A Tour of the Cell

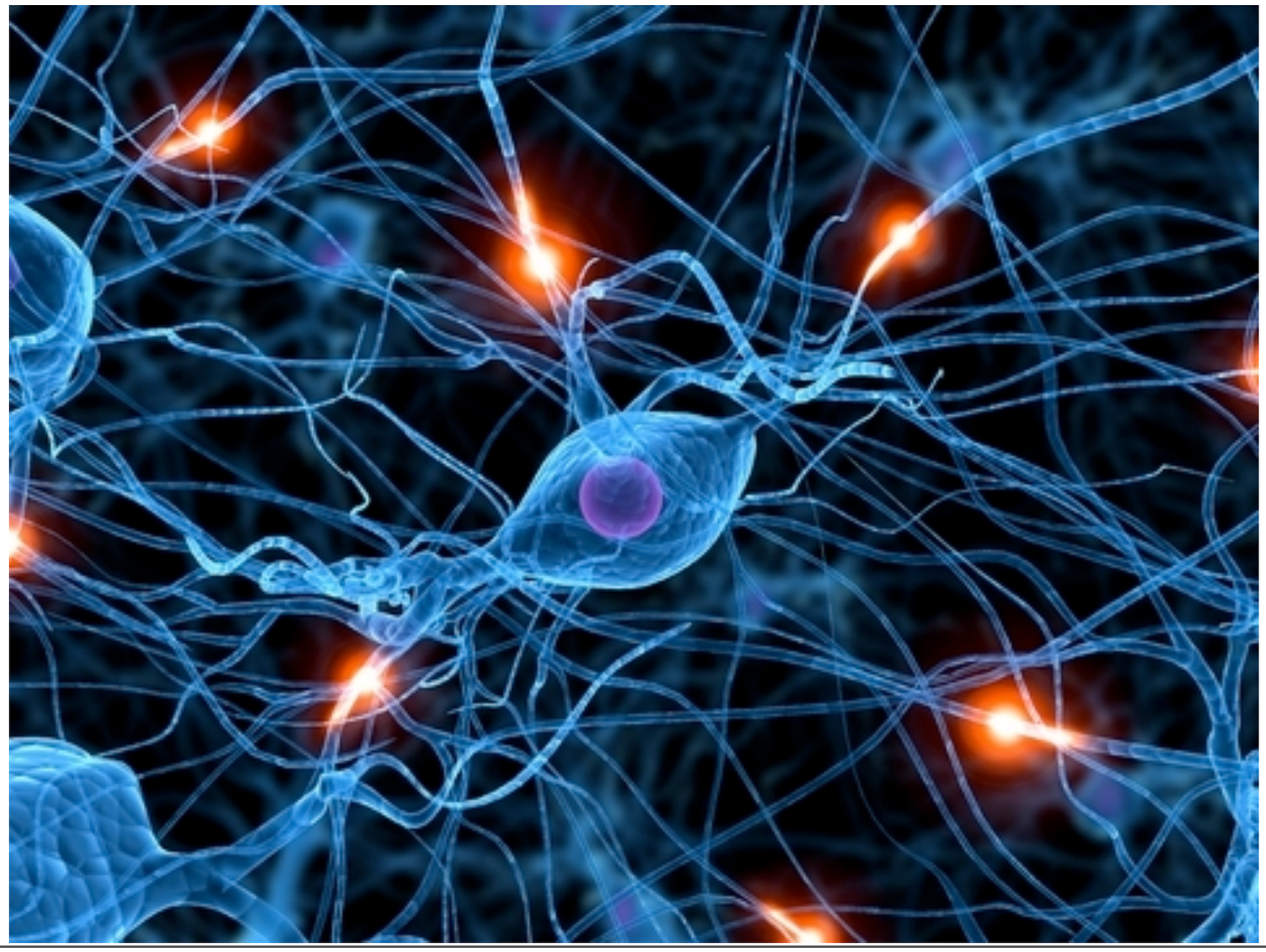
PREFACE

- **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 many 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.**

Tour of the Cell

I.

Main Idea: Biologists use microscopes and biochemistry technique called cell fractionation to study cells.



BIOLOGISTS USE MICROSCOPES AND THE TOOLS OF BIOCHEMISTRY TO STUDY CELLS

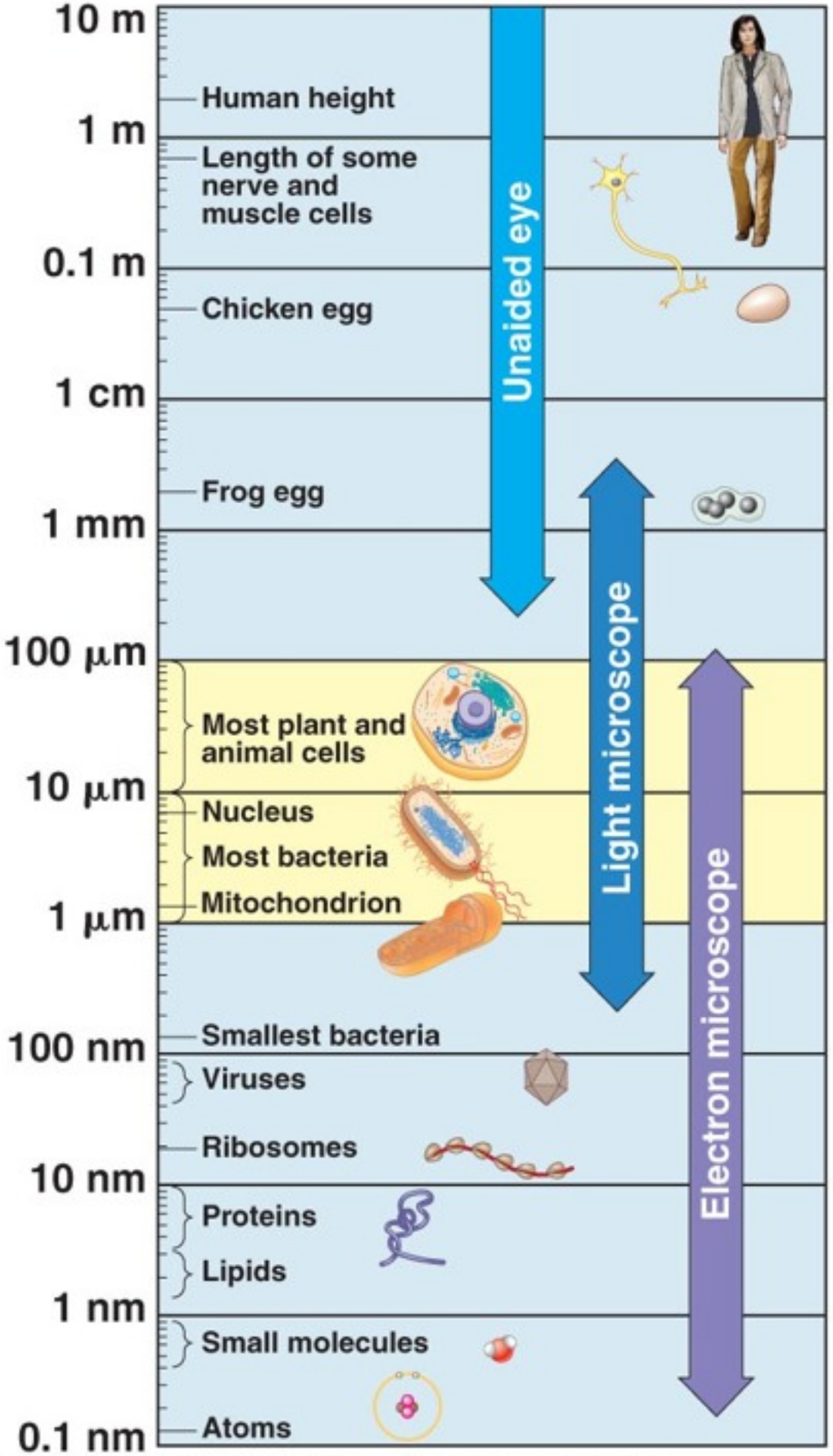
A. Microscopy

- Microscope Pioneers
  - 1590 Zaccharrias Janssen (Dutch eyeglass maker)
  - 1665 Robert Hooke (English physicist)
  - 1670 Anton van Leeuwenhoek (Dutch, worked in dry goods store) "The Father of Microscopy"

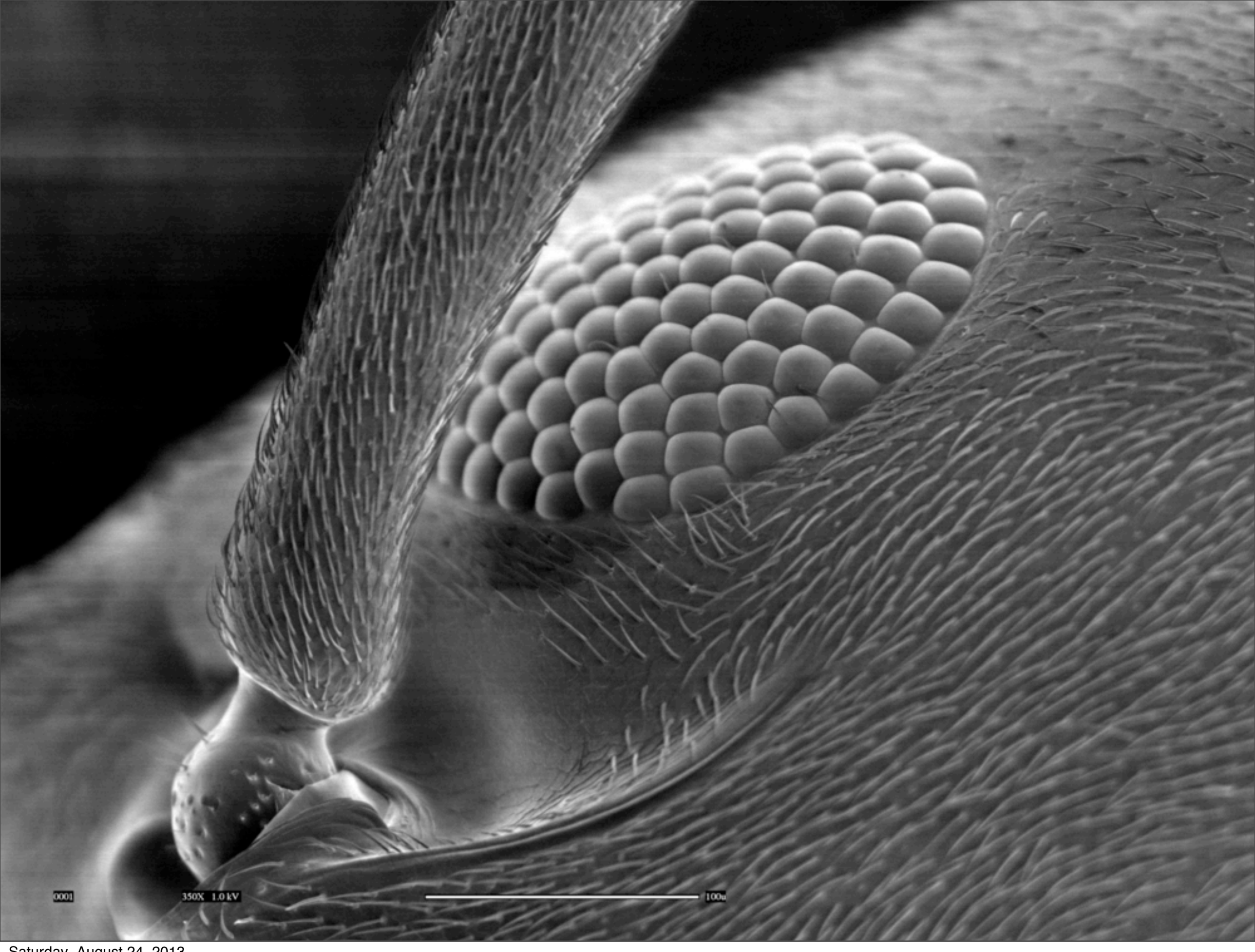
All the Small Things, Blink 182

A. Microscopy

- There 3 Important parameters in microscopy
  - ***Magnification*** ratio of an object's image size to its real size
  - ***Resolution*** clarity of the image, the minimum distance two points can be separated and still distinguished as two points
  - ***Contrast*** accentuates differences in parts of the sample



Electron microscopes can see smaller structures than light microscopes HOWEVER electron microscopes can not view living organisms where as light microscopes can!



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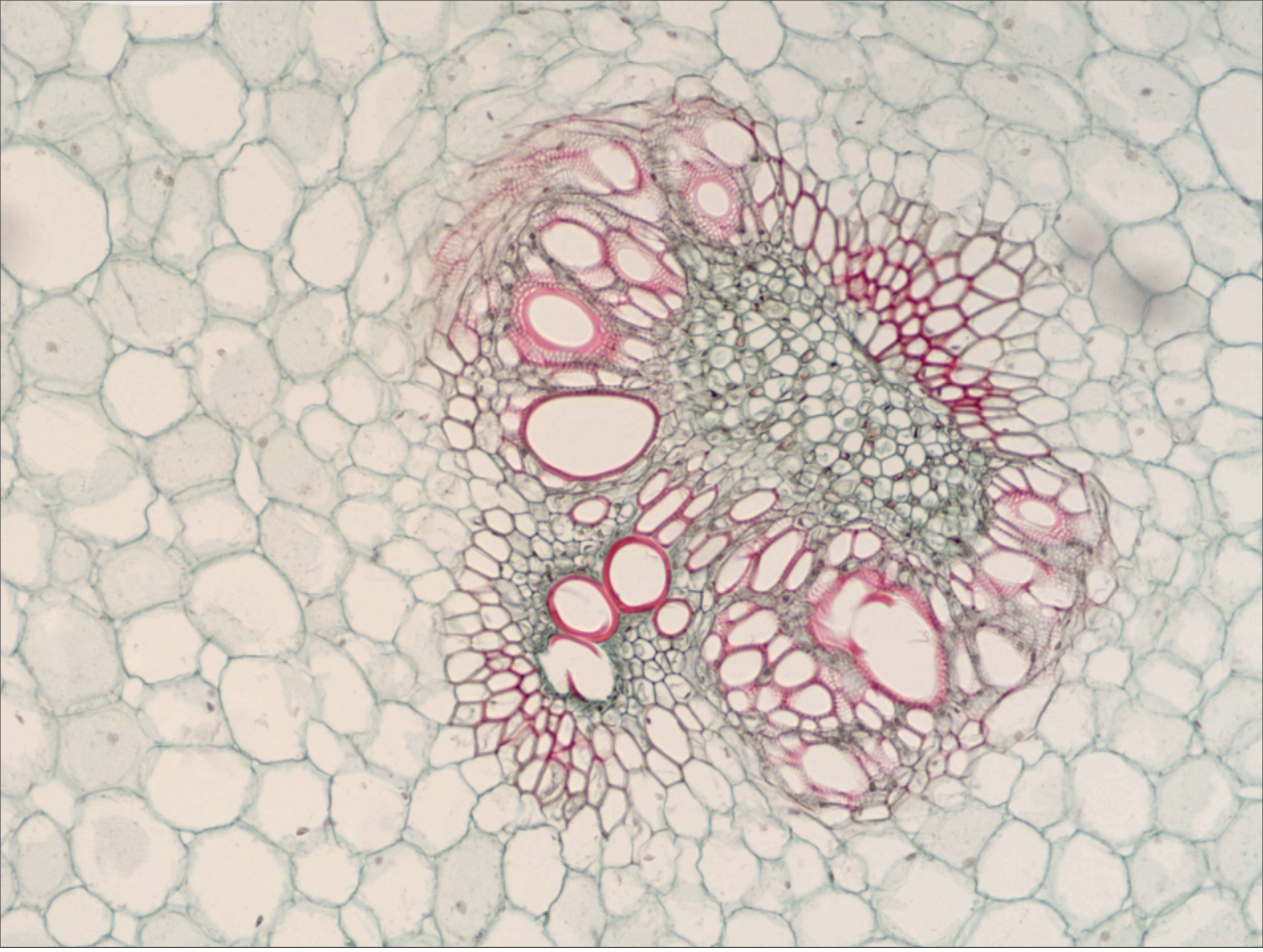

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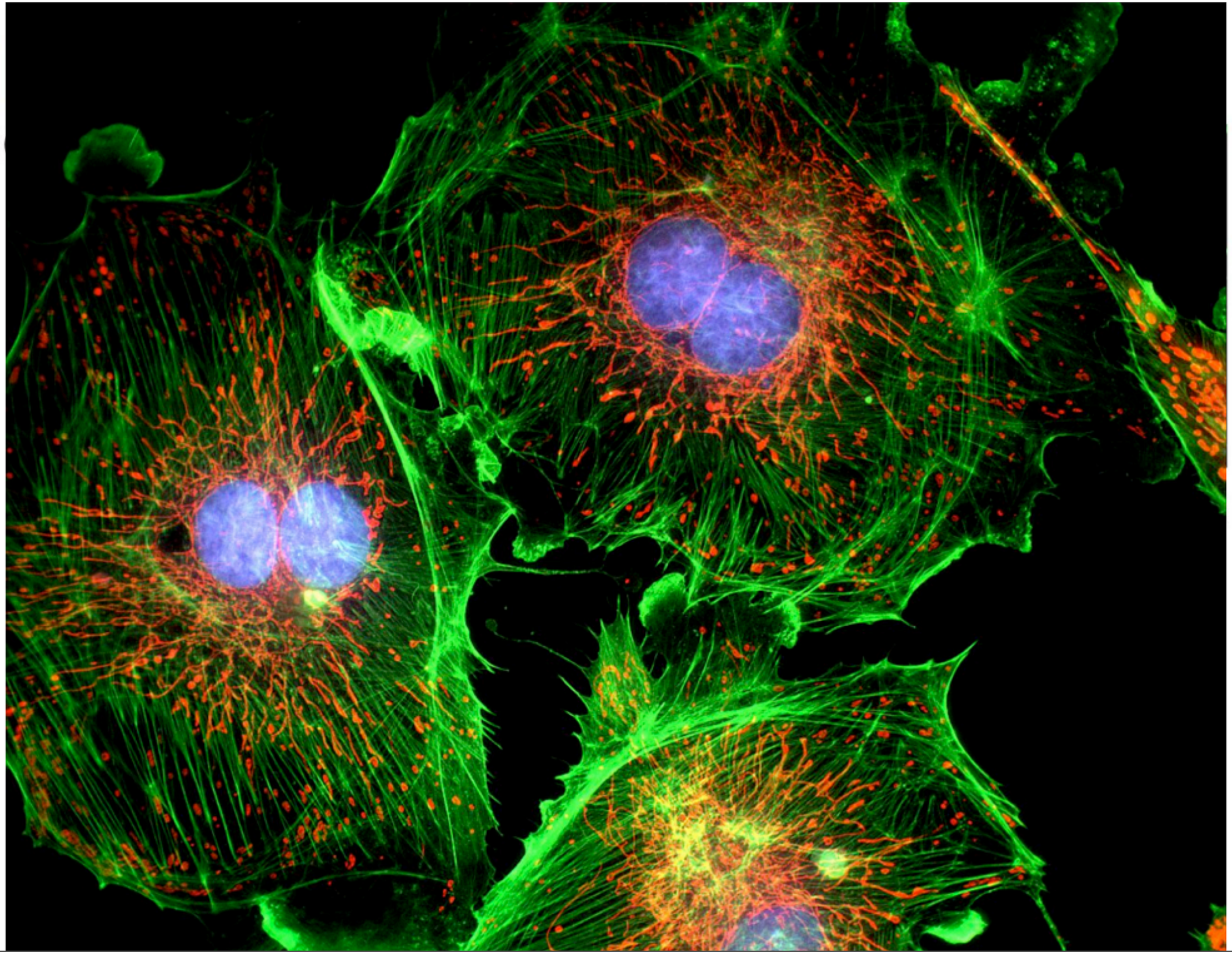
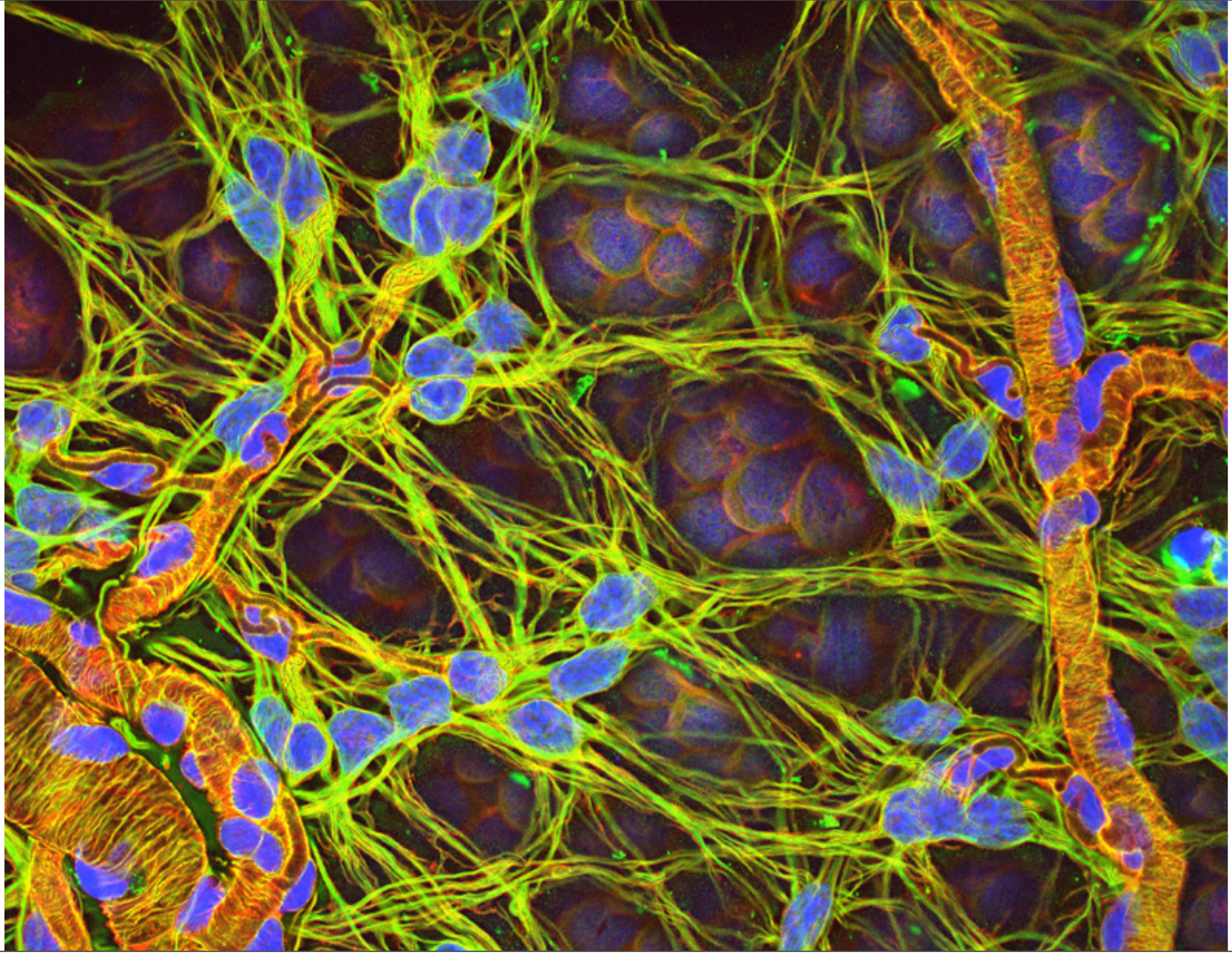
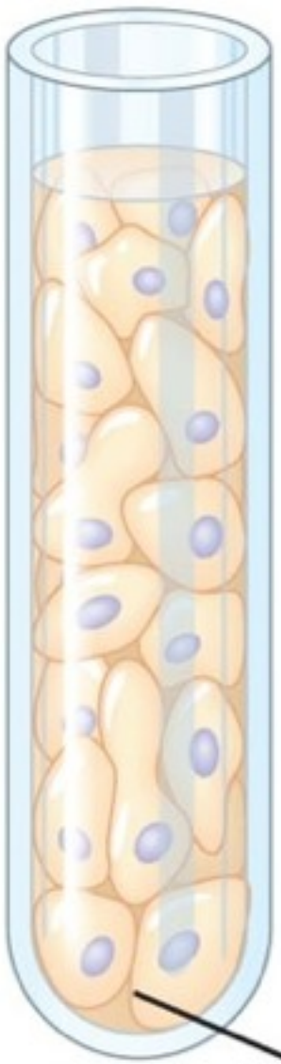




B. Cell Fractionation

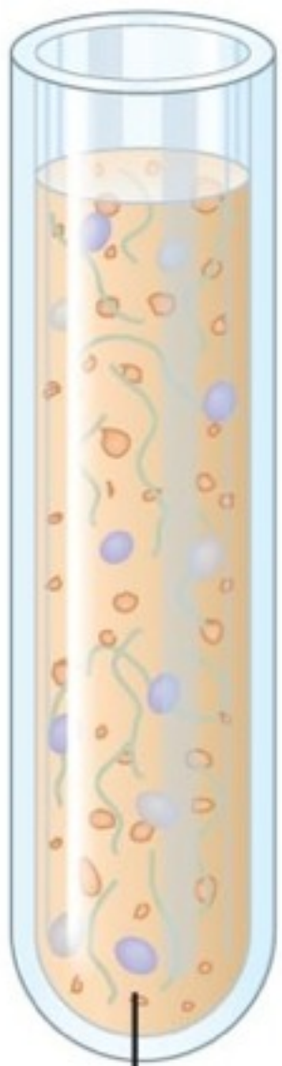
- *Cell Fractionation* breaks cells into pieces and separates organelles and structures from each other based on their weight.
  - *Centrifugation* the heaviest components will settle on the bottom of the test tube, called a pellet.
  - After the "pellet" is removed faster spinning can result in smaller components collecting at the bottom (pellet)

TECHNIQUE

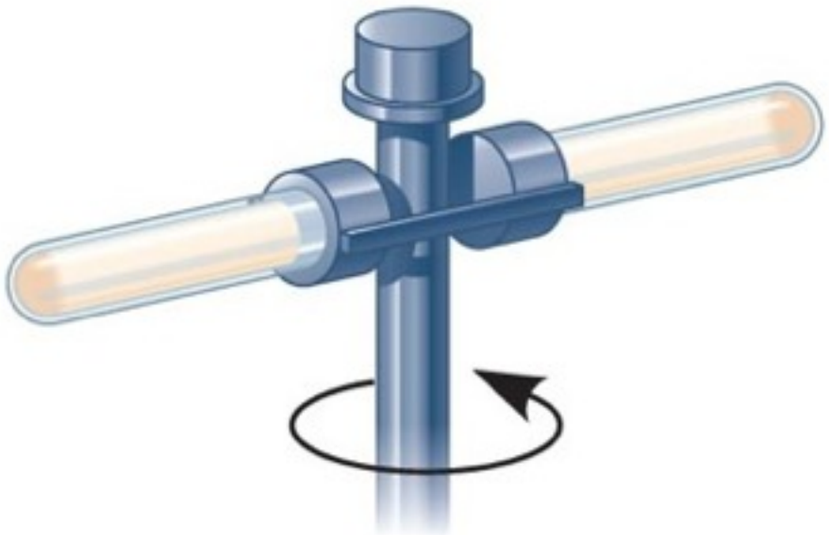


Tissue cells

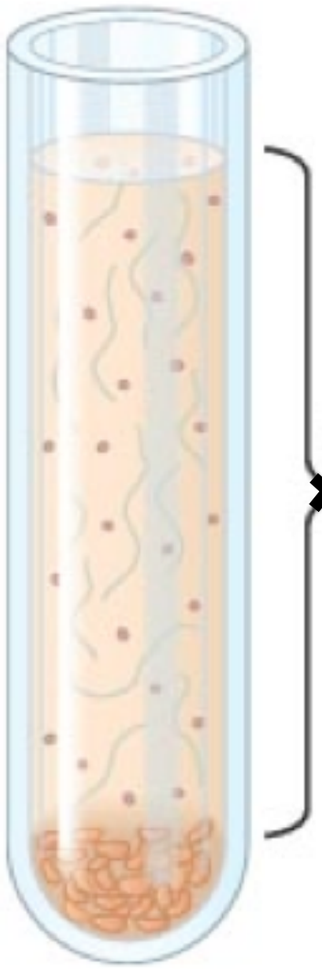
Homogenization



Homogenate



Differential centrifugation



Biochemical Tests

Electron Microscopy

Reveal enzymes involved in cell respiration

+

Reveal mitochondria

Together this data help determine the function of an organelle... that mitochondria may carry out cell respiration

Tour of the Cell

II.

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.

EUKARYOTIC CELLS HAVE INTERNAL MEMBRANES THAT COMPARTMENTALIZE THEIR FUNCTIONS

A. Comparing Eukaryotic and Prokaryotic cells

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

Although all cells share these common features the first and most distinct differences between cells are seen in the division between eukaryotes and prokaryotes.

- **PROKARYOTES**
  - **older, less complex**
  - **No nucleus (DNA in nucleoid region)**
  - **No membrane bound organelles**
  - **smaller**
- **EUKARYOTES**
  - **younger, more complex**
  - **Has nucleus (contains DNA)**
  - **Has membrane bound organelles**
  - **larger**

These differences are just the beginning a more comprehensive list is forth coming!

SIZE MATTERS

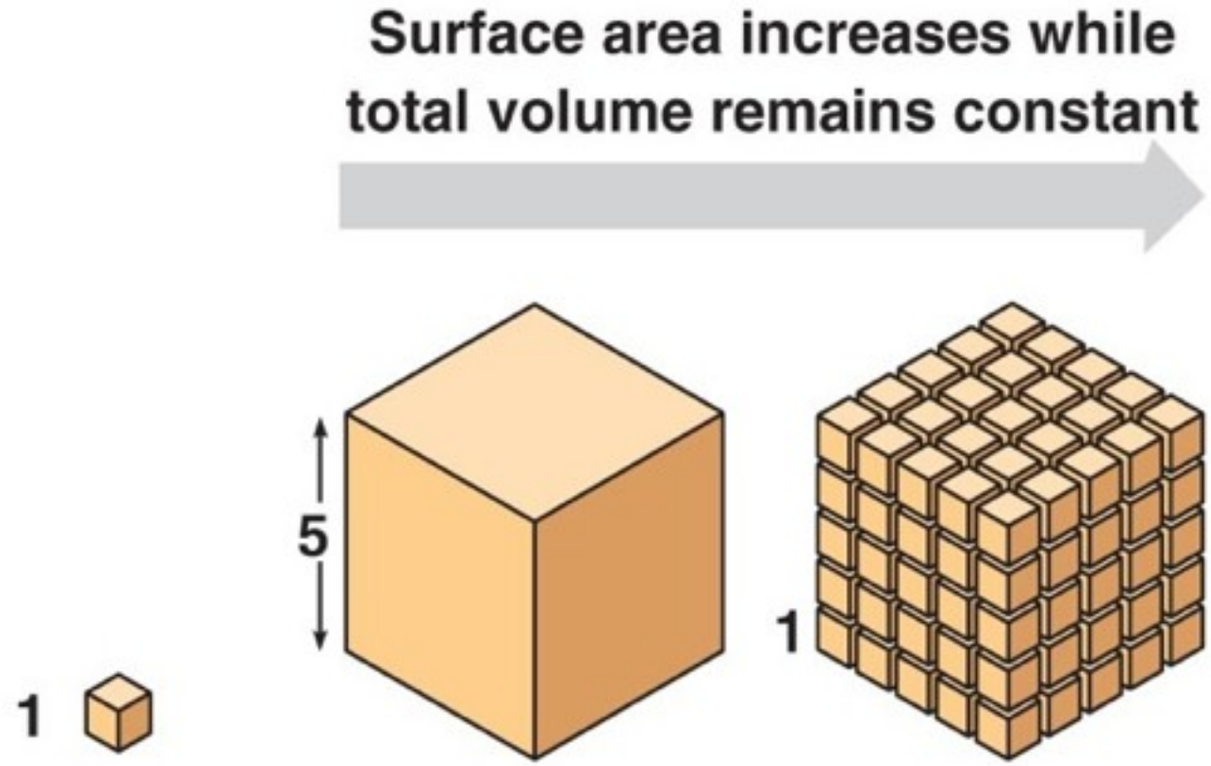
The logistics to carry out metabolism sets the lower limit on cell size

The requirements for metabolism set the upper limit on cell size

The ratio of surface area to volume is critical

Volume (cubed function) grows proportionately more than its surface area (squared function)

Thus a smaller object has a greater SA:V ratio

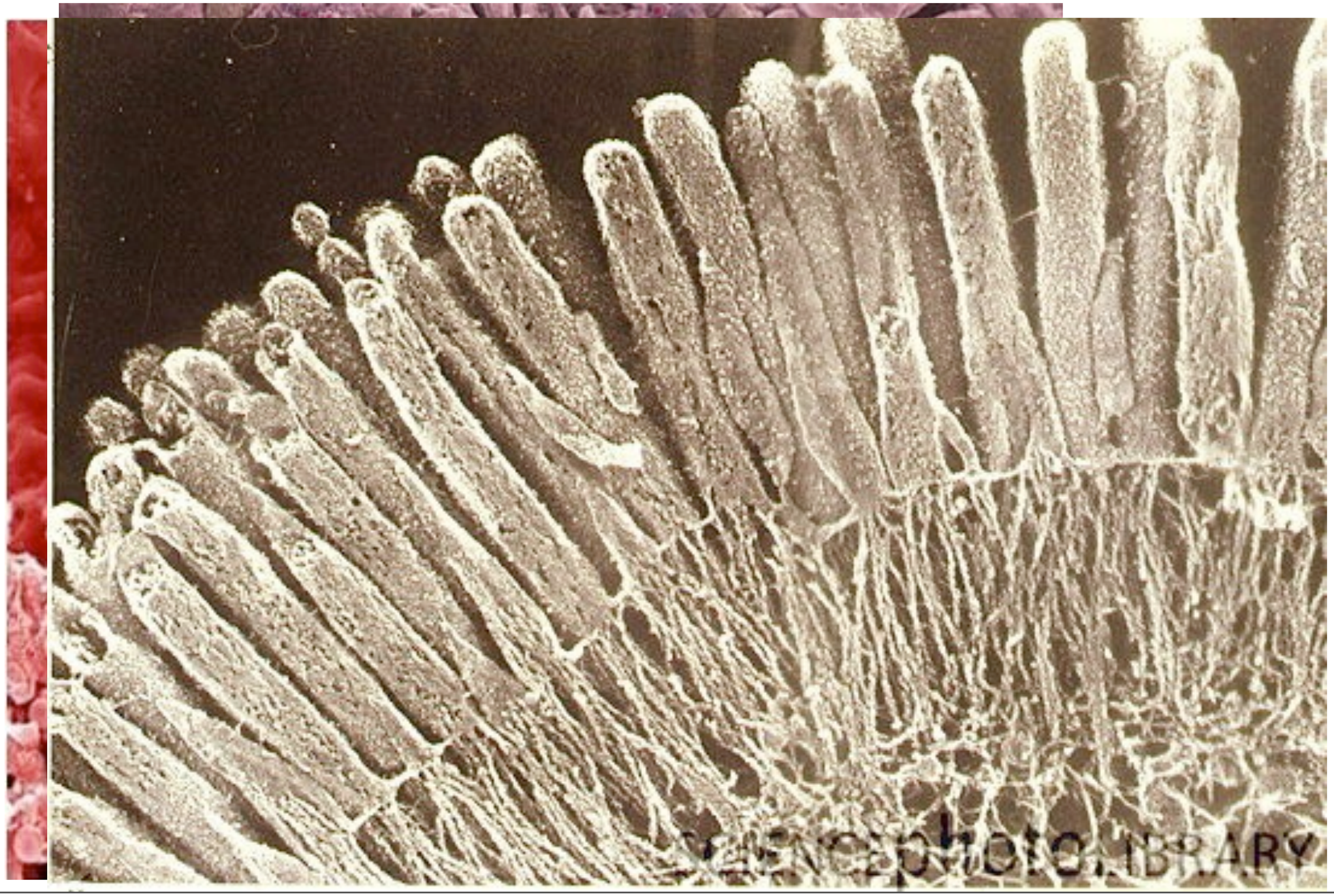


Total surface area [Sum of the surface areas (height × width) of all box sides × number of boxes]	6	150	750
Total volume [height × width × length × number of boxes]	1	125	125
Surface-to-volume (S-to-V) ratio [surface area ÷ volume]	6	1.2	6

Bigger is Better!

A Big SA:V ratio is especially important for cells that continually exchange with its surroundings

Can think of any cells or tissues that continually exchange with its environment?



Intestine

Pancreas

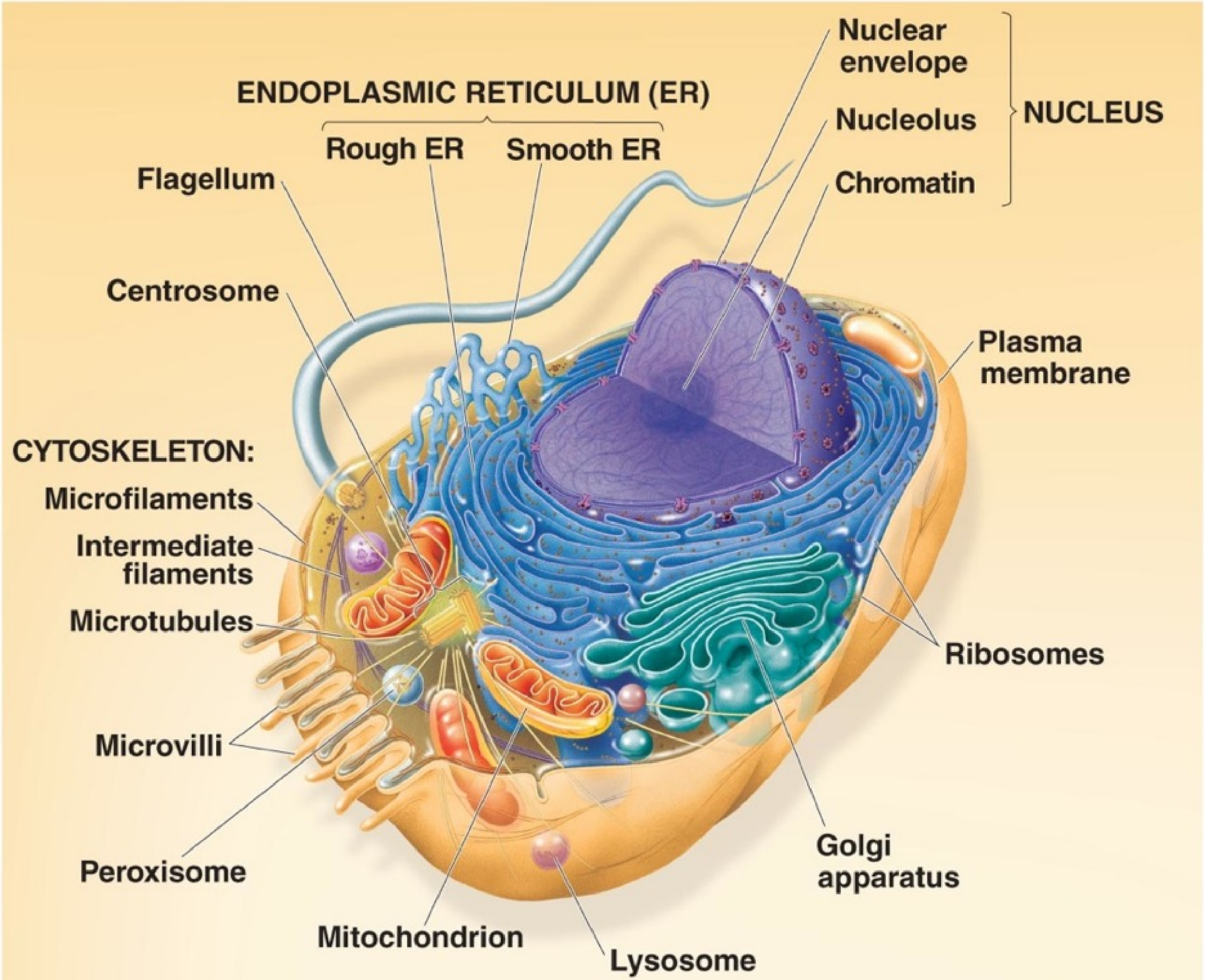
Alveoli

1. A Panoramic View of the Eukaryotic Cell

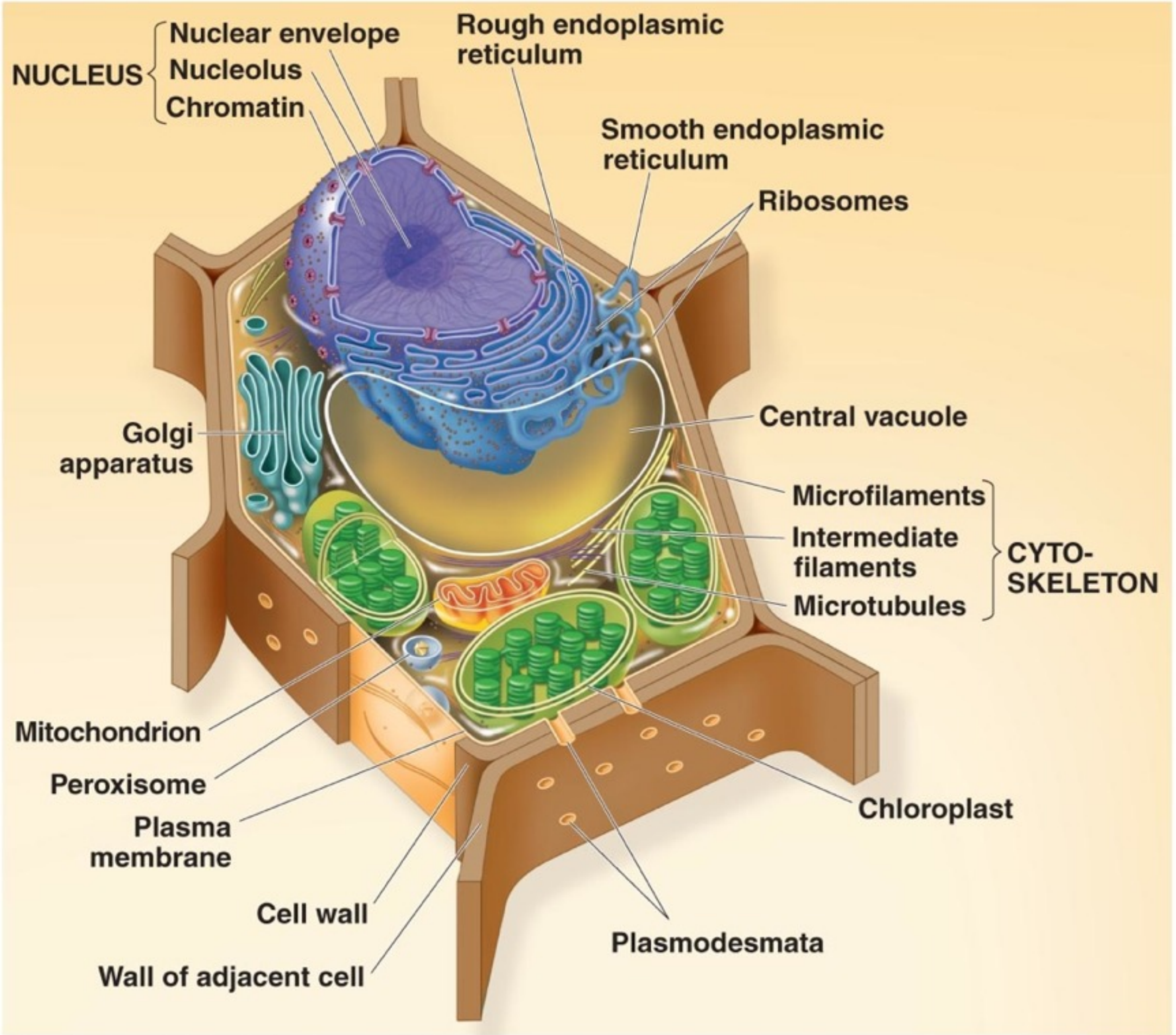
- Eukaryotic cells have elaborately arranged internal membranes that divide the cell into compartments.
    - Compartments provide different local environments that facilitate specific metabolic functions some of which are antagonistic.
- The membranes themselves are loaded with enzymes and thus participate directly in the cell's metabolism.

Membranes are so fundamental to the organization of cells and cellular functions we will dedicate an entire chapter to them

COMING SOON TO A THEATER NEAR YOU

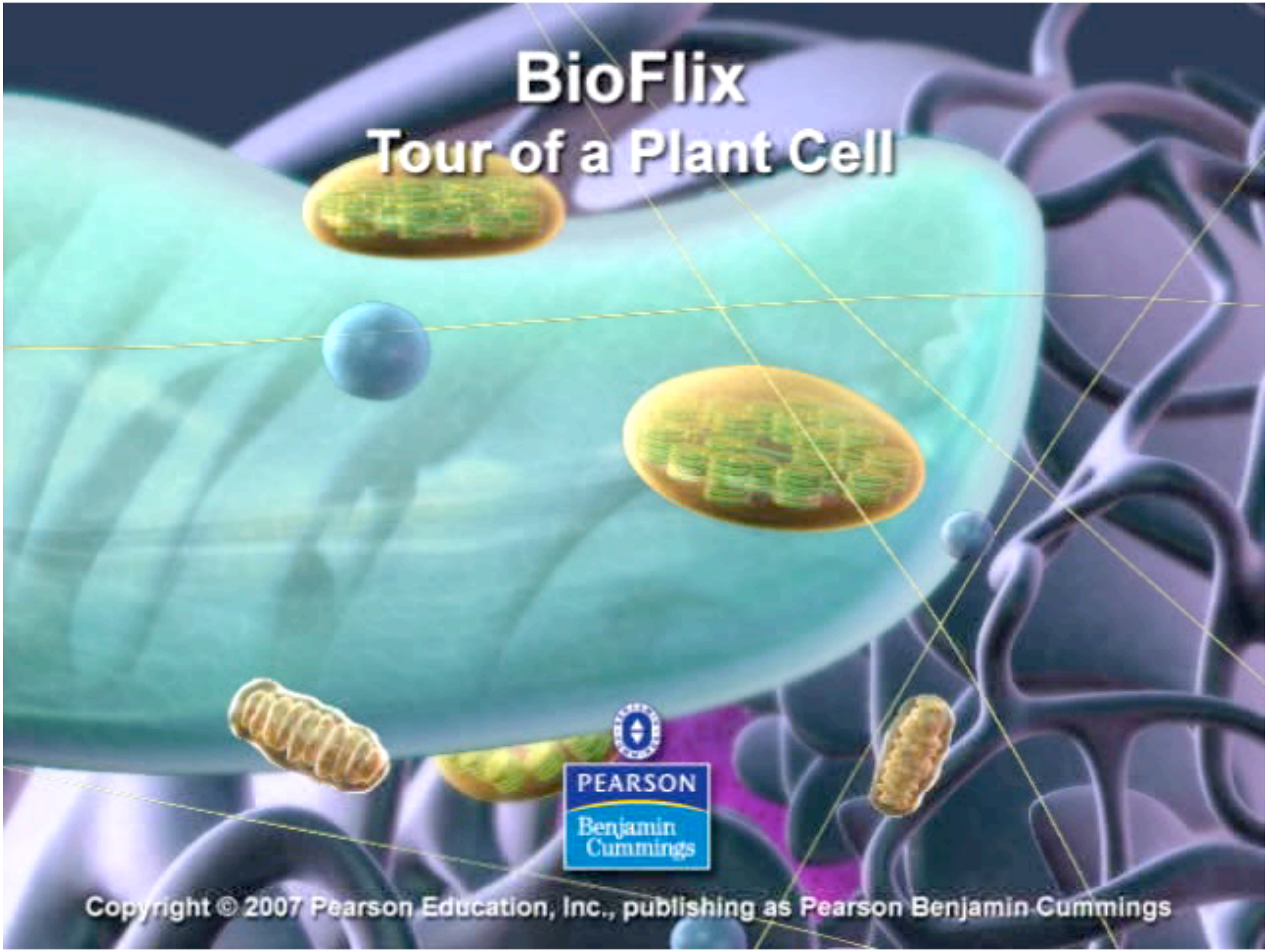

ENDOPLASMIC RETICULUM (ER)
Rough ER
Smooth ER
Nuclear envelope
Nucleolus
Chromatin
NUCLEUS
Flagellum
Centrosome
Plasma membrane
CYTOSKELETON:
Microfilaments
Intermediate filaments
Microtubules
Ribosomes
Microvilli
Peroxisome
Golgi apparatus
Mitochondrion
Lysosome

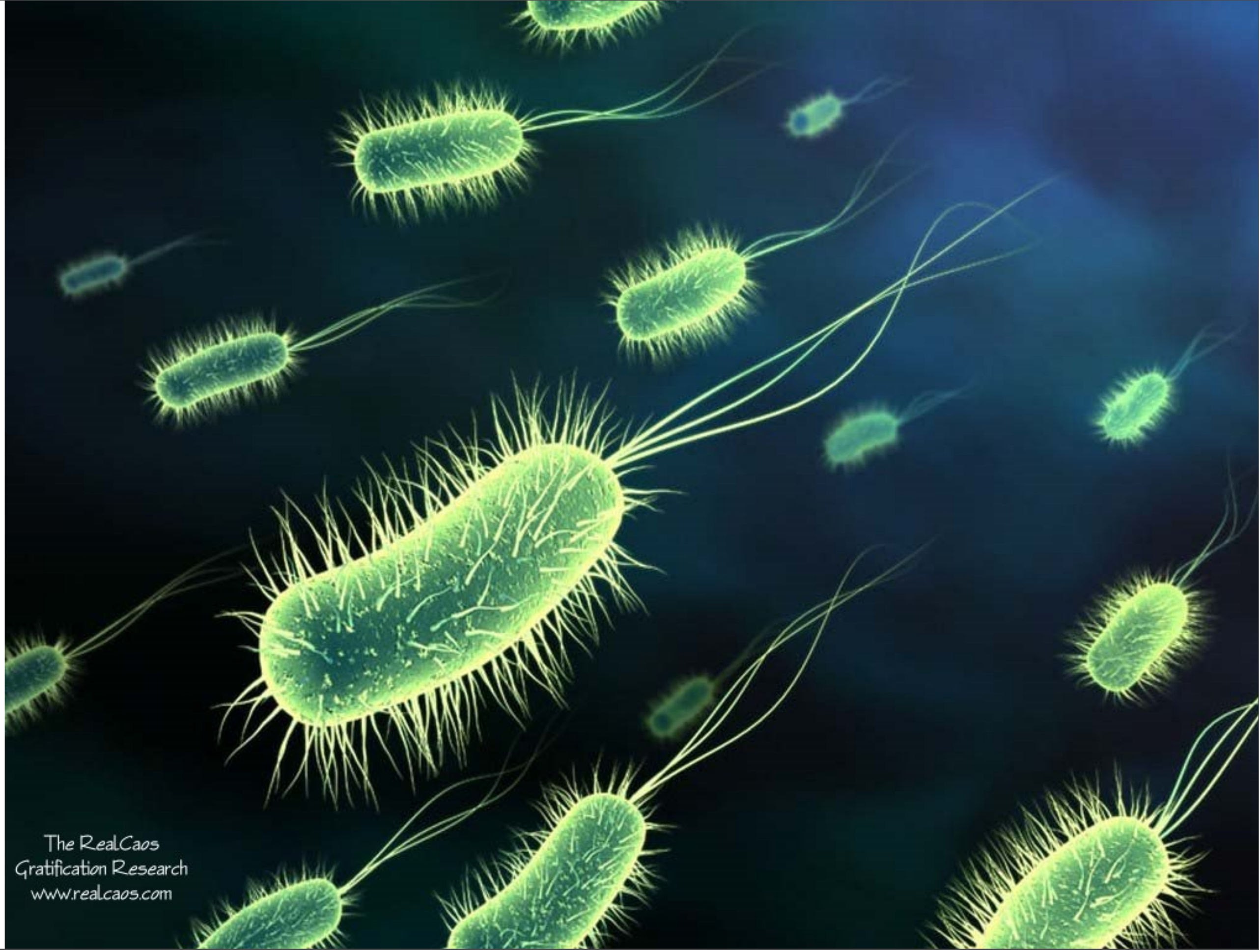
BioFlix
Tour of an Animal Cell


NUCLEUS
Nuclear envelope
Nucleolus
Chromatin
Rough endoplasmic reticulum
Smooth endoplasmic reticulum
Ribosomes
Golgi apparatus
Central vacuole
Microfilaments
Intermediate filaments
Microtubules
CYTO-SKELETON
Mitochondrion
Peroxisome
Plasma membrane
Cell wall
Wall of adjacent cell
Plasmodesmata
Chloroplast

BioFlix

Tour of a Plant Cell



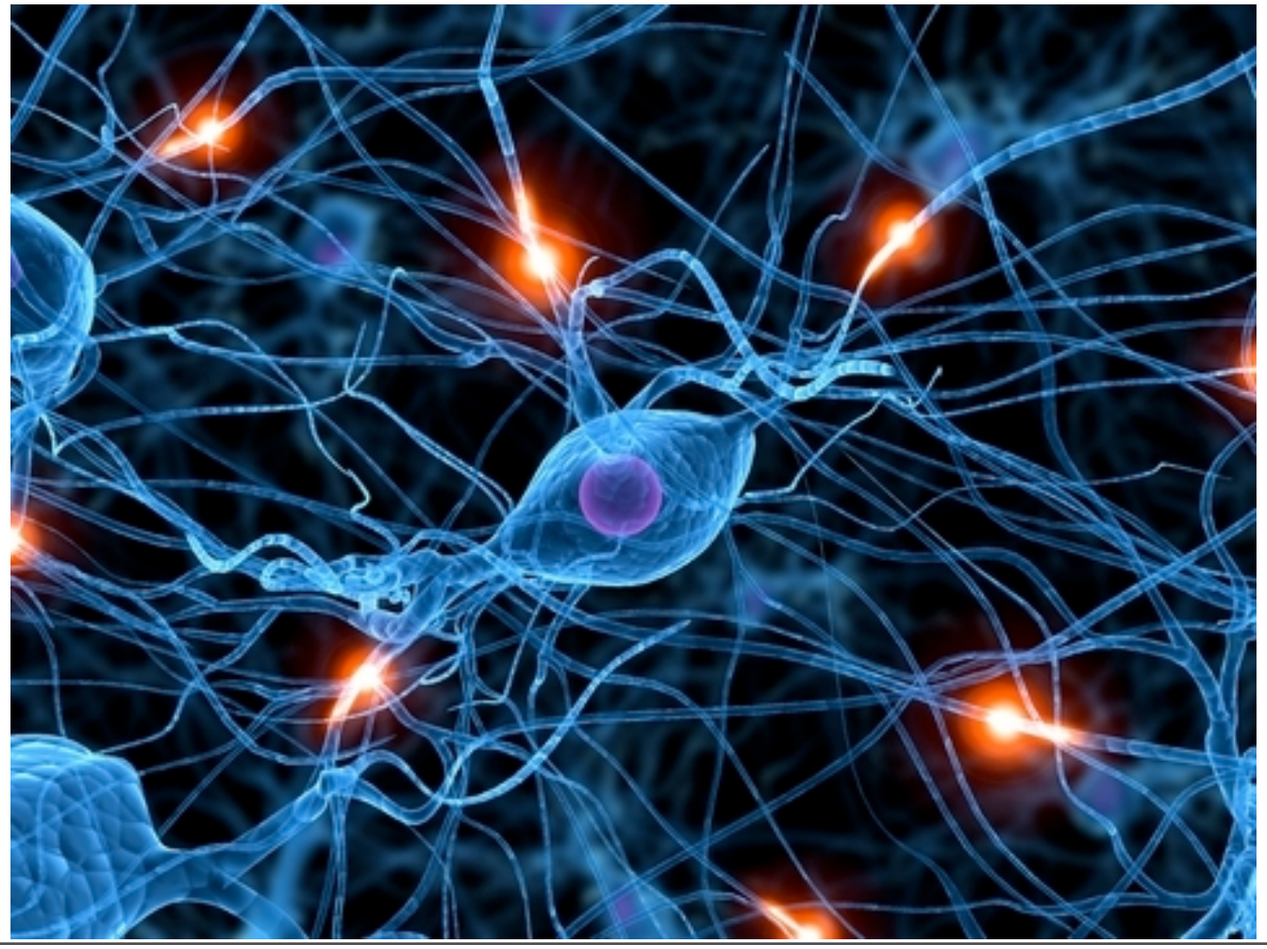

The RealCaos
Gratification Research
www.realcaos.com

Tour of the Cell

III.

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

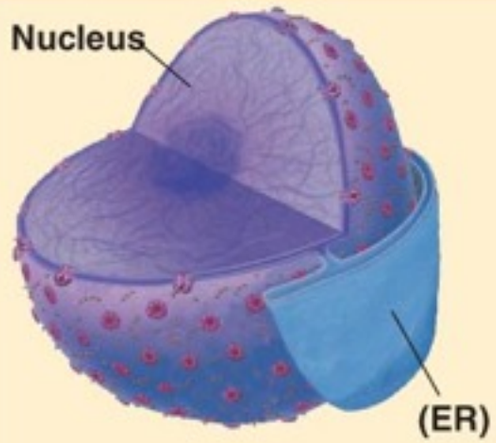
Main Idea: The nucleus contains the "blueprints" for proteins and the ribosomes serve as the "builders" of proteins.



THE EUKARYOTIC CELL'S GENETIC INSTRUCTIONS ARE HOUSED IN THE NUCLEUS AND CARRIED OUT BY THE RIBOSOMES

A. The Nucleus: Information Central

- The nucleus is usually the most prominent feature in a cell.
- The nucleus contains <u>most</u> of a cell's genes.
  - *The mitochondria and chloroplasts contain the rest.*

	Cell Component	Structure	Function
Concept 6.3 The eukaryotic cell's genetic instructions are housed in the nucleus and carried out by the ribosomes		Surrounded by nuclear envelope (double membrane) perforated by nuclear pores. The nuclear envelope is continuous with the endoplasmic reticulum (ER).	Houses chromosomes, made of chromatin (DNA, the genetic material, and proteins); contains nucleoli, where ribosomal subunits are made. Pores regulate entry and exit of materials.

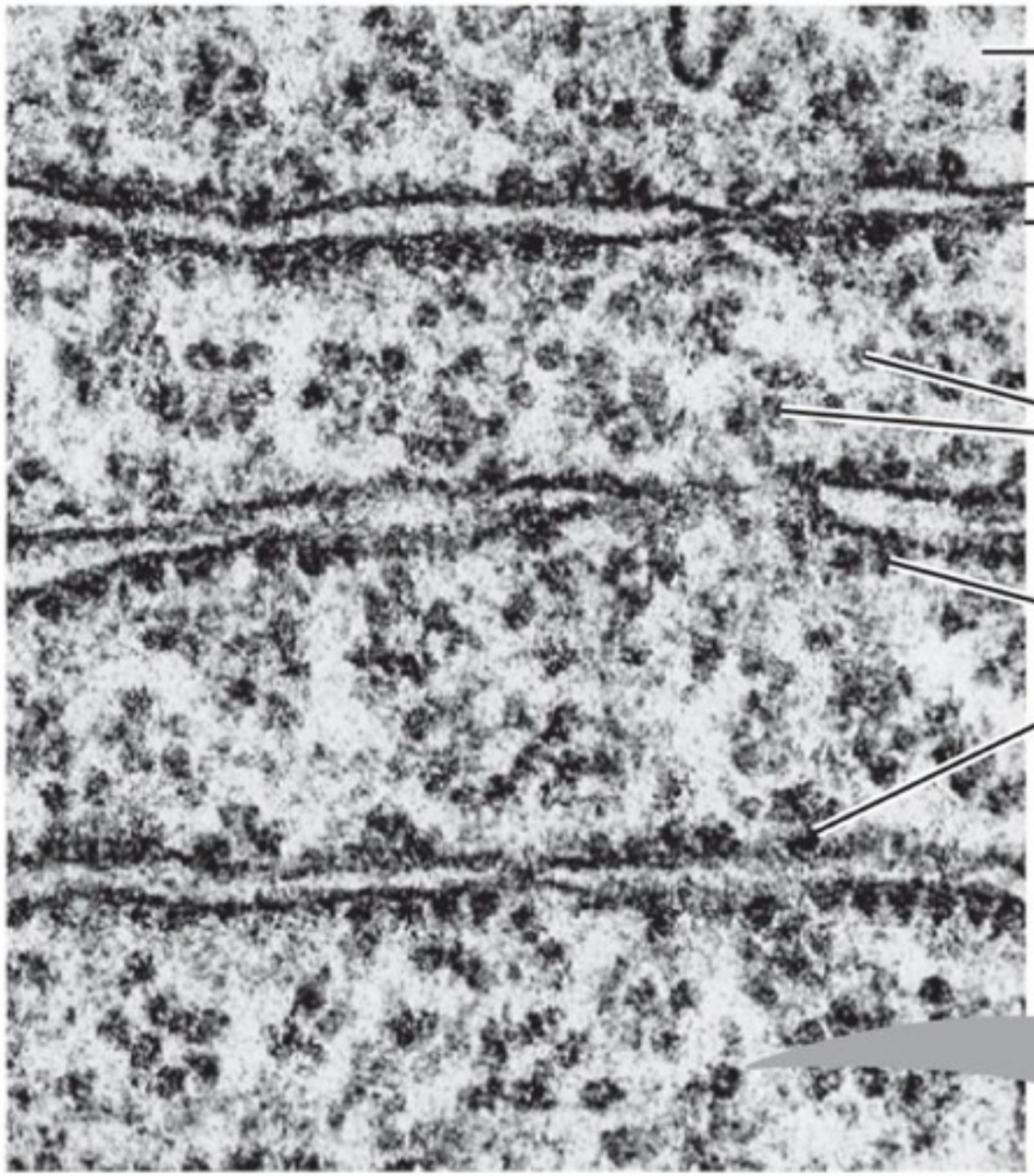
The Nucleus: review

- *nuclear envelope*, **perforated double membrane**
- *pore complex*, **regulates exchange of proteins/RNA in & out**
- *chromatin*, **more accessible, unraveled DNA (most of time)**
- *chromosomes*, **highly condensed DNA packaged for replication**
- *nucleolus*, **synthesizes rRNA, assembles ribosomes**

B. 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



TEM showing ER and ribosomes

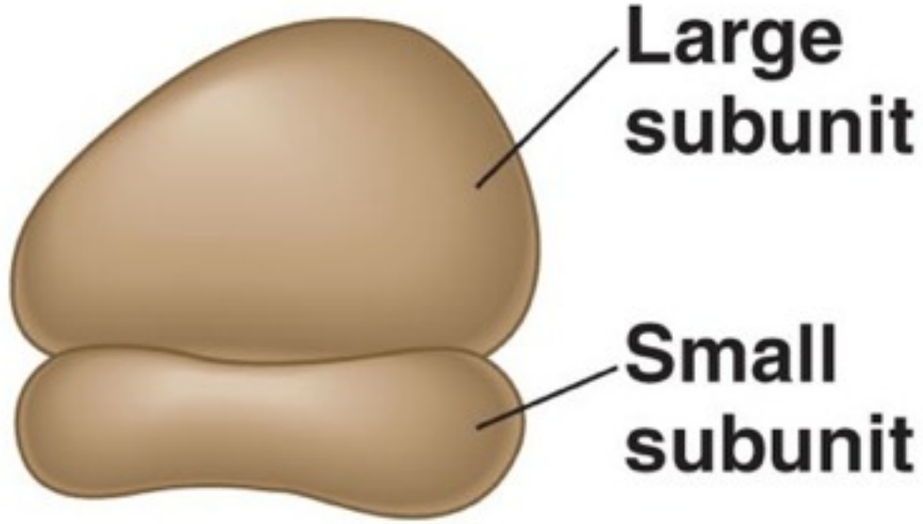
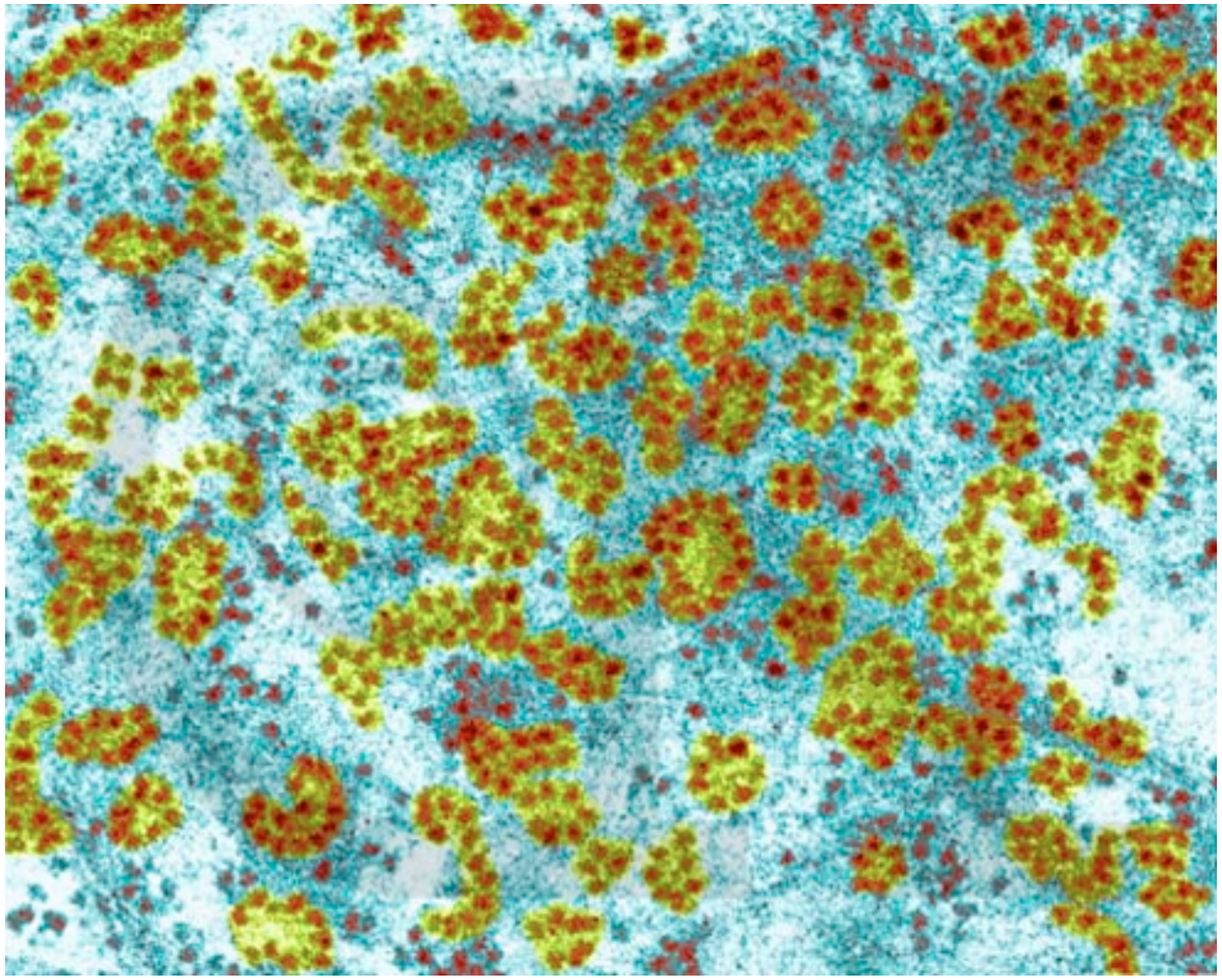
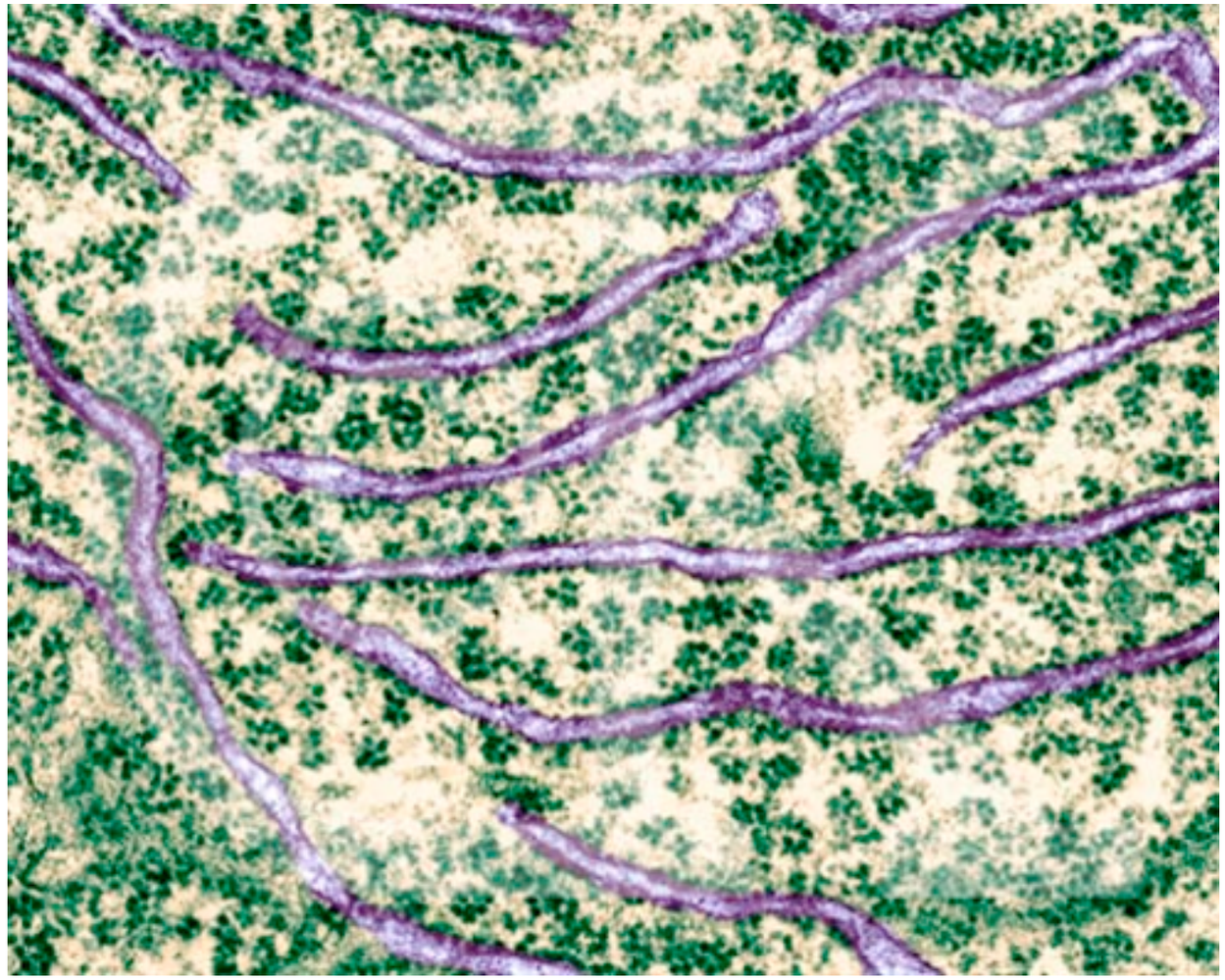


Diagram of a ribosome





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

metabolically active, secretes enzymes

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

liver cells, pancreas cells, stomach cells

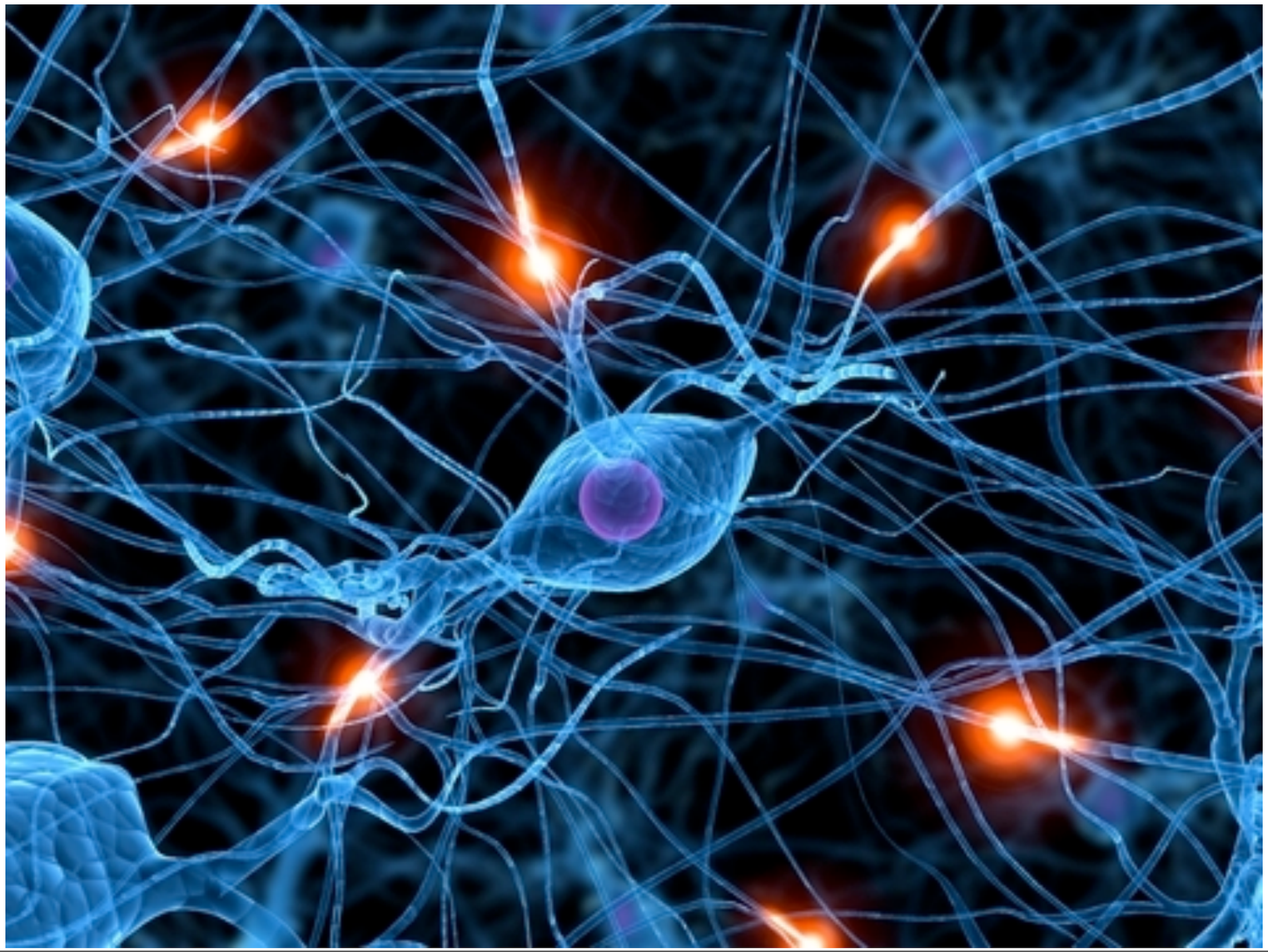
Mature red blood cells expel their nucleus, how many ribosomes would expect to find in these cells?

zero

Tour of the Cell

IV.

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

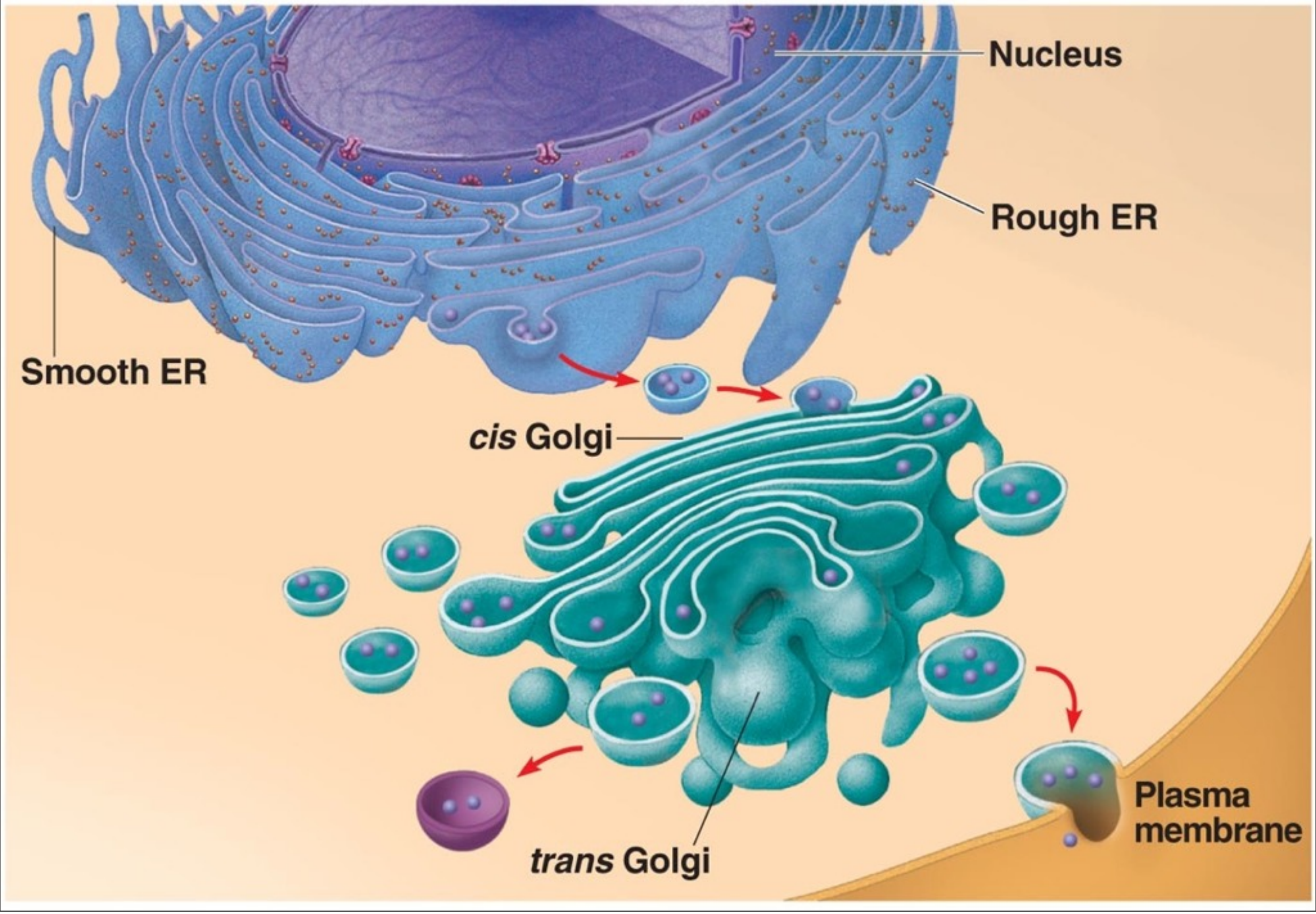
Structures

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

Functions

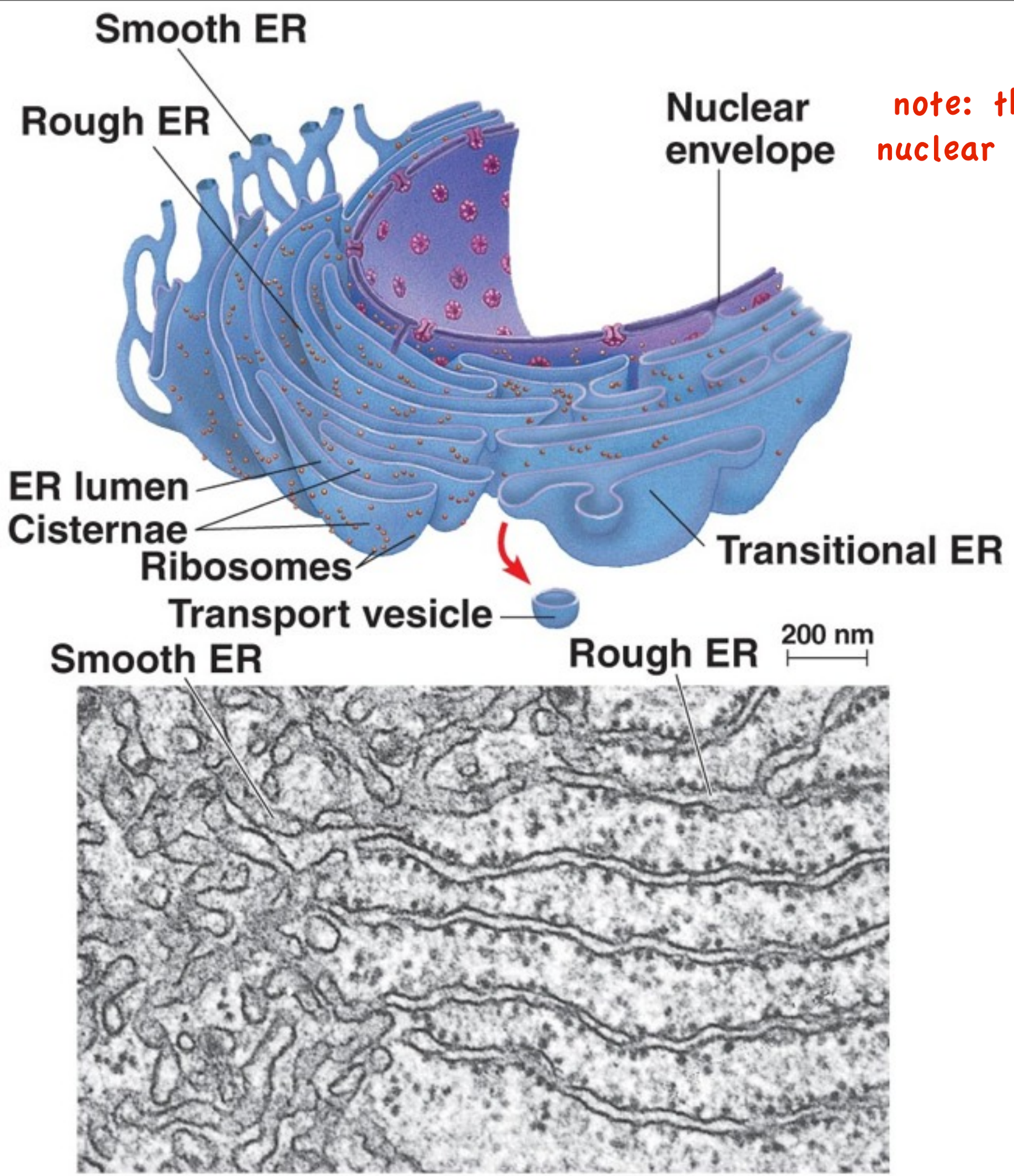
- Protein Synthesis
- Transportation of Proteins
- Chemical Reactions (metabolism)
- Transportation of Lipids
- Detoxification of Poisons

Endomembrane System



A. 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)



note: the cytoplasmic side of nuclear envelope has ribosomes

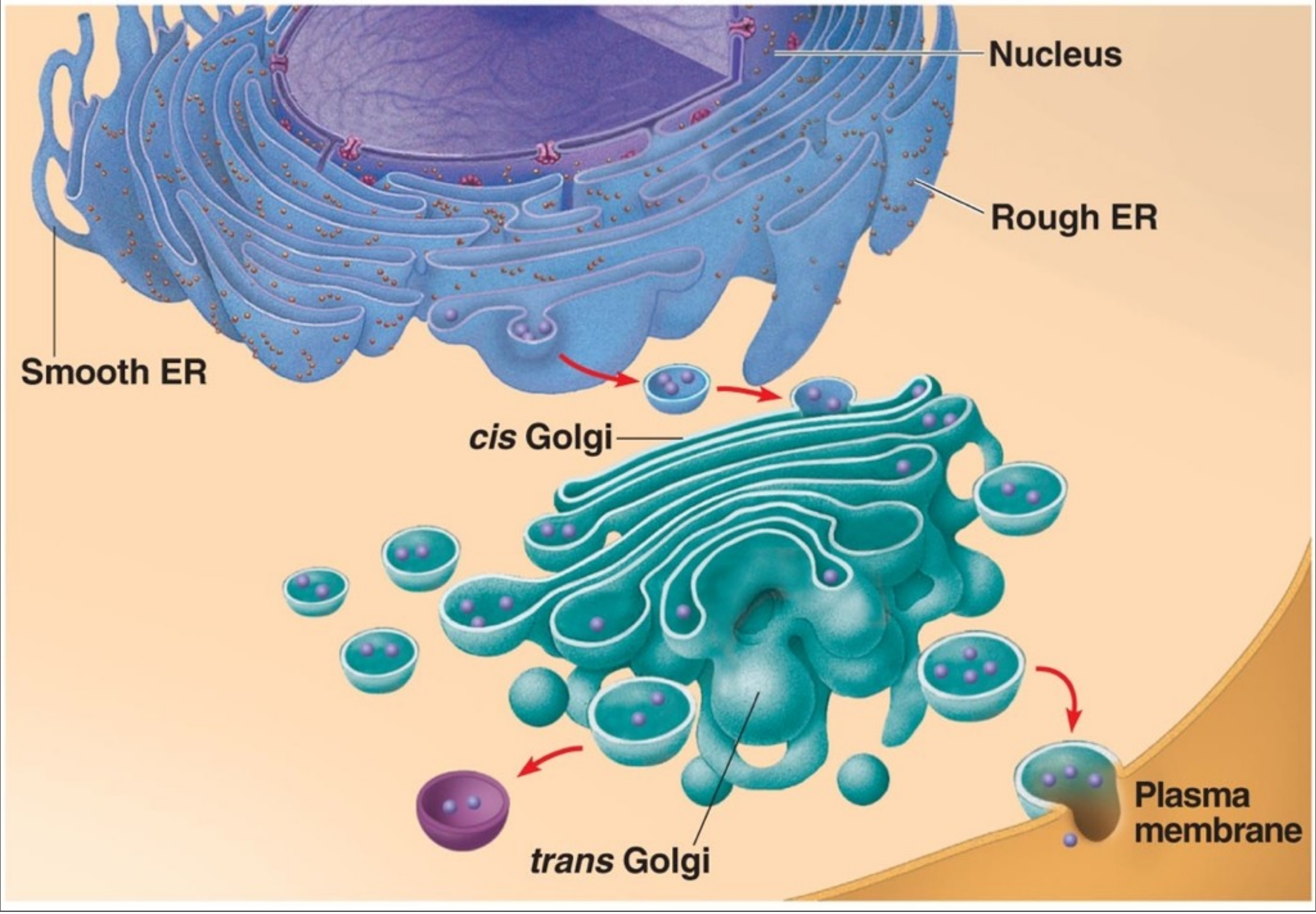
I. Functions of Smooth ER

- **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**

2. Functions of Rough ER

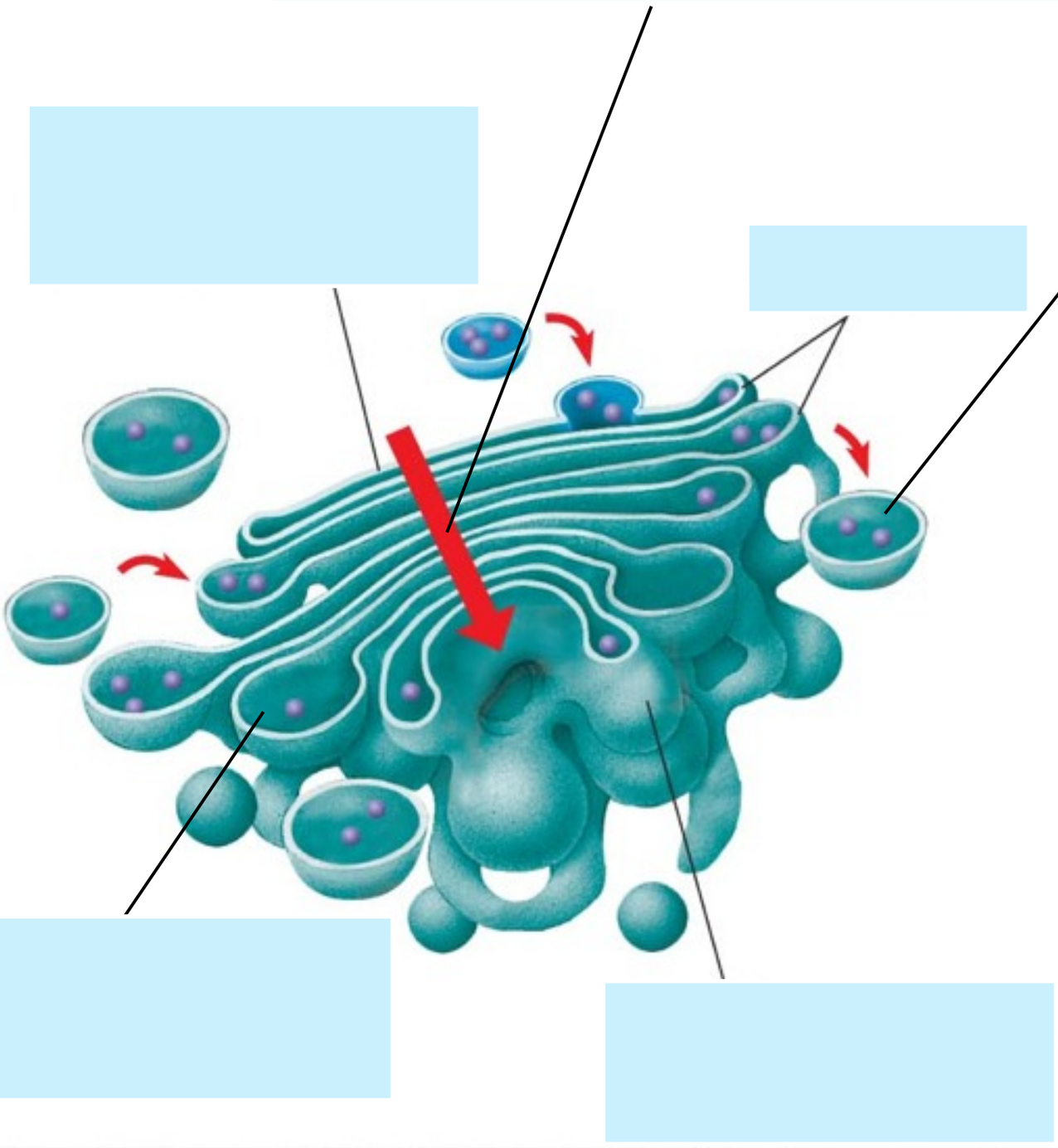
- **The rough E.R. is still "E.R." it has the same functions as the smooth E.R. + some!**
- The rough E.R. specializes in producing proteins that are destined for export or to become part of a membrane, they are called ***secretory proteins***
  - Most *secretory proteins* are ***glycoproteins***, they 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

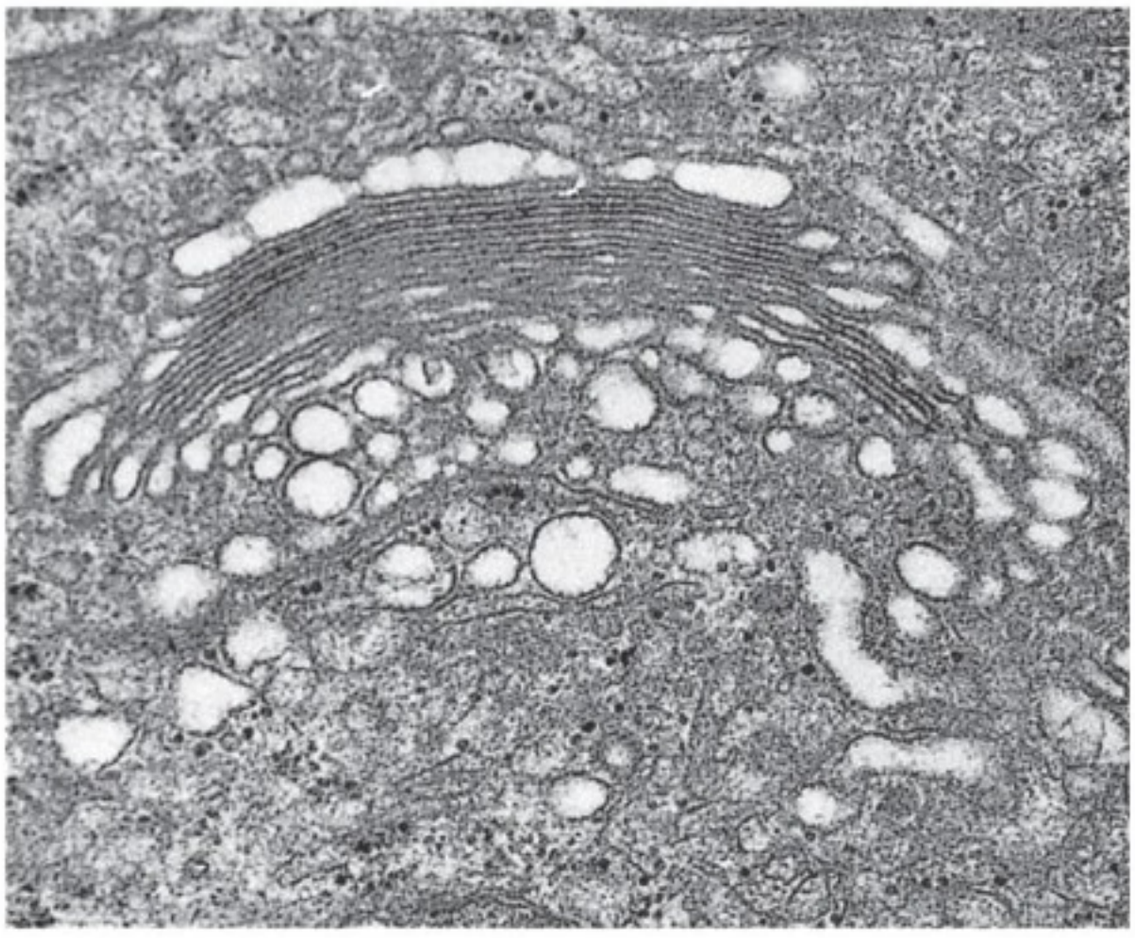
Let's take a look at this again



B. 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*





TEM of Golgi apparatus

C. 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**

Animal Cells Only

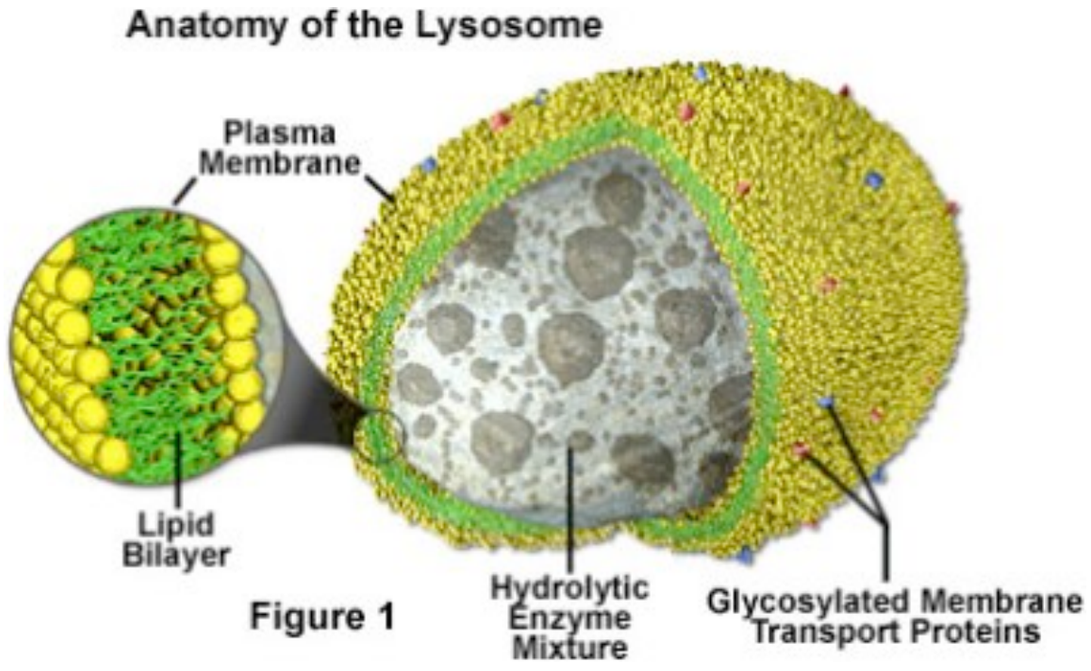
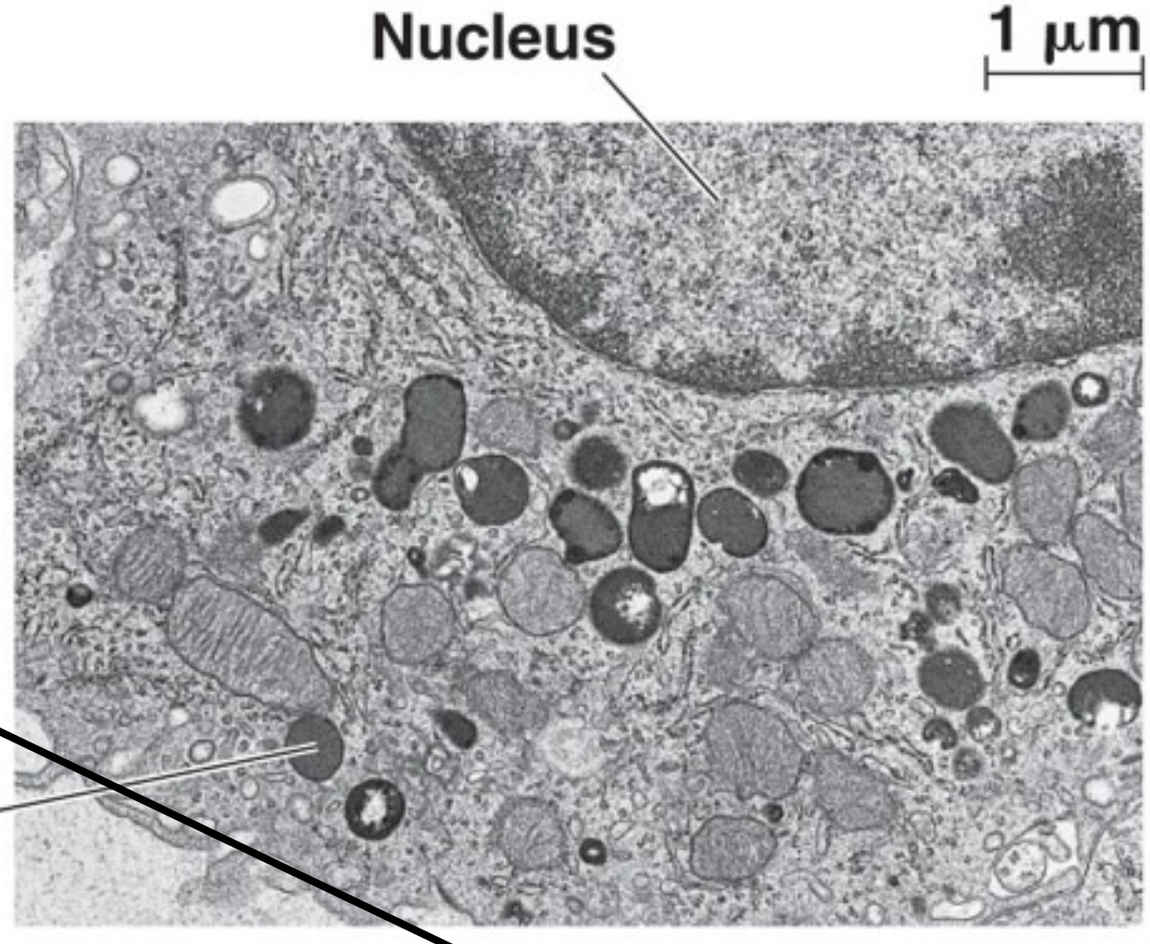
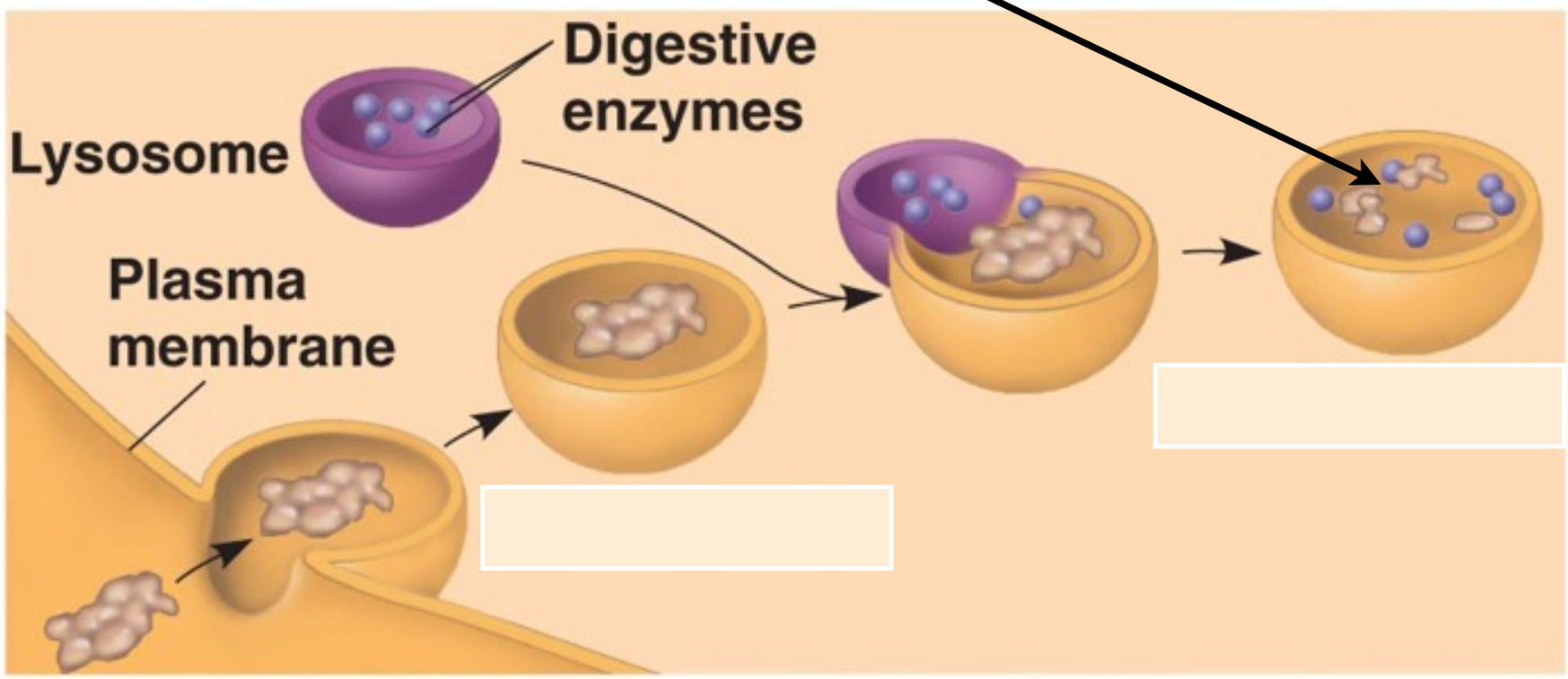


Figure 1

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



White Blood Cells fight infections through phagocytosis



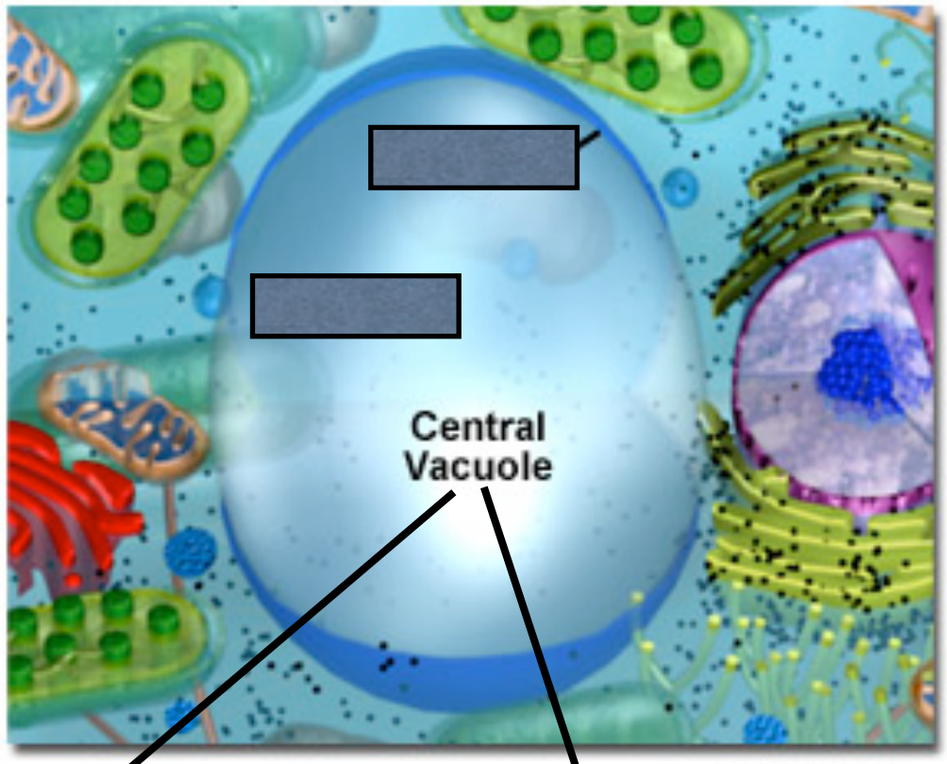
(a) Phagocytosis

D. Vacuoles: Diverse Maintenance Compartments

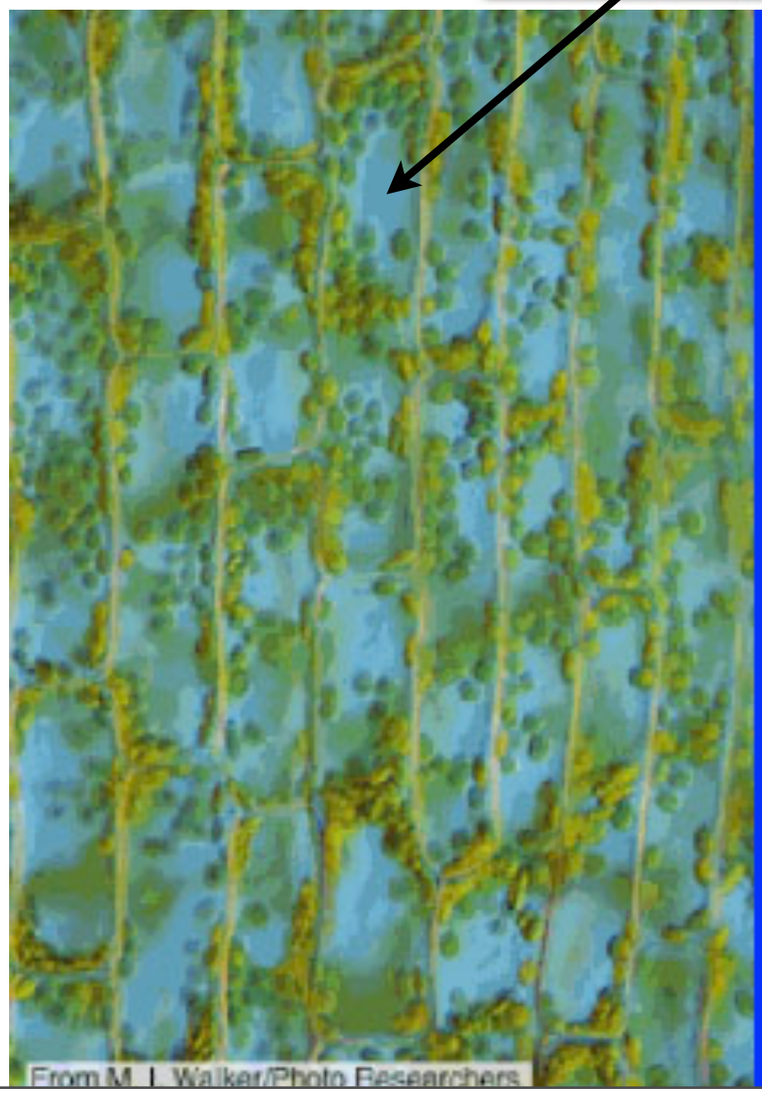
- Large vesicles derived from E.R. or Golgi
  - **Theme: Internal environment different from external environment**
- Performs a variety of functions:
  - *Food vacuoles*; protists (last slide)
  - *Contractile Vacuoles*; freshwater protists (use them to pump out excess water thus controlling solute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

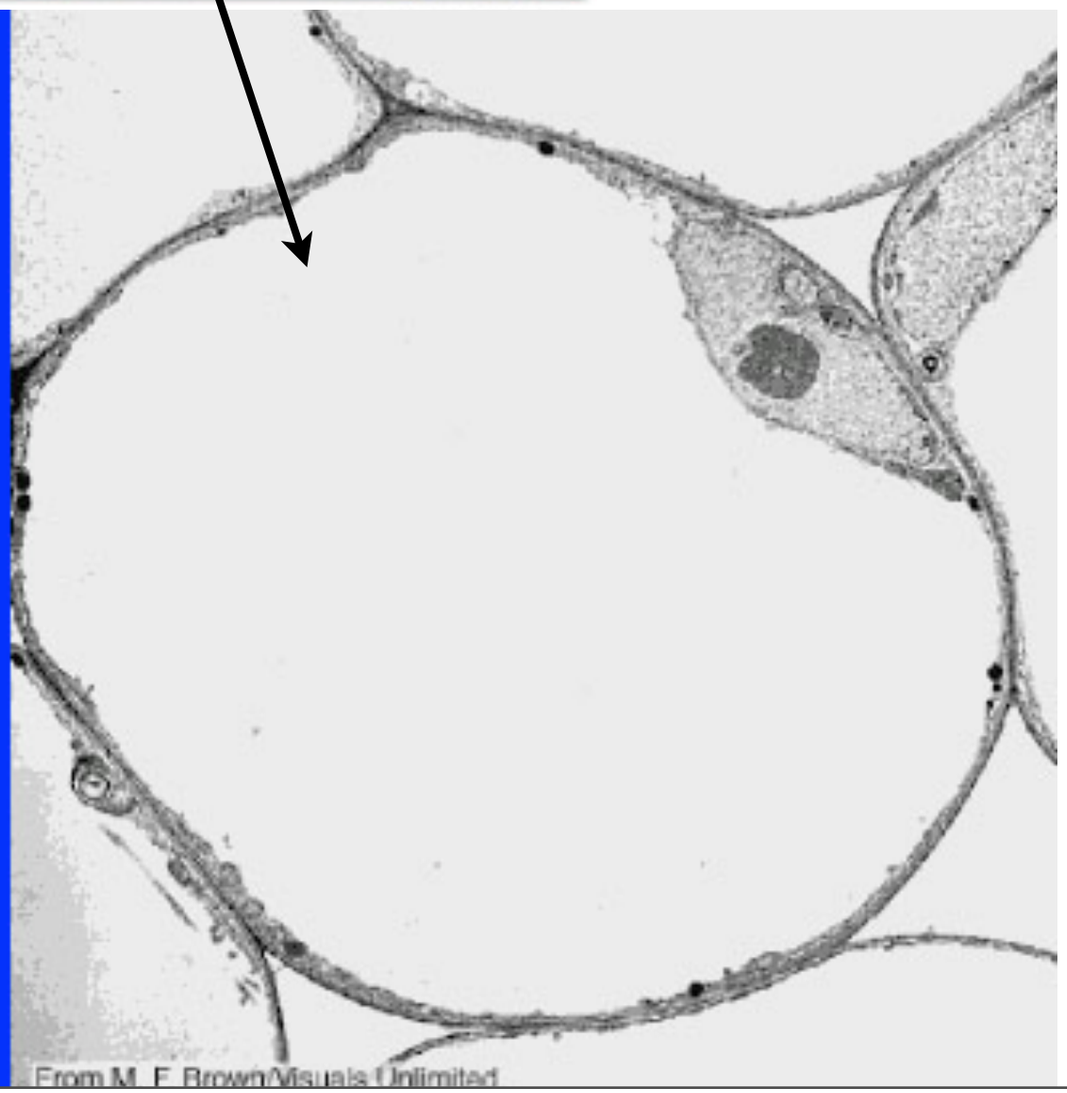
I Will Survive, Gloria Gaynor

Plant Cells Only

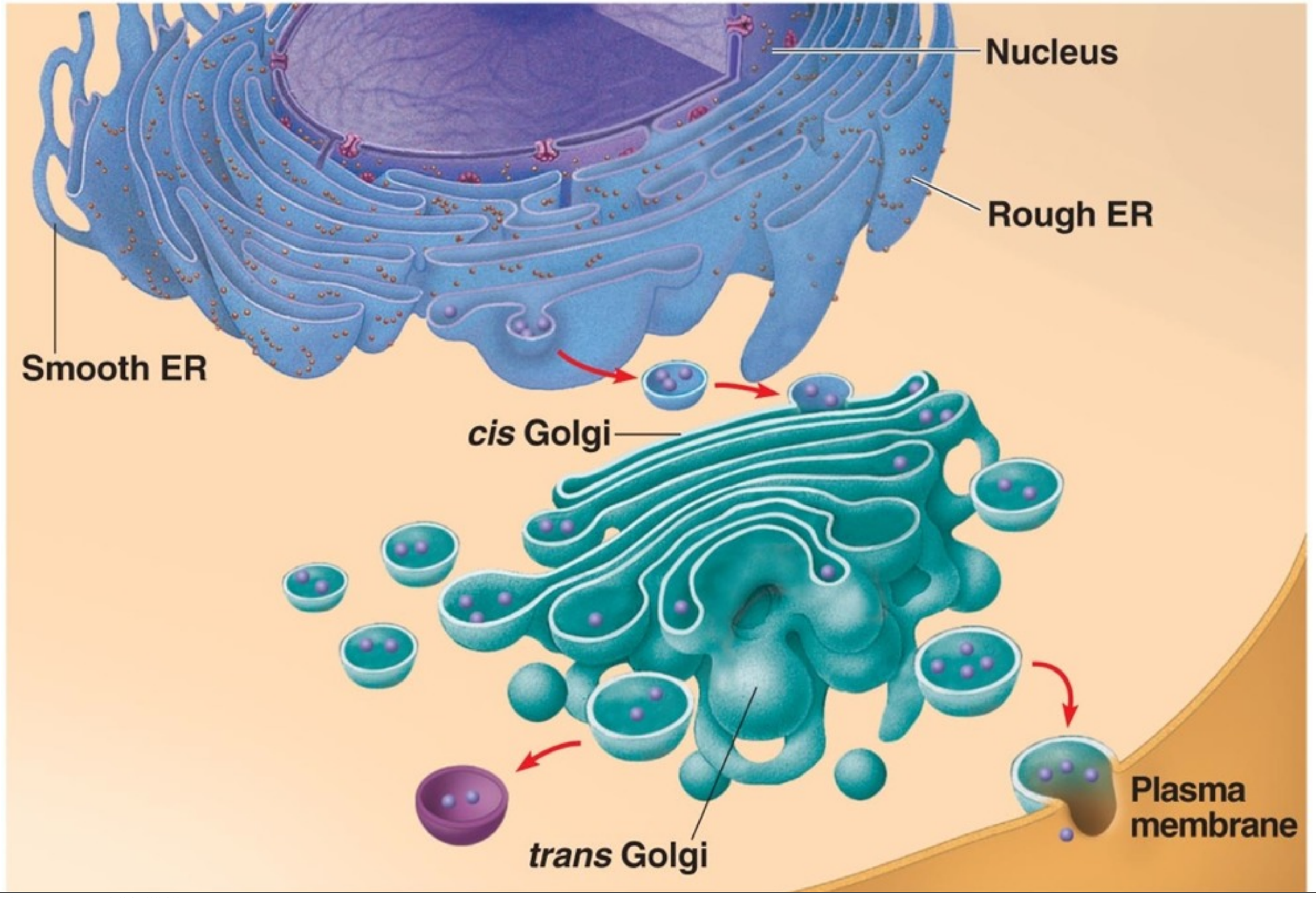


Can account for 50-70% of Cell Volume





E. The Endomembrane System: Review

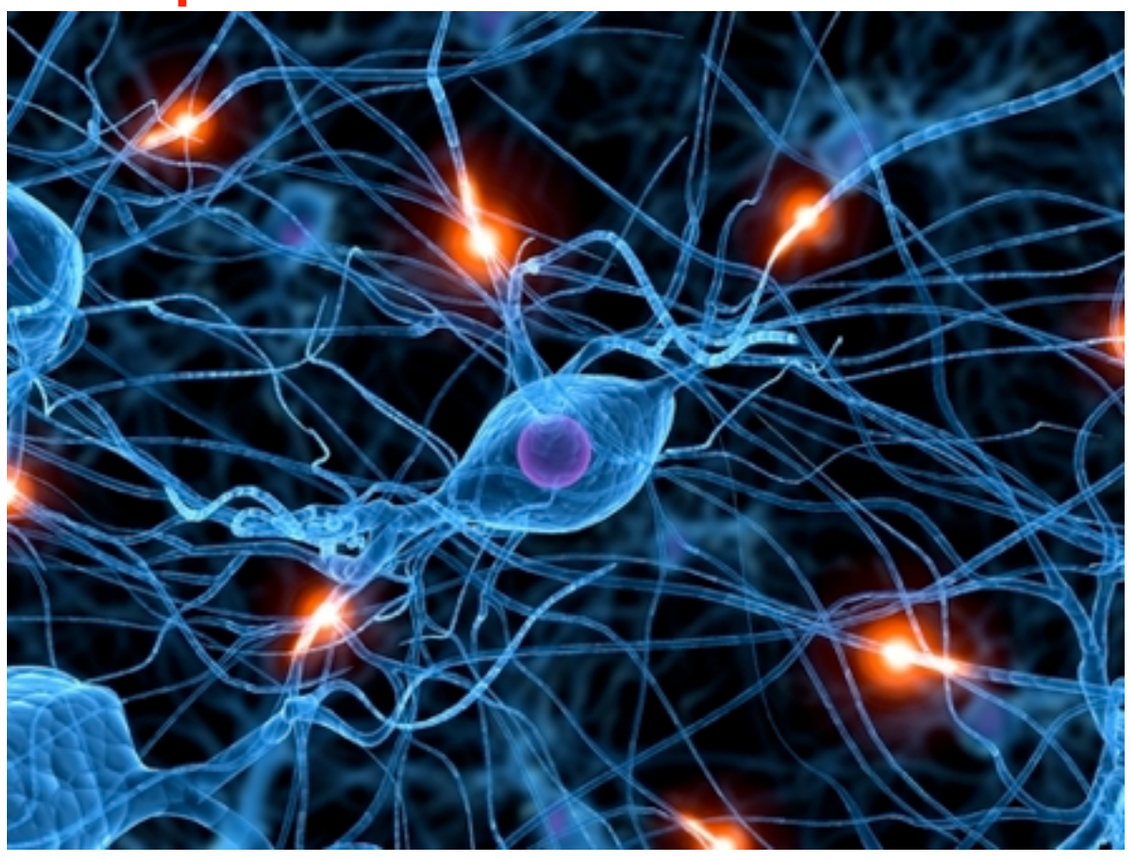


Tour of the Cell

V.

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.

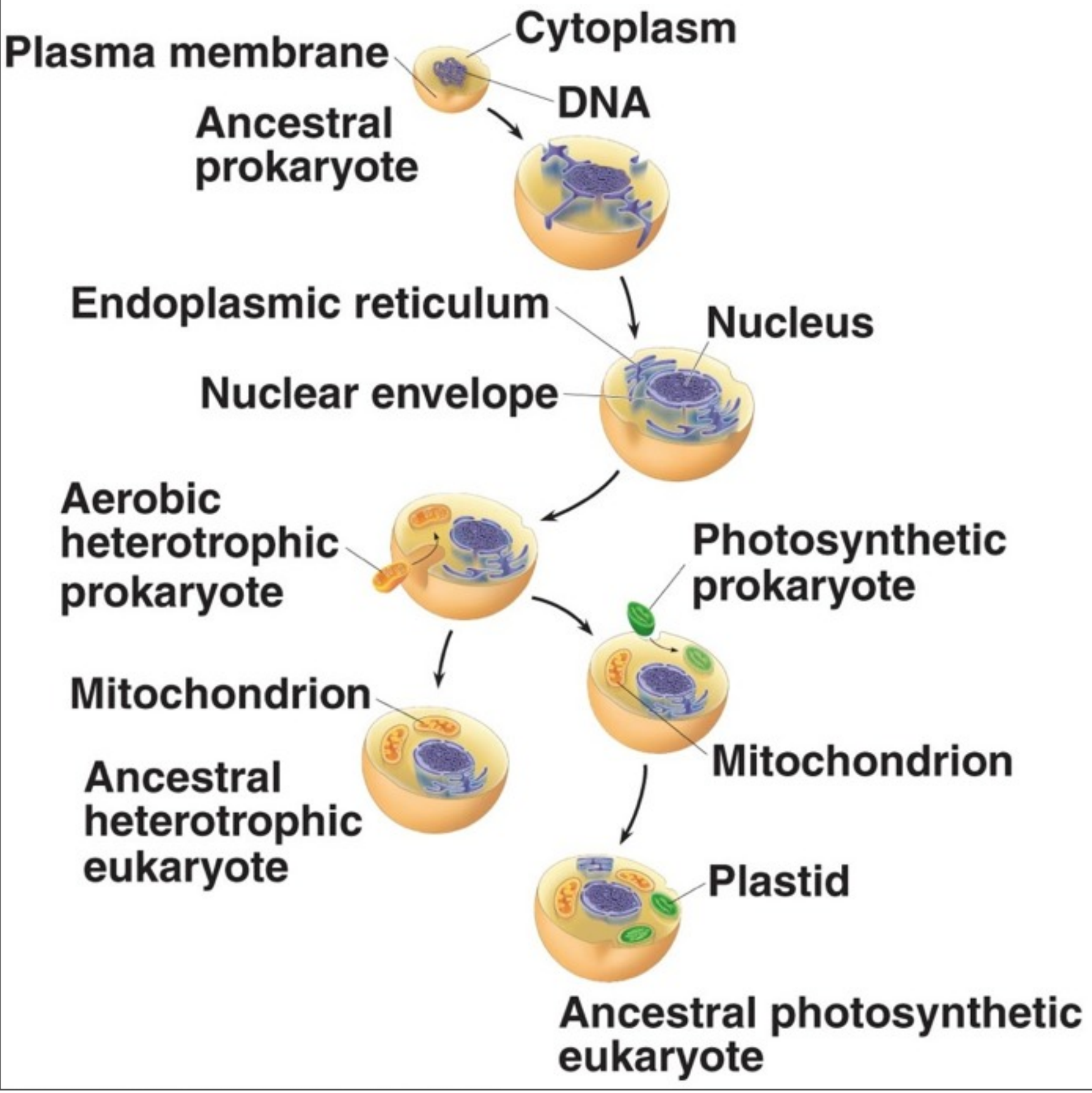
Main Idea: The mitochondria and chloroplasts also have similar evolutionary origins.



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



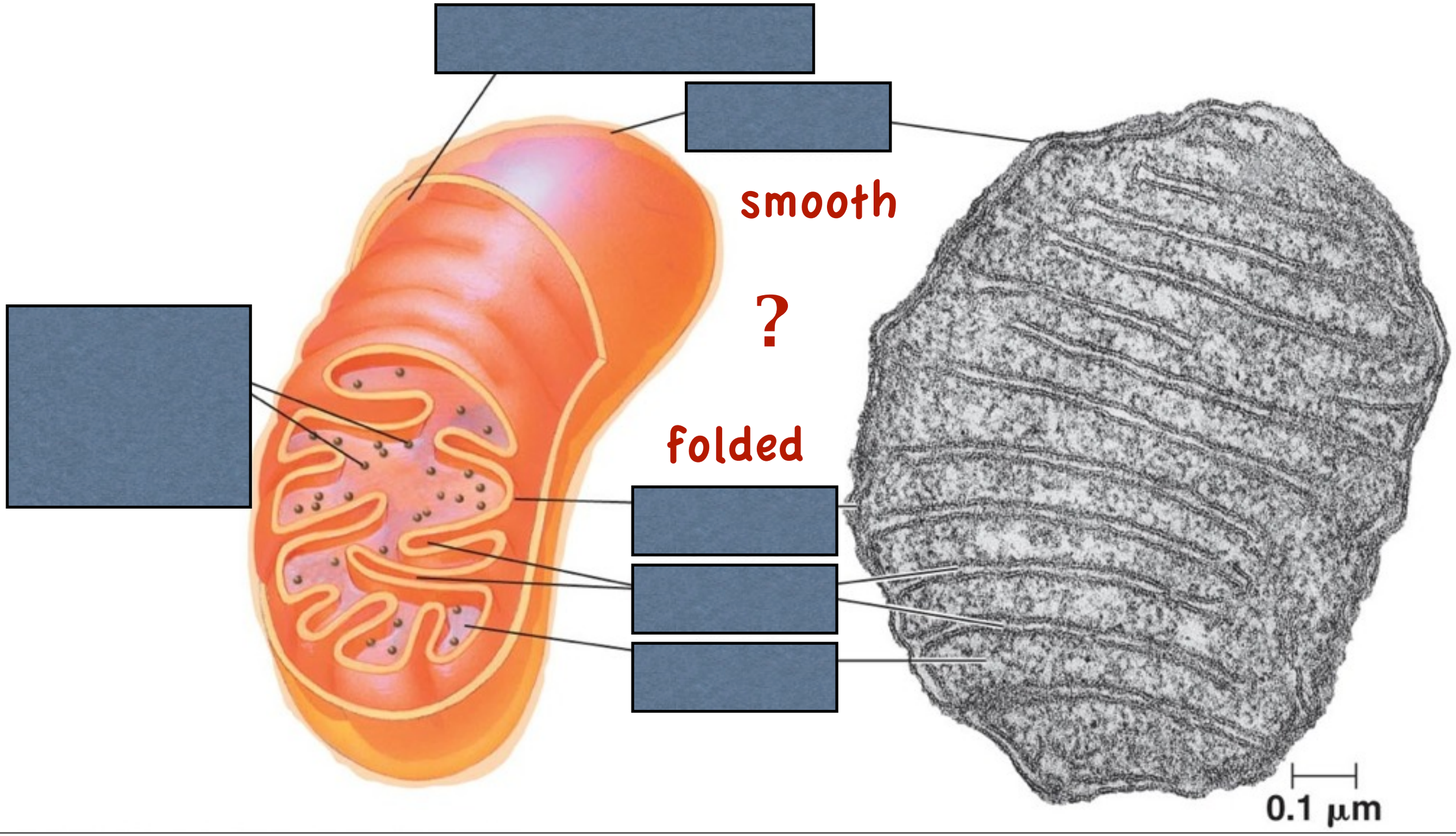
B. Mitochondria: Chemical Energy Conversion

- **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.

Fuel, Metallica

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



C. 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.**

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

Clocks, Coldplay

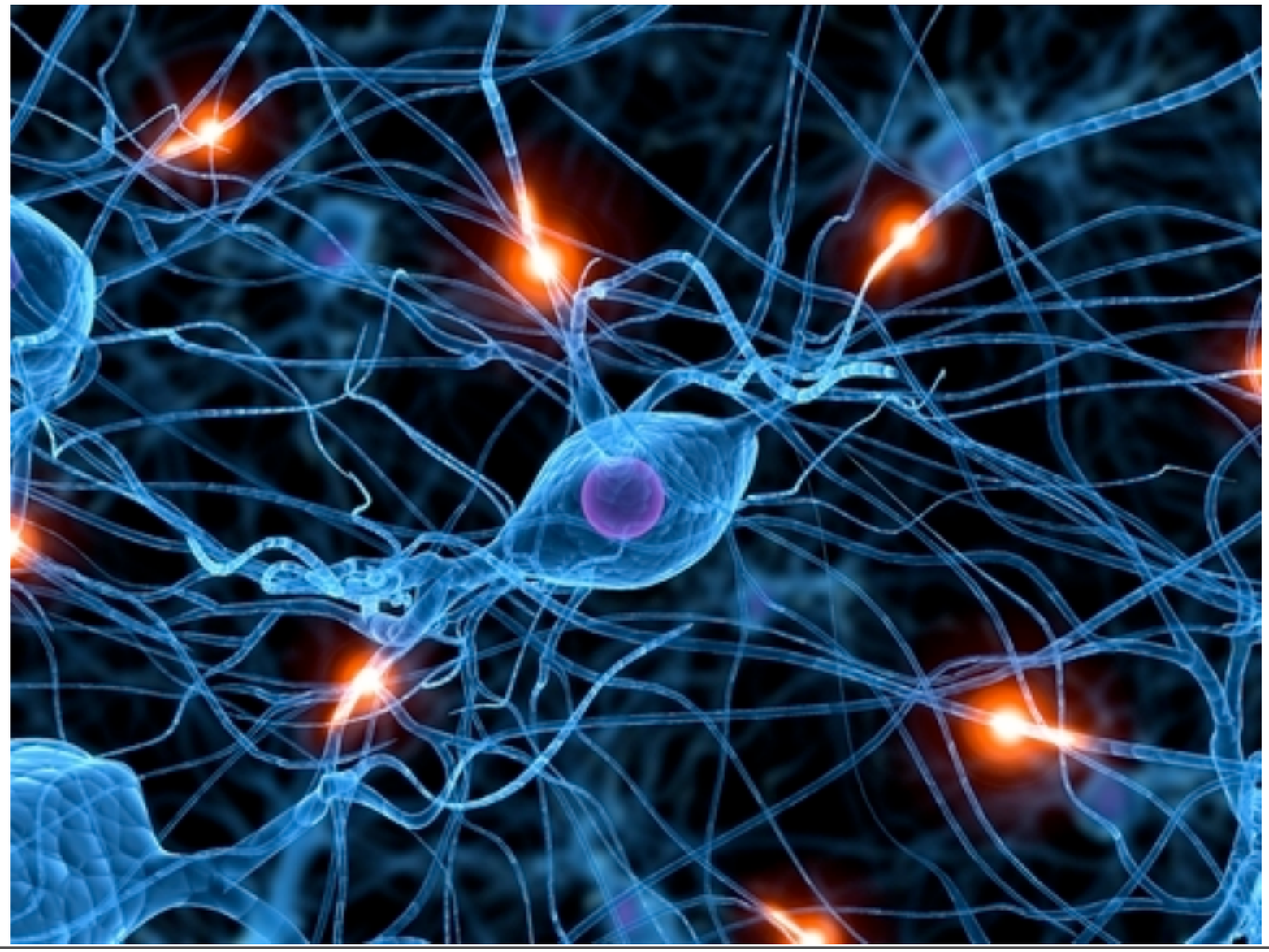
Comparing Mitochondria and Chloroplasts

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

VI.

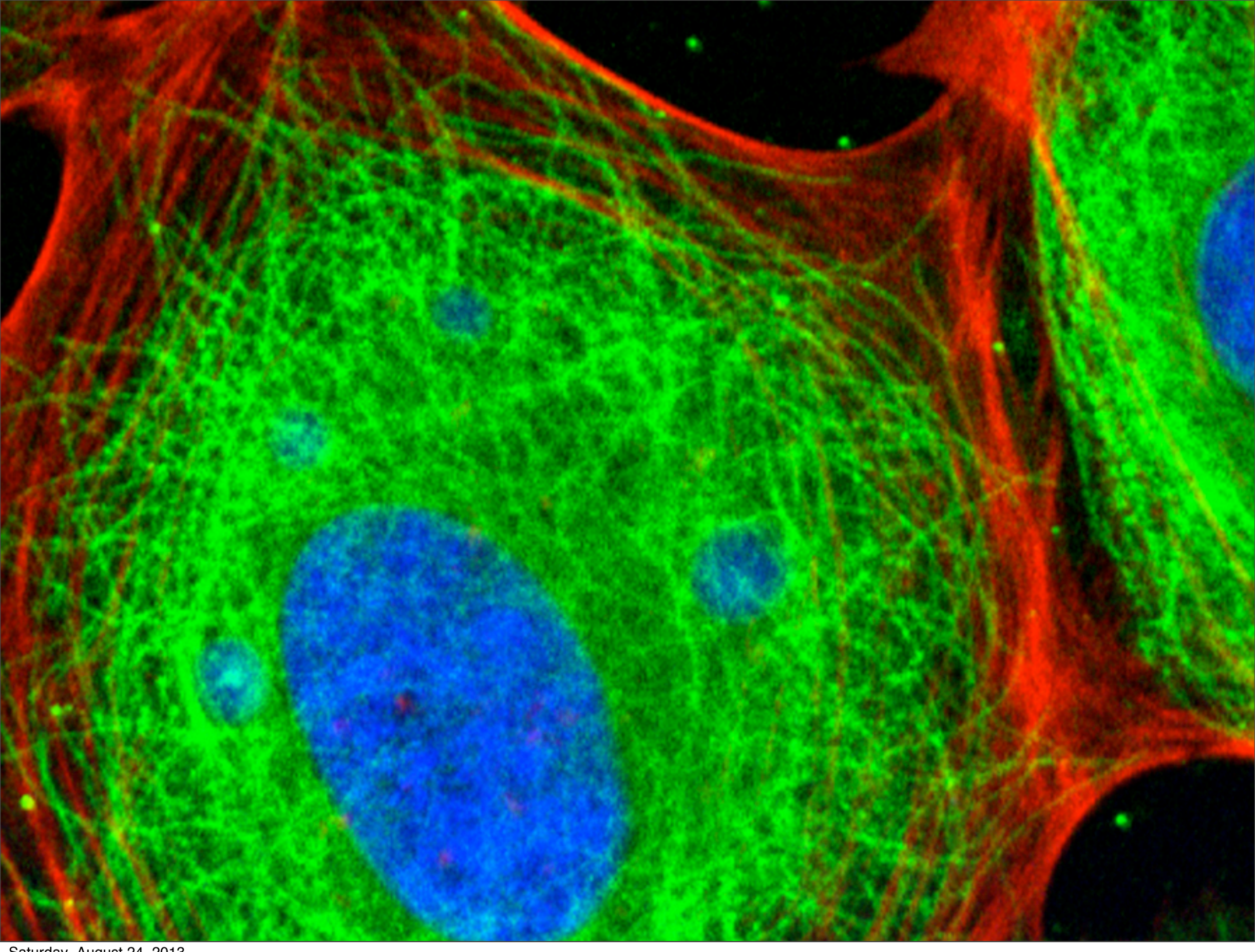
Main Idea: Protein fibers provide structure to cells and these fibers indirectly control cellular activities.



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

A. 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



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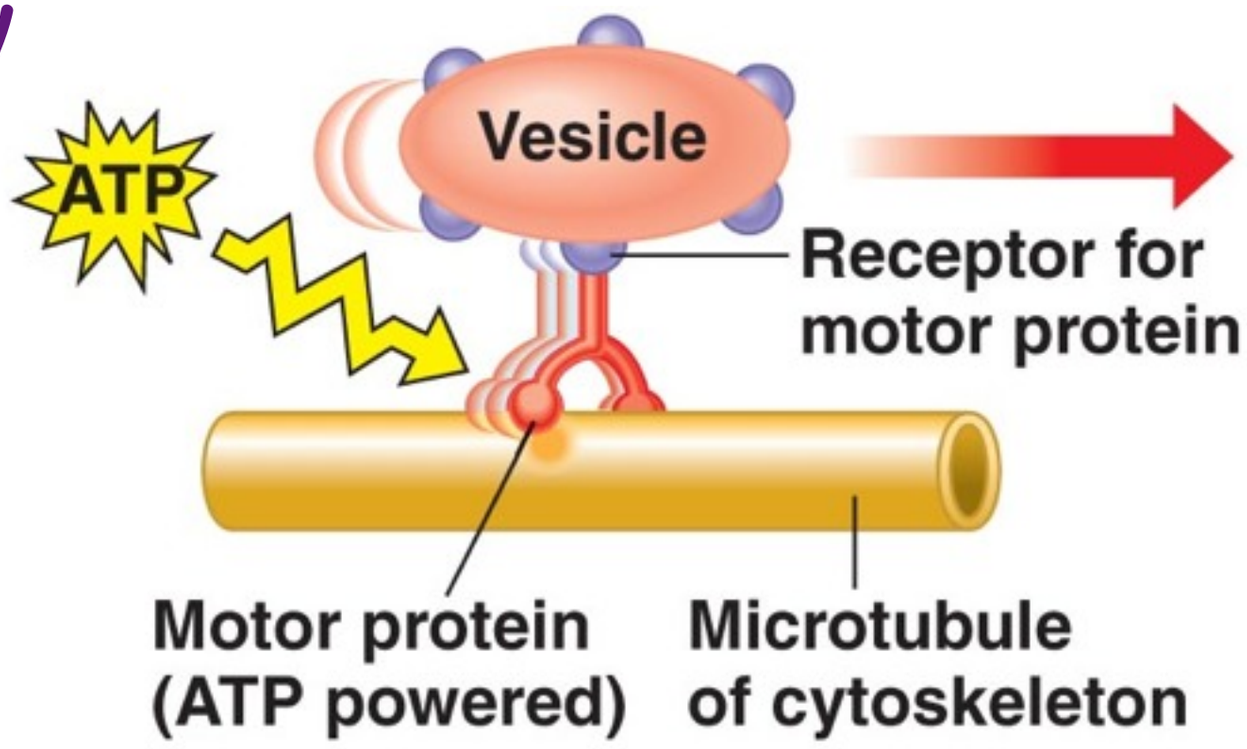
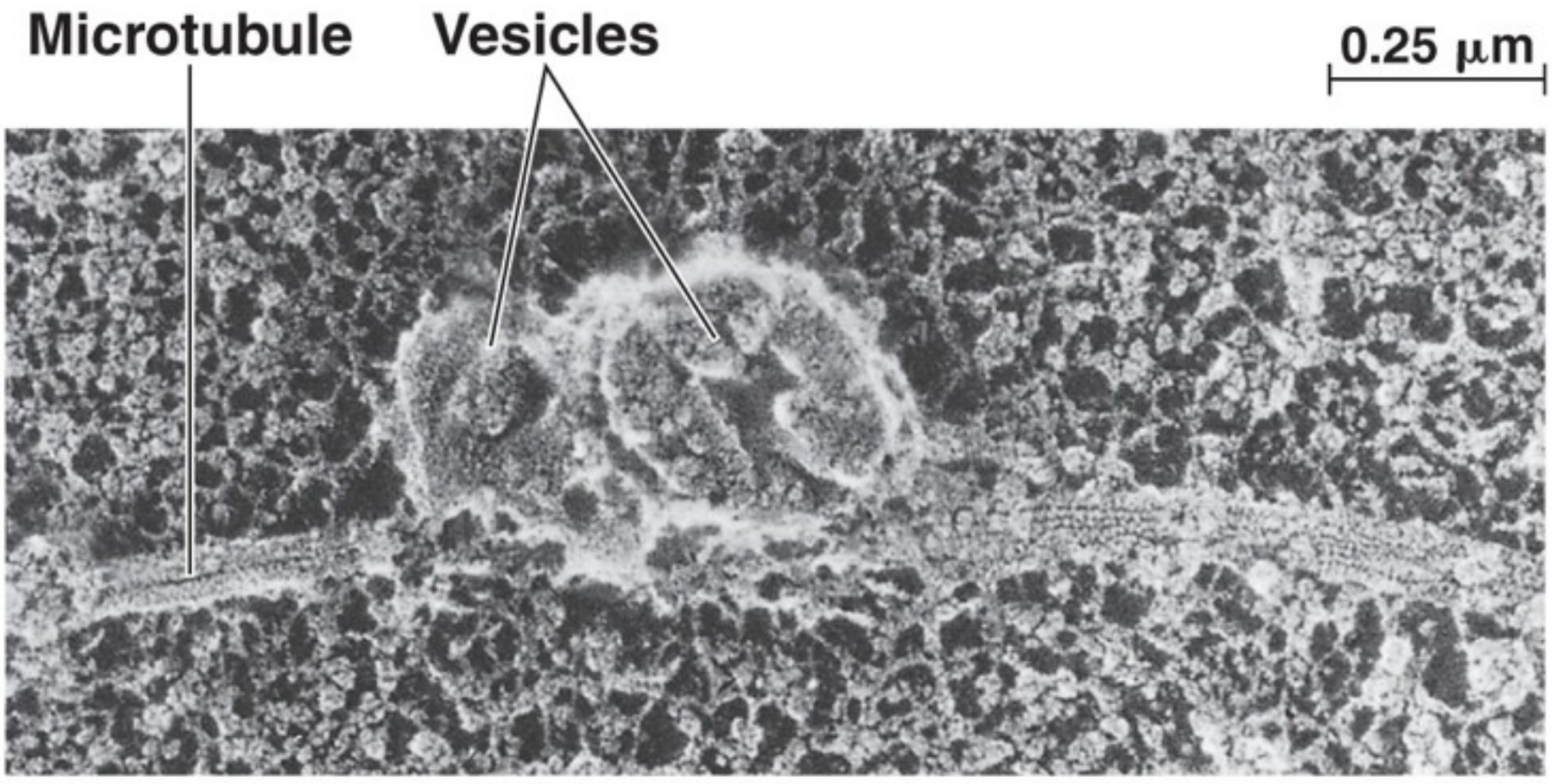
Motility


ATP
Vesicle
Receptor for
motor protein
Motor protein
(ATP powered)
Microtubule
of cytoskeleton

(a)


Microtubule
Vesicles
0.25 μm

B. Components of the Cytoskeleton

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

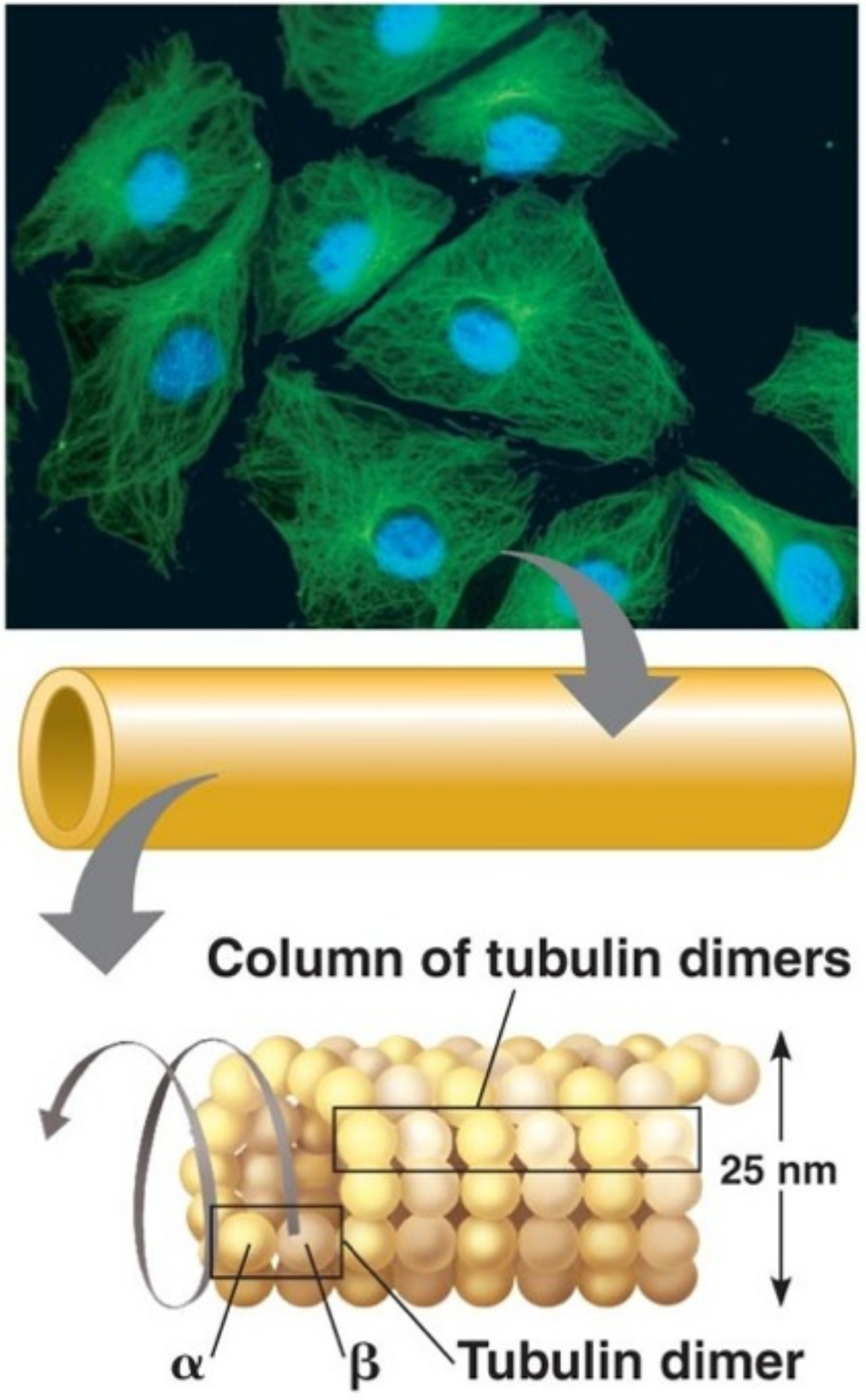
1. Microtubules

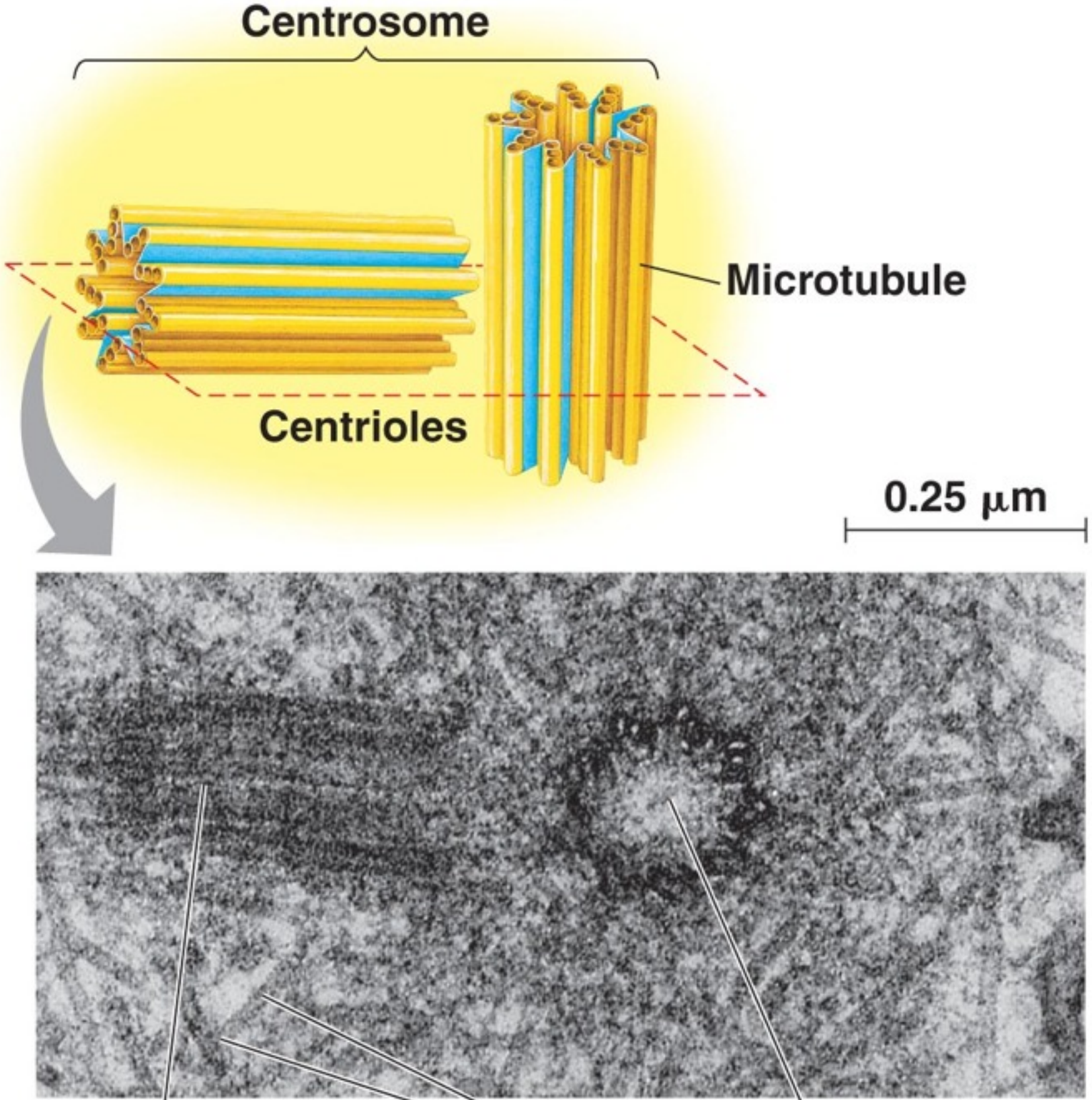
- Found in all eukaryotic cells

a. Centrosomes and Centrioles

- *Centrosome* is a region near the nucleus, considered to be the "microtubule organizing center"
  - Not found in plants and fungi
- The *centrioles* are located within the centrosome

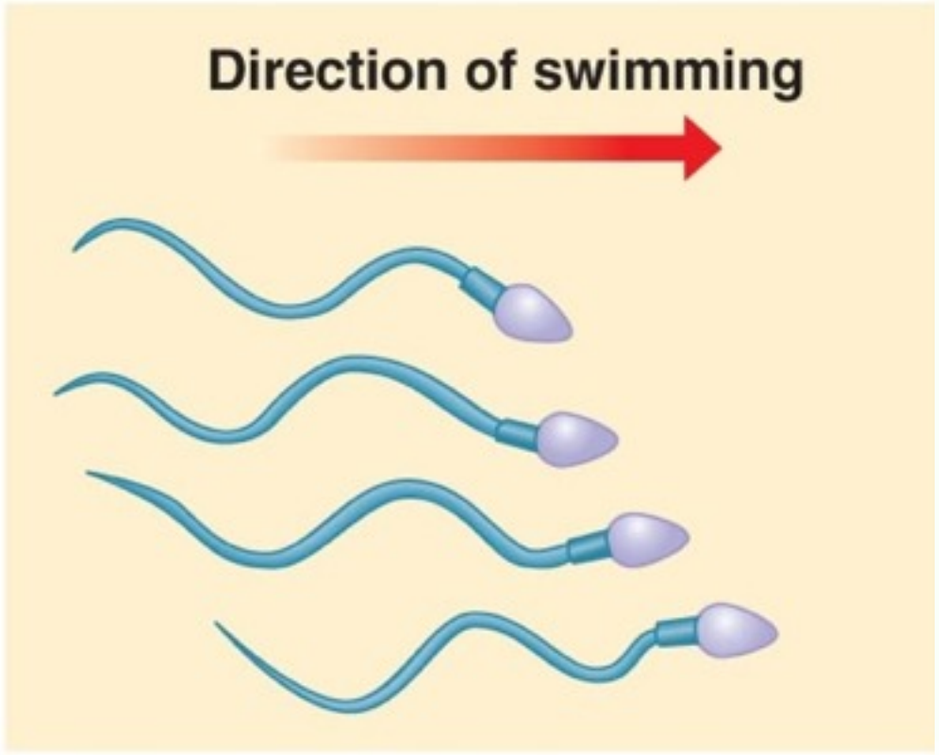
Property	Microtubules (Tubulin Polymers)
Structure	Hollow tubes; wall consists of 13 columns of tubulin molecules
Diameter	25 nm with 15-nm lumen
Protein subunits	Tubulin
Main functions	Maintenance of cell shape Cell motility Chromosome movements in cell division Organelle movements




Centrosome
Microtubule
Centrioles
0.25 μm
Longitudinal section of one centriole
Microtubules
Cross section of the other centriole

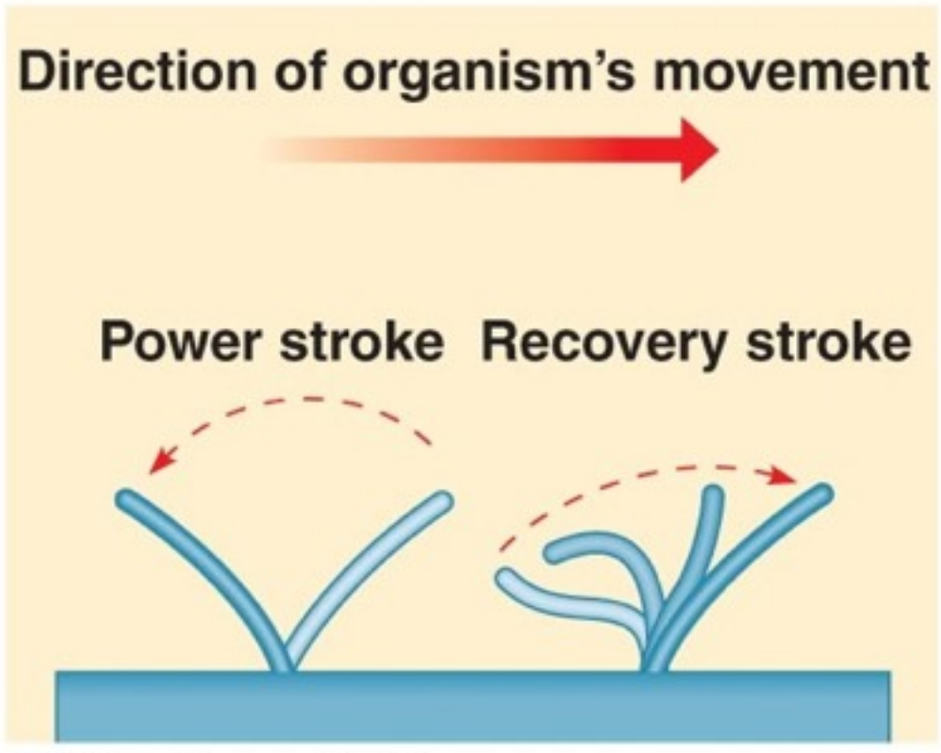
b. Cilia and Flagella

- **Cellular extensions that project from the cell.**
- Cilia and Flagella have similar diameters but cilia usually occur in large numbers where flagella are limited to one or a few
- The structure of these extensions are the same
  - The microtubule arrangement is referred to as "9+2"
- Many unicellular eukaryotes use cilia or flagella for locomotion
  - Sperm of animals, plants and fungi use flagella to move
  - Cilia is often used to move fluid over a surface
  - ATP provides energy for movement



(a) Motion of flagella

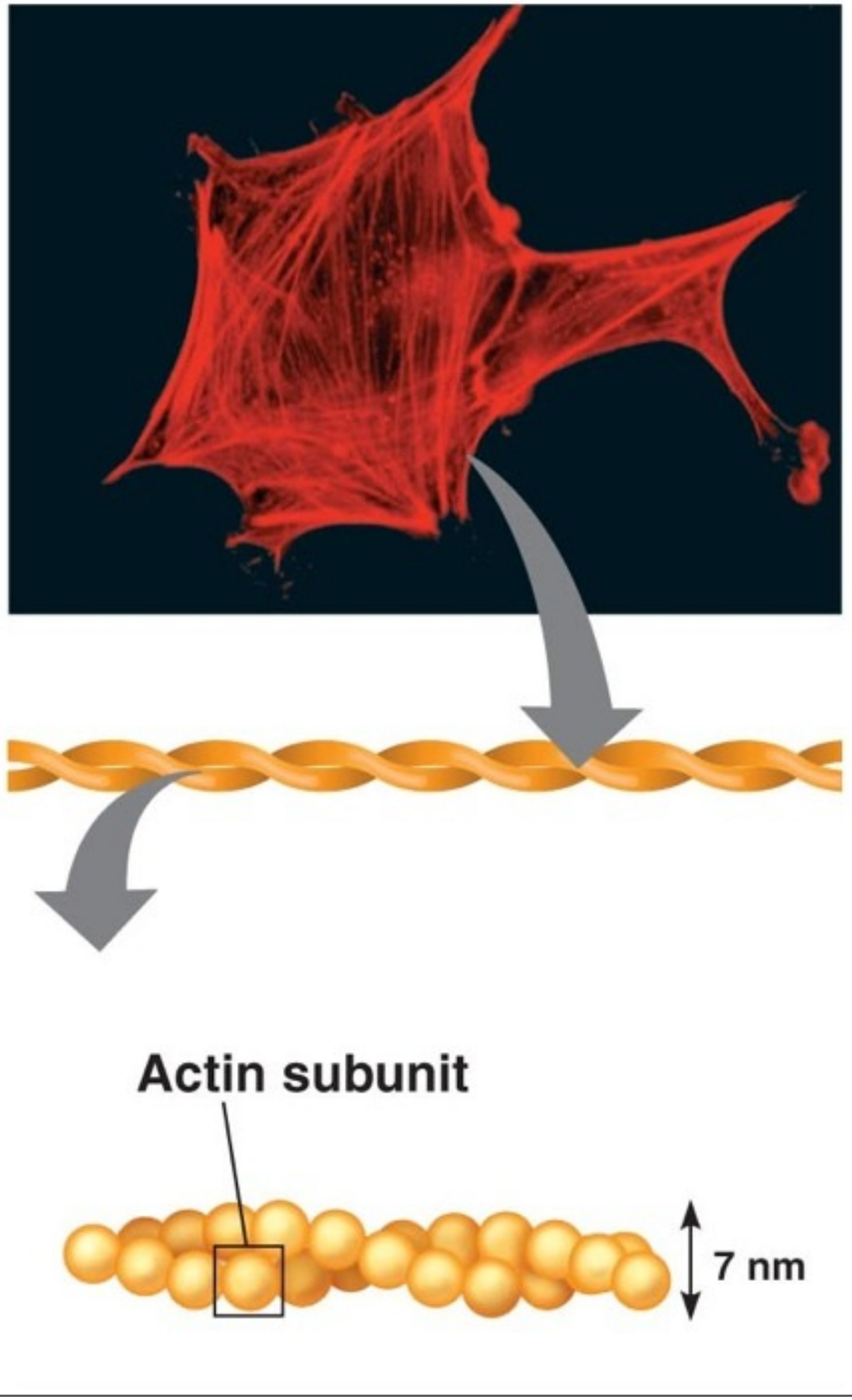
5 μm



(b) Motion of cilia

15 μm

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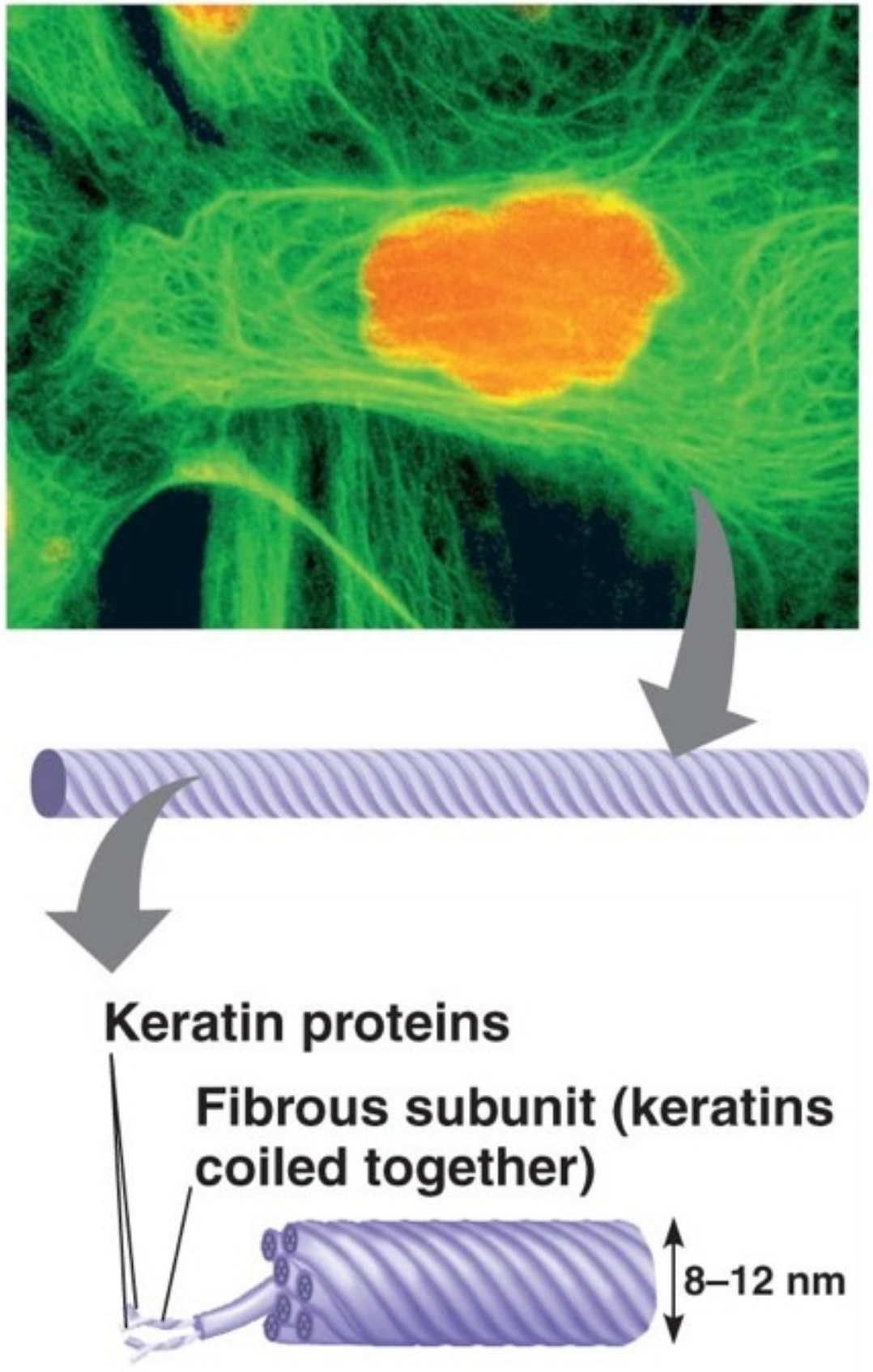
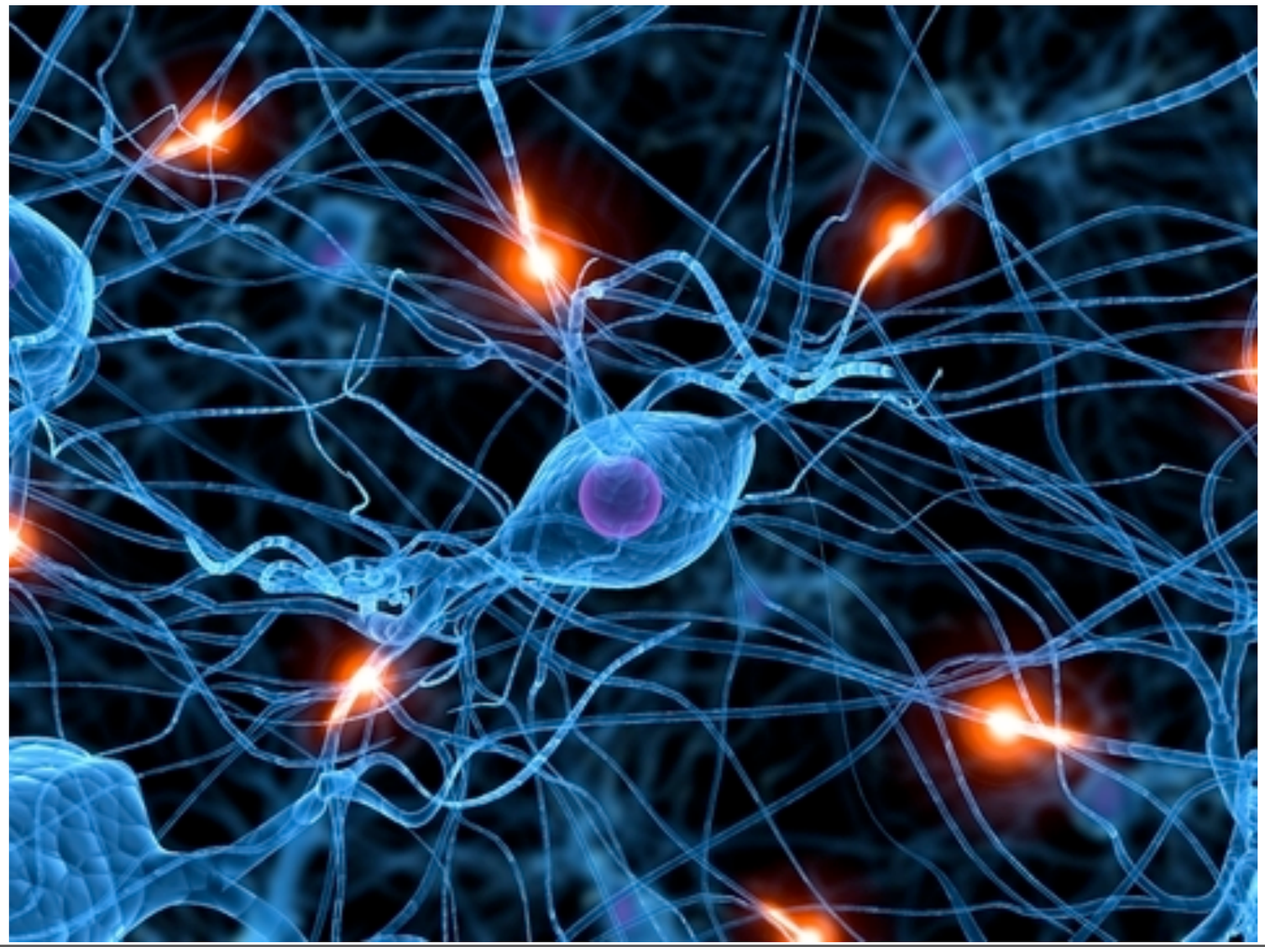
Property	Intermediate Filaments
Structure	Fibrous proteins supercoiled into thicker cables
Diameter	8–12 nm
Protein subunits	One of several different proteins of the keratin family
Main functions	Maintenance of cell shape
	Anchorage of nucleus and certain other organelles
	Formation of nuclear lamina



Tour of the Cell

VII.

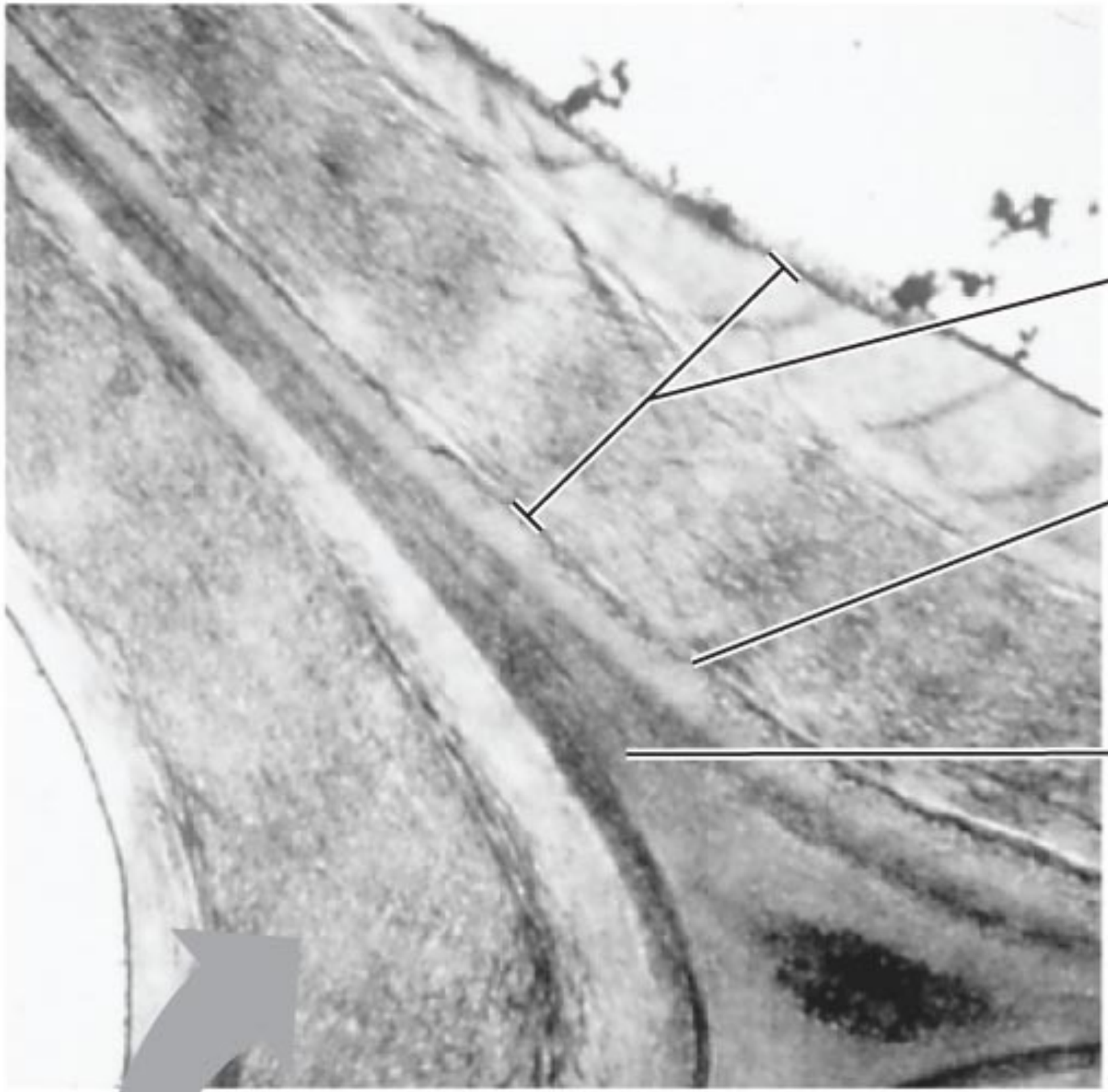
Main Idea: There are structures outside the cell, on its surface, that are involved in many important cellular functions.



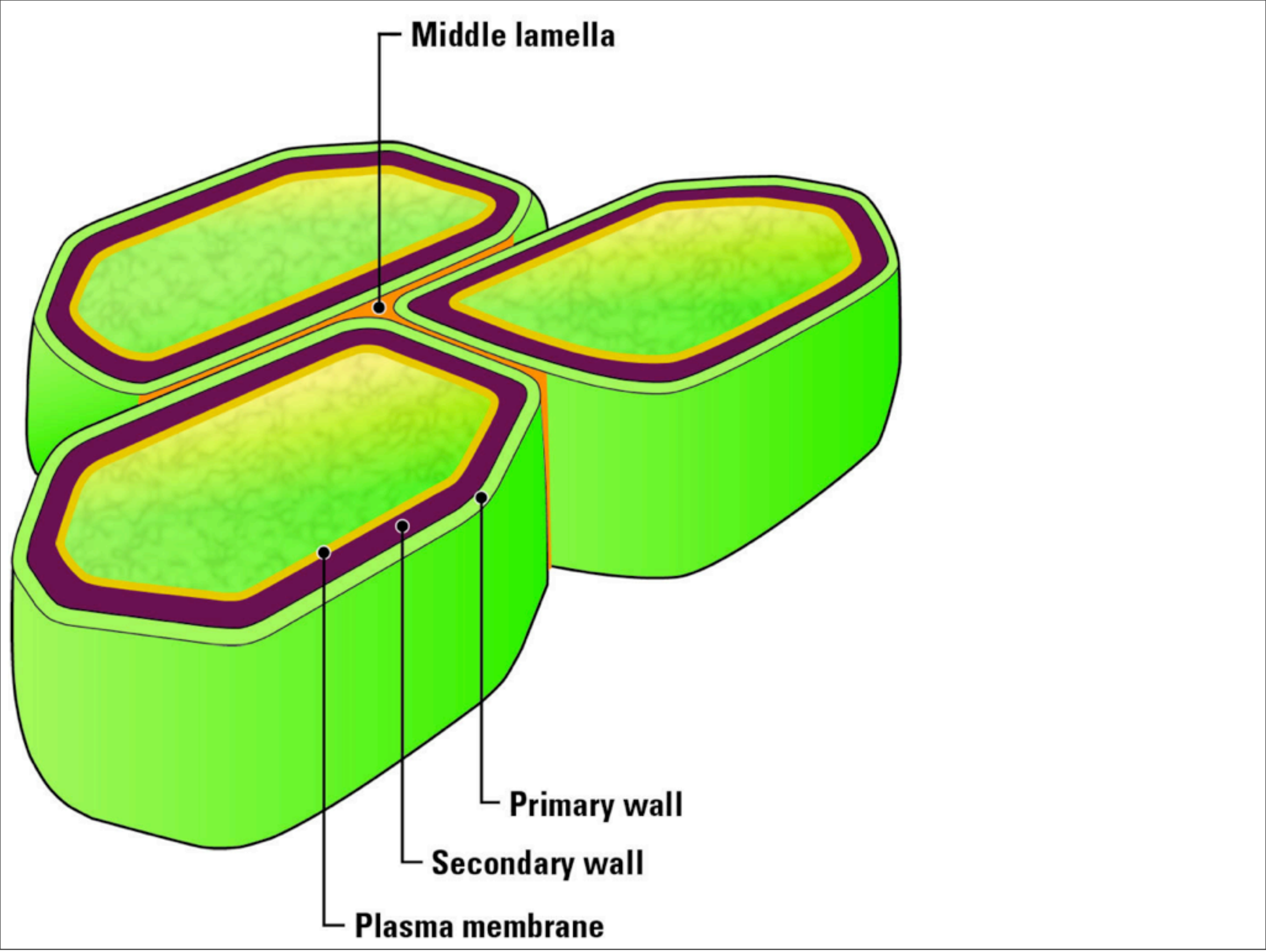
EXTRACELLULAR COMPONENTS AND CONNECTIONS BETWEEN CELLS HELP COORDINATE CELLULAR ACTIVITIES

A. Cell Walls of Plants

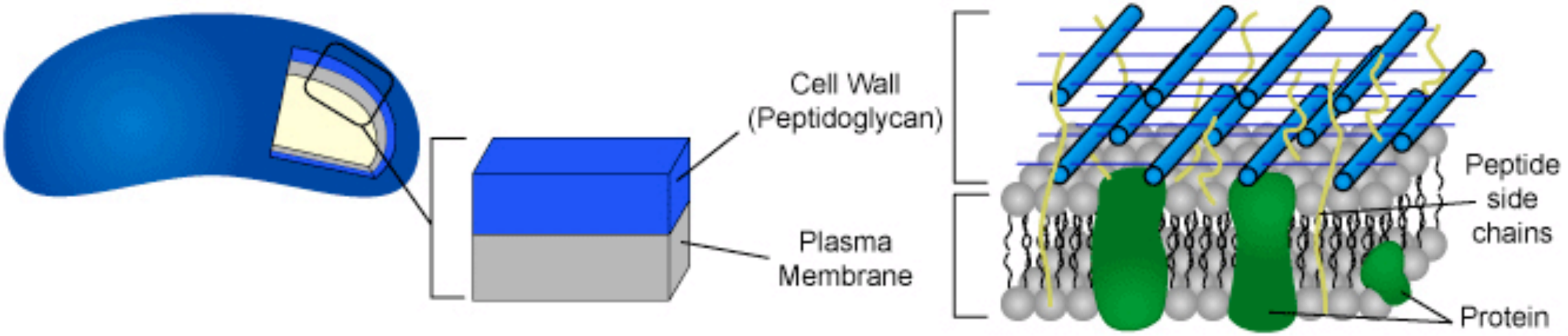
- Cell wall lies outside plasma membrane
- It protects, shapes and prevents excess water intake.
- They are found in *plants*, *bacteria*, *fungi* and some *protists*.


Secondary cell wall
Primary cell wall
Middle lamella
1 μm

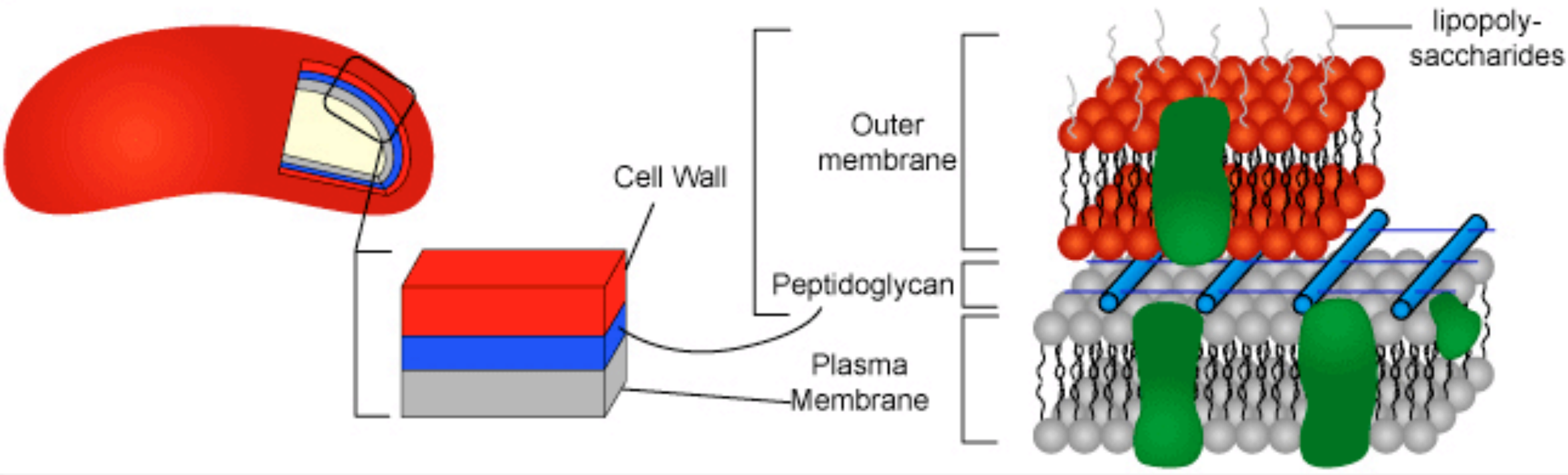
Nature copied once more


Middle lamella
Primary wall
Secondary wall
Plasma membrane

Gram^{+} Bacteria

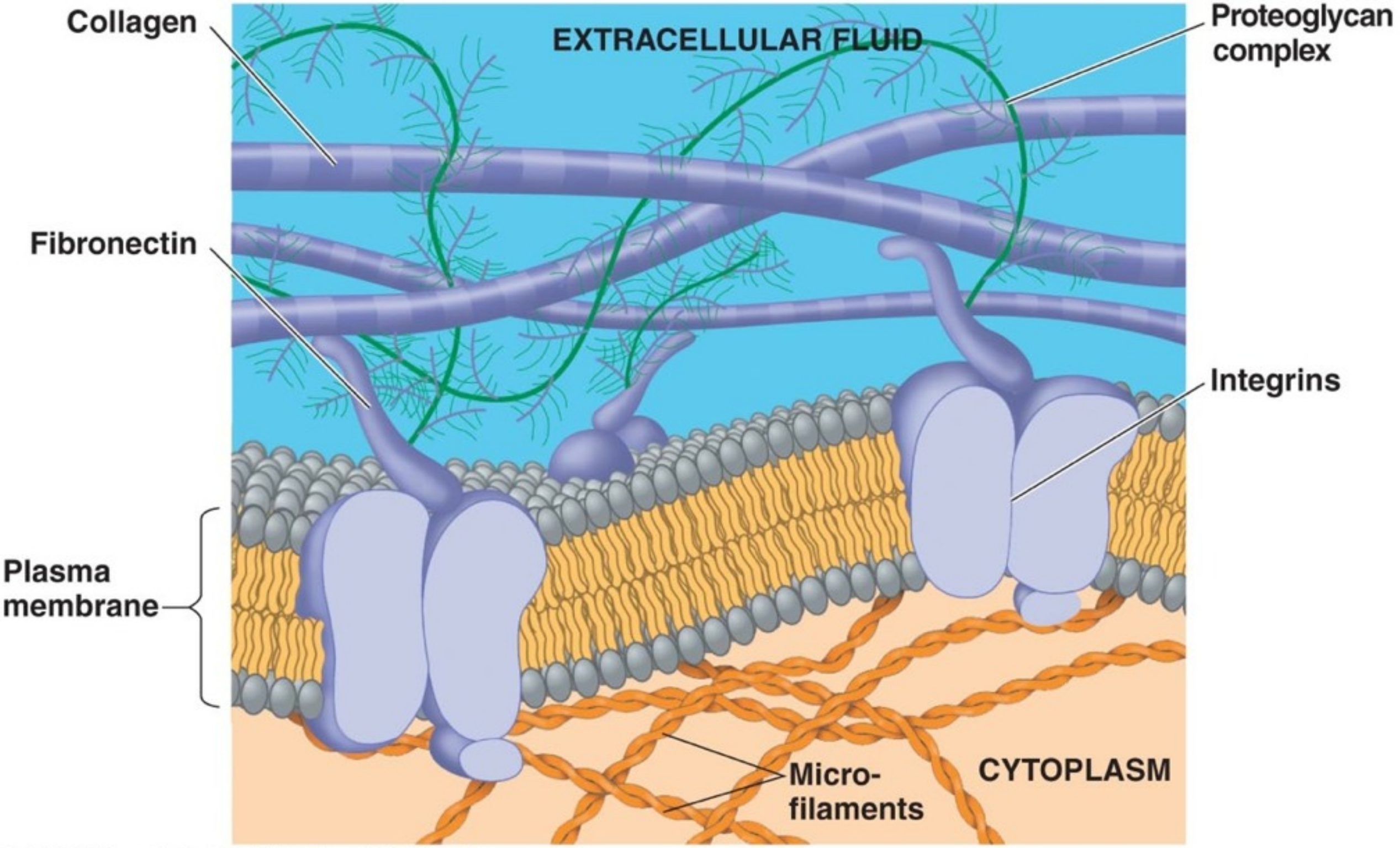


Gram^{-} Bacteria



B. The Extracellular Matrix (ECM) of Animal Cells

- Animal cells lack cell walls but they an elaborate ECM
- The main ingredient of ECM is glycoproteins
    - The most abundant glycoprotein is collagen
        - Collagen accounts for 40% of total protein in the body
- The ECM is structurally important
- In addition the ECM can regulate cell activity, specifically it can influence the activity of genes

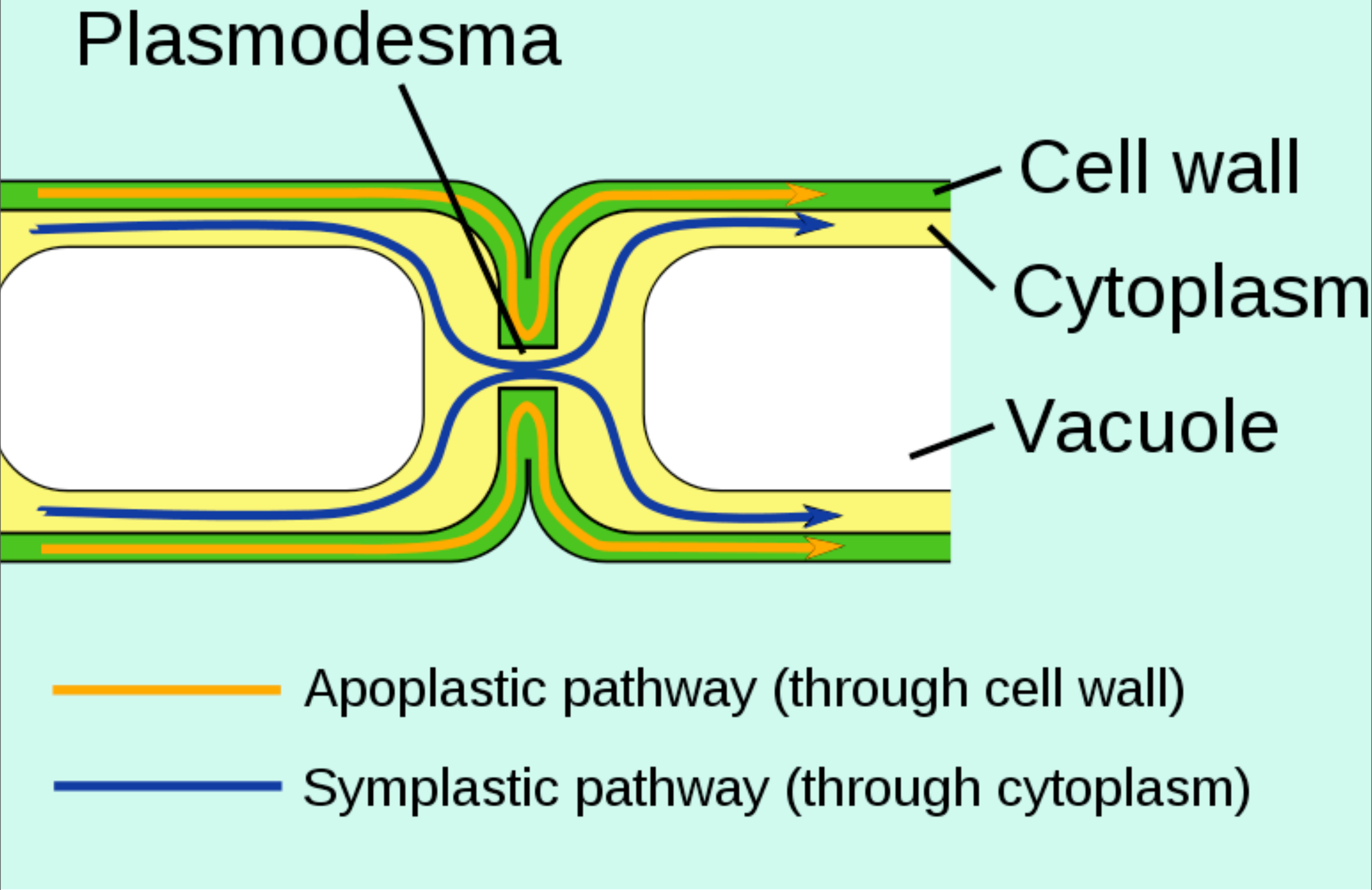


C. Cell Junctions

- Neighboring cells often adhere, interact, and communicate through direct physical contact.

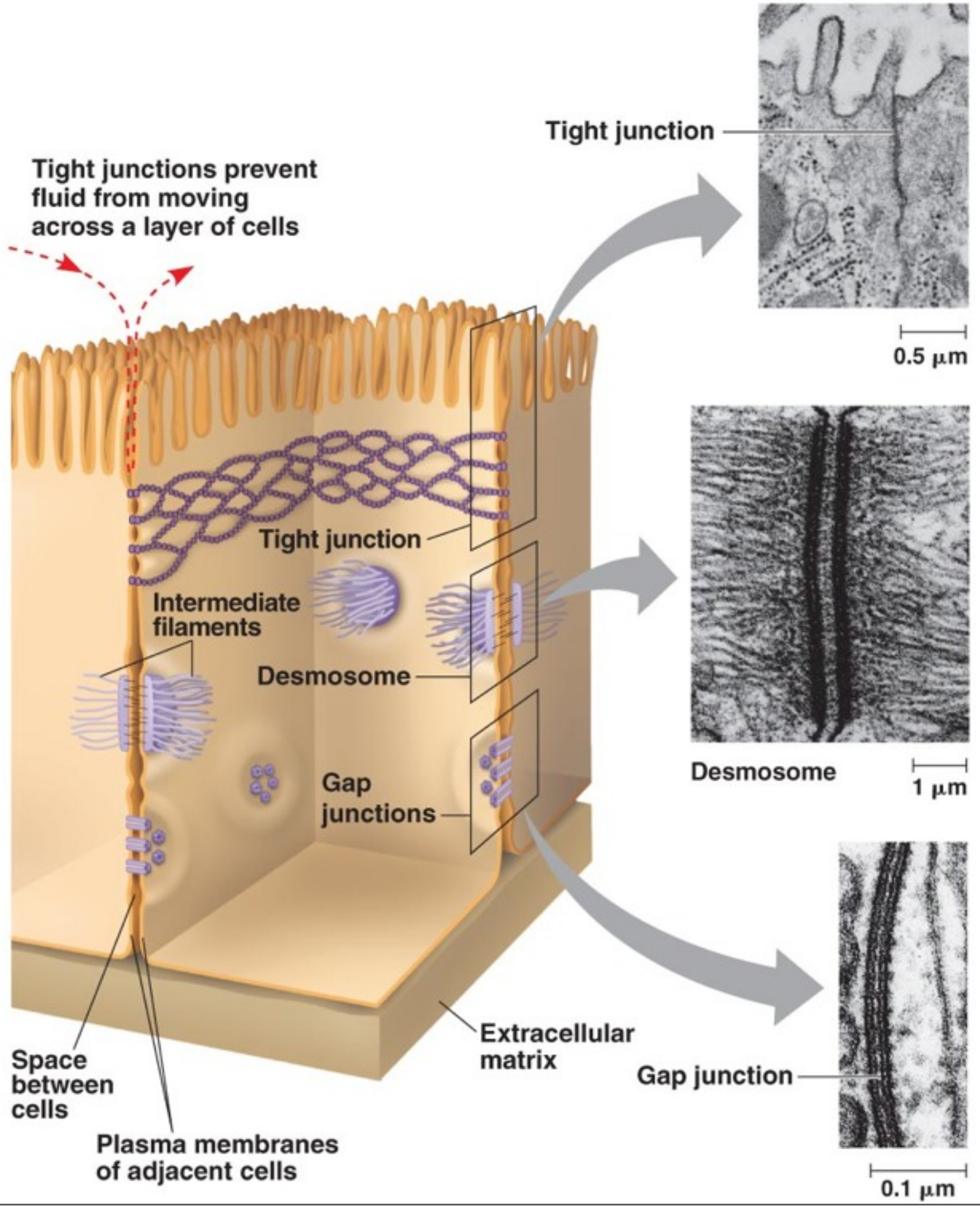
1. Plasmodesmata in Plant Cells

- Cell walls are perforated, cytosol can pass through adjacent cells
- These connections unify most plant cells into one living continuum.
    - Specifically water, small solutes and some proteins and RNA can also pass freely through these connections


Plasmodesma
Cell wall
Cytoplasm
Vacuole
Apoplastic pathway (through cell wall)
Symplastic pathway (through cytoplasm)

2. Tight Junctions, Desmosomes, and Gap Junctions in Animal Cells

- Three types of cell junctions
- **Tight Junctions**; proteins bind cells together very tightly
- **Desmosomes**; acts like "rivets", fastening cells together into strong sheets
- **Gap Junctions**; provide cytoplasmic channels from one cell to another
  - proteins form pores through molecules may pass
  - essential for cell communication between certain cells like the those that make up the heart


Tight junctions prevent fluid from moving across a layer of cells
Tight junction
0.5 μm
Tight junction
Intermediate filaments
Desmosome
Gap junctions
Desmosome
1 μm
Extracellular matrix
Space between cells
Plasma membranes of adjacent cells
Gap junction
0.1 μm

Comparing Animal and Plant Cells

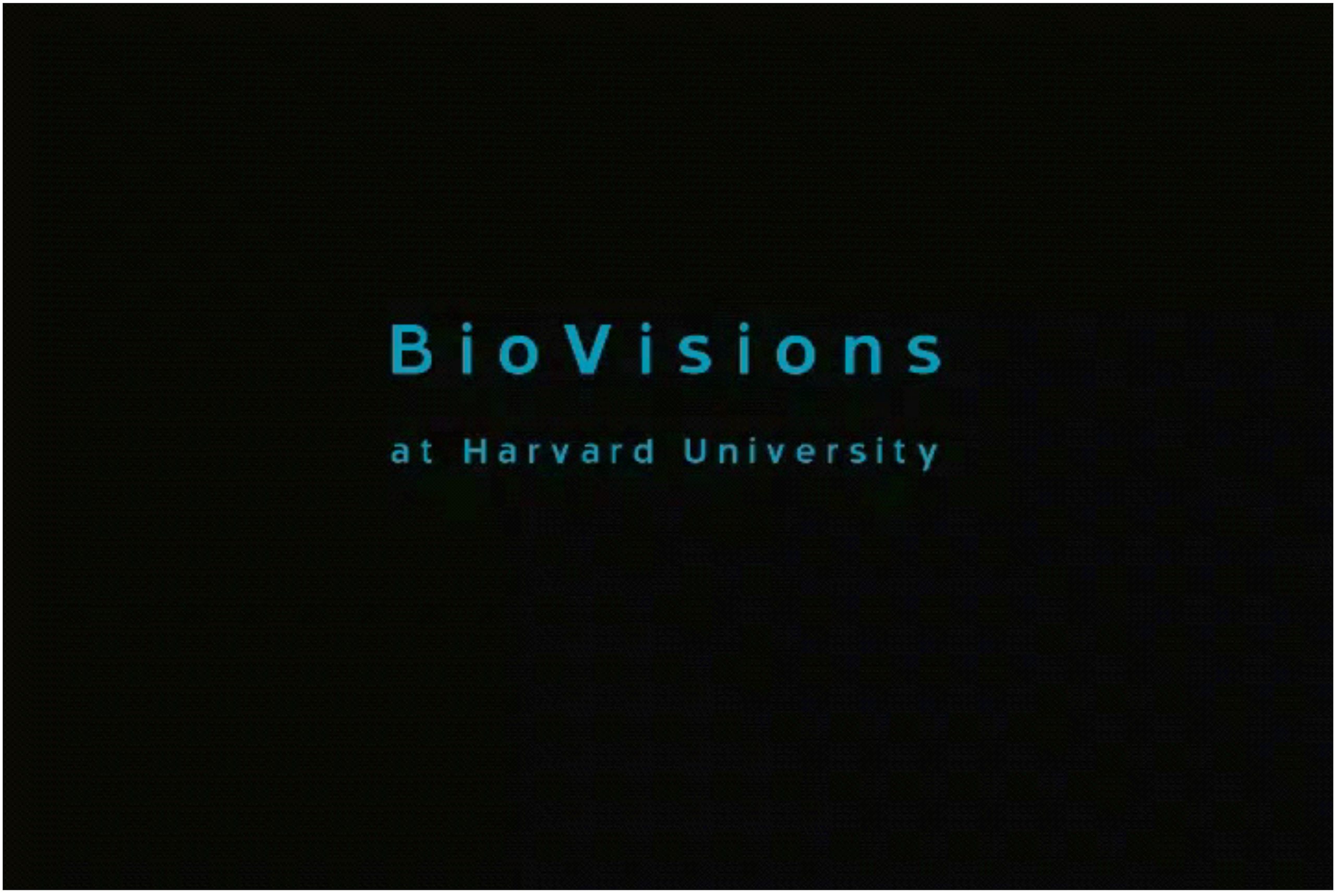
Animal Cells

- Lysosomes
- Centrioles
- Flagella
- Gap Junctions

Plant Cells

- Chloroplasts
- Central Vacuoles
- Cell wall
- Plasmodesmata

Most cell organelles and structures are shared by both cell types


BioVisions
at Harvard University