# Lecture 1 (9/6/24)

- Reading for "last" lecture: Ch1, 1-3, 10-12 ← **Review of ORGO**
- Reading for today: Ch1, 6-9, 13-14, 19-25 ← **Review of ORGO**
  - Ch13, 466-469
  - Ch2, 43

**Review of HS CELL BIOLOGY** → Ch1, 13-14

**Review of THERMO** → 13-14, 19-25

- Homework #1: Not due until after we get access to *Achieve*.

## NEXT

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

# Lecture 1 (9/6/24)

## OUTLINE

What is Biochemistry?

Themes throughout the Course

**Molecular Components of Life**

Thermodynamics review

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 Definition

Complementary macromolecules

dynamic

Albert L. Lehninger, 1917–1986

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"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."

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

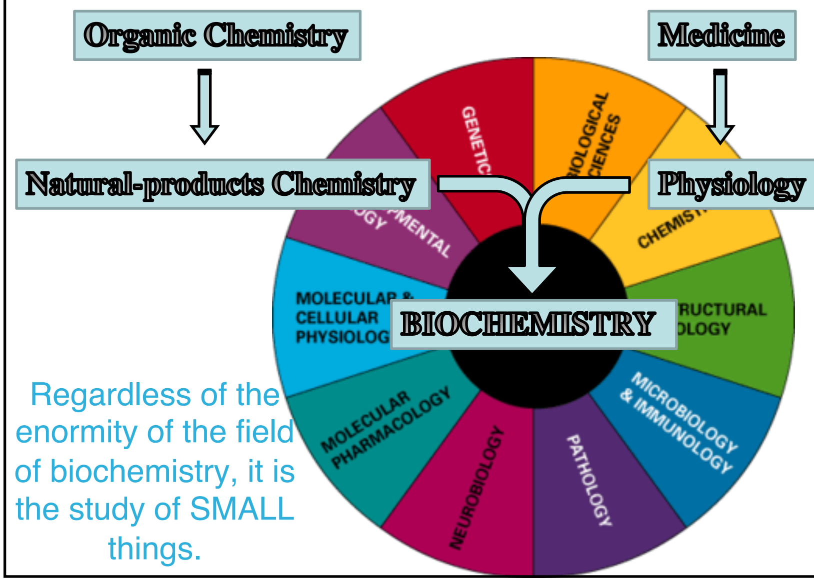
There are THREE repetitive themes:

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

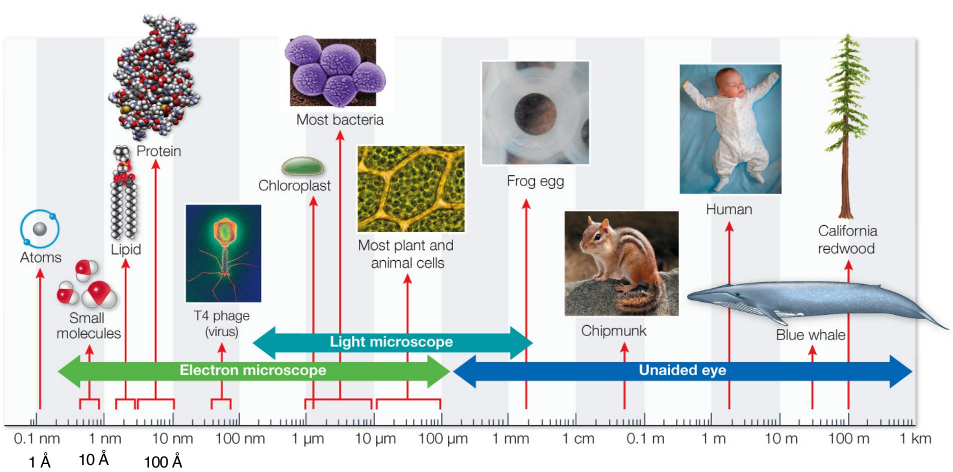
For each of the biological components of life, we will describe them in these terms.

# History of Biochemistry




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

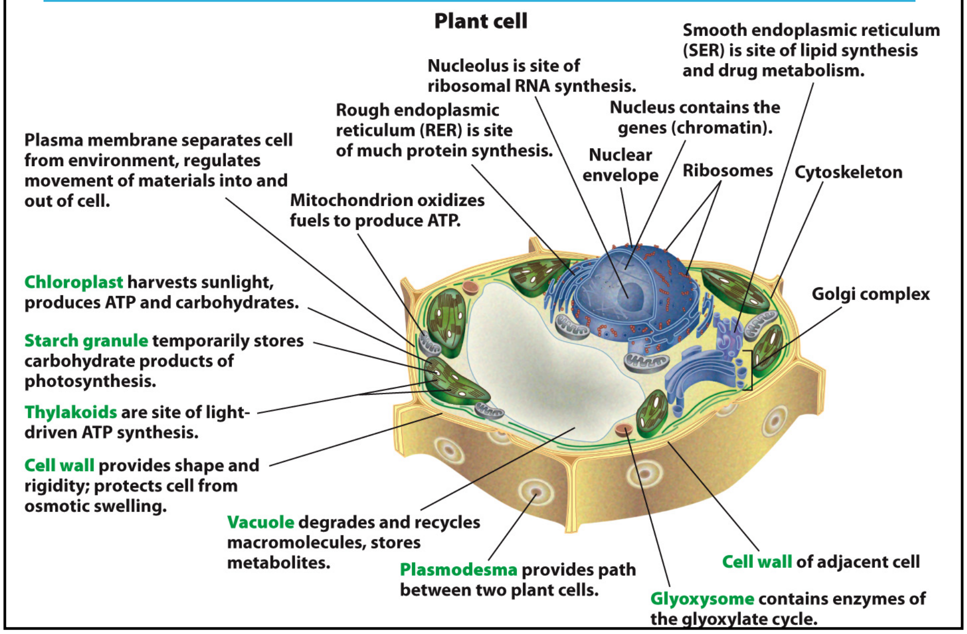
# Sizes of Things



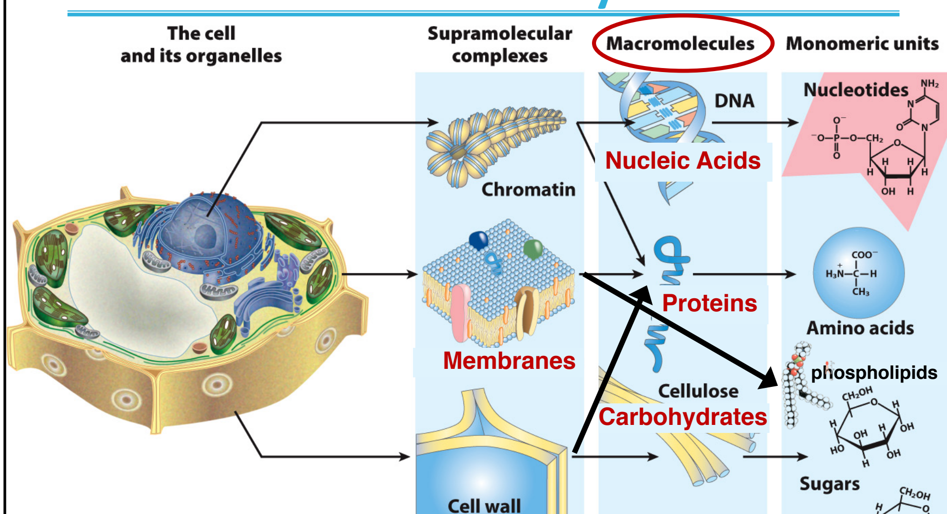

Scaler
http://www.htwins.net/scale2/

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 *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

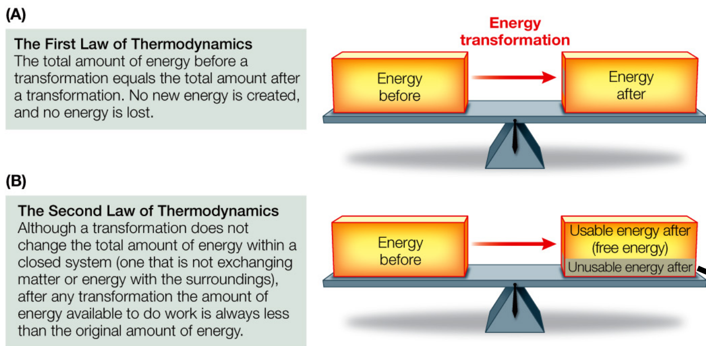
## Energetics of Life

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

<u>1st & 2nd Laws of Thermodynamics:</u>

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

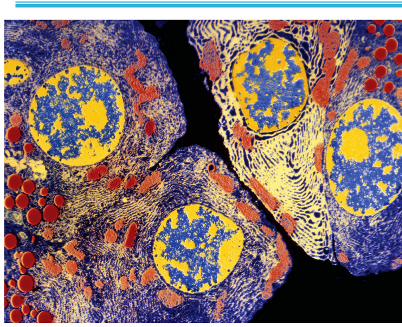



S; entropy

$\Delta S_{universe} > 0$ (i.e., ⊕)

# 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:

Chaos ⇌ Cell

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

(small) (large)

$\Delta S_{system} =$ ⊖

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

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

⊕

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."

A little more about "coupling"……..

## 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:

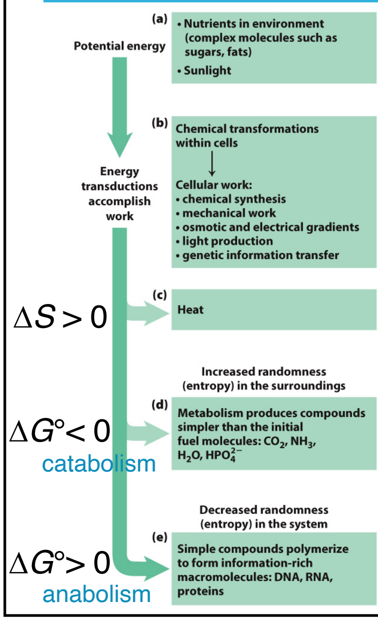
$$aA + bB \rightleftharpoons cC + dD$$

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

And

$$\Delta G° = -RTlnK_{eq}$$

# 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 ($\Delta G° > 0$).
    - 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 ($\Delta G$) 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 $\Delta H$?

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

$H_{product}$ (more heat, less bonds) – $H_{reactant}$ (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 $\Delta S$?

Look at each side of the reaction:

$S \rightleftharpoons P$

If more organized, S is less

If more disordered, S is more.

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

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

Less disorder, more organized | More disorder

***+ΔS 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**

***–ΔS makes less favorable***