Biochemistry

Lecture 1

OUTLINE

- What is Biochemistry?
- Themes throughout the Course
- Molecular Components of Life Thermodynamics review
- Water
- Carbohydrates
- Proteins
- Vitamins
- Diseases

- 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

Central Themes of Biochemistry I

- There are THREE repetitive themes:

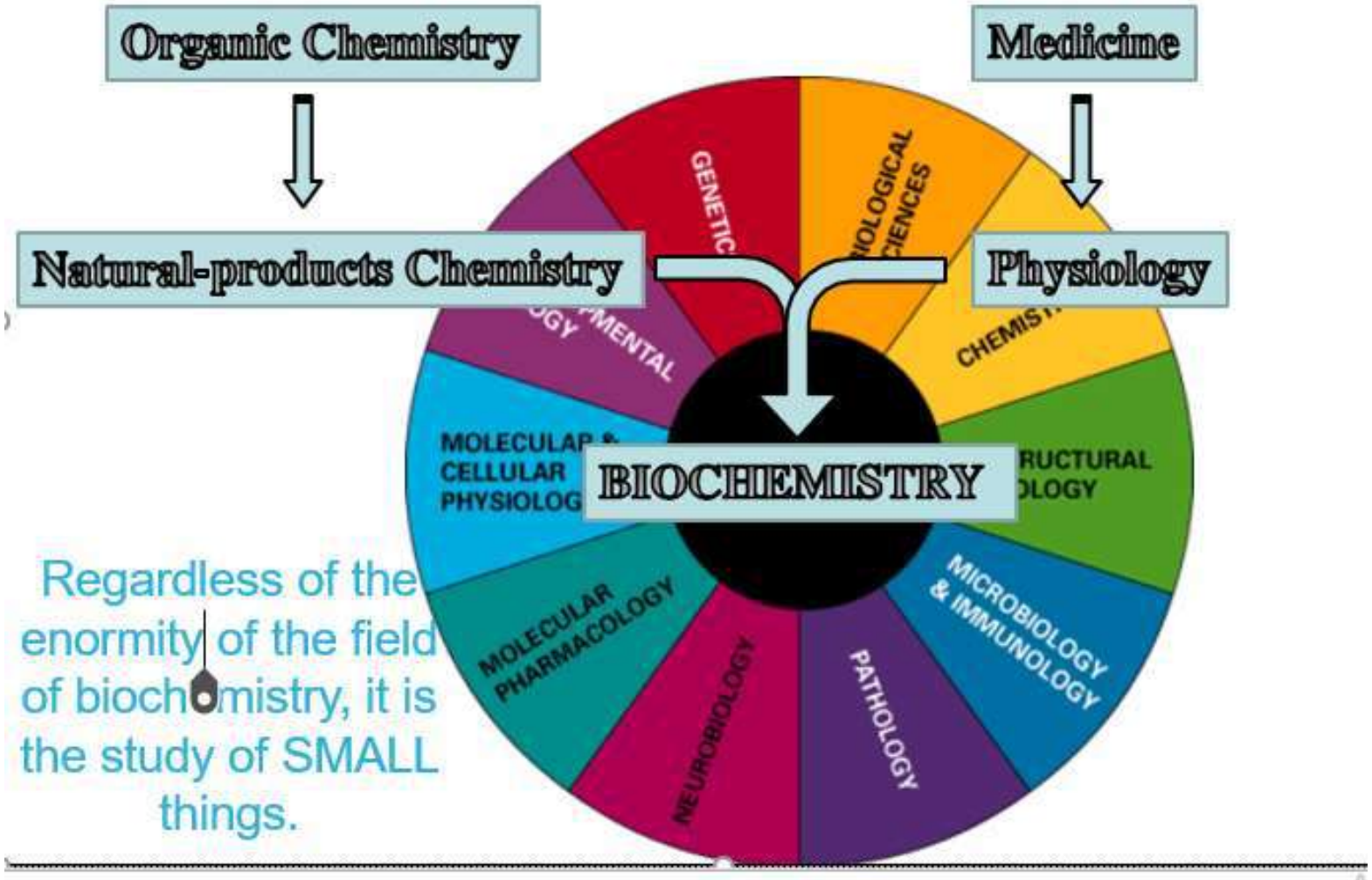
1. **Chemical Basis**: try to explain life in terms of equilibria, kinetics, reactivity, and thermodynamic quantities

2. **Complementarity**: Form & Function.

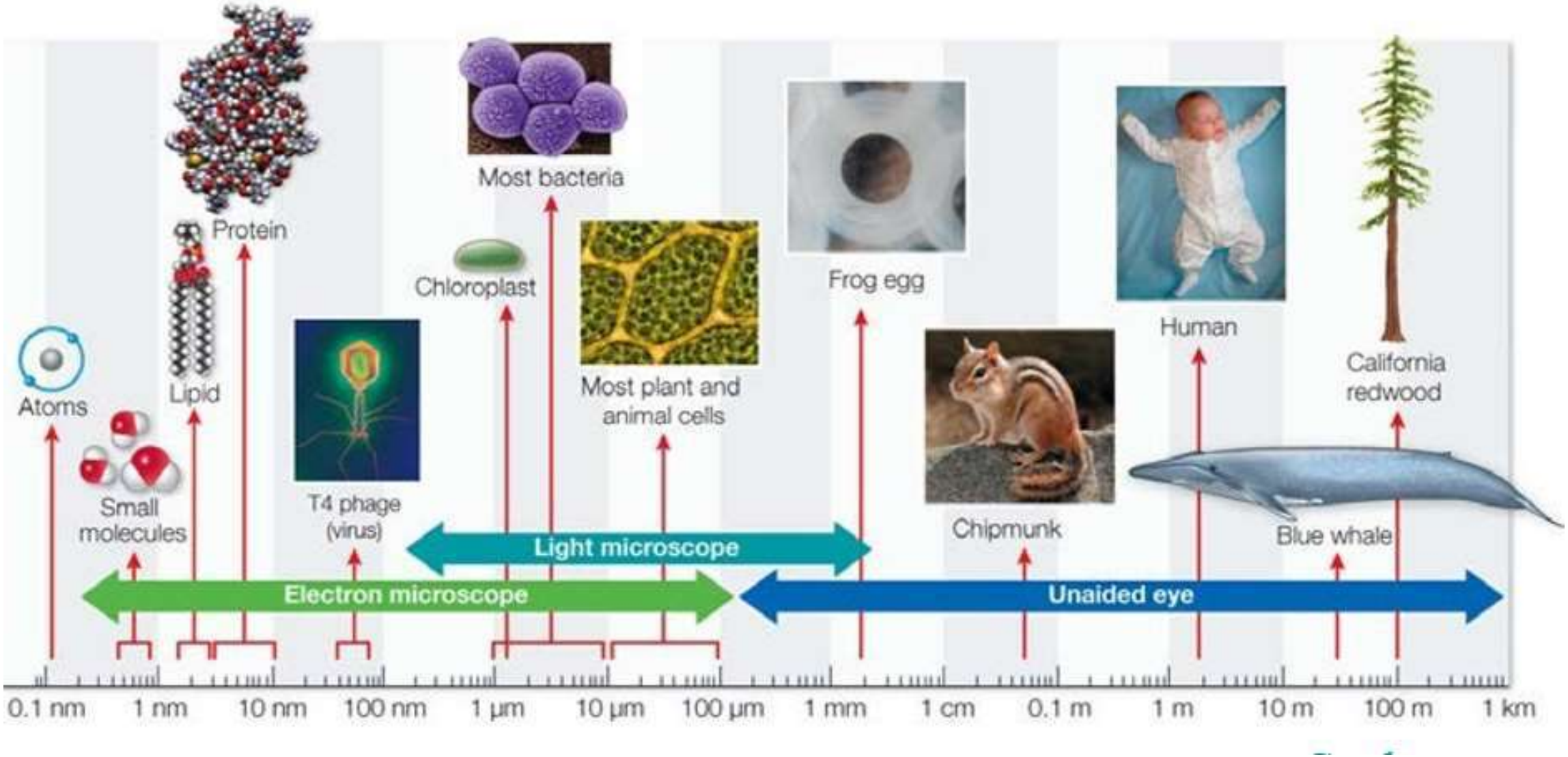
3. **The 4 S's**:
    - Size
    - Shape
    - Solubility
    - Stability

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

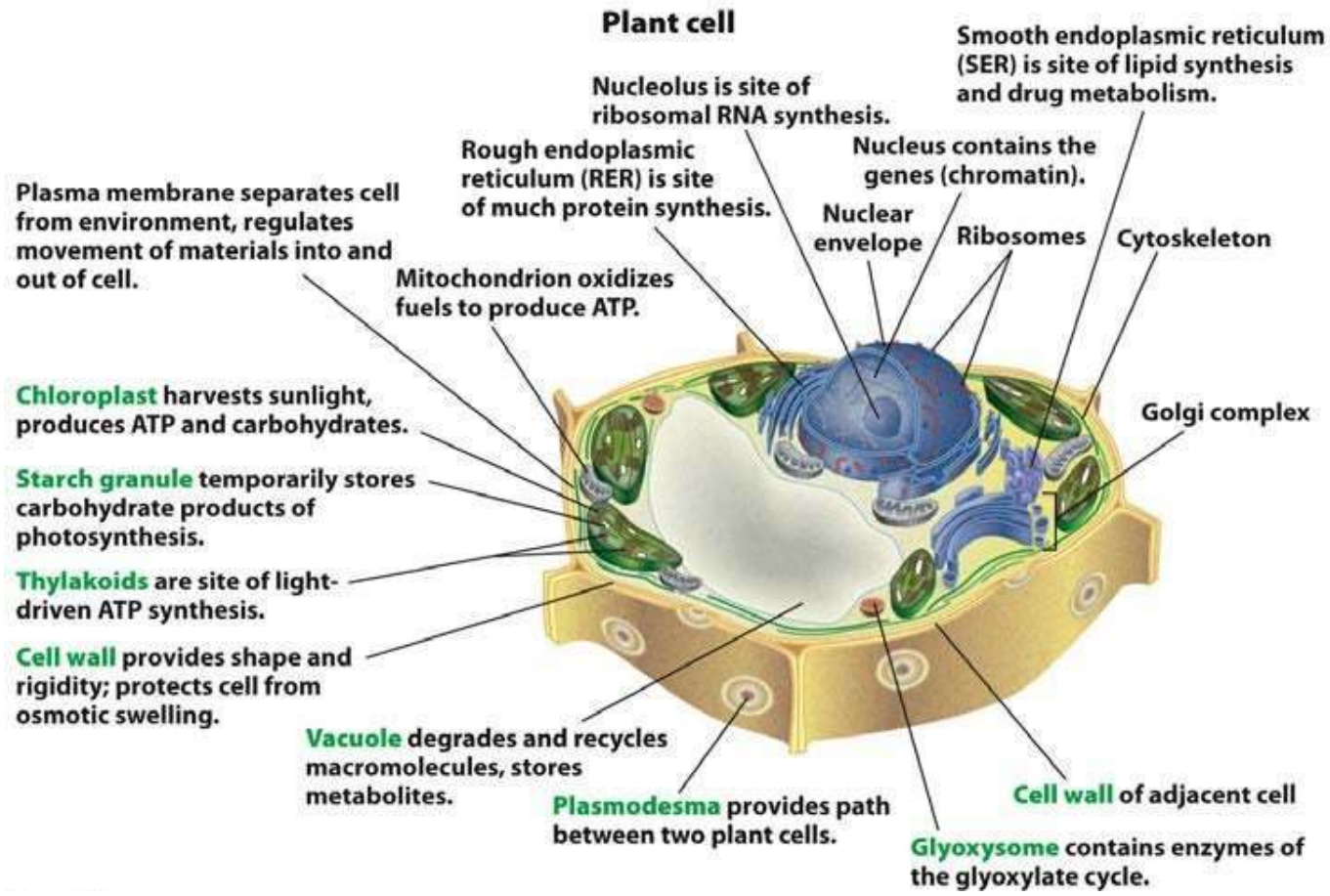
History of Biochemistry



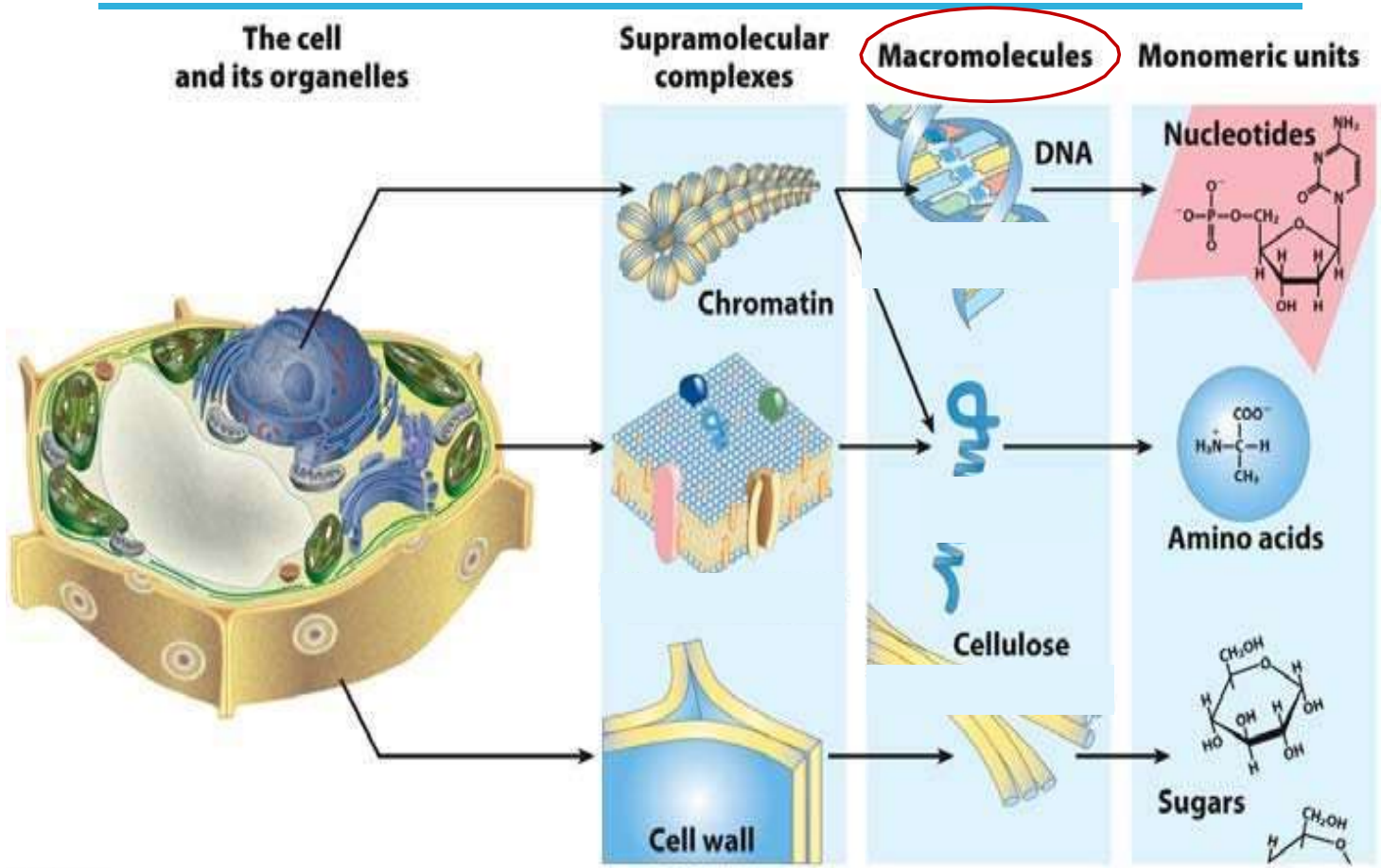
Sizes of Things



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

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:

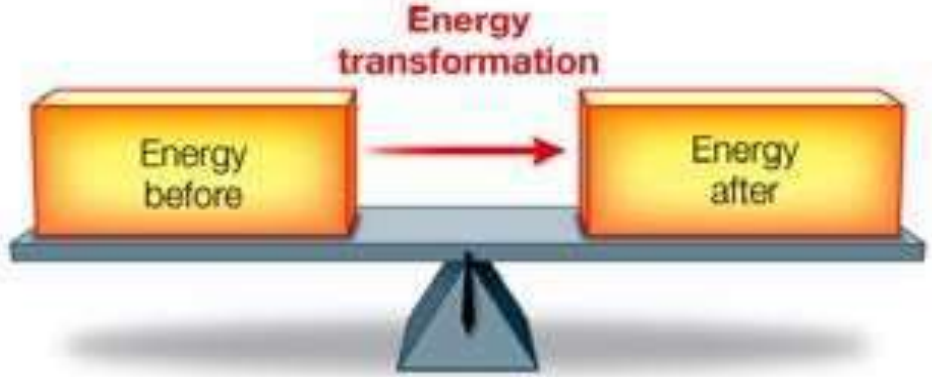
1) **Energy can never be created or destroyed, but can be interconverted.**

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.]

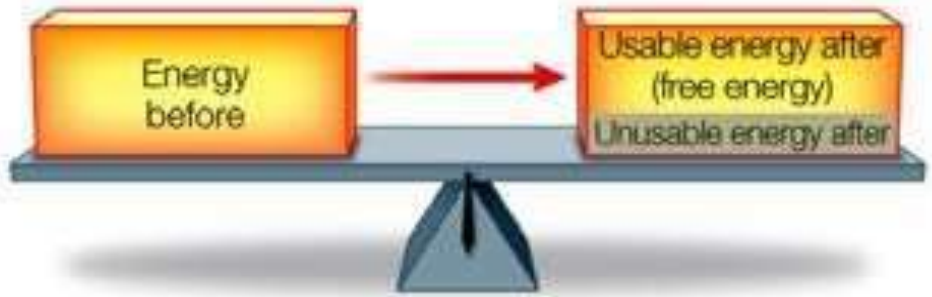
(A)

The First Law of Thermodynamics
The total amount of energy before a transformation equals the total amount after a transformation. No new energy is created, and no energy is lost.



(B)

The Second Law of Thermodynamics
Although a transformation does not change the total amount of energy within a closed system (one that is not exchanging matter or energy with the surroundings), after any transformation the amount of energy available to do work is always less than the original amount of energy.



Another statement of the second law is that in a closed system, with repeated energy transformations, free energy decreases and unusable energy (disorder) increases—a phenomenon known as the increase in **entropy**.

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

- As the entropy* of the universe increases, creating and maintaining order requires work and energy.
- 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.

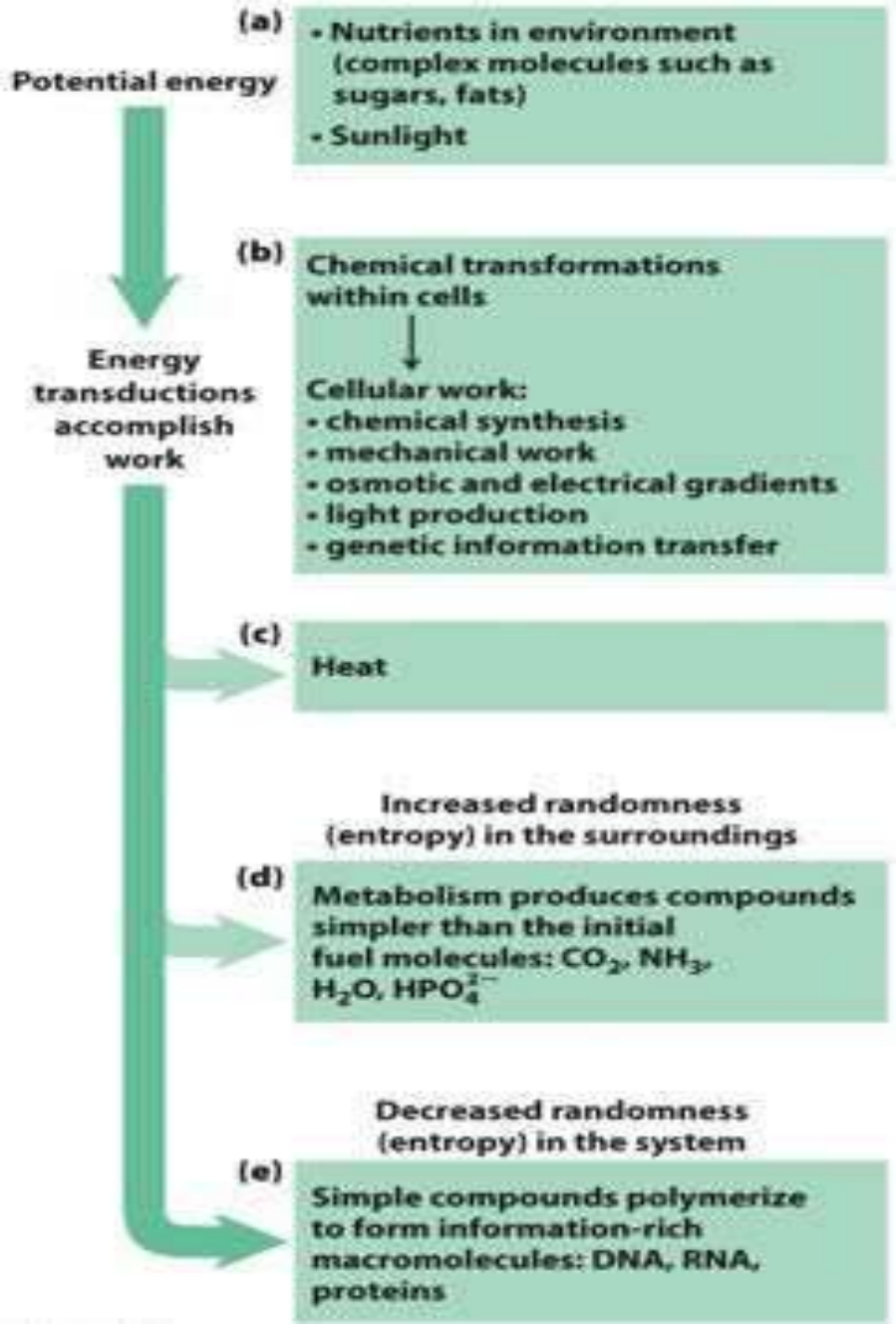
- It takes energy to impose order on a system. Unless energy is applied to a system, it will be arranged randomly or “disordered.”
- A little more about “coupling”……..

- **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).

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)
    - $G = H - TS$
- Now consider the differences in energy states between **substrates** and **products** in a reaction:

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

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

- For Free Energy, ΔG:
  - Magnitude of ΔG depends on:
    - $\Delta G = \Delta H - T\Delta S$
    - ΔH—total energy added ($\Delta H > 0$) or released ($\Delta H < 0$)
    - ΔS—change in entropy, more randomness ($\Delta S > 0$) or more order ($\Delta S < 0$); Positive changes in entropy make ΔG more negative. Negative changes in entropy make ΔG more positive.

Properties of Water

1)Water has a high boiling point and relatively low melting point; its range in the liquid state is large

2)The heat of vaporization is high (more heat to change to vapor state than to raise temperature of the liquid state)

3)Liquid is more dense than the solid (e.g., most metals and other substances the solid is more dense)

4)High viscosity relative to its molecular weight (MW)

5)High surface tension

Biochemistry

- The word **‘BIOCHEMISTRY’-**
- means -**Chemistry of Living beings** or **Chemical Basis of Life.**

❑ **“Life” in Biochemistry point of view is:**

Hundreds of Biochemical reactions and **Biochemical processes**

❑Occurring in **sub cellular organelles of a cell in an organized manner.**

Historical Developments of Biochemistry

- Biochemistry emerged in the **late 18th and early 19th century.**

- The **term Biochemistry** was first introduced by the **German Chemist Carl Neuberg in 1903.**

- In the **1940s Clinical Biochemistry evolved, as an autonomous field.**

S.No	Pioneer Workers	Discovery/Work
1	Berzilus	Enzymes Catalysis
2	Edward Buchner	Enzyme Extraction
3	Louis Pasteur	Fermentation Process
4	Lohmann	Role of Creatine PO4 in muscles
5	Hans Kreb	TCA Cycle
6	Banting and Macleod	Insulin
7	Fiske and Subbarow	Role of ATPs

S.No	Pioneer Worker	Discovery/Work
8	Watson and Crick	Double Stranded DNA
9	Landsteiner	Protein Structure
10	Peter Mitchell	Oxidative Phosphorylation
11	Nirenberg	Genetic Code on mRNA
12	Paul Berg	Recombinant DNA Technology
13	Karry Mullis	Polymerase Chain Reaction
14	Khorana	Synthesized Gene

Aim And Objectives To Study Biochemistry

- To know the various Biomolecules composed in Human body:
  - Chemistry/Structure
  - Occurrence/Location
  - Functions/Role

- **Determination of mode of action of Biomolecules** is by:

  - **Isolation and Structural elucidation** of Biomolecules.

- **Understand completely all the organized Biochemical processes**
- Occurring in **living cells at the molecular/sub cellular level .**

- **Identification of disease mechanisms:**
  - Study of **Inborn Errors of metabolism.**
  - Study of **Oncogenes in cancer cells.**

Branches of Biochemistry

- **Bacterial Biochemistry**-Deals with Microbes.
- **Plant Biochemistry-** Deals with Plants.
- **Animal Biochemistry-**Deals with animals.
- **Industrial Biochemistry**-Deals with industrial products involved with microorganisms.

- **Medical Biochemistry-**Deals with chemical basis of human body.
- **Clinical Biochemistry-** Deals with clinical diseases/pathological conditions of human body.
- **Clinical Biochemistry** supports:

Diagnosis, Therapy and Research of Medical field.

Chemical Composition of Human body

- **Study of Biochemical aspects of Cell and its sub cellular organelles**.
- Study of various Biochemical constituents of cell:

(Chemistry, properties , functions, metabolism and related disorders).

① **Carbohydrates**
② **Lipids**
③ **Proteins**
④ **Vitamins**
⑤ **Minerals**
⑥ **Water**

Nutrition and Metabolism of Biomolecules

- Study of Food and its constituents
- Dietary Nutrients builds human body and maintain health
- Major prerequisite for the maintenance of health is that
- There should be optimal dietary intake of constituents with good quality and appropriate quantity.
- Biochemical research has impact on **Nutrition** & **Preventive Medicine.**

- ✓Catabolic and Anabolic pathways related to Biomolecules for Human vitality
- ✓Energy rich biomolecules get catabolized in body cells to liberate chemical form of energy ATP used for various body activities.
- ✓Various biomolecules are biosynthesized to perform vital functions of human body.
- ✓To maintain normal health of a human body:
- ✓Biomolecules in human body work Cooperatively with good coordination ,Regulation and Interrelationship.

Steps involved in metabolism

- Ingestion
- Digestion
- Absorption
- Transport
- Uptake and
- Assimilation of food constituents in human body

Roles Of Important Biomolecules

- **Carbohydrates** serves as primary source of energy.

- **Lipids** serves as secondary source of energy.

- **Proteins** are structural and functional units of human body which are of prime importance and survival of human beings.

- **Vitamins:** Fat soluble and Water soluble vitamins have specific functions which serve as accessory growth factors.

- **Enzymes** are biomolecules which are Biocatalysts catalyzes specific biochemical reactions of metabolic pathways and considered as functional units of metabolism.

- **Minerals:** Inorganic elements major and minor type has important role in building and functioning of human bodies.

- **Hormones** the Endocrine substances, chemical messengers of human body. They bring good coordination and regulate enzyme activities of metabolism.

Biochemical Aspects of Health and Disease

- **Healthy body** in biochemical point of view is with-
  - **Normal metabolic functions** in the body cells.
  - **Balanced levels** of all the **biochemical constituents**

- **Unhealthy/Diseased body** in biochemical point of view is with:
  - **Derangement in their metabolic functions**.
  - **Imbalanced levels of biochemical constituents**

- **Health** depends on a harmonious balance of biochemical reactions occurring in the body
- **Disease** reflects abnormalities in biomolecules, biochemical reactions, or biochemical processes in a human body.

Biochemistry and Medicine are Intimately related

- In a specific diseased condition there occurs derangements in the hormonal actions
- Which affects, homeostatic mechanisms and metabolic processes
- Which in turn alters the normal concentrations of biochemical constituents in body cells and their fluids.

- Metabolic changes associated with specific disorders may give rise to a changes in the body fluids.
- **Biochemical profile of a particular body fluid is analyzed** for example
  - **Blood Glucose in Diabetes mellitus**;
  - **Glucose levels in the cerebrospinal fluid in bacterial meningitis** (which are greatly reduced).
- Hence, specific parameters are looked for in a specific body fluid when a disease is suspected

- Suspected diseased cases by a physician are investigated for the levels of biochemical parameters
- In various collected biological specimens viz Blood/plasma/serum/urine/CSF/other body fluids

❖The collected specimens are analyzed in a Clinical Biochemistry Laboratory using **various analytical methods** to obtain the results.

❖The obtained **results are compared with** the values with respective **normal/reference range.**

❖Results are reported to a physician for confirming the diagnosis and treatment of the patient.

Books For Biochemistry

1. Lippincott's
2. Harper
3. Vasudevan
4. U Satyanarayana
5. S K Gupta
6. Mohammed Rafi
7. Lehninger