The Molecular Logic of Life

<u>What distinguishes living organisms from inanimate objects?</u>

- Degree of chemical complexity and organisation
- Living organisms extract, transform and use energy from their environment (energy is important for structure, mechanical, chemical, osmotic and other types of work).
- Precise self-replication and self-assembly e.g. bacterial replication

Living organisms are enormously diverse, yet similar at the cellular and chemical levels.

Biochemistry describes in molecular terms the structure, mechanisms and chemical processes shared by all organisms, and provides organising principles that underlie life in all of its diverse forms – **Molecular logic of life**.

- All macromolecules are constructed from a few simple compounds.
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- Carbon atoms covalently joined with other carbon atoms and with the hydrogen, oxygen and nitrogen.

- Organic compounds with relative molecular mass less than about 500, such as amino acids, nucleotides and monosaccharides, serve as **monomeric subunits of macromolecules** such as proteins, nucleic acids and polysaccharides.

- A single protein may have 1000 or more amino acids, and deoxyribonucleic acids has millions of nucleotides
- eg. *Escherichia coli* have several proteins, nucleic acids molecules, carbohydrates and lipids.

- **DNA** (Deoxyribonucleic acid) are constructed from only four different kinds of simple monomeric subunits the **deoxyribonucleotides**

- **RNA** (Ribonucleic acid) are composed of just four types of **ribonucleotides**

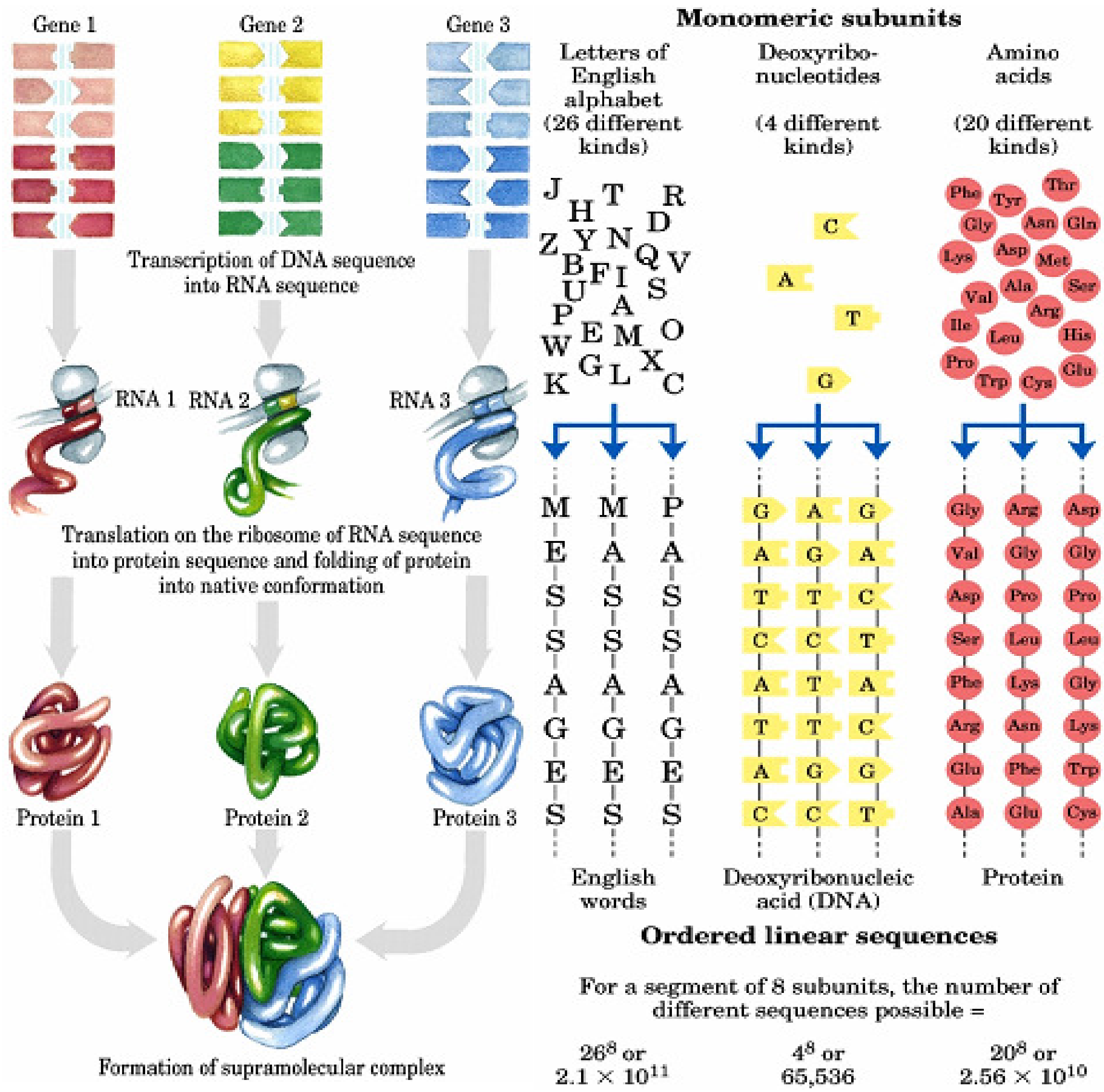
- **Proteins** are composed of 20 different kinds of **amino acids**

- All proteins are built identical in all living organisms

- All living organisms build molecules from same kind of monomeric subunits

- The structure of a macromolecule determines its specific biological function

- Each genus and species is defined by its distinctive set of macromolecules

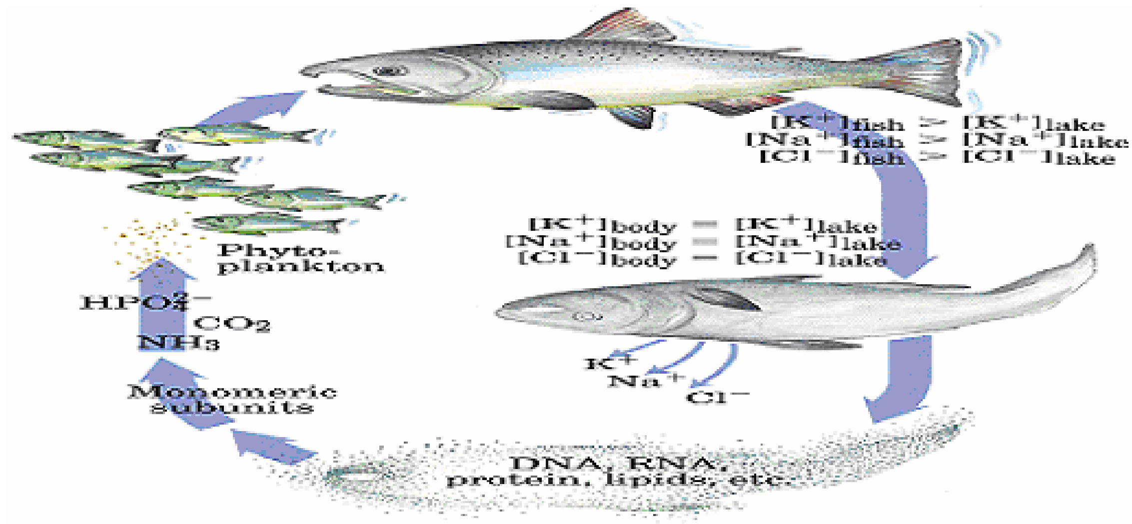


Energy

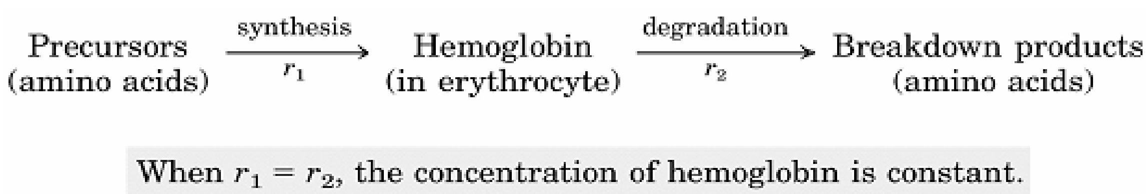
The central theme in biochemistry (both its making & storage)

Organisms are **never at equilibrium with their surroundings**

Oily membrane enclosed the water soluble molecules. The molecules and ions contained within a living organism differ in kind and in concentration from these in the organism's surroundings.



Molecular composition reflects a dynamic steady state.
Molecules are synthesized and then broken down by continuous chemical reactions involving a constant flux of mass and energy through the system.



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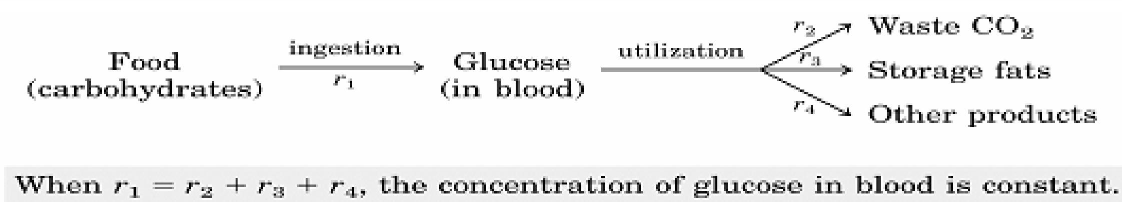


(b)

The constancy of contraction is the result of a **dynamic steady state.**
Organisms transform energy and matter from their surroundings.
Biochemistry examines the processes by which energy is extracted, channeled and consumed.

Bioenergetics - the energy transformations and exchanges on which all living organisms depend

System - all the reactants and products present, the solvent and the immediate atmosphere – in short, everything within a defined region of space

Universe - the system and its surroundings together

- if a system exchanges neither matter nor energy with its surroundings, it is said to be **closed**

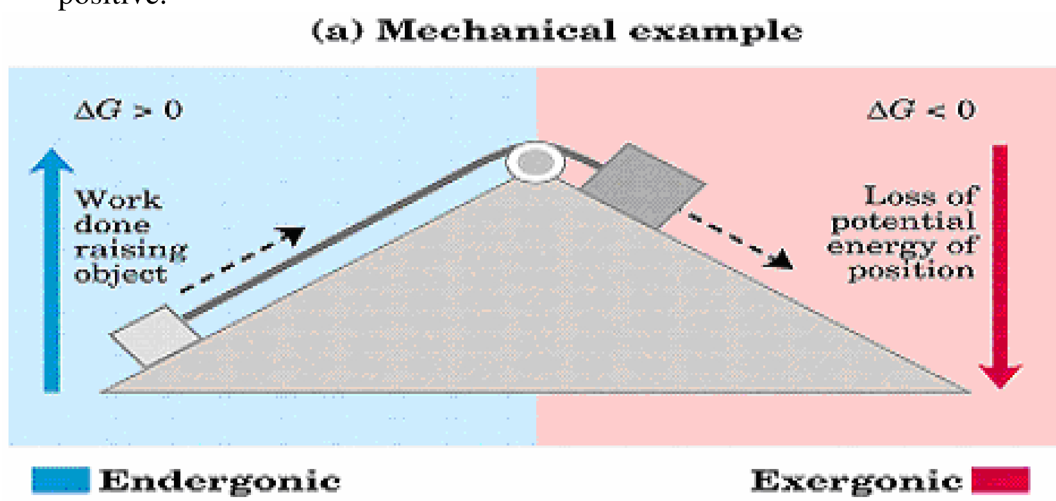
- if the system exchanges energy but not matter with its surroundings, it is an **isolated** system
- if it exchanges both energy and material with its surroundings it is as **open** system

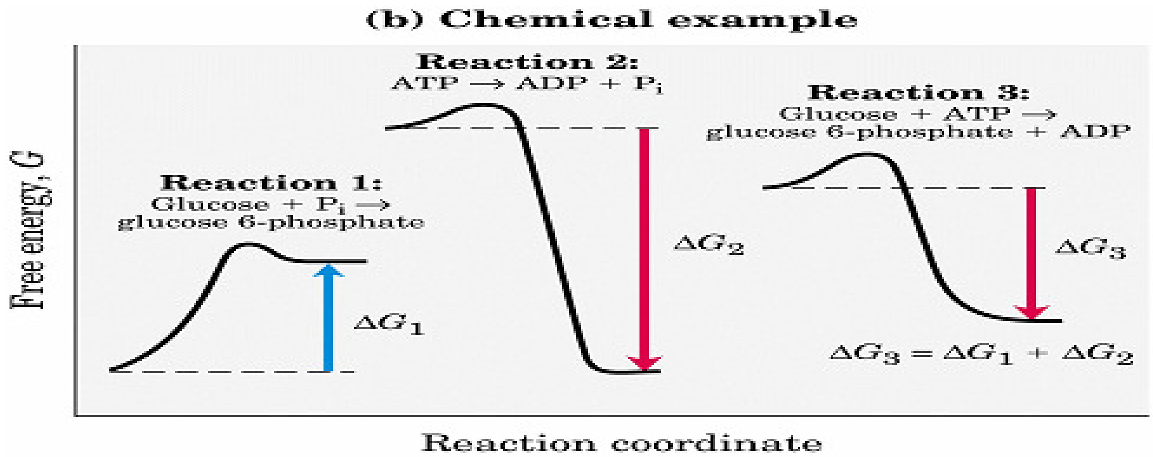
The flow of electrons provides energy for organisms

- Nearly all living organisms derive their energy, directly or indirectly from the radiant energy of sunlight, which arises from thermonuclear fusion reactions occurring in the sun.
- Virtually all energy transductions in cells can be traced to the **flow of electrons** from one molecule to another, in a 'downhill' flow from higher to lower electrochemical potential.
- All these reactions involving electron flow are oxidation-reduction reactions; some reactant is oxidised (loses electrons) as another is reduced (gain electrons).
- The flow of electrons in **oxidation-reduction reactions;** underlies energy transductions in living cells.
- Living organisms are interdependent, exchanging energy and matter via the environment.

Energy coupling links reactions

- The amount of energy actually available to do work is called the free energy, **G**.
- Chemical reactions in closed systems proceed spontaneously until **equilibrium** is reached. When a system is at equilibrium, the rate of product formation exactly equals the rate at which product is converted to reactant, thus a 'steady state' is achieved.
- The energy change as the system moves from its initial state to equilibrium, with no changes in temperature or pressure, is given by the free-energy change, **ΔG**.
- **Exergonic** – the products have less free energy than the reactants, thus give out energy. Reaction occurs spontaneously. ΔG is therefore negative.
- **Endergonic** – reaction require an input of energy, and their ΔG is therefore positive.





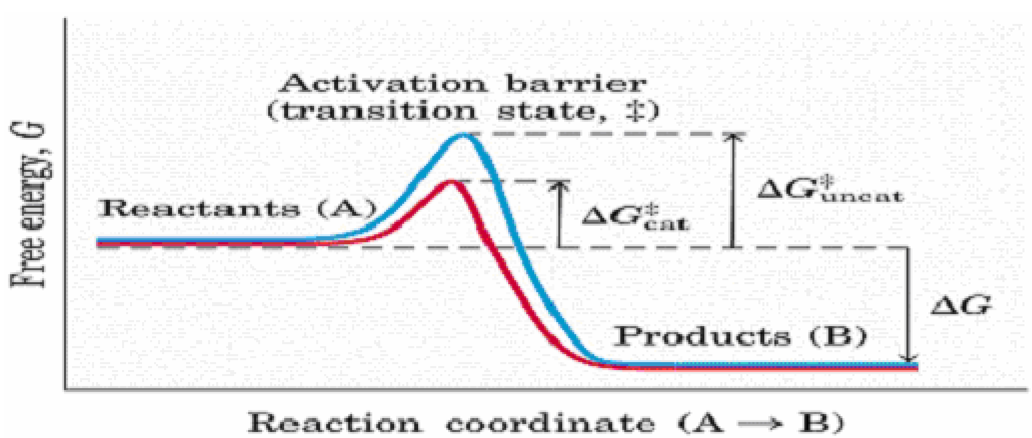
Enzymes promote sequences of chemical reactions

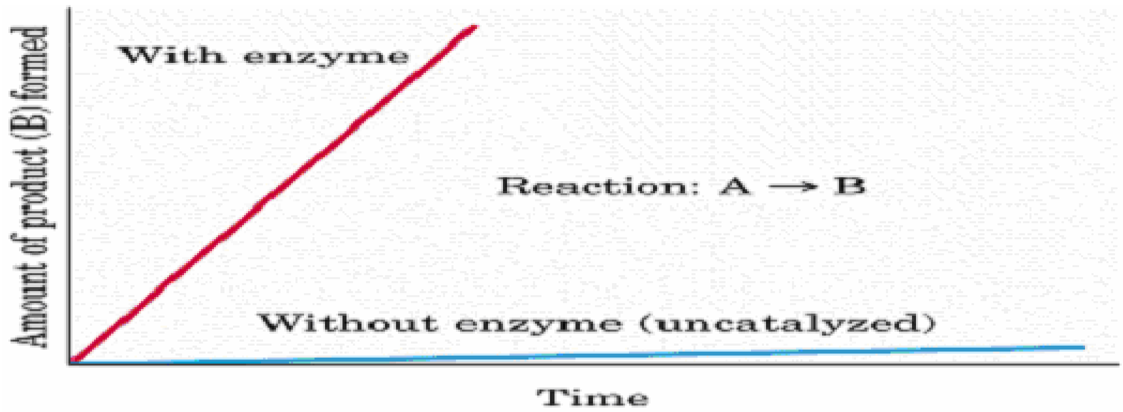
An exergonic reaction does not necessarily proceed rapidly. The path from reactant(s) to product(s) almost invariably involves an energy barrier, called **activation barrier**.

The breaking of existing bonds and formation of new ones generally requires the distortion of the existing bonds, creating a **transition state** of higher free energy than either reactant or product. **Activation energy (ΔG*) –** the amount of energy (in joules) required to convert all the molecules in 1 mole of a reacting substance from the ground state to the transition state.

Enzyme – biocatalysts that, like all other catalysts, greatly enhance the rate of specific chemical reactions without being consumed in the process.

Enzyme-catalysed chemical reactions in cells are functionally organised into many different sequences of consecutive reactions called **pathways**, in which one reaction becomes the reactant in the next.

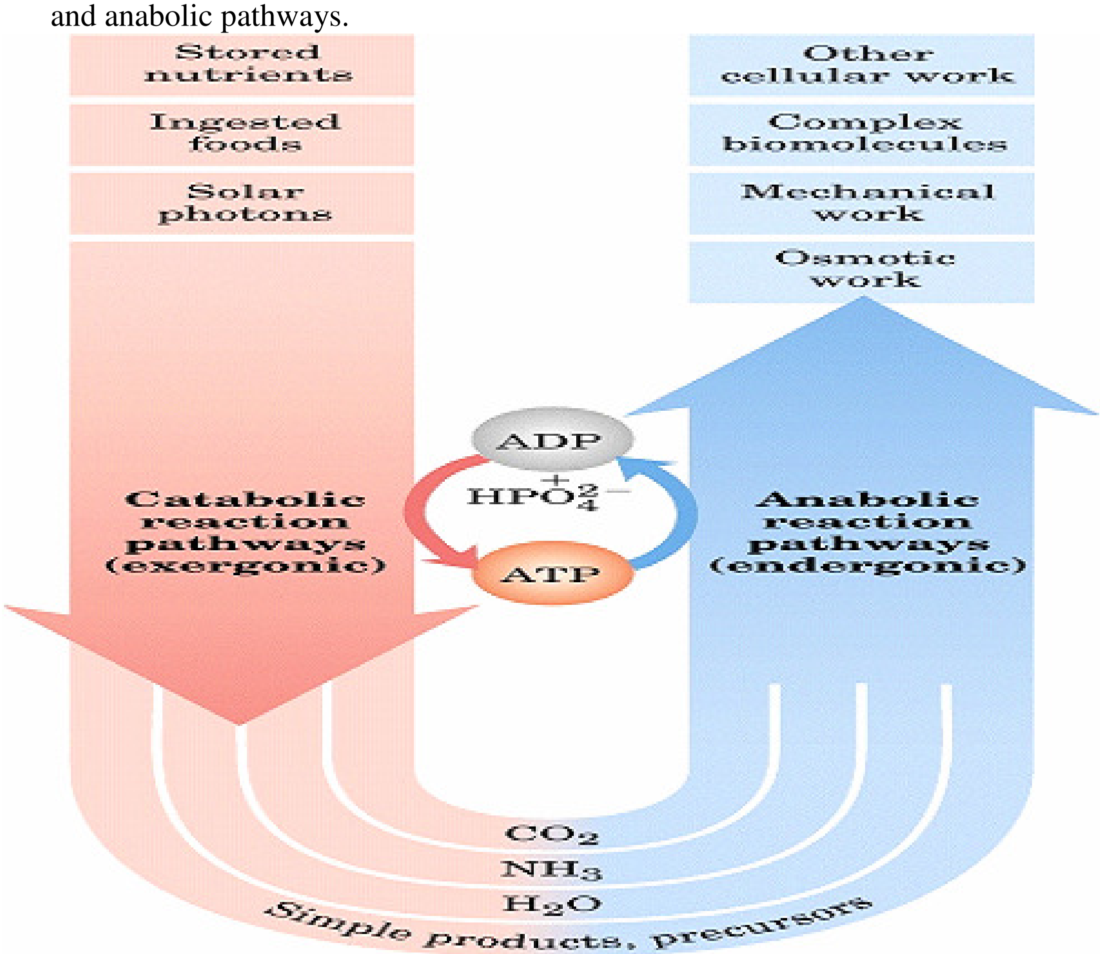




- **Catabolism –** The phase of intermediary metabolism concerned with the energy-yielding **degradation** of nutrient molecules.

- **Anabolism –** The phase of intermediary metabolism concerned with energy-requiring **biosynthesis** of cell components from smaller precursors.

- The overall network of enzymes-catalysed pathways constitutes **cellular metabolism.** **ATP** is the universal carrier of metabolic energy, linking catabolic and anabolic pathways.



Living cells are self-regulating chemical engines, continually adjusting for maximum economy. One mechanism of control is **feedback inhibition** which keeps the production and utilisation of each metabolic intermediate in balance.