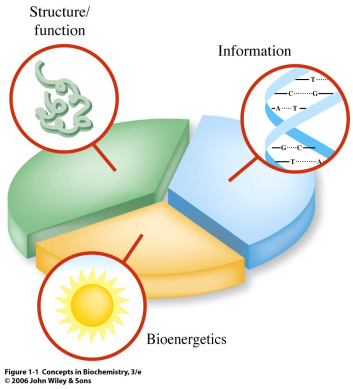
What is Biochemistry?

- Simplest definition: "Chemistry of the living cell"
- Uses basic laws of chemistry, biology and physics to explain processes of living cells
- GOAL: Describe life processes at the molecular level and answer the question:
- The study of life at the molecular level



Why study biochemistry?

- **Lead us to fundamental understanding of life**
- **Understand important issues in <u>medicine, health, and nutrition</u>**
  - Has led to greater molecular understanding of diseases such as diabetes, sickle cell anemia, and cystic fibrosis.
  - Next frontier: AIDS, cancer, Alzheimer's Disease
- **Advance biotechnology industries**
  - Biotechnology is the application of biological cells, cell components, and biological properties to technically and industrially useful operations

Three areas to study:

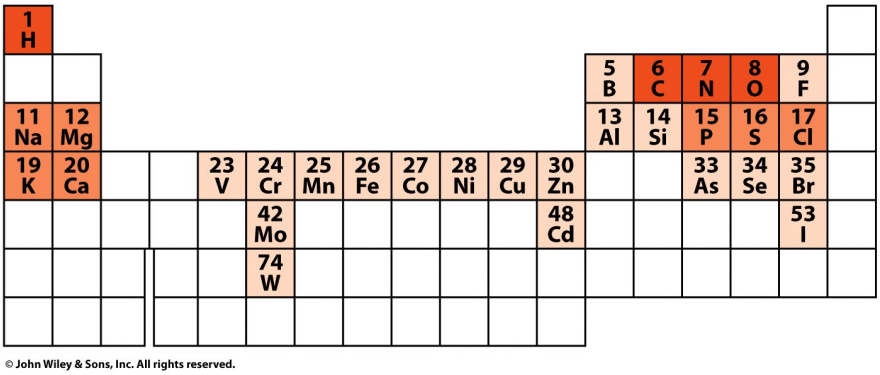
1. **Structural and Functional Biochemistry:** Chemical structures and 3D arrangements of molecules.
2. **Informational Biochemistry:** Language for storing biological data and for transmitting that data in cells and organisms.
3. **Bioenergetics:** The flow of energy in living organisms and how it is transferred from one process to another.

Tools to study biochemistry:

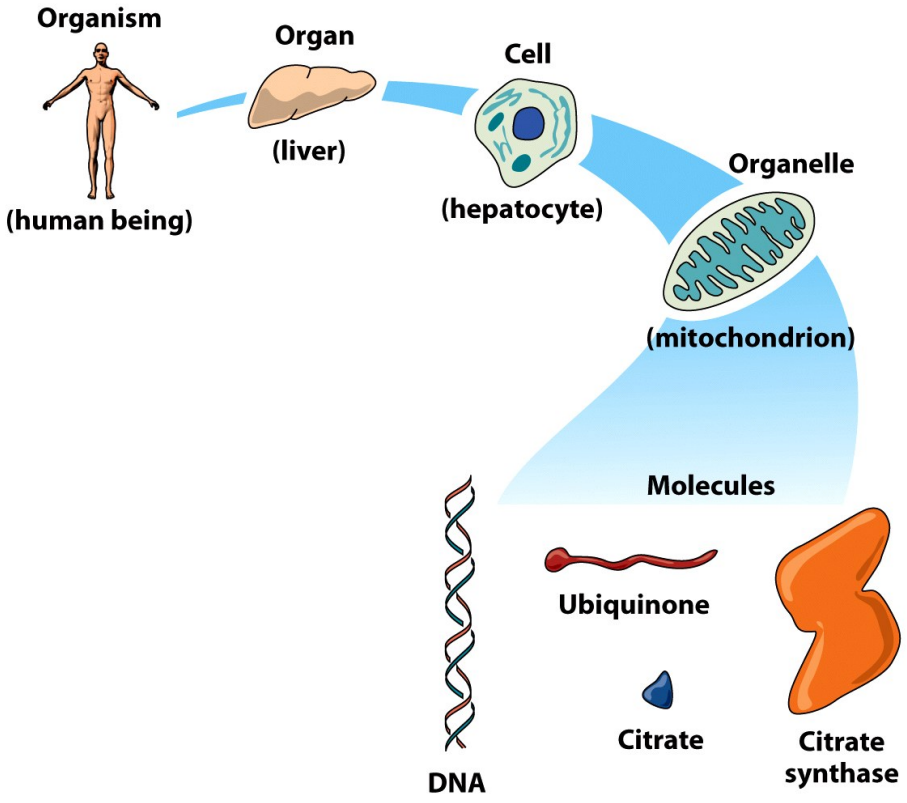
- Know chemical structures and reactivities of molecules that participate in cellular reactions
- Know biological function of cellular molecules
- Know how all of the pieces and different pathways fit together

*Use knowledge from <u>general chemistry, organic chemistry, and biology and apply it to biological systems. Concepts and mechanisms are the same.</u>

LIVING SYSTEMS APPEAR COMPLEX BUT THERE IS AN UNDERLYING SIMPLICITY AND ELEGANCE:



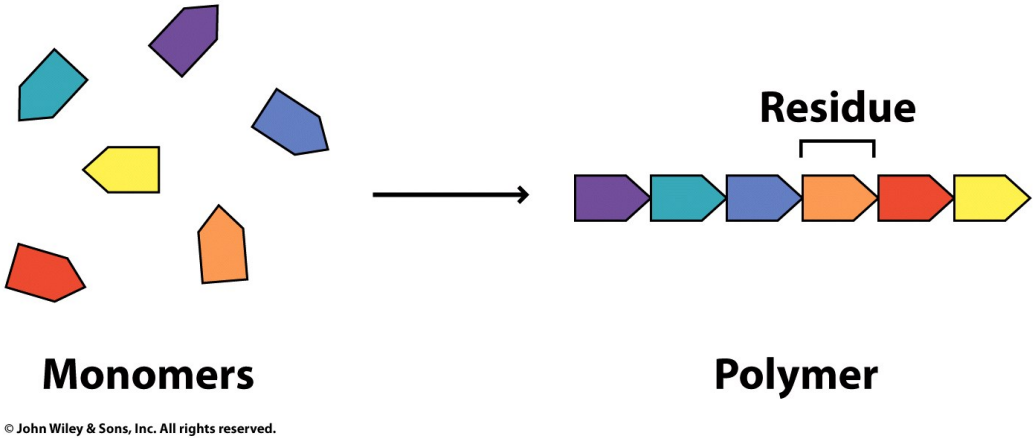
- Most biological compounds are made of only **SIX** elements: C, H, O, N, P, S
- Only 31 chemical elements occur naturally in plants and animals
- All organisms have similar biochemical pathways.
- All organisms use the same genetic code.
- Limited number of molecular building blocks make up larger macromolecules



4 MAJOR CLASSES OF BIOMOLECULES SERVE AS BUILDING BLOCKS FOR LARGER MACROMOLECULES:

1. **Carbohydrates**: e.g. glucose, fructose, sucrose
   - mainly used as sources of cellular energy
2. **Lipids:** commonly known as fats
   - organic compounds that are not very water soluble
   - used as sources of cellular energy
   - components of cell membranes
3. **Amino Acids:**
   - 20 natural amino acids in total
   - Used as building blocks for proteins
4. **Nucleotides:**
   - 5 in total
   - Used as building blocks for DNA and RNA precursors
5. **OTHER:**
   - **Vitamins:** organic compounds necessary for proper growth and development
   - **Heme:** Organometallic compound containing iron; important for transporting oxygen in your blood stream.

Building blocks are used to create **macromolecules**: **polymer of several, hundreds, to sometimes millions of building blocks**



Examples:

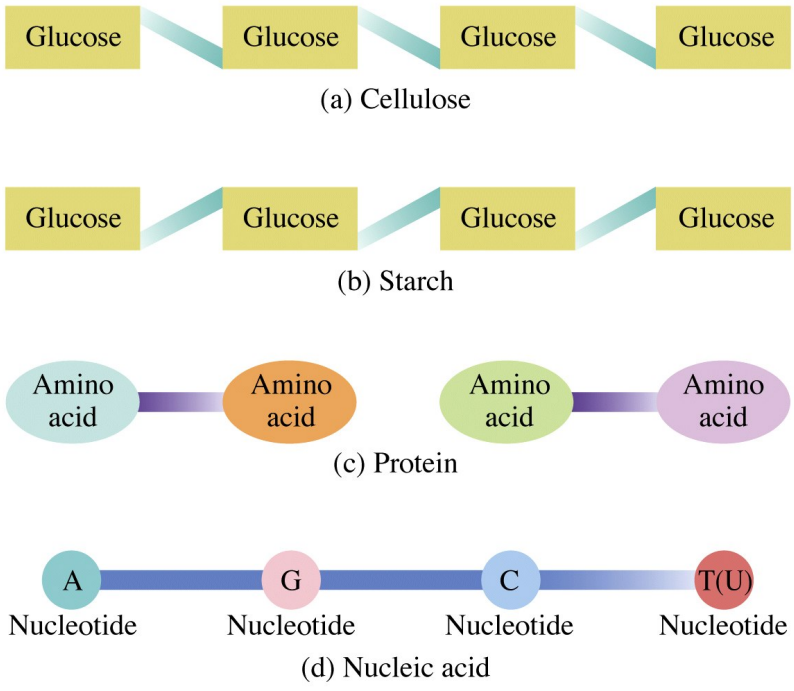


Figure 1-6 Concepts in Biochemistry, 3/e
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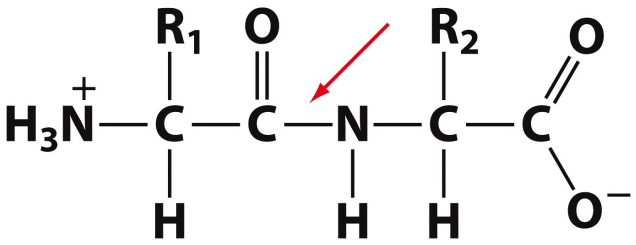
- **Starch and Cellulose:** polymers of glucose molecules that differ only by how the glucose monomers are linked.
- **Proteins/polypeptides:** amino acid monomers linked together
- **DNA:deoxyribonucleic acid**
  - Heteropolymer of monomeric nucleotides
  - Storage of genetic information
- **RNA: ribonucleic acid**
  - Heteropolymer of monomeric nucleotides
  - Involved in the TRANSFER of the genetic information encoded by DNA

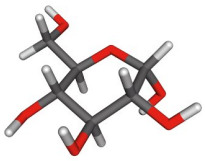
Biomacromolecules:

- self-assemble into **cellular structures** and **complexes**.
- recognize and interact with one another in specific ways to perform essential cellular functions (e.g. membranes are complexes of lipids and proteins)
- Interactions are weak and reversible
- Molecules have **three dimensions and shapes**! Much of biochemistry relies on this fact.

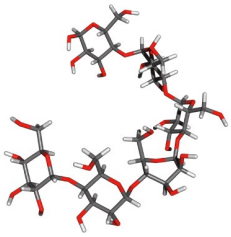
Dipeptide



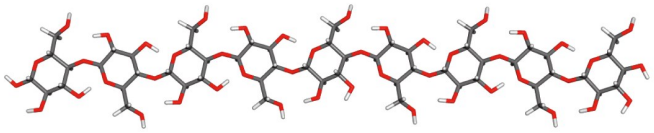
Glucose



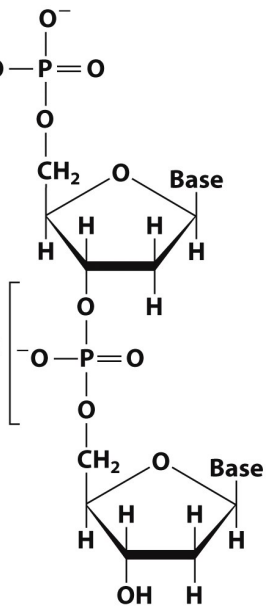
Starch



Cellulose



Phosphodiester bond



Dinucleotide

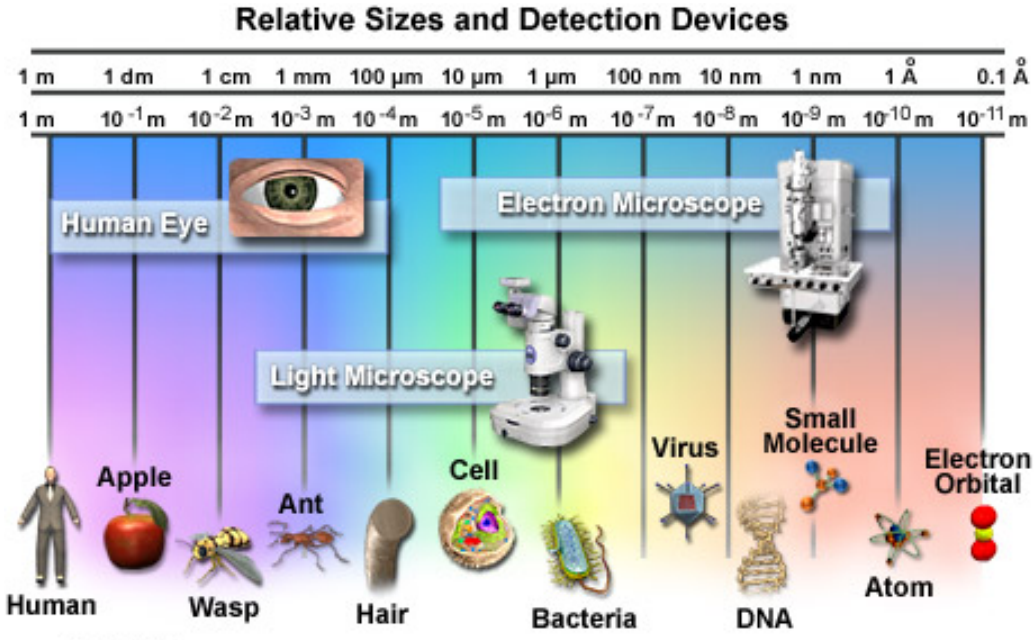


Figure 1

ORGANISMS:

2 basic classes of organisms

-Prokaryotes (e.g. *E.coli*)
-Eukaryotes

We will focus on eukaryotic cells and the biochemistry that occurs in these cells.

Similar processes occur in ALL cells, including prokaryotes. In fact, much of the biochemistry that we understand was first uncovered in prokaryotic systems.

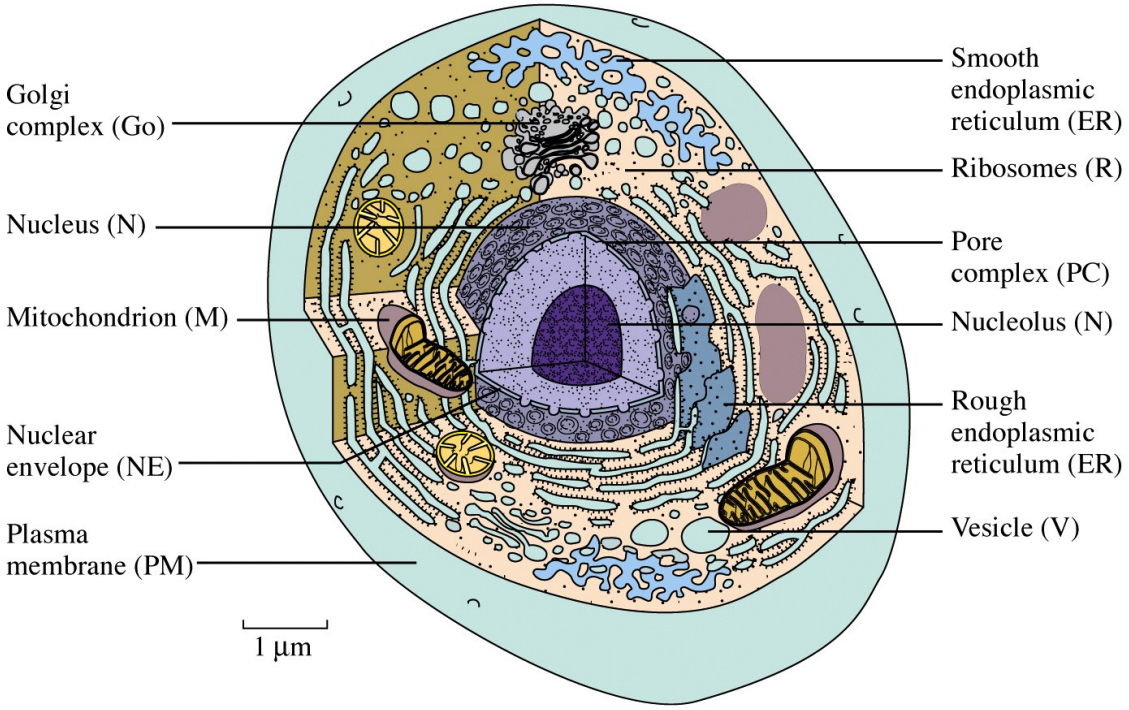


Figure 1-11a part 1 Concepts in Biochemistry, 3/e

EUKARYOTES: *Typical Eukaryotic Cell – Animal*

a. Class includes plants, animals, fungi, protozoans, yeasts and some algaes.
b. Large cells (10-100 µm in diameter). 10X bigger than prokaryotes.
c. Surrounded by a membrane called **plasma membrane**
    i. Composed of lipids and proteins
    ii. Serves as chemical barrier to the outside environment

d. Contain INTERNAL **membranes** and **compartments**. (Unique feature)
    i. Compartments = organelles
    ii. Organelles contain organized complexes of macromolecules that perform a certain biological function.
    iii. Most enzymes are compartmentalized
    iv. Compartmentalization results in **separation of biological function**!!

    We'll see a lot of this phenomenon throughout the course.

e. No cell wall in animal cells.
f. Plants, fungi, algae generally have a cell wall.

EUKARYOTIC CELL PARTS:

TABLE 5.2 EUKARYOTIC CELL STRUCTURES AND THEIR FUNCTIONS

Structure	Description	Function
Structural Elements		
Cell wall	Outer layer of cellulose or chitin; or absent	Protection; support
Cytoskeleton	Network of protein filaments	Structural support; cell movement
Flagella and cilia	Cellular extensions with 9 + 2 arrangement of pairs of microtubules	Motility or moving fluids over surfaces
Plasma Membrane and Endomembrane System		
Plasma membrane	Lipid bilayer in which proteins are embedded	Regulates what passes into and out of cell; cell-to-cell recognition
Endoplasmic reticulum	Network of internal membranes	Forms compartments and vesicles; participates in protein and lipid synthesis
Nucleus	Structure (usually spherical) surrounded by double membrane that contains chromosomes	Control center of cell; directs protein synthesis and cell reproduction
Golgi complex	Stacks of flattened vesicles	Packages proteins for export from the cell; forms secretory vesicles
Lysosomes	Vesicles derived from Golgi complex that contain hydrolytic digestive enzymes	Digest worn-out organelles and cell debris; play role in cell death
Peroxisomes	Vesicles formed from the ER containing oxidative and other enzymes	Isolate particular chemical activities from rest of cell
Energy-Producing Organelles		
Mitochondria	Bacteria-like elements with double membrane	Sites of oxidative metabolism; provides ATP for cellular energy
Chloroplasts	Bacteria-like organelles found in plants and algae; complex inner membrane consists of stacked vesicles	Sites of photosynthesis
Elements of Gene Expression		
Chromosomes	Long threads of DNA that form a complex with protein	Contain hereditary information
Nucleolus	Site of genes for rRNA synthesis	Assembles ribosomes
Ribosomes	Small, complex assemblies of protein and RNA, often bound to endoplasmic reticulum	Sites of protein synthesis

1. Cytoplasm/cytosol

- Viscous aqueous environment (NOT free flowing)
- Contains small molecules, nutrients, salts, soluble proteins
- 20-30% of cytosol is protein – Very concentrated
- Highly organized environment **
- A major site of cellular metabolism (e.g. glycolysis)
- Contains cytoskeleton

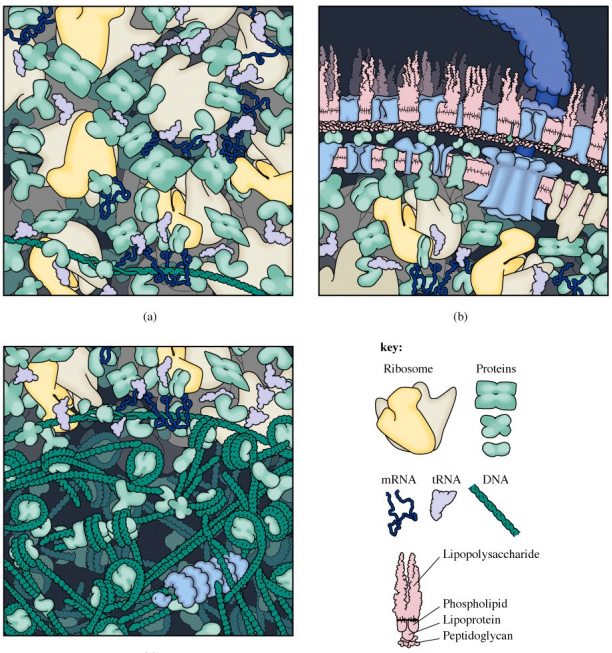


Figure 1-10 Concepts in Biochemistry, 3/e
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2. Cytoskeleton

- 3-dimensional matrix made of protein fibers
- Functions to give cells shape, allows cells to move, guides internal organelle movement.

3. Nucleus

- Site of most DNA and RNA synthesis
- Storage of genetic information
- Bound by a double membrane
- Largest organelle in eukaryotic cells

4. Endoplasmic Reticulum (ER)

- Network of interconnected, closed, membrane-bounded vesicles
- Attached to cell and nuclear membrane
- Used for manufacturing, modification and transport of cellular materials
- Two types:
  * **Smooth** ER = site of lipid synthesis
  * **Rough** ER = site of protein synthesis via **ribosomes**
- Ribosomes are made up of RNA and proteins not bound by a membrane

5. Lysosomes

- Internal sacs bound by a single membrane
- Responsible for degrading cell components that have become obsolete for the cell or organism.
- Internal pH ~5 (very acidic)
- Compartmentalization ESSENTIAL! Sequesters this biological activity from the rest of the cell.
- Enzymes in lysosomes degrade polymers into their individual building blocks.

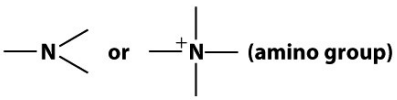
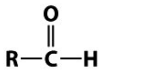
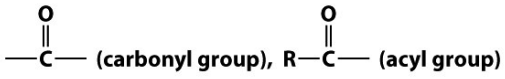
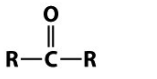
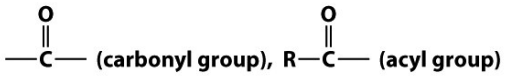
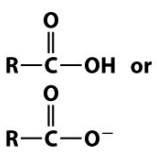
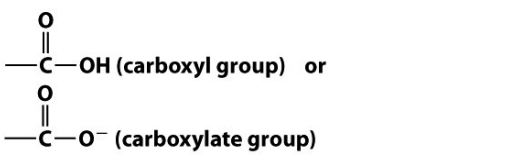
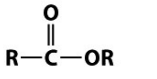
6. Golgi Apparatus

- Flattened vesicles of lipid/protein/sugar
- Usually found near smooth ER and nucleus
- Involved in protein and fat processing and trafficking to other organelles (e.g. lysosomes, plasma membranes) – Distribution and shipping department for cell materials.

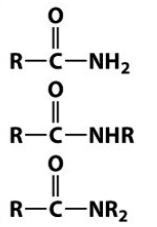
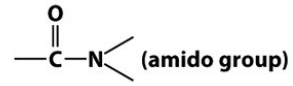
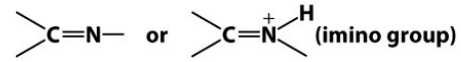
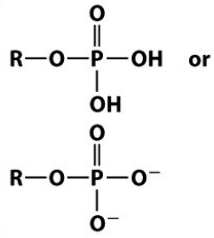
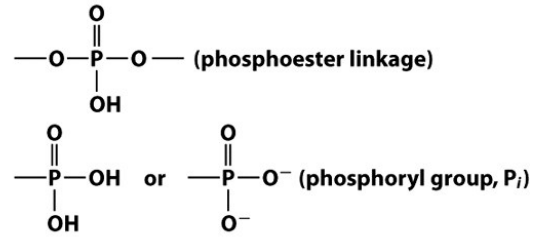
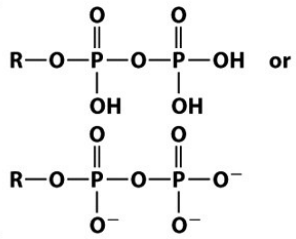
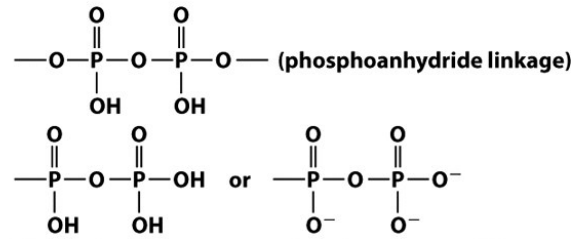
7. Mitochondria

- Have double membrane (inner and outer)
- Place where most oxidative energy production occurs = "powerhouse" of the cell
- Form ATP – Convert oxygen and nutrients to energy
- Small, typically the size of a bacterium
- Contain a circular DNA molecule like that of bacteria (own genome)
- Because of the double membrane, size and presence of own genome, mitochondria are believed to be descendents of a bacteria that was engulfed by a larger cell billions of years ago = **endosymbiotic hypothesis.**
- A cell can have over 1000 mitochondria! Depends on need for energy---muscle cells have a lot of mitochondria.

TABLE 1-1 | Common Functional Groups and Linkages in Biochemistry

Compound Name	Structure[a]	Functional Group
Amine[b]	RNH_2 or RNH_3^+; R_2NH or $R_2NH_2^+$; R_3N or R_3NH^+	 (amino group)
Alcohol	ROH	—OH (hydroxyl group)
Thiol	RSH	—SH (sulfhydryl group)
Ether	ROR	—O— (ether linkage)
Aldehyde		 (carbonyl group), (acyl group)
Ketone		 (carbonyl group), (acyl group)
Carboxylic acid[b] (Carboxylate)		 (carboxyl group) or (carboxylate group)
Ester		 (ester linkage)

[a]R represents any carbon-containing group. In a molecule with more than one R group, the groups may be the same or different.
[b]Under physiological conditions, these groups are ionized and hence bear a positive or negative charge.

Compound Name	Structure[a]	Functional Group
Amide		 (amido group)
Imine[b]	$R{=}NH$ or $R{=}NH_2^+$; $R{=}NR$ or $R{=}NHR^+$	 (imino group)
Phosphoric acid ester[b]		 (phosphoester linkage); (phosphoryl group, P_i)
Diphosphoric acid ester[b]		 (phosphoanhydride linkage); (diphosphoryl group, pyrophosphoryl group, PP_i)

[a]R represents any carbon-containing group. In a molecule with more than one R group, the groups may be the same or different.
[b]Under physiological conditions, these groups are ionized and hence bear a positive or negative charge.