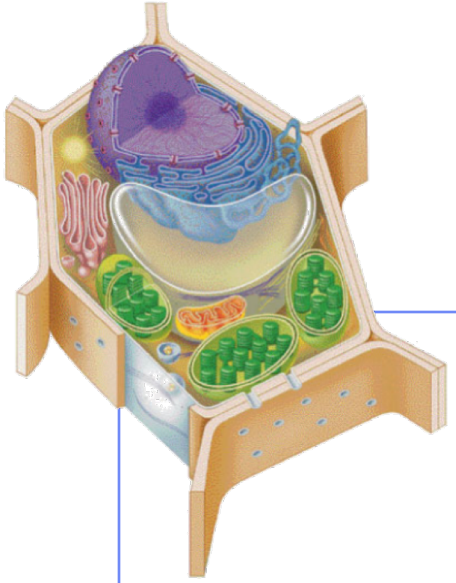
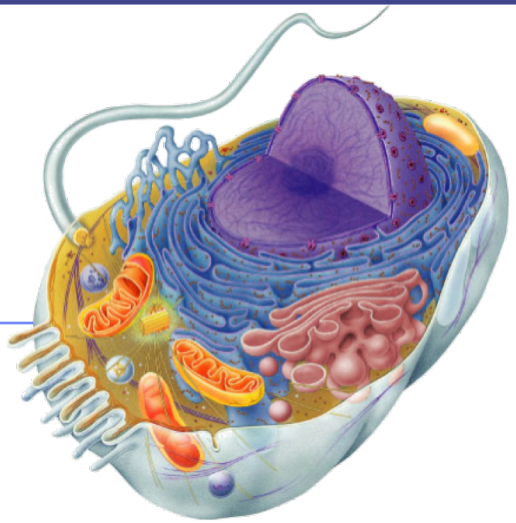
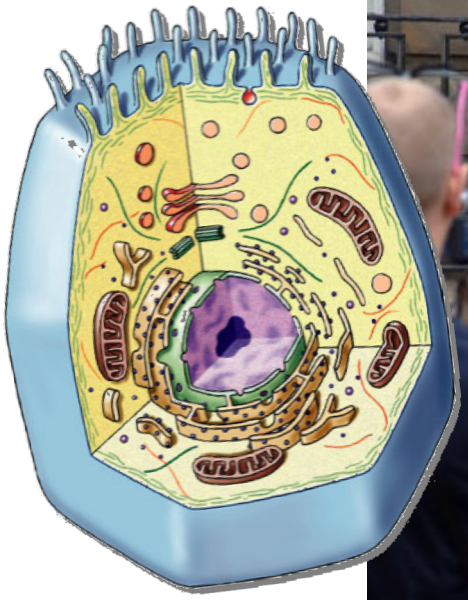


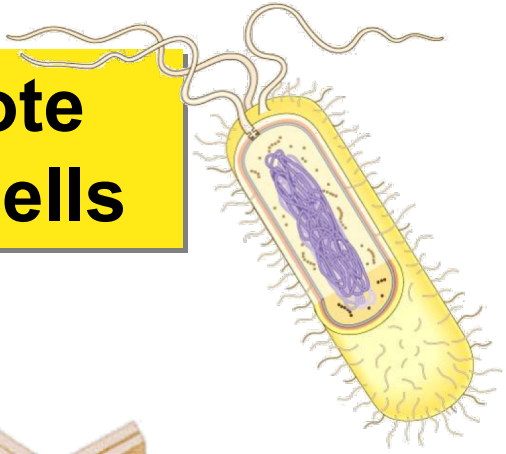


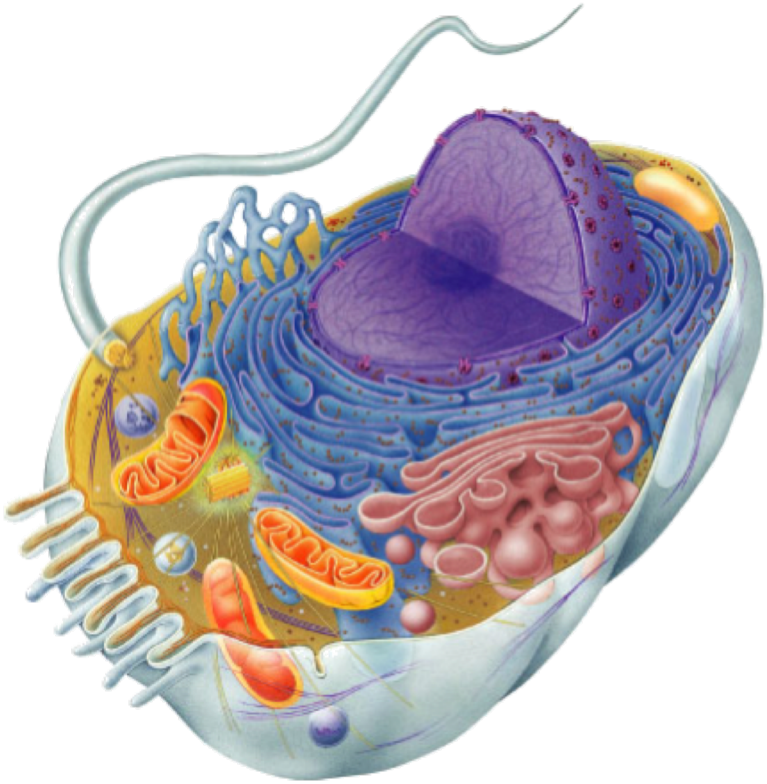
Tour of the Cell

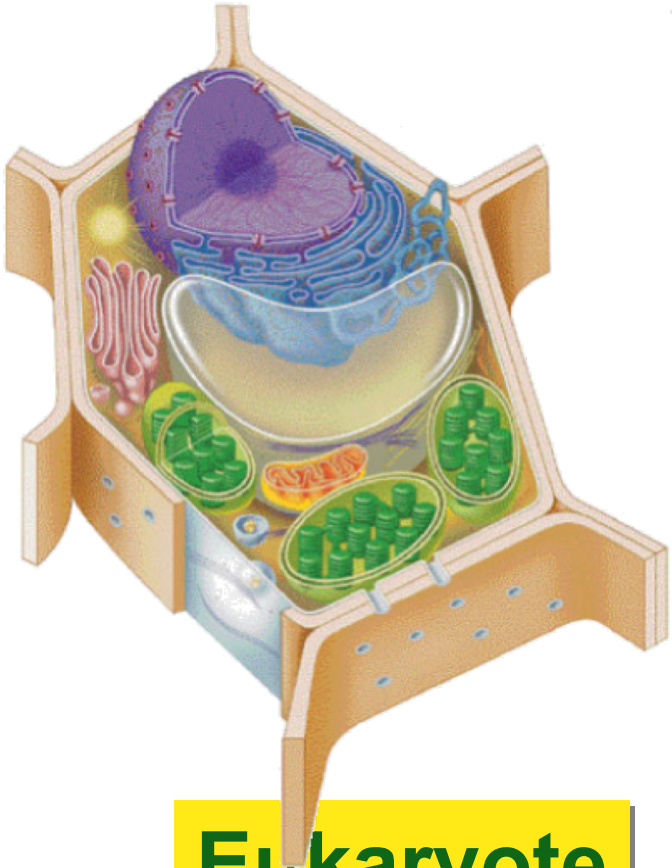


Types of cells

Prokaryote bacteria cells







Eukaryote animal cells

Eukaryote plant cells

Prokaryotic Cells

- Simple Cells. No membrane bound nucleus, and no membrane-bound organelles.
  - Genetic material (circular DNA) is found in a region of the cell known as the nucleoid. They do not have chromosomes.
- Reproduce by binary fission and produce two identical daughter cells.
- Classified in the kingdom Monera (bacteria group)
- Prokaryotic structures:
  - **Plasma Membrane:** A selective barrier around a cell composed of a double layer of phospholipids. Made of lipids, proteins, and carbohydrates.
  - **Cell Wall:** A wall or barrier that functions to shape and protect cells. Present in ALL prokaryotes.
  - **Ribosomes**: Made of RNA and they build enzyme parts (proteins). Prokaryotic cell ribosomes are smaller (70S, with 50S and 30S subunits) than eukaryotic cells (80S, with 60S and 40S subunits).
  - **Flagella**, when present, deliver motion by twisting like a screw.

Eukaryotic Cells

- More complex than Prokaryotic cells.
  - Have a membrane bound nucleus.
  - Can be unicellular or multicellular
  - Membrane bound organelles (little organs)
  - Two exclusive clubs
    - Animal cells and Plant cells

The Nucleus

- The nucleus has two phospholipid bilayers, each similar to the plasma membrane.
- The nucleus contains DNA, the hereditary information of the cell.
- Normally, the DNA is spread out within the nucleus as a thread-like matrix called chromatin.
- On the surface of the nuclear envelope are nuclear pores, which serve as passageways for proteins and RNA molecules.

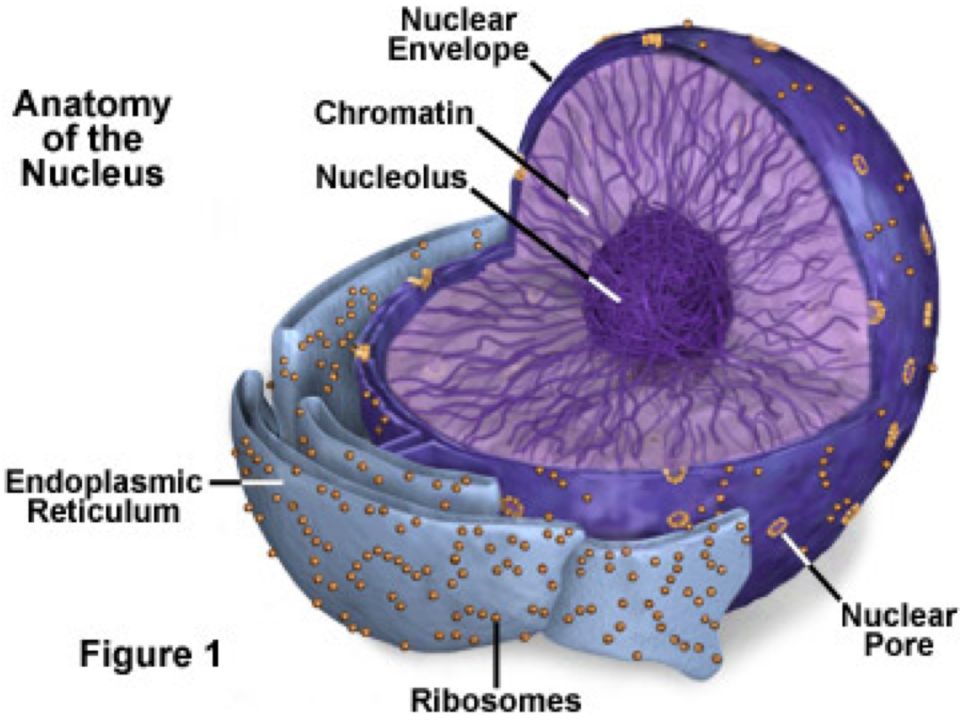
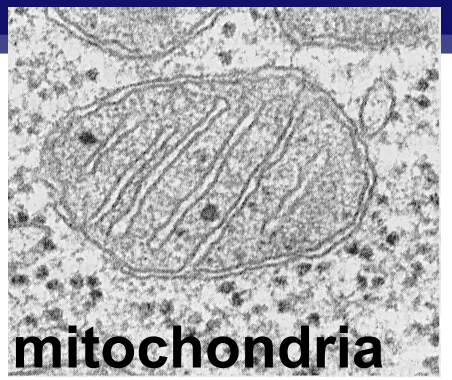
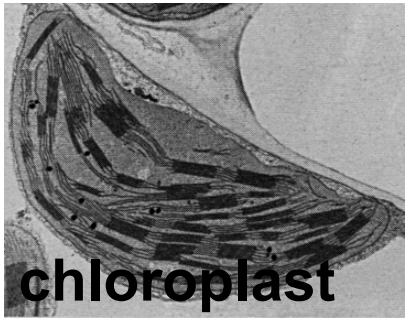


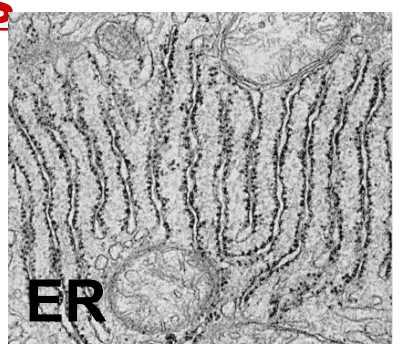
Figure 1

Why organelles?

- **Specialized structures**
  - specialized functions
    - cilia or flagella for locomotion
- **Containers**
  - partition cell into compartments
  - create different local environments
    - separate pH, or concentration of materials
  - distinct & incompatible functions
    - lysosome & its digestive enzymes
- **Membranes as sites for chemical reactions**
  - unique combinations of lipids & proteins
  - embedded enzymes & reaction centers
    - chloroplasts & mitochondria



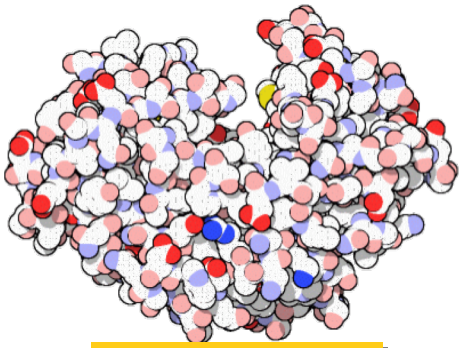




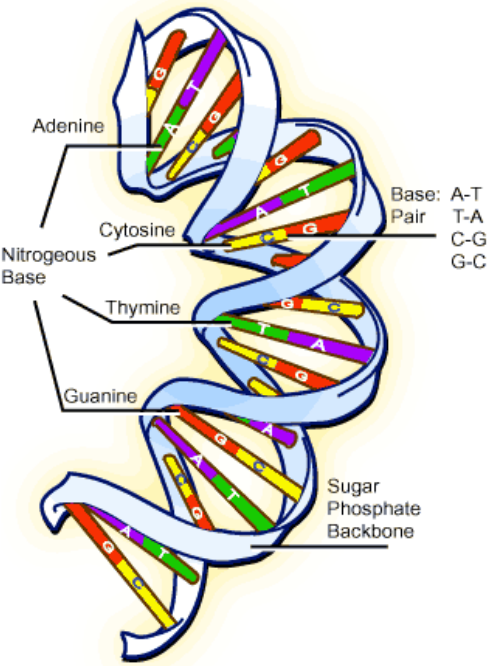
Cells gotta live!

- What jobs do cells have to do?
  - building proteins
    - proteins control every cell function
  - make energy
    - for daily life
    - for growth
  - build more cells
    - growth
    - reproduction
    - repair

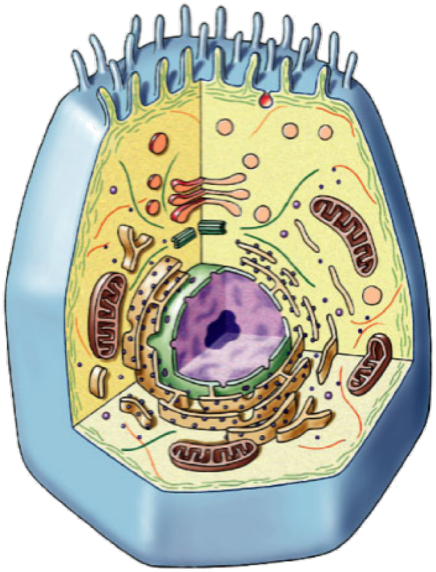
Why study protein production?



proteins



DNA



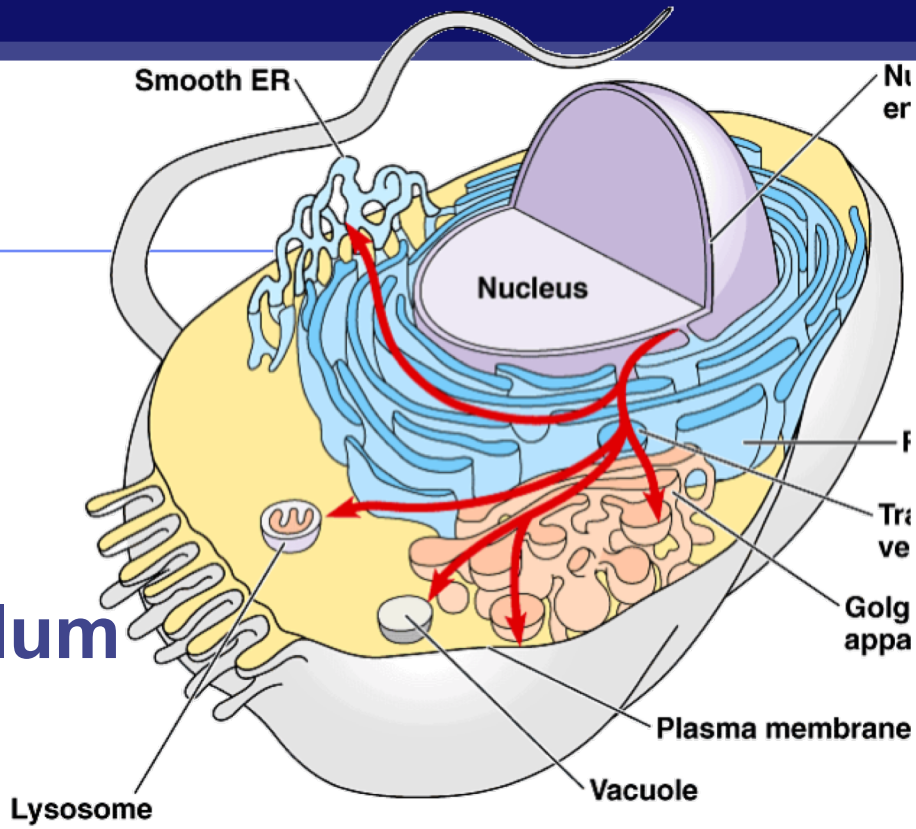
cells

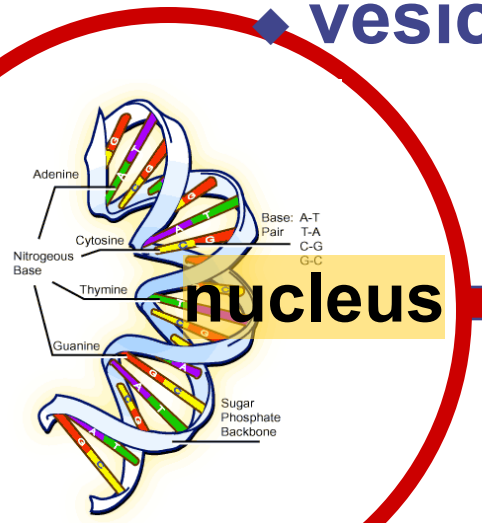
organism

Repeat after me…
DNA gets the glory, but Proteins do all the work!

Building Proteins

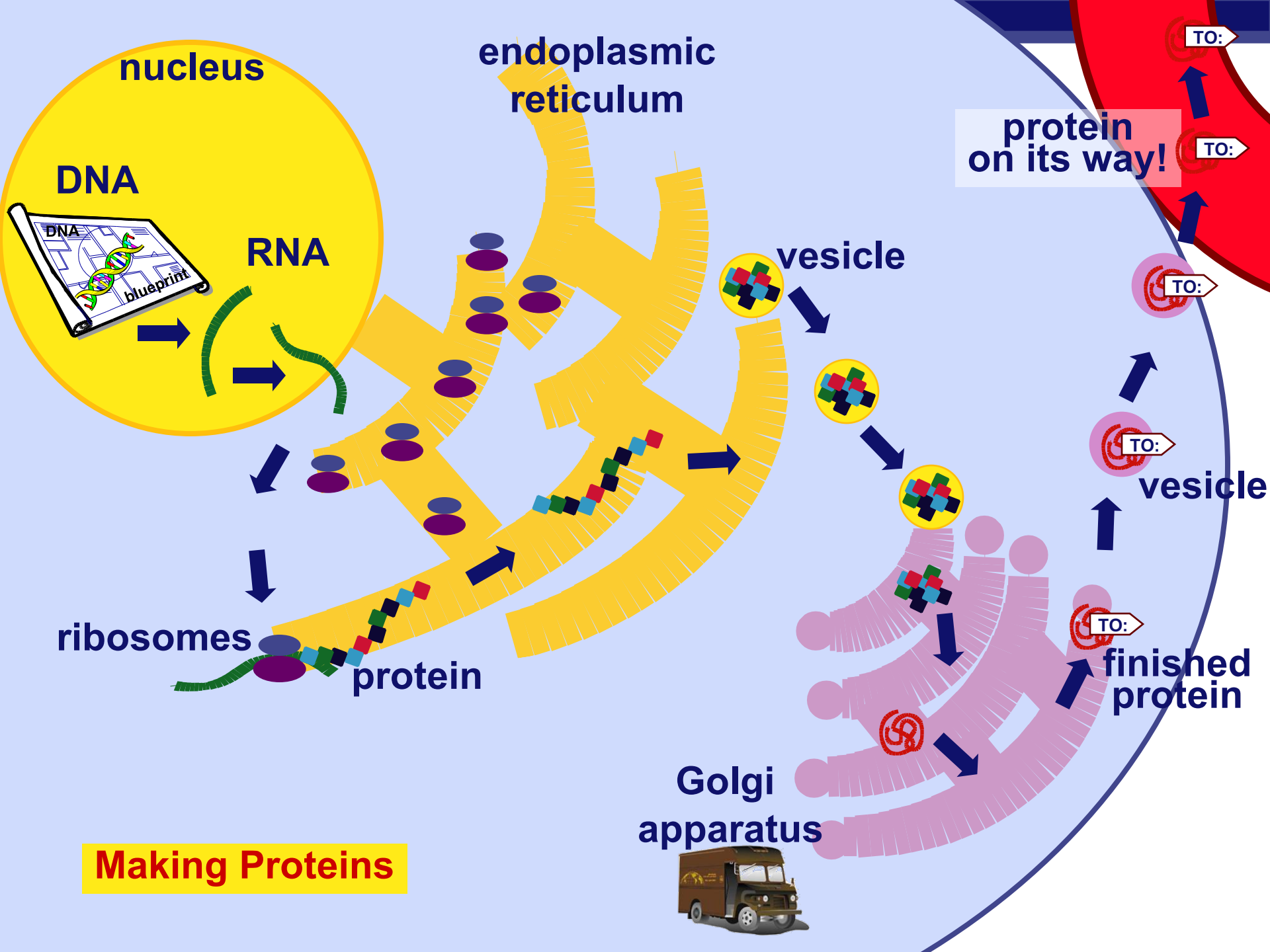
- Organelles involved
  - nucleus
  - ribosomes
  - endoplasmic reticulum (ER)
  - Golgi apparatus
  - vesicles



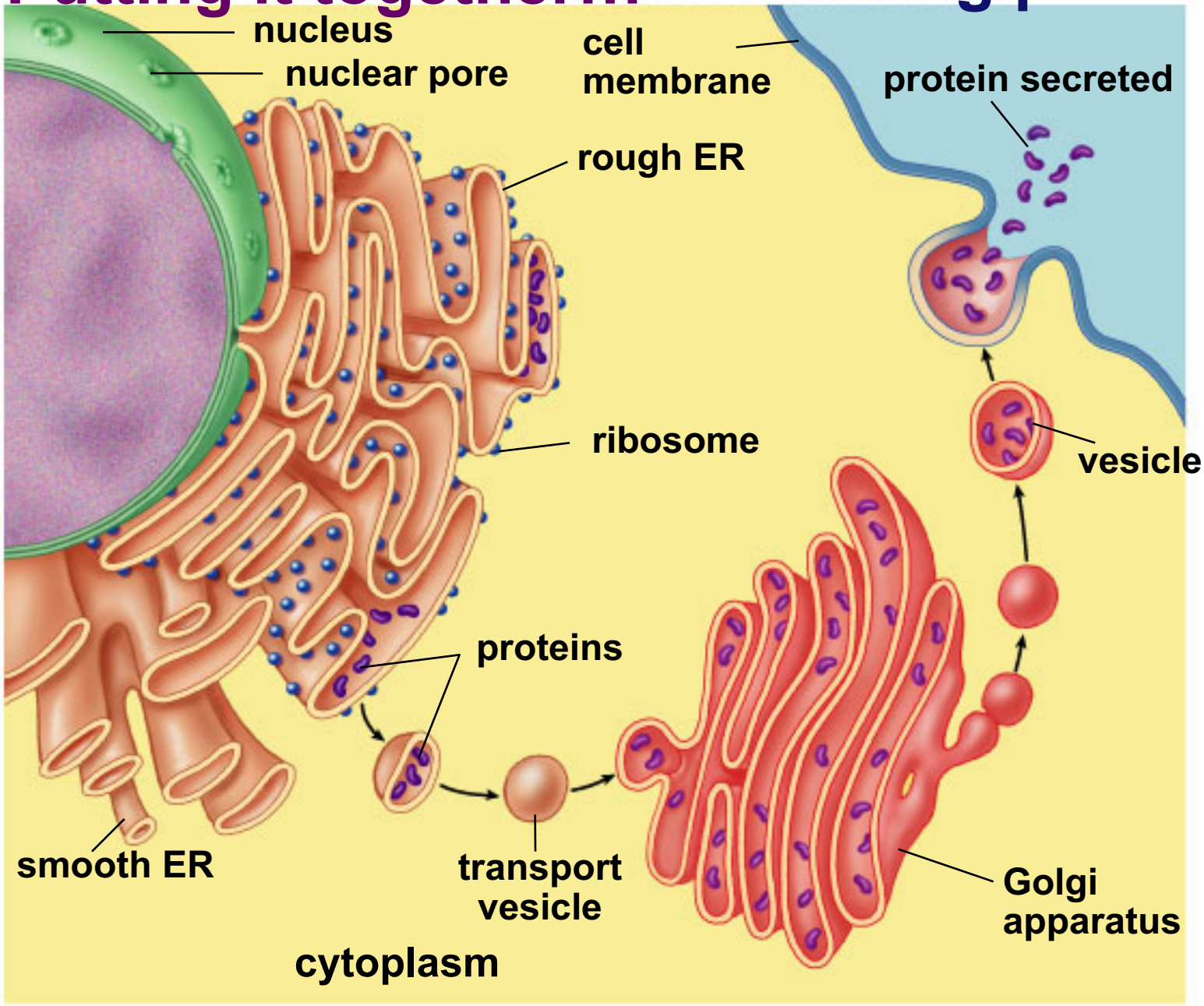


The Protein Assembly Line

nucleus → ribosome → ER → Golgi apparatus → vesicles

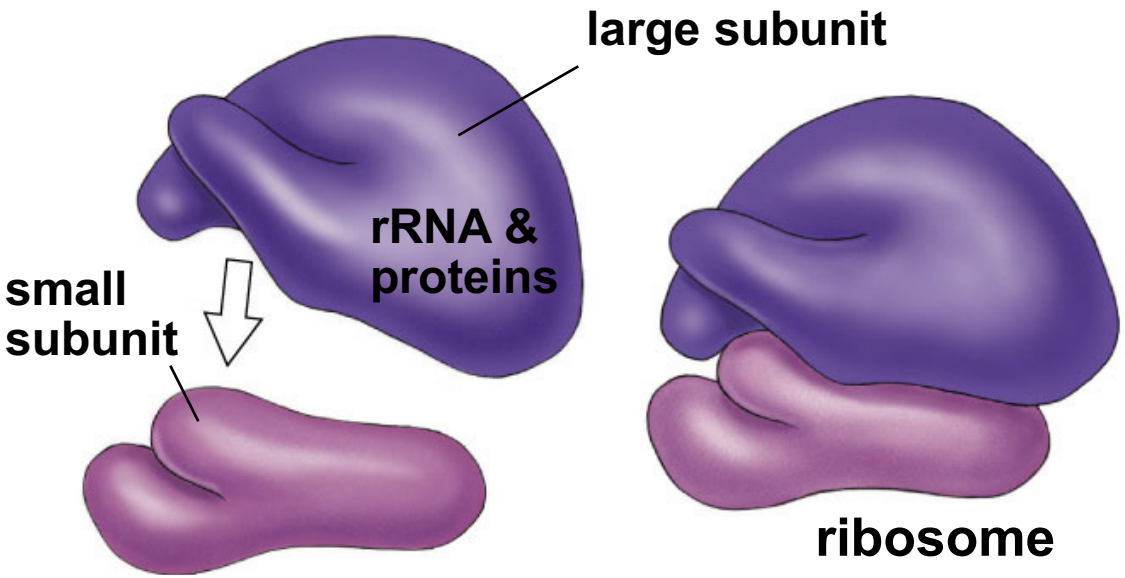

nucleus
DNA
DNA
blueprint
RNA
endoplasmic reticulum
ribosomes
protein
vesicle
Golgi apparatus
protein on its way!
TO:
TO:
TO:
TO:
vesicle
TO:
finished protein
Making Proteins

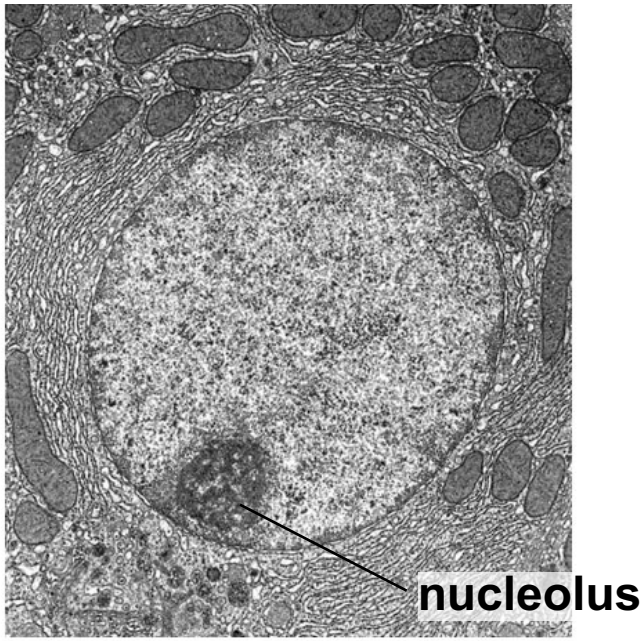
Putting it together… Making proteins



Nucleolus

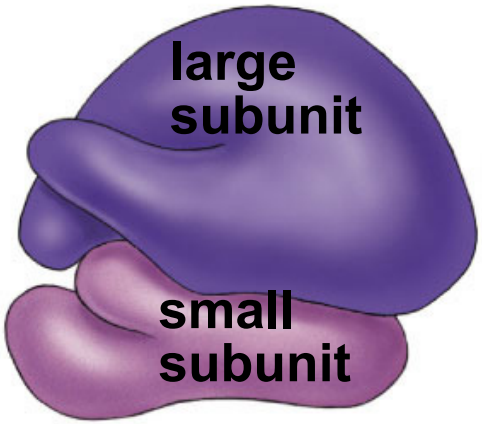
- Function
  - ribosome production
    - build ribosome subunits from rRNA & proteins
    - exit through nuclear pores to cytoplasm & combine to form functional ribosomes

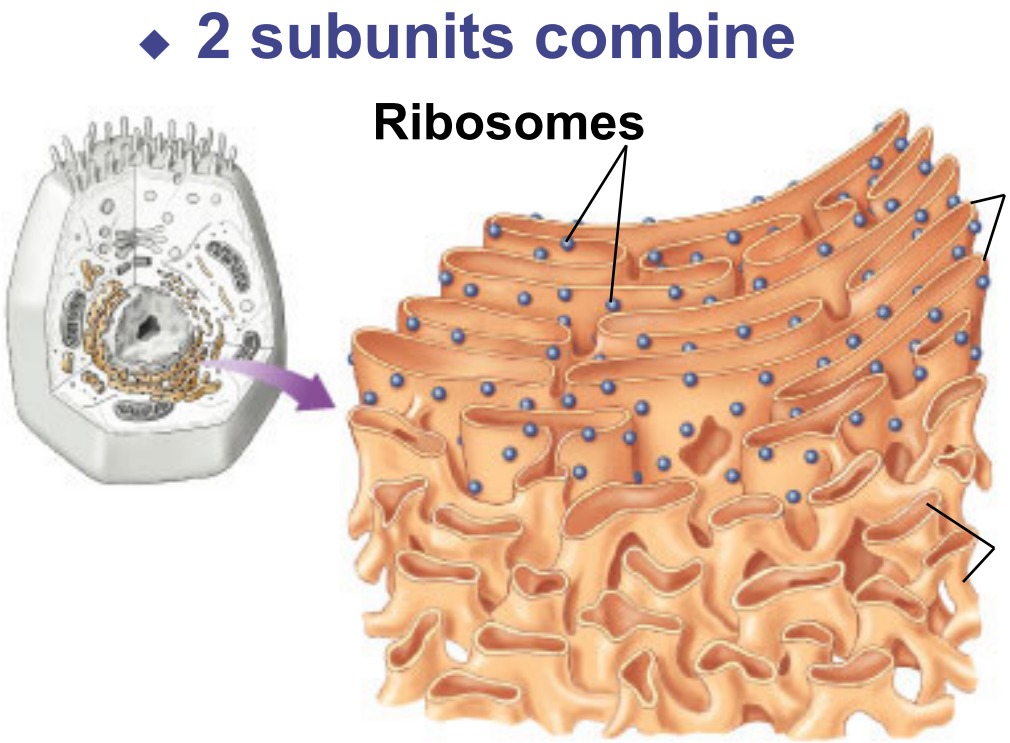


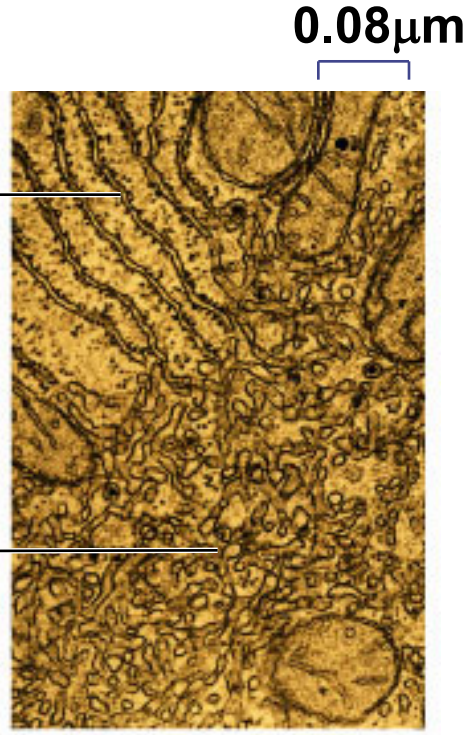


Ribosomes

- Function
  - protein production
- Structure
  - rRNA & protein
  - 2 subunits combine

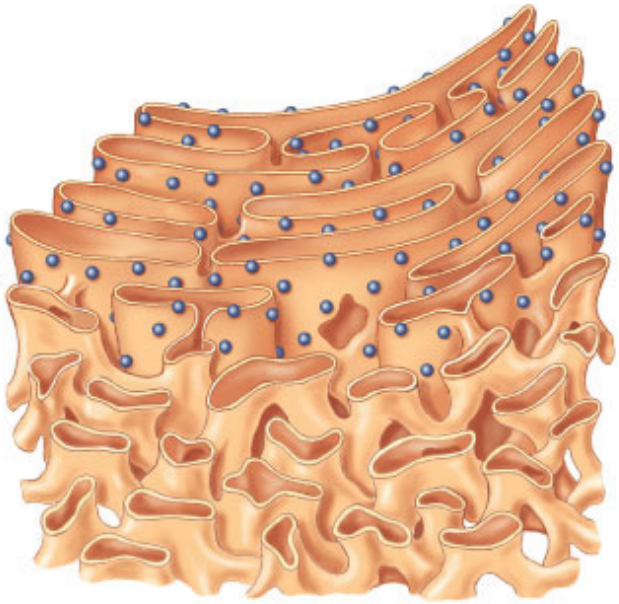


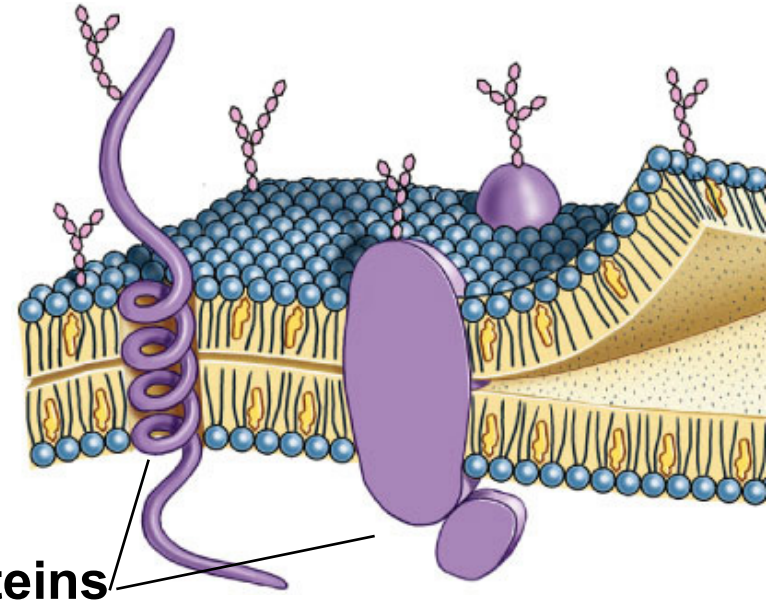




Types of Ribosomes

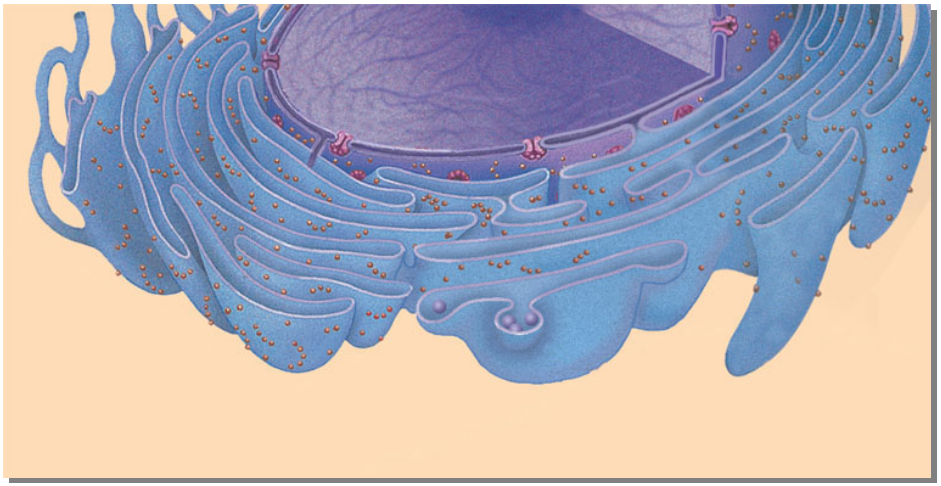
- **Free ribosomes**
  - suspended in cytosol
  - synthesize proteins that function in cytosol
- **Bound ribosomes**
  - attached to endoplasmic reticulum
  - synthesize proteins for export or for membranes



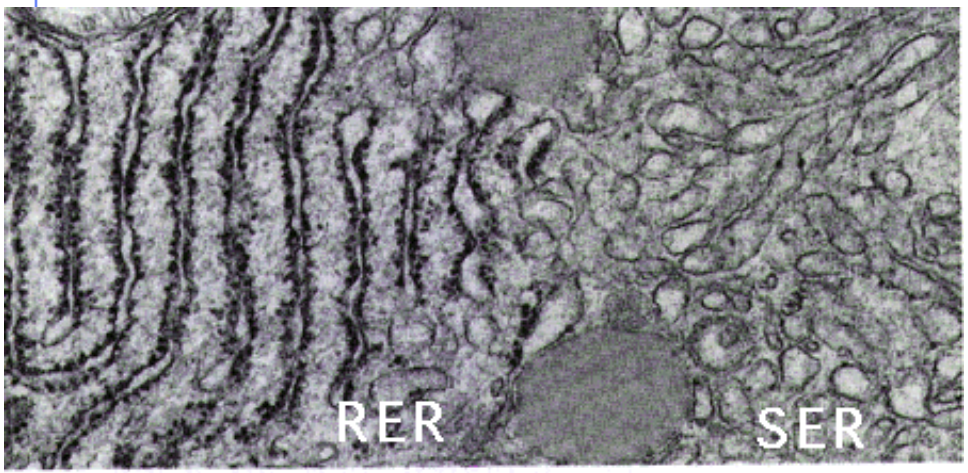


Endoplasmic Reticulum

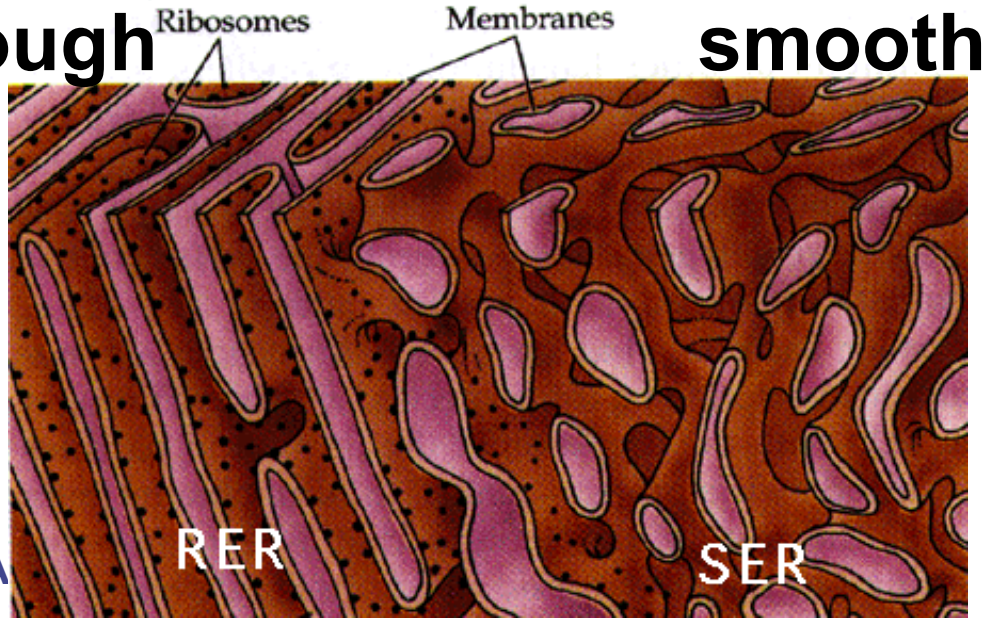
- Function
  - processes proteins
  - manufactures membranes
  - synthesis & hydrolysis of many compounds
- Structure
  - membrane connected to nuclear envelope & extends throughout cell



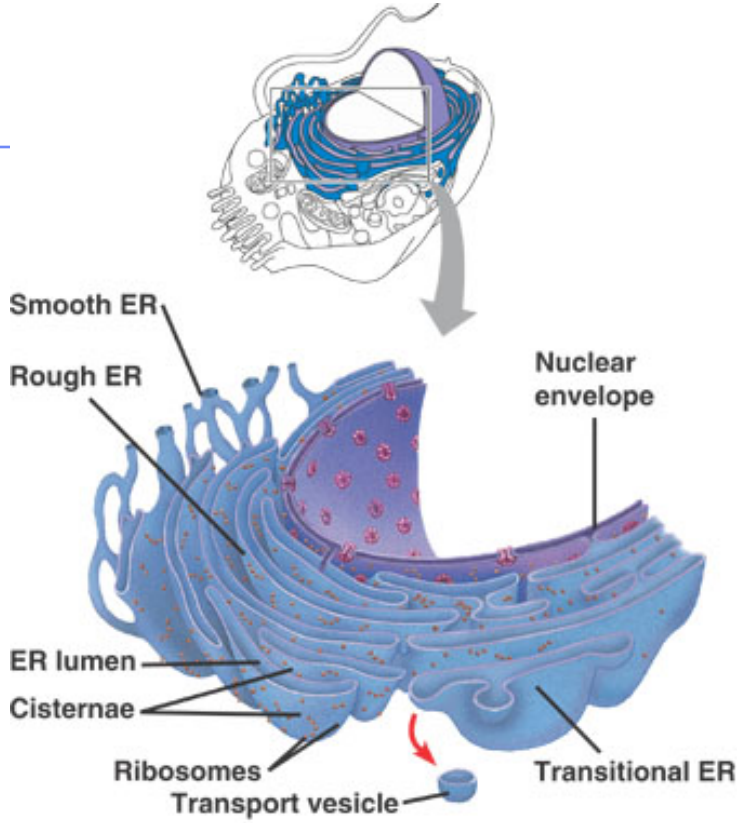
Types of ER

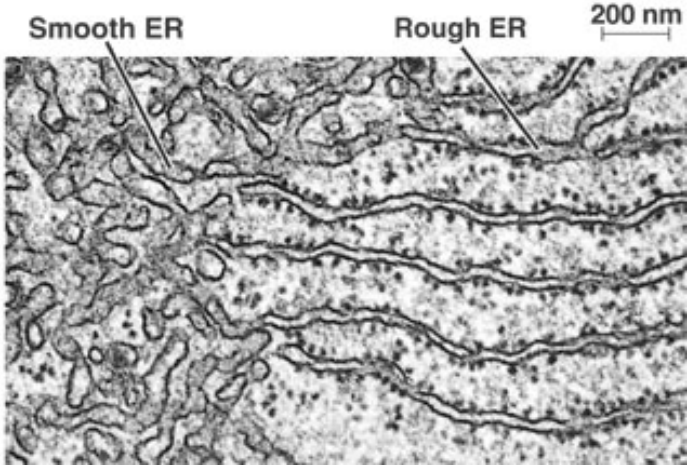


rough



smooth





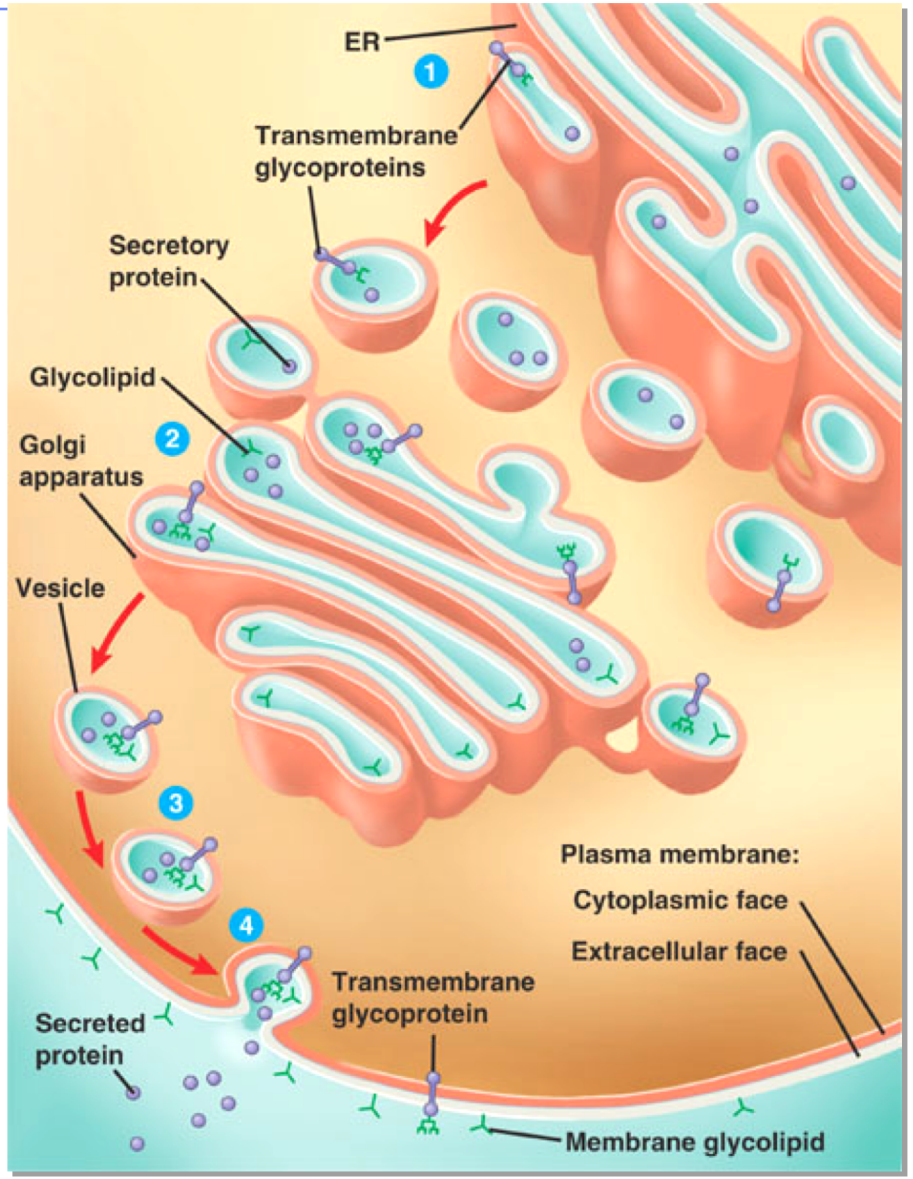
A

Smooth ER function

- Membrane production
- Many metabolic processes
  - synthesis
    - synthesize lipids
      - oils, phospholipids, steroids & sex hormones
  - hydrolysis
    - hydrolyze glycogen into glucose
      - in liver
    - detoxify drugs & poisons
      - in liver
      - ex. alcohol & barbiturates

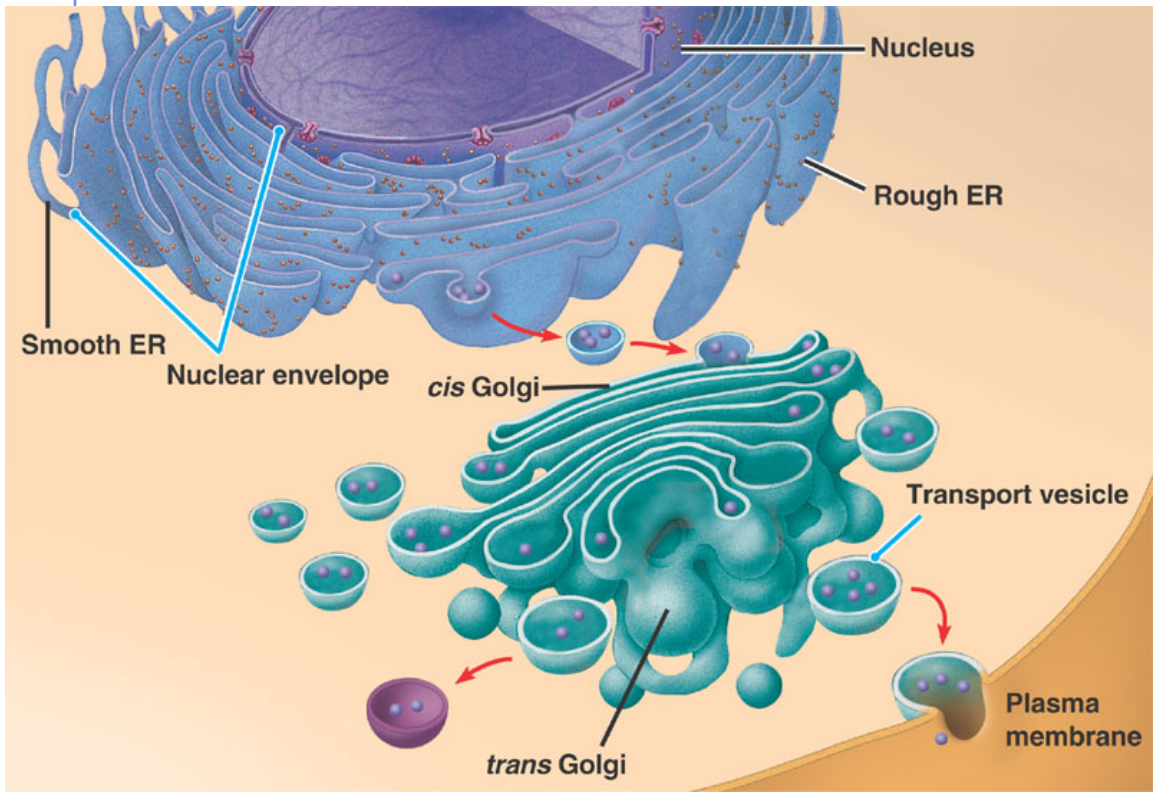
Membrane Factory

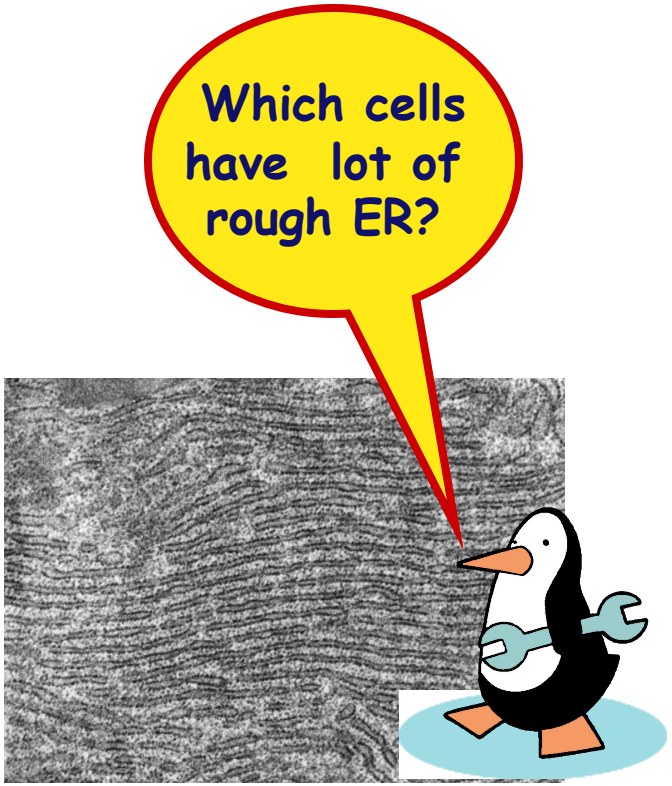
- Build new membrane
  - synthesize phospholipids
    - builds membranes
  - ER membrane expands
    - bud off & transfer to other parts of cell that need membranes



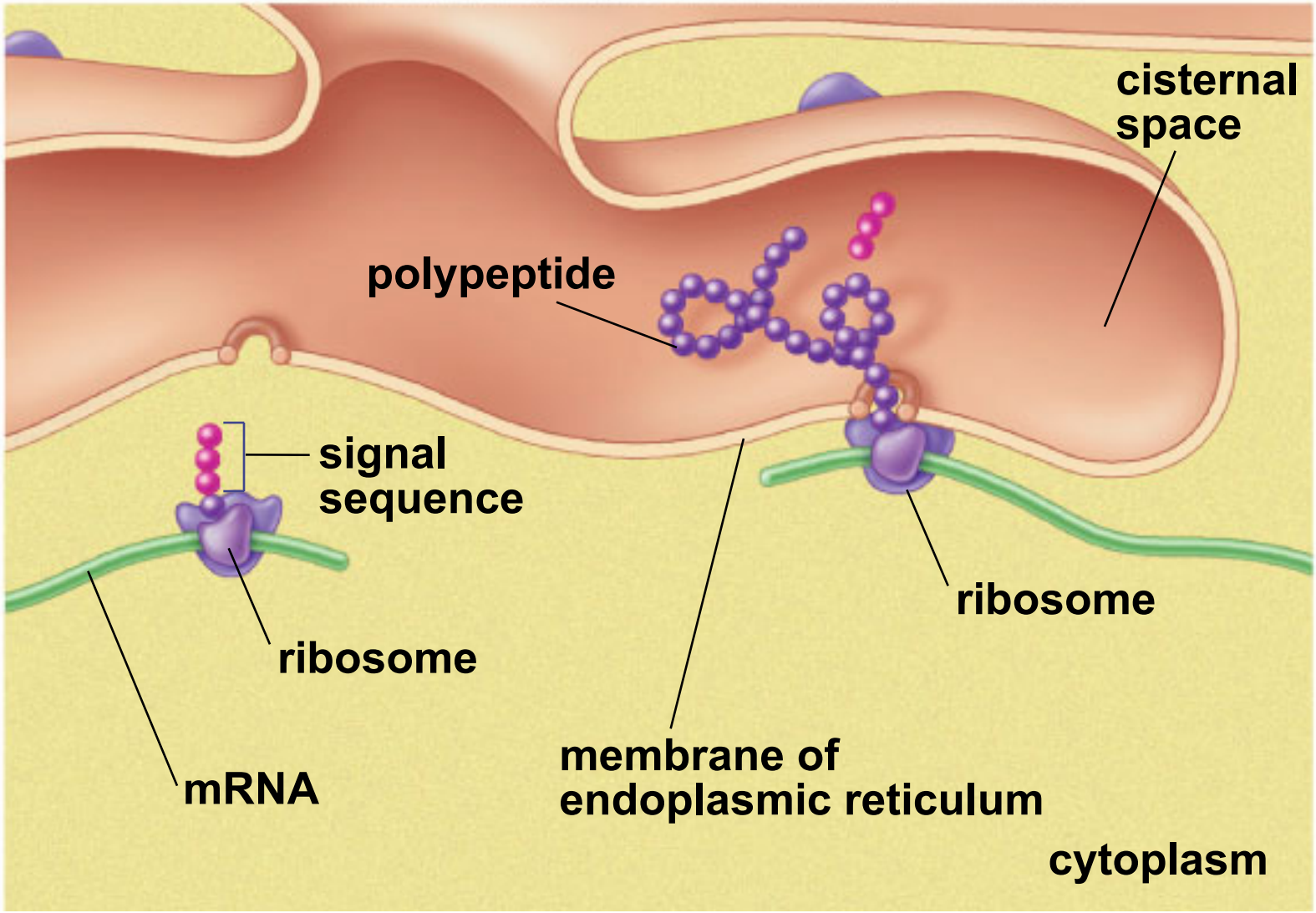
Rough ER function

- Produce proteins for export out of cell
  - protein secreting cells
  - packaged into transport vesicles for export



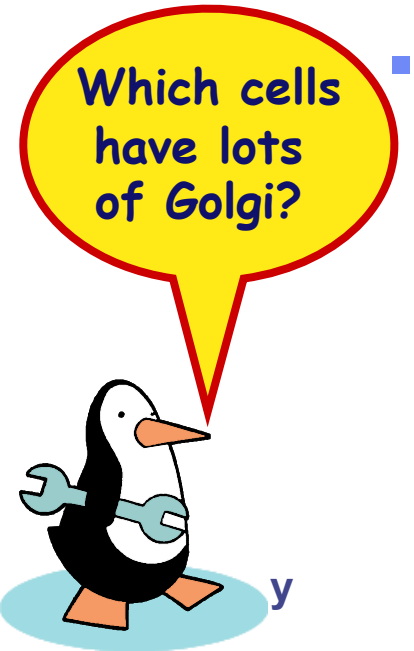


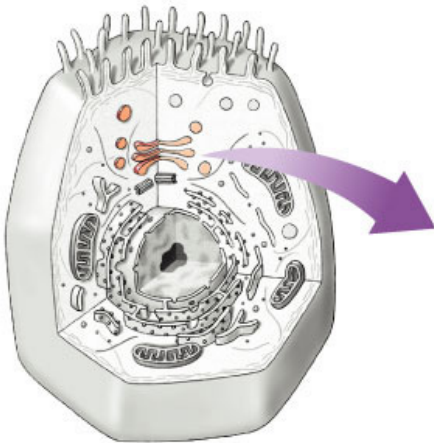
Synthesizing proteins

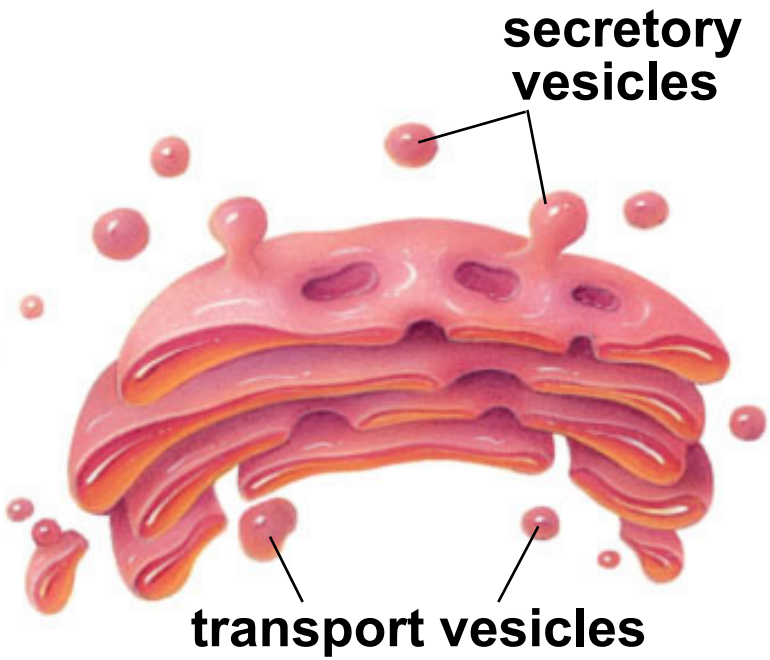


Golgi Apparatus

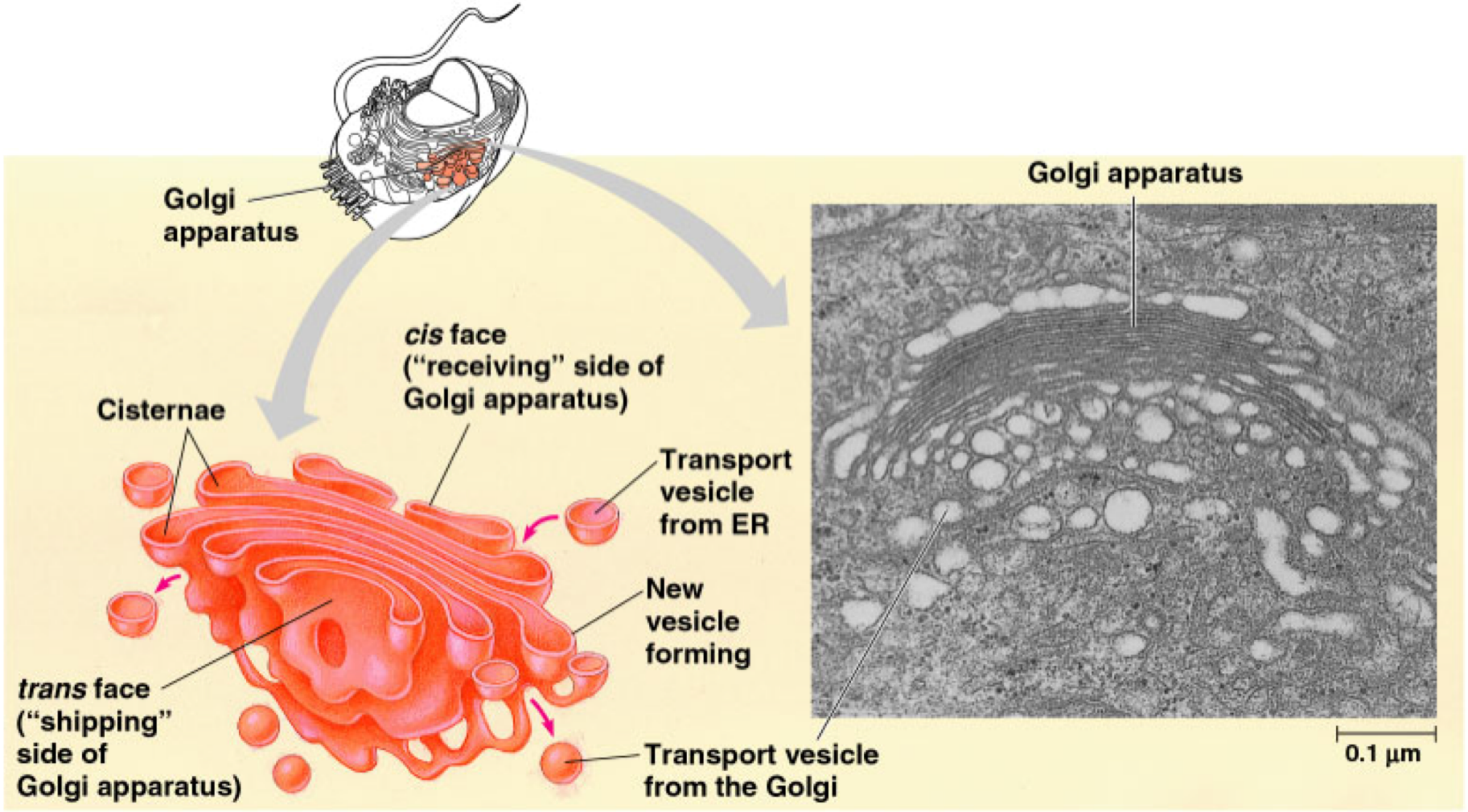
- **Function**
  - finishes, sorts, tags & ships cell products
    - like "UPS shipping department"
  - ships products in **vesicles**
    - membrane sacs
    - "UPS trucks"



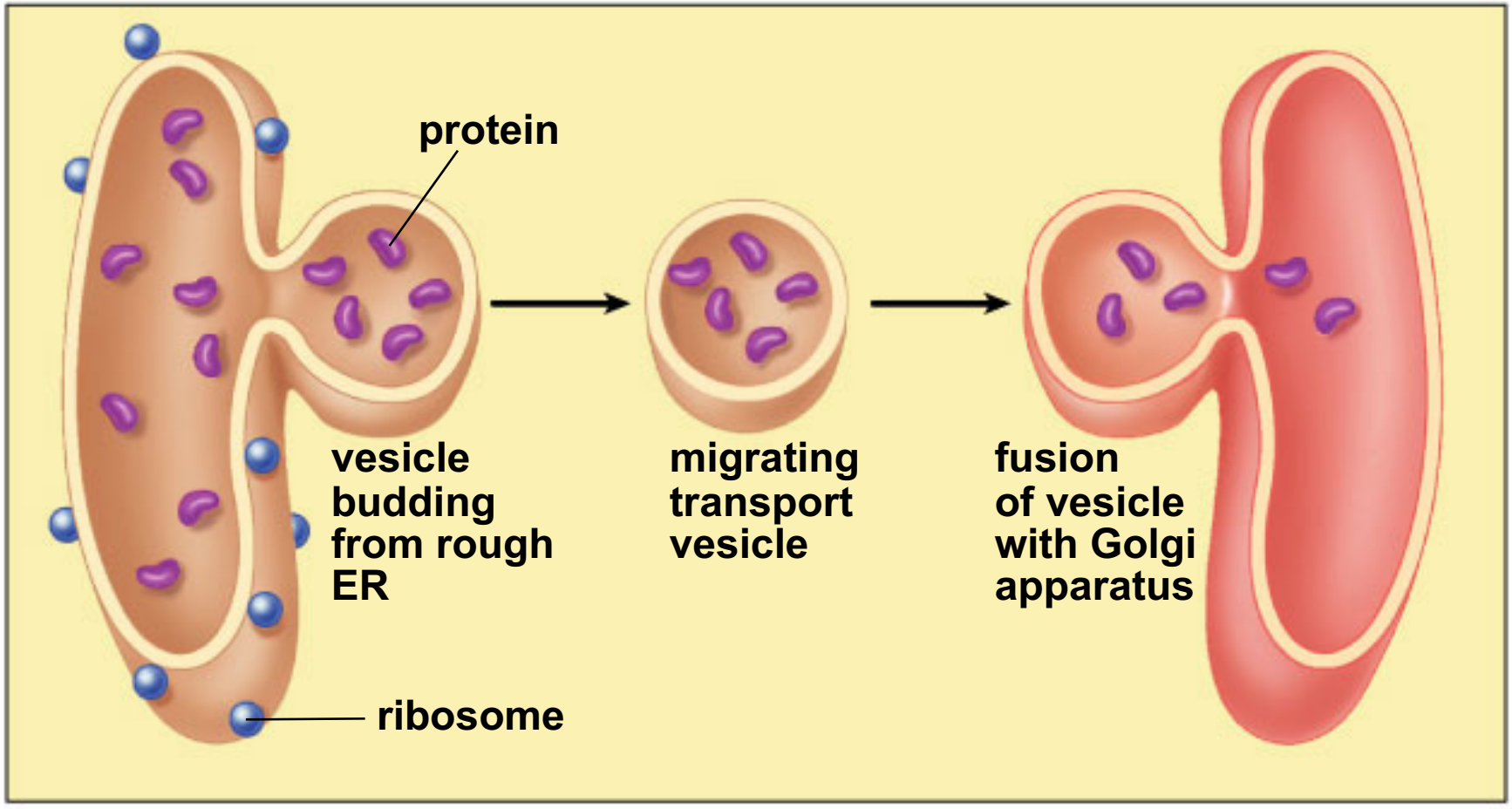


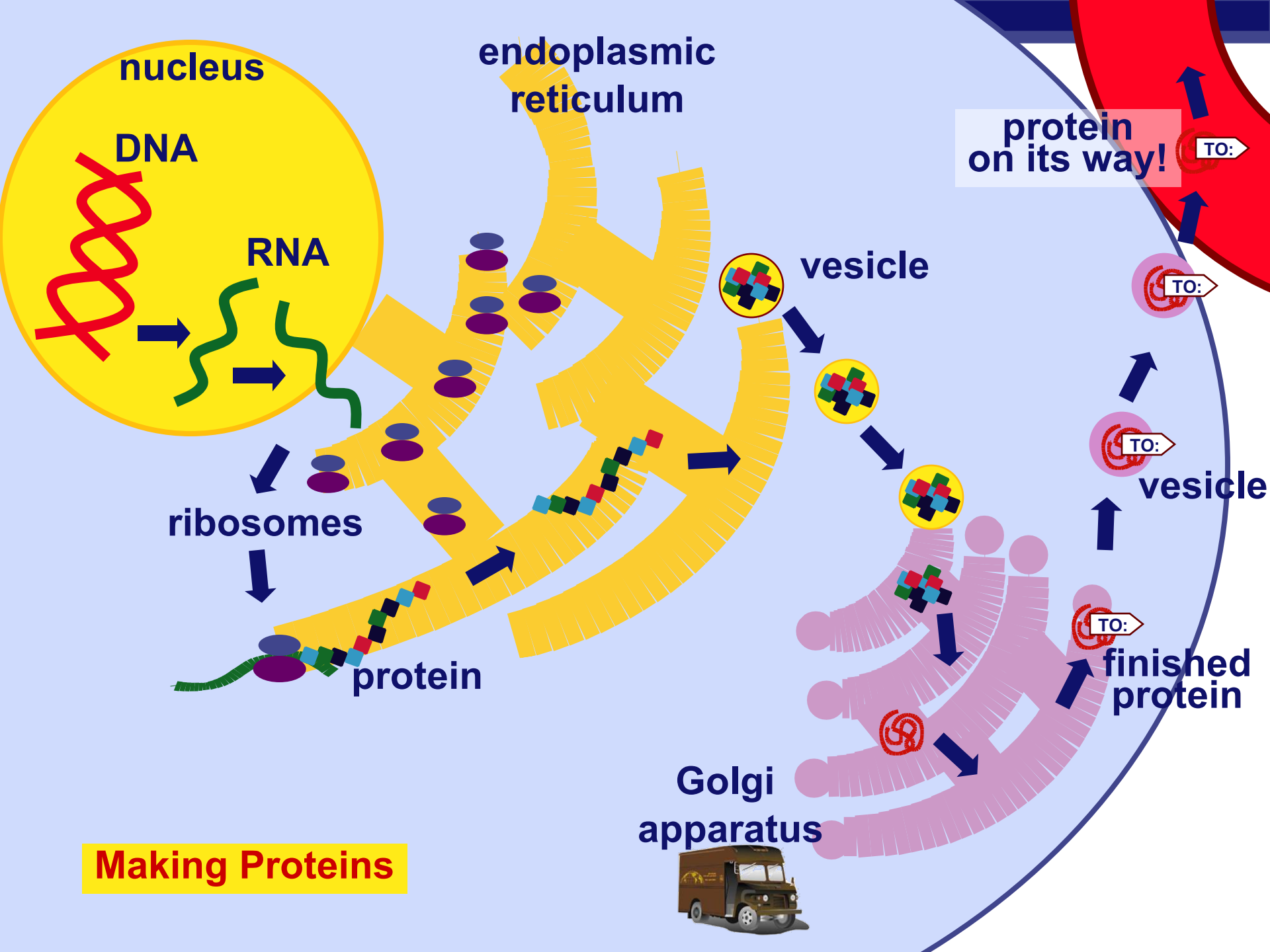


Golgi Apparatus

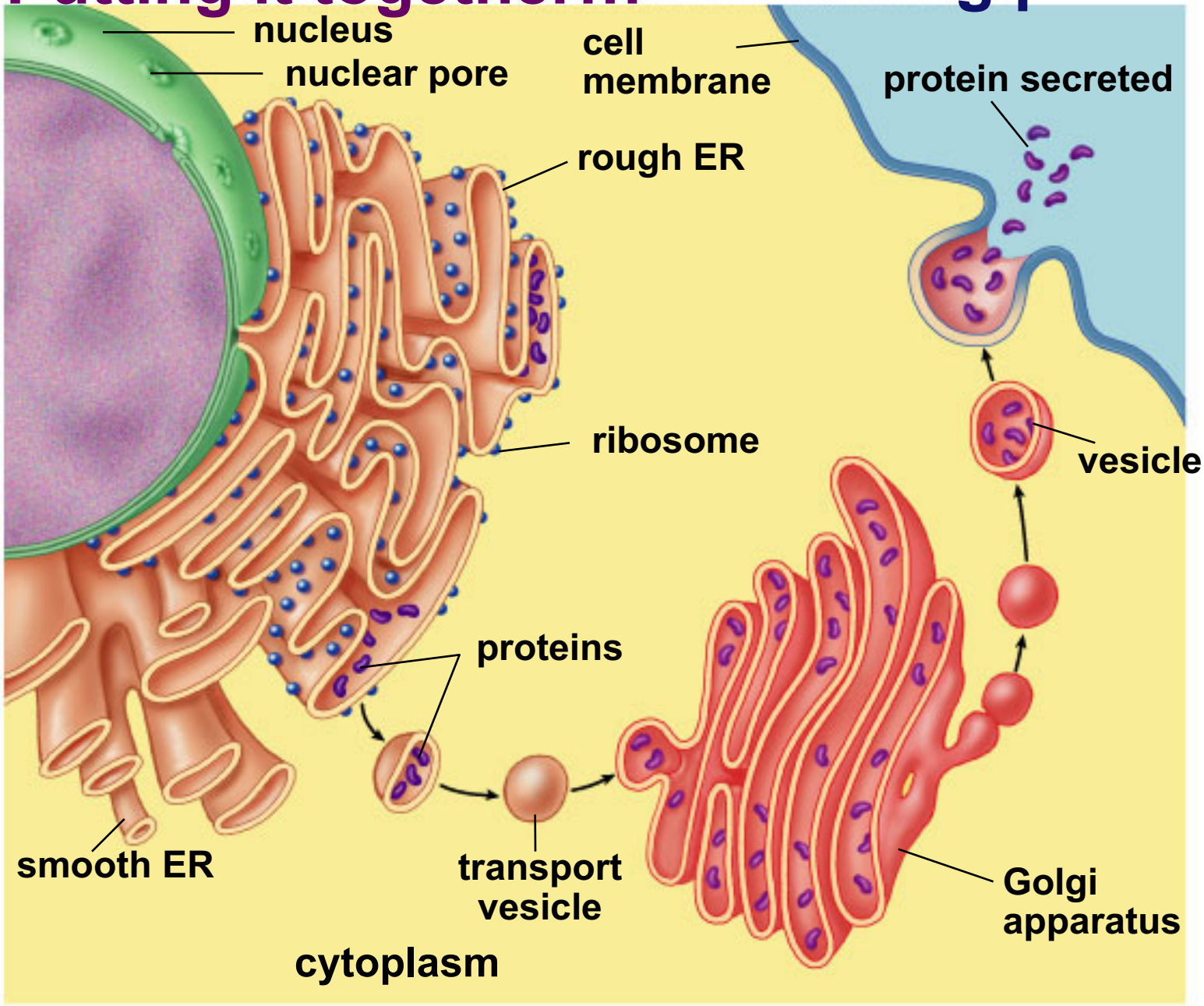


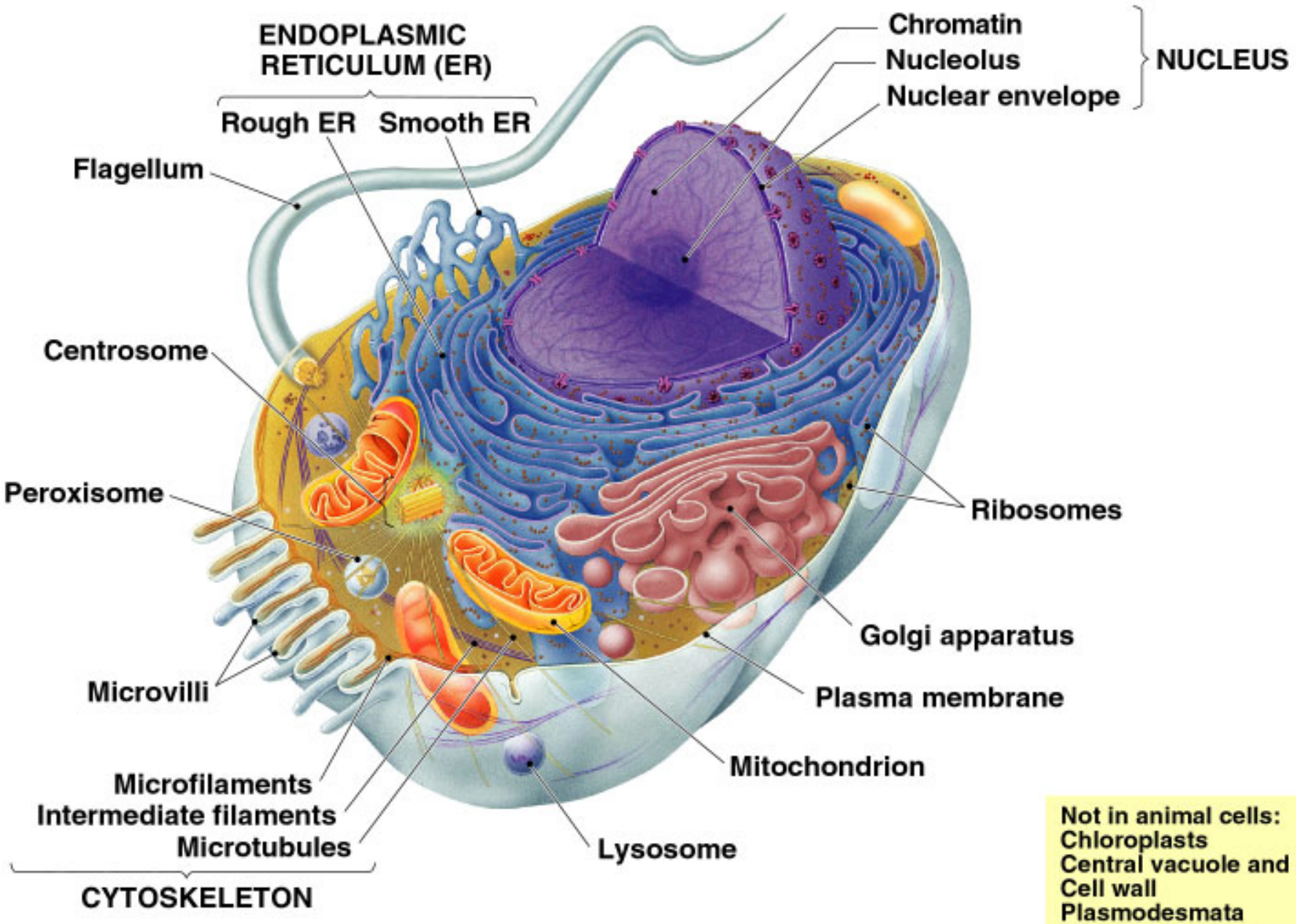
Vesicle transport



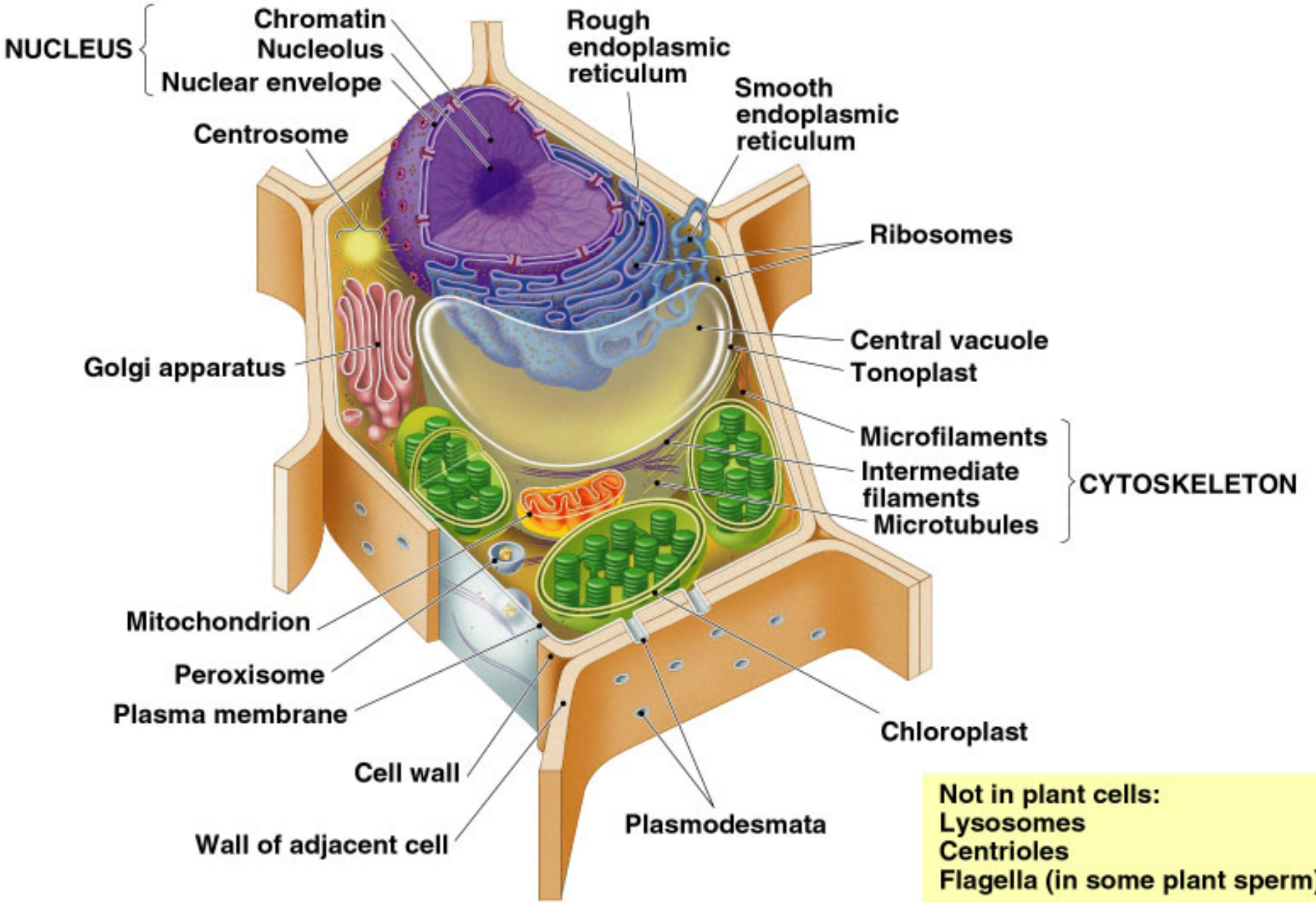

nucleus
DNA
RNA
endoplasmic reticulum
ribosomes
protein
vesicle
Golgi apparatus
finished protein
vesicle
protein on its way!
TO:
TO:
TO:
TO:
Making Proteins

Putting it together… Making proteins



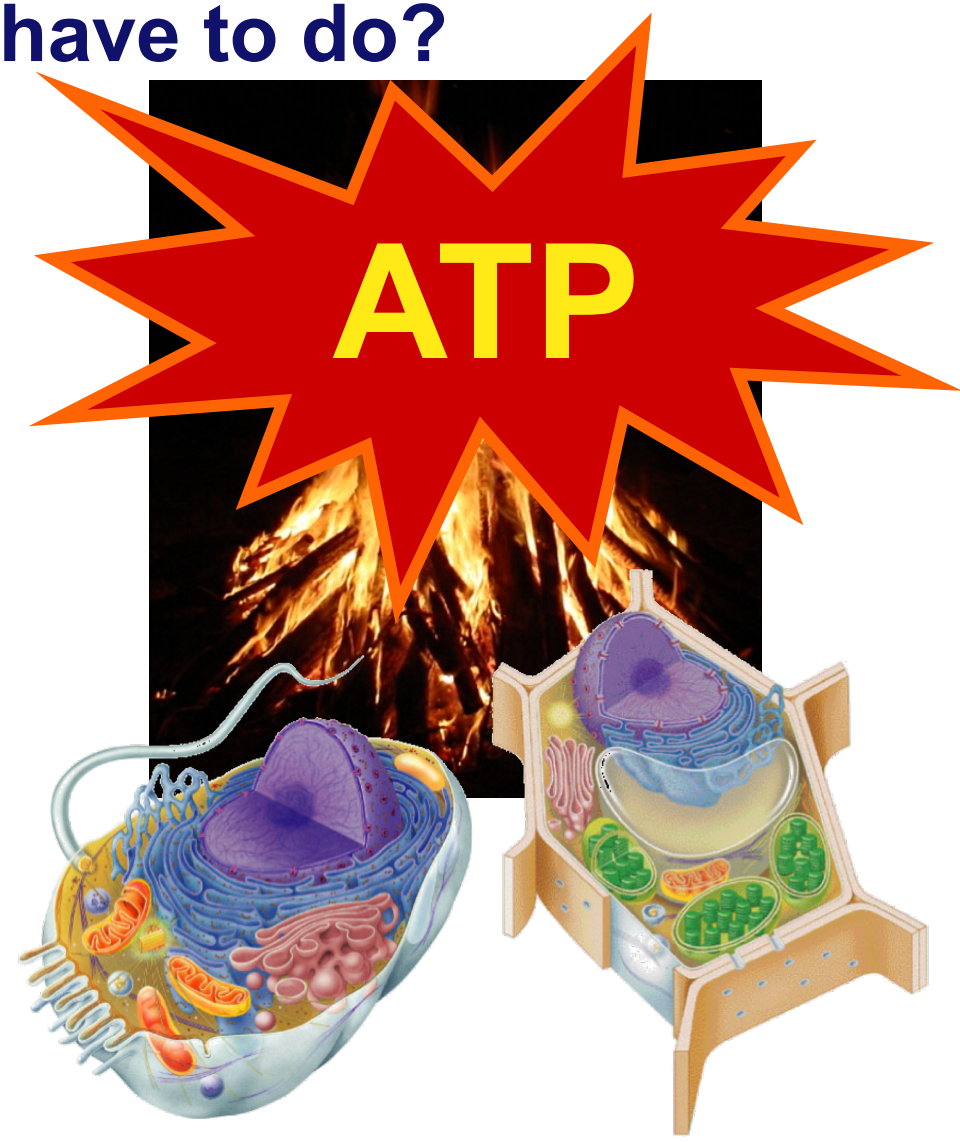


Not in animal cells:
Chloroplasts
Central vacuole and tonoplast
Cell wall
Plasmodesmata


NUCLEUS
Chromatin
Nucleolus
Nuclear envelope
Centrosome
Rough endoplasmic reticulum
Smooth endoplasmic reticulum
Ribosomes
Golgi apparatus
Central vacuole
Tonoplast
Microfilaments
Intermediate filaments
Microtubules
CYTOSKELETON
Mitochondrion
Peroxisome
Plasma membrane
Cell wall
Wall of adjacent cell
Plasmodesmata
Chloroplast
Not in plant cells:
Lysosomes
Centrioles
Flagella (in some plant sperm)

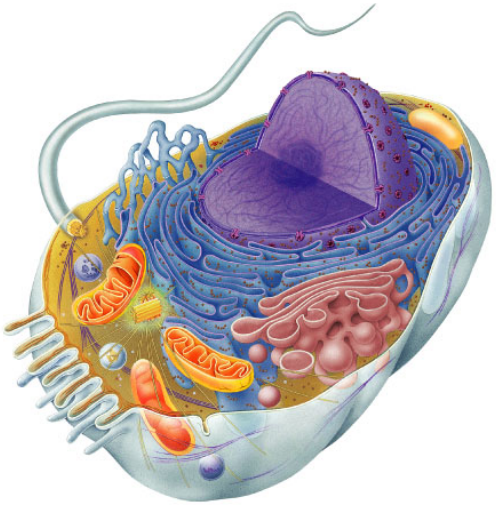
Cells gotta live!

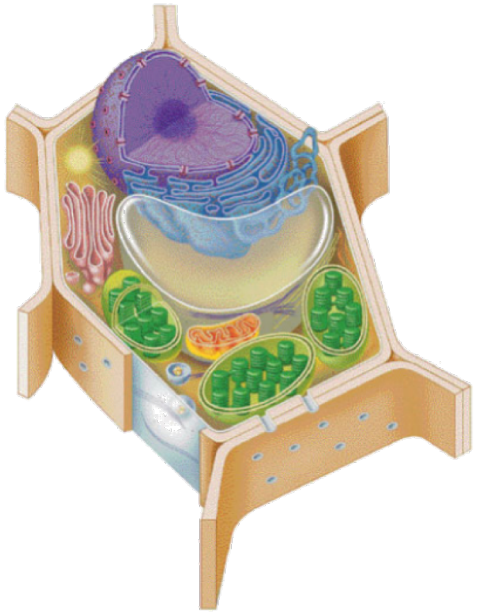
- What jobs do cells have to do?
  - make proteins
    - proteins control every cell function
  - make energy
    - for daily life
    - for growth
  - build more cells
    - growth
    - reproduction
    - repair



Cells need power!

- Making energy
  - take in food & digest it
  - take in oxygen (O_2)
  - make ATP
  - remove waste

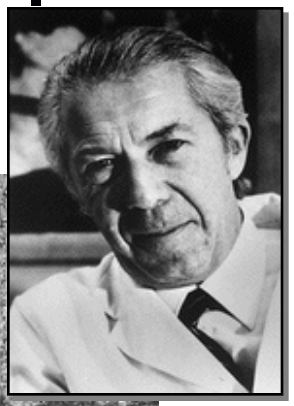




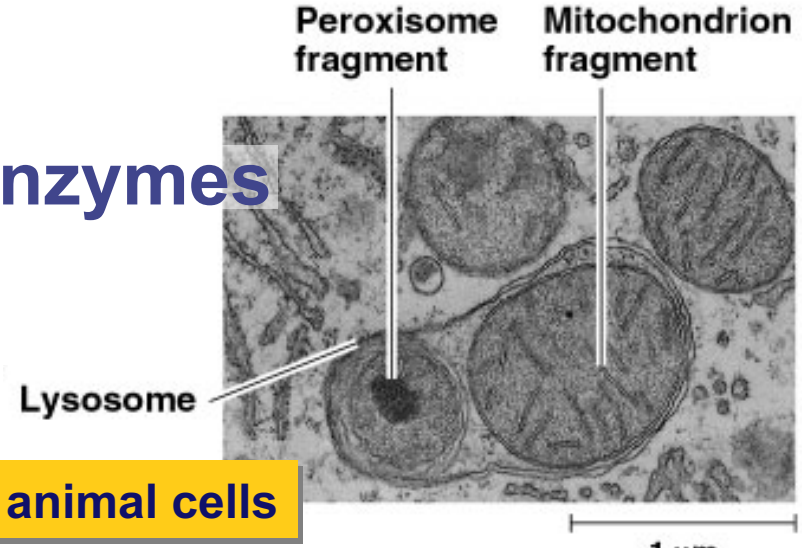
1960 | 1974

Lysosomes

Christian de Duve



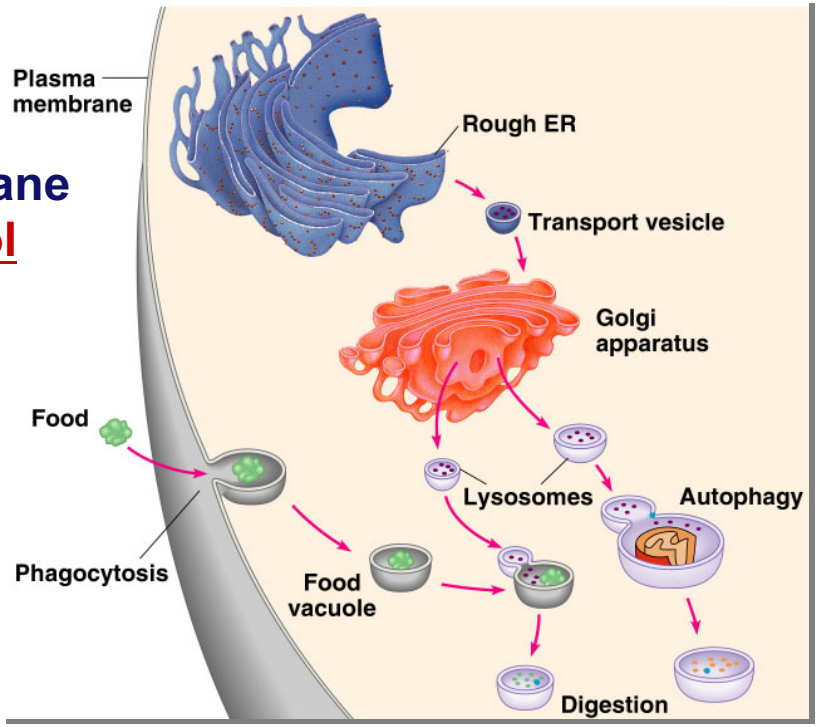
- Function
  - little “stomach” of the cell
    - digests macromolecules
  - “clean up crew” of the cell
    - cleans up broken down organelles
- Structure
  - vesicles of digestive enzymes



only in animal cells

Lysosomal enzymes

- Lysosomal enzymes work best at pH 5
  - organelle creates custom pH
  - how?
    - proteins in lysosomal membrane pump H^+ ions from the cytosol into lysosome
  - why?
    - enzymes are very sensitive to pH
  - why?
    - enzymes are proteins — pH affects structure
  - why is this an adaptation: digestive enzymes which function at pH different from cytosol?
    - digestive enzymes won't function well if some leak into cytosol = don't want to digest yourself!

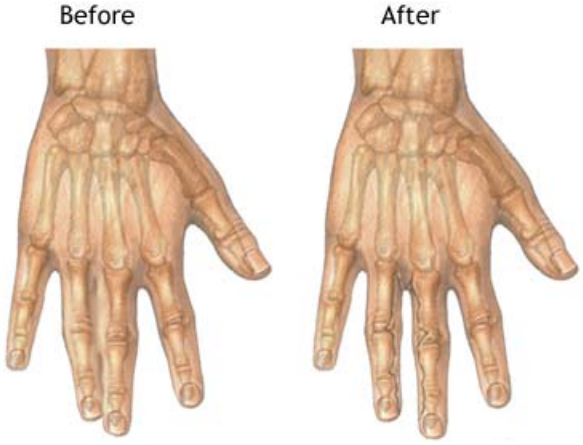


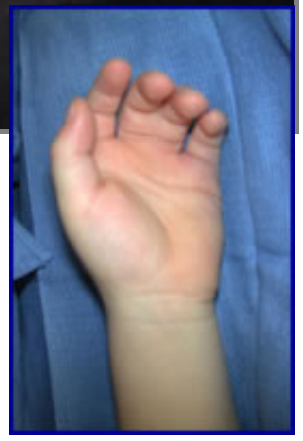
But sometimes cells need to die…

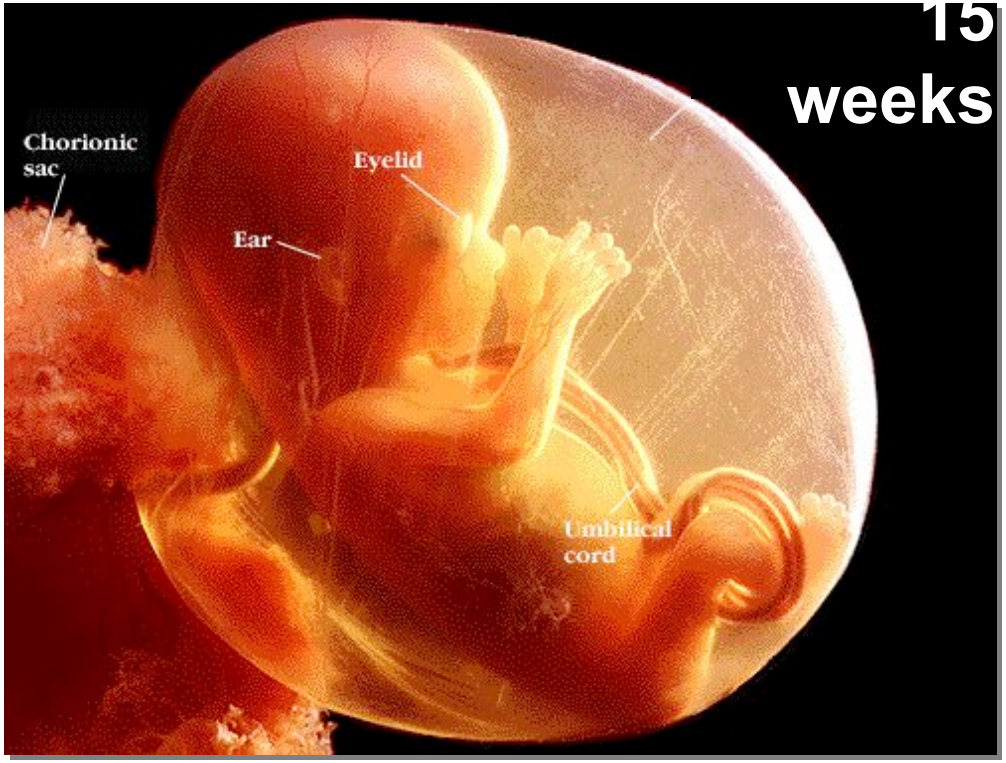
- Lysosomes can be used to kill cells when they are supposed to be destroyed
  - some cells have to die for proper development in an organism
    - apoptosis
      - "auto-destruct" process
      - lysosomes break open & kill cell
    - ex: tadpole tail gets re-absorbed when it turns into a frog
    - ex: loss of webbing between your fingers during fetal development
    - ex: self-destruct of cancerous cell

Fetal development

syndactyly







When things go wrong…

- Diseases of lysosomes are often fatal
  - digestive enzyme not working in lysosome
  - picks up biomolecules, but can't digest one
    - lysosomes fill up with undigested material
  - grow larger & larger until disrupts cell & organ function
    - lysosomal storage diseases
      - more than 40 known diseases
    - example:
      Tay-Sachs disease
      build up undigested fat
      in brain cells

From food to making Energy

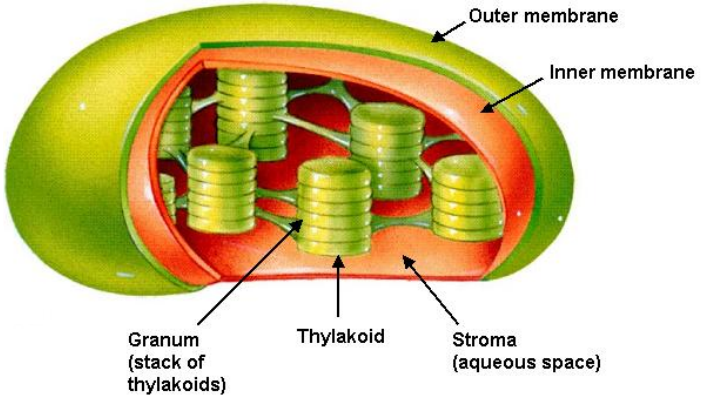
- Cells must convert incoming energy to forms that they can use for work
  - mitochondria:
    from glucose to ATP

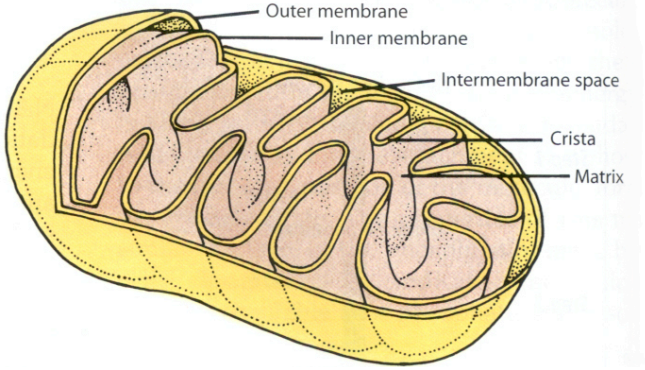
  - chloroplasts:
    from sunlight to ATP & carbohydrates
    - ATP = immediate energy
    - carbohydrates = stored energy

Mitochondria & Chloroplasts

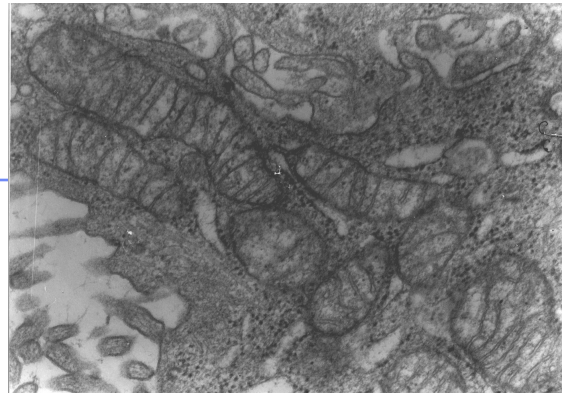
Lynn Margulis
U of M, Amherst

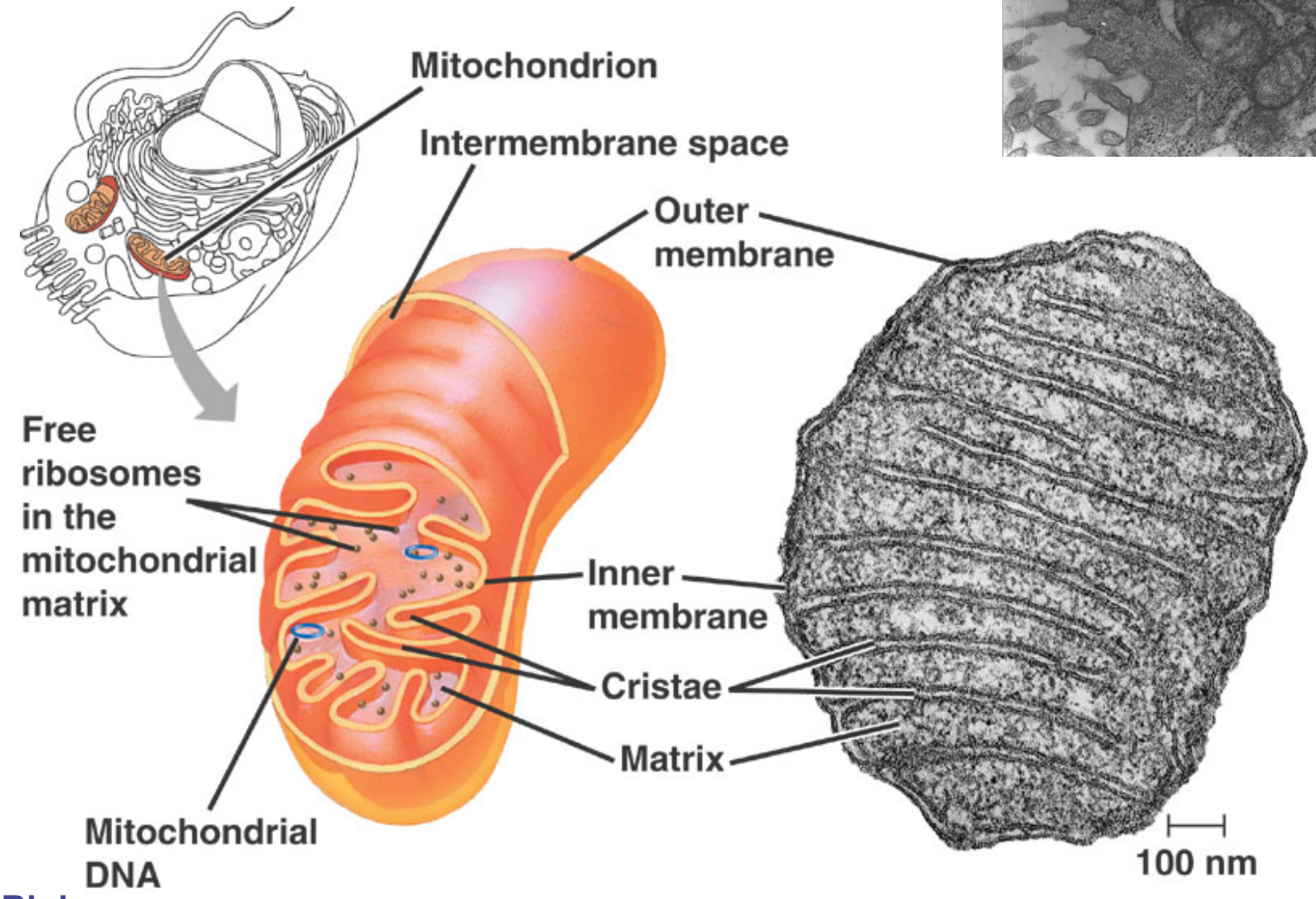
- Important to see the similarities
  - transform energy
    - generate ATP
  - double membranes = 2 membranes
  - semi-autonomous organelles
    - move, change shape, divide
  - internal ribosomes, DNA & enzymes





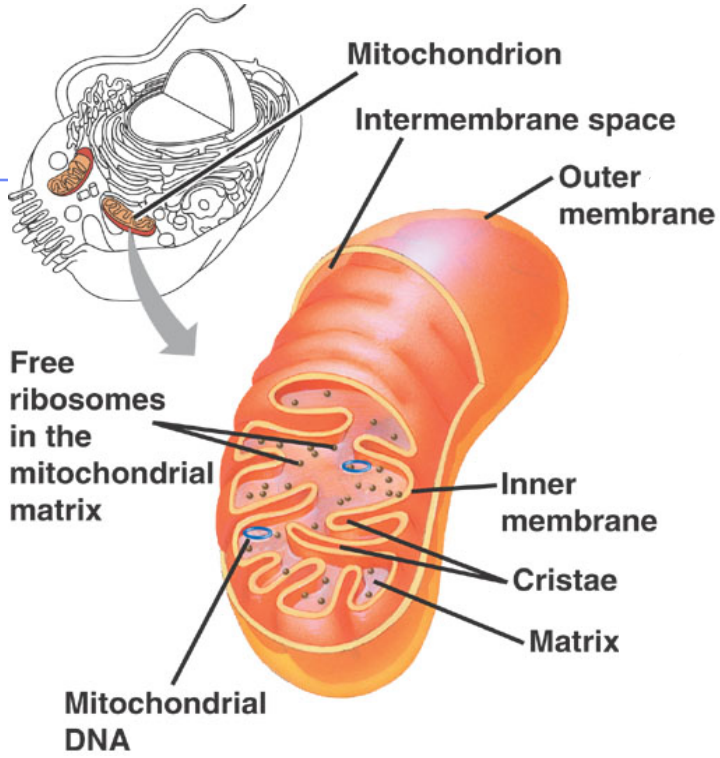
Mitochondria





Mitochondria

- Structure
  - 2 membranes
    - smooth outer membrane
    - highly folded inner membrane
      - cristae
  - fluid-filled space between 2 membranes
  - internal fluid-filled space
    - mitochondrial matrix
    - DNA, ribosomes & enzymes

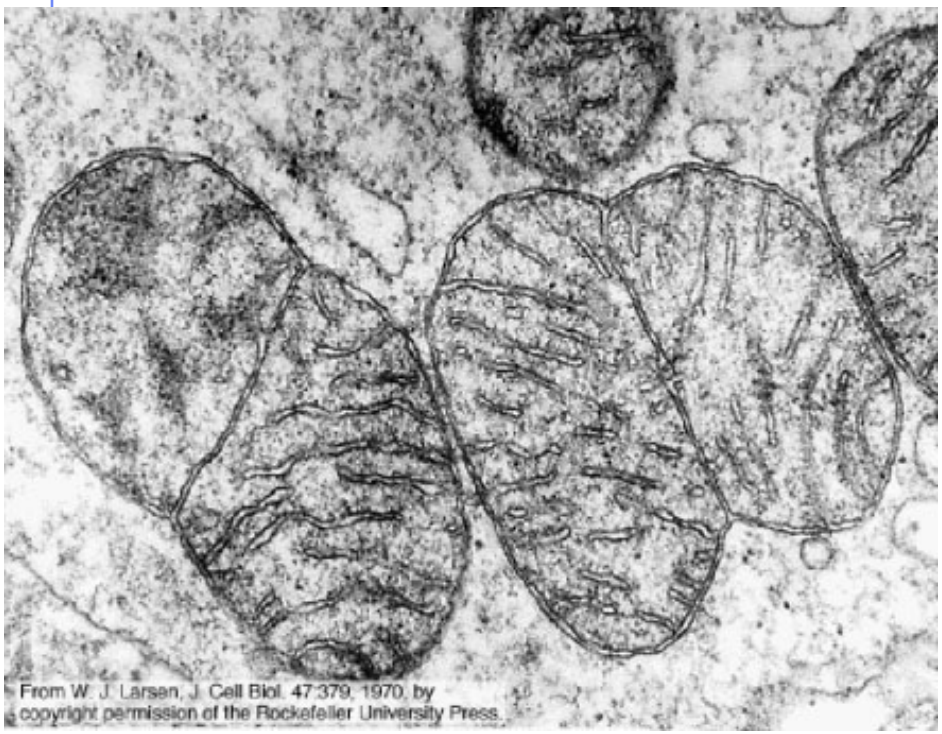


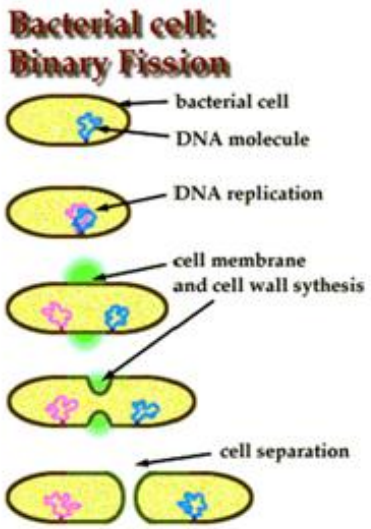
Why 2 membranes?

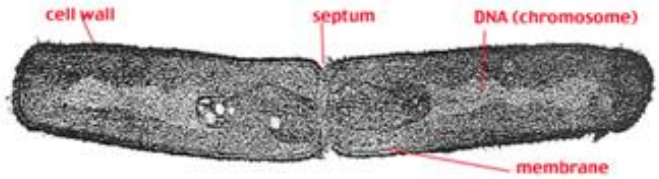
increase surface area for membrane-bound enzymes that synthesize ATP

Dividing Mitochondria

Who else divides like that?



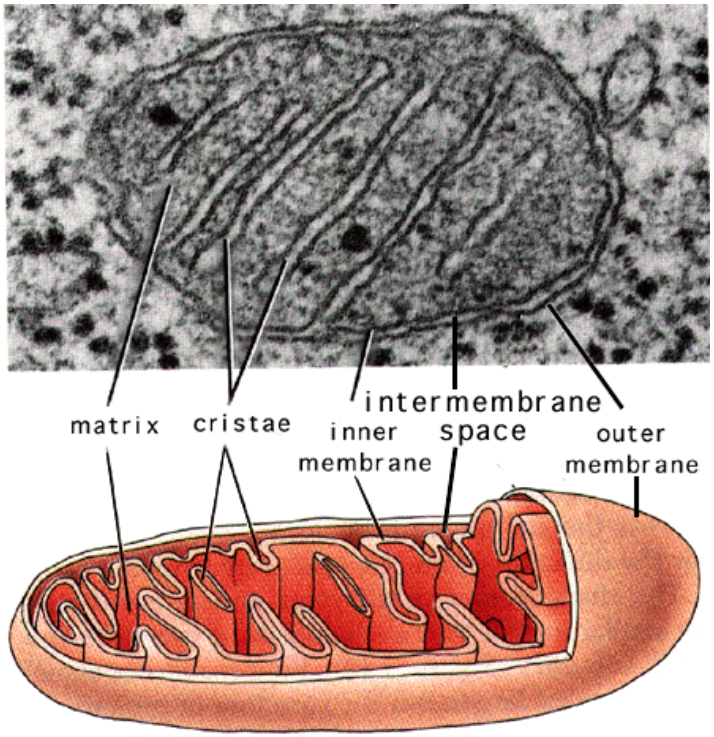




What does this tell us about the evolution of eukaryotes?

Mitochondria

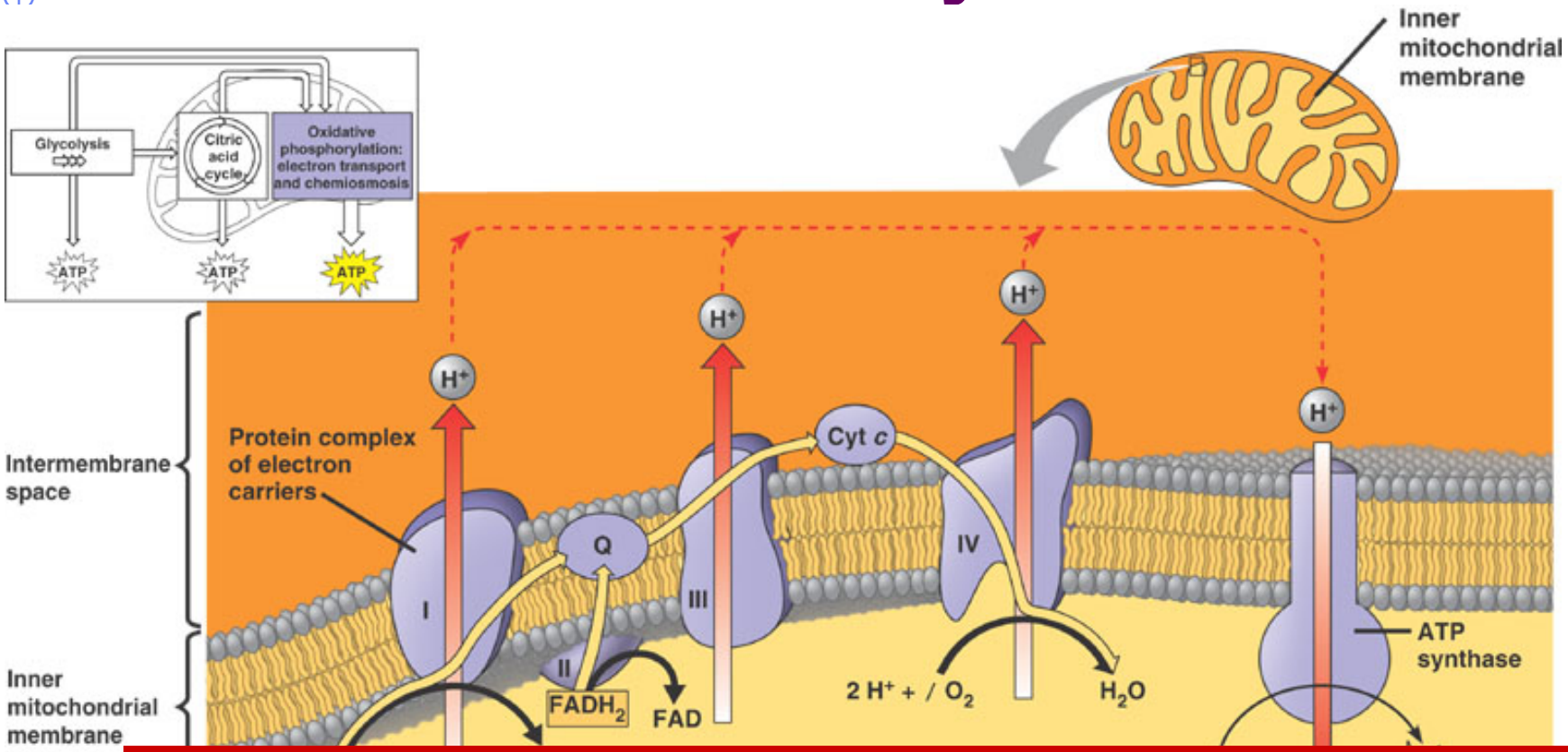
- Almost all eukaryotic cells have mitochondria
  - there may be 1 very large mitochondrion or 100s to 1000s of individual mitochondria
  - number of mitochondria is correlated with aerobic metabolic activity
    - more activity = more energy needed = more mitochondria



What cells would have a lot of mitochondria?

active cells:
- muscle cells
- nerve cells

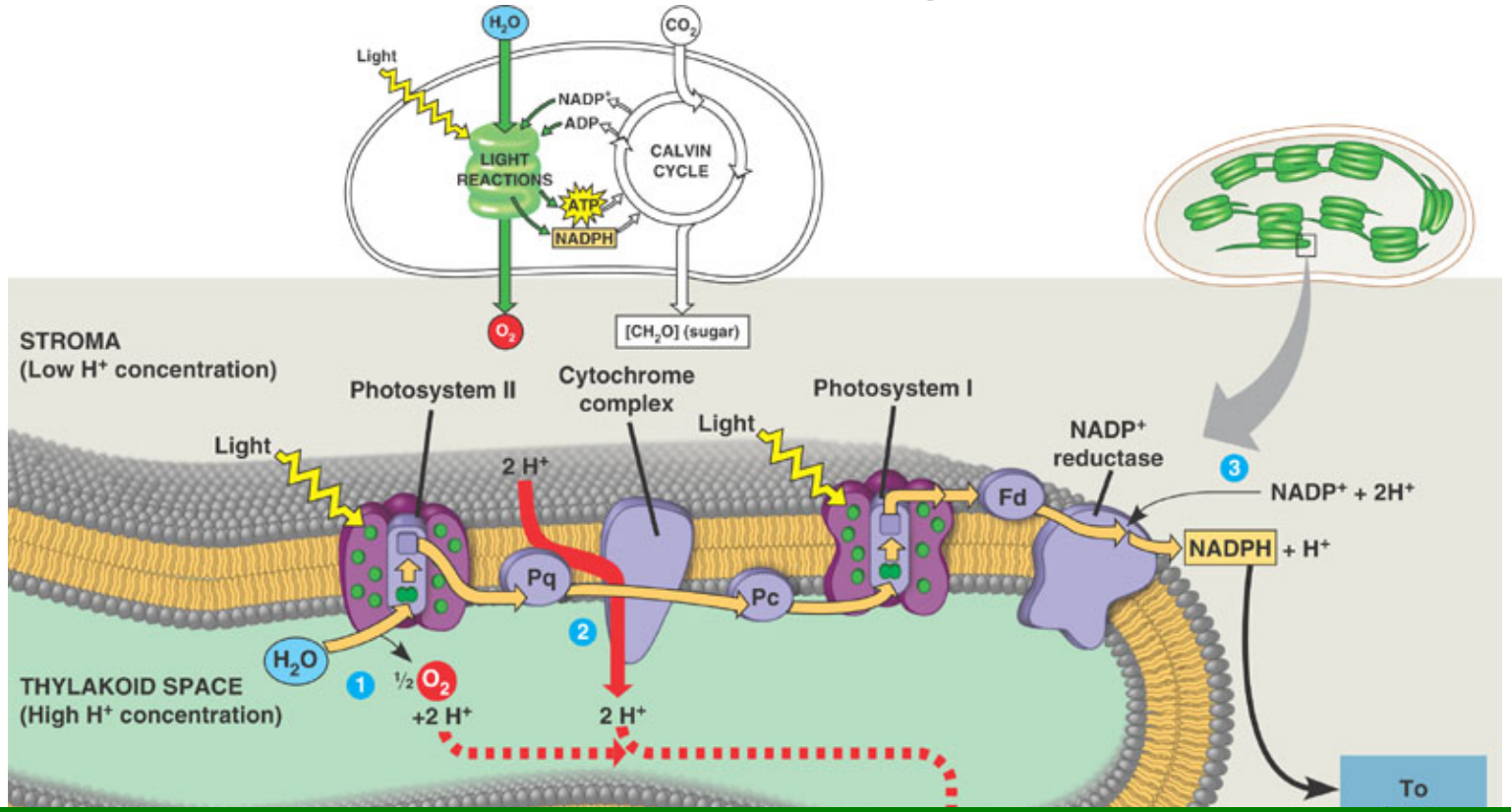
Membrane-bound Enzymes



glucose + oxygen → carbon dioxide + water + energy

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$

Membrane-bound Enzymes

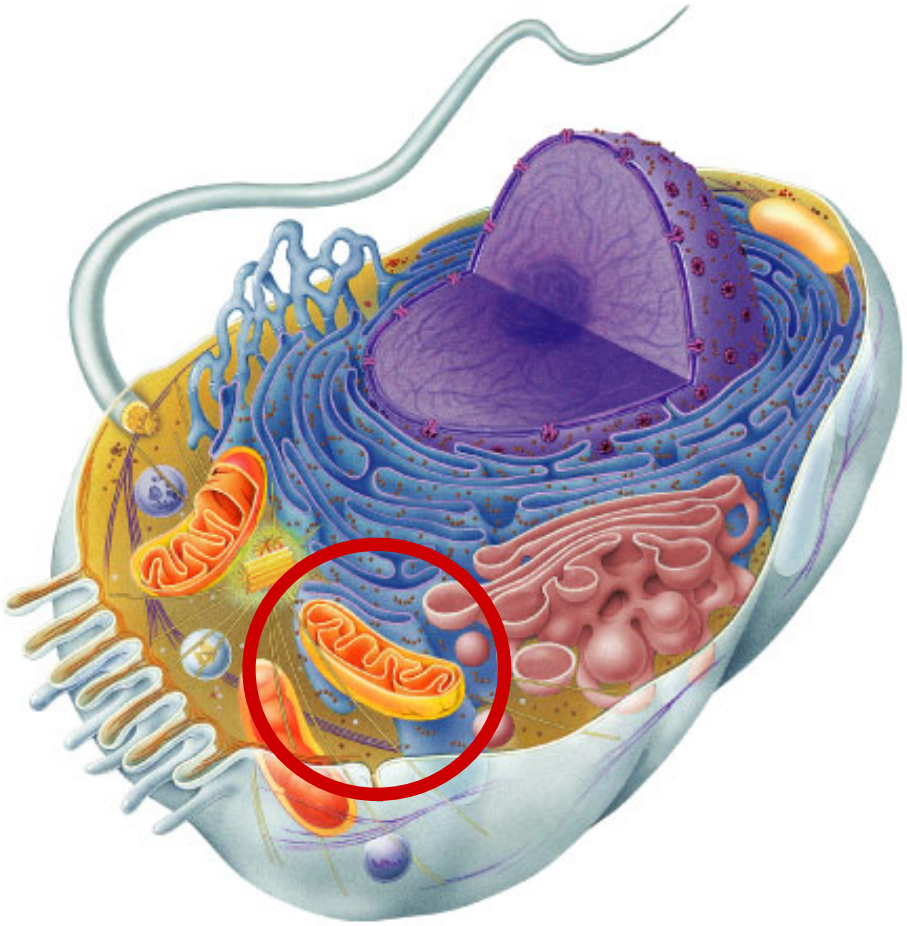


carbon dioxide + water + energy → glucose + oxygen

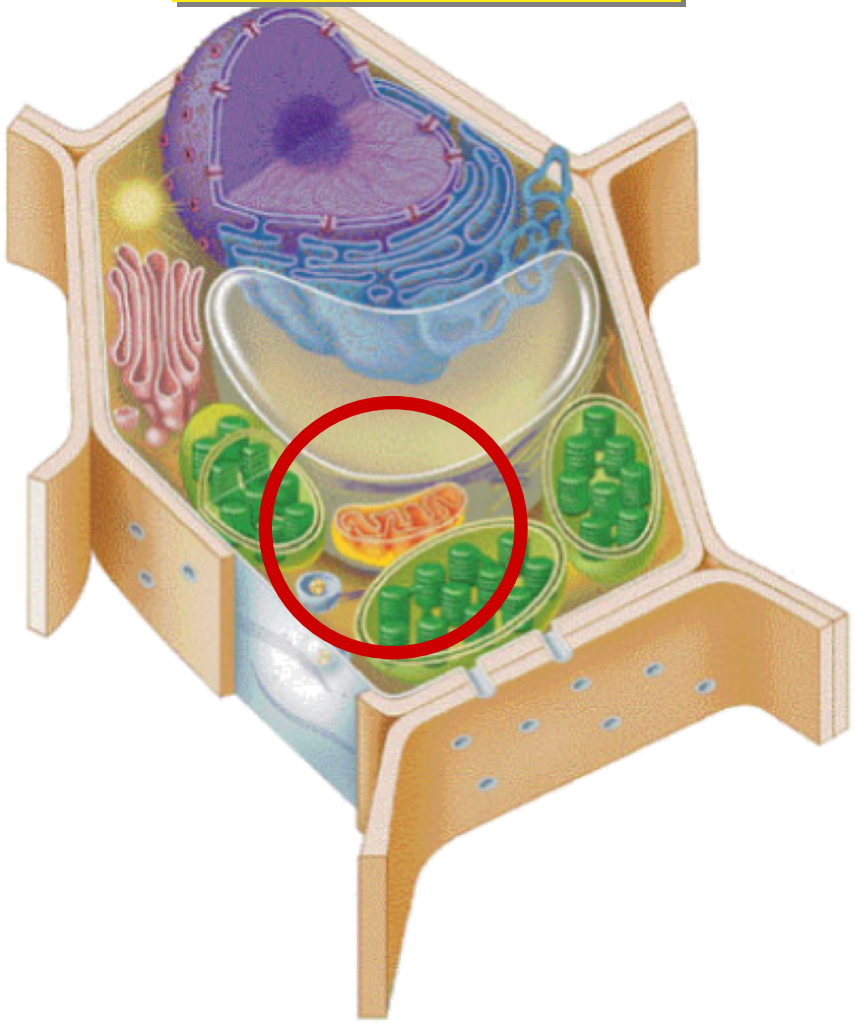
$$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

Mitochondria are everywhere!!

animal cells

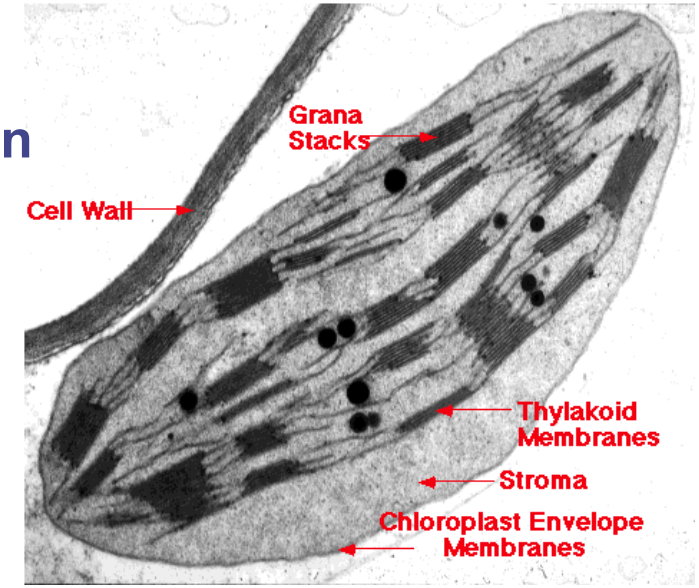


plant cells

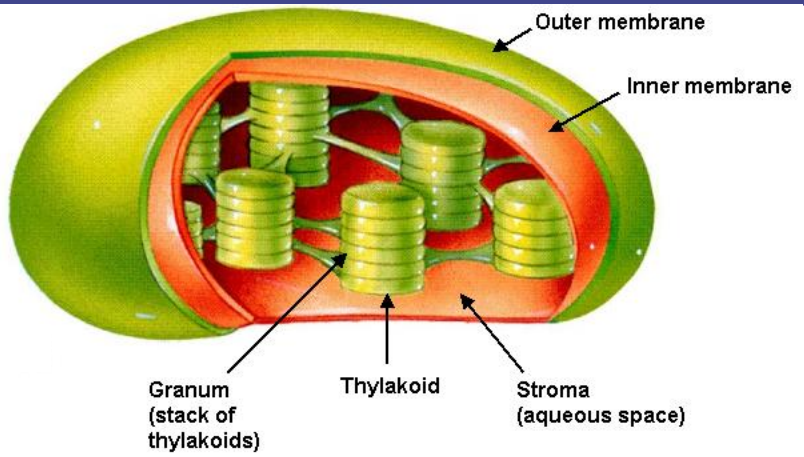


Chloroplasts

- Chloroplasts are plant organelles
  - class of plant structures = plastids
    - amyloplasts
      - store starch in roots & tubers
    - chromoplasts
      - store pigments for fruits & flowers
    - chloroplasts
      - store chlorophyll & function in photosynthesis
      - in leaves, other green structures of plants & in eukaryotic algae



Chloroplasts

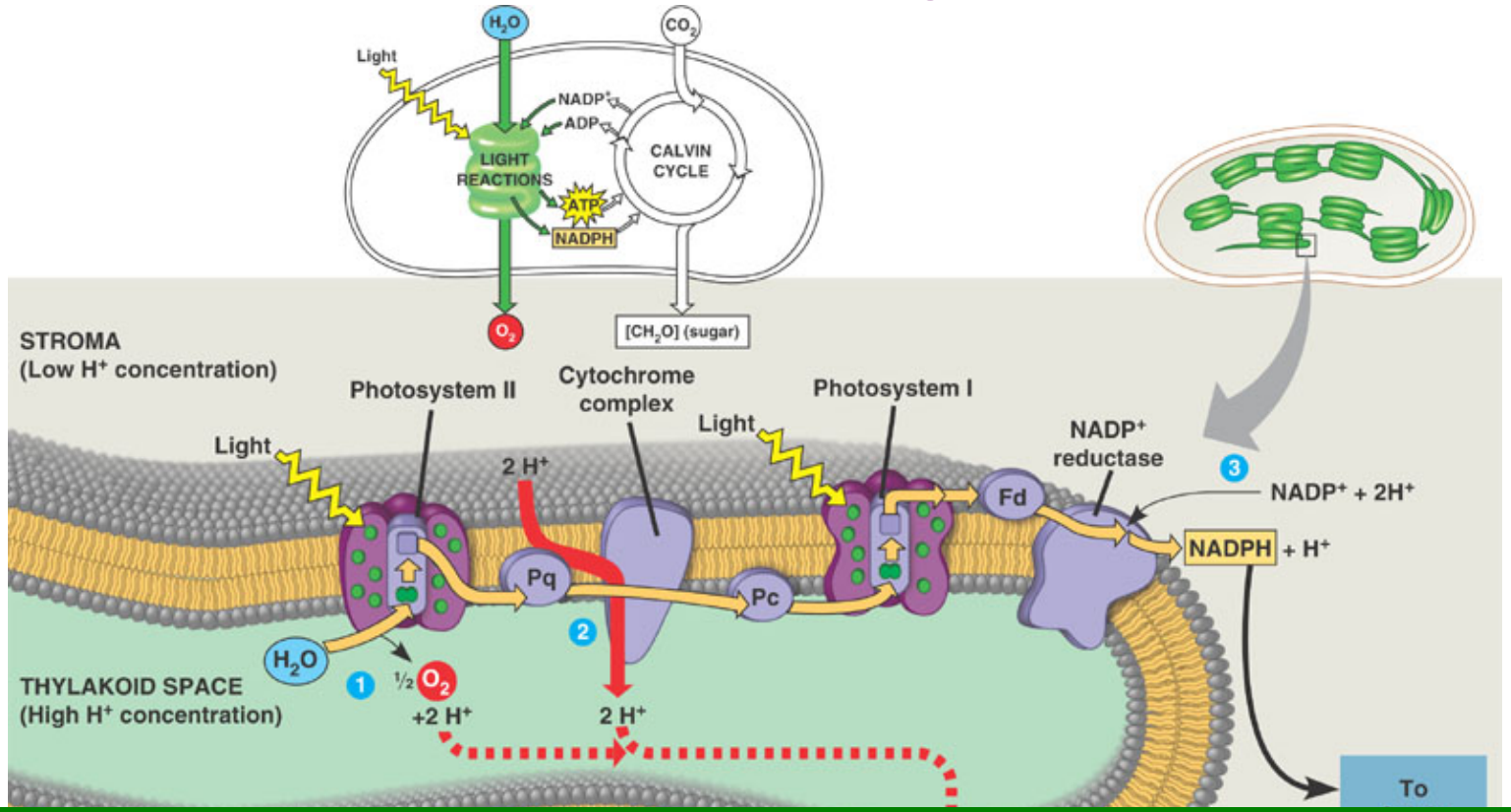


- **Structure**
  - 2 membranes
  - stroma = internal fluid-filled space
    - DNA, ribosomes & enzymes
    - thylakoids = membranous sacs where ATP is made
    - grana = stacks of thylakoids

Why internal sac membranes?

increase surface area for membrane-bound enzymes that synthesize ATP

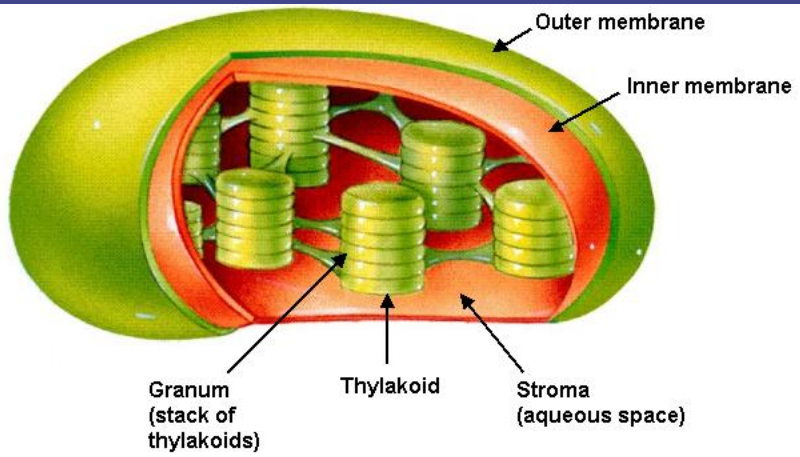
Membrane-bound Enzymes



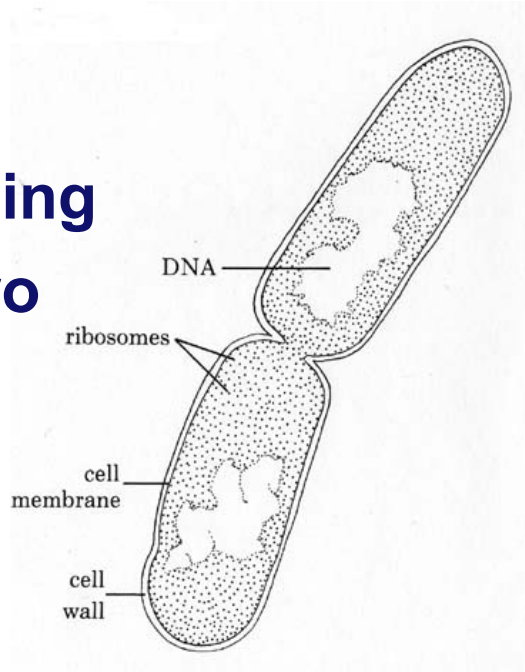
carbon dioxide + water + energy → glucose + oxygen

$$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

Chloroplasts



- Function
  - photosynthesis
  - generate ATP & synthesize sugars
    - transform solar energy into chemical energy
    - produce sugars from CO_2 & H_2O
- Semi-autonomous
  - moving, changing shape & dividing
  - can reproduce by pinching in two

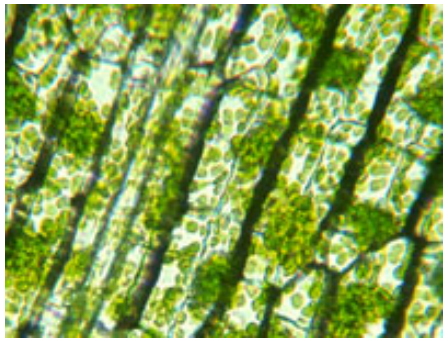


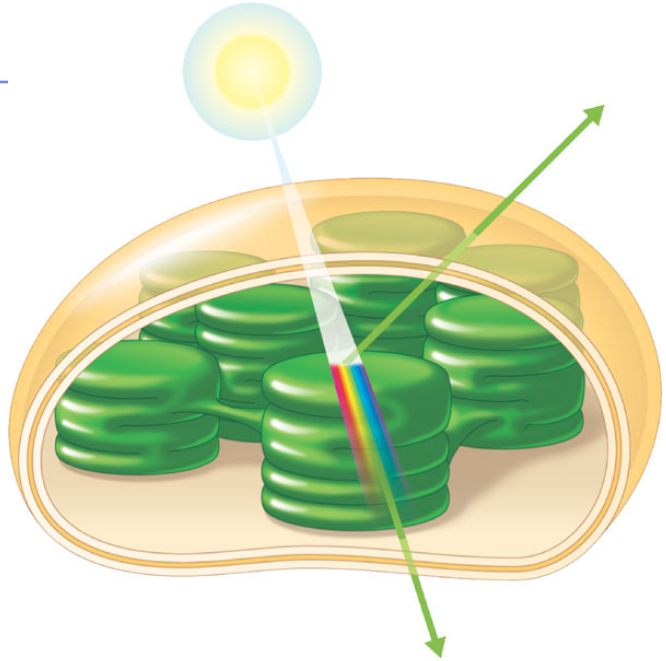
Who else divides like that?

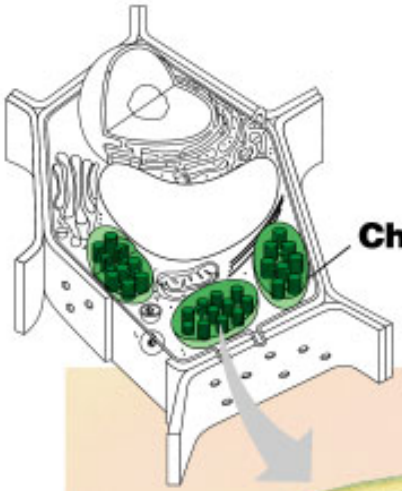
bacteria!

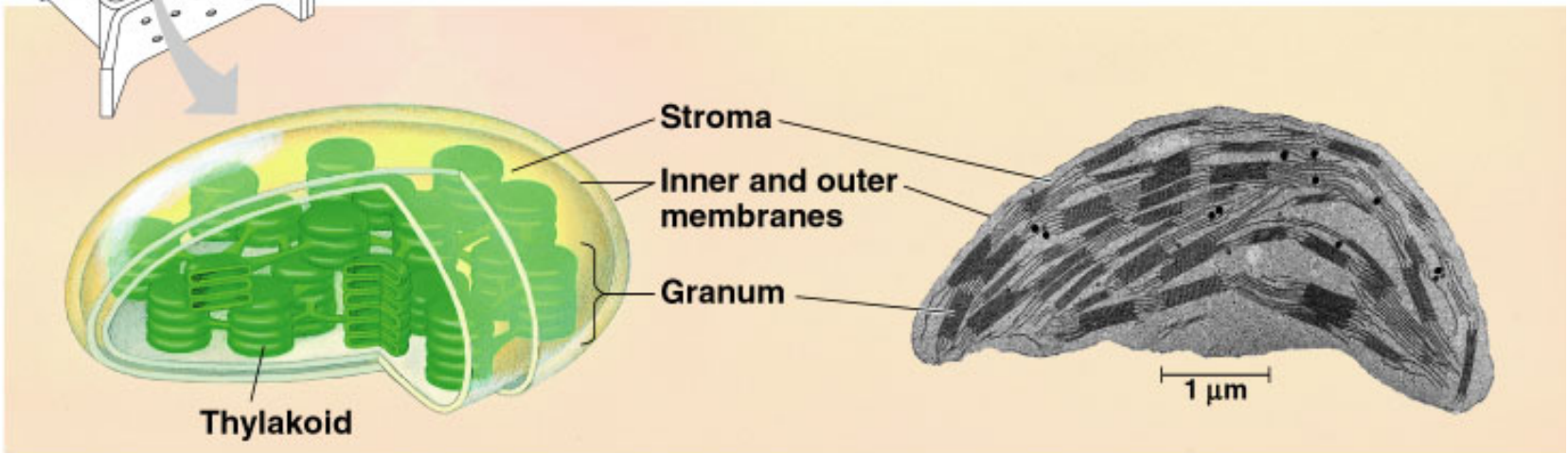
Chloroplasts

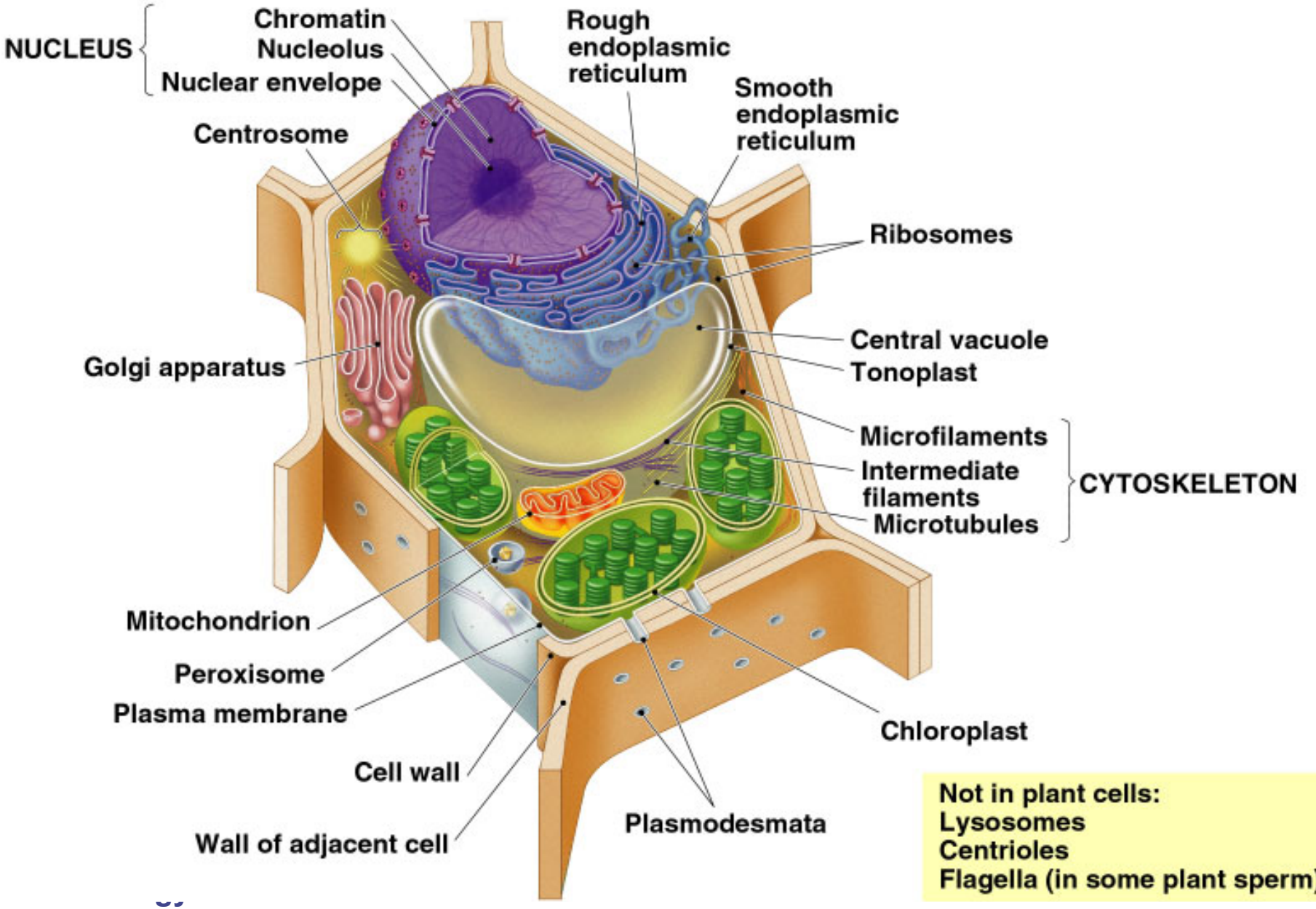
Why are chloroplasts green?









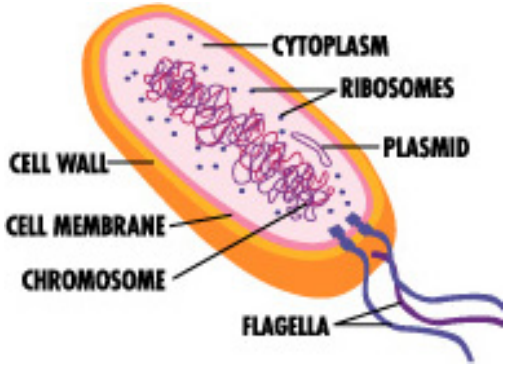

NUCLEUS
Chromatin
Nucleolus
Nuclear envelope
Centrosome
Rough endoplasmic reticulum
Smooth endoplasmic reticulum
Ribosomes
Central vacuole
Tonoplast
Golgi apparatus
Microfilaments
Intermediate filaments
Microtubules
CYTOSKELETON
Mitochondrion
Peroxisome
Plasma membrane
Cell wall
Wall of adjacent cell
Plasmodesmata
Chloroplast
Not in plant cells:
Lysosomes
Centrioles
Flagella (in some plant sperm)

Mitochondria & chloroplasts are different

- Organelles not part of endomembrane system
- Grow & reproduce
  - semi-autonomous organelles
- Proteins primarily from free ribosomes in cytosol & a few from their own ribosomes
- Own circular chromosome
  - directs synthesis of proteins produced by own internal ribosomes
    - ribosomes like bacterial ribosomes

Who else has a circular chromosome not bound within a nucleus?

bacteria



1981 | ??

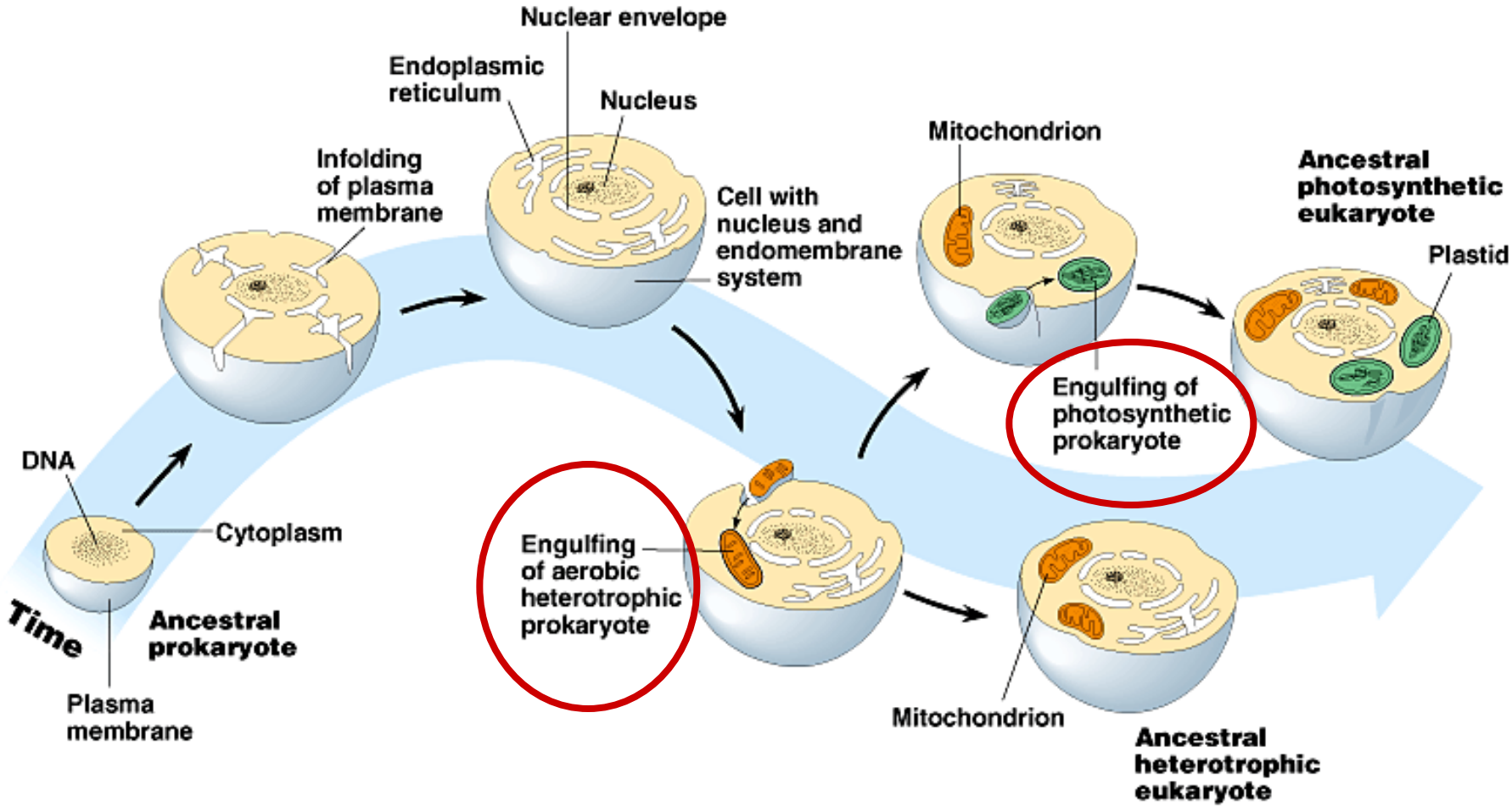
Endosymbiosis theory

- Mitochondria & chloroplasts were once free living bacteria
  - engulfed by ancestral eukaryote
- Endosymbiont
  - cell that lives within another cell (host)
    - as a partnership
    - evolutionary advantage for both
      - one supplies energy
      - the other supplies raw materials & protection

Lynn Margulis
U of M, Amherst

Endosymbiosis theory

Evolution of eukaryotes



Compare the equations

Photosynthesis

carbon dioxide + water + energy → glucose + oxygen

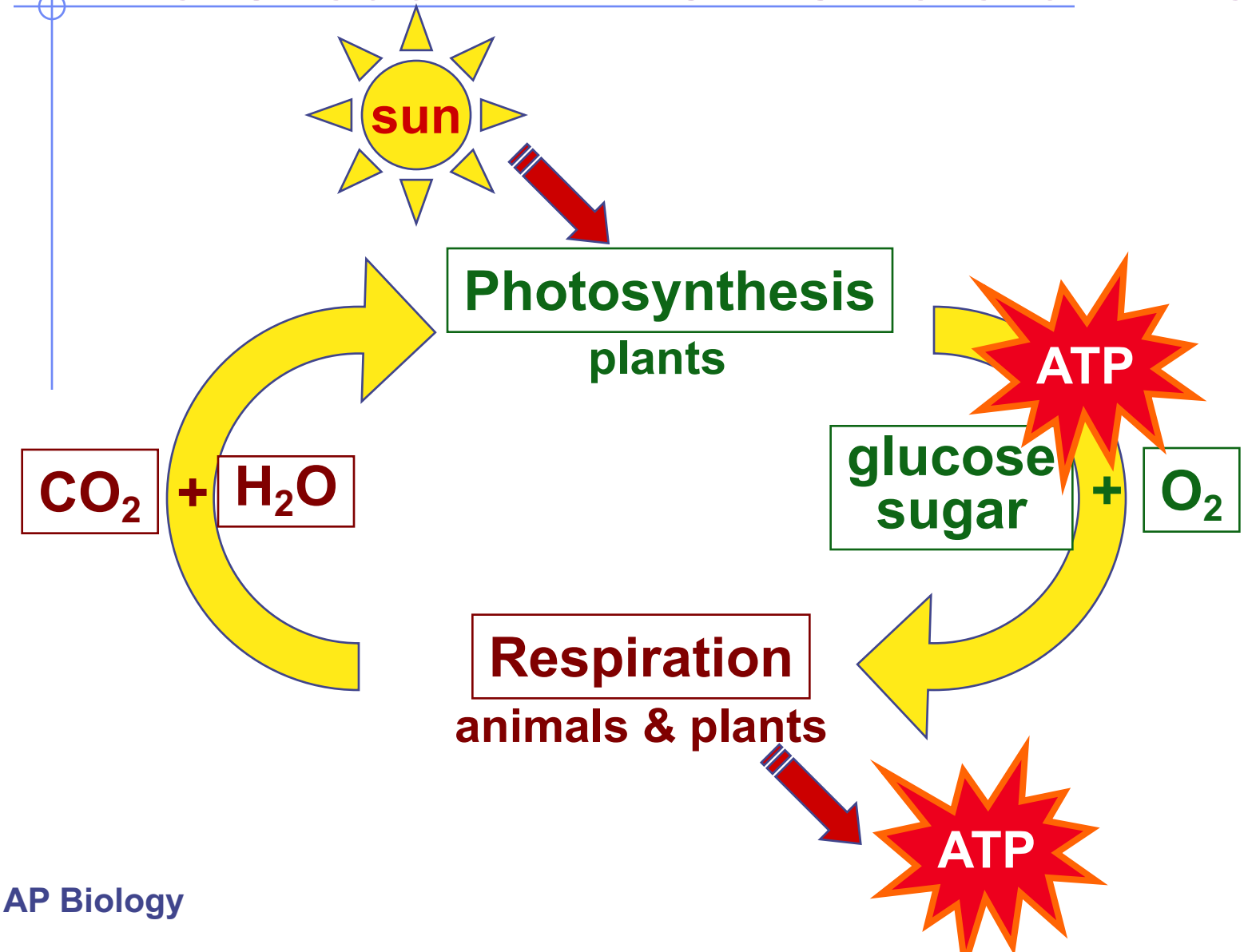
$$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

Respiration

glucose + oxygen → carbon dioxide + water + energy

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$$

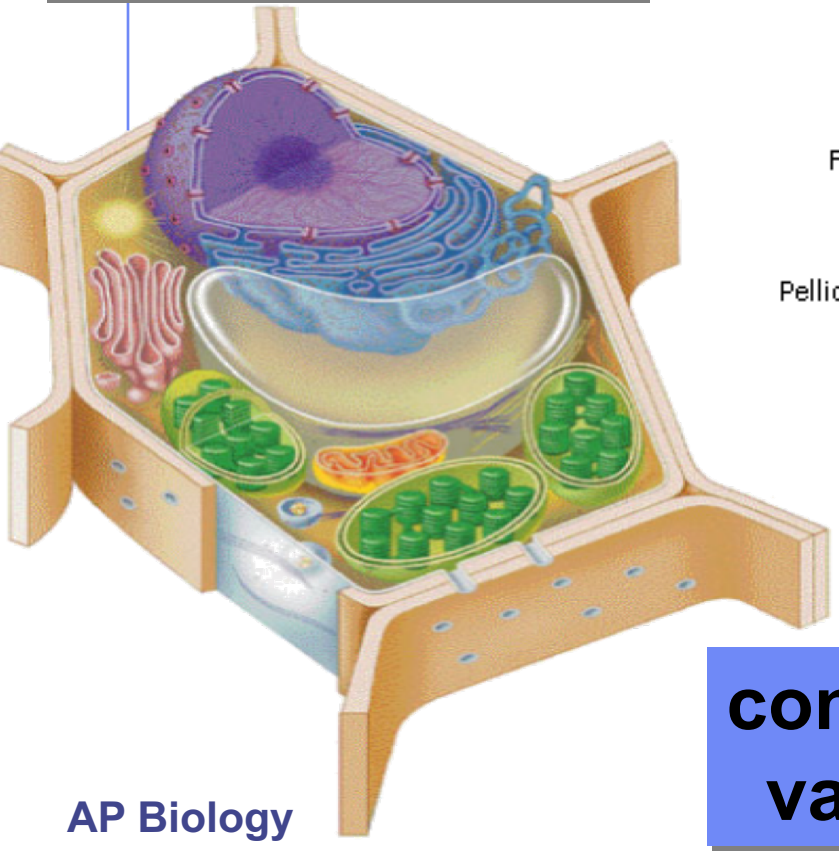
The Great ENERGY Circle of Life



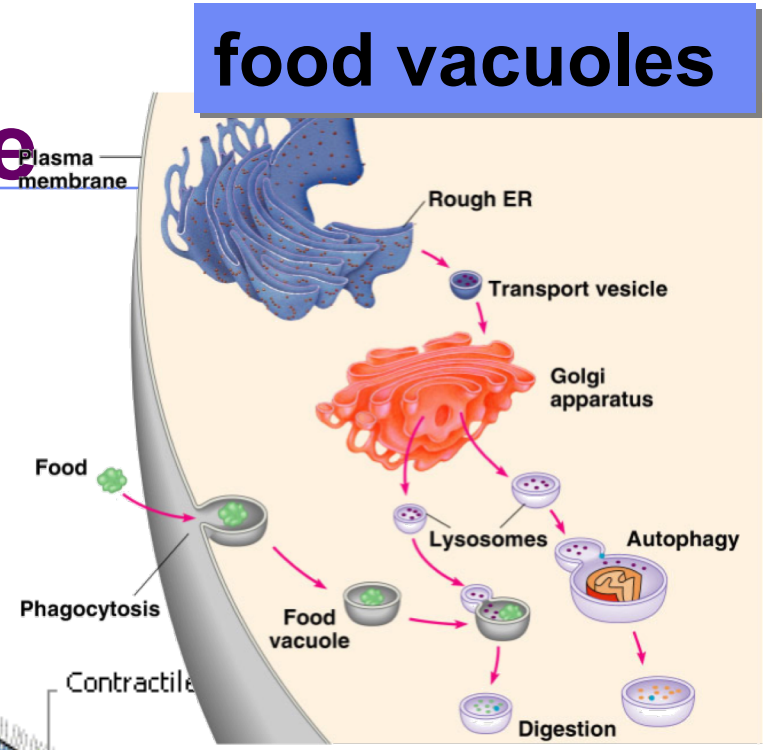
Food & water storage

plant cells

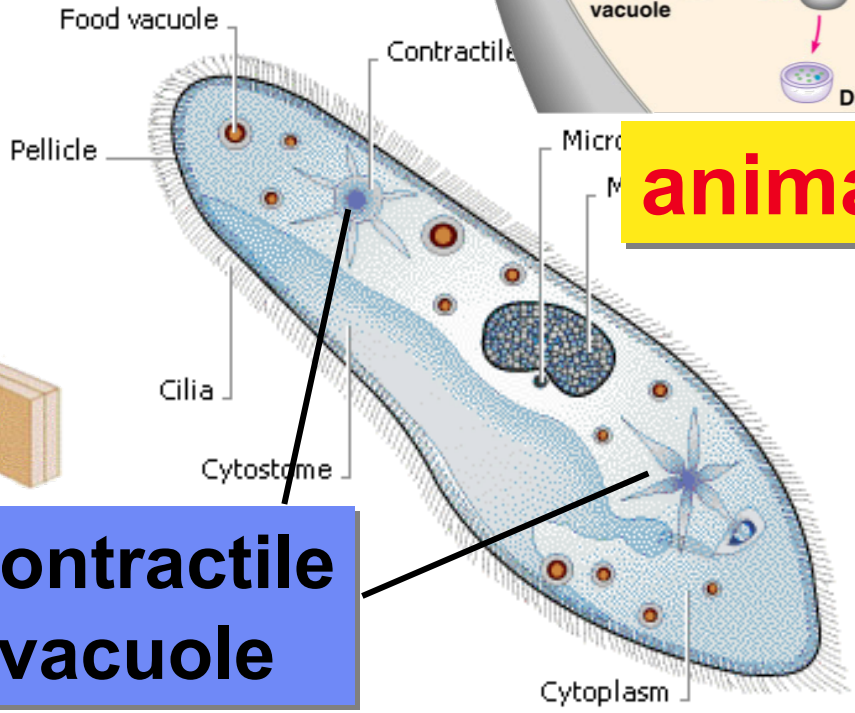
central vacuole



food vacuoles



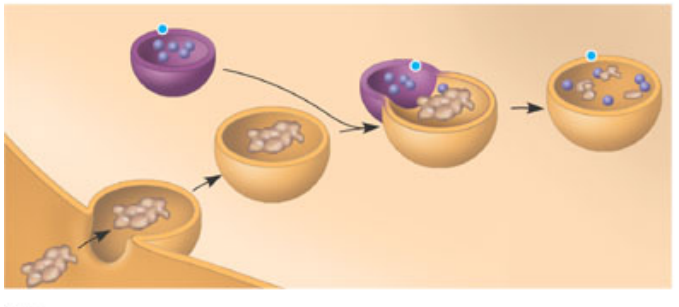
animal cells

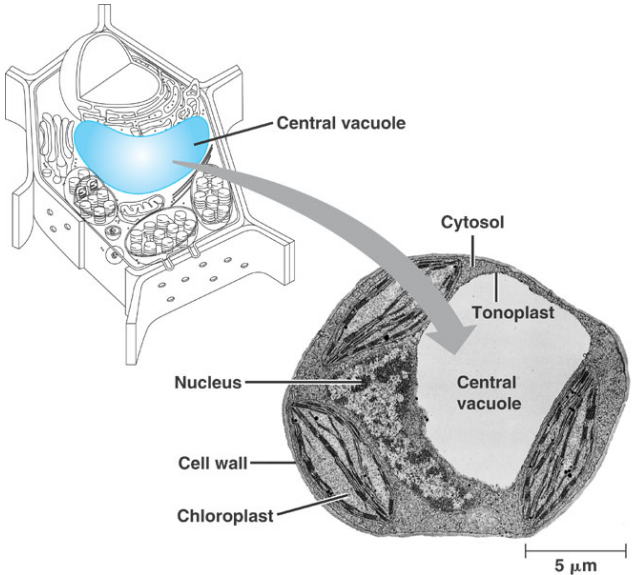


contractile vacuole

Vacuoles & vesicles

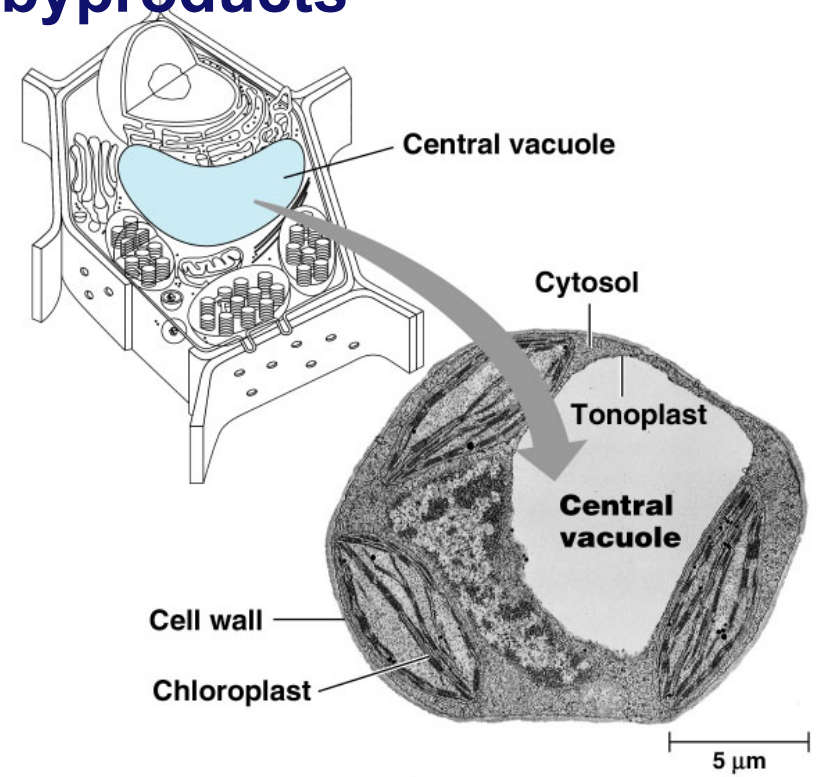
- **Function**
  - little "transfer ships"
    - **Food vacuoles**
      - phagocytosis, fuse with lysosomes
    - **Contractile vacuoles**
      - in freshwater protists, pump excess H_2O out of cell
    - **Central vacuoles**
      - in many mature plant cells





Vacuoles in plants

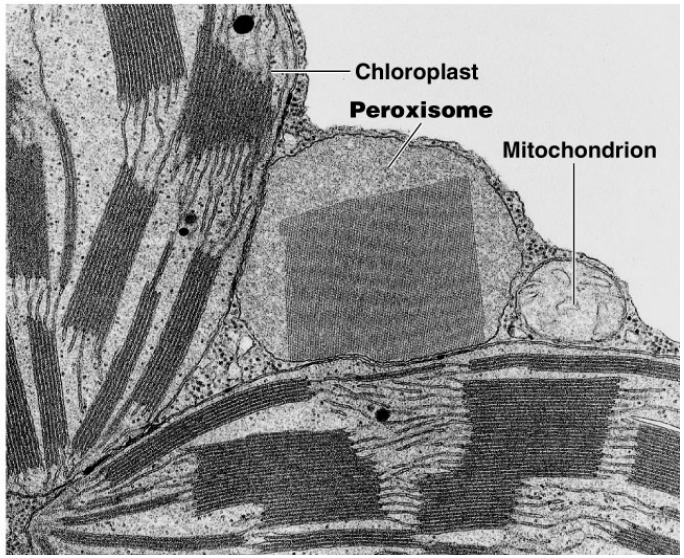
- **Functions**
  - **storage**
    - stockpiling proteins or inorganic ions
    - depositing metabolic byproducts
    - storing pigments
    - storing defensive compounds against herbivores
    - selective membrane
      - control what comes in or goes out



Peroxisomes

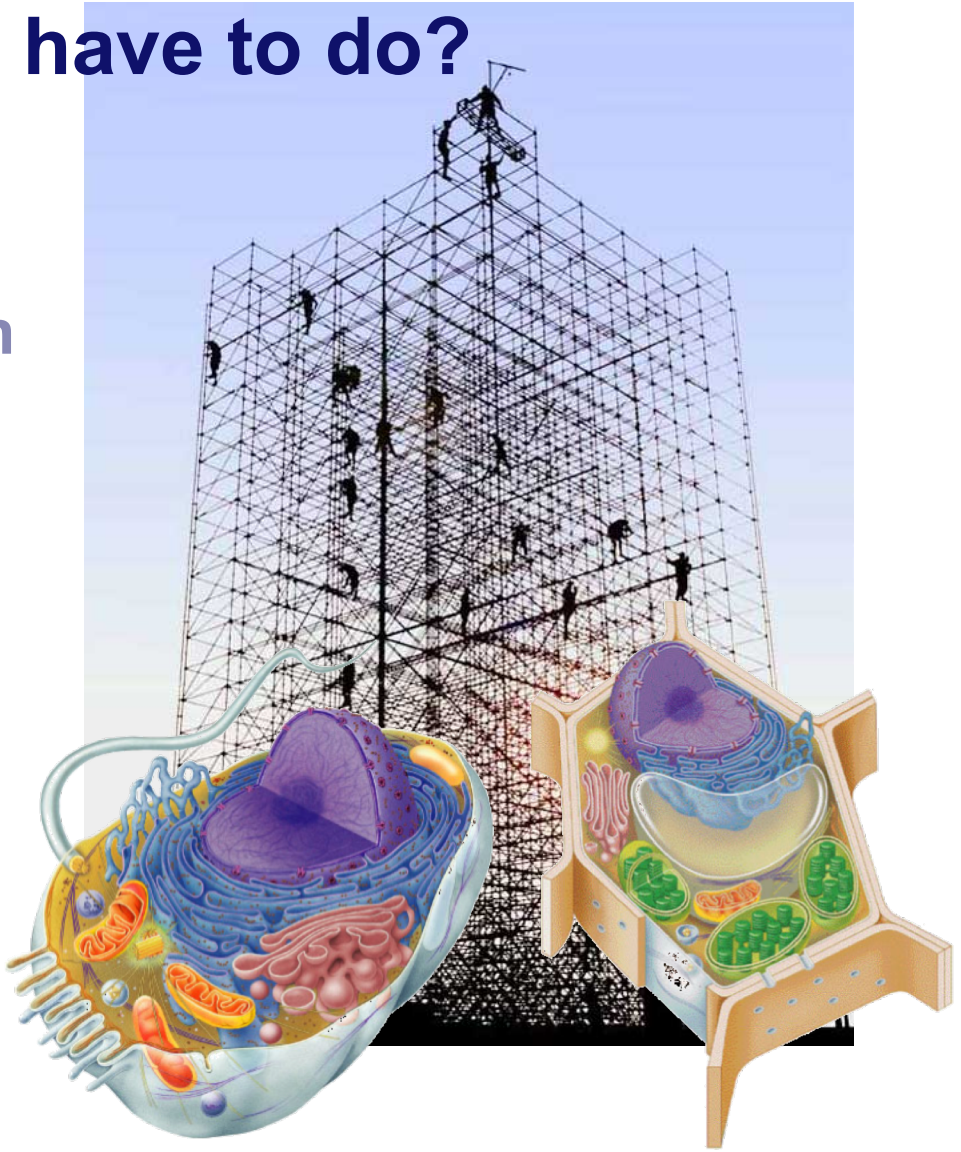
- Other digestive enzyme sacs
  - in both animals & plants
  - breakdown fatty acids to sugars
    - easier to transport & use as energy source
  - detoxify cell
    - detoxifies alcohol & other poisons
  - produce peroxide (H_2O_2)
    - must breakdown

      $H_2O_2 \rightarrow H_2O$

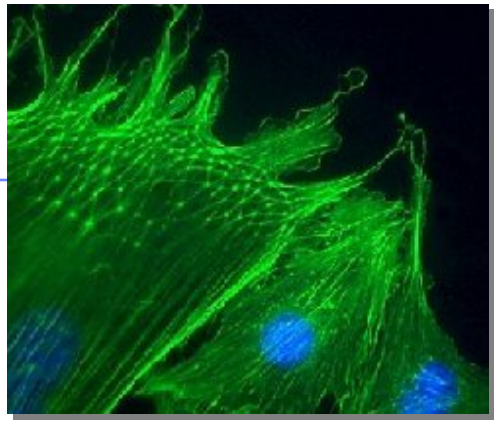


Cells gotta live!

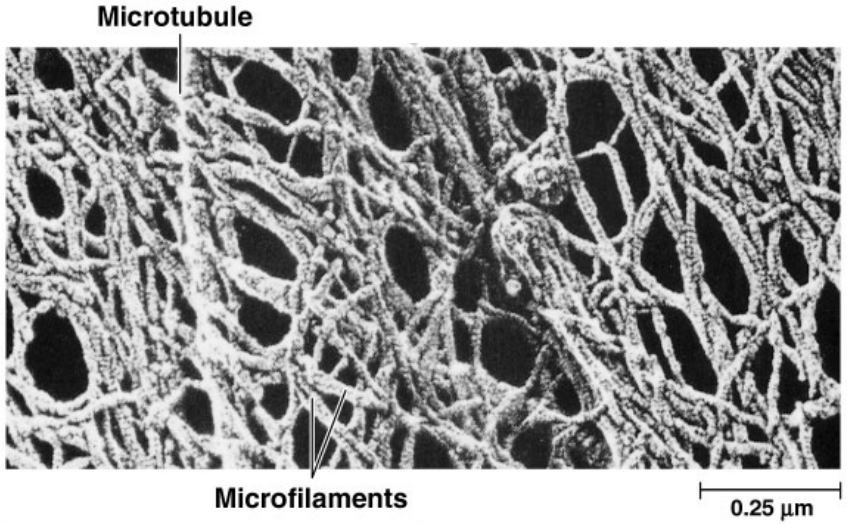
- What jobs do cells have to do?
  - building proteins
    - proteins control every cell function
  - make energy
    - for daily life
    - for growth
  - build more cells
    - growth
    - reproduction
    - repair



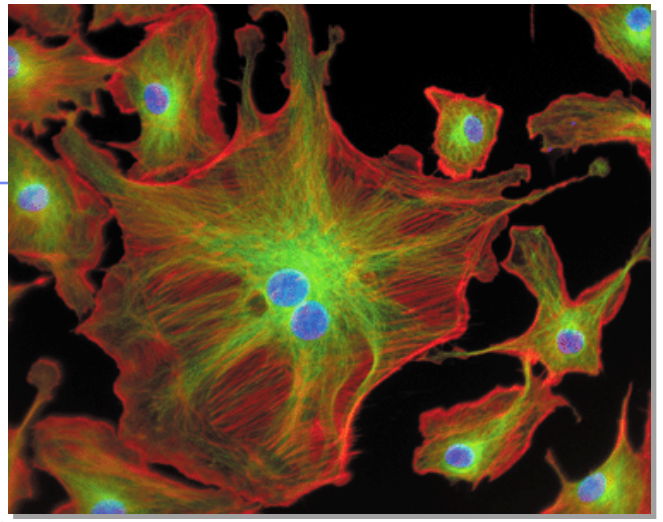
Cytoskeleton



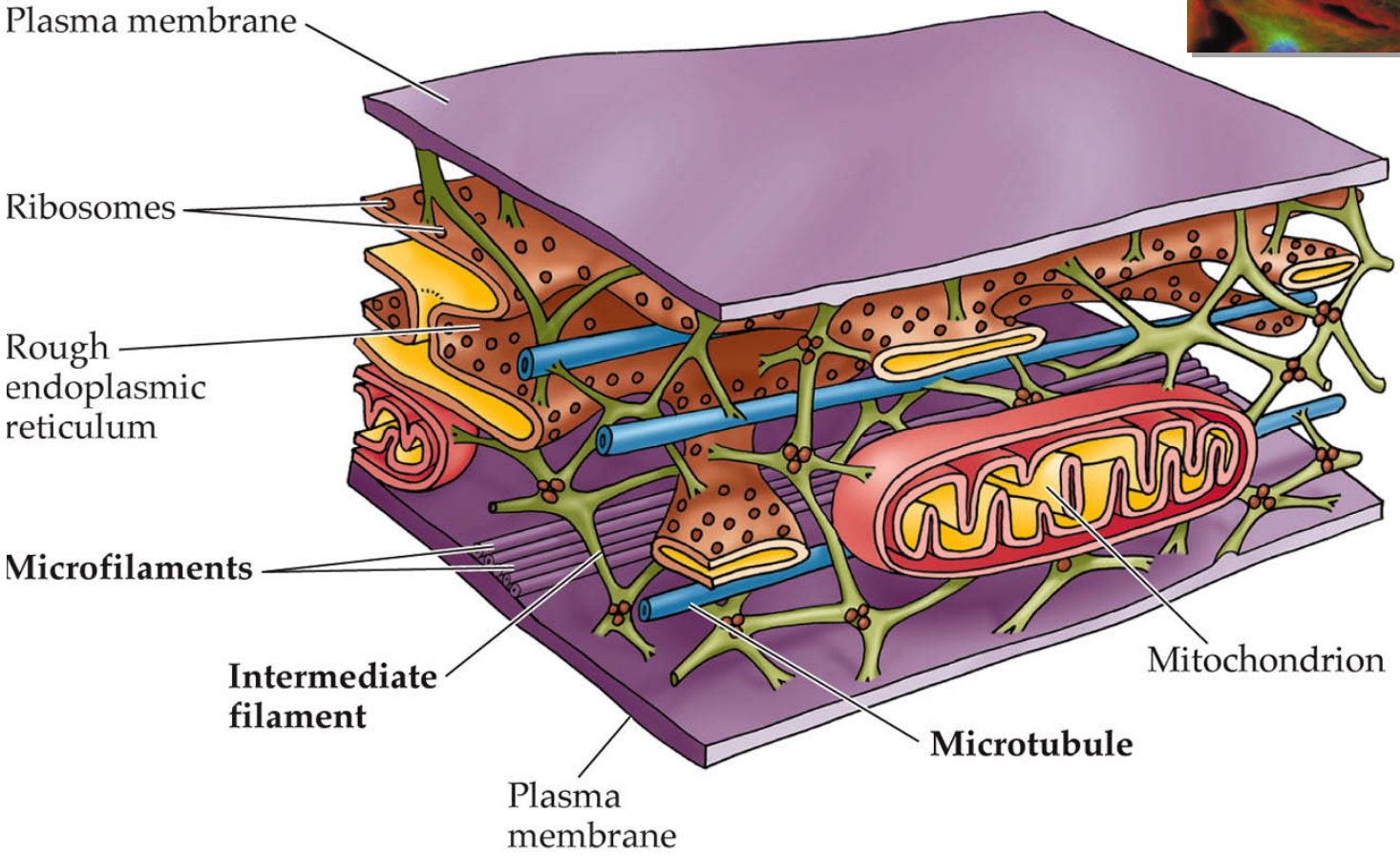
- Function
  - structural support
    - maintains shape of cell
    - provides anchorage for organelles
      - protein fibers
        - microfilaments, intermediate filaments, microtubules
  - motility
    - cell locomotion
    - cilia, flagella, etc.
  - regulation
    - organizes structures & activities of cell



Cytoskeleton

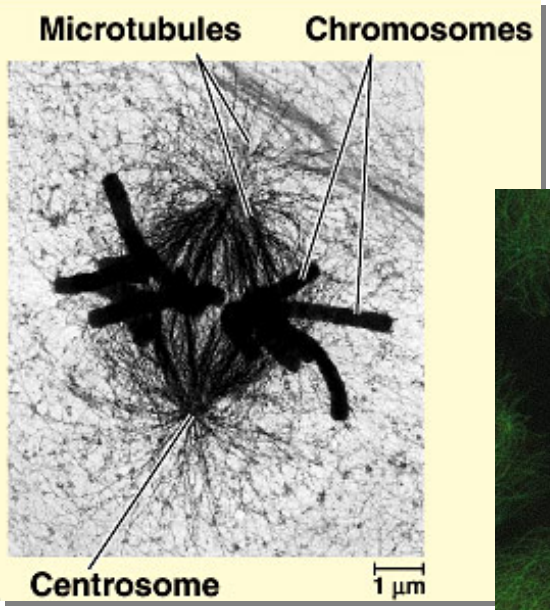


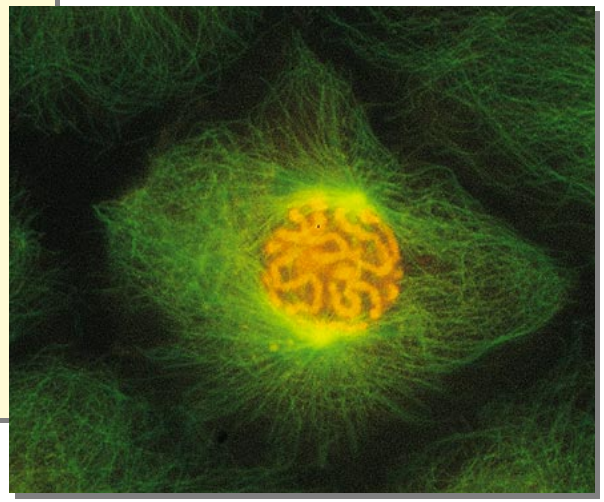
- actin
- microtubule
- nuclei

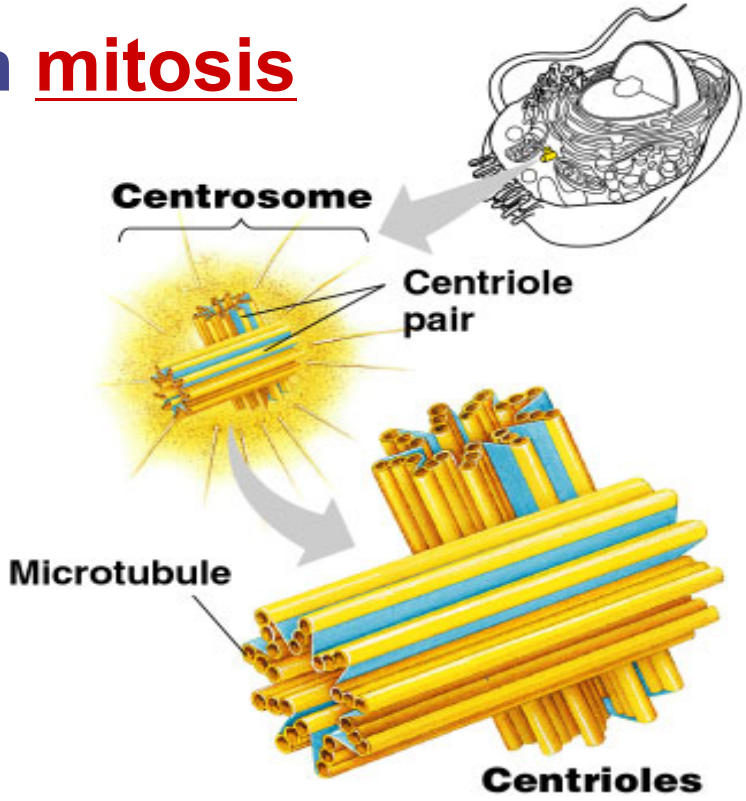


Centrioles

- Cell division
  - in animal cells, pair of centrioles organize microtubules
  - guide chromosomes in mitosis



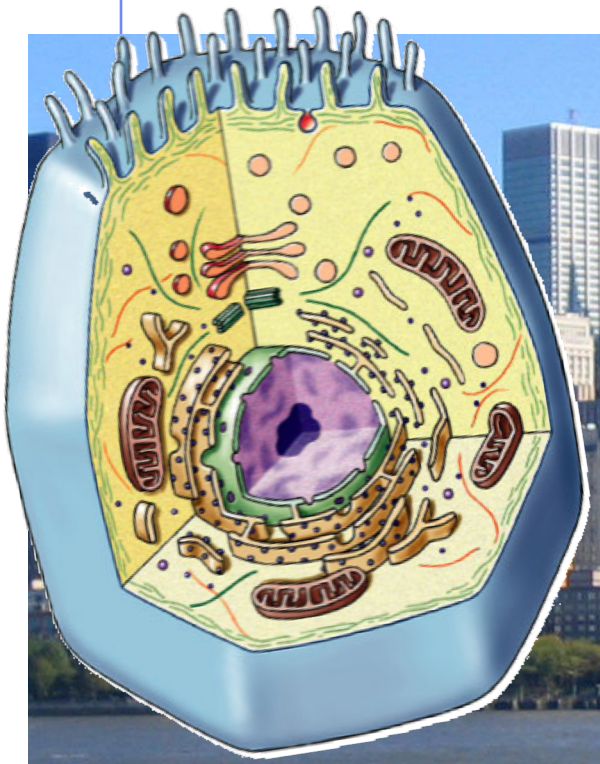


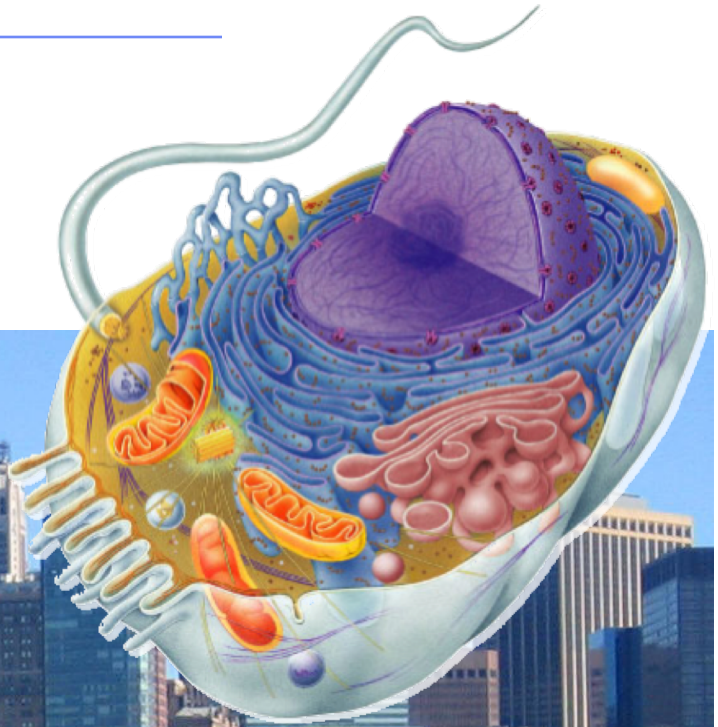


Coordination of Cellular Activities

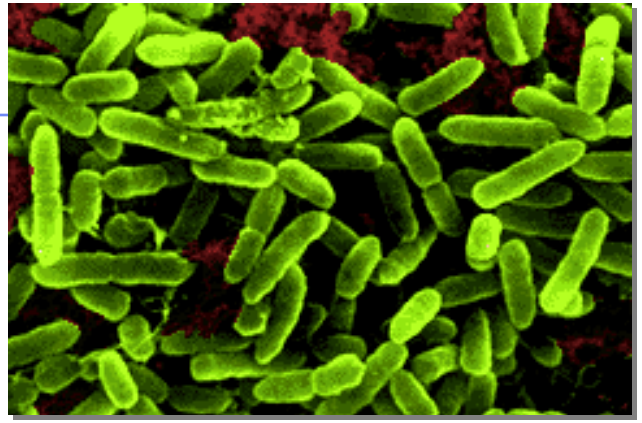
- Cell Wall: Protects the plant and helps maintain its shape. It is outside the plasma membrane. Made of cellulose.
  - Prokaryotes and Fungi have cell walls but not of cellulose.
- Plasmodesmata are channels that perforate adjacent plant cell walls and allow the passage of some molecules cell to cell
- Extracellular matrix of animal cells is situated just external to the plasma membrane; it is made of glycoproteins secreted by the cell.
- Animal cells have three types of intercellular junctions:
  - **Tight junctions** are sections of animal cell membranes where two neighboring cells are fused, making the membranes watertight.
  - **Desmosomes** fasten adjacent animal cells together, functioning like rivets to fasten cells into strong sheets.
  - **Gap junctions** provide channels between adjacent animal cells through which ions, sugars, communication molecules, and other small molecules can pass.

Cell Size

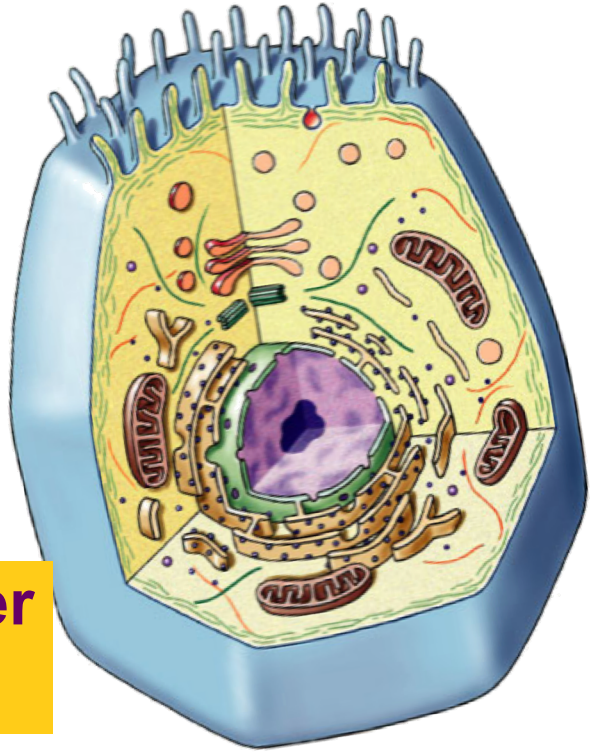




Limits to cell size



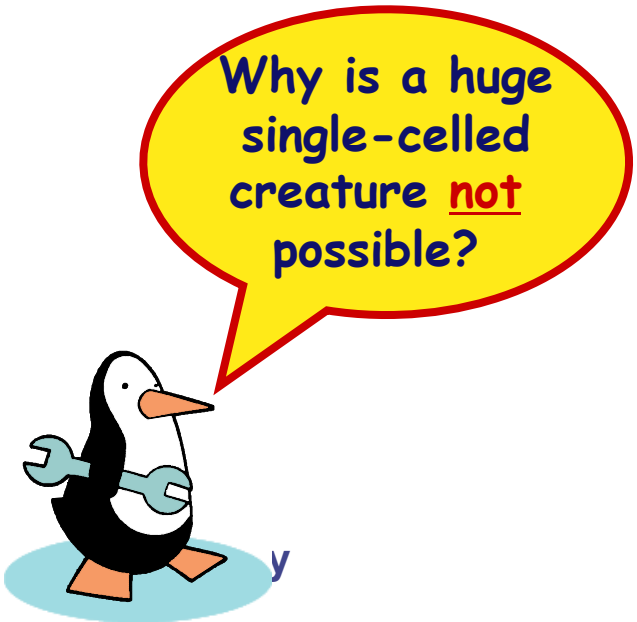
- Lower limit
  - smallest bacteria
    - mycoplasmas
    - 0.1 to 1.0 micron (μm = micrometer)
  - most bacteria
    - 1-10 microns
- Upper limit
  - eukaryotic cells
    - 10-100 microns

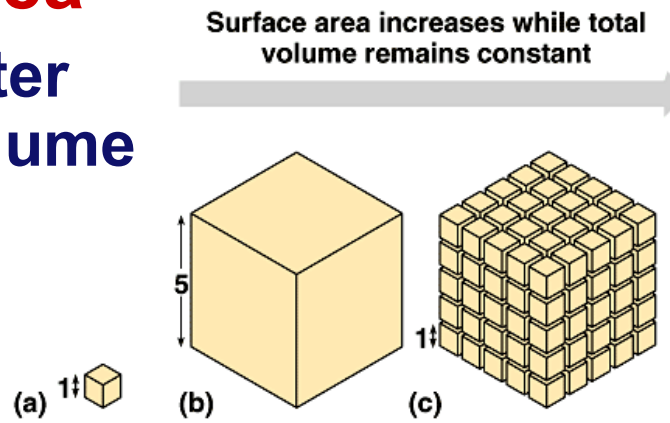


- micron = micrometer = 1/1,000,000 meter
- diameter of human hair = ~20 microns

What limits cell size?

- Surface to volume ratio
  - as cell gets bigger its **volume increases faster than its surface area**
    - smaller objects have greater ratio of surface area to volume



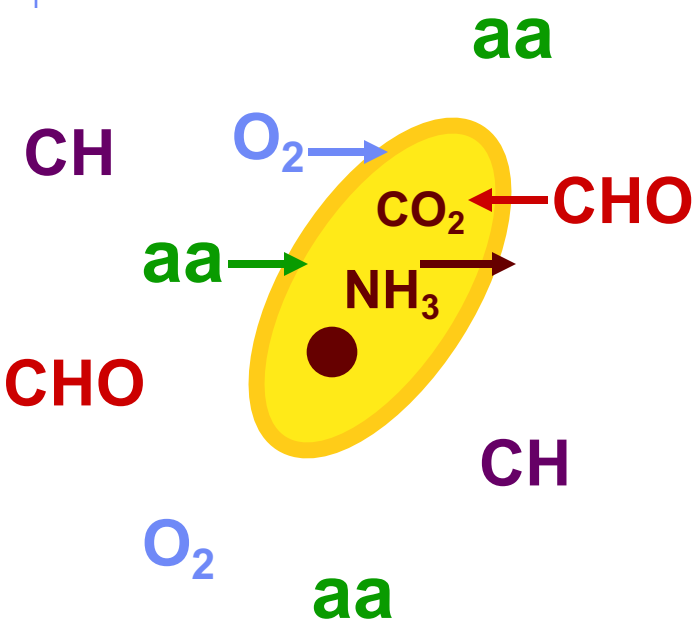


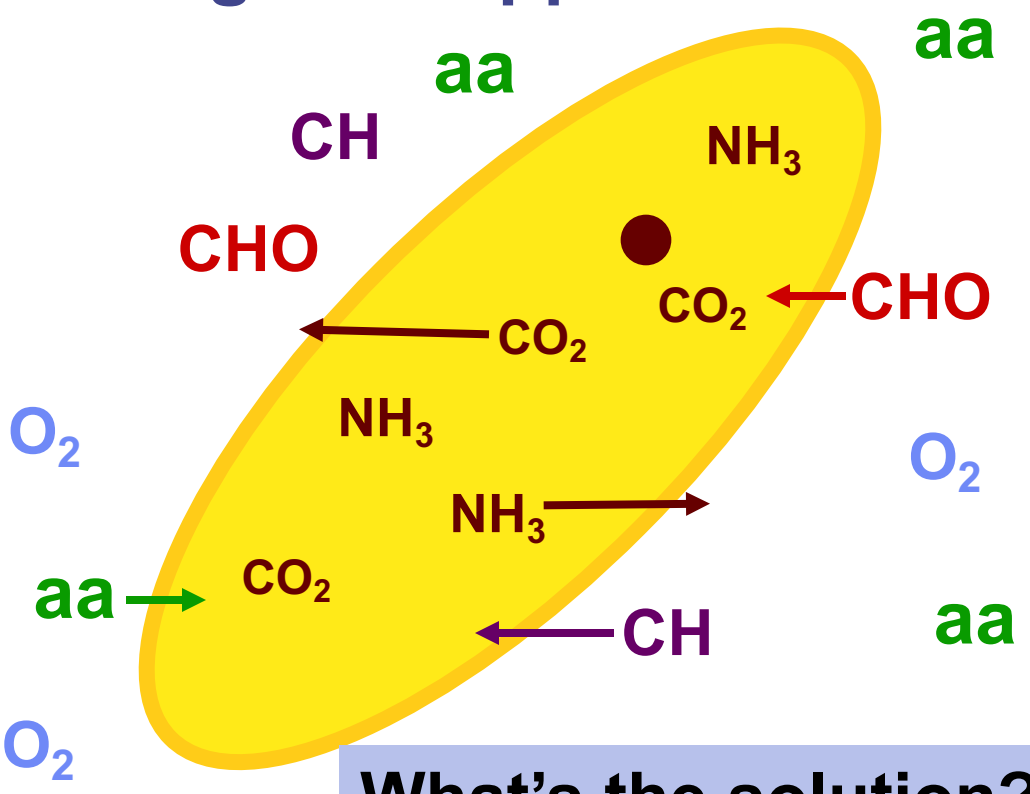
Total surface area (height × width × number of sides × number of boxes)	6	150	750
Total volume (height × width × length × number of boxes)	1	125	125
Surface-to-volume ratio (area ÷ volume) **s:v**	**6:1**	**~1:1**	**6:1**

Limits to cell size

- Metabolic requirements set upper limit
  - in large cell, cannot move material in & out of cell fast enough to support life

What process is this?



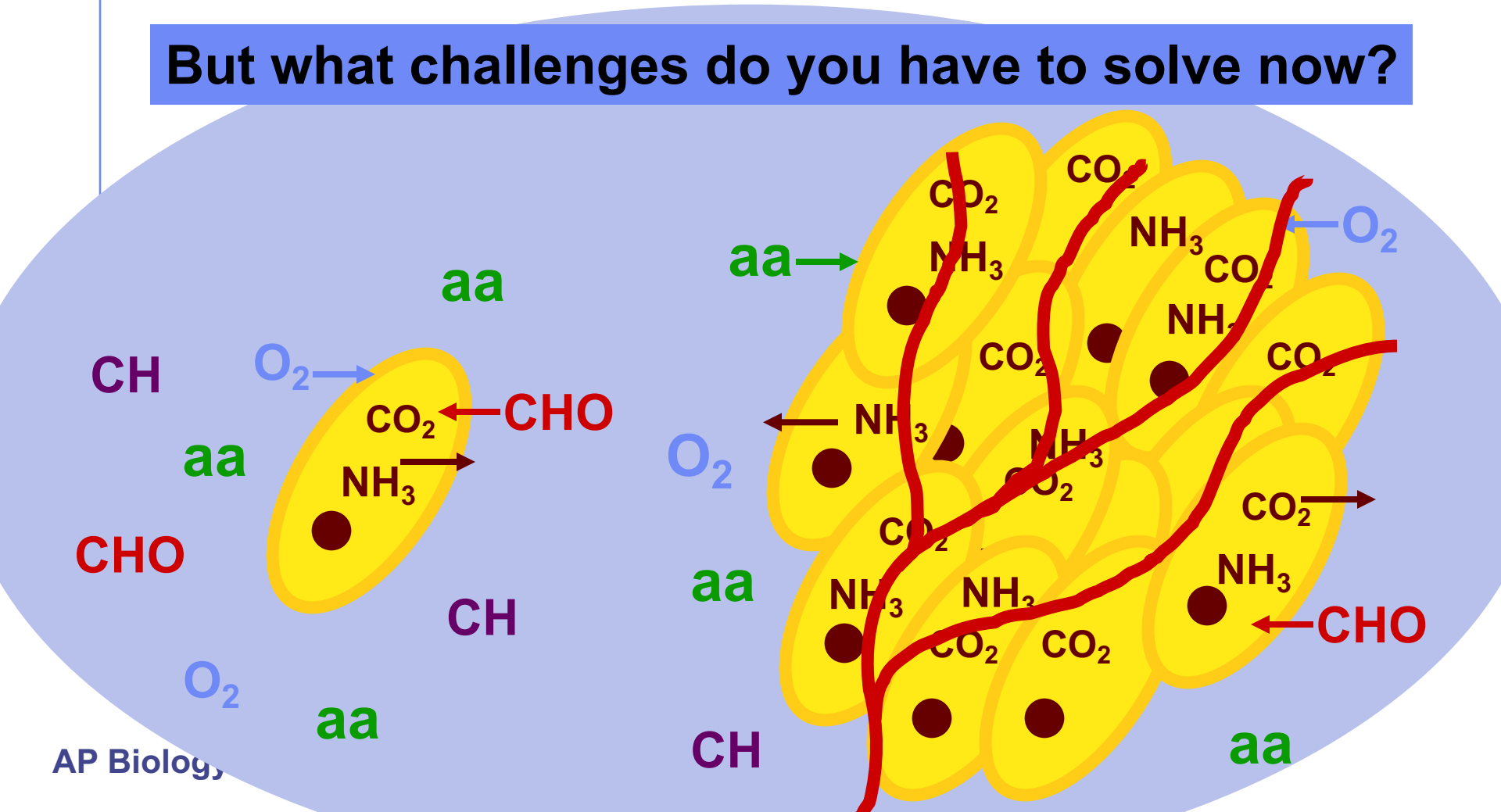


What's the solution?

How to get bigger?

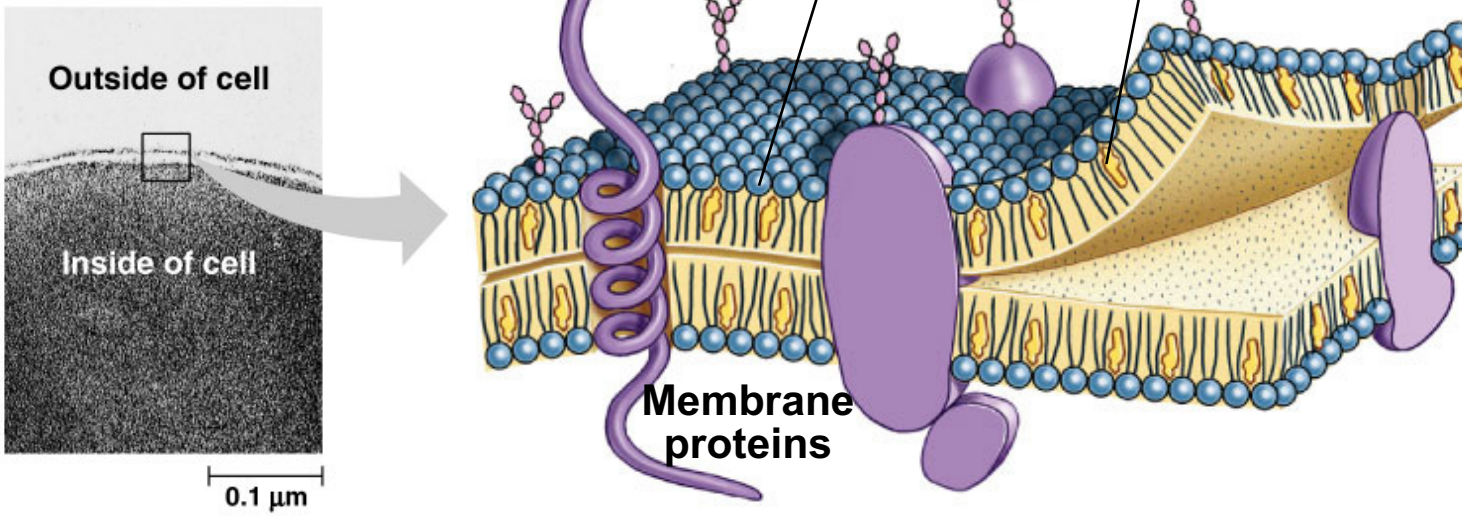
- Become multicellular (cell divides)

But what challenges do you have to solve now?



Cell membrane

- **Exchange structure**
  - **plasma membrane functions as selective barrier**
    - allows passage of O_2 & nutrients **IN**
    - allows passage of products & wastes **OUT**



Any Questions??