Big Idea 1: The process of evolution drives the diversity and unity of life.

Enduring understanding 1.B: Organisms are linked by lines of descent from common ancestry.

Essential knowledge 1.B.1: Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today.

a. Structural and functional evidence supports the relatedness of all domains.

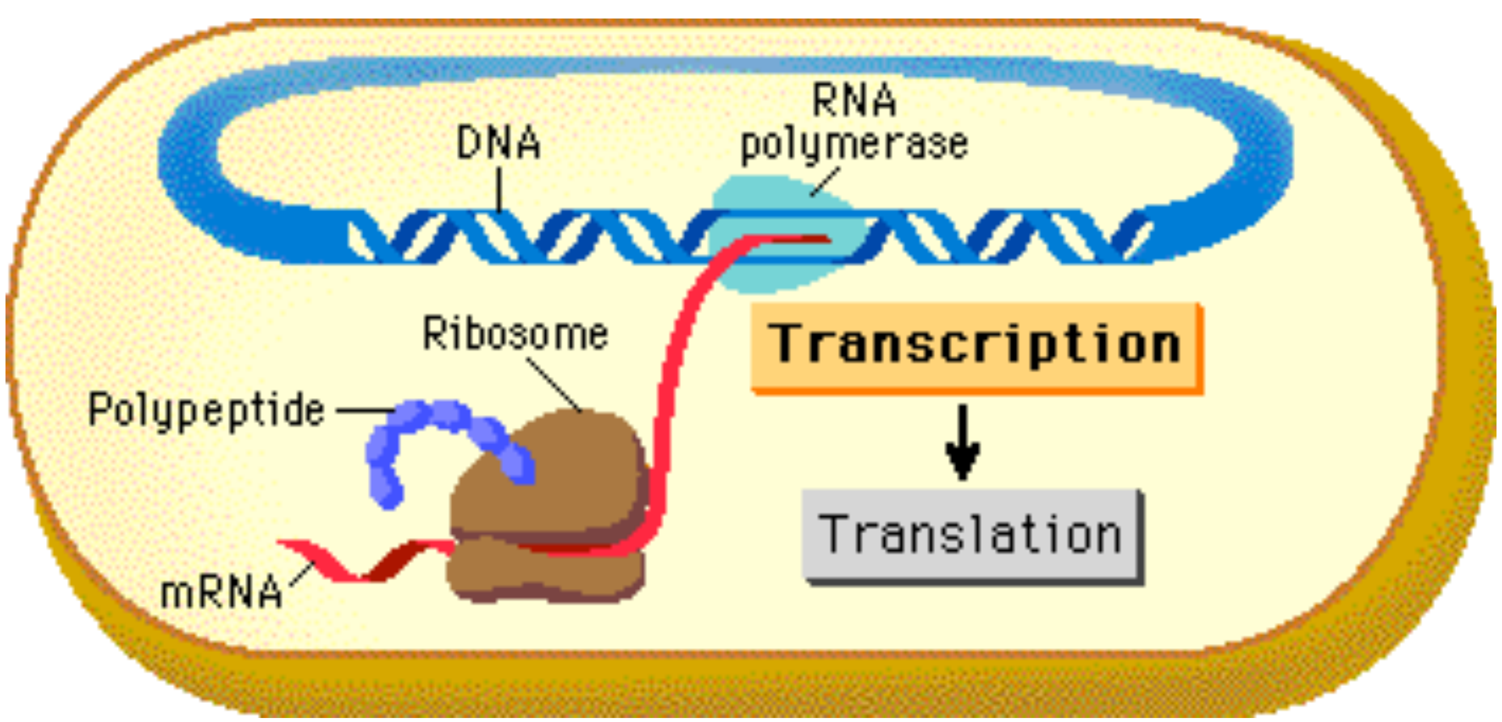
Evidence of student learning is a demonstrated understanding of each of the following:

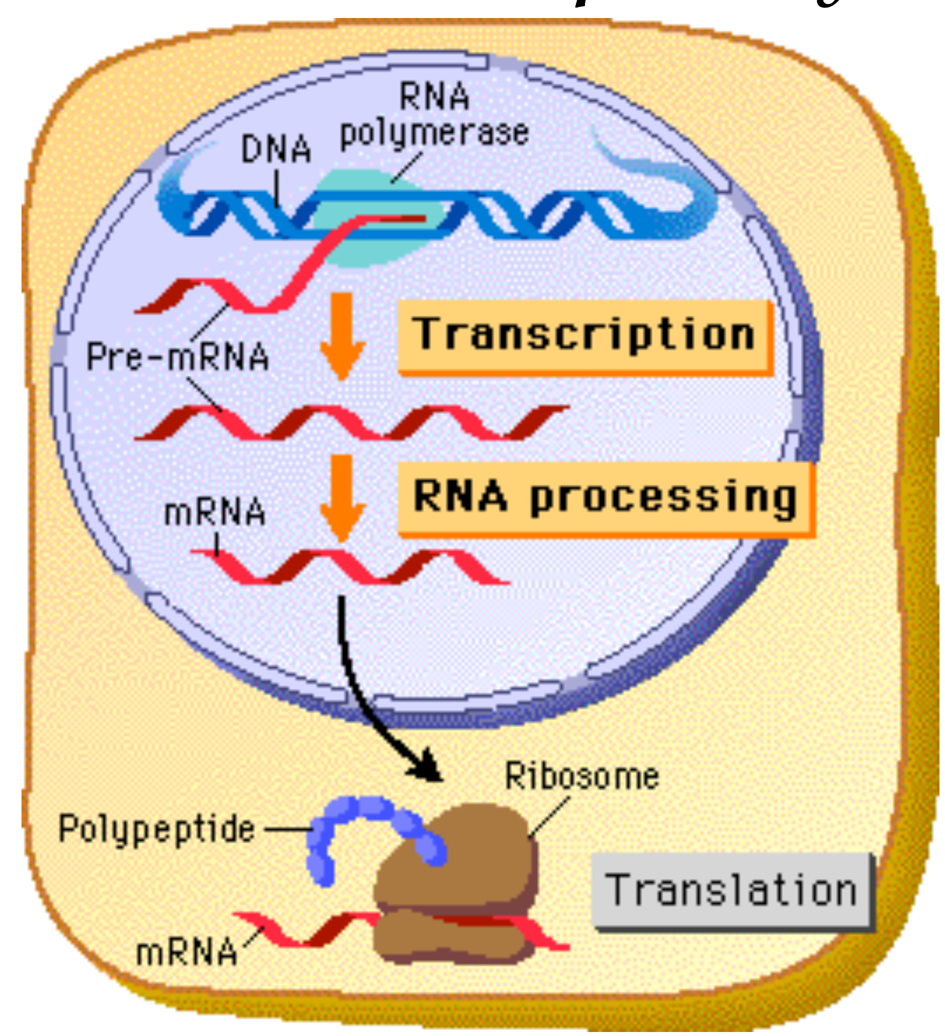
1. DNA and RNA are carriers of genetic information through transcription, translation and replication. [See also **3.A.1**]
2. Major features of the genetic code are shared by all modern living systems. [See also **3.A.1**]

The Central Dogma

DNA → RNA → Protein

- **Transcription & Translation occurs in every organism.**
  - ***The mechanics are the same or very similar in all cells***
  - ***However, one very important difference exists between prokaryotes and eukaryotes***





Protein Synthesis (The Basics)

- The flow of genetic information involves two processes.
  - ***Transcription*, the synthesis of RNA using info stored in the DNA**
    - DNA serves as a template for mRNA
    - Their forms differ but their language is the same
  - ***Translation*, is the building of a polypeptide using the info stored in mRNA**
    - The language differs between nucleic acids and proteins
    - The cell must translate a nucleotide sequence into an amino acid sequence of the polypeptide

The Genetic Code

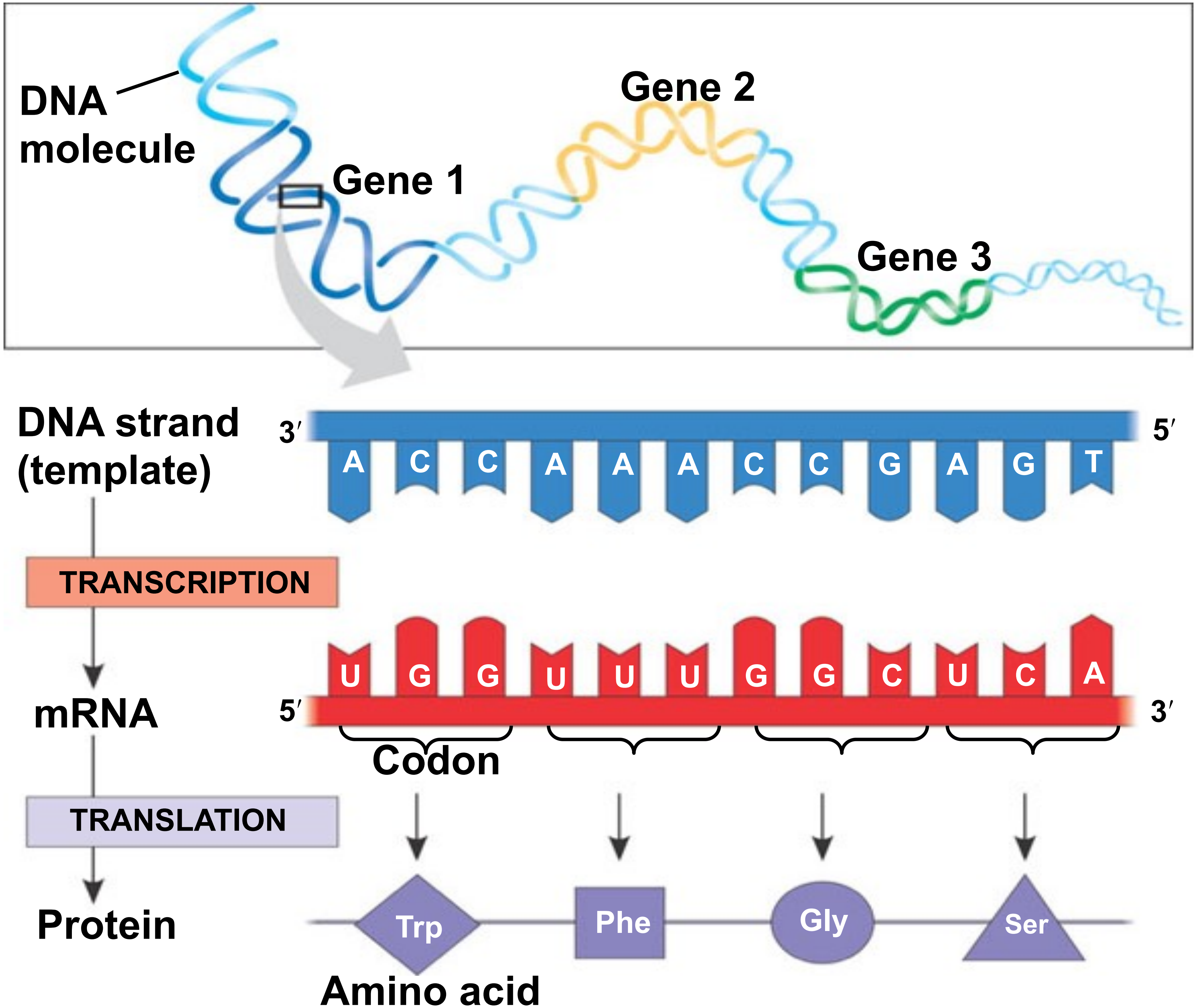
- We know that the language of life (nucleic acids) is written in a ***<u>triplet code</u>***.

- ***DNA uses three non-overlapping nucleotides to code for three non-overlapping nucleotides (codons) of mRNA which in turn codes for a single amino acid.***

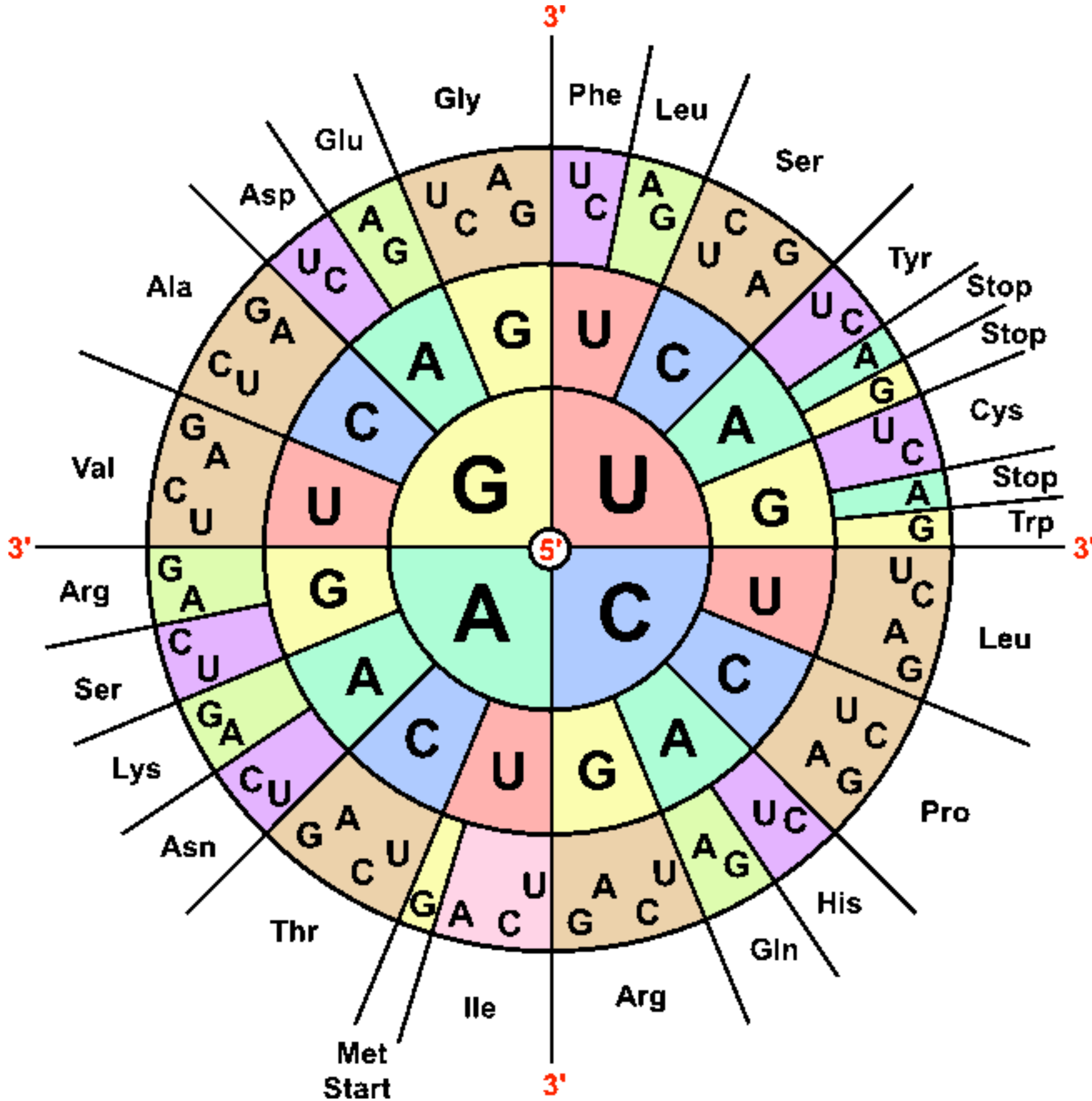
Second Position

First Position	U		C		A		G		Third Position
U	UUU	Phe / F	UCU	Ser / S	UAU	Tyr / Y	UGU	Cys / C	U
	UUC		UCC		UAC		UGC		C
	UUA	Leu / L	UCA		UAA	STOP	UGA	STOP	A
	UUG		UCG		UAG	STOP	UGG	Trp / W	G
C	CUU	Leu / L	CCU	Pro / P	CAU	His / H	CGU	Arg / R	U
	CUC		CCC		CAC		CGC		C
	CUA		CCA		CAA	Gln / Q	CGA		A
	CUG		CCG		CAG		CGG		G
A	AUU	Ile / I	ACU	Thr / T	AAU	Asn / N	AGU	Ser / S	U
	AUC		ACC		AAC		AGC		C
	AUA		ACA		AAA	Lys / K	AGA	Arg / R	A
	AUG	Met / M	ACG		AAG		AGG		G
G	GUU	Val / V	GCU	Ala / A	GAU	Asp / D	GGU	Gly / G	U
	GUC		GCC		GAC		GGC		C
	GUA		GCA		GAA	Glu / E	GGA		A
	GUG		GCG		GAG		GGG		G

The Genetic Code



Another Amino Acid Look Up Table



Recall The Genetic Code

- The genetic code has some noteworthy characteristics.
  - **Redundancy**
    - AGU = serine, AGC = serine, multiple codons exist for the same amino acid
  - **No Ambiguity**
    - AGU = serine, any codon always codes for the same amino acid, it never changes
  - **Universal* (nearly)**
    - This code is identical from bacteria to blue whales!

*A shared genetic code supports the idea common ancestry among all living organisms

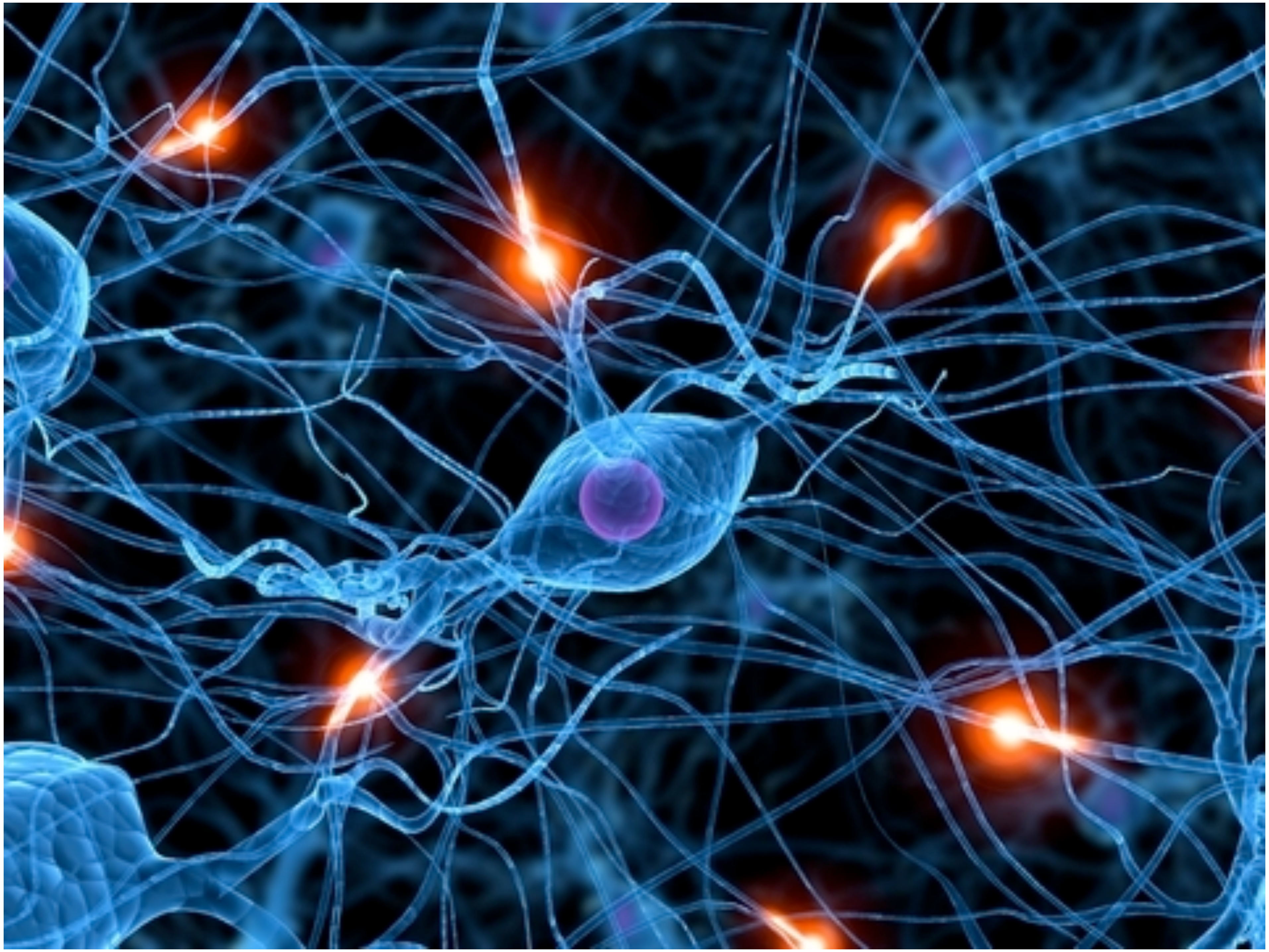
Essential knowledge 1.B.1: Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today.

a. Structural and functional evidence supports the relatedness of all domains.

Evidence of student learning is a demonstrated understanding of each of the following:

3. Metabolic pathways are conserved across all currently recognized domains. [See also **3.D.1**]

Cell Communication



PREFACE

- You will recall that *Sensing* and consequently *Responding* to the environment is an essential function of living organisms...**Cell to Cell Communication** underlies this essential function!
- We will focus on those *universal* mechanisms of **Cellular Communication**.
- Evidence suggests that **Cell Communication** *evolved in early* in earth's history because so many diverse organisms share universal mechanisms and signaling molecules.
- Although cells can sense and respond to variety of stimuli, we will focus on **Cellular Communication** that involves *chemical messaging* between cells.

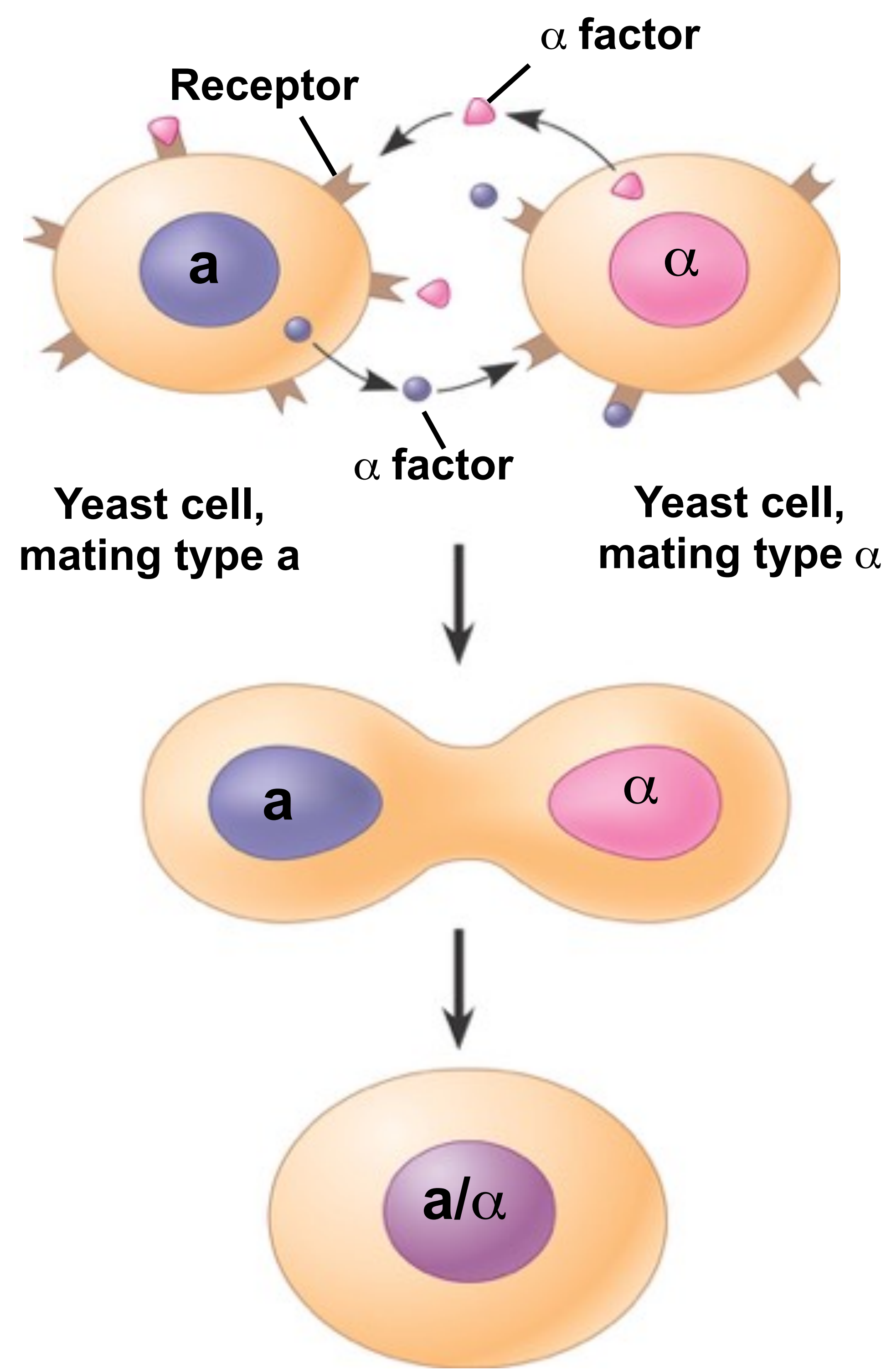
- Yeasts identify their mates through cell signaling
    - Turns out this mechanism is very similar to mechanisms in eukaryotic animal cells

The similarities in the signal transduction pathway can be explained through common ancestry, but the common ancestor of yeast and animals dates back to over a billion years ago.

1. **Exchange of mating factors.** Each cell type secretes a mating factor that binds to receptors on the other cell type.

2. **Mating.** Binding of the factors to receptors induces changes in the cells that lead to their fusion.

3. **New a/α cell.** The nucleus of the fused cell includes all the genes from the a and a cells.



- Recently biologists have uncovered very similar to mechanisms between bacteria and plant cells.
  - Some evidence suggests that cell communication first evolved in ancient bacteria and then later organisms adopted these mechanisms for multicellular benefits.
  - In fact cell signaling remains important to bacteria even today.
    - ***Quorum sensing***, bacteria sense chemicals signals, bacteria in turn can monitor their density, this allows bacteria to alter behavior and synchronize their actions.
      - ***Biofilms***, is such an aggregation of cells where they stick to a surface and derive nutrition from it.

Cell Respiration

Main Idea: The first step in cell respiration (catabolism of glucose) is to simply cut the 6 carbon glucose into two 3 carbon products. This is step is shared by all living organisms today.

PREFACE

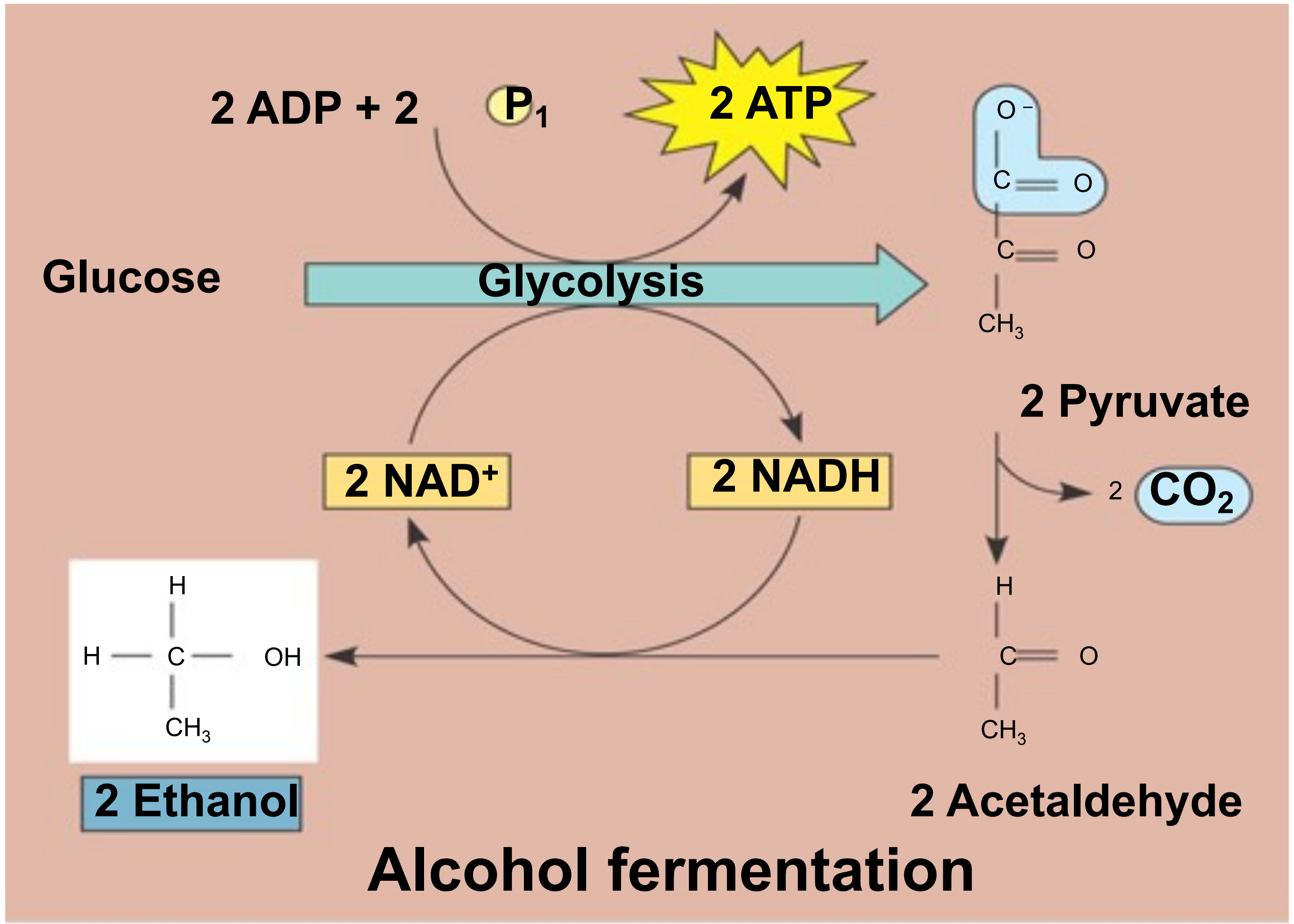
- Cellular processes require energy.
- ATP is the cellular energy choice (fuel) that powers cell processes.
- Cell respiration is the process that transfers the chemical bond energy of large organic compounds into the chemical bonds of ATP.
- Photosynthesis builds these large organic molecules using CO2 as building blocks and solar radiation as the energy source.
- The sun is the ultimate source of energy that powers cellular work.

The Evolution of Glycolysis

- Glycolysis is likely the most ancient and most common way to produce ATP.
  - The cytosolic location implies antiquity
  - The fact that no oxygen is required implies antiquity
  - The fact that no membrane is required also implies antiquity
  - And finally that the fact that it is found in virtually every cell also implies antiquity

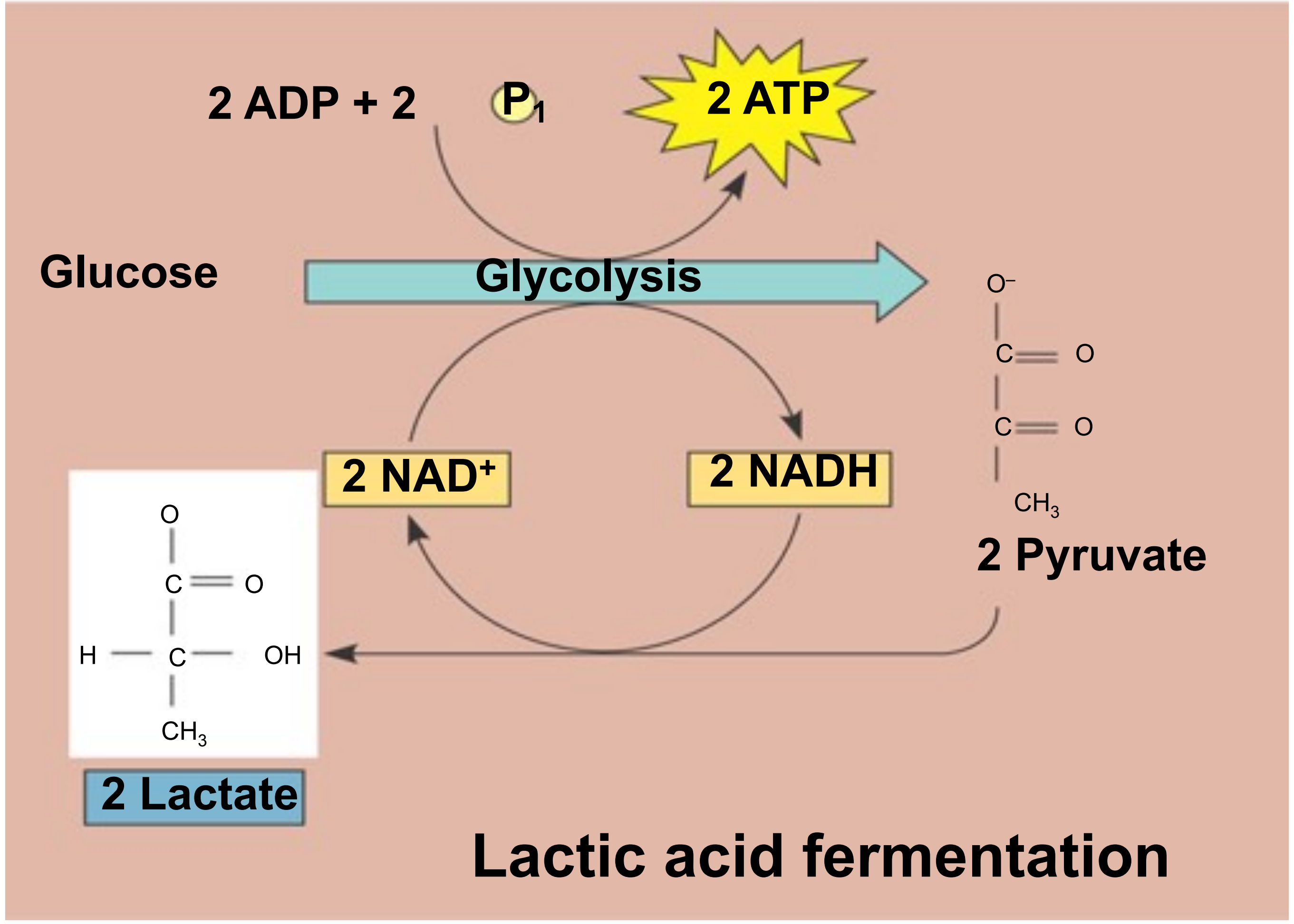
Two Types of Fermentation

Many bacteria and yeasts use this alcohol fermentation in anaerobic conditions, they are used in brewing and baking



Bacteria and fungi that use this lactic fermentation are used in the dairy industry to make cheeses and yogurts

**also used by muscle cells but will discuss later*



Essential knowledge 1.B.1: Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today.

b. Structural evidence supports the relatedness of all eukaryotes.
[See also **2.B.3**, **4.A.2**]

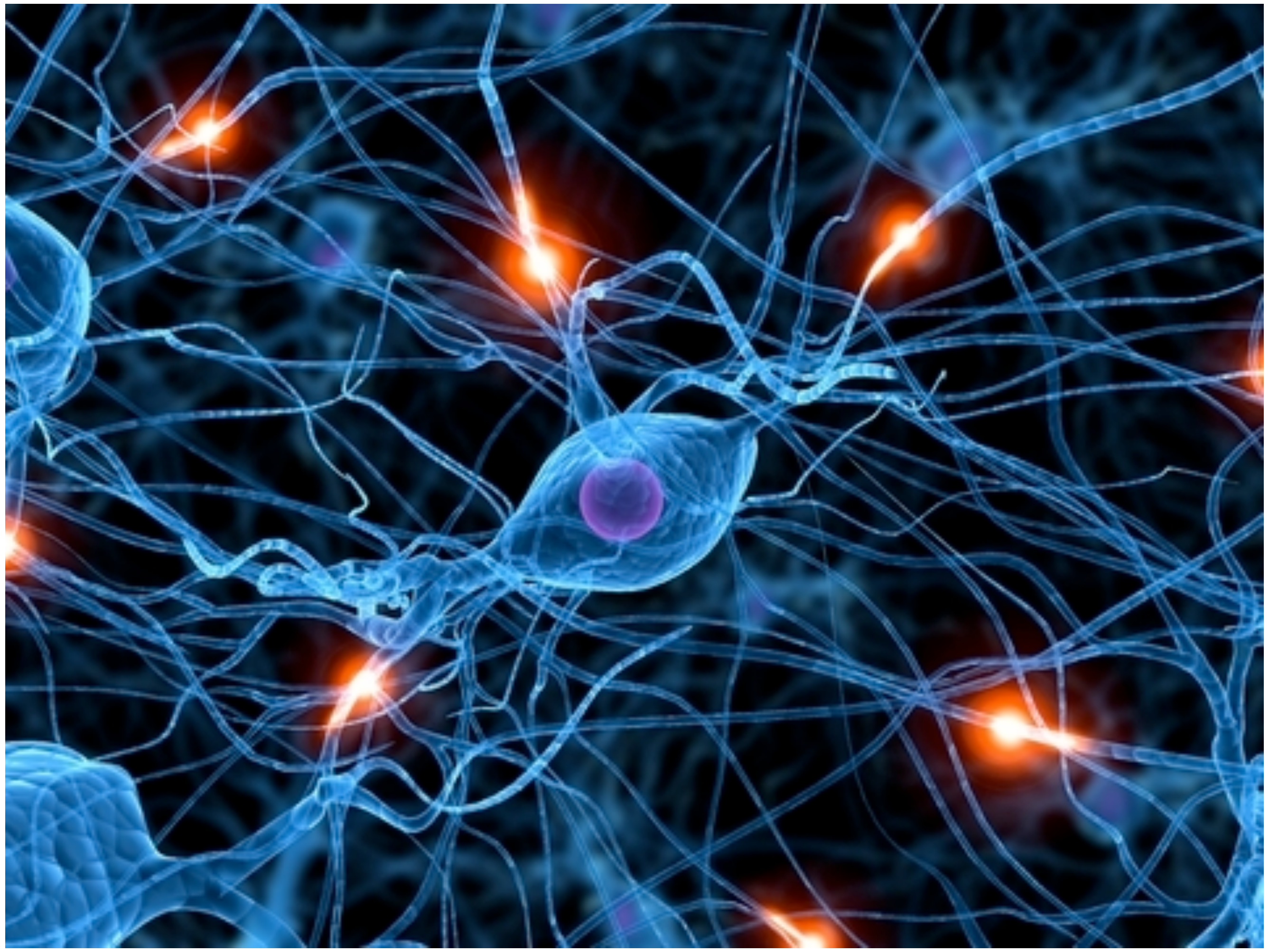
To foster student understanding of this concept:

- Cytoskeleton (a network of structural proteins that facilitate cell movement, morphological integrity and organelle transport)
- Membrane-bound organelles (mitochondria and/or chloroplasts)
- Linear chromosomes
- Endomembrane systems, including the nuclear envelope

Tour of the Cell

Main Idea: Their are two distinct types of cells *eukaryotes* & *prokaryotes*.

Main Idea: Prokaryotes belong to the domains of bacteria and archaea. Eukaryotes belong to protista, fungi, animals and plants.



Comparing Eukaryotic and Prokaryotic cells

- ALL cells share some common features:
  - plasma membranes (selective barrier)
  - cytosol (semifluid substance)
  - chromosomes (information carrier)
  - ribosomes (protein builders)

The Tree of Life

- Physiological, structural, molecular and genetic evidence has been used in generating the tree of life. (Here are <u>some</u> examples)

Descriptions	**Explanations**		
Differences	**Eukaryotes**	**Archaea**	**Eubacteria**
Reproduction	**Mitosis/ Meiosis**	**Binary Fission**	**Binary Fission**
Multicellularity Exists	+	-	-
Nucleus	+	-	-
Membrane Bound Organelles	+	-	-
Microtubules/Filaments	+	-	-
Peptidoglycan Cell Wall	-	-	+
Chromosome shape	**linear**	**circular**	**circular**
Chromosome number	**multiple**	**single**	**single**

Tour of the Cell

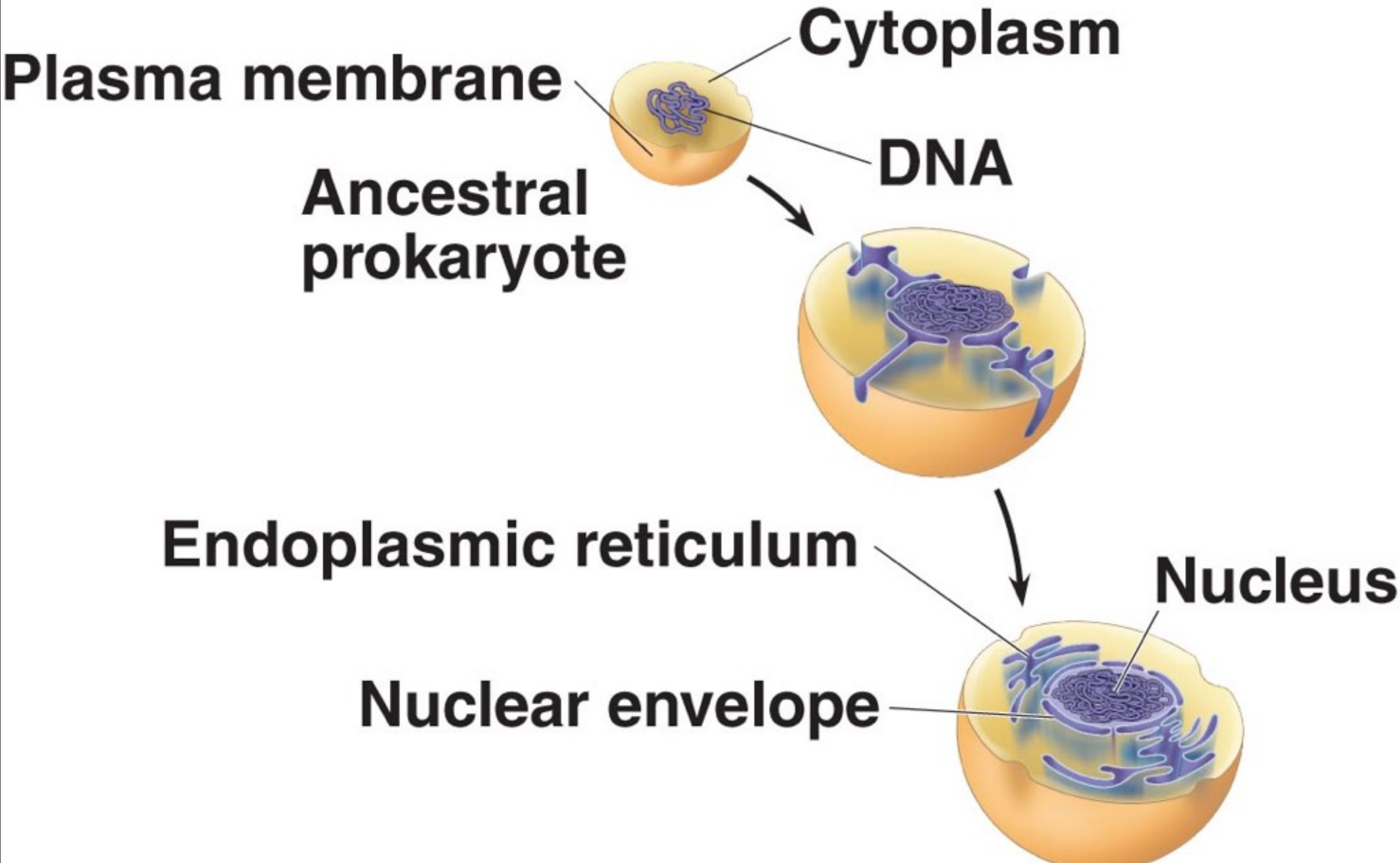
Main Idea: In Eukaryotic cells the mitochondria and chloroplasts are the organelles that convert energy into forms that the cell can use to do work.

Main Idea: The mitochondria and chloroplasts also have similar evolutionary origins.

MITOCHONDRIA AND CHLOROPLASTS CHANGE ENERGY FROM ONE FORM TO ANOTHER

- ***Chloroplasts*** **use solar energy to build sugars from carbon dioxide and water.**
- ***Mitochondria*** **use the stored chemical energy in macromolecules such as sugars and fats to generate ATP (cellular fuel).**

A. Evolutionary Origins: Mitochondria and Chloroplasts



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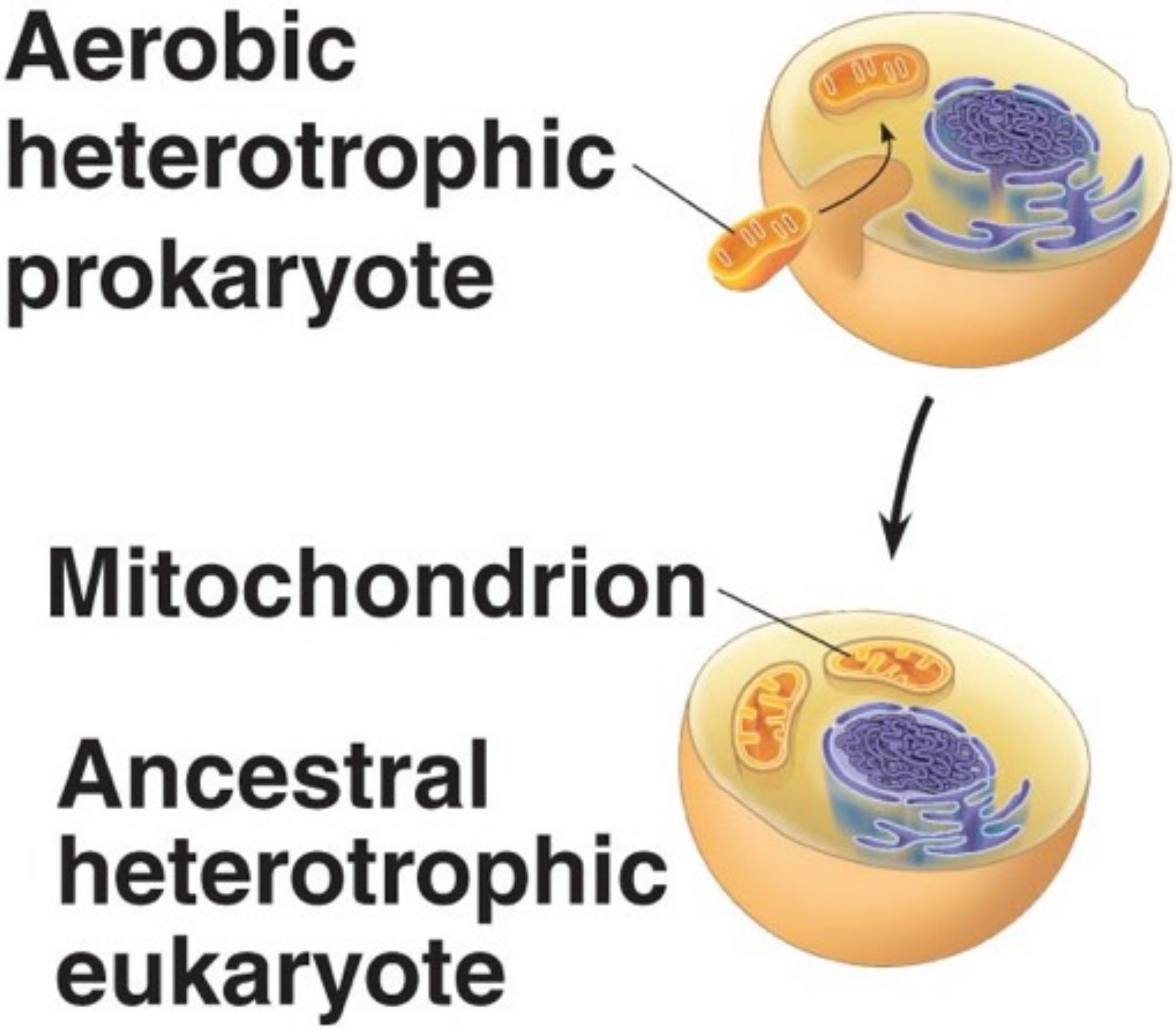

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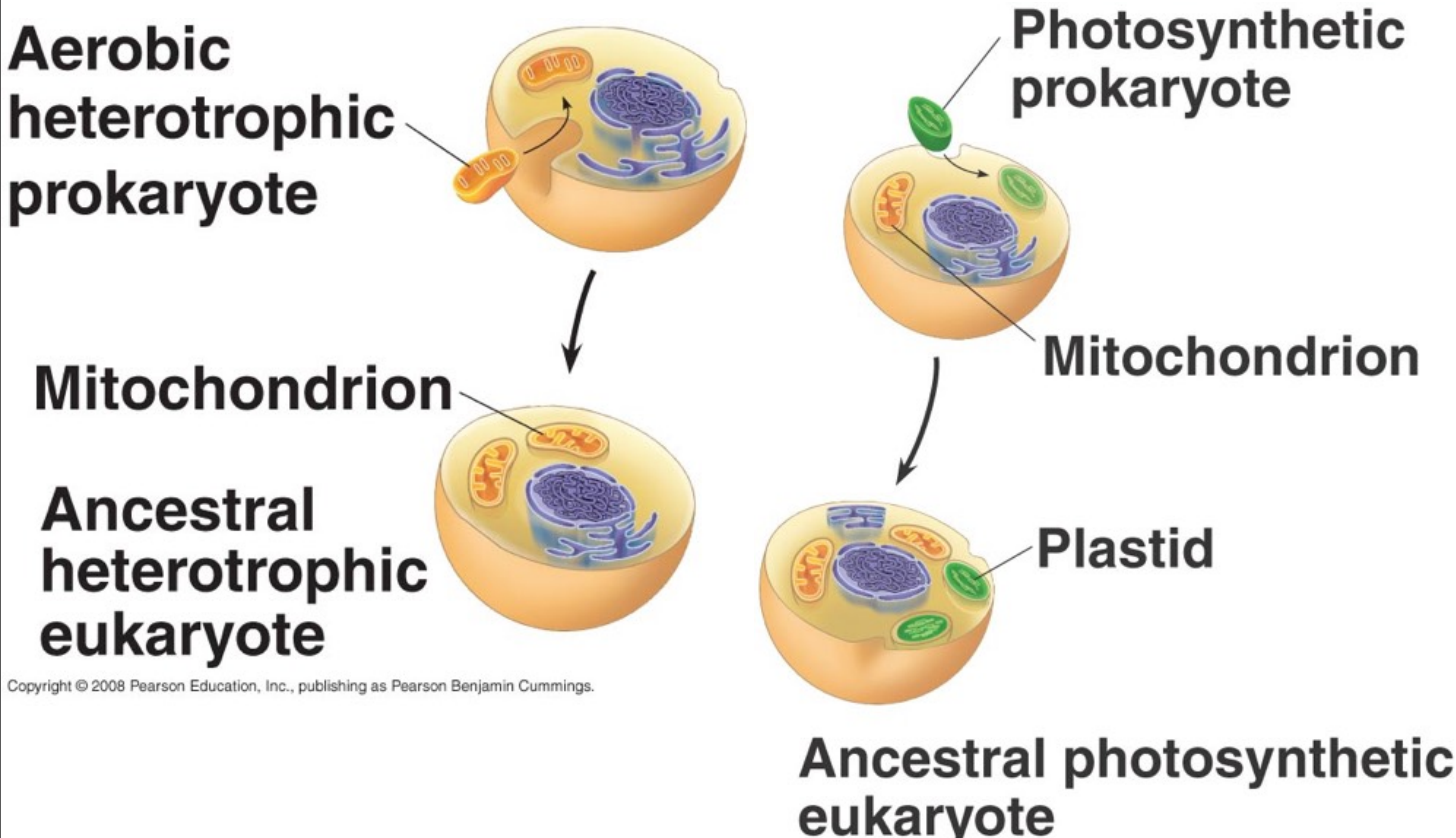

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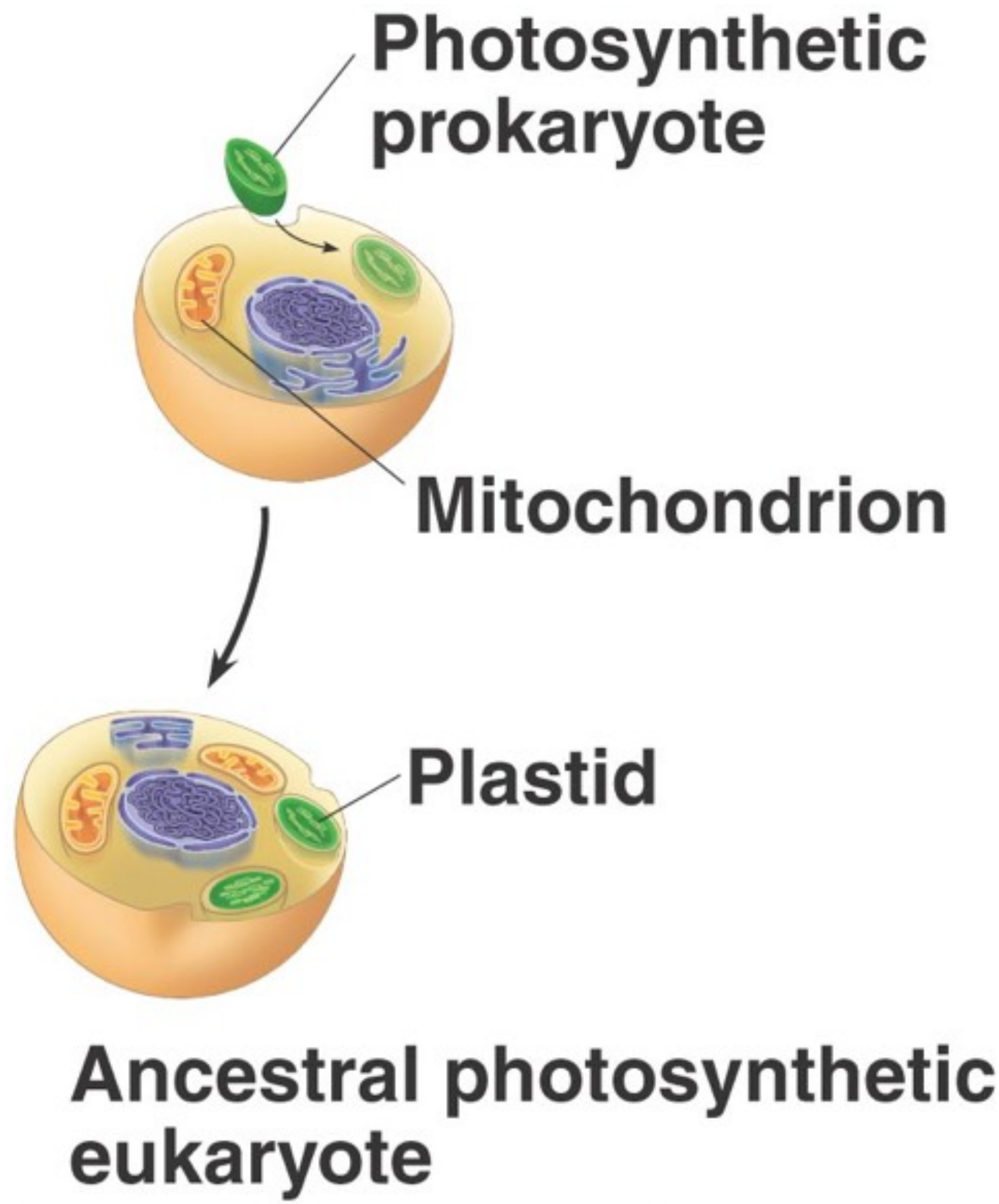

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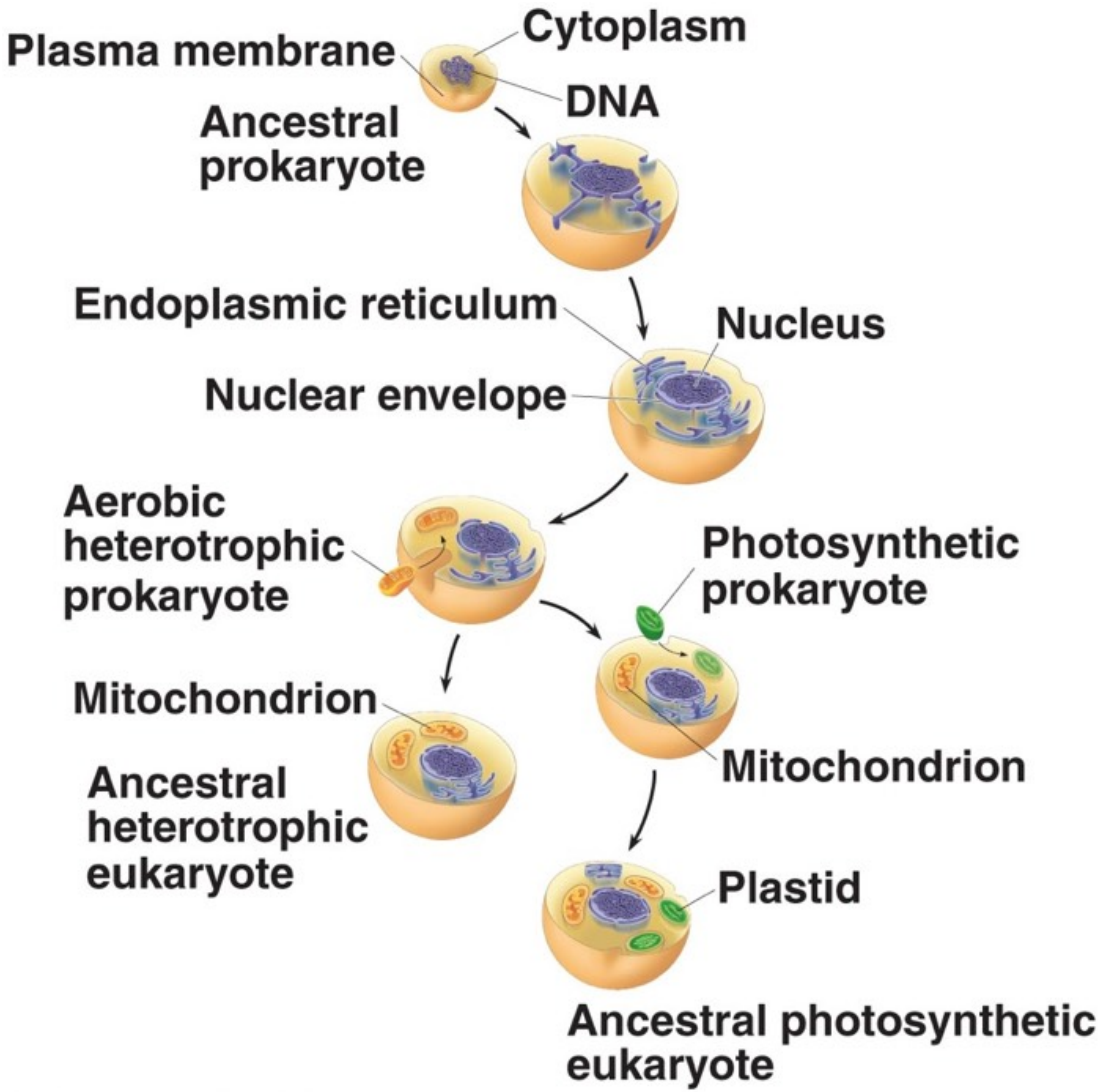

Origins of Mitochondria and Chloroplasts

Proposed Mitochondrial Ancestors

↓

Heterotrophic Prokaryotes

Proposed Chloroplasts Ancestors

↓

Autotrophic Prokaryotes

- Almost all eukaryotes have mitochondria but far less eukaryotes have chloroplasts therefore it is hypothesized that mitochondria are older than chloroplasts.
- Most speciation involves populations diverging, becoming more dissimilar to the point where they now longer can produce "fertile offspring". A common symbol for evolution is the tree, its branches represent new lineages.
- This story is unique because two species are merging to become one new species.

Evidence of Endosymbiosis

- Mito/Chloro are similar in size.
- Mito/Chloro similar enzymes in their membranes.
- Mito/Chloro replication resembles binary fission.
- Mito/Chloro DNA is circular.
- Mito/Chloro have their own ribosomes.
- Mito/Chloro ribosomes are the similar in size.
- Mito/Chloro rRNA sequence is similar.

} PROKARYOTES

B. Mitochondria: Chemical Energy Conversion

- **Found in nearly all eukaryotic cells**
  - animals, plants, fungi and most protists
- **A cell can have one, but more often has hundreds or thousands**
  - number correlates to metabolic level of the cell
- **Mitochondria are dynamic; they move, they grow and occasionally pinch into two**

Footnote: We will look at this organelle in more detail in the cell respiration unit.

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Footnote: We will look at this organelle in more detail in the cell respiration unit.

Fuel, Metallica

Chloroplasts: Capture of Light Energy

- **Found in plants and algae**
  - chloroplasts contain a green pigment called chlorophyll
- **Chloroplasts are dynamic; they move, they grow and occasionally pinch into two**
- **Belong to the family of plastids, organelles that manufacture and store compounds. Most contain pigments. (see next slide)**

Footnote: We will look at this organelle in more detail in the cell respiration unit.

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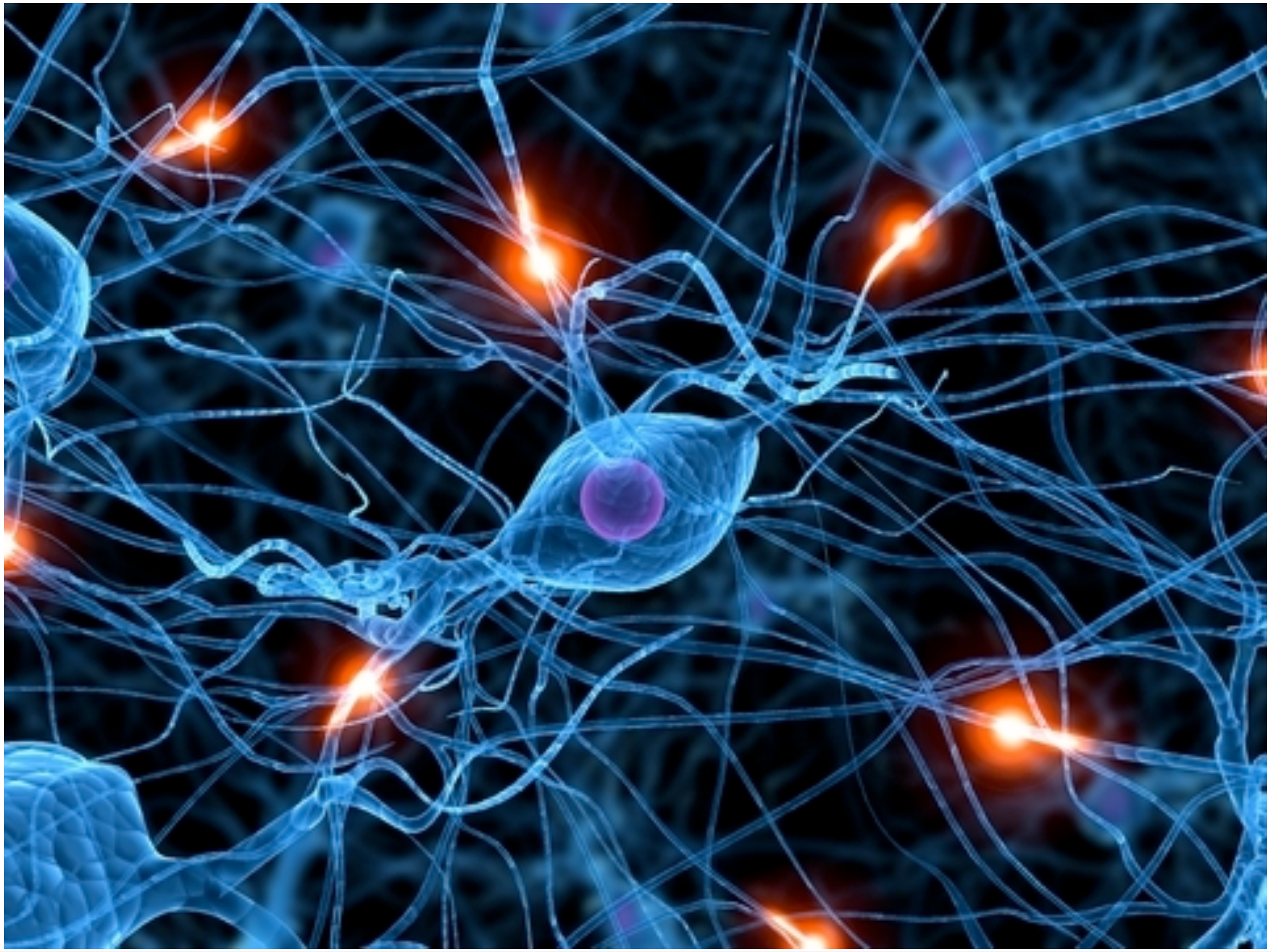
Clocks, Coldplay

Comparing Mitochondria and Chloroplasts

Mitochondria	Chloroplasts
• Converts energy to useable forms.	• Ditto
• Not part of endomembrane system.	• Ditto
• Has double membrane.	• Ditto
• Grows and reproduces.	• Ditto
• Has its own DNA and ribosomes.	• Ditto
• Semi-autonomous.	• Ditto
• Site for cell respiration	• Site for photosynthesis
• Found in both animal and plant cells	• Found in plant cells and eukaryotic algae

Tour of the Cell

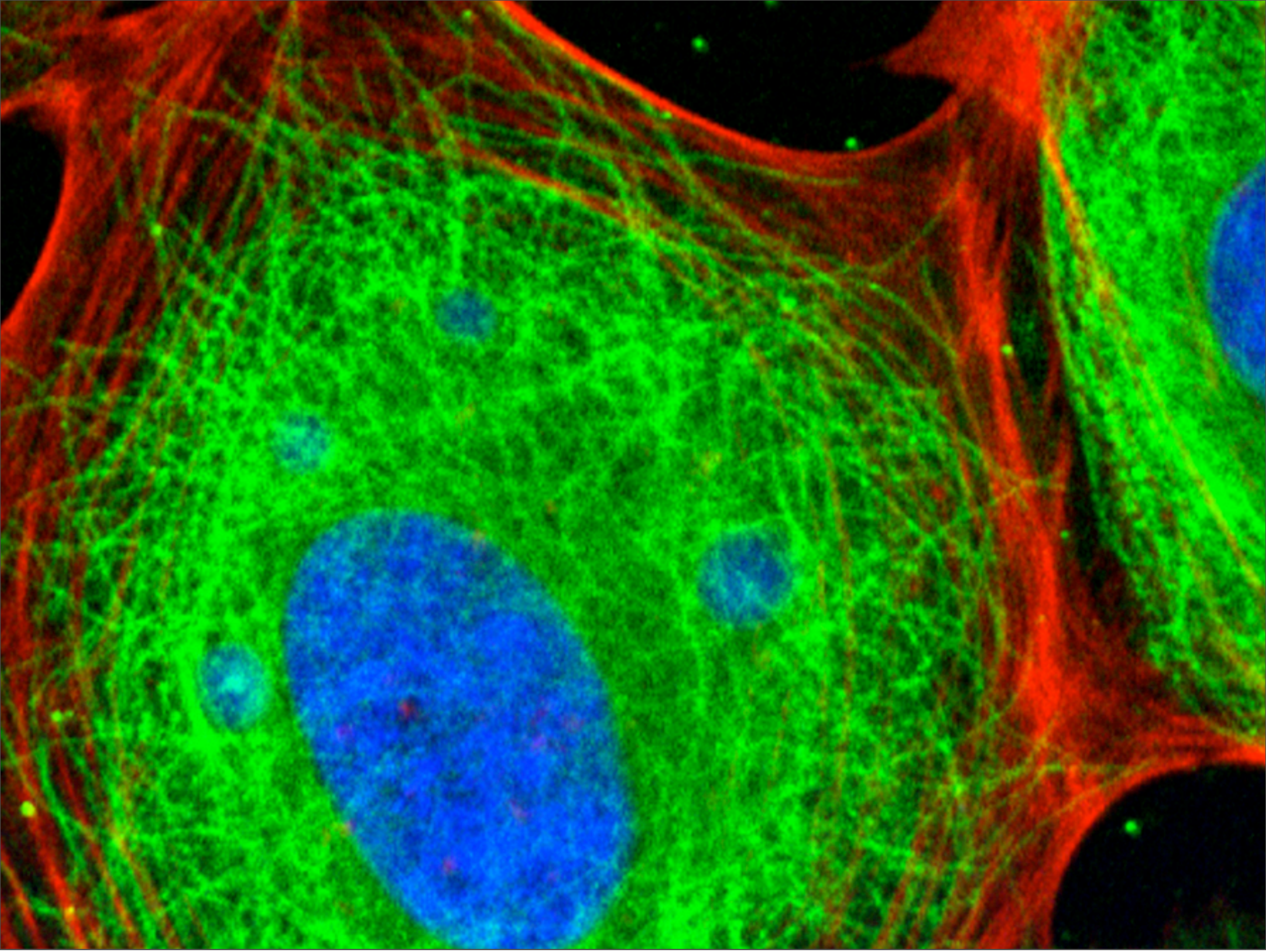
Main Idea: Protein fibers provide structure to cells and these fibers indirectly control cellular activities.



THE CYTOSKELETON IS A NETWORK OF FIBERS THAT ORGANIZES STRUCTURES AND ACTIVITIES IN THE CELL

Roles of the Cytoskeleton: Support and Motility

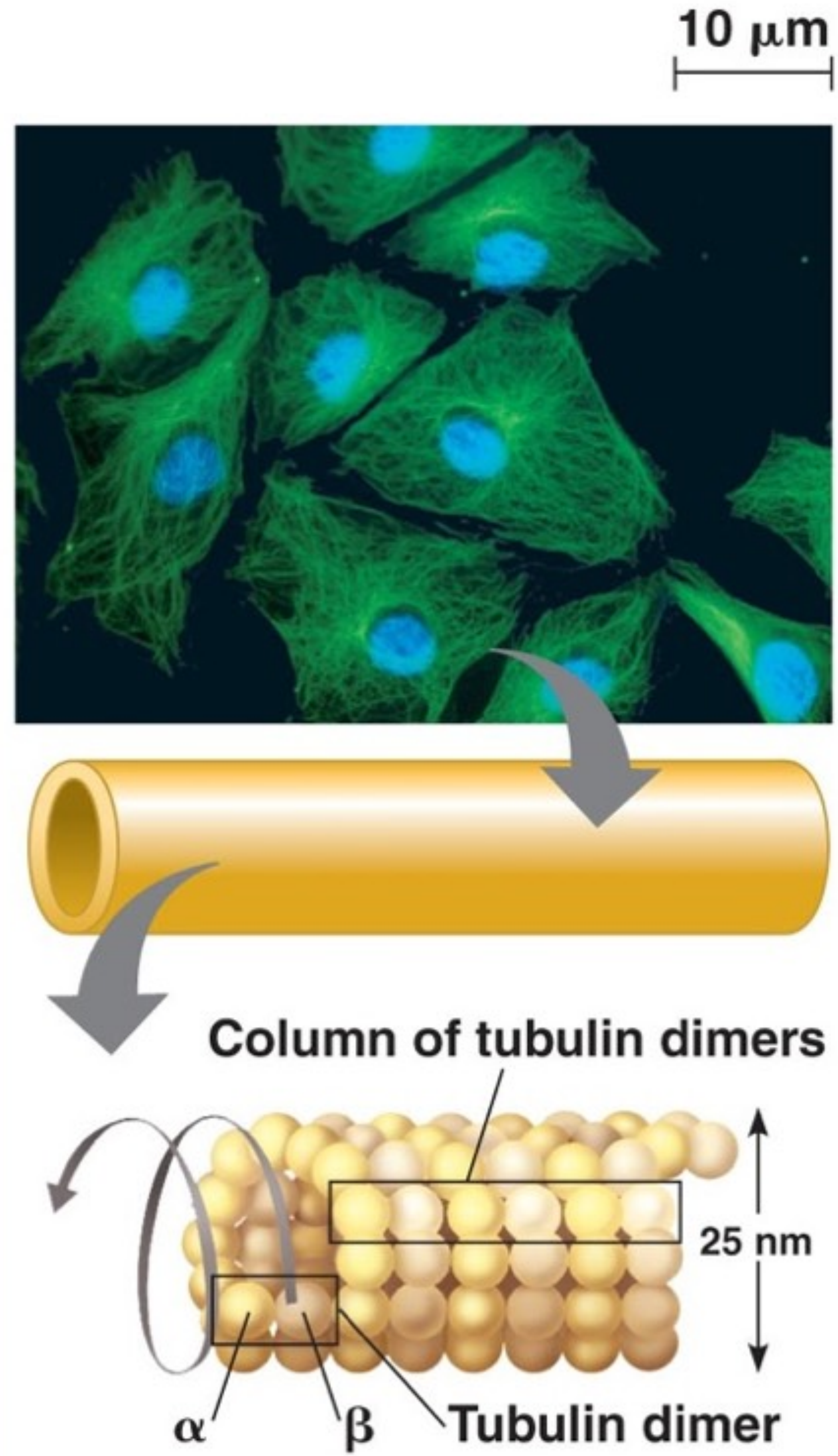
- Provide **support** and maintain **shape**
  - *especially important for animal cells (no cell walls)*
- **Anchors** organelles
- **Motility**; the cell itself and components within the cell



Components of the Cytoskeleton

- Thick = **Microtubules**
- Medium = **Intermediate Filaments**
- Thin = **Microfilaments**

Property	Microtubules (Tubulin Polymers)
Structure	Hollow tubes; wall consists of 13 columns of tubulin molecules
Diameter	25 nm with 15-nm lumen
Protein subunits	Tubulin
Main functions	Maintenance of cell shape Cell motility Chromosome movements in cell division Organelle movements



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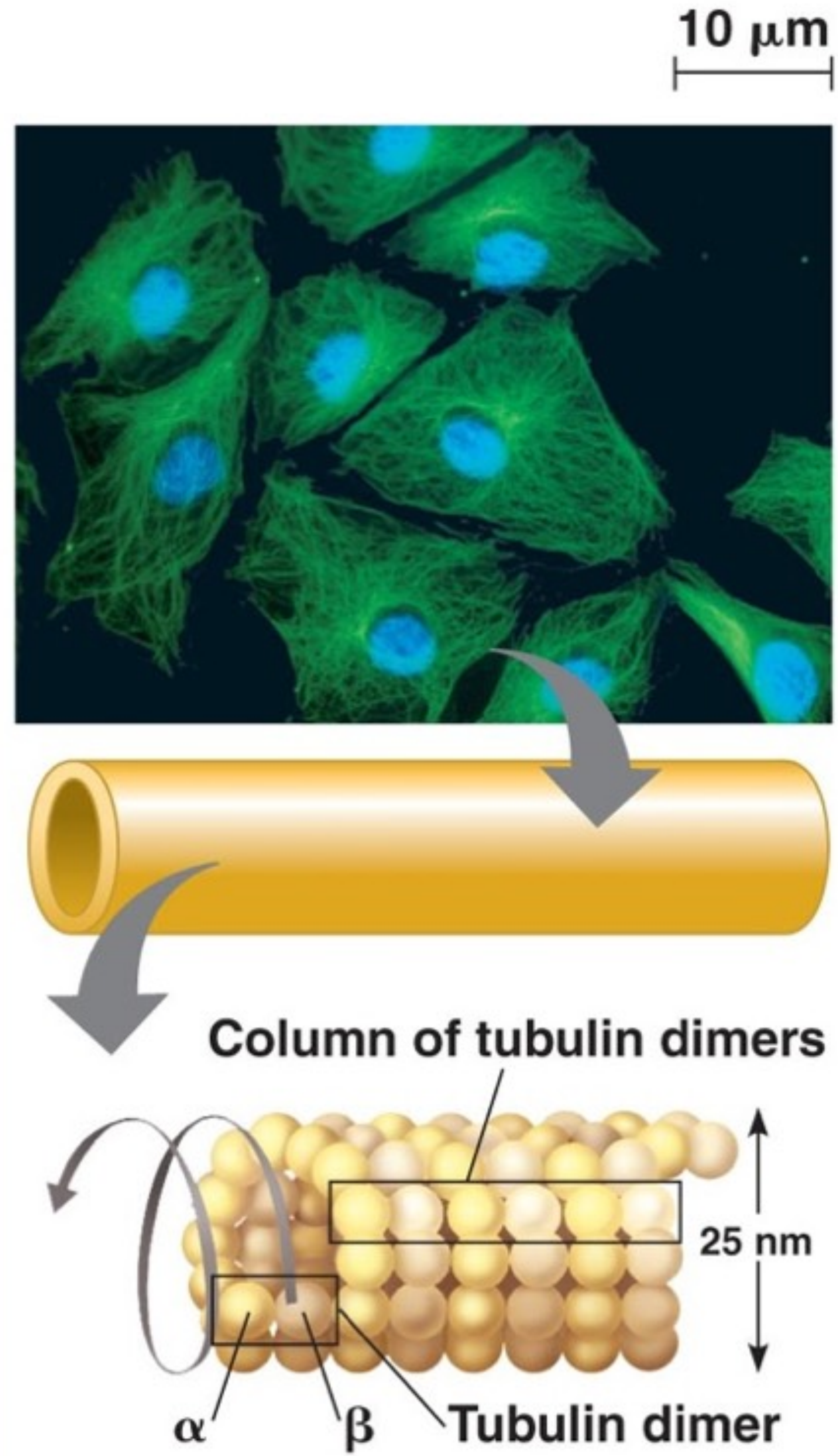

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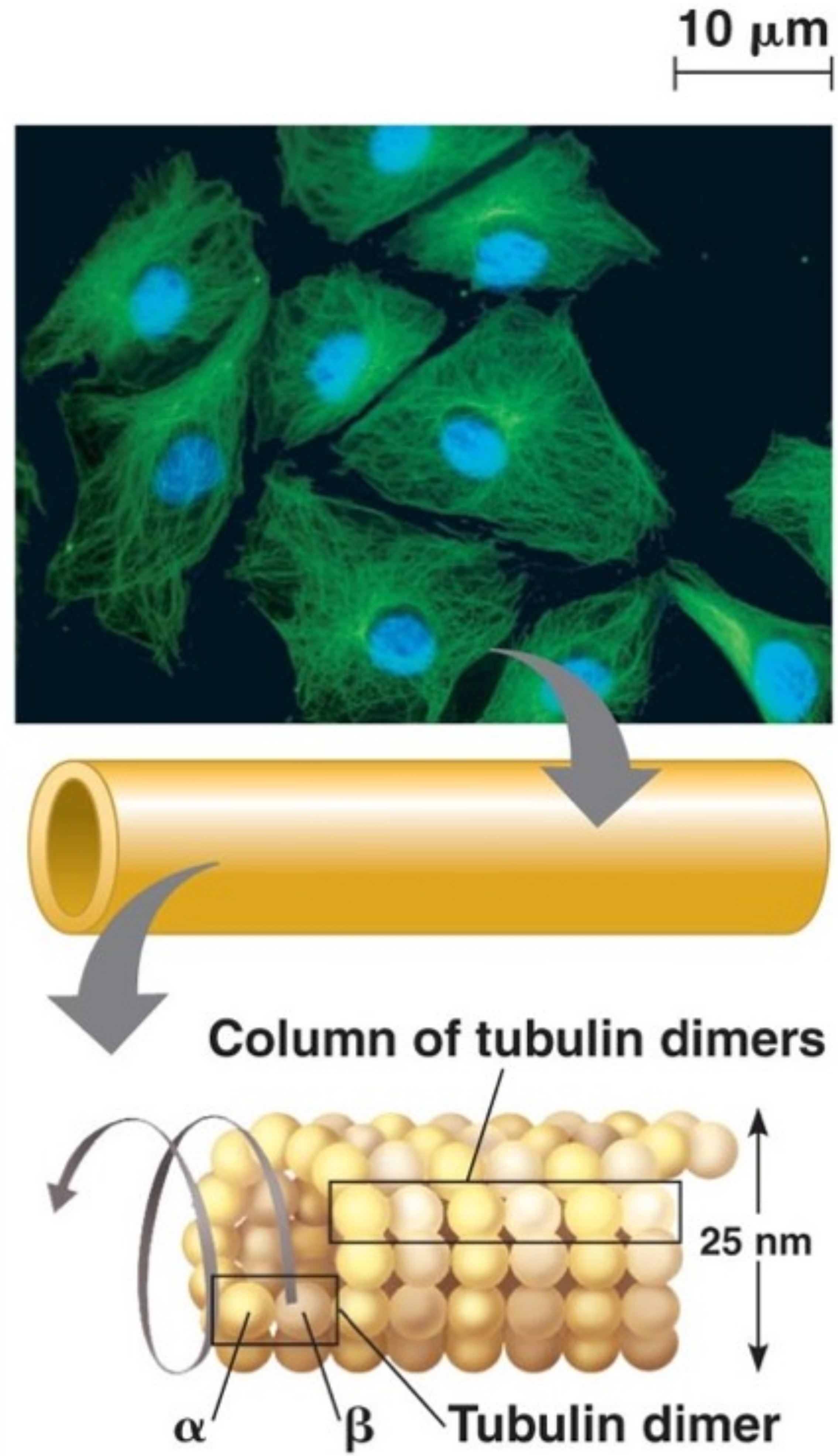
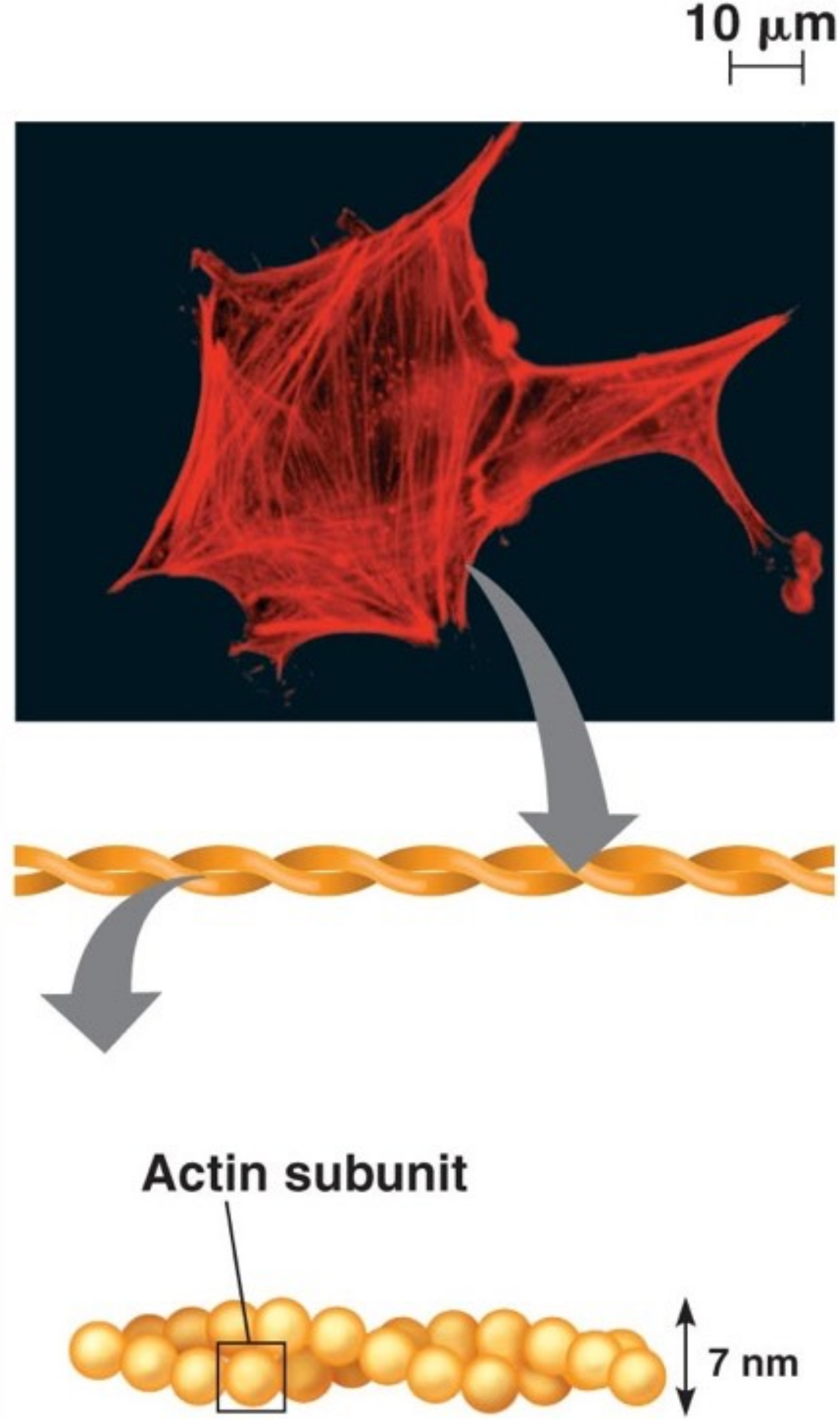


Property	Microfilaments (Actin Filaments)
Structure	Two intertwined strands of actin
Diameter	7 nm
Protein subunits	Actin
Main functions	Maintenance of cell shape Changes in cell shape Muscle contraction Cytoplasmic streaming Cell motility Cell division



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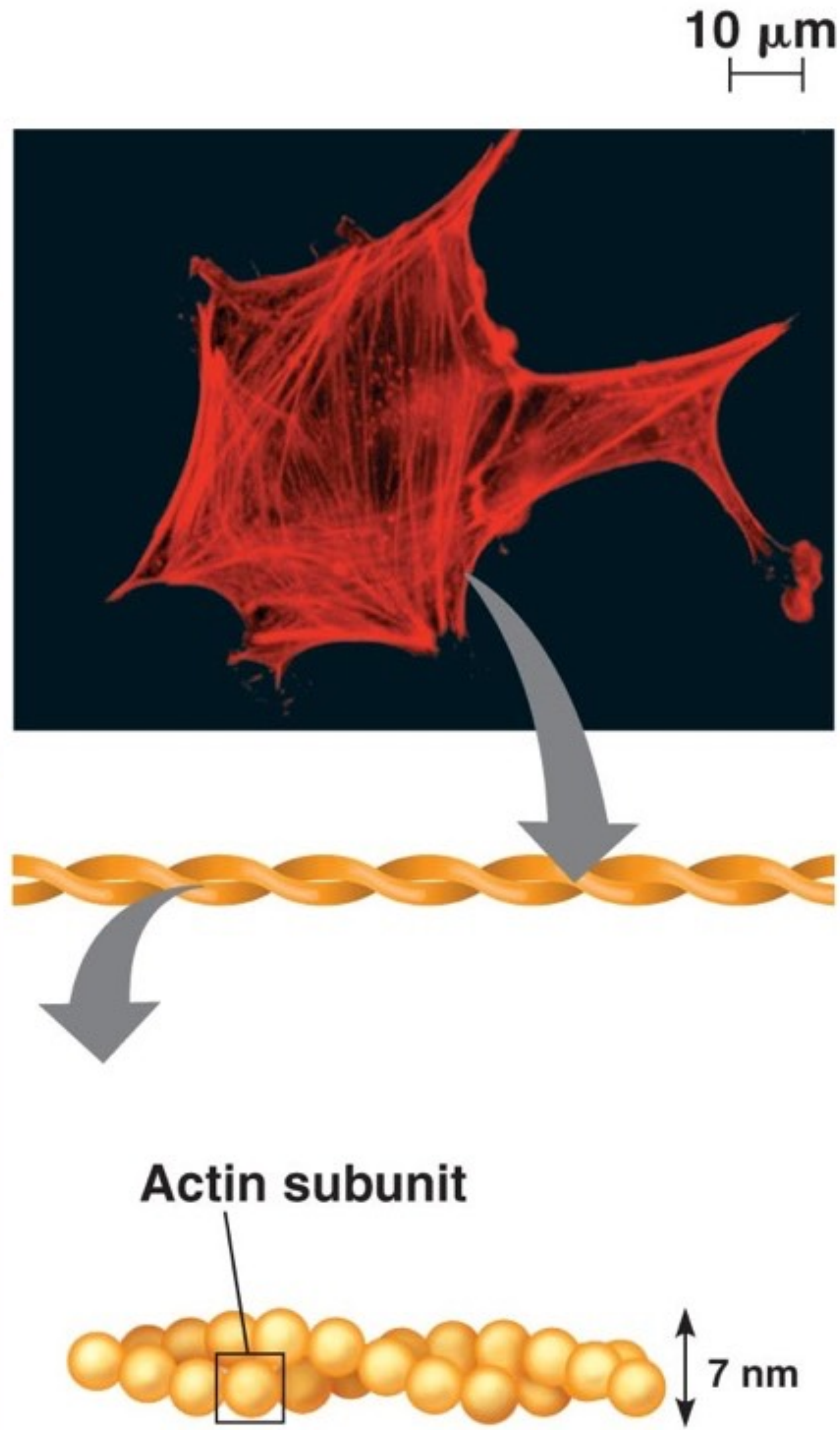

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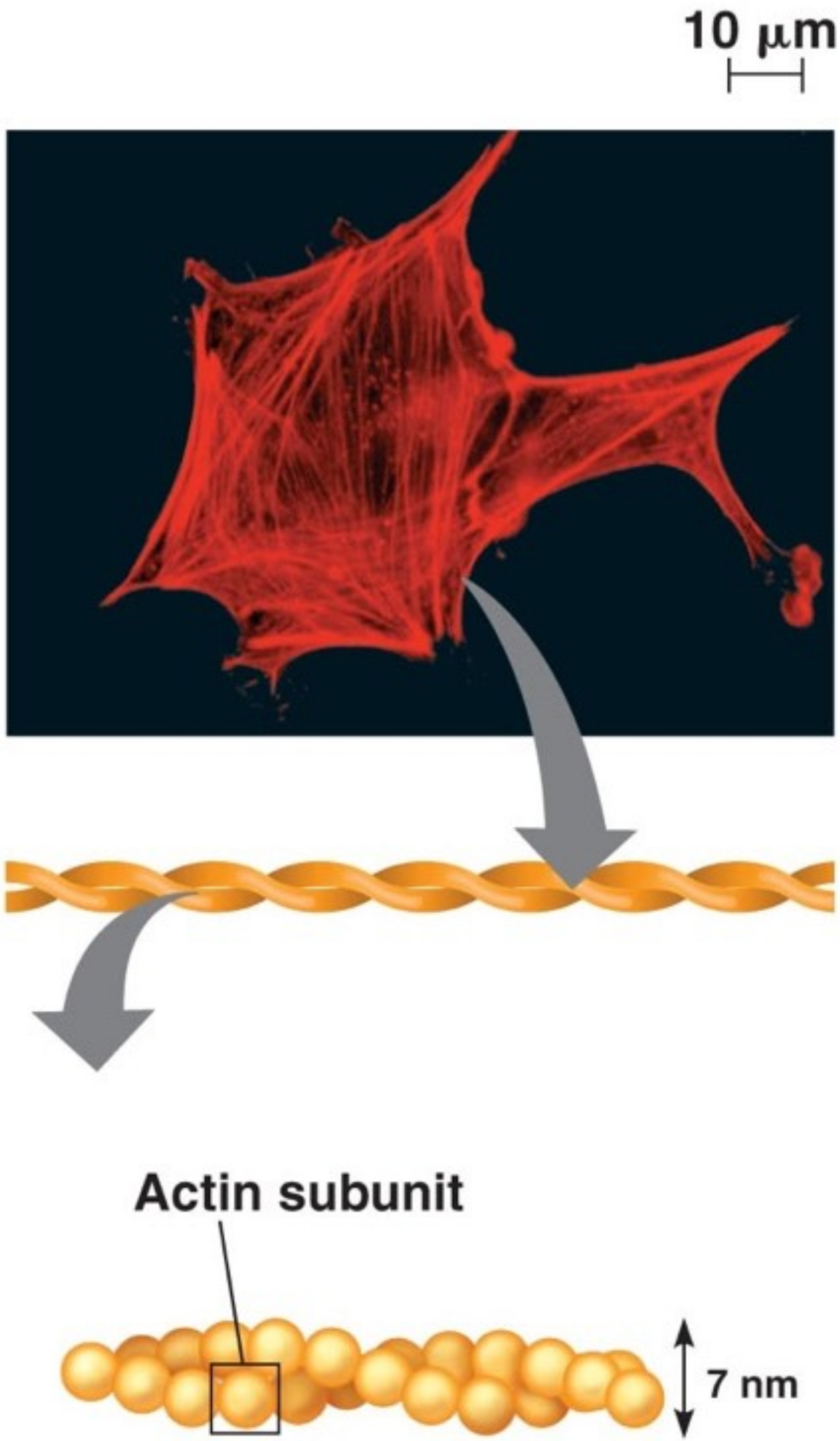

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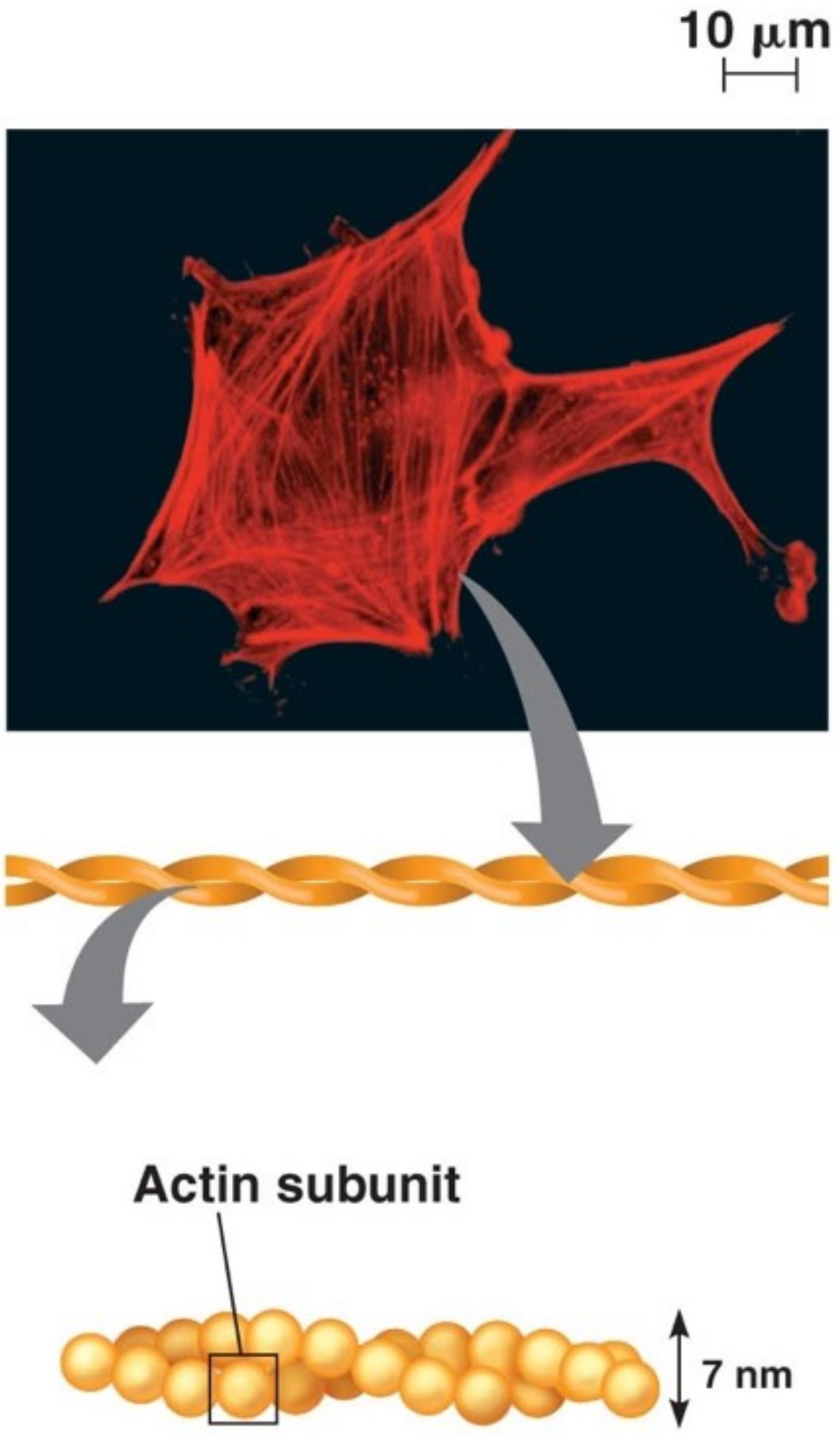
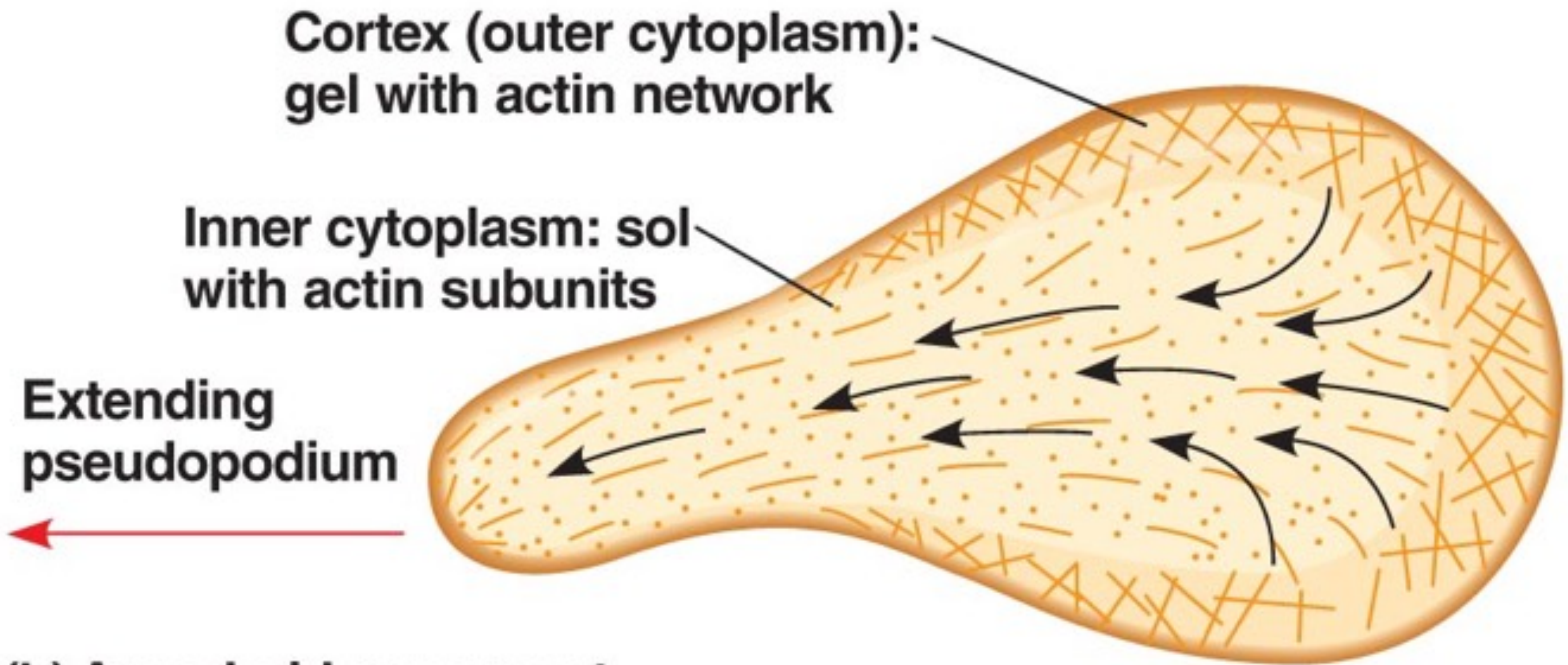
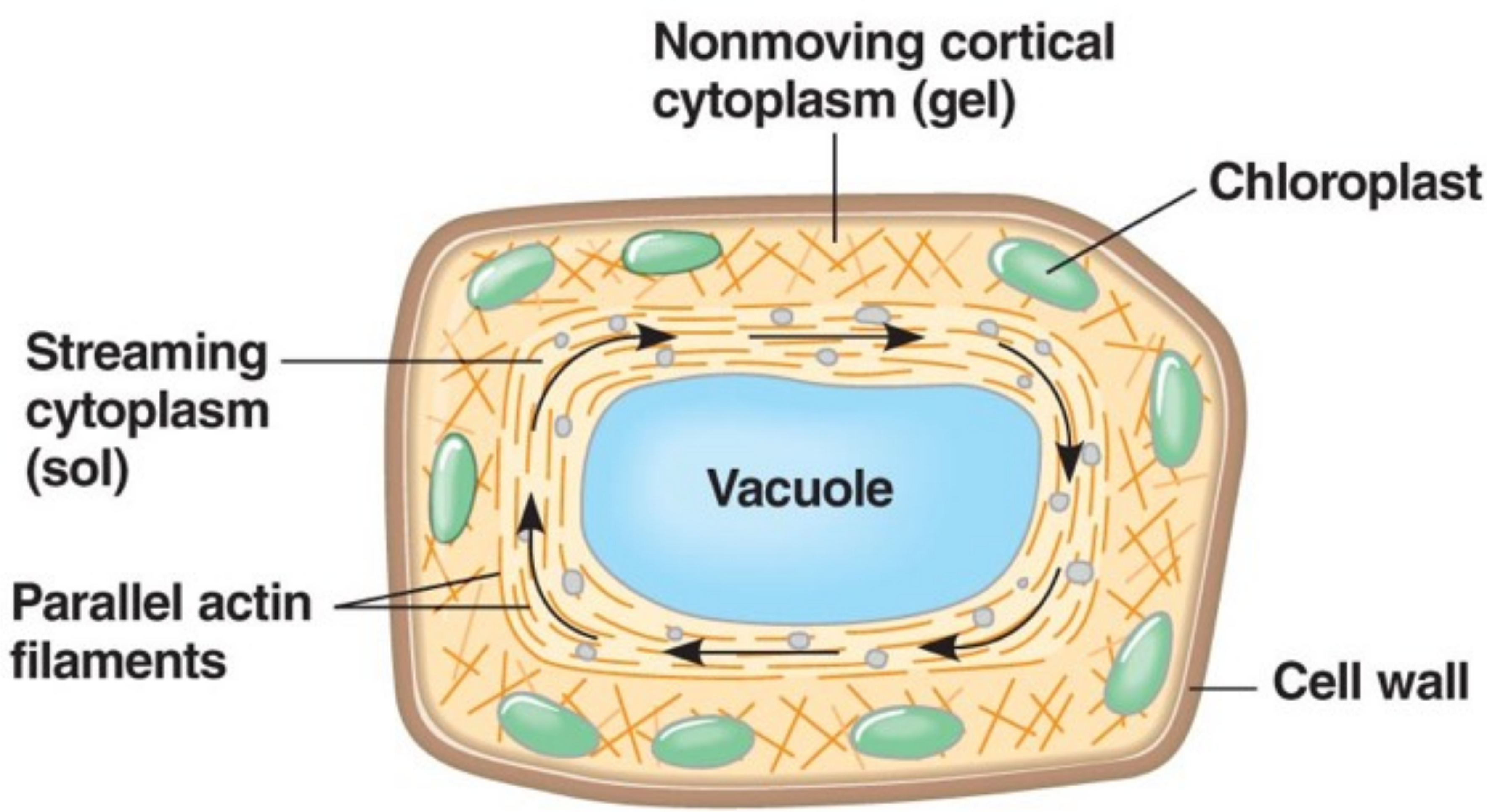
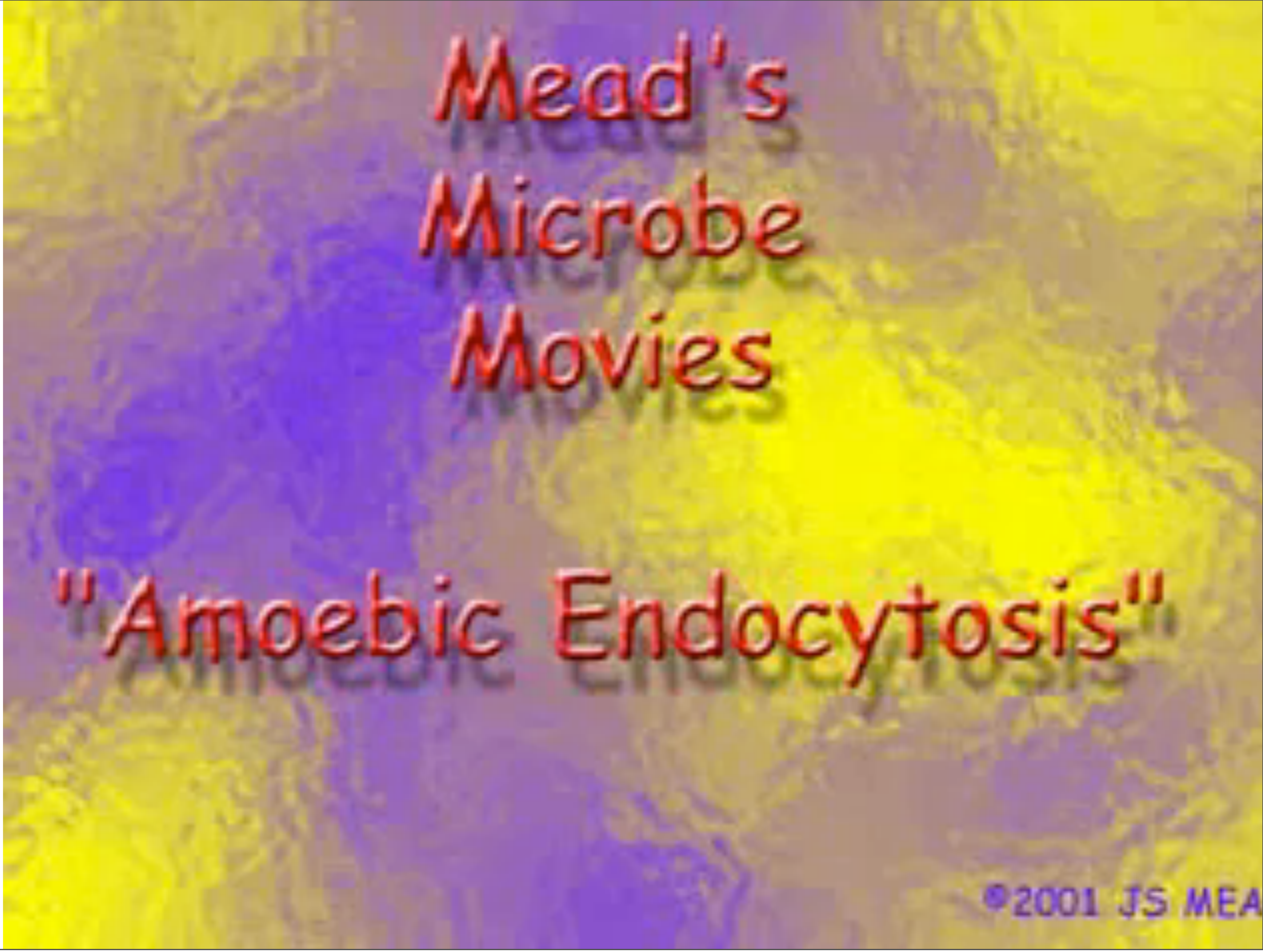




(b) Amoeboid movement



(c) Cytoplasmic streaming in plant cells


Mead's
Microbe
Movies
"Amoebic Endocytosis"
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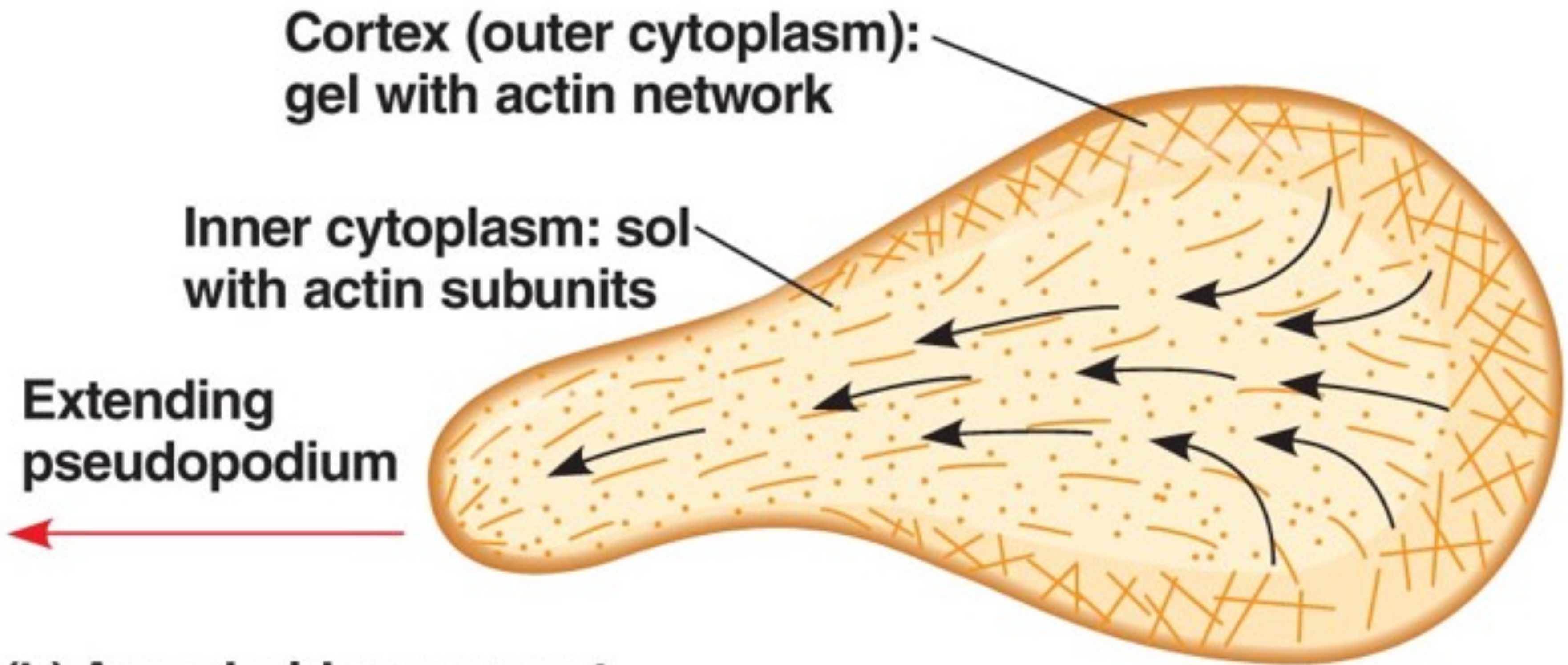

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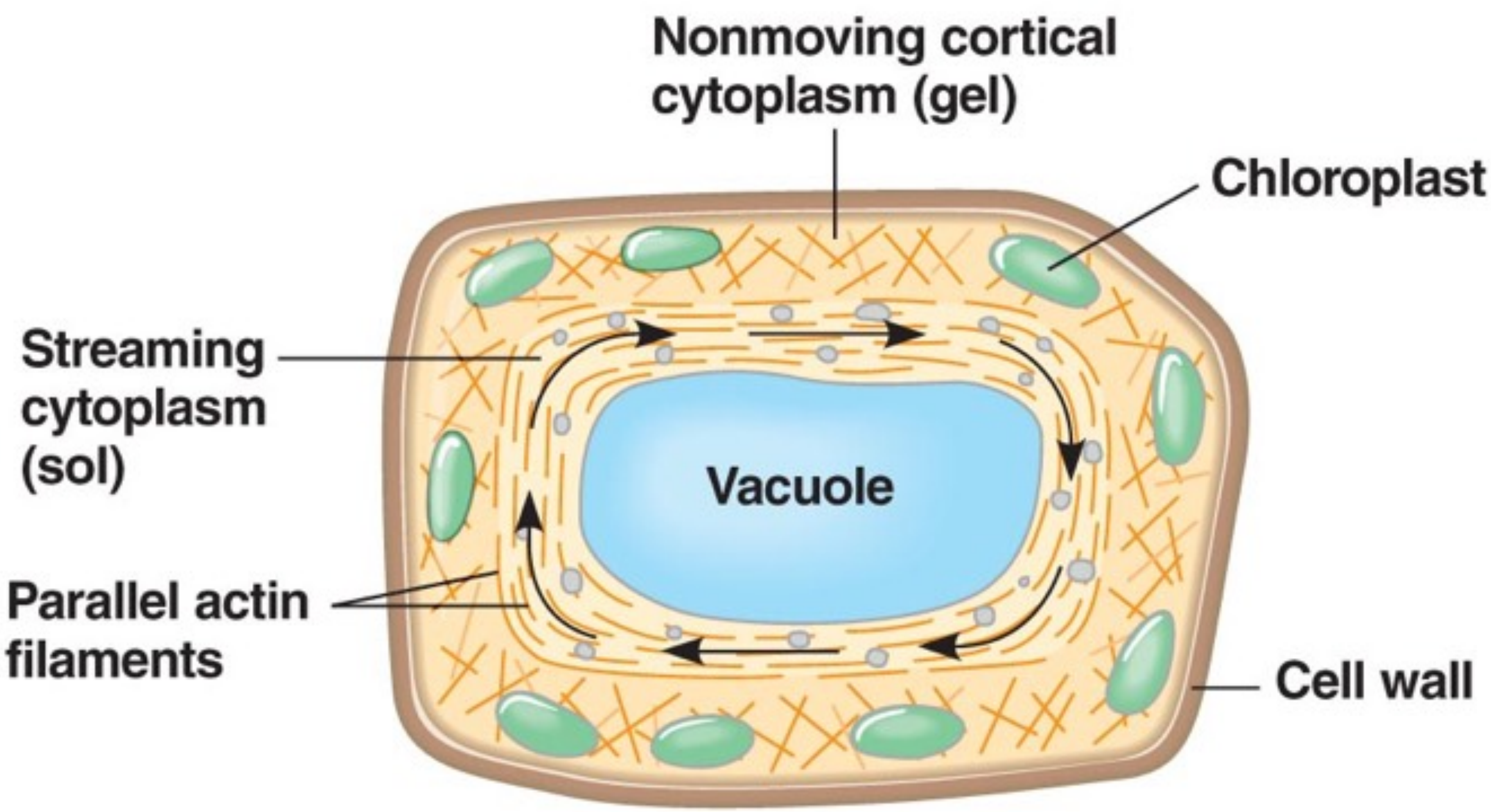

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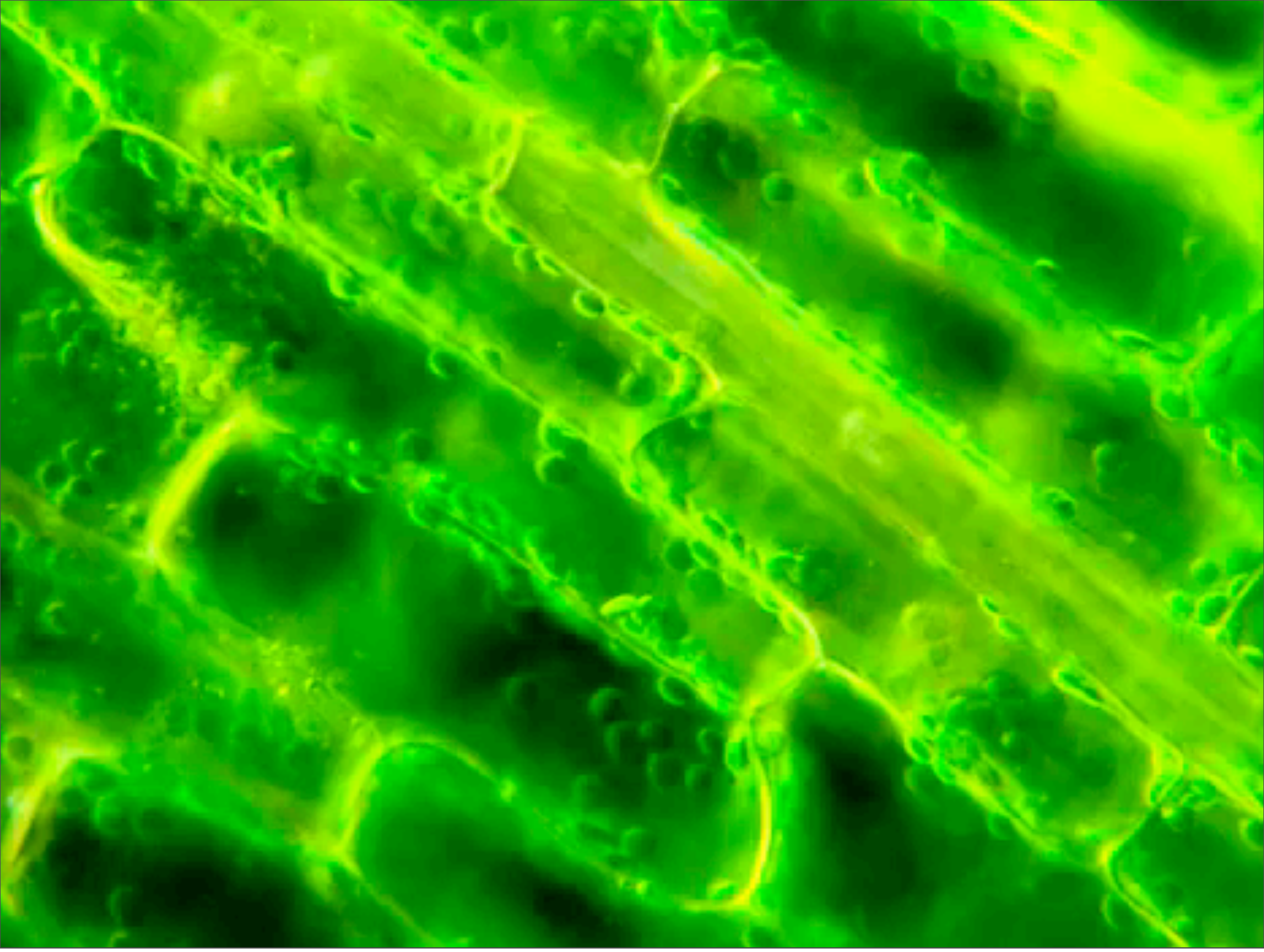

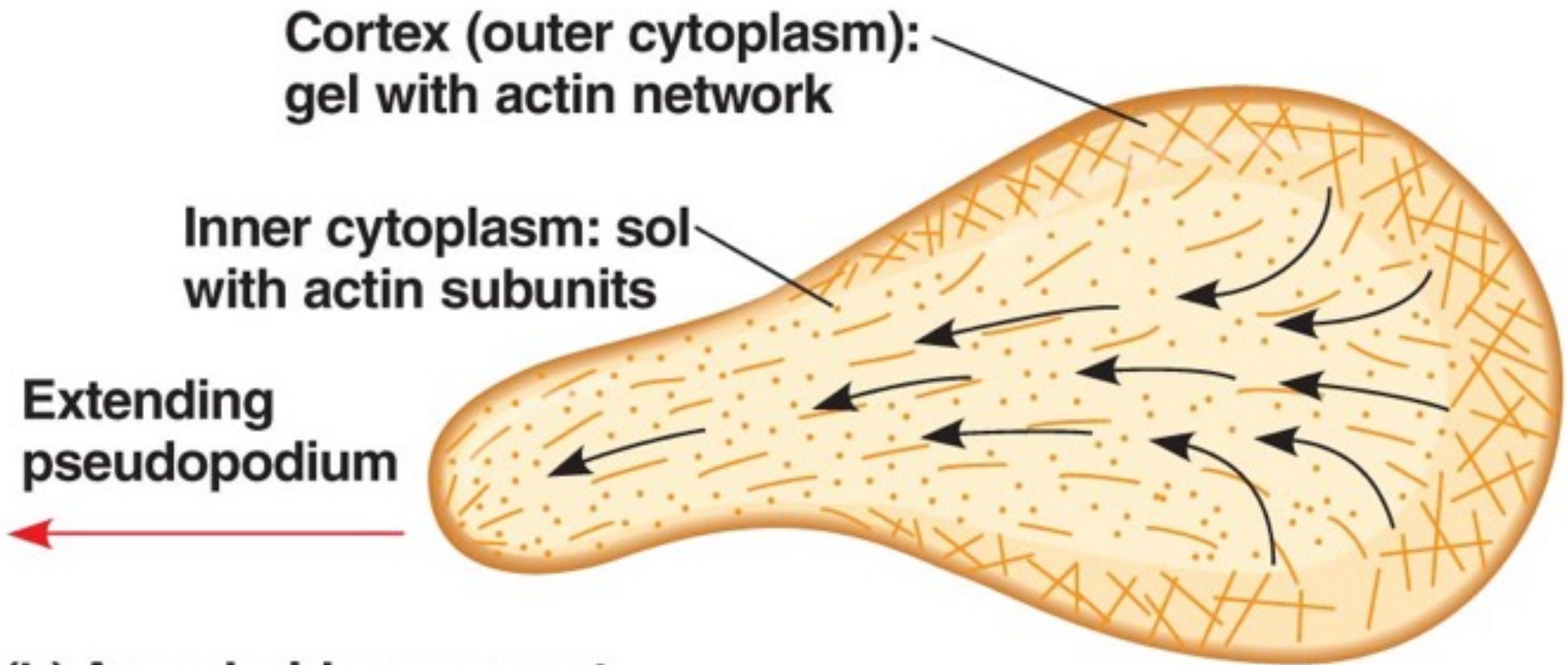

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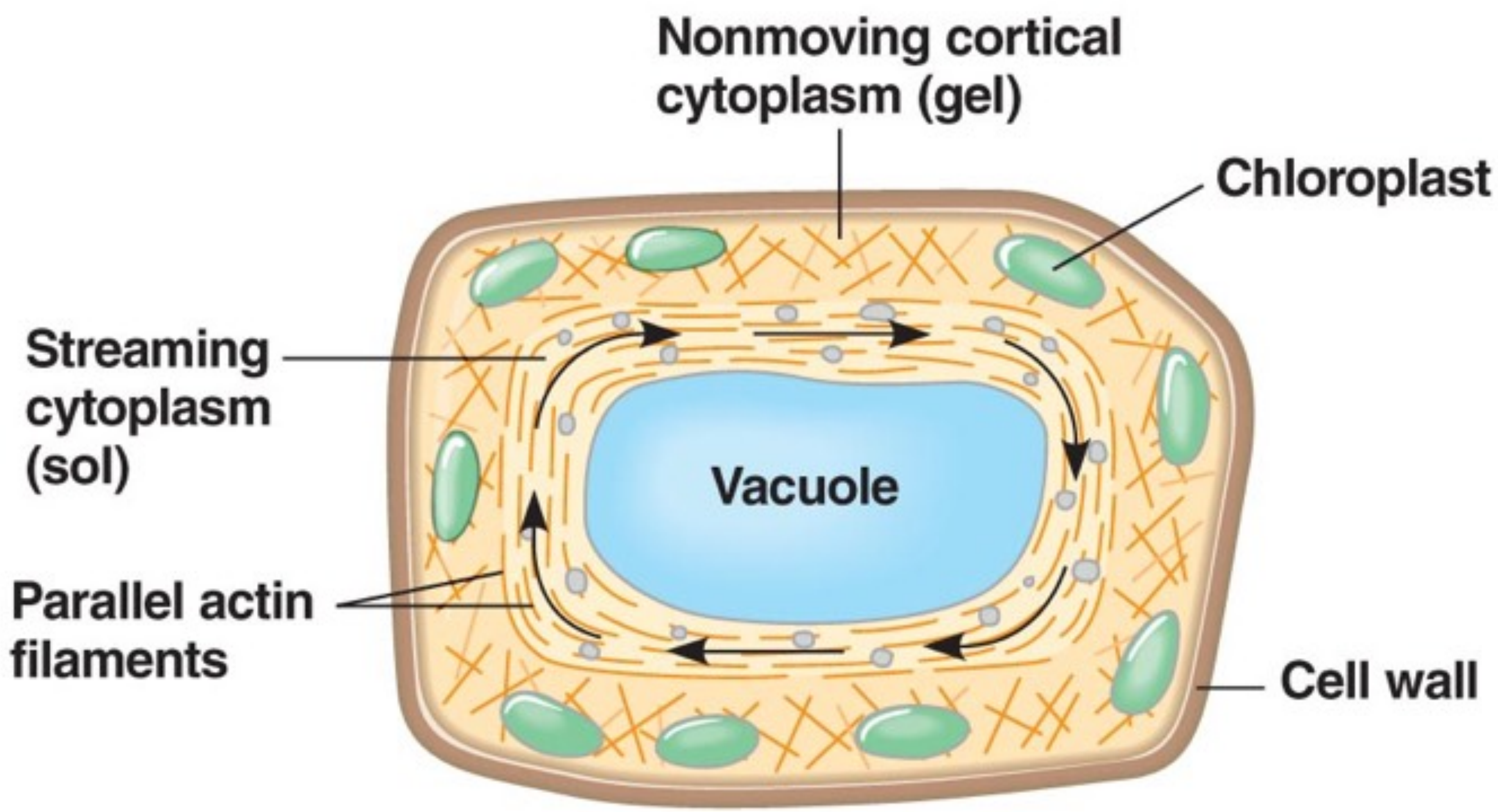
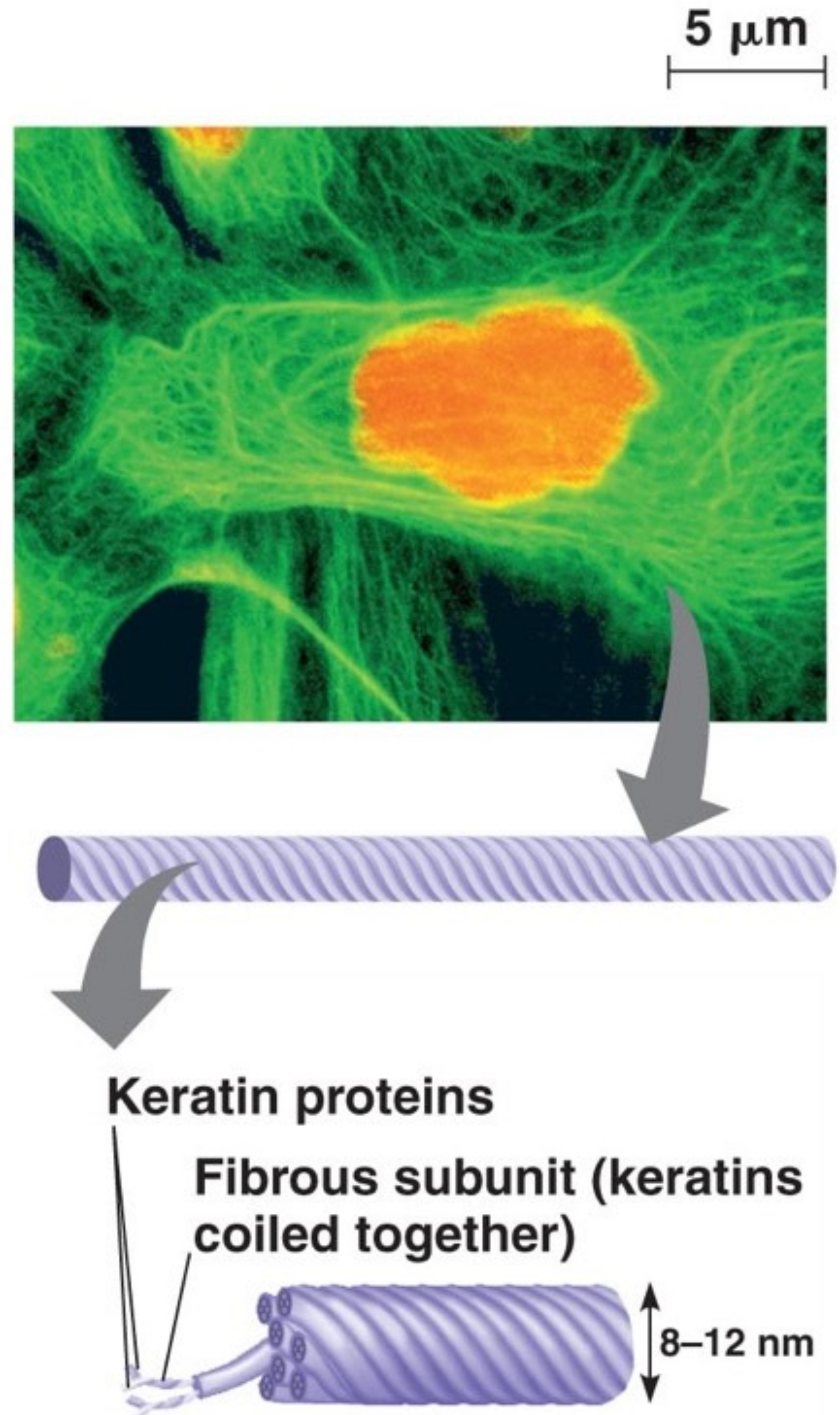


(c) Cytoplasmic streaming in plant cells

Property	Intermediate Filaments
Structure	Fibrous proteins supercoiled into thicker cables
Diameter	8–12 nm
Protein subunits	One of several different proteins of the keratin family
Main functions	Maintenance of cell shape Anchorage of nucleus and certain other organelles Formation of nuclear lamina



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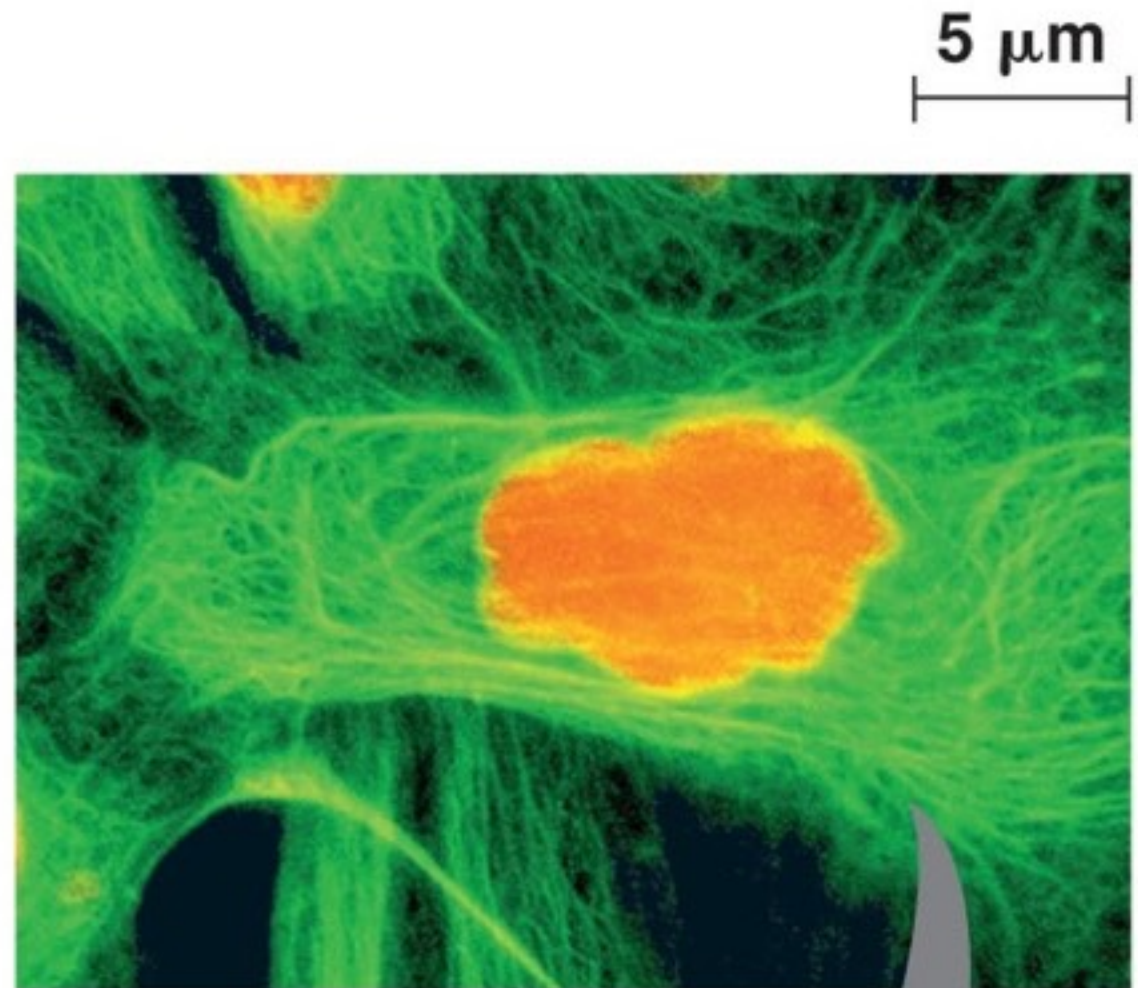
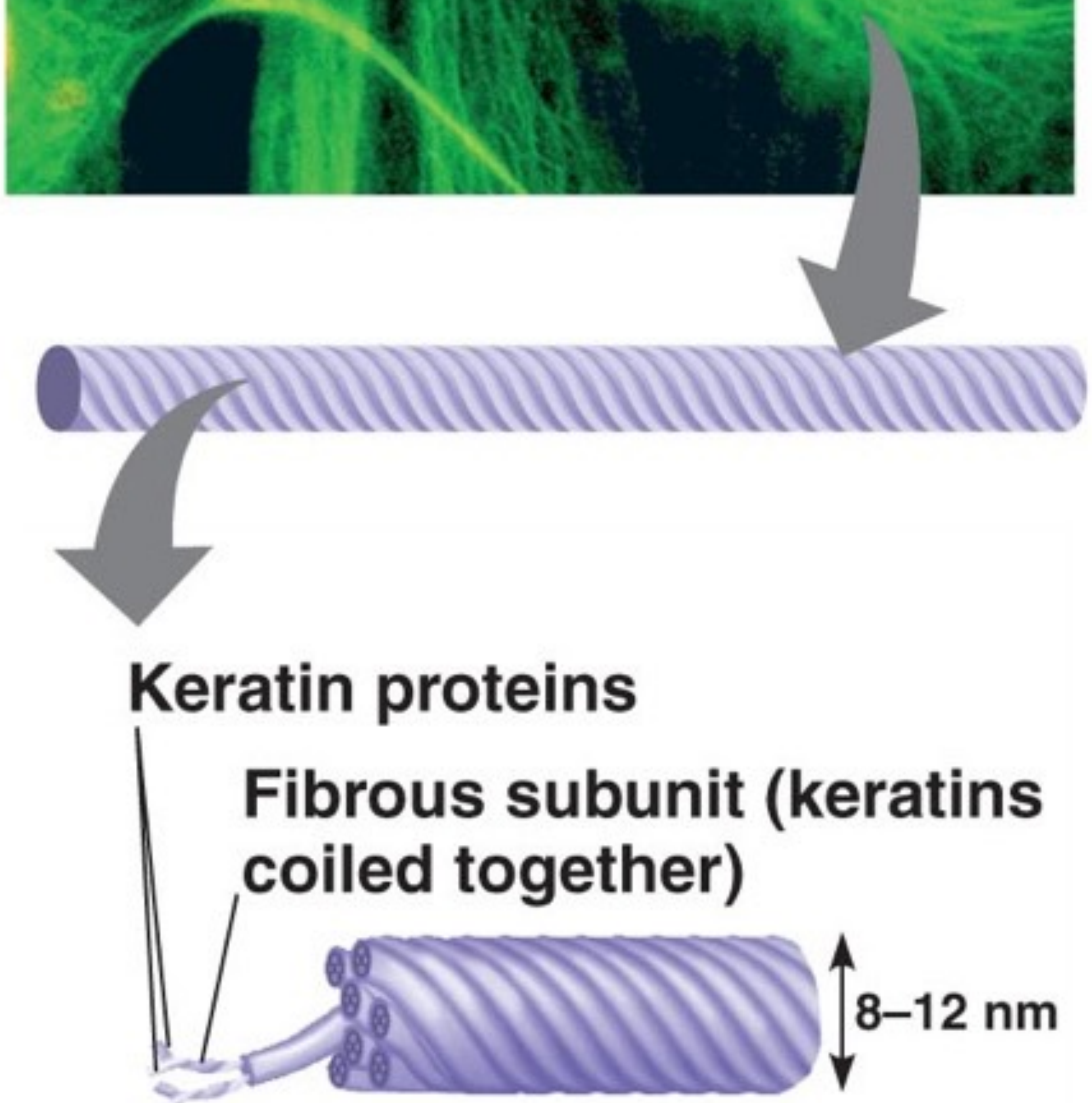
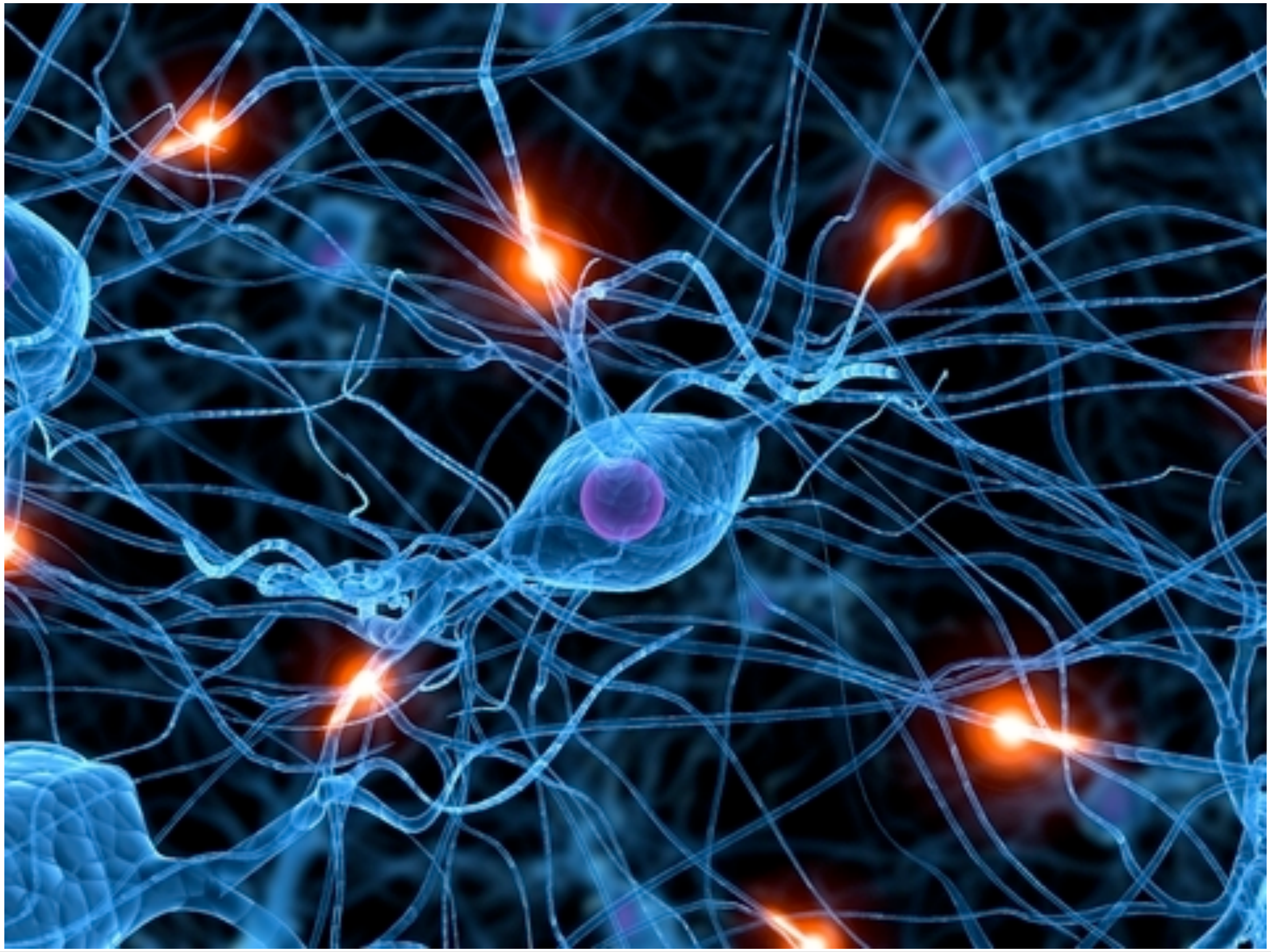




Tour of the Cell

Main Idea: Membrane bound organelles work together to perform a variety of important metabolic functions.



THE ENDOMEMBRANE SYSTEM REGULATES PROTEIN TRAFFIC AND PERFORMS METABOLIC FUNCTIONS IN THE CELL

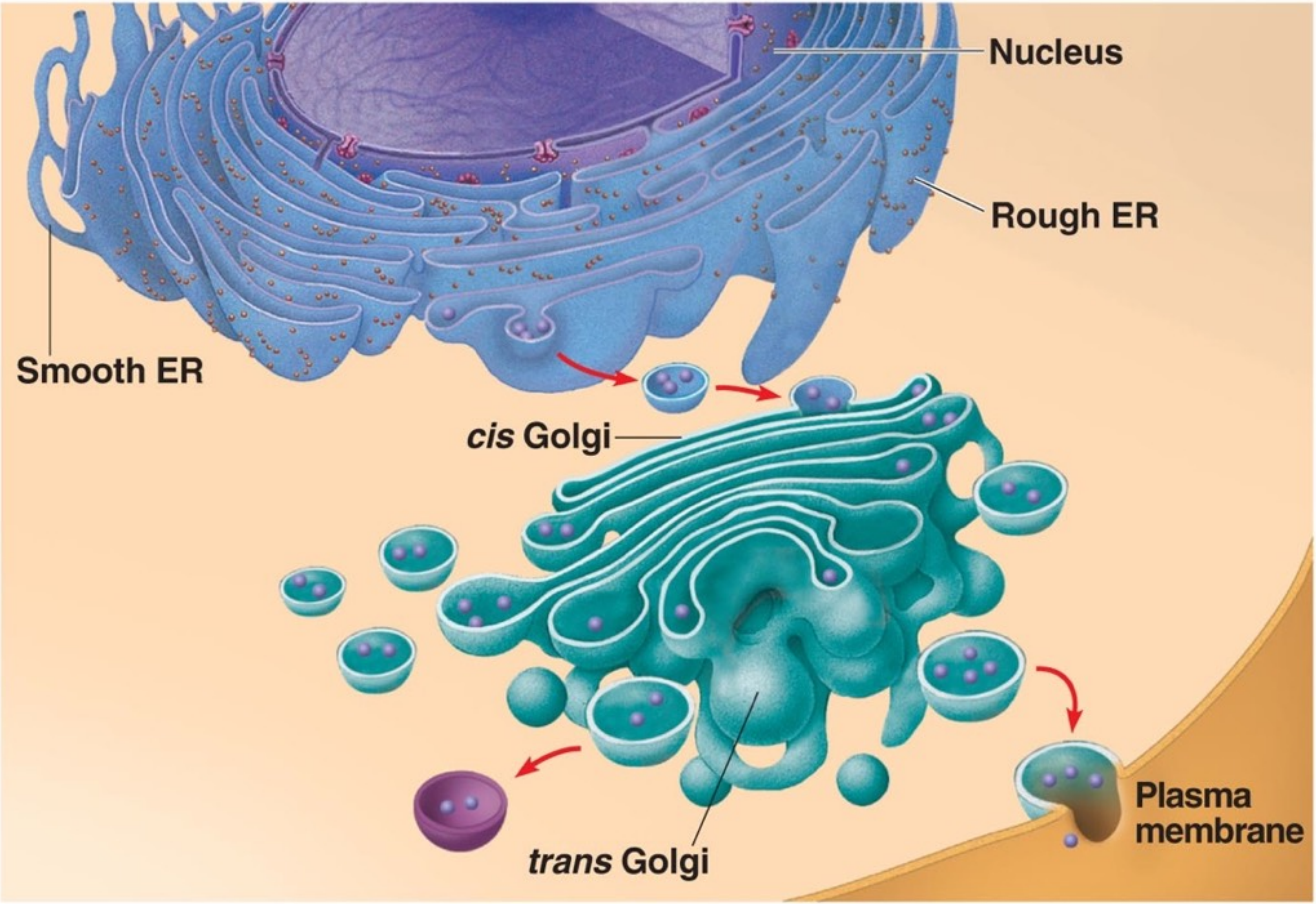
Structures

- Nuclear Envelope
- Endoplasmic Reticulum
- Golgi Apparatus
- Lysosomes
- Vesicles
- Plasma Membrane

Functions

- Protein Synthesis
- Transportation of Proteins
- Chemical Reactions (metabolism)
- Transportation of Lipids
- Detoxification of Poisons

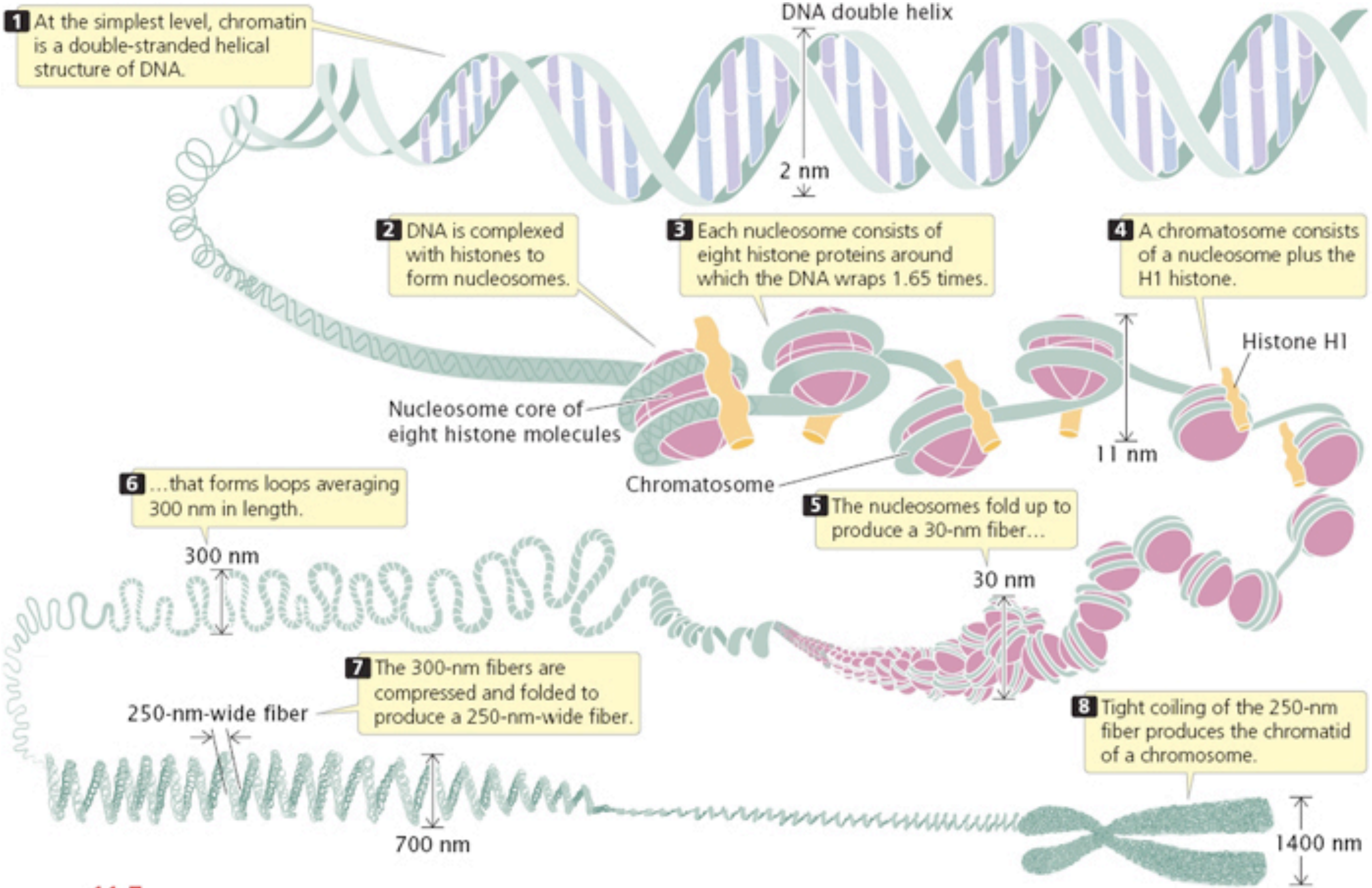
Endomembrane System



Molecular Basis of Inheritance

Main Idea: DNA is packaged around proteins in cells, in varying forms, some forms more accessible than others.

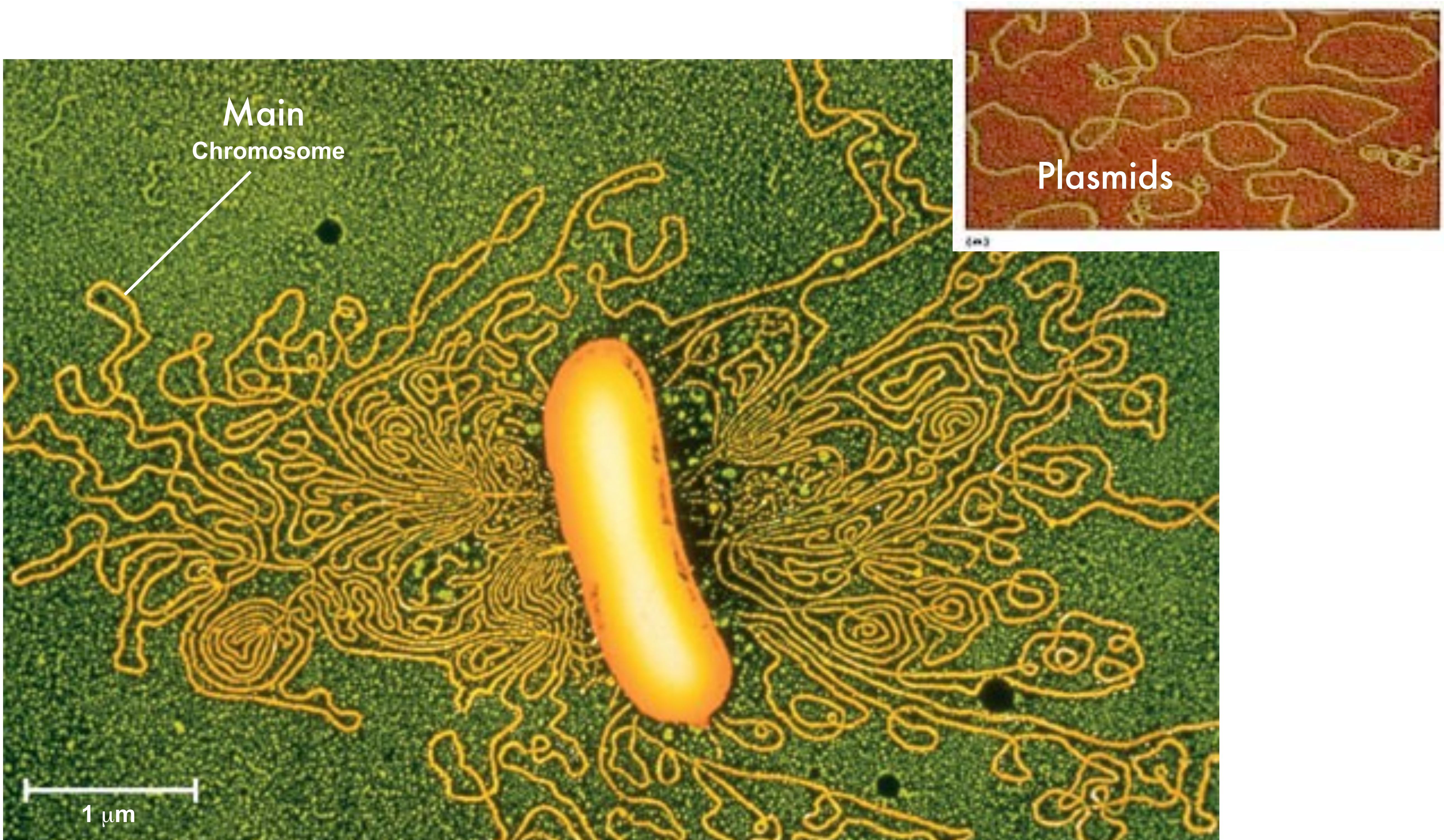
Chromatin & Chromosomes



Where do bacteria store their DNA?

- Bacterial DNA is found in a large circular chromosome with very few proteins.
- The chromosome is located in a nucleoid region.
    - *remember no membrane bound organelles like a nucleus*
- Some bacteria have small circular accessory chromosome called plasmids.
    - *these reproduce independent from the main chromosome*
    - *these are often utilized in the biotech industry*
    - *they often carry resistant type genes (called r plasmids)*

Bacterial Chromosome



Learning Objectives

LO 1.14 The student is able to pose scientific questions that correctly identify essential properties of shared, core life processes that provide insights into the history of life on Earth. [See **SP 3.1**]

LO 1.15 The student is able to describe specific examples of conserved core biological processes and features shared by all domains or within one domain of life, and how these shared, conserved core processes and features support the concept of common ancestry for all organisms. [See **SP 7.2**]

LO 1.16 The student is able to justify the scientific claim that organisms share many conserved core processes and features that evolved and are widely distributed among organisms today. [See **SP 6.1**]