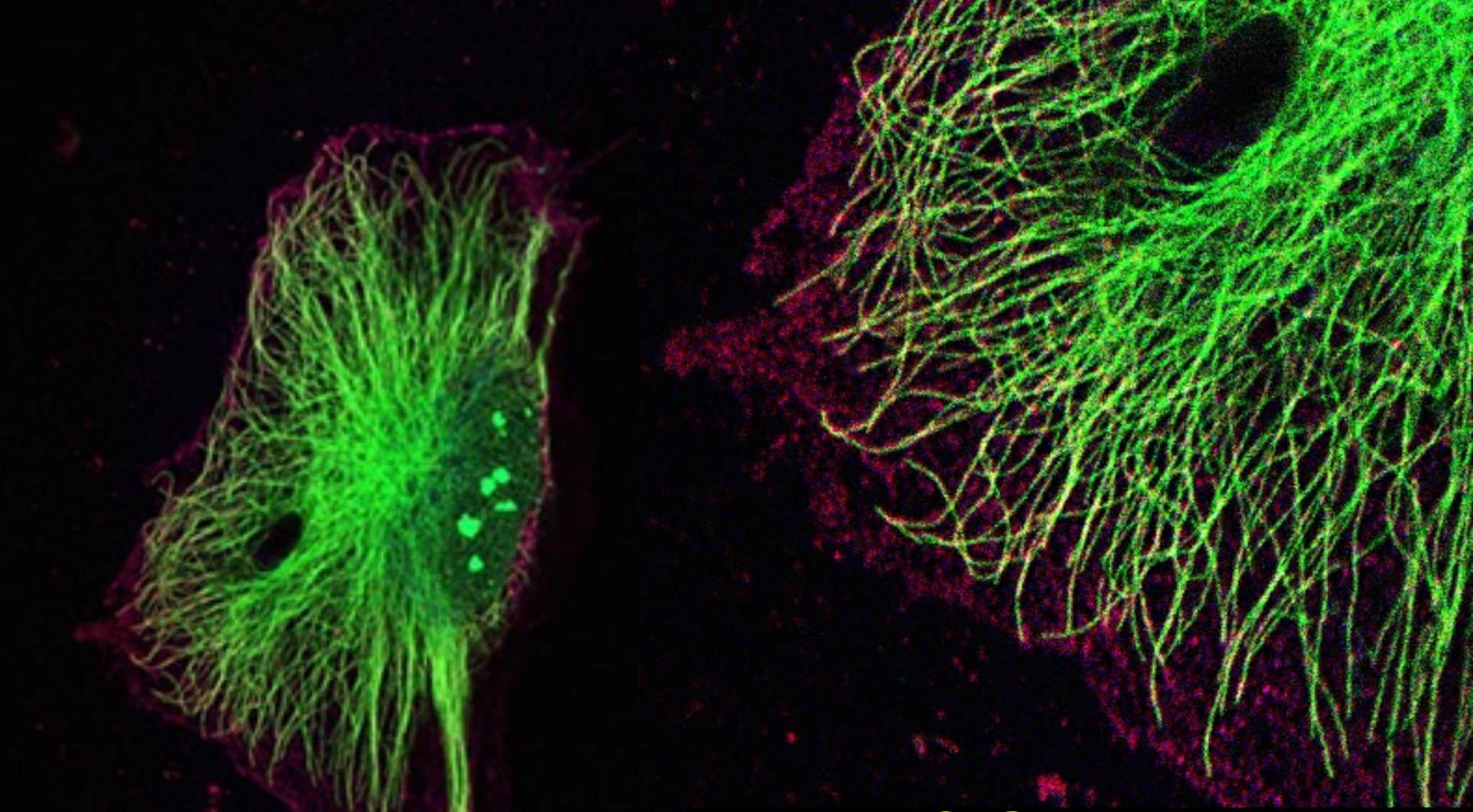


Biology of Cells

KT Chow

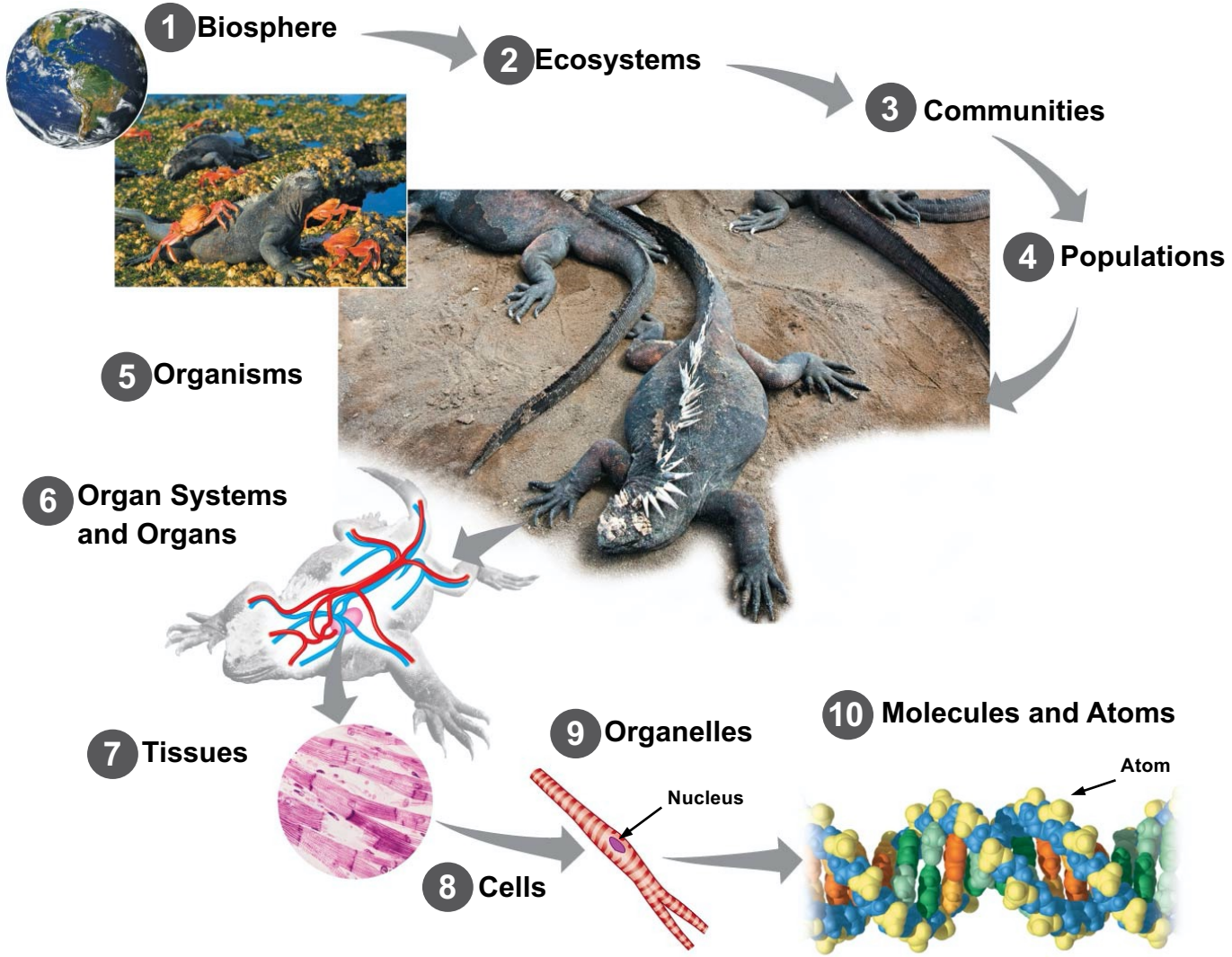
2021-21 Sem A

Outline

- Introduction on cell biology
- How do we visualize cells – microscopy
- Cell organelles
- Prokaryotic and eukaryotic cells

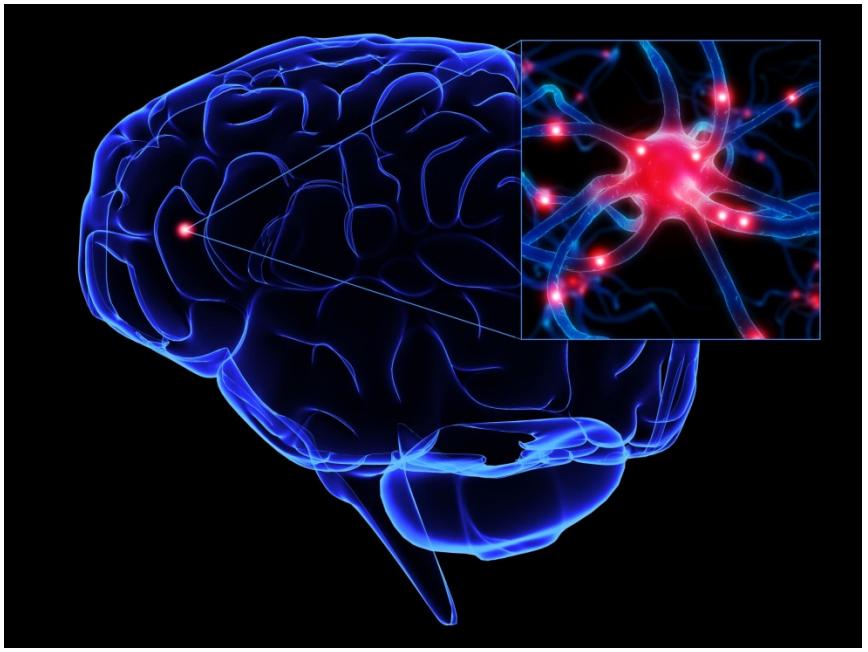
Hierarchy of biological organization

Biosphere	That part of Earth inhabited by living organisms; includes both the living and nonliving components
Ecosystem	A community together with its nonliving surroundings
Community	Two or more populations of different species living and interacting in the same area
Species	Very similar, potentially interbreeding organisms
Population	Members of one species inhabiting the same area
Multicellular organism	An individual living thing composed of many cells
Organ system	Two or more organs working together in the execution of a specific bodily function
Organ	A structure usually composed of several tissue types that form a functional unit
Tissue	A group of similar cells that perform a specific function
Cell	The smallest unit of life
Molecule	A combination of atoms
Atom	The smallest particle of an element that retains the properties of that element



Cell Biology

- How many neurons in our brain?
  100 billion
- How many cells in our body?
  50-75 trillion (1 trillion = 1,000,000,000,000)
- How many bacteria in our body?
  ~100 trillion



Cell evolution - tree of life

based on "molecular phylogeny"
(genome sequences)

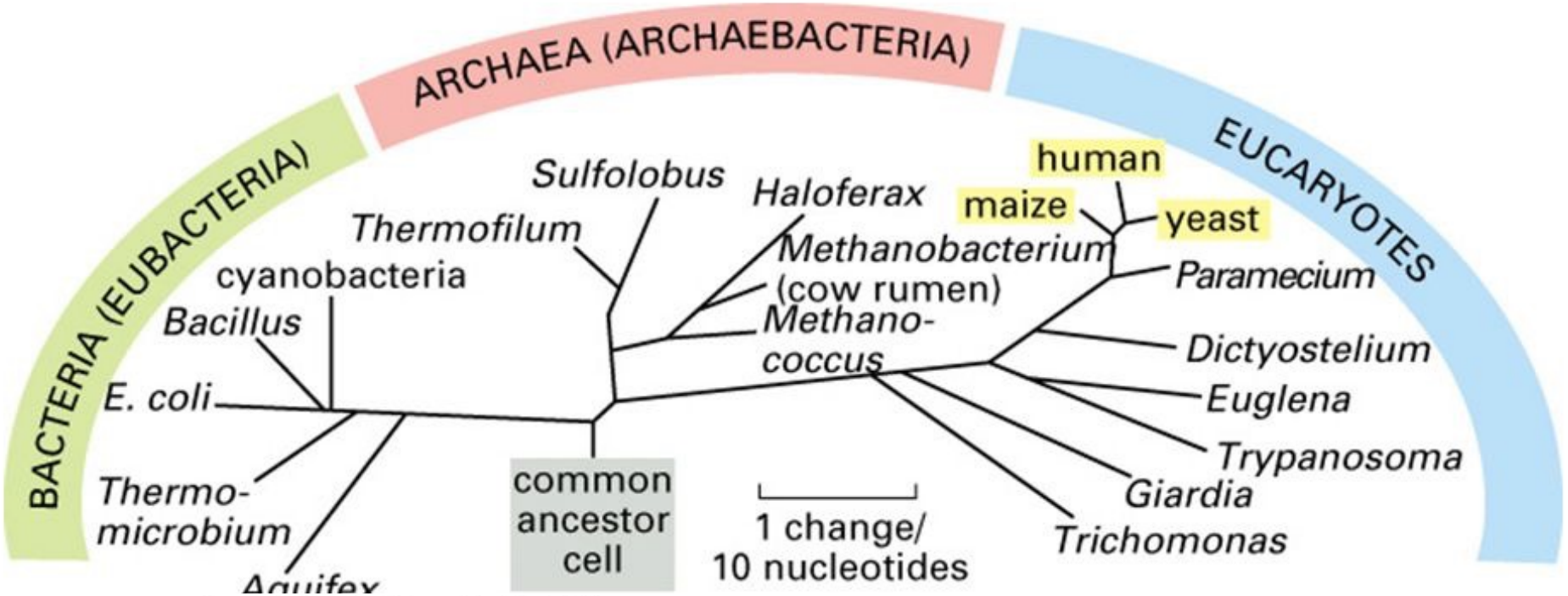
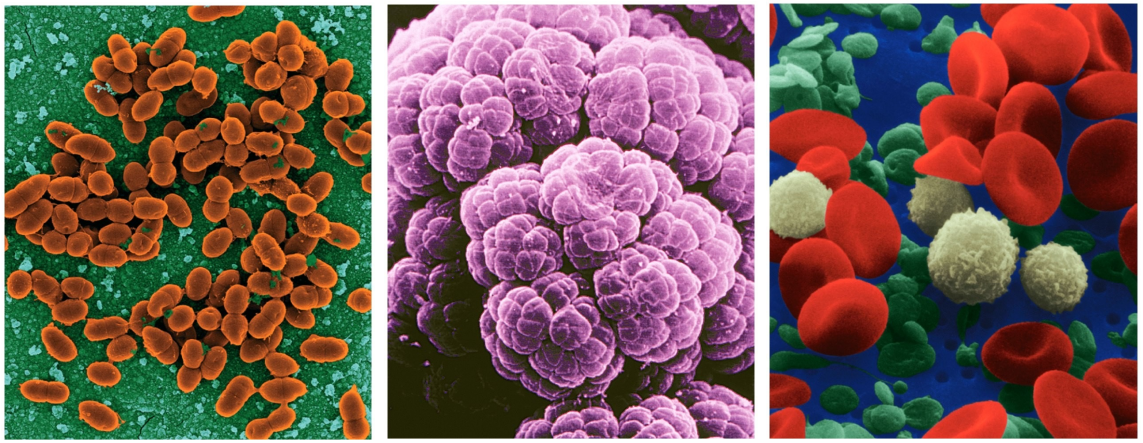


Figure 1–21. Molecular Biology of the Cell, 4th Edition.

The three domains of life

Bacteria	Archaea	Eukaryotes
Lactococcus lactis	*Methanosarcina*	*Red blood cells, leukocytes, platelets*



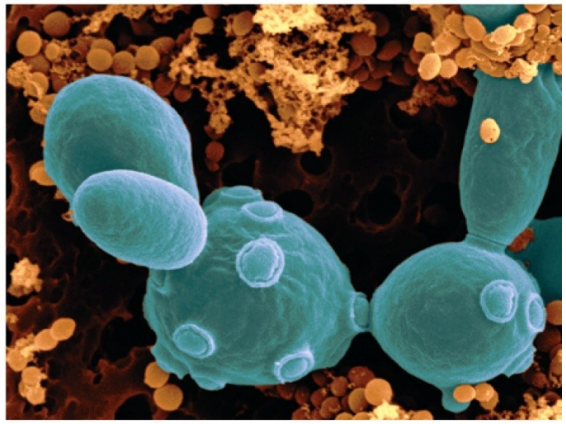
ALL LIFE IS CELLULAR

- The cell is the level at which the properties of life emerge.
- Cells are the lowest level of structure that can perform all activities required for life.
- Cells are the subunits that make up multicellular organisms.

Introduction on Cell Biology

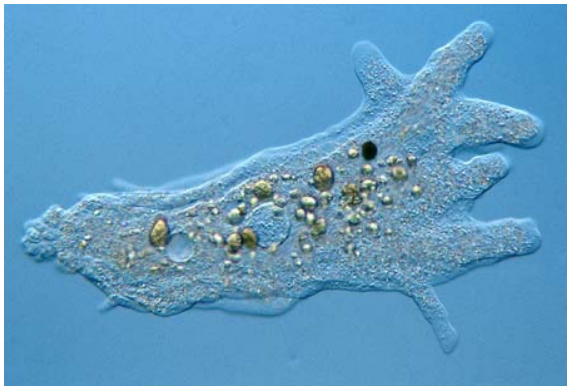
Unicellular (single-celled) organisms → Microorganisms

Bacteria



Yeast - Fungi

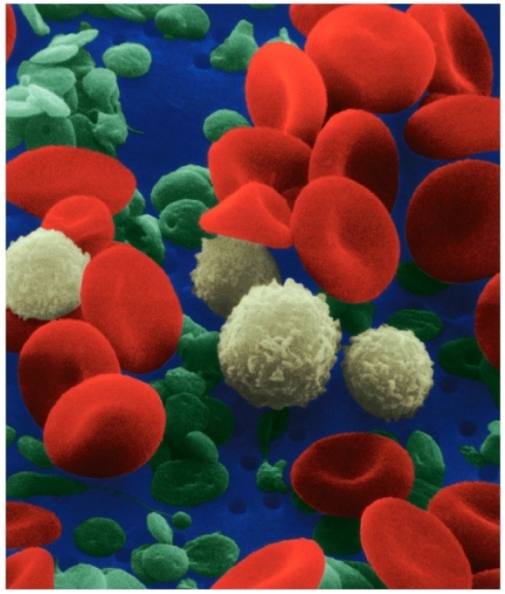
Archea



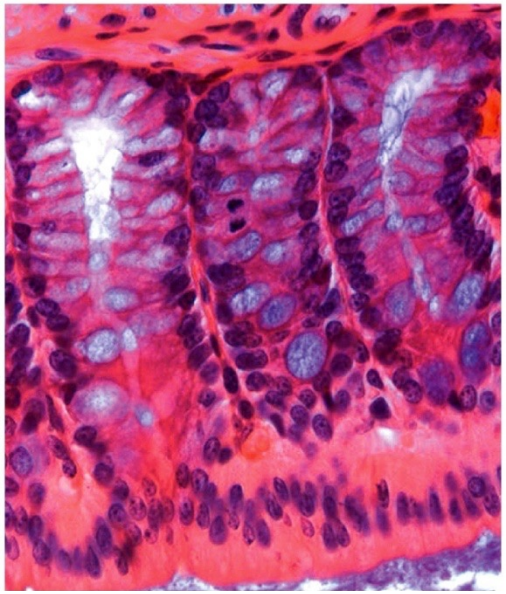
Amoeba

Introduction on Cell Biology

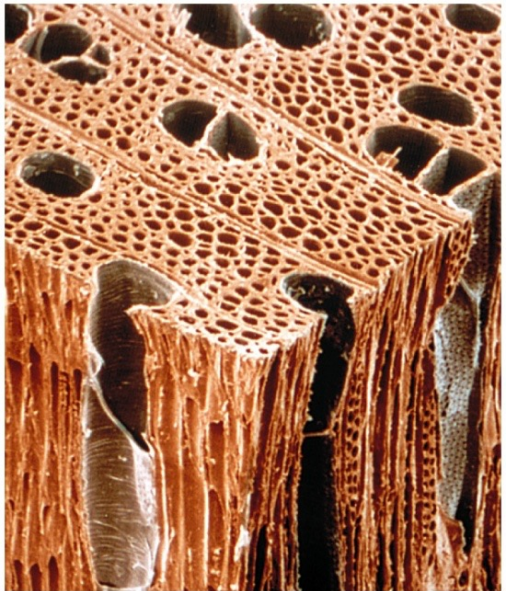
Multicellular organisms → higher degree or organization of cells within the organism → specialization of cells



Human blood cells



Human skin cells

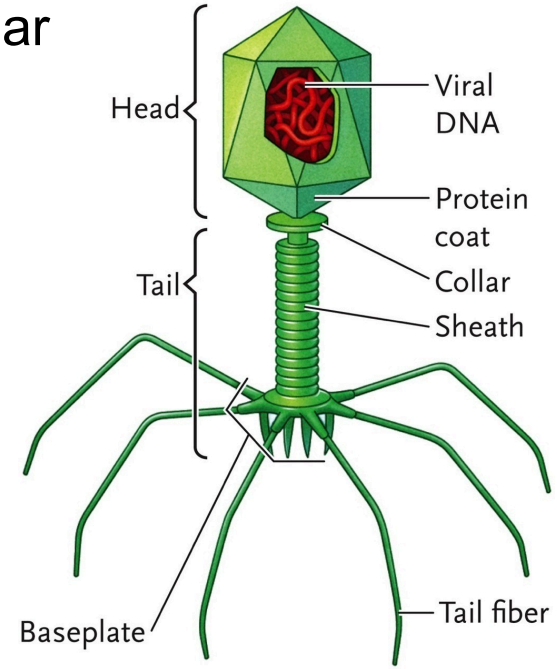


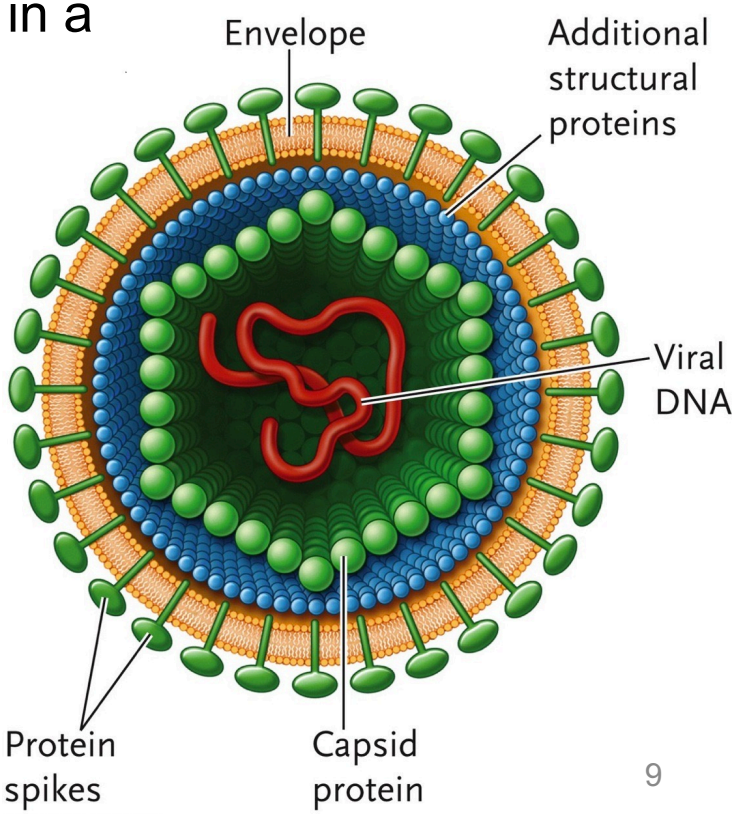
Plant cells

Introduction on Cell Biology

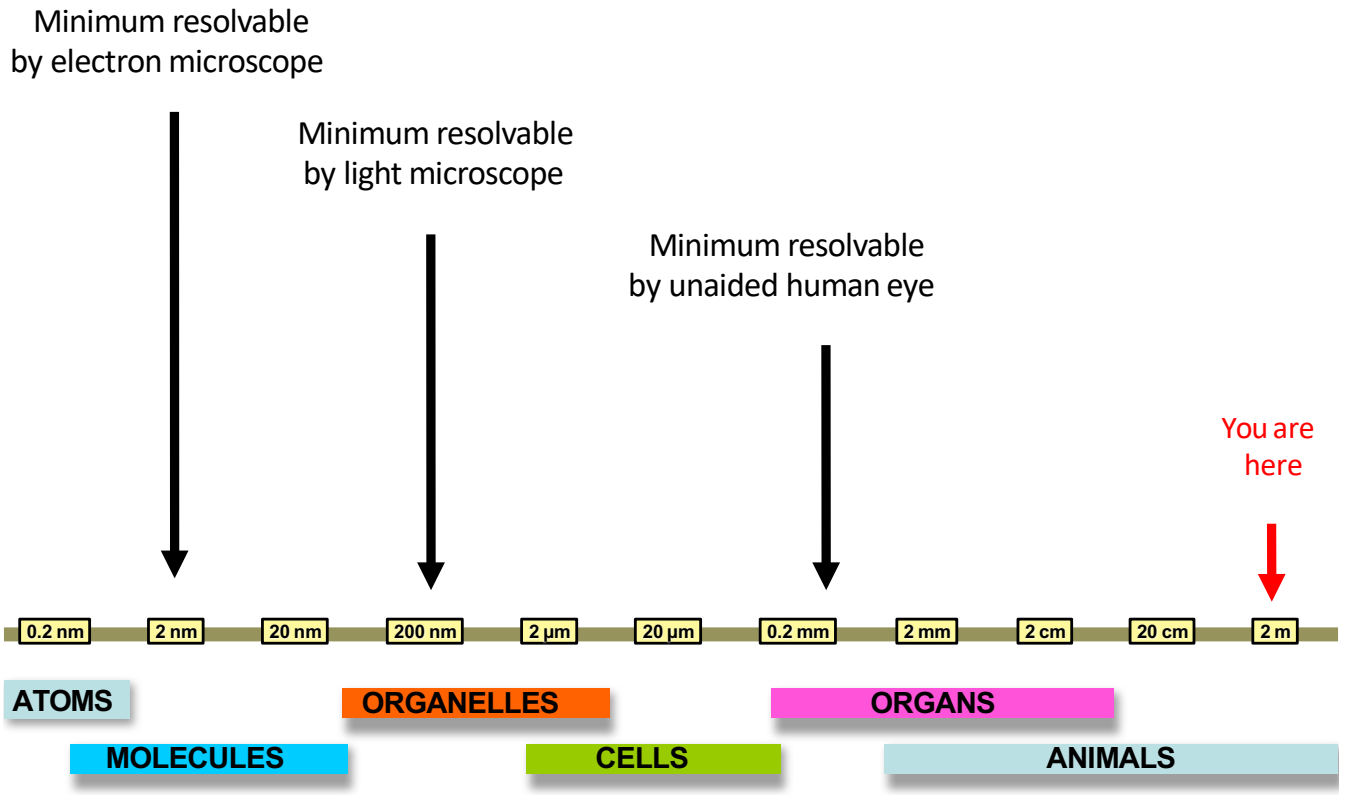
Viruses -> are NOT living organisms

- Consist of DNA *or* RNA core
- Core is surrounded by a protein coat
- Coat may be enclosed in a lipid envelope
- Viruses are replicated only when they are in a living host cell
- **NOT** cellular



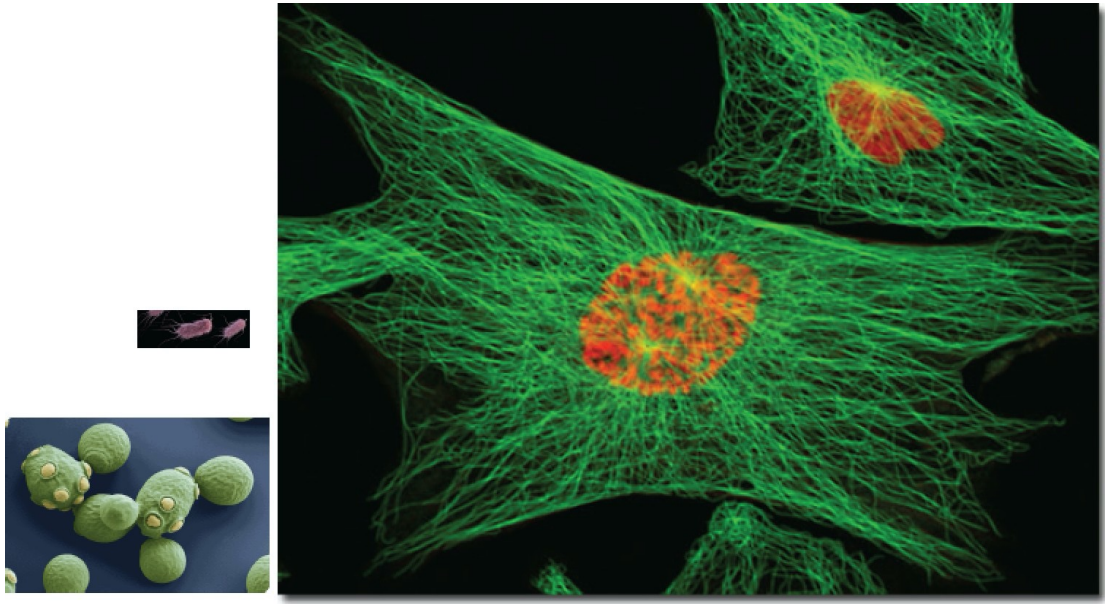


The scale of life



Cell size

cells are small, but vary widely in size



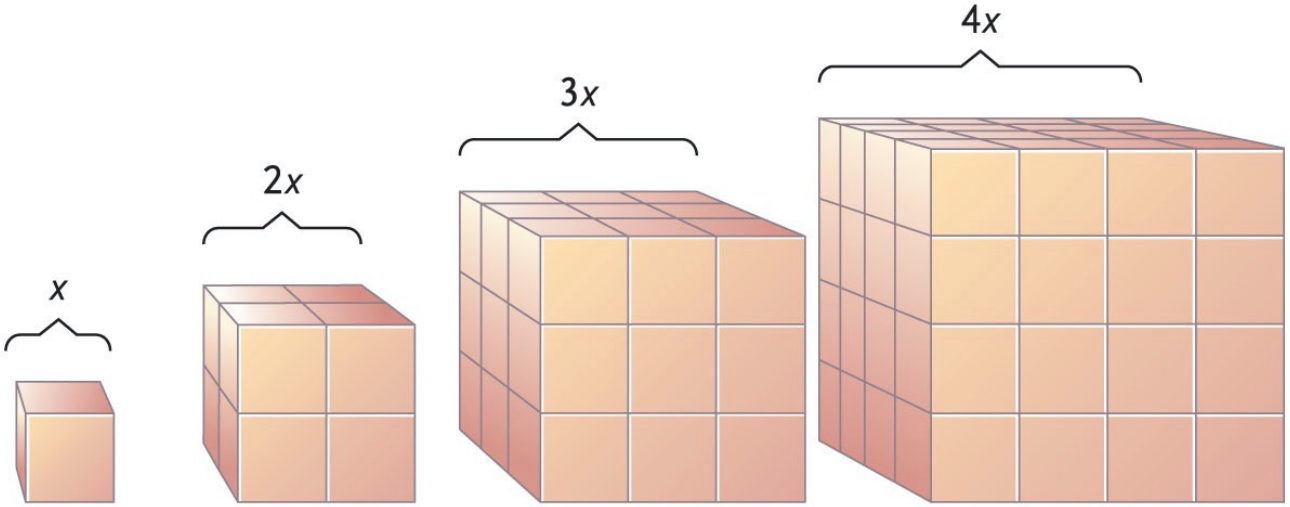
Cell	Radius (µm)	Volume (fl)
Bacterium	0.5-1	1
Yeast	2.5	60
Human fibroblast	25	5000

Cell size

A cell must

- be large enough to house DNA, proteins, and structures needed to survive and reproduce, but
- remain small enough to allow for a surface-to-volume ratio that will allow adequate exchange with the environment.

Surface area to volume ratio is important in the exchange of molecules



Total surface area	$\mathbf{6x^2}$	$6(2x)^2 = \mathbf{24x^2}$	$6(3x)^2 = \mathbf{54x^2}$	$6(4x)^2 = \mathbf{96x^2}$
Total volume	$\boldsymbol{x^3}$	$(2x)^3 = \mathbf{8x^3}$	$(3x)^3 = \mathbf{27x^3}$	$(4x)^3 = \mathbf{64x^3}$
Surface area/ volume ratio	**6:1**	**3:1**	**2:1**	**1.5:1**

Cell size: fun facts

- Smallest known cell:
- Largest known cell:
- Largest single-celled organism:
- Smallest cell in human body:
- largest cell in human body:
- Length of a giraffe nerve cell:
- Potentially the longest cell ever existed:

Fun reading: https://whyevolutionistrue.wordpress.com/2011/05/28/the-longest-cell-in-the-history-of-life/

Look up: Mycoplasma, Caulerpa

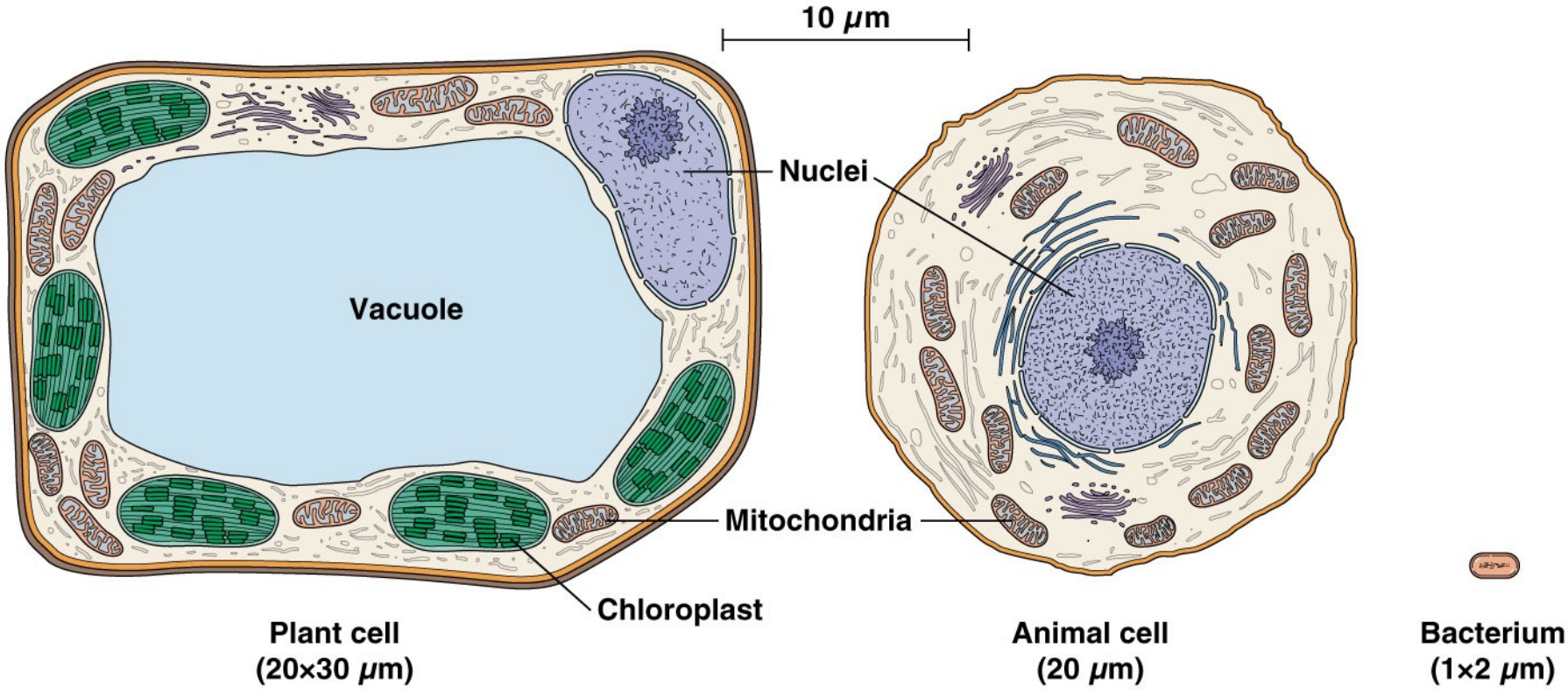
How do we visualize cell?

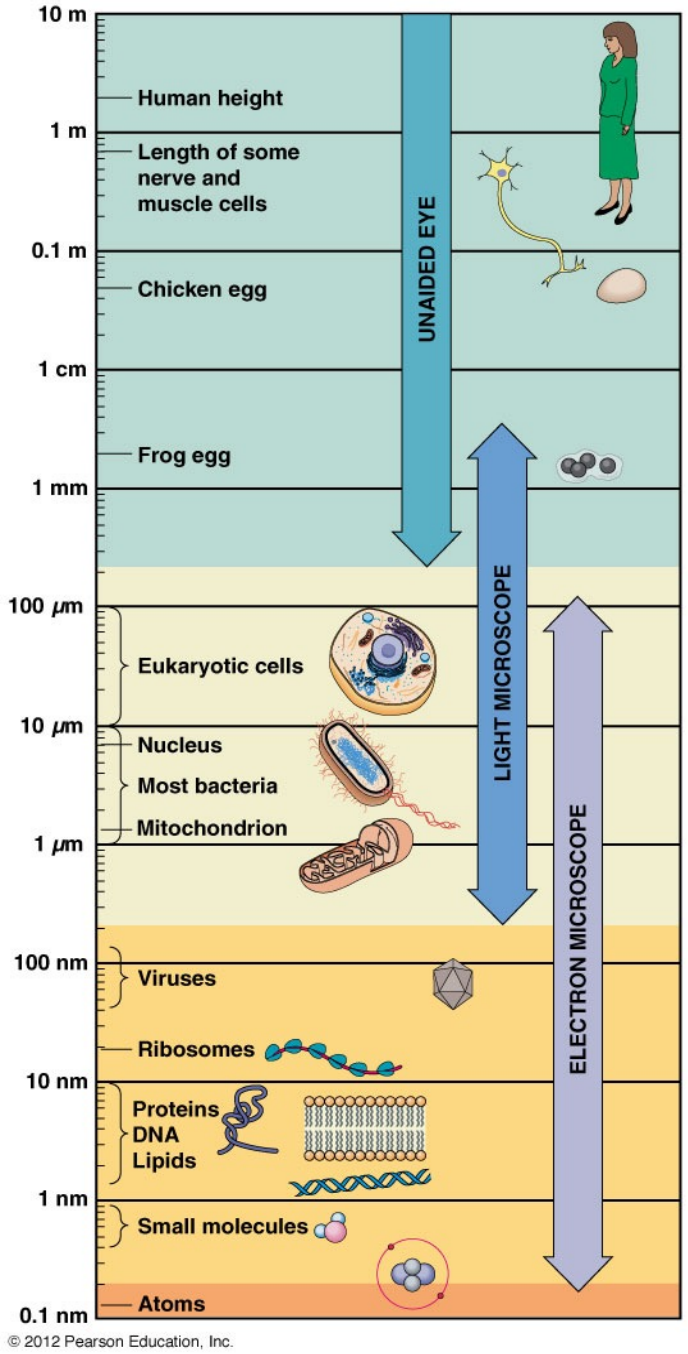
Seeing cells requires microscopes

- The diameter of an average fish egg is 1 mm.
- The average diameter of a strand of human hair is 0.1 mm.
- Human eyes cannot see objects smaller than 0.1 mm in diameter.
- Microscope is needed for viewing things smaller than 0.1 mm.

Salmon roe
(Eggs mass in the ovary)
(6-9 mm)

Caviar
(Eggs of sturgeon)
(2.5 mm)

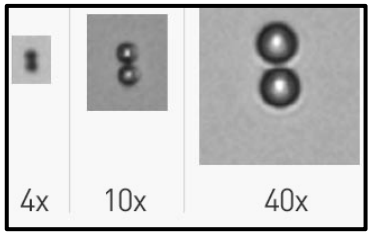

10 μm
Nuclei
Vacuole
Mitochondria
Chloroplast
Plant cell
(20×30 μm)
Animal cell
(20 μm)
Bacterium
(1×2 μm)



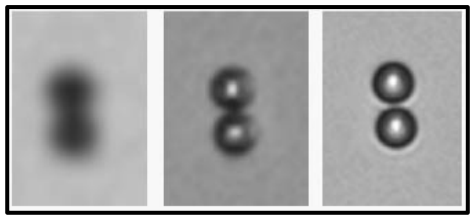
1 meter = 10^2 cm = 10^3 mm = 10^6 μm = 10^9 nm

1 meter (m) = 10^0 meter (m) = 39.4 inches
1 centimeter (cm) = 10^{-2} m = 0.4 inch
1 millimeter (mm) = 10^{-3} m
1 micrometer (μm) = 10^{-3} mm = 10^{-6} m
1 nanometer (nm) = 10^{-3} μm = 10^{-9} m

Seeing cells requires microscopes



Two 6 µm beads taken at 4x, 10x, and 40x magnifications.



Same images matched in size to show differences in resolution

Concepts:

1) Magnification: increase in size

2) Resolution (r):

r = the smallest resolvable distance between two objects

r $\propto \lambda$: wavelength of illumination [Light microscope vs. Electron microscope]

r $1/\propto$ *NA*: numerical aperture, takes into account refraction index [air vs. oil]

3) Contrast: difference between object and surroundings

4) Signal to noise

Images from ThermoFisher

Light microscopy

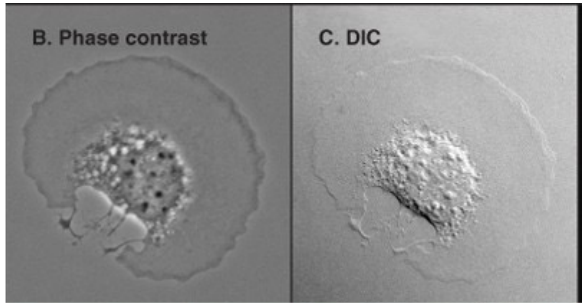
Illumination by visible light
Max resolution: ~200 nm

Fritz Zernike
Nobel prize in physics 1953
for phase contrast

Compound Microscope

- Interference can be used to convert changes in the **phase of light** (invisible to human eye) into intensity changes that are visible

- Phase contrast and differential interference contrast (DIC) exploit **differences in refractive index**: allows visualization of structure



Distinguish basic parts of cell:
Nucleus, cytoplasm, PM

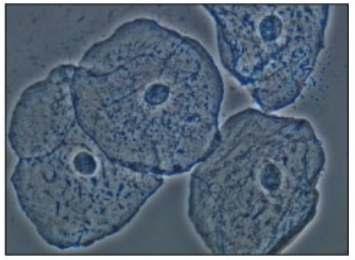
Images from:
http://www.microscopyu.com/
http://nobelprize.org
Pollard, Cell Biology2e

Light microscopy

Table 1-1 **Different Types of Light Microscopy: A Comparison**

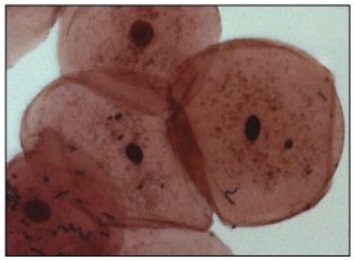
Light Micrographs of Human Cheek Epithelial Cells

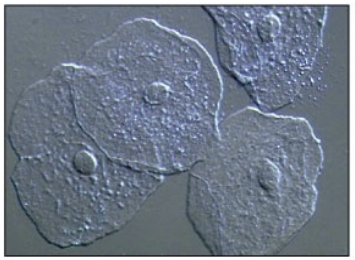
Brightfield (unstained specimen): Passes light directly through specimen; unless cell is naturally pigmented or artificially stained, image has little contrast.



Phase contrast: Enhances contrast in unstained cells by amplifying variations in refractive index within specimen; especially useful for examining living, unpigmented cells.

Brightfield (stained specimen): Staining with various dyes enhances contrast, but most staining procedures require that cells be fixed (preserved).





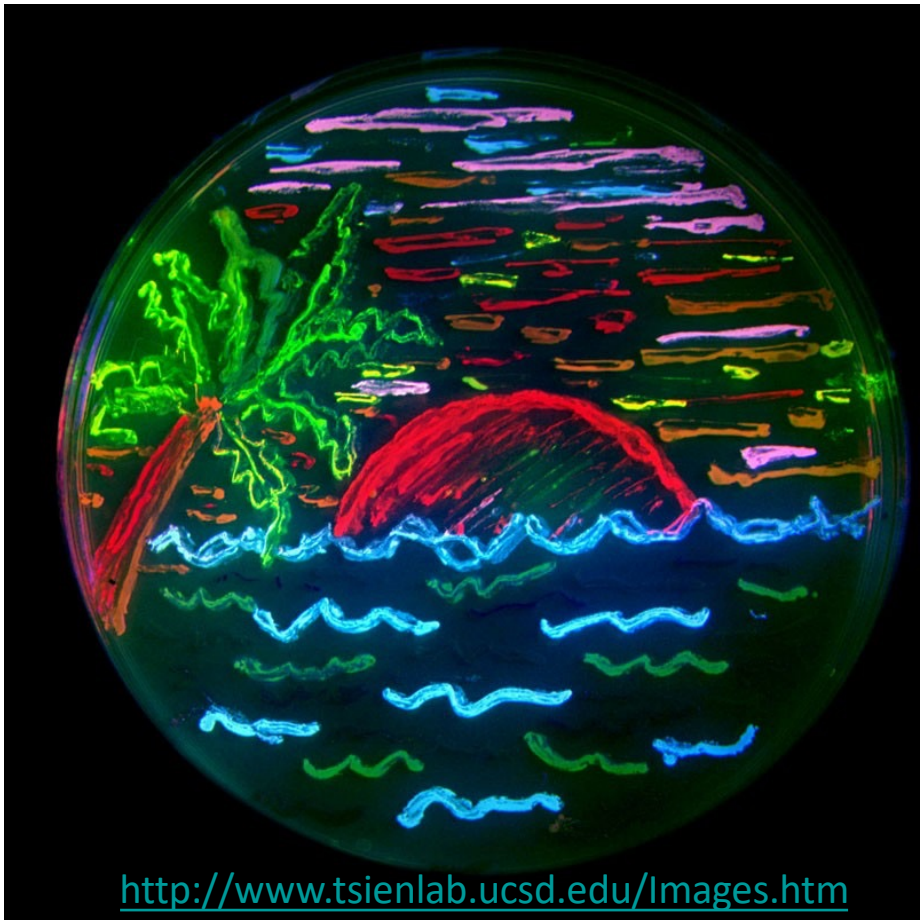
Differential interference contrast: Also uses optical modifications to exaggerate differences in refractive index.

20 μm

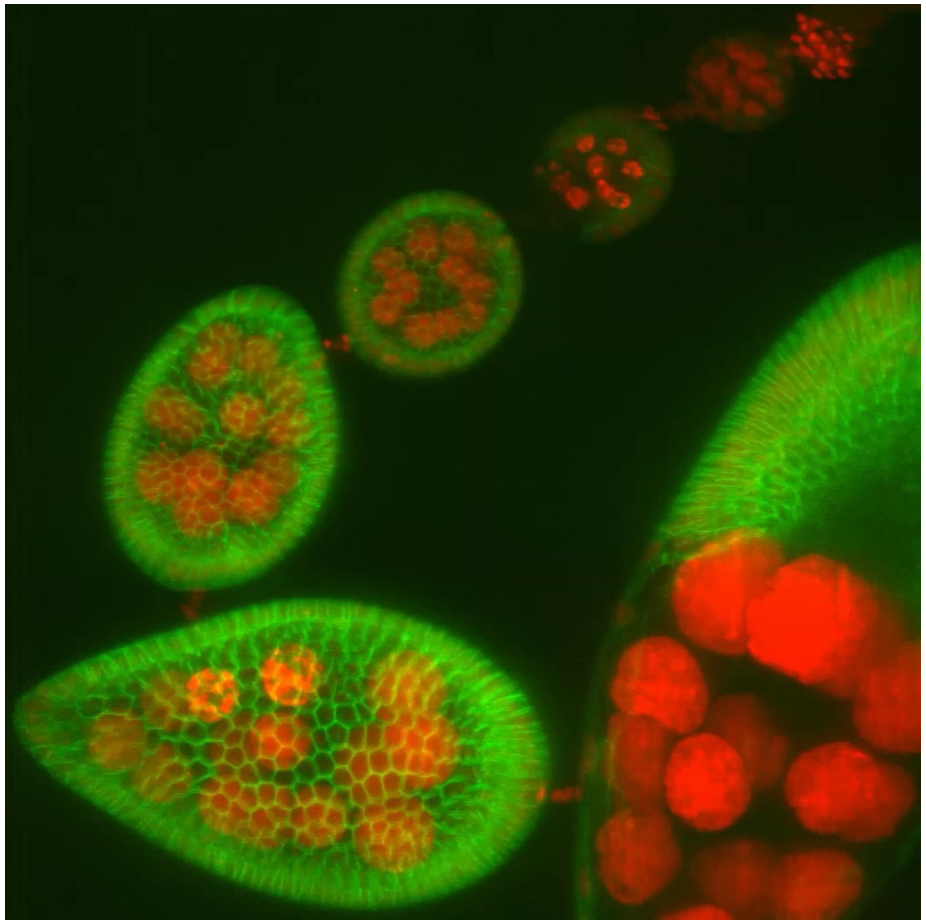
Source: Adapted from Campbell and Reece, *Biology,* 6th ed. (San Francisco: Benjamin Cummings, 2002), p. 110.

Fluorescence microscope

Bacteria expressing different fluorescent proteins



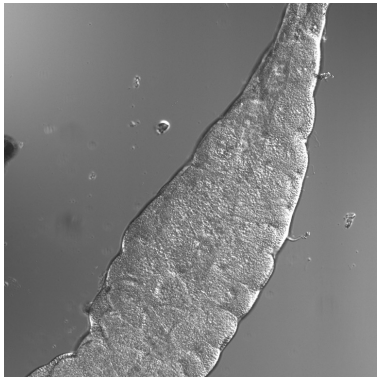
Live Drosophila egg chambers

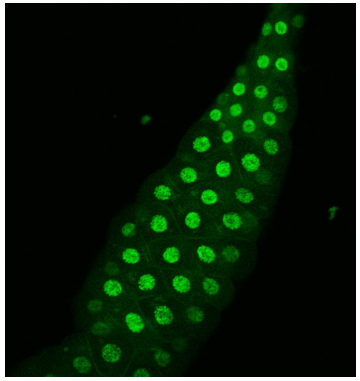


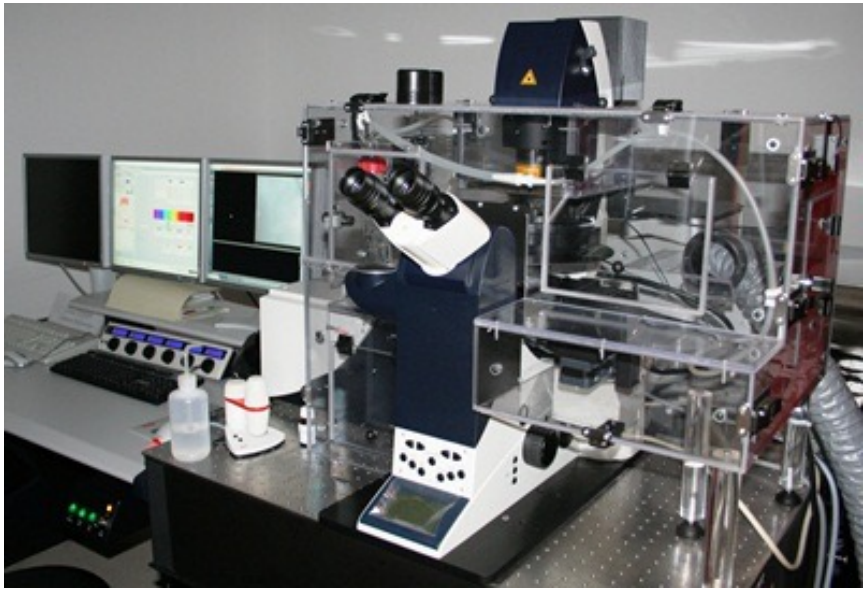
Fluorescence microscope is an optical microscope that visualize objects with fluorescence or light emitting property.

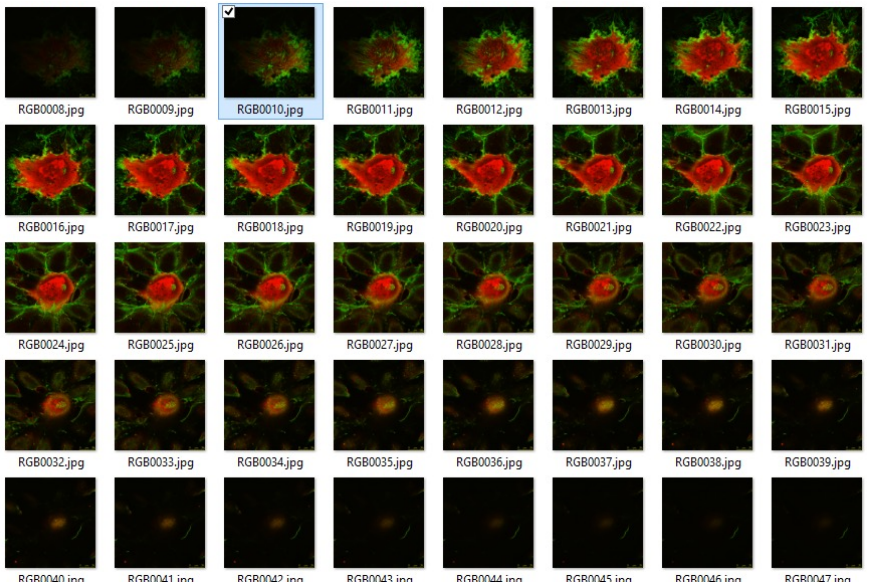
Laser scanning confocal microscope

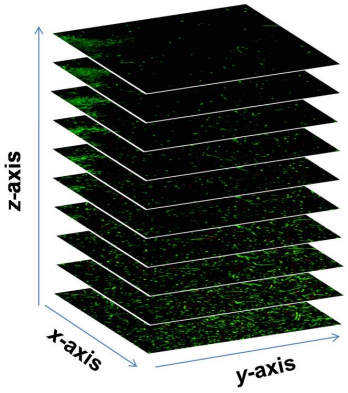
- obtains optical images with high resolution and images of different selected depths.

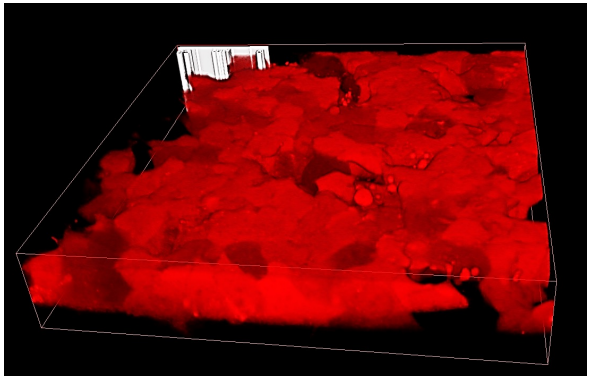










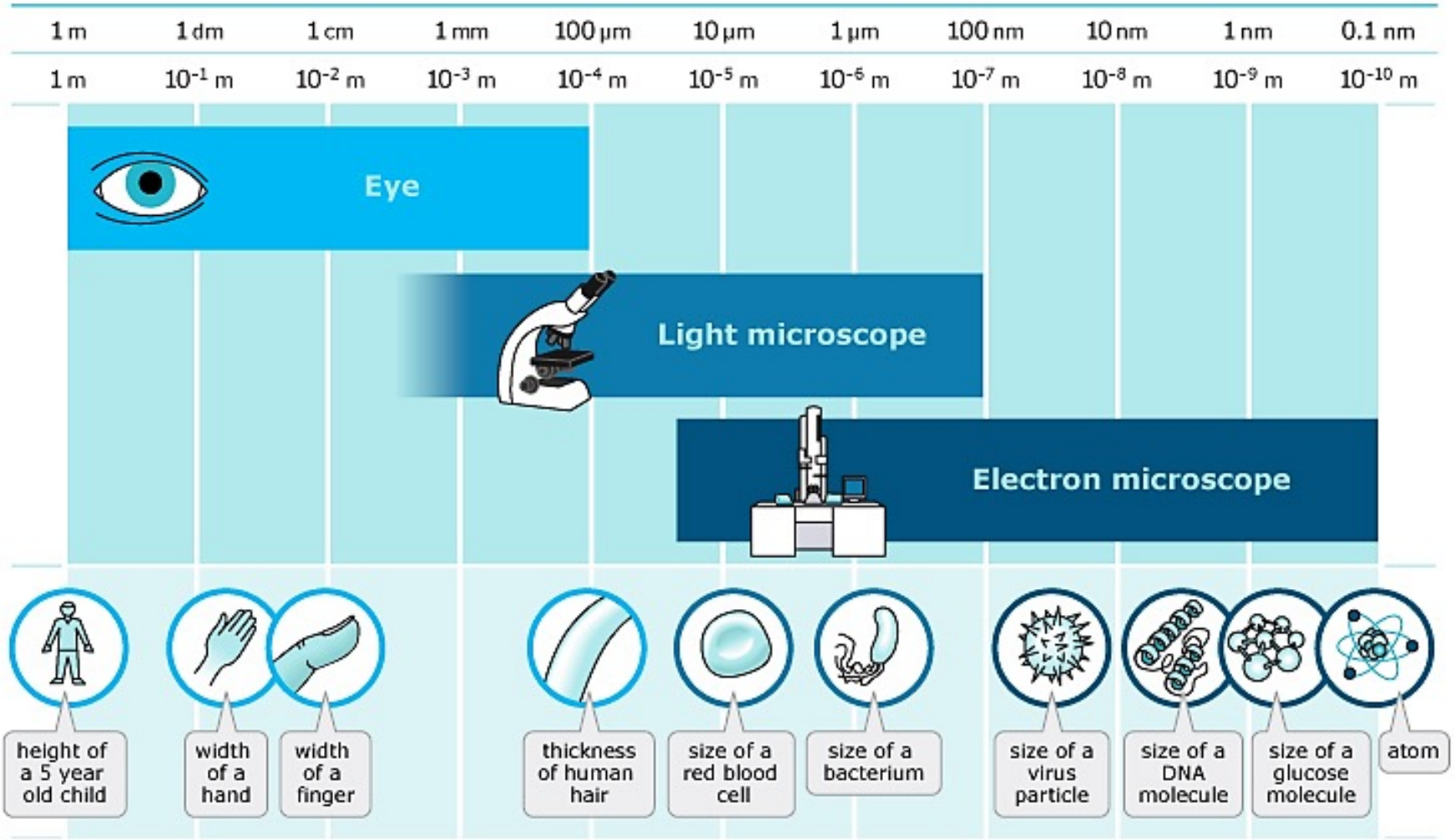


http://www.microscopyu.com/tutorials/java/virtual/confocal/index.html

Visualizing living cells with light

- *Phase contrast/differential interference contrast microscopy* exploit differences in the phase of light passing through a structure with a refractive index different than the surrounding medium
- *Fluorescence microscopy* detects fluorescent dyes, or labels, to show locations of substances in the cell
- *Confocal scanning* uses a laser beam to illuminate a single plane of a fluorescently labeled specimen

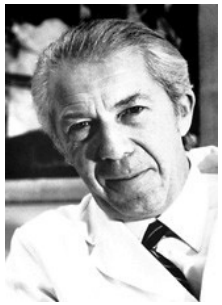
Resolving power of microscopes



Electron microscopy

- The **electron microscope** uses a beam of electrons (shorter λ) rather than light for illumination
- resolution ~0.2 nm
- magnification up to 100,000X

Albert Claude



Christian de Duve

George Palade

Nobel Prize in Physiology or Medicine 1974

For their discoveries concerning the structural and functional organization of the cell

Images from: http://www.microscopyu.com/, http://nobelprize.org, ASCB

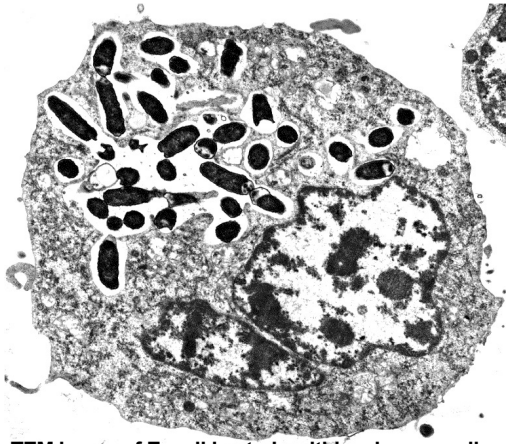
Electron microscopy

Transmission electron microscopy (TEM)

electrons are transmitted through the specimen

"ultrastructure"

Fix cells, cut VERY thin sections (~100nm), stain with heavy metals that scatter electrons and create contrast

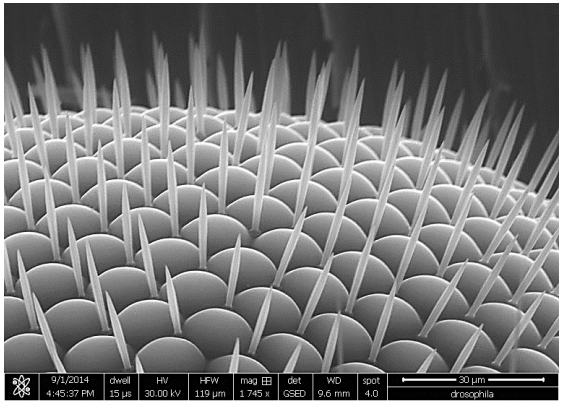


TEM image of E. coli bacteria within a human cell inside endocytic vesicles. Magnification 10,000x. (Scaletsky 1996)

Scanning electron microscopy (SEM)

the surface of a specimen is scanned, electrons deflected from the outer surface are detected

Visualizes objects as three-dimensional photographic images



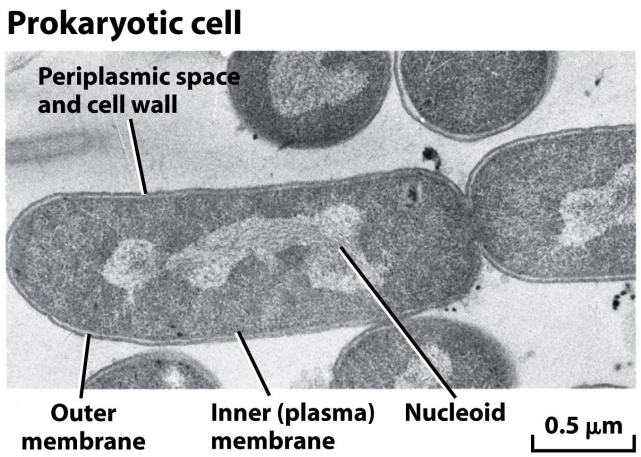
SEM image of Drosophila compound eye. Magnification 1,745x. (Utah State University)

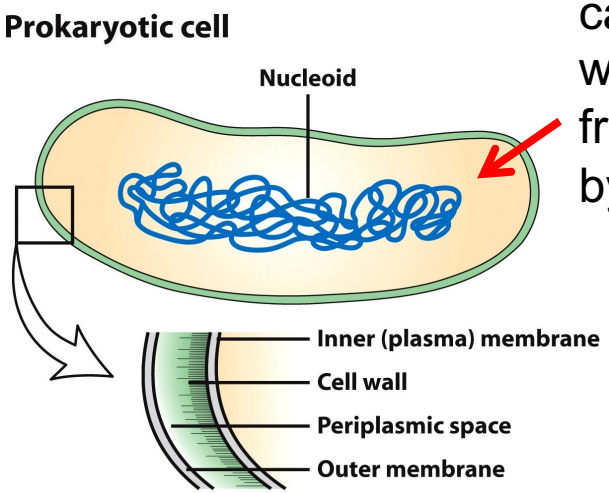
Cell organization: prokaryotes

Even simple cells have a high degree of internal organization

No: "organelles" (nor nucleus)

Yes: microcompartments, cytoskeleton





DNA is coiled into a nucleus-like region called the nucleoid, which is not partitioned from the rest of the cell by membranes.

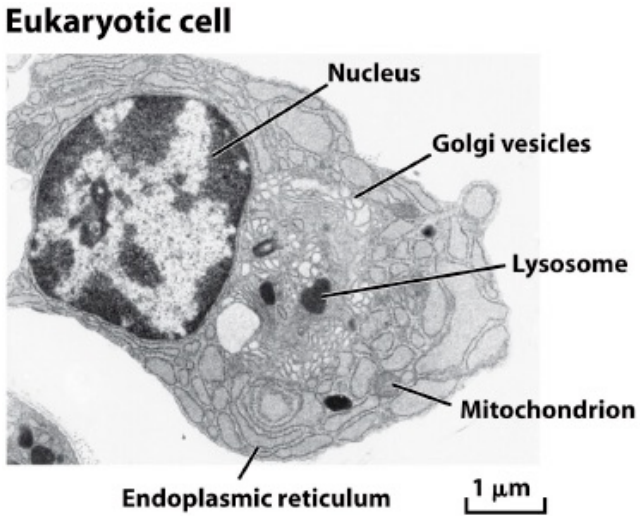
Image from Lodish, Molecular Cell Biology 6e

Cell organization: eukaryotes

Membrane-bound organelles that perform specific functions

Compartments

Cytoskeleton



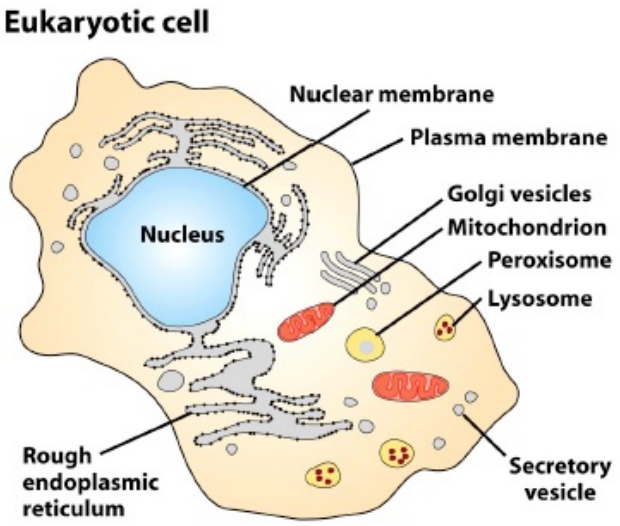
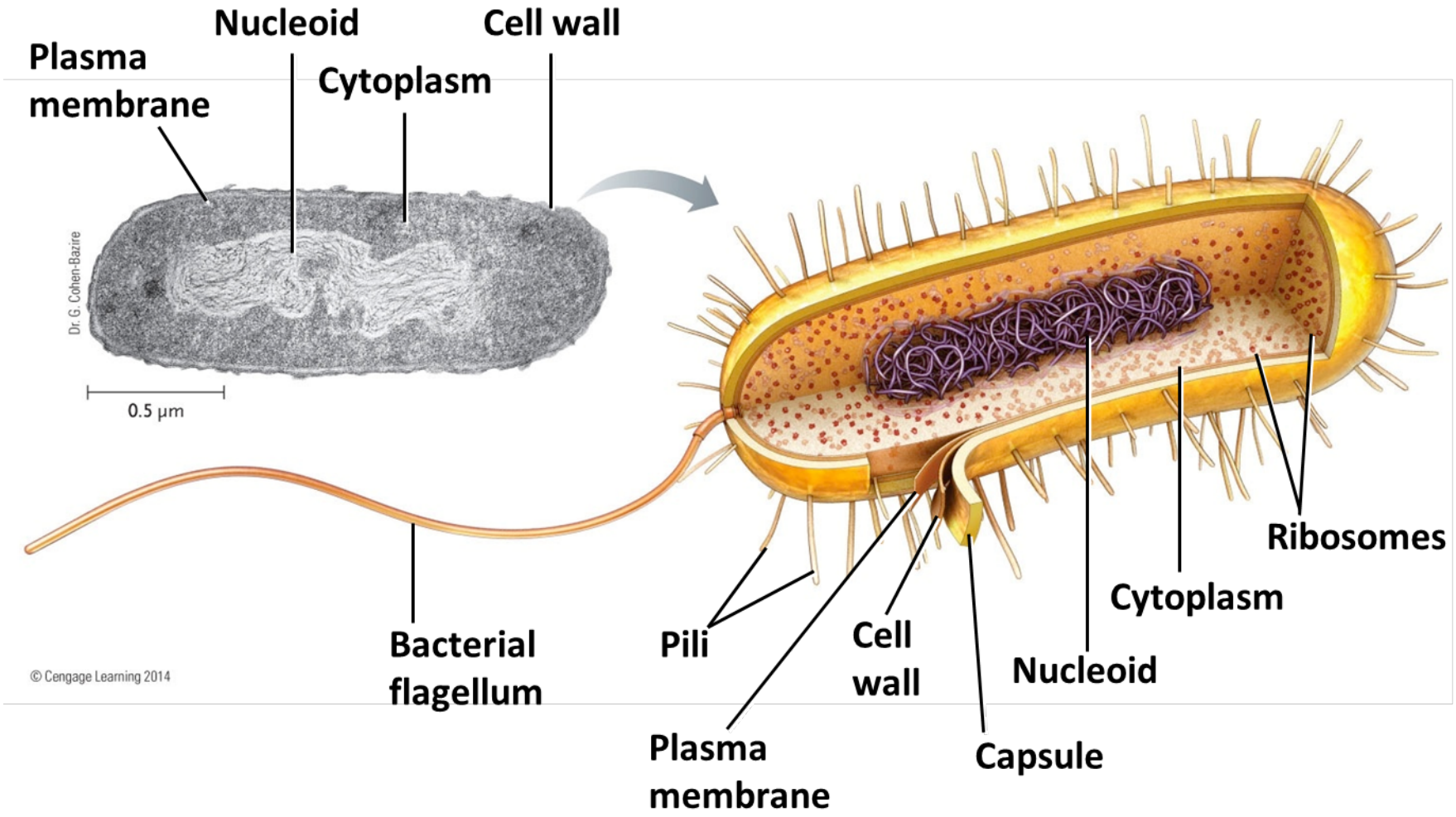


Image from Lodish, Molecular Cell Biology 6e

Organelles

membrane-bound subcellular structures that can

carry out a specialized functions for the cells



Bacteria lack classical membrane-bound organelles, but have microcompartments

Just 6 liters (1.5 gallons) of seawater contain more bacteria than there are people on Earth!

An animal cell

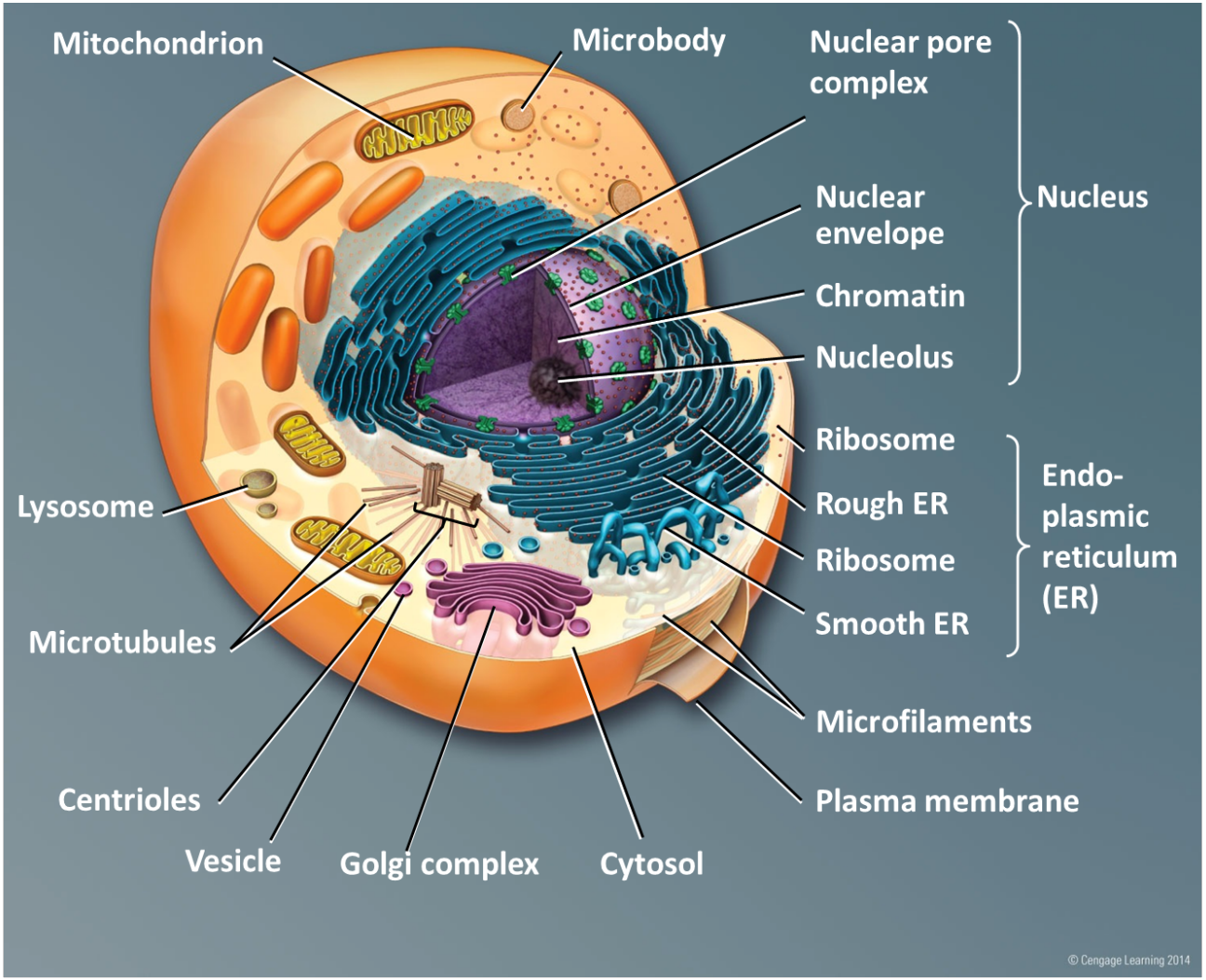


Figure 5-9a p98

A plant cell

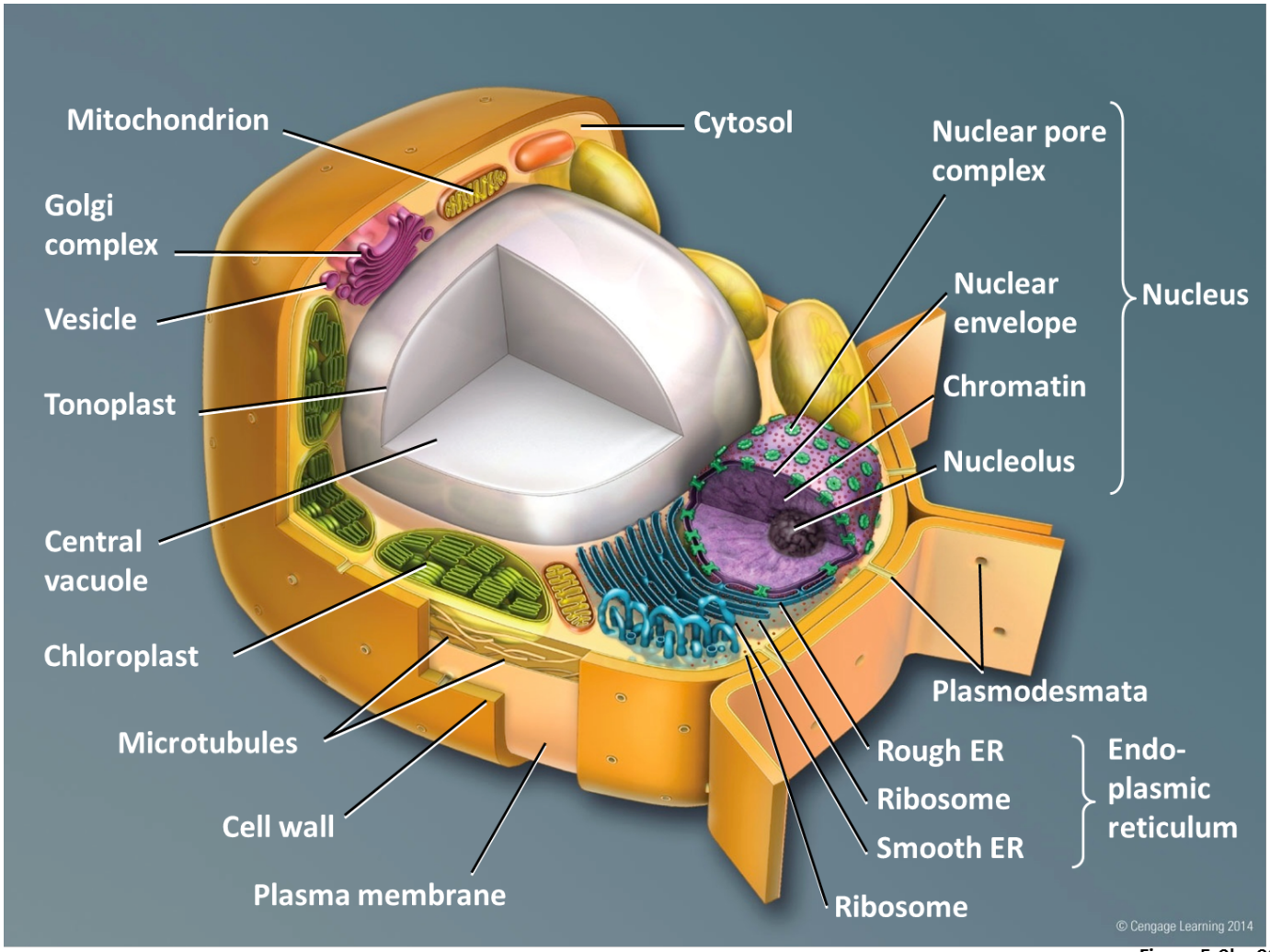


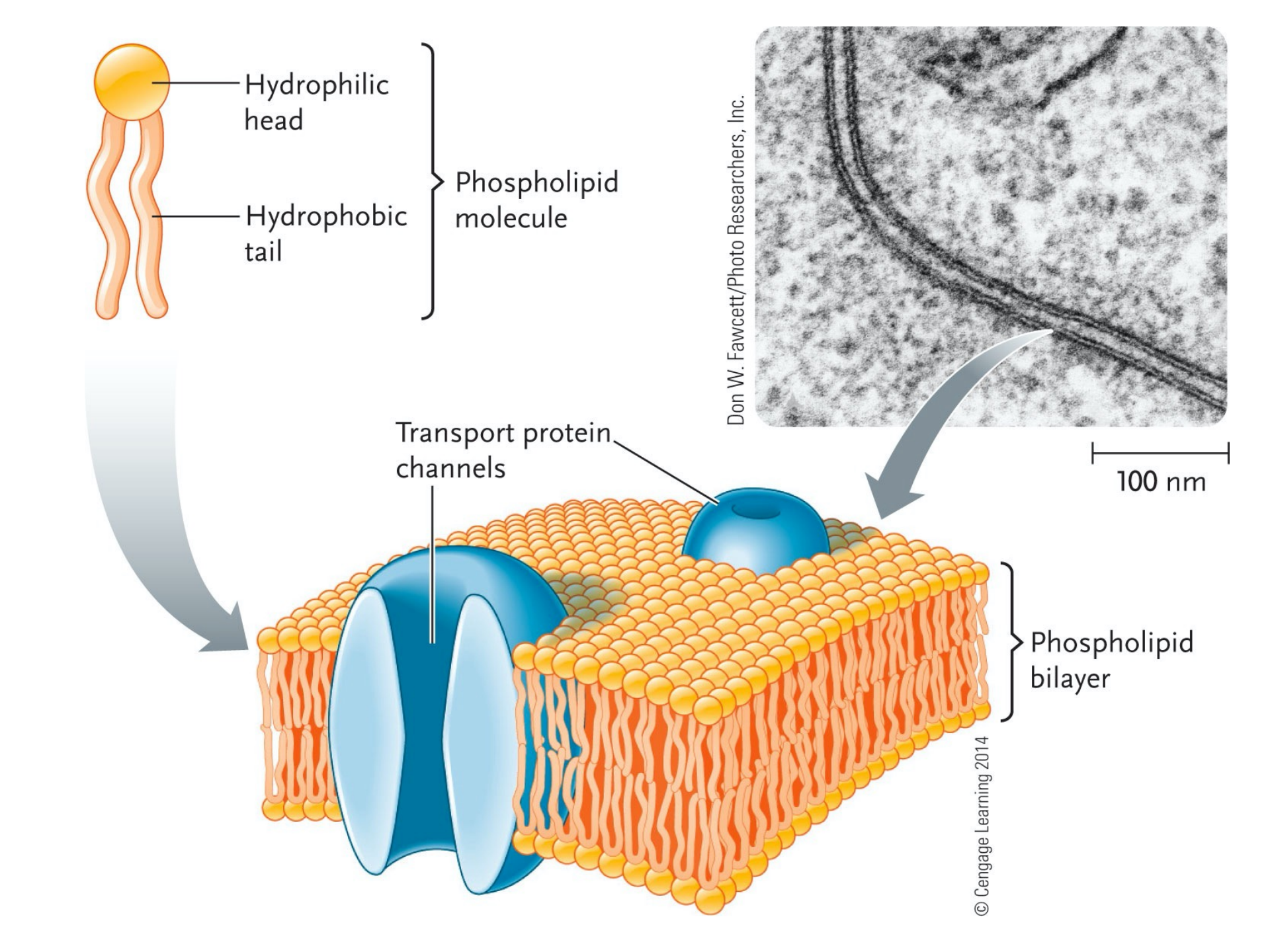
Figure 5-9b p99

Plasma Membrane

https://www.youtube.com/watch?v=Qqsf_UJcfBc

Plasma membrane

- The **plasma membrane** forms a flexible boundary between the living cell and its surroundings.
- The small size of cells relates to the need to exchange materials across the plasma membrane
- Phospholipids form a two-layer sheet called a **phospholipid bilayer** in which
  - hydrophilic heads face outward, exposed to water, and
  - hydrophobic tails point inward, shielded from water.


Hydrophilic head
Hydrophobic tail
Phospholipid molecule
Don W. Fawcett/Photo Researchers, Inc.
100 nm
Transport protein channels
Phospholipid bilayer
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Plasma membrane

- Membrane proteins are either
  - attached to the membrane surface or
  - embedded in the phospholipid bilayer.
- Some proteins form channels that shield ions and other hydrophilic molecules as they pass through the hydrophobic center of the membrane.
- Other proteins serve as pumps, using energy to actively transport molecules into or out of the cell.

The fluid mosaic model of cell membranes

- "two-dimensional fluid"
- The lipid bilayer is fluid and flexible, which allows lateral diffusion of membrane components such as lipids and proteins

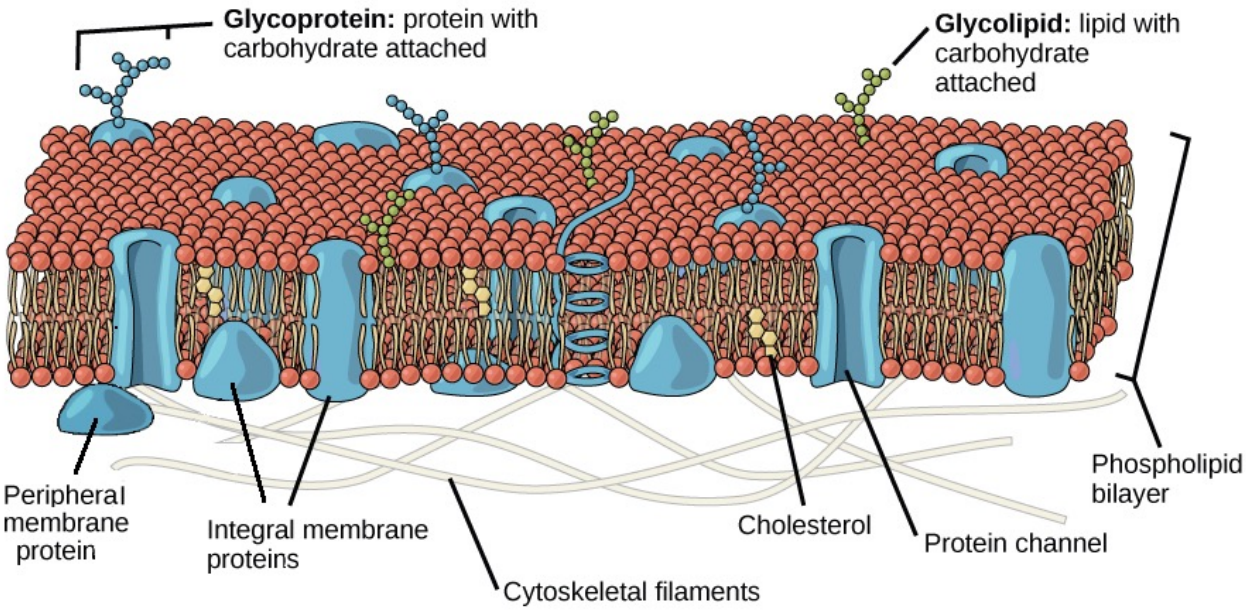


Image from Khan Academy

Membranes are fluid mosaics of lipids & proteins

- Membrane proteins perform many functions.

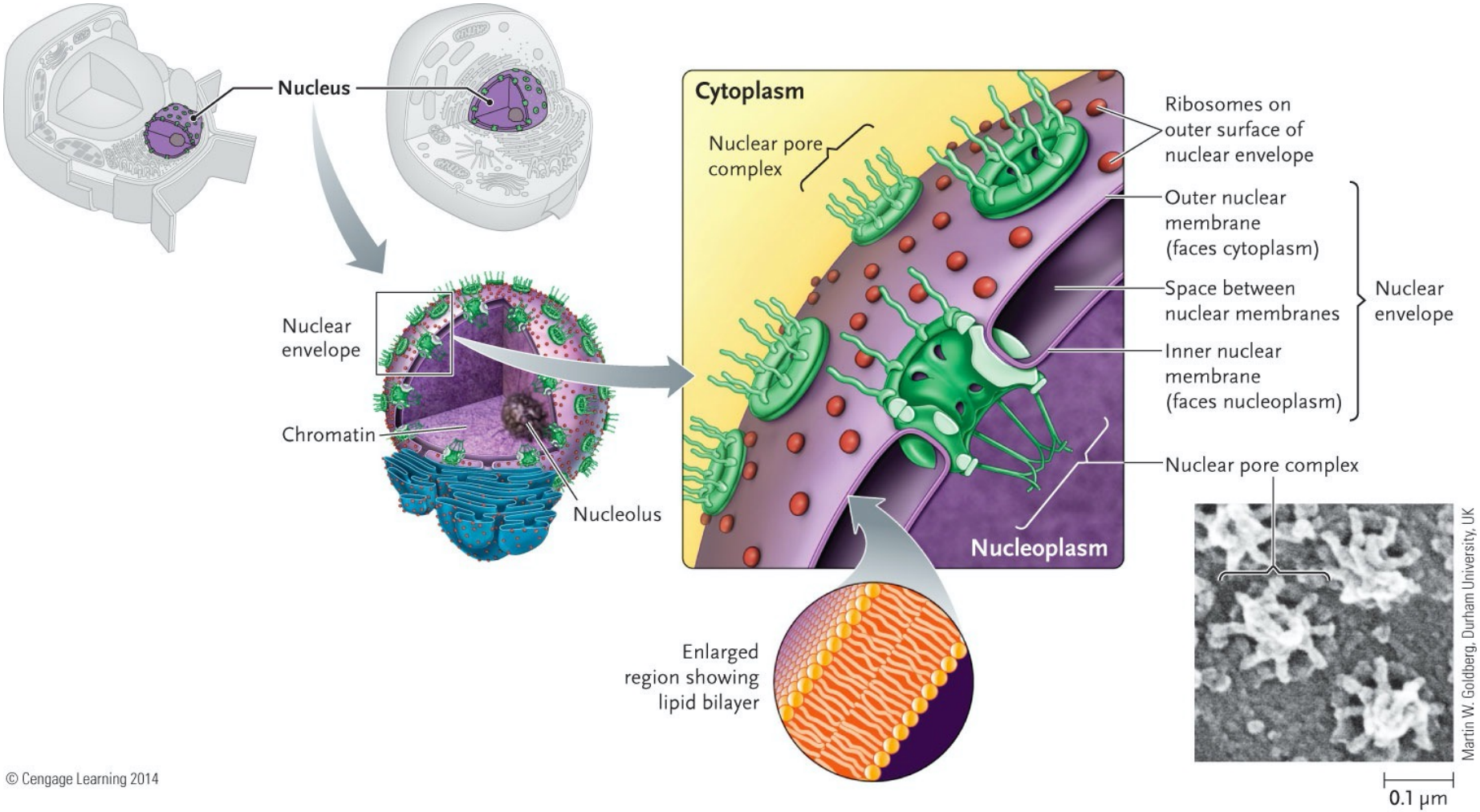
1. maintain cell shape and coordinate changes inside and outside the cell through their attachment to the cytoskeleton and extracellular matrix.
2. function as receptors for chemical messengers from other cells.
3. function as enzymes.

https://www.youtube.com/watch?v=Qqsf_UJcfBc

Membranes are fluid mosaics of lipids & proteins

4. Some membrane glycoproteins are involved in cell-cell recognition.
5. Participate in the intercellular junctions that attach adjacent cells to each other.
6. Membranes may exhibit **selective permeability**, allowing some substances to cross more easily than others.

The Nucleus



The nucleus is the cell's genetic control center

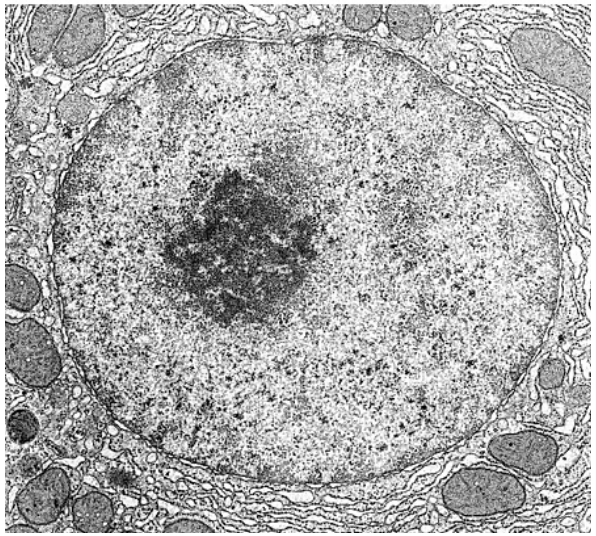
- The **nucleus**
  - contains most of the cell's DNA and
  - controls the cell's activities by directing protein synthesis by making messenger RNA (mRNA).
- DNA is associated with many proteins in structures called **chromosomes**.

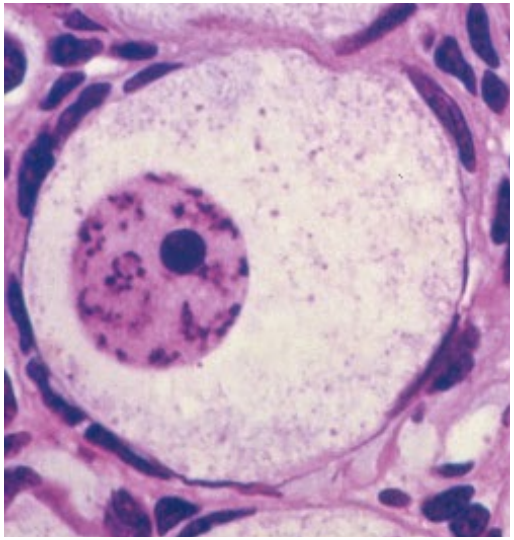
The nucleus is the cell's genetic control center

- The **nuclear envelope**
  - is a double membrane and
  - has pores that allow materials to flow in and out of the nucleus.
- The nuclear envelope is attached to a network of cellular membranes called the endoplasmic reticulum.

The nucleus is the cell's genetic control center

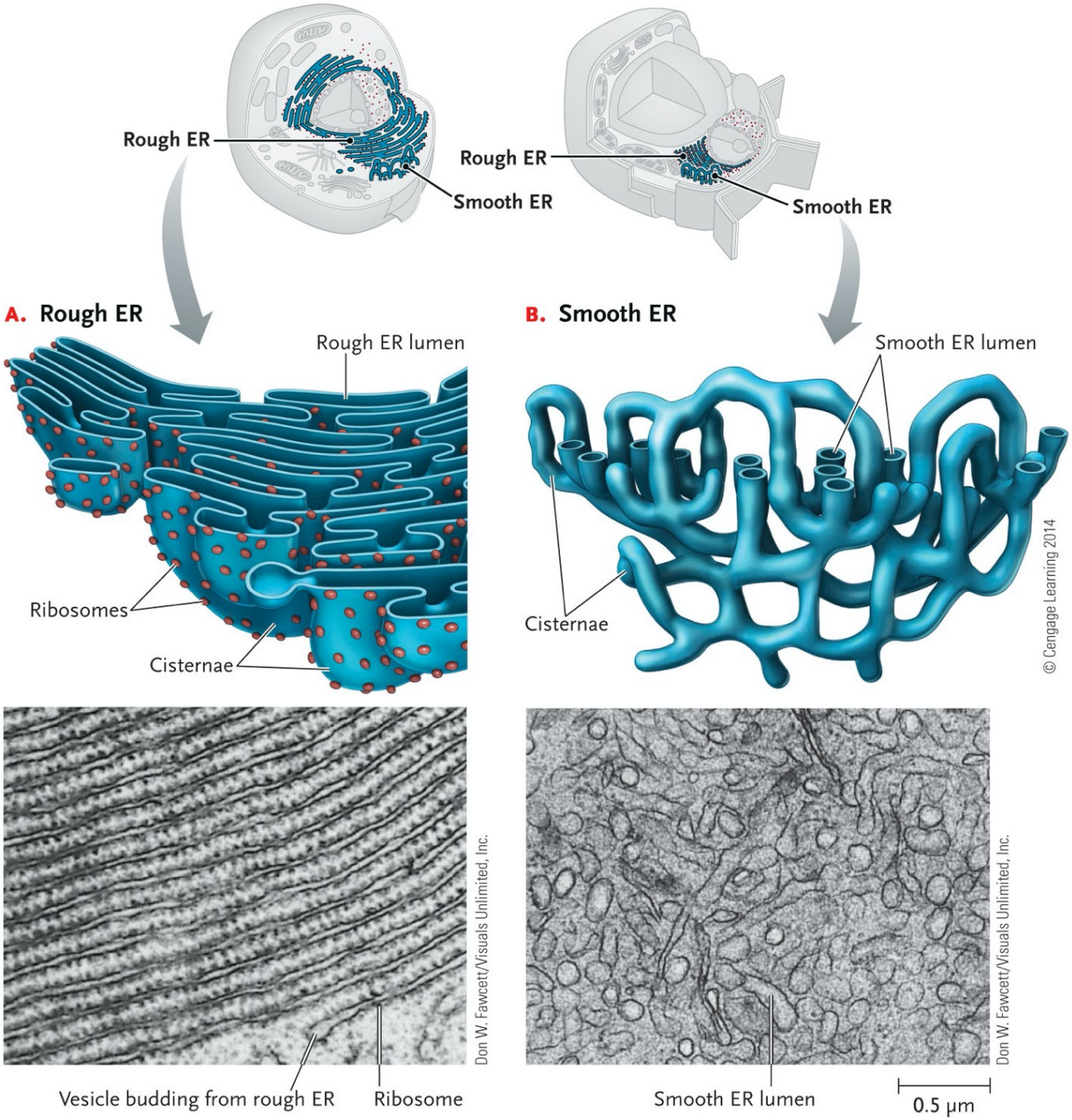
- The **nucleolus** is
  - a prominent structure in the nucleus and
  - the site of ribosome synthesis.





The Endoplasmic Reticulum

(ER)


Rough ER
Smooth ER
Rough ER
Smooth ER
A. Rough ER
Rough ER lumen
Ribosomes
Cisternae
B. Smooth ER
Smooth ER lumen
Cisternae
© Cengage Learning 2014
Don W. Fawcett/Visuals Unlimited, Inc.
Vesicle budding from rough ER
Ribosome
Don W. Fawcett/Visuals Unlimited, Inc.
Smooth ER lumen
0.5 μm

The ER is a biosynthetic factory

- There are two kinds of endoplasmic reticulum—smooth and rough.
  - **Smooth ER** lacks attached ribosomes.
  - **Rough ER** contains ribosomes on the outer surface of membranes.
  - Although physically interconnected, smooth and rough ER differ in structure and function.

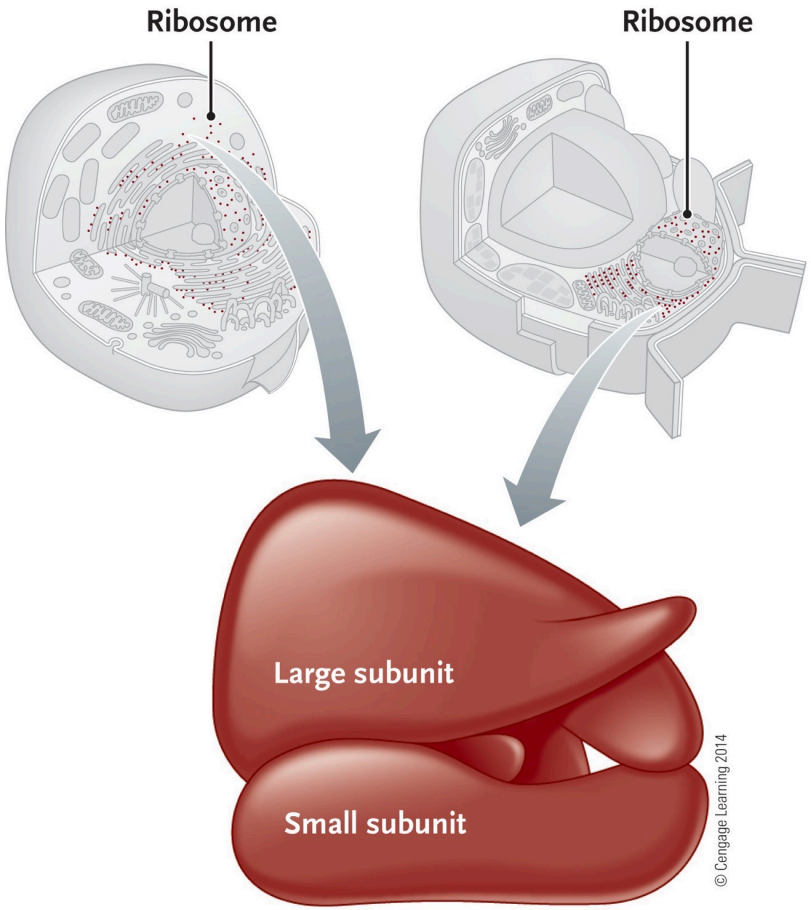
The ER is a biosynthetic factory

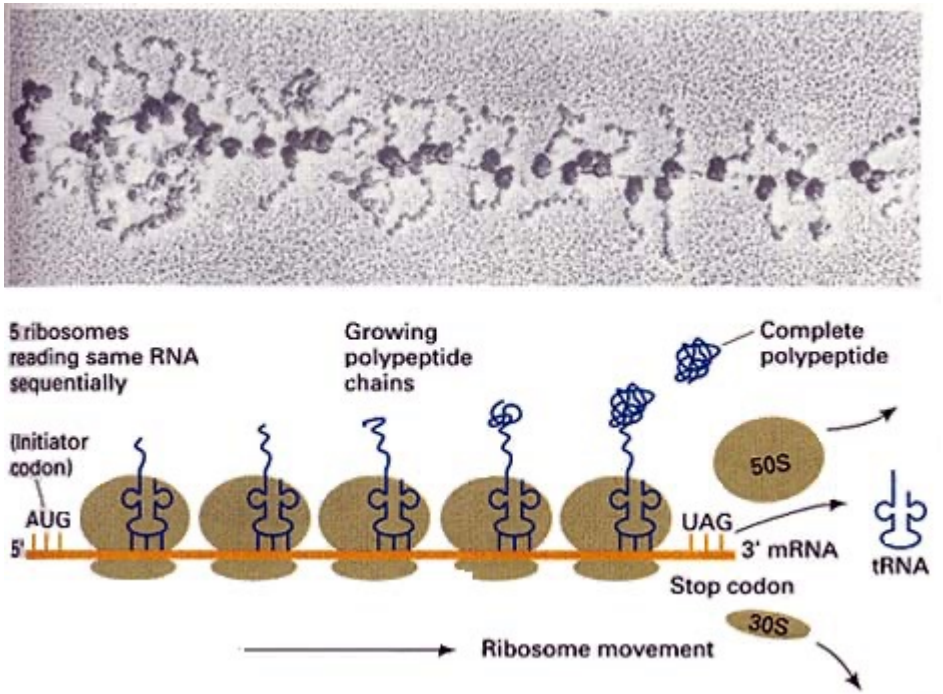
- Smooth ER is involved in a variety of diverse metabolic processes.
  - Smooth ER produces enzymes important in the synthesis of lipids, oils, phospholipids, and steroids.
  - Other enzymes help process drugs, alcohol, and other potentially harmful substances.
  - Some smooth ER helps store calcium ions.

The ER is a biosynthetic factory

- Rough ER
  - Makes additional membrane for itself
  - Makes proteins destined for secretions.
  - Protein folding unit – to produce accurate biochemical conformation

The Ribosome

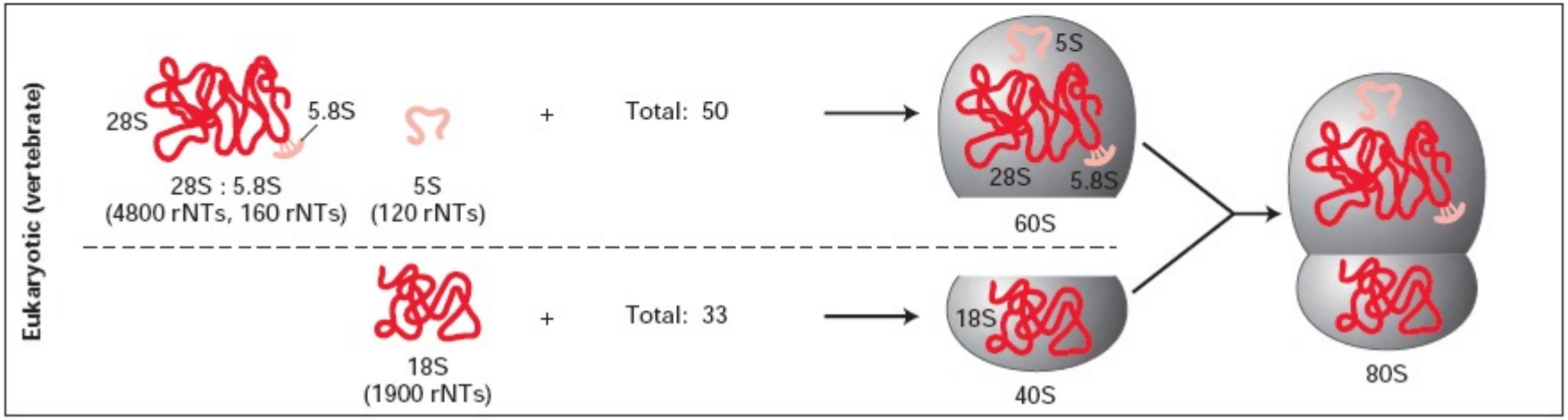




Protein Translation

Ribosomes make proteins for use in the cell and export

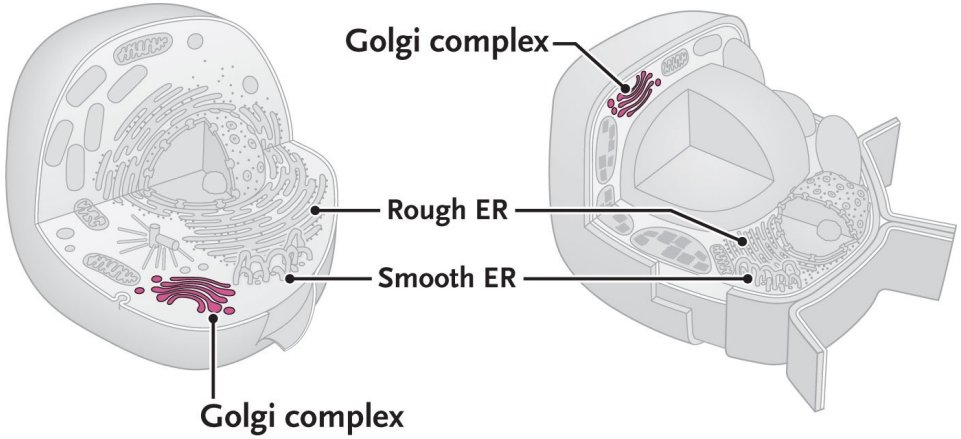
- **Ribosomes** are involved in the cell's protein synthesis.
  - Ribosomes are synthesized from rRNA produced in the nucleolus.
  - Cells that must synthesize large amounts of protein have a large number of ribosomes.

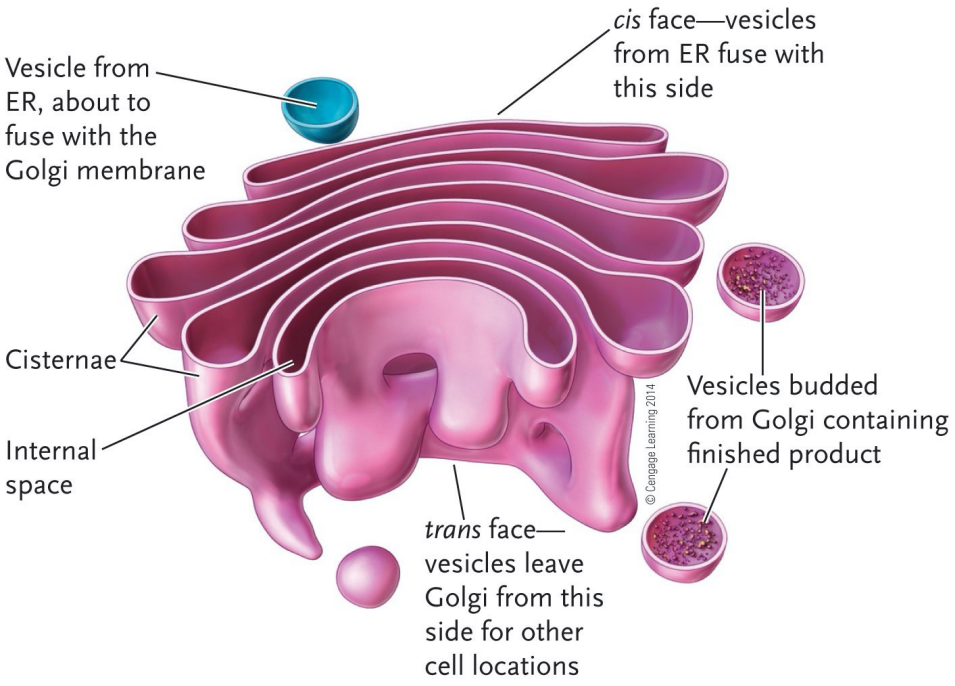


Ribosomes make proteins for use in the cell and export

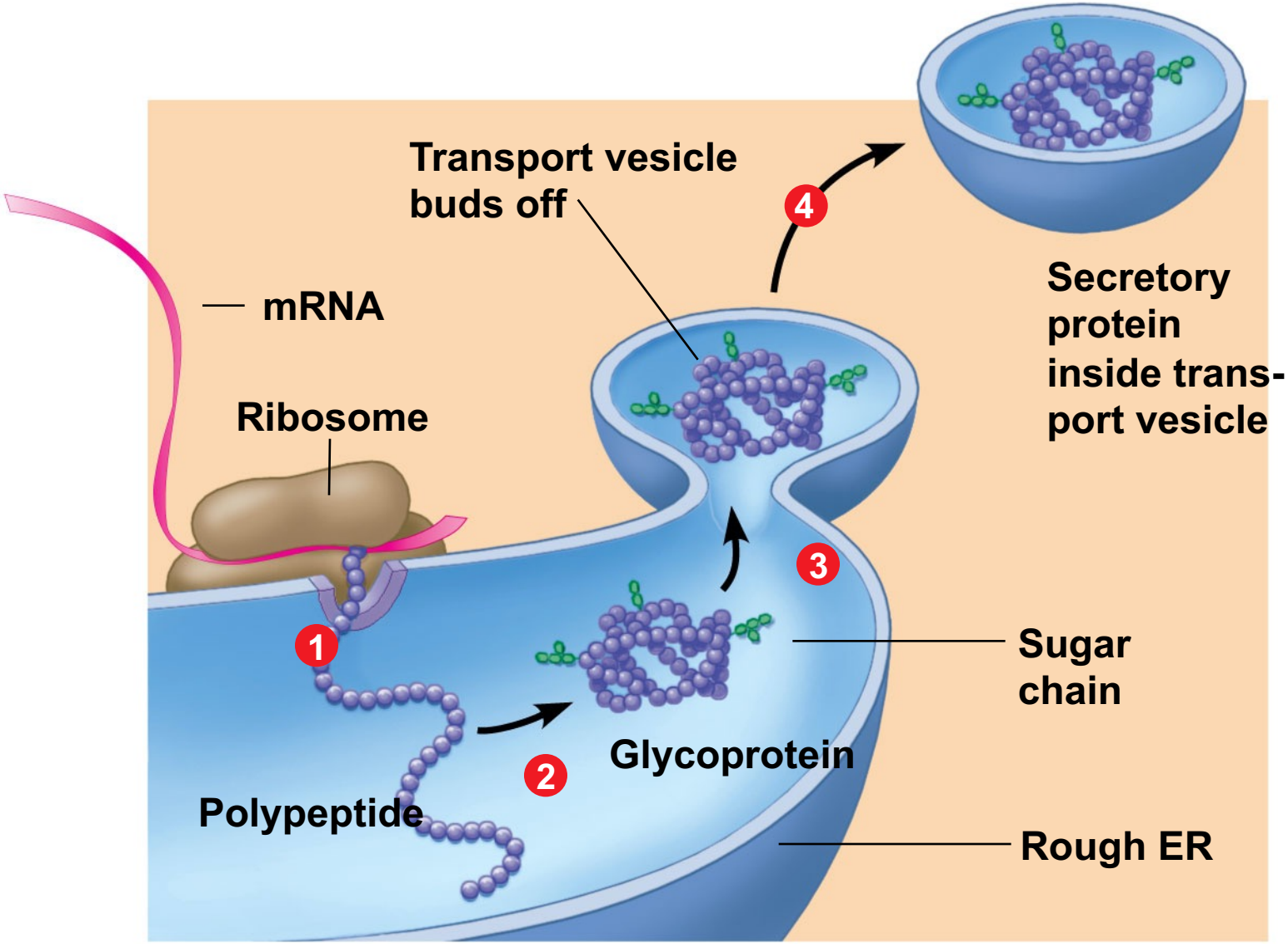
- Some ribosomes are free ribosomes; others are bound.
  - *Free ribosomes* are
    - suspended in the cytoplasm and
    - typically involved in making proteins that function within the cytoplasm.
  - *Bound ribosomes* are
    - attached to the endoplasmic reticulum (ER) associated with the nuclear envelope and
    - associated with proteins packed in certain organelles or exported from the cell.

Golgi Apparatus





Biophoto Associates/Photo Researchers, Inc.



Retrieved from Chapter 4 A tour of the cell (P.99) of Campbell Biology: Concepts and Connections, 7th edition.
Jane B. Reece, Martha R. Taylor, Eric J. Simon, Jean L. Dickey.

The Golgi Complex

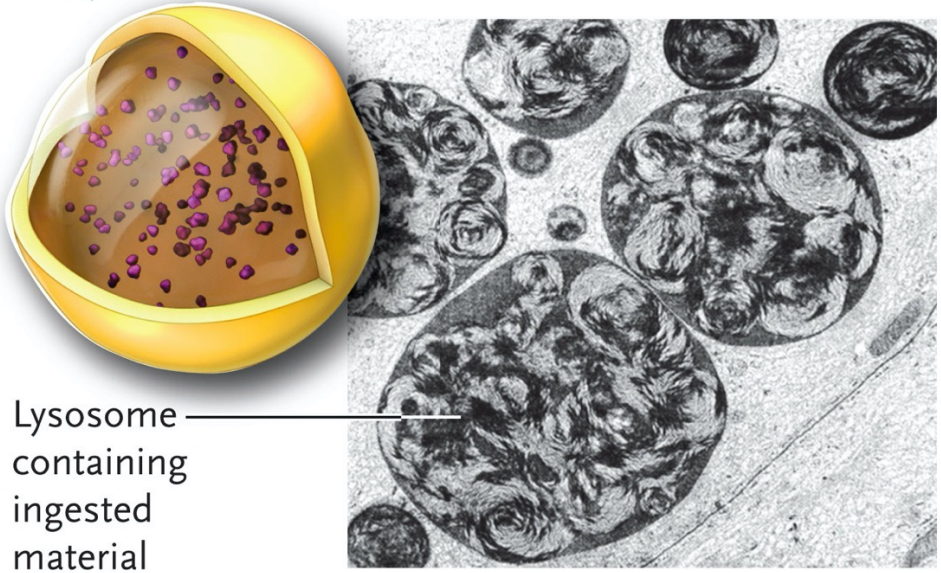
- The **Golgi complex,** closely related to the ER in proximity and function, consists of a stack of flattened vesicles known as *cisternae*

- It plays an important role in processing and packaging secretory proteins, and in complex polysaccharide synthesis

- It accepts vesicles that bud off of the ER

Lysosome

Lysosome



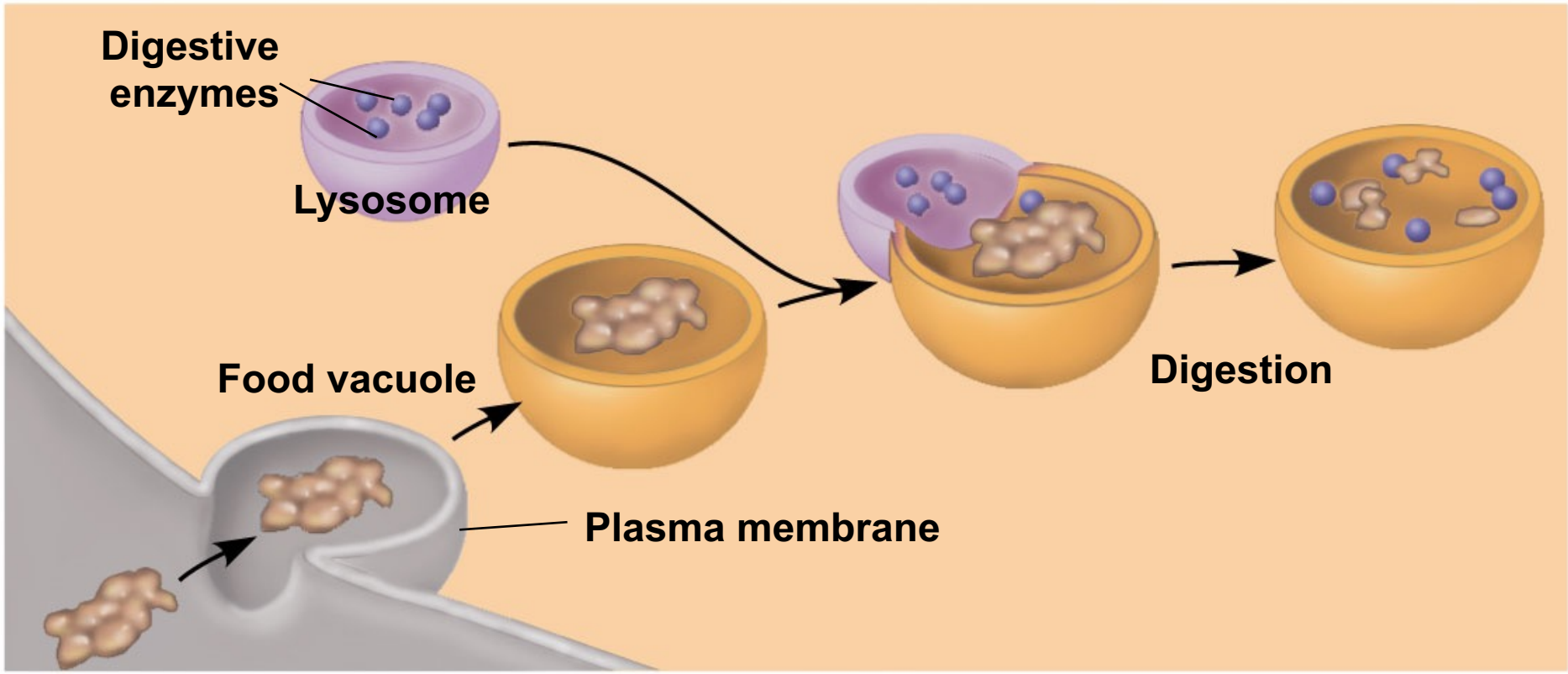
Lysosome containing ingested material

Lysosomes are digestive compartments

- A **lysosome** is a membranous sac containing digestive enzymes.
  - The enzymes and membrane are produced by the ER and transferred to the Golgi apparatus for processing.
  - The membrane serves to safely isolate these potent enzymes (*hydrolases*) from the rest of the cell.

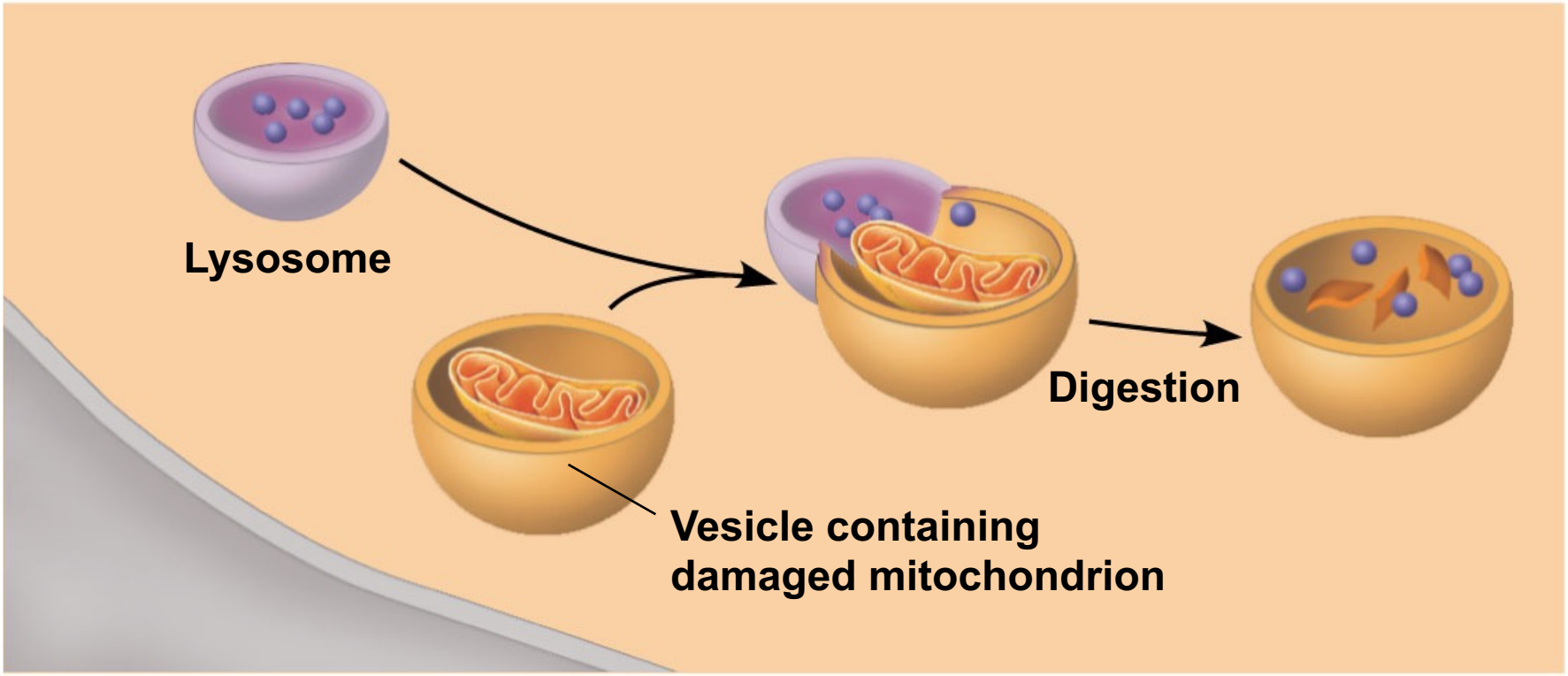
Lysosomes are digestive compartments

- Lysosomes help digest food particles engulfed by a cell.
  1. A food vacuole binds with a lysosome.
  2. The enzymes in the lysosome digest the food.
  3. The nutrients are then released into the cell.


Digestive enzymes
Lysosome
Food vacuole
Plasma membrane
Digestion

Lysosomes are digestive compartments

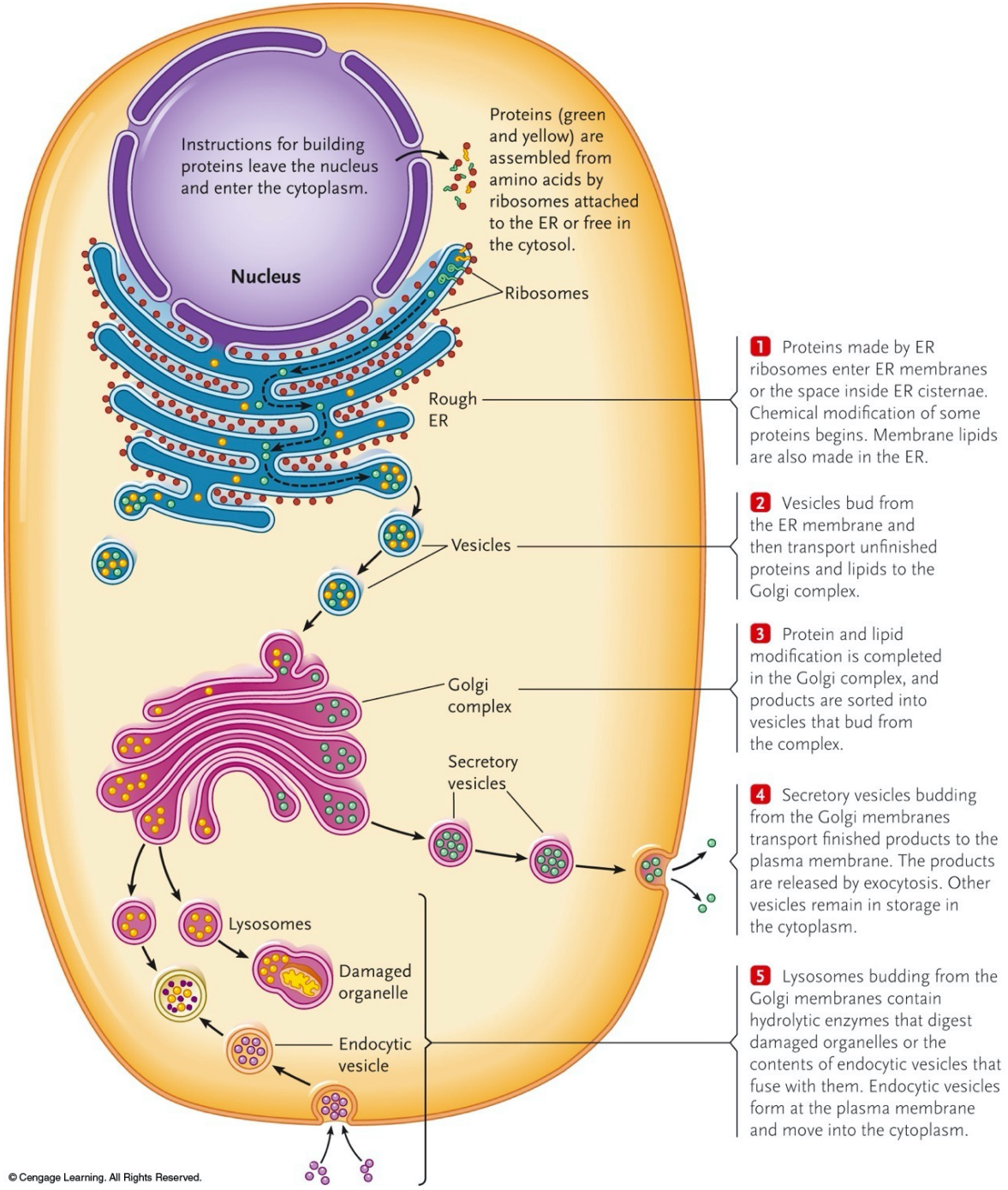
- Lysosomes also help remove or recycle damaged parts of a cell.
  1. The damaged organelle is first enclosed in a membrane vesicle.
  2. Then a lysosome
     - fuses with the vesicle,
     - dismantles its contents, and
     - breaks down the damaged organelle.


Lysosome
Digestion
Vesicle containing
damaged mitochondrion

The Endomembrane System

Cell organelles are connected through the endomembrane system

- The **endomembrane system** includes
  - the nuclear envelope,
  - endoplasmic reticulum (ER),
  - Golgi apparatus,
  - lysosomes,
  - vacuoles, and
  - the plasma membrane.

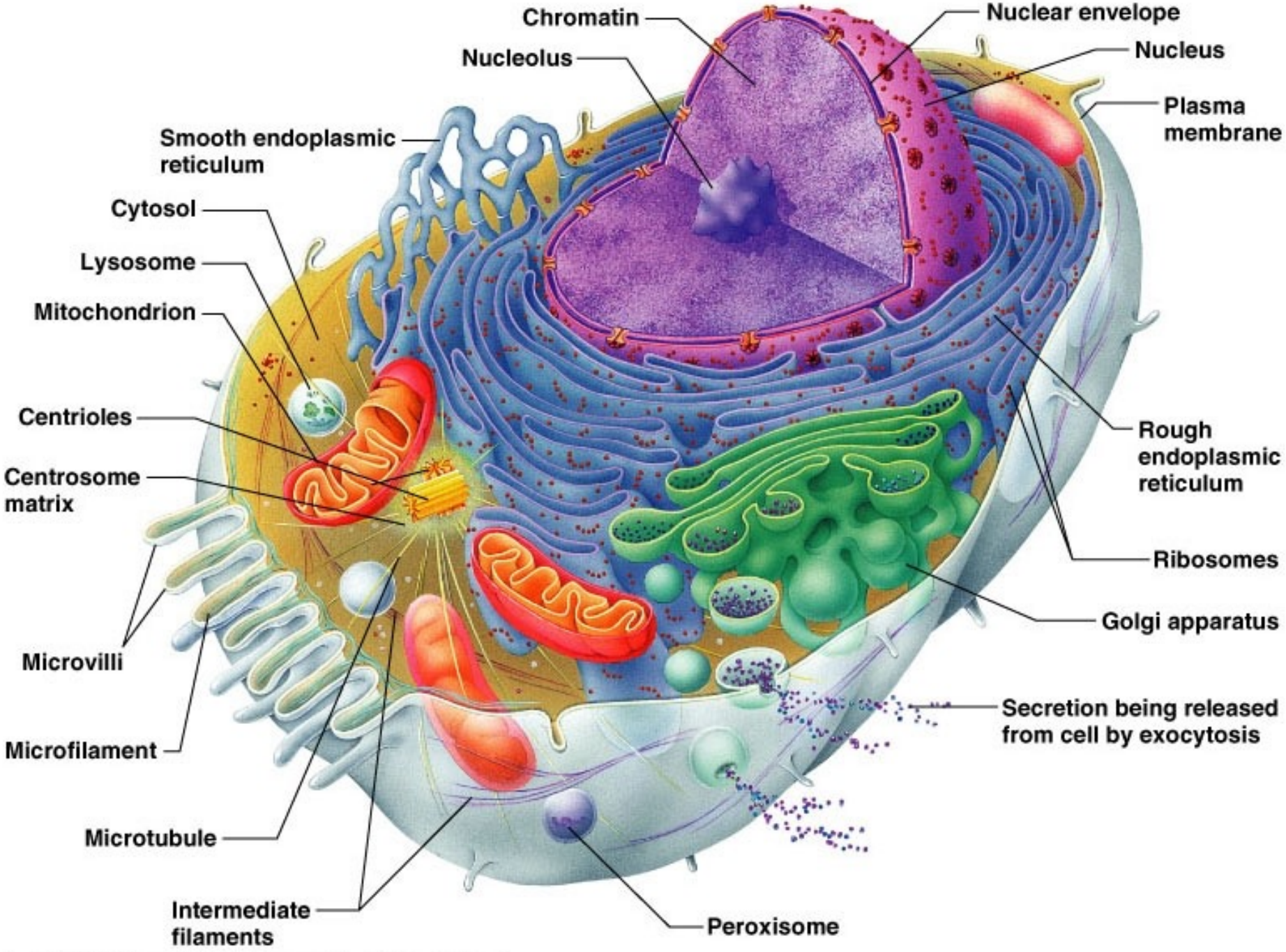


Cell organelles are connected through the endomembrane system

- Many of the membranes within a eukaryotic cell are part of the **endomembrane system**.
- Some of these membranes are physically connected and some are related by the transfer of membrane segments by tiny **vesicles** (sacs made of membrane).
- Many of these organelles work together in the
  - synthesis,
  - storage, and
  - export of molecules.

Cell organelles are connected through the endomembrane system

- The Golgi apparatus serves as a molecular warehouse and finishing factory for products manufactured by the ER.
  - Products travel in transport vesicles from the ER to the Golgi apparatus.
  - One side of the Golgi apparatus functions as a receiving dock for the product and the other as a shipping dock.
  - Products are modified as they go from one side of the Golgi apparatus to the other and travel in vesicles to other sites.



Cytoskeleton

Cytoskeleton

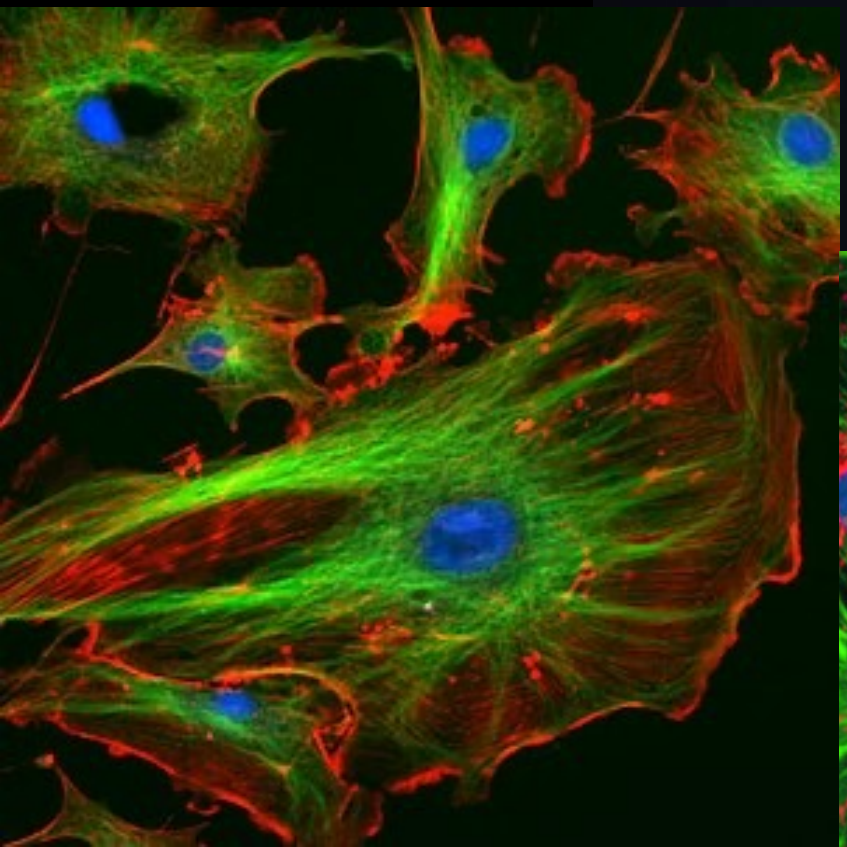
Eukaryotic cells possess a skeletal system- a cytoskeleton.

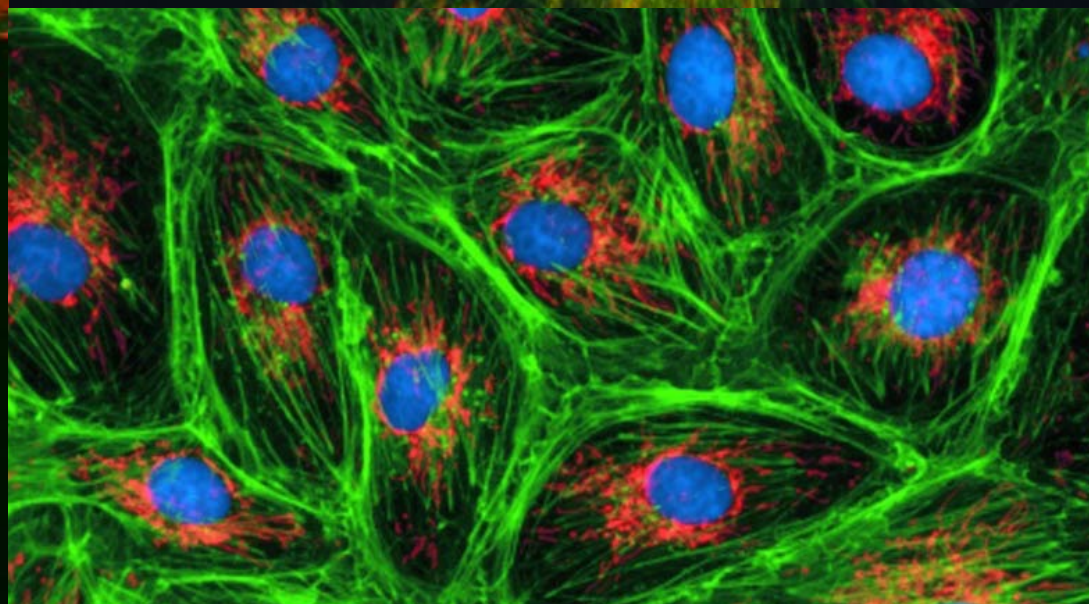
It plays a role in:

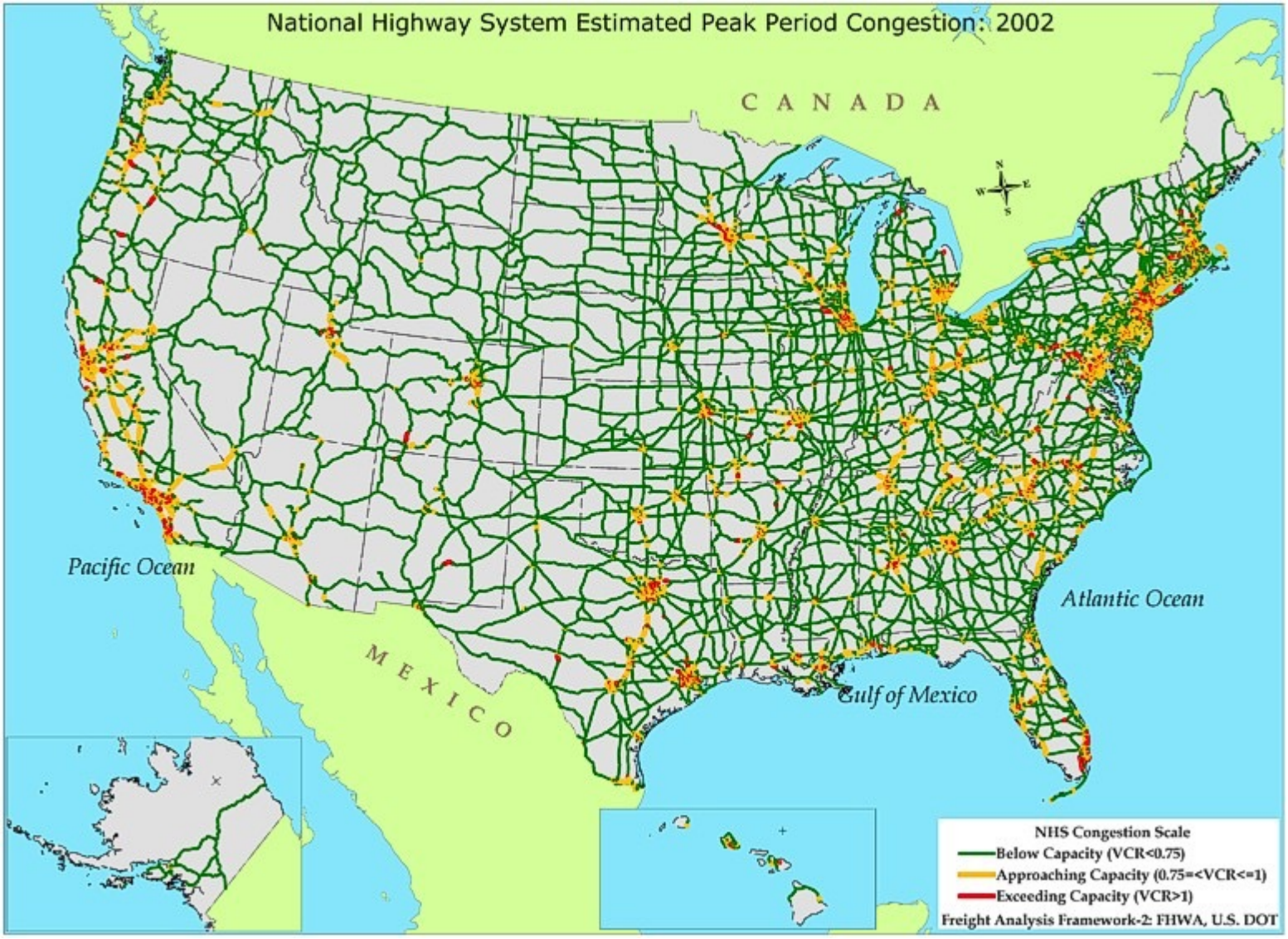
- mediating the cell movement.
- determining the shape of the cells and maintaining the cell shape.
- Providing a network for transport of materials or organelles within the cells.
- Helping cell division.

Cytoskeleton gives a cell shape and structure

- Microtubules
- Intermediate filaments
- Actin filaments



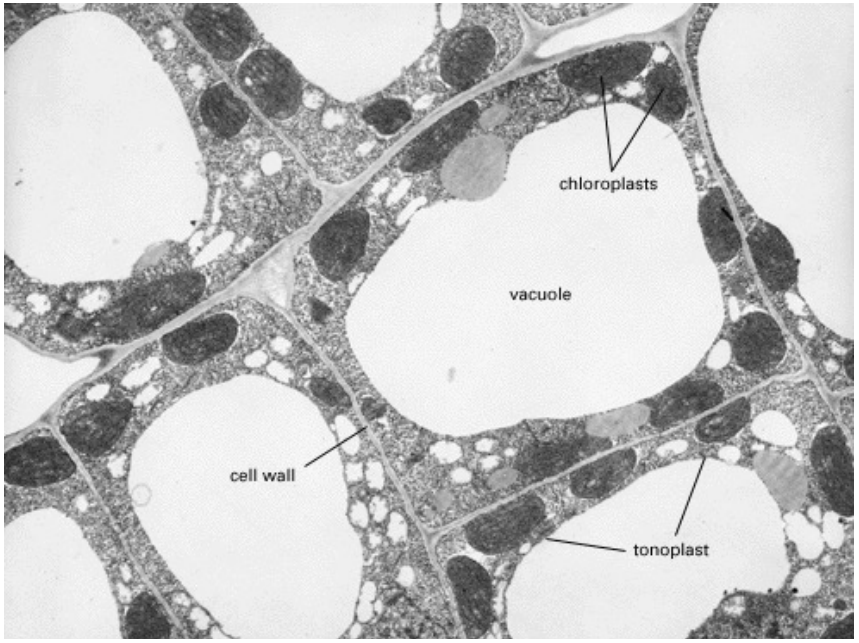



National Highway System Estimated Peak Period Congestion: 2002
CANADA
Pacific Ocean
MEXICO
Gulf of Mexico
Atlantic Ocean
NHS Congestion Scale
Below Capacity (VCR<0.75)
Approaching Capacity (0.75=<VCR<=1)
Exceeding Capacity (VCR>1)
Freight Analysis Framework-2: FHWA, U.S. DOT

Vacuole

Vacuoles function in the general maintenance of the cell

- **Vacuoles** are large vesicles that have a variety of functions.
  - Some protists have contractile vacuoles that help to eliminate water from the protist.
  - In plants, vacuoles may have digestive functions, contain pigments, or contain poisons that protect the plant.



Turgidity

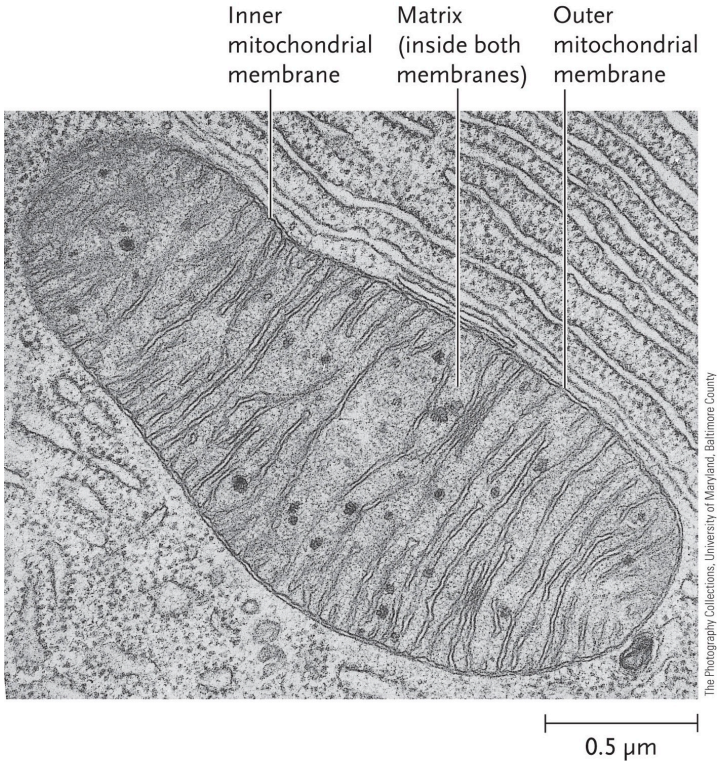
- Maintain the *turgor pressure* that keeps the plant from wilting
- Chemicals in the vacuole forming concentrated solution create the hydrostatic pressure produced within plant cell
- Tissues wilt when the central vacuole no longer presses against the cell contents (fails to provide adequate pressure)

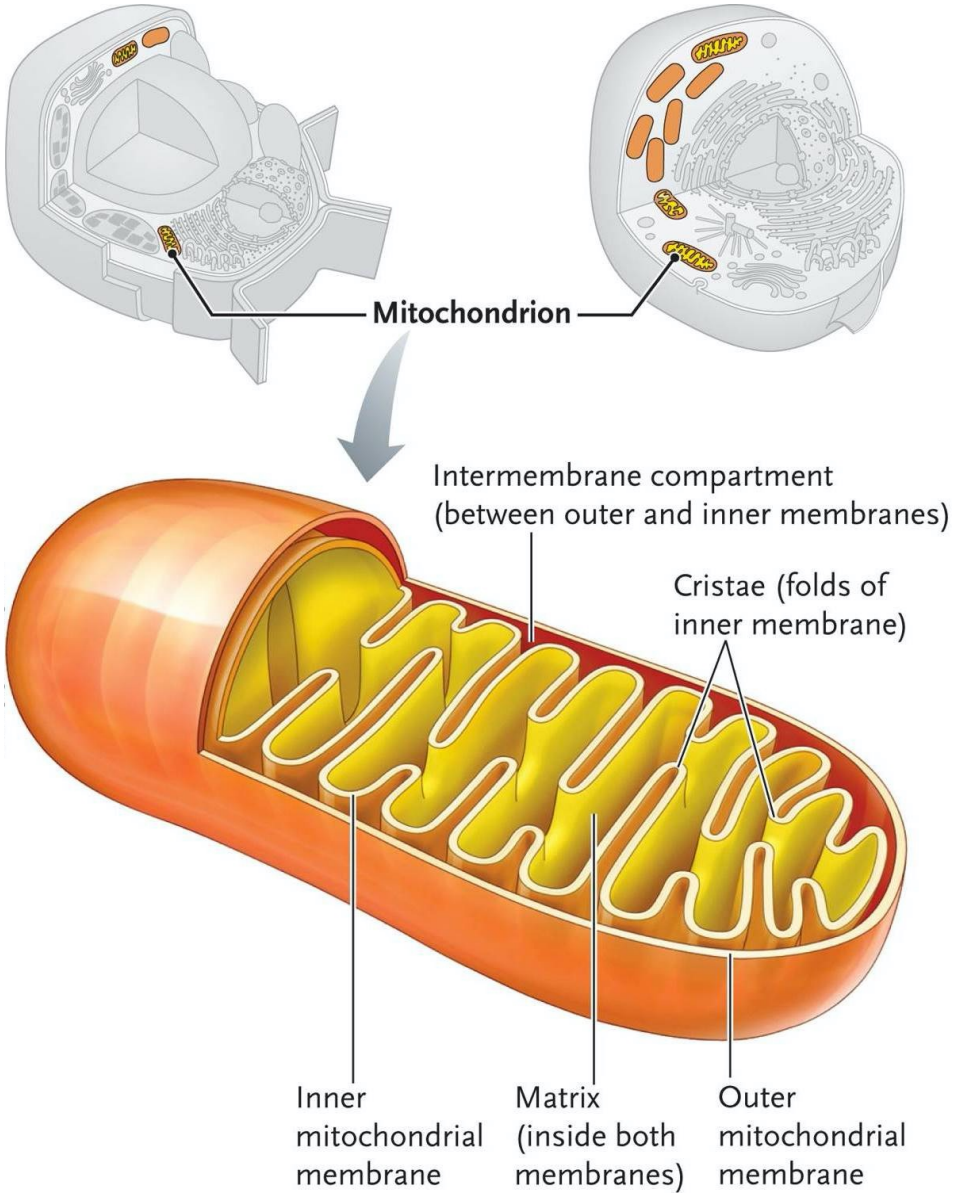
Turgid

Wilted

ENERGY-CONVERTING ORGANELLES

Mitochondria

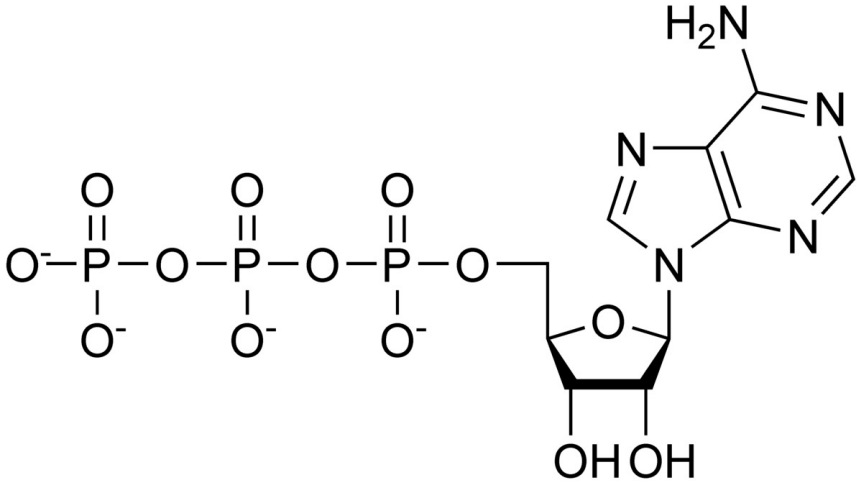

Inner mitochondrial membrane
Matrix (inside both membranes)
Outer mitochondrial membrane
0.5 µm
The Photography Collections, University of Maryland, Baltimore County


Mitochondrion
Intermembrane compartment (between outer and inner membranes)
Cristae (folds of inner membrane)
Inner mitochondrial membrane
Matrix (inside both membranes)
Outer mitochondrial membrane

Mitochondria harvest chemical energy from food

- **Mitochondria** are organelles that carry out cellular respiration in nearly all eukaryotic cells.
- Cellular respiration converts the chemical energy in foods to chemical energy in the form of **ATP molecules** (adenosine triphosphate).

ATP

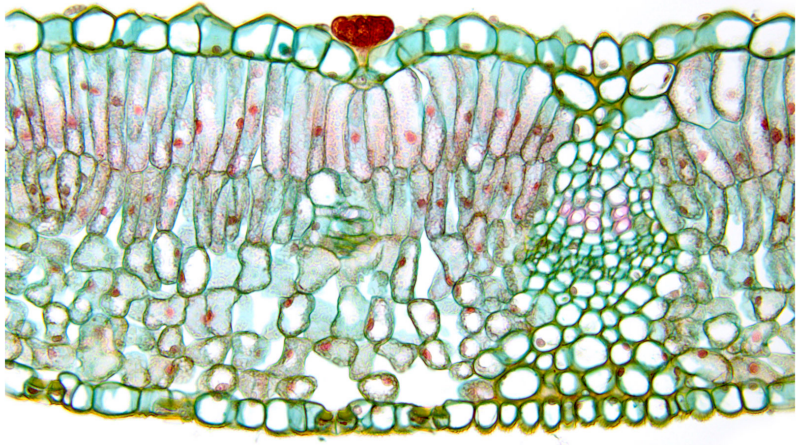


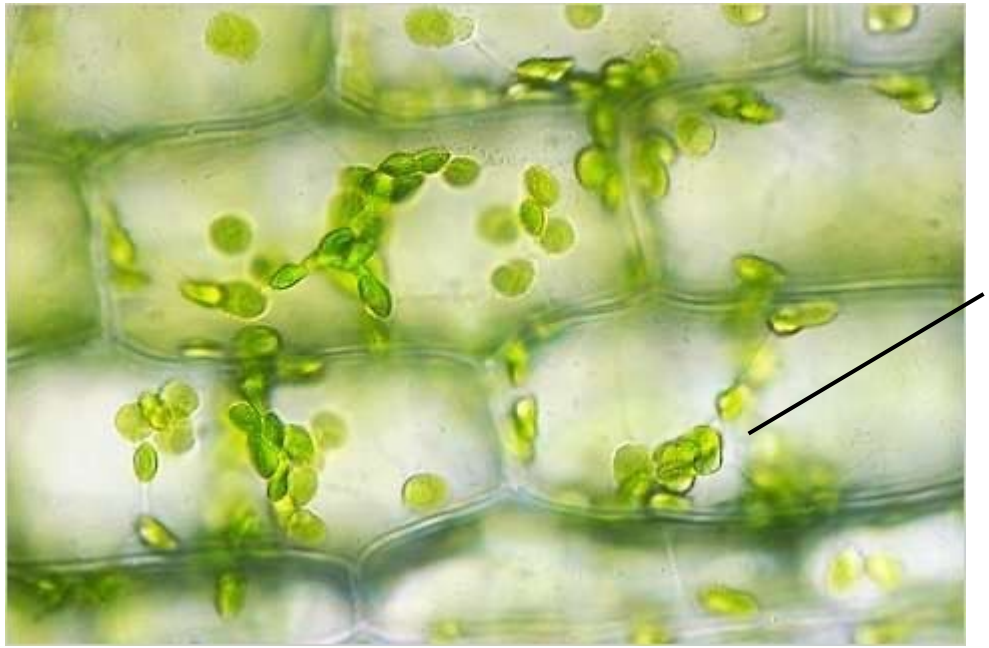
Mitochondria harvest chemical energy from food

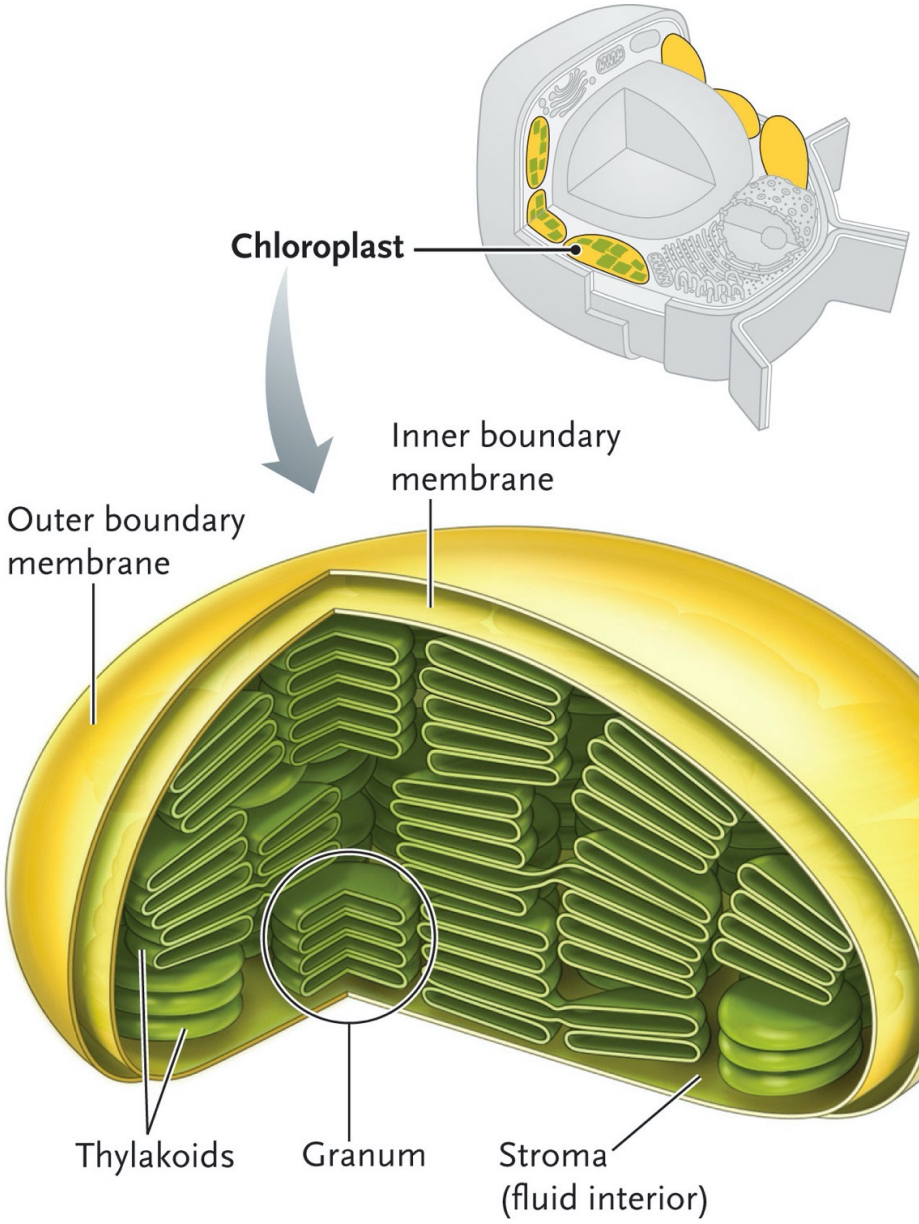
- Mitochondria have two internal compartments.
  1. The intermembrane space is the narrow region between the inner and outer membranes.
  2. The **mitochondrial matrix** contains
     - the mitochondrial DNA,
     - ribosomes, and
     - many enzymes that catalyze some of the reactions of cellular respiration.

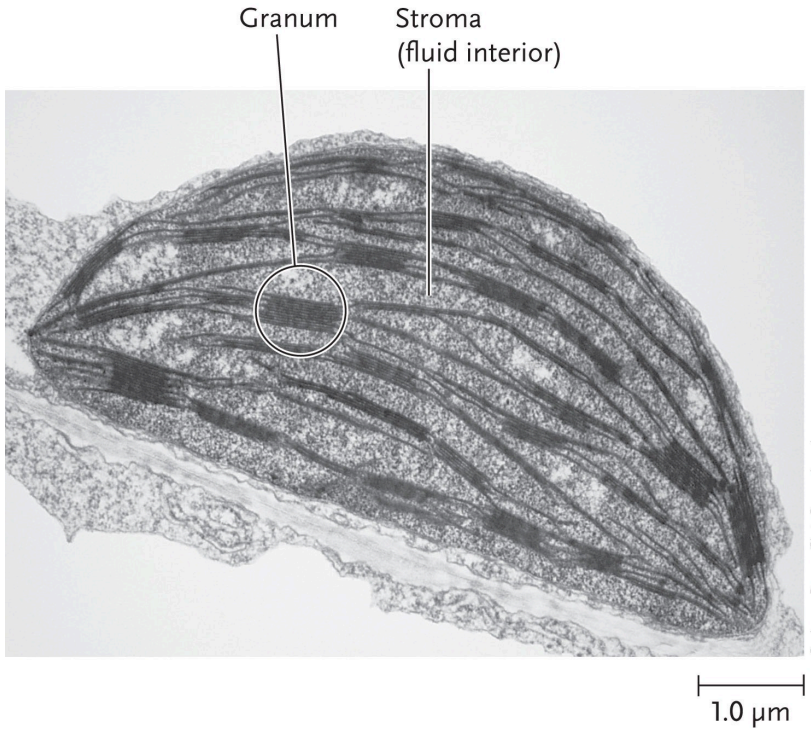
Chloroplast

Chloroplasts and the structure of a leaf









Chloroplasts convert solar energy to chemical energy

- **Chloroplasts** are the photosynthesizing organelles of all photosynthesizing eukaryotes.
- Photosynthesis is the conversion of light energy from the sun to the chemical energy of sugar molecules.

Chloroplasts convert solar energy to chemical energy

- Chloroplasts are partitioned into compartments.
  - Between the outer and inner membrane is a thin intermembrane space.
  - Inside the inner membrane is
    - a thick fluid called **stroma** that contains the chloroplast DNA, ribosomes, and many enzymes and
    - a network of interconnected sacs called **thylakoids**.
    - In some regions, thylakoids are stacked like poker chips. Each stack is called a **granum**, where green chlorophyll molecules trap solar energy.

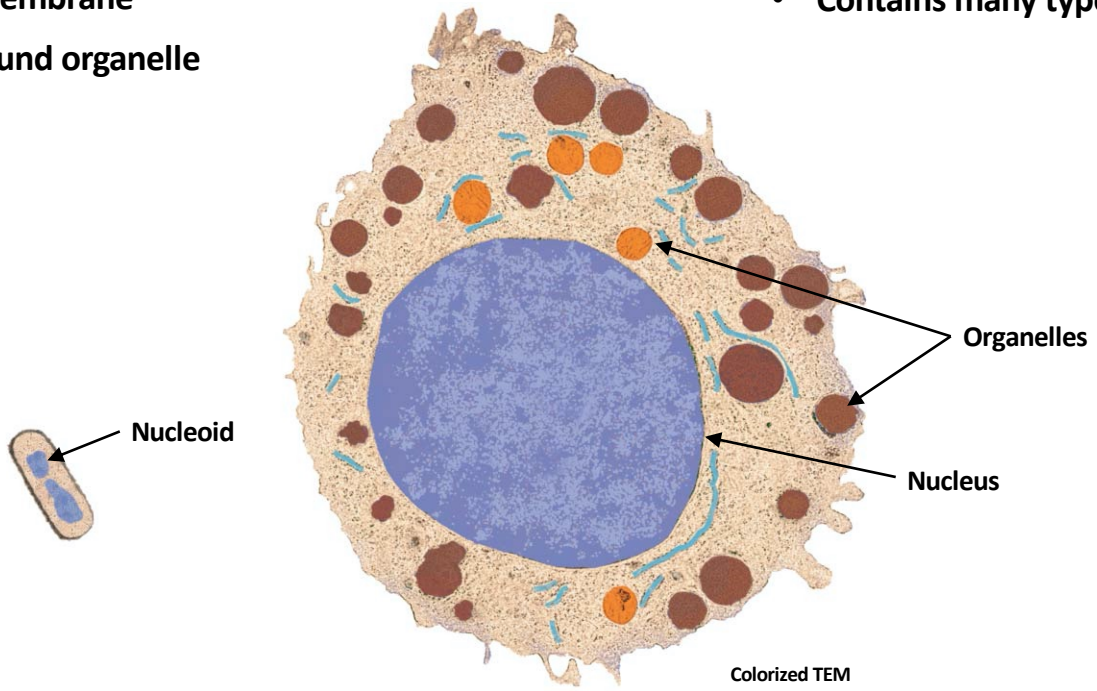
Prokaryotic vs. Eukaryotic Cells

Prokaryotic cell

- Older (appeared ~3.5 billion years ago)
- Smaller
- Simpler structure
- DNA concentrated in nucleoid region, which is not enclosed by membrane
- Lacks membrane-bound organelle

Eukaryotic cell

- Younger (appeared ~2.1 billion years ago)
- Larger
- More complex structure
- Nucleus enclosed by membrane
- Contains many types of organelles



Prokaryotic cells are structurally simpler than eukaryotic cells

- The DNA of prokaryotic cells is coiled into a region called the **nucleoid**, but no membrane surrounds the DNA.
- The **surface** of prokaryotic cells may
  - be surrounded by a chemically complex cell wall,
  - have a capsule surrounding the cell wall,
  - have short projections that help attach to other cells or the substrate, or
  - have longer projections called **flagella** that may propel the cell through its liquid environment.

Eukaryotic cells are partitioned into functional compartments

- The structures and organelles of eukaryotic cells perform **four** basic functions.
  1. The nucleus and ribosomes are involved in the genetic control of the cell.
  2. The endoplasmic reticulum, Golgi apparatus, lysosomes, vacuoles, and peroxisomes are involved in the manufacture, distribution, and breakdown of molecules.

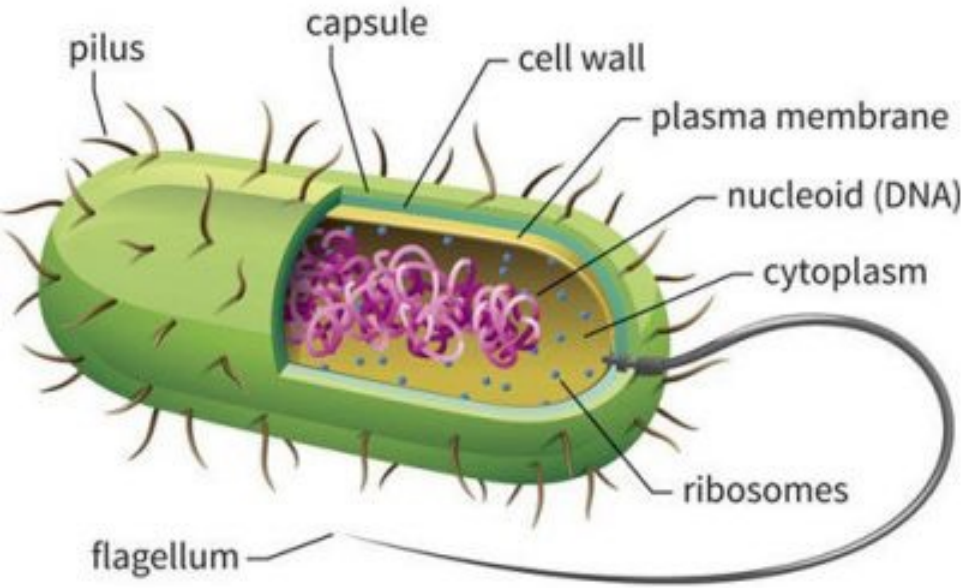
Eukaryotic cells are partitioned into functional compartments

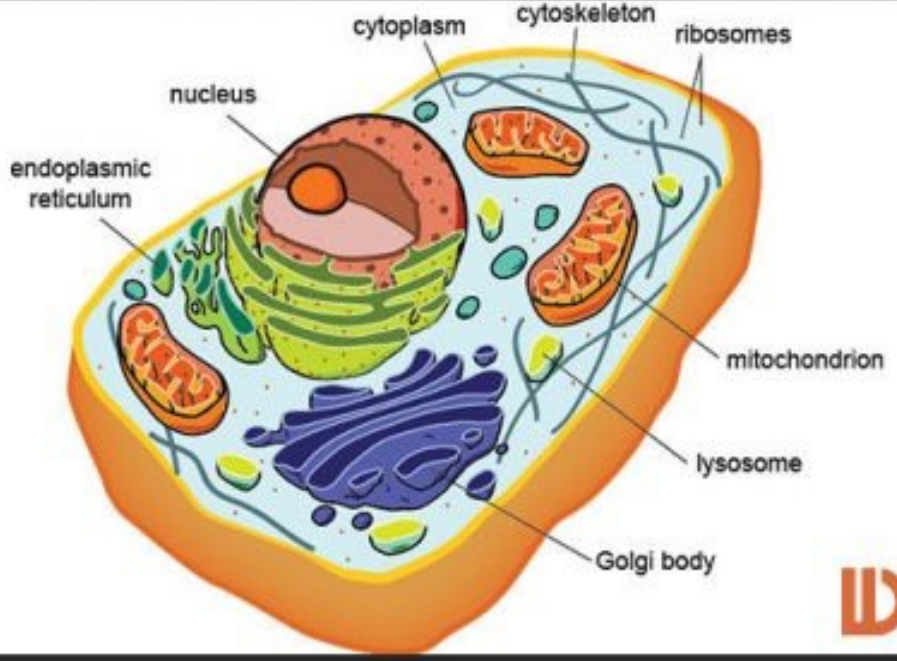
3. Mitochondria in all cells and chloroplasts in plant cells are involved in energy processing.
4. Structural support, movement, and communication between cells are functions of the cytoskeleton, plasma membrane, and cell wall.

The internal membranes of eukaryotic cells partition it into compartments.

***Cellular metabolism**, the many chemical activities of cells, occurs within organelles.*

PROKARYOTIC CELL VS EUKARYOTIC CELL





Eukaryotic cells are partitioned into functional compartments

- Almost all of the organelles and other structures of animals cells are present in plant cells.
- A few exceptions exist:
  - Lysosomes and centrioles are **not** found in plant cells.
  - Plant cells, but not animal cells, have
    - a rigid cell wall,
    - chloroplasts, and
    - a central vacuole.

Organelle	Plant/Animal or both	Job / Function
Cell Wall	Plants, Prokaryotes, NOT ANIMALS	Provides and maintains the shape of the cell and serves as a protective barrier. In plants, wall is made of **cellulose**. Bacterial cell walls are made of **peptidoglycan.**
Chloroplast	Plants, NOT ANIMALS	Uses the energy from sunlight to form glucose molecules from CO_2 and H_2O. Glucose is an energy STORAGE molecule.
Nucleus	All Eukaryotes	**Protective container for the cell's DNA.** DNA never leaves the nucleus, but messages (mRNA) can be sent to other parts of the cell.
Ribosomes	ALL CELLS	Smallest organelle found in ALL cells. **Builds proteins** by putting together long chains of Amino Acids according to the mRNA message (a copy of a piece of DNA). Thousands in each cell.
Mitochondria	All Eukaryotes	**Powerhouse of the cell.** Converts glucose into ATP, an energy molecule used in almost every reaction the cell does.
Cell Membrane	ALL CELLS	**Controls what molecules are allowed in and out of the cell.** Also called the Plasma Membrane. Made of a sea of phospholipids molecules that together form the outer barrier of the cell.
Cytoplasm (A.K.A. Cytosol)	ALL CELLS	**The liquid that fills the cell.** Contains lots of proteins and dissolved ions that are involved in many cell reactions.
Vacuole	All Eukaryotes	Basically, a membrane enclosed sac that can be filled with anything the cell needs to keep separate. **Stores food, water, etc.** In plants the vacuole also helps the cell maintain its rigidity.
Golgi Body	All Eukaryotes	Receives products from the ER and adds final **modifications**. It also **sorts** these products and **sends** them to their final destinations.
Lysosomes	All Eukaryotes	A membrane enclosed bag of digestive juices. **Breaks down large molecules** and old cell parts into their components that can be **recycled** to build new cell parts
Rough ER	All Eukaryotes	Large folded membrane system studded with ribosomes. **Ribosomes build proteins and the ER helps fold or modify them.** Products are shipped to the Golgi.
Smooth ER	All Eukaryotes	Large folded membrane system. **Puts together lipids** and is important in making new membranes.
Microtubules & Microfilaments	All Eukaryotes	Long tubes or cord-like structures **that provide the cell's internal structure and allow cell movement**. Other organelles are anchored to this network called the cytoskeleton. Work together in muscle contraction, and the motion of cilia and flagella

Inner life of the cell

Short version: https://www.youtube.com/watch?v=wJyUtbn0O5Y
Full Version: https://www.youtube.com/watch?v=B_zD3NxSsD8

END