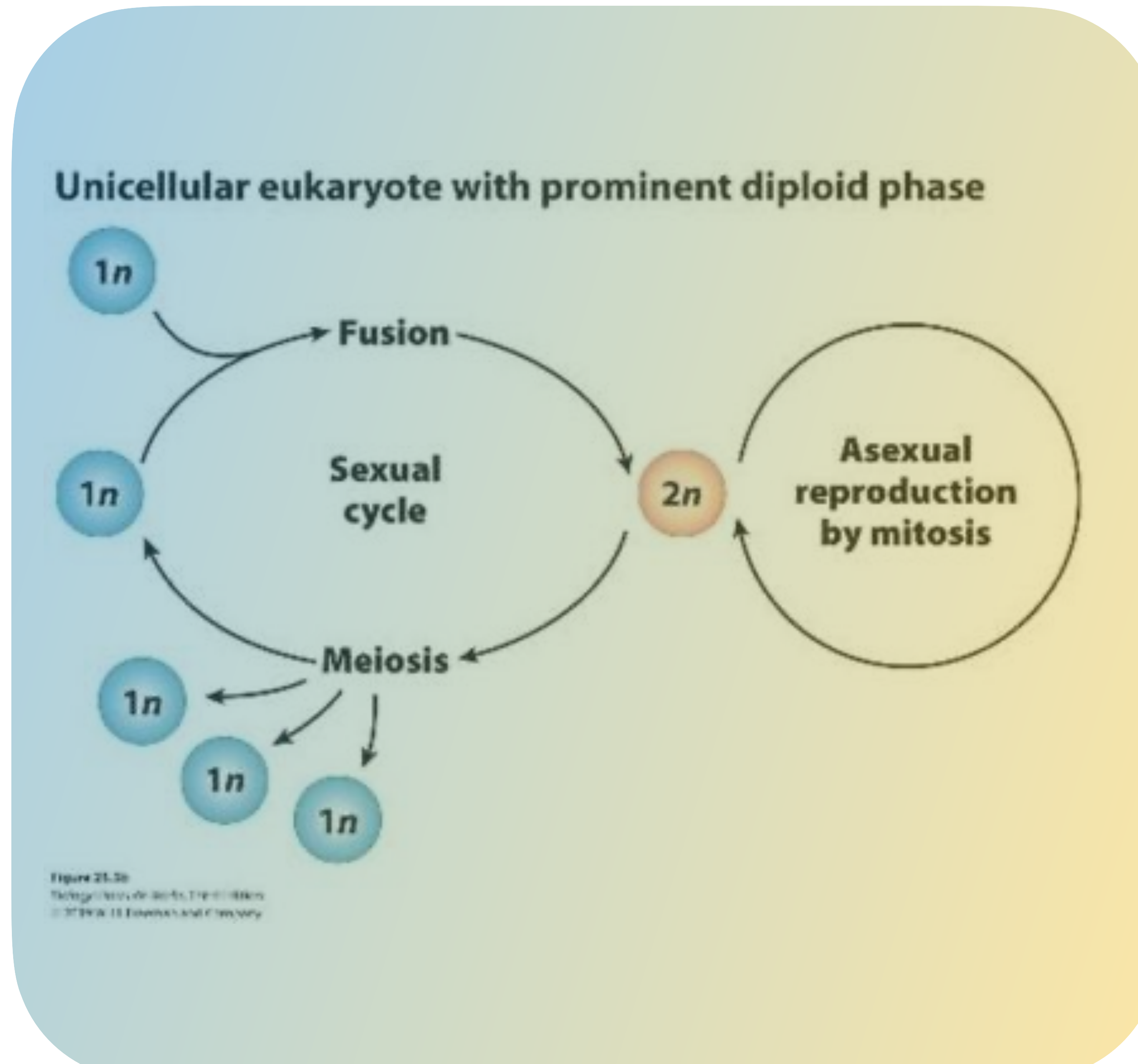
16 chromosomes Haploid
32 chromosomes Diploid

16 pr of chromosomes (D)

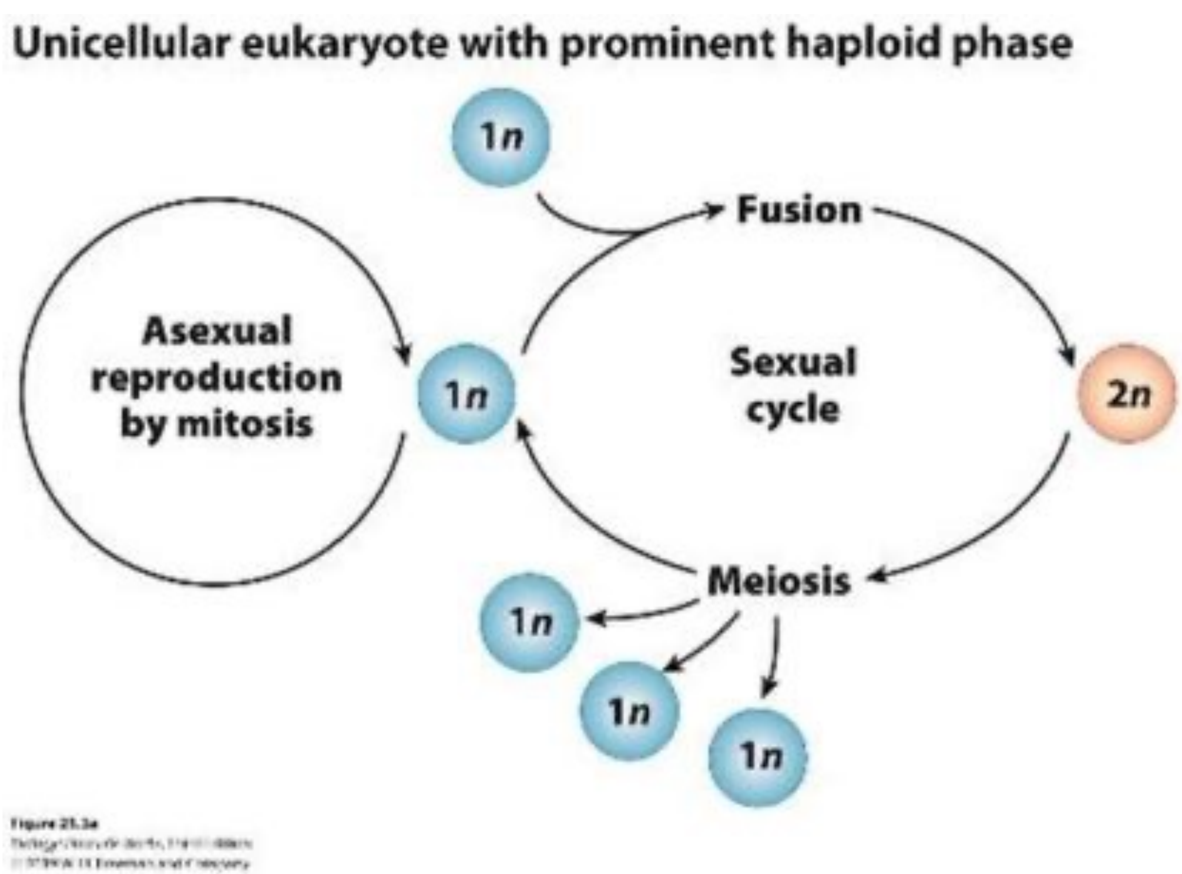


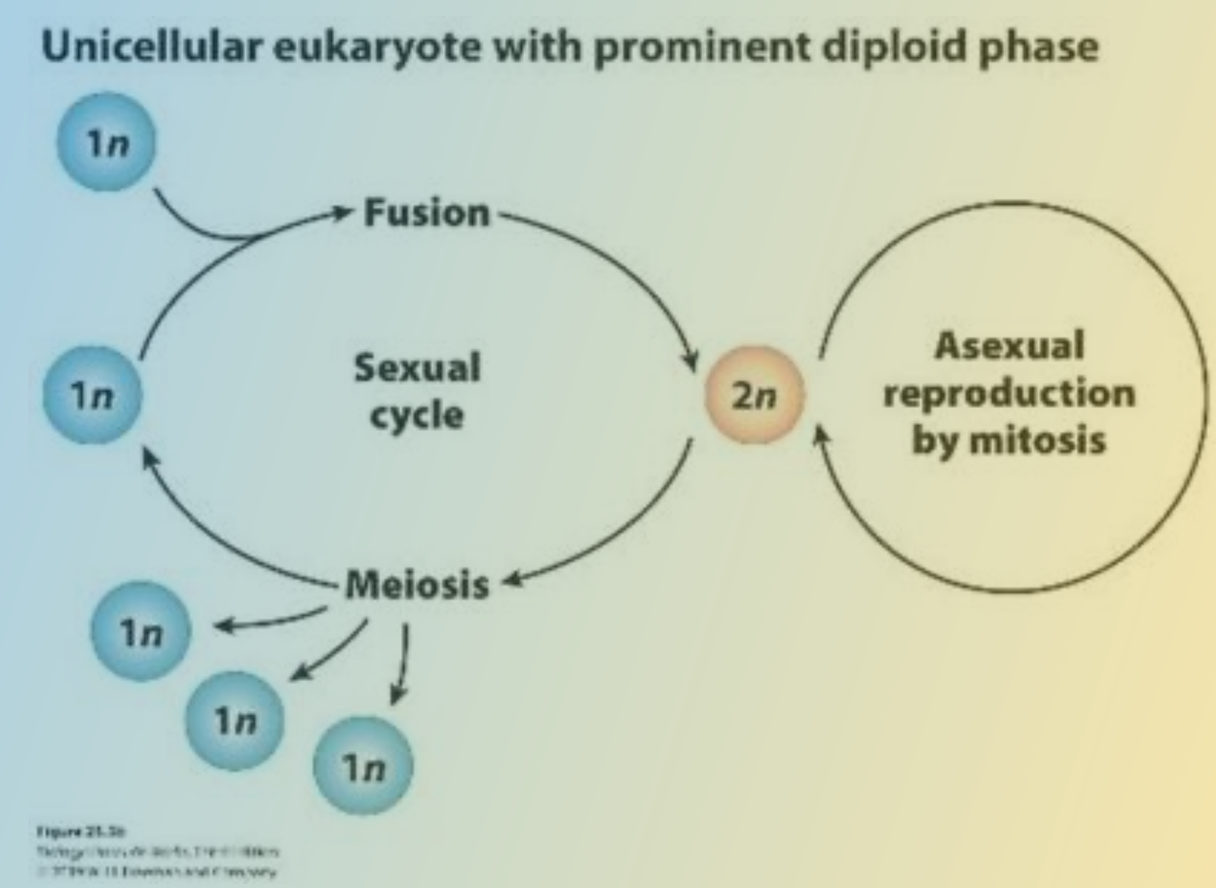
Eukaryotic Life Cycles (1/2)





Eukaryotic Life Cycles (1/2)





Eukaryotic Life Cycle in Plants

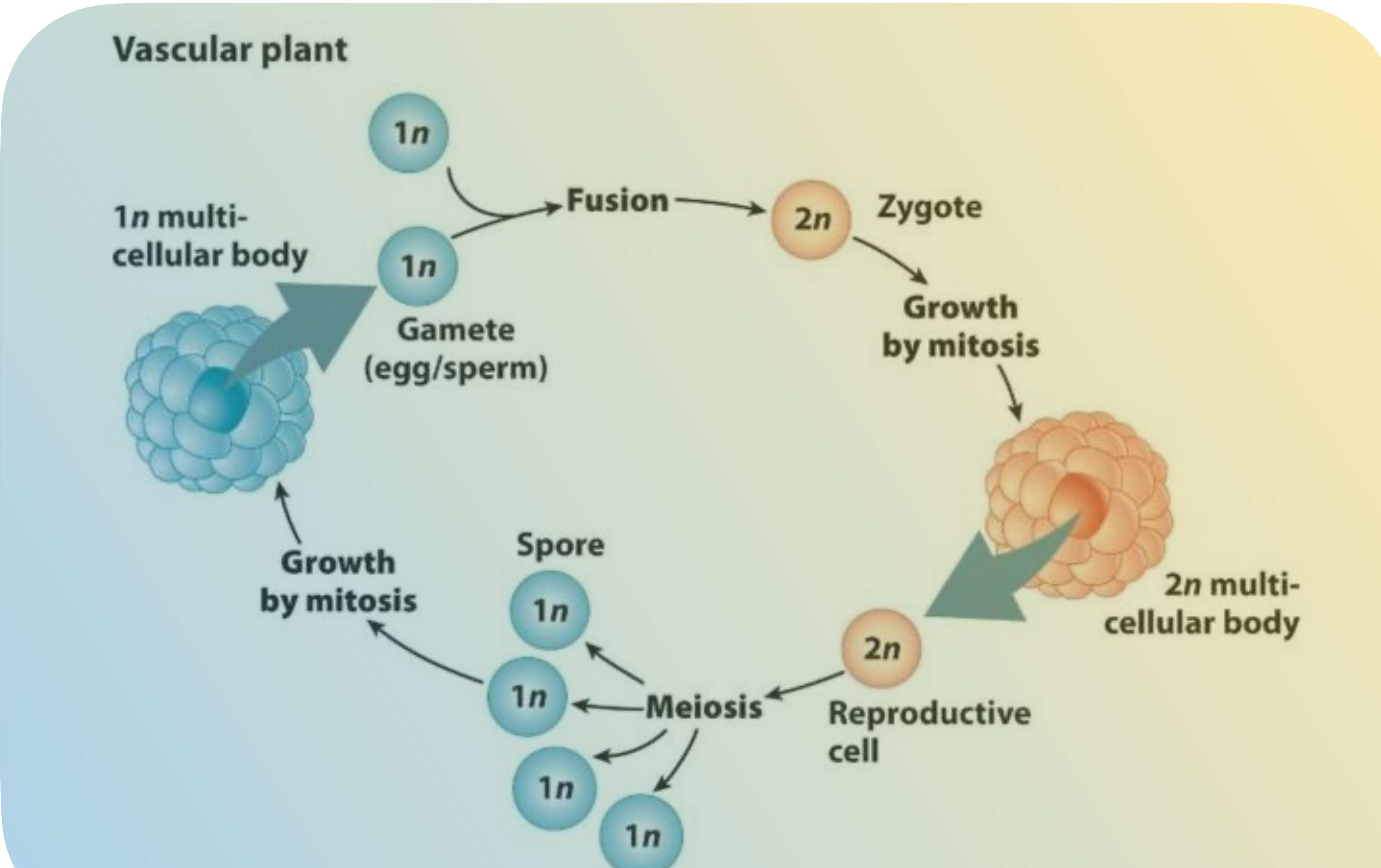
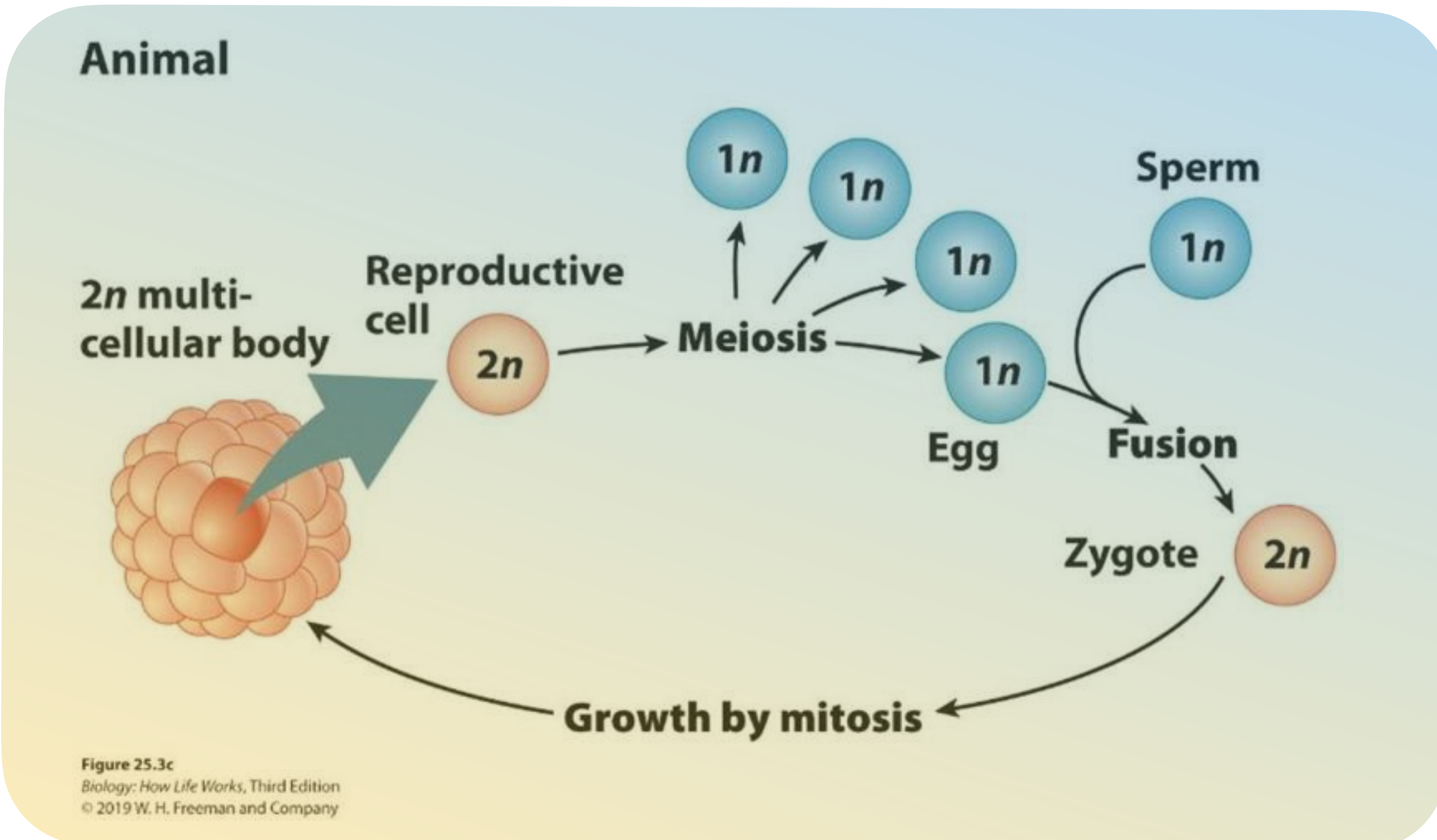
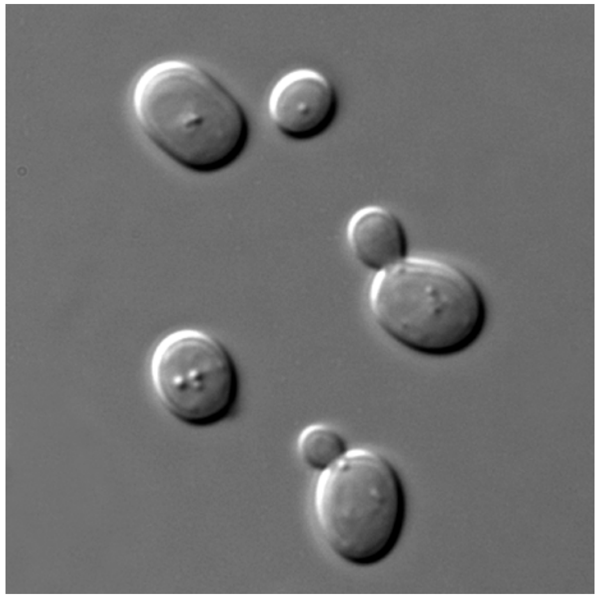


Figure 25.3d
Biology: How Life Works, Third Edition

Eukaryotic Life Cycle in Animals





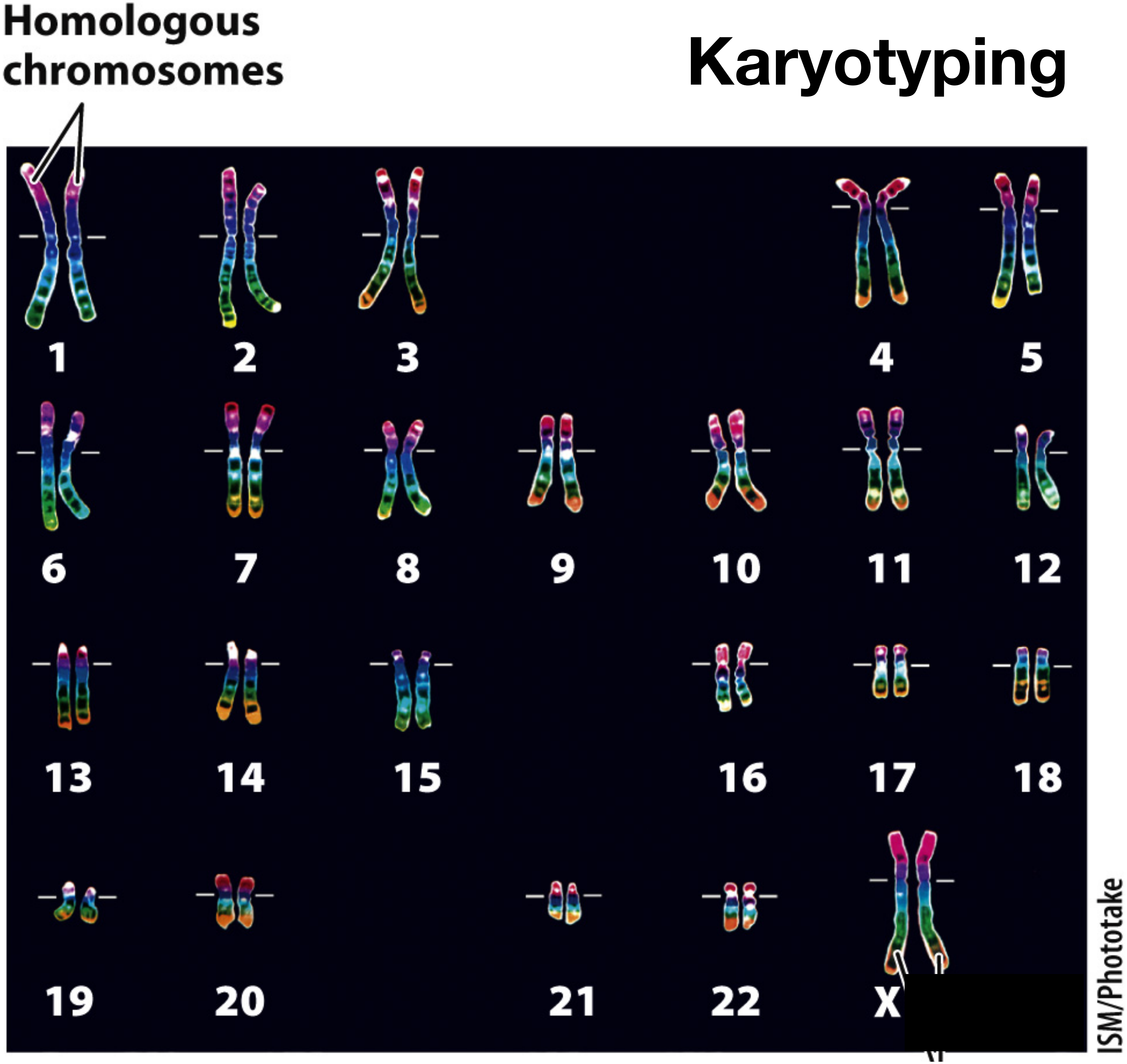
16 chromosomes Haploid
32 chromosomes Diploid

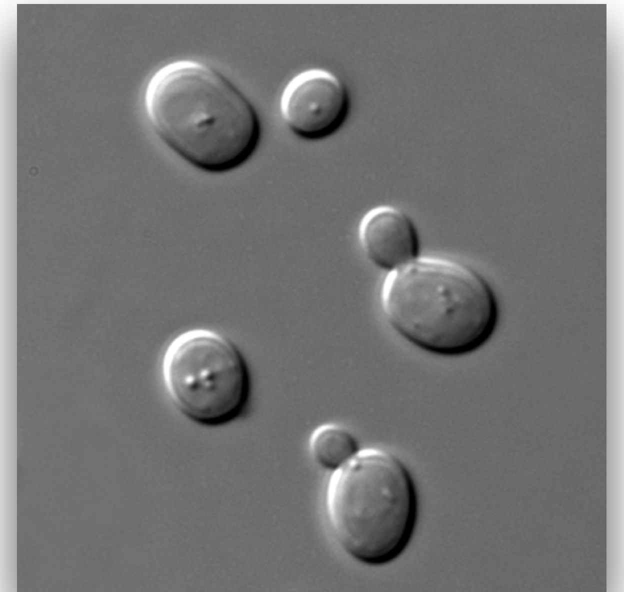
16 pr of chromosomes (D)

46 Chromosomes Diploid
23 or 24(?) chromosomes Haploid
22 pr. of autosomes
XX and XY

64 Chromosomes Diploid
32 or 33 chromosomes
31 pr of autosomes
XX and XY

Karyotyping





16 chromosomes Haploid
32 chromosomes Diploid

16 pr of chromosomes (D)

46 Chromosomes Diploid
23 chromosomes Haploid
22 pr. of autosomes
XX and XY

64 Chromosomes Diploid
32 chromosomes
31 pr of autosomes
XX and XY

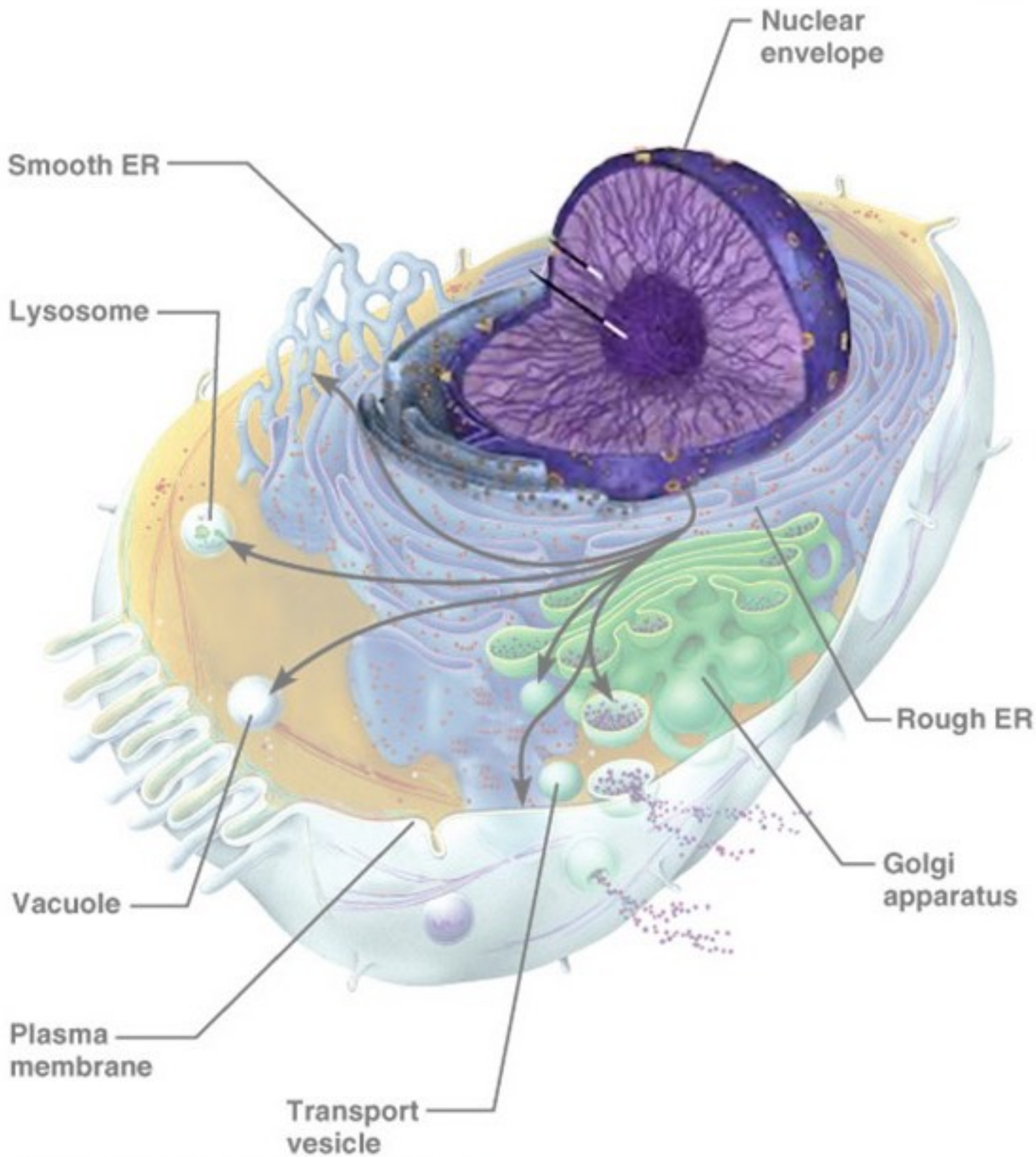

Nuclear
envelope
Smooth ER
Lysosome
Rough ER
Golgi
apparatus
Vacuole
Plasma
membrane
Transport
vesicle

Figure 3.23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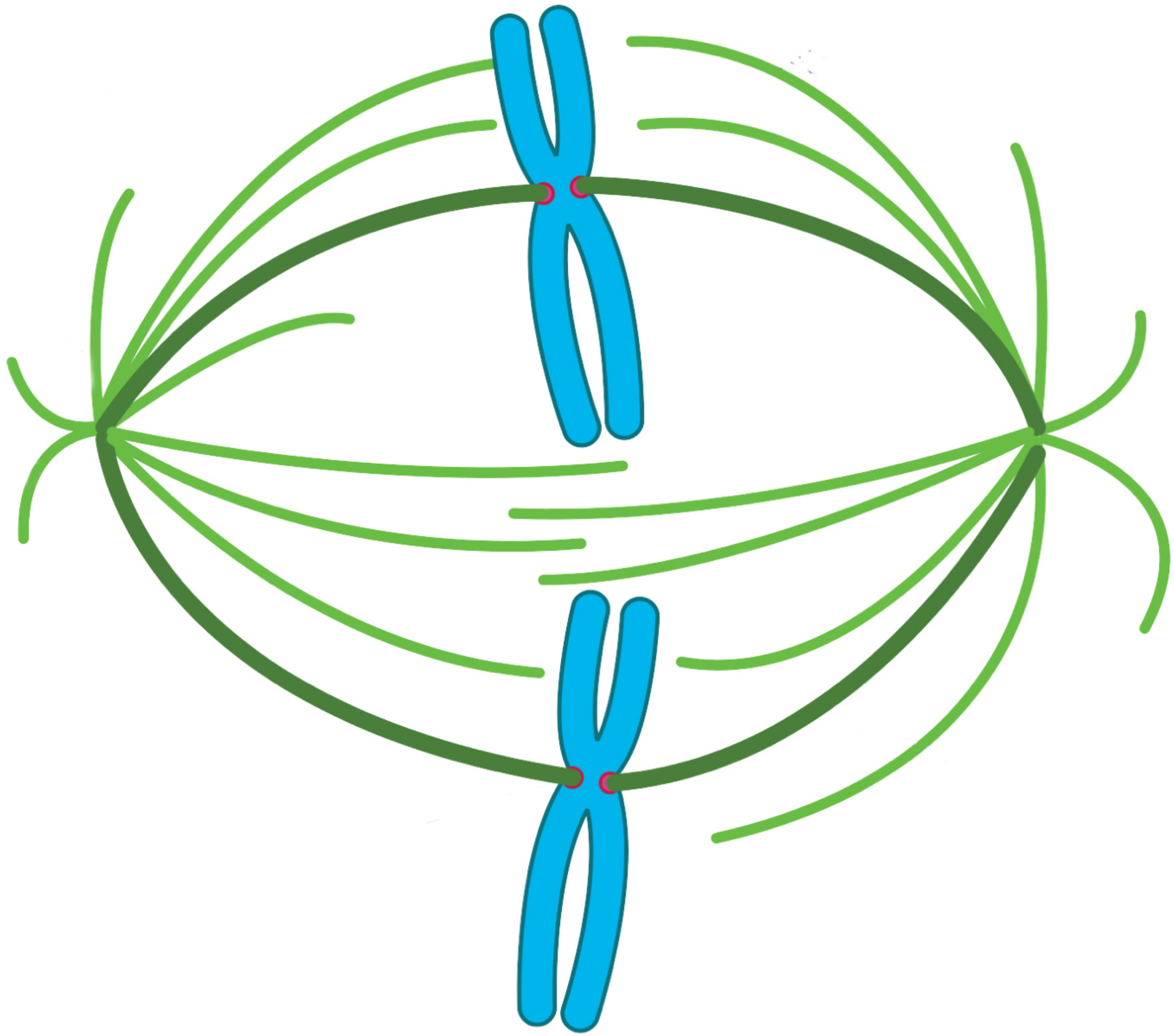
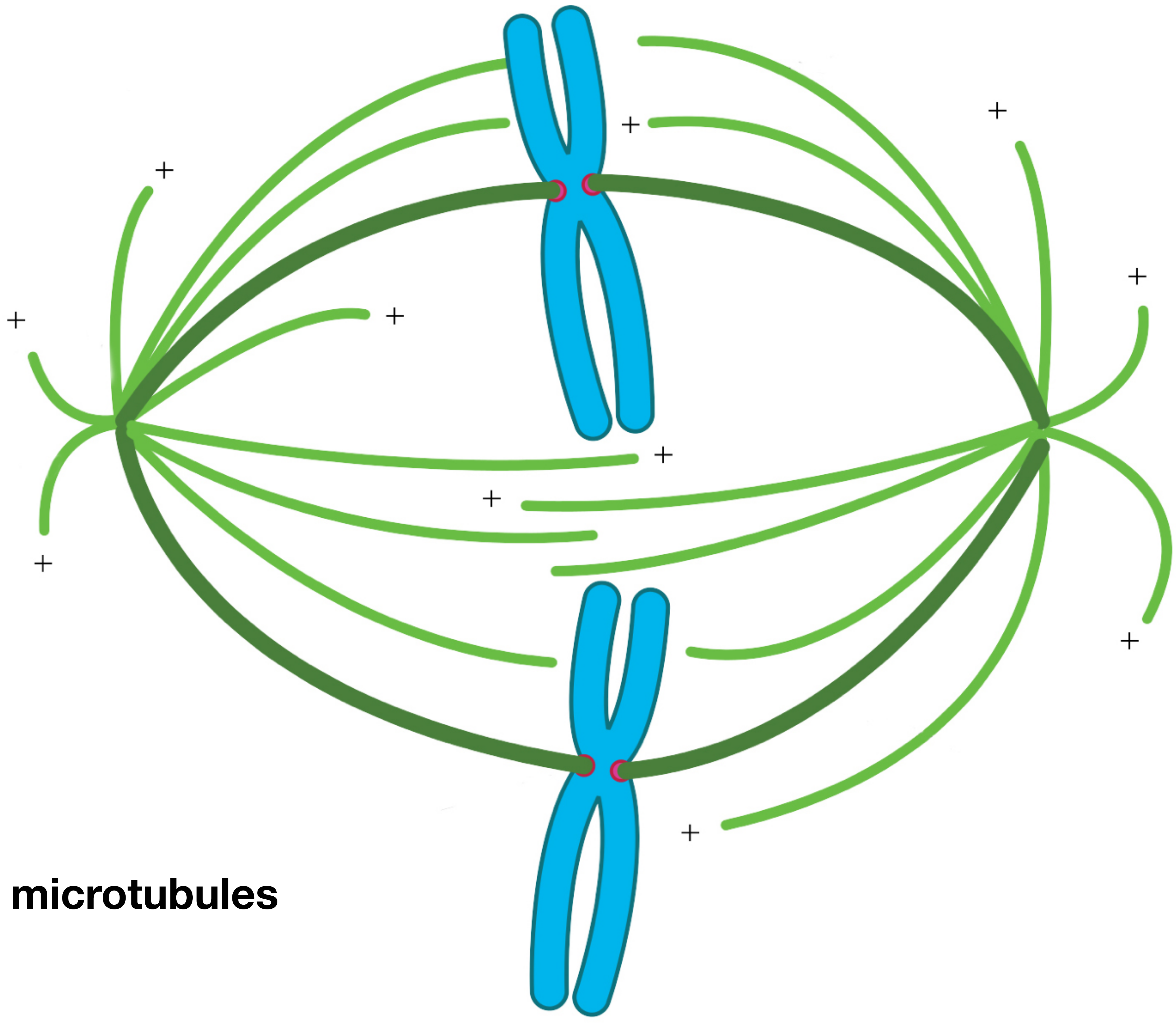
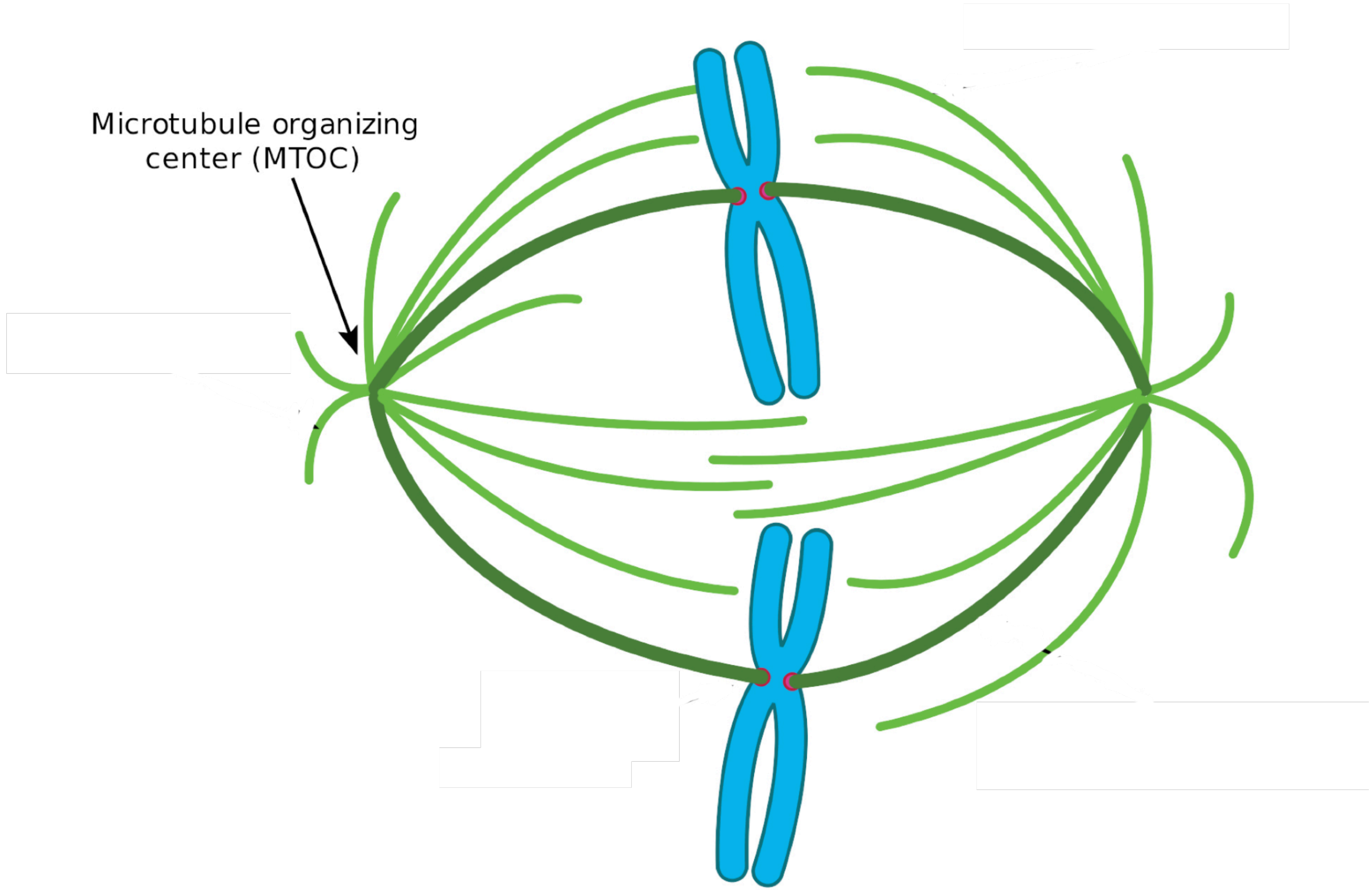
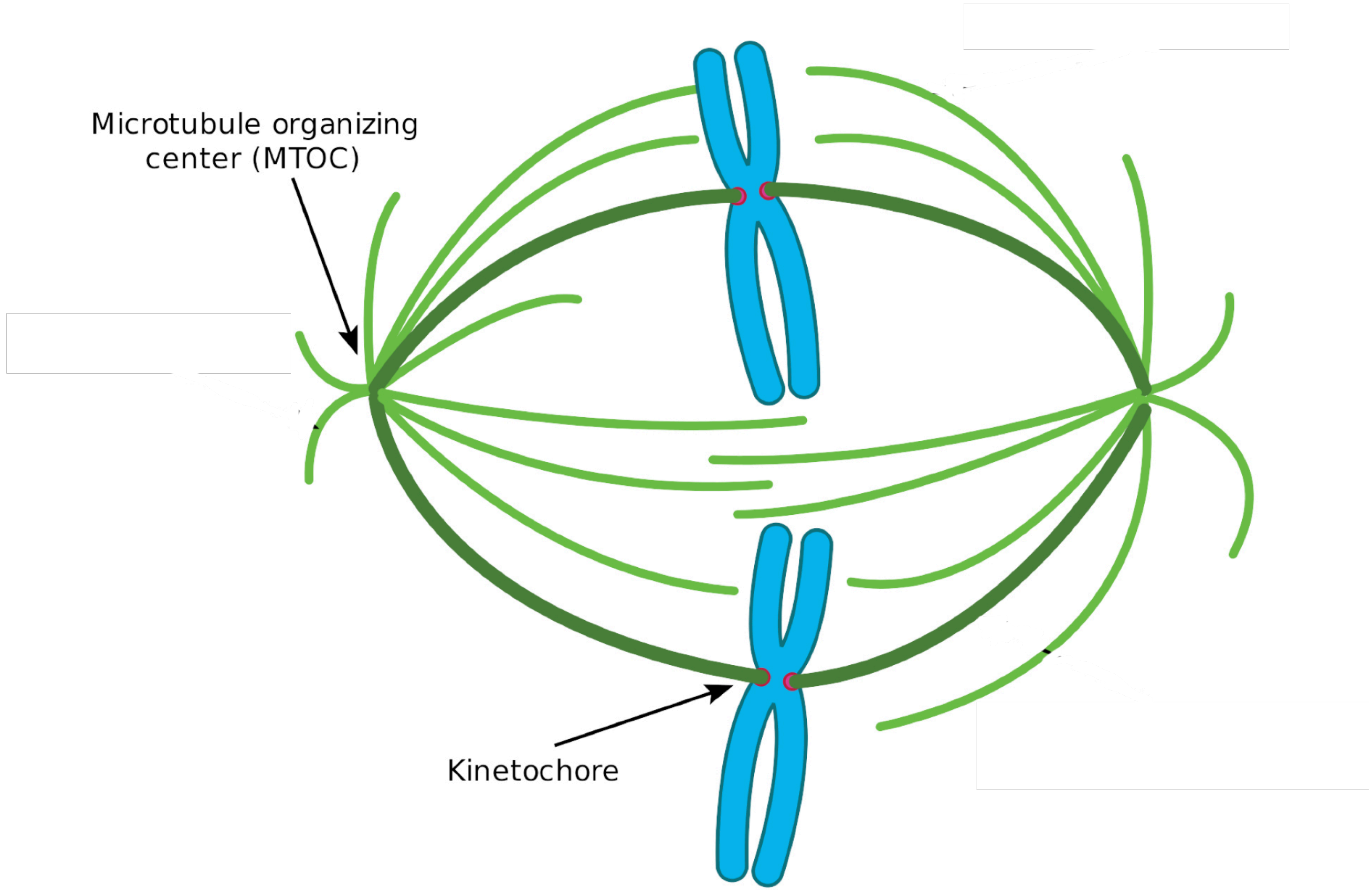


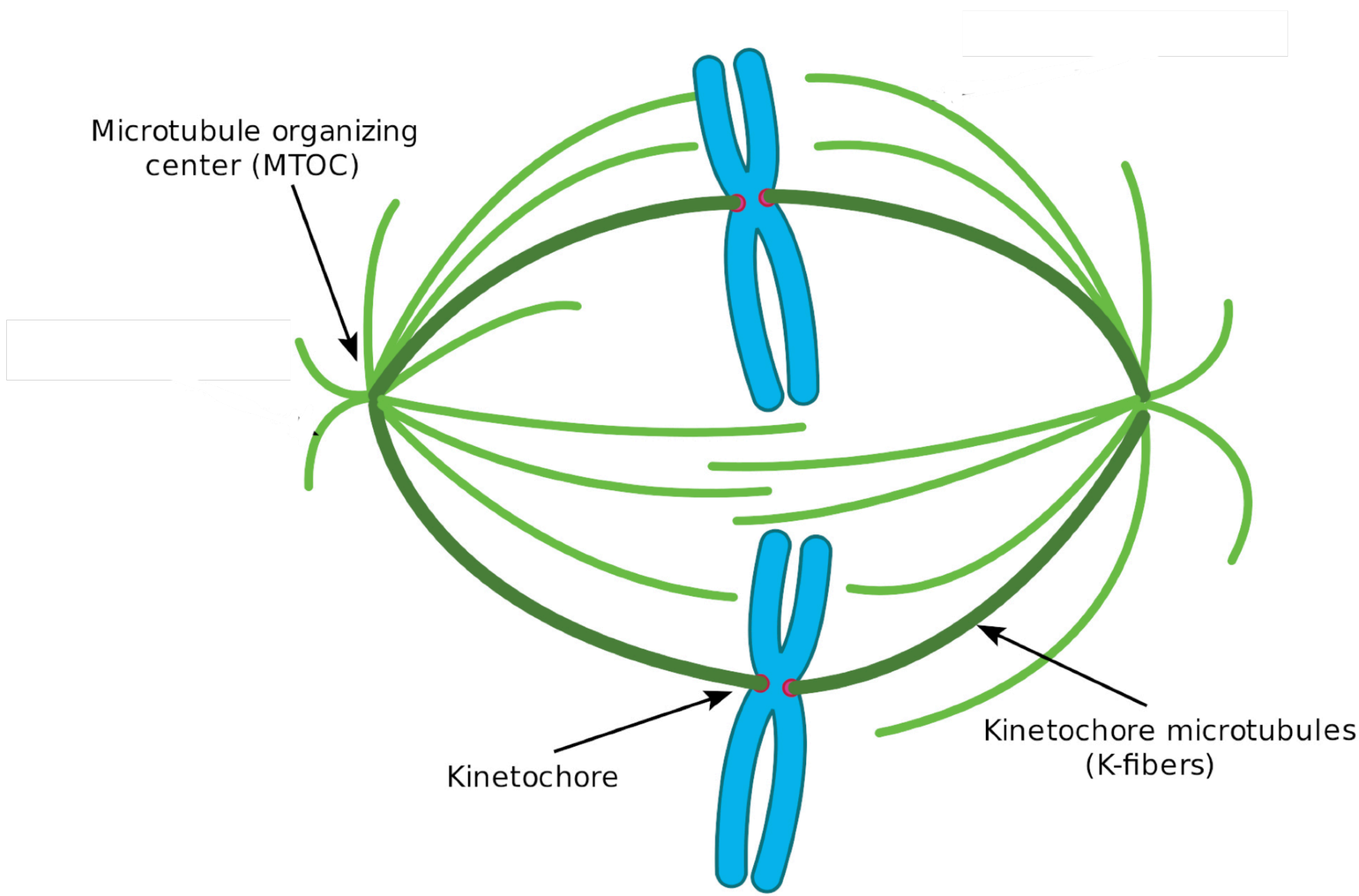


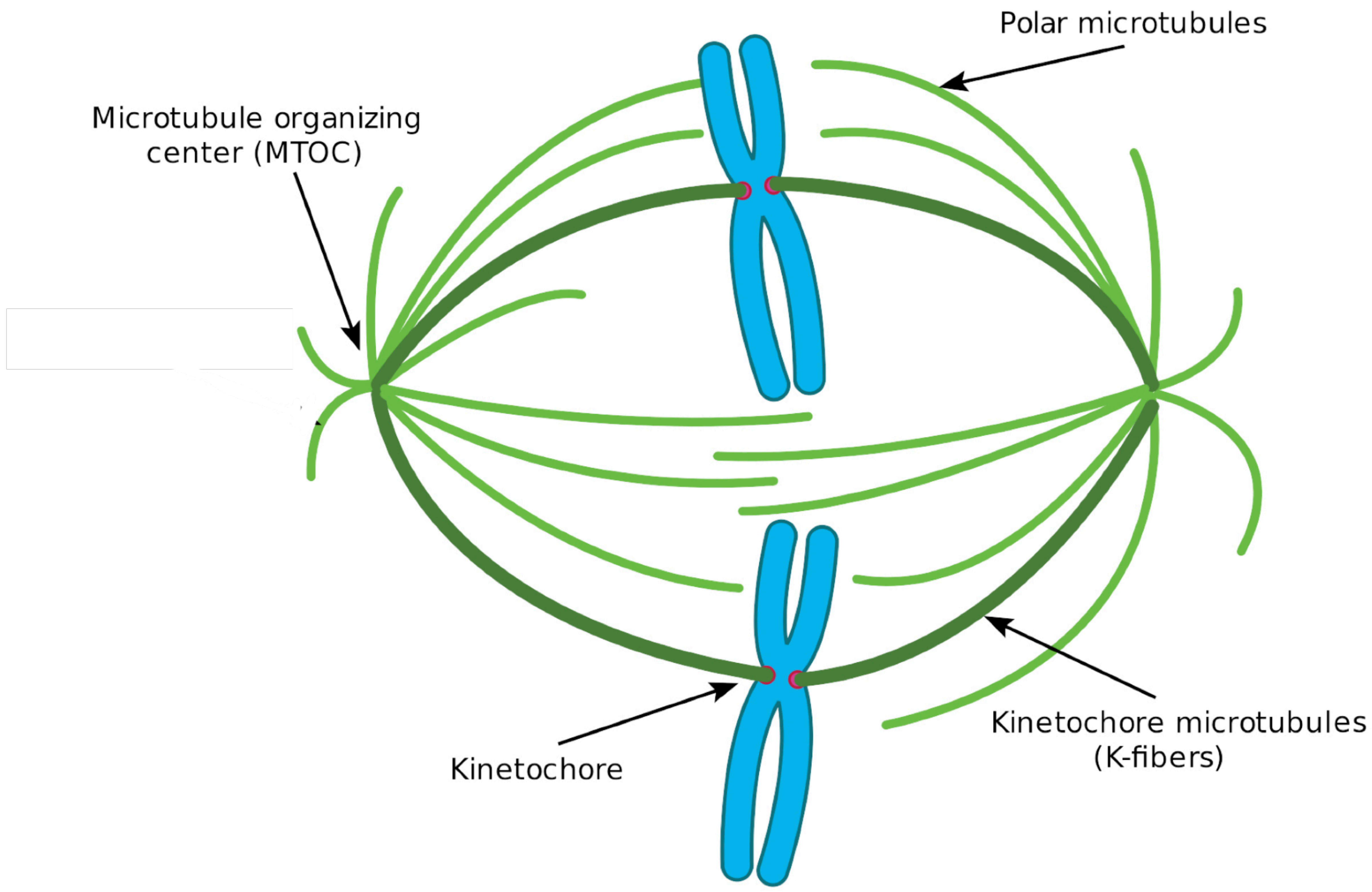
3 different kinds of microtubules


Microtubule organizing center (MTOC)

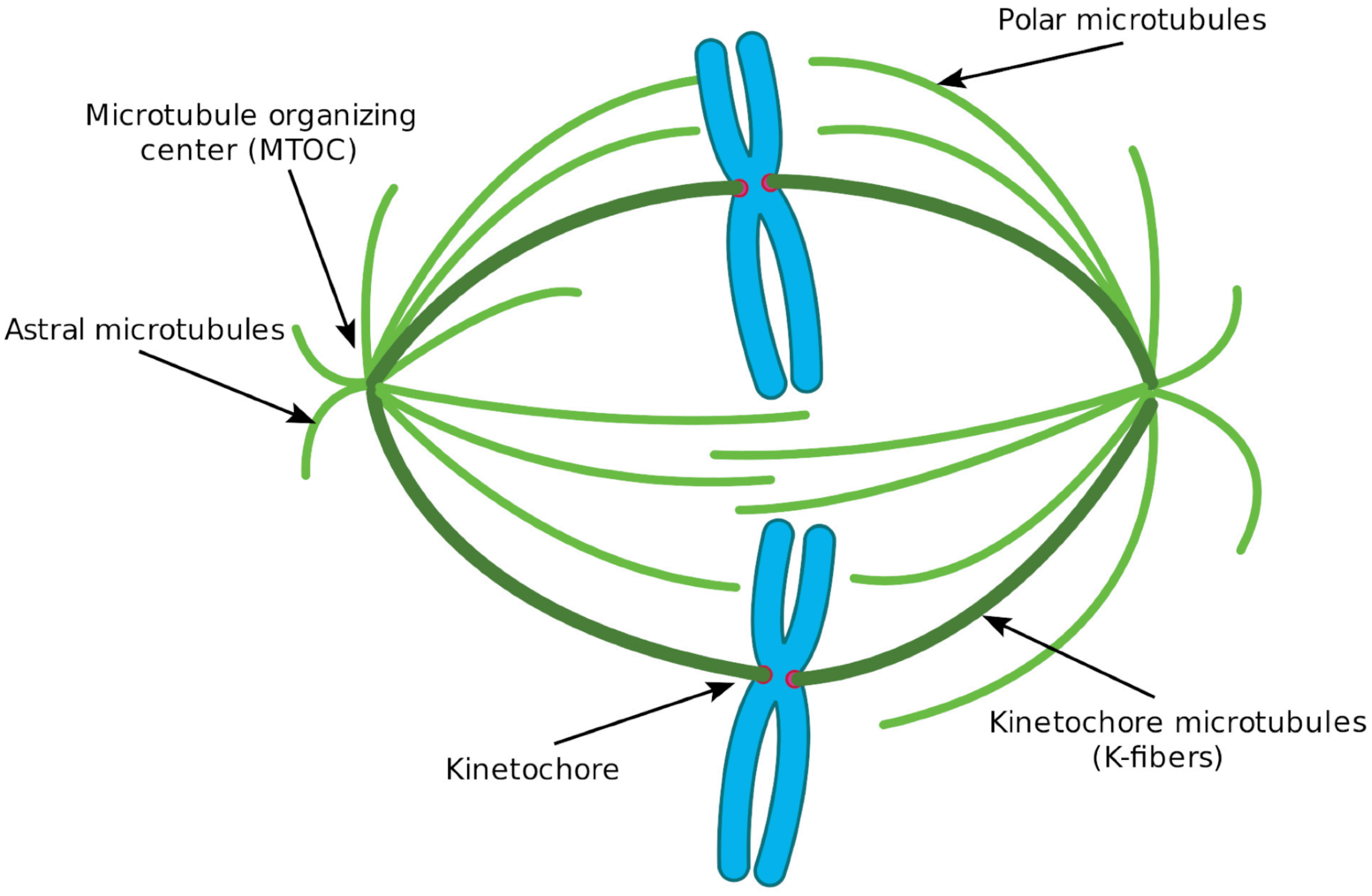


Microtubule organizing center (MTOC)
Kinetochore


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



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


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

Metaphase

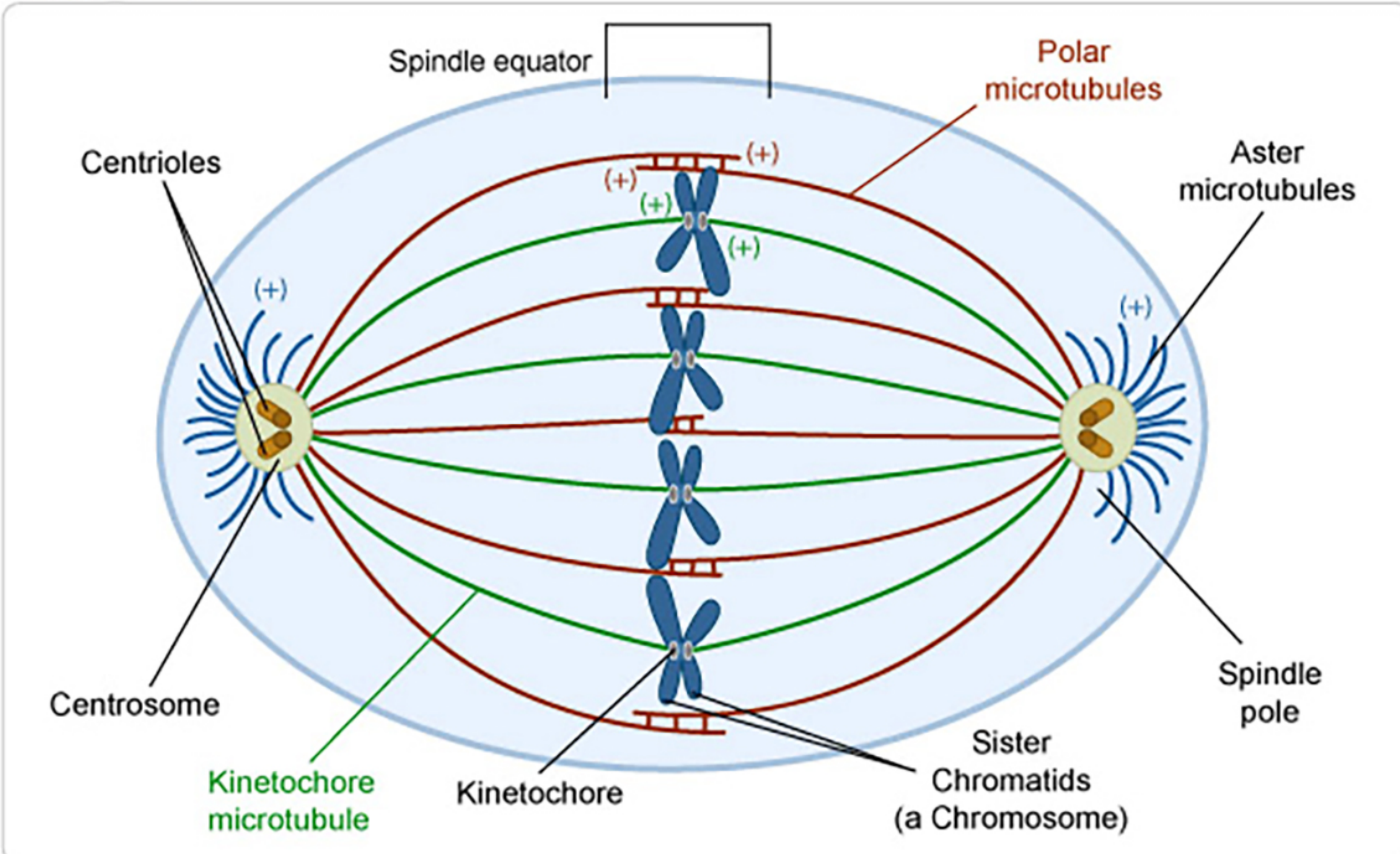


Figure 2. The mitotic spindle at metaphase. At metaphase, the chromosomes align at the spindle equator. Each sister chromatid of the chromosome is attached to kinetochore microtubules (shown in green). These microtubules emanate from the centrosomes at spindle poles and attach to the chromosomes at the kinetochores (one for each sister chromatid).

In addition to the kinetochore microtubules, there are two other distinct types of microtubules in the spindle: the polar microtubules (shown in red), which grow out from the centrosomes and have opposing microtubules overlapping at the spindle equator; and the aster microtubules (shown in blue), which grow out from the centrosomes toward the cortex of the cell. For all three types of microtubules, the minus ends are at the centrosomes and the plus ends (indicated as +) grow away from the centrosomes.

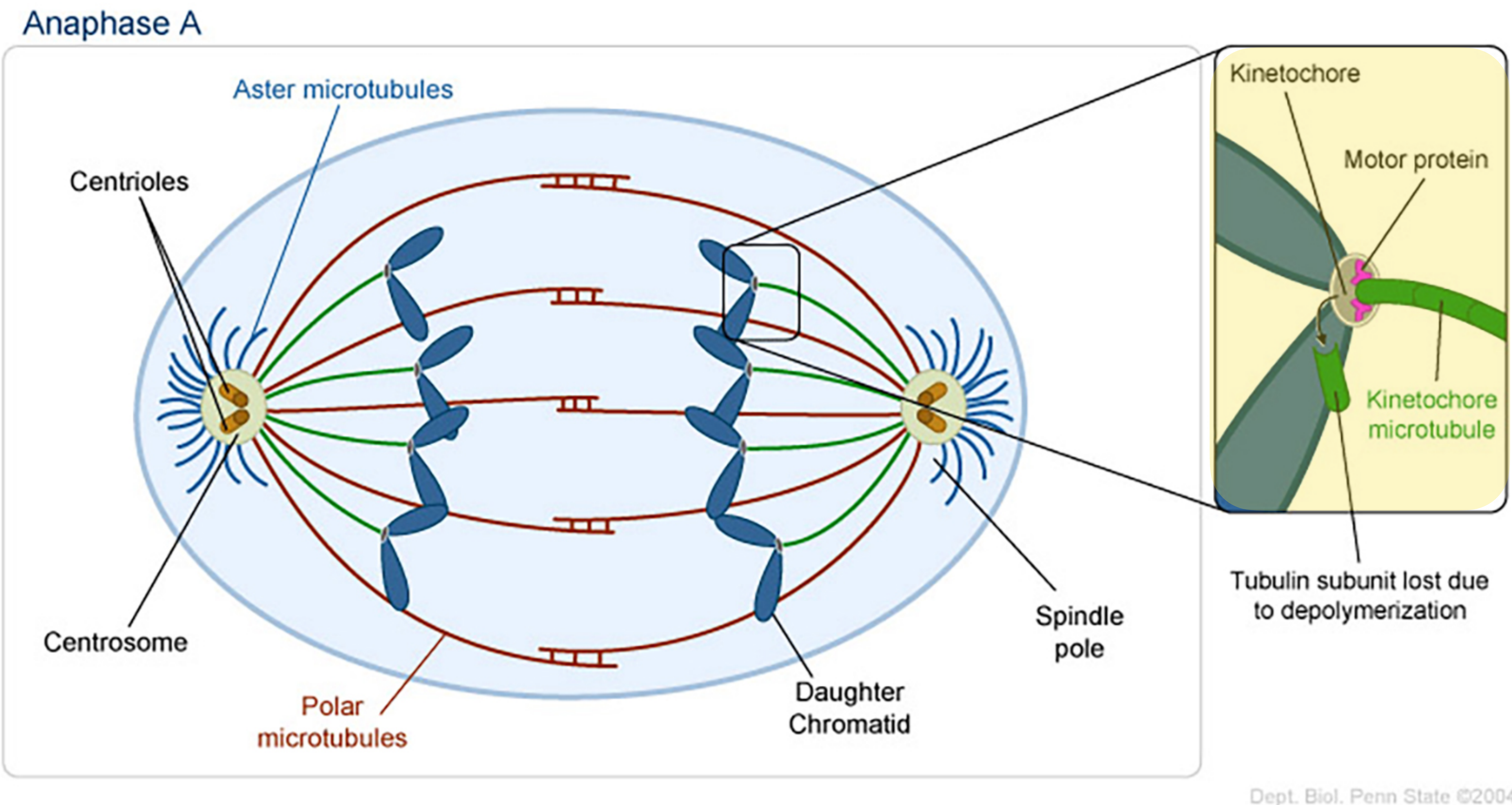


Figure 3. The mitotic spindle at anaphase A. During anaphase A, the pairs of sister chromatids are separated and move toward the spindle poles. This occurs through the action of the kinetochore microtubules (illustrated in the inset). These microtubules shorten at their plus ends, while the motor proteins attached to the kinetochores of the chromatids travel toward the minus ends; thereby, the sister chromatids remain attached to the shortening microtubules.

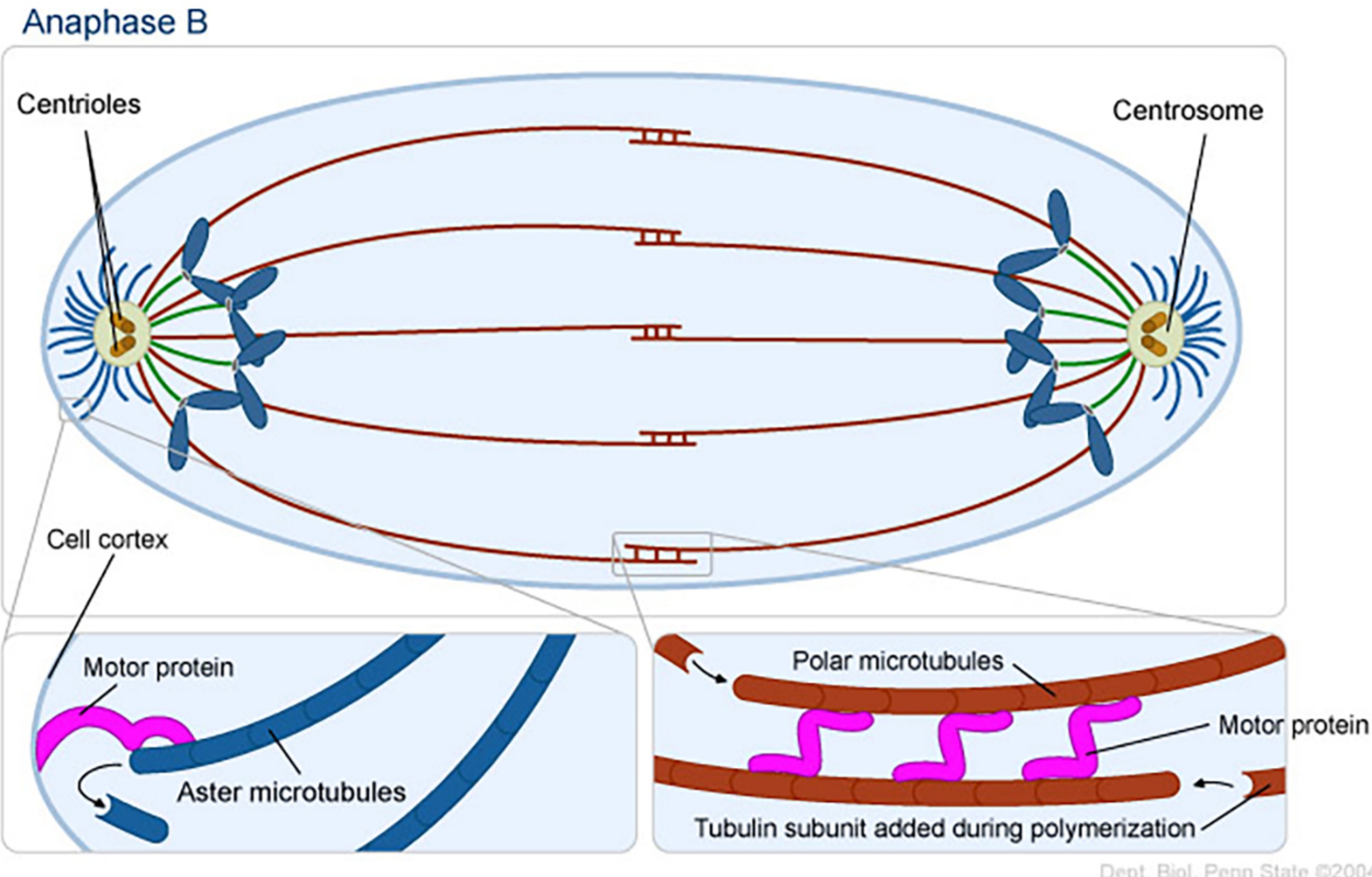
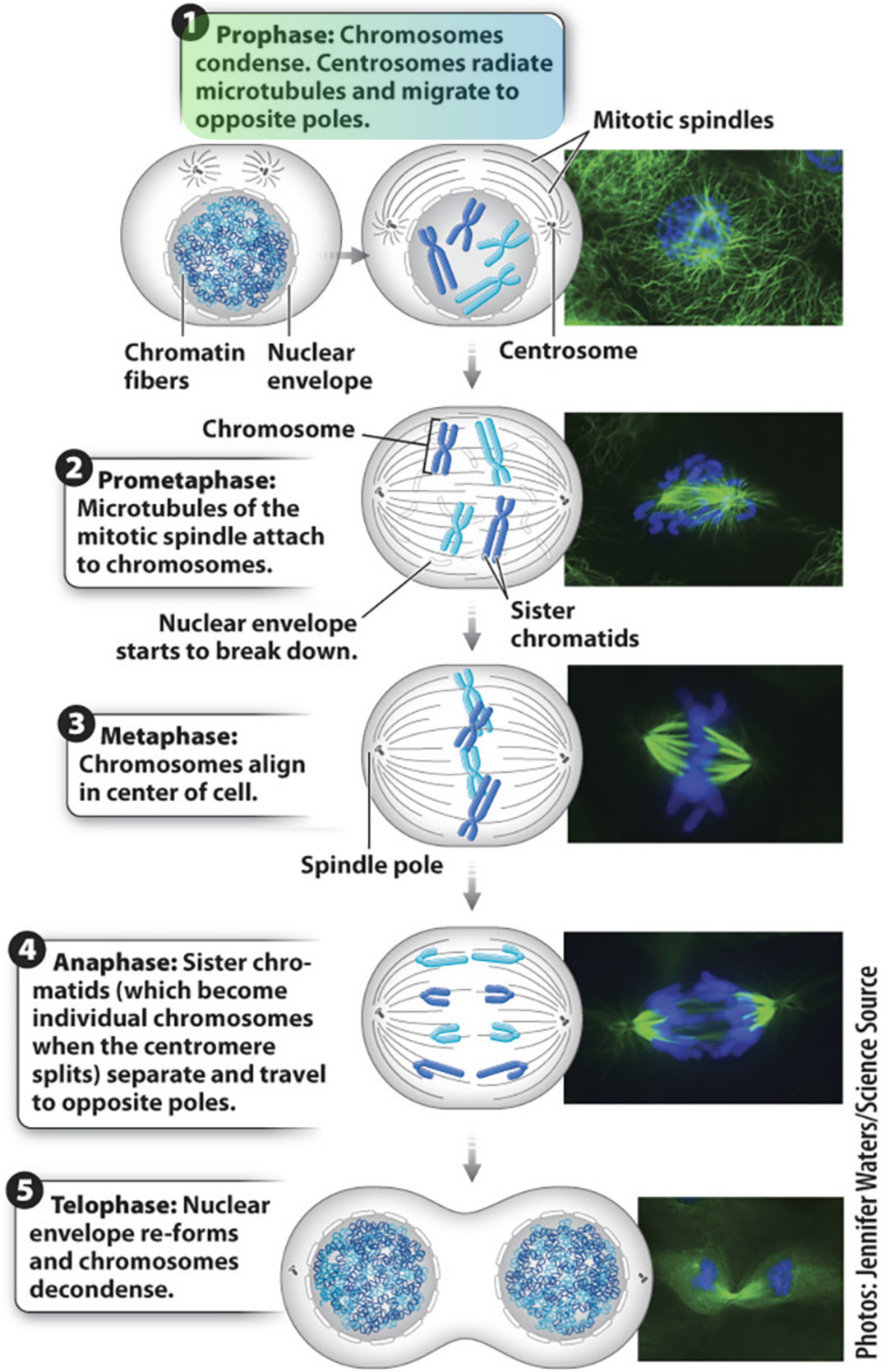
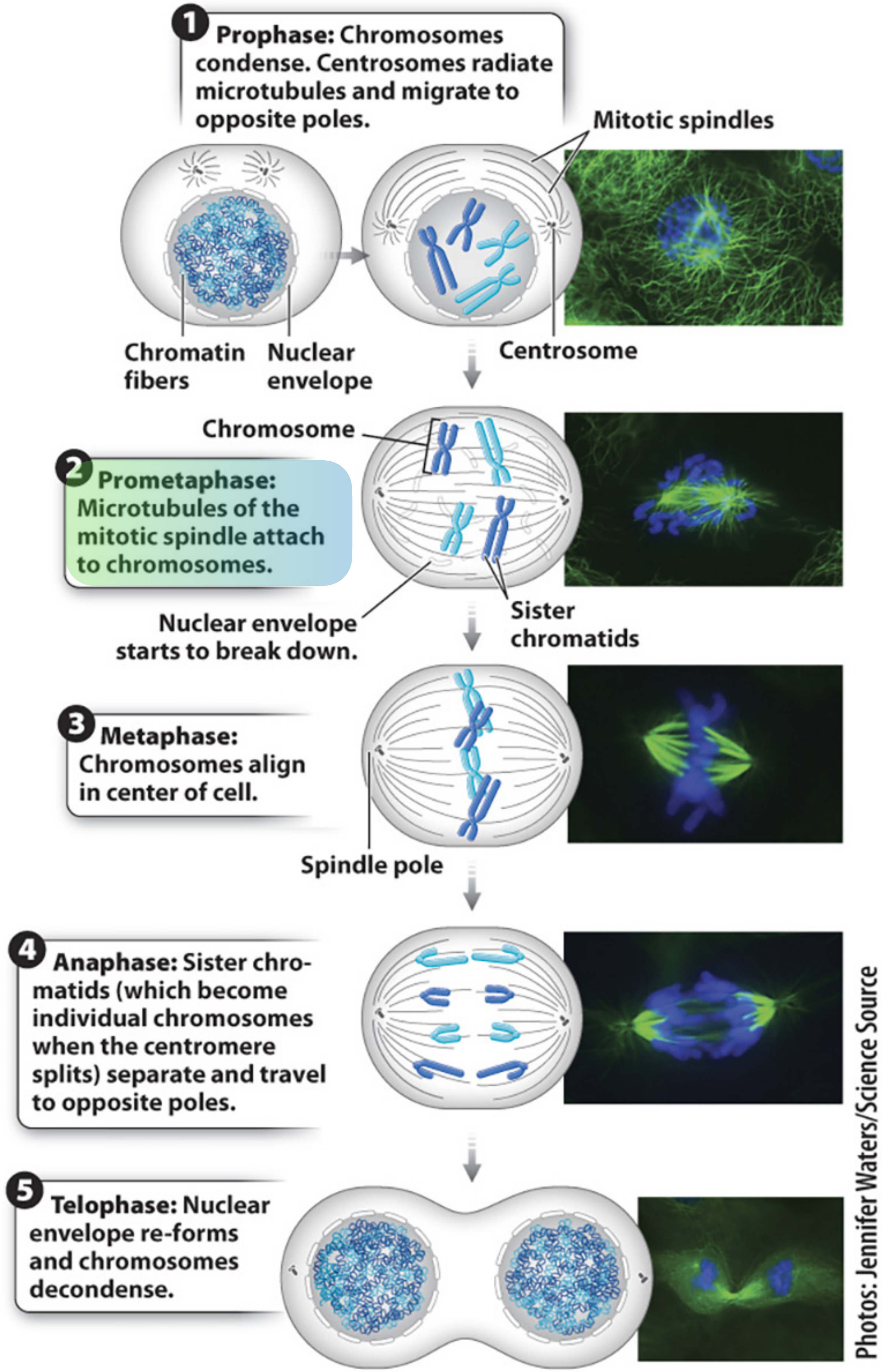


Figure 4. The mitotic spindle at anaphase B. During anaphase B, the spindle poles move further apart. This occurs through the combined action of the polar microtubules and the aster microtubules.

The action of the polar microtubules is shown in the inset on the right. Overlapping polar microtubules grow by polymerization at their plus ends, while the cross-linked motor proteins travel toward the plus ends, thereby pushing the overlapping polar microtubules past each other and the spindle poles further apart. The action of the aster microtubules is shown in the inset to the left. The aster microtubules depolymerize at their plus ends, while the motor proteins linked to the cell's cortex travel toward the minus ends, thereby pulling the attached spindle poles closer to the cortex and further apart from each other.


1 Prophase: Chromosomes condense. Centrosomes radiate microtubules and migrate to opposite poles.
Mitotic spindles
Chromatin fibers
Nuclear envelope
Centrosome
Chromosome
2 Prometaphase: Microtubules of the mitotic spindle attach to chromosomes.
Nuclear envelope starts to break down.
Sister chromatids
3 Metaphase: Chromosomes align in center of cell.
Spindle pole
4 Anaphase: Sister chromatids (which become individual chromosomes when the centromere splits) separate and travel to opposite poles.
5 Telophase: Nuclear envelope re-forms and chromosomes decondense.
Photos: Jennifer Waters/Science Source


1 Prophase: Chromosomes condense. Centrosomes radiate microtubules and migrate to opposite poles.
Mitotic spindles
Chromatin fibers
Nuclear envelope
Centrosome
Chromosome
2 Prometaphase: Microtubules of the mitotic spindle attach to chromosomes.
Nuclear envelope starts to break down.
Sister chromatids
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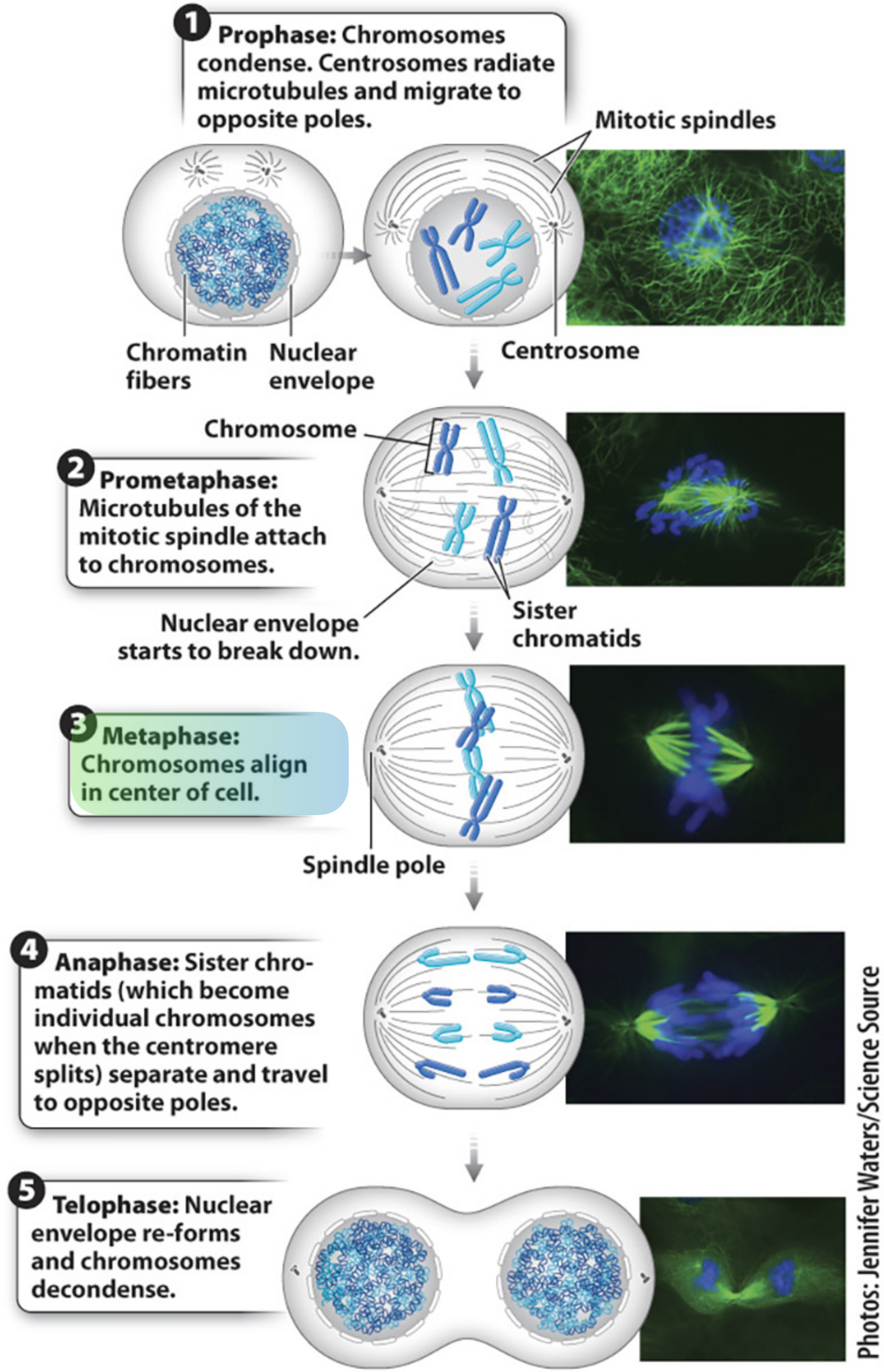
1 Prophase: Chromosomes condense. Centrosomes radiate microtubules and migrate to opposite poles.
Mitotic spindles
Chromatin fibers
Nuclear envelope
Centrosome
Chromosome
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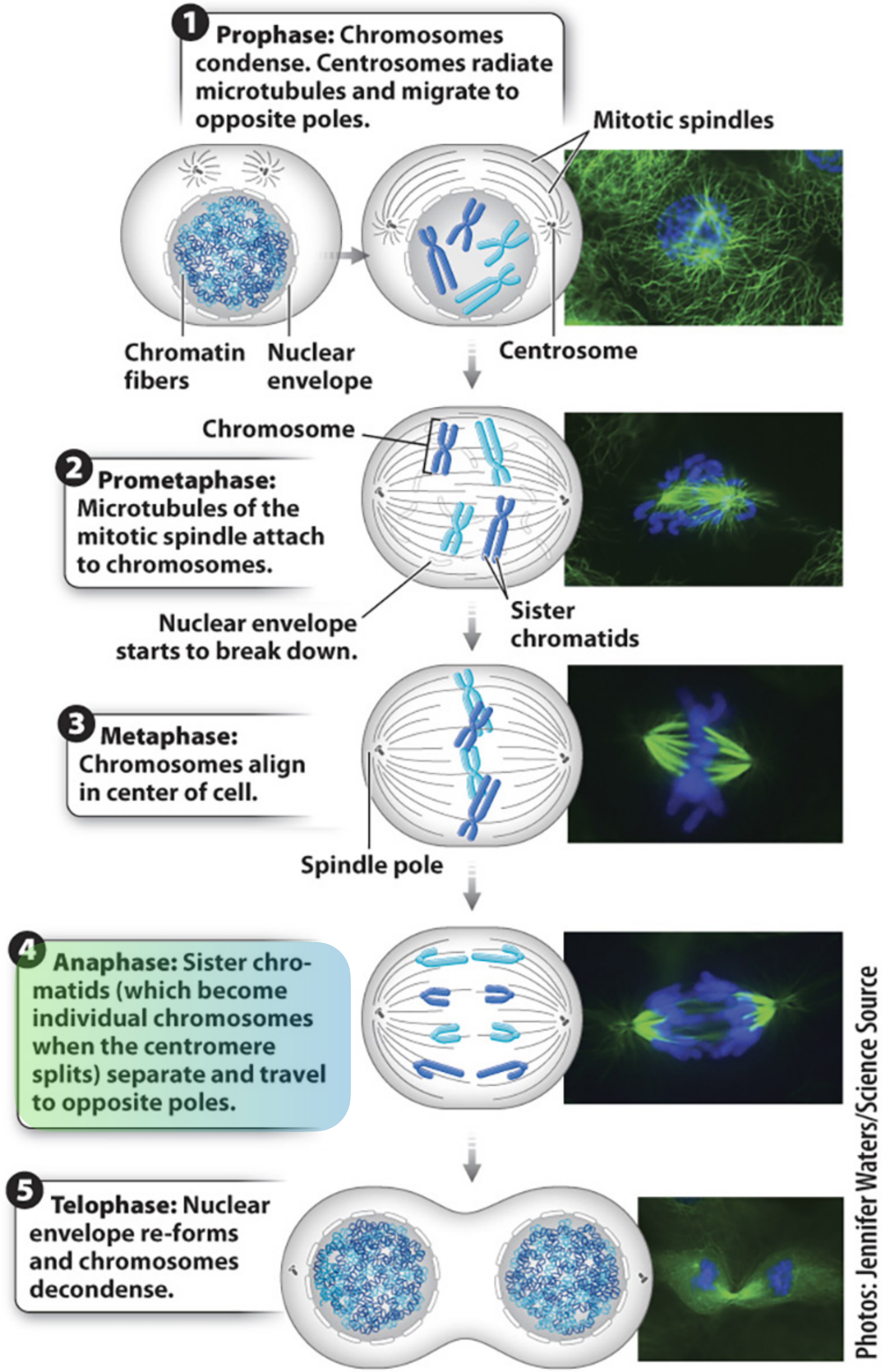
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Mitotic spindles
Chromatin fibers
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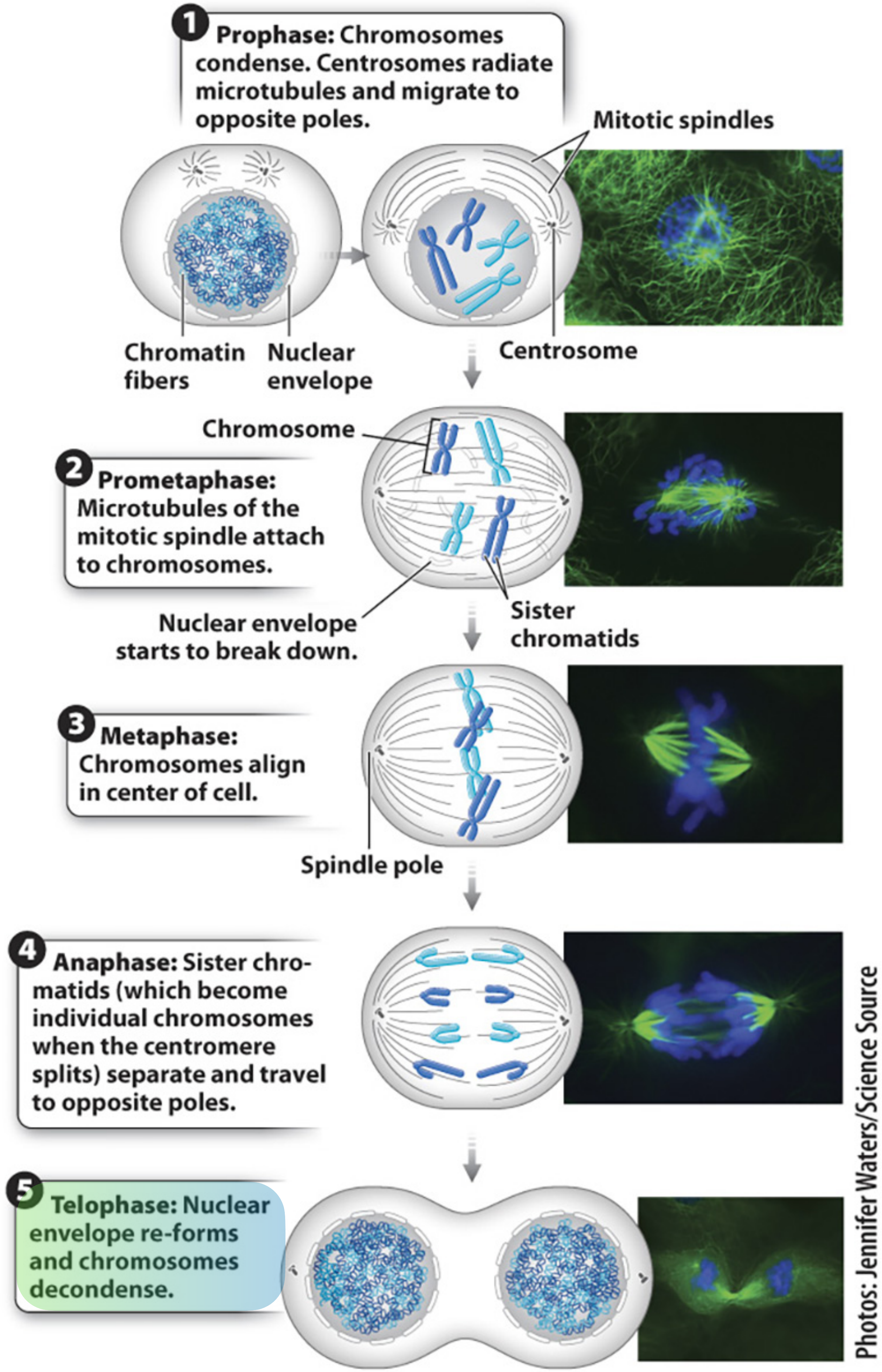

1 Prophase: Chromosomes condense. Centrosomes radiate microtubules and migrate to opposite poles.
Mitotic spindles
Chromatin fibers
Nuclear envelope
Centrosome
Chromosome
2 Prometaphase: Microtubules of the mitotic spindle attach to chromosomes.
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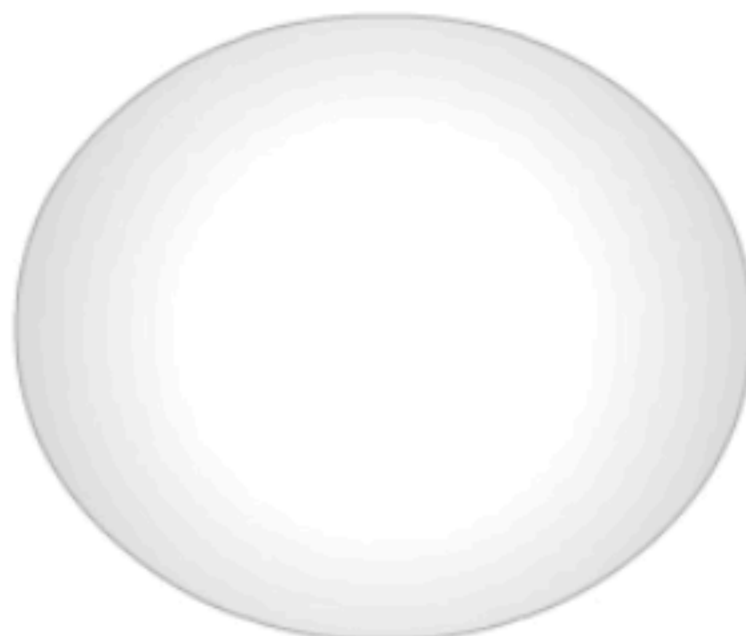
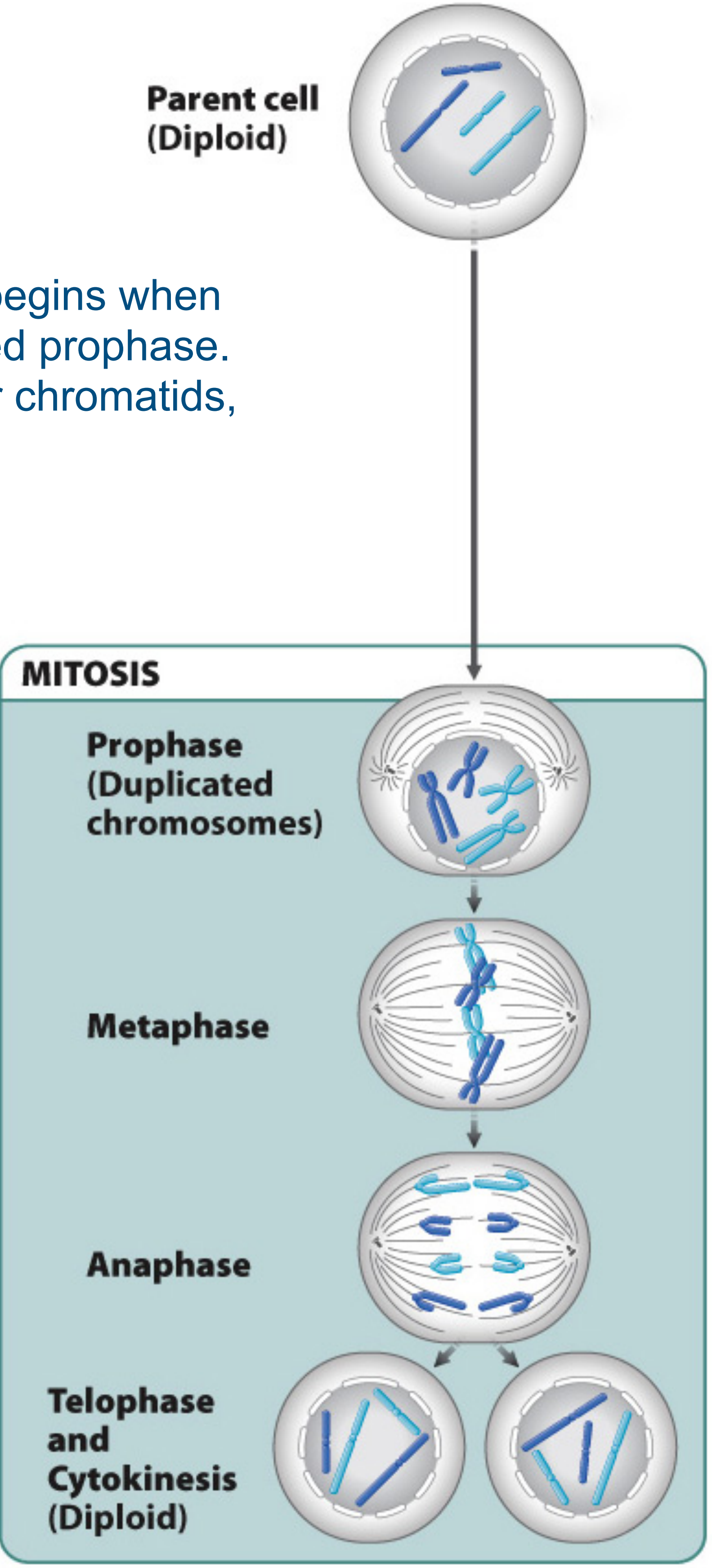
3 Metaphase: Chromosomes align in center of cell.
Spindle pole
4 Anaphase: Sister chromatids (which become individual chromosomes when the centromere splits) separate and travel to opposite poles.
5 Telophase: Nuclear envelope re-forms and chromosomes decondense.
Photos: Jennifer Waters/Science Source

Mitotic Cell Division

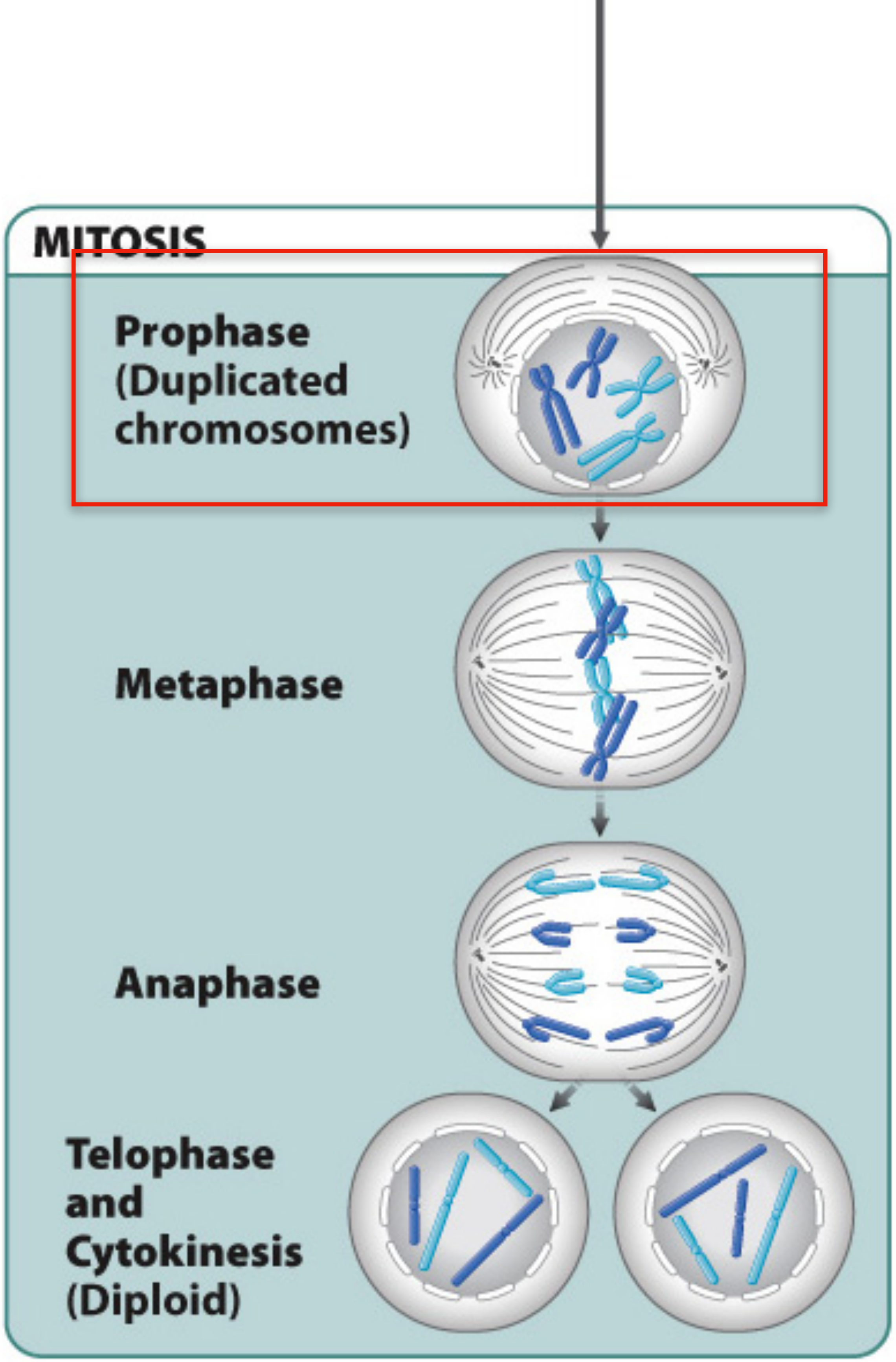


In mitotic cell division, a single parent cell divides into two daughter cells.

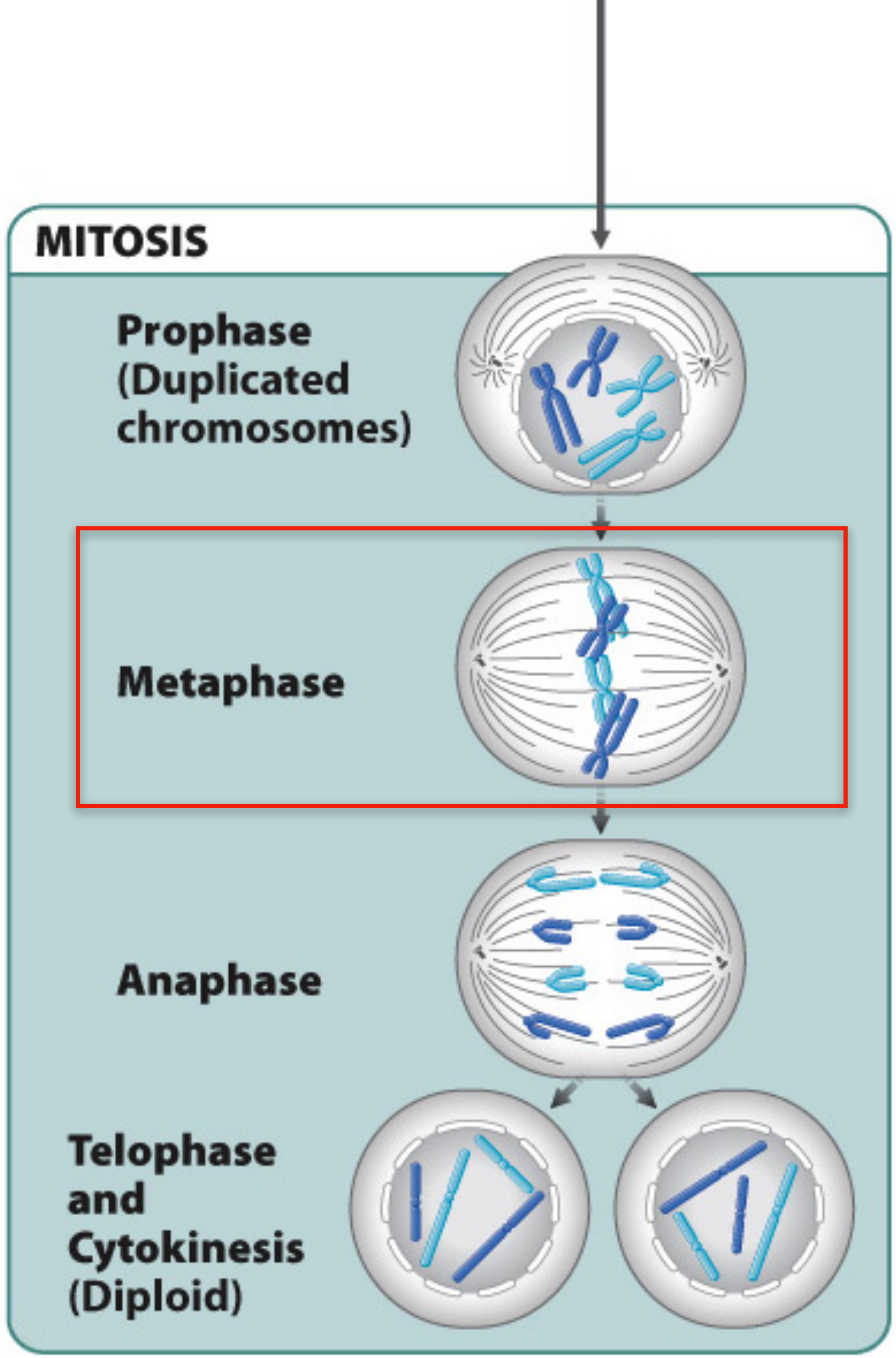
After a cell's DNA is replicated, mitosis begins when chromosomes condense in a stage called prophase. Each chromosome consists of two sister chromatids, held together at the centromere.



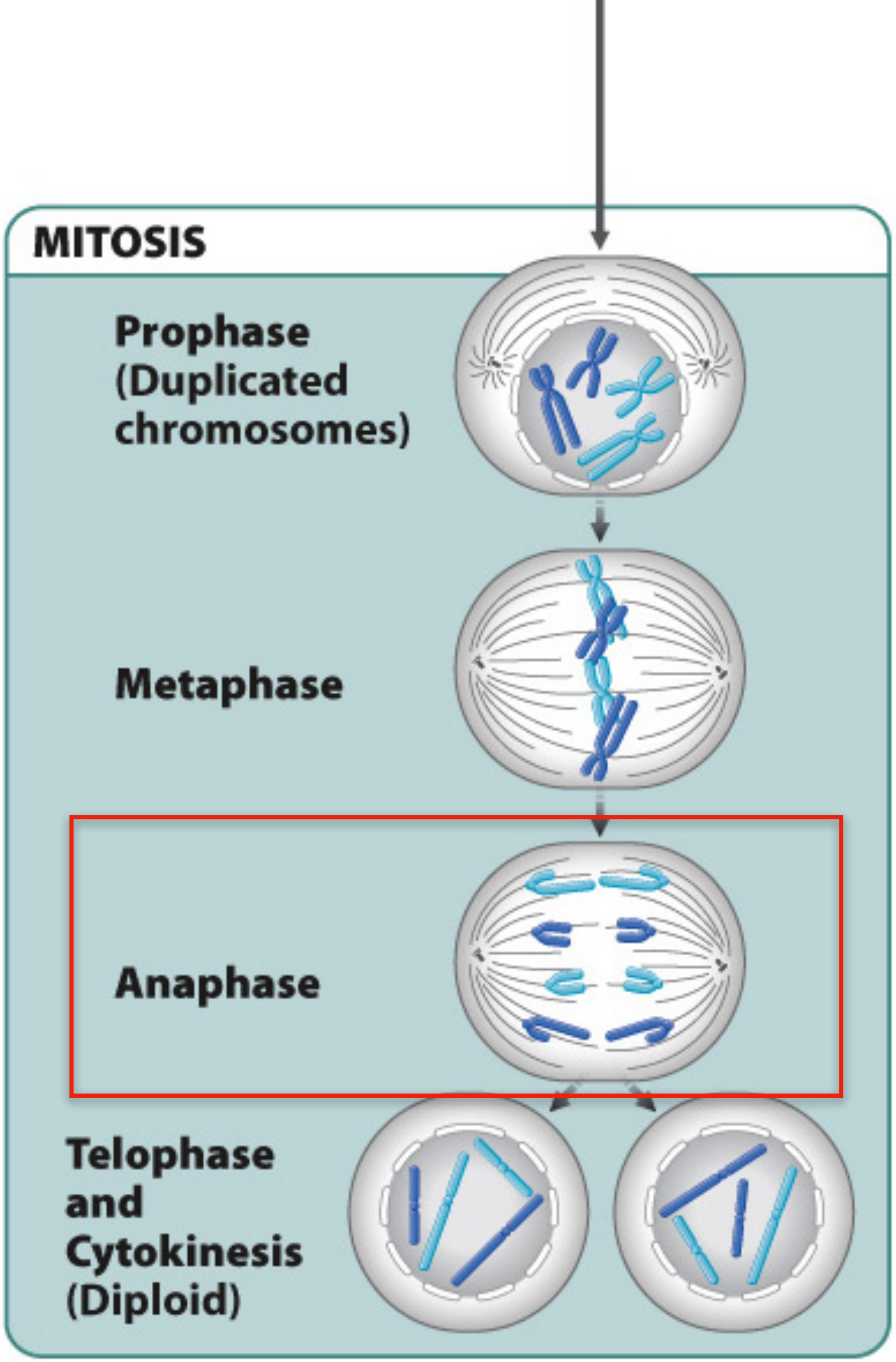
At the same time, **centrosomes** migrate to opposite poles of the cell and the mitotic spindle begins to form.

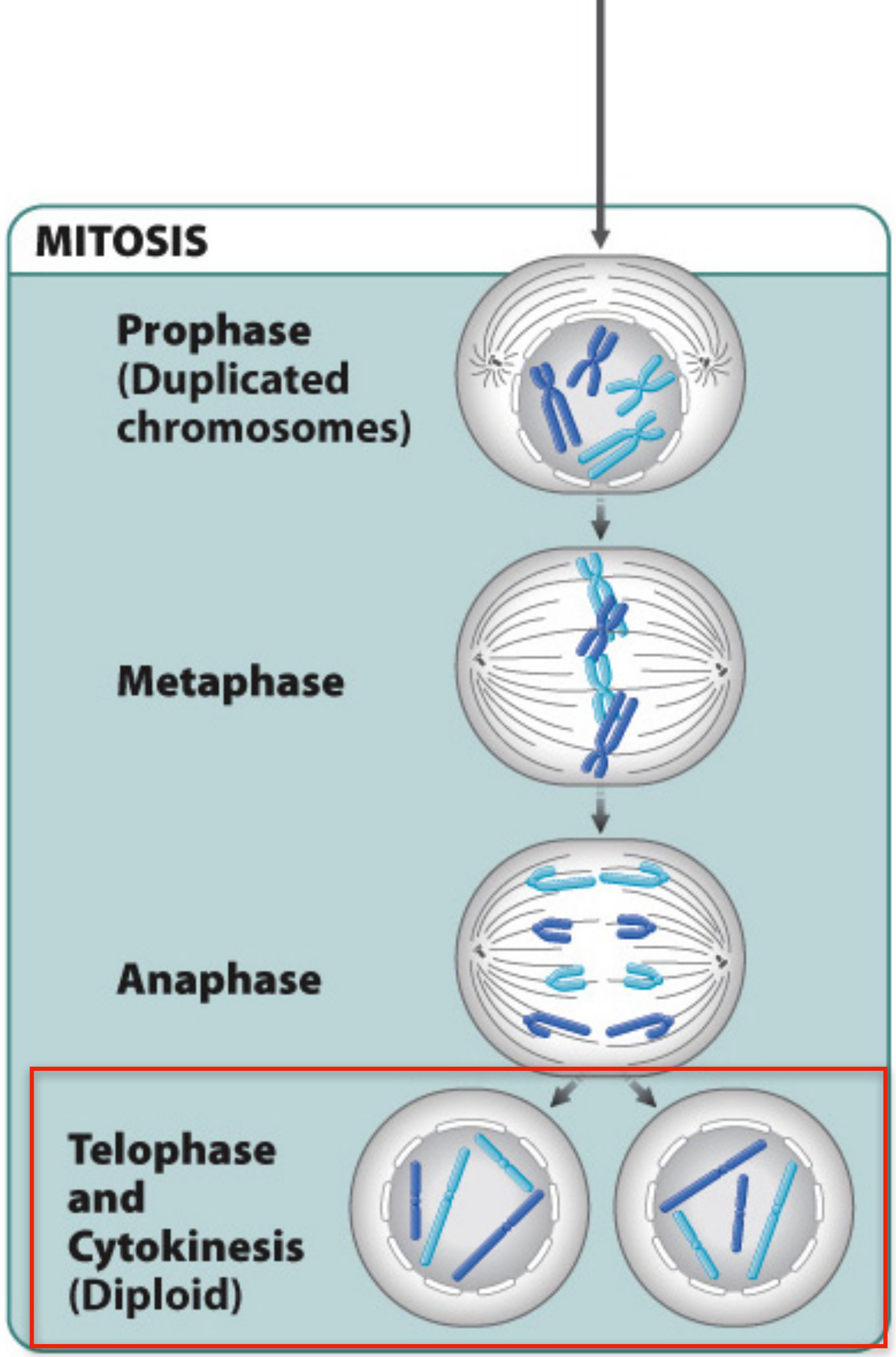


The microtubules of the mitotic spindle attach to the chromosomes in prometaphase, and align them in the center of the cell during metaphase.



The centromeres holding the sister chromatids together then split, and the chromatids, each now considered to be a full fledged chromosome, travel to opposite poles of the cell during anaphase.

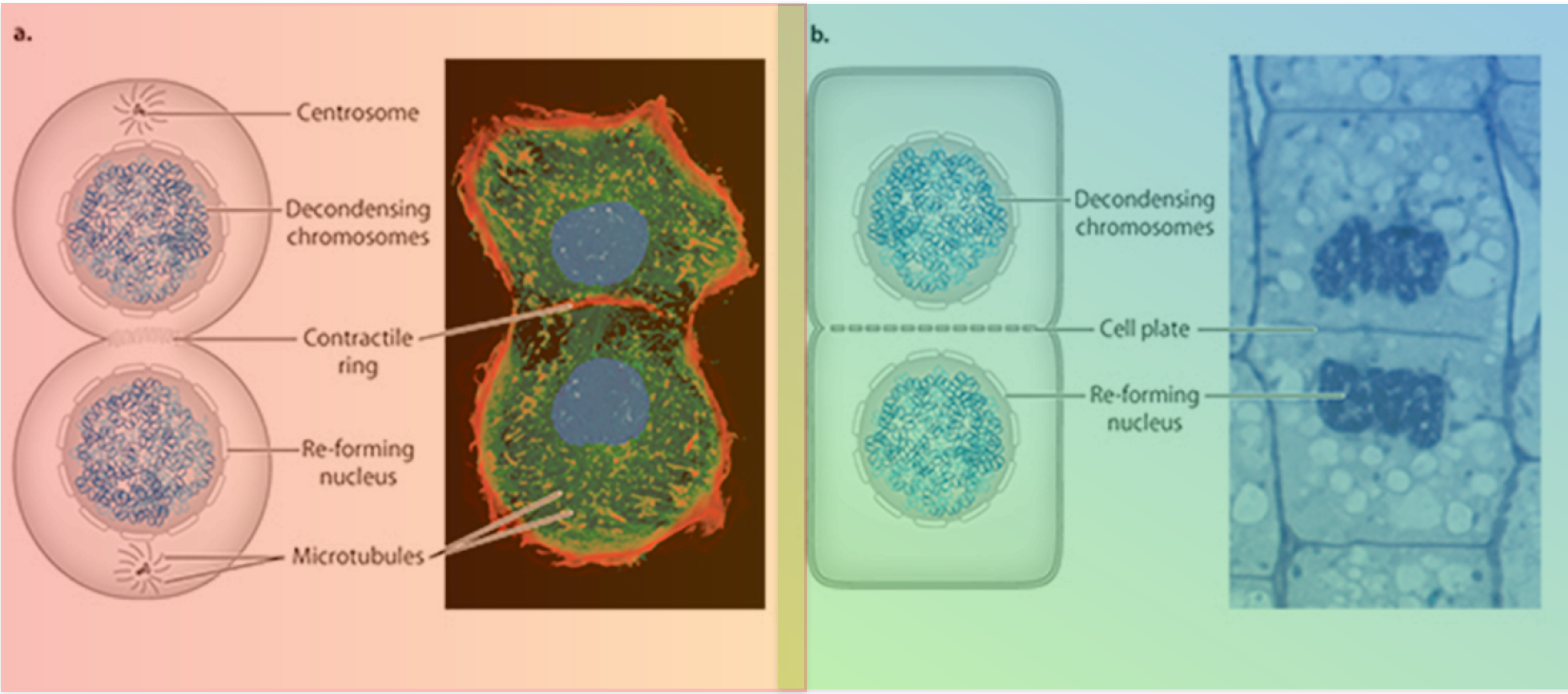




Finally, the chromosomes decondense, and a new **nuclear envelope** forms around each set of chromosomes during telophase.

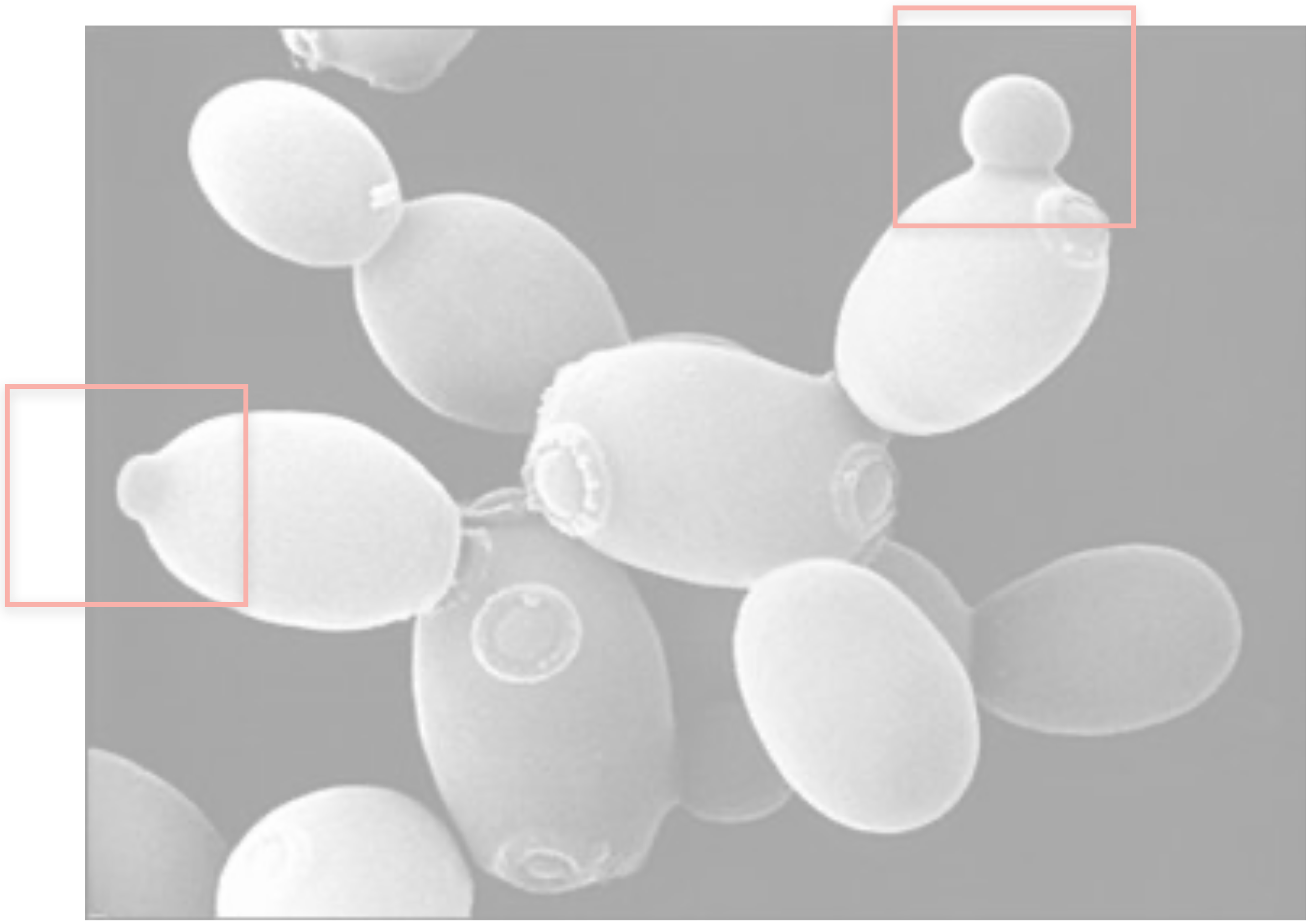
In animal cells, a contractile ring forms and completes the process of **mitotic cell division**, physically separating the **two daughter cells.**

The daughter cells are **genetically IDENTICAL** to each other and the parent cell, except for occasional mutations that might occur.


a.
Centrosome
Decondensing chromosomes
Contractile ring
Re-forming nucleus
Microtubules
b.
Decondensing chromosomes
Cell plate
Re-forming nucleus

Mitosis: **The Distribution of EXACT COPIES of Genetic Information, whereby a single cell, gives rise to two genetically "identical" cells: but more specifically, a single nucleus gives rise to two genetically "identical" nuclei, one for each of the two new daughter cells.**

Asexual reproduction involves the generation of a new individuals that are effectively genetically "identical" to the parent. It involves a cell or cells that were generated by **mitosis**.



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 9.11 Asexual Reproduction

- Variation of cells is principally due, therefore to the "forces of evolution" that we have discussed previously...
- **NS**, **GD**, **GF** and **Muts**,-as well as other potential **environmental effects**.

Natural Selection: ”the gradual process by which heritable biological traits become either more or less common in a population as a function of the effect of inherited traits on the differential reproductive success of organisms interacting with their environment”

Genetic drift: a random change in allelic frequency over time and appreciate this as being a key mechanism of evolutionary change.

Gene flow: is the movement of genes **into** or **out of** a population. Such movement is due to migration of individual organisms that reproduce in their new populations. This intermingling of individuals from different populations could bring or take alleles that would otherwise be absent or rare (may be even lost) from one population to another population. In other words, gene flow **adds** or **detracts** variety to a given population’s gene pool.

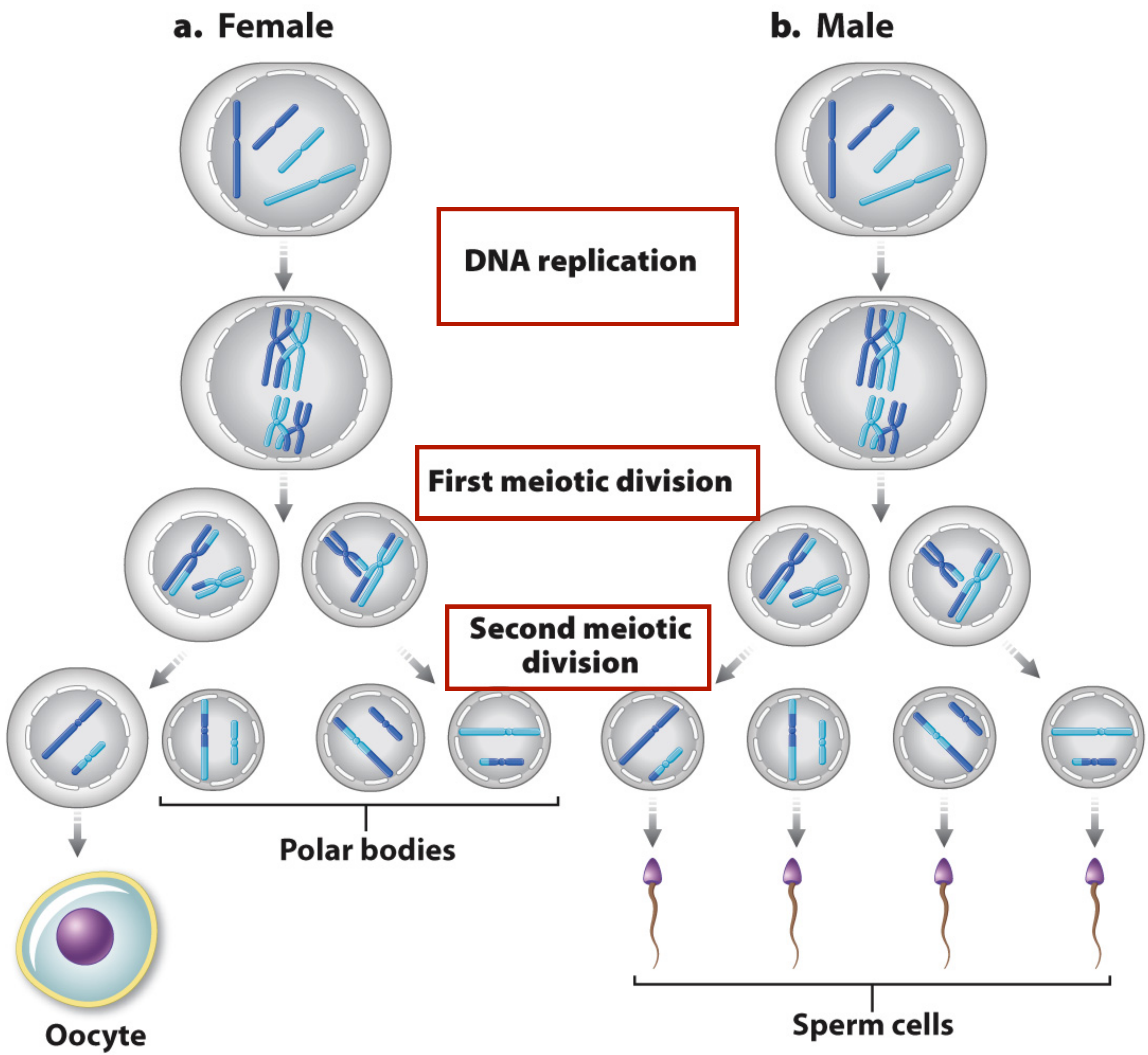
Mutations: localized changes in the DNA blueprint that may or may not change the phenotypic characteristics, ultimately providing small changes in genes /alleles -see Genetic Drift

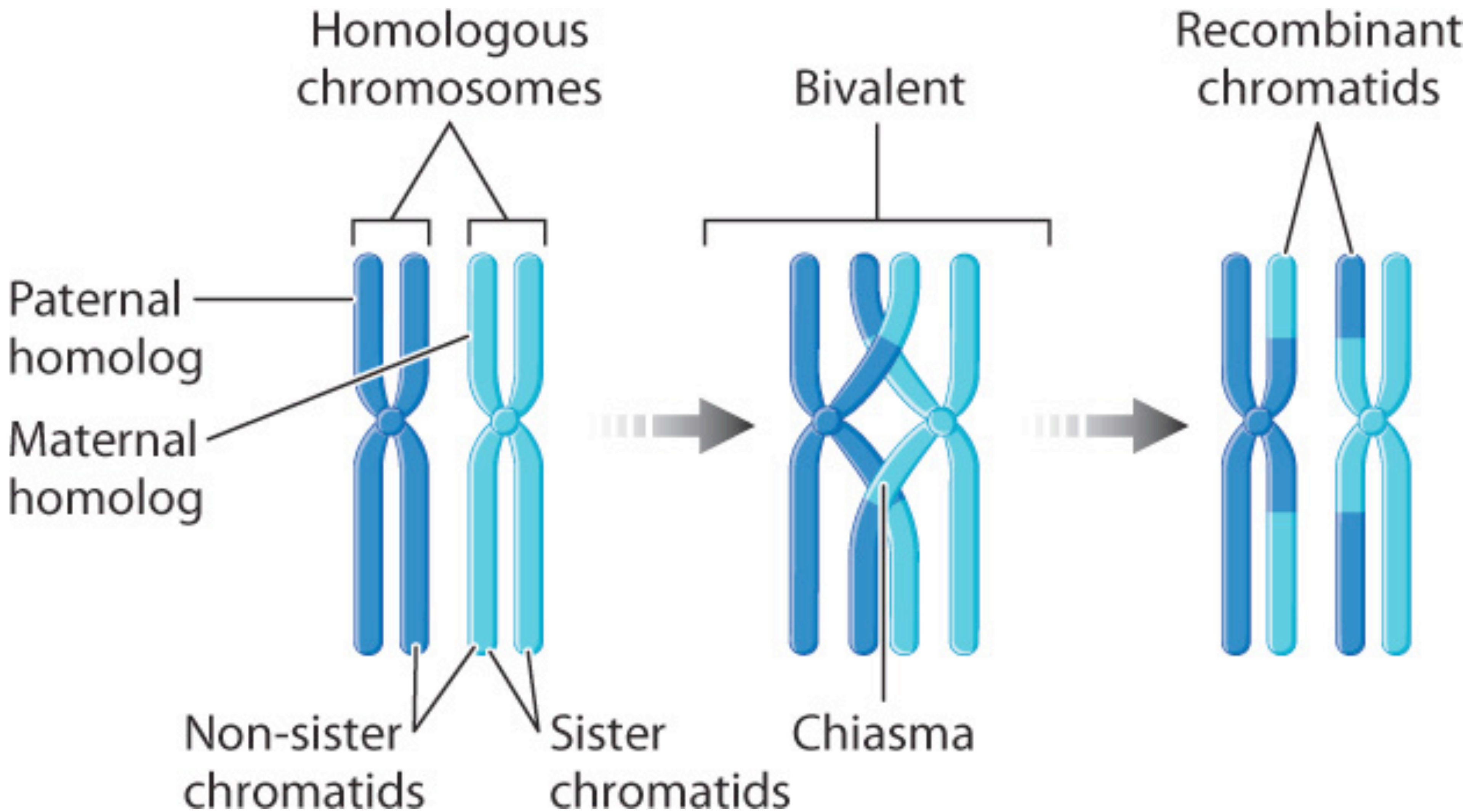
Sexual reproduction, on the other hand, involves the process of…

Meiosis and provides for increase "inherent variation”.

- Two parental sets of chromosomes, each contribute to the formation of one cell that is genetically **different** from either of the two original parents.

Meiosis is designed to create variety among the offspring beyond that which can be attributed to simple mutations or the environment.


a. Female
b. Male
DNA replication
First meiotic division
Second meiotic division
Polar bodies
Oocyte
Sperm cells


Homologous chromosomes
Bivalent
Recombinant chromatids
Paternal homolog
Maternal homolog
Non-sister chromatids
Sister chromatids
Chiasma