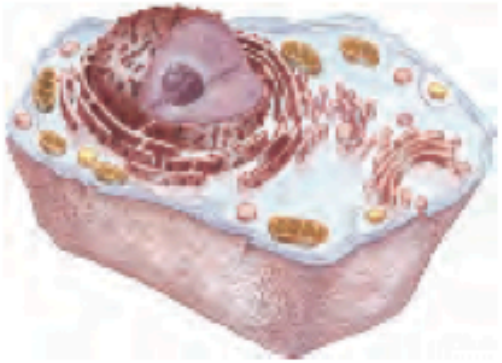


chapter 1

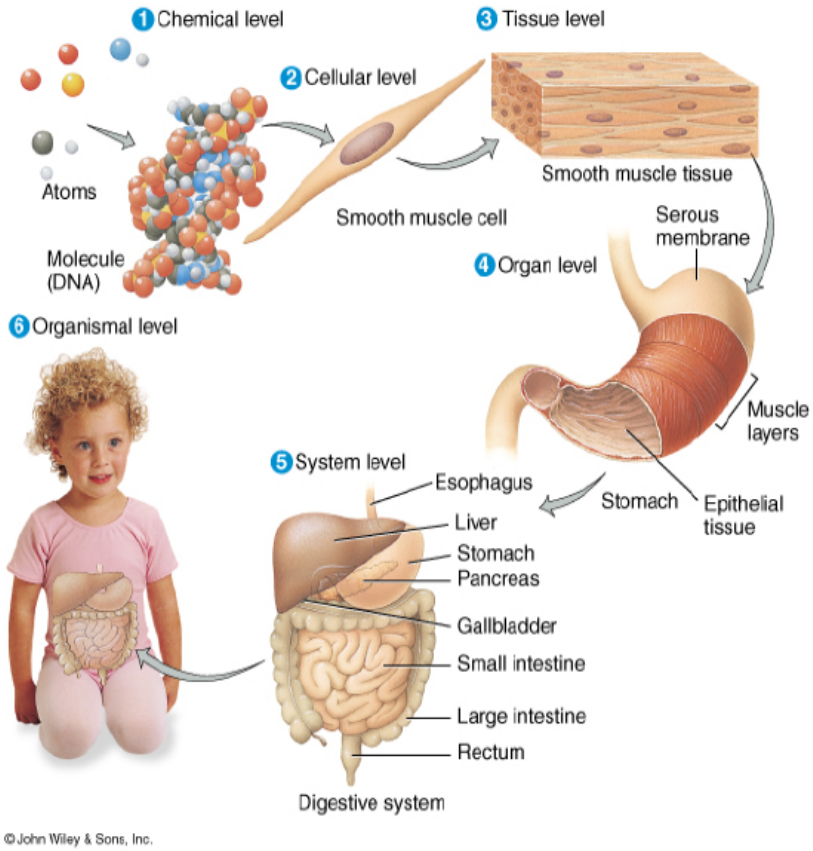
THE FOUNDATIONS OF BIOCHEMISTRY

Dr.Bilgen Osman

The foundations of biochemistry

Biochemistry asks

- how the remarkable properties of living organisms arise from the thousands of different lifeless biomolecules.
- When these molecules are isolated and examined individually, they conform to all the physical and chemical laws that describe the behavior of inanimate matter
- The study of biochemistry shows how the collections of inanimate molecules that constitute living organisms interact to maintain and perpetuate life animated solely by the physical and chemical laws that govern the nonliving universe.



The foundations of biochemistry

The first question that Biochemistry asks is

- What are the distinguishing features of living organisms?

- The answers are
  - A high degree of chemical complexity and microscopic organization.
  - Systems for extracting, transforming, and using energy from the environment
  - Reproducibility of living things

The foundations of biochemistry

- To put it all simple term,

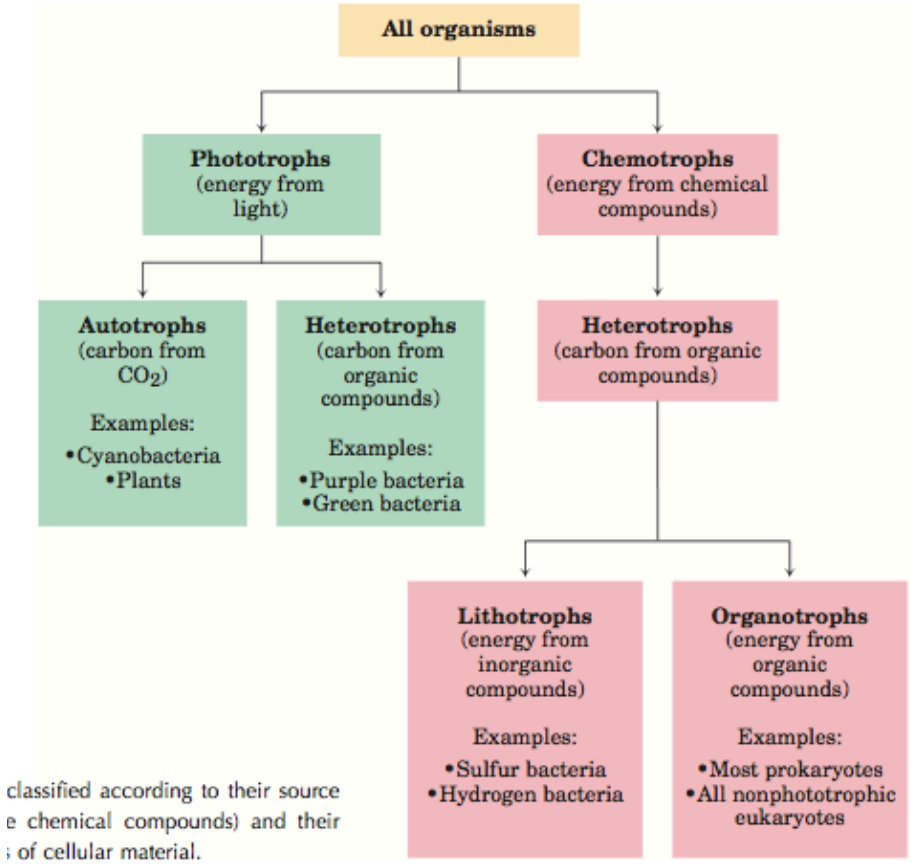
✓ Biochemistry describes in molecular terms the structures, mechanisms, and chemical processes shared by all organisms

✓ and provides organizing principles that underlie life in all its diverse forms, principles we refer to collectively as *the molecular logic of life.*

✓ Although biochemistry provides important insights and practical applications in medicine, agriculture, nutrition, and industry, its ultimate concern is with the wonder of life itself.

Classification of organisms according to energy source

- All organisms fall into two groups according to the souce of energy they used
- The organisms extracting energy from light (phototrophs) fall into two groups: Autotrophs and Heterotrophs
- The organisms extracting energy from chemical compounds (heterotrophs) fall into two groups: Lithotrophs and Organotrophs



classified according to their source
e chemical compounds) and their
of cellular material.

The foundations of biochemistry

We will talk about:

- Cellular foundations
- Chemical foundations

Cellular foundations

- The unity and diversity of organisms become apparent even at the cellular level.
- The smallest organisms consist of single cells and are microscopic.
- Larger, multicellular organisms contain many different types of cells, which vary in size, shape, and specialized function.
- Despite these obvious differences, all cells of the simplest and most complex organisms share certain fundamental properties, which can be seen at the biochemical level.

Observing Cells

- Light microscope
  - Can observe living cells in true color
  - Magnification of up to ~1000x
  - Resolution ~ 0.2 microns – 0.5 microns



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Observing Cells

- Electron Microscopes
  - Preparation needed kills the cells
  - Images are black and white – may be colorized
  - Magnifcation up to ~100,000
    - Transmission electron microscope (TEM)
      - 2-D image
    - Scanning electron microscope (SEM)
      - 3-D image



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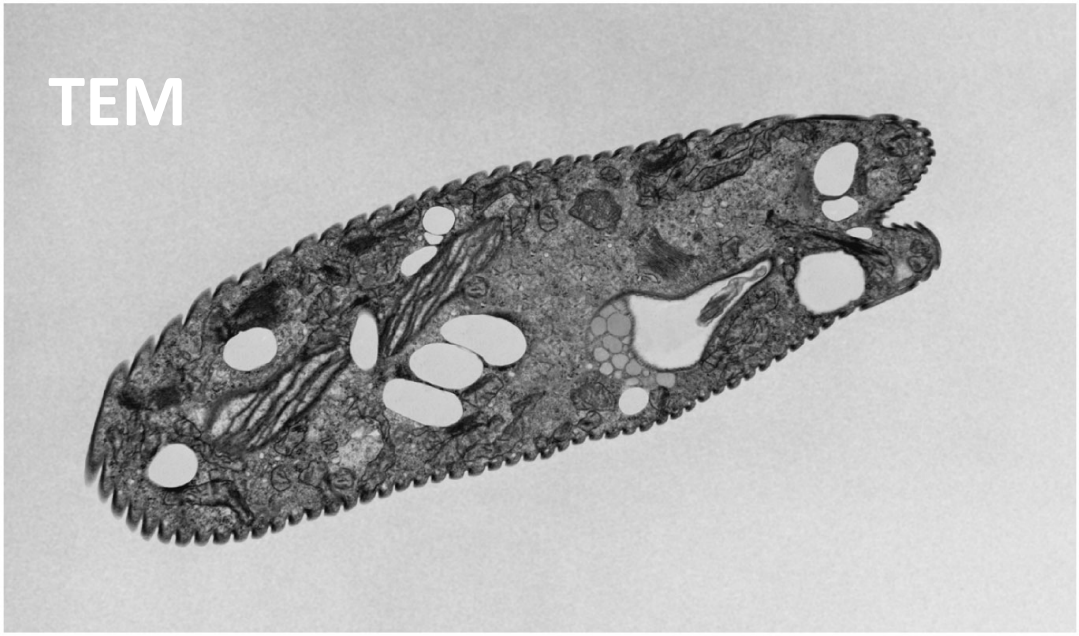

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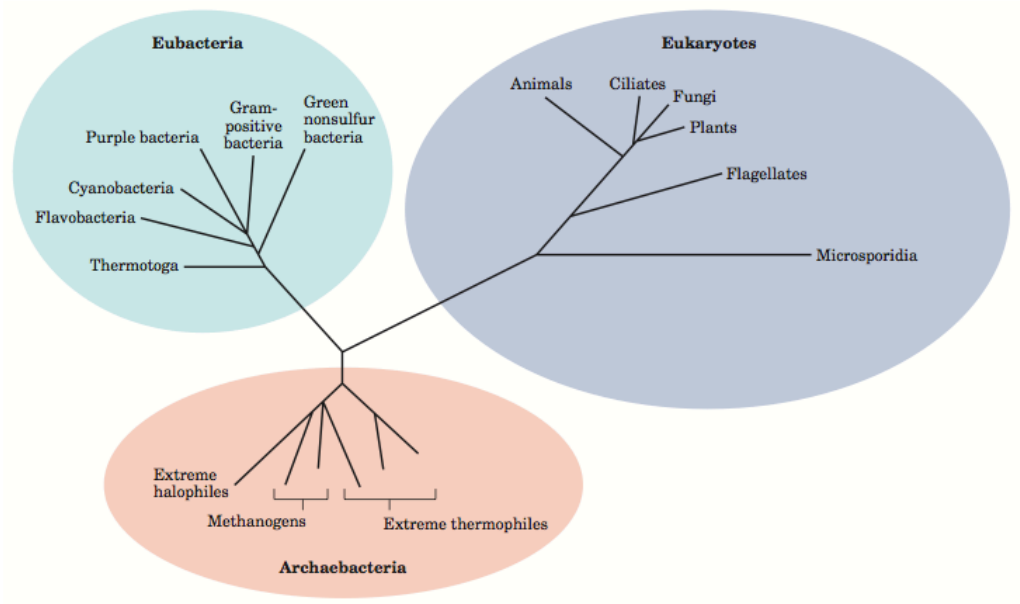
Cell types

- The are two main cell type
- Prokaryotes and Eukaryotes words come from greeks
  - ‘Karyote’ means nucleus. Prokaryote means before nucleus. Prokaryotic cells does not contain nucleus
- All living organisms fall into one of three large groups
- Prokaryotes fall into two groups: Eubacteria and Archeabacteria



Cellular dimensions

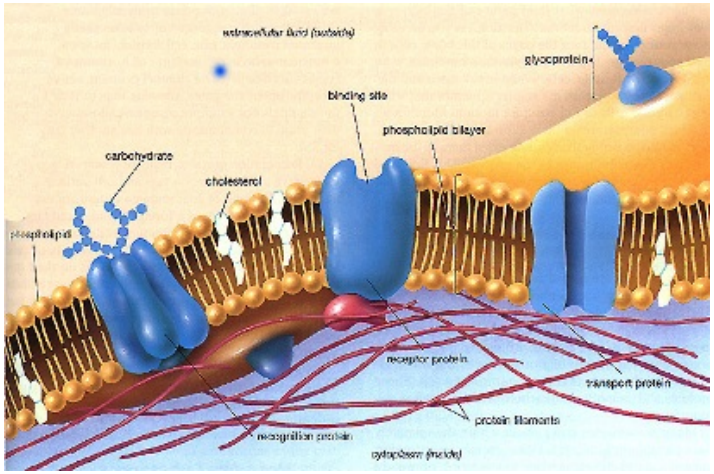
- Most cells are microscopic, invisible to the unaided eye.
- Animal and plant cells (eukaryote) are typically 5 to 100 µm in diameter, and
- Many bacteria (prokaryote) are only 1 to 2 µm long

Cell Structure

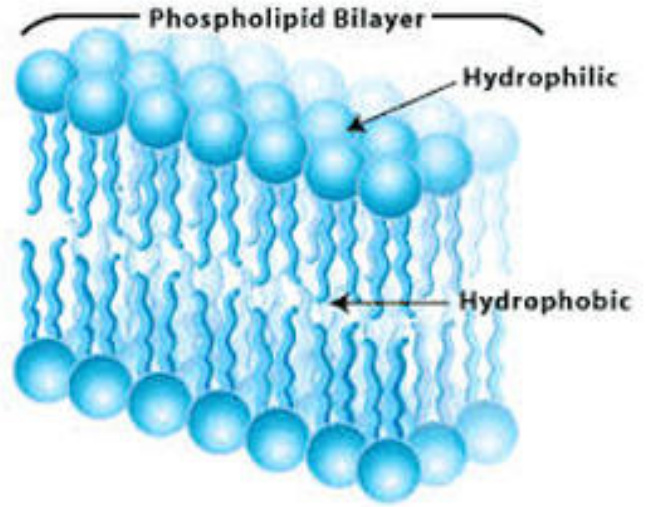
- **All cells have:**
  - an outermost plasma membrane
  - genetic material in the form of DNA
  - cytoplasm with ribosomes

Plasma Membrane

- All membranes are phospholipid bilayers with embedded proteins

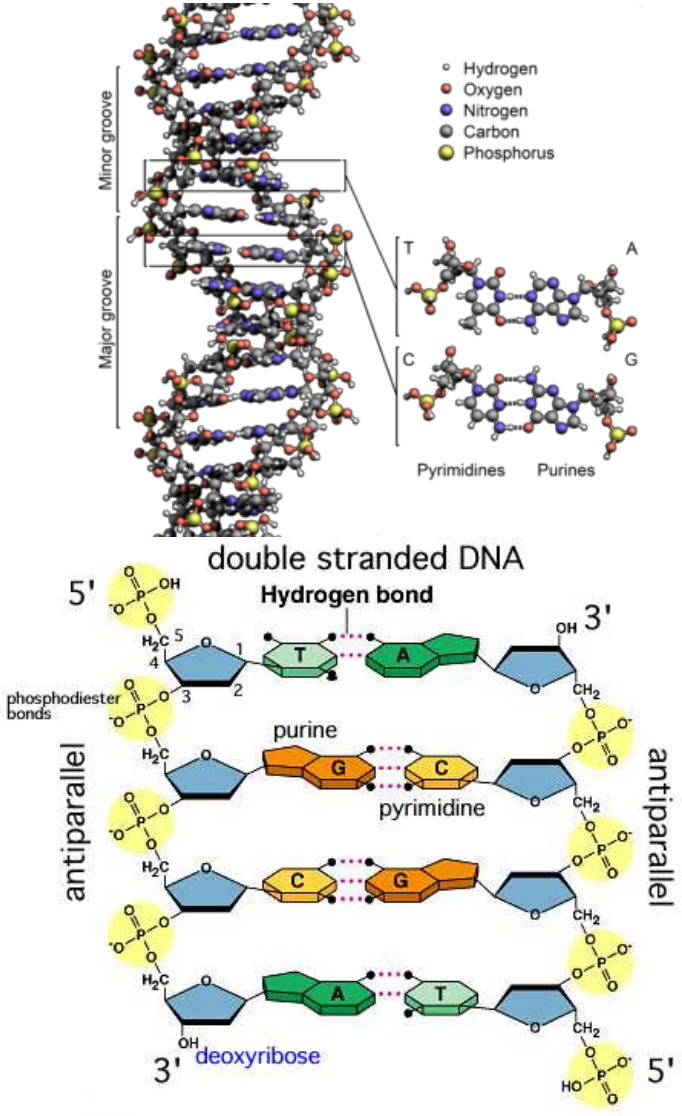


- The outer plasma membrane
  - isolates cell contents
  - controls what gets in and out of the cell
  - receives signals



Genetic material in the form of DNA

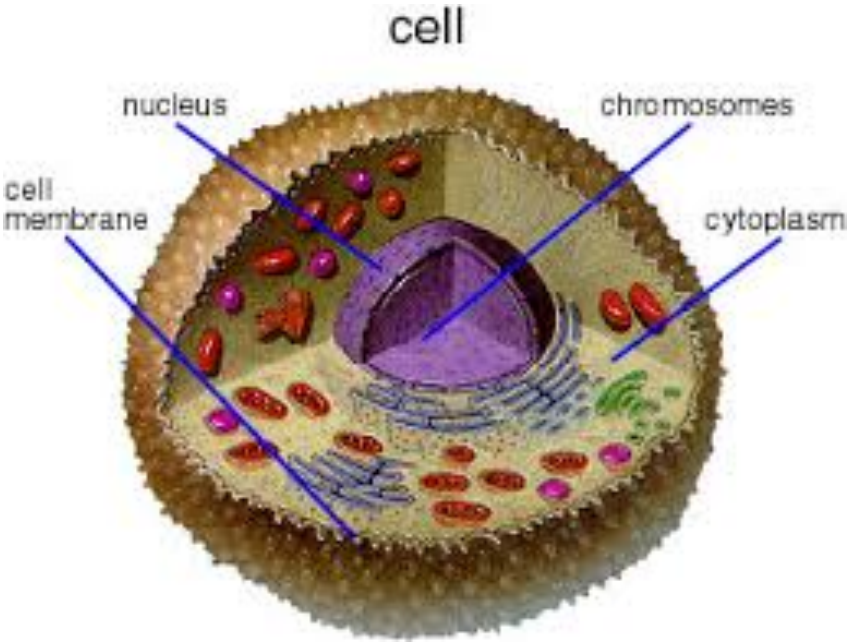
- Prokaryotes – no membrane around the DNA
- Eukaryotes – DNA is within a membrane



Cytoplasm with ribosomes

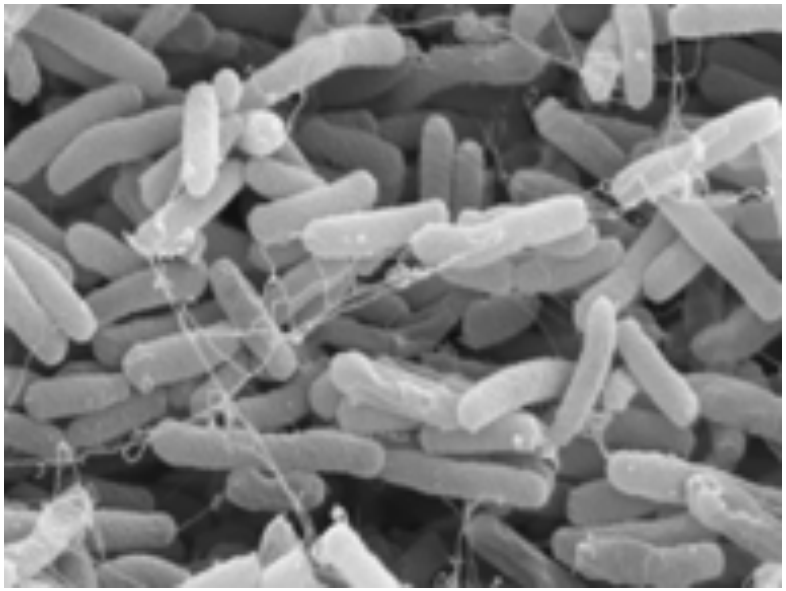
- Cytoplasm – fluid area inside outer plasma membrane and outside DNA region

- Ribosomes – make proteins



Prokaryotic Cell Structure

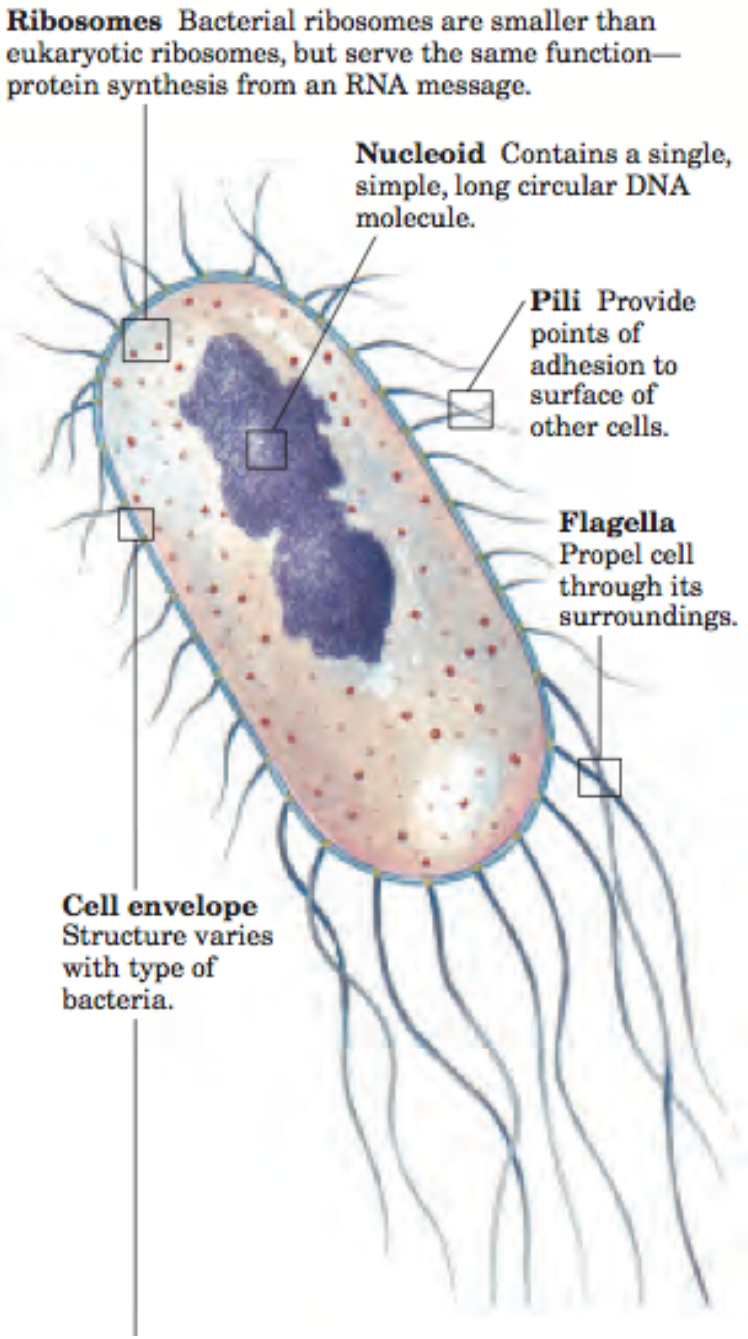
- Prokaryotic Cells are smaller and simpler in structure than eukaryotic cells.
  - Typical prokaryotic cell is E.Coli
  - Prokaryotic cells do NOT have:
    - Nucleus
    - Membrane bound organelles



Prokaryotic Cell Structure

- **Structures**
  - Plasma membrane
  - Cell wall
  - Cytoplasm with ribosomes
  - Nucleoid
  - Flagella* and pili*

*present in some,
but not all prokaryotic cells



Eukaryotic Cells

- **Structures in all eukaryotic cells**
  - Nucleus
  - Ribosomes
  - Endomembrane System
    - Endoplasmic reticulum – smooth and rough
    - Golgi apparatus
    - Vesicles
  - Mitochondria
  - Cytoskeleton

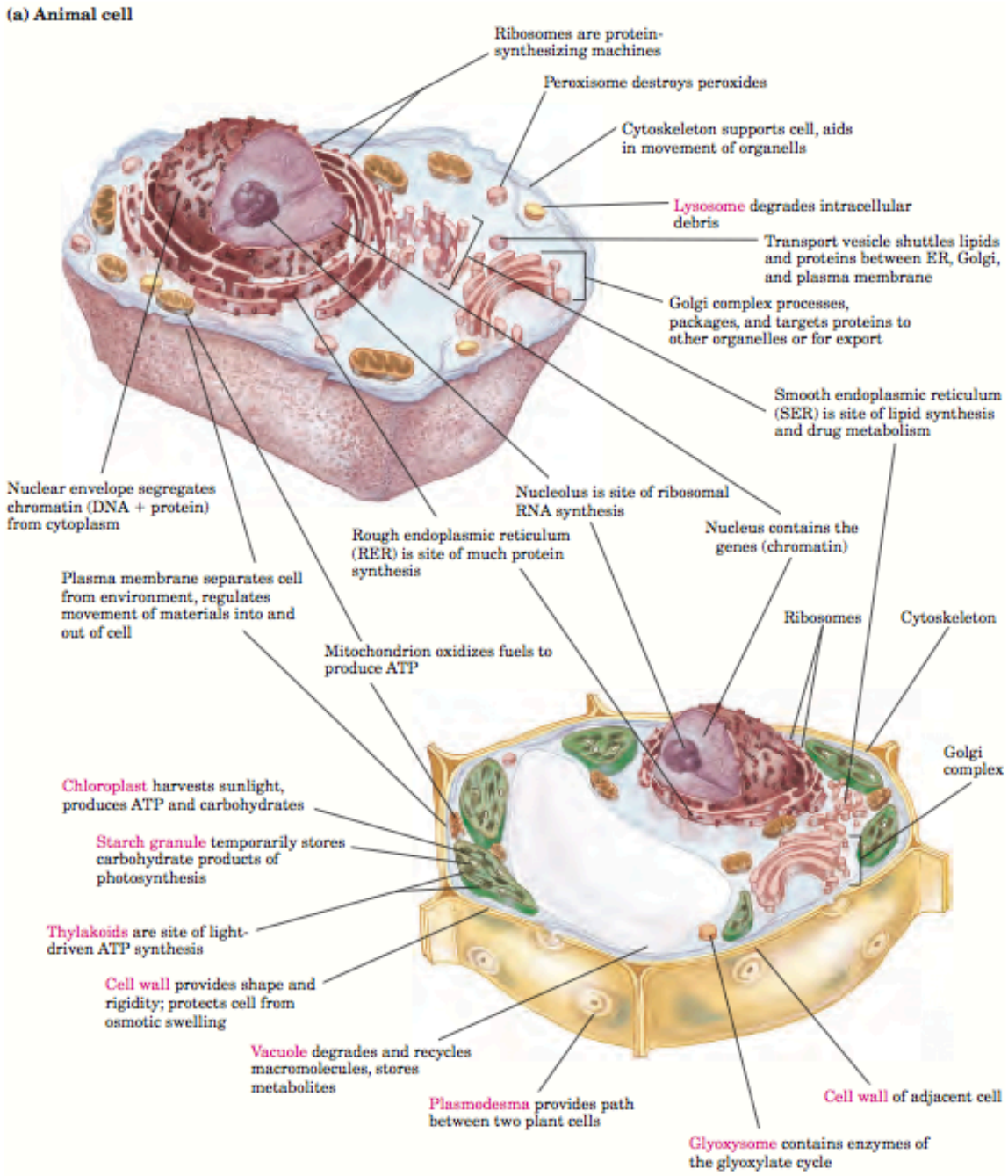


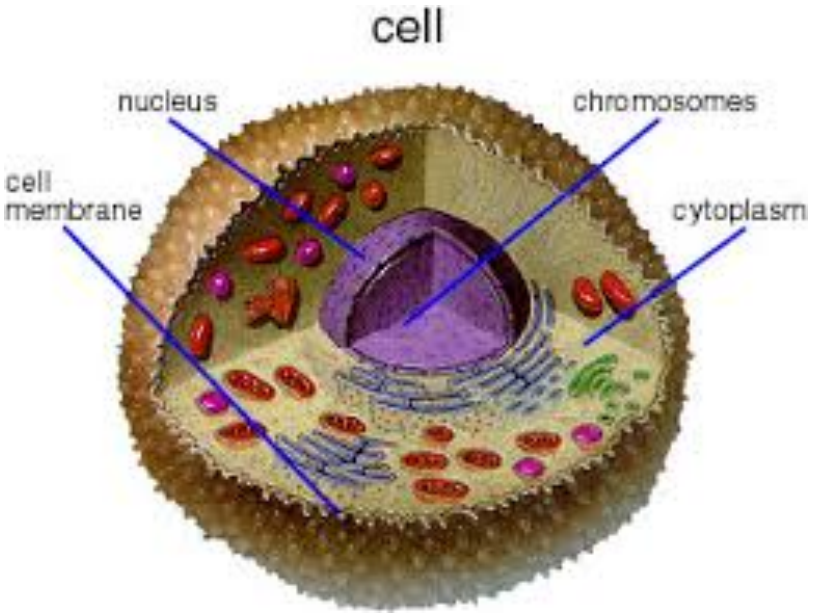
FIGURE 1–7 Eukaryotic cell structure. Schematic illustrations of the

Nucleus

- **Function** – isolates the cell's genetic material, DNA
  - DNA directs/controls the activities of the cell
    - DNA determines which types of RNA are made
    - The RNA leaves the nucleus and directs the synthesis of proteins in the cytoplasm

Nucleus

- **Structure**
  - Nuclear envelope
    - Two Phospholipid bilayers with protein lined pores
      - Each pore is a ring of 8 proteins with an opening in the center of the ring
  - Nucleoplasm – fluid of the nucleus



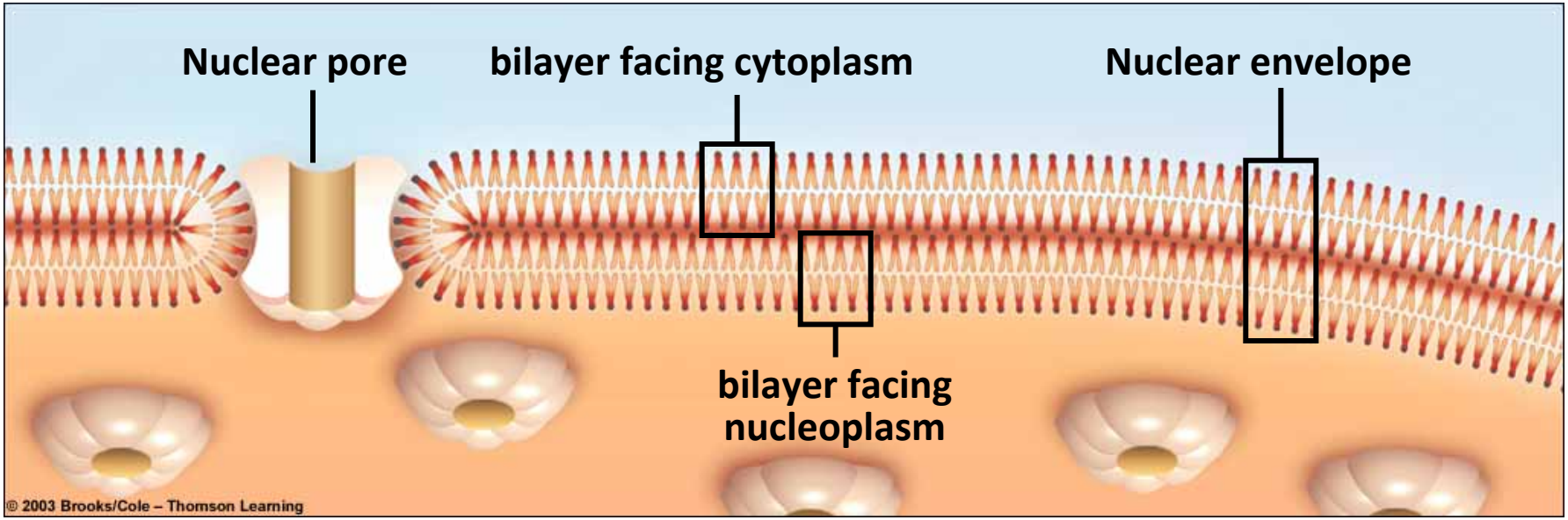

Nuclear pore
bilayer facing cytoplasm
Nuclear envelope
bilayer facing nucleoplasm
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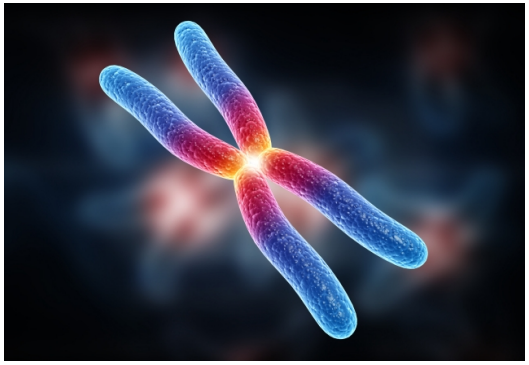
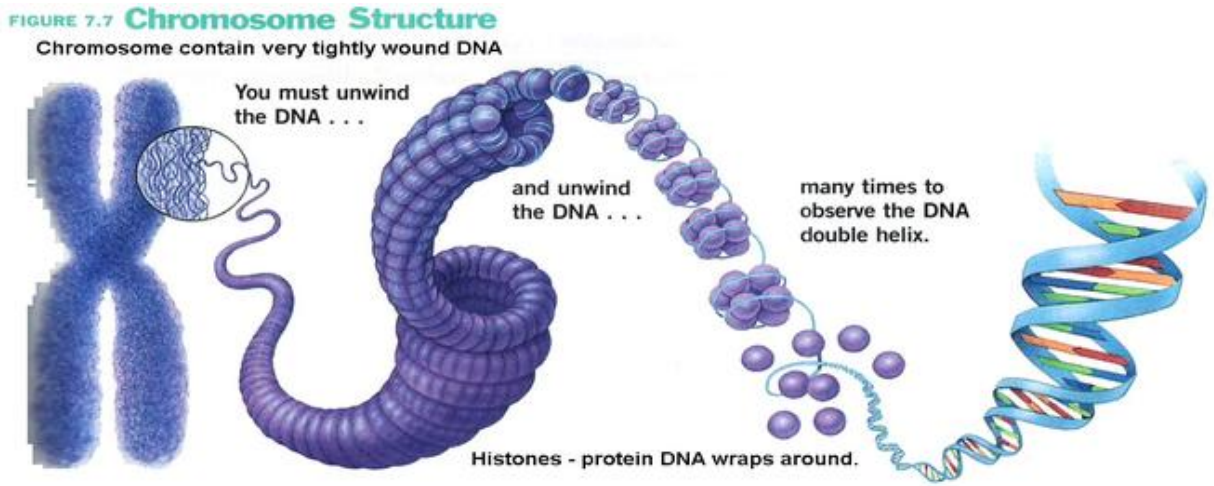
Fig. 4-17, p.61

Nucleus

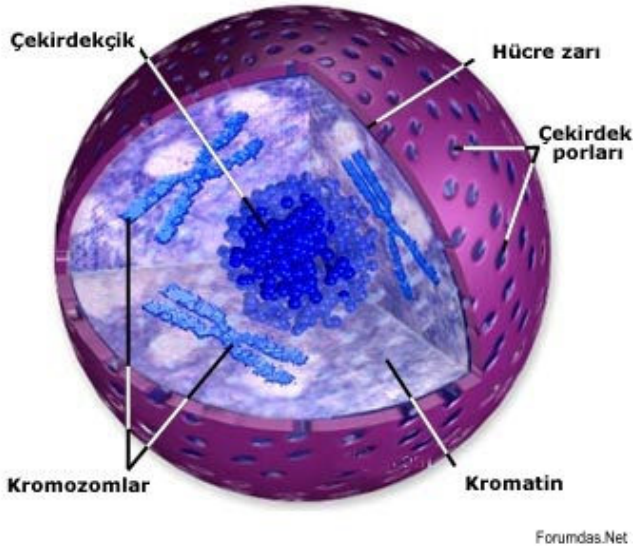


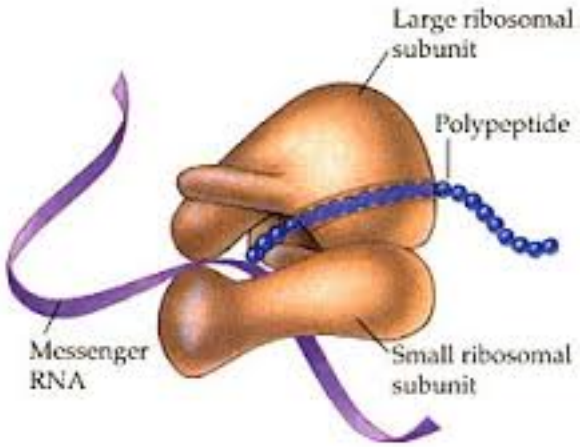
- DNA is arranged in chromosomes
  - Chromosome – fiber of DNA with proteins attached
  - Chromatin – all of the cell's DNA and the associated proteins



Nucleus

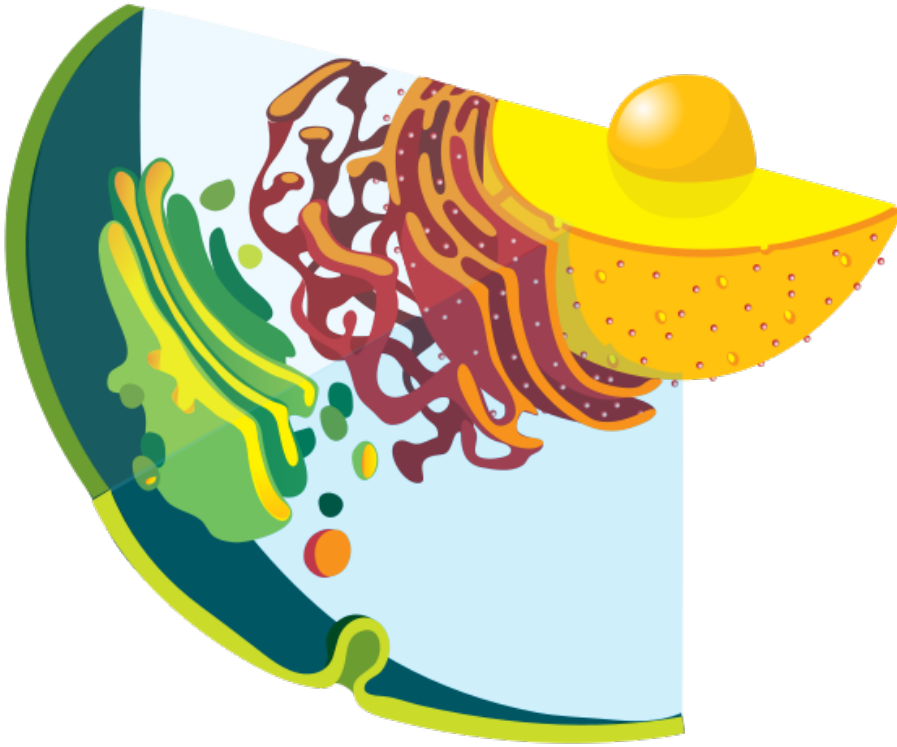
- **Structure,** *continued*
  - Nucleolus
    - Area of condensed DNA
    - Where ribosomal subunits are made
      - Subunits exit the nucleus via nuclear pores





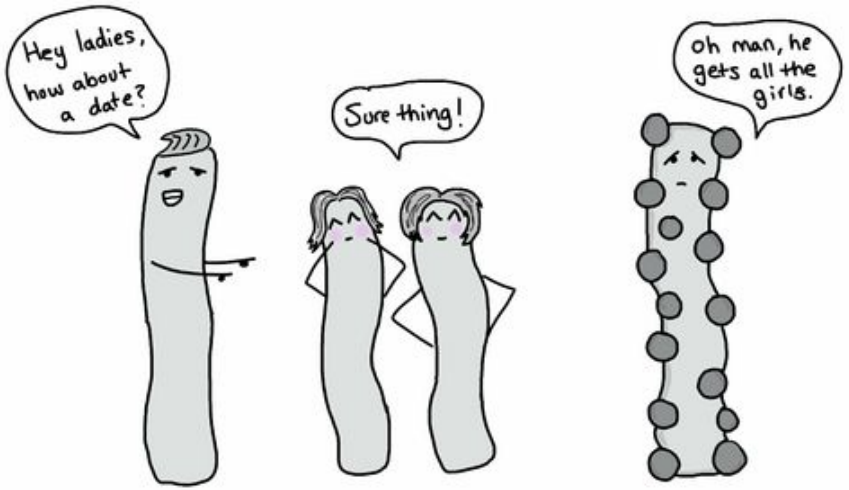
Endomembrane System

- Series of organelles responsible for:
  - Modifying protein chains into their final form
  - Synthesizing of lipids
  - Packaging of fully modified proteins and lipids into vesicles for export or use in the cell



Structures of the Endomembrane System

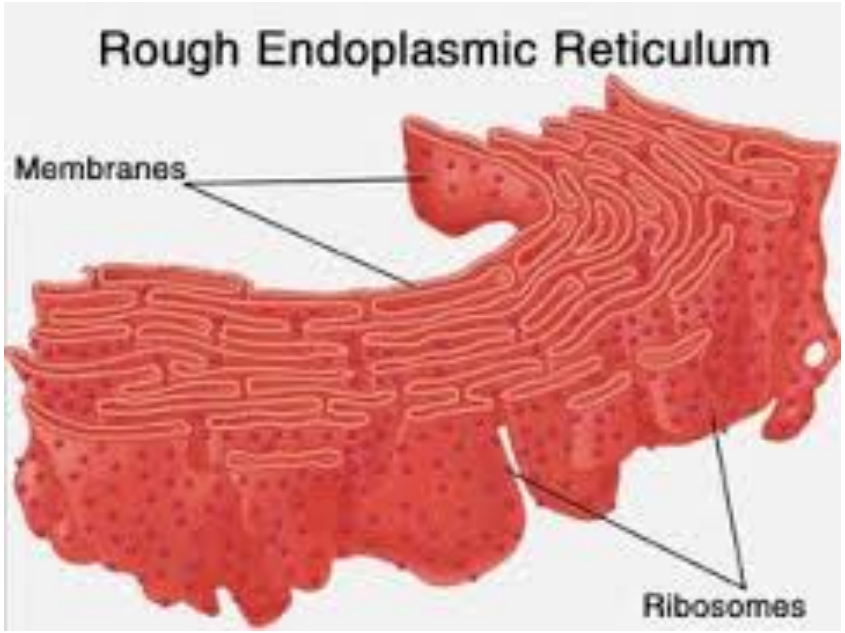
- Endoplasmic Reticulum (ER)
  - Continuous with the outer membrane of the nuclear envelope
  - Two forms - smooth and rough
- Transport vesicles
- Golgi apparatus



Smooth Endoplasmic Reticulum

Endoplasmic Reticulum

- Rough Endoplasmic Reticulum (RER)
  - Network of flattened membrane sacs create a "maze"
    - RER contains enzymes that recognize and modify proteins
  - Ribosomes are attached to the outside of the RER and make it appear rough



Endoplasmic Reticulum

- Function RER
  - Proteins are modified as the move through RER
  - Once modified, proteins are packaged in transport vesic for transport to Golgi body

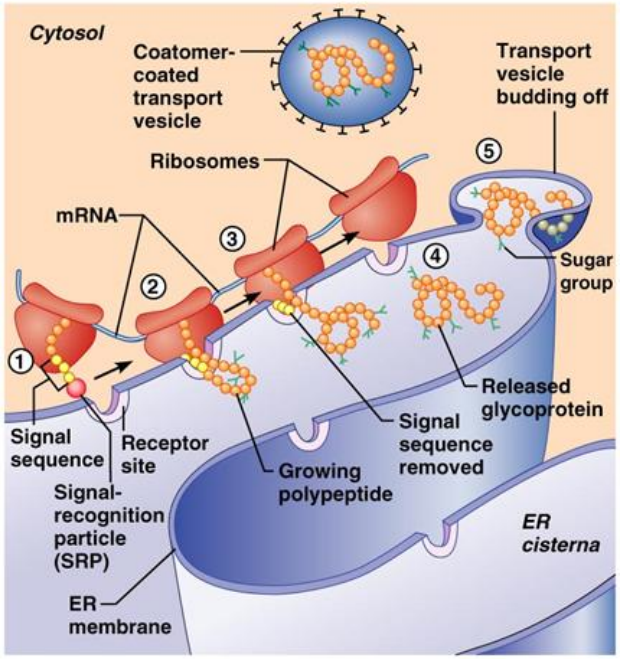


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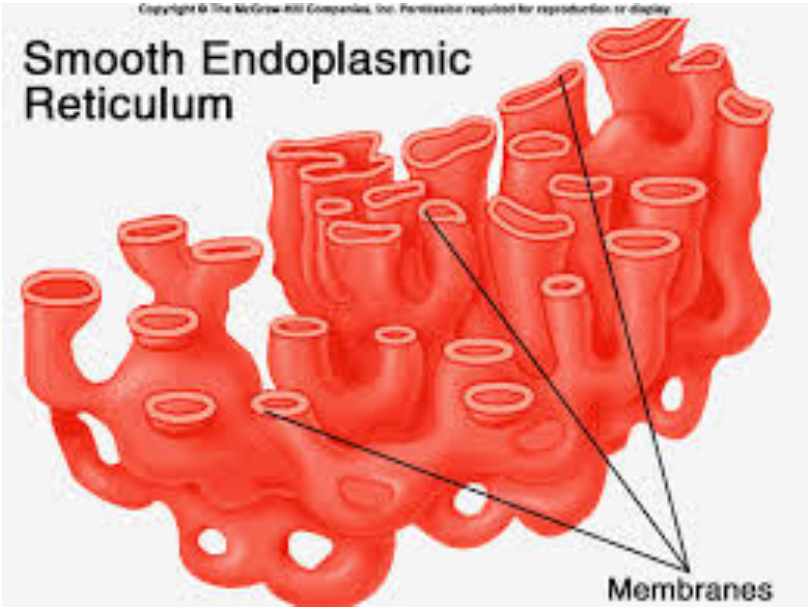
Figure 3.19

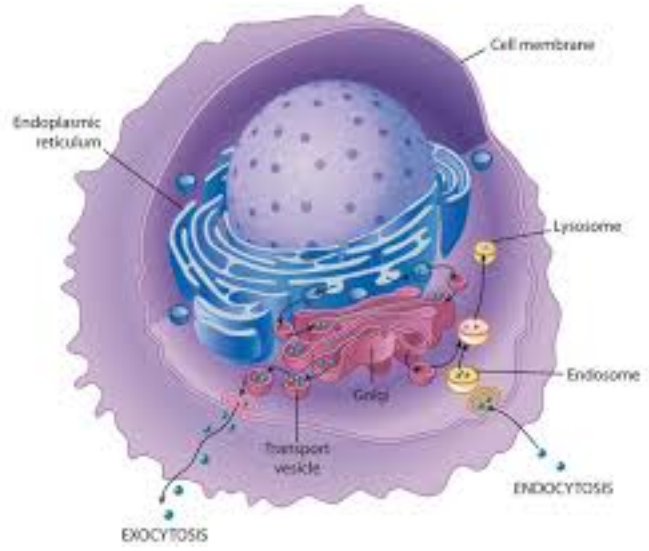
Endomembrane System

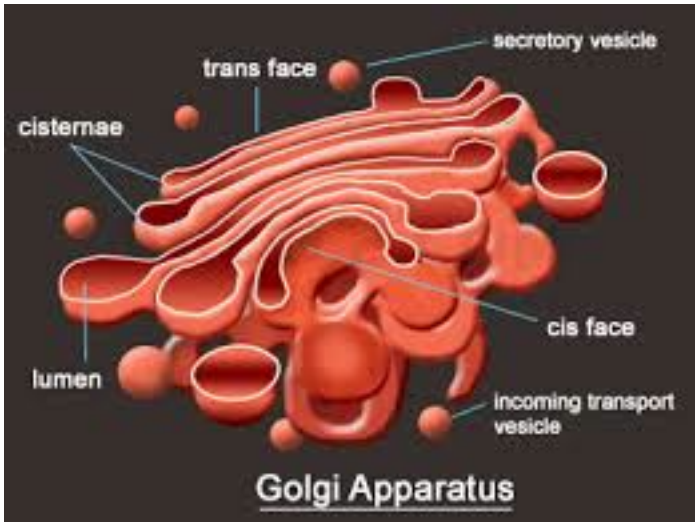
- Smooth ER (SER)
  - Tubular membrane structure
  - Continuous with RER
  - No ribosomes attached
- Function SER
  - Lipids are made inside the SER
    - fatty acids, phospholipids, sterols..
  - Lipids are packaged in transport vesicles and sent to the Golgi



Golgi Apparatus

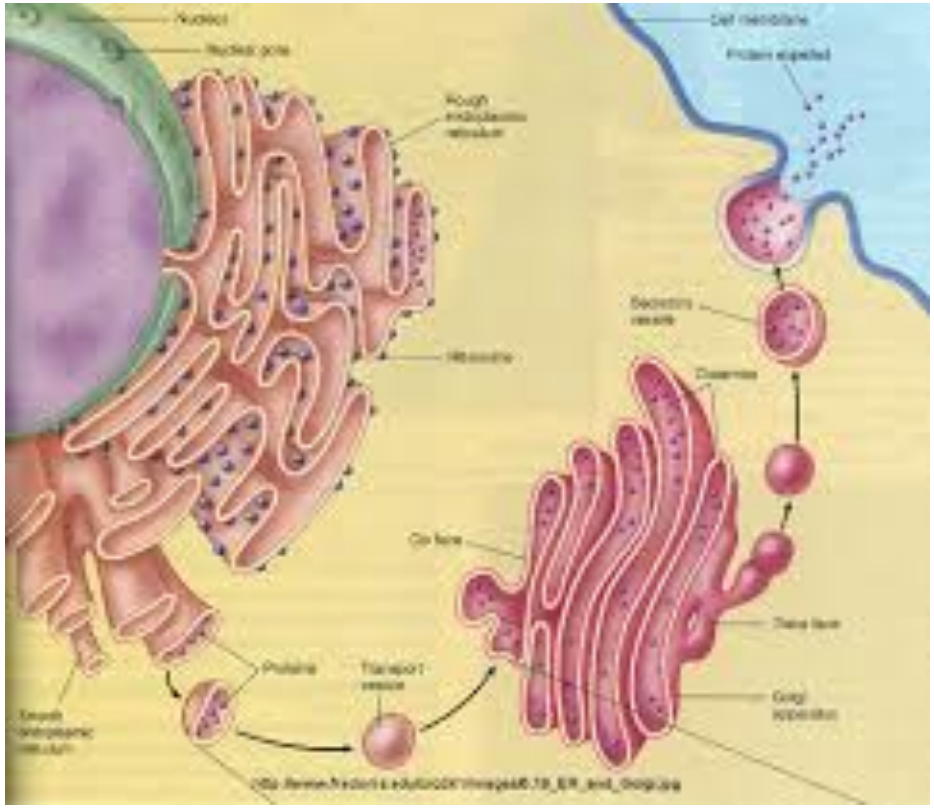
- Golgi Apparatus
  - Stack of flattened membrane sacs
- Function Golgi apparatus
  - Completes the processing substances received from the ER
  - Sorts, tags and packages fully processed proteins and lipids in vesicles





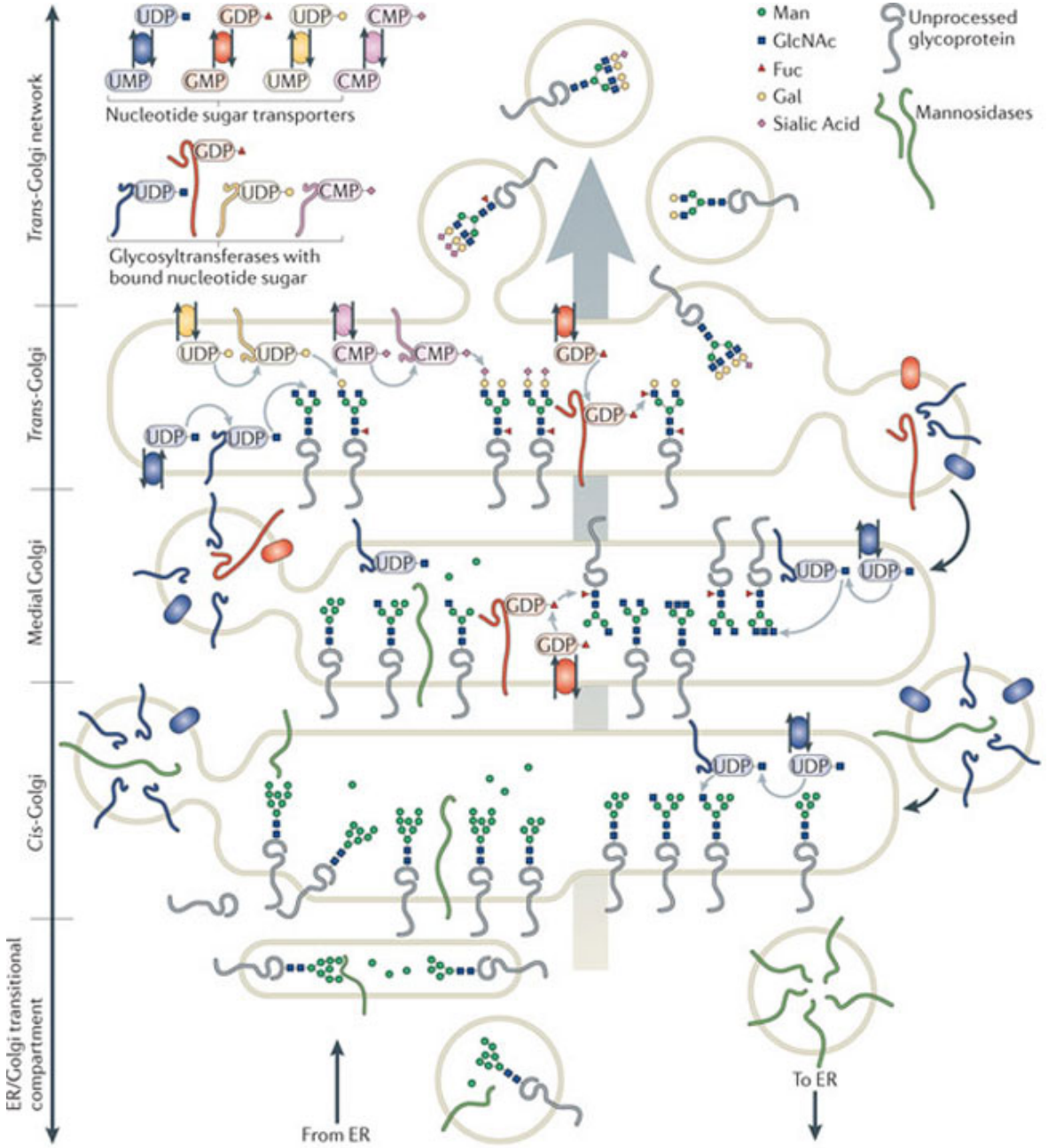
Golgi Apparatus

- Golgi apparatus receives transport vesicles from the ER on one side of the organelle
  - Vesicle binds to the first layer of the Golgi and its contents enter the Golgi

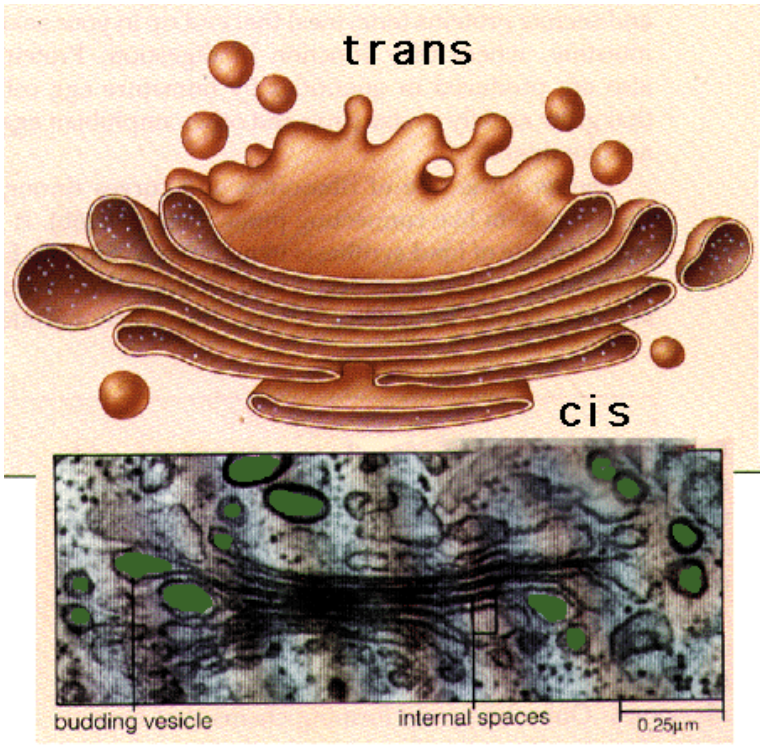


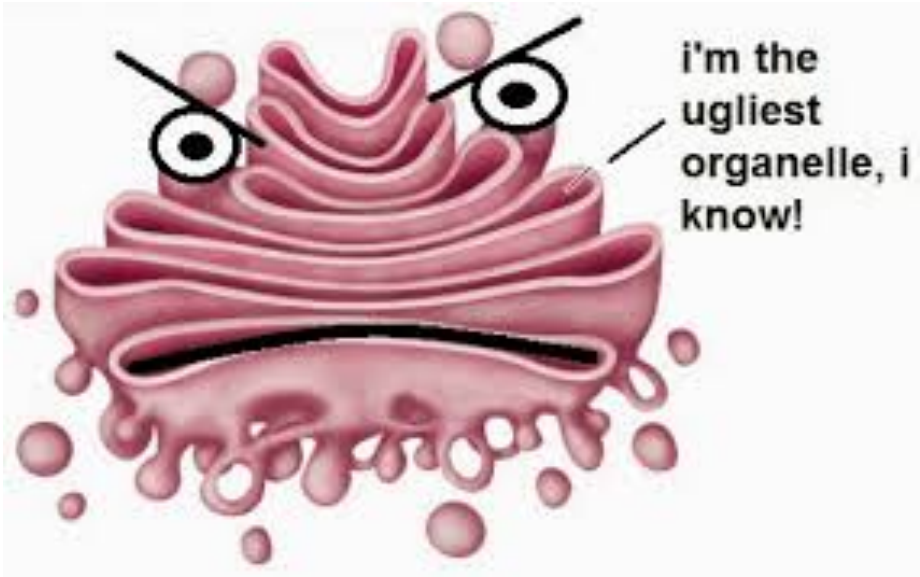
Golgi Apparatus

- The proteins and lipids are modified as they pass through layers of the Golgi
- Molecular tags are added to the fully modified substances
  - These tags allow the substances to be sorted and packaged appropriately.
  - Tags also indicate where the substance is to be shipped.


Trans-Golgi network
Trans-Golgi
Medial Golgi
Cis-Golgi
ER/Golgi transitional compartment
UDP
GDP
UDP
CMP
UMP
GMP
UMP
CMP
Nucleotide sugar transporters
GDP
UDP
UDP
CMP
Glycosyltransferases with bound nucleotide sugar
Man
GlcNAc
Fuc
Gal
Sialic Acid
Unprocessed glycoprotein
Mannosidases
From ER
To ER

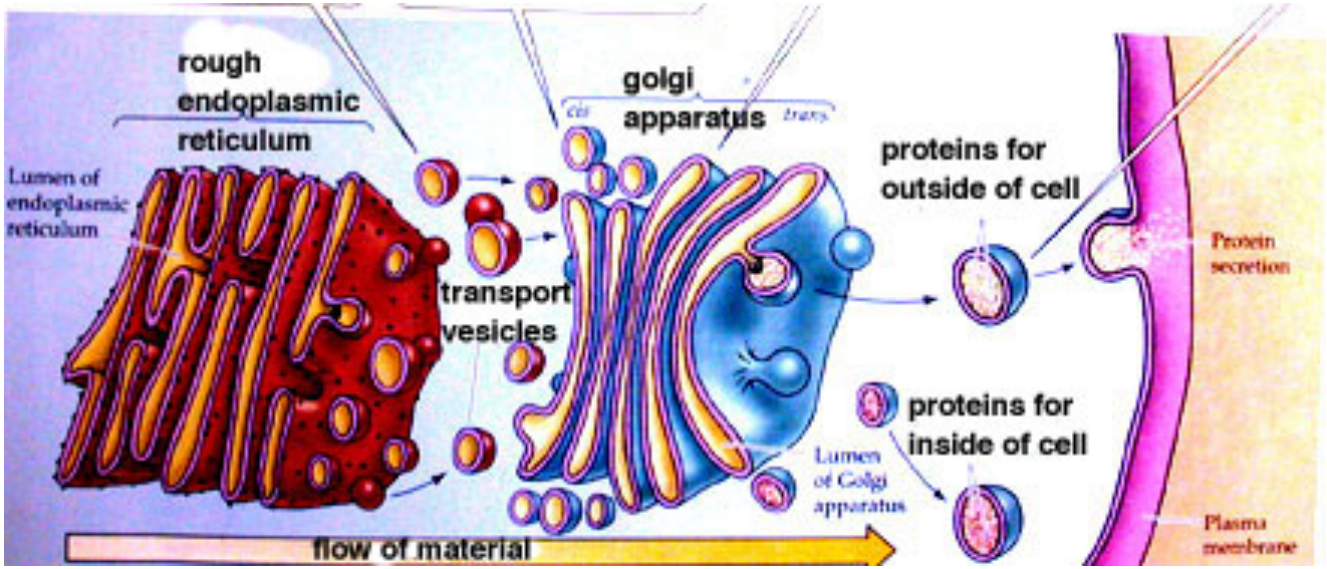
Golgi Apparatus





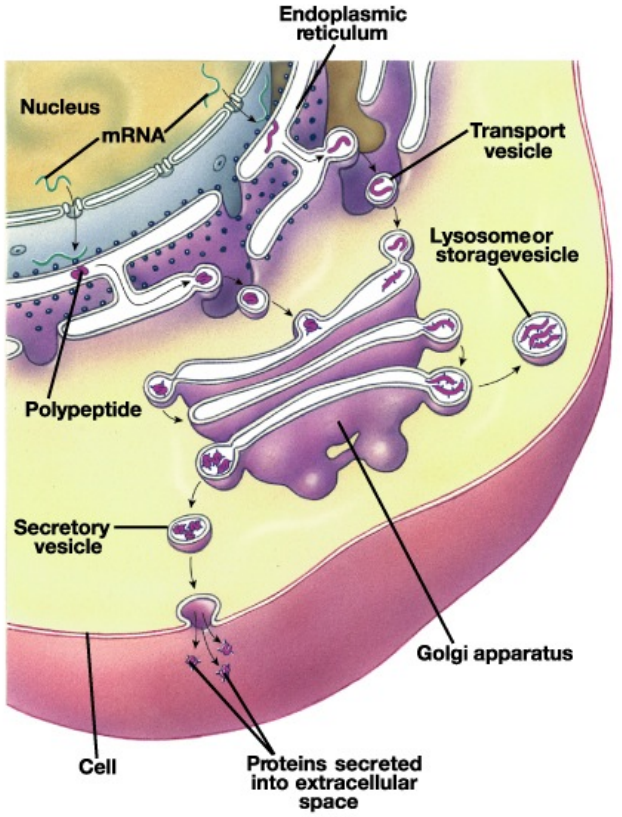
Transport Vesicles

- Transport Vesicles
  - Vesicle = small membrane bound sac
  - Transport modified proteins and lipids from the ER to the Golgi apparatus (and from Golgi to final destination)



Endomembrane System

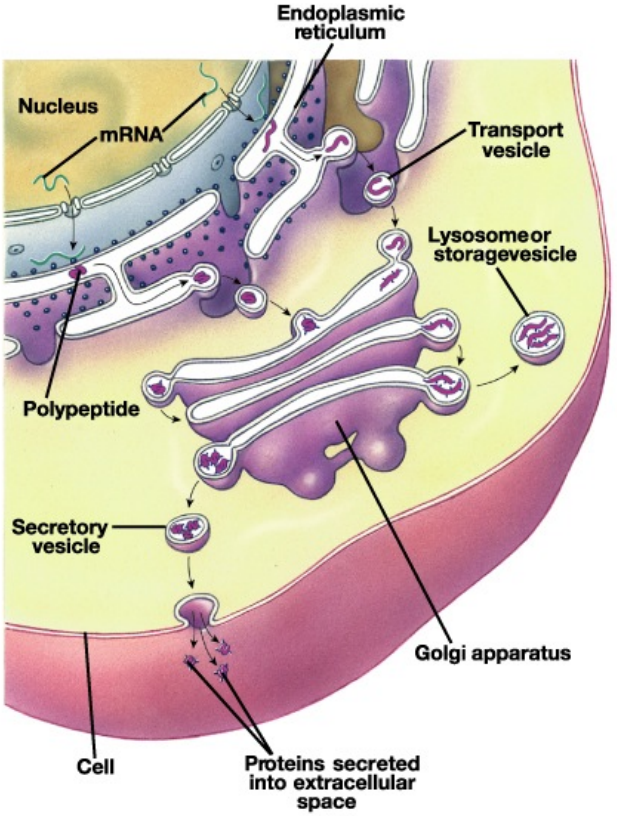
- Putting it all together
  - DNA directs RNA synthesis → RNA exits nucleus through a nuclear pore → ribosome → protein is made → proteins with proper code enter RER → proteins are modified in RER and lipids are made in SER → vesicles containing the proteins and lipids bud off from the ER



Endomembrane System

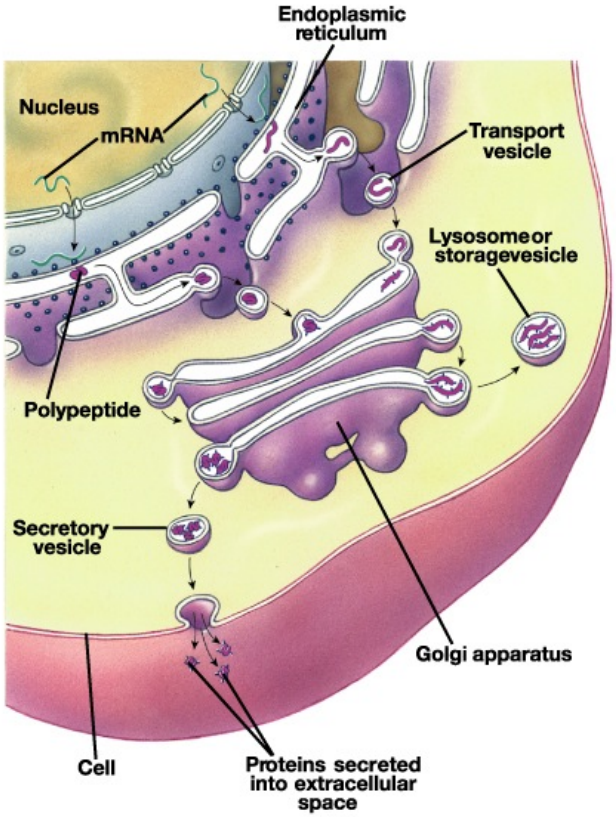
- Putting it all together

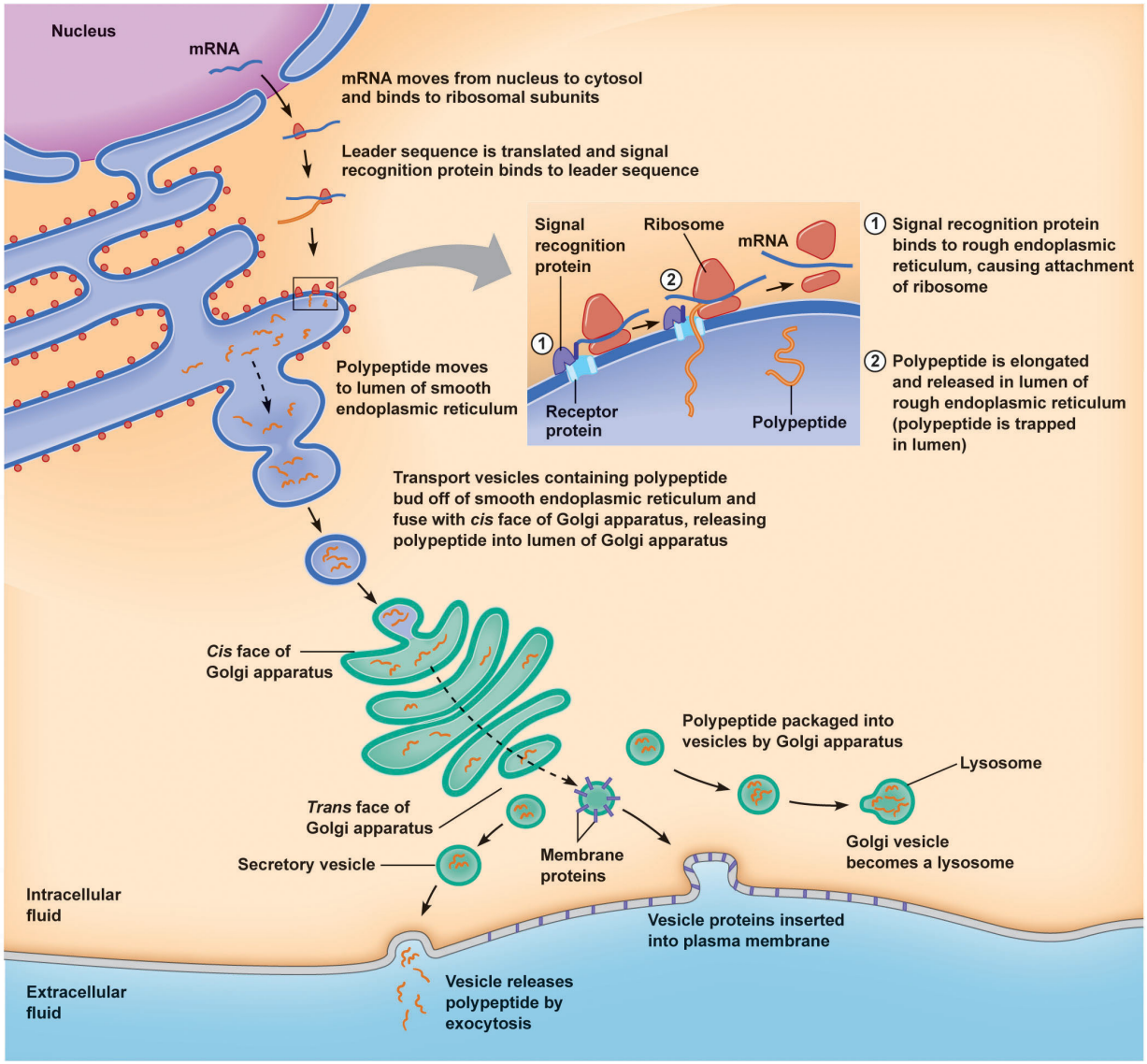
  →ER vesicles merge with Golgi body → proteins and lipids enter Golgi → each fully modified as it passes through laye of Golgi → modifie products are tagge sorted and bud off Golgi vesicles → …



Endomembrane System

- Putting it all togethe
  - →Golgi vesicles eith merge with the plasma membran and release their contents and remain in the cell and serve a purpo
  - →Another animation





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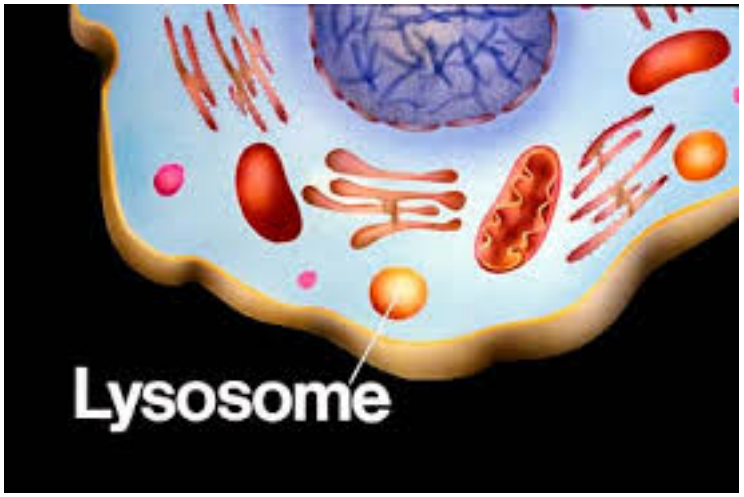
Vesicles

- Vesicles - small membrane bound sacs
  - Examples
    - Golgi and ER transport vesicles
    - Peroxisome
      - Where fatty acids are metabolized
      - Where hydrogen peroxide is detoxified
    - Lysosome
      - contains digestive enzymes
      - Digests unwanted cell parts and other wastes

Lysosomes

- The lysosome is an example of an organelle made at the Golgi apparatus.
  - Golgi packages digestive enzymes in a vesicle. The vesicle remains in the cell and:
    - Digests unwanted or damaged cell parts
    - Merges with food vacuoles and digest the contents



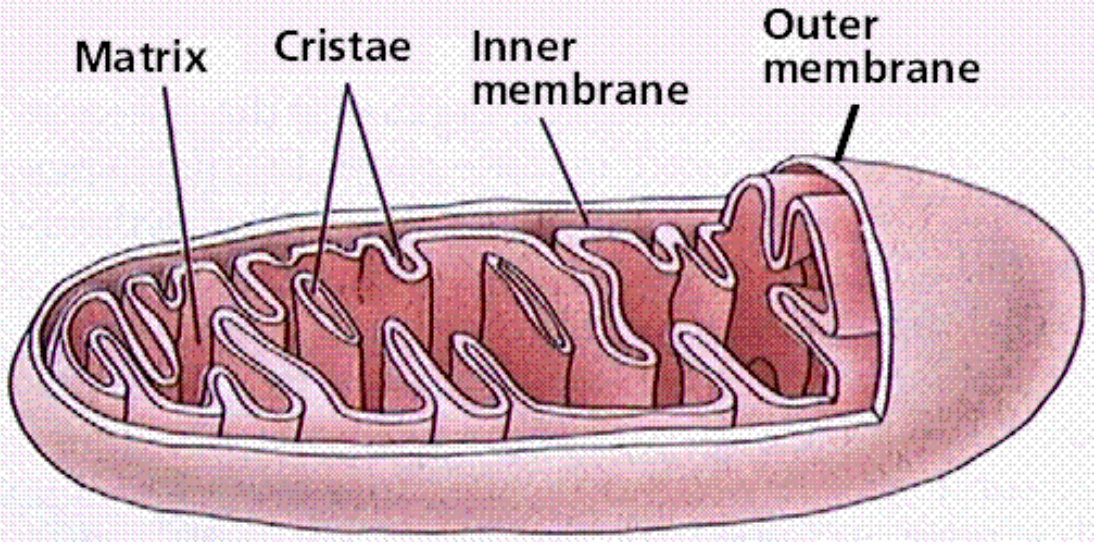


Mitochondria

- Function – synthesis of ATP
  - 3 major pathways involved in ATP production
    1. Glycolysis
    2. Krebs Cycle
    3. Electron transport system (ETS)

Mitochondria

- Structure:
  - ~1-5 microns
  - Two membranes
    - Outer membrane
    - Inner membrane - Highly folded
      - Folds called cristae
  - Intermembrane space (or outer compartment)
  - Matrix
    - DNA and ribosomes in matrix

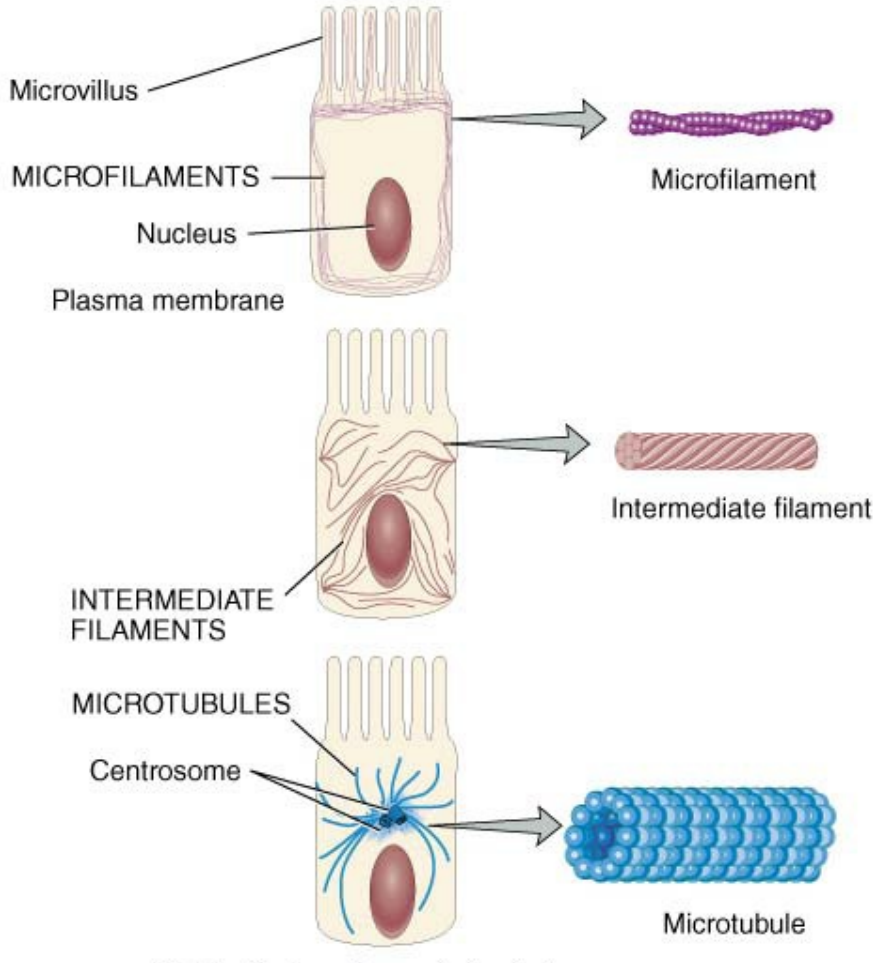


Vacuoles

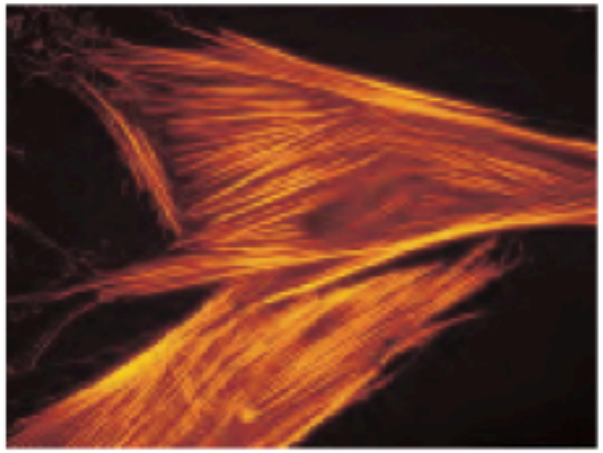
- Vacuoles are membrane sacs that are generally larger than vesicles.
  - Examples:
    - Food vacuole - formed when protists bring food into the cell by endocytosis
    - Contractile vacuole – collect and pump excess water out of some freshwater protists
    - Central vacuole – covered later

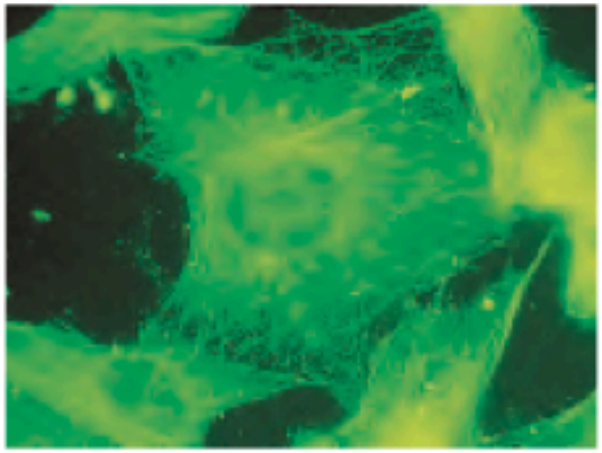
Cytoskeleton

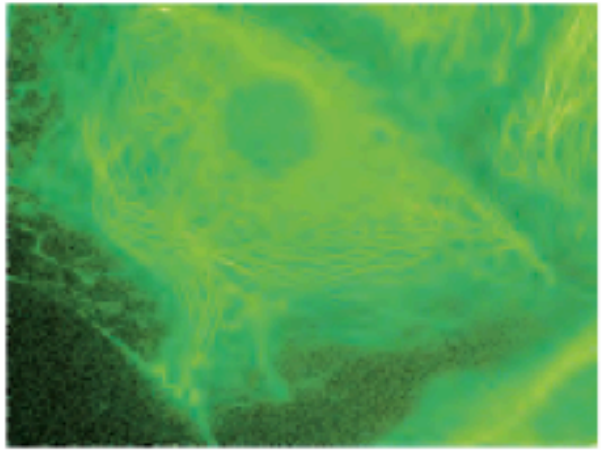
- Function
  - gives cells internal organization, shape, and ability to move
- Structure
  - Interconnected system of microtubules, microfilaments, and intermediate filaments
  - All are proteins

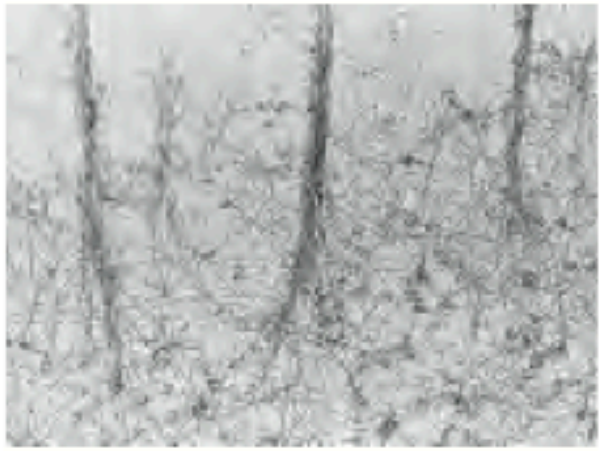


Cytoskeleton

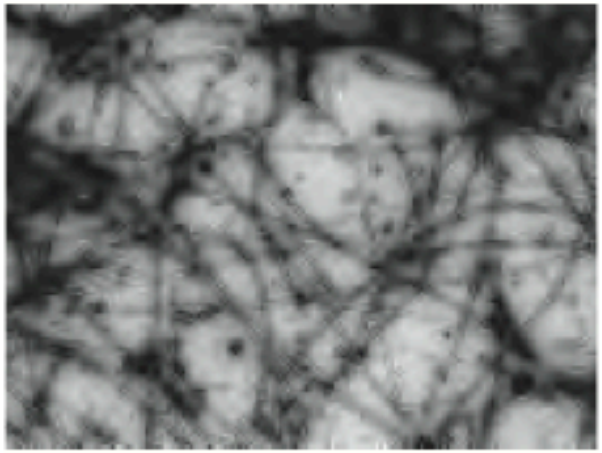




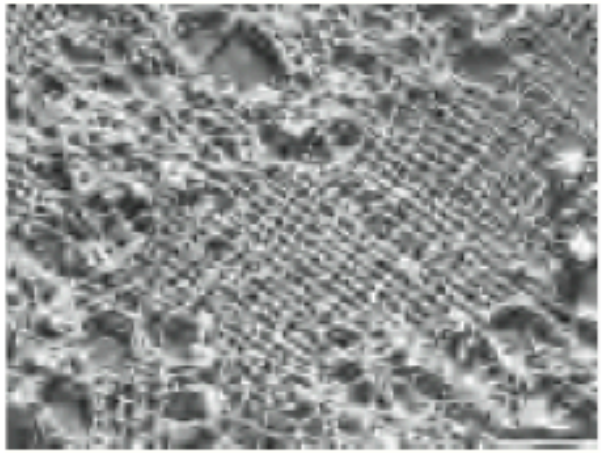




Actin stress fibers
(a)



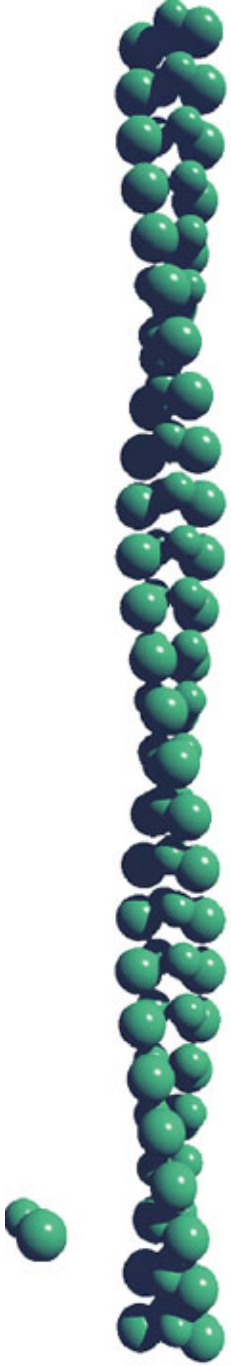
Microtubules
(b)



Intermediate filaments
(c)

Microfilaments

- Thinnest cytoskeletal elements (rodlike)
- Composed of the globular protein **actin**
- Enable cells to change shape and move



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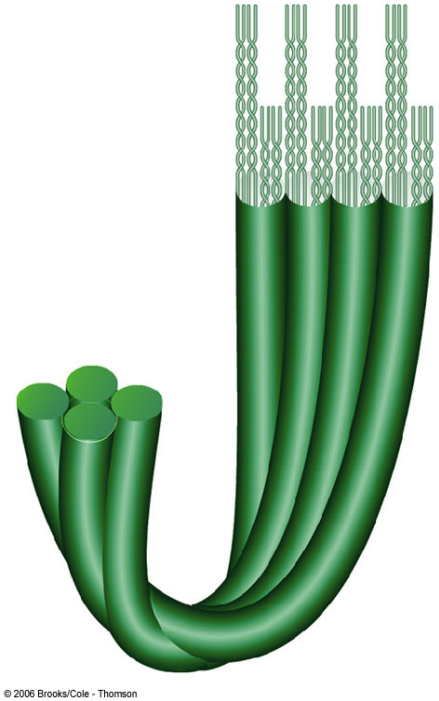
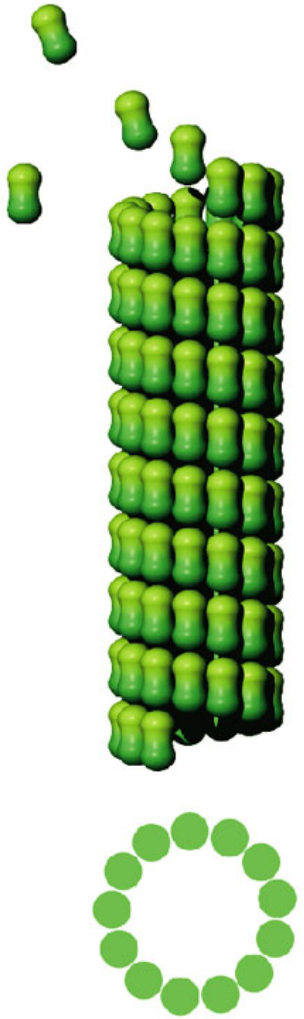
Cytoskeleton

- Intermediate filaments
  - Present only in animal cells of certain tissues
  - Fibrous proteins join to form a rope-like structure
    - Provide internal structure
    - Anchor organelles in place.



Cytoskeleton

- Microtubules – long hollow tubes made of tubulin proteins (globular)
  - Anchor organelles and act as tracks for organelle movement
  - Move chromosomes around during cell division
    - Used to make cilia and flagella



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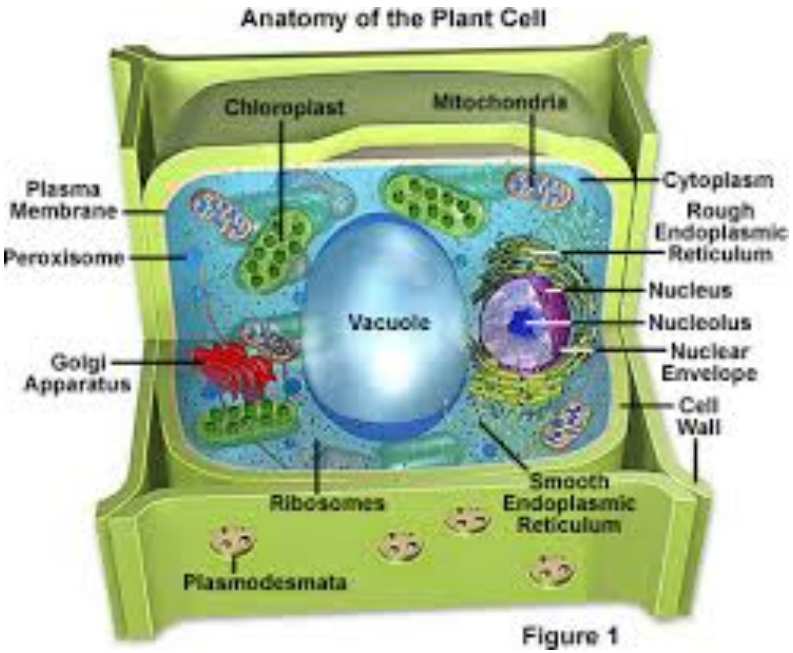
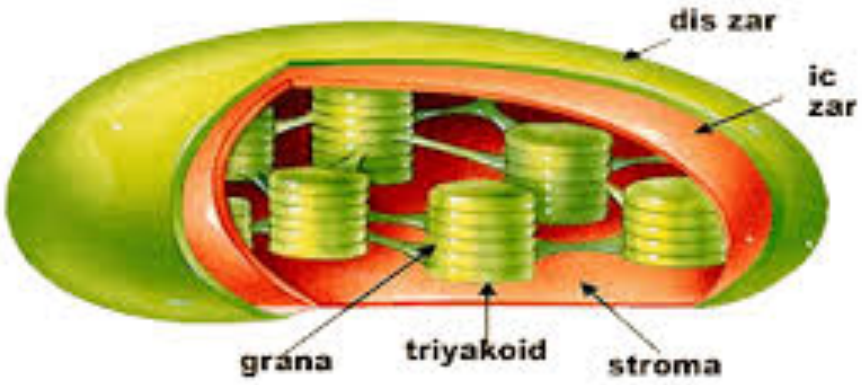
Plant Cell Structures

- Structures found in plant, but not animal cells
  - Chloroplasts
  - Central vacuole
  - Other plastids/vacuoles – chromoplast, amyloplast
  - Cell wall



Chloroplasts

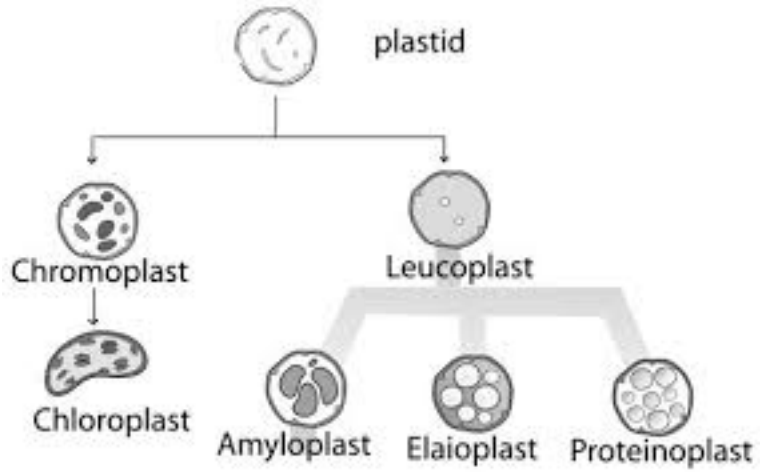
- Function – site of photosynthesis
- Structure
  - 2 outer membranes
  - Thylakoid membrane system
    - Stacked membrane sacs called granum
  - Chlorophyll in granum
  - Stroma
    - Fluid part of chloroplast



Plastids/Vacuoles in Plants

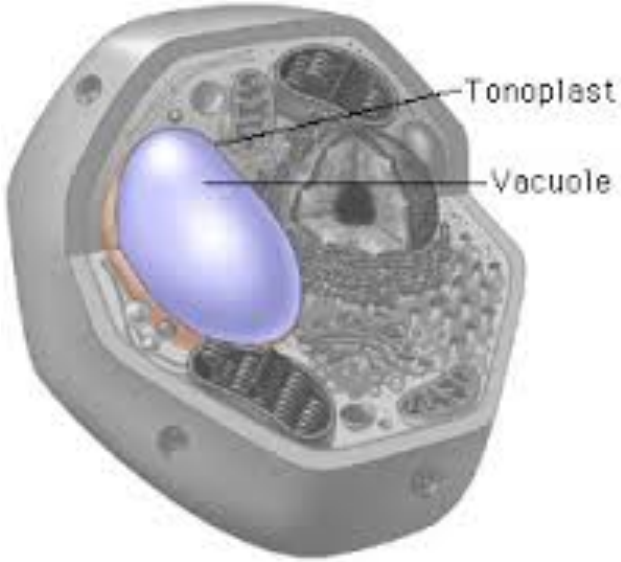
- Chromoplasts – contain colored pigments
    - Pigments called carotenoids

- Amyloplasts – store starch



Central Vacuole

- Function – storage area for water, sugars, ions, amino acids, and wastes
  - Some central vacuoles serve specialized functions in plant cells.
    - May contain poisons to protect against predators

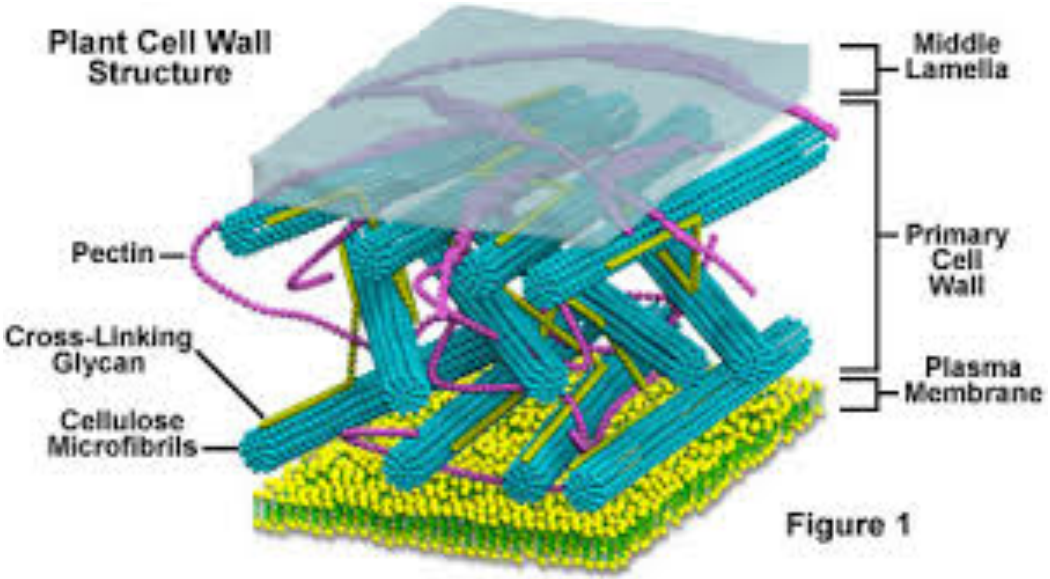


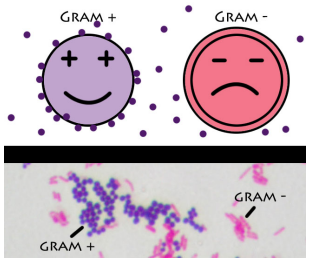
Central Vacuole

- Structure
  - Large membrane bound sac
  - Occupies the majority of the volume of the plant cell

Cell Wall

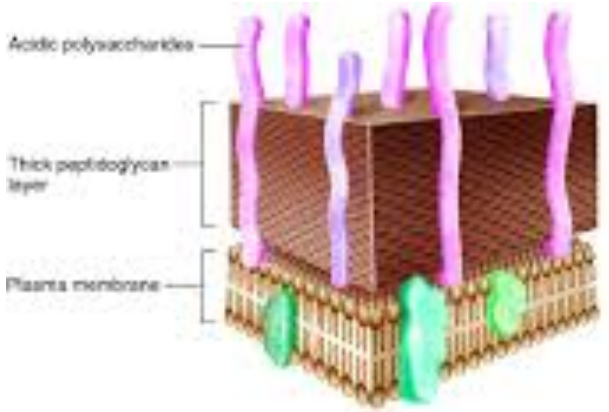
- Function – provides structure and protection
  - Never found in animal cells
  - Present in plant, bacterial, fungus, and some protists
- Structure
  - Wraps around the plasma membrane
  - Made of cellulose and other polysaccharides



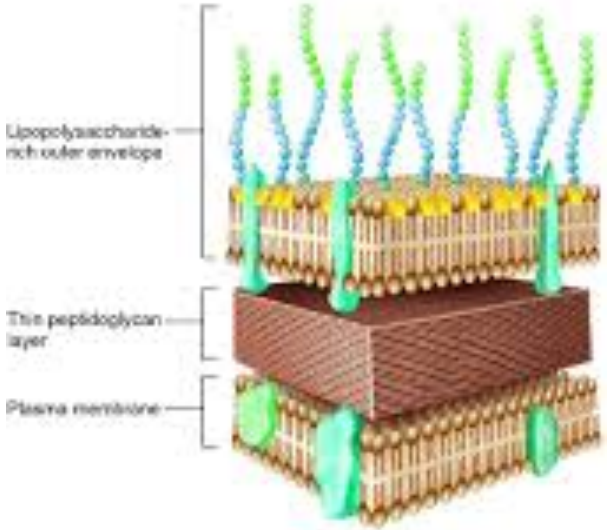


Bacteria cell

- Gram (+) and gram (-) bacteria cells have different cell surface
- Gram (+) bacteria cell has thick cell wall. No outer envelope
- Gram (-)bacteria cell has thinner cell wall and outer envelope formed from lipids



(a) Gram-positive: thick cell wall, no outer envelope



(b) Gram-negative: thinner cell wall, with outer envelope