Lecture 1 (9/5/25)

- Reading for "last" lecture: Ch1, 1-3, 10-12
- Reading for today: Ch1, 6-9, 13-14, 19-25

  Ch13, 466-469

  Ch2, 43

Review of ORGO

Review of HS CELL BIOLOGY

Review of THERMO

- Homework #1: Due Sunday midnight on *Achieve*.

NEXT

- Reading: Ch2, 43-53; 53-64
- Homework #2:
- Homework #3:

Lecture 1 (9/5/25)

OUTLINE

What is Biochemistry?

Themes throughout the Course

Molecular Components of Life

Thermodynamics review

WATER

YouTubeShort that ushers many of the themes of biochemistry: Animals, quantitative accuracy, teamwork, energy

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 Definition

Complementary macromolecules

dynamic

Albert L. Lehninger, 1917–1986

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Self-replicating

Bio-energetics

metabolism

enzymes

Molecular biology

evolution

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

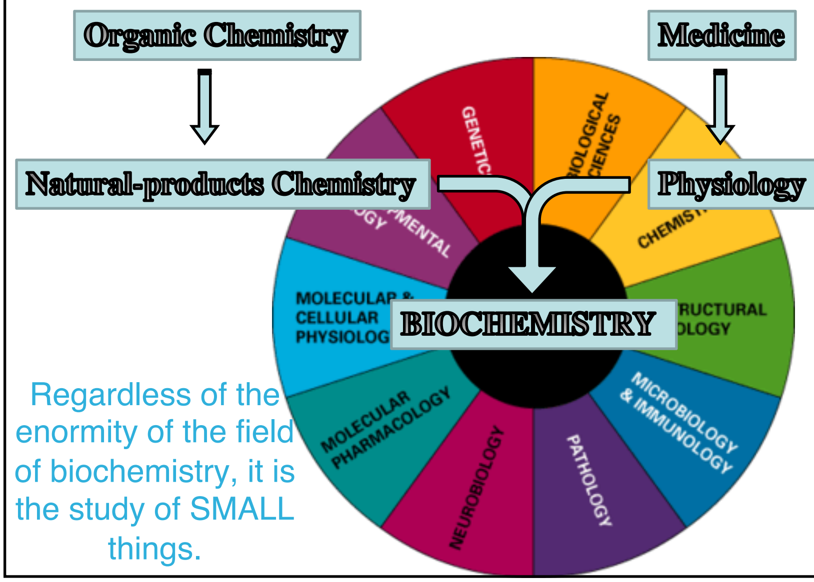
There are THREE repetitive themes:

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

    Size
    Shape
    Solubility
    Stability

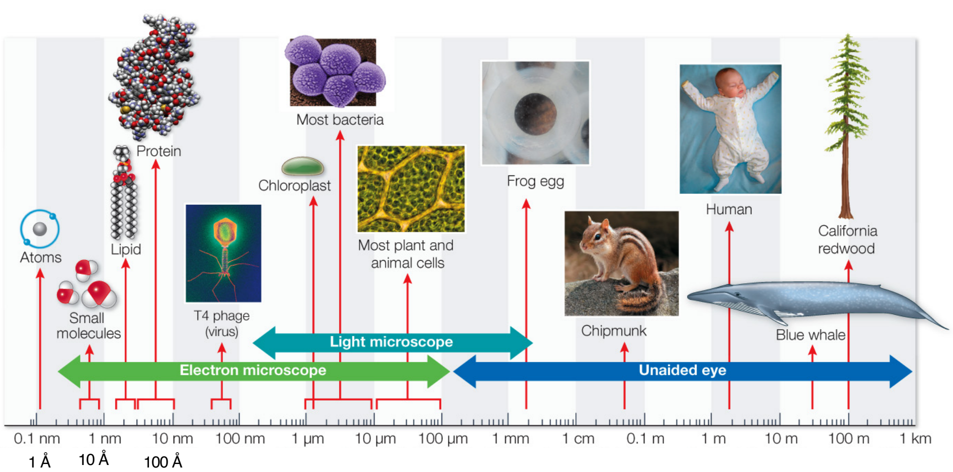
For each of the biological components of life, we will describe them in these terms.

History of Biochemistry



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

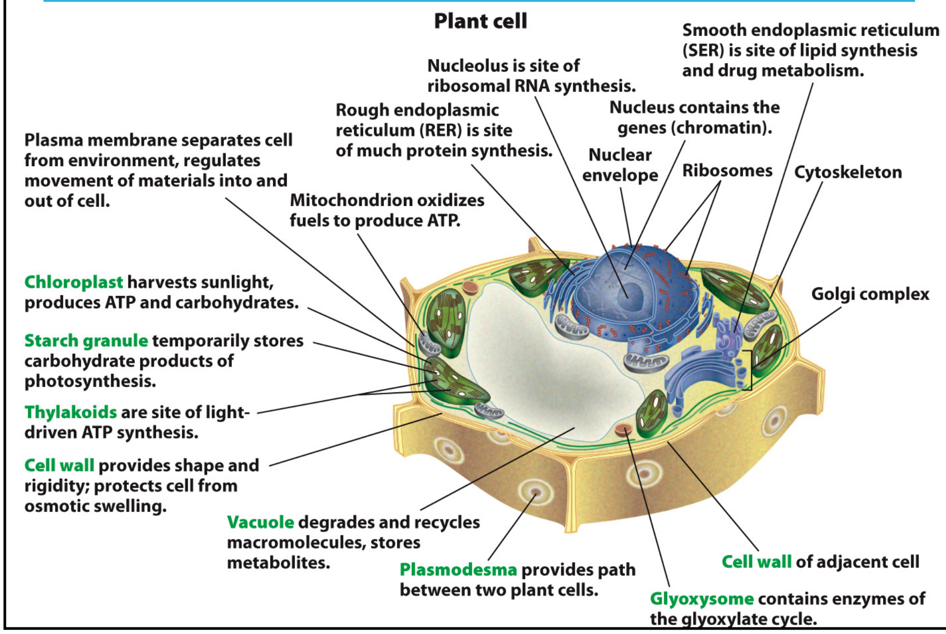
Sizes of Things



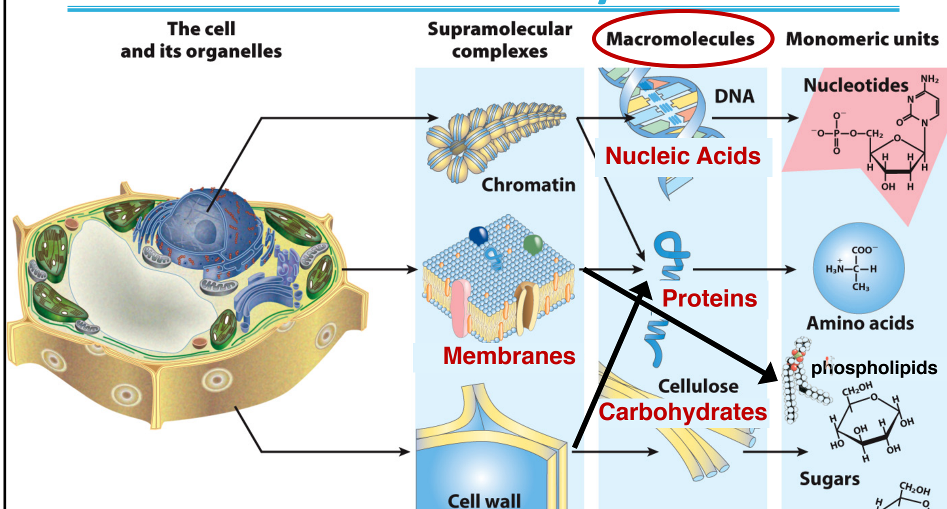
Scaler
http://www.htwins.net/scale2/

Å = Angstrom (diameter of hydrogen atom)

Cells are complex ORGANIZED units of life



The Molecular Hierarchy of Structure



Proteins: covalent polymer of amino acids

Nucleic Acids: covalent polymer of nucleotides

Carbohydrates: covalent polymer of monosaccharides

Membranes/Lipids: non-covalent supramolecular complex of phospholipids

Components of Life

Data from the bacteria *Escherichia 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

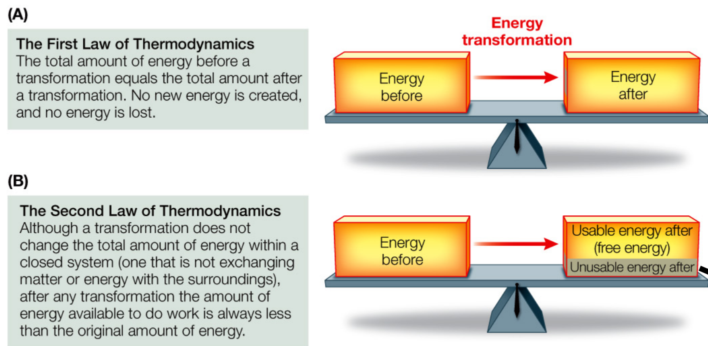
Energetics of Life

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

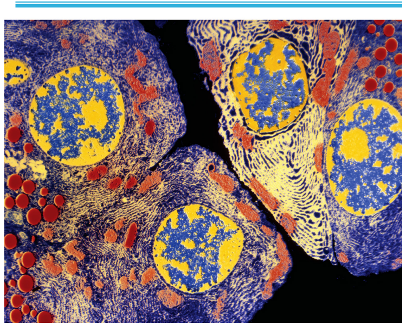


S; entropy

$\Delta S_{universe} > 0$ (i.e., $\oplus$)

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

Complexity and Organization



Take as the <u>system</u>, the reactions creating the cell:

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

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

(small) (large)

$$\Delta S_{system} = \ominus$$

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

- Creating and maintaining order requires work and energy. The entropy* of the universe must increase (2nd Law)
- Living organisms exist in a dynamic steady state and are never at equilibrium with their surroundings.
- Energy **coupling** allows living organisms to transform 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."

Equilibrium and Δ*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:

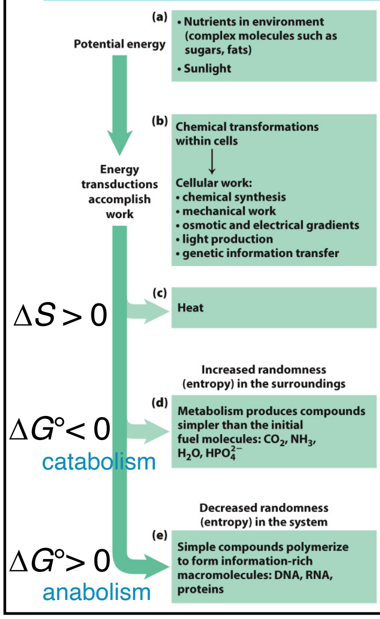
$$aA + bB \rightleftharpoons cC + dD$$

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

And

$$\Delta G^{\circ} = -RT\ln K_{eq}$$

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 ($\Delta G° > 0$).
    - Creating order requires work and energy.

Quantifying Thermodynamics

In any system:

Total energy = usable energy + unusable energy

enthalpy (**H**)* = **free energy** (**G**) + **entropy** (**S**)

or $H = G + TS$ (T = absolute temperature)

$G = H - TS$

***equal to the system's internal energy plus the product of its pressure and volume**. In a closed system at constant pressure, the heat absorbed or released equals the change in enthalpy.

Now consider the differences in energy states between **substrates** and **products** in a **reaction:**

$$\mathbf{S} \rightleftharpoons \mathbf{P}$$

Change in energy can be measured in calories or joules.

Change in free energy (ΔG) in a reaction is the difference in free energy of the products and the reactants: $\Delta G = \Delta H - T\Delta S$

Quantifying Thermodynamics

For Total Energy (Enthalpy), what is magnitude of ΔH?

Look at each side of the reaction:

$$S \rightleftharpoons P$$

If bonds here are to be broken, its at a lower energy state, H is less

If bonds are being broken to make P, need to add energy, H is more

$$H_{product}\ (\text{more heat, less bonds}) - H_{reactant}\ (\text{less heat, more bonds}) = +\Delta H$$

Heat energy is added or adsorbed

Ice $\rightleftharpoons$ **Water** at T > 0° C

More bonds — Less bonds

If the other way around, with product having more bonds, its at a lower energy state, then $-\Delta H$ *(energy is released)*:

Quantifying Thermodynamics

For Entropy, what is magnitude of ΔS?

Look at each side of the reaction:

$$S \rightleftharpoons P$$

If more organized, S is less

If more disordered, S is more.

$$S_{product}\ (\text{more}) - S_{reactant}\ (\text{less}) = +\Delta S$$

Ice $\rightleftharpoons$ **Water** at T > 0° C

Less disorder, more organized — More disorder

*$+\Delta S$ adds to **favorability***

Don't forget that a $+\Delta S$ will contribute to a favorable reaction due to the $-T\Delta S$ term being a negative value.

Amino acids $\rightleftharpoons$ **Protein**

More disorder — Less disorder

*$-\Delta S$ makes **less favorable***

Quantifying Thermodynamics

For Free Energy, ΔG:

Magnitude of ΔG depends on:

$$\Delta G = \Delta H - T\Delta S$$

- ΔH—total energy added (ΔH > 0) or released (ΔH < 0)
- ΔS—change in entropy, more randomness (ΔS > 0) or more order (ΔS < 0); Positive changes in entropy make ΔG more negative. Negative changes in entropy make ΔG more positive.

Quantifying Thermodynamics

The interplay of enthalpy and entropy in the simple ice/water reaction, as a function of the temperature: