Enrichment course in Biology

1. Cellular organization

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Learning objectives

- What are the major characteristics of cell?
- How a cell functions?
- What are the structures and functions of the cell organelles?

Cells are the basic functional units of lives...

- building blocks of muticellular organisms
  - cell → tissue → organs → organ systems
    → whole organism

- able to perform vital physiological processes to maintain its life

- combined and coordinated action of different cells
  = function of tissue, organ, organ system and the organism

http://thinkprogress.org/politics/2010/09/09/118141/stem-cell-stay/

Diversity of cells in human body

All cells in the body comes from a fertilized egg

→ become **embryonic stem cell** that give rise to all types of cells

Properties of stem cells

1. self-renewal (i.e. divide to make more stem cells)
2. able to give rise to different cell types (pluripotent)

** given the right condition/stimulation*

Cellular diversity

1. every cell in the body have the same genetic composition (DNA)

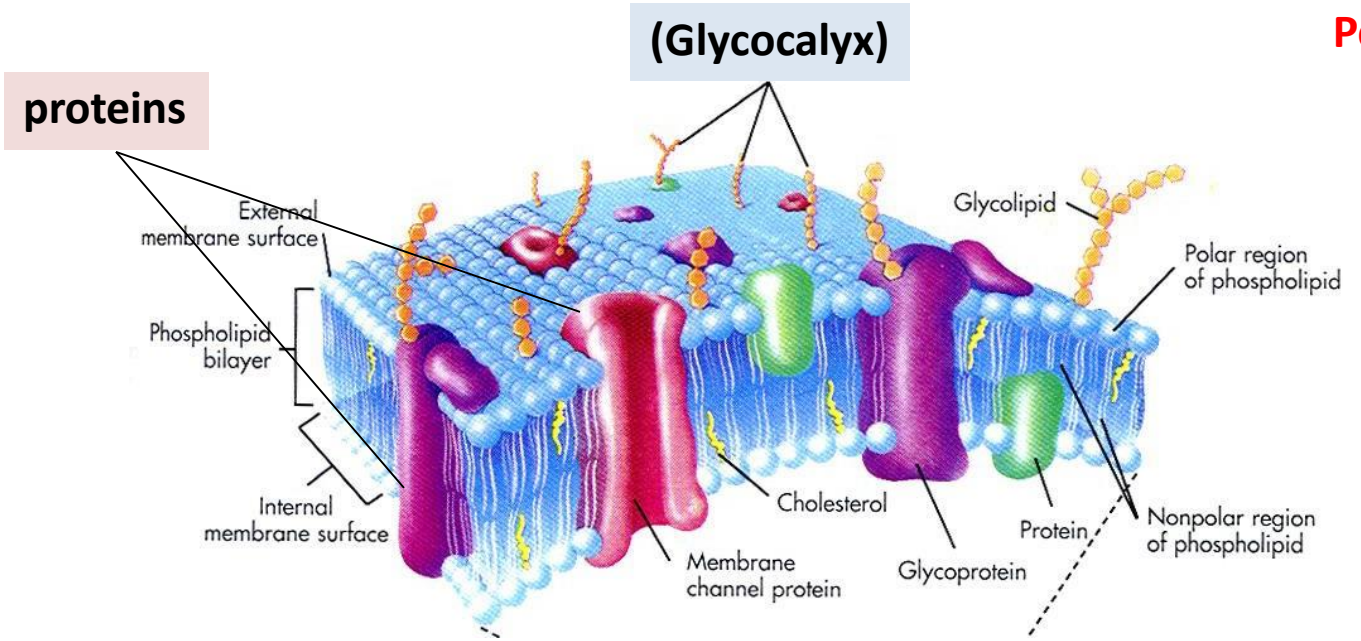
   * except in lymphocytes (a kind of white blood cells for specific immunity)

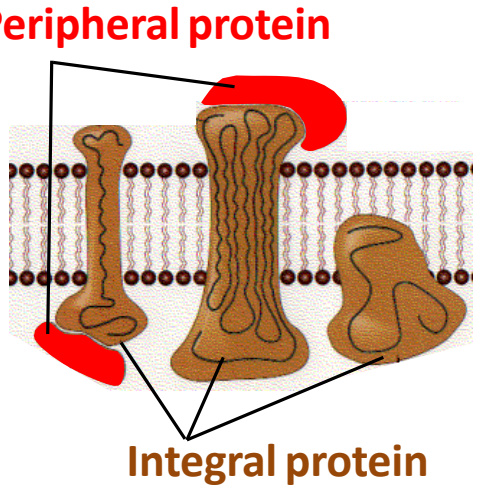
2. human has ~ 20000 genes, each gene makes 1 protein
3. different types of cells make different combinations of protein

   → different cells performs different functions

Plasma membrane

1. defines cell boundary
2. separates intracellular substances and extracellular substances
3. phospholipid bilayer interspersed with cholesterol
4. fluid mosaic model: proteins float and drift across the membrane freely (like iceberg floating in the sea)





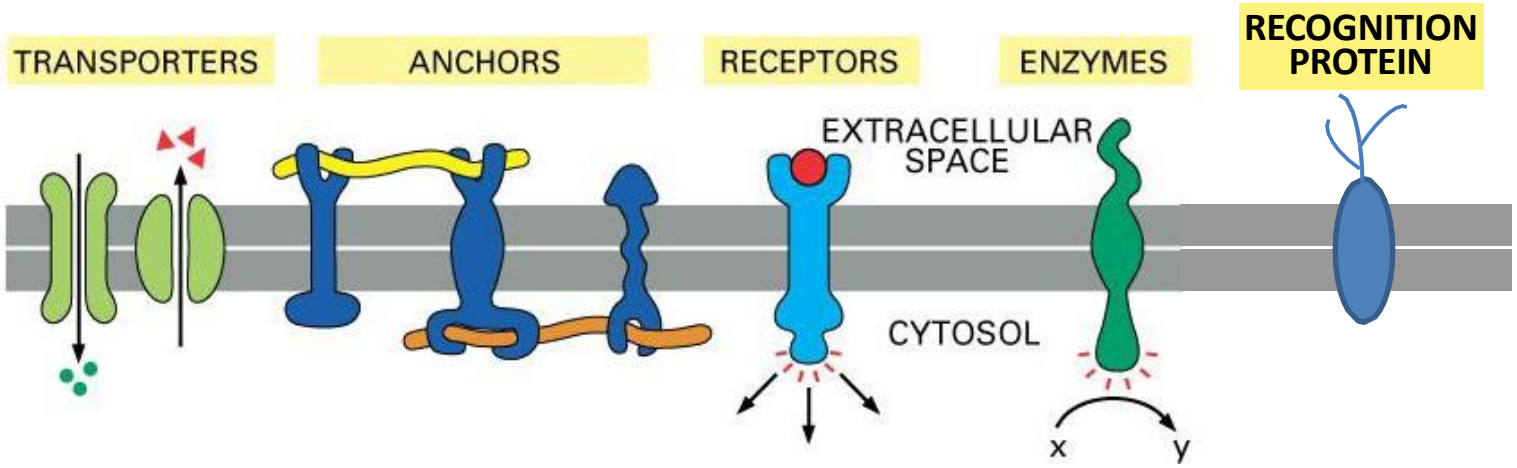
Plasma membrane – fluid mosaic model

http://www.youtube.com/watch?v=owEgqrq51zY&feature=related

Functions of plasma membrane

Depends on the proteins present in the membrane

1. Transporters to control entry and exit of substances
   - carrier proteins, channels
2. Anchoring proteins allow cell attachment (to another cell/extracellular matrix)
3. Receptor proteins response to chemical signals (e.g. hormone)
4. Enzymes - e.g. on intestinal cells for digestion of food
5. Recognition proteins – glycoproteins (proteins with carbohydrate chains attached)
   (e.g. antigens of ABO blood group)



http://www.accessexcellence.org/RC/VL/GG/ecb/membrane_proteins.php

Transport across plasma membrane

- Diffusion
  - Simple diffusion
  - Facilitated diffusion
- Osmosis
- Active transport
- Endocytosis and pinocytosis

Diffusion

Net movement of molecules

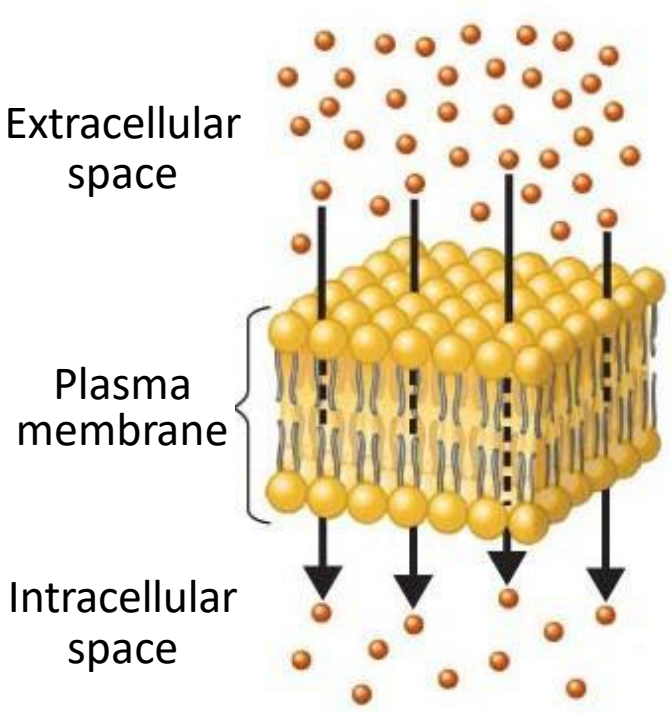
High concentration → Low concentration

Given time ↓

Equilibrium

http://upload.wikimedia.org/wikipedia/commons/1/1f/Dispersion.gif

Diffusion across plasma membrane



Simple diffusion across lipid bilayer

Biological membrane is **selectively permeable**
- not all substances are allowed to pass

What can diffuse through the lipid bilayer?
- small molecules
- nonpolar molecules
- uncharged particles
- e.g. O_2, CO_2

Passive
- No energy needed

Factors affecting rates of diffusion:

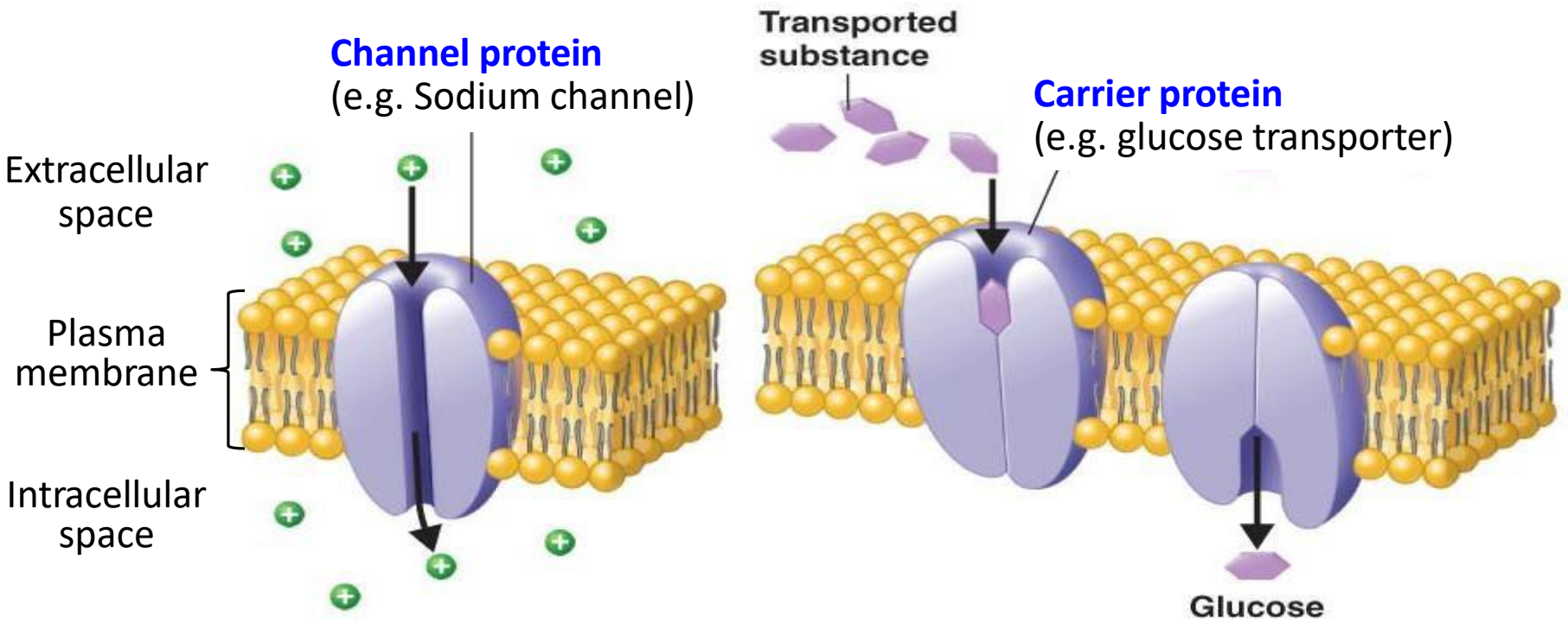
1. Steepness of the concentration gradient
2. Temperature
3. Size/mass of the molecule
4. Surface area
5. Diffusion distance

http://www2.raritanval.edu/departments/Science/full-time/Weber/Microbiology%20Majors/SoftChalkeCoursesubmission/chapter4sub/figure_04_17_labeled.jpg

Facilitated diffusion

- larger molecules
- polar molecules, e.g. glucose
- charged molecules, e.g. ions

→ **Need Help!!!**



Most of these transporter proteins are specific

Passive

http://www2.raritanval.edu/departments/Science/full-time/Weber/Microbiology%20Majors/SoftChalkeCoursesubmission/chapter4sub/figure_04_17_labeled.jpg

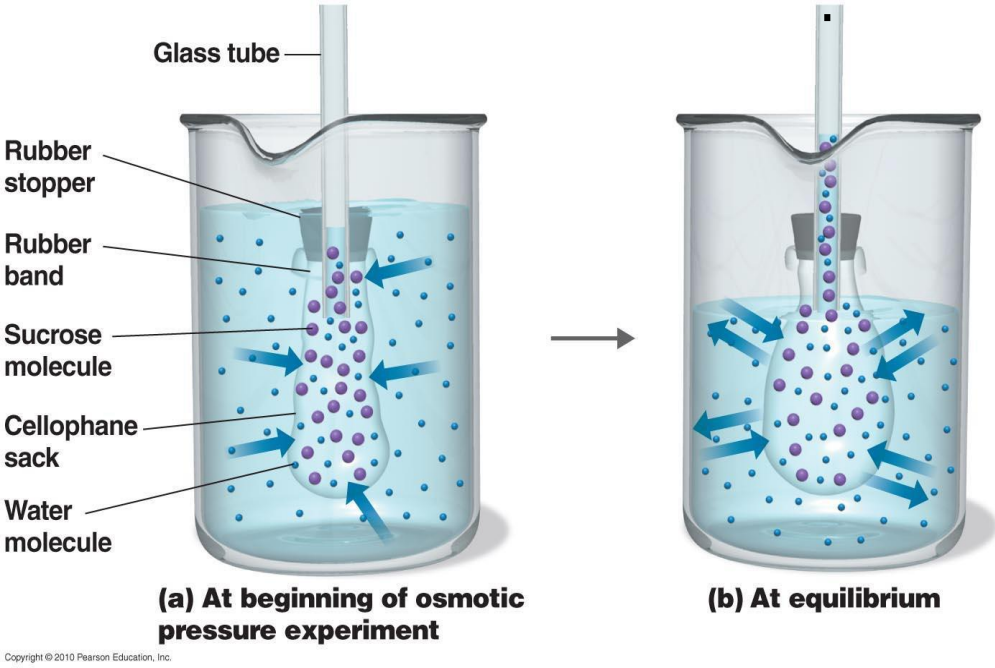
Osmosis = diffusion of water molecules

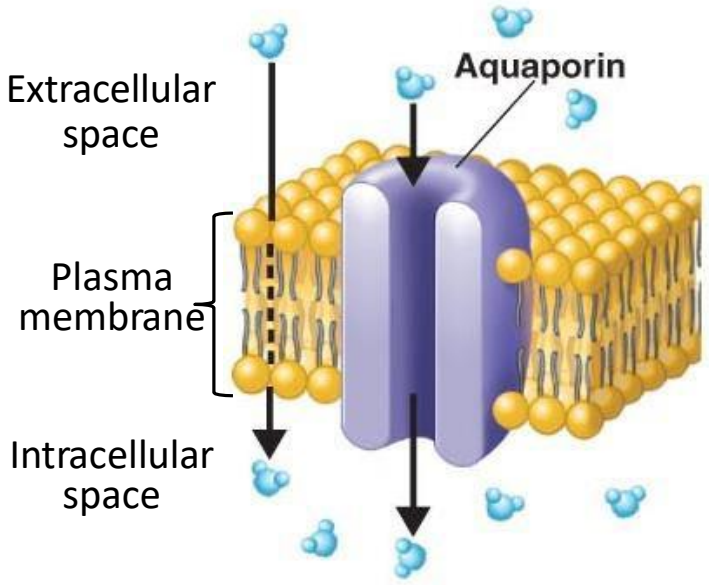
Selectively permeable membrane

Higher water potential
(lower solute conc.)

Net movement of water molecules

Lower water potential
(higher solute conc.)





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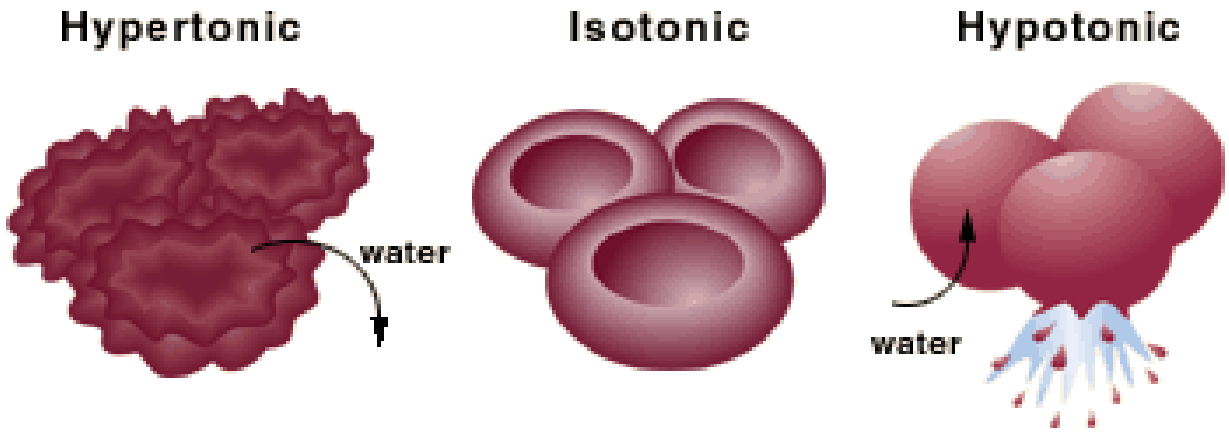
http://www2.raritanval.edu/departments/Science/full-time/Weber/Microbiology%20Majors/SoftChalkeCoursesubmission/chapter4sub/chapter4sub_print.html

Importance of osmosis

Hypertonic solution = higher solute concentration outside of the cell

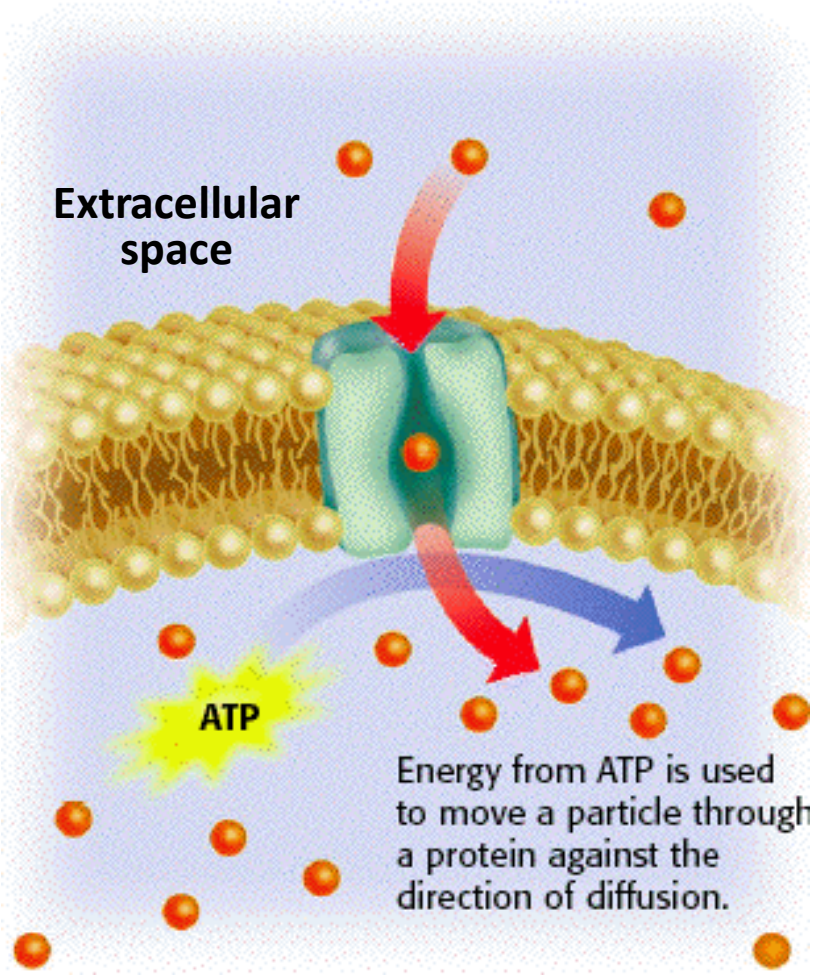
Isotonic solution = same solute concentration

Hypotonic solution = lower solute concentration outside of the cell



http://wpcontent.answcdn.com/wikipedia/commons/thumb/f/f4/Infuuszakjes.jpg/250px-Infuuszakjes.jpg

Active transport



Transport of substances against concentration gradient

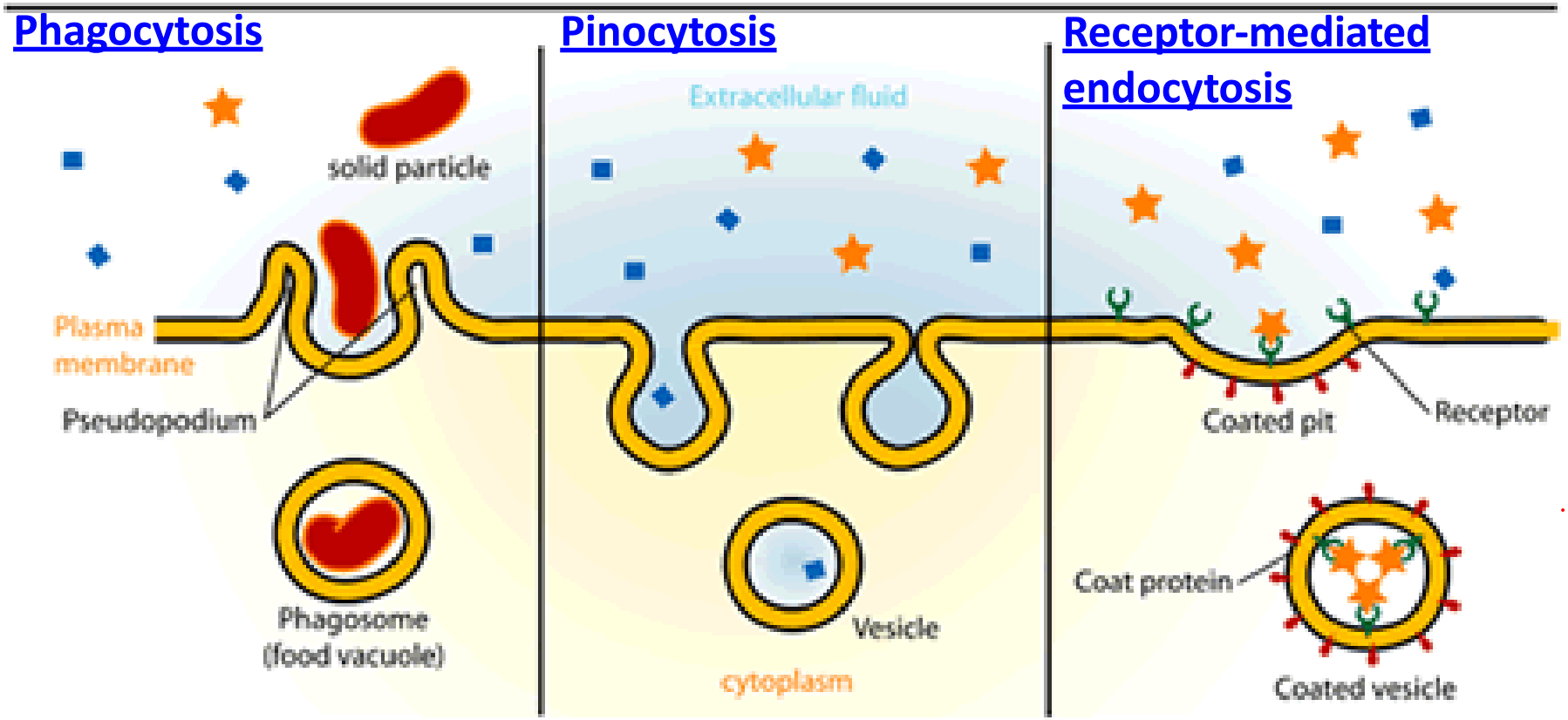
i.e. low conc. -------> high conc.

* Require energy (from ATP → ADP)

- Unidirectional → prevent leakage

-e.g. Na^+ / K^+ - ATPase
- remove Na^+ from cell
- transport K^+ into cell

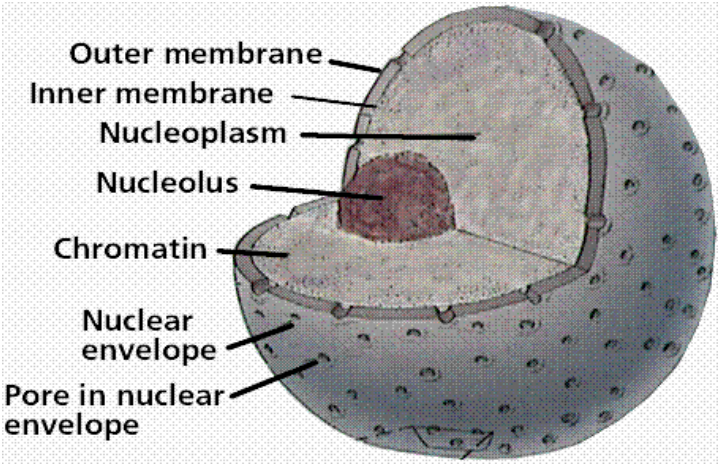
Endocytosis



Active process that requires energy

http://ccaoscience.wordpress.com/notes/transport-protein/

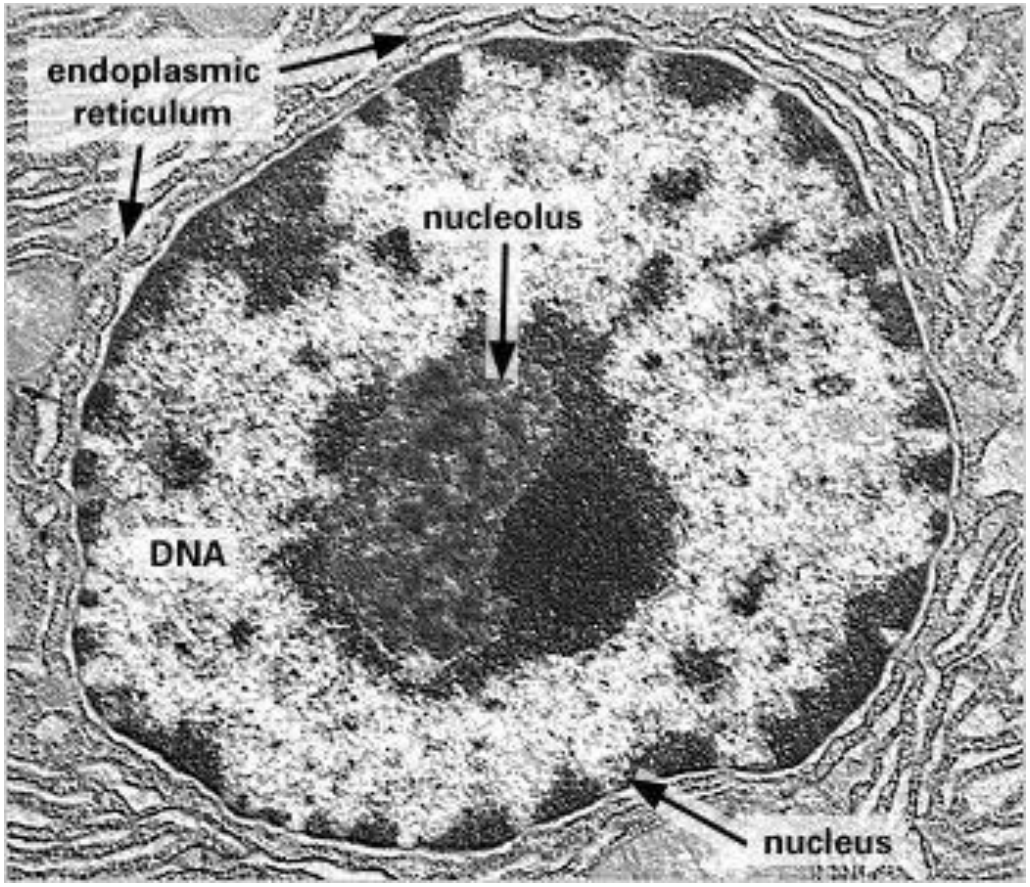
Nucleus



- double membrane (nuclear envelope)
- nuclear pores
  - for transport of protein and RNA
- nucleoplasm (nuclear lamina)
  - A network of fine filament that provides support to the nucleus
- nucleolus
  - ribosomal RNA synthesis

DNA in nucleus

1. Chromatin
   a. euchromatin
      - stained lightly in EM
      - contains active genes
   b. heterochromatin
      - stained darkly in EM
      - contains inactive genes
2. Chromosome
   - condensed chromatin during mitosis

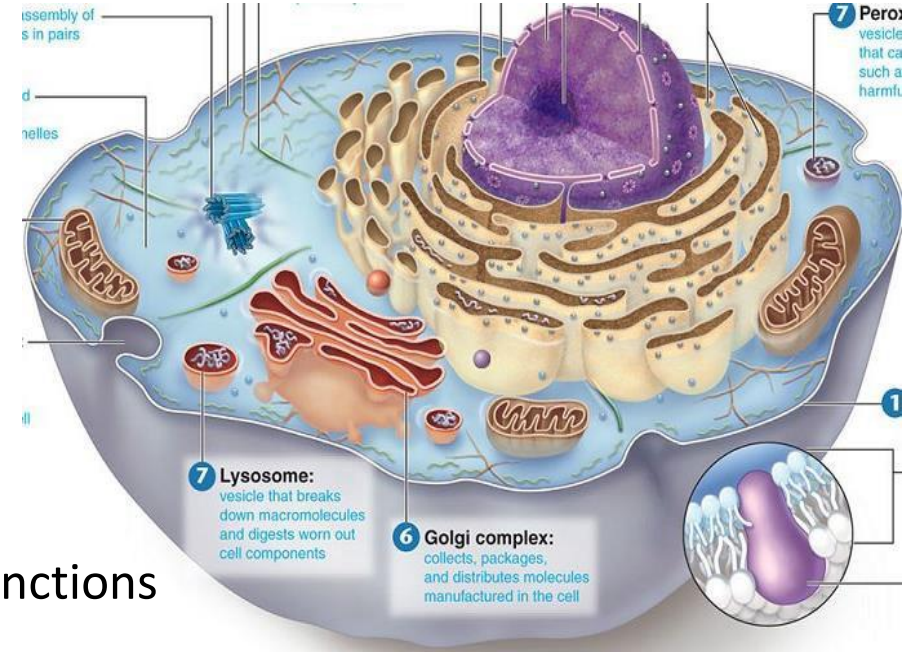


http://carolguze.com/text/442-1-humangenome.shtml
http://www.frontiers-in-genetics.org/page.php?id=protein-synthesis_en

Cytoplasm

1. Cytosol

- fluid that is contained within the plasma membrane
- contains various soluble substances
  - proteins
  - ions (intracellular [K^+] is higher)
  - nutrients
  - wastes



2. Organelles

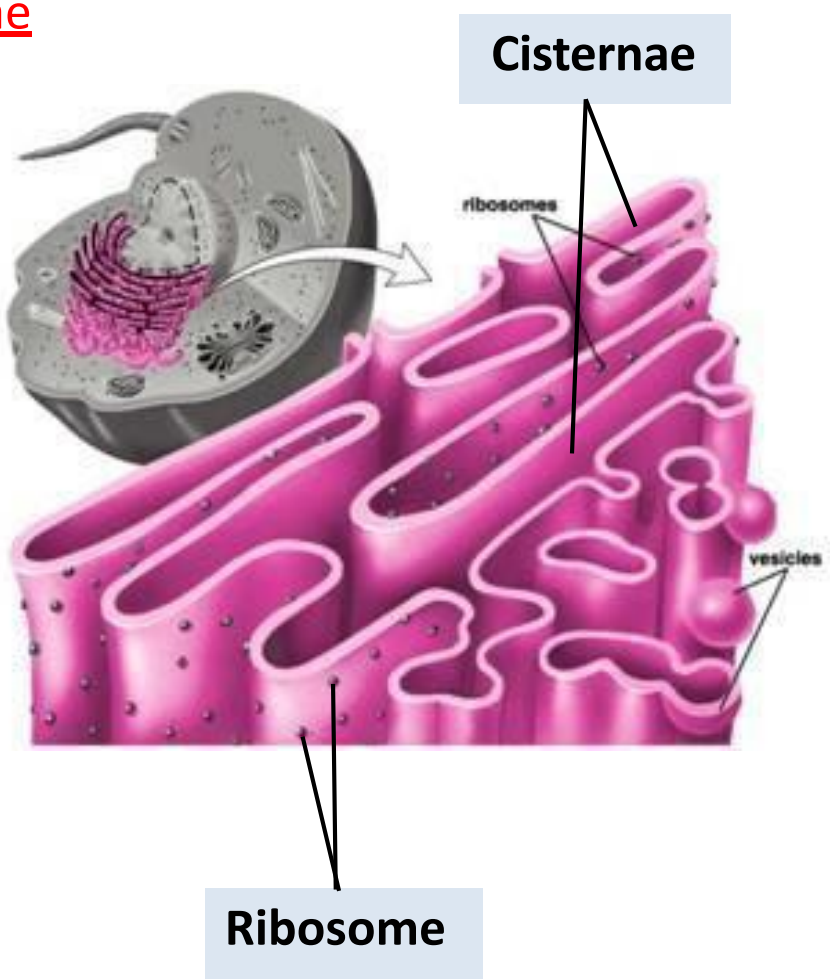
- suspended in the cytoplasm
- different organelles have different functions

3. Cytoskeleton

- structural support, movement, intracellular transport

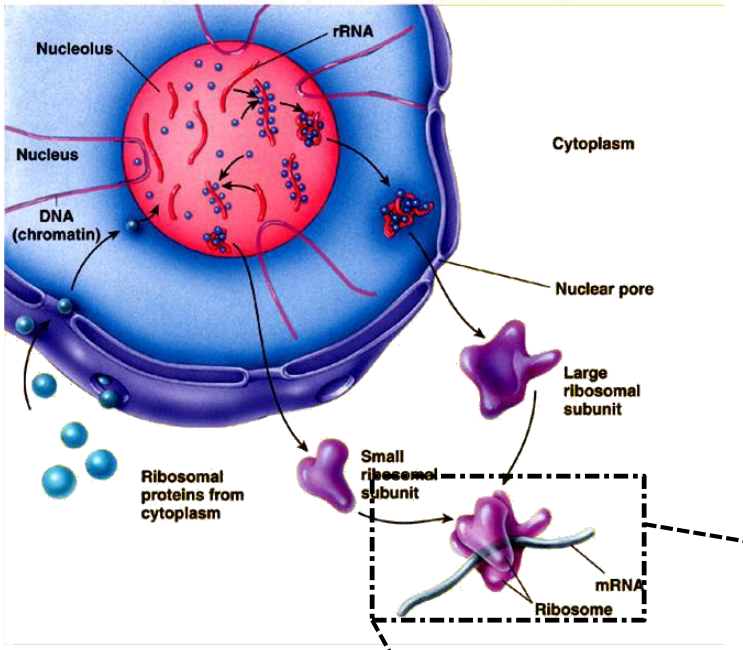
Endoplasmic reticulum (ER)

- A network of membranes that form hollow tubes, flattened sheets and chambers called cisternae
- Continuous with the outer membrane of the nucleus
- **Smooth ER (sER)**
  - no ribosome
  - site of carbohydrate and lipid synthesis (e.g. adipocytes)
  - site of detoxification (e.g. liver cells)
- **Rough RE (rER)**
  - ribosome attached for synthesis of protein (e.g. hormones, enzymes)
  - form vesicles to transport proteins to Golgi apparatus

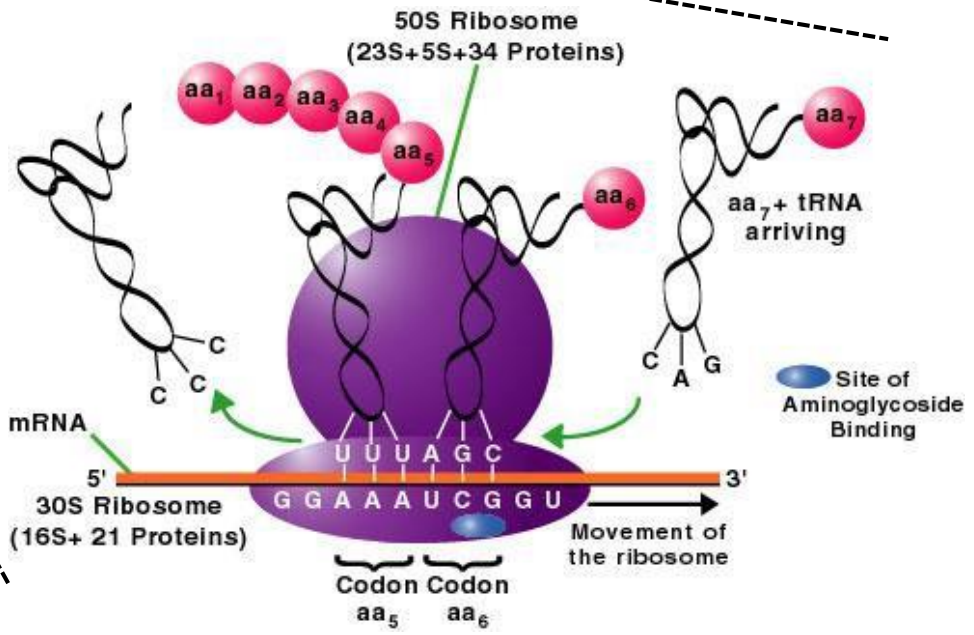


http://kconline.kaskaskia.edu/bcambron/Biology%20117/Cells.htm

Ribosomes

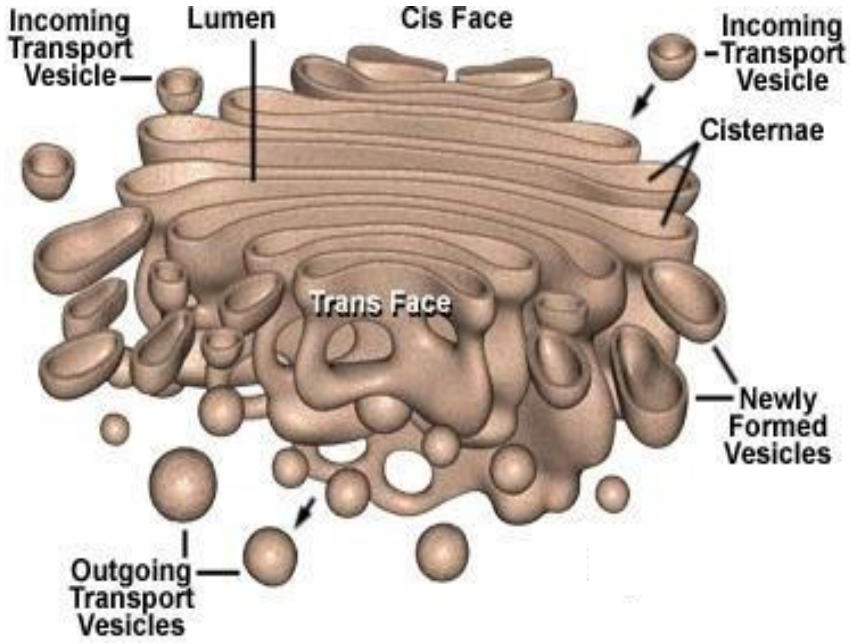


- sites of protein synthesis
- made of protein and ribosomal RNA (rRNA)
- composed of a large and a small subunit
- free in cytoplasm or attached to rER



Golgi apparatus

- Stack of flat membranous discs called cisternae
- **Cis face** receives and fuses with vesicles from rER
- Protein transported across the cisternae and packaged into vesicles for export or to form lysosomes at the **trans face**
- During transport, the proteins are modified (e.g. addition of carbohydrate or lipids)

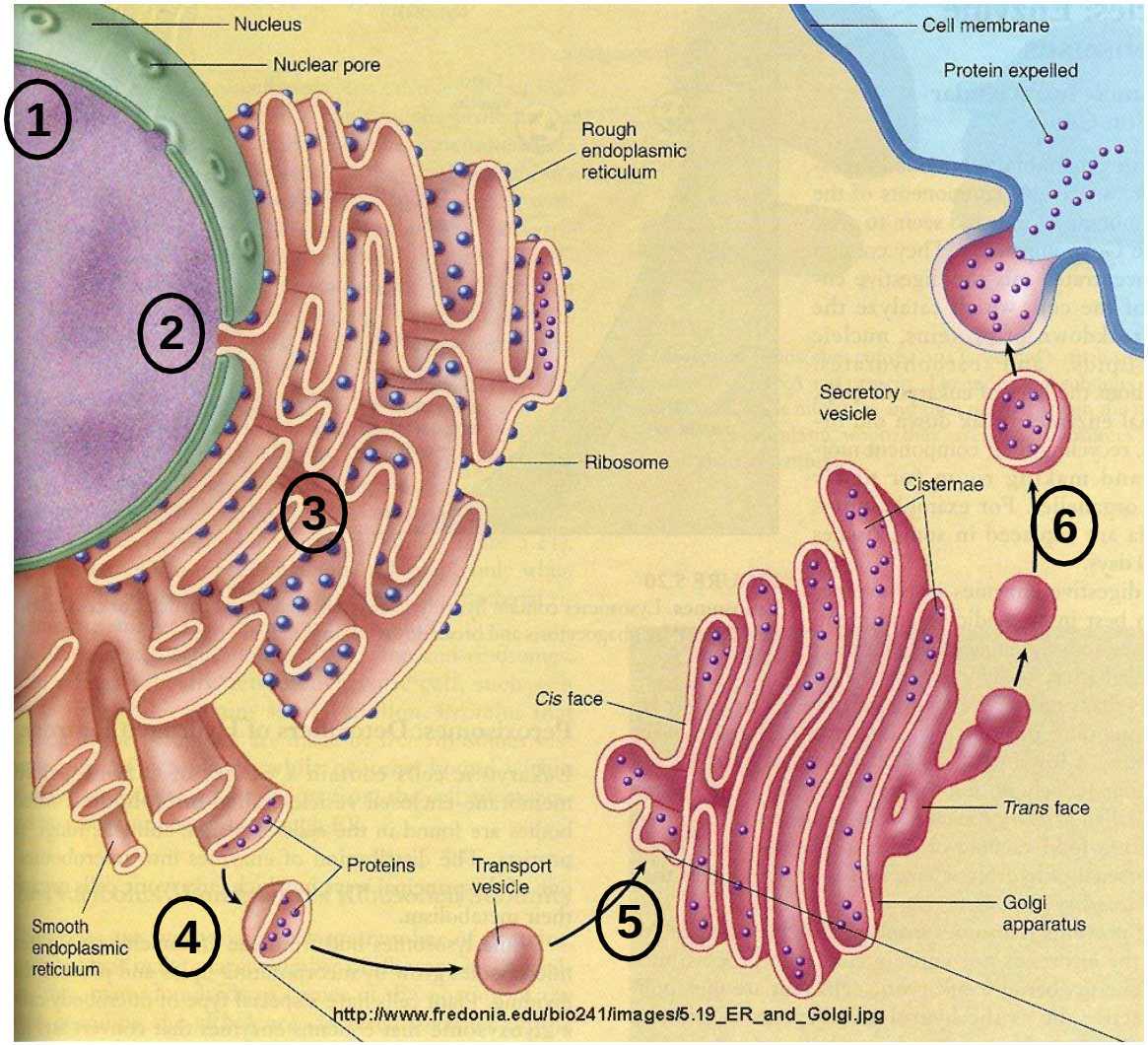


Functions of Golgi apparatus

1. Modify and packaging of protein for export
2. Renew and modify the plasma membrane
3. Formation of lysosomes

http://micro.magnet.fsu.edu/cells/golgi/golgiapparatus.html

Protein synthesis

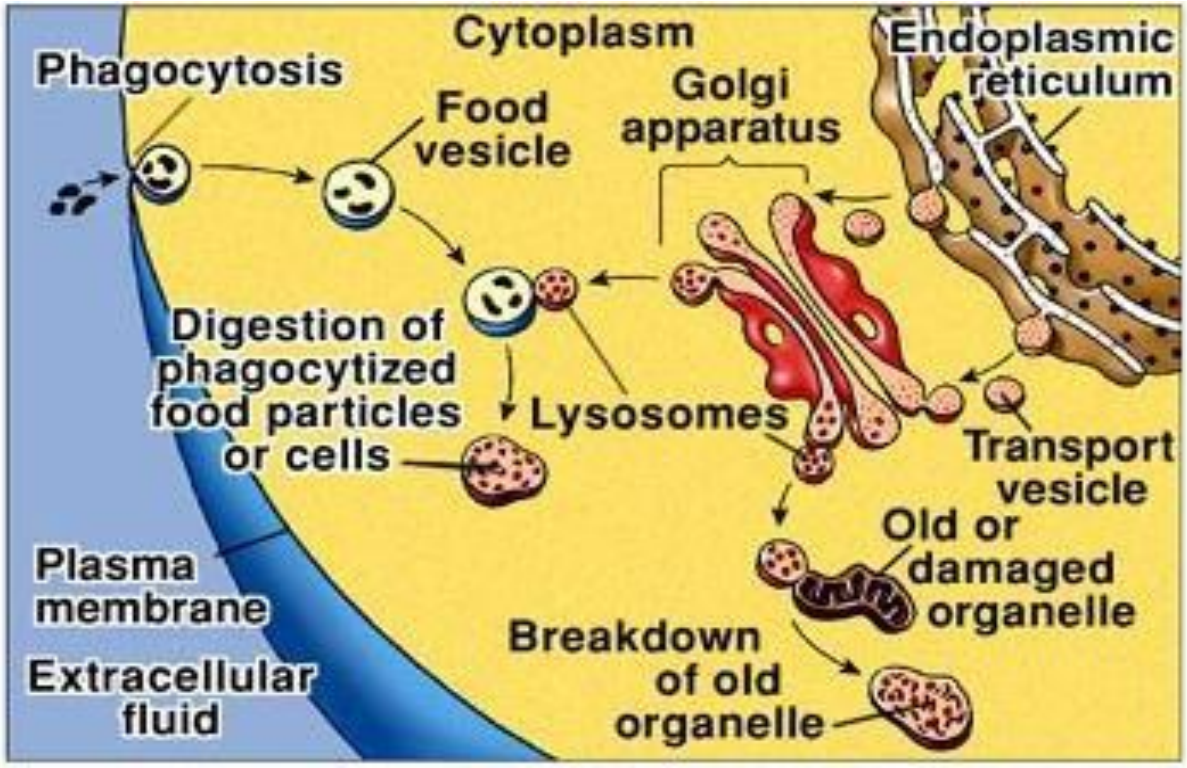


1. Transcription occurs in nucleus to synthesize mRNA
2. mRNA pass through nuclear pore and gets into the cytoplasm
3. mRNA binds to ribosomes on the rER and translation begins
4. The polypeptide produced is packaged into transport vesicle
5. The transport vesicle fuses with Golgi apparatus where protein is modified
6. The modified protein is then packaged into secretory vesicles for secretion

http://creationrevolution.com/2010/11/golgi-apparatus-steel-industry-of-the-simple-cell-%E2%80%93-part-6/

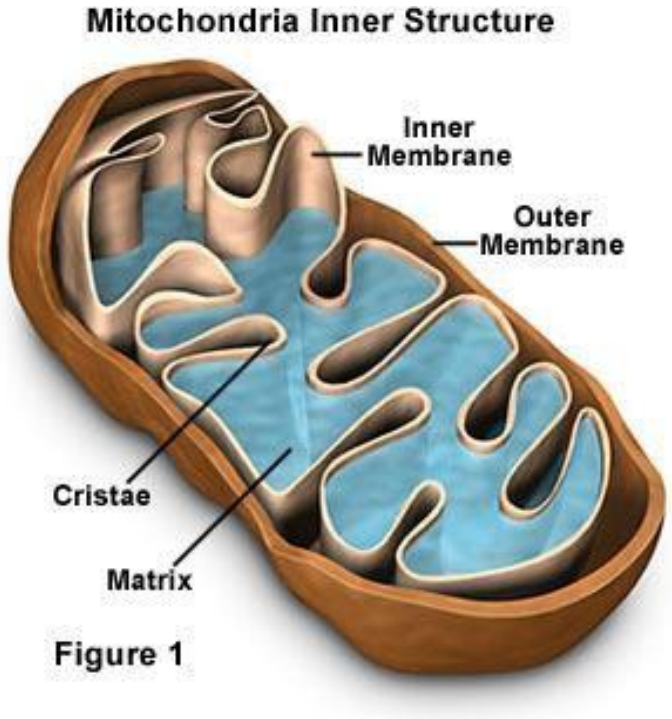
Lysosome

- from Golgi apparatus
- contains digestive enzymes in acidic environment
- fuses with endocytosed/phagocytosed material for degradation
- fuses with old damaged organelles for destruction
- provides an isolated environment for destruction of unwanted materials



Mitochondrion

- oblong shaped organelle
- **double membrane**
  - outer membrane surrounds the organelle
  - inner membrane folds into structures called **cristae** to increase surface area
- matrix contains enzymes of the TCA cycle to breakdown sugars to **produce energy** (ATP)
- inner membrane contains protein complexes of the electron transport chain for generation of energy (ATP)
- **mitochondrial DNA**
  - from mother



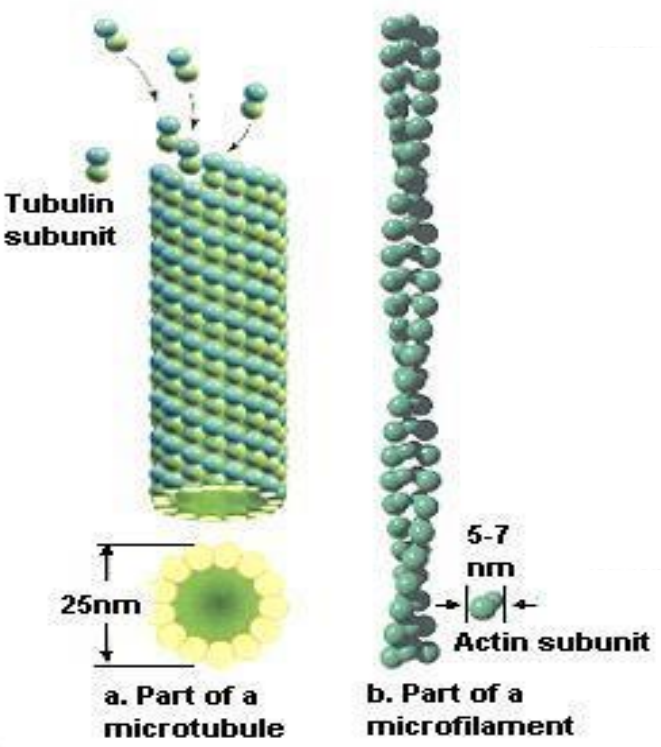
Function of mitochondrion

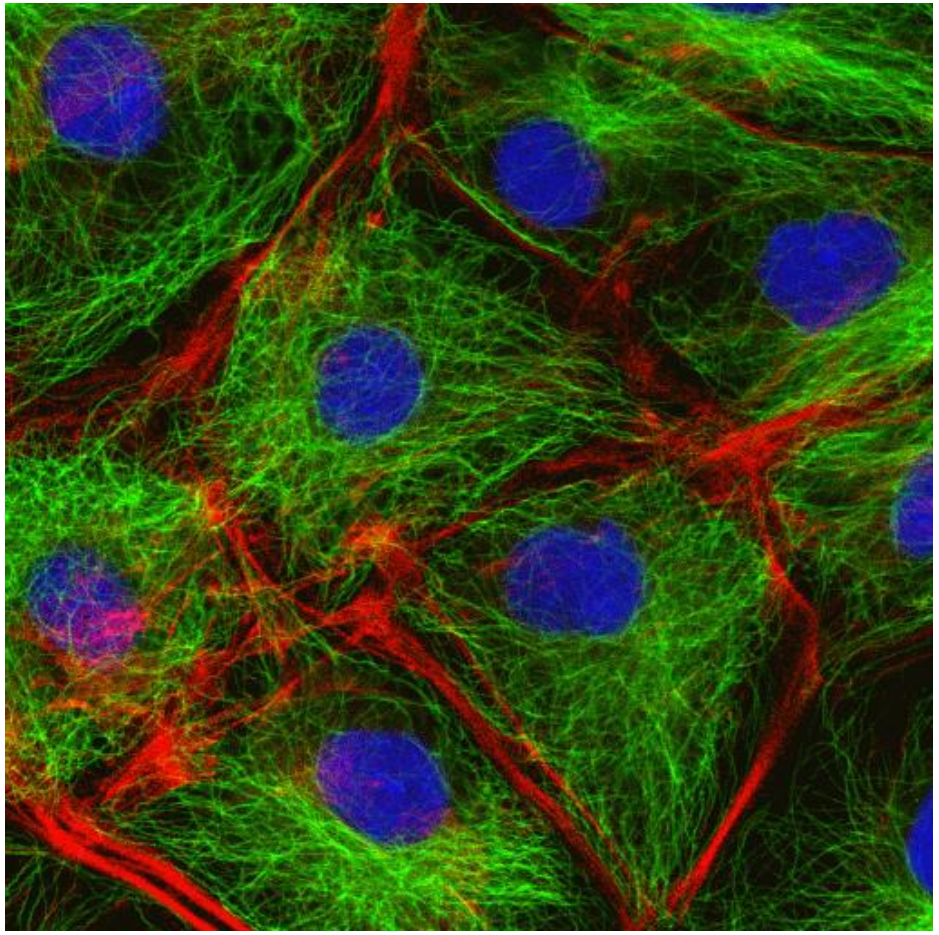
- produce energy through aerobic respiration

http://www.cartage.org.lb/en/themes/sciences/zoology/animalphysiology/anatomy/animalcellstructure/Mitochondria/Mitochondria.htm

Cytoskeleton

- microfilaments
- intermediate filaments
- microtubules

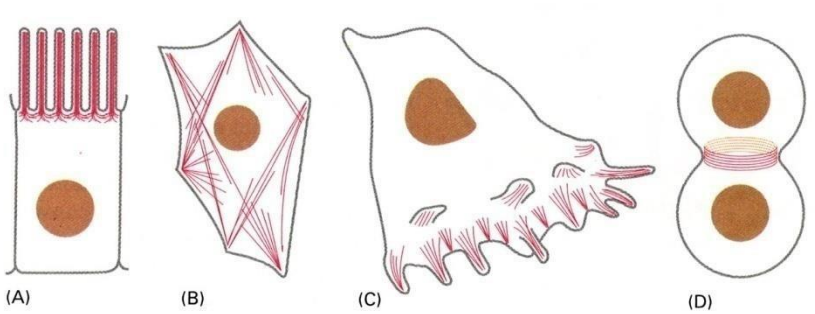




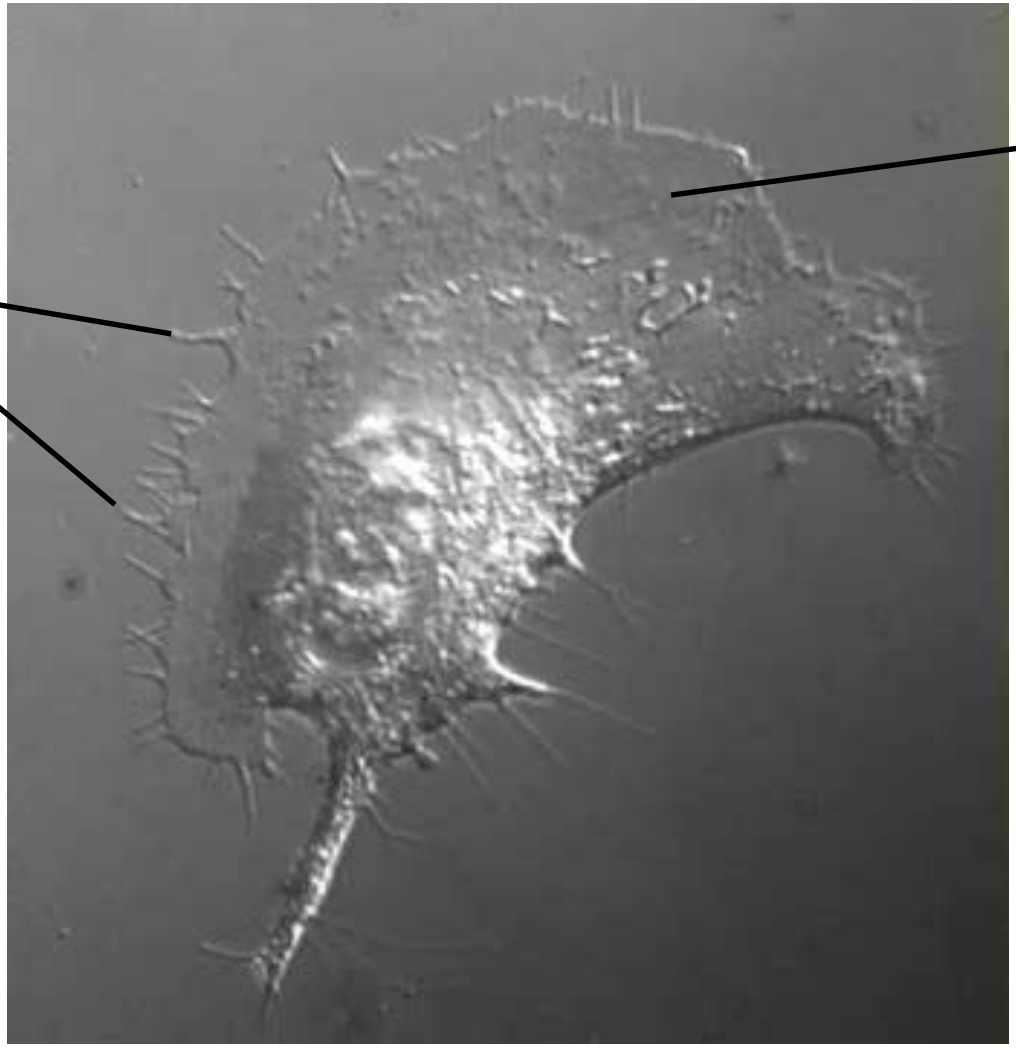
http://www.bscb.org/?url=softcell/cytoskeleton

Cytoskeleton (skeleton of the cells)

- **Microfilament** (e.g. actin)
  - thinnest
  - mostly found in the periphery
  - roles
    - **Microvilli**
    - Stress fibers for **cell attachment**
    - Filipodia and lamellidopodia for **cell movement**
    - Cleavage of a dividing cell into daughter cells (**cytokinesis**)
    - Interact with myosin for **contraction** (e.g. muscle cells)



The following movie shows a moving cells with Lamellipodia and filopodia



http://www.youtube.com/watch?v=Q4MyWPKQsfQ

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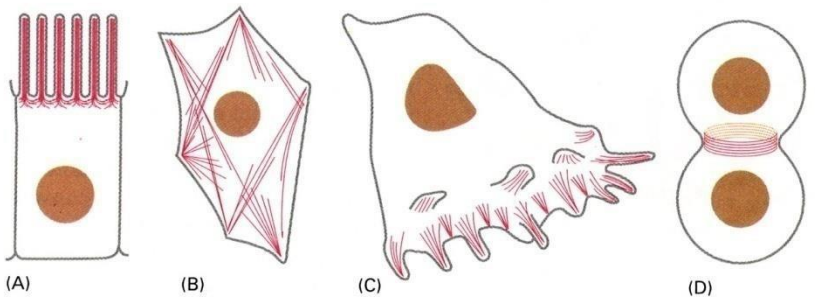
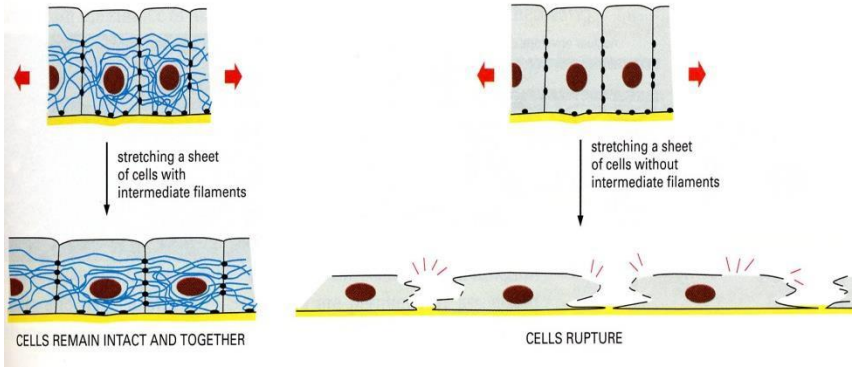


- **Intermediate filament** (e.g. keratin)
  - provide structural support for cells to **withstand mechanical stress**



- **Microtubule**
  - hollow tubes built from tubulin
  - roles
    - **Cilia**
    - **Centrioles**
    - **Spindle fibers in mitosis**
    - **Transport of organelles and vesicles**

Prokaryotes and Eukaryotes

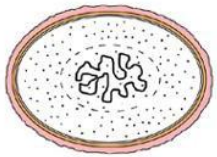
There are 2 types of cells

1. Prokaryotic cell

   : small and simple
   : e.g. bacteria

2. Eukaryotic cell

   : much larger and more complex
   : e.g. yeast, plant cell, animal cell



Prokaryotic Cell

Animal (Eukaryotic) Cell

Comparisons of the 2 types of cells

	Prokaryotes	Eukaryotes
Cell size	Smaller (0.5 – 2 μm)	Larger (2 – 100 μm)
Structural complexity	Simpler	More complex
Presence of cell wall?	Yes	Not in animal cell
Presence of cell membrane?	Yes	Yes
Presence of membrane - bounded organelles?	No	Yes
Presence of nucleus	No	Yes
DNA - number - shape - location	one circular cytoplasm	> one (46 in a human cell) linear nucleus

Suggested reading

Martini, F. H., Nath, J. L., & Bartholomew, E.F. (2012). *Fundamentals of anatomy and physiology.* (9th Ed.). San Francisco : Pearson/Benjamin Cummings (Chapter 3, p63-80 & p85-96)

Fox, S. I. (2011). *Human Physiology.* (12th Ed.) New York : McGraw-Hill (Chapter 3.1 - 3.2, Chapter 6.1 to 6.3)

Silverthron, D. U. (2013). *Human Physiology: an integrated approach.* (6th Ed.). Upper Saddle River, N.J. ; Harlow : Pearson Education. (Chapter 3, p65-76 & Chapter 5, p129-160)

You can also use any physiology textbook that you can find the Medical library. Look for the chapter dedicated for cellular structure and function.