

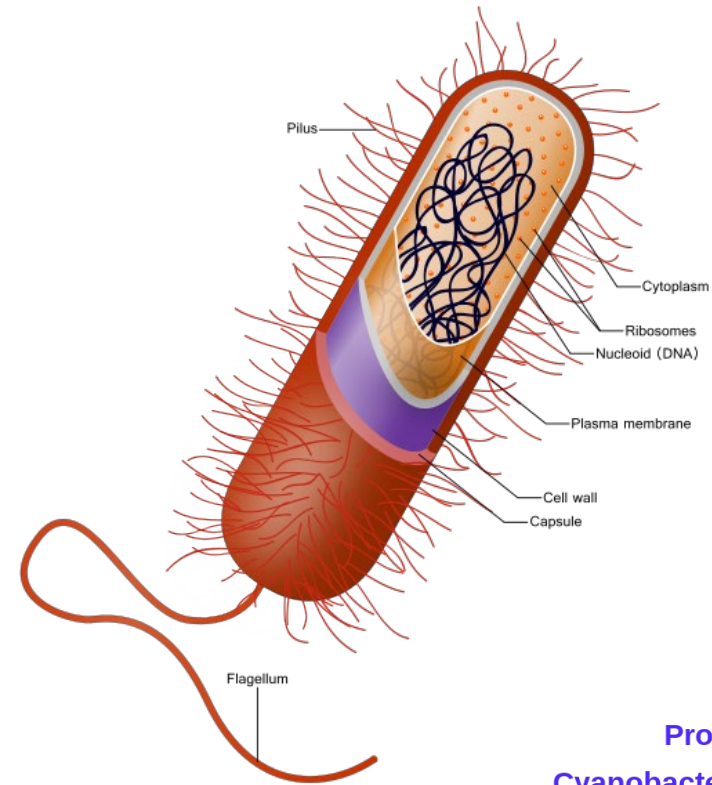
Lecture 2 – Cell Biology



Prof. Sebastian Maerkl

Cell Structure and Function

The tree of life

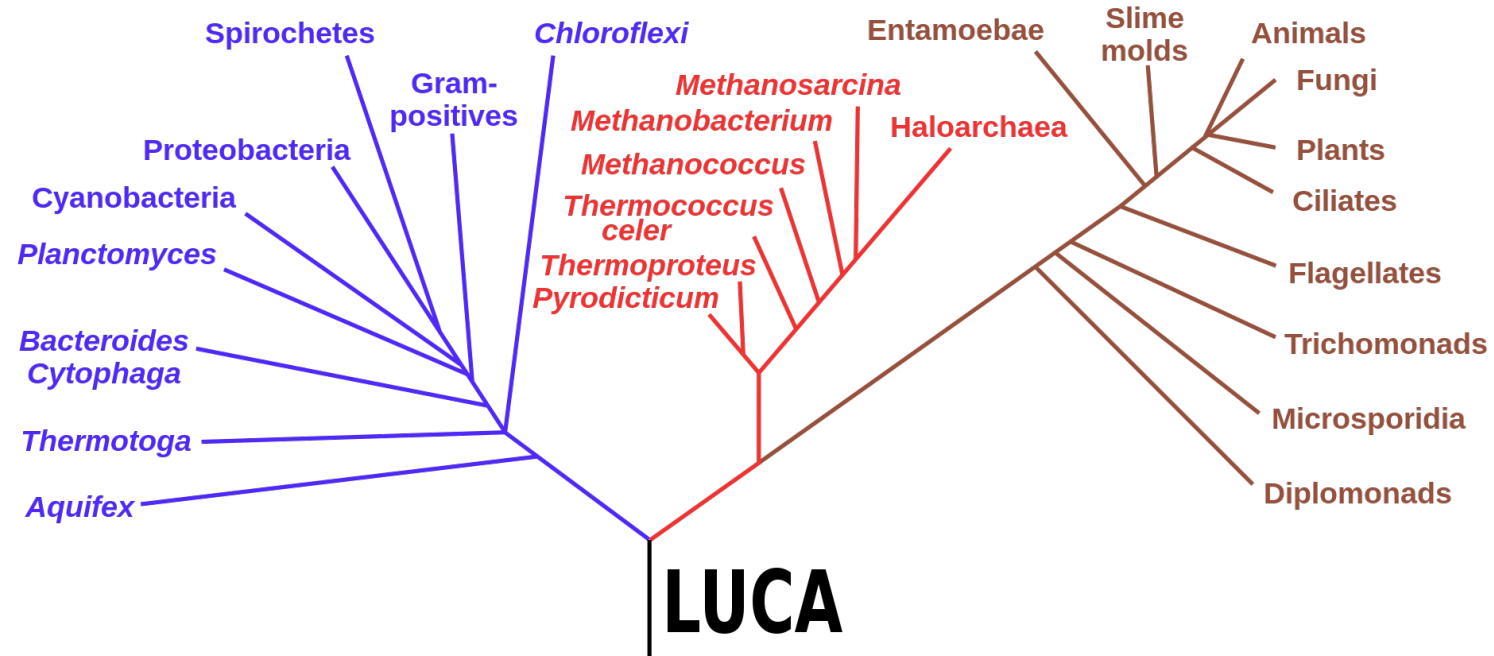
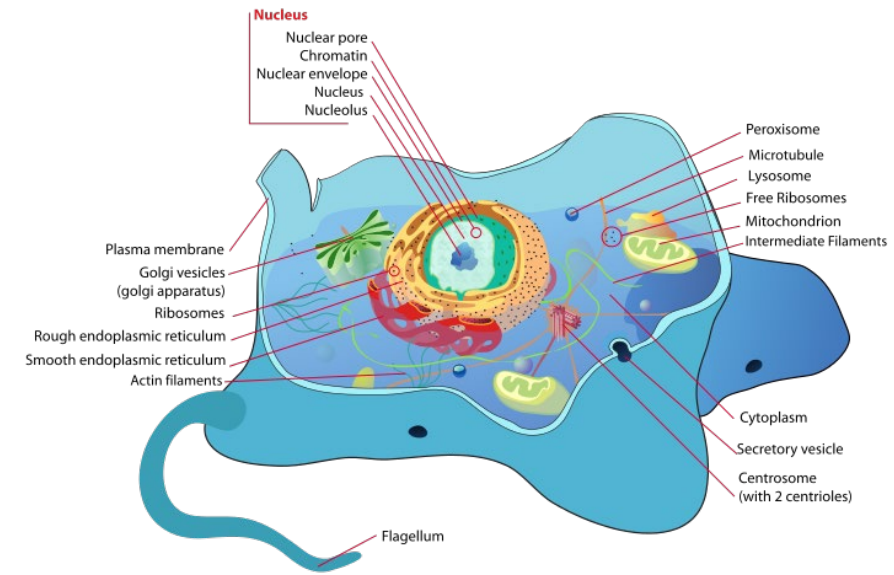


Prokaryotes (lacking a nucleus)

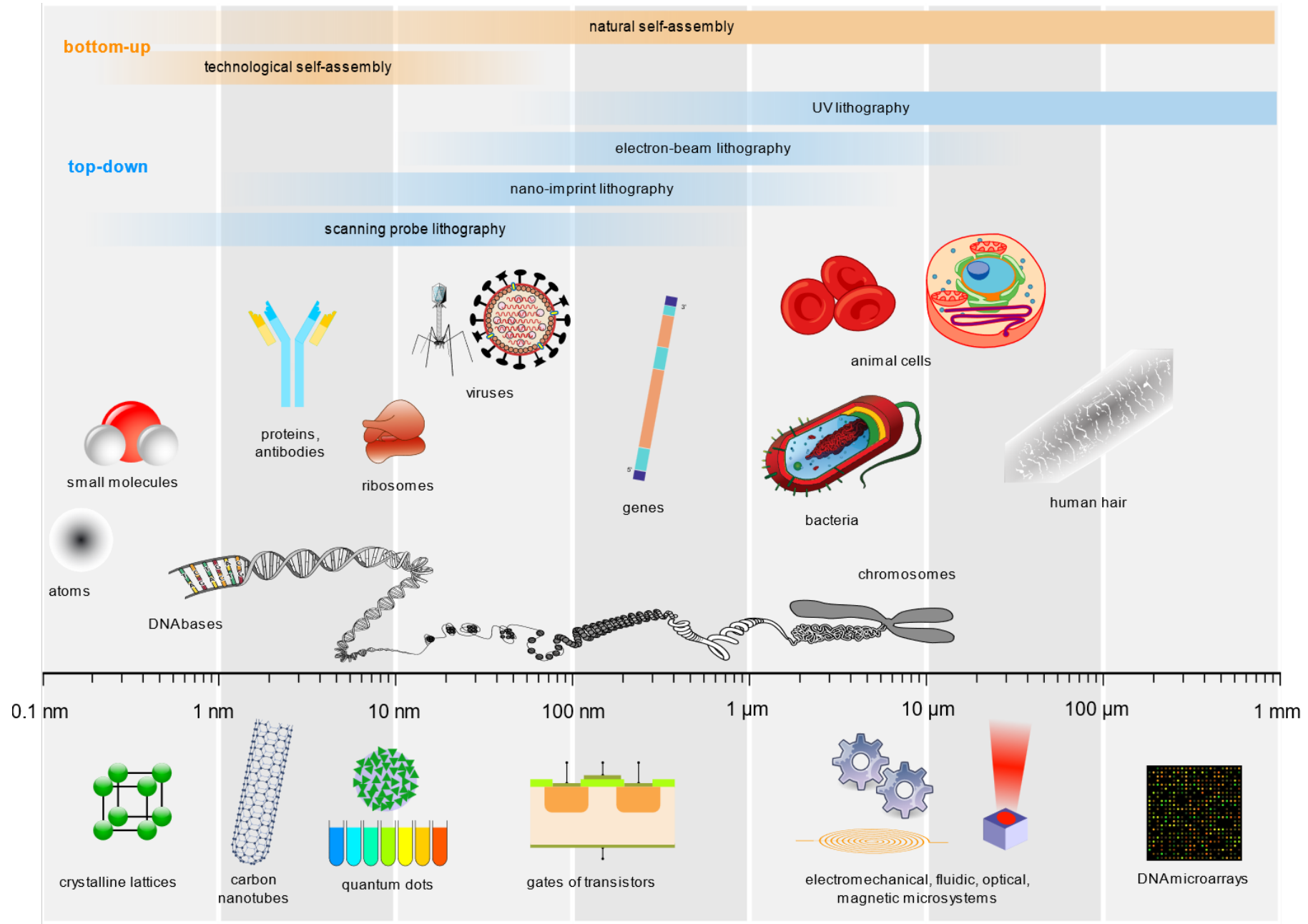
Bacteria

Archaea

Eukaryota

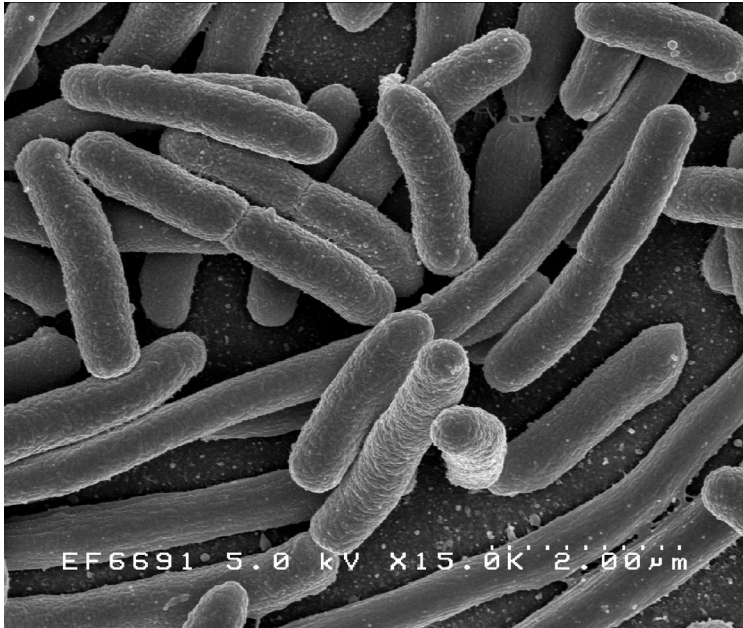


Biological Length Scales



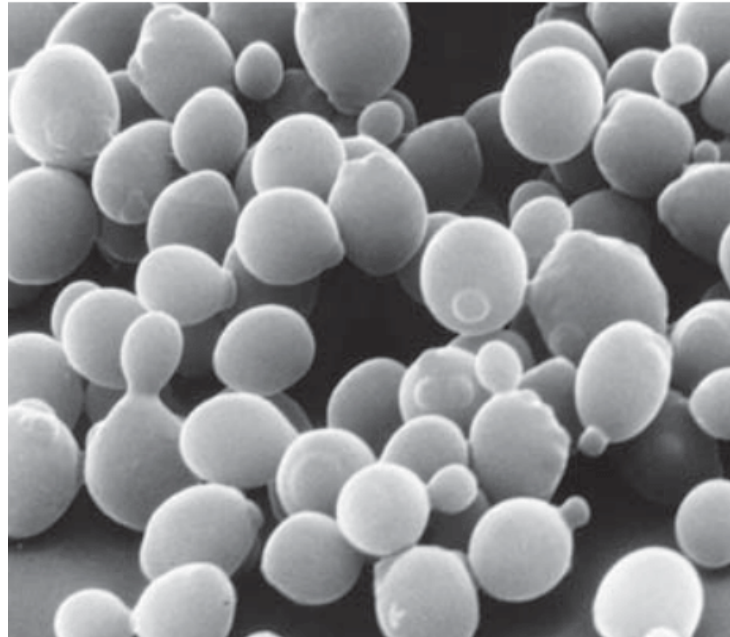
Biological Length Scales

E. coli



Size: $2 \times 1 \mu\text{m}$
Volume: 1 fL
Weight: 1 pg

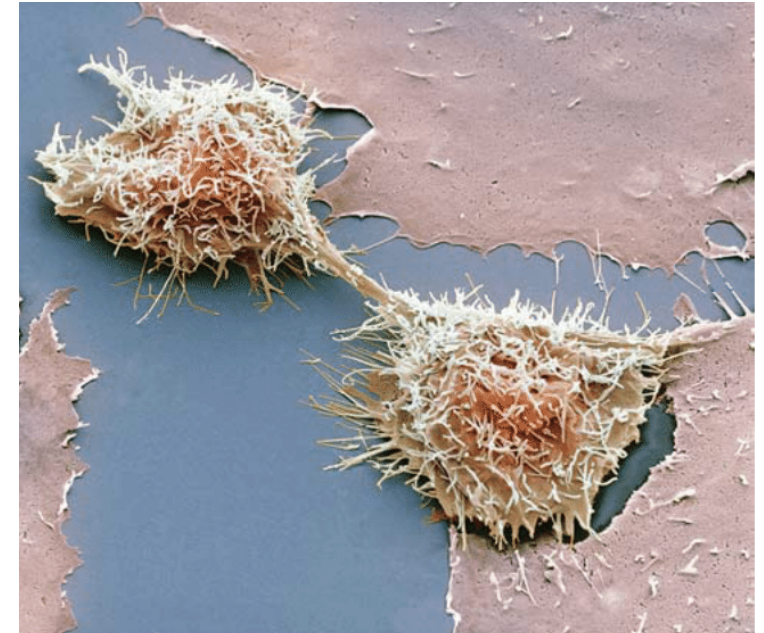
S. cerevisiae (yeast)



10 μm

Size: 4-6 μm (diameter)
Volume: 30 - 60 fL
Weight: 30 - 60 pg

HeLa cell



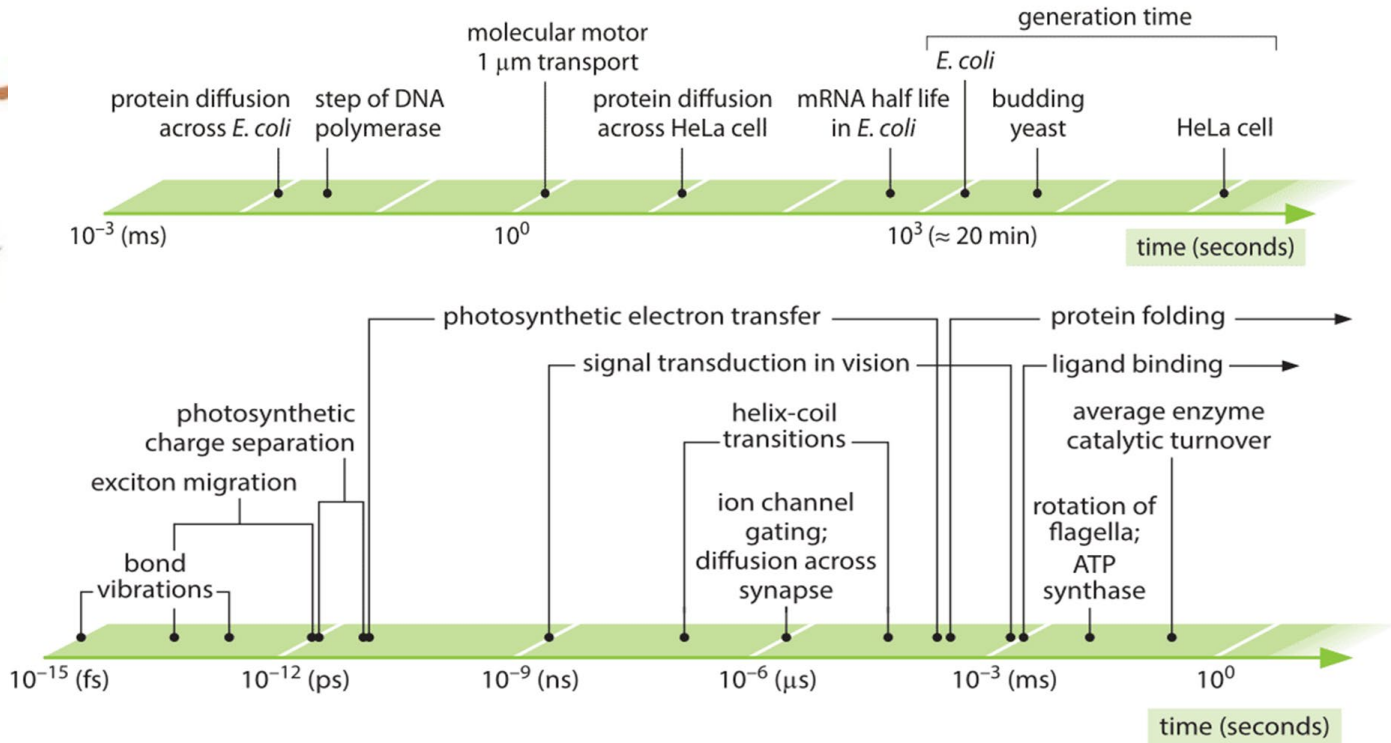
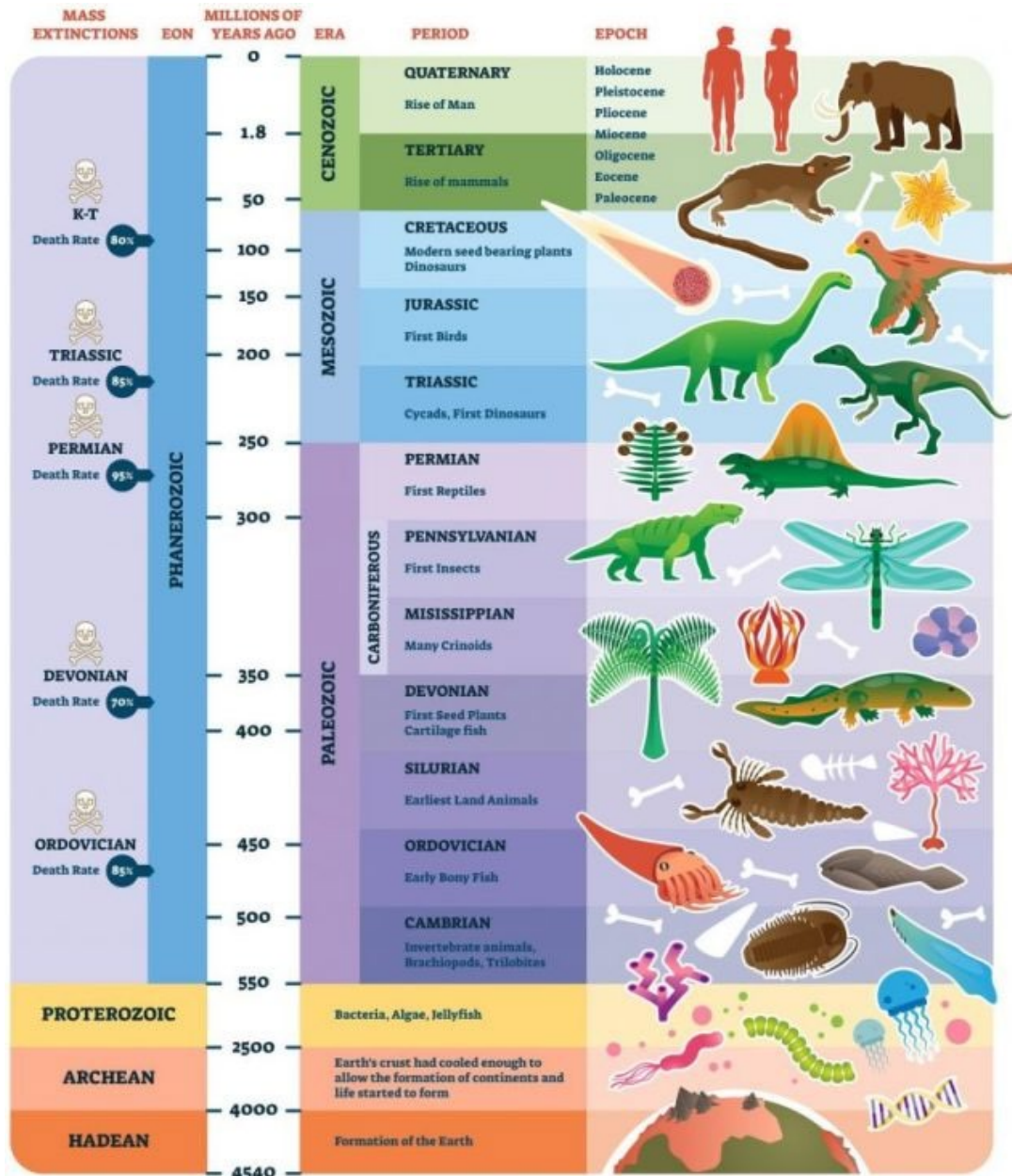
10 μm

Size: 10 - 100 μm (dia.)
Volume: 3000 fL
Weight: 3000 pg

cell type	average volume (μm^3)	BNID
sperm cell	30	109891, 109892
red blood cell	100	107600
lymphocyte	130	111439
neutrophil	300	108241
beta cell	1,000	109227
enterocyte	1,400	111216
fibroblast	2,000	108244
HeLa, cervix	3,000	103725, 105879
hair cell (ear)	4,000	108242
osteoblast	4,000	108088
alveolar macrophage	5,000	103566
cardiomyocyte	15,000	108243
megakaryocyte	30,000	110129
fat cell	600,000	107668
oocyte	4,000,000	101664

$1 \mu\text{m}^3 = 1\text{fL}$

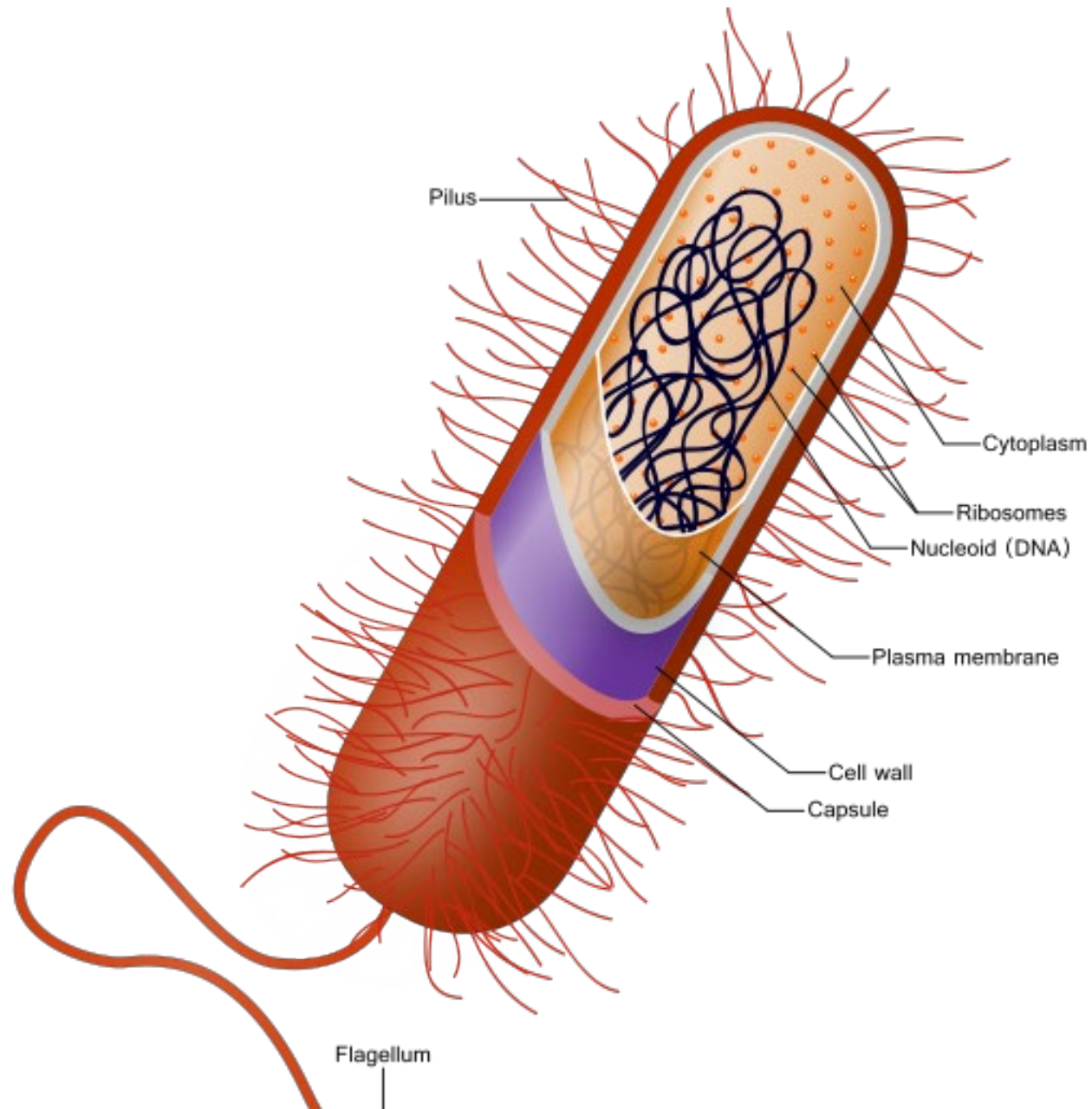
Biological Time Scales



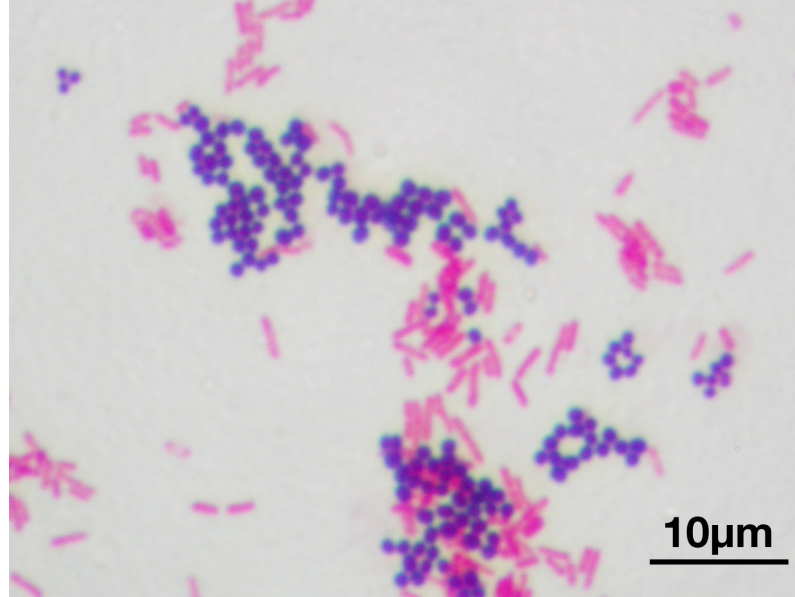
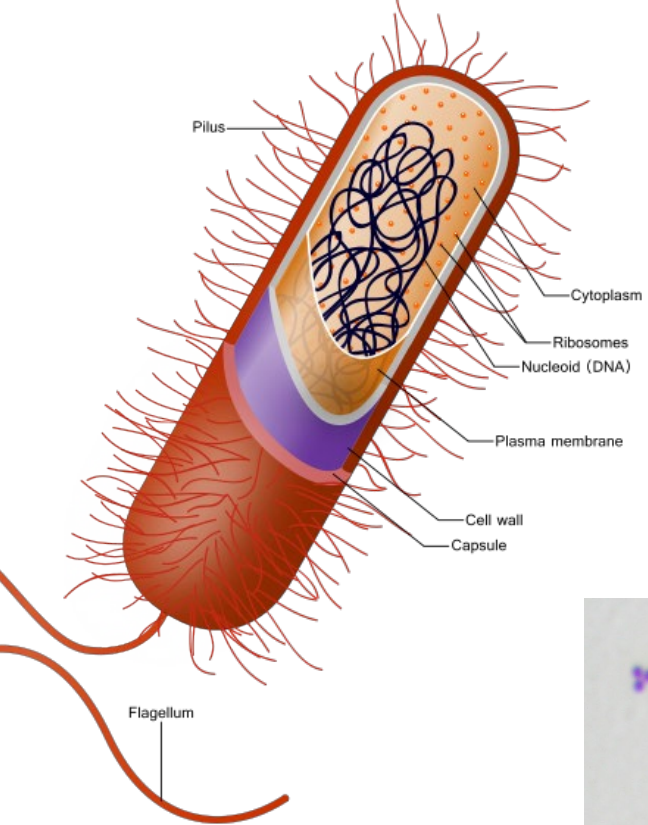
Origin of Life \sim 3.8 – 4.3 billion years ago

Prokaryotes

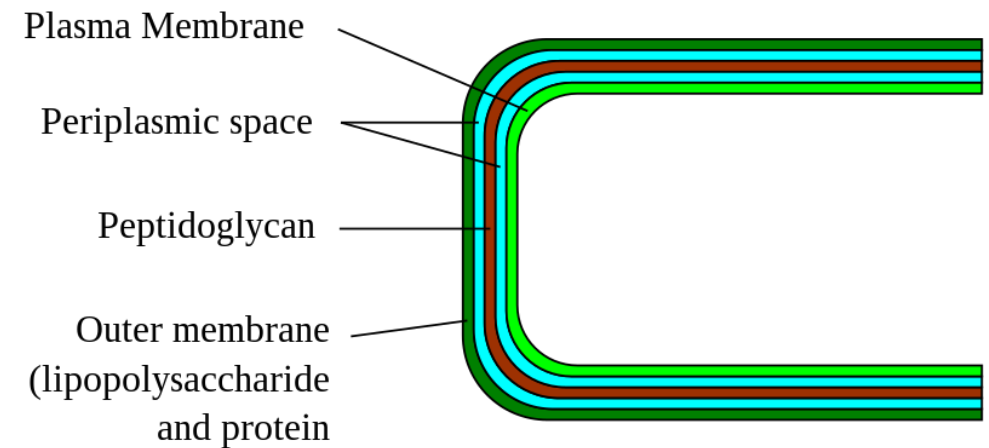
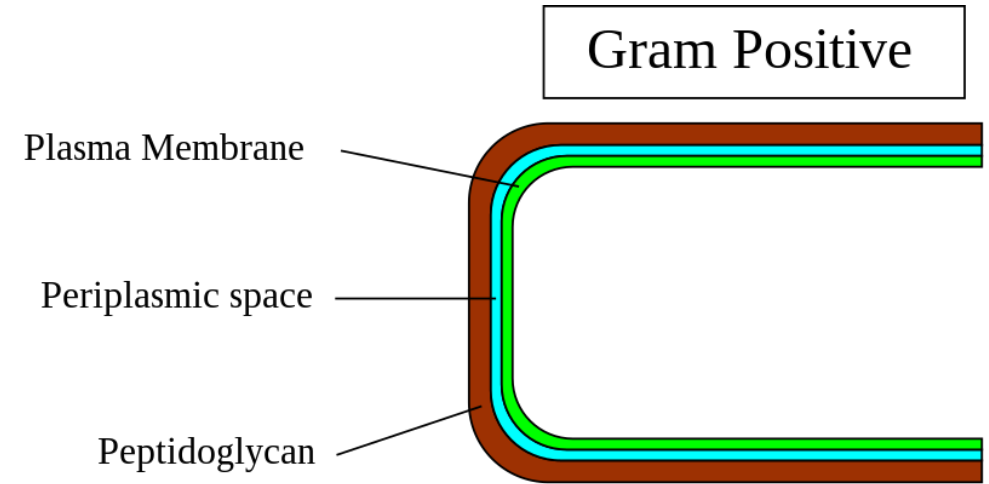
Cell Physiology Prokaryotes



Two main classes of bacteria: Gram + and Gram -

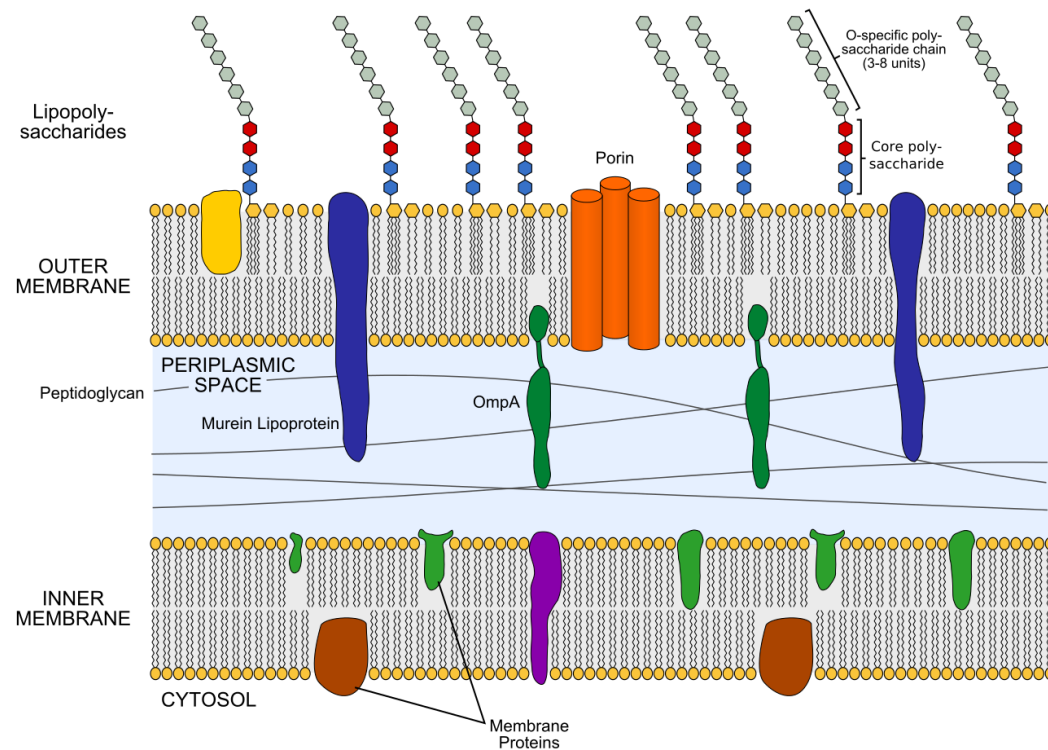
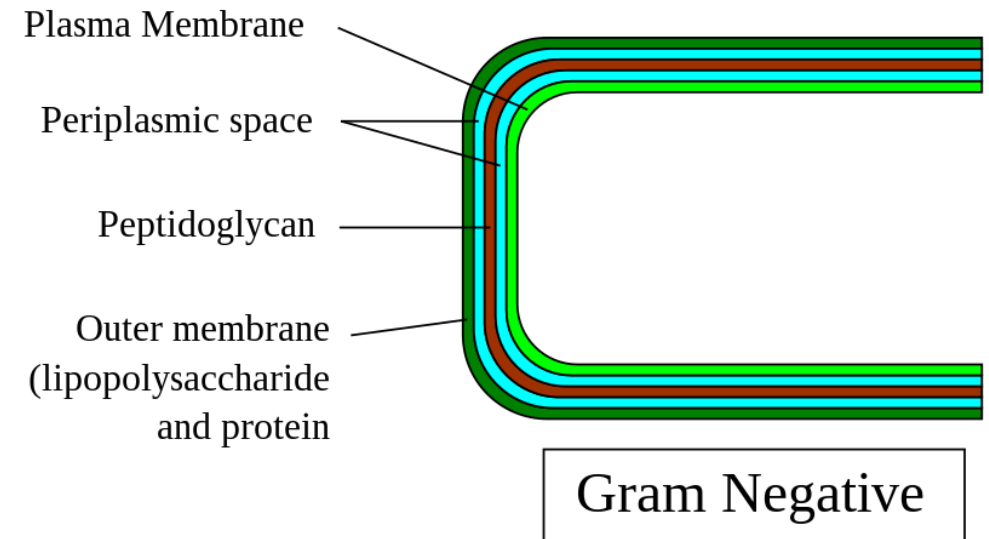
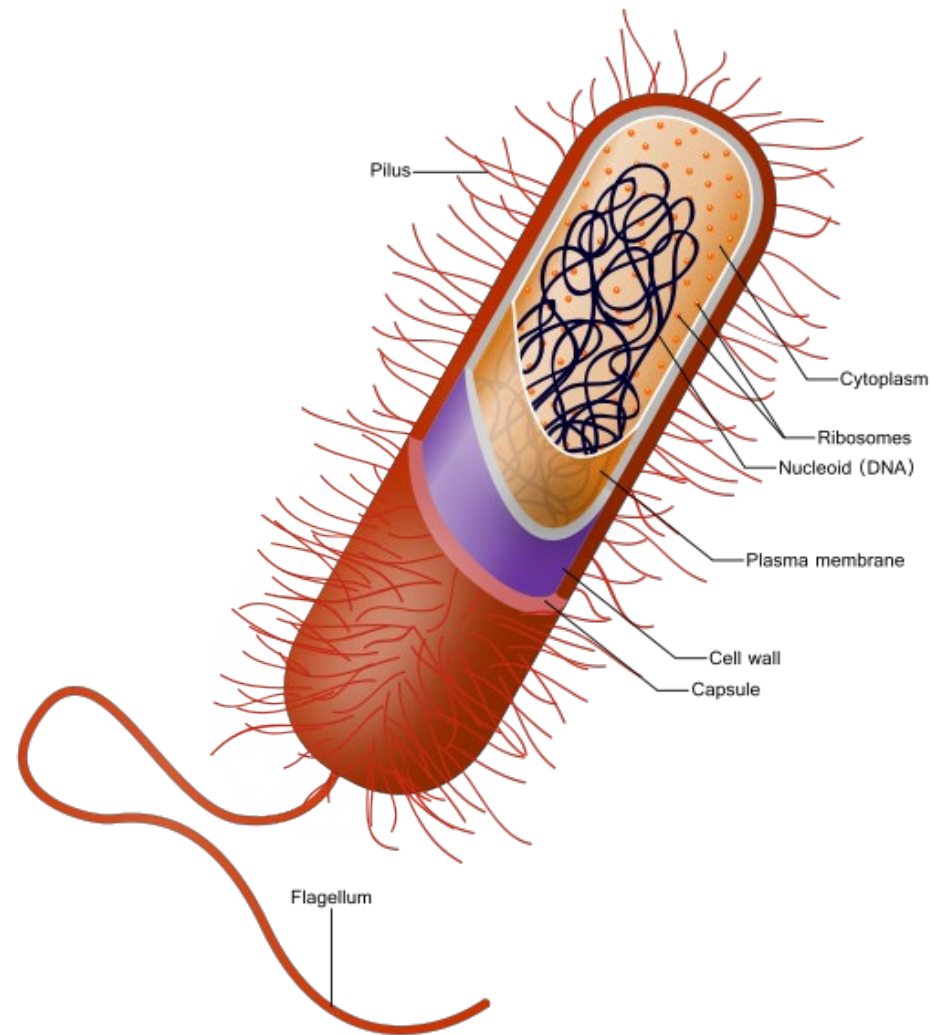


S. aureus gram-positive cocci, in purple
and *Escherichia coli* gram-negative bacilli, in red

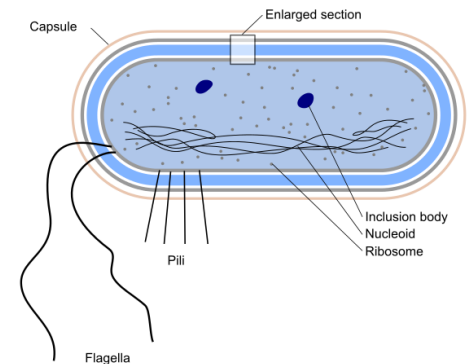


Gram Negative

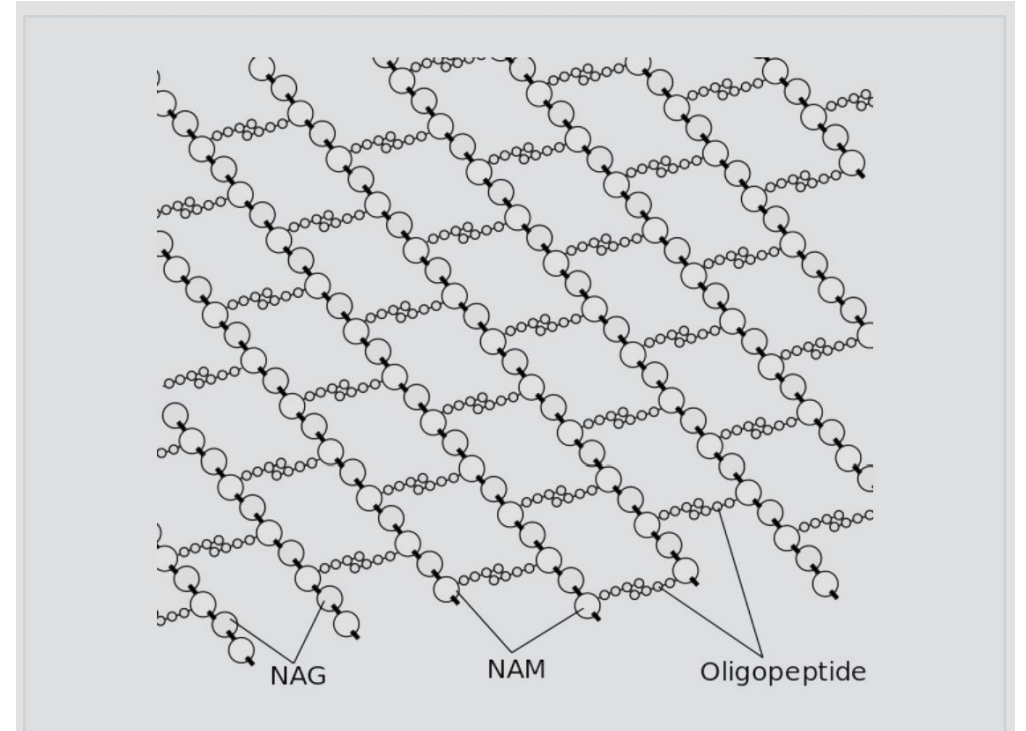
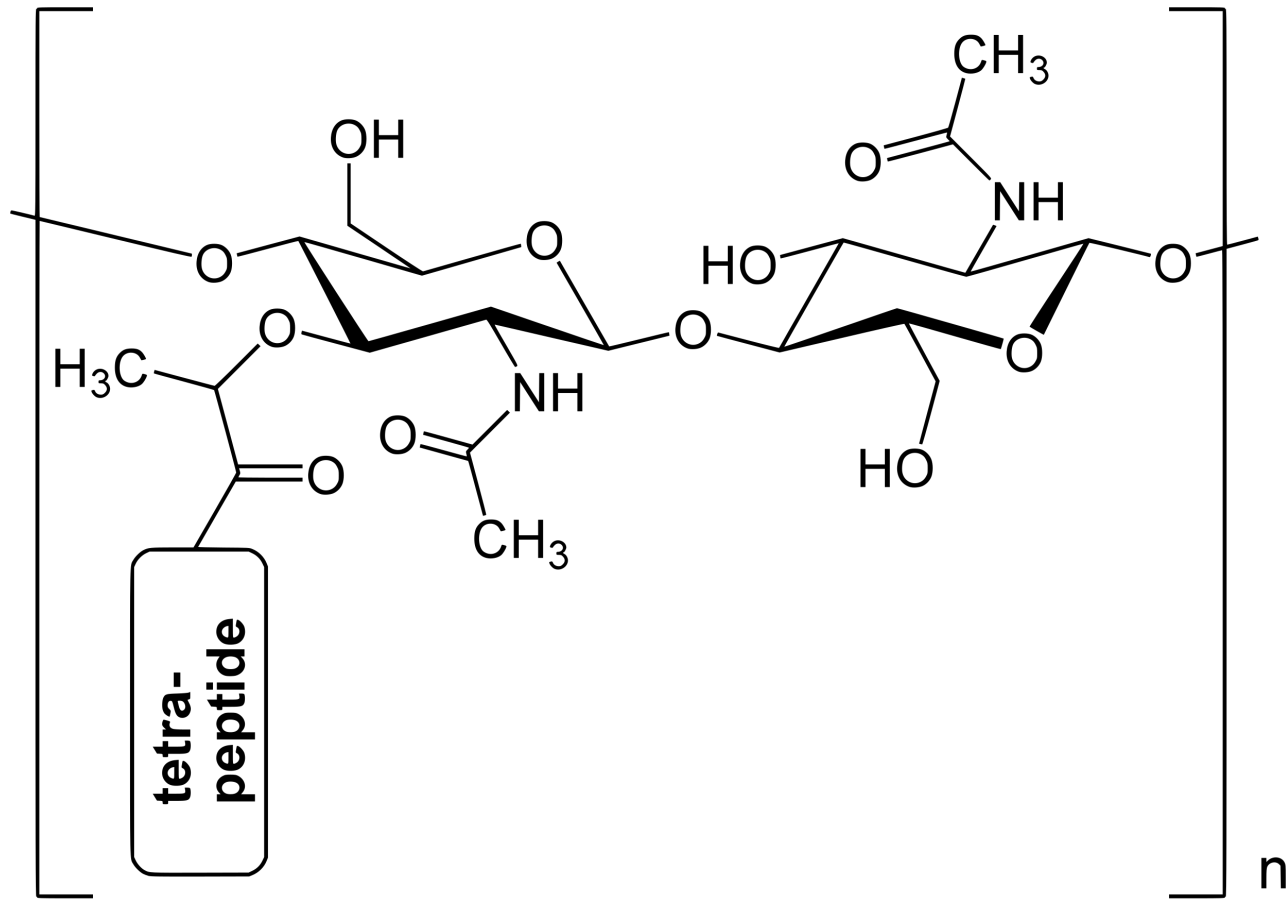
Cell Physiology Prokaryotes



Gram Negative Bacterial Cell Wall

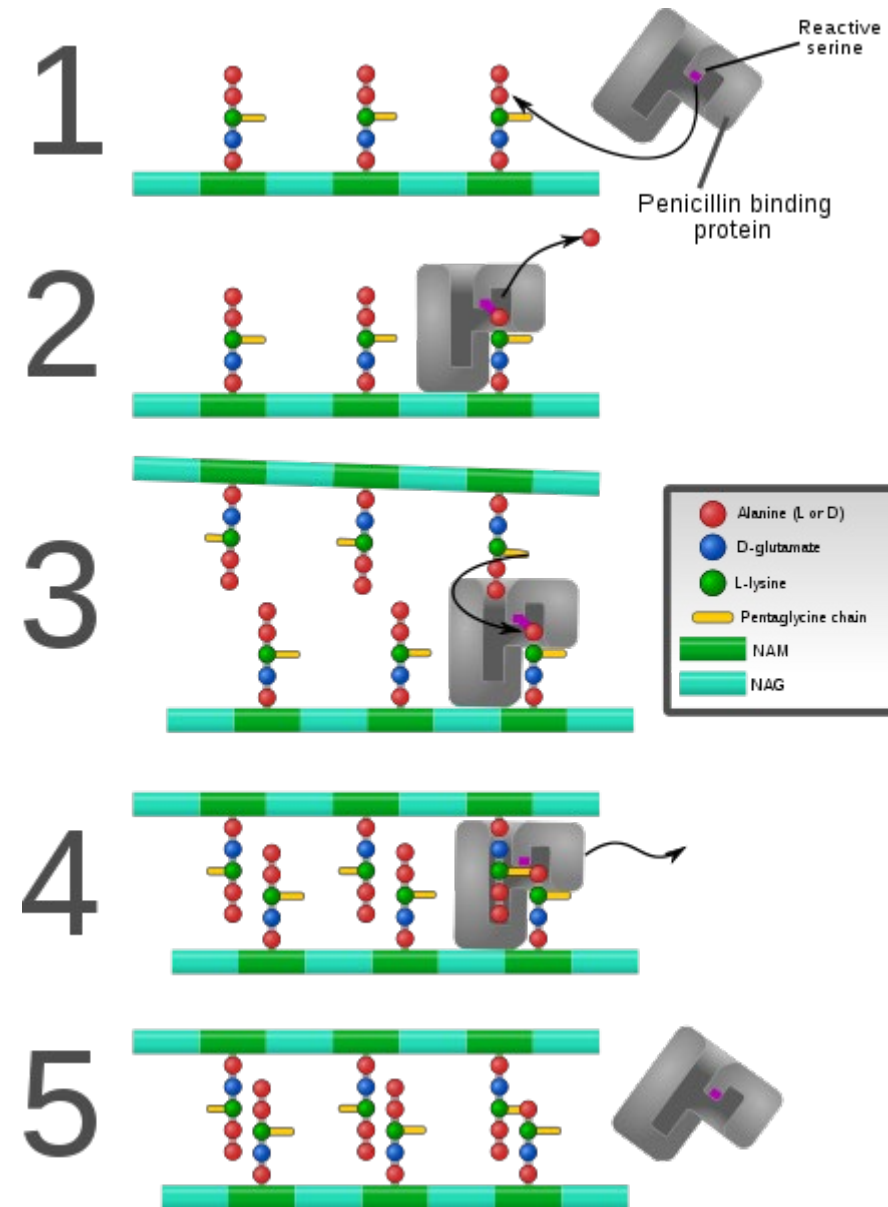


Peptidoglycan

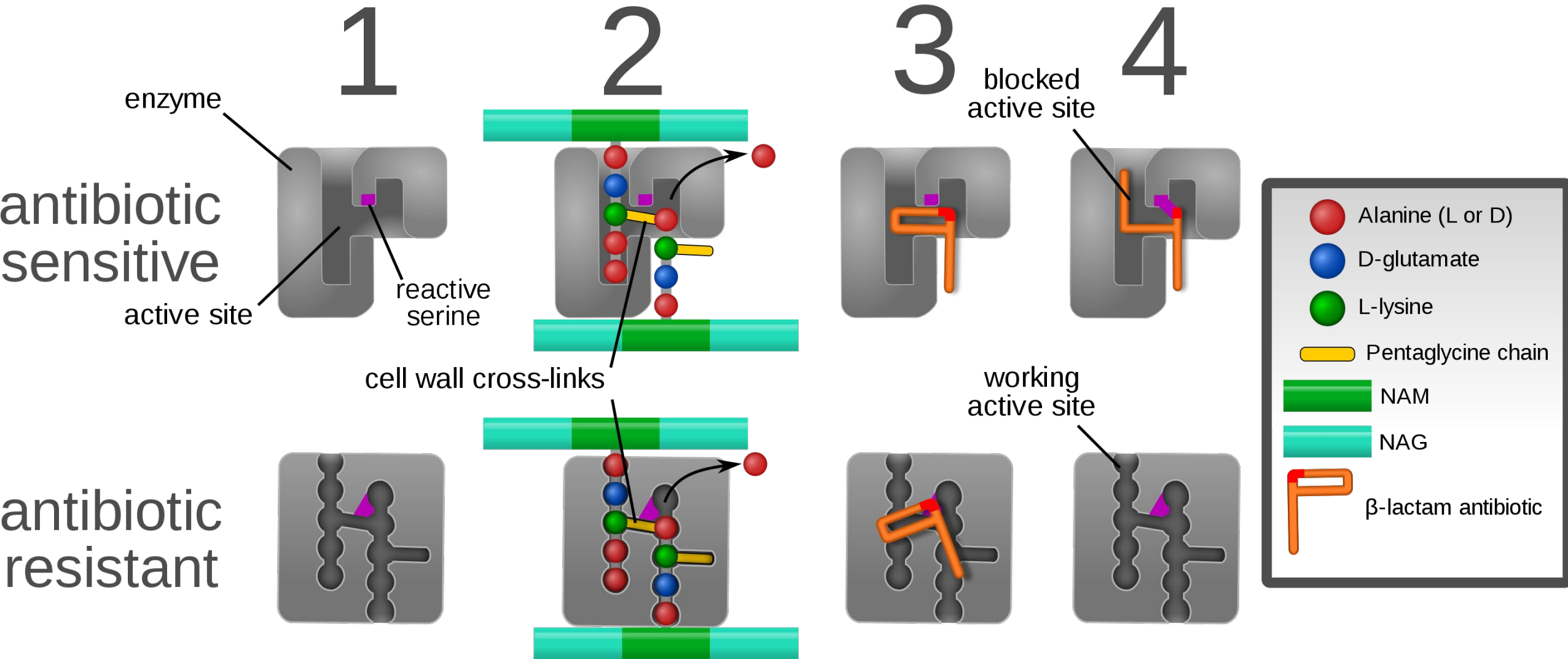


The structure of peptidoglycan. NAG = *N*-acetylglucosamine (also called GlcNAc or NAGA), NAM = *N*-acetylmuramic acid (also called MurNAc or NAMA).

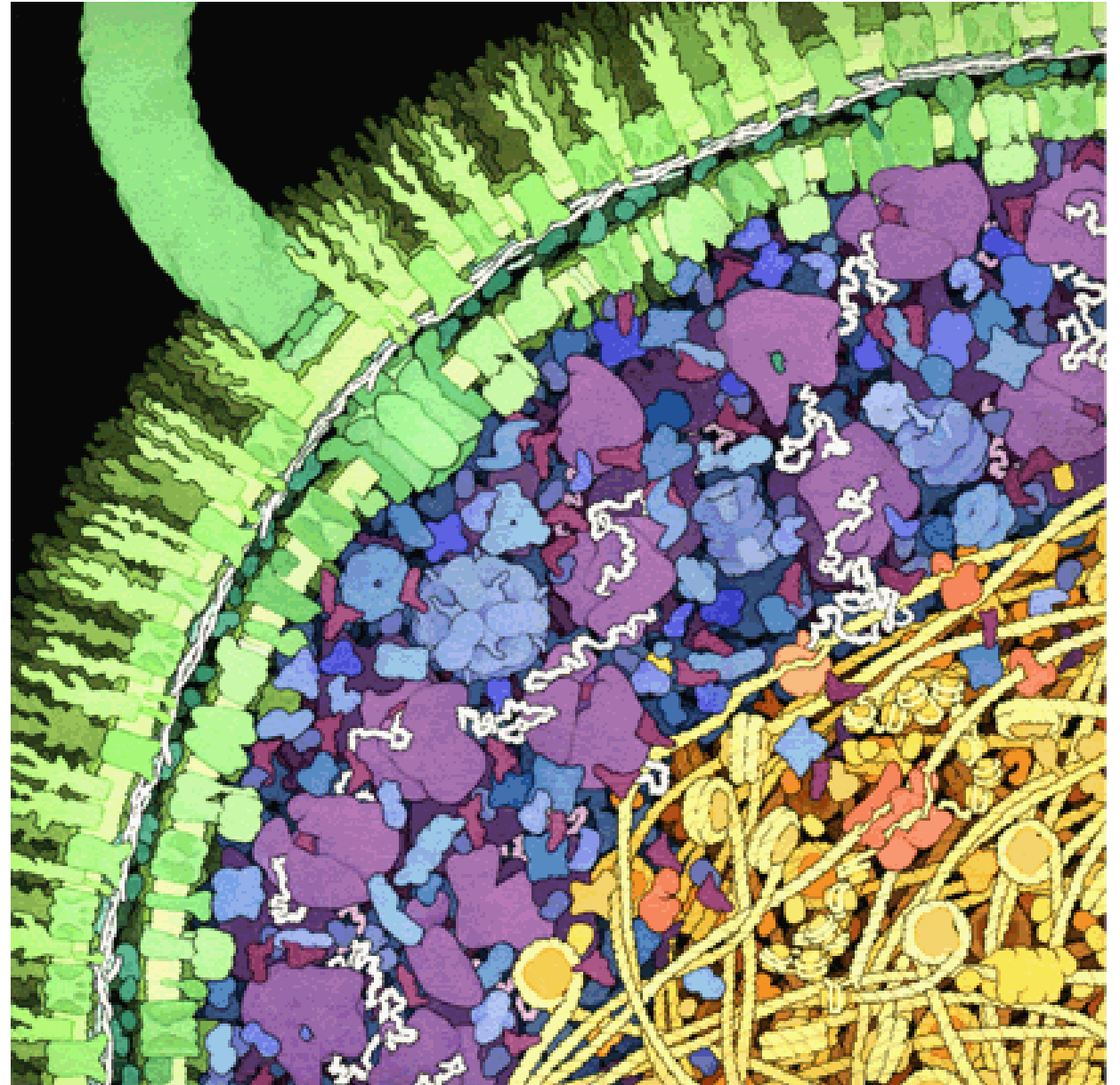
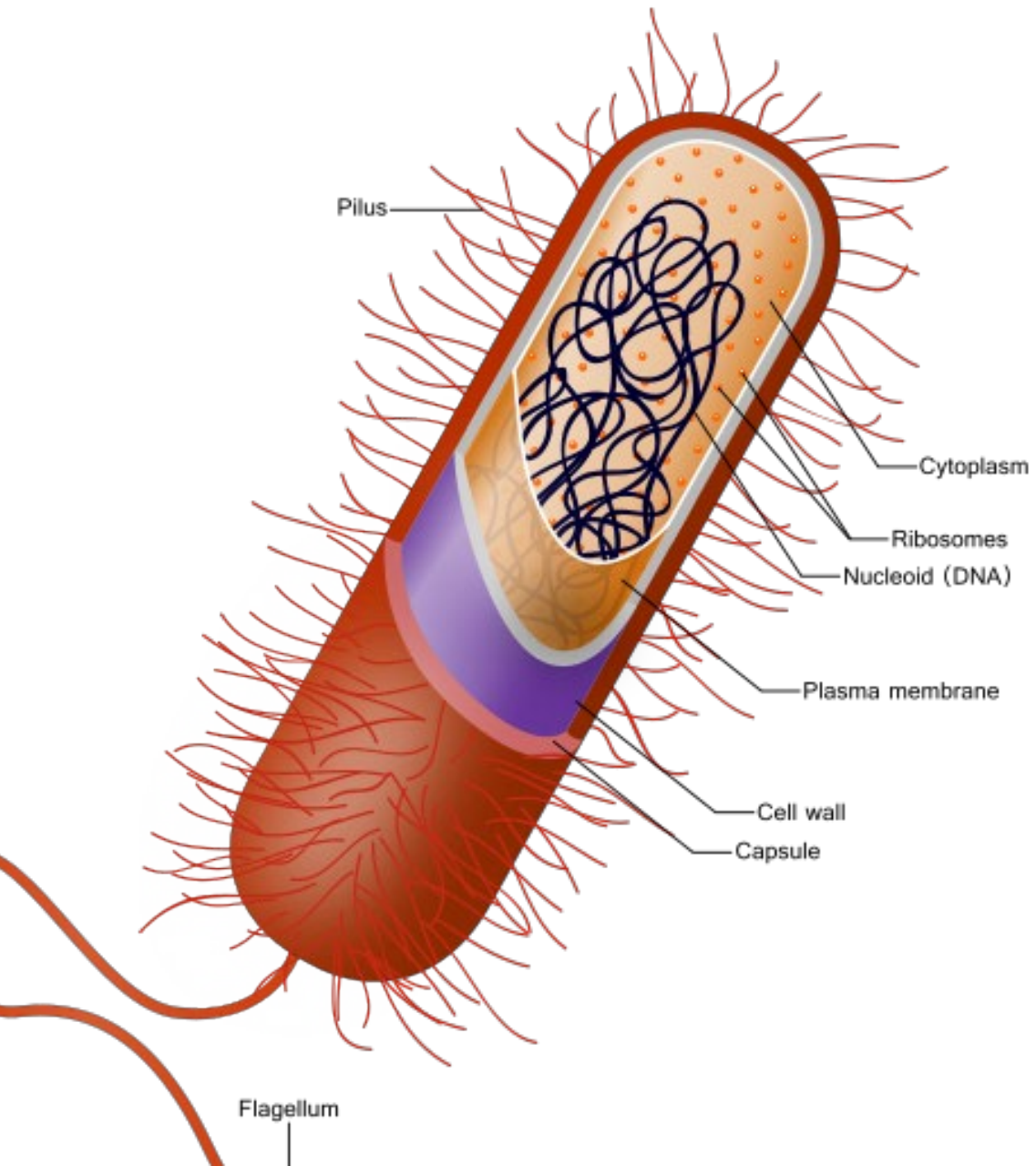
Peptidoglycan



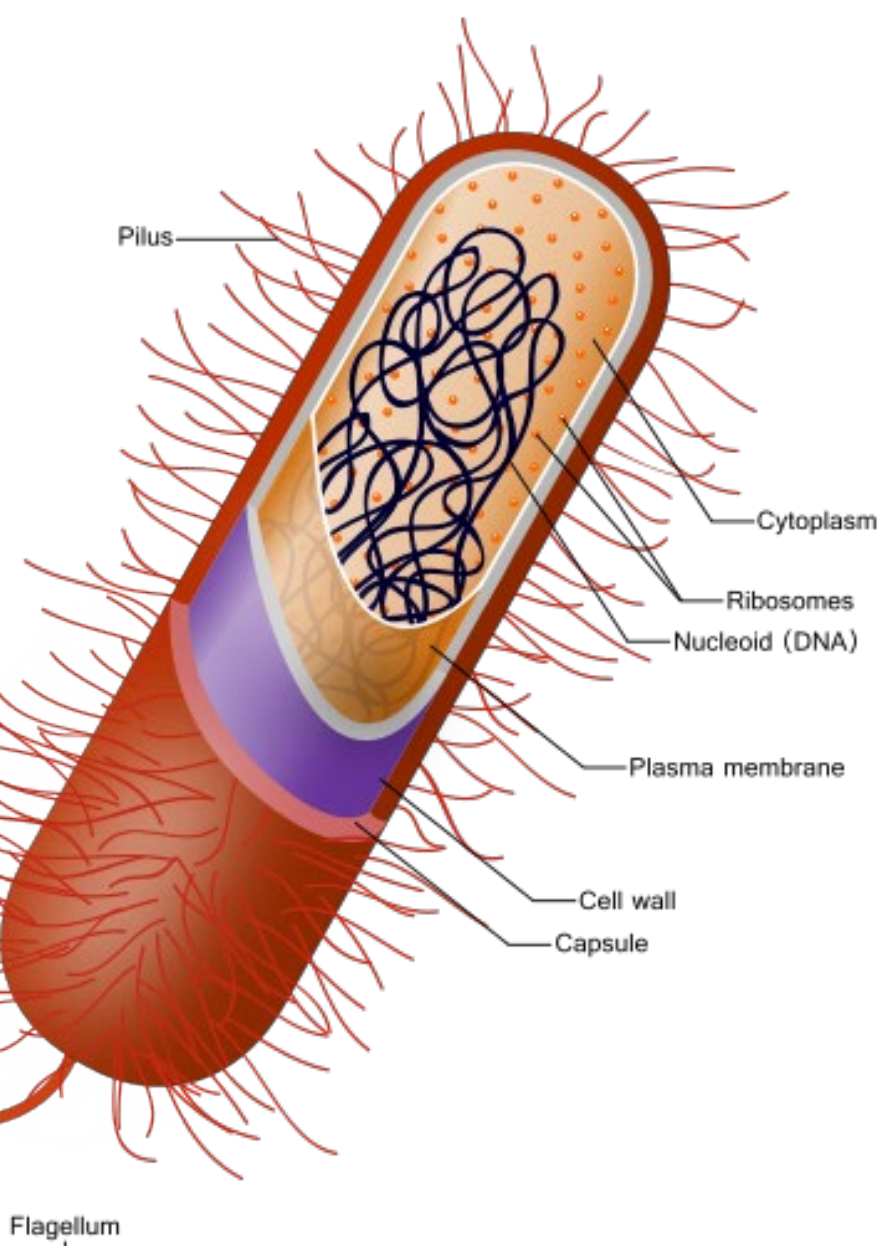
Peptidoglycan



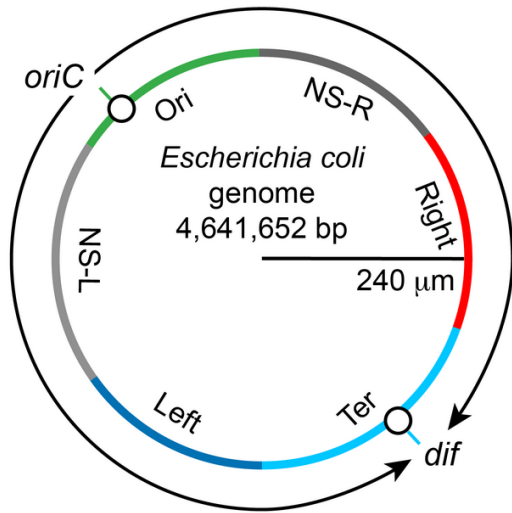
Cell Physiology Prokaryotes



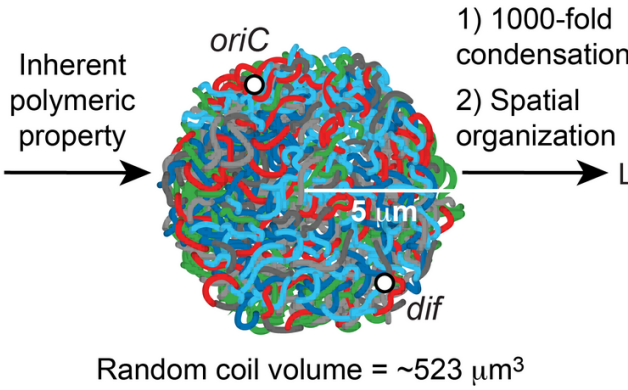
Nucleoid



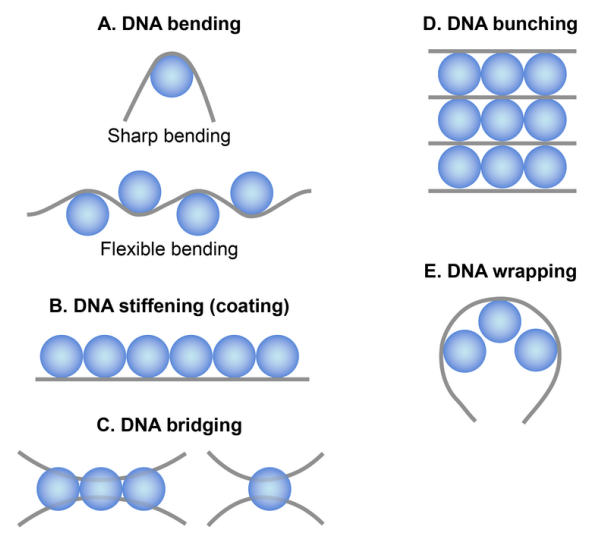
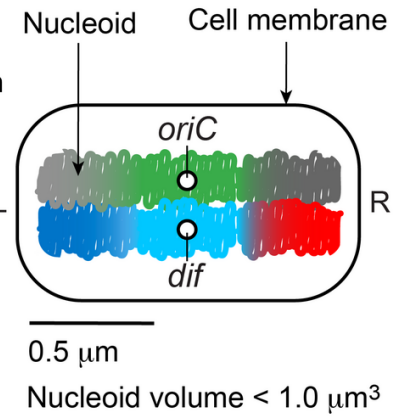
A. Circular *E. coli* genome



B. Random coil of the DNA

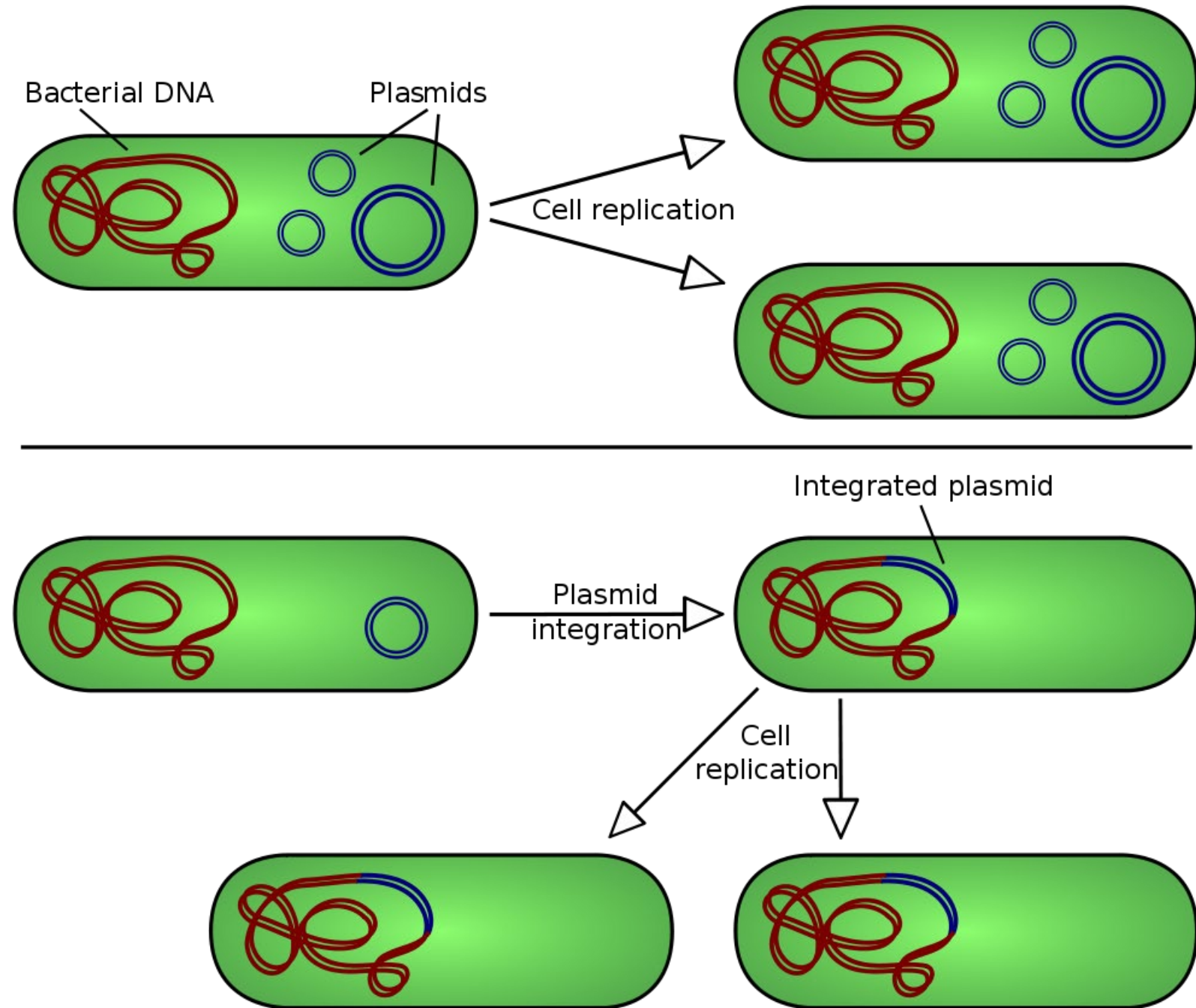
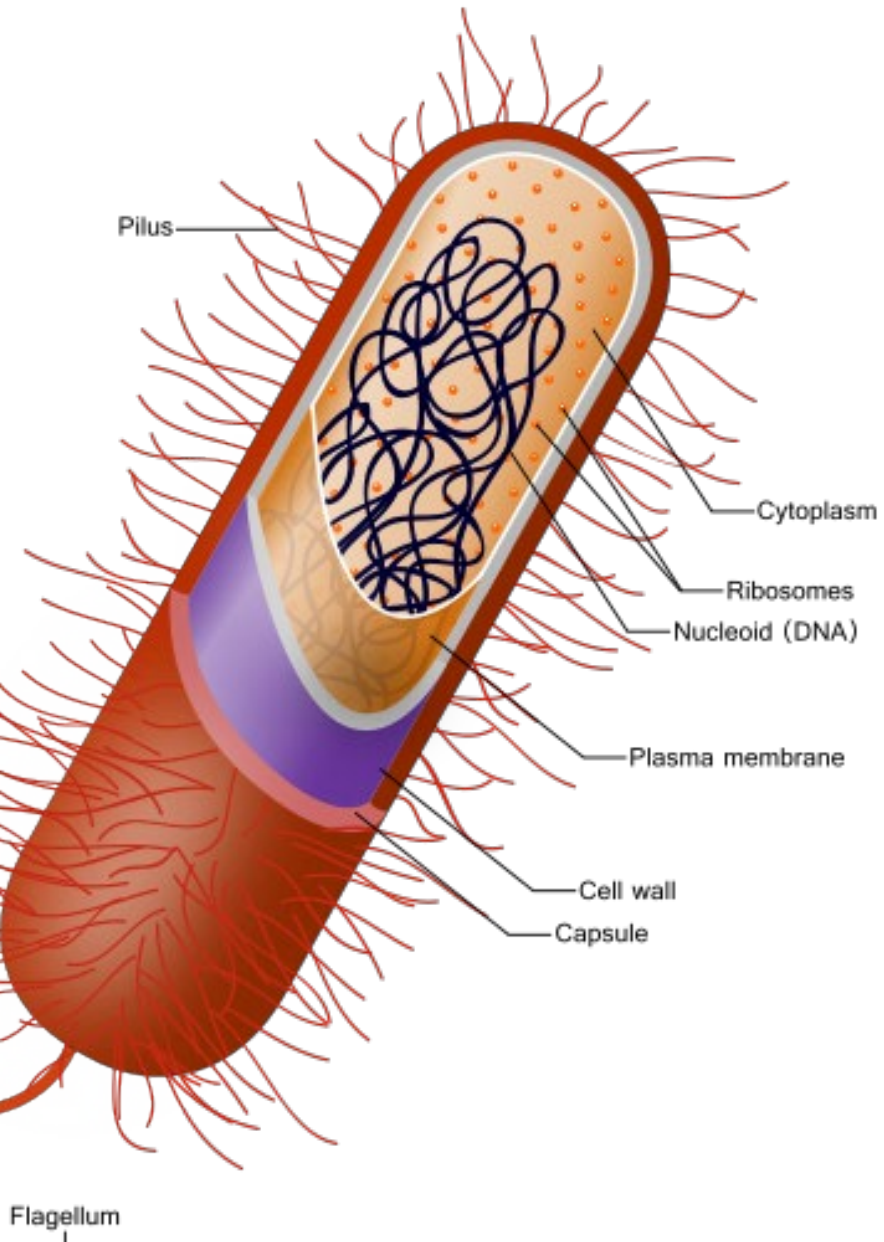


C. Genome organization *in vivo*



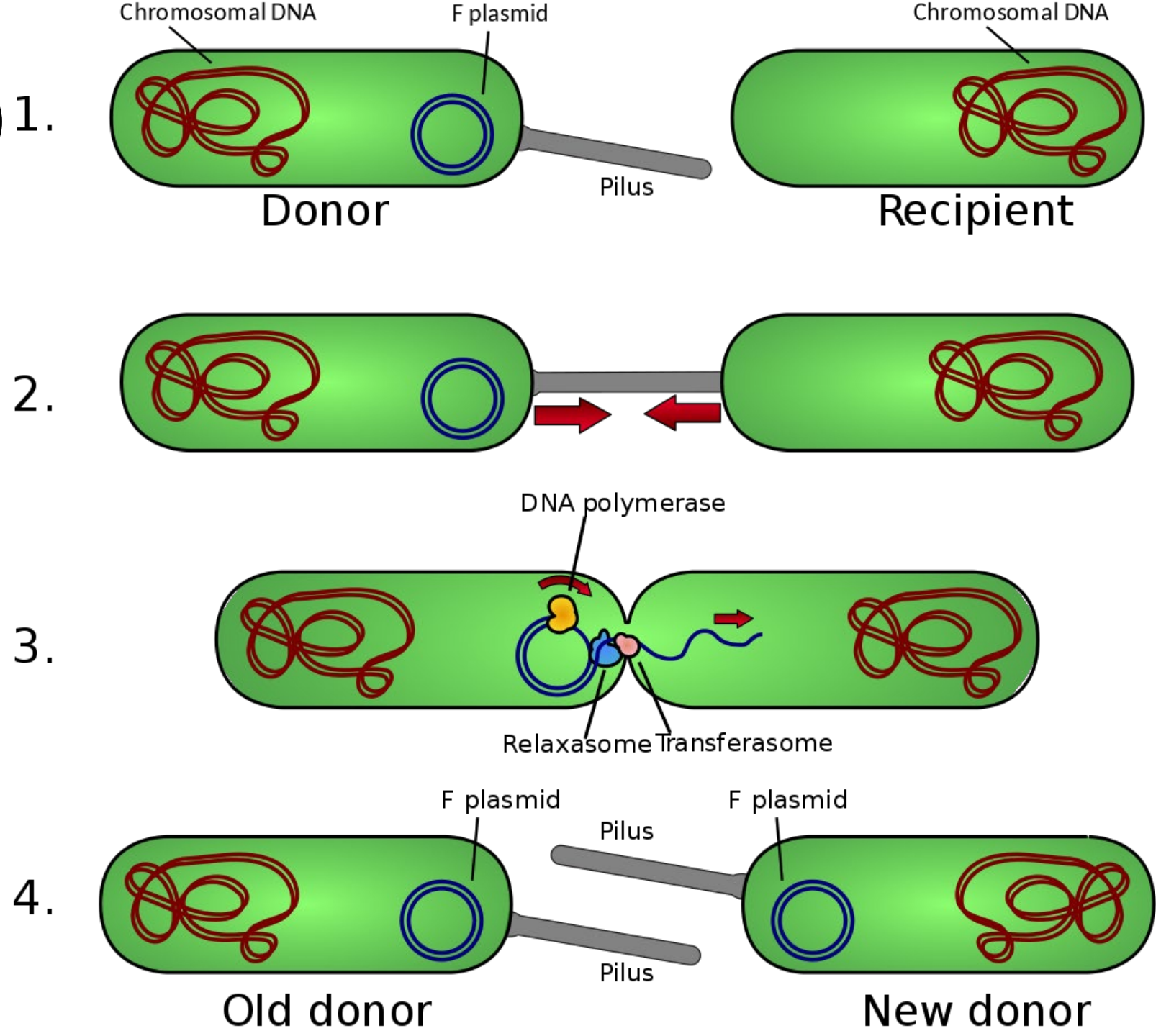
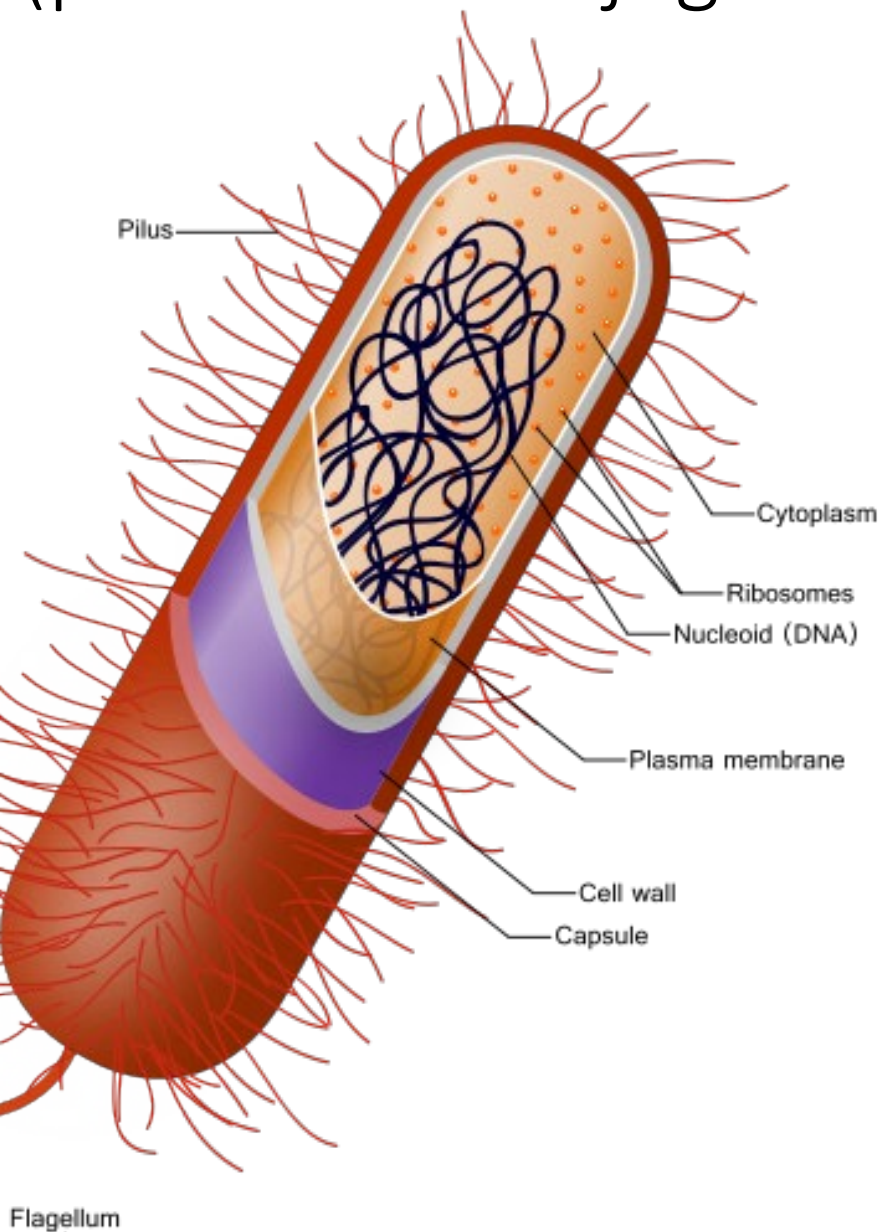
NAP	DNA organization
HU	DNA bending, bunching, and stiffening
IHF	DNA bending
H-NS	DNA stiffening and bridging
Fis	DNA bending and bridging

Plasmid

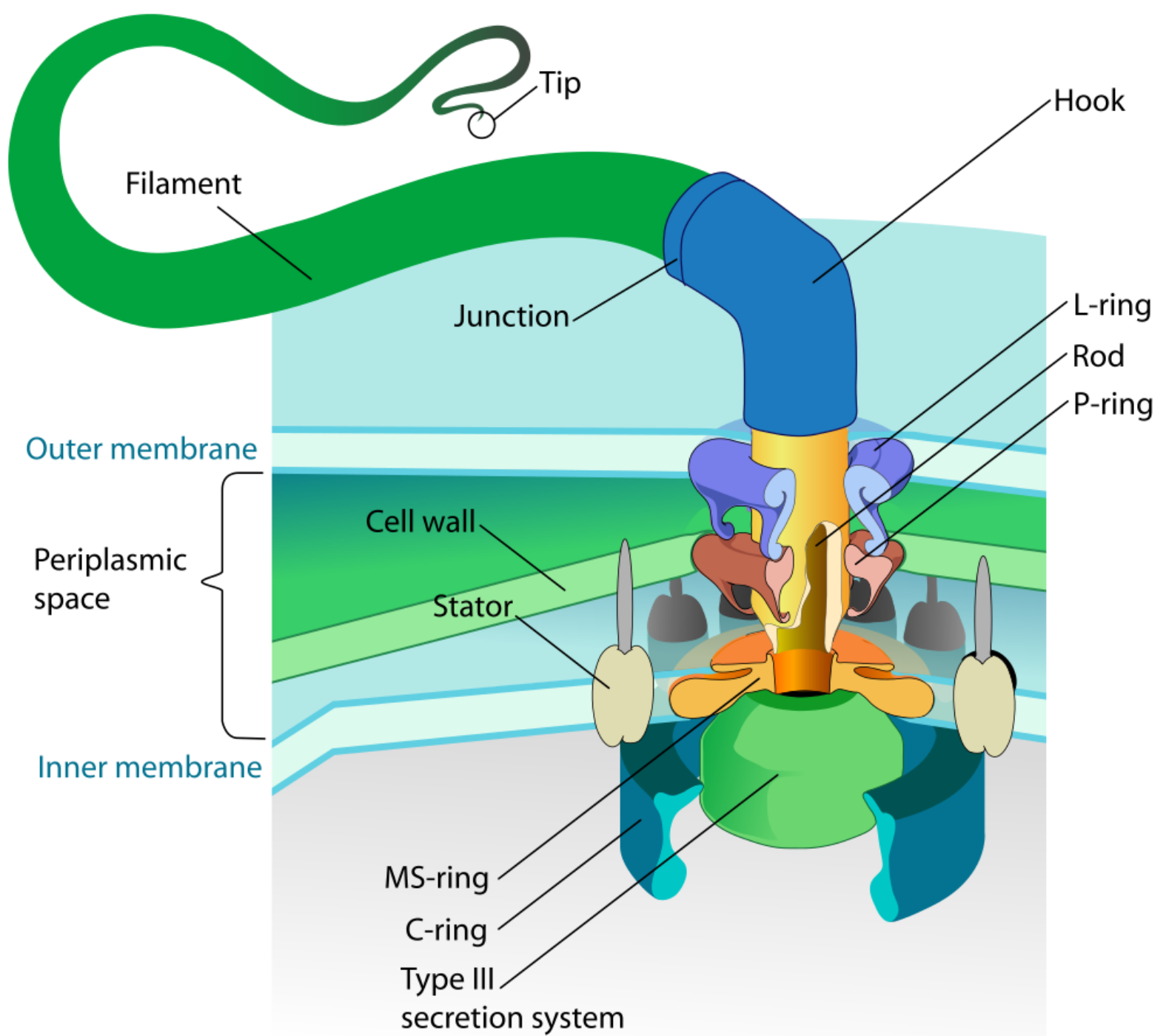
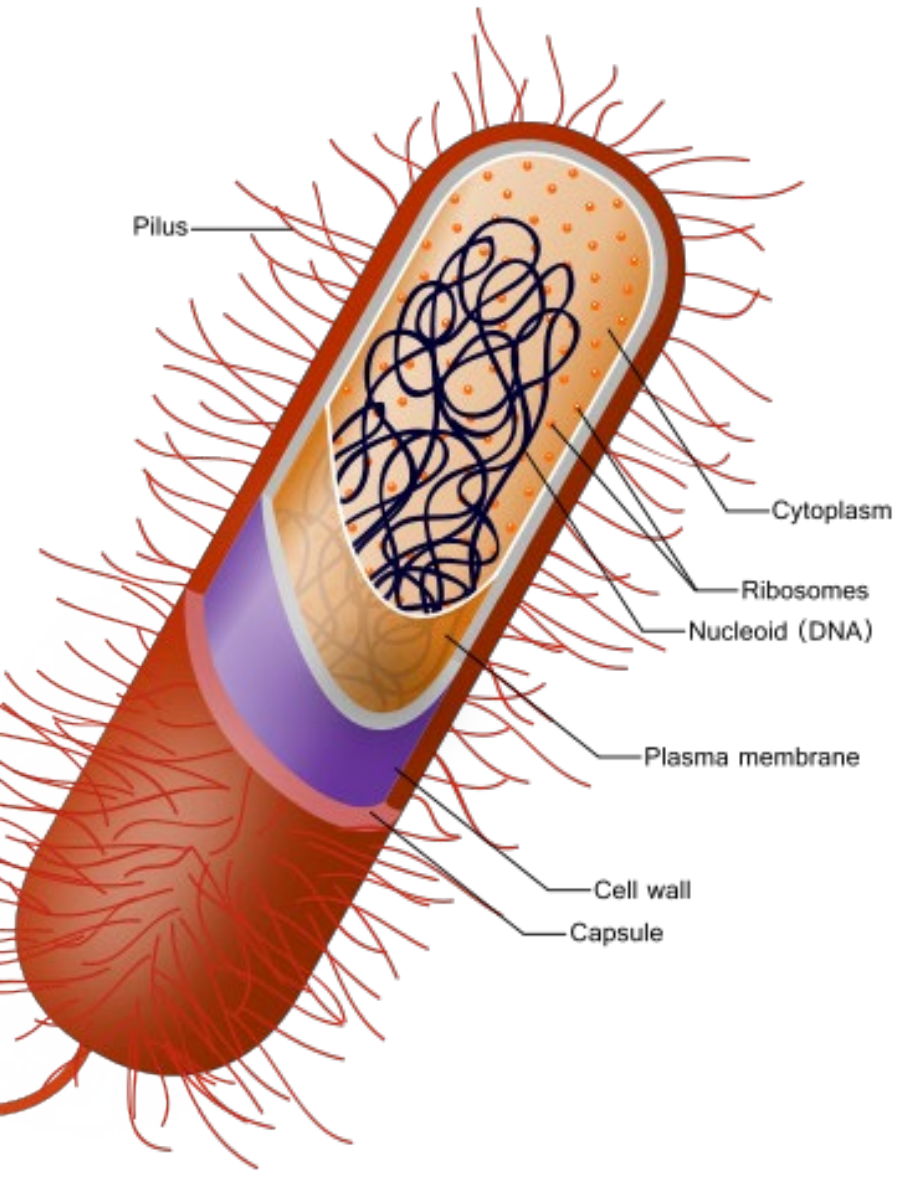


Pilus

(process of conjugation) 1.



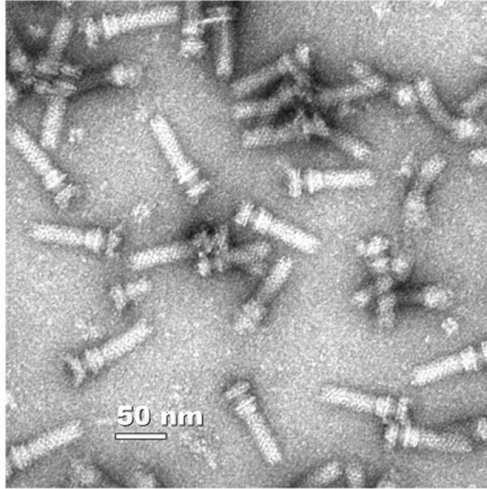
Flagellum



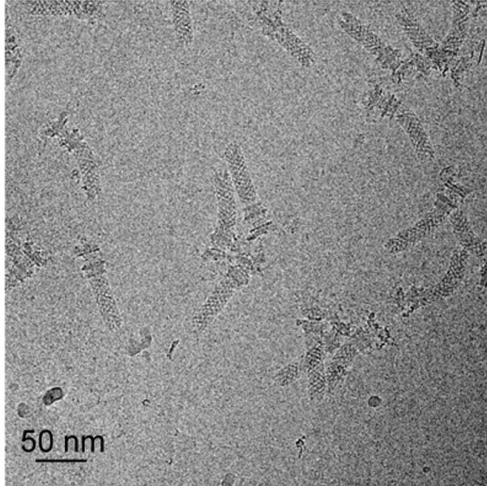
Flagellum

Cryo-Electron Microscopy (Cryo-EM)

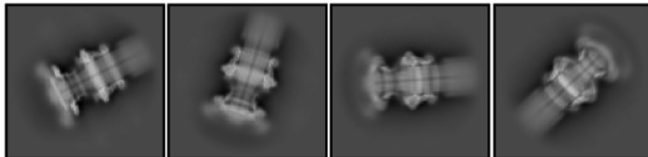
A



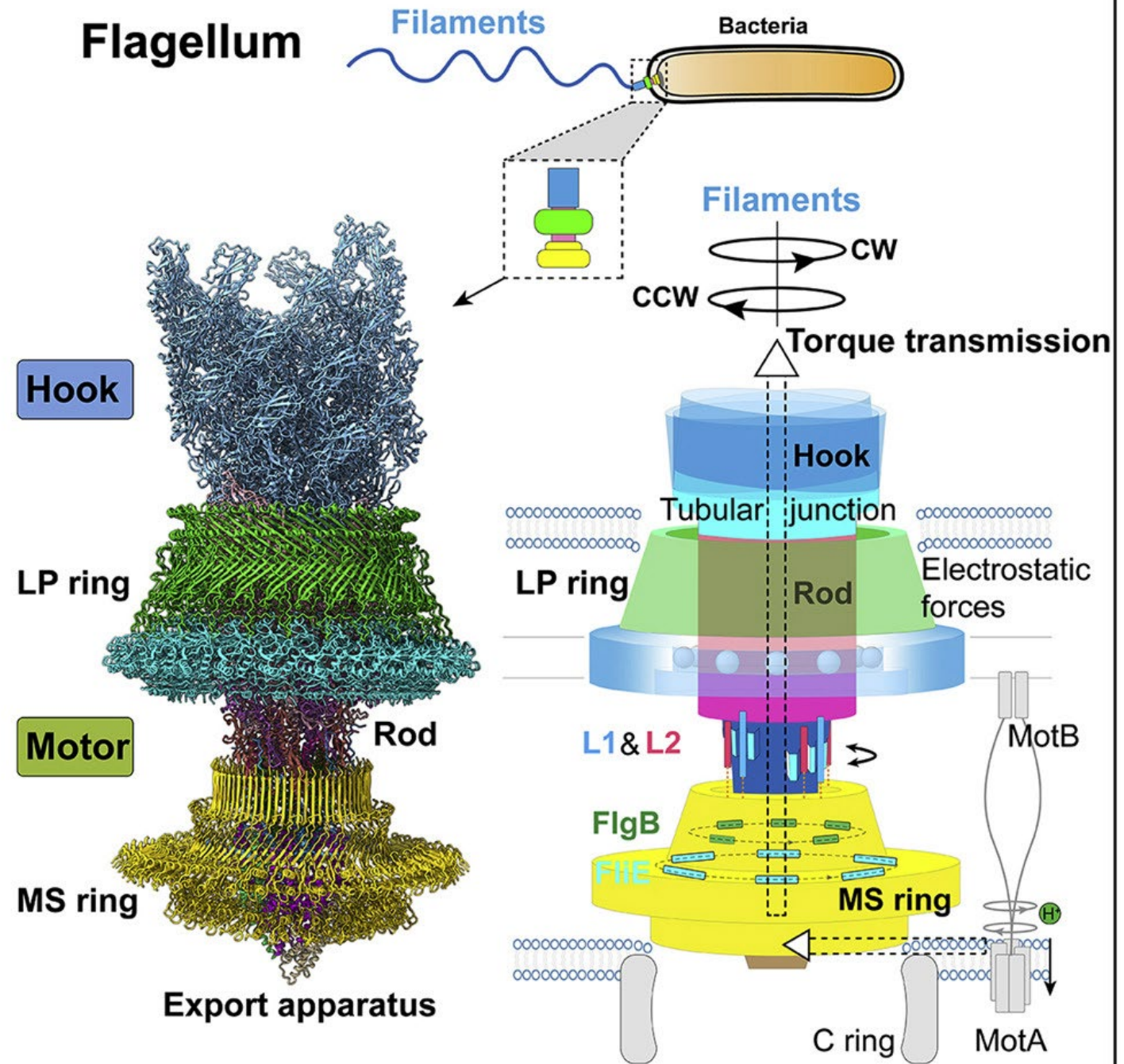
B



C

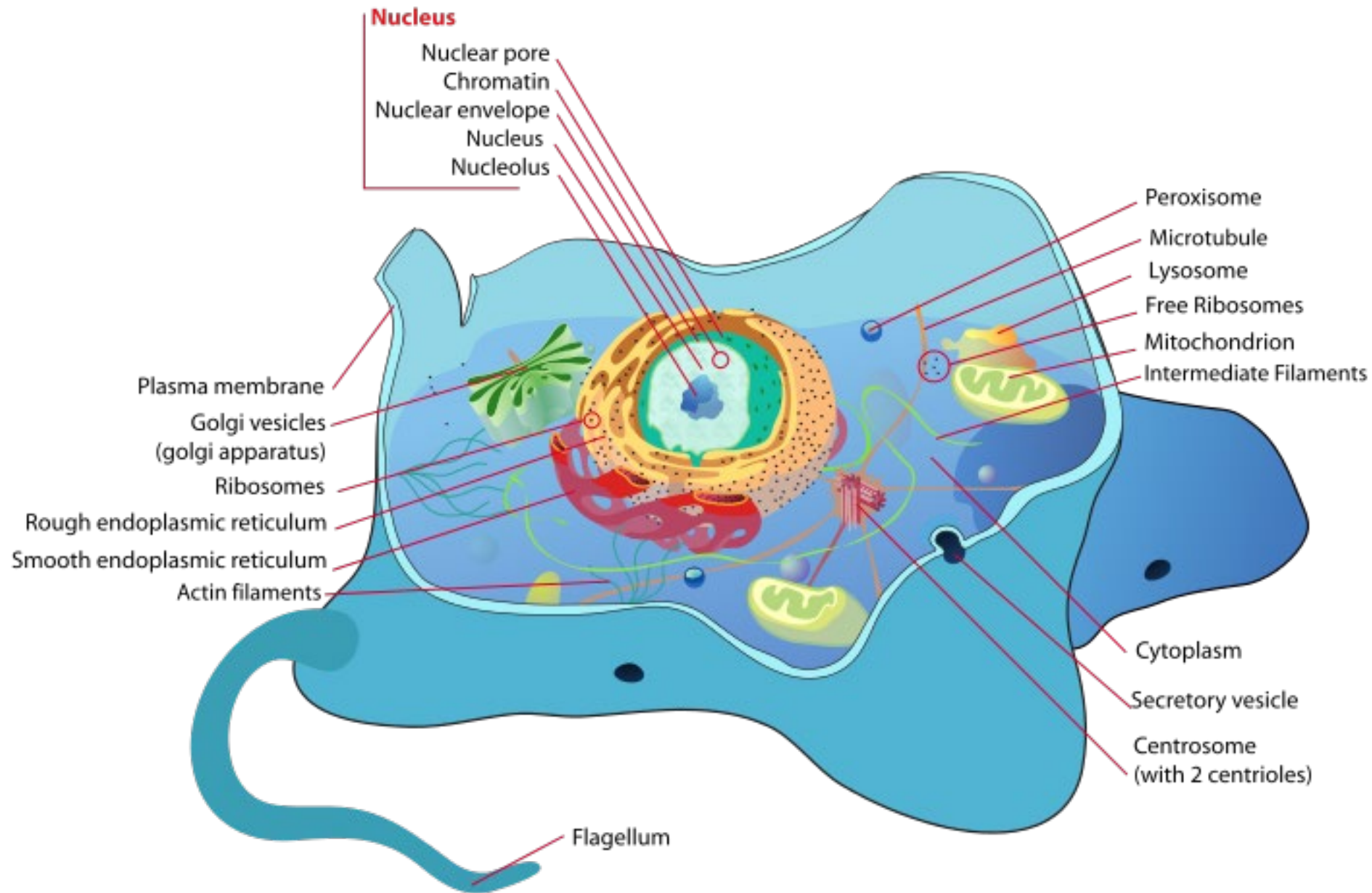


Flagellum

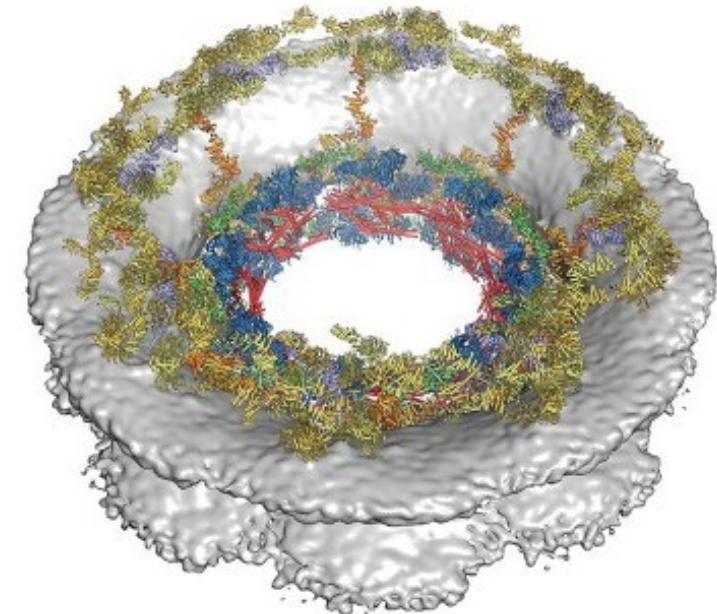
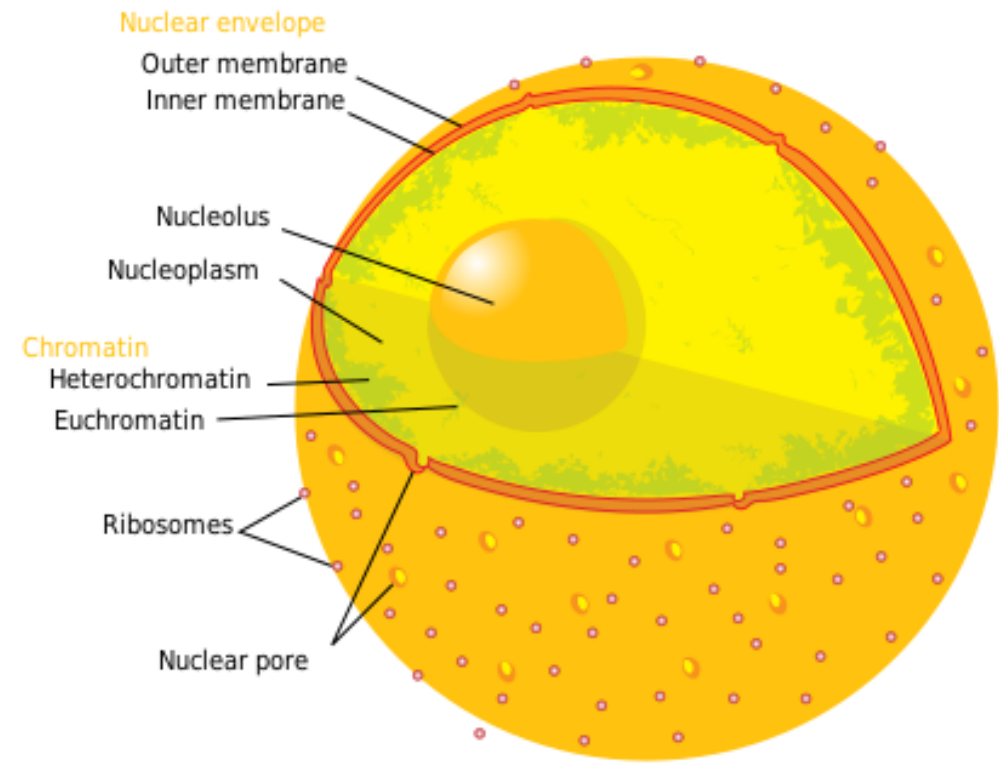
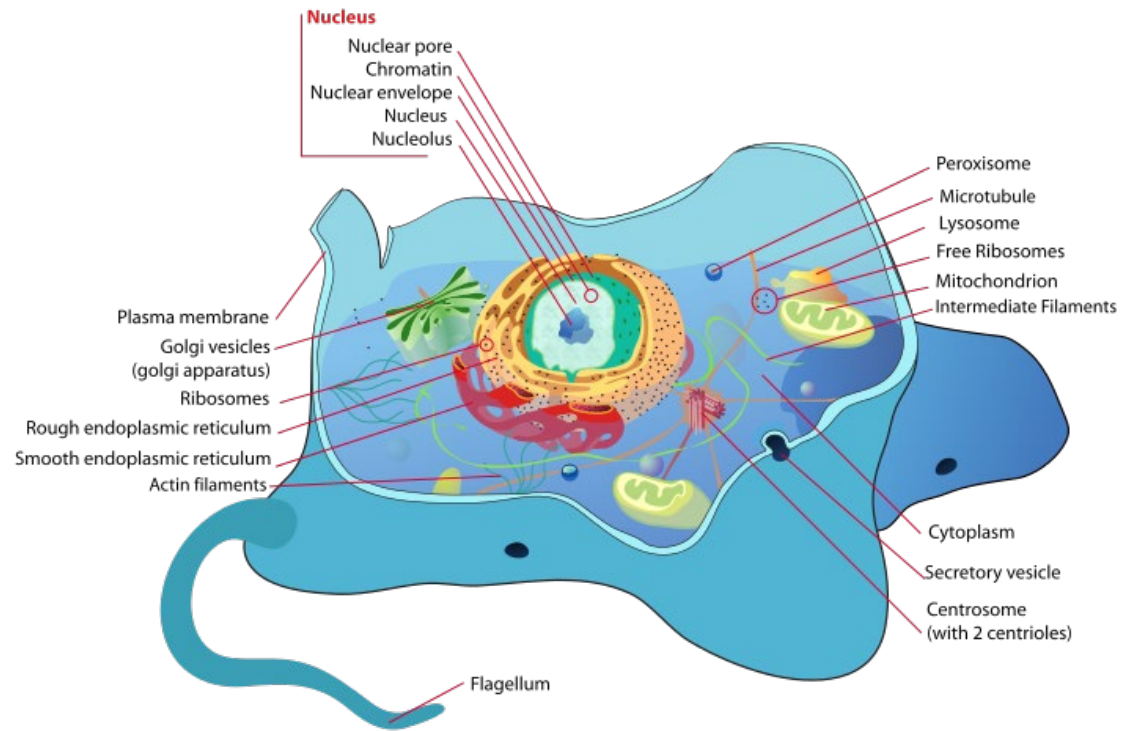


Eukaryotes

Cell Physiology Eukaryotes



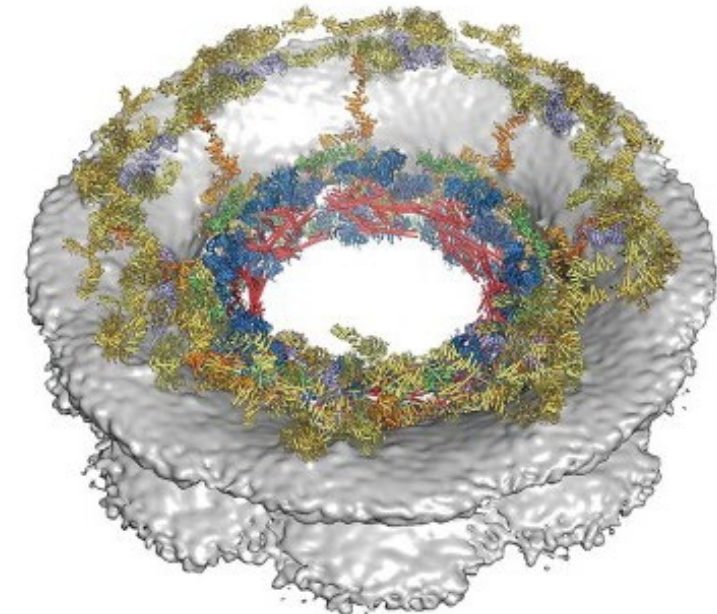
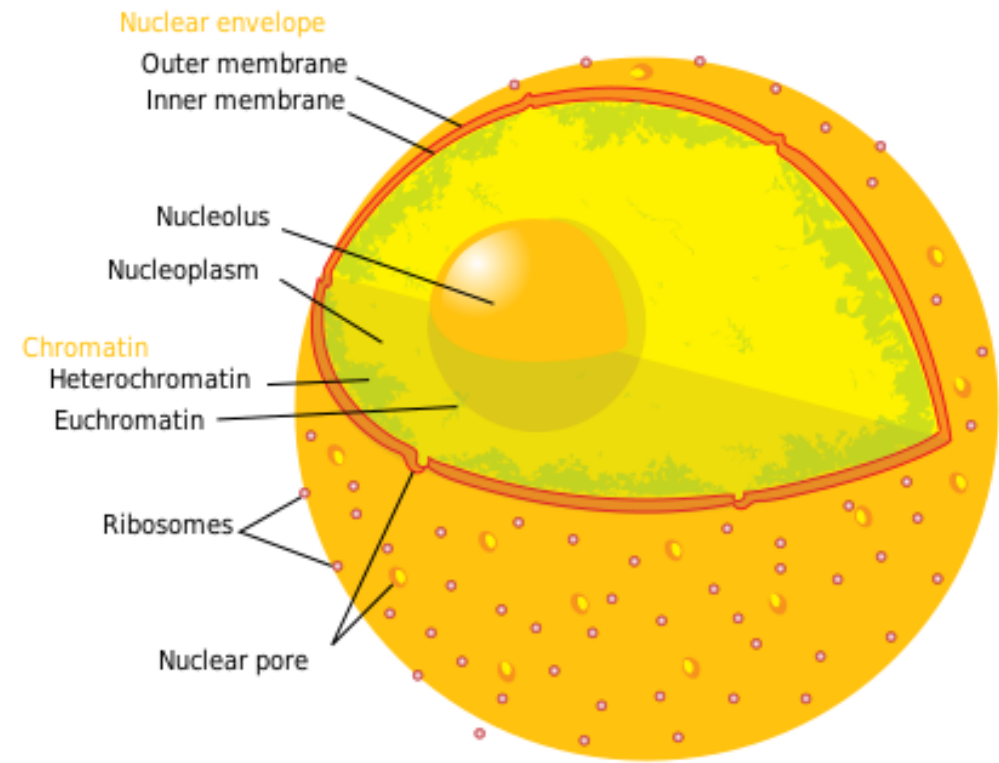
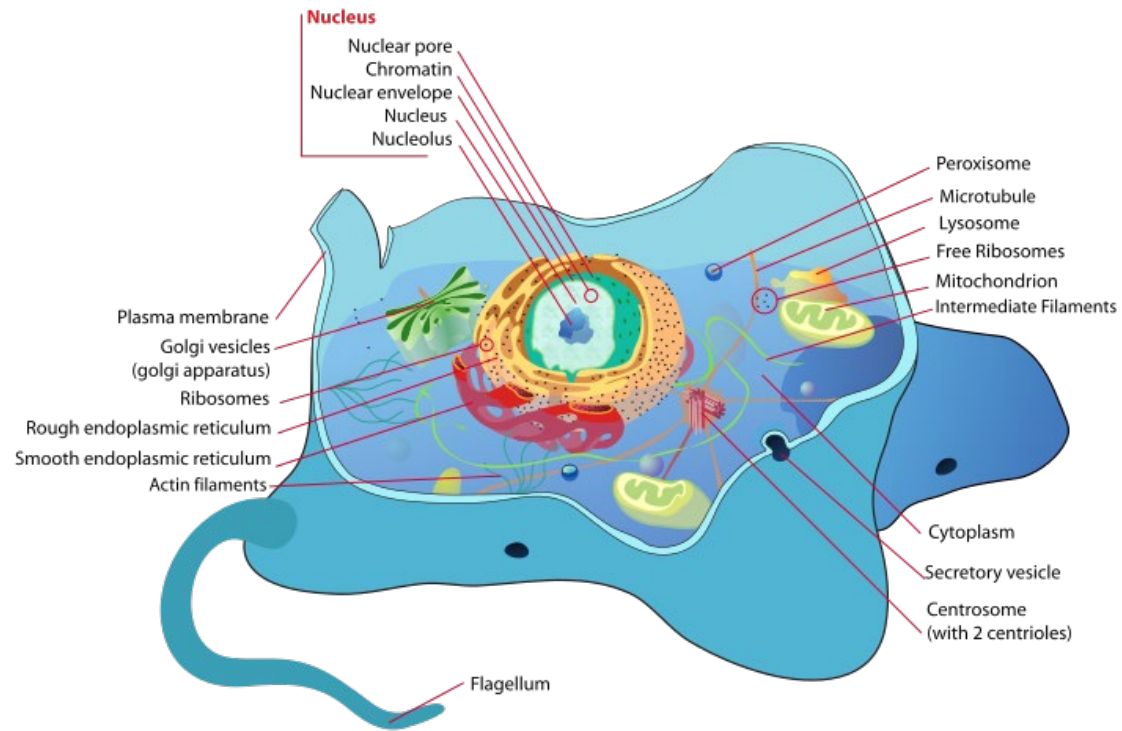
Nucleus



Nucleus:

- Genetic Control Center
- Transcription Site
- Nuclear Envelope Regulation

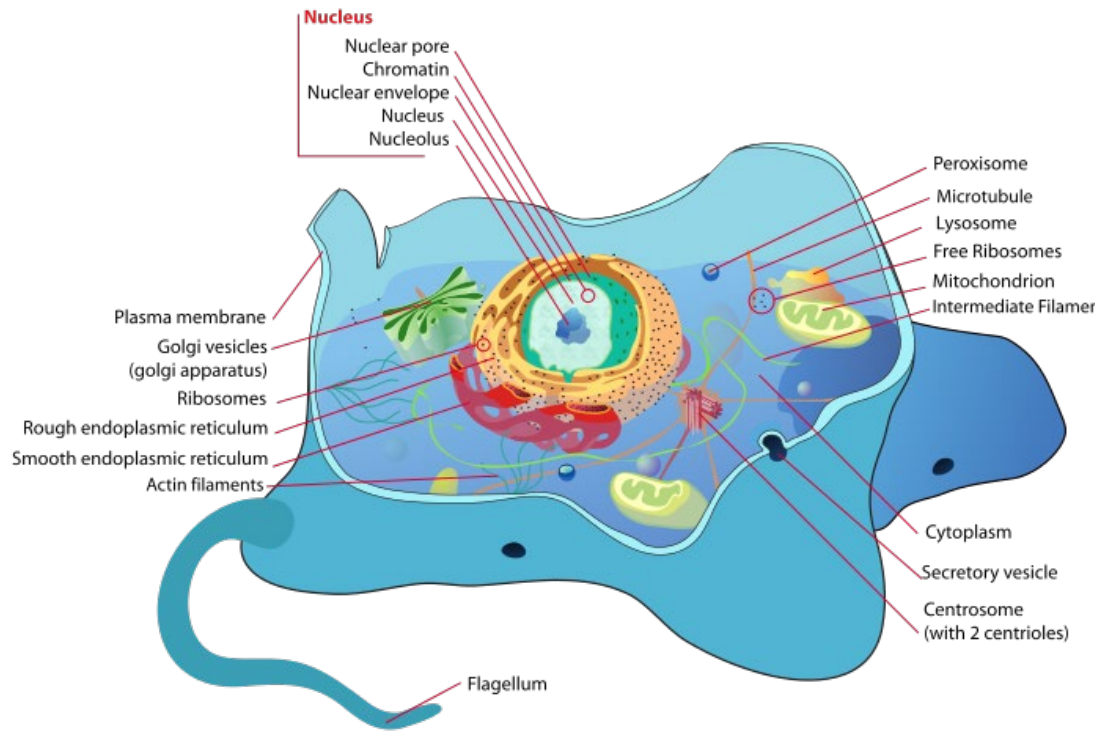
Nucleolus



Nucleolus:

- Ribosomal RNA (rRNA) Synthesis
- Ribosome Assembly

Endoplasmic reticulum



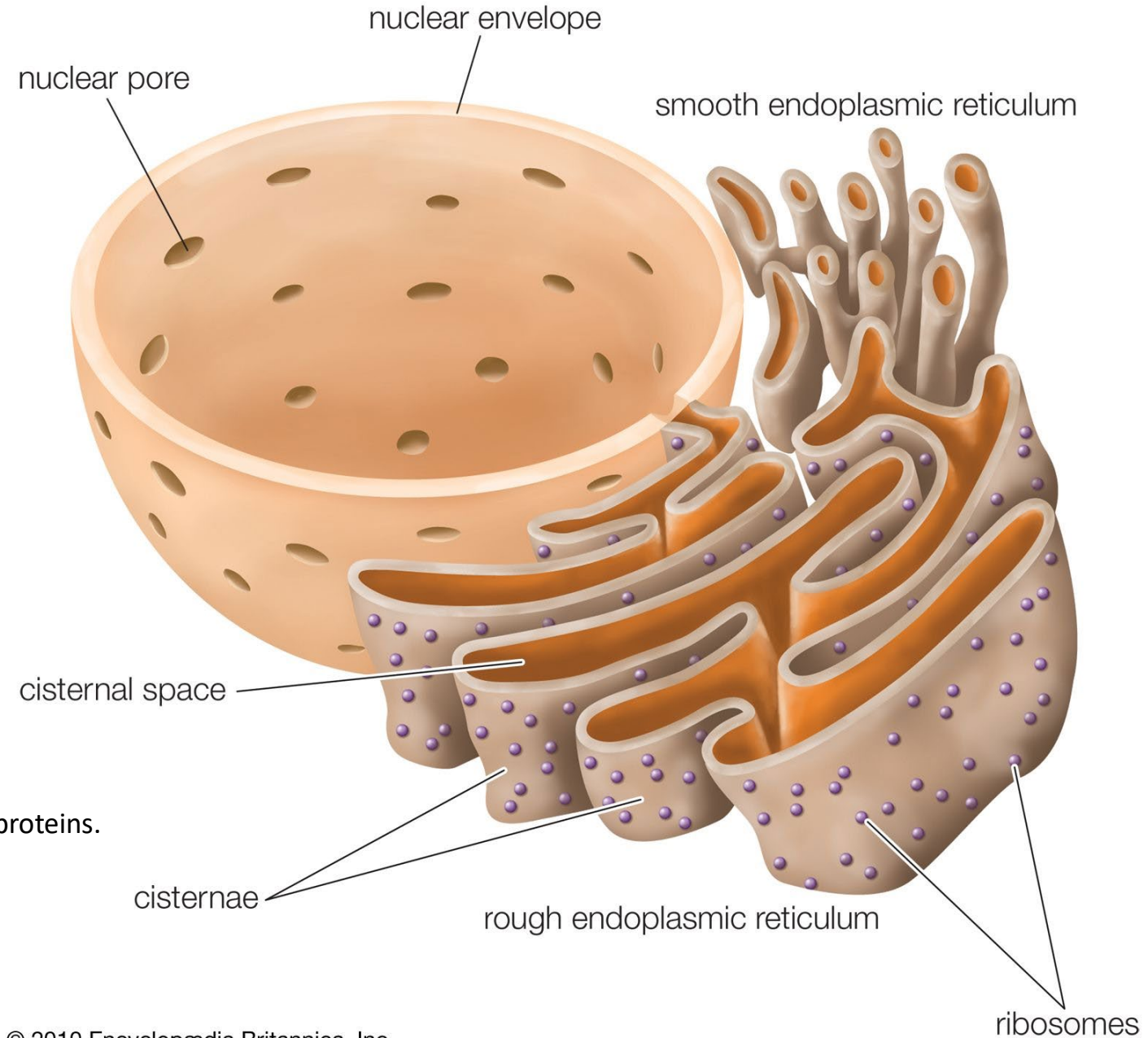
Rough Endoplasmic Reticulum (RER):

- Studded with ribosomes on its cytoplasmic surface.
- Site of protein synthesis and initial folding.
- Plays a crucial role in the synthesis of membrane-bound and secreted proteins.

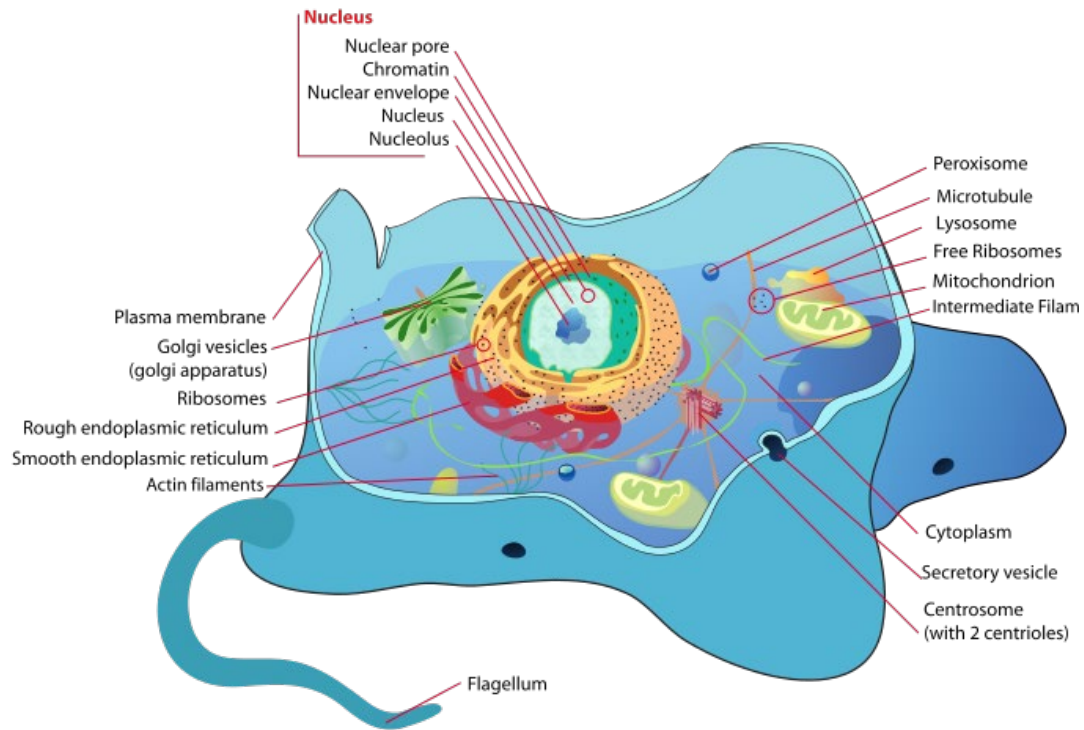
Smooth Endoplasmic Reticulum (SER):

- Lacks ribosomes on its cytoplasmic surface.
- Involved in lipid synthesis, including phospholipids and steroids.
- Detoxification processes, breaking down drugs and toxins.
- Storage of calcium ions important for cellular signaling.

Endoplasmic reticulum



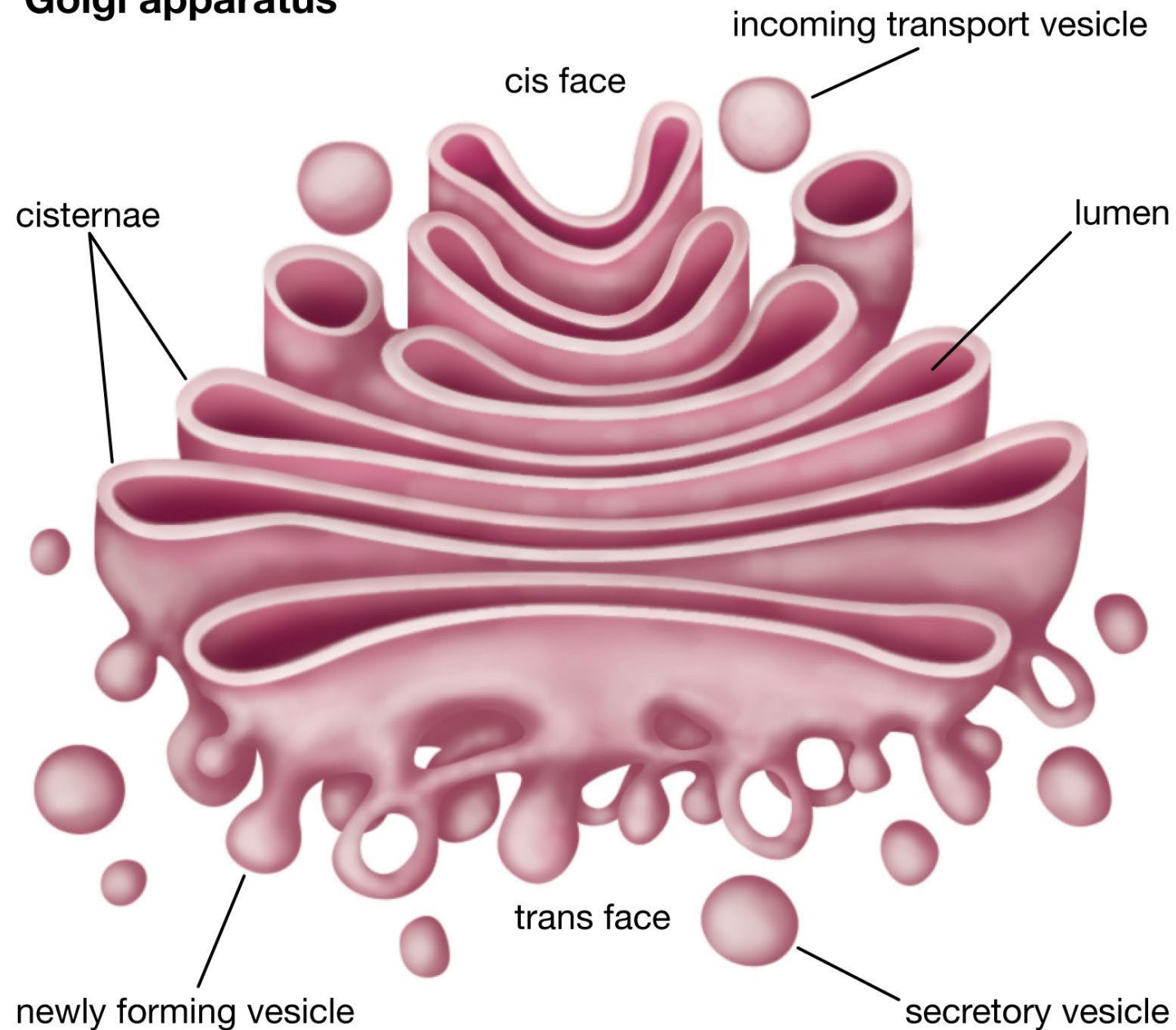
Golgi Apparatus



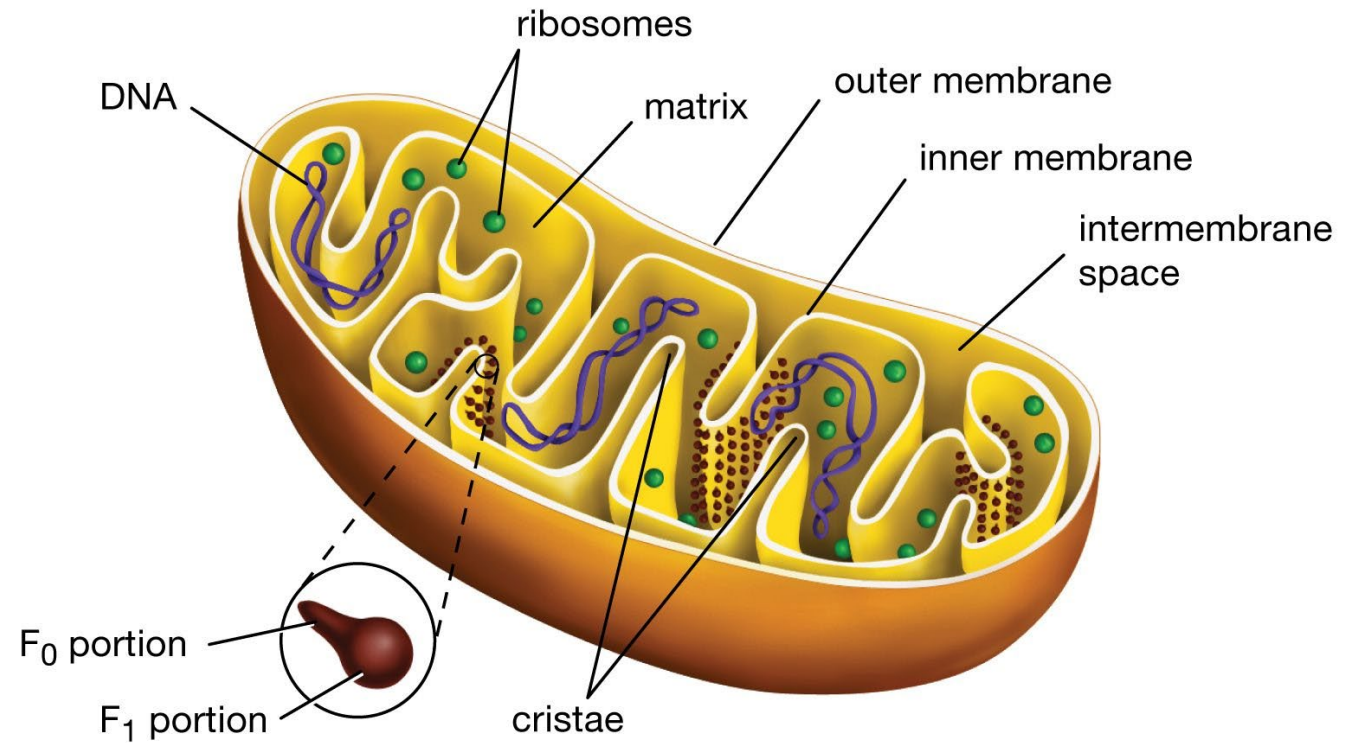
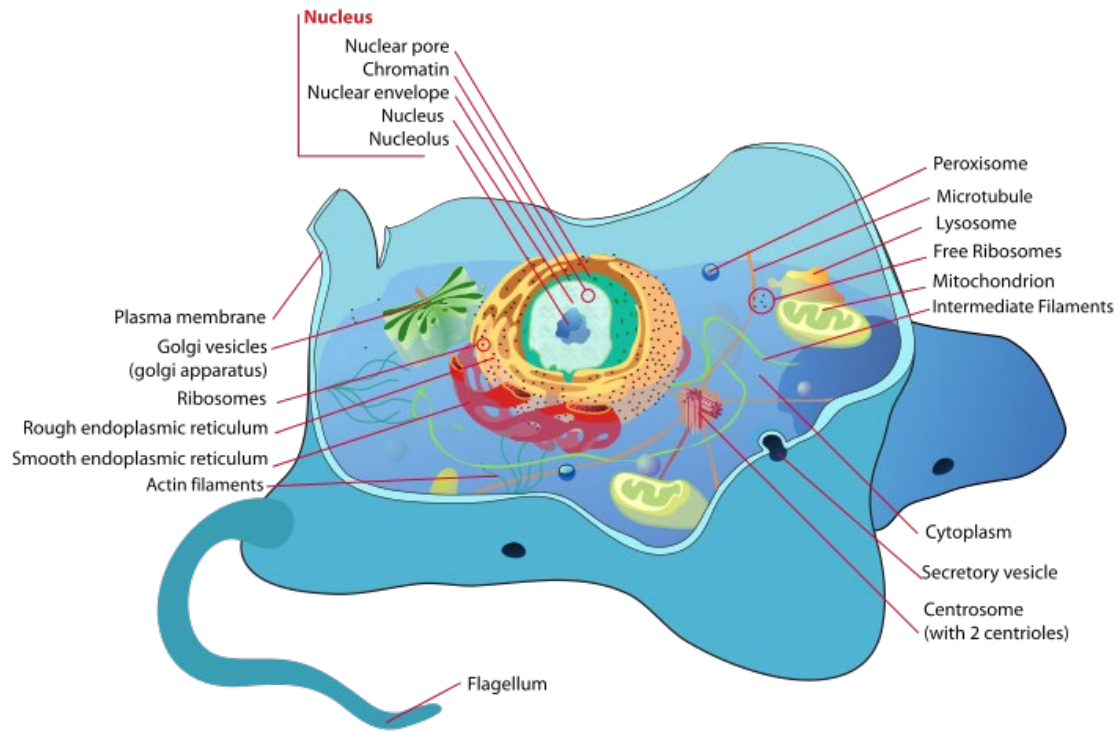
Function:

- Receives and processes proteins and lipids synthesized in the endoplasmic reticulum.
- Modifies and sorts these molecules for transport to specific cellular destinations.
- It resides at the intersection of the secretory, lysosomal, and endocytic pathways.

Golgi apparatus



Mitochondria



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ATP Production:

- Mitochondria are the primary site for ATP synthesis through oxidative phosphorylation, providing the cell with essential energy for various processes.

Cellular Respiration:

- Participates in the breakdown of glucose through cellular respiration, generating energy in the form of ATP.

Calcium Regulation:

- Regulates intracellular calcium levels, influencing signaling pathways and maintaining cellular homeostasis.

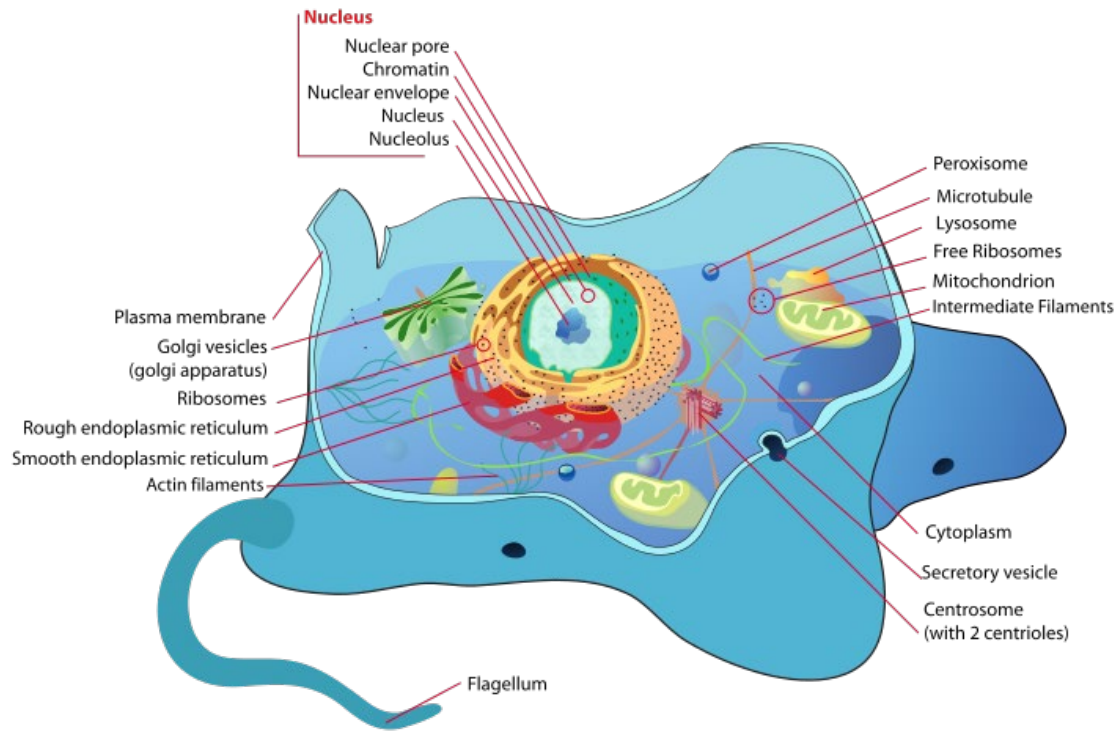
Apoptosis Control:

- Plays a role in the regulation of apoptosis (programmed cell death), contributing to cellular development, maintenance, and elimination.

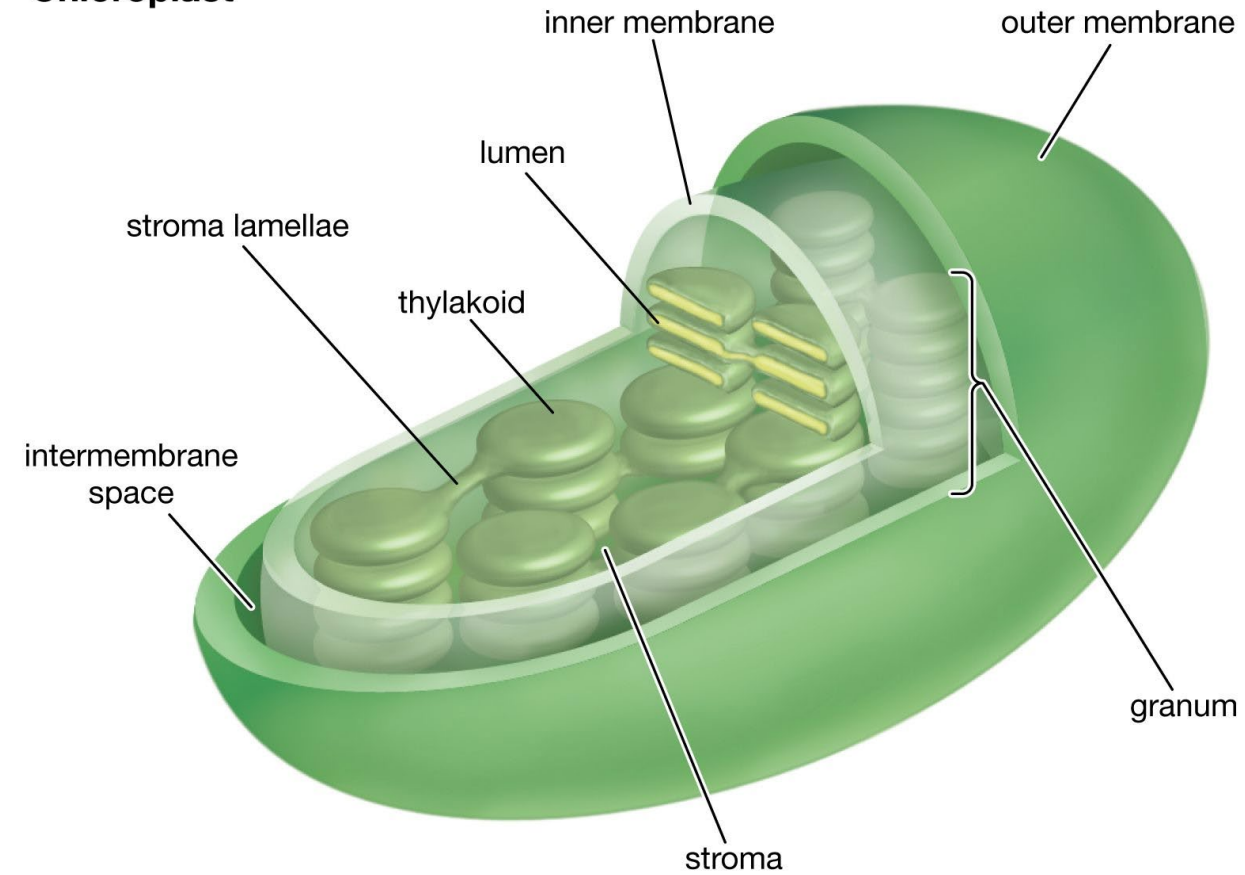
Metabolic Coordination:

- Acts as a central player in cellular metabolism, coordinating various metabolic pathways and ensuring energy balance within the cell.

Chloroplast



Chloroplast



Photosynthesis:

- Chloroplasts are the primary site for photosynthesis, converting light energy into chemical energy (glucose) in the presence of chlorophyll.

Synthesis of Organic Molecules:

- Produce organic molecules, such as glucose, through photosynthesis, providing a source of energy for plant cells.

Oxygen Production:

- Generate oxygen as a byproduct during the light-dependent reactions of photosynthesis.

Storage of Starch:

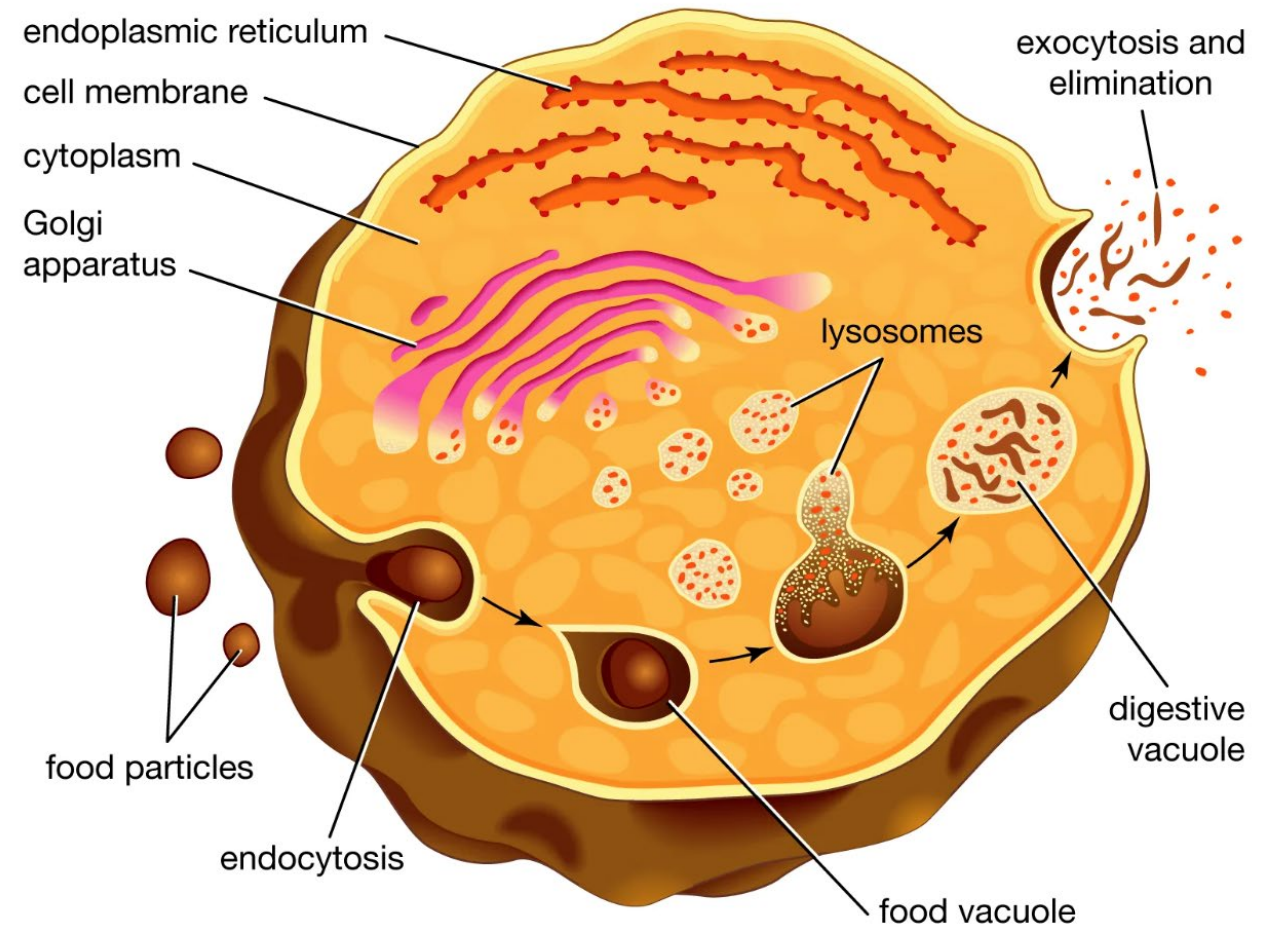
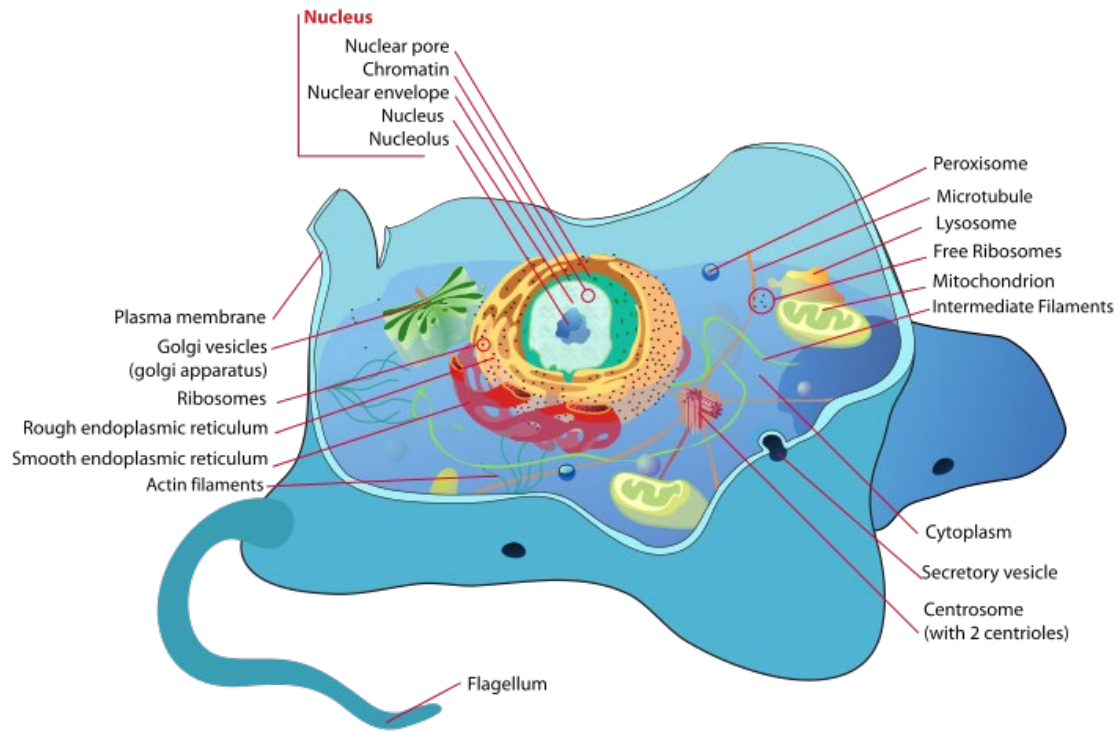
- Act as storage organelles for starch, a complex carbohydrate synthesized during photosynthesis and used for energy storage.

Pigment Containment:

- Contain pigments like chlorophyll, carotenoids, and xanthophylls, responsible for capturing light energy during photosynthesis.

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Vacuole



Storage and Maintenance:

- Vacuoles store various substances, including nutrients, ions, and waste products, helping maintain cellular homeostasis.

Detoxification:

- Vacuoles play a role in detoxifying harmful substances by isolating and containing them within the vacuolar membrane.

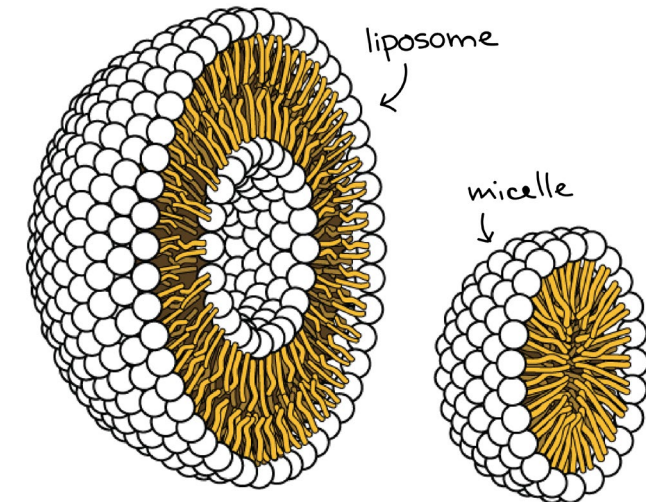
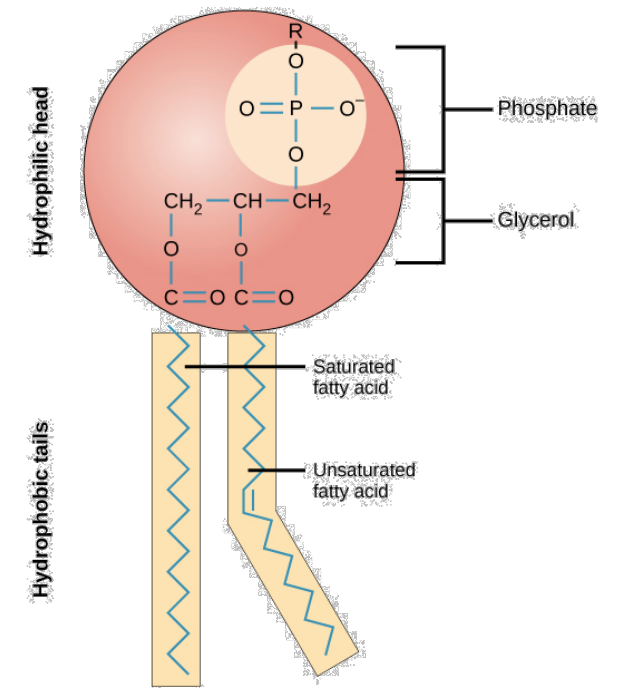
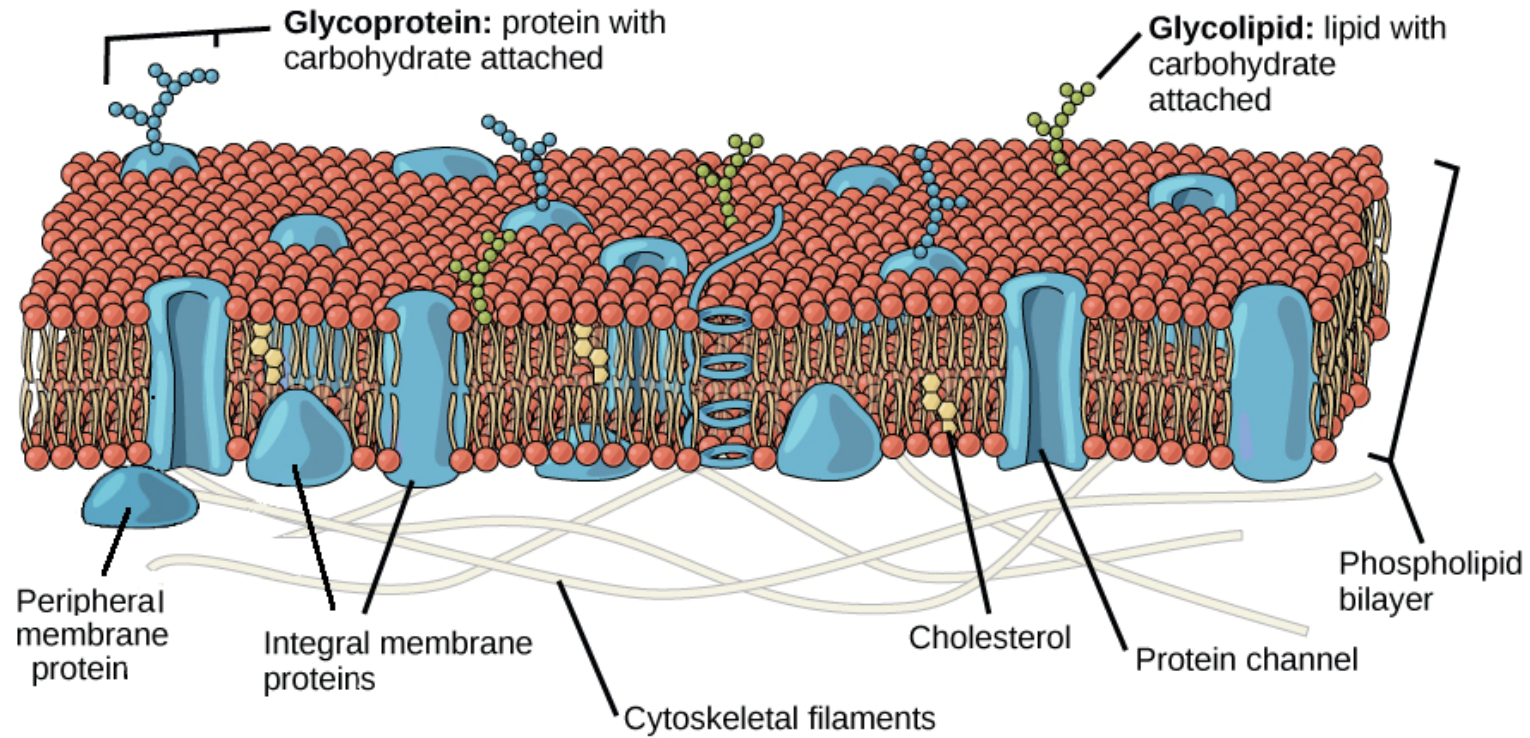
Digestion and Recycling:

- Some vacuoles function as lytic vacuoles, containing enzymes for breaking down cellular waste and recycling components.

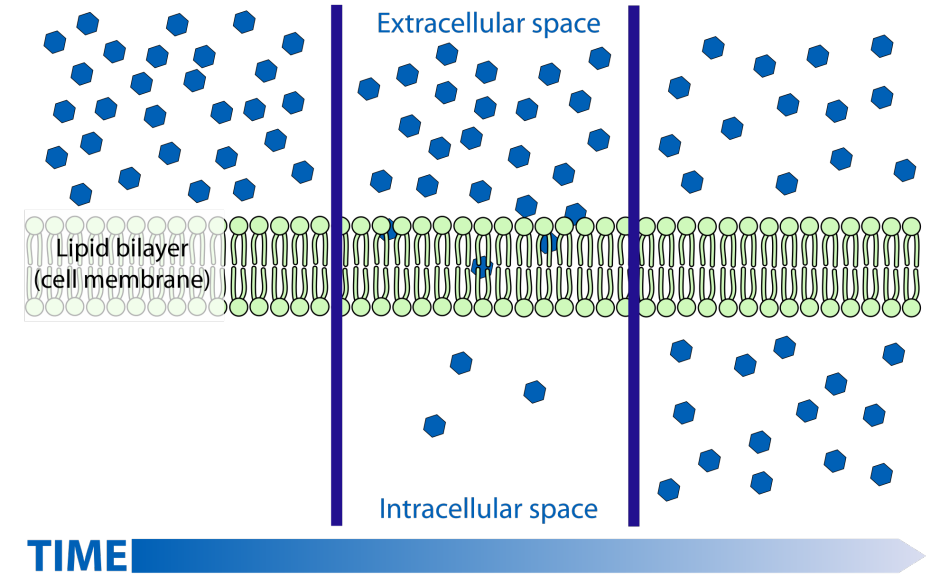
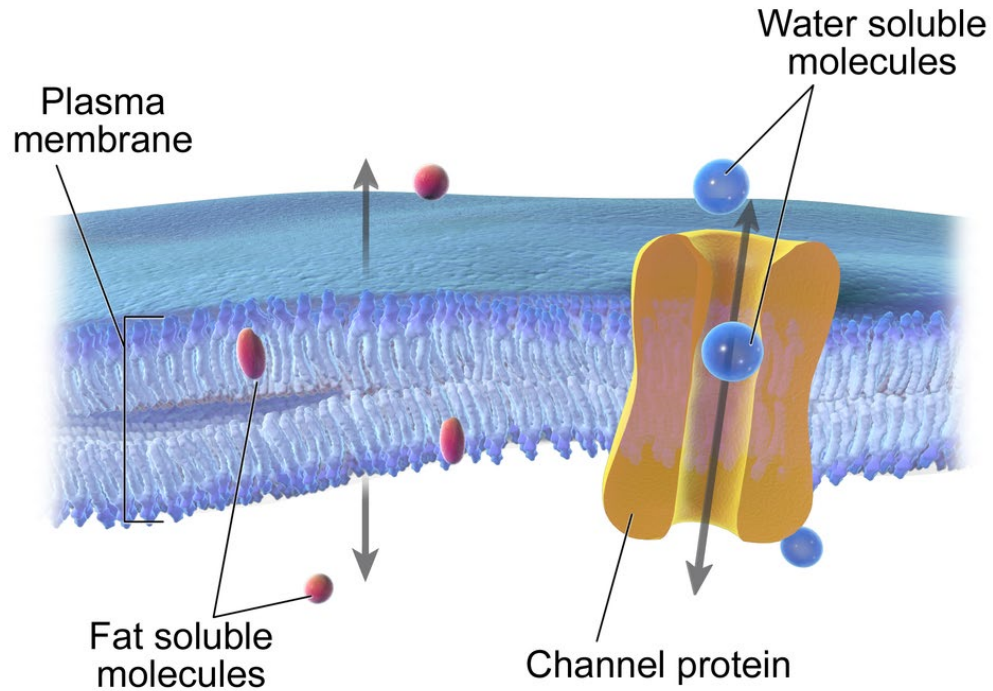
Turgor Pressure, Structural Support, Size:

- Plant cells often have large central vacuoles filled with water, contributing to turgor pressure, which helps maintain cell shape and rigidity.

Membrane Structure and Function



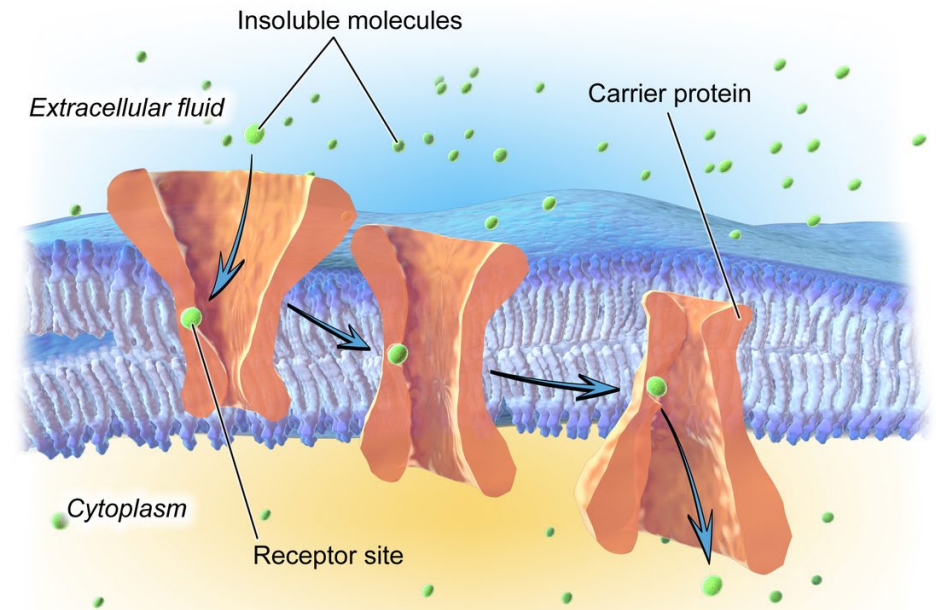
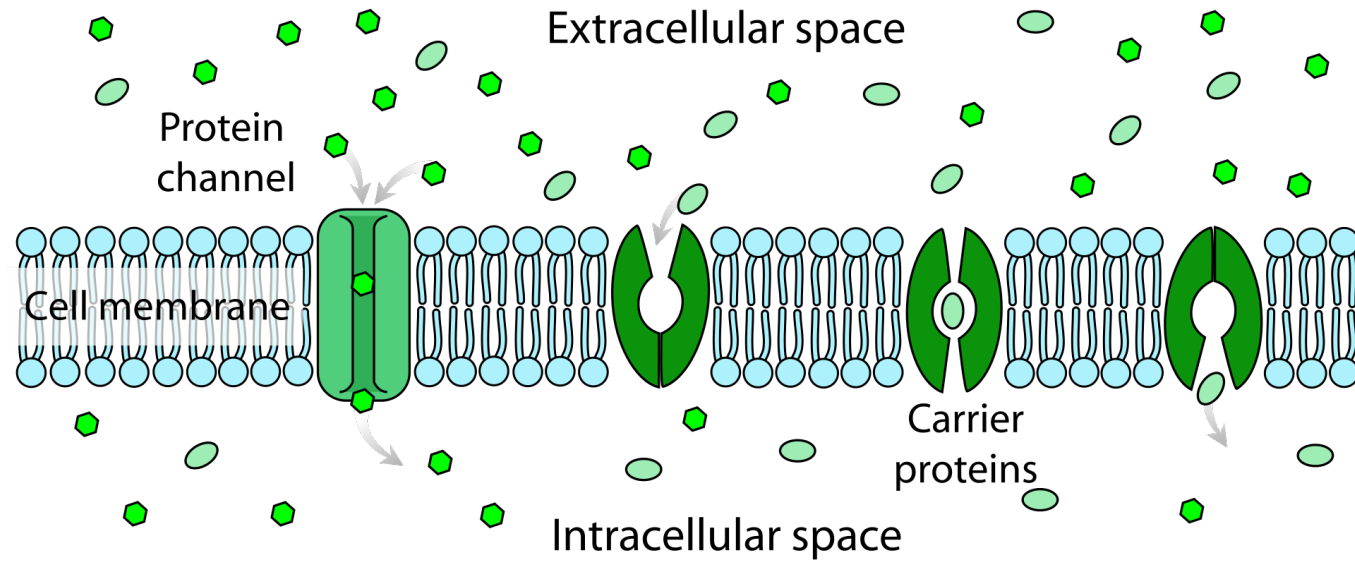
Membrane Transport: simple diffusion



Diffusion Across the Plasma Membrane

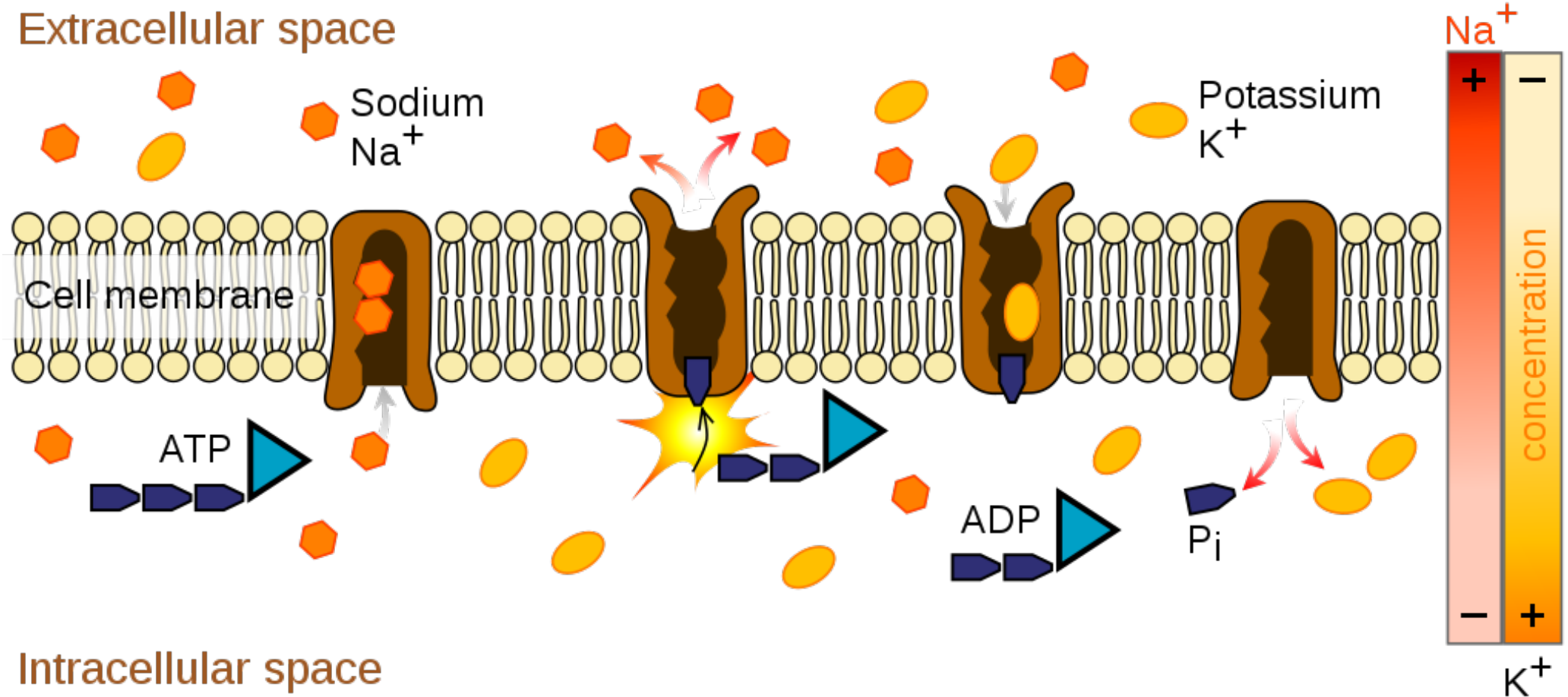
Only small, non-polar molecules, such as oxygen and carbon dioxide, can diffuse easily across the membrane.

Membrane Transport: facilitated diffusion / passive transport

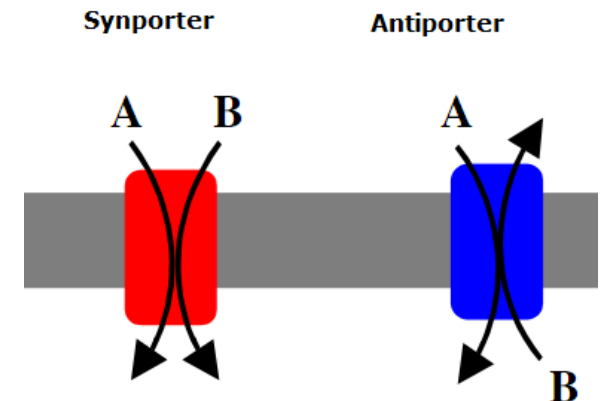
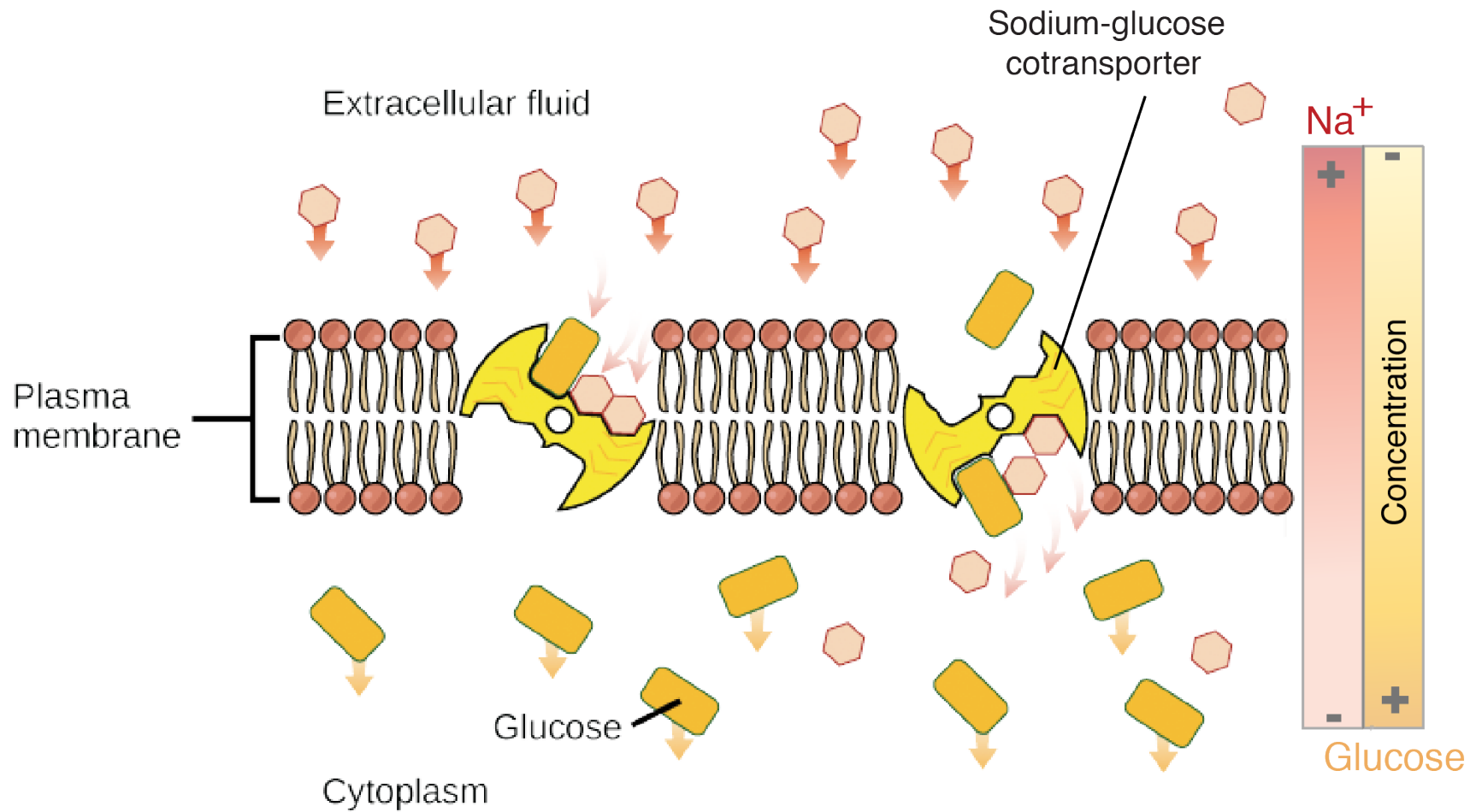


Facilitated Diffusion

Membrane Transport: primary active transport



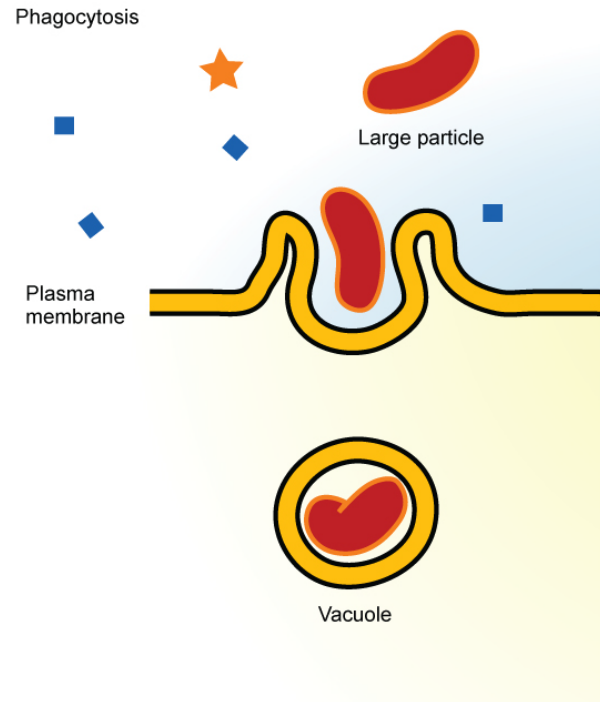
Membrane Transport: secondary active transport



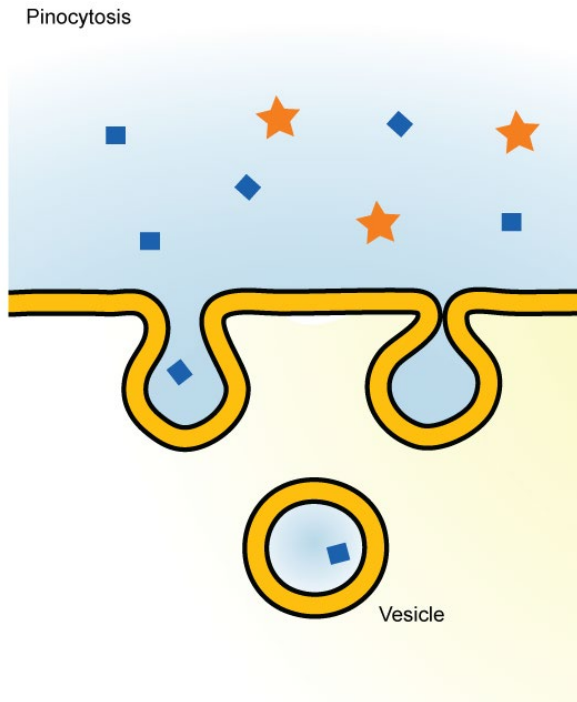
Membrane Transport: bulk transport

Endocytosis

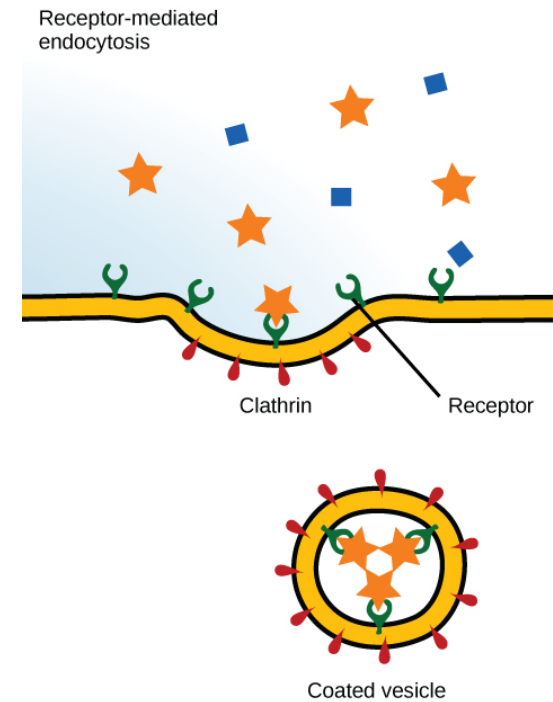
Phagocytosis



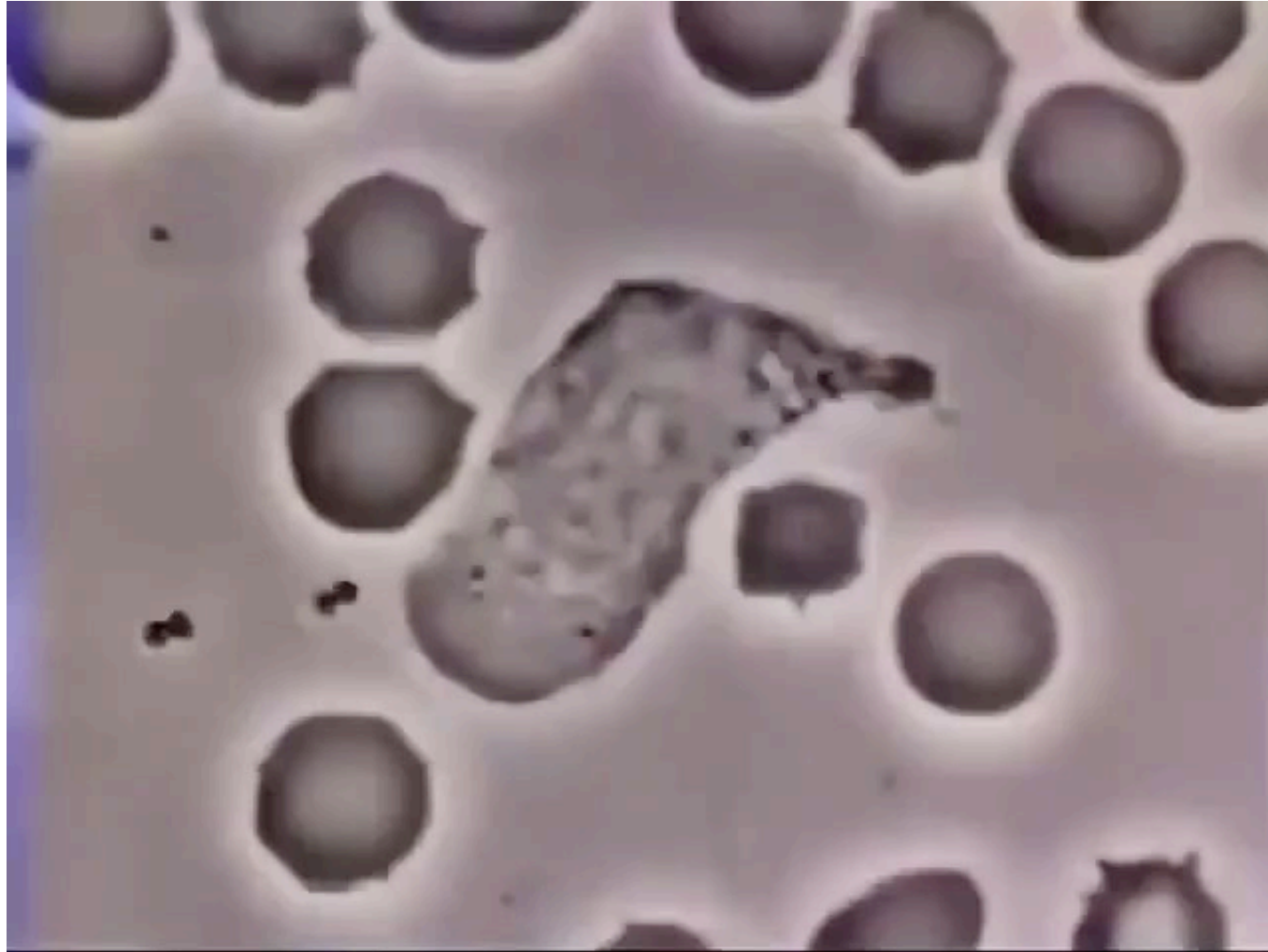
Pinocytosis



Receptor-mediated

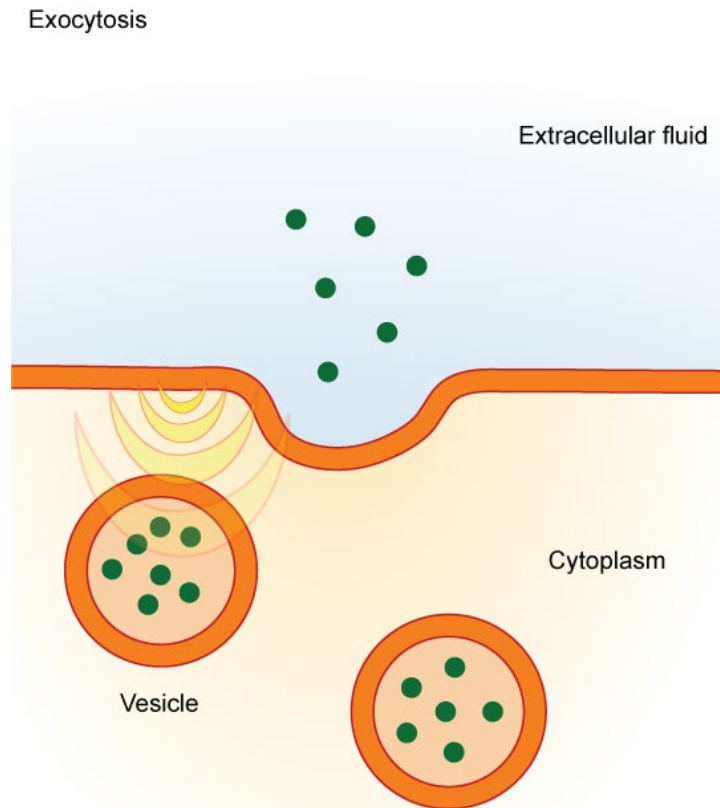


Membrane Transport: bulk transport



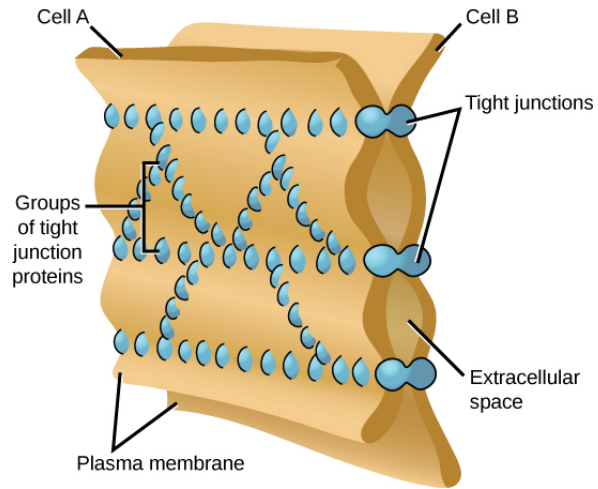
Membrane Transport: bulk transport

Exocytosis



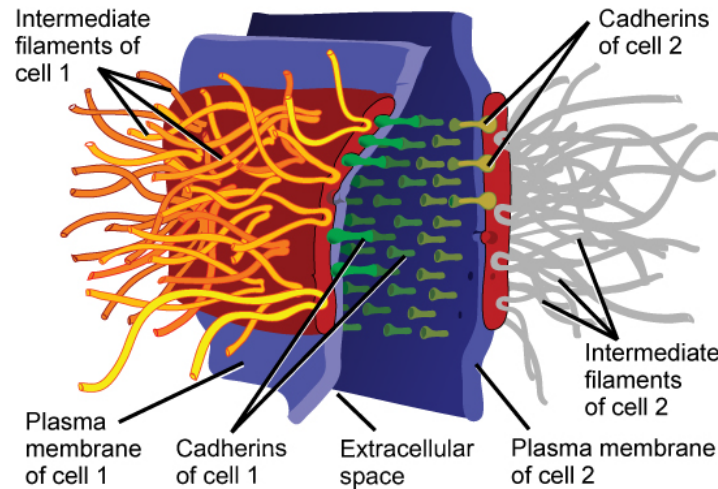
Cell – cell interactions

Tight Junctions



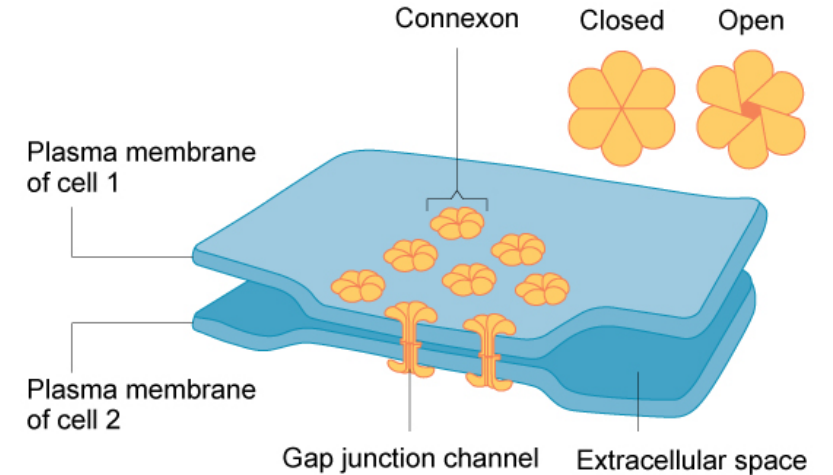
A **tight junction** is a watertight seal between two adjacent animal cells. The cells are held tightly against each other by proteins (predominantly two proteins called claudins and occludins).

Desmosomes



Desmosomes act like spot welds between adjacent epithelial cells. Short proteins called cadherins in the plasma membrane connect to intermediate filaments to create desmosomes. The cadherins join two adjacent cells together and maintain the cells in a sheet-like formation in organs and tissues that stretch, like the skin, heart, and muscles.

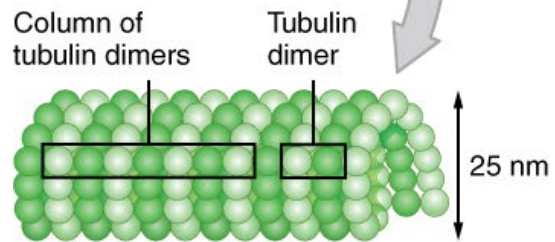
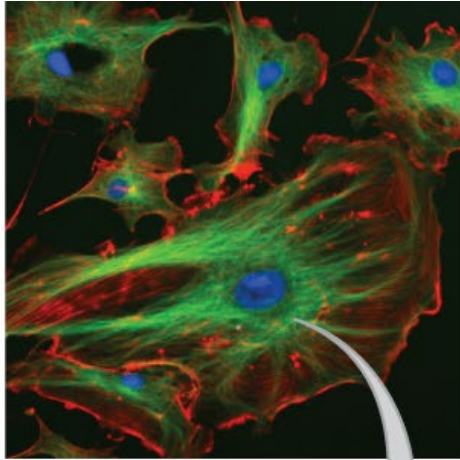
Gap Junctions



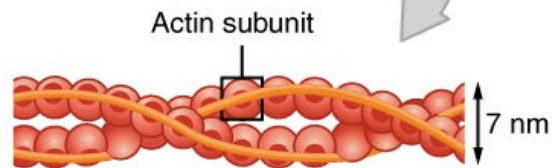
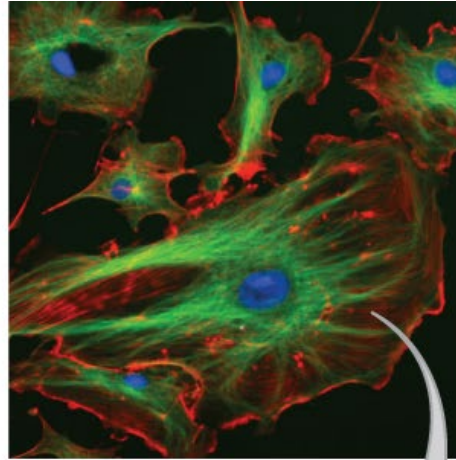
Gap junctions in animal cells are channels between adjacent cells that allow for the transport of ions, nutrients, and other substances that enable cells to communicate.

Cytoskeleton

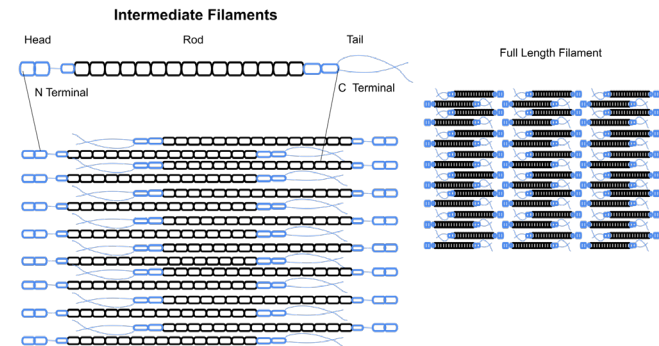
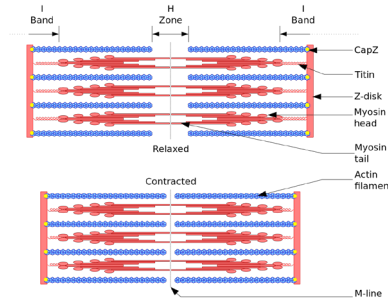
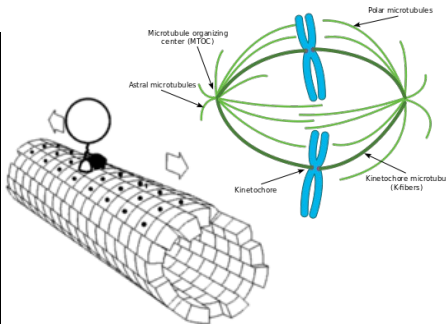
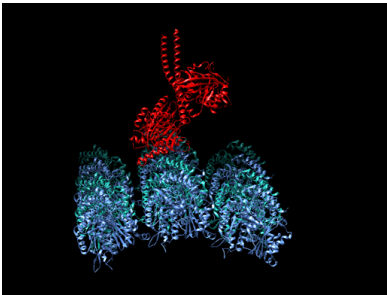
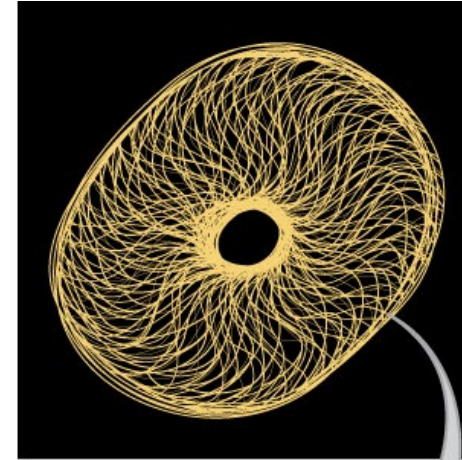
Microtubules



Microfilaments

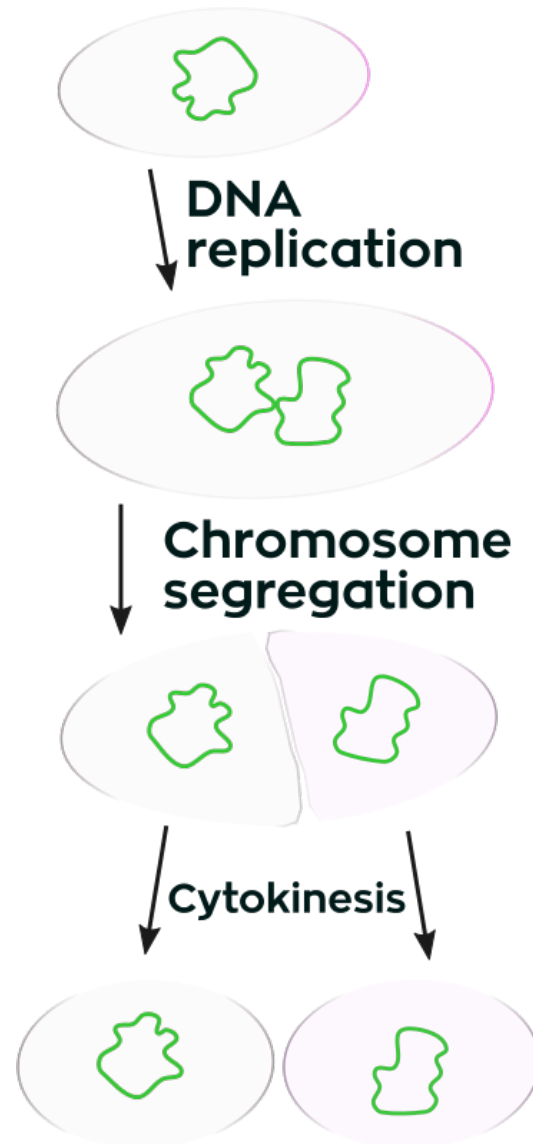


Intermediate Filaments

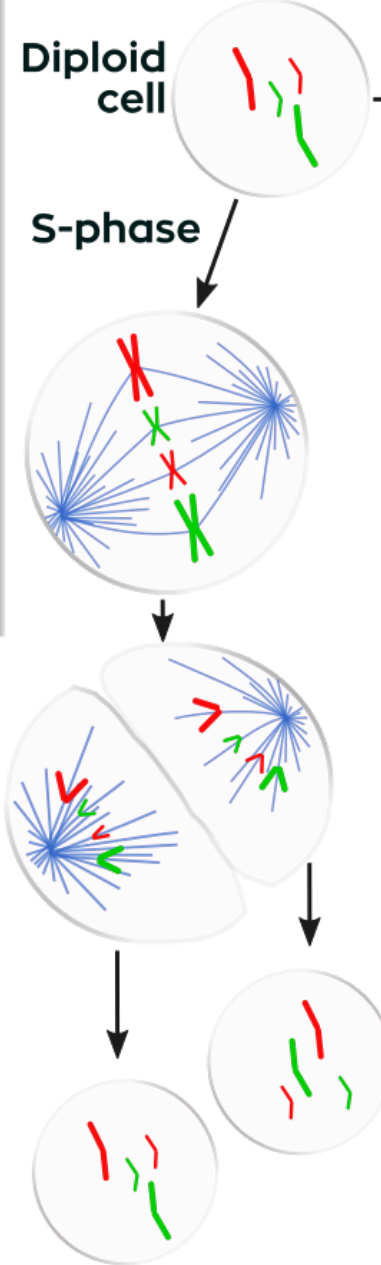


Cell Division

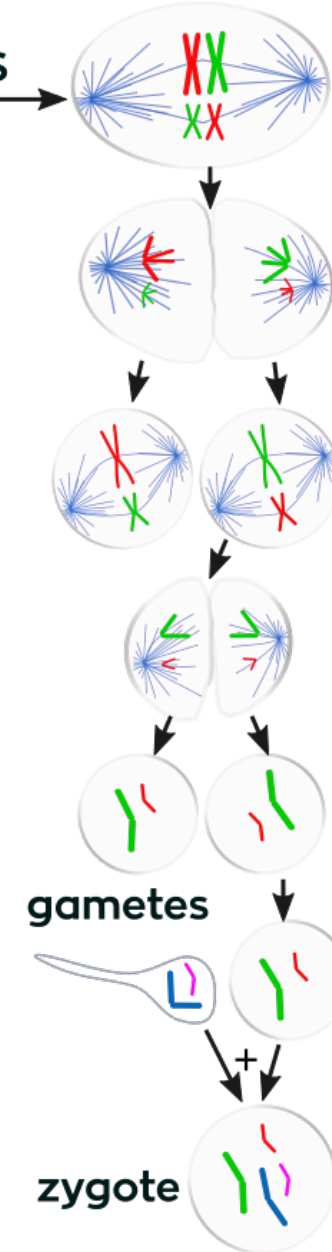
Binary fission



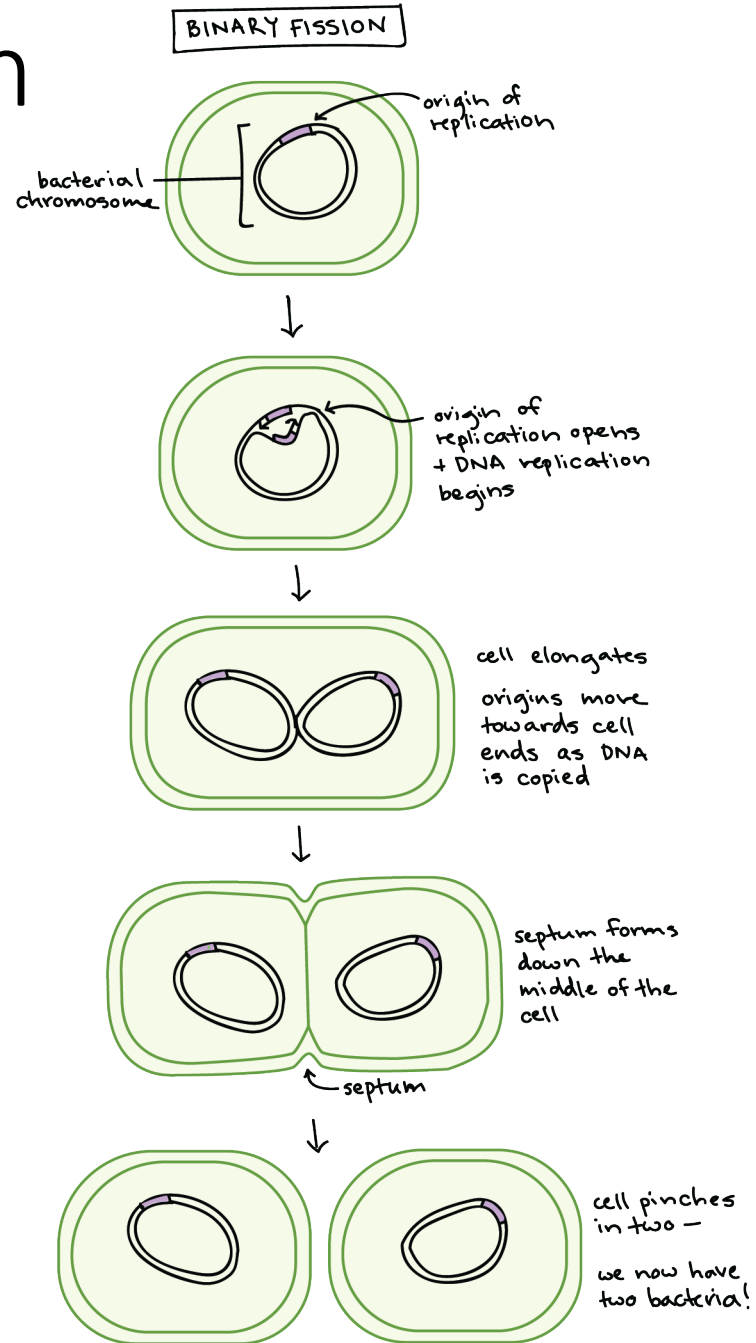
Mitosis



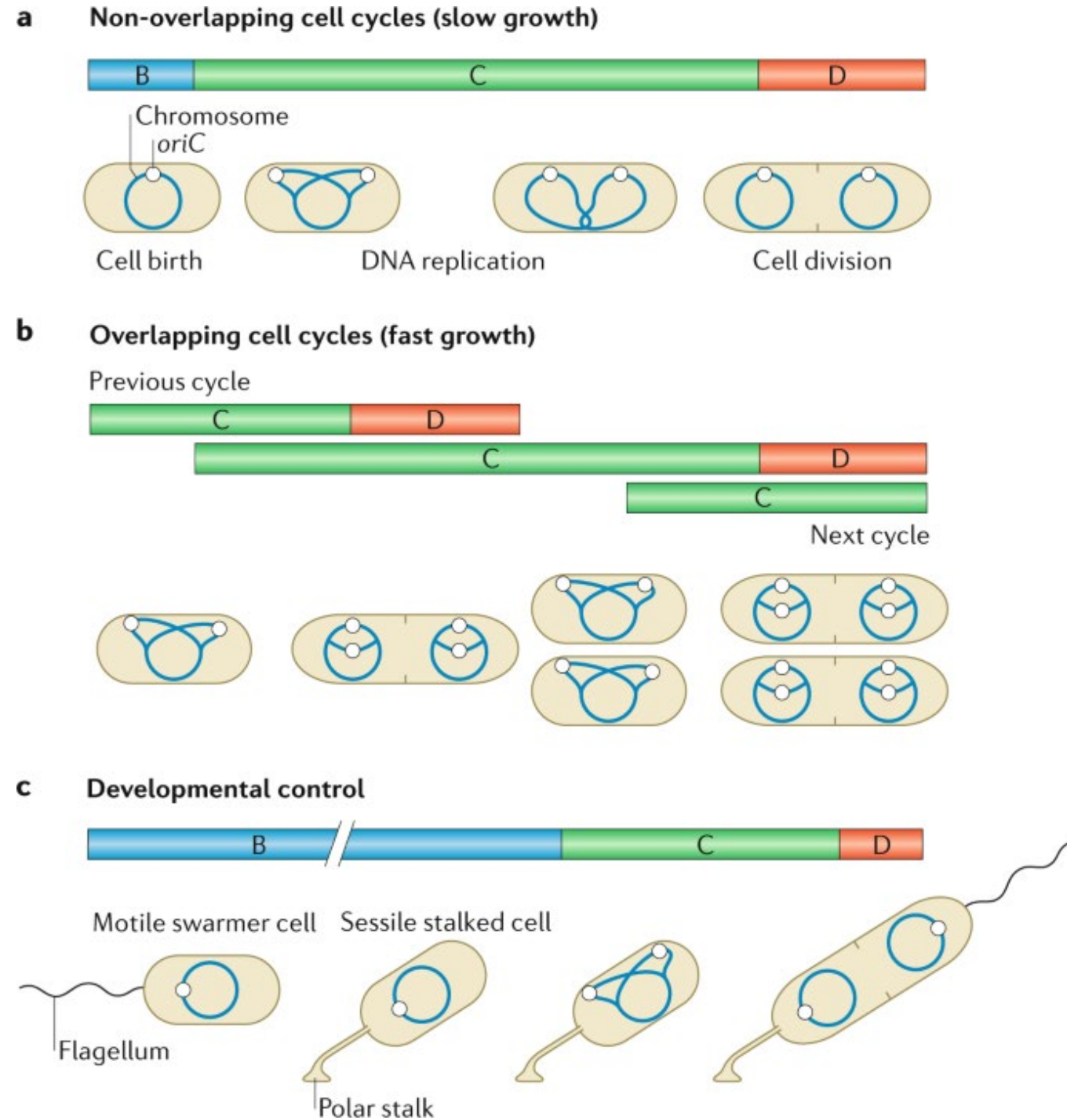
Meiosis



Bacterial Cell Division



Bacterial Cell Division



Eukaryotic Cell Division

The Cell Cycle

Interphase

The cell grows and copies its DNA

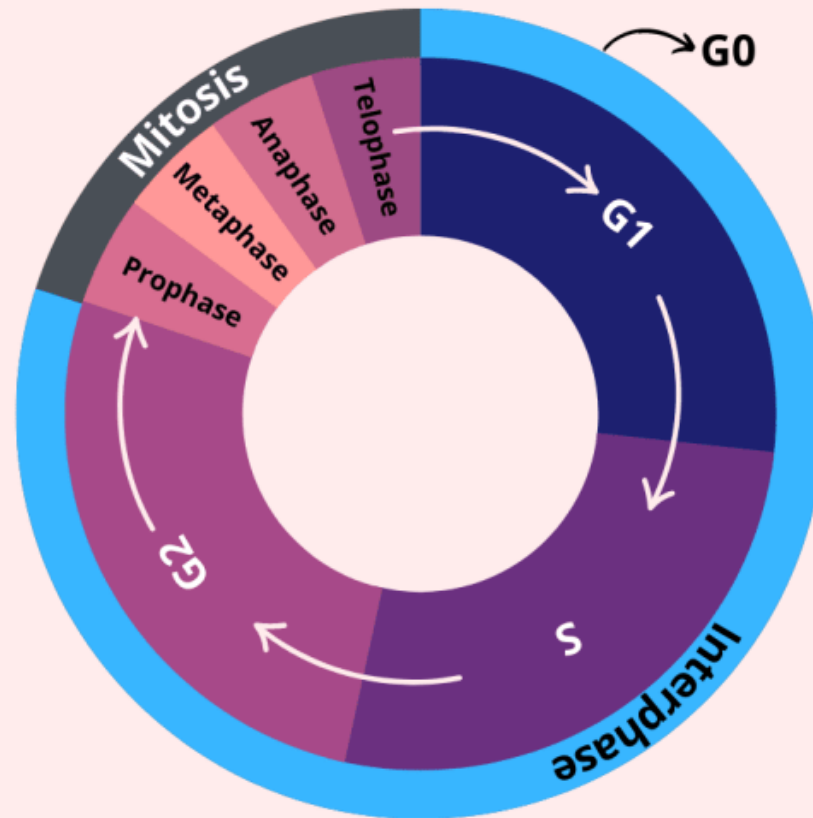
- **G₁**: Cell growth
- **S**: DNA synthesis
- **G₂**: More growth, preparation for mitosis

Mitosis

The cell divides its DNA and cytoplasm, forming two new cells

- **Prophase**
- **Metaphase**
- **Anaphase**
- **Telophase**

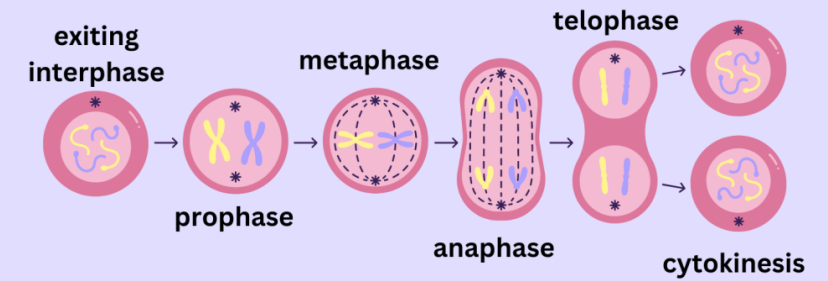
G₀: Resting state where the cell performs its functions and is not preparing to divide



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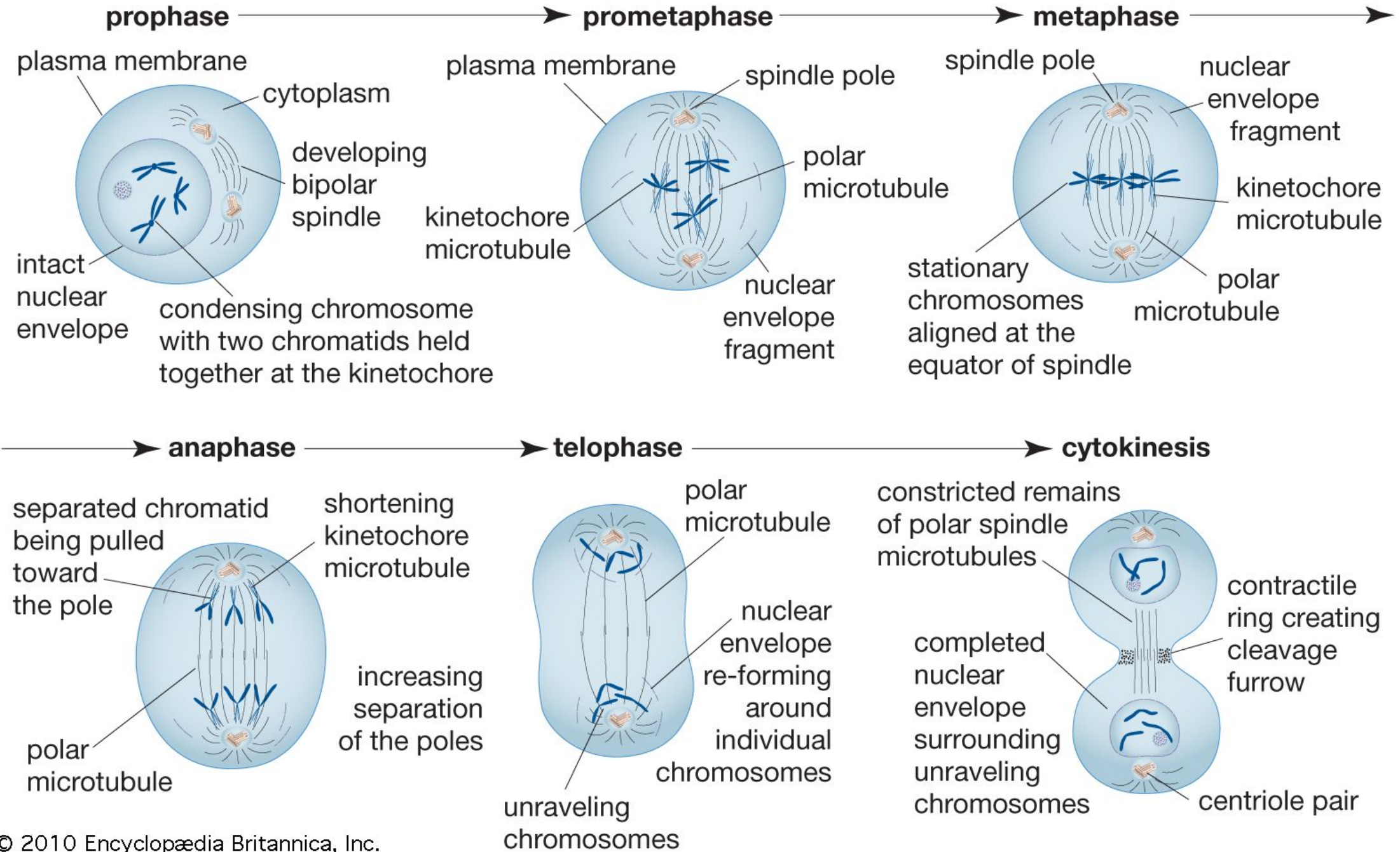
Mitosis

Mitosis is the division of the nucleus and cytoplasm so that a single cell forms two identical daughter cells.



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Mitosis, or somatic cell division



Cell Division

