Lecture 1 (9/4/20)

- Reading from Wed: Ch1, 1-5, 12-14
- Reading for today: Ch1, 8-11, 15-16, 21-27
  Ch13, 496-497
  Ch2, 47
- Problems for today: Ch1 (text) 1,2,3,4,7
  Ch13 (text) 1,2,3,4
  Ch2 (text) 3 **(study guide) 1,2**

Review of ORGO

Review of HS CELL BIOLOGY

Review of THERMO

NEXT

- Reading: Ch2, 47-58
- Problems: Ch2 (text) 1,2
  Ch2 **(study guide) 3,4,5,6,7**

Lecture 1 (9/4/20)

OUTLINE

What is Biochemistry?

Themes throughout the Course

Molecular Components of Life

Thermodynamics

WATER

Biochemistry Definition

Albert L. Lehninger, 1917–1986

(Source: Alan Mason Chesney Medical Archives of the Johns Hopkins Medical Institutions.)

A living cell is a self-assembling, self-adjusting, self-perpetuating isothermal open system. This system consists of many consecutive, linked organic reactions that are promoted by organic catalysts produced by the cell; it operates on the principle of maximum economy of parts and processes.

Biochemistry Is the Chemistry of Living Matter

Living matter is characterized by:

- a high degree of complexity and organization
- the extraction, transformation, and systematic use of energy to create and maintain structures and to do work
- the interactions of individual components being dynamic and coordinated
- the ability to sense and respond to changes in surroundings
- a capacity for fairly precise self-replication while allowing enough change for evolution

In order to understand these processes, biochemists have tended to isolate individual components and study them: reductionists

Central Themes of Biochemistry I

There are THREE repetitive themes:

1. **Chemical Basis**: try to explain life in terms of equilibria, kinetics, reactivity, and thermodynamic quantities
2. **Complementarity**: Form & Function.
3. Do they still teach the 3 R's?
   (Reading, 'Riting, 'Rithmatic)

Shape
Solubility
Stability

For each of the biological components of life, we will describe them in these terms.

Central Themes of Biochemistry I

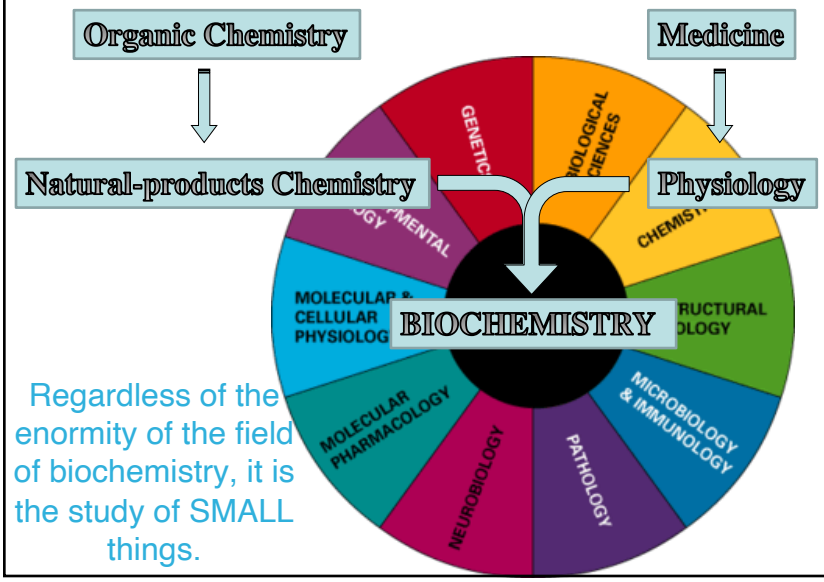
There are THREE repetitive themes:

1. **Chemical Basis**: try to explain life in terms of equilibria, kinetics, reactivity, and thermodynamic quantities
2. **Complementarity**: Form & Function.
3. **The 4 S's**:

Size
Shape
Solubility
Stability

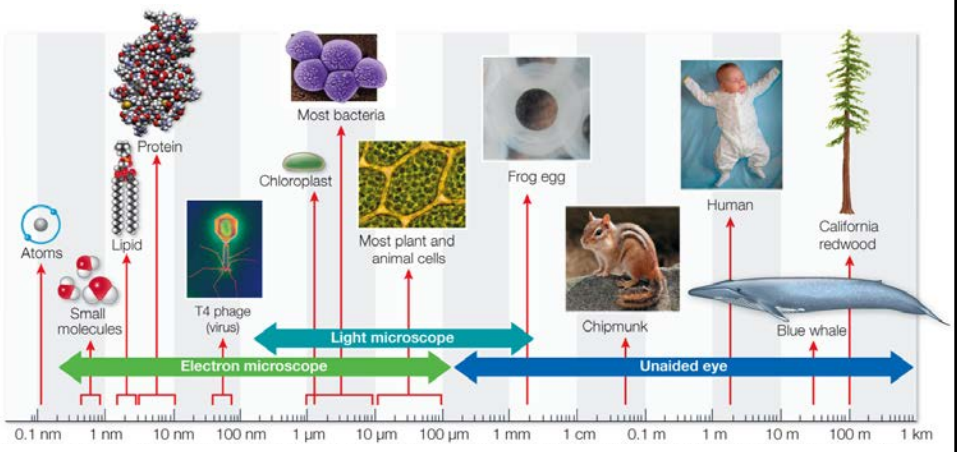
For each of the biological components of life, we will describe them in these terms.

History of Biochemistry



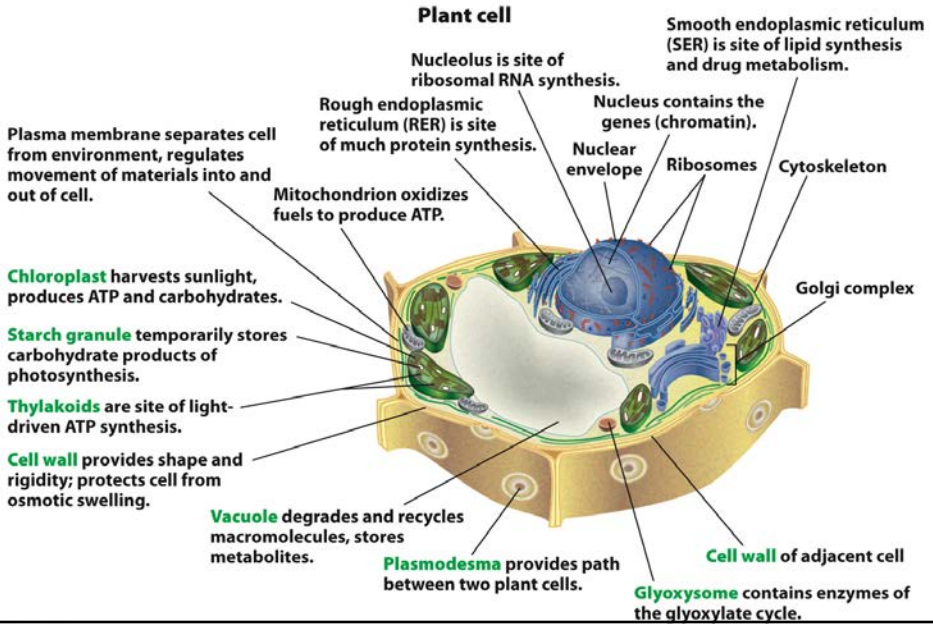
Regardless of the enormity of the field of biochemistry, it is the study of SMALL things.

Sizes of Things

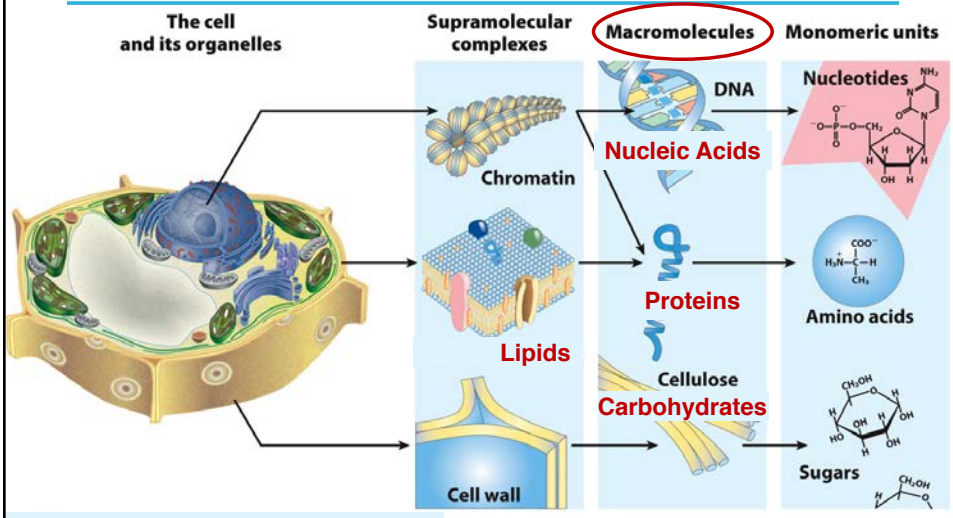


Scaler
http://www.htwins.net/scale2/

Cells are complex ORGANIZED units of life



The Molecular Hierarchy of Structure



Nucleic Acids: covalent polymer of nucleotides

Proteins: covalent polymer of amino acids

Carbohydrates: covalent polymer of monosaccharides

Lipids/membranes: non-covalent supramolecular complex of phospholipids

Components of Life

Data from *E. coli:*

Component	% by weight	Complexity*
Water	70	1
Protein	15	3000
Nucleic Acids	7	1001
Carbohydrate	3	50
Lipids	2	40
Small organics	2	500
Inorganics	1	12

*number of types

Before we discuss each component, lets review thermodynamics that makes these possible

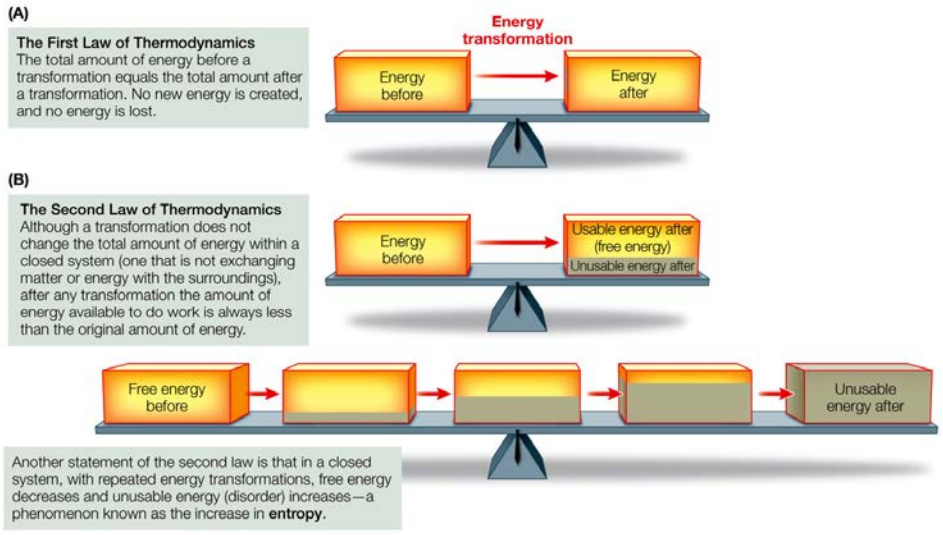
Energetics of Life

The **laws of thermodynamics** (thermo, "energy"; dynamics, "change") apply to all matter and all energy transformations in the universe.

1st & 2nd Laws of Thermodynamics:

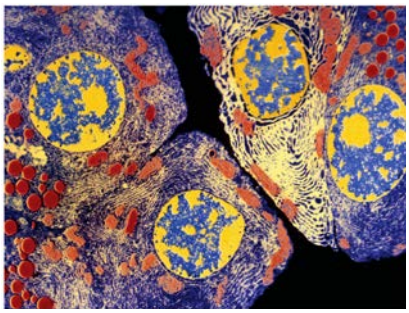
1) **Energy can never be created or destroyed, but can be interconverted.**
2) **The universe tends toward more disorder (randomness)** [When energy is converted from one form to another, some of that energy becomes unavailable to do work.]

Energetics of Life



Organisms Work Against the Second Law Big-Time to Build the Cell

Complexity and Organization



Take as the system, the reactions creating the cell:

$$\text{Chaos} \rightleftharpoons \text{Cell}$$

$$\Delta S_{system} = S_{cell} - S_{chaos}$$

(small) (large)

$\Delta S_{system} = \ominus$

$\Delta S_{universe} > 0$ ($\oplus$) (2^{nd} Law)

$\Delta S_{universe} = \Delta S_{system} + \Delta S_{surroundings}$

$\oplus$

Entropy of surroundings can increase by release of heat by the system: First Law to the rescue!!!

Organisms Use the First Law Big-Time (perform energy transformations) to Stay Alive

- Living organisms exist in a dynamic steady state and are never at equilibrium with their surroundings.
- As the entropy* of the universe increases, creating and maintaining order requires work and energy.
- Energy **coupling** allows living organisms to transform matter into energy.

**Entropy* is a measure of the disorder in a system.*

It takes energy to impose order on a system. Unless energy is applied to a system, it will be arranged randomly or "disordered."

A little more about "coupling"……..

Equilibrium and $\Delta G°$ Measure Favorability of a Reaction

Not all biochemical reactions are favorable in the direction that the cell needs.

Recall from gen-chem, for a given reaction:

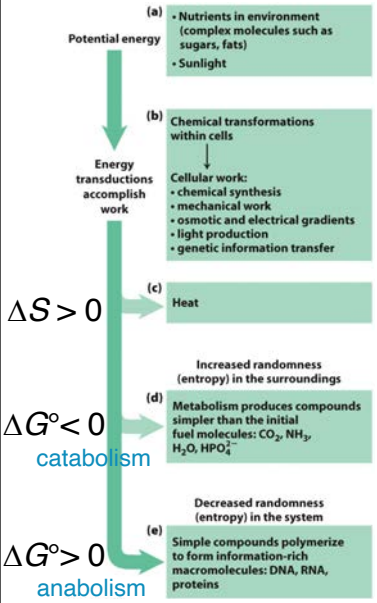
$$aA + bB \rightleftharpoons cC + dD$$

$$K_{eq} = \frac{[C]_{eq}^{c}[D]_{eq}^{d}}{[A]_{eq}^{a}[B]_{eq}^{b}}$$

And

$$\Delta G° = -RTlnK_{eq}$$

Organisms Use the First Law Big-Time (perform energy transformations) to Stay Alive

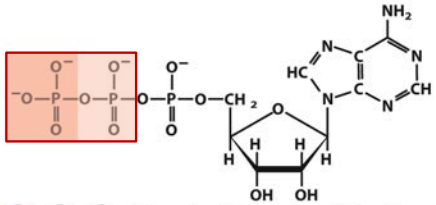


Favorable and Unfavorable Reactions

- The breakdown of some metabolites releases a significant amount of energy (**exergonic**).
  - Their cellular concentration is far higher than their equilibrium concentration.
  - Metabolites, such as ATP, NADH, NADPH, can be synthesized using the energy from sunlight and fuels…..
- Synthesis of complex molecules and many other metabolic reactions requires energy (**endergonic**).
  - A reaction might be thermodynamically unfavorable ($\Delta G^\circ > 0$).
    - Creating order requires work and energy.

Energy Coupling

- Chemical coupling of exergonic and endergonic reactions allows otherwise unfavorable reactions.
- TWO basic mechanisms:
  - e.g., The hydrolysis of the "high-energy" molecule (ATP), which is exergonic, is coupled with an otherwise endergonic reaction during an enzyme mechanism.
  - e.g., a series of otherwise endergonic reactions during a metabolic pathway are linked in the reaction series to an overwhelming exergonic reaction (all catalyzed by enzymes).



Inorganic phosphate = P_i

Pyrophosphate = PP_i

Adenosine (Adenosine *tri*phosphate, ATP)