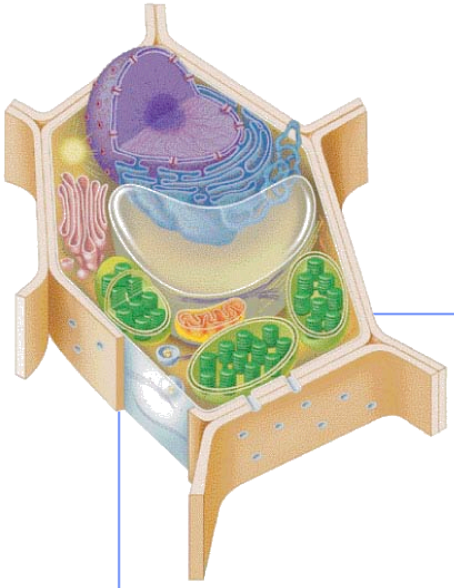
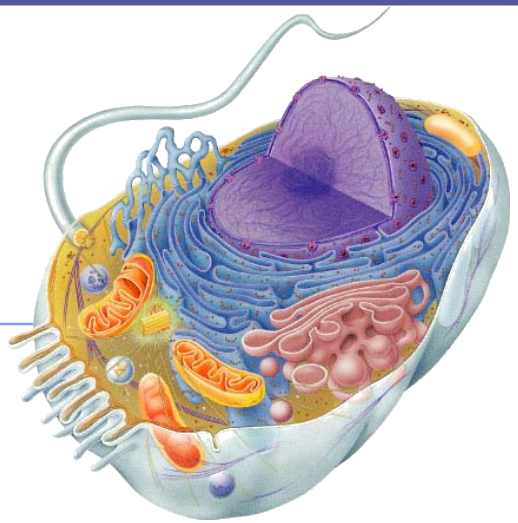
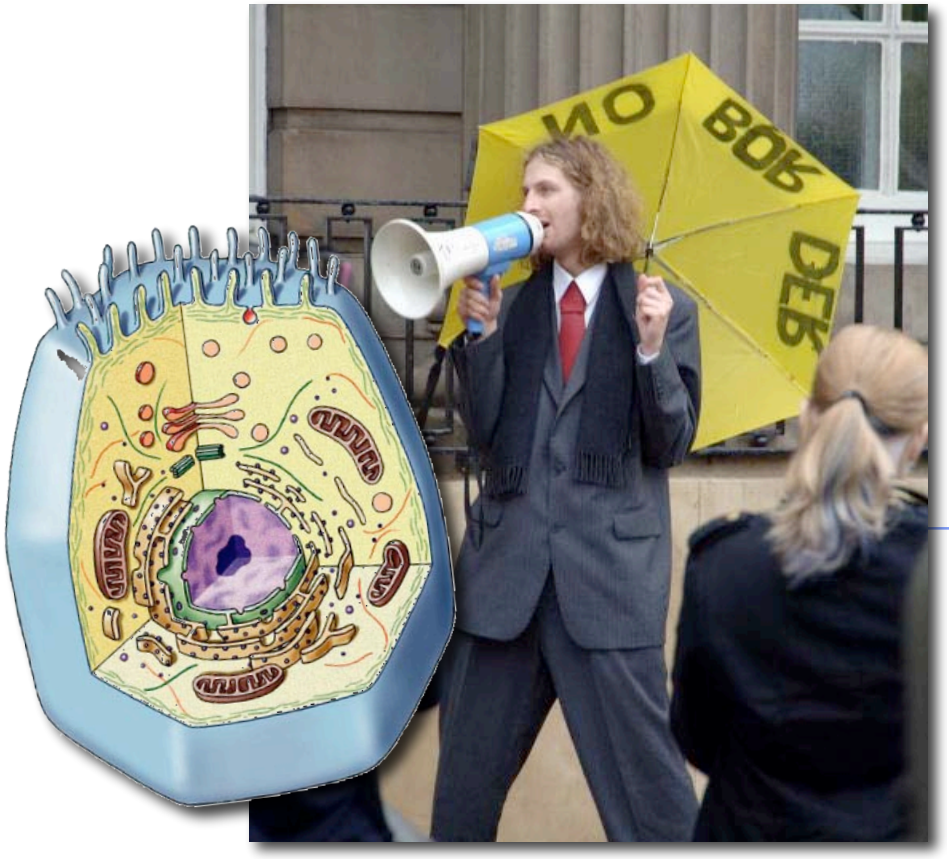


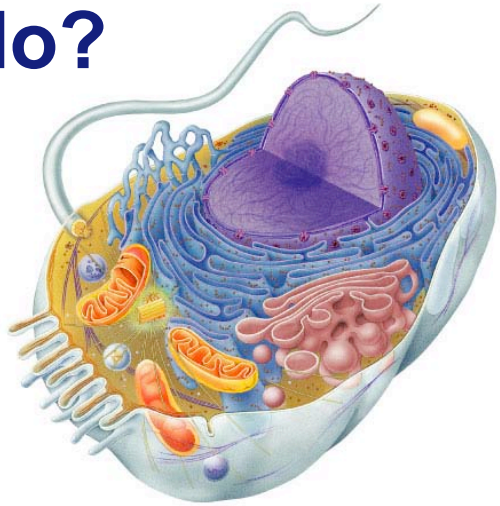


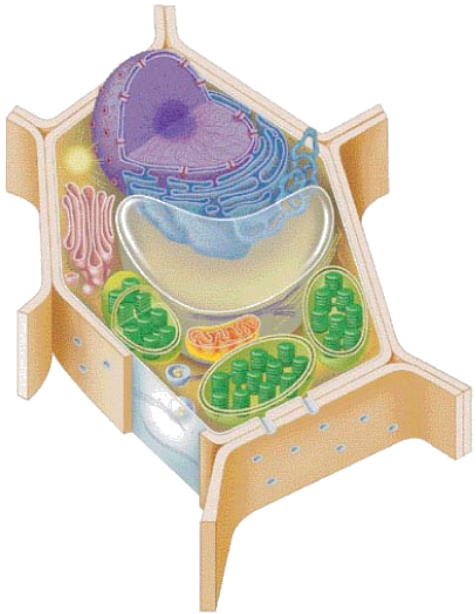
Tour of the Cell 2



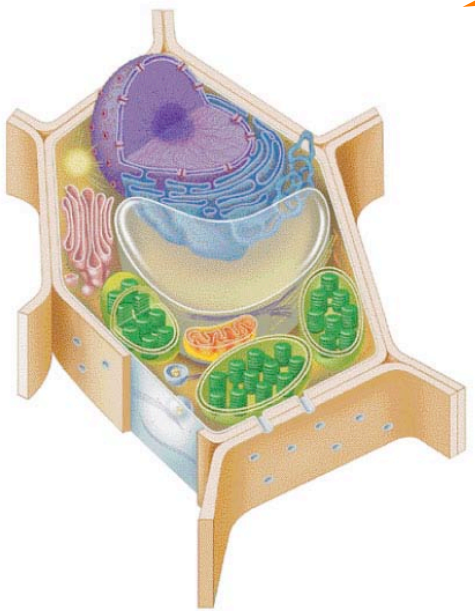
Cells gotta work to live!

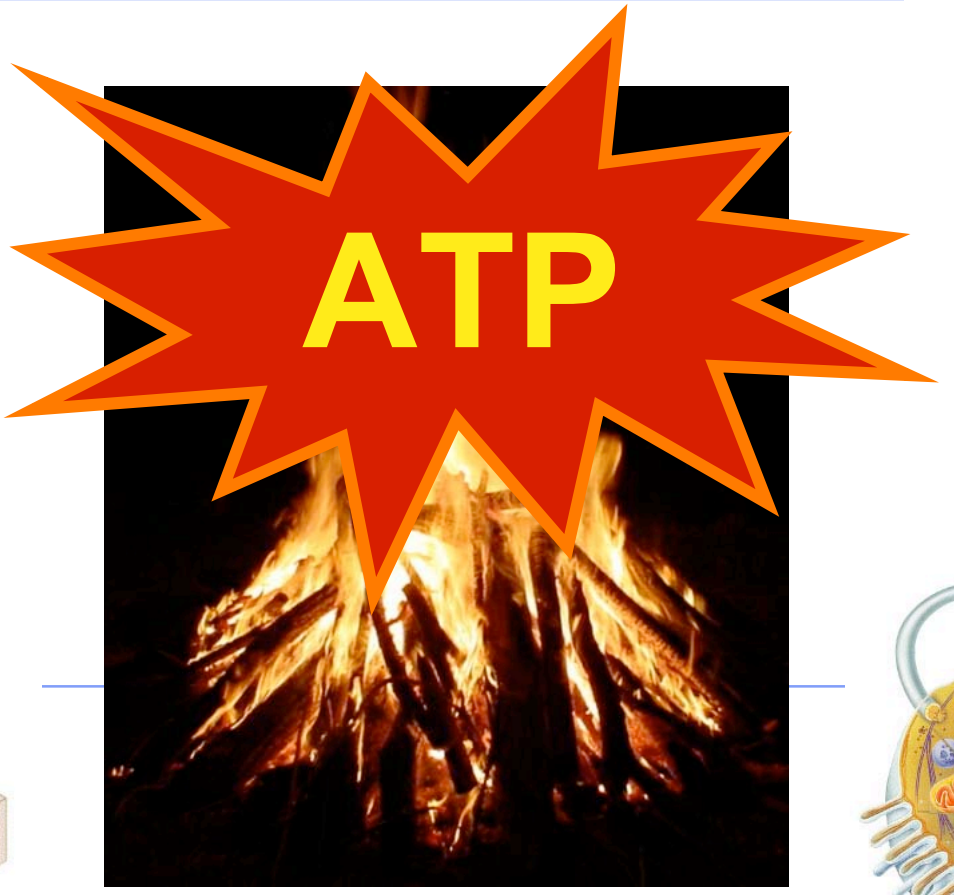
- What jobs do cells have to do?
  - make proteins
    - proteins control every cell function
  - make energy
    - for daily life
    - for growth
  - make more cells
    - growth
    - repair
    - renewal

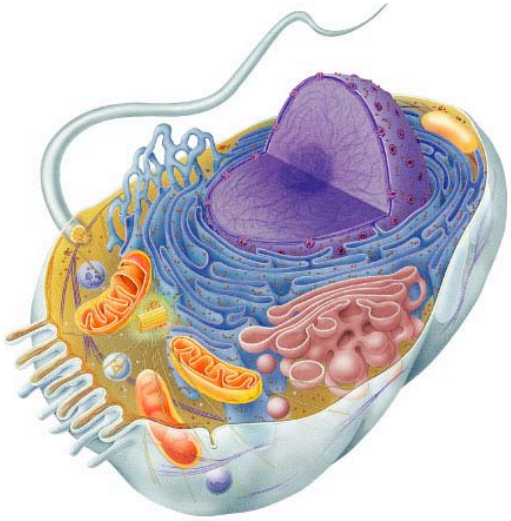




Making Energy

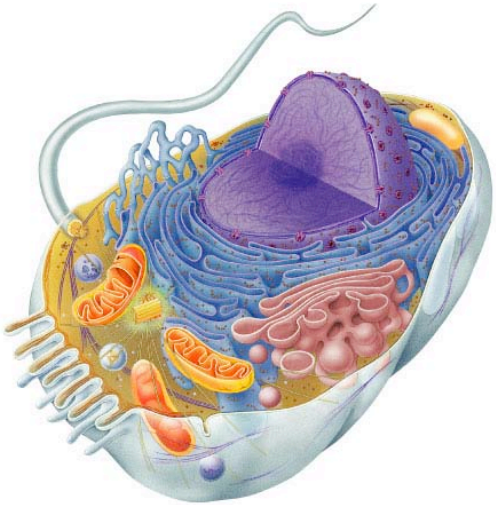


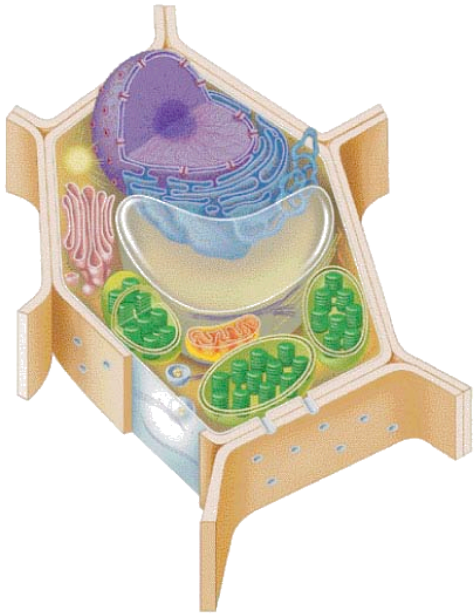




Cells need power!

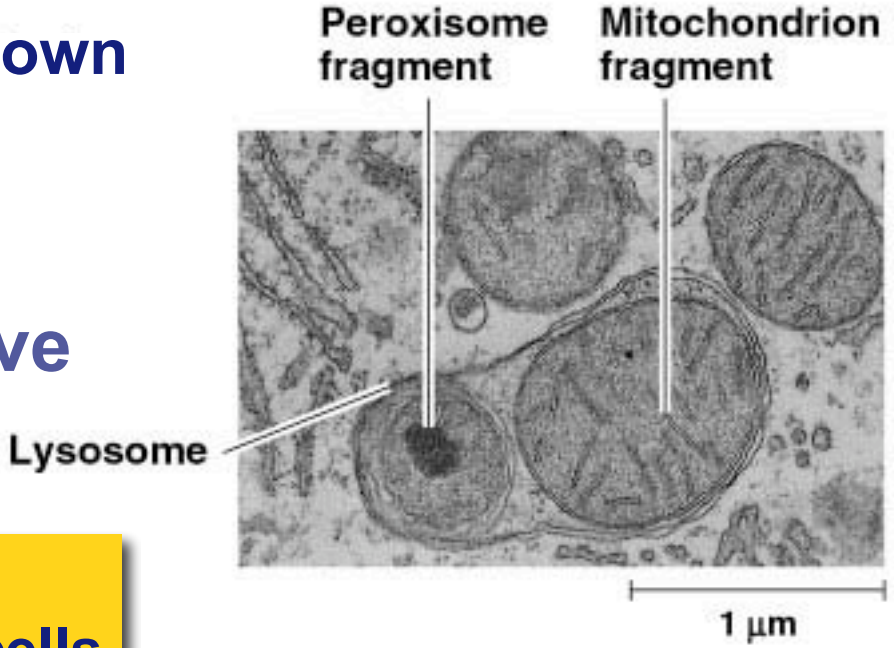
- **Making energy**
  - take in food & digest it
  - take in oxygen (O_2)
  - make ATP
  - remove waste





Lysosomes

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



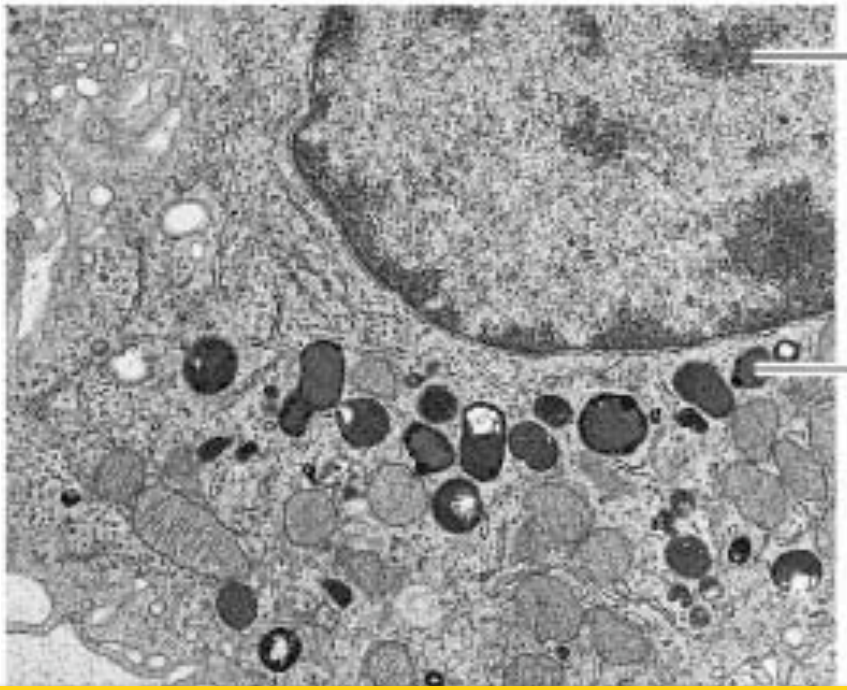
(b) A lysosome in action

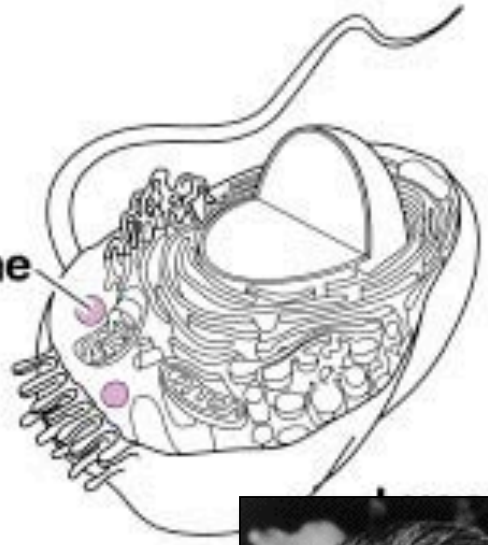
synthesized by rER, transferred to Golgi

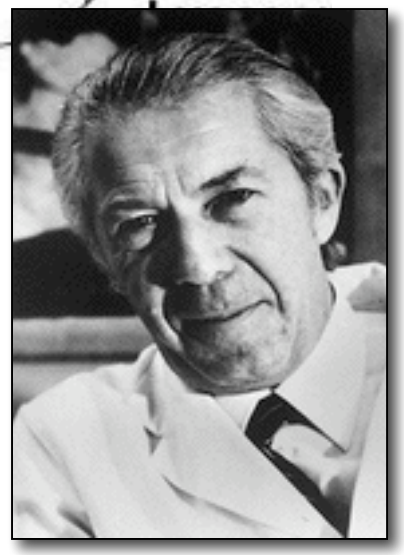
only in animal cells

1960 | 1974

Lysosomes





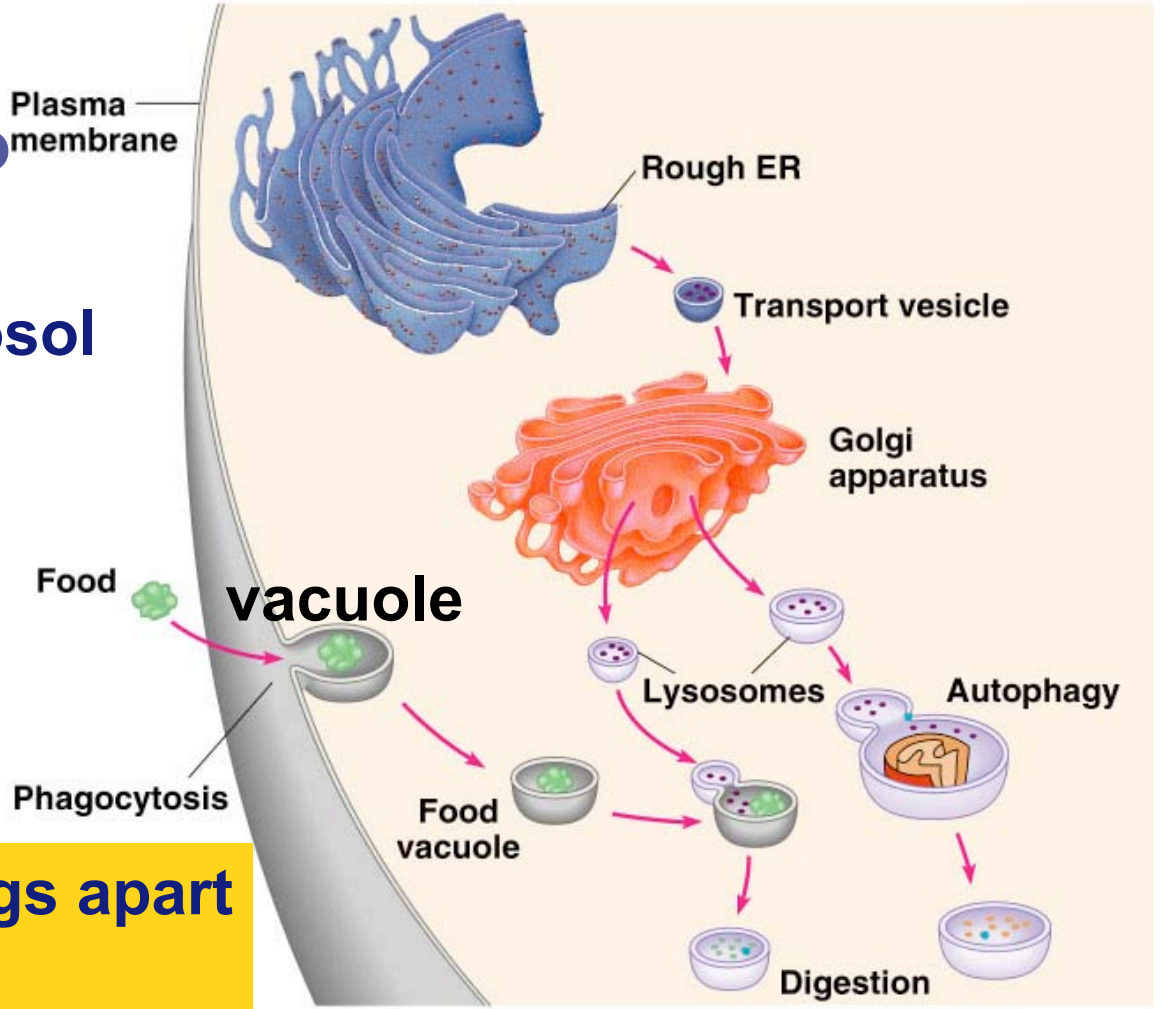


white blood cells attack & destroy invaders = digest them in lysosomes

1974 Nobel prize: Christian de Duve
Lysosomes discovery in 1960s

Cellular digestion

- Lysosomes fuse with food vacuoles
  - polymers digested into monomers
    - pass to cytosol to become nutrients of cell



- lyso– = breaking things apart
- –some = body

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 evolve 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!

When things go bad…

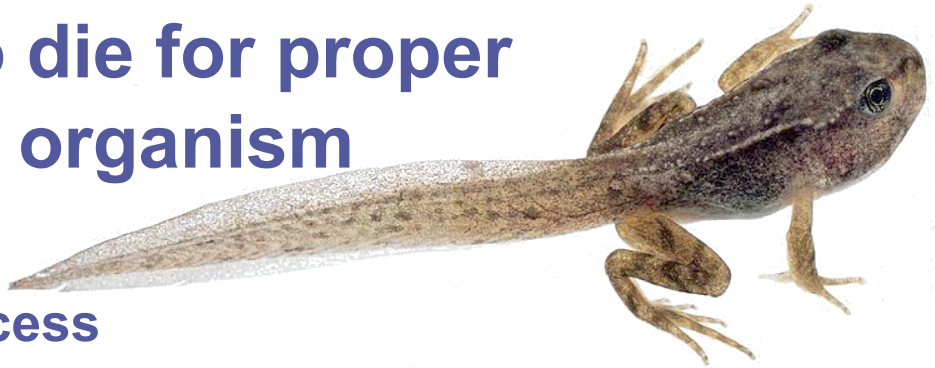
- **Diseases of lysosomes are often fatal**
  - digestive enzyme not working in lysosome
  - picks up biomolecules, but can't digest one
    - lysosomes fill up with undigested material
  - grow larger & larger until disrupts cell & organ function
    - lysosomal storage diseases
      - more than 40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

Lysosomal storage diseases

- Lipids
  - Gaucher's disease
  - Niemann-Pick disease
  - Tay Sachs
- Glycogen & other poylsaccharides
  - Farber disease
  - Krabbe disease
- Proteins
  - Schindler's disease

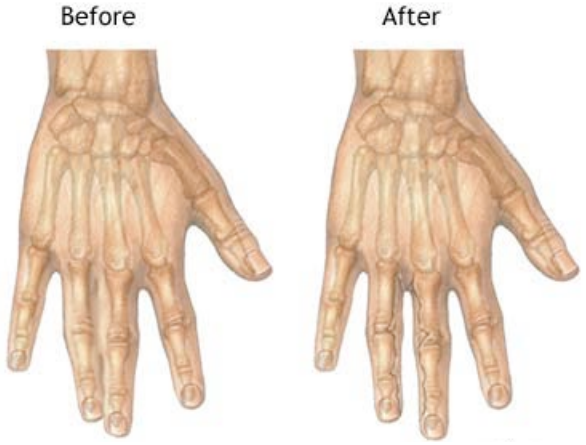
But sometimes cells need to die…

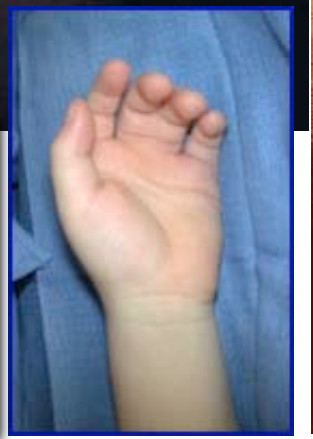
- Lysosomes can be used to kill cells when they are supposed to be destroyed
  - some cells have to die for proper development in an organism
    - apoptosis
      - "auto-destruct" process
      - lysosomes break open & kill cell
    - ex: tadpole tail gets re-absorbed when it turns into a frog
   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



Fetal development

syndactyly





Apoptosis

- programmed destruction of cells in multi-cellular organisms
  - programmed development
  - control of cell growth
    - example:
      if cell grows uncontrollably this self-destruct mechanism is triggered to remove damaged cell
    - cancer must over-ride this to enable tumor growth

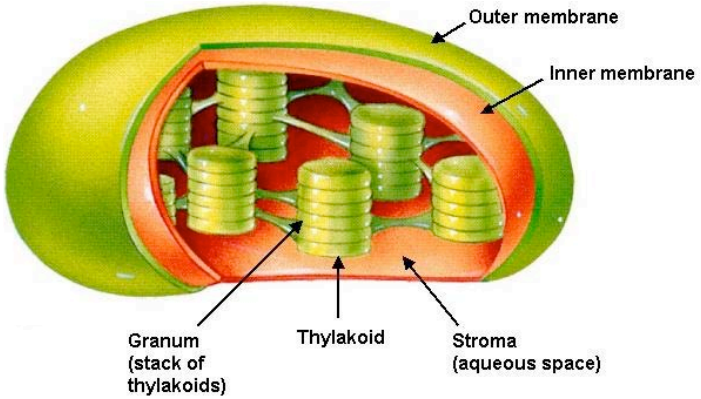
Making Energy

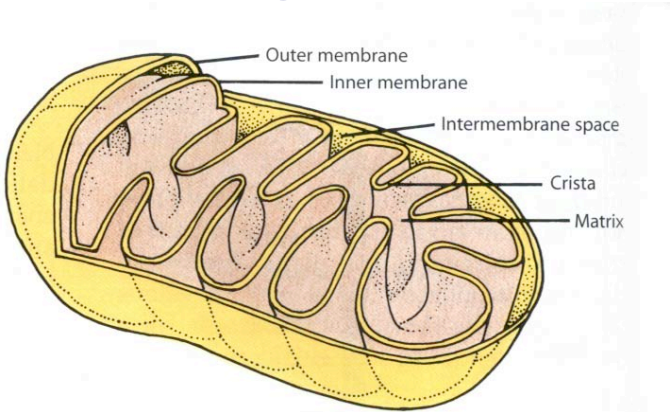
- Cells must convert incoming energy to forms that they can use for work
  - mitochondria:
    from glucose to ATP

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

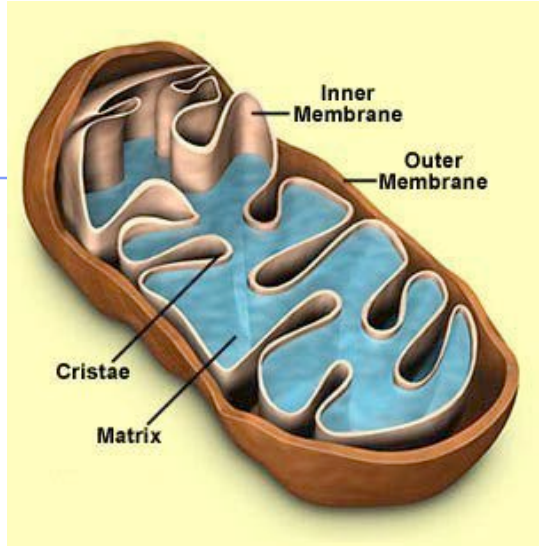
Mitochondria & Chloroplasts

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





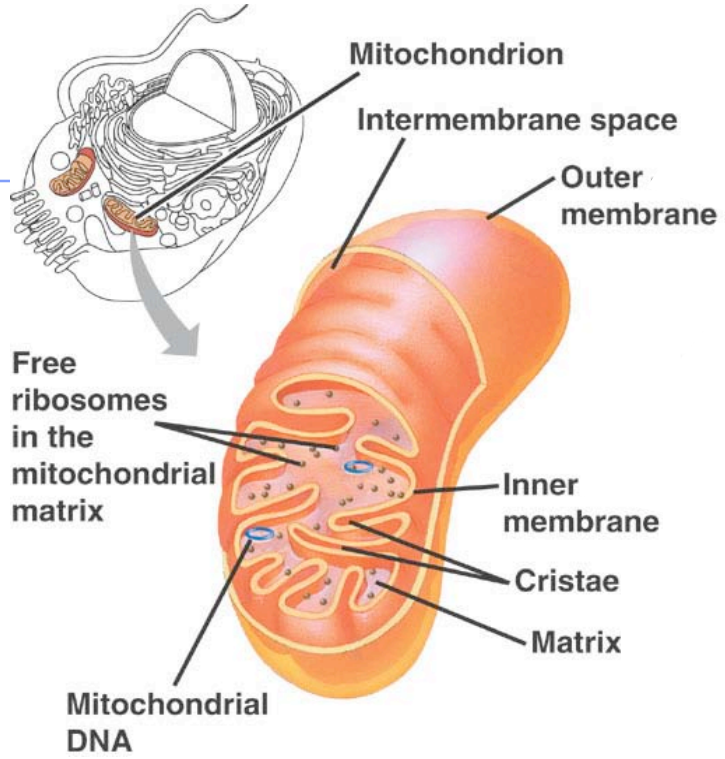
Mitochondria



- **Function**
  - cellular respiration
  - generate ATP
    - from breakdown of sugars, fats & other fuels
    - in the presence of oxygen
      - break down larger molecules into smaller to generate energy = catabolism
      - generate energy in presence of O_2 = aerobic respiration

Mitochondria

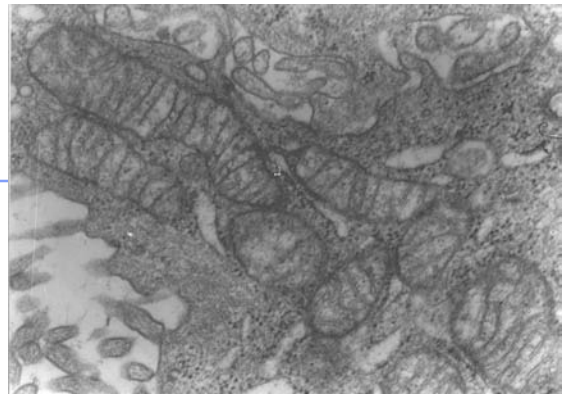
- **Structure**
  - 2 membranes
    - smooth outer membrane
    - highly folded inner membrane
      - cristae
  - fluid-filled space between 2 membranes
  - internal fluid-filled space
    - mitochondrial matrix
    - DNA, ribosomes & enzymes

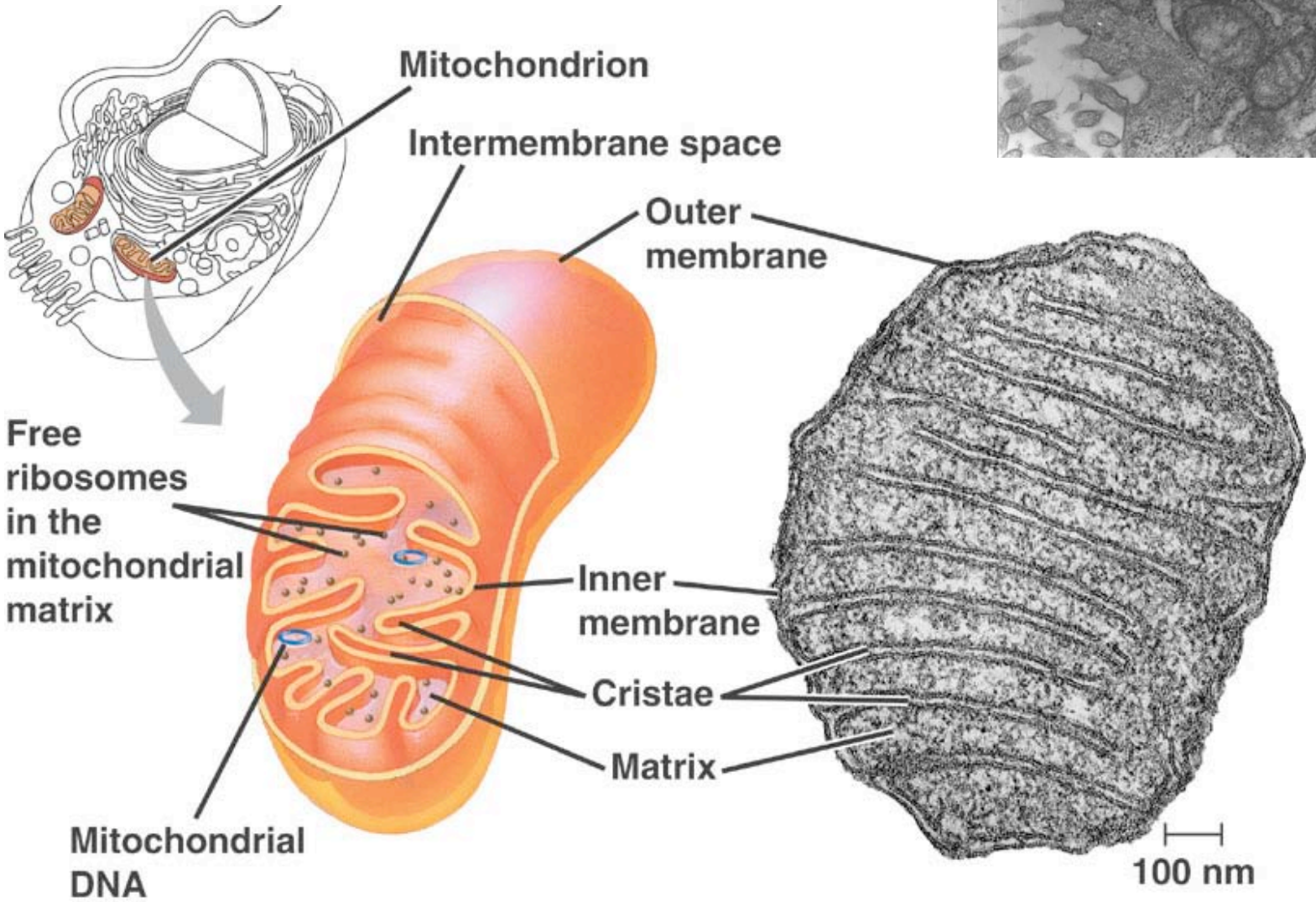


Why 2 membranes?

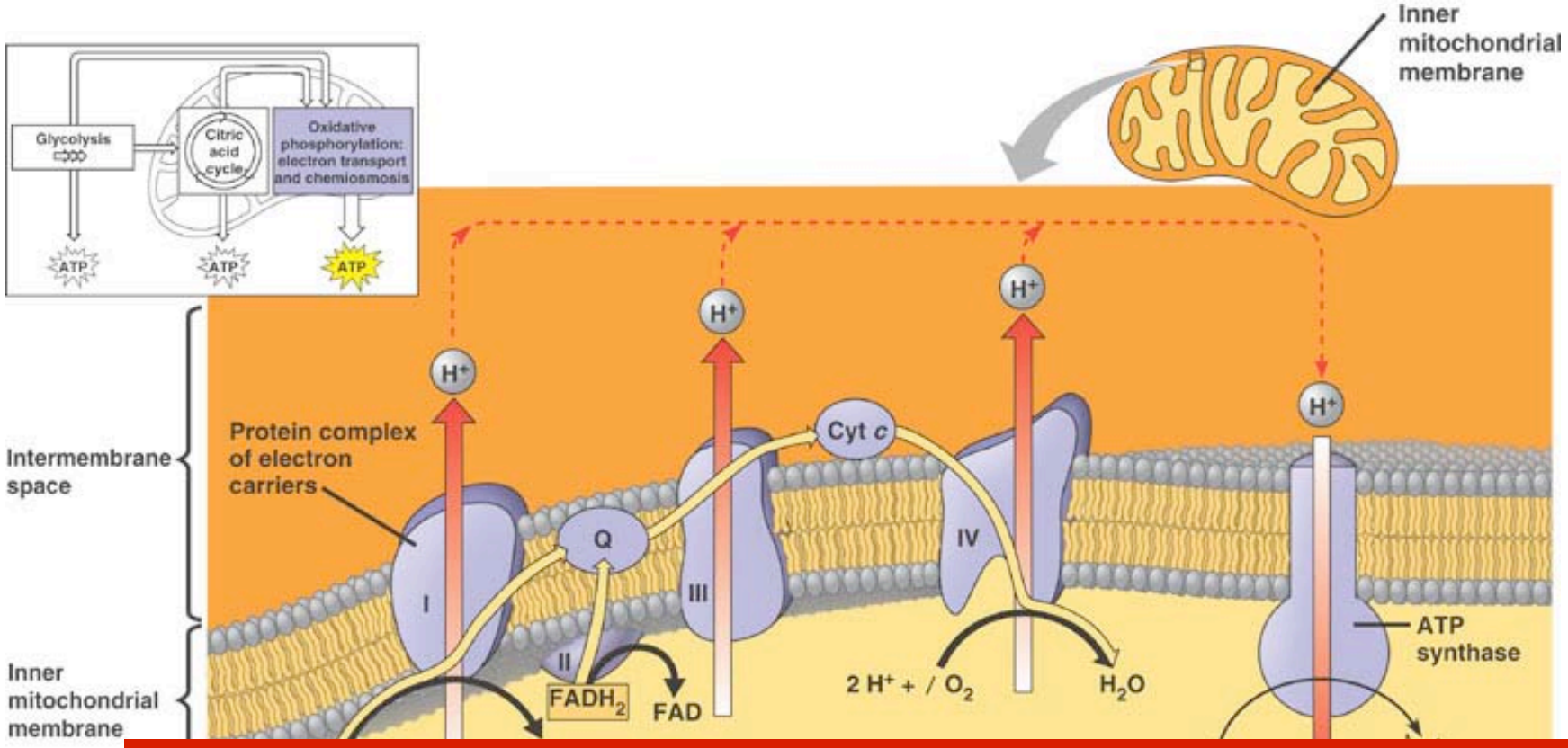
increase surface area for membrane-bound enzymes that synthesize ATP

Mitochondria





Membrane-bound Enzymes

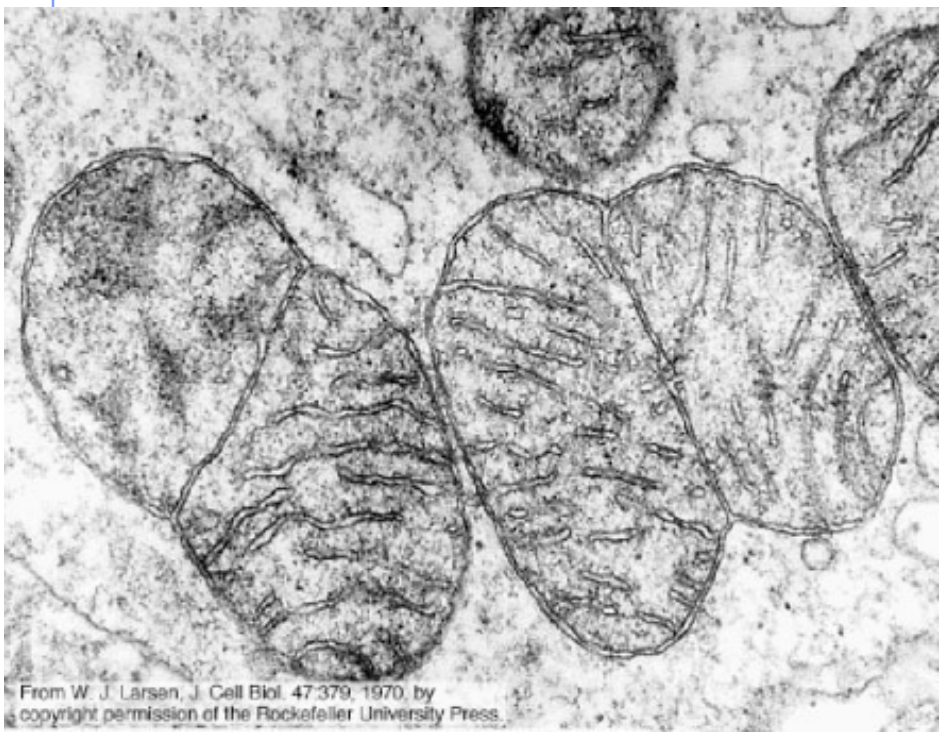


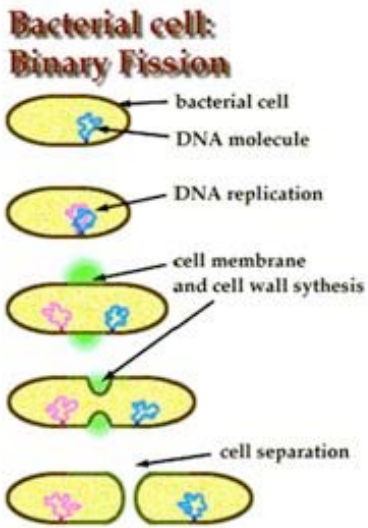
glucose + oxygen → carbon + water + energy
dioxide

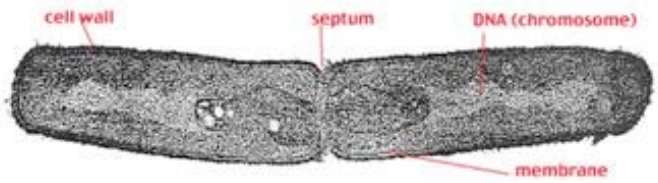
$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$$

Dividing Mitochondria

Who else divides like that?



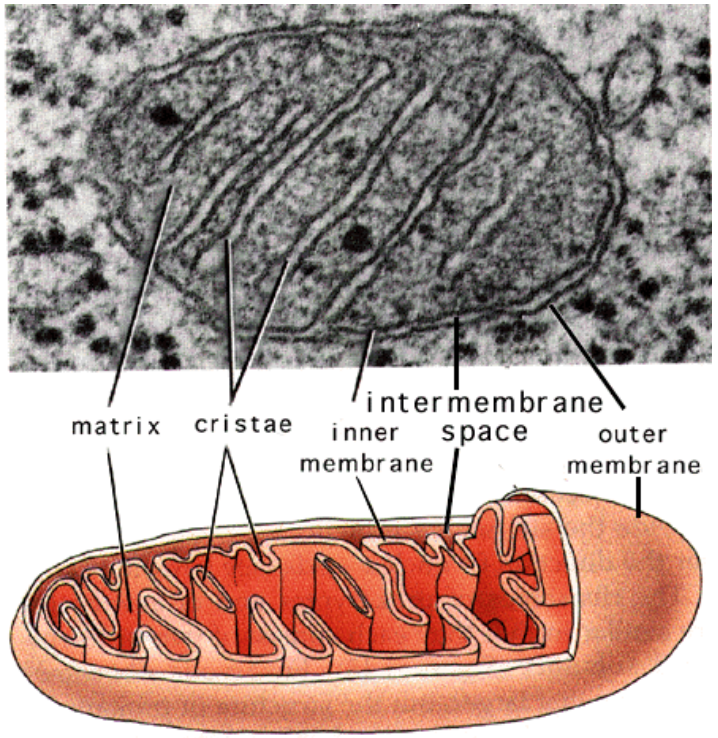




What does this tell us about the evolution of eukaryotes?

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

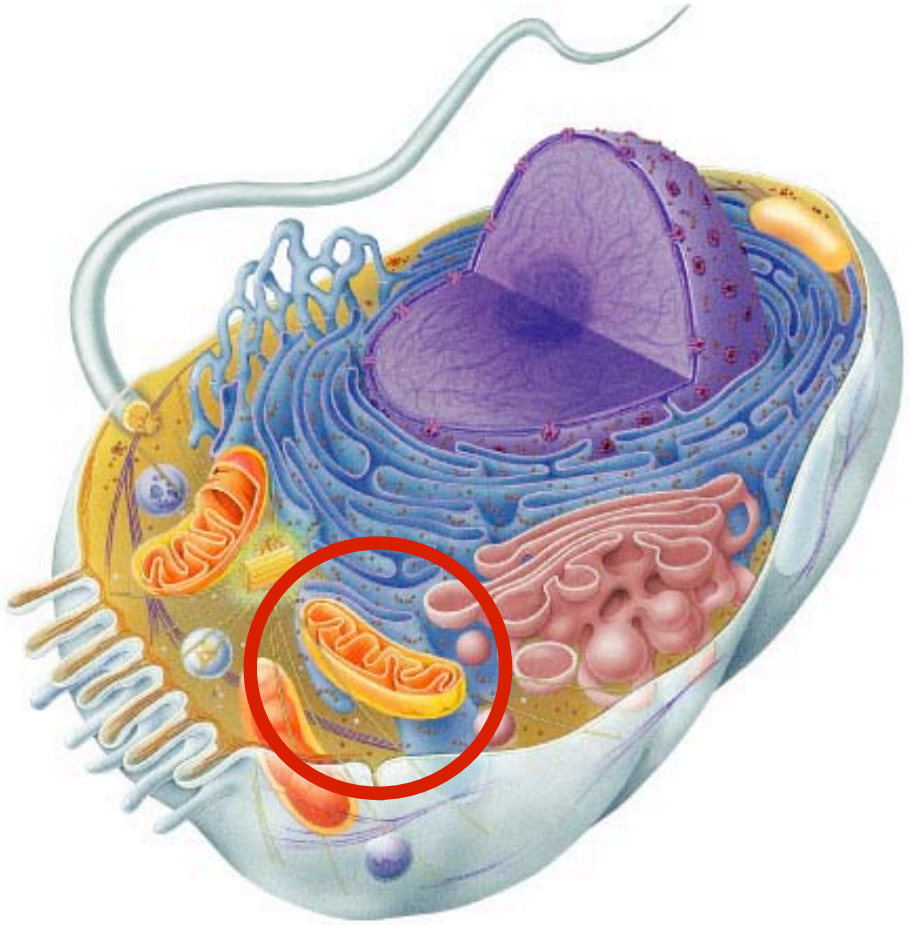


What cells would have a lot of mitochondria?

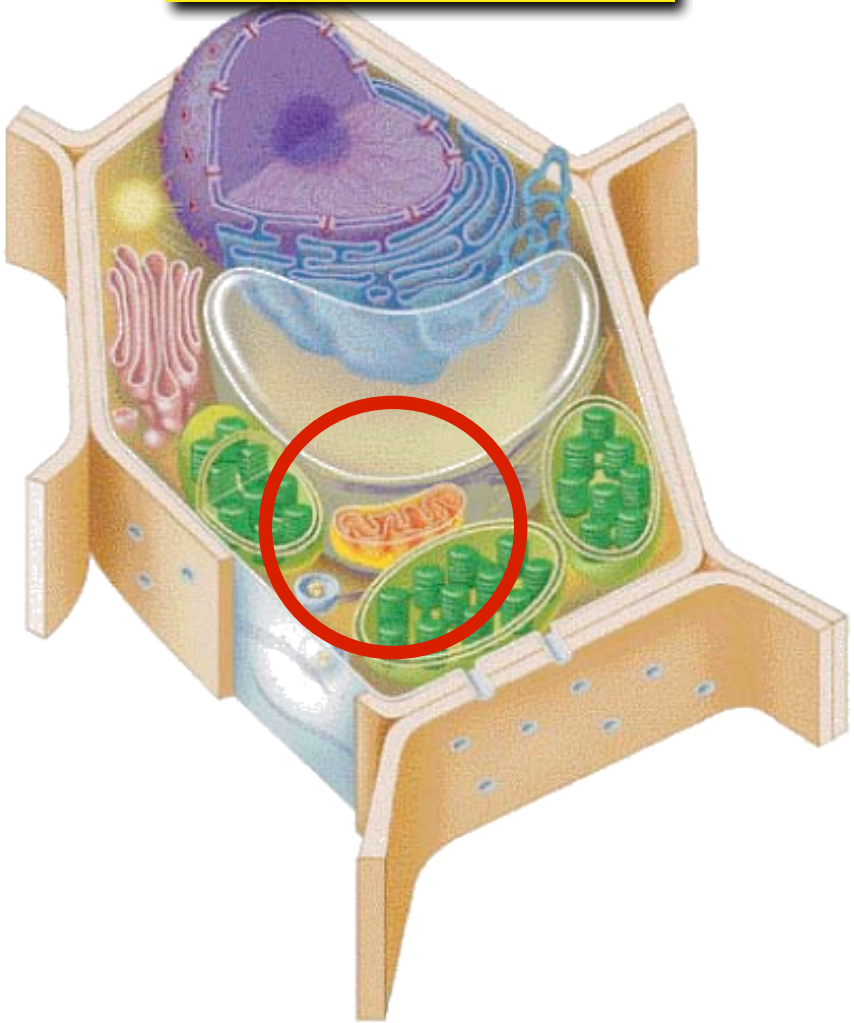
active cells:
- **muscle cells**
- **nerve cells**

Mitochondria are everywhere!!

animal cells

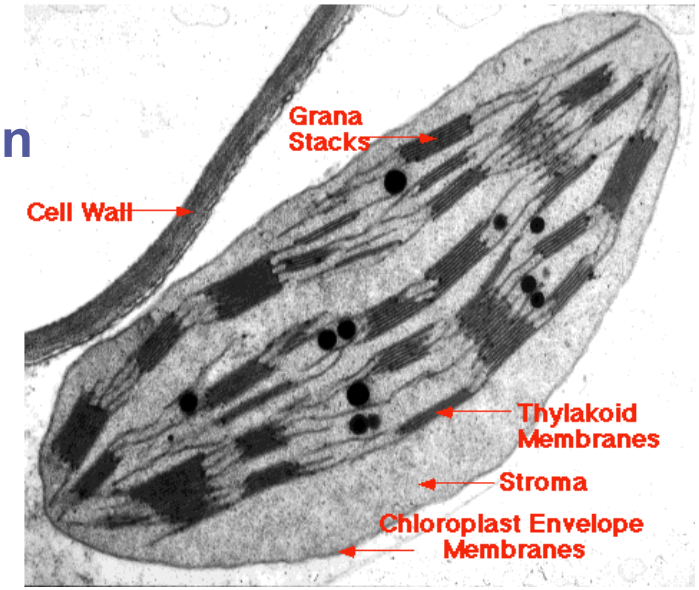


plant cells

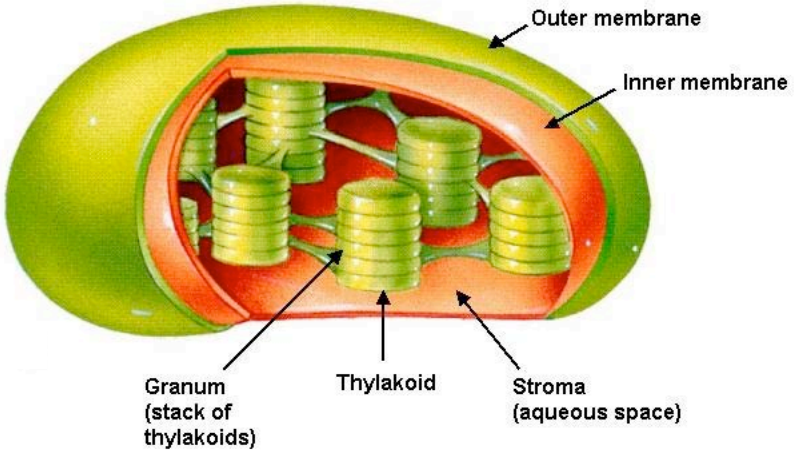


Chloroplasts

- 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



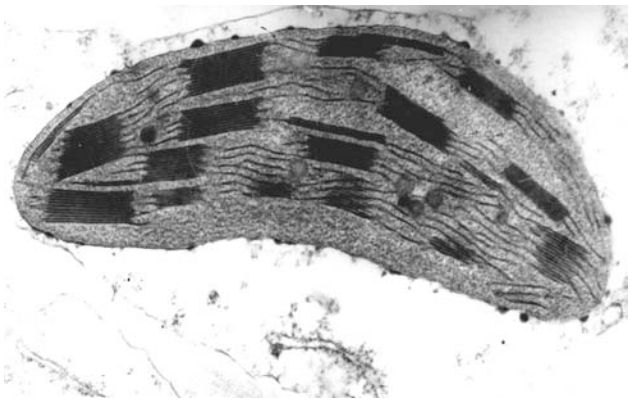
Chloroplasts



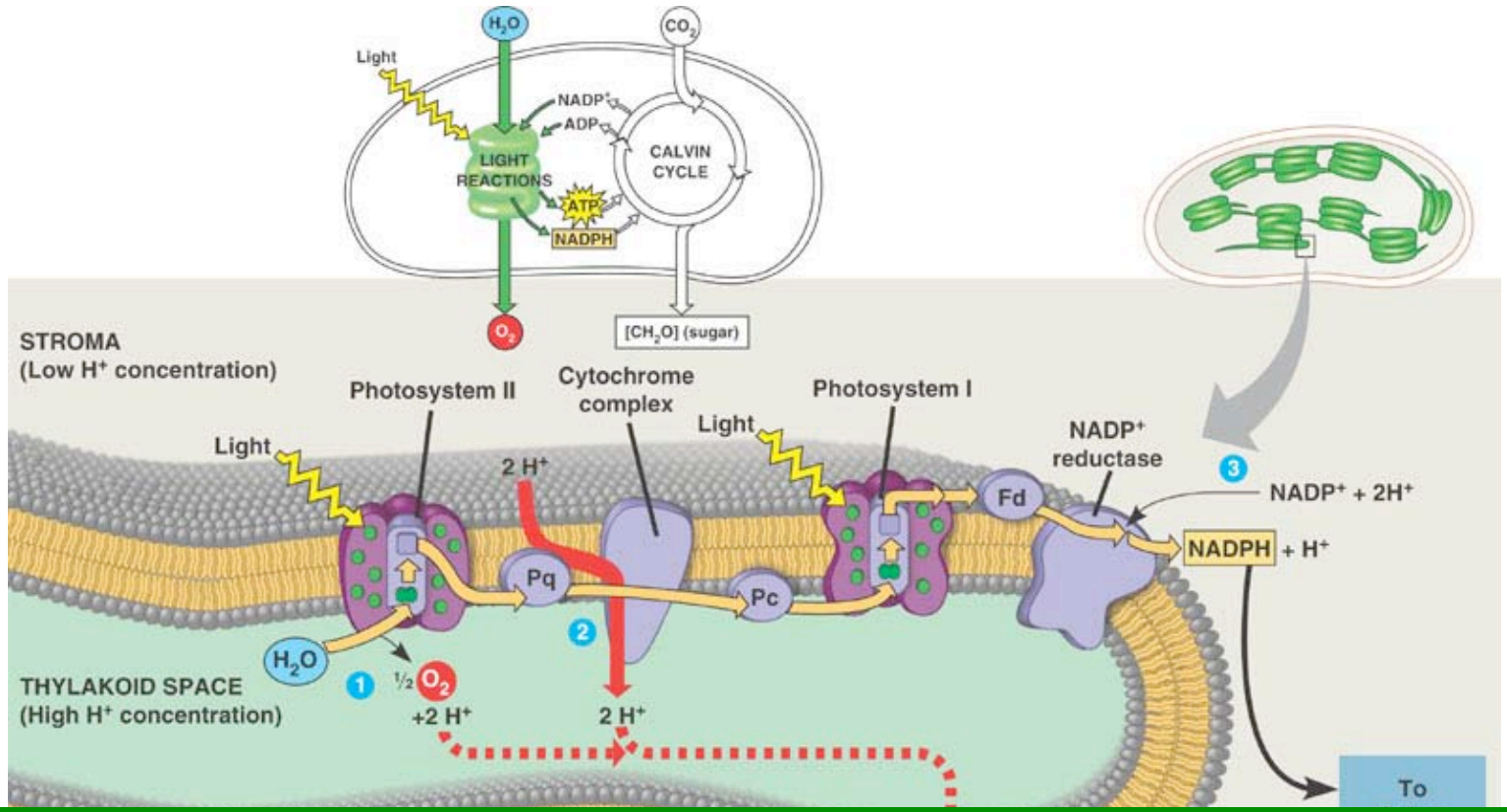
- **Structure**
  - 2 membranes
  - stroma = internal fluid-filled space
    - DNA, ribosomes & enzymes
    - thylakoids = membranous sacs where ATP is made
    - grana = stacks of thylakoids

Why internal sac membranes?

increase surface area for membrane-bound enzymes that synthesize ATP



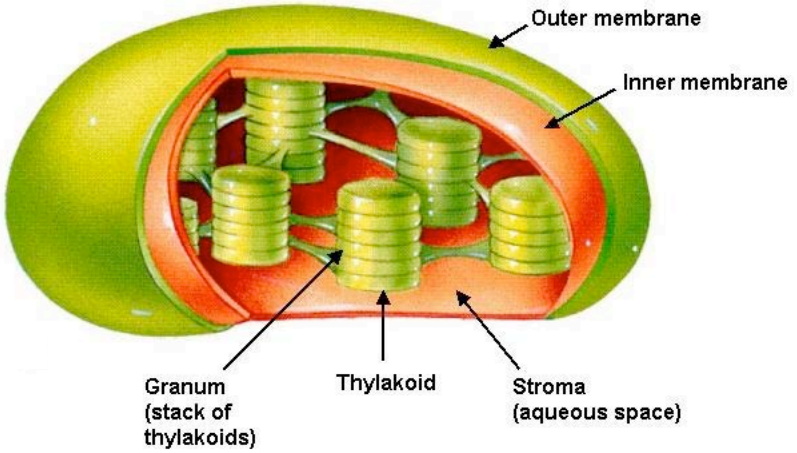
Membrane-bound Enzymes



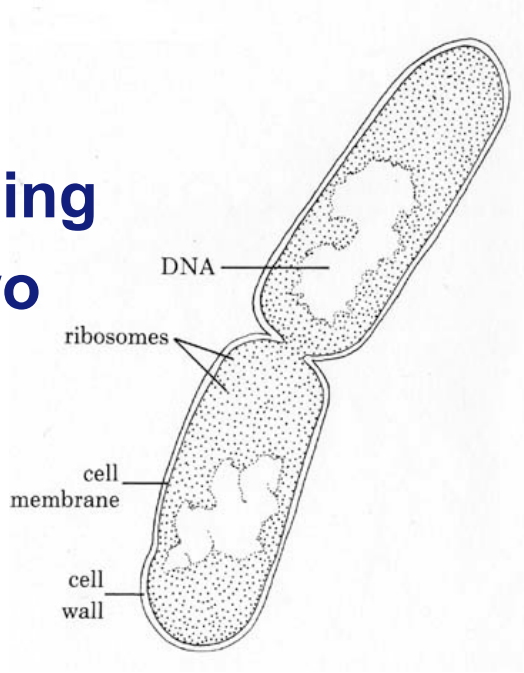
carbon dioxide + water + energy → glucose + oxygen

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

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**

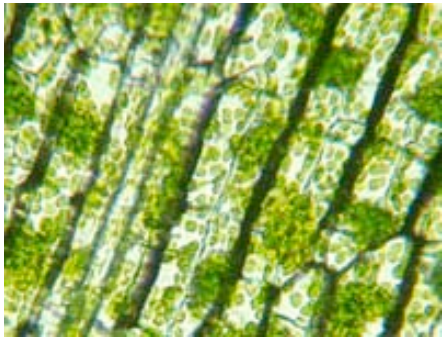


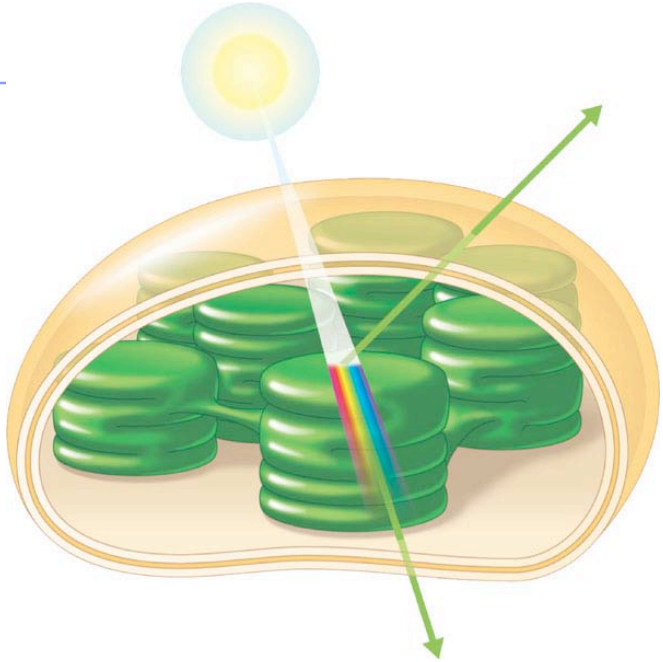
Who else divides like that?

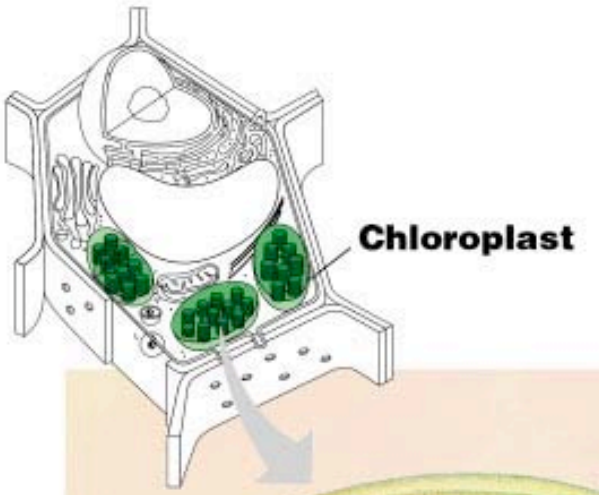
bacteria!

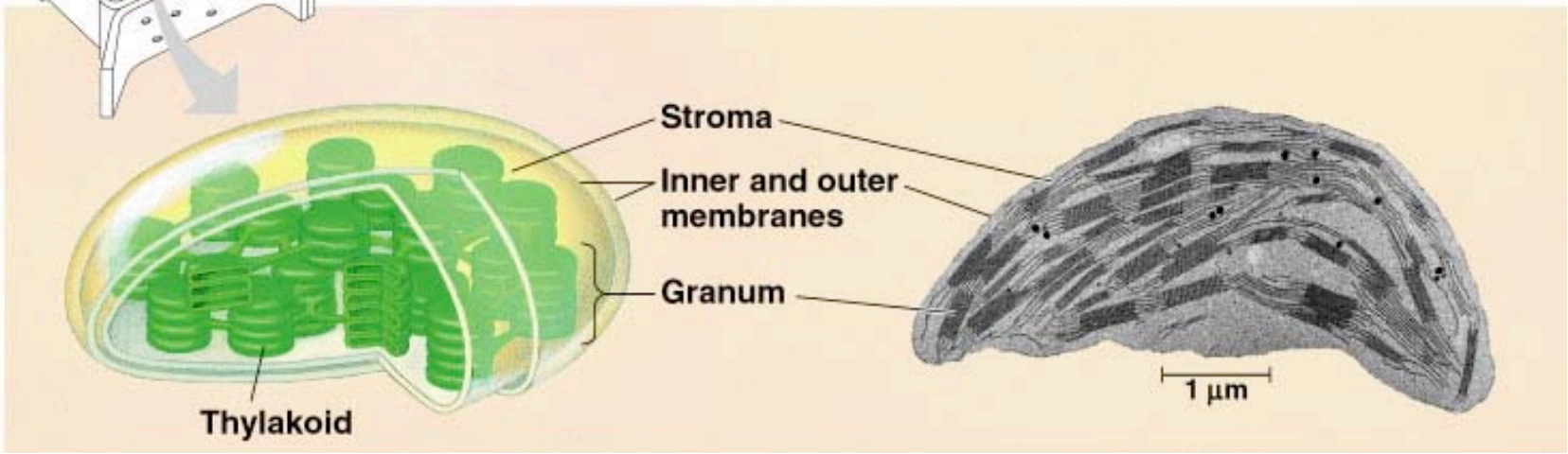
Chloroplasts

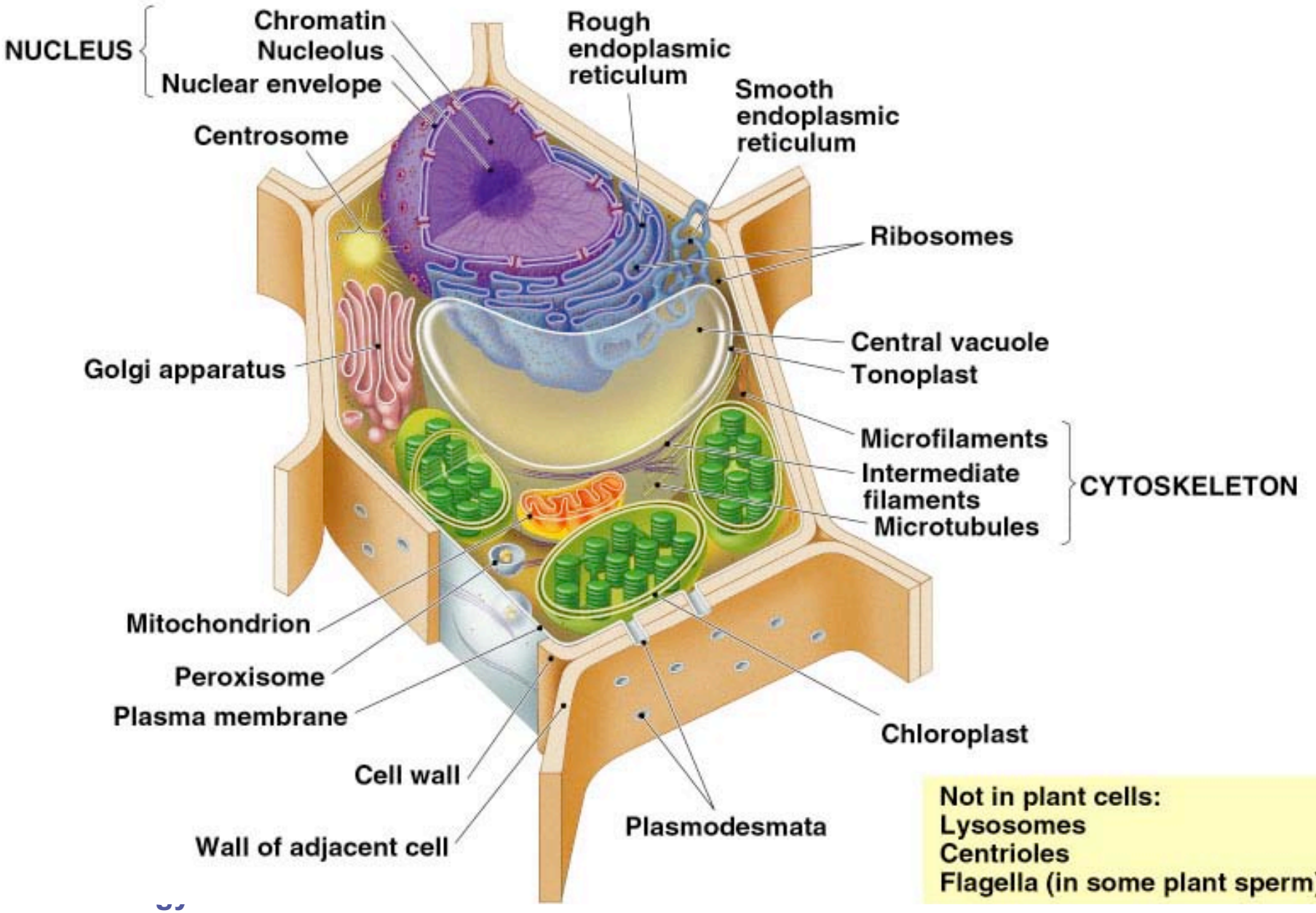
Why are chloroplasts green?









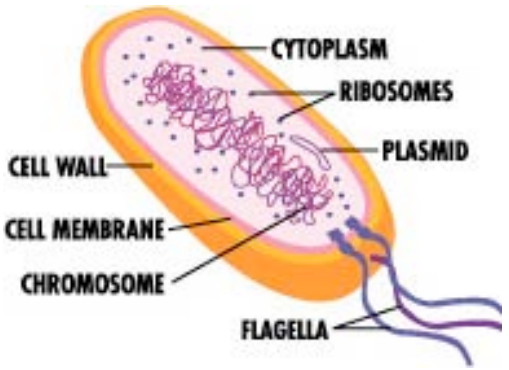

NUCLEUS
Chromatin
Nucleolus
Nuclear envelope
Centrosome
Rough endoplasmic reticulum
Smooth endoplasmic reticulum
Ribosomes
Central vacuole
Tonoplast
Golgi apparatus
Microfilaments
Intermediate filaments
Microtubules
CYTOSKELETON
Mitochondrion
Peroxisome
Plasma membrane
Cell wall
Wall of adjacent cell
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 | ??

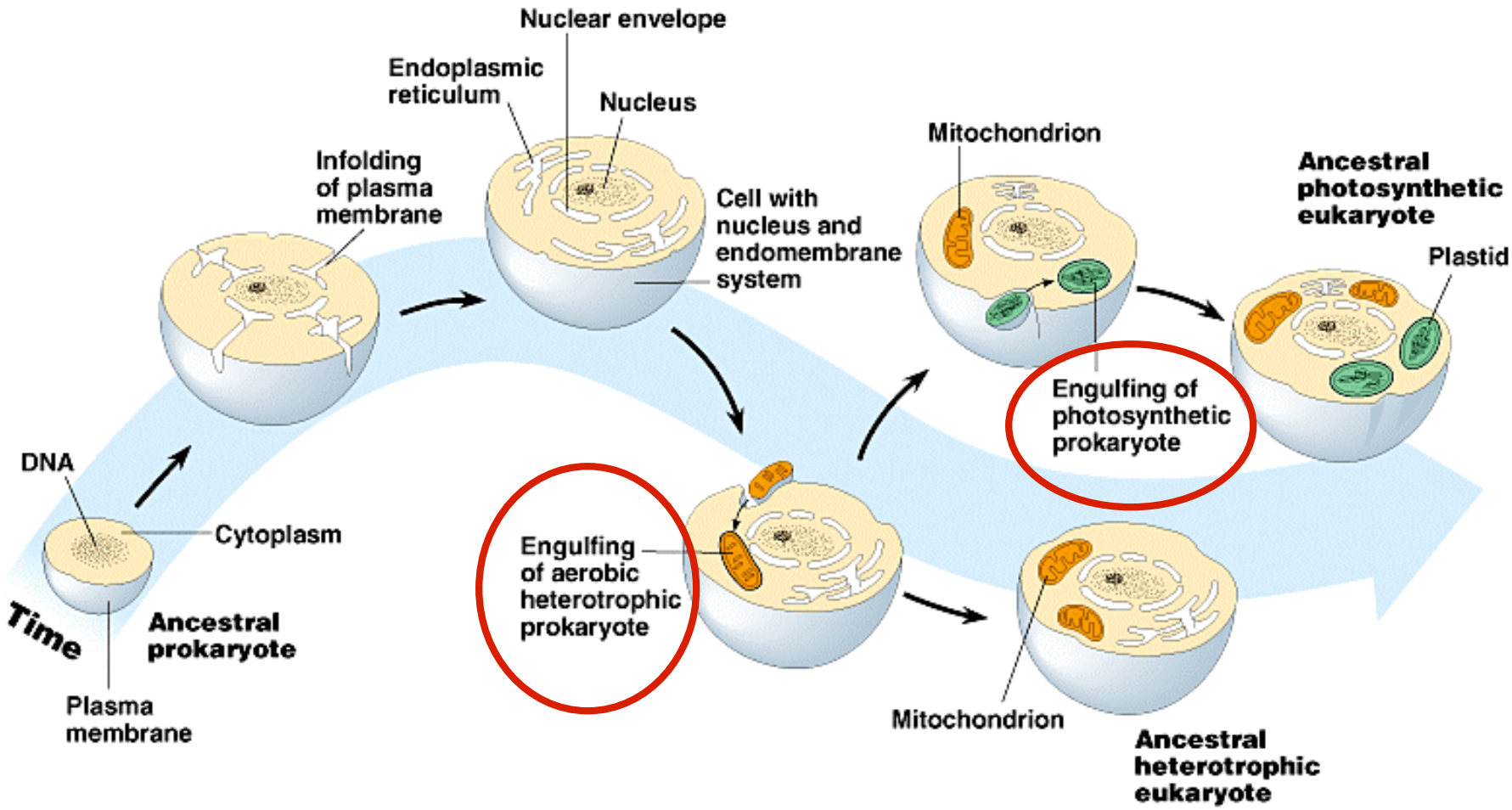
Endosymbiosis theory

- 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

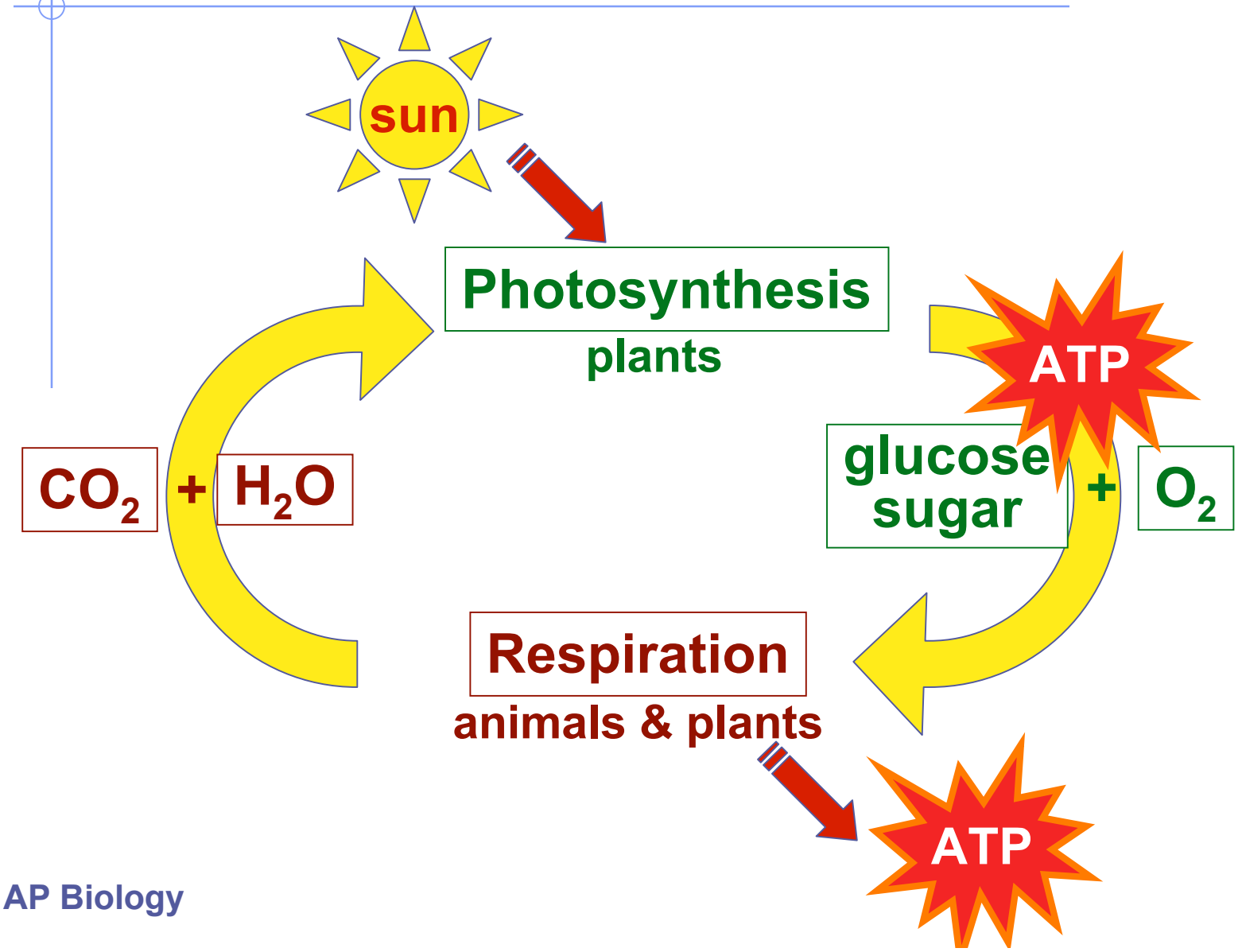
$$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

Respiration

glucose + oxygen → carbon dioxide + water + energy

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

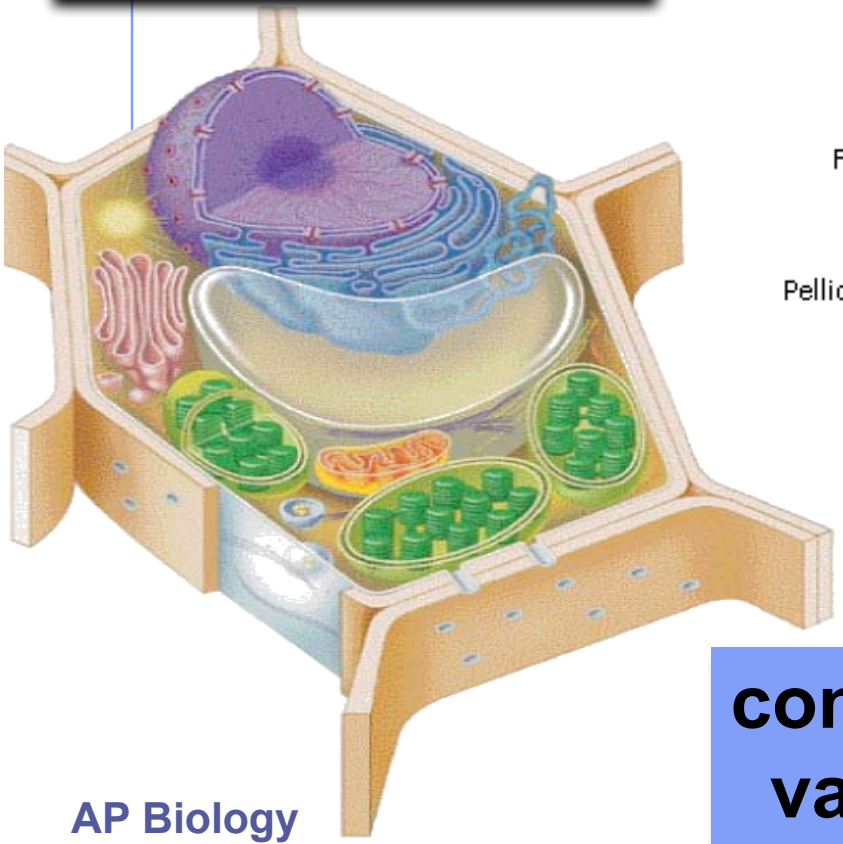
The Great ENERGY Circle of Life



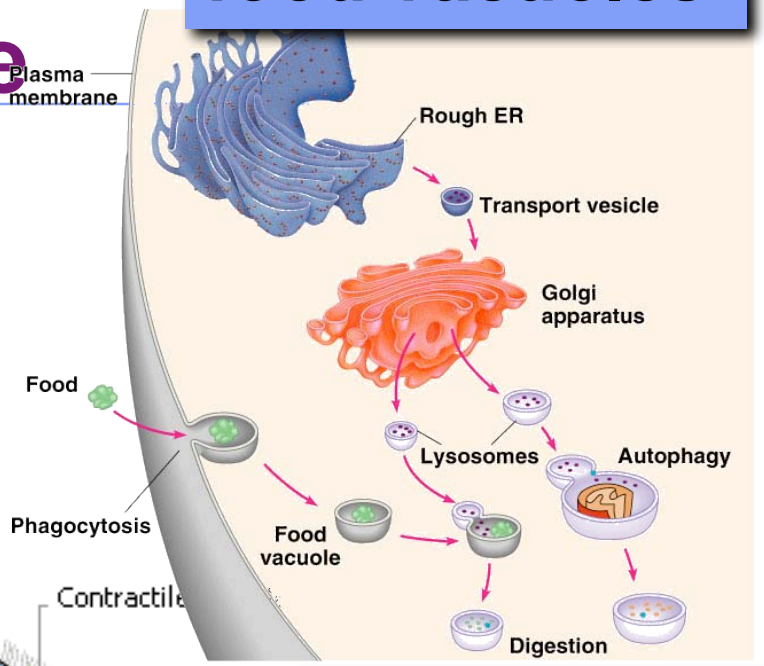
Food & water storage

plant cells

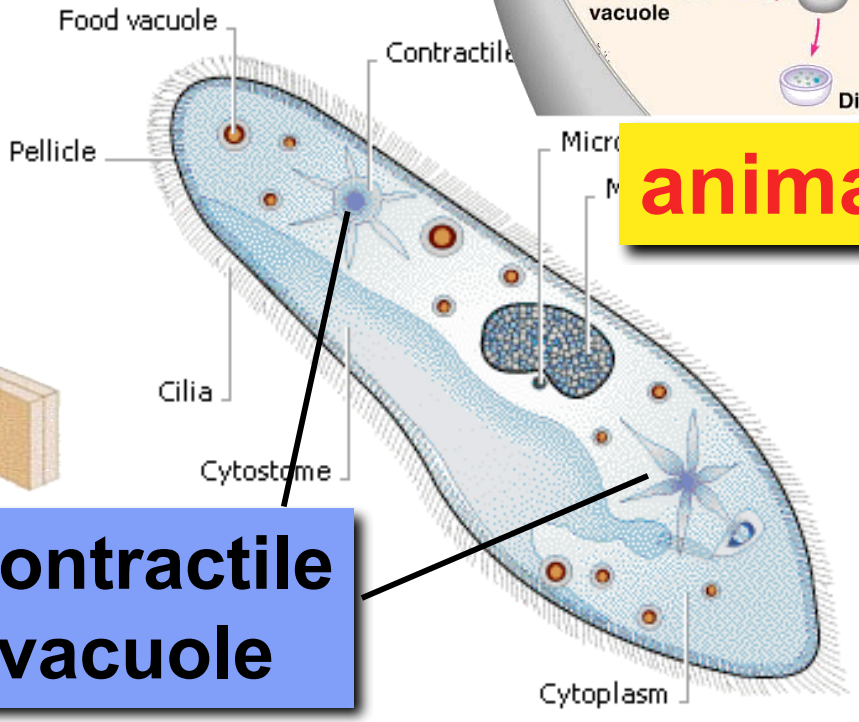
central vacuole



food vacuoles



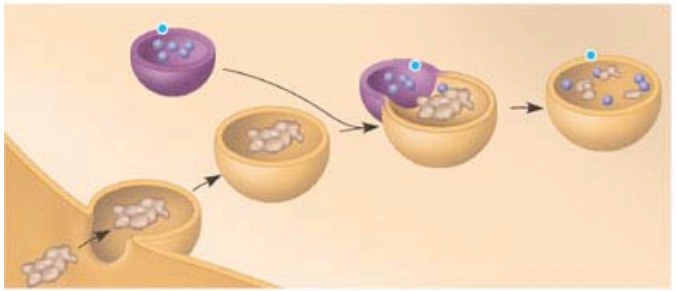
animal cells

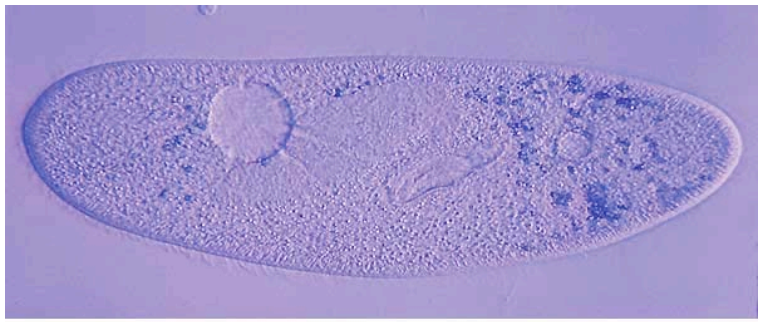


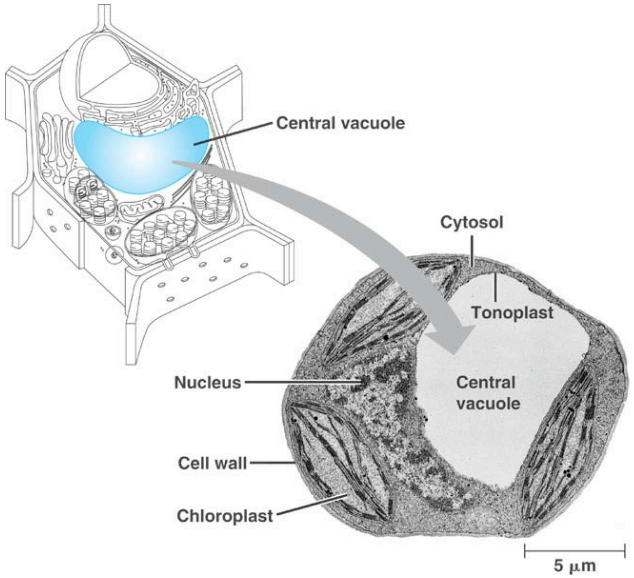
contractile vacuole

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

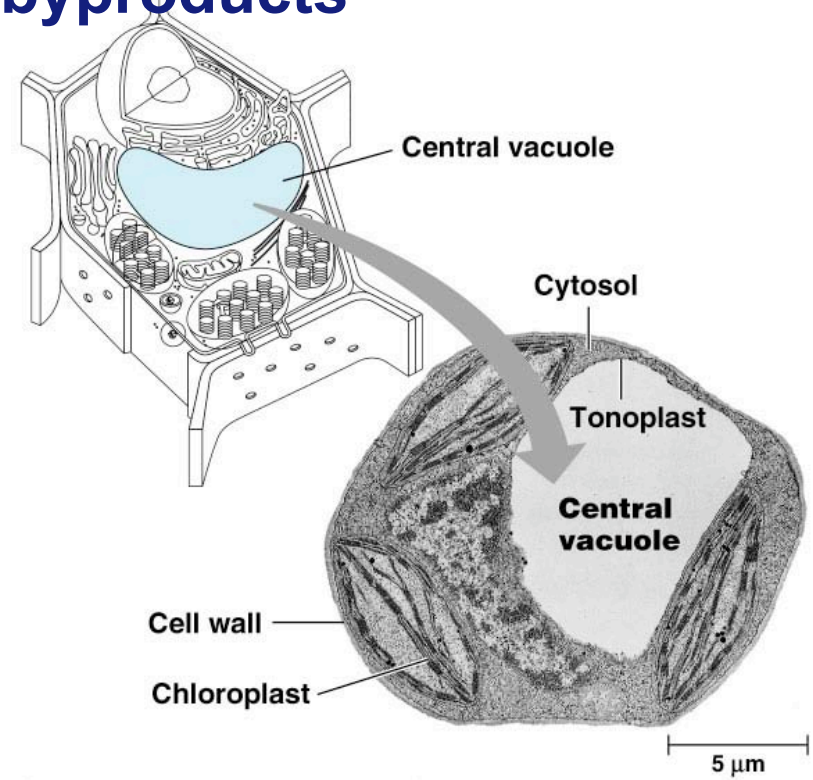






Vacuoles in plants

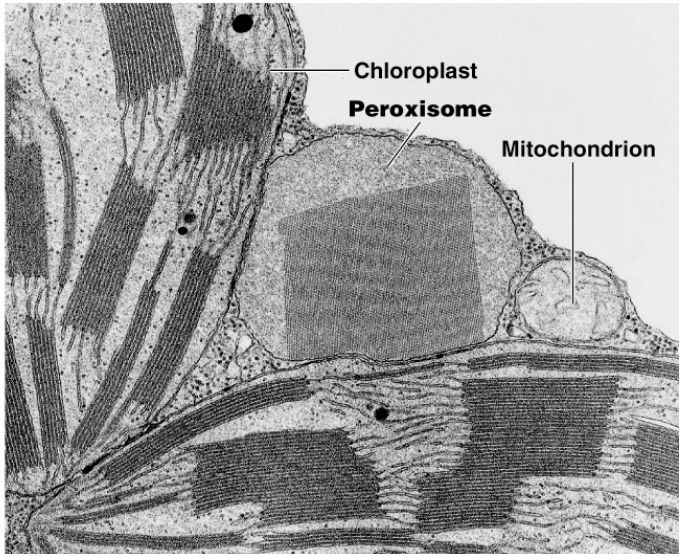
- **Functions**
  - **storage**
    - stockpiling proteins or inorganic ions
    - depositing metabolic byproducts
    - storing pigments
    - storing defensive compounds against herbivores
    - selective membrane
      - control what comes in or goes out



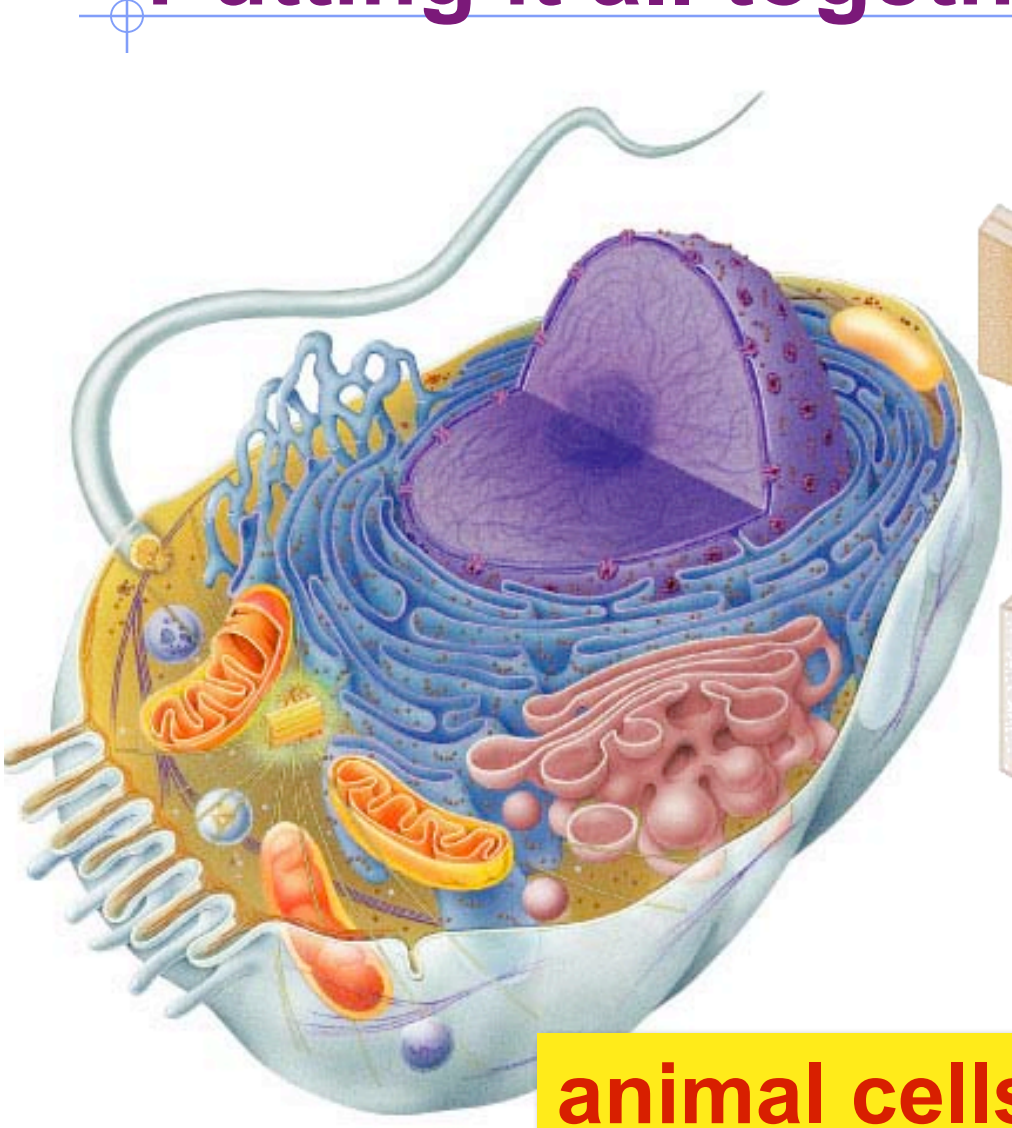
Peroxisomes

- 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

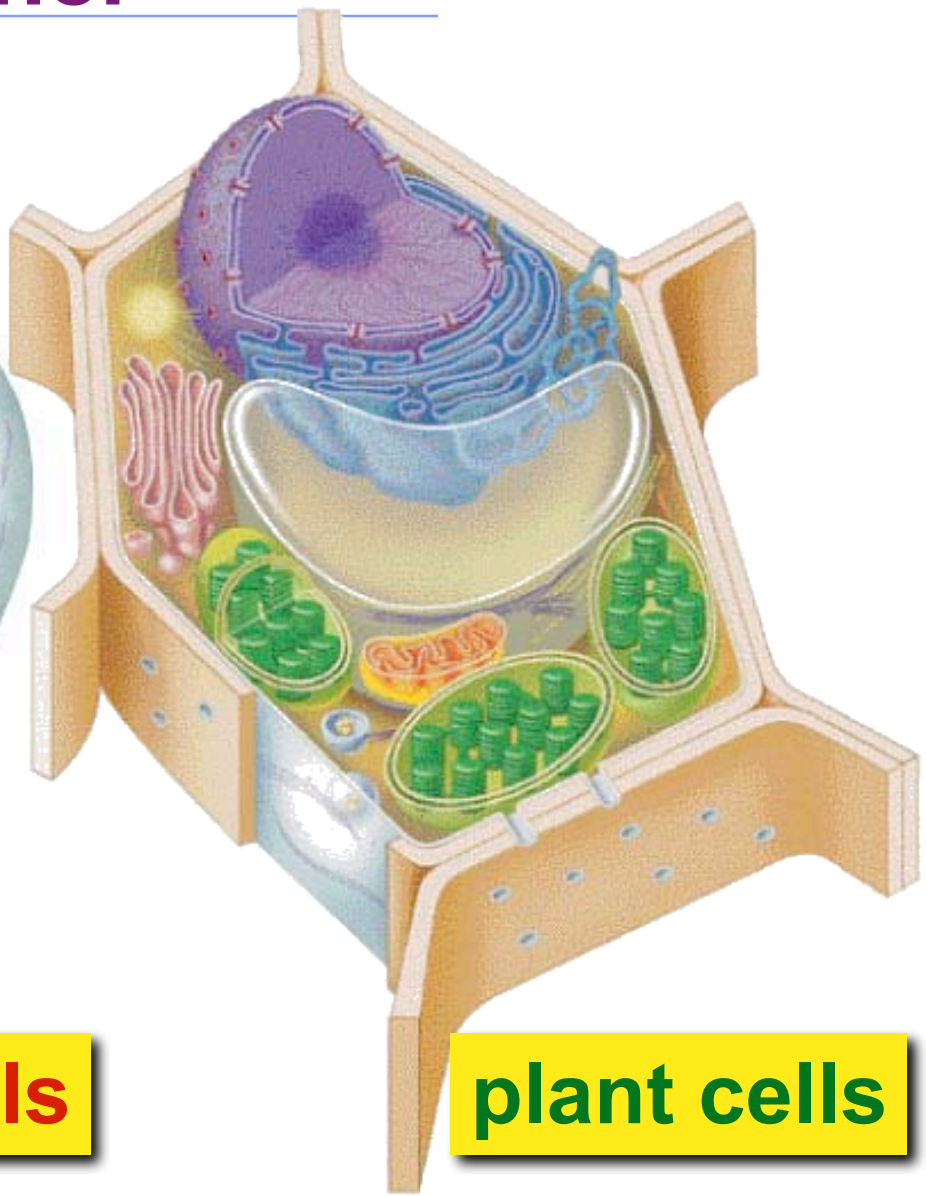
      $H_2O_2 \rightarrow H_2O$



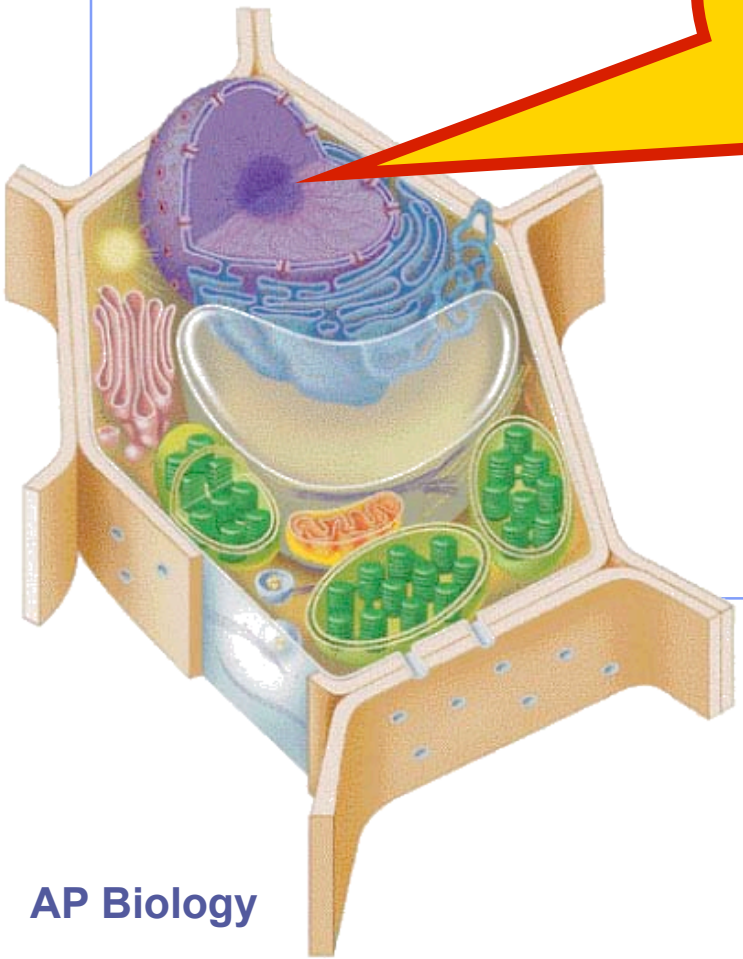
Putting it all together



animal cells



plant cells



Any Questions??