Introduction to Cell Biology

Cell Structure & Function

Learning Objectives:

- Define the term “cell”.
- Describe cell theory.
- Explain the relation of cell size to the diffusion of substances into and out of cells.
- List the factors affecting rate of diffusion.
- Describe Prokaryotic and Eukaryotic cells.
- Enumerate cell organelles and describe their functions.
- Describe the function of cells in general.

Introduction:

- All organisms are composed of cells; the gossamer wing of a butterfly is a thin sheet of cells and so is the glistening outer layer of your eyes.
- The meat or cucumber you eat is composed of cells, and its contents soon become part of your own cells.
- Some organisms are made of a single cell too small to see with your naked eyes.
- Others, like human and animals are composed of millions of specialized cells.
- Cells are so much a part of life that we cannot imagine an organism that is not cellular in nature.

WHAT IS A CELL?

The cell is the smallest unit capable of carrying out the processes associated with life.

Classical Properties of Living Organisms:

Reproduction
Nutrition
Respiration
Excretion
Irritability/respond
Movement
Growth

How cells fulfill these criteria of Living Organisms:

Cell replication
Nutrition
Respiration
Excretion
Respond to environment
Movement within and externally
Grow in number and size

Historical Background:

❖ **Cytology** = *The study of cells.*

- Because the cells are so small (*microscopic in size*), they were not discovered until the invention of the microscope in the 17th century.
- Robert Hooke was the first to observe cells in 1665, naming the shapes he saw in cork *cellullae* (Latin, "small rooms").
- *Another early microscopist, Leeuwenhoek first observed living cells, which termed "animalcules", or little animals.*
- *After theses early efforts, a century and a half passed before biologist fully recognized the importance cells. Schleiden & Schwann saw cells in almost all living tissues they look at in 1839. Thus, the cell theory was born* ***"all living things are made of cells"***
- (50 yrs. later) Rudolf Virchow: "***all cells come from cells***"

Historical Background: "contd."

- **The cell theory includes the following three principles:**

  - ✓ *All organisms consist of one or more cells.*
  - ✓ *The cells are the smallest living things, the basic units of organization of all organisms.*
  - ✓ *All cells arise only from pre-existing cells by division.*

- In 1930 Electron microscope allowed the study of cell organelles in details. LM limit: 200nm (0.2 µm) " see mitochondria but not ribosomes", EM limit for biological sample is 0.5 nm.

❖ **Biochemistry:**

- *1820's : Wohler synthesized urea.*
- *1860's : Pasteur discovered enzymes in yeasts.*
- *1920's : First biochemical pathways elucidated. More are elucidated every year.*

❖ **Genetics:**

- *1860's : Mendel did the first breeding experiments with peas.*
- *1900's: Chromosomal theory of heredity.*
- *1953: Watson & Crick proposed the DNA double helix and deciphered the genetic code, laying foundation for modern genetic analysis and engineering.*

Sizes of Cells:

- Most cells are relatively small for ***reasons related to the diffusion of substances into and out of cells.***

- The rate of diffusion is affected by a number of variables:
  - ***Surface area available fro diffusion.***
  - ***Temperature.***
  - ***Concentration gradient of diffusion substance.***
  - ***Distance over which diffusion must occur .***

- As the cell size increases, the length of time of diffusion from outside to inside the cell increases as well.

- Larger cells need more energy and produce a greater quantity of waste.

Sizes of Cells: "contd."

- The advantage of small cell size is readily apparent in terms of ***the surface area-to-volume ratio:***

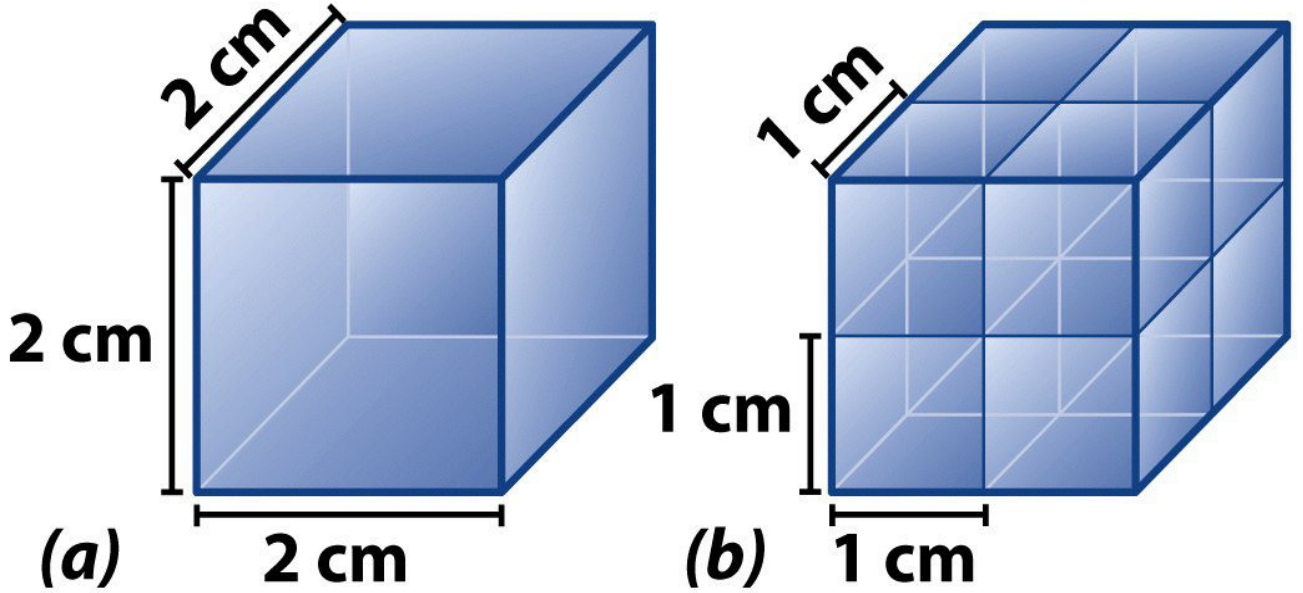
Linear Dimension	Surface Area	Volume	Surface Area to Volume Ration
2μ	24μm^2	8 μm^3	3
4μ	96μm^2	64 μm^3	1.5

From the above table , you can see that for a mere doubling of linear dimensions, the surface area is increased four-fold, but the volume is increased eight -fold, resulting in a halving of the surface area:volume ratio

Surface area of a cube: $6S^2$
Volume of a cube: S^3
S=Side length

1 m= 1000 mm, 1 mm= 1000 μm, 1 μm= 1000 nm
1 nm= 10 Ångstrom units (Å)

Sizes of Cells: "contd."



Number of cells	1	8
Total surface area	24 cm^2	48 cm^2
Total volume	8 cm^3	8 cm^3
Surface area/volume	24/8 = 3:1	48/8 = 6:1

Surface area of a cube: $6S^2$
Volume of a cube: S^3
S=Side length

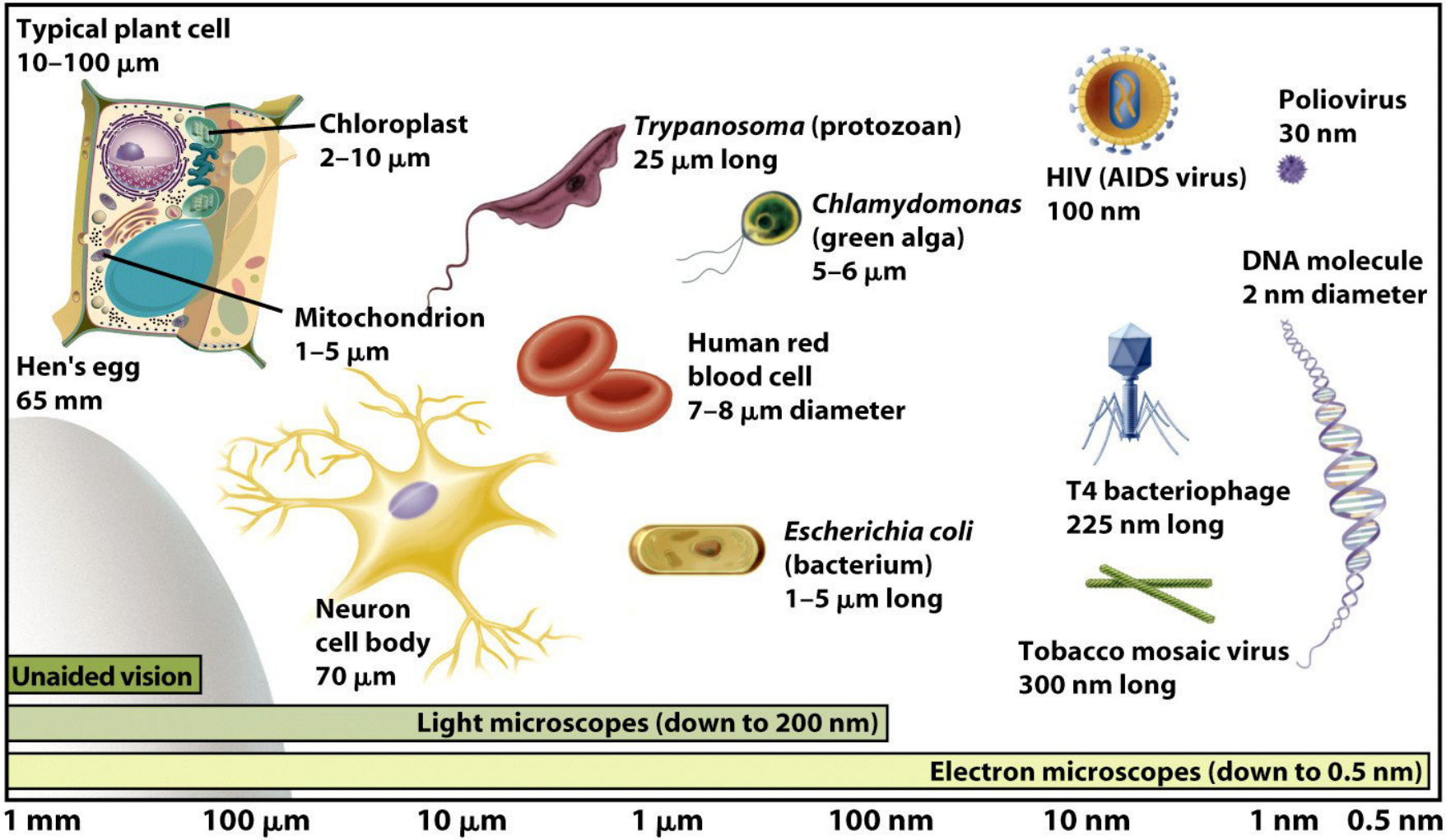
Sizes of Cells: "contd."

WHY DOES THIS MATTER

Sizes of Cells: "contd."

- For the cell to function, ***biochemical reactants must meet often enough to interreact.***
- ***The smaller the cell, the more likely it is that a certain number of molecules can meet.***
- As the cell becomes larger, the number of molecules inside it must increase 8-fold to fill the volume and allow the same biochemical reactions to occur.
- But as the cell becomes larger, the smaller surface area allows fewer molecules to be transported in across the cell membrane for nutrition.
- So the cell stops functioning efficiently .

Sizes of Cells: "contd."



Types of Cells:

- All cells have a cell membrane, a phospholipid bilayer with protein embedded in it, and they are made up of cytoplasm, or cytosol, inside the membrane.

- **Two Types of Cells:**
  - **Prokaryotic**
  - **Eukaryotic**

Types of Cells – Prokaryotic Cells:

- **The simplest, most primitive cell (Greek, pro= before; karyon= nucleus).**

- **Do not have structures (organelles) surrounded by membranes in the cytoplasm (Few internal structures). 0.3-5μ in linear dimensions.**

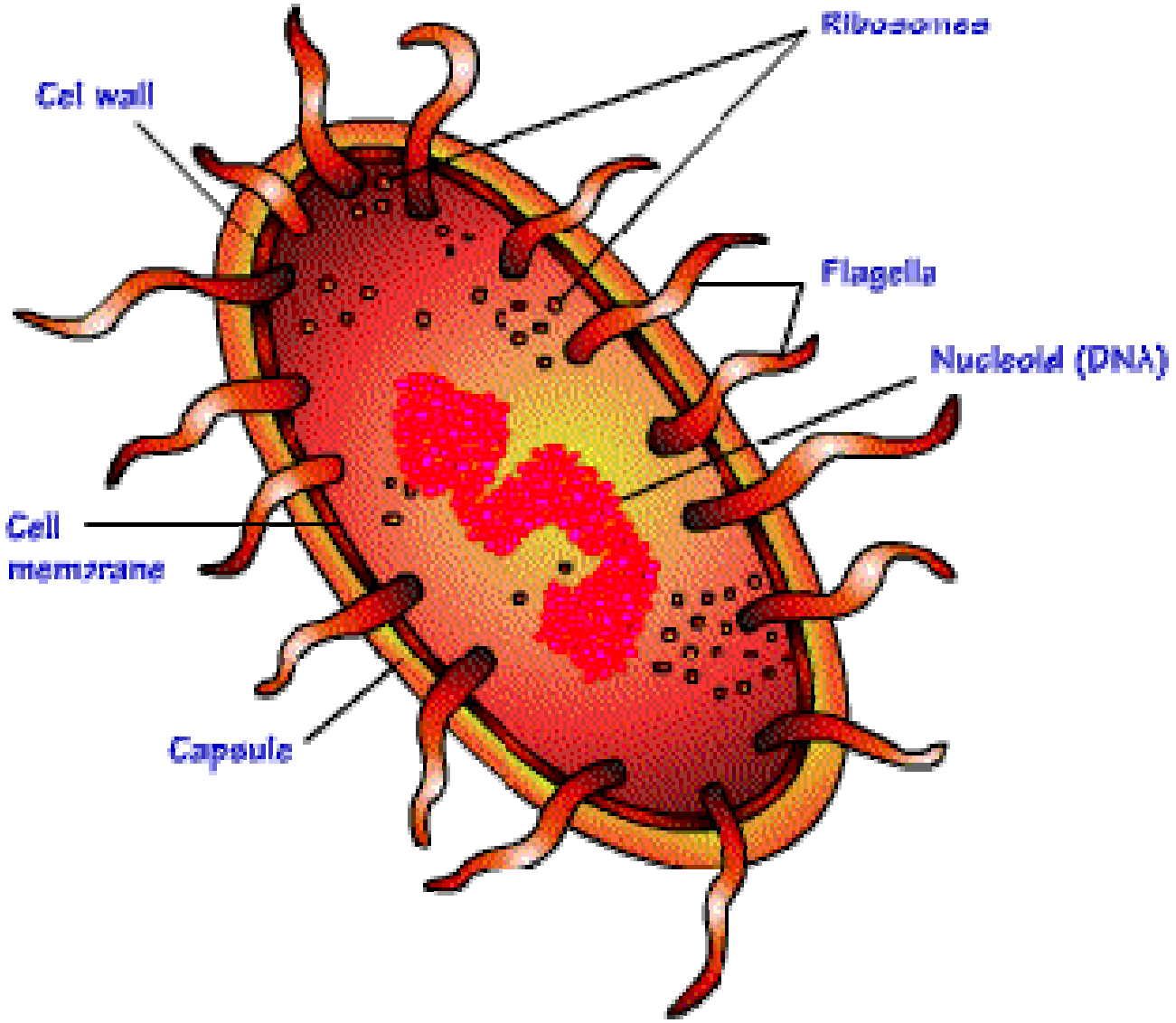
- **They do all carry *DNA, RNA* and *ribosomes.***

  - ***Nucleoid = region of DNA concentration***
  - ***The DNA carries their blue-print***
  - ***The RNA forms copies of parts of the blue print.***
  - ***RNA is used to direct protein synthesis which occurs on the ribosomes.***

- **Prokaryotes cannot grow beyond a few μm. This is called:**
  THE PROBLEM OF CONCENTRATION. (no small organelles)

- **Examples: Bacteria and blue green algae.**

Types of Cells – Prokaryotic Cells:



http://library.thinkquest.org/C004535/prokaryotic_cells.html

Types of Cells – Eukaryotic Cells:

- Contain ***organelles surrounded by membranes***.

- ***Compartmentalization*** of the cell into organelles overcomes the problem of concentration to some extent, allowing plant and animal cells to grow to 10- 40 µm.

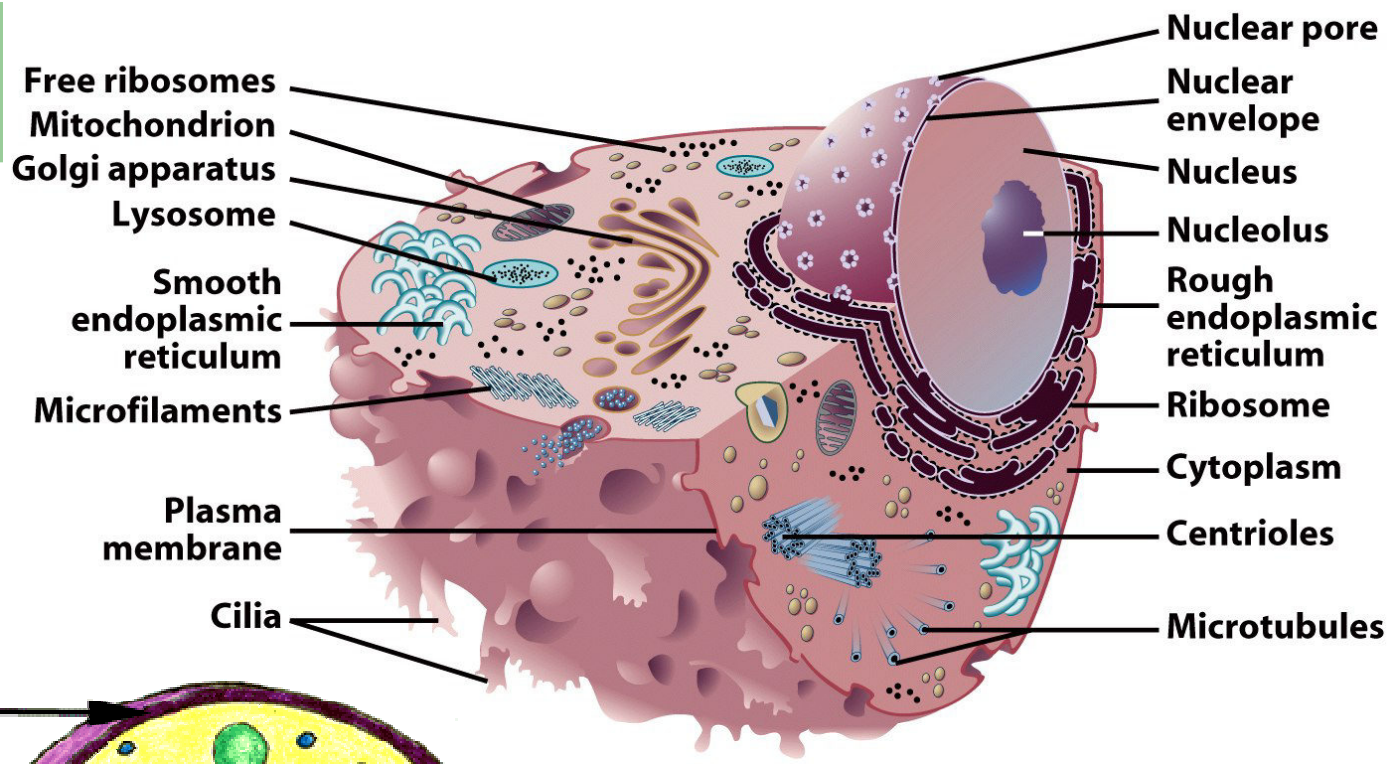
- Organelles have smaller volumes, to maintain necessary molecular concentrations; e.g. mitochondria are 1µm wide by 7µm long, lysosomes are 0.5µm diameter.

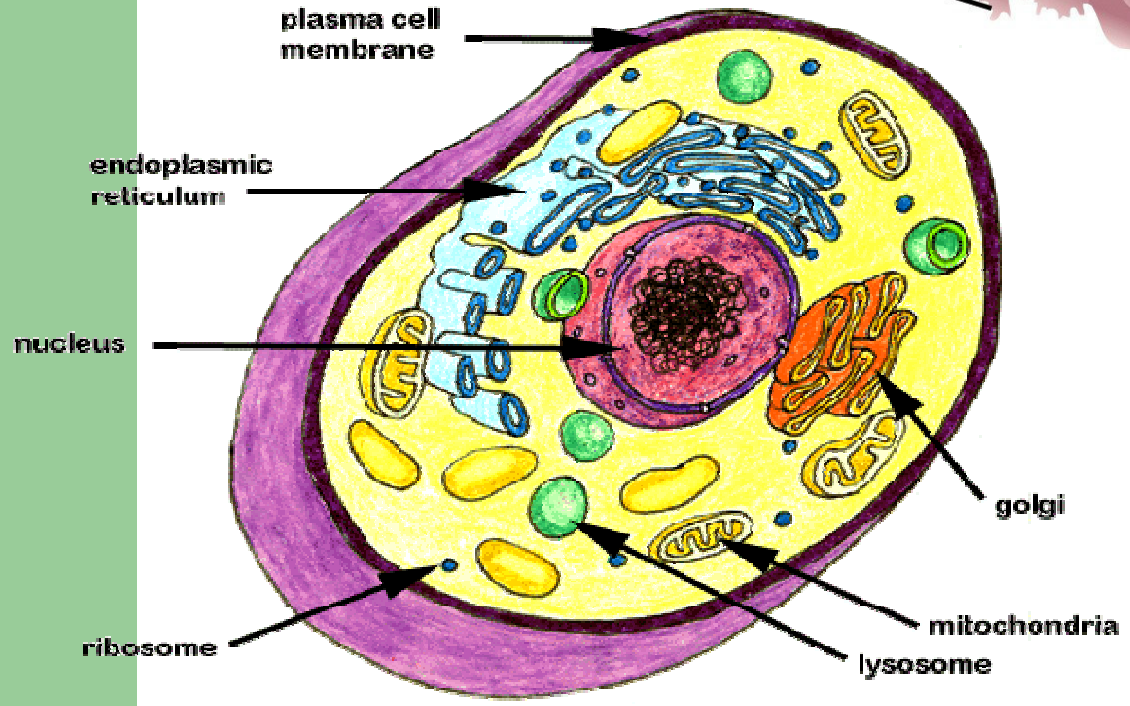
- Cells with internal compartmentalization are called eukaryotic (Gk. Eu= good or true). Found in most living organisms: fungi, protists, plant, and animal cells.

Types of Cells – Eukaryotic Cells: "contd."

- Surrounding the cell is the cell membrane; ***a double layer outer membrane*** of cell that controls movement in and out of the cell.

- Inside the cell are the **organelles:**
  - **Nucleus:** information storage, software library, was called the " ***brain of the cell***'
  - **Rough Endoplasmic Reticulum (RER):** membrane with ribosomes, protein/fat synthesis.
  - **Smooth Endoplasmic Reticulum (SER):** site for fat synthesis and other metabolic reactions.
  - **Golgi apparatus:** packaging station.
  - **Lysosomes:** bags of digestive enzymes, " suicide bag".
  - **Mitochondria:** Power house, work with oxygen, have their own DNA
  - **Peroxisomes**: (catabolism of long chain & branched FA, ***plasmalogin synthesis*** "a phospholipid critical for brain function. They have no DNA.
  - Structural organelles-made from microfilaments & microtubules:
    - ✓ **Cytoskeleton:** maintain complex shapes of cells
    - ✓ **Cell cortex:** form firm anchor underlying the cell membrane
    - ✓ **Cilia & flagella:** structures for locomotion, formed from microtubules.
    - ✓ **Muscle filaments:** actin & myosin, for contraction.
    - ✓ **Centrioles:** forms poles of mitotic spindle, made from microtubules.





"Typical" Animal Cell

Cells Function:

- Almost all cells perform the same functions as we see in the whole body:

  - **Respiration:** almost all cells oxidize glucose to obtain energy and make **ATP** ***(Adenosine-5'-triphosphate coenzyme: ATP transports chemical energy within cells for metabolism.***)

  - **Nutrition:** Phototrophs trap sun light to make nutrients, chemotrophs eat organisms. In our bodies, all cell can concentrate nutrients to higher levels than outside the cell.

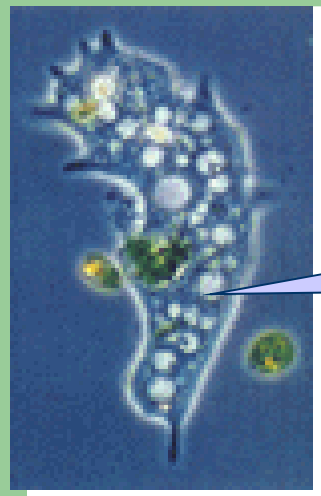
  - **Creating an intracellular environment**: all cells select certain ions and not others.

  - **Communication:** all cells have electrical properties, many cells fire action potentials. Many cells have receptors to pick up hormonal (or other types of) signals from outside.

  - **Locomotion:** cilia, flagella, muscle filaments

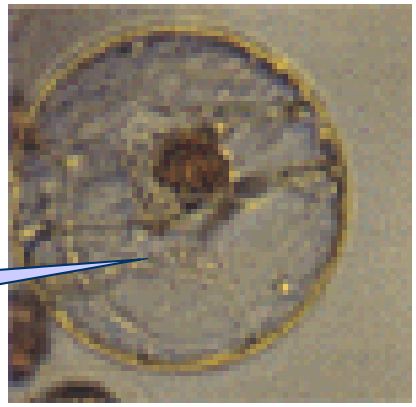
  - **Reproduction:** mitosis (cell replacement and tissue growth), meiosis (for gametes).

Examples of Cells:

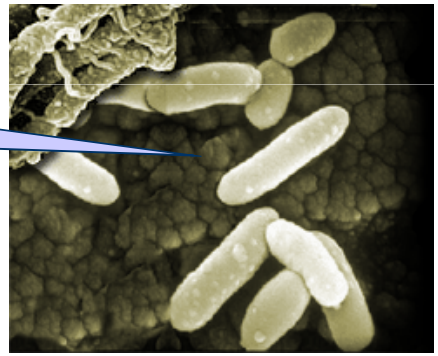


Amoeba Proteus

Plant Stem



Bacteria



Nerve Cell

Red Blood Cell