

Big Idea 4: Biological systems interact, and these systems and their interactions possess complex properties.

Enduring understanding 4.A:
Interactions within biological
systems lead to complex
properties.

PREFACE

- **Cells are fundamental to life, the cell is the simplest collection of matter than can be alive.**
- All organisms are made of cells (or a single cell)
- Large complex organisms are made of cells
- Specialized cells working in cooperation make up these multicellular organisms.
- Specialized cells working together form tissues, specialized tissues work together to form organs, specialized organs form systems that together carry out life functions for the complex large, organism. There exists many unique cells however all cells share common features.
- **There exists many unique cells however all cells share common features.**

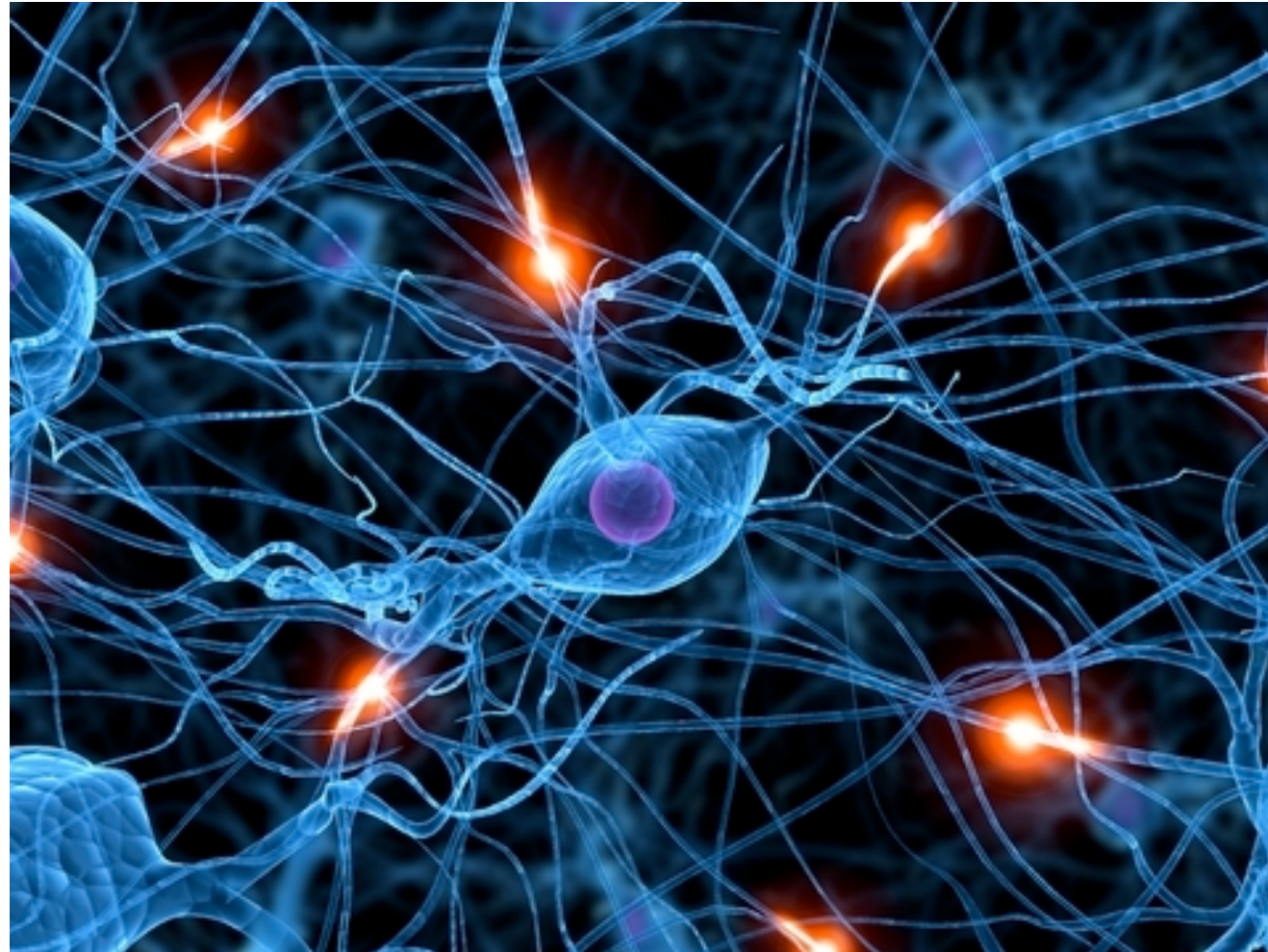
Essential knowledge 4.A.2: The structure and function of subcellular components, and their interactions, provide essential cellular processes.

a. Ribosomes are small, universal structures comprised of two interacting parts: ribosomal RNA and protein. In a sequential manner, these cellular components interact to become the site of protein synthesis where the translation of the genetic instructions yields specific polypeptides. [See also 2.B.3]

Tour of the Cell

Main Idea: The nucleus and ribosomes are most involved in the genetic control of a cell.

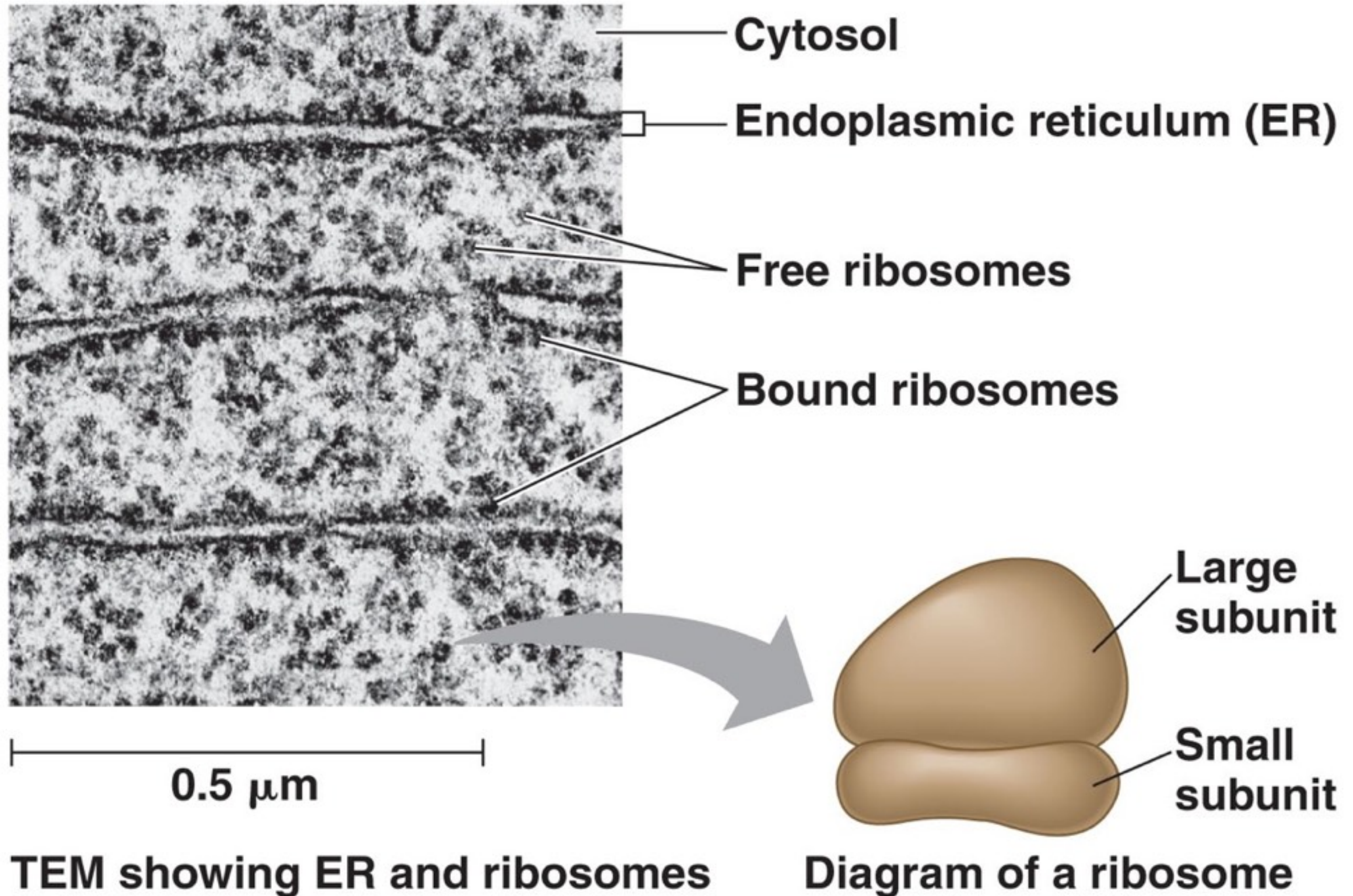
Main Idea: The nucleus contains the “blueprints” for proteins and the ribosomes serve as the “builders” of proteins.



The Ribosomes: Protein Factories

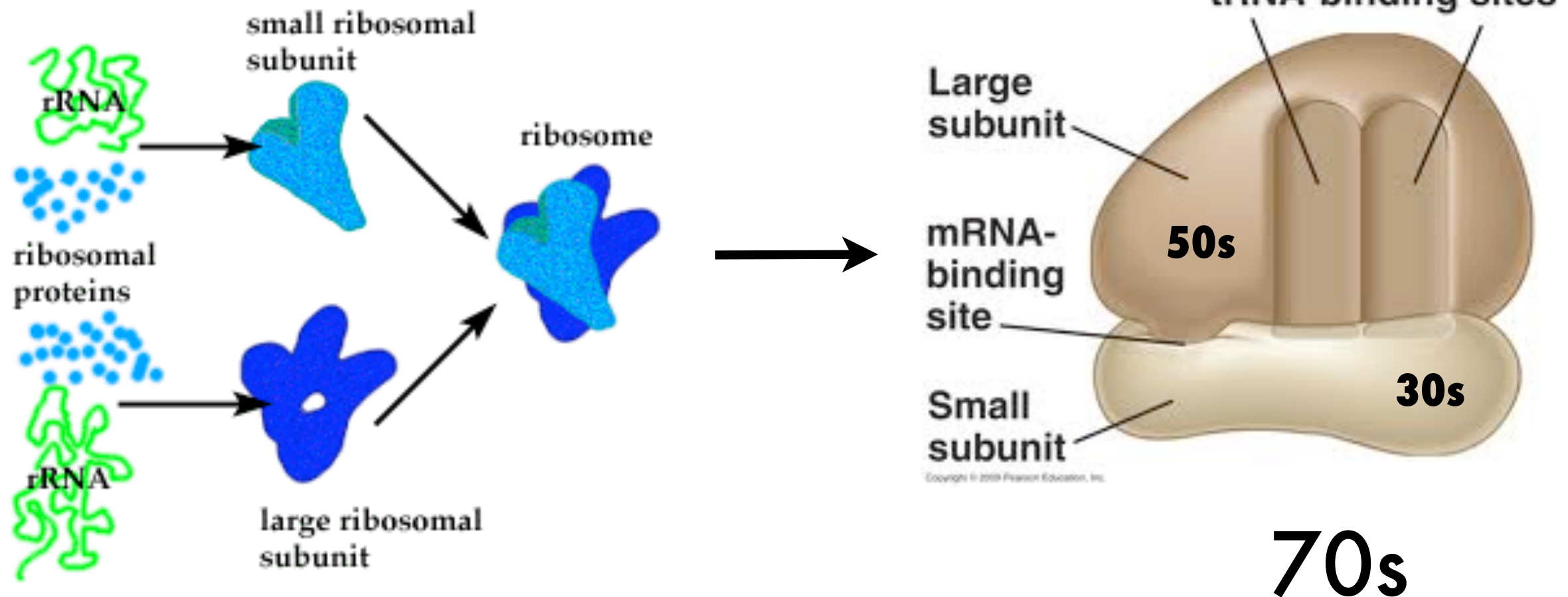
- Complexes of rRNA and Protein
- Carrying out protein synthesis
 - Proteins are built in locations 1.) in cytoplasm or 2.) outside surface of the endoplasmic reticulum
- *Free ribosomes* assemble proteins in cytoplasm
 - these proteins are often destined to remain inside the cell
- *Bound ribosomes* assemble proteins on the surface of the endoplasmic reticulum or nuclear envelope
 - these proteins are often destined for insertion into membranes or to be exported from the cell

Ribosomes: continued

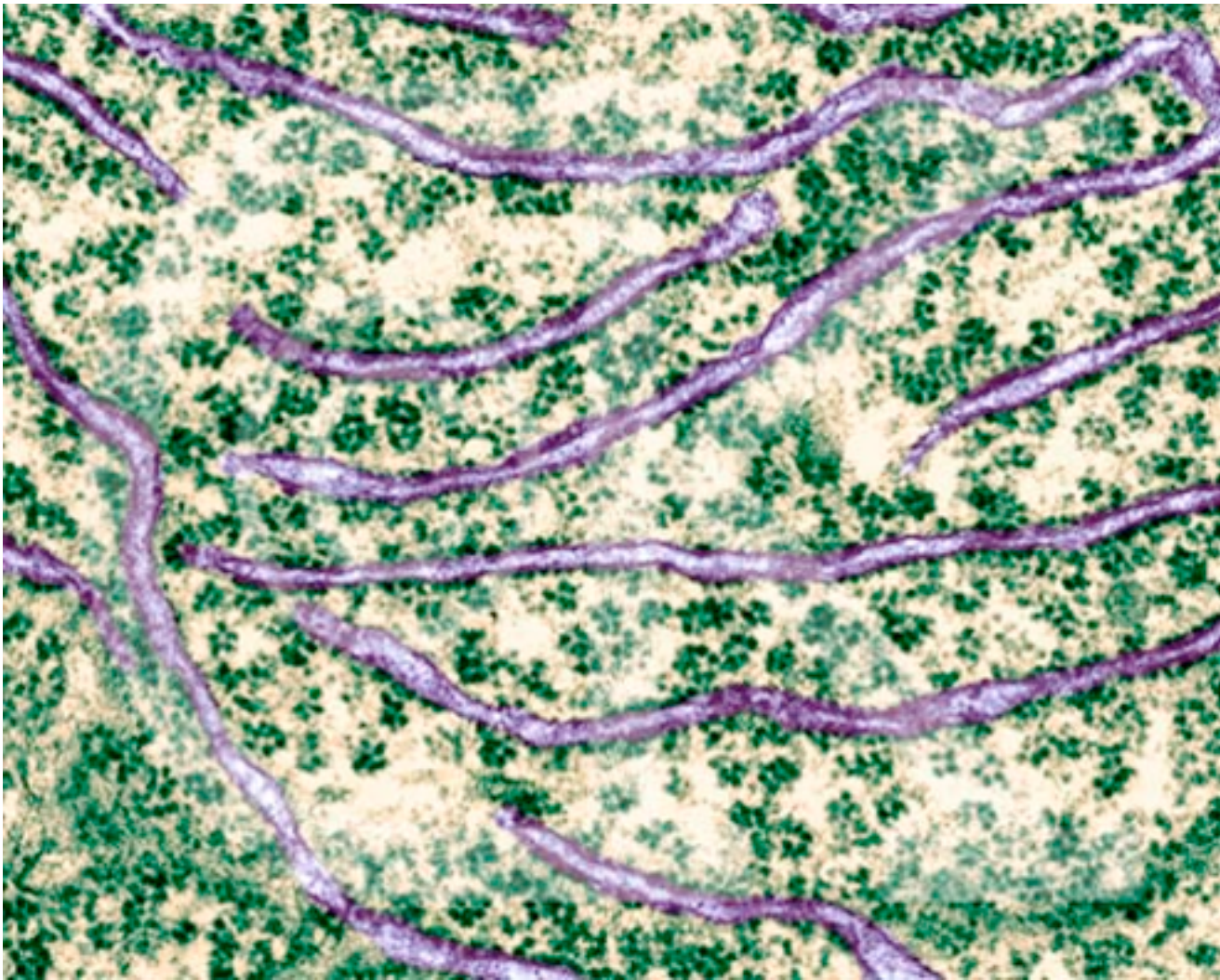
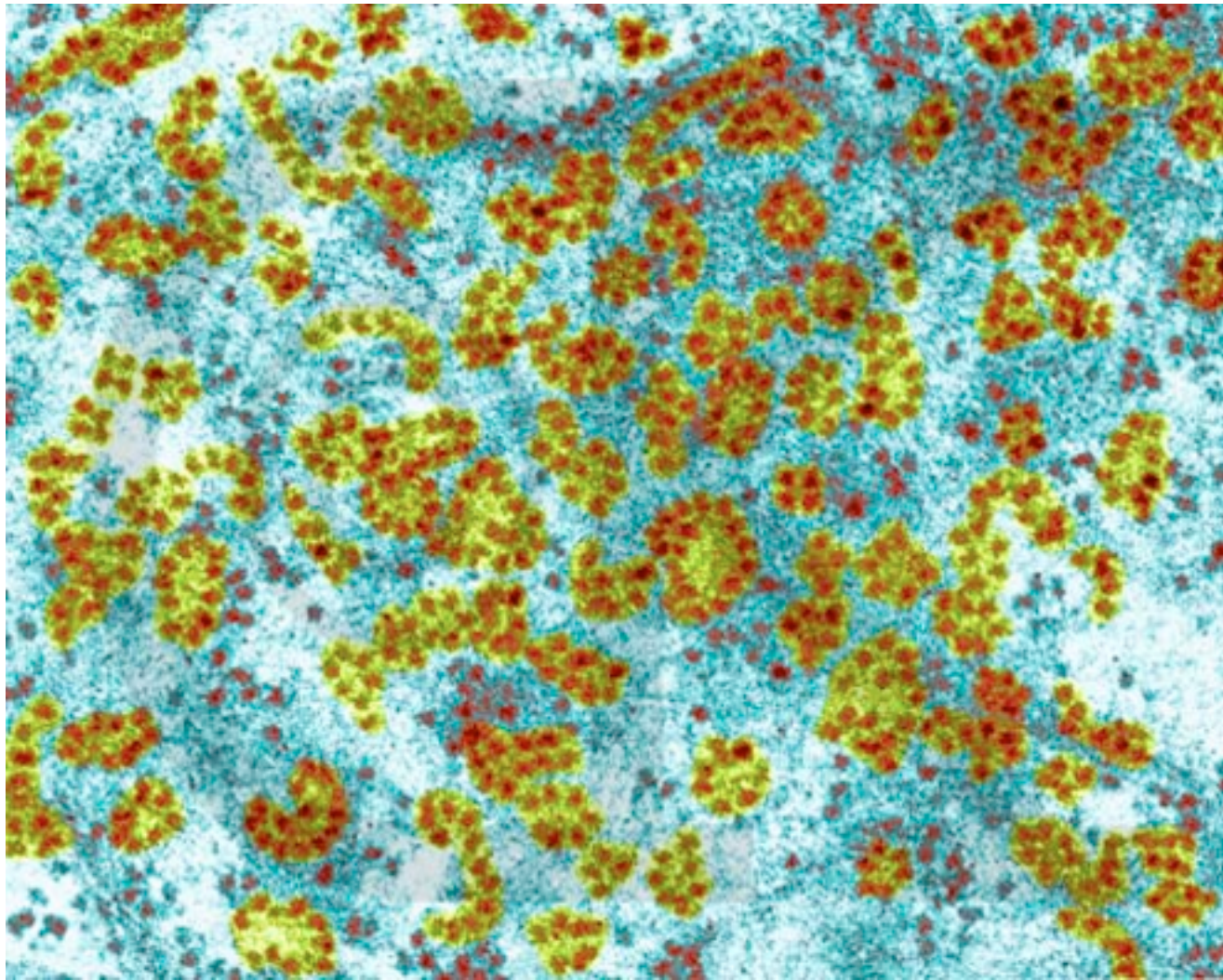


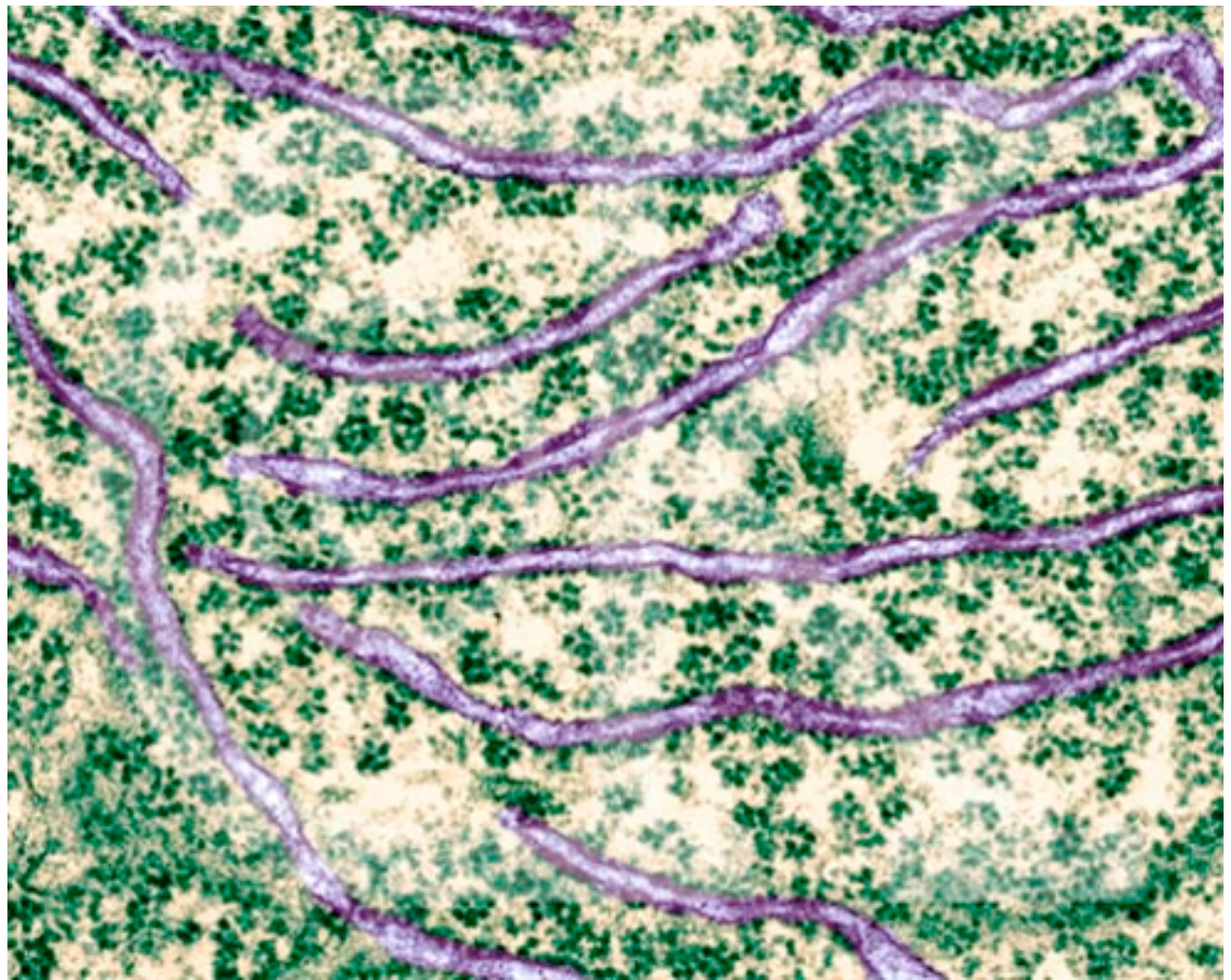
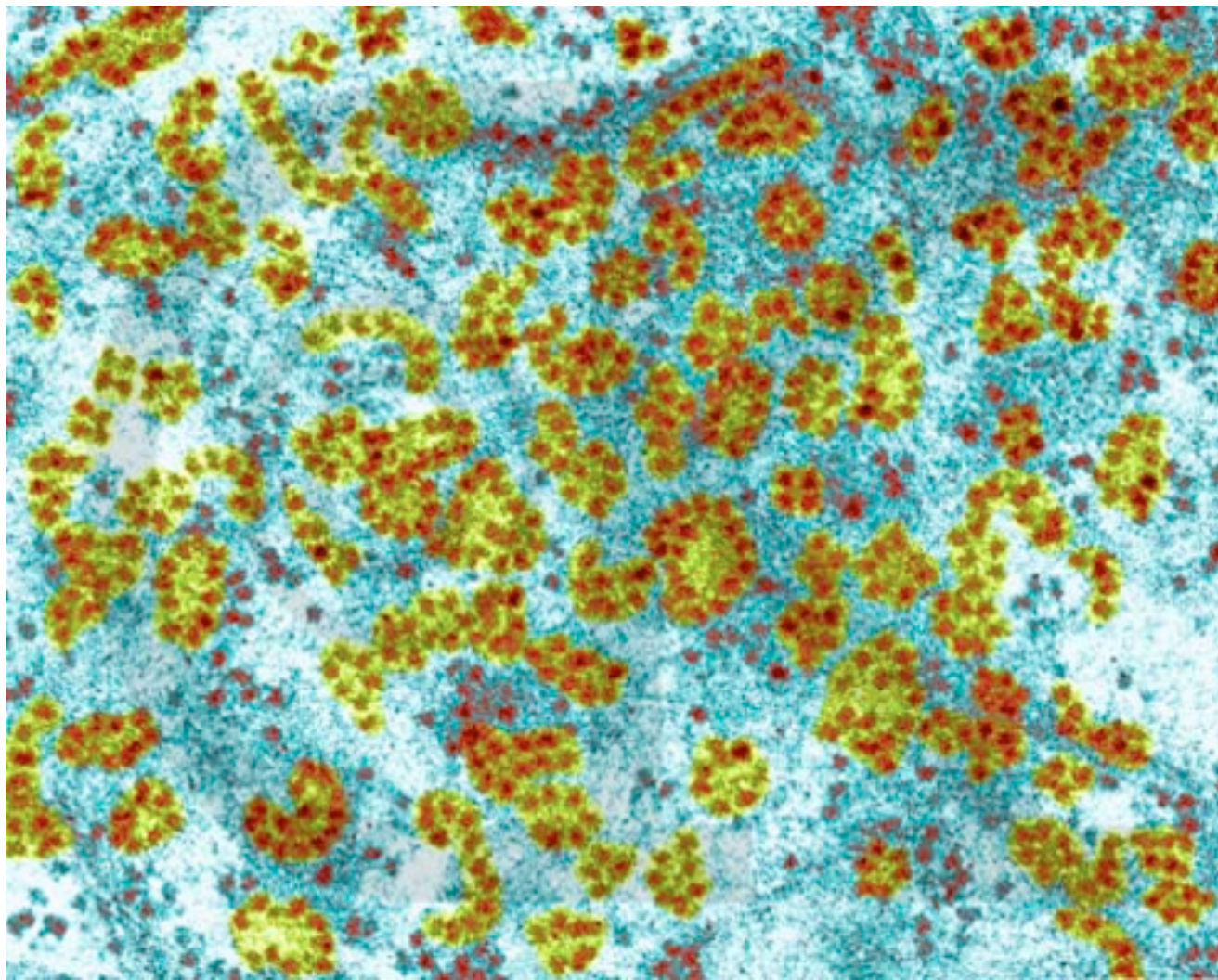
Ribosomes

Translation: the ribosome

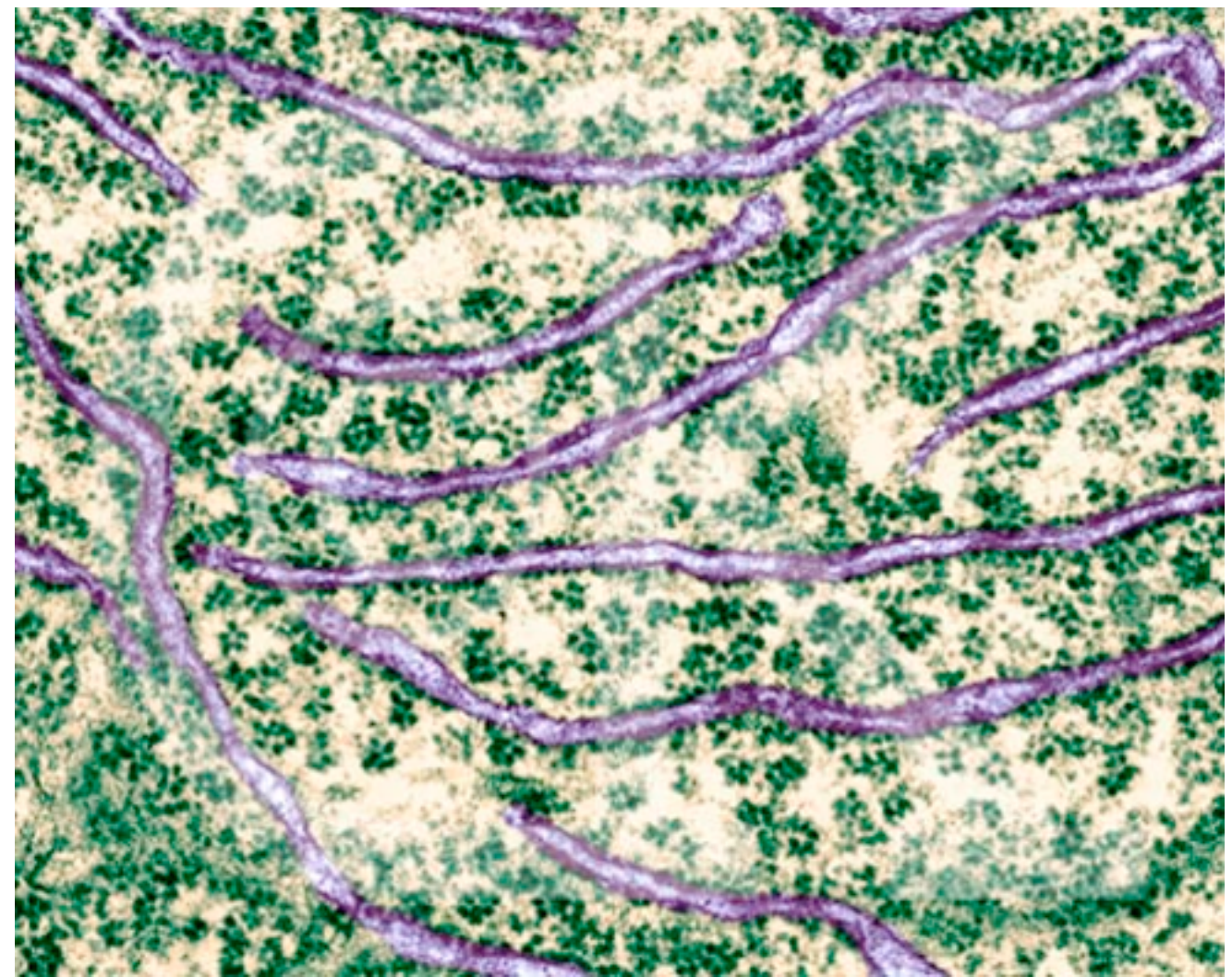
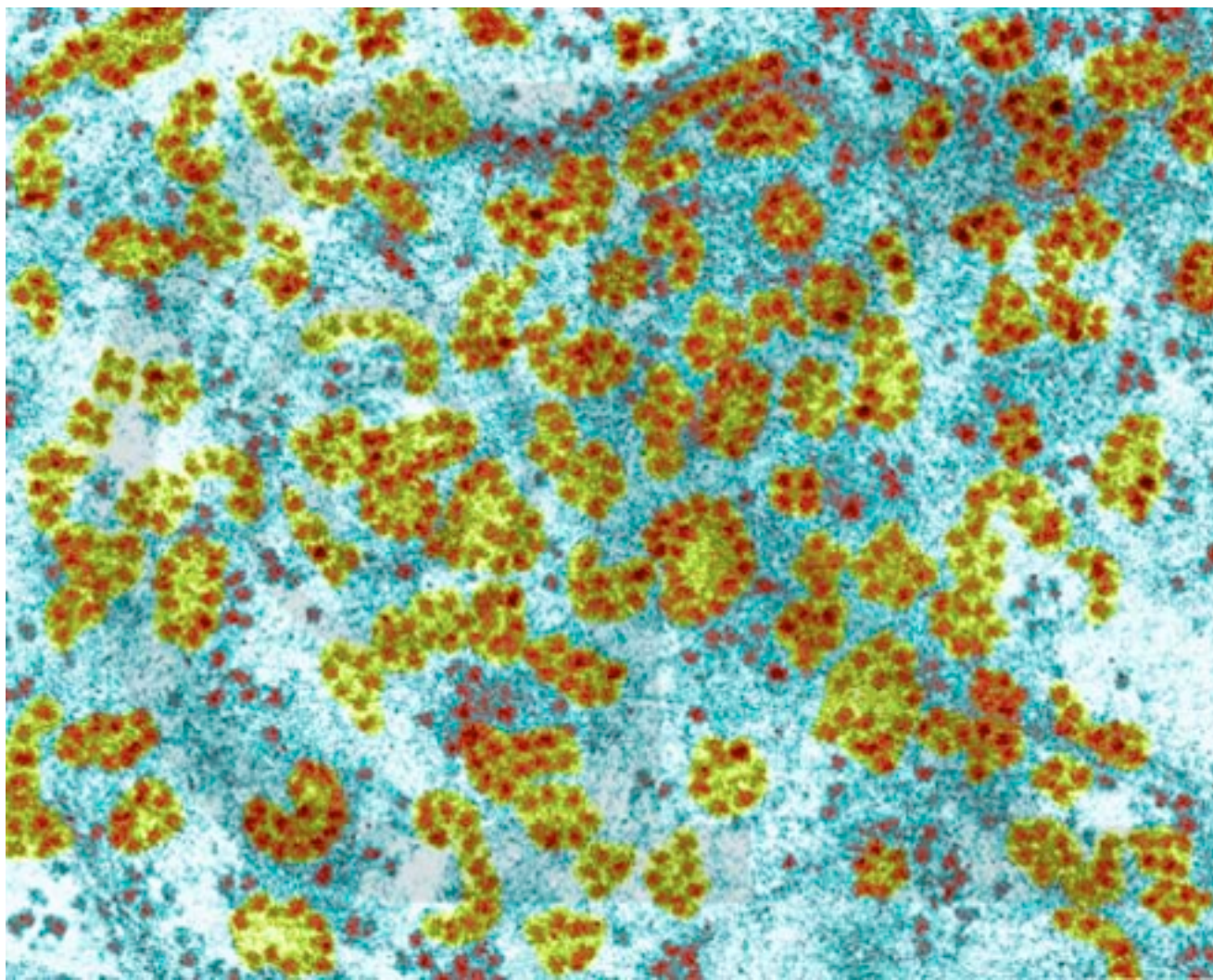


rRNA is the most abundant type of cellular RNA



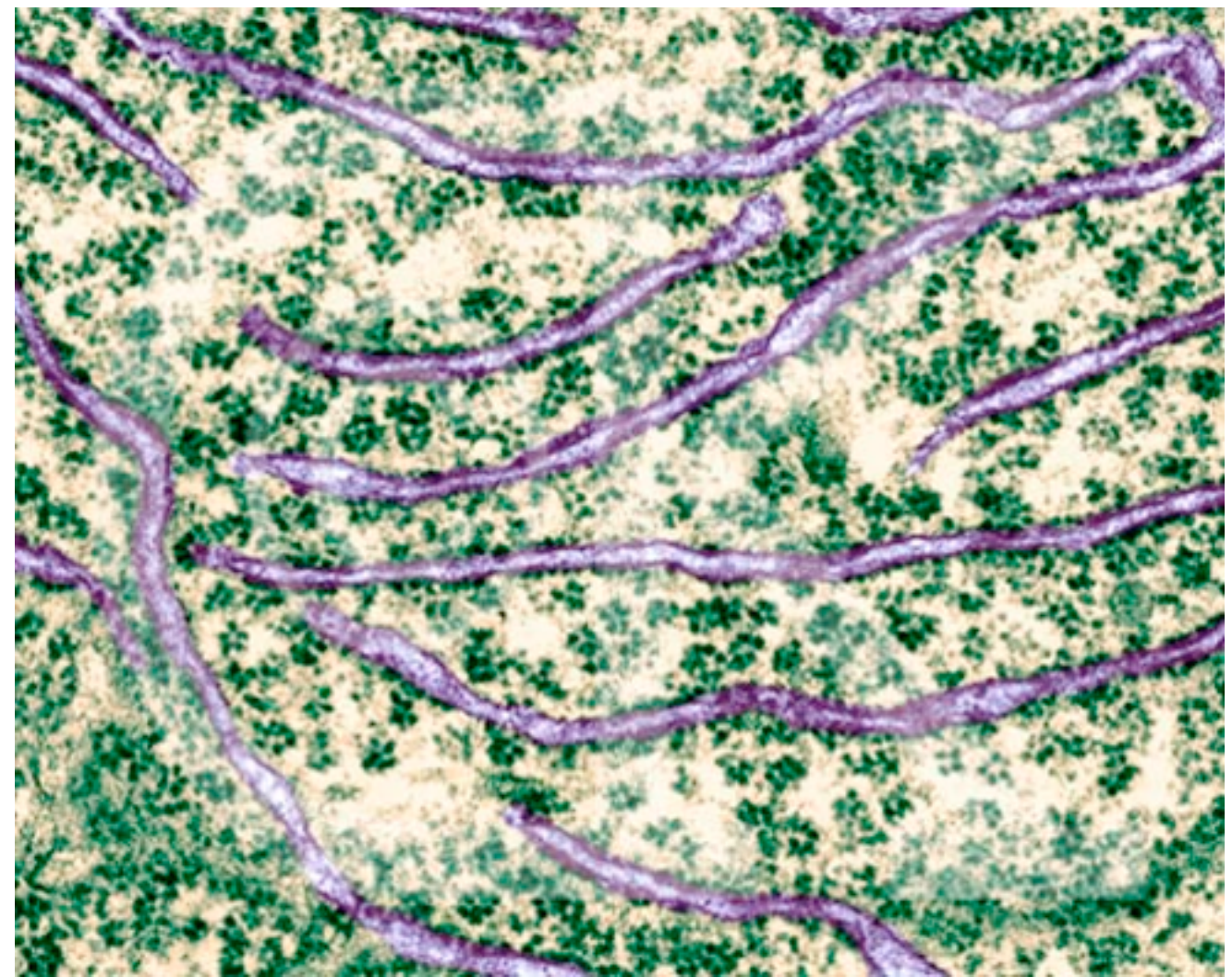
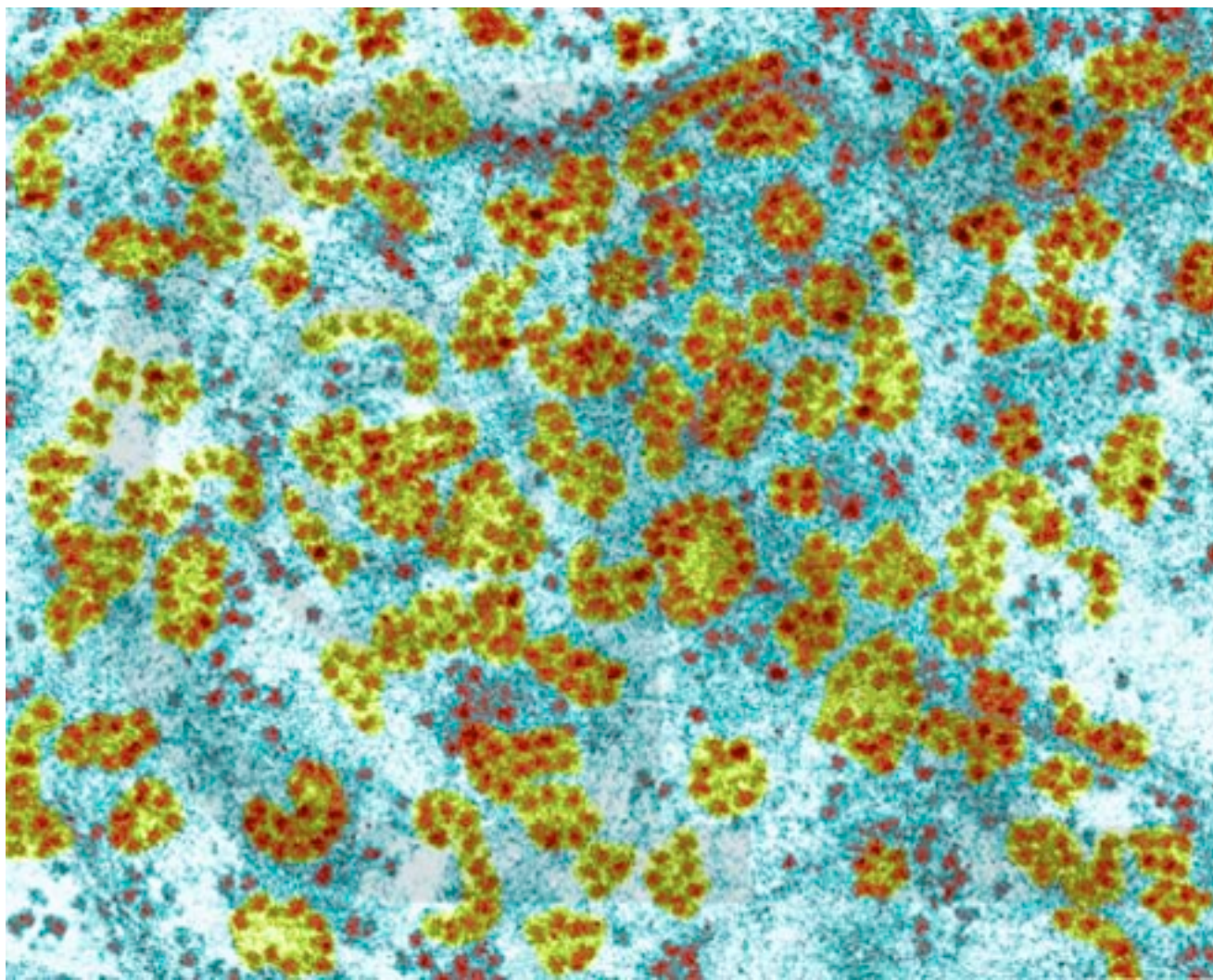


What trait(s) would a cell have if it possessed an above average number of ribosomes?



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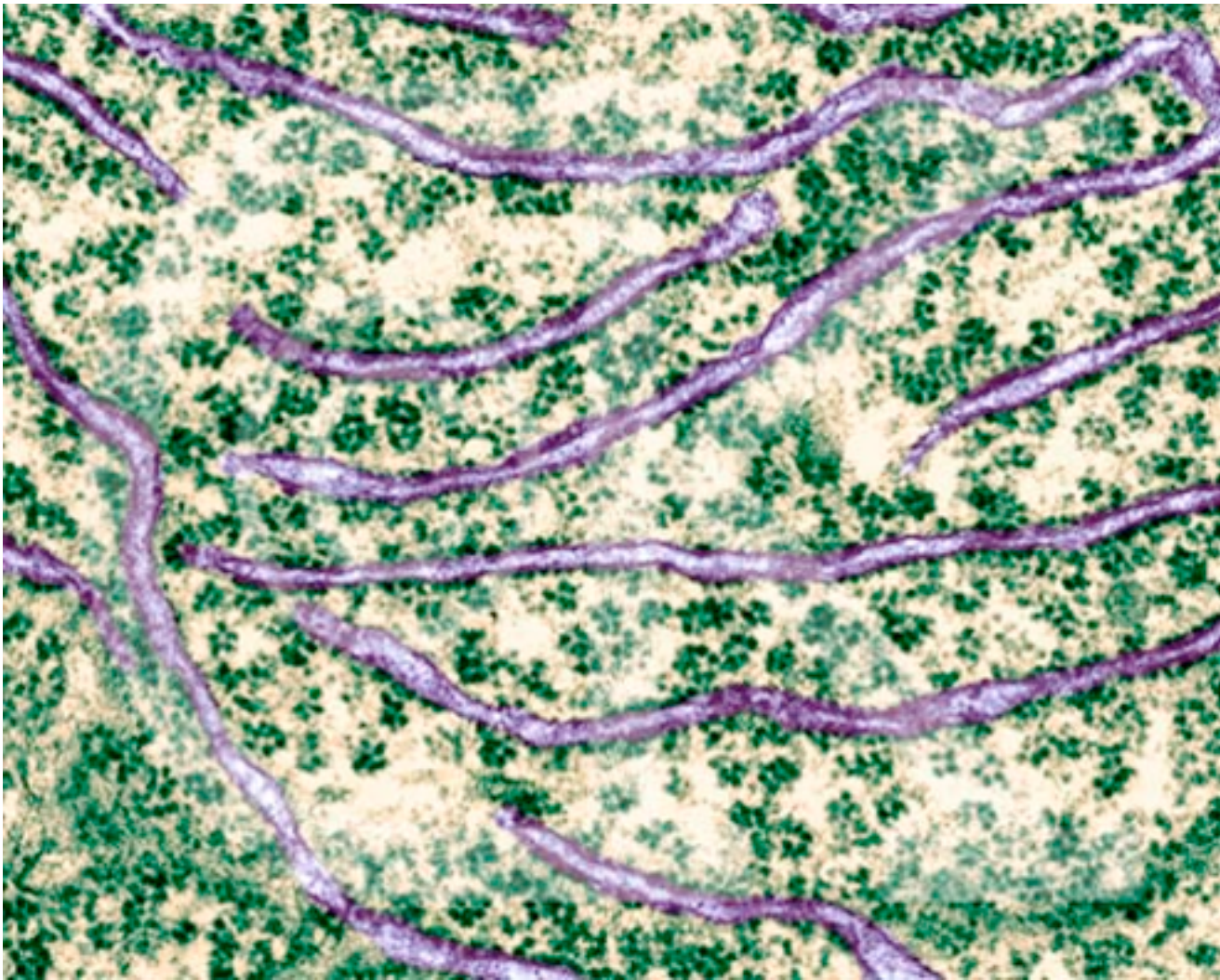
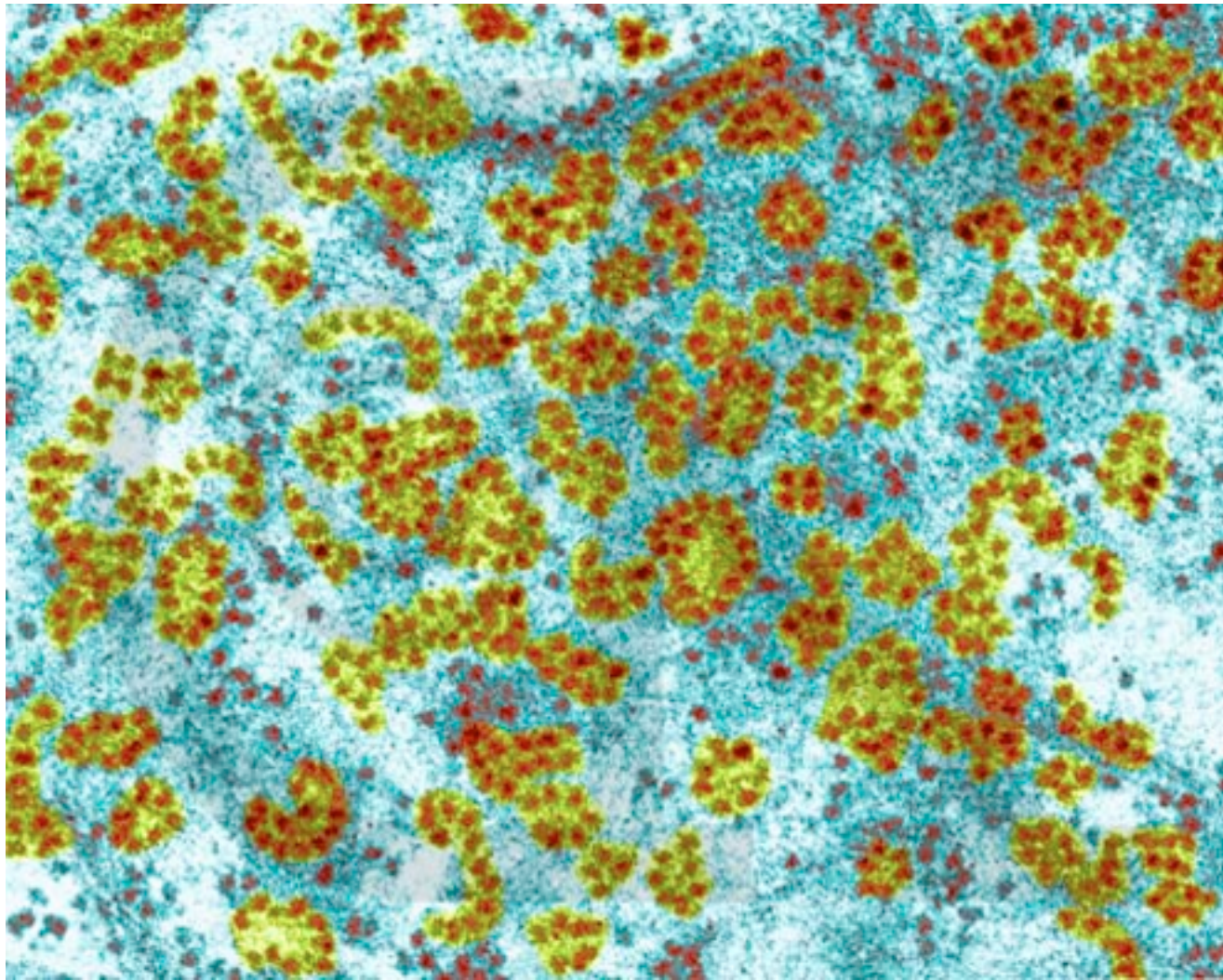
Can you think of cell types in your body that might have an above average number of ribosomes?

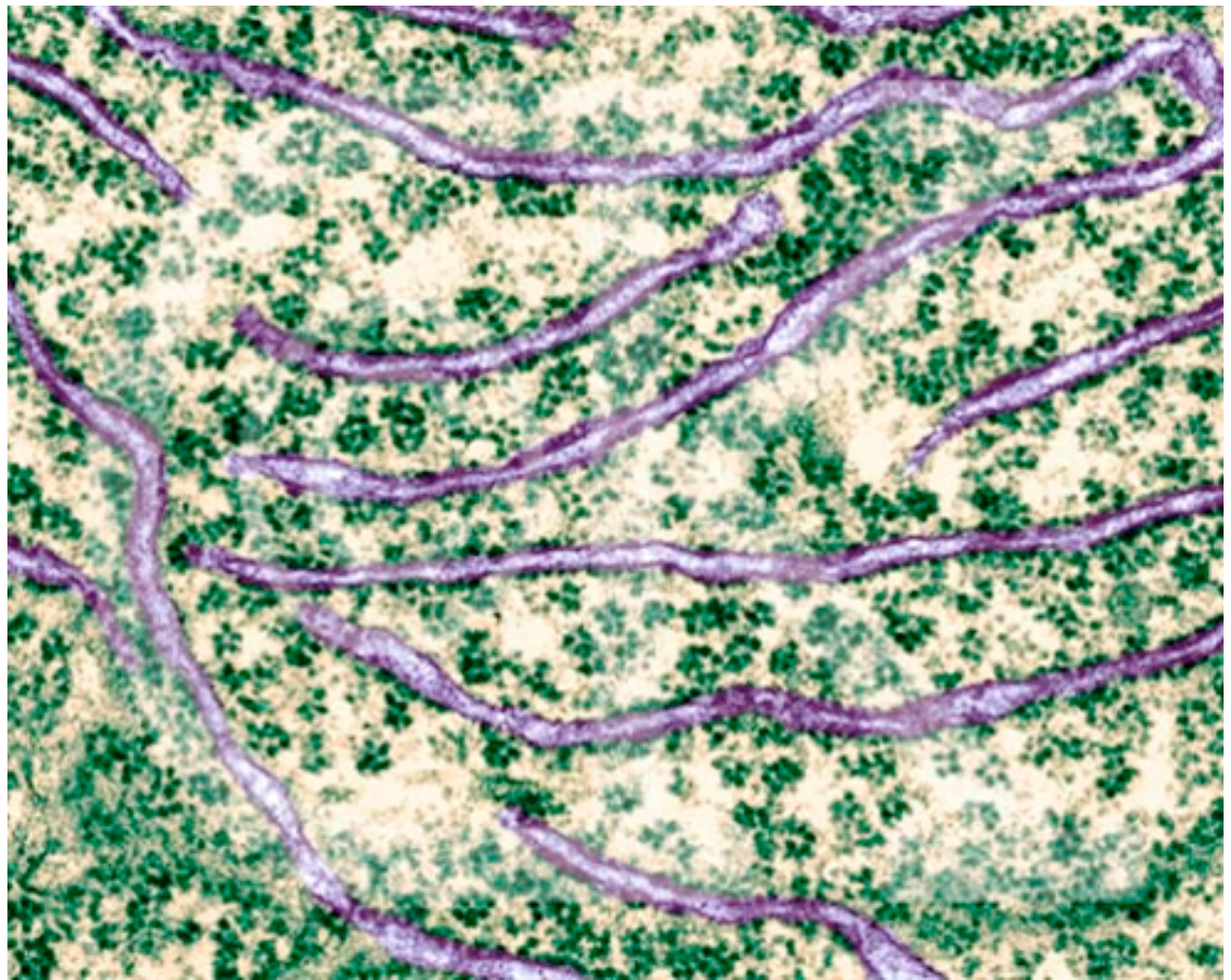
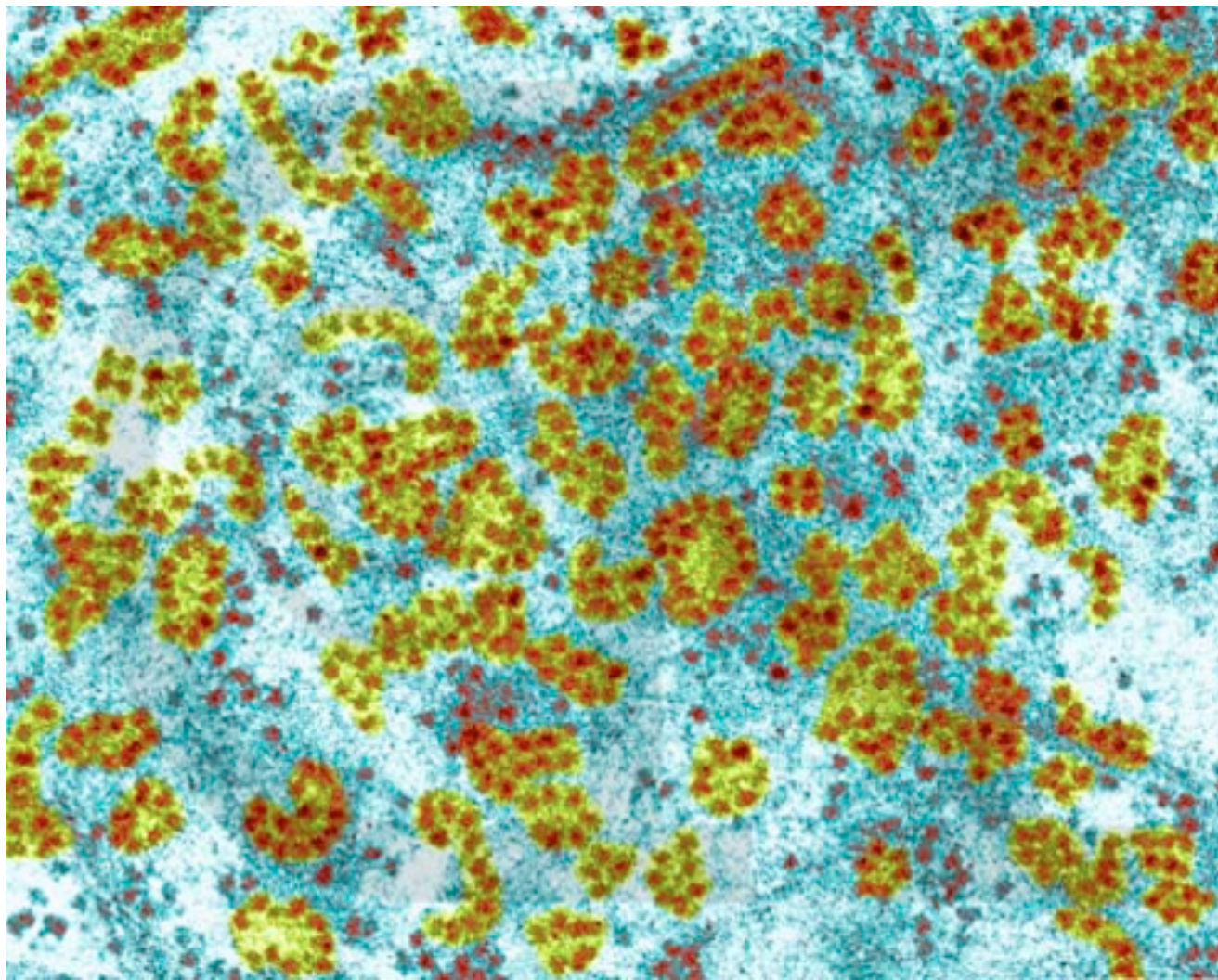


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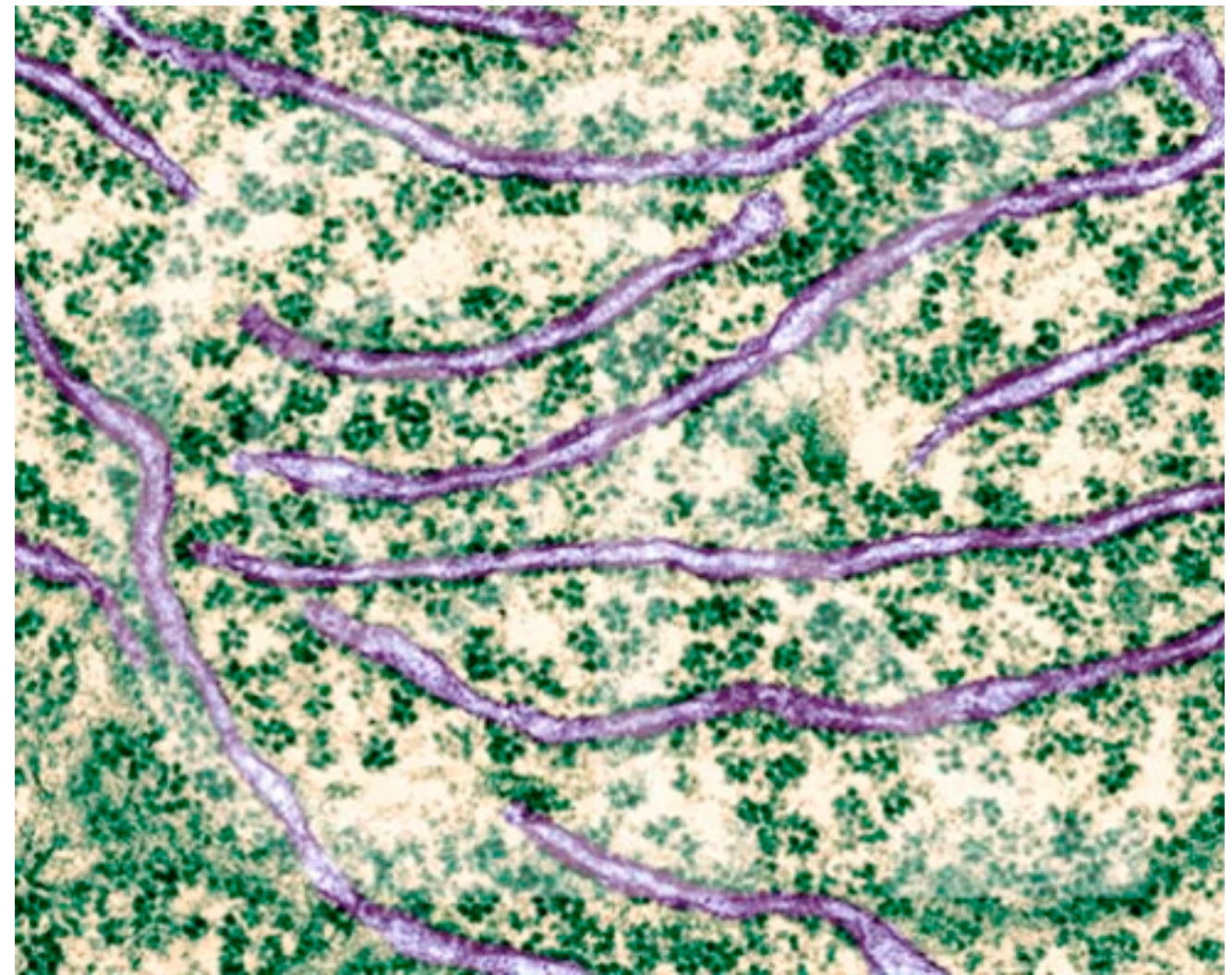
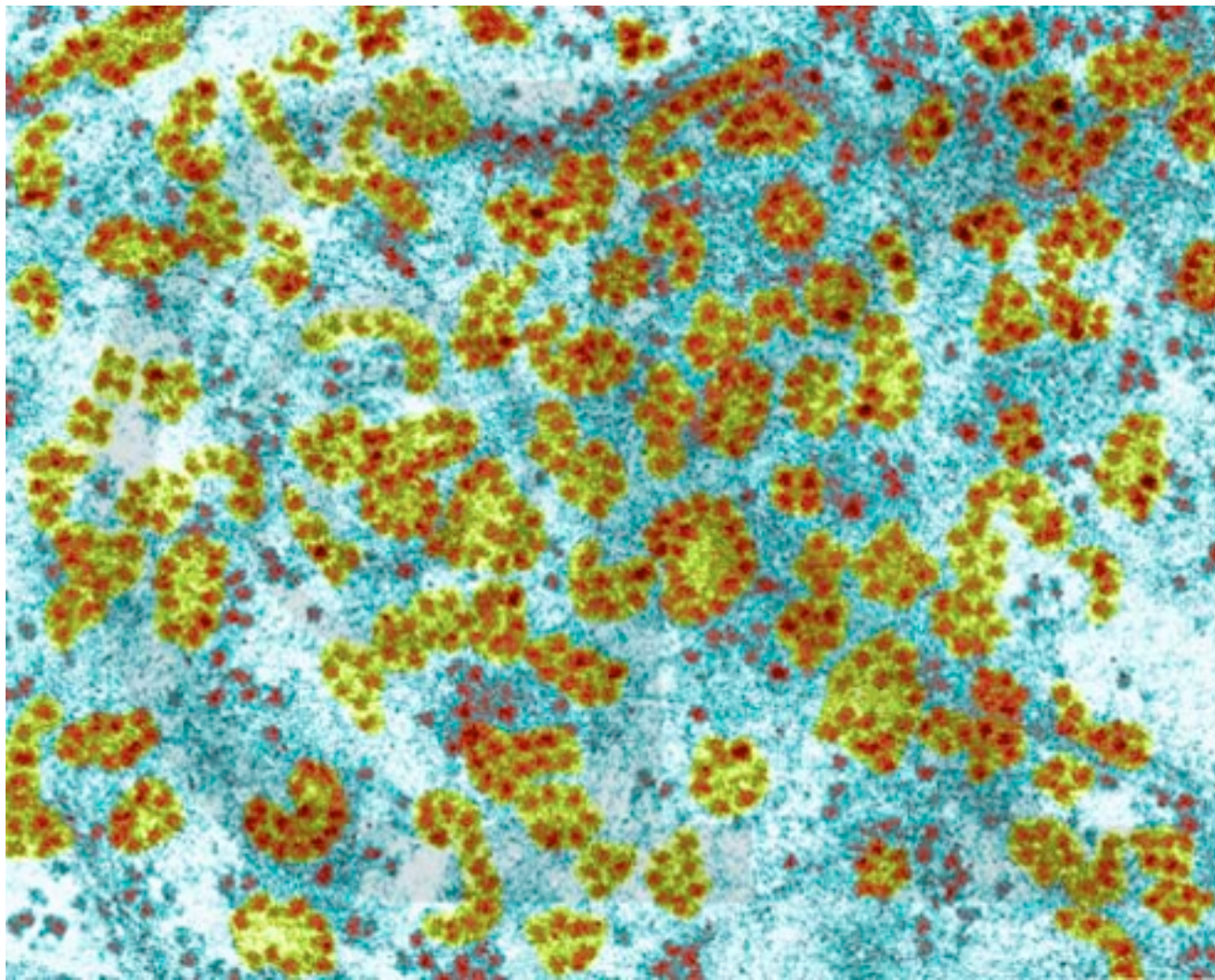
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Mature red blood cells expel their nucleus, how many ribosomes would expect to find in these cells?



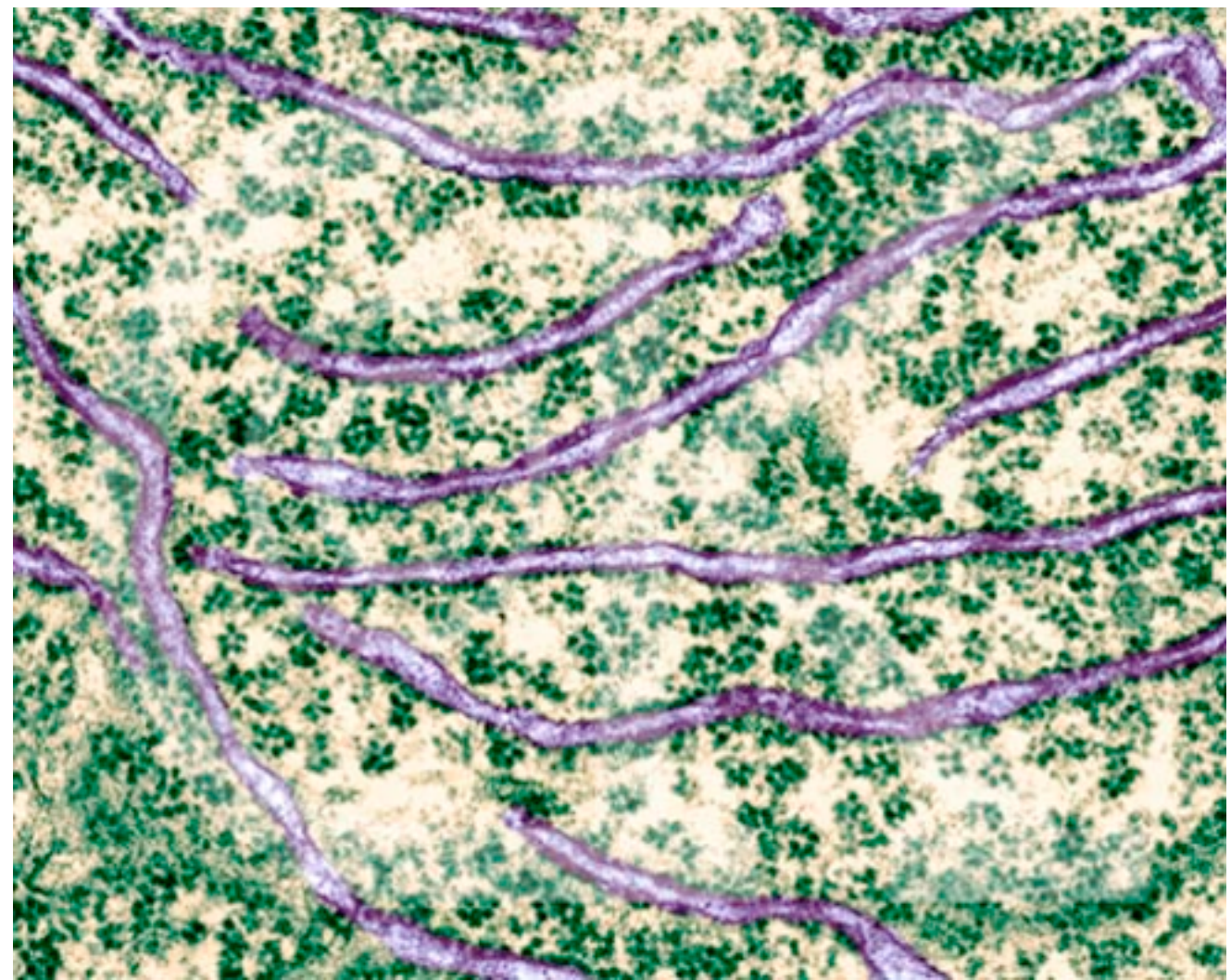
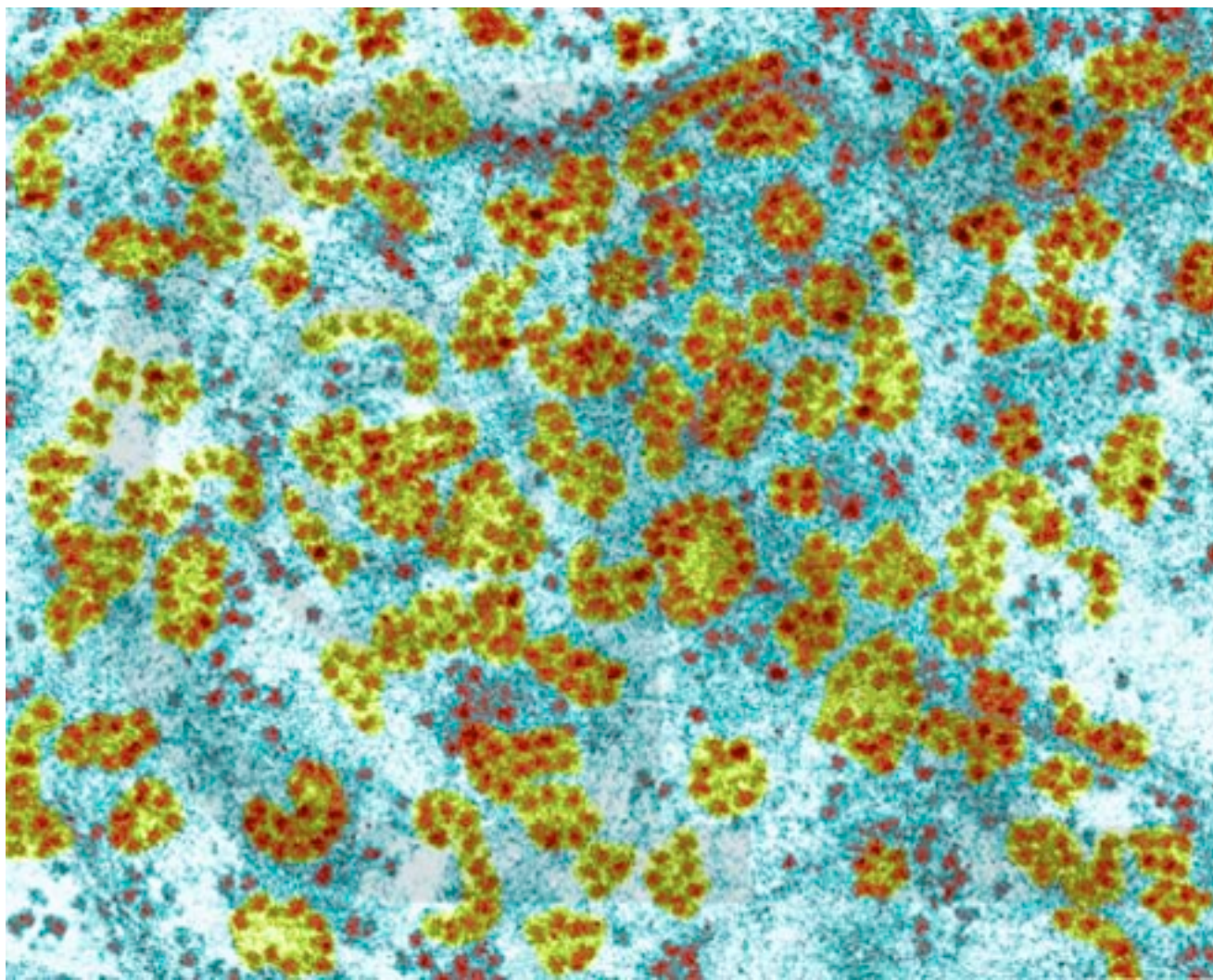


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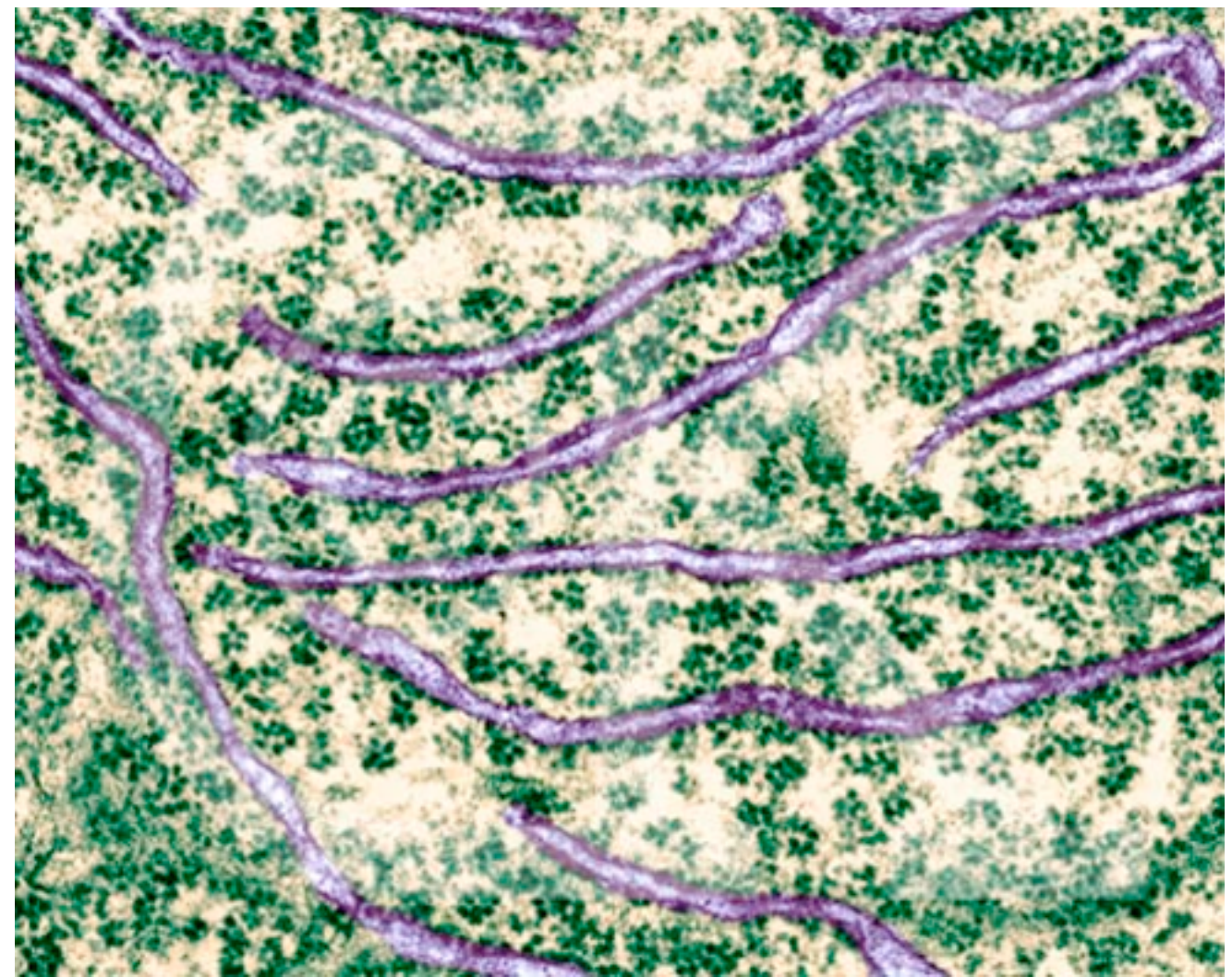
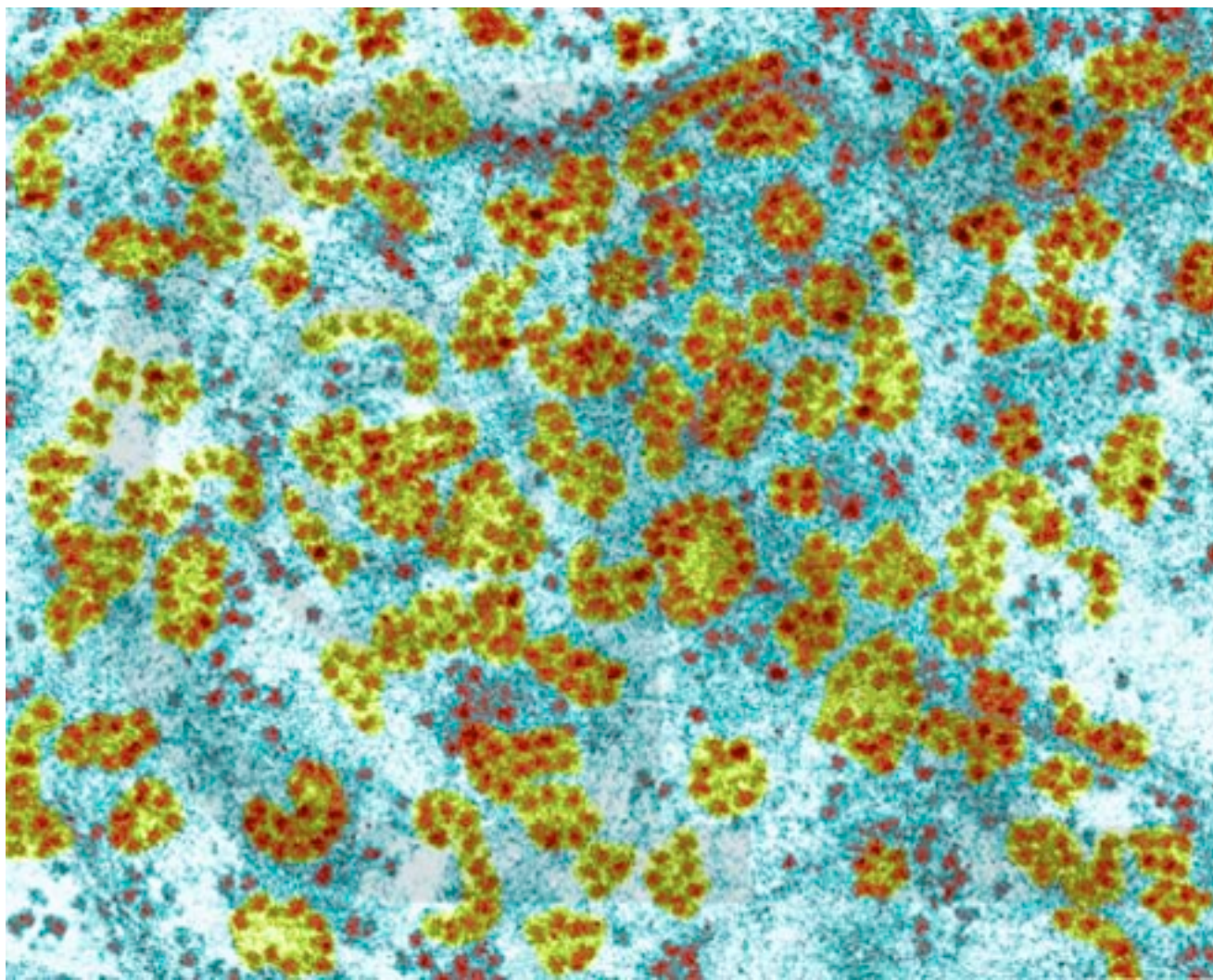
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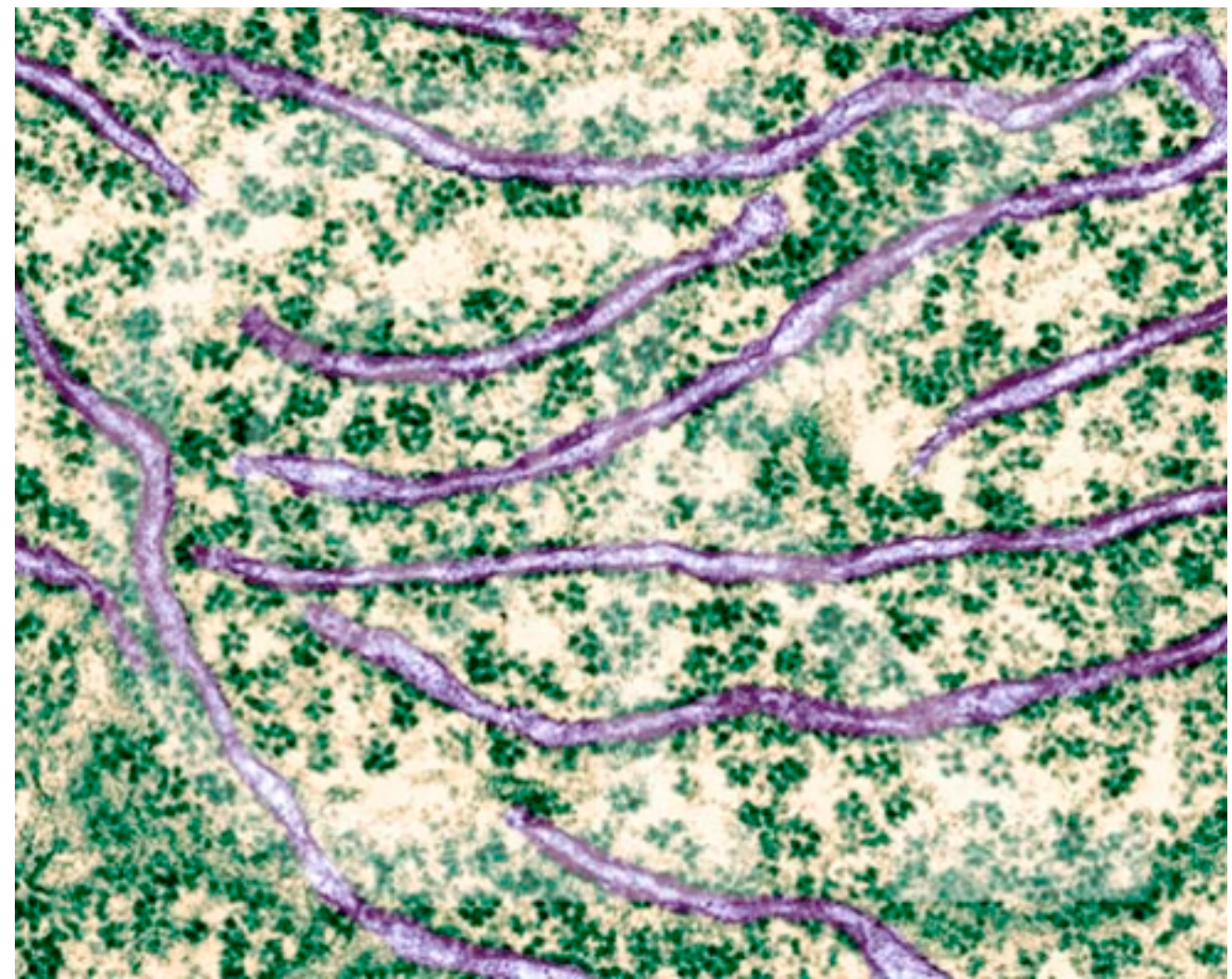
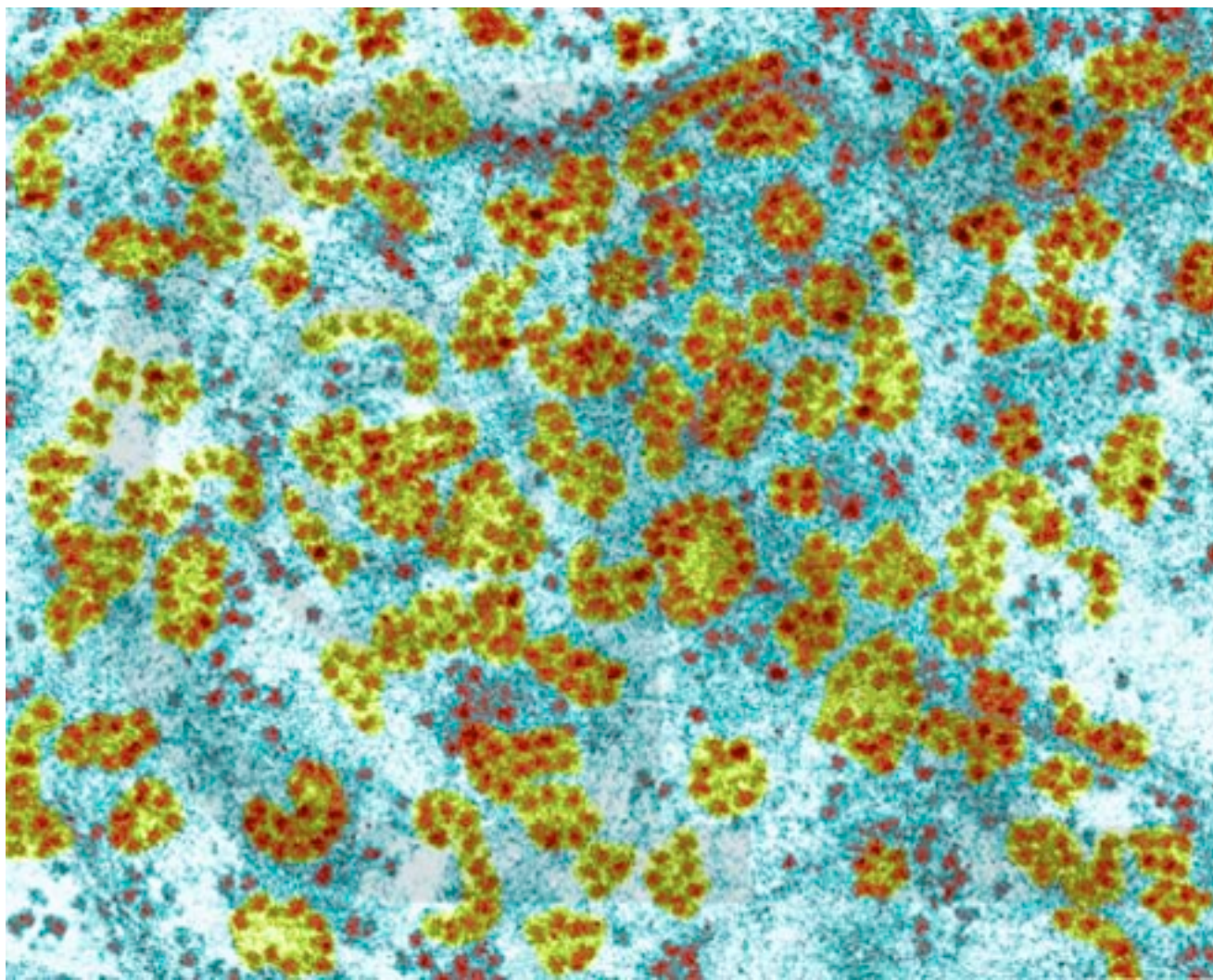
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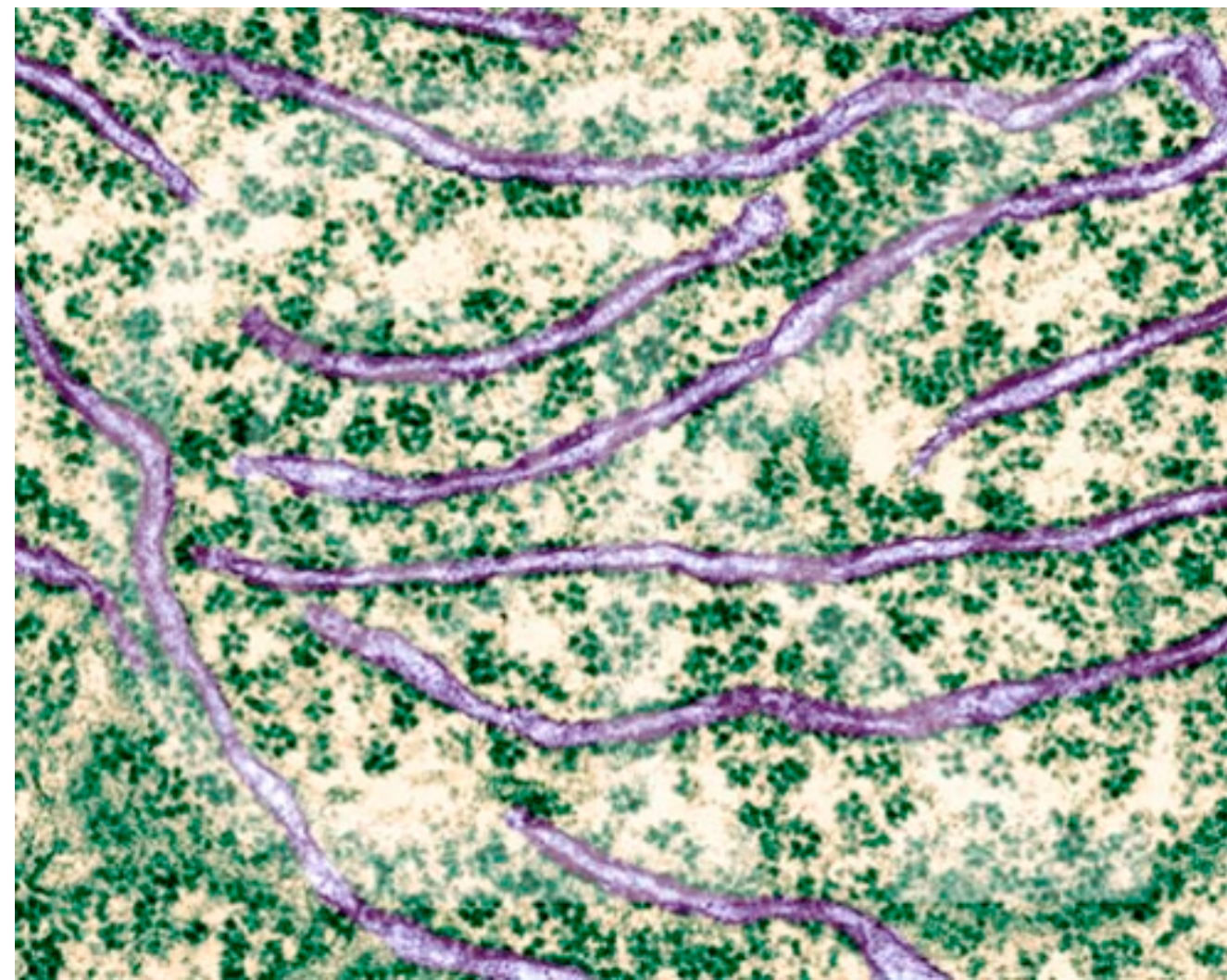
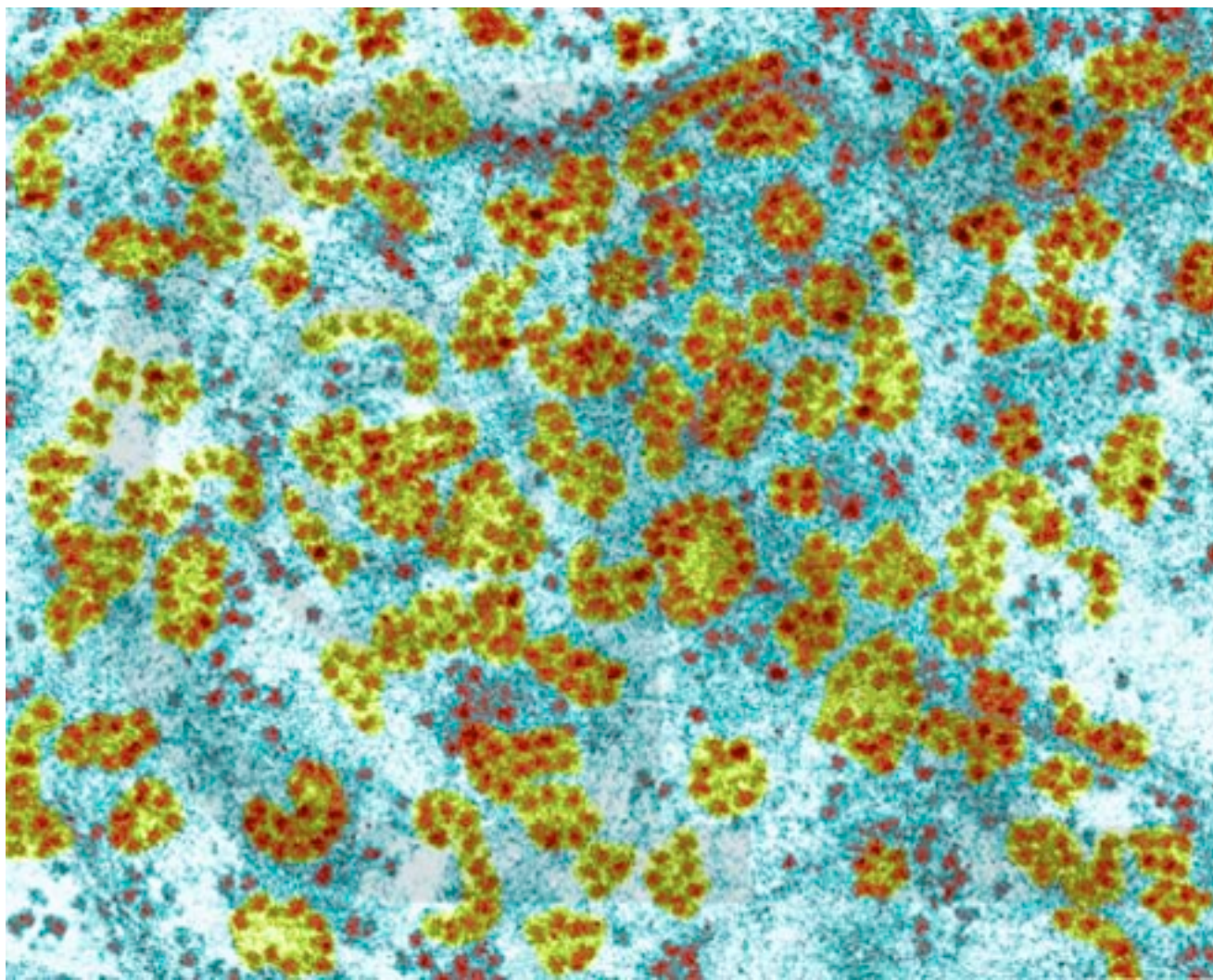
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Can you think of cell types in your body that might have an above average number of ribosomes? **liver cells, pancreas cells, stomach cells**

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What trait(s) would a cell have if it possessed an above average number of ribosomes?
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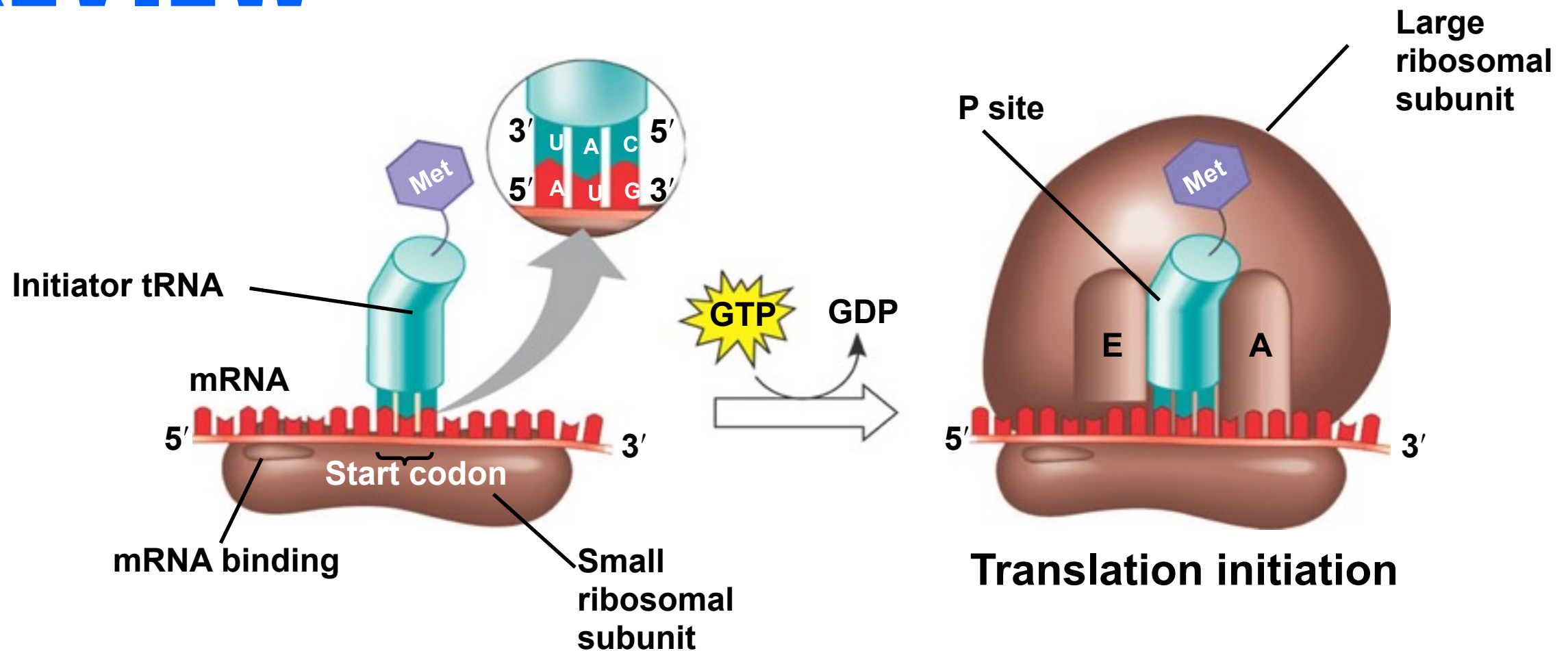
Can you think of cell types in your body that might have an above average number of ribosomes?
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Mature red blood cells expel their nucleus, how many ribosomes would expect to find in these cells?
zero

Translation- Initiation

REVIEW

"The Processes"



1.

A small ribosomal subunit binds to a molecule of mRNA. In a prokaryotic cell, the mRNA binding site on this subunit recognizes a specific nucleotide sequence on the mRNA just upstream of the start codon. An initiator tRNA, with the anticodon UAC, base-pairs with the start codon, AUG. This tRNA carries the amino acid methionine (Met).

2.

The arrival of a large ribosomal subunit completes the initiation complex. Proteins called initiation factors (not shown) are required to bring all the translation components together. **GTP provides the energy for the assembly.** The initiator tRNA is in the P site; the A site is available to the tRNA bearing the next amino acid.

Translation- Elongation

"The Processes"

1.

Codon recognition. The anticodon of an incoming aminoacyl tRNA base-pairs with the complementary mRNA codon in the A site. Hydrolysis of GTP increases the accuracy and efficiency of this step.

2.

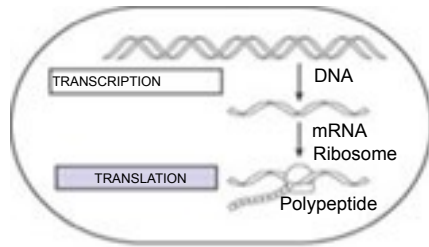
Peptide bond formation. An rRNA molecule of the large subunit catalyzes the formation of a peptide bond between the new amino acid in the A site and the carboxyl end of the growing polypeptide in the P site. This step attaches the polypeptide to the tRNA in the A site.

3.

Translocation. The ribosome translocates the tRNA in the A site to the P site. The empty tRNA in the P site is moved to the E site, where it is released. The mRNA moves along with its bound tRNAs, bringing the next codon to be translated into the A site.

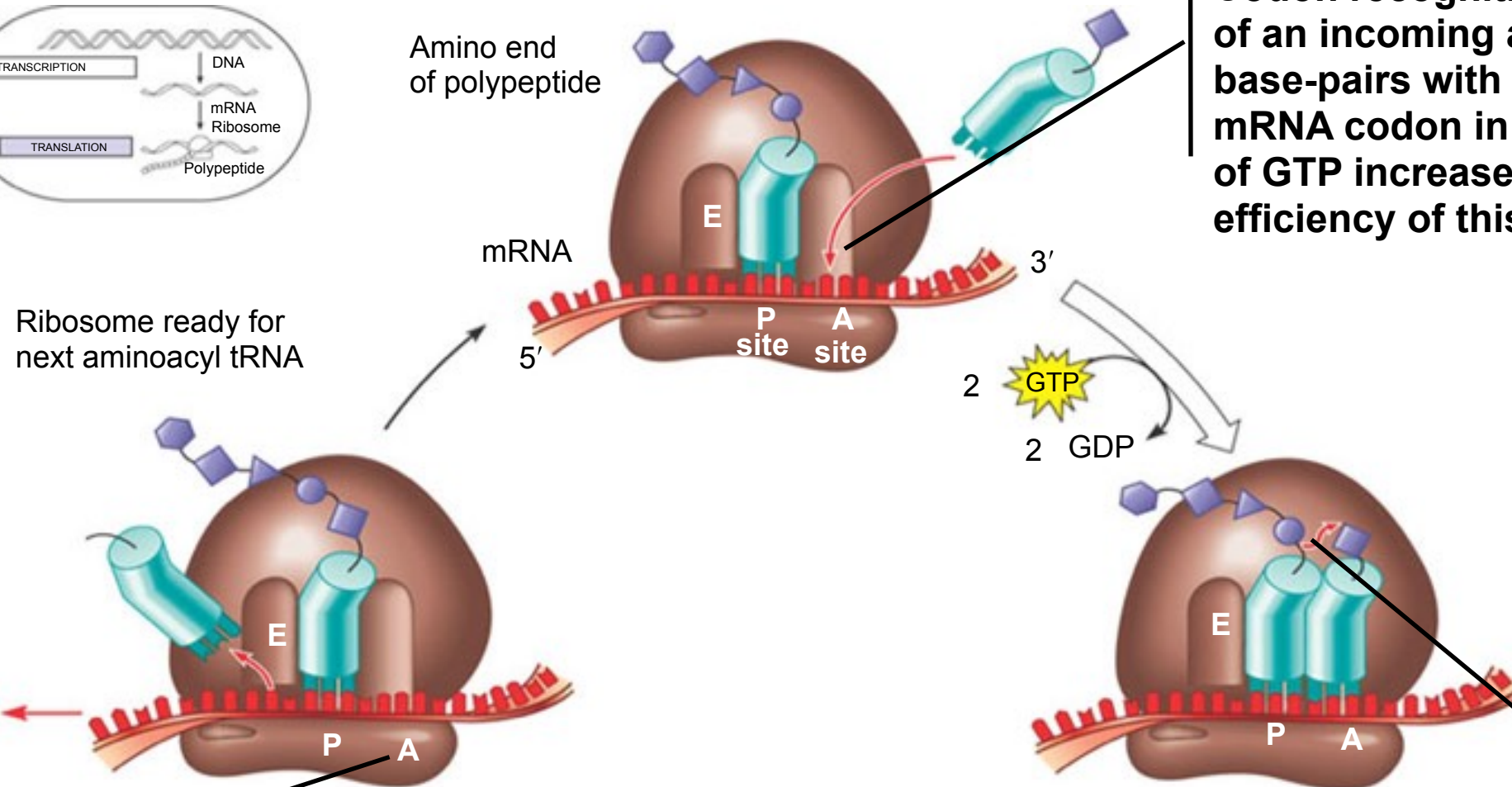
Translation- Elongation

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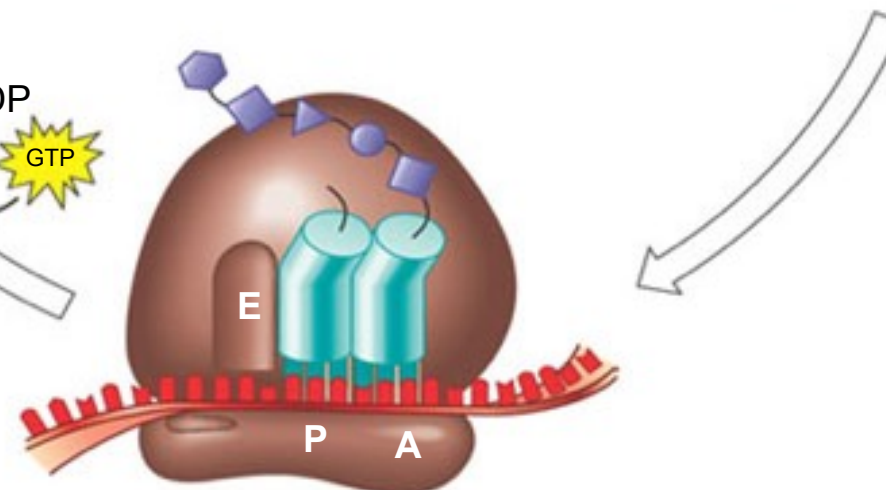
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Translation- Termination

“The Processes”

Keep in mind this polypeptide now
↓ must fold into a 3-D molecule
before it becomes functional

When a ribosome reaches a stop codon on mRNA, the A site of the ribosome accepts a protein called a release factor instead of tRNA.

1.

The release factor hydrolyzes the bond between the tRNA in the P site and the last amino acid of the polypeptide chain. The polypeptide is thus freed from the ribosome.

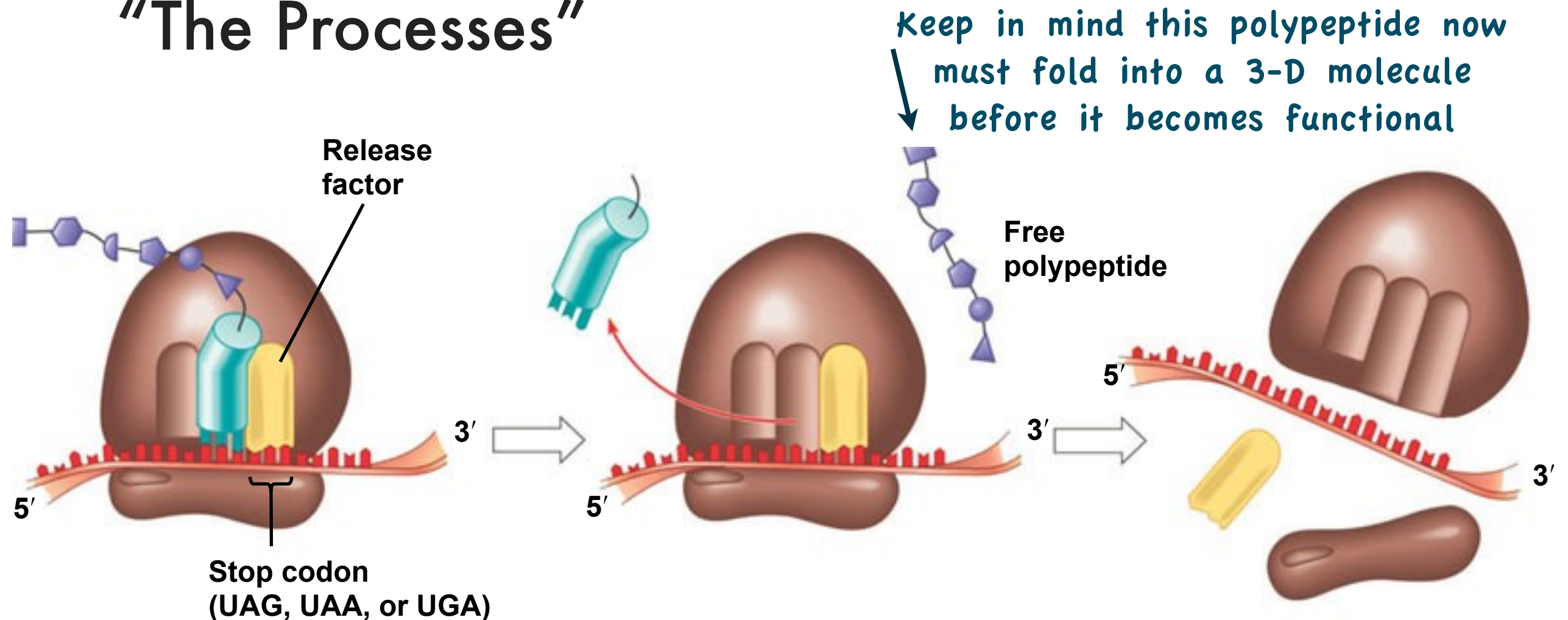
2.

The two ribosomal subunits and the other components of the assembly dissociate. **This also requires energy- 2GTP molecules.**

3.

Translation- Termination

"The Processes"



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3.

Final Summary

TRANSCRIPTION

RNA is transcribed from a DNA template.

5' RNA transcript

DNA

RNA polymerase

Poly-A

RNA PROCESSING

In eukaryotes, the RNA transcript (pre-mRNA) is spliced and modified to produce mRNA, which moves from the nucleus to the cytoplasm.

Exon

RNA transcript (pre-mRNA)

Intron

NUCLEUS

Cap

FORMATION OF INITIATION COMPLEX

After leaving the nucleus, mRNA attaches to the ribosome.

CYTOPLASM

Aminoacyl-tRNA synthetase

Amino acid tRNA

AMINO ACID ACTIVATION

Each amino acid attaches to its proper tRNA with the help of a specific enzyme and ATP.

mRNA

Growing polypeptide

Poly-A

Activated amino acid

Ribosomal subunits

5' Cap

Poly-A

TRANSLATION

A succession of tRNAs add their amino acids to the polypeptide chain as the mRNA is moved through the ribosome one codon at a time. (When completed, the polypeptide is released from the ribosome.)

Anticodon

Codon

Ribosome

Essential knowledge 4.A.2: The structure and function of subcellular components, and their interactions, provide essential cellular processes.

b. Endoplasmic reticulum occurs in two forms: smooth and rough. [See also 2.B.3]

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

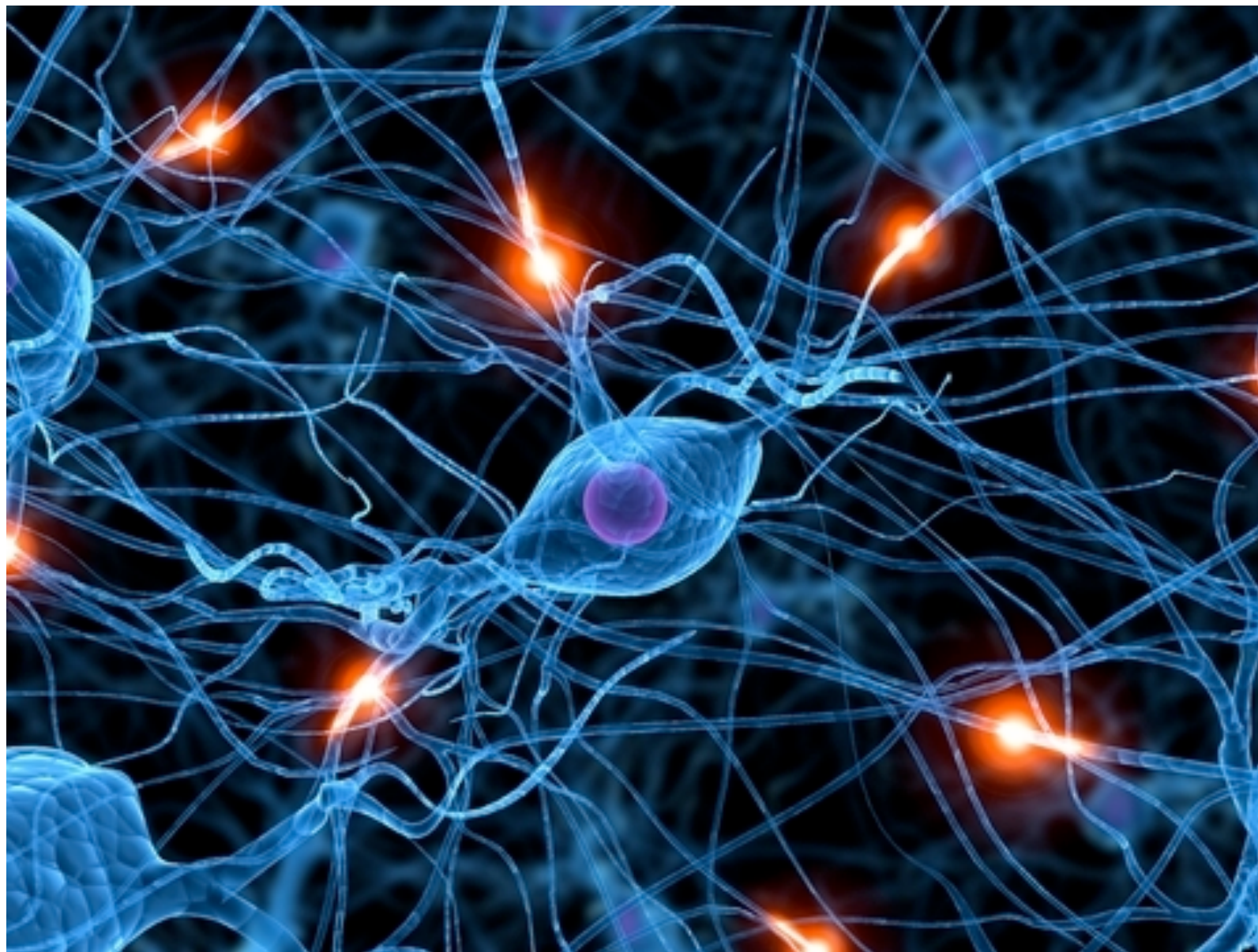
1. Rough endoplasmic reticulum functions to compartmentalize the cell, serves as mechanical support, provides site-specific protein synthesis with membrane-bound ribosomes and plays a role in intracellular transport.

2. In most cases, smooth ER synthesizes lipids.

✗ Specific functions of smooth ER in specialized cells are beyond the scope of the course and the AP Exam.

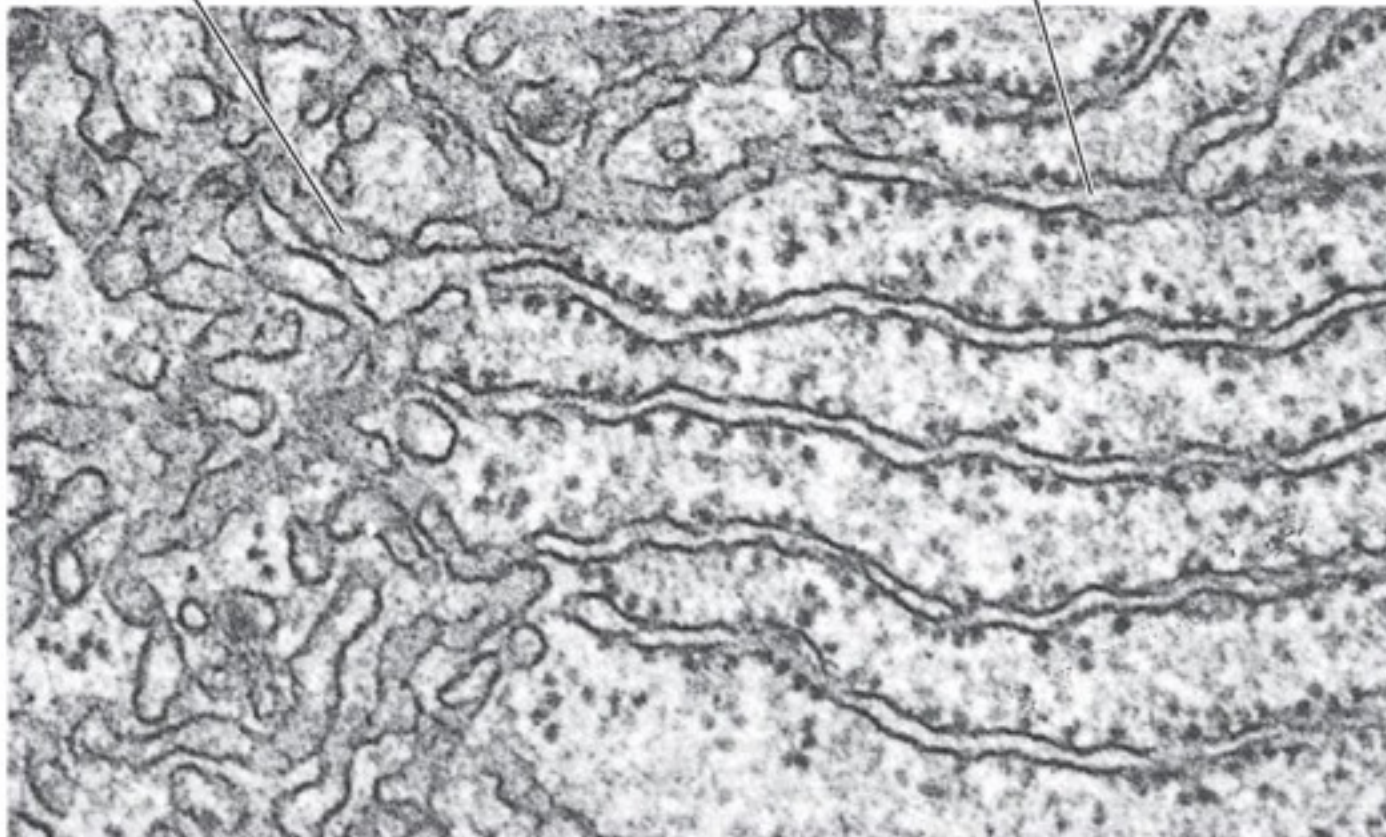
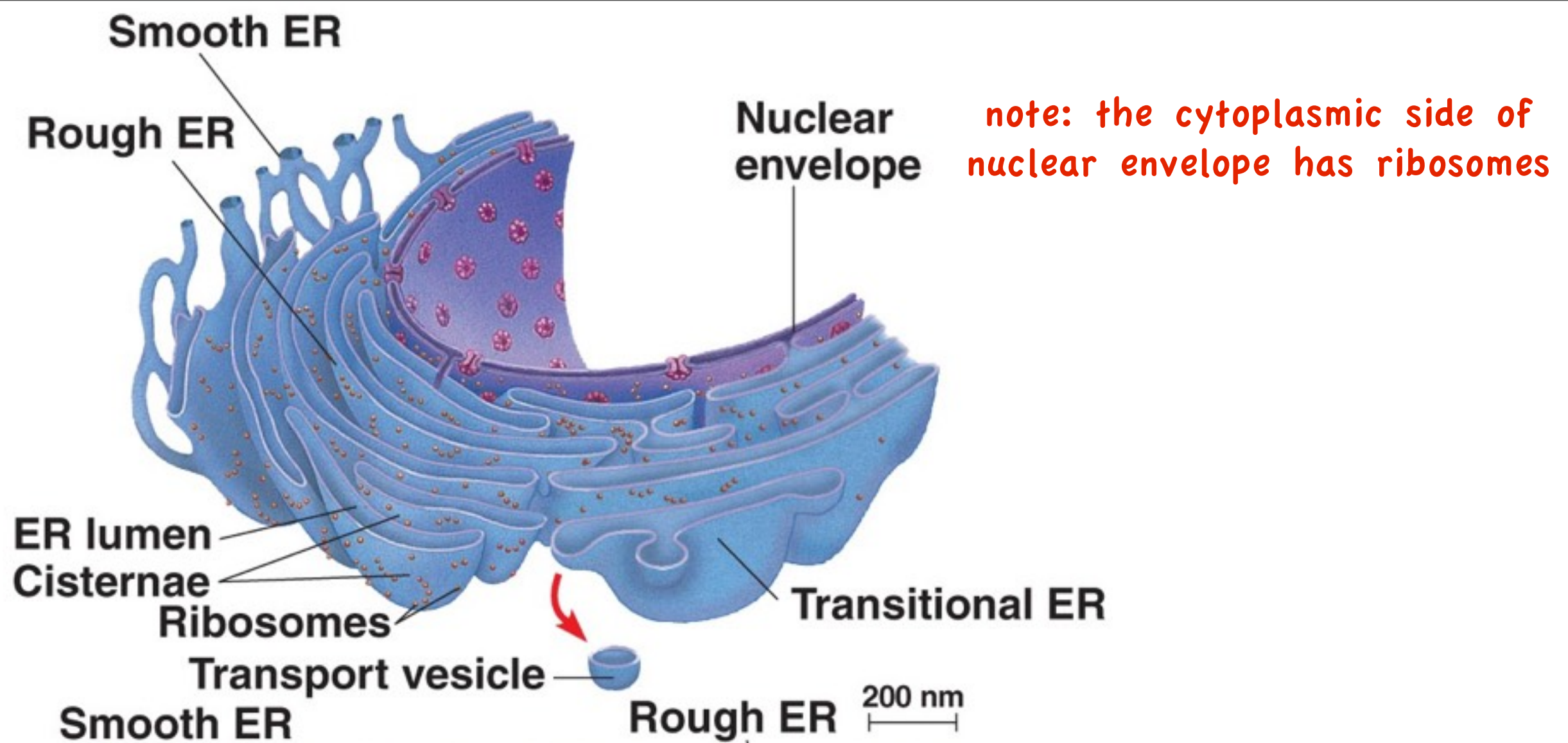
Tour of the Cell

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



The Endoplasmic Reticulum: Biosynthetic Factory

- **extensive network of membranes**
- **accounts for more than half of the total cell membrane**
- **two distinct types (each differs in structure and function)**
 - **Smooth E.R. (lacks ribosomes)**
 - **Rough E.R. (has ribosomes)**

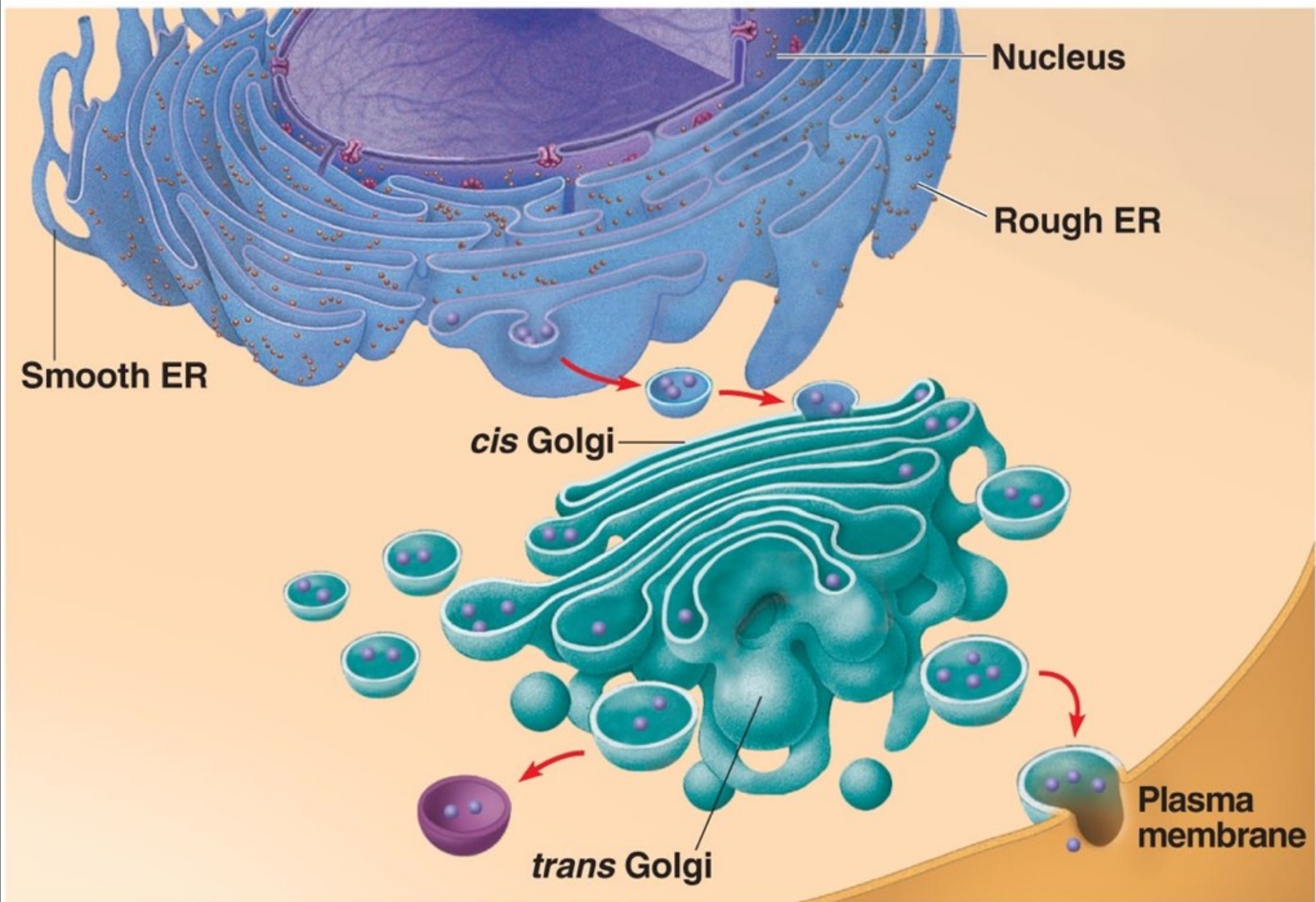


Functions of Smooth ER

- **Diverse functions that vary with cell type.**
- **Synthesis of lipids, *phospholipids* and *steroids***
 - *testes, ovaries, adrenal glands* produce sex hormones as a result they have an abundance of smooth E.R.
- **Enzymes that help detoxify drugs and poison**
 - adding hydroxyl groups to drugs/poison makes them more soluble and easier to secrete
 - drug addicts have more smooth E.R.
 - additional smooth E.R. contributes to their increased tolerance for drugs
- **Stores calcium in muscle cells**

Functions of Rough ER

- **The rough E.R. is still “E.R.” it has the same functions as the smooth E.R. + some!**
- The rough E.R. specializes in producing proteins that are destined for export or to become part of a membrane, they are called ***secretory proteins***
- Most *secretory proteins* are ***glycoproteins***, they have sugars attached to them
 - These proteins are kept separate from cytoplasmic proteins by the endomembrane system
- ***Transport vesicles*** move these proteins from the E.R. to their destination



Essential knowledge 4.A.2: The structure and function of subcellular components, and their interactions, provide essential cellular processes.

c. The Golgi complex is a membrane-bound structure that consists of a series of flattened membrane sacs (cisternae). [See also 2.B.3]

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

1. Functions of the Golgi include synthesis and packaging of materials (small molecules) for transport (in vesicles), and production of lysosomes.

The Golgi Apparatus: Shipping & Receiving Center

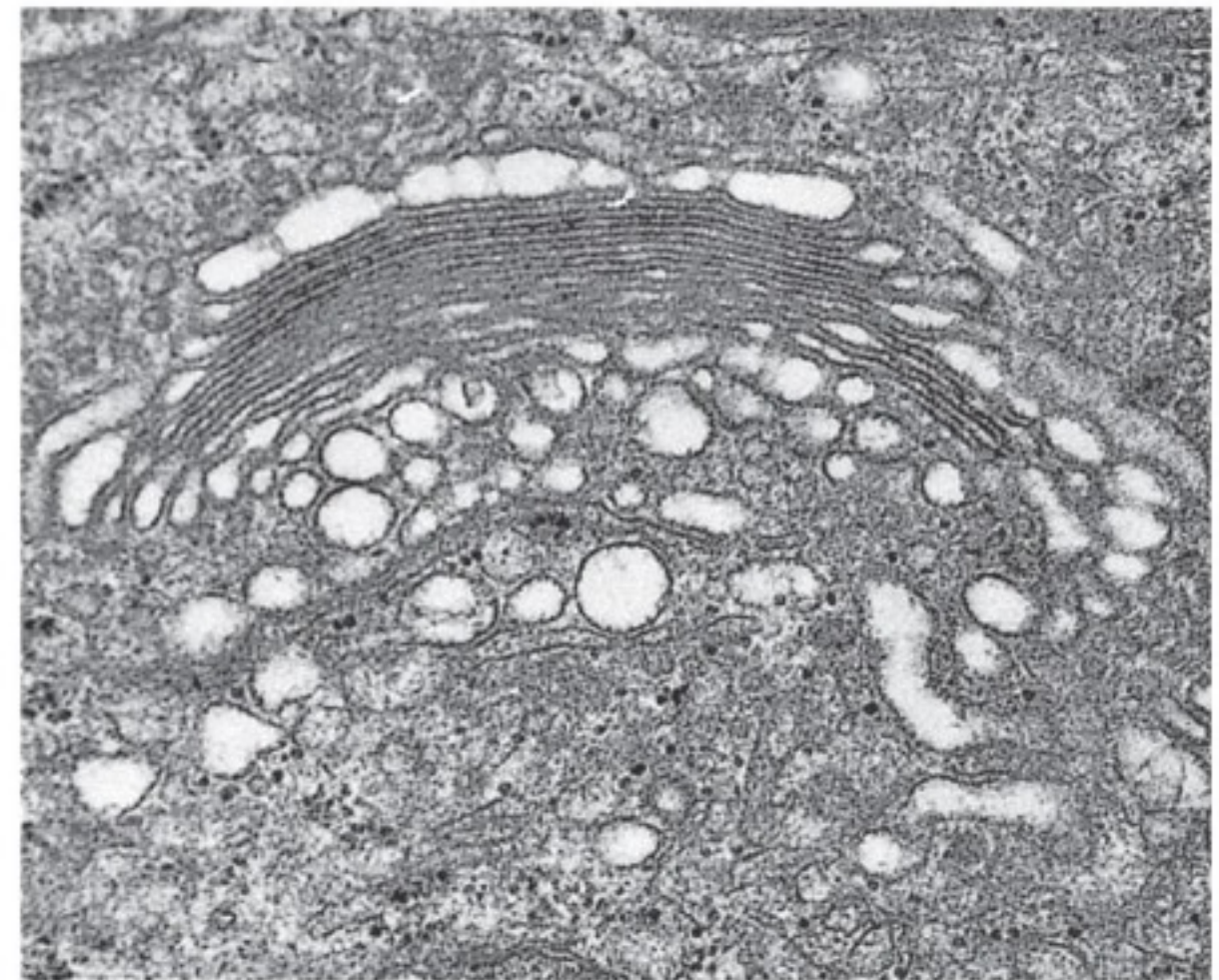
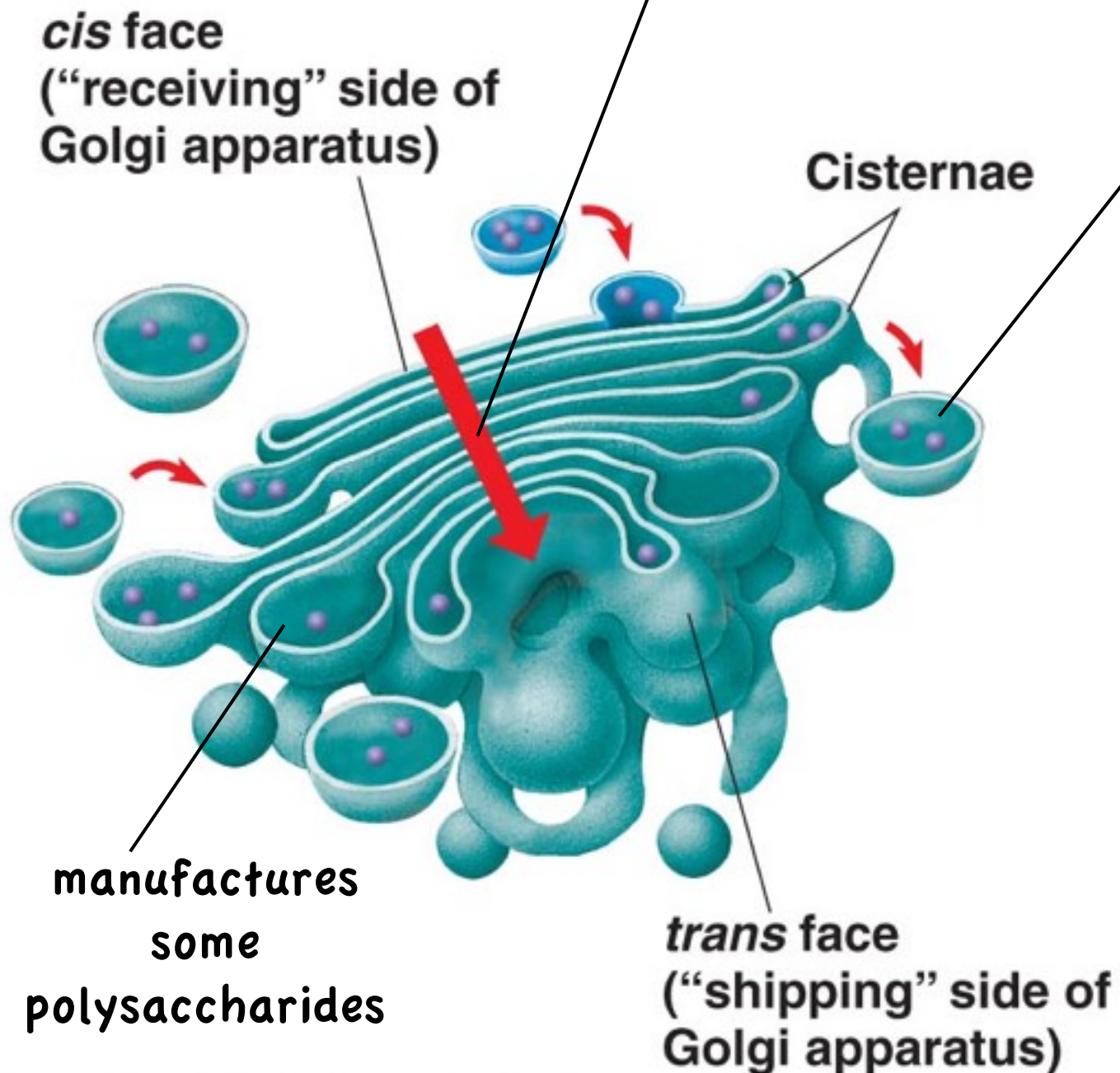
- Receives products of E.R., *these products are modified then stored or sent to their destination.*
- The Golgi stacks have distinct structural directionality
 - The E.R. side is called the *cis side... it receives*
 - The side closest to the plasma membrane is called the *trans side...it ships*

Specifically modifies glycoproteins & phospholipids

cisternal maturation model

sorts and
targets proteins
“adds zip codes”

0.1 μm



TEM of Golgi apparatus

Essential knowledge 4.A.2: The structure and function of subcellular components, and their interactions, provide essential cellular processes.

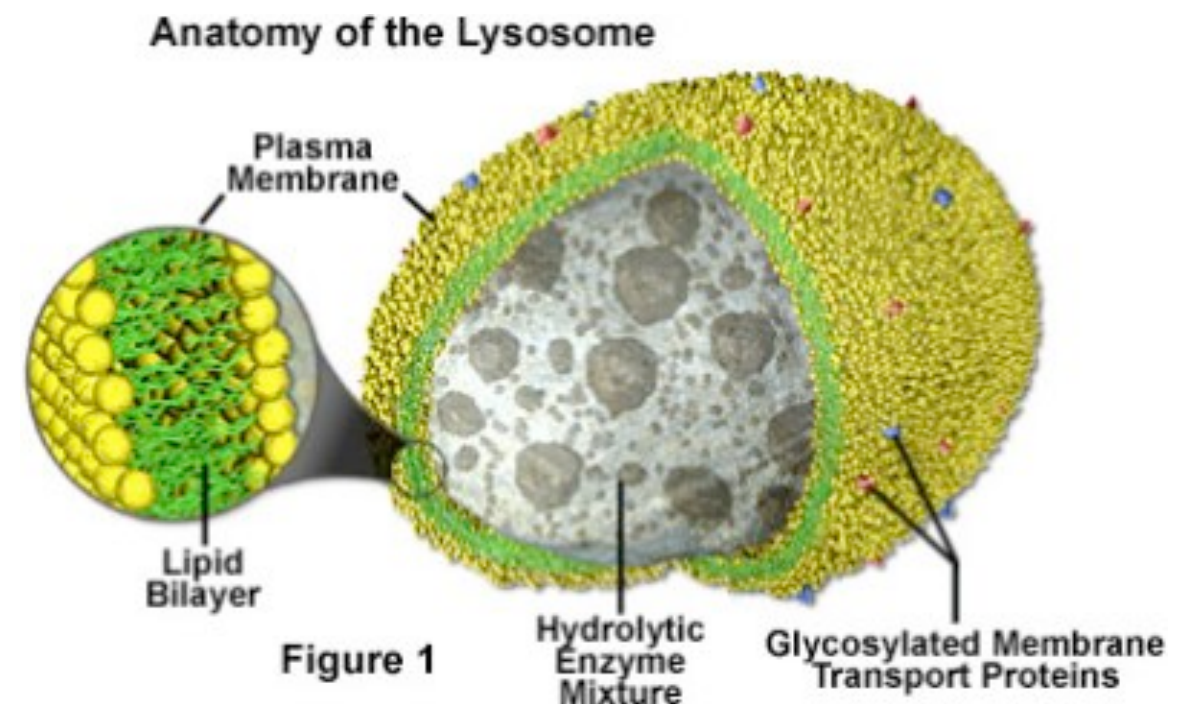
*e. Lysosomes are membrane-enclosed sacs that contain hydrolytic enzymes, which are important in intracellular digestion, the recycling of a cell's organic materials and programmed cell death (apoptosis). Lysosomes carry out intracellular digestion in a variety of ways. [See also 2.B.3]

✗ Specific examples of how lysosomes carry out intracellular digestion are beyond the scope of the course and the AP Exam.

**out order, I want to teach mitochondria and chloroplasts together*

Lysosomes: Digestive Compartments

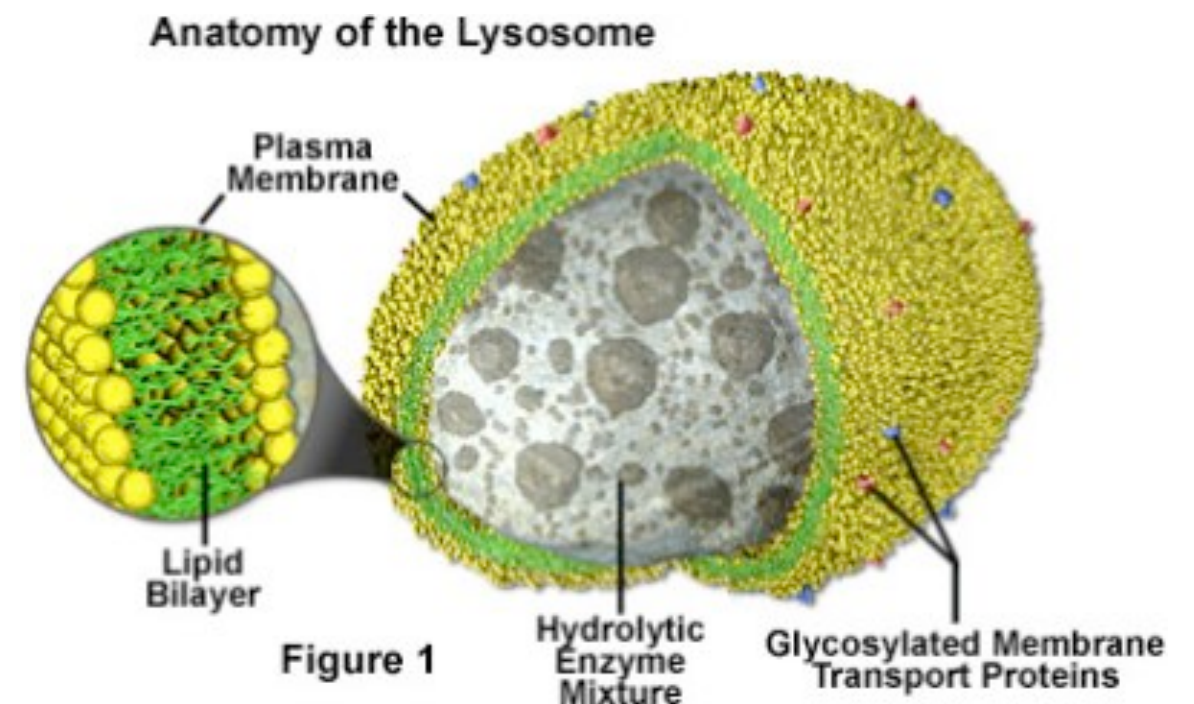
- A membranous sac of hydrolytic enzymes that animal cell uses to digest macromolecules
- These hydrolytic enzymes work best in acidic environments, found in lysosomes
- **Theme: Internal environment different from external environment**



Lysosomes: Digestive Compartments

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Animal Cells Only



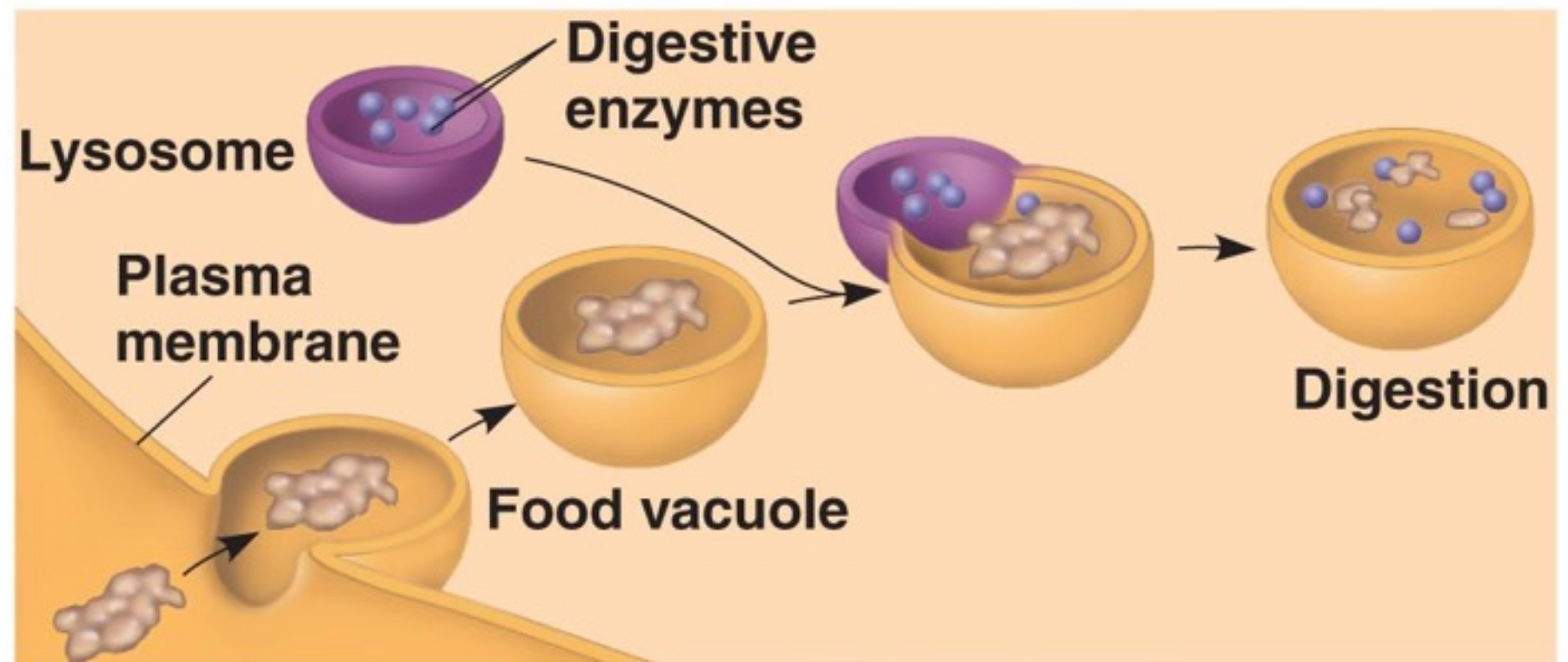
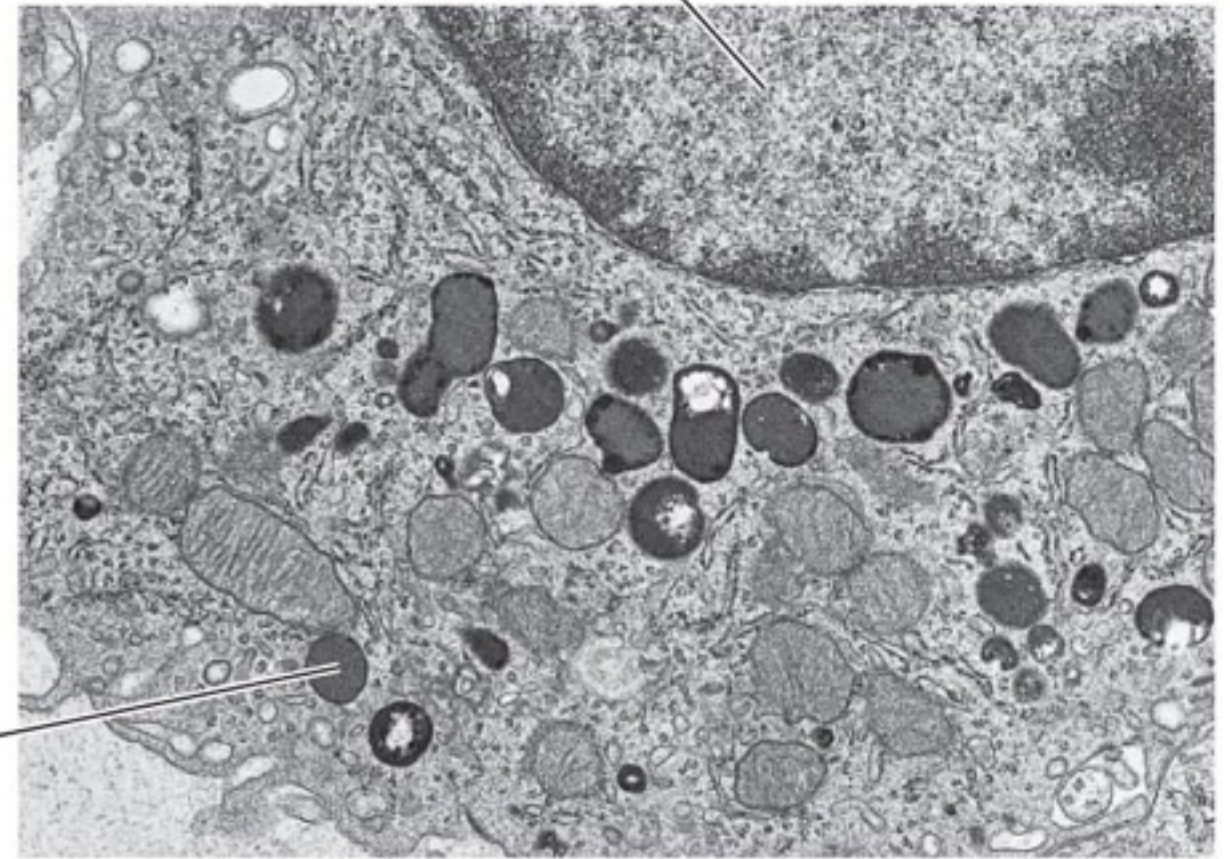
Amoebas and other protists eat by engulfing smaller organisms or food particles

Now nutrients for cell

Lysosome

Nucleus

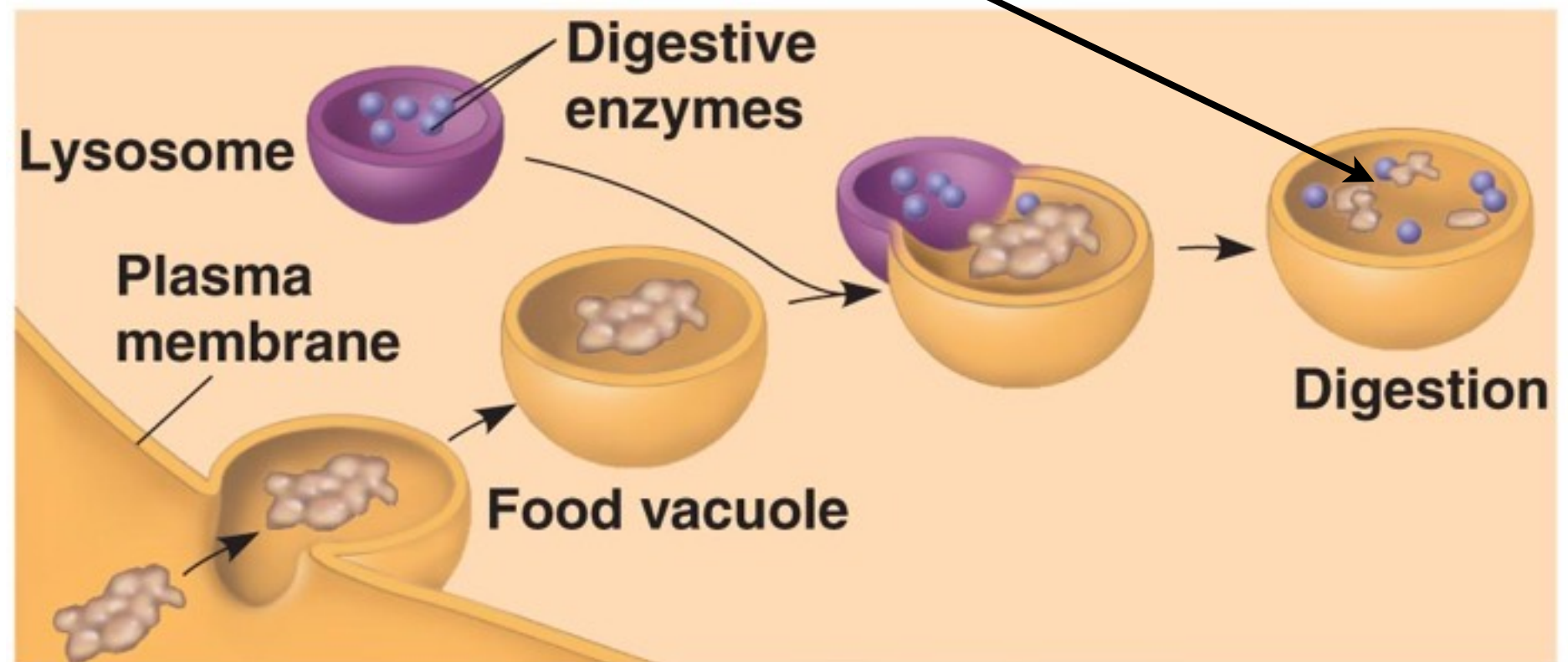
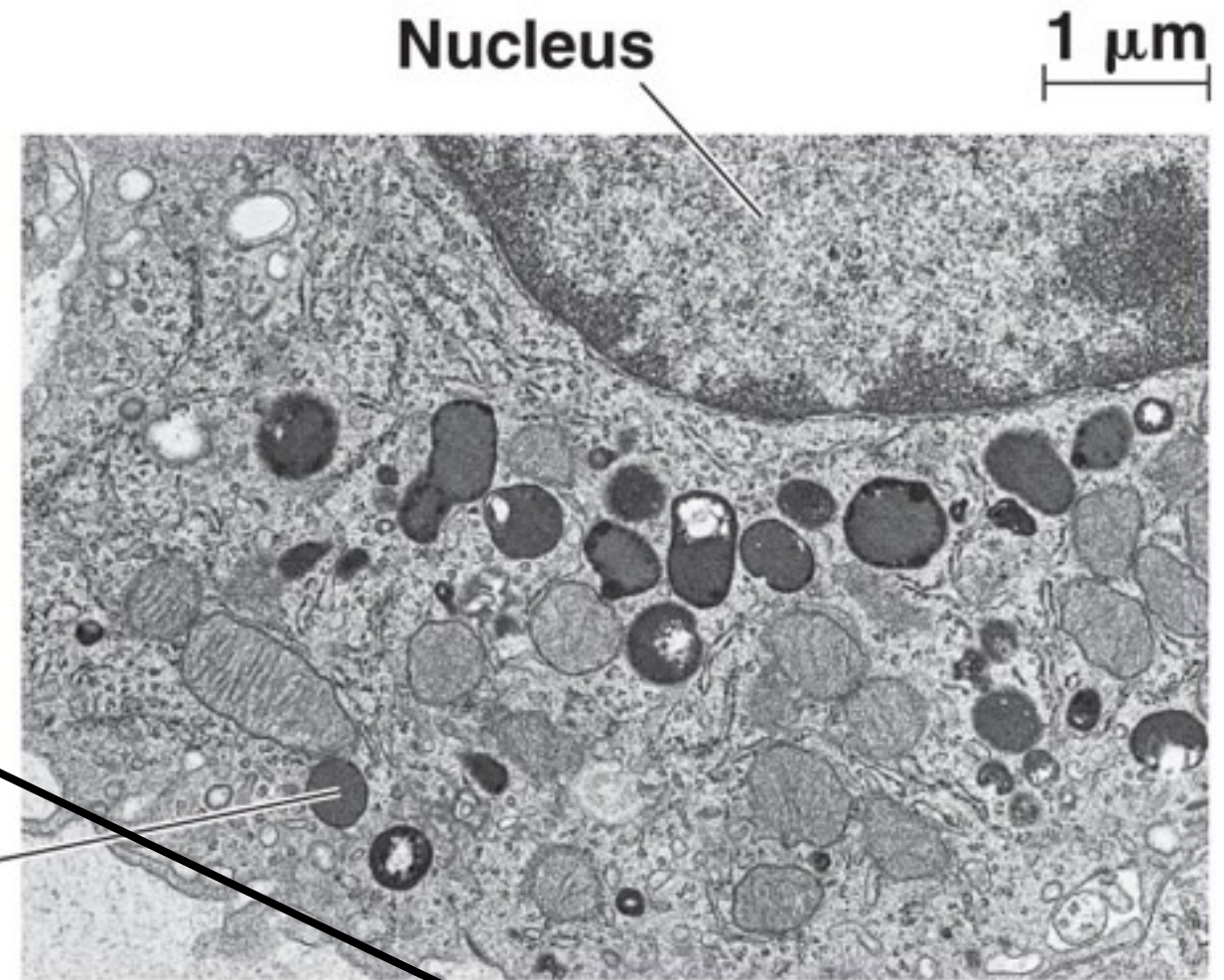
1 μm



(a) Phagocytosis

Amoebas and other protists eat by engulfing smaller organisms or food particles

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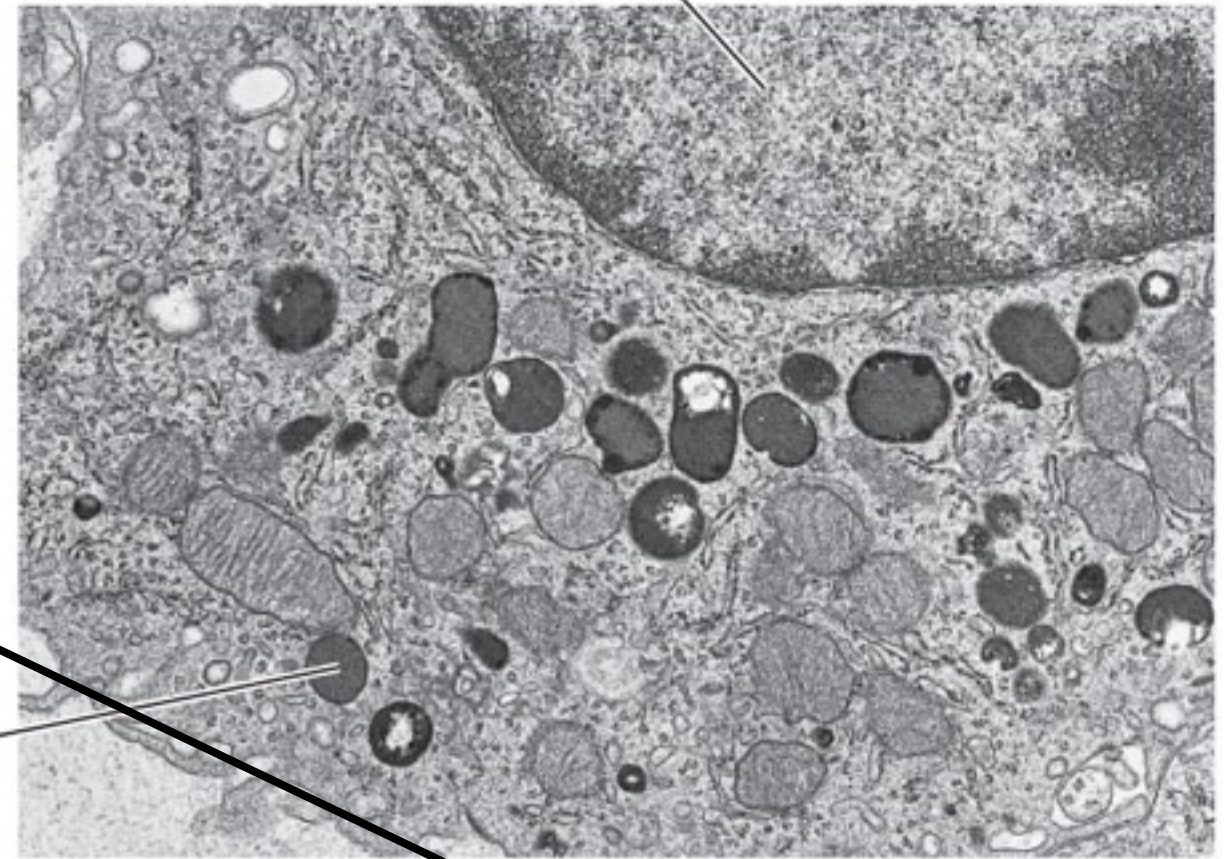
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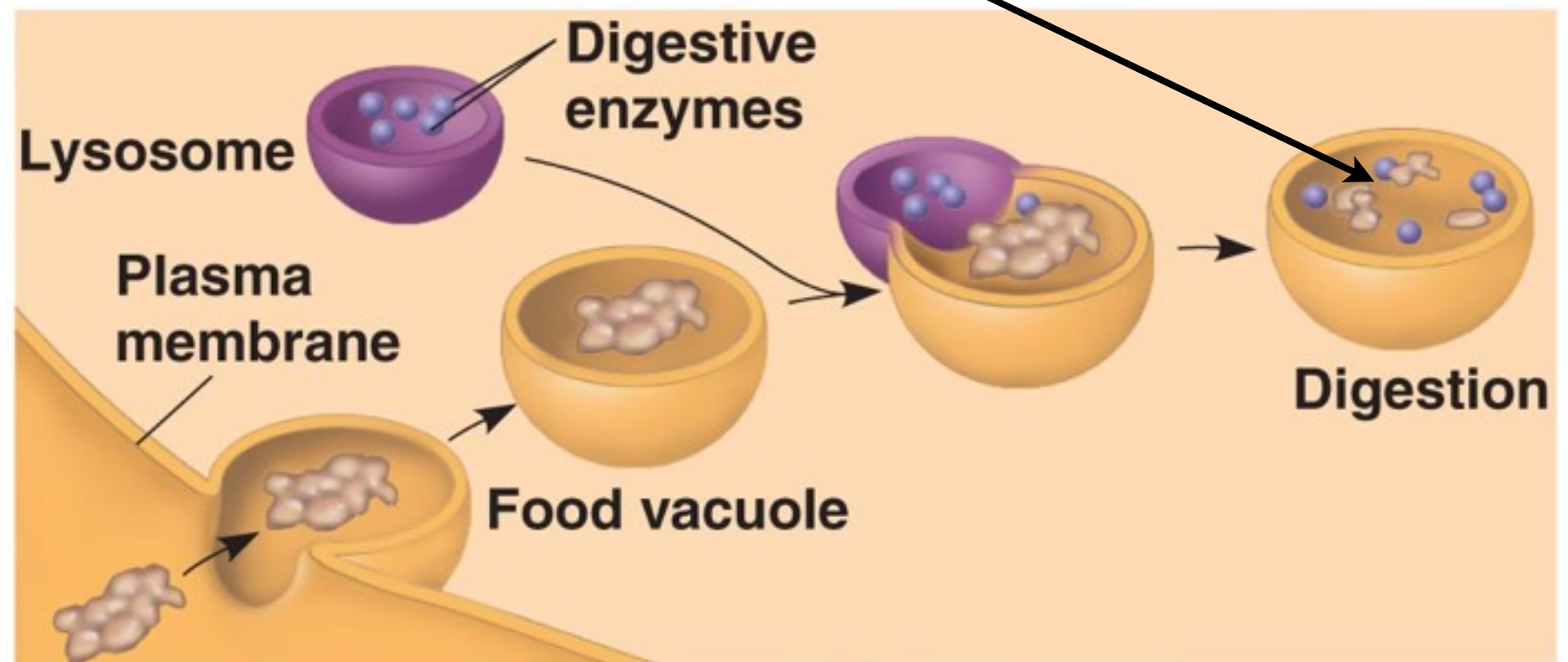
Lysosome

Nucleus

1 μm

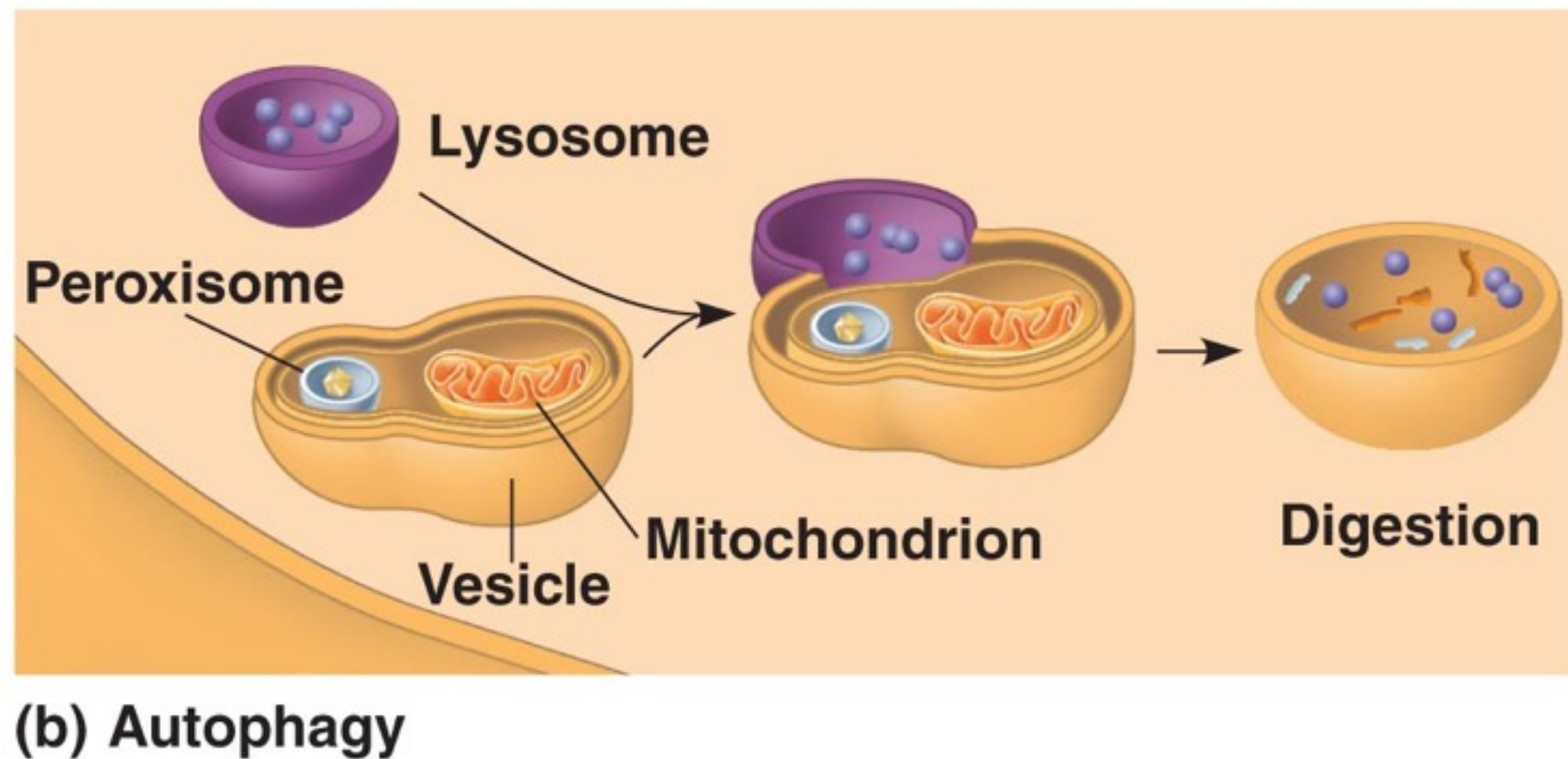
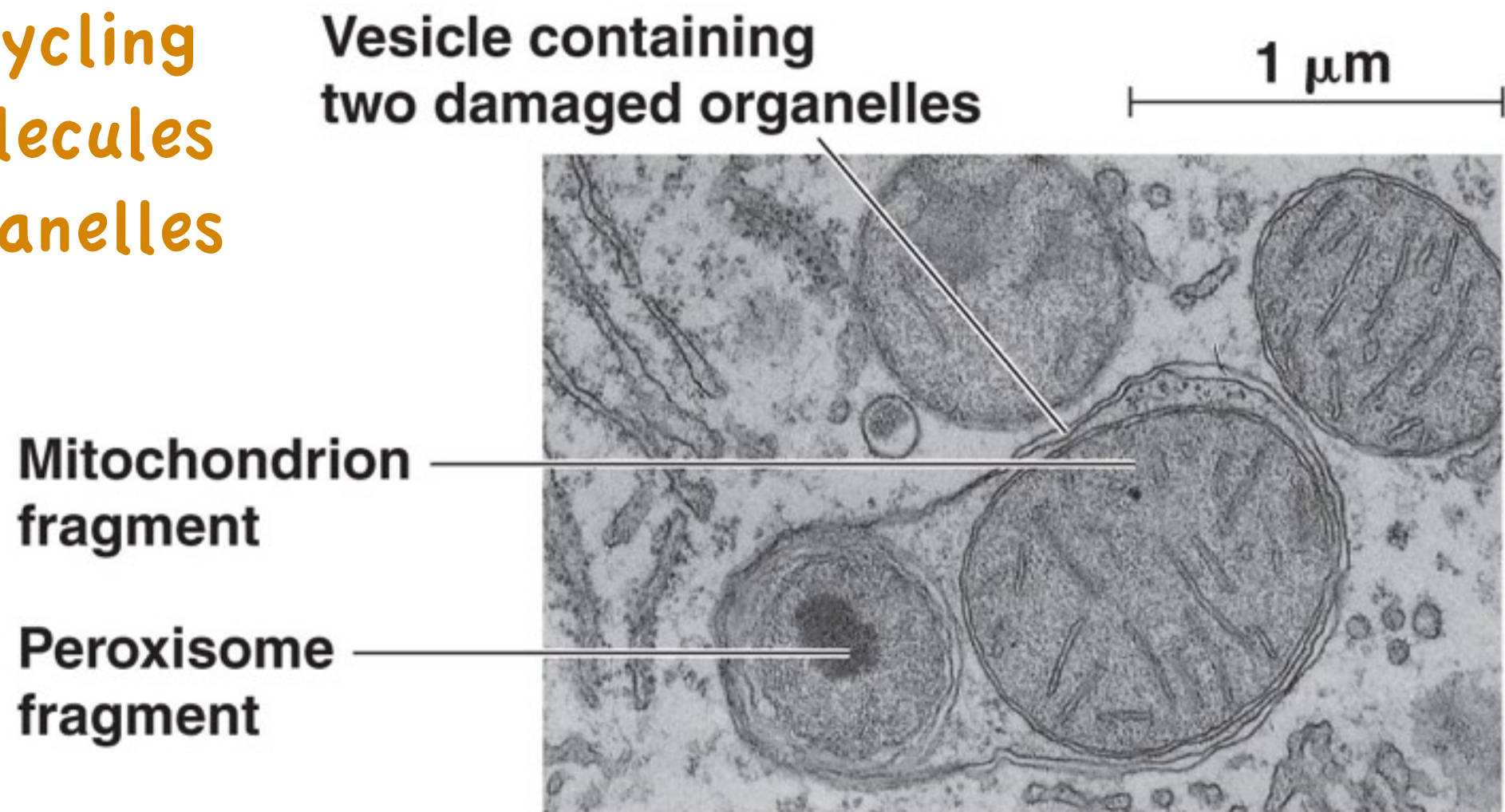


White Blood Cells fight infections through phagocytosis



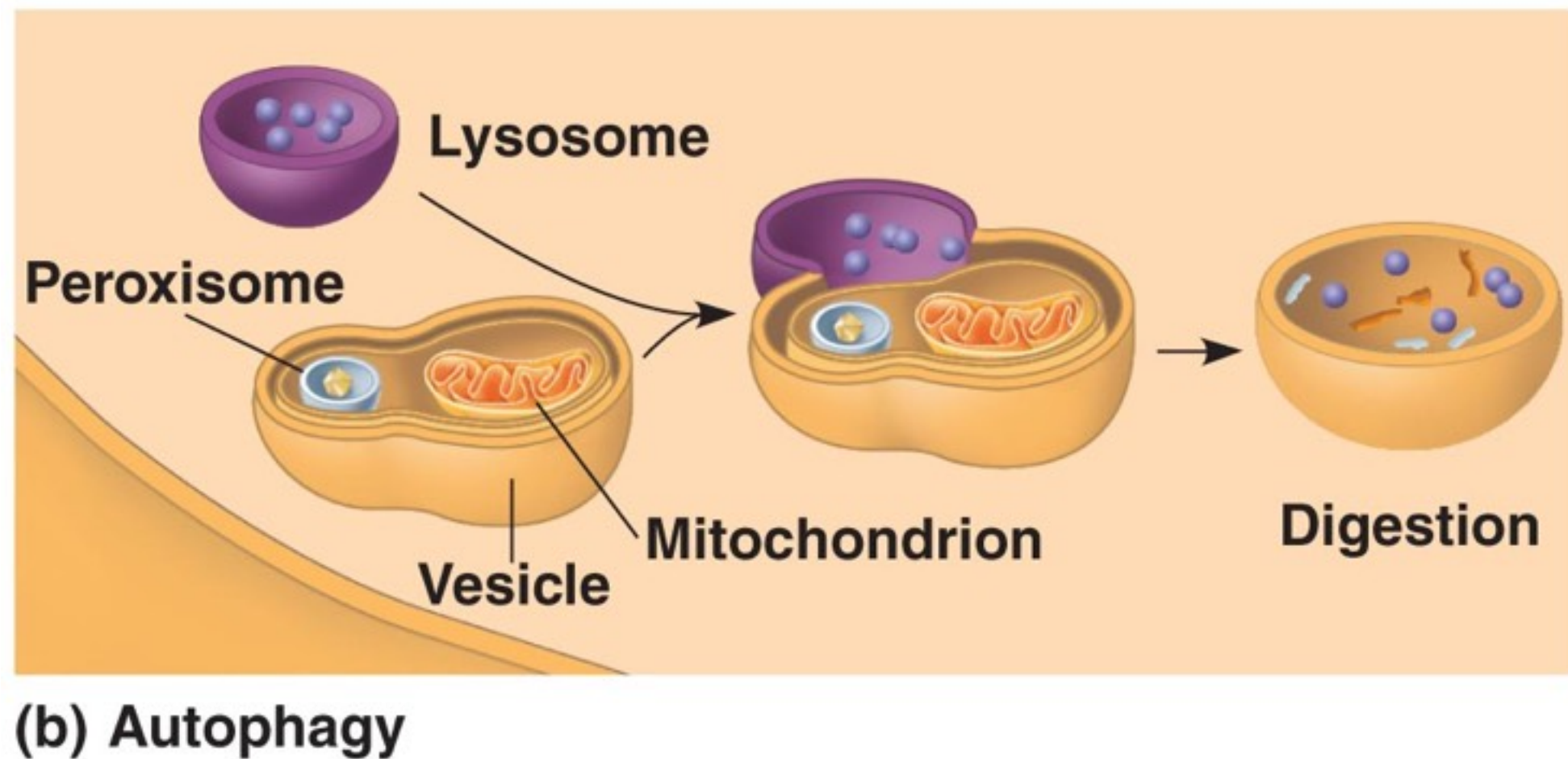
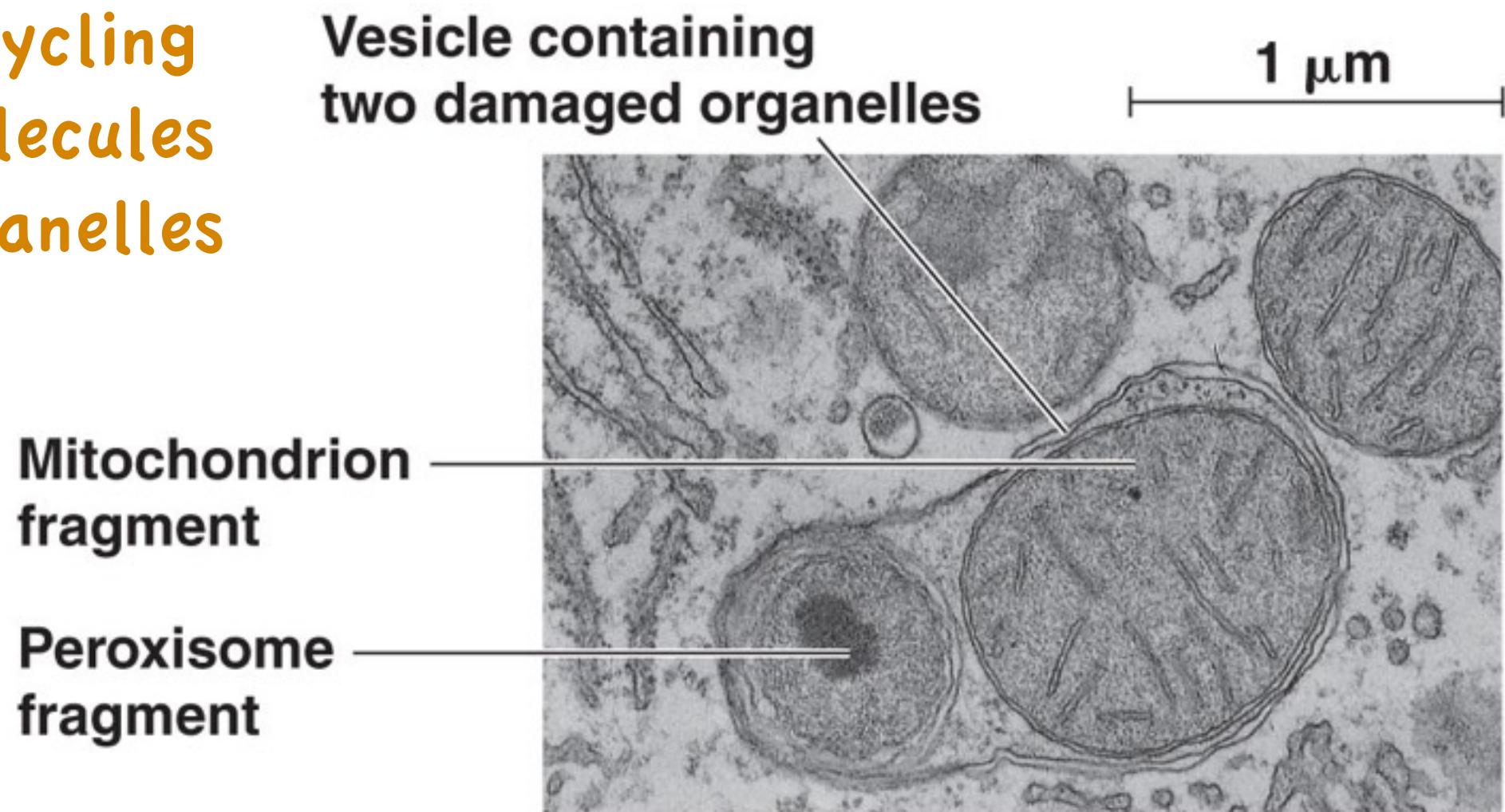
(a) Phagocytosis

Cellular Recycling of macromolecules and old organelles



Cellular Recycling of macromolecules and old organelles

Human liver
cells recycle
half of its
molecules
each week



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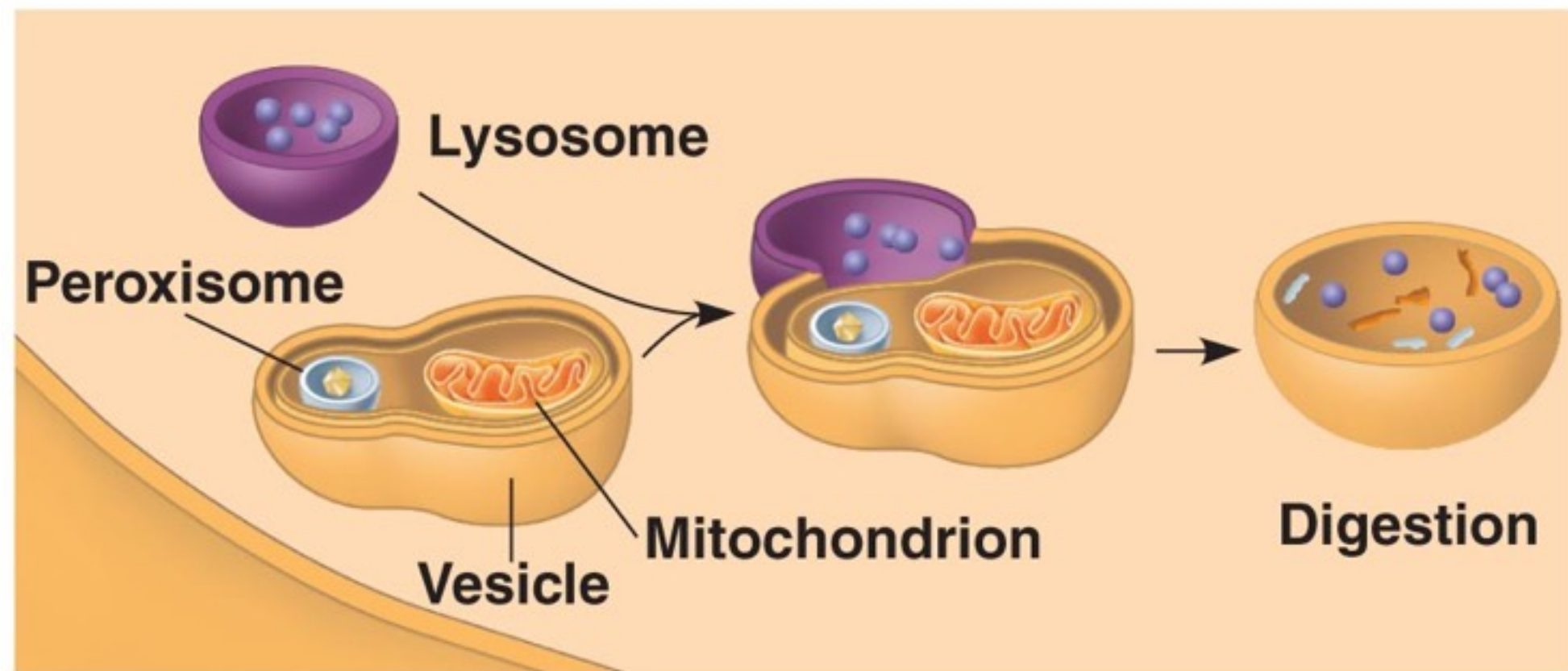
Lysosomal
Disease:
“Tay-Sachs”
missing a
lipid digesting
enzyme in
brain cells

Vesicle containing
two damaged organelles

1 μm

Mitochondrion
fragment

Peroxisome
fragment



(b) Autophagy

Essential knowledge 4.A.2: The structure and function of subcellular components, and their interactions, provide essential cellular processes.

f. A vacuole is a membrane-bound sac that plays roles in intracellular digestion and the release of cellular waste products. In plants, a large vacuole serves many functions, from storage of pigments or poisonous substances to a role in cell growth. In addition, a large central vacuole allows for a large surface area to volume ratio. [See also 2.A.3, 2.B.3]

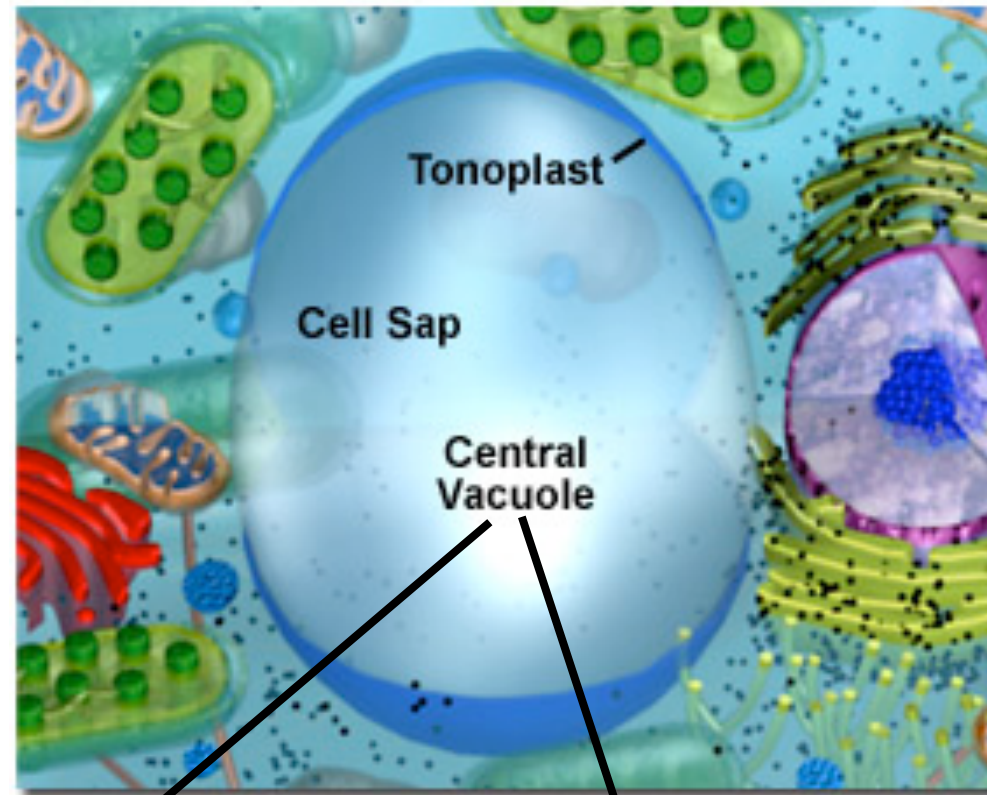
Vacuoles: Diverse Maintenance Compartments

- Large vesicles derived from E.R. or Golgi
 - **Theme: Internal environment different from external environment**
- Performs a variety of functions:
 - *Food vacuoles; protists (last slide)*
 - *Contractile Vacuoles; freshwater protists (use them to pump out excess water thus controlling solute concentrations)*

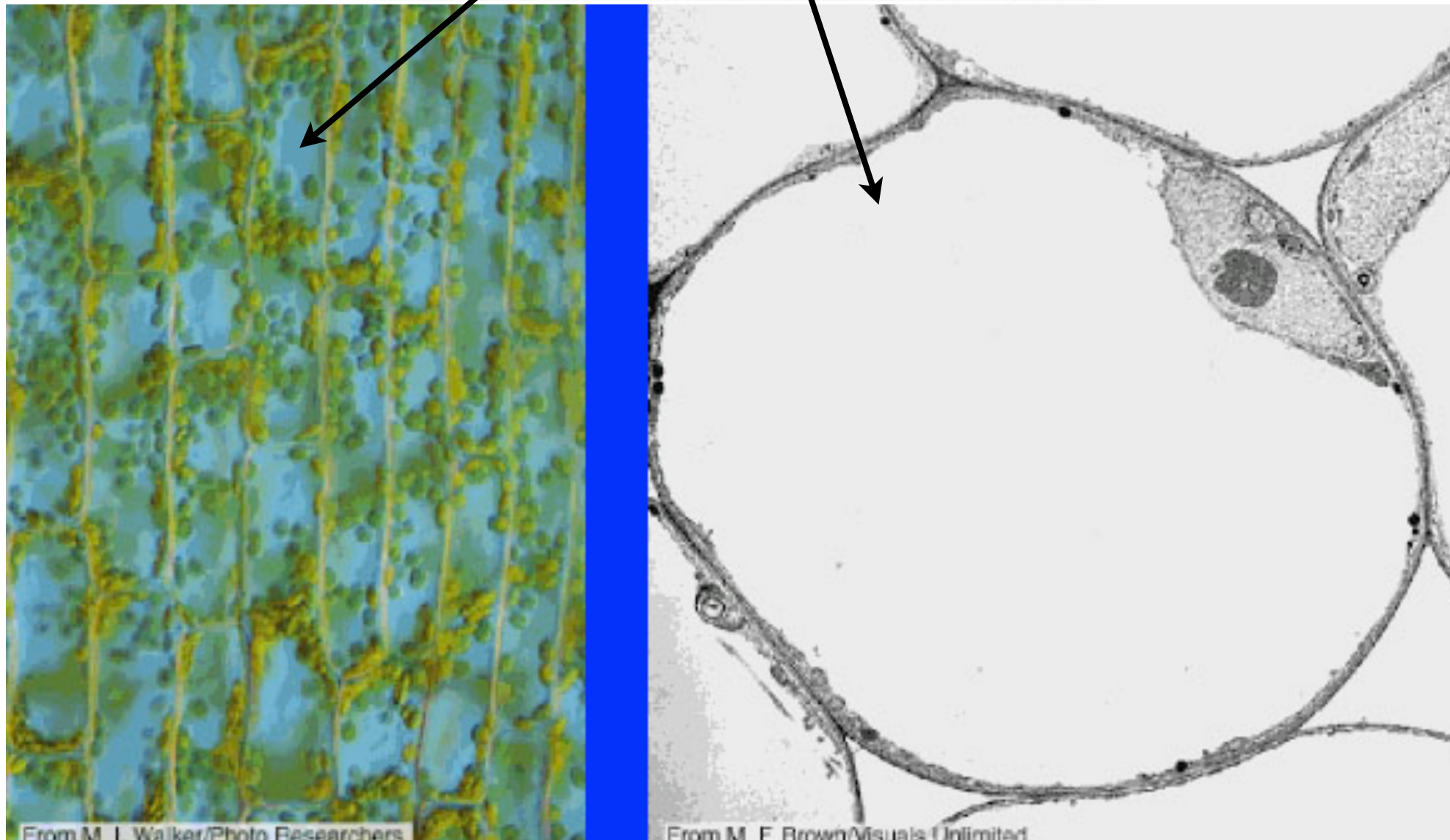
Vacuoles: continued

- Performs a variety of functions, perhaps plants and fungi show the most variation in their use of vacuoles:
 - *Hydrolytic vacuoles*; analogous to animal lysosomes
 - *Storage Vacuoles*;
 - a reserve of important organic compounds
 - a reserve of poisonous compounds for defense
 - container of pigments to attract pollinators
 - *Central Vacuoles*; a large vacuole that is repository of inorganic ions (calcium, potassium)
 - Important for plant cell growth, water is absorbed... cell enlarges with minimal investment in new cytoplasm

Plant Cell Central Vacuole

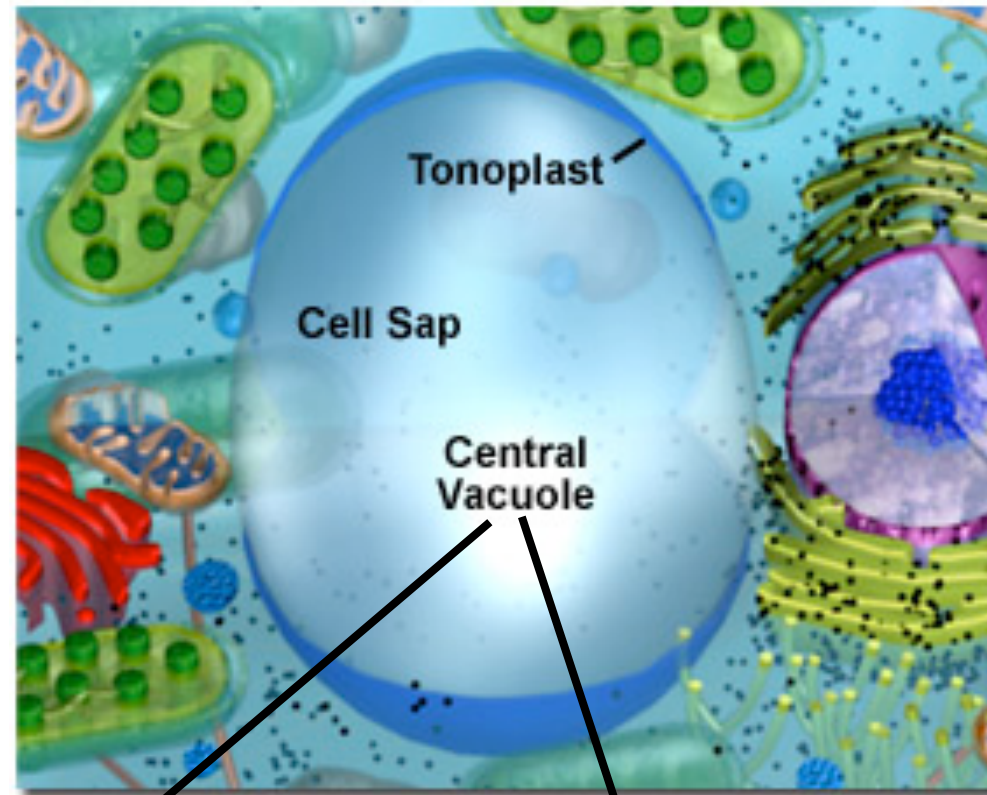


**Can account
for 50-70% of
Cell Volume**

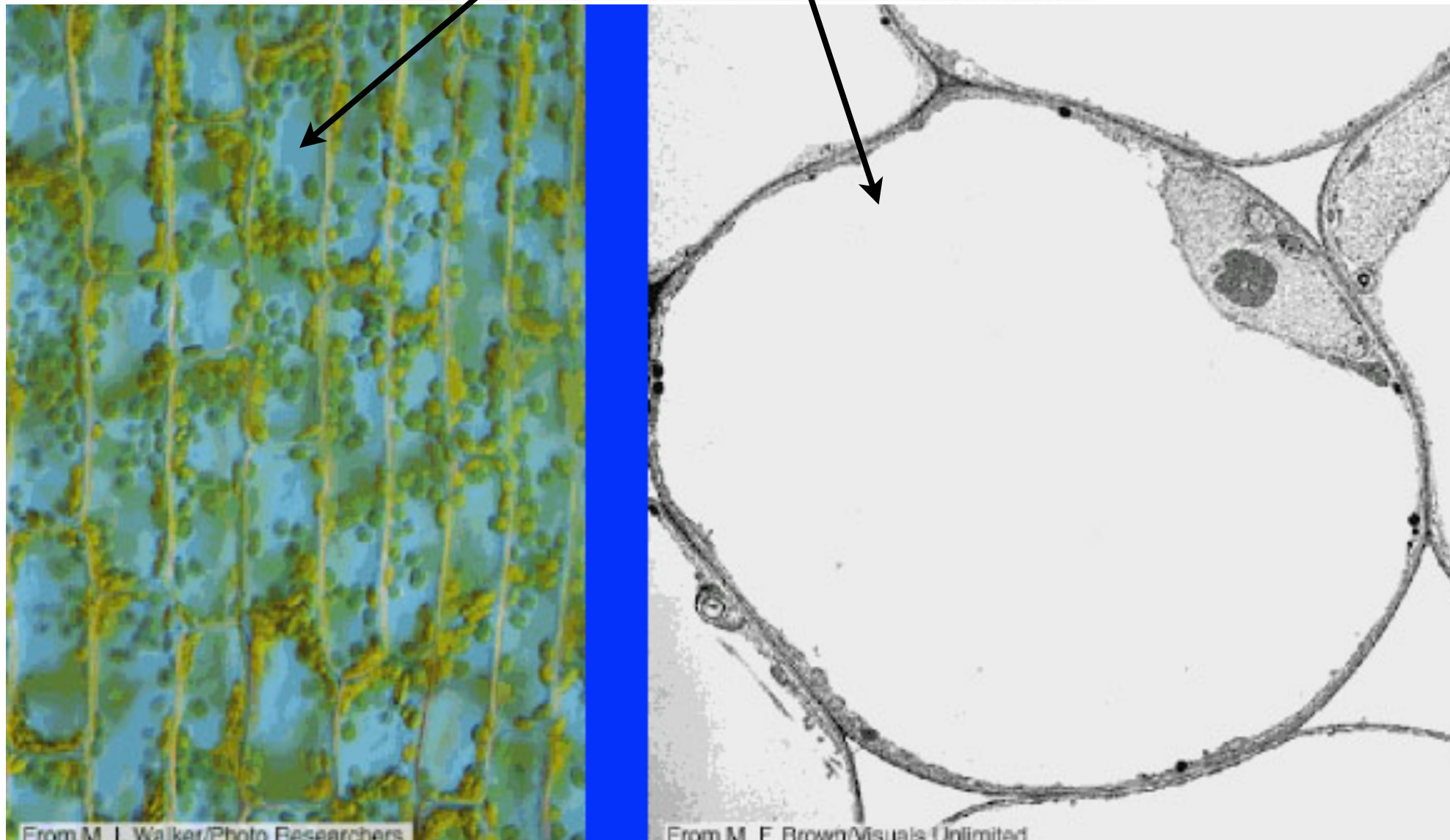


**Plant Cells
Only**

Plant Cell Central Vacuole



**Can account
for 50-70% of
Cell Volume**



Essential knowledge 4.A.2: The structure and function of subcellular components, and their interactions, provide essential cellular processes.

d. Mitochondria specialize in energy capture and transformation. [See also 2.A.2, 2.B.3]

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

1. Mitochondria have a double membrane that allows compartmentalization within the mitochondria and is important to its function.
2. The outer membrane is smooth, but the inner membrane is highly convoluted, forming folds called cristae.
3. Cristae contain enzymes important to ATP production; cristae also increase the surface area for ATP production.

Essential knowledge 4.A.2: The structure and function of subcellular components, and their interactions, provide essential cellular processes.

f. Chloroplasts are specialized organelles found in algae and higher plants that capture energy through photosynthesis.
[See also 2.A.2, 2 B.3]

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

1. The structure and function relationship in the chloroplast allows cells to capture the energy available in sunlight and convert it to chemical bond energy via photosynthesis which fuel carbon-fixing reactions in the Calvin-Benson cycle. Carbon fixation occurs in the stroma, where molecules of CO₂ are converted to carbohydrates.

Essential knowledge 4.A.2: The structure and function of subcellular components, and their interactions, provide essential cellular processes.

2. Chloroplasts contain chlorophylls, which are responsible for the green color of a plant and are the key light-trapping molecules in photosynthesis. There are several types of chlorophyll, but the predominant form in plants is chlorophyll a.

✗ The molecular structure of chlorophyll a is beyond the scope of the course and the AP Exam.

3. Chloroplasts have a double outer membrane that creates a compartmentalized structure, which supports its function. Within the chloroplasts are membrane-bound structures called thylakoids. Energy-capturing reactions housed in the thylakoids are organized in stacks, called “grana,” to produce ATP and, which fuel carbon-fixing reactions in the Calvin-Benson cycle. Carbon fixation occurs in the stroma, where molecules of CO₂ are converted to carbohydrates.

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.

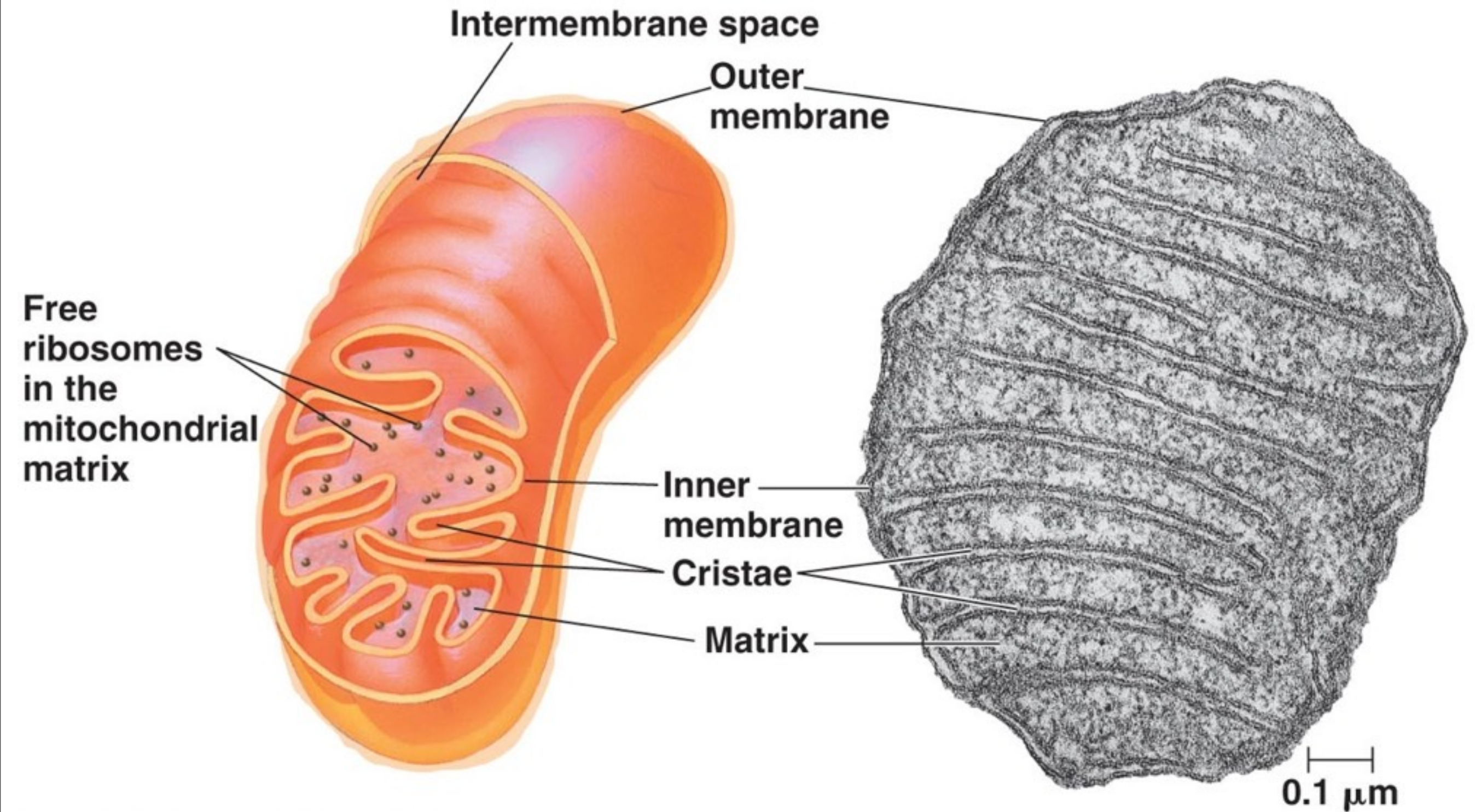


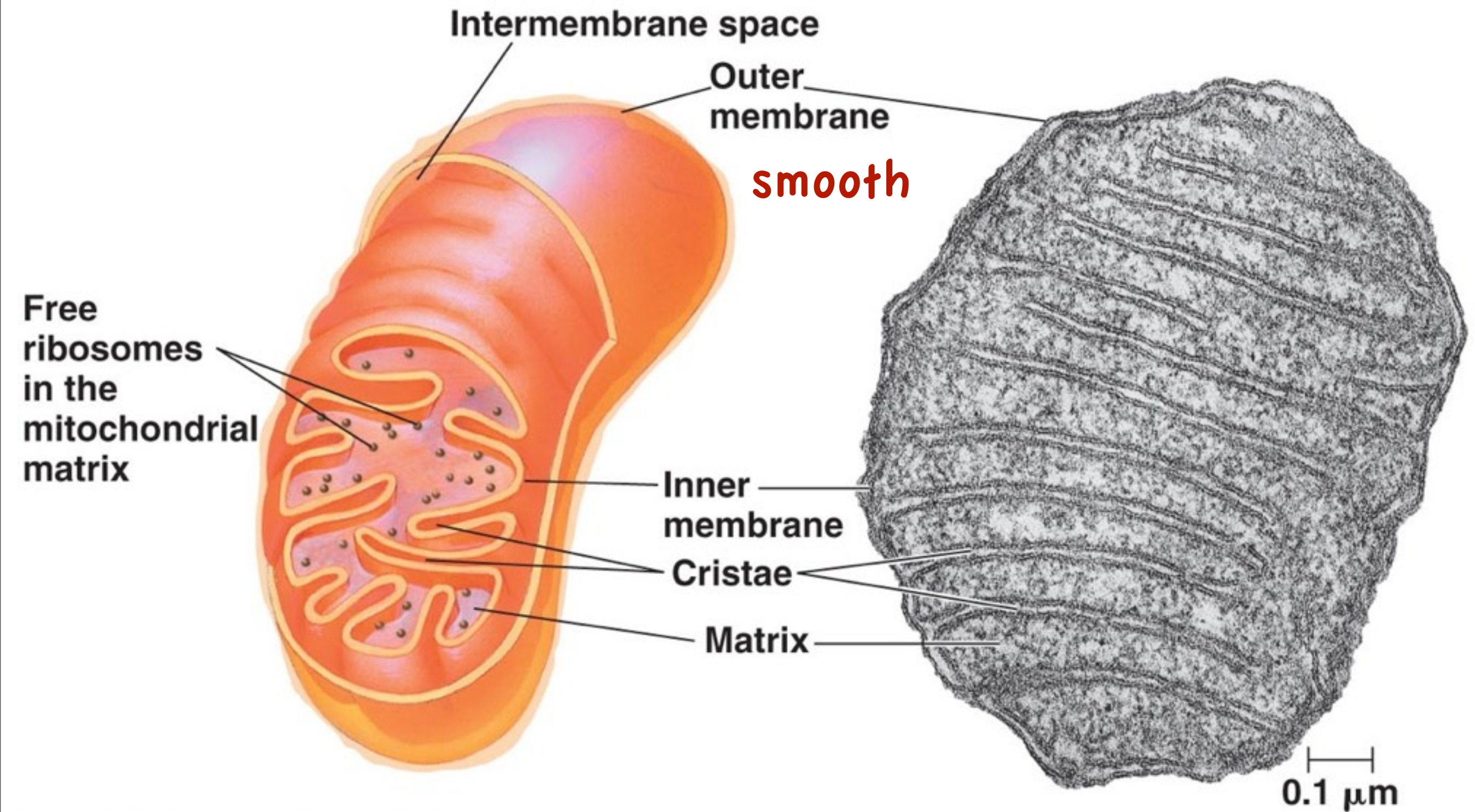
MITOCHONDRIA AND CHLOROPLASTS CHANGE ENERGY FROM ONE FORM TO ANOTHER

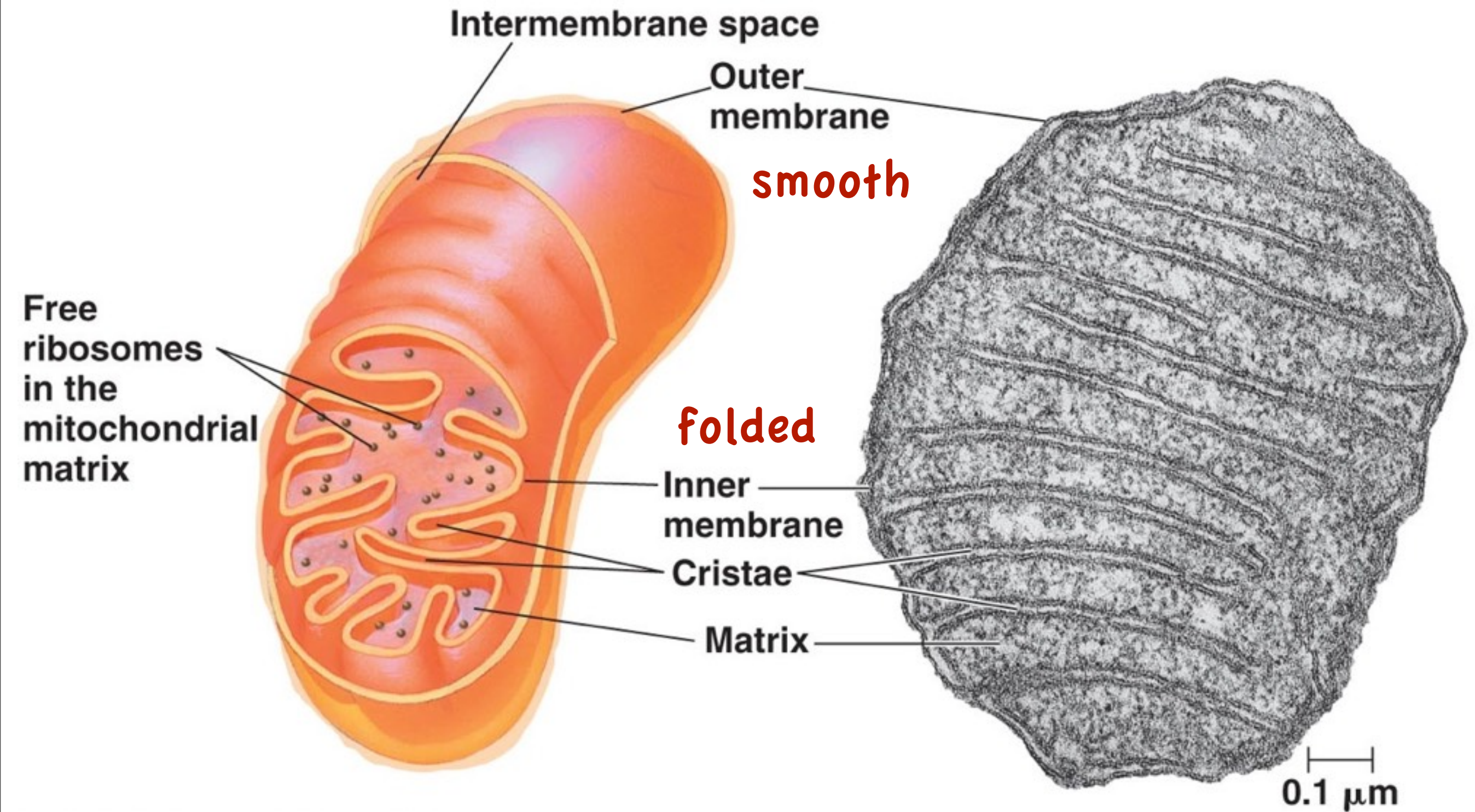
- ***Chloroplasts* use solar energy to build sugars from carbon dioxide and water.**
- ***Mitochondria* use the stored chemical energy in macromolecules such as sugars and fats to generate ATP (cellular fuel).**

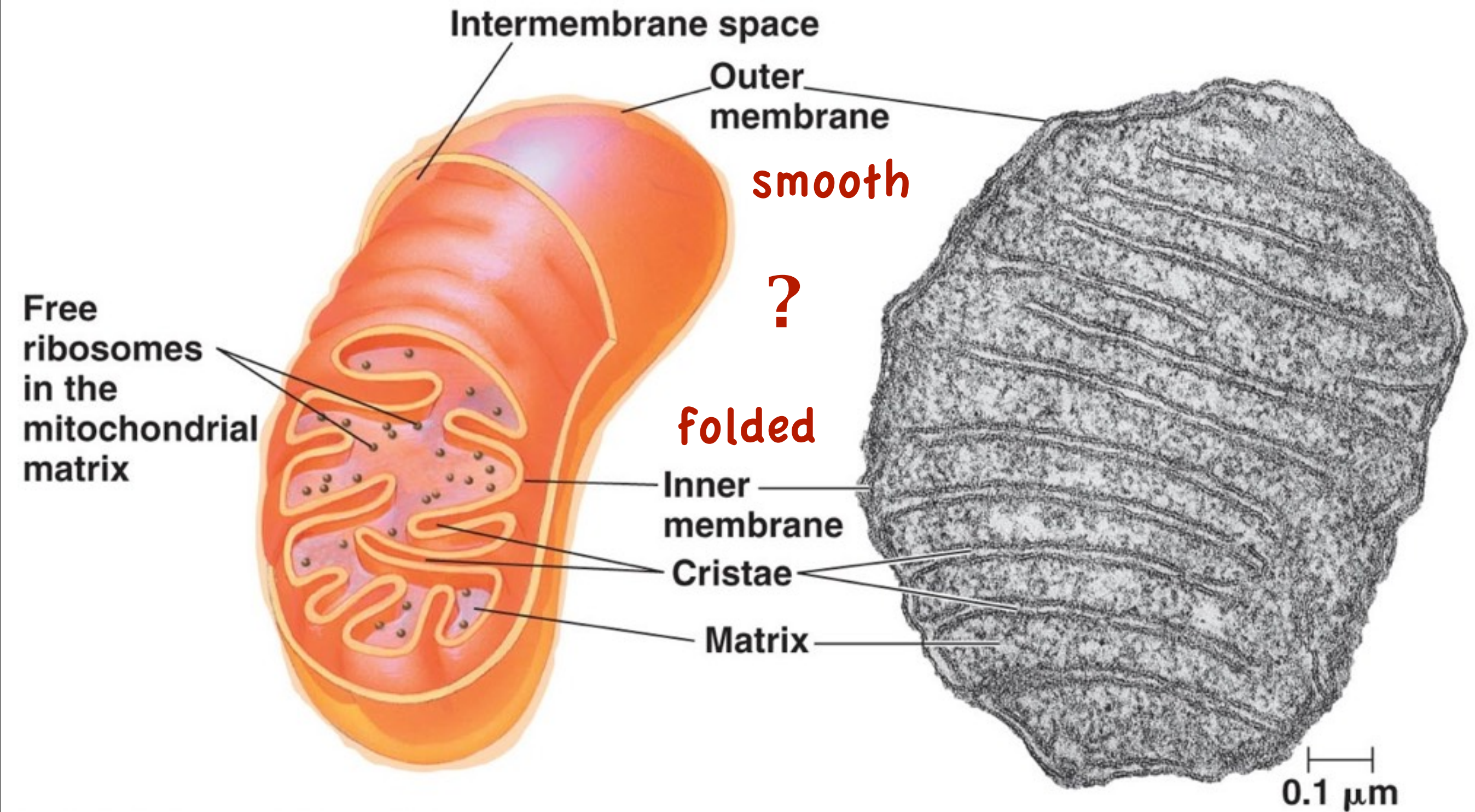
Mitochondria: Chemical Energy Conversion

- **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**

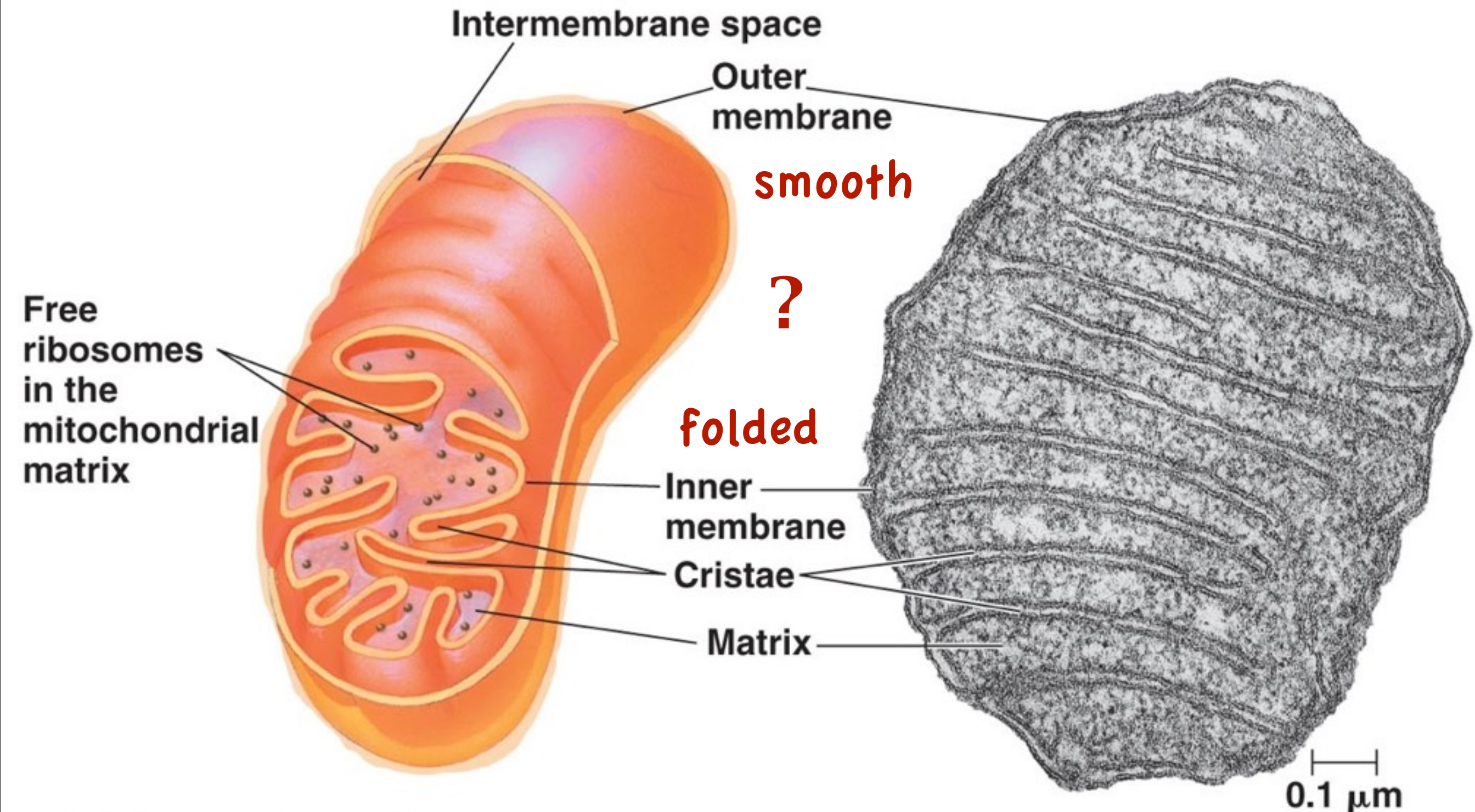








We will learn more about each area and its contents and functions in the cell respiration unit

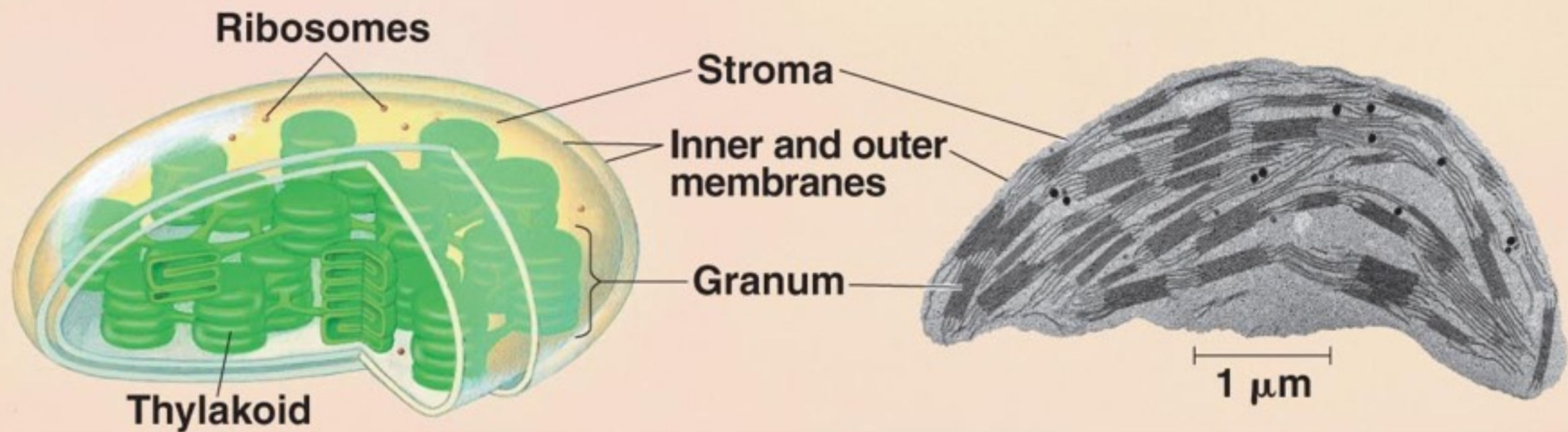
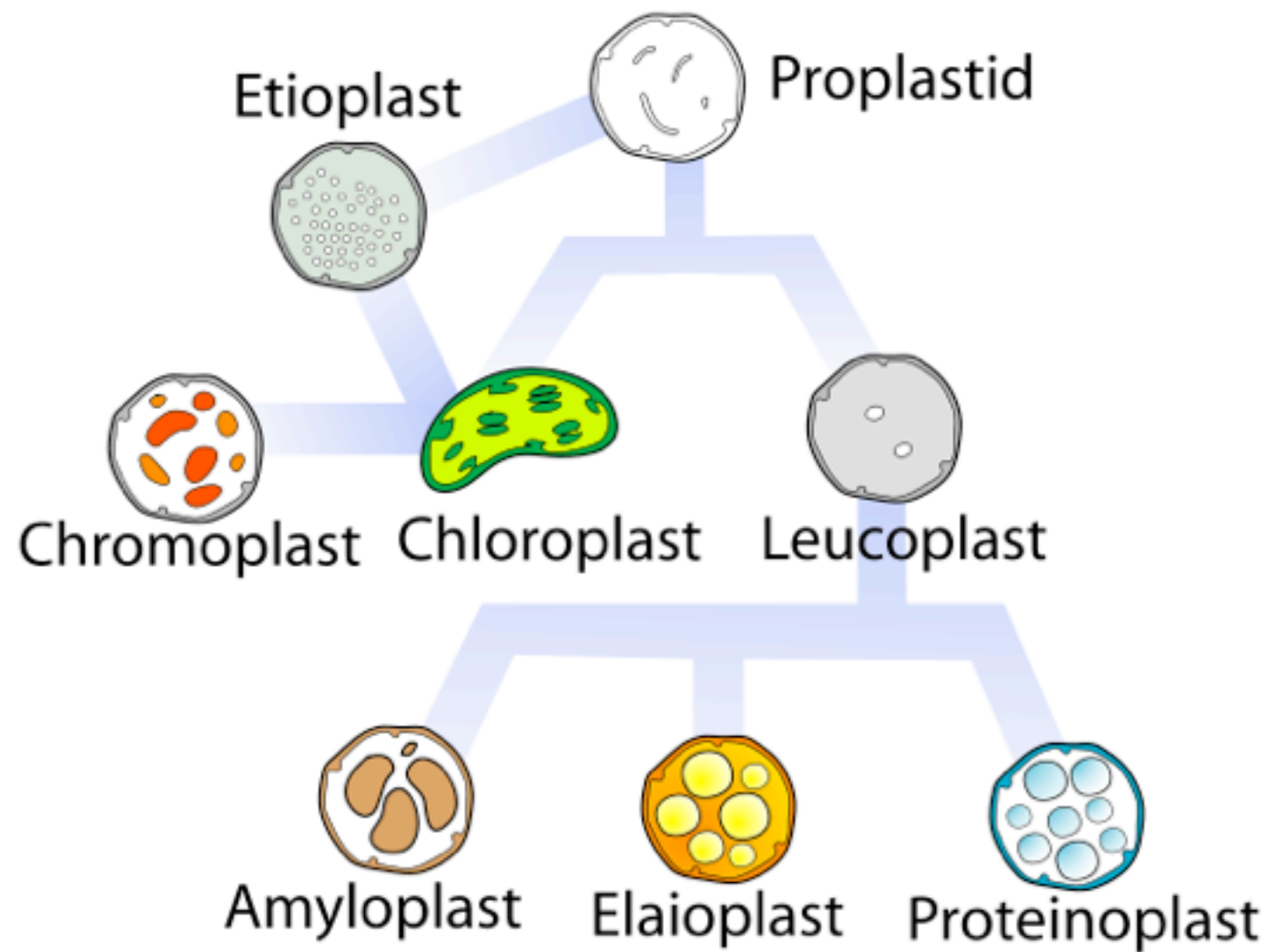


Chloroplasts: Capture of Light Energy

- **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.

Plastids



Comparing Mitochondria and Chloroplasts

Mitochondria

- **Converts energy to useable forms.**
- **Not part of endomembrane system.**
- **Has double membrane.**
- **Grows and reproduces.**
- **Has its own DNA and ribosomes.**
- **Semi-autonomous.**

-
- **Site for cell respiration**
 - **Found in both animal and plant cells**

Chloroplasts

- **Ditto**
- **Ditto**
- **Ditto**
- **Ditto**
- **Ditto**
- **Ditto**

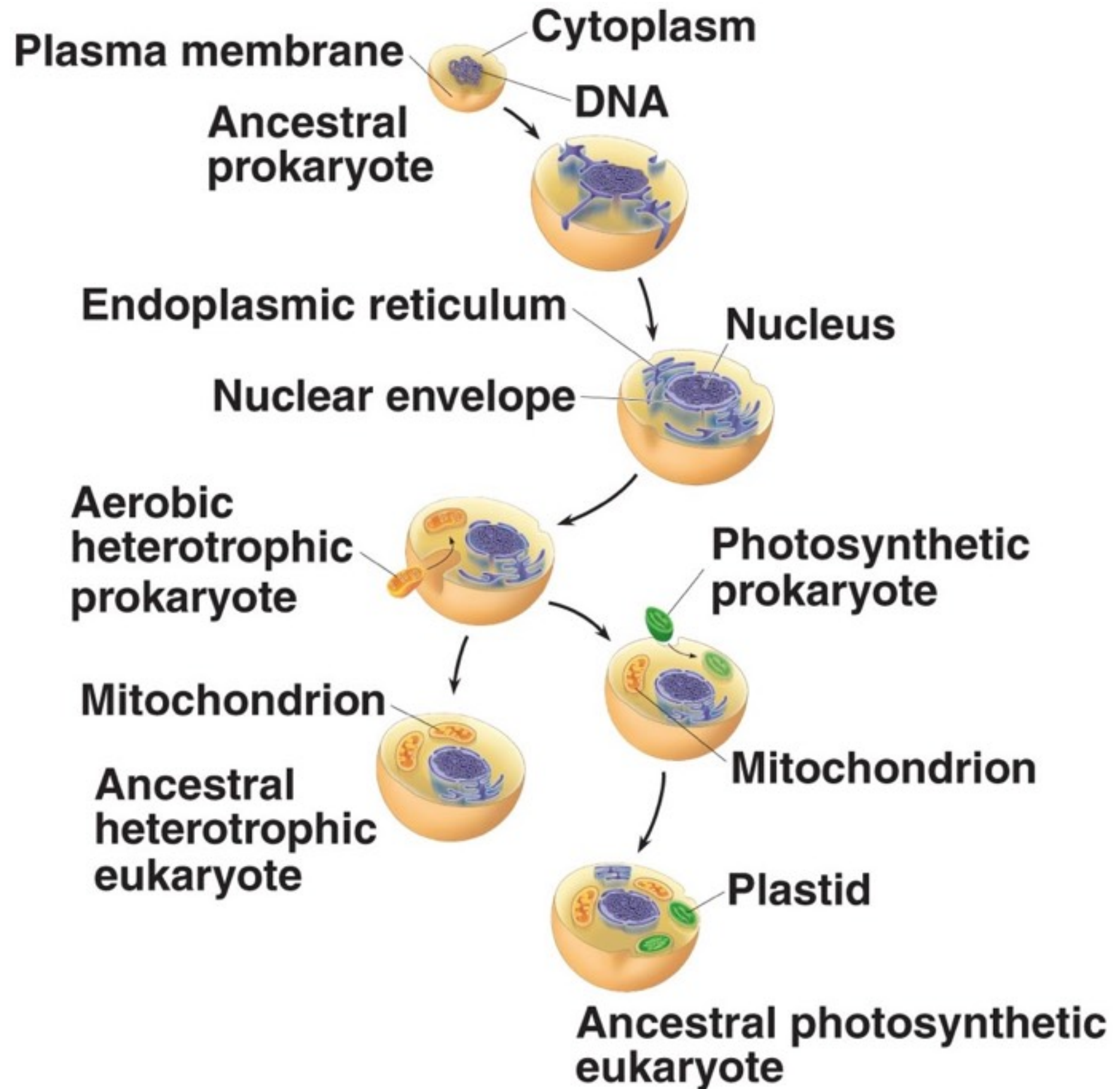
-
- **Site for photosynthesis**
 - **Found in plant cells and eukaryotic algae**

Evolutionary Origins:

Mitochondria and Chloroplasts

Evolutionary Origins:

Mitochondria and Chloroplasts



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

Learning Objectives:

LO 4.4 The student is able to make a prediction about the interactions of subcellular organelles. [See SP 6.4]

LO 4.5 The student is able to construct explanations based on scientific evidence as to how interactions of subcellular structures provide essential functions. [See SP 6.2]

LO 4.6 The student is able to use representations and models to analyze situations qualitatively to describe how interactions of subcellular structures, which possess specialized functions, provide essential functions. [See SP 1.4]