Biochemistry

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"Living things are composed of lifeless molecules" (Albert Lehninger)

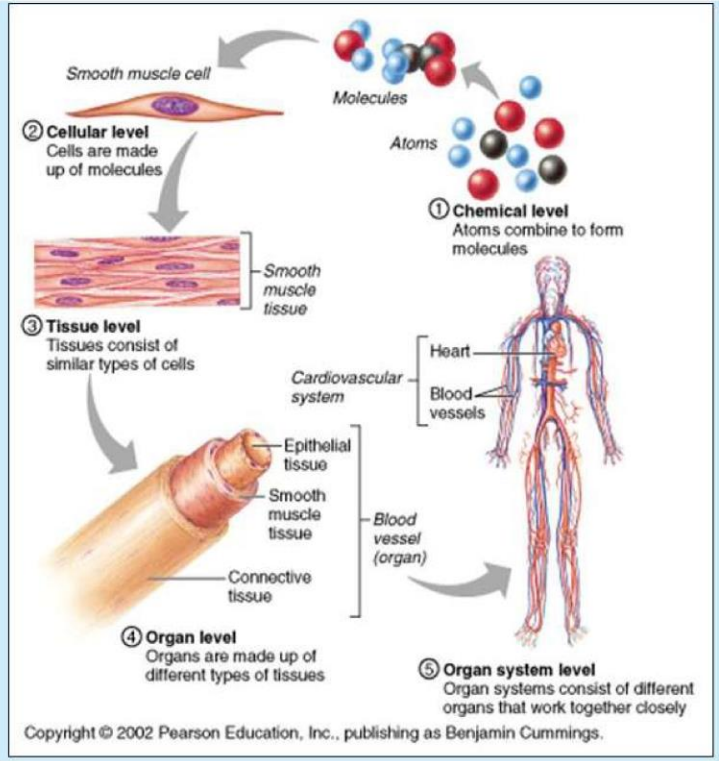
Where is the borderline?

Organism

Molecules

Biochemistry asks how the remarkable properties of living organisms arise from the thousands of different lifeless biomolecules.

Physical laws – chemical reactions



Atoms

Molecule

Organelle

Cell

Tissue

Organ

Organ System

Organism

Living Organisms vs lifeless matter

A high degree of chemical complexity and microscopic organization.

Systems for extracting, transforming, and using energy from the environment

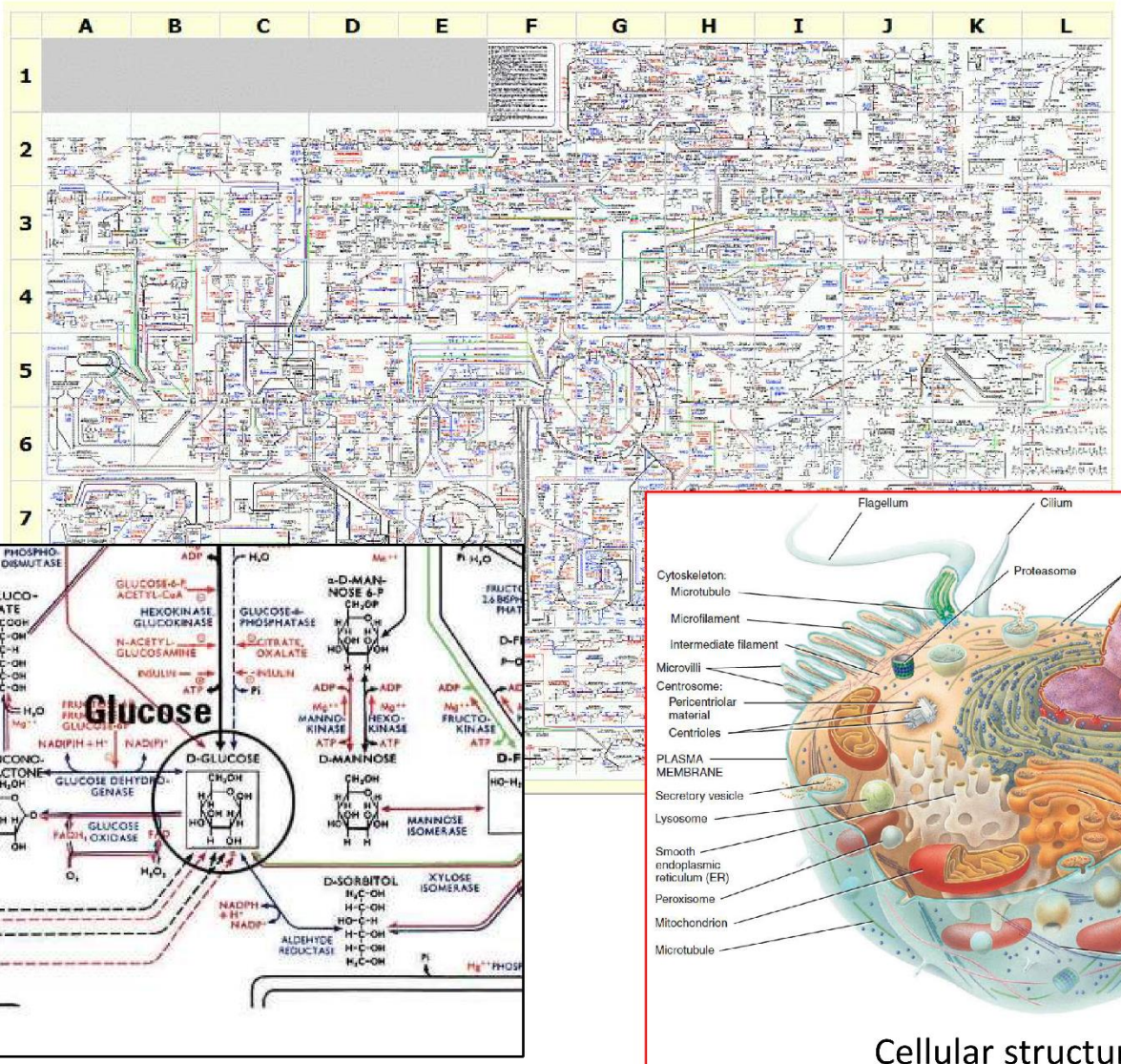
A capacity for precise self-replication and self-assembly

Mechanisms for sensing and responding to alterations in their surroundings

Evolutionary change

1. Structure
2. Function
3. Direction
4. *Coordination*
   Interaction
   Adaptation

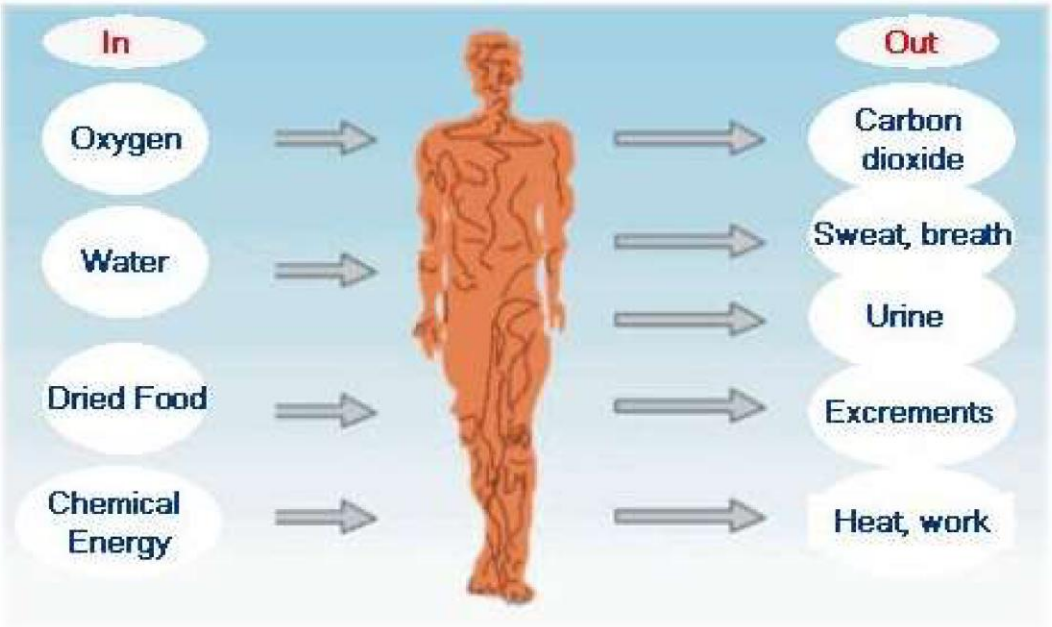
A high degree of chemical complexity and microscopic organization (structure).



Metabolic pathway map

Cellular structure

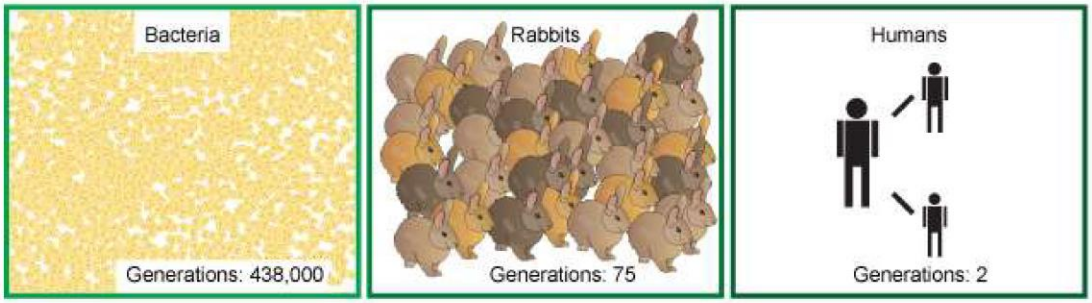
Systems for extracting, transforming, and using energy from the environment (function)



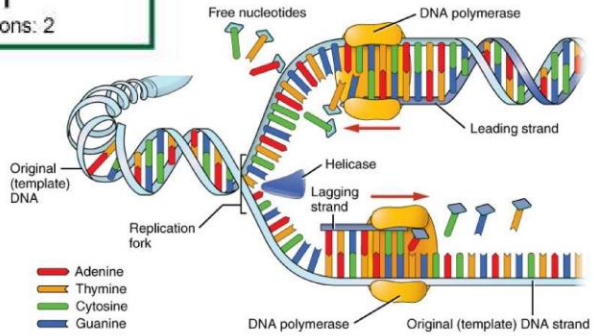
Energy in Reactions:

- some chemical reactions release energy, and other reactions absorb it
- living organisms carry out many reactions that require, or absorb, energy
- this means every organism must have a source of energy
- ENERGY TRANSFORMATION!

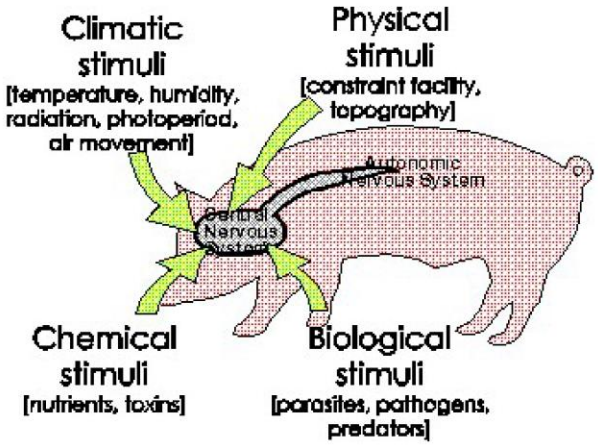
A capacity for precise self-replication and self-assembly (direction)



Viruses?



Structural/Behavioral/Physiological adaptation



Plant Response to Herbivores

- ✓ Plants damaged by insects can release volatile chemicals to warn other plants of the same species
- ✓ These volatile molecules can also function as an "early warning system" for nearby plants of the same species.
- ✓ **Methyljasmonic acid** can activate the expression of genes involved in plant defenses

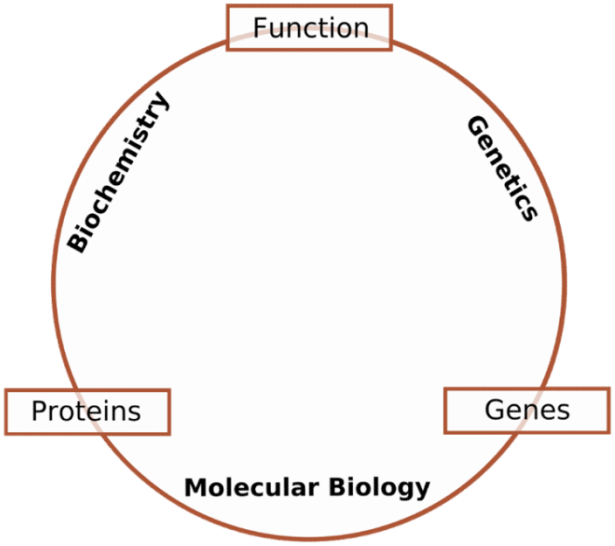
1. **Organisms are complicated and highly organized**

2. **Biological structures serve functional purposes**
   Living systems are actively engaged in energy transformations

3. **Living systems have a remarkable capacity for self-replication**

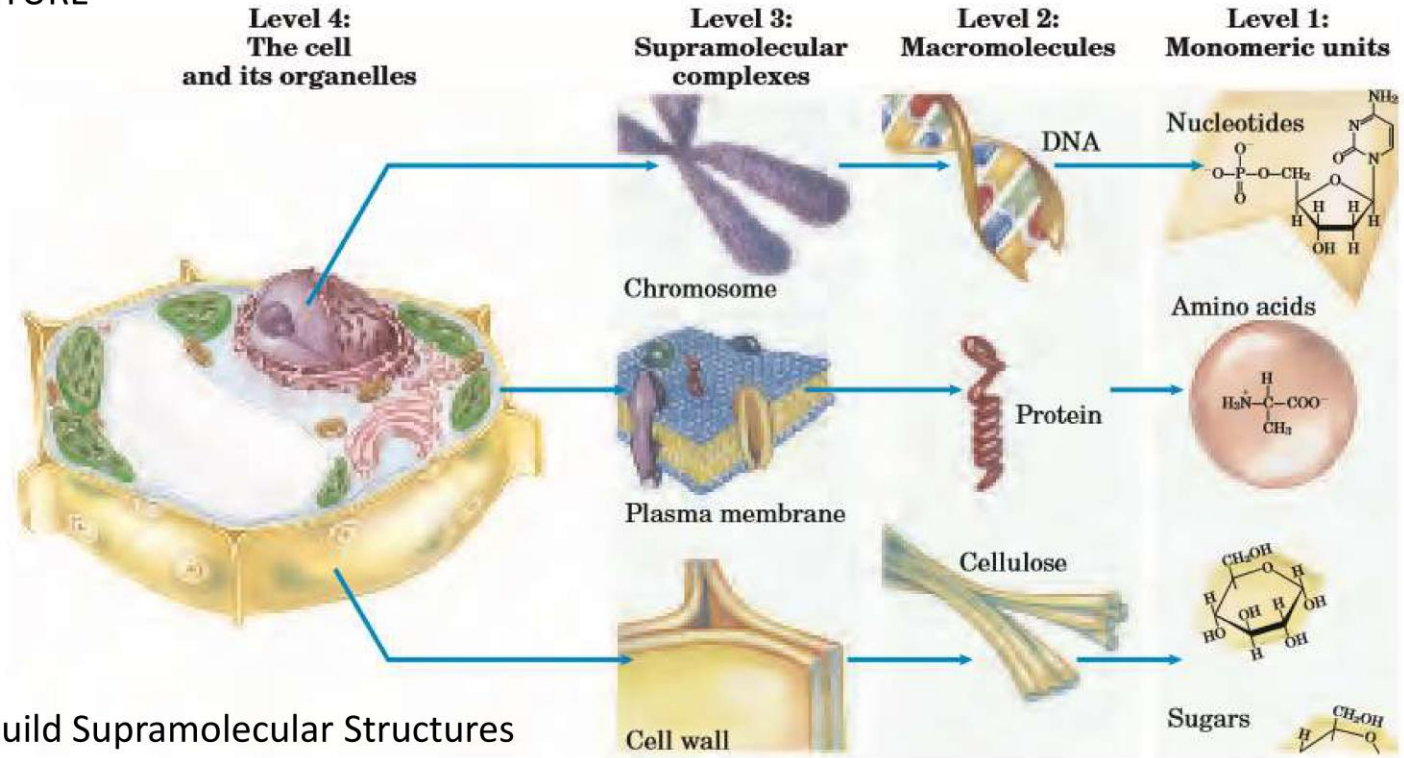
4. **Living systems sense and react to the environmental changes**

Position of Biochemistry and other sciences



biochemistry provides important insights and practical applications in medicine,
agriculture,
nutrition, and industry

STRUCTURE



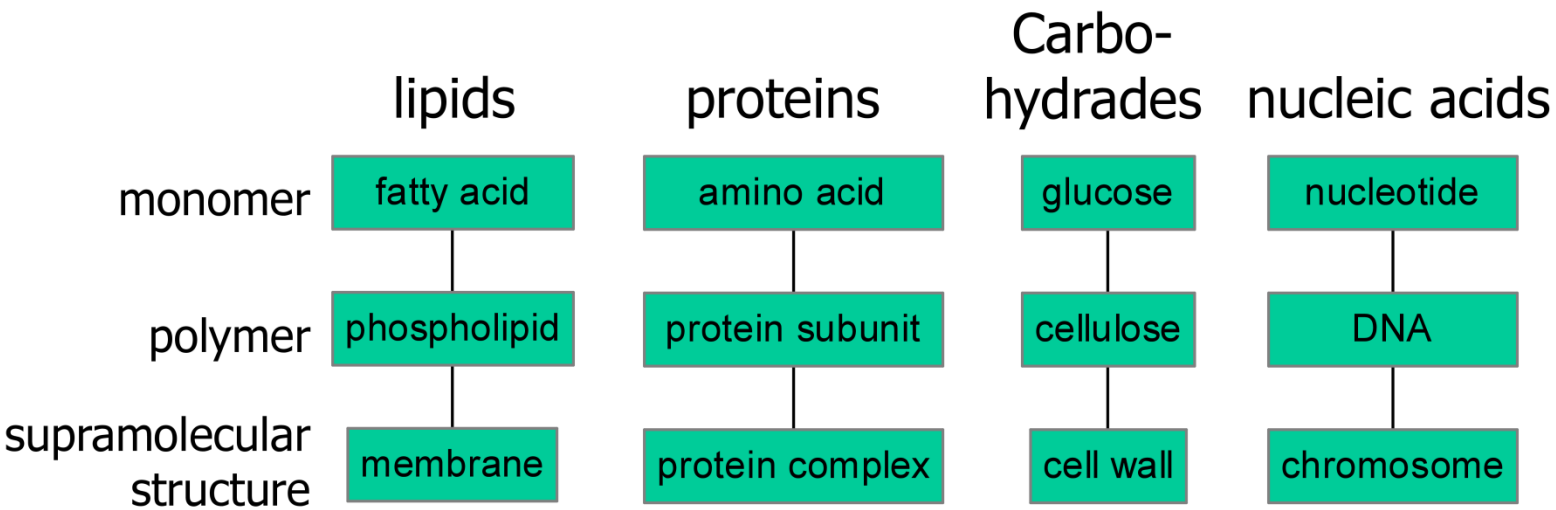
Cells Build Supramolecular Structures

Biopolymers – 1. informational source
2. structure (cell wall/cellular skeleton)
3. chemical transformation (enzymes)
biological function
4*. energy source (sugar, starch)

Low molecular weight compounds!

Biopolymers – essential components of life

Biopolymers –	*Monomers –*
proteins	*aminoacids + etc*
lipids	*fatty acids, choline, glycerol*
nucleic acids	*nucleotides (heterocyclic bases, sugar, phosphate)*
carbohydrates (polysaccharides)	*Sugars + etc*



Bonding in biopolymers

- Bonds –
- 1. Covalent
- 2. Noncovalent
- A) hydrogen
- B) ionic
- C) hydrophobic
- D) Van der Waals interactions

Covalent bonds

- Covalent bonds – strong

Hold the atoms together!

- Noncovalent bonds – weaker

Form the 3D structure of molecules and molecular complexes

NB: The network of weak bonds can be as powerful as strong bond

Covalent bonding

- Electron structure of the outer shell of atom defines the number of covalent bonds an atom can form

H -1

C – 4

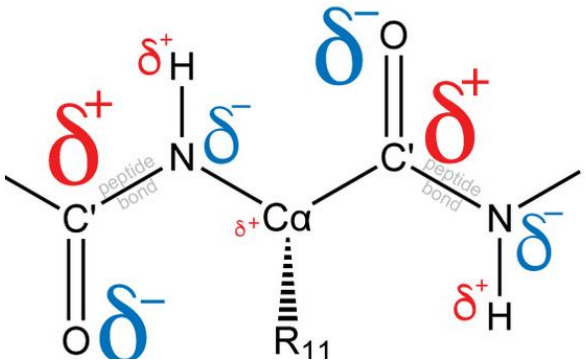
N – 3

P – upto 5

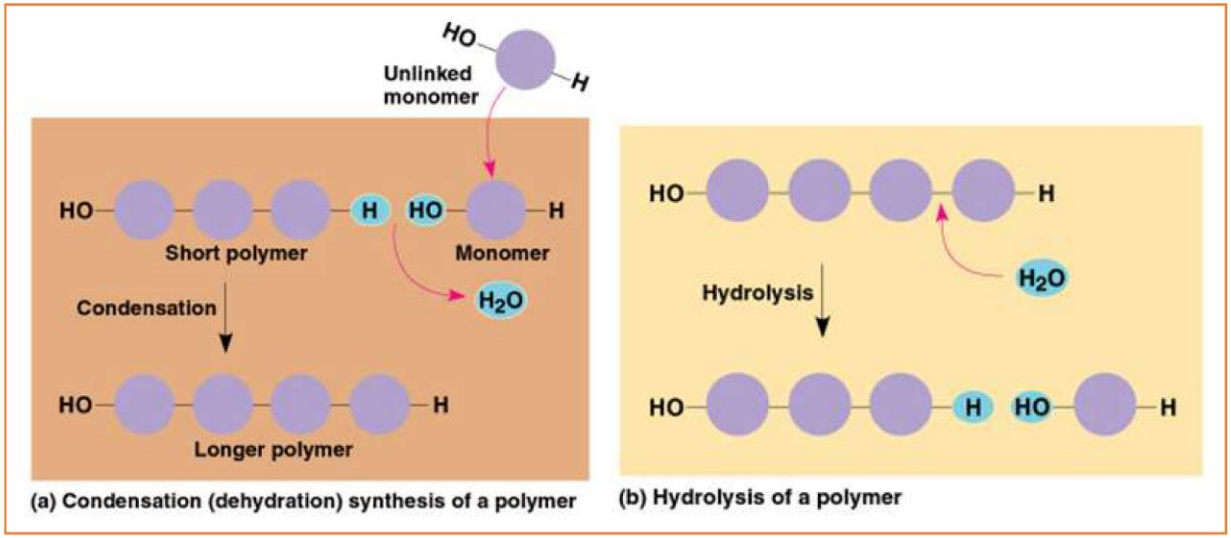
O – 2

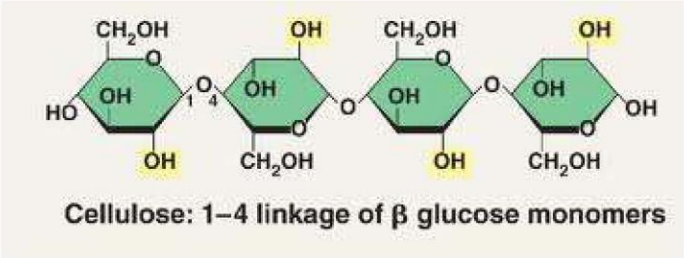
S – upto 6

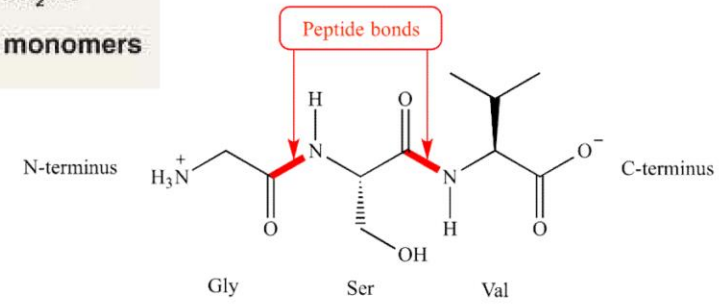
- If two atoms of different electronegativity are connected by covalent bonding then the bond will be dipolar

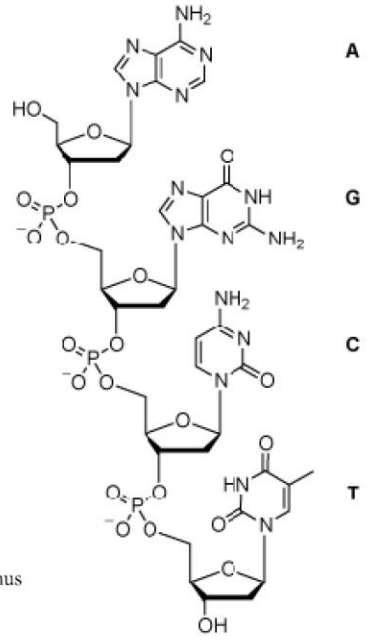


Majority of biopolymers consists of monomers connected by covalent bonds

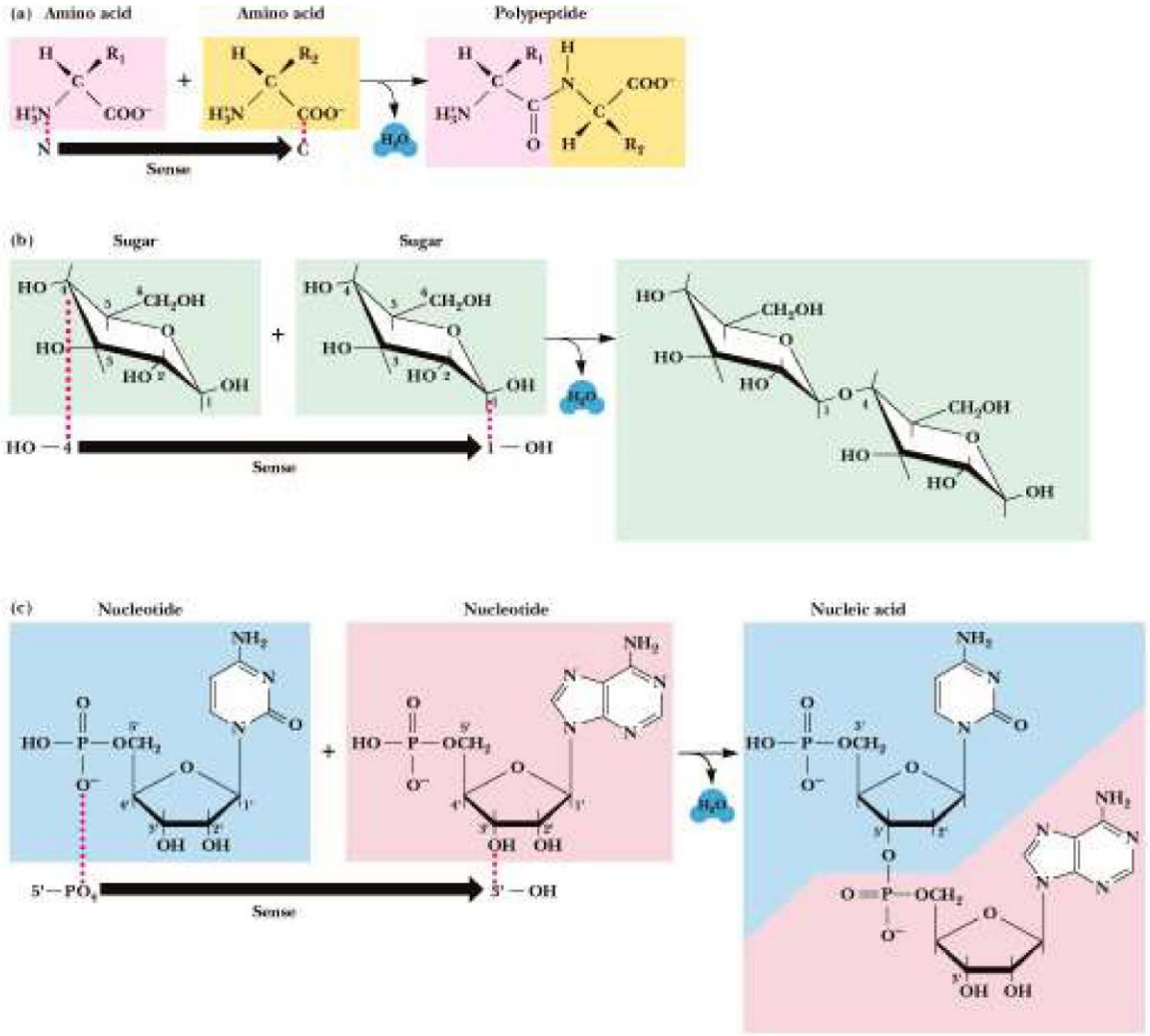






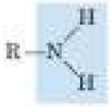


Building blocks of common biopolymers

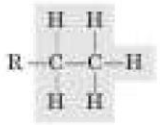


Methyl

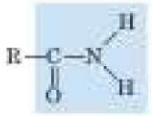
Amino



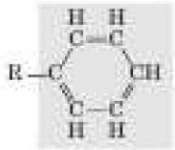
Ethyl



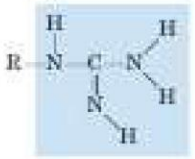
Amido



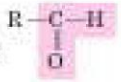
Phenyl



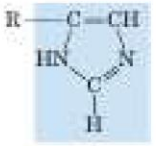
Guanidino



Carbonyl (aldehyde)

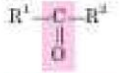


Imidazole



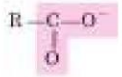
Covalent bonds found in biopolymers

Carbonyl (ketone)



Sulfhydryl

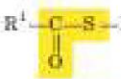
Carboxyl



Disulfide

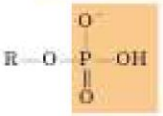
Hydroxyl (alcohol)

Thioester

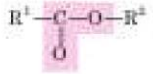


Ether

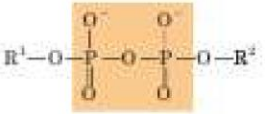
Phosphoryl



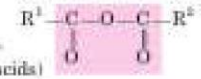
Ester



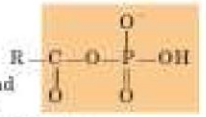
Phosphoanhydride

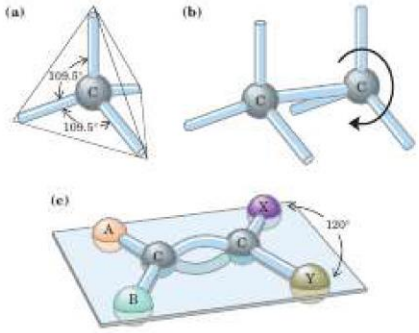


Anhydride (two carboxylic acids)



Mixed anhydride (carboxylic acid and phosphoric acid; also called acyl phosphate)

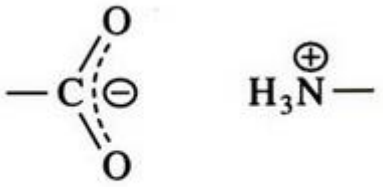




Ionic bonding

- Ionic bonds forms between ions
  - Ions are generated, when electrons are transferred from 1 atom to another
  - The moiety that lost electron will be **positively** charged
  - The moiety that gained electron will be **negatively** charged

  - Ionic bond – a bond between positively and negatively charged moieties (molecules/parts of molecules/groups)
  - Ionic bond do not have fixed geometric orientation

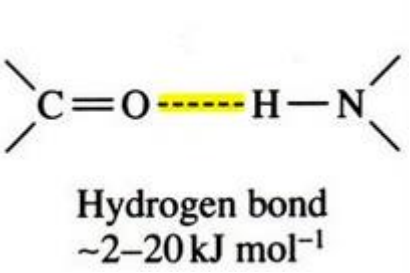


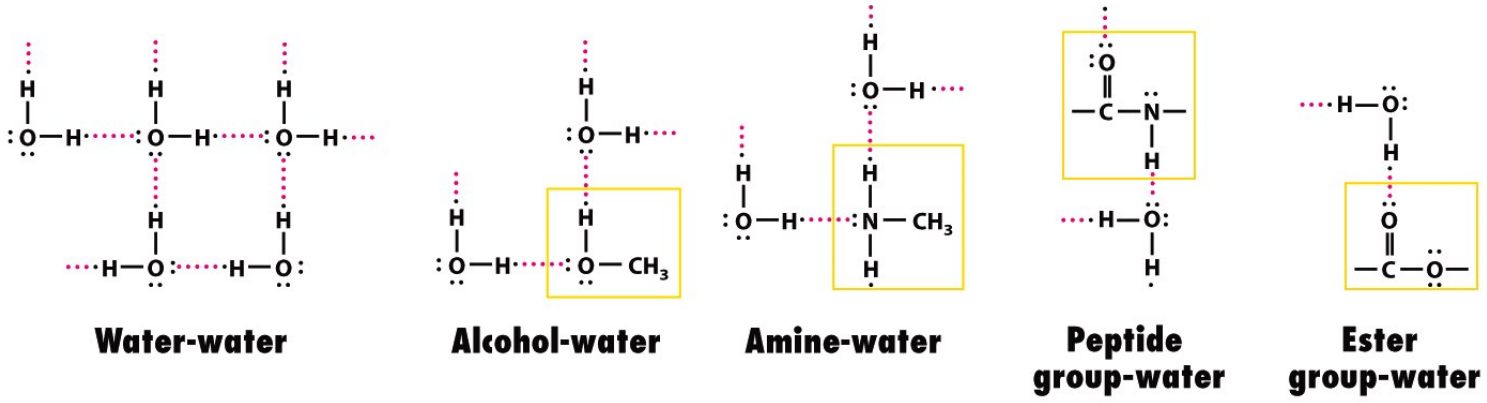
Charge-charge interaction
~40–200 kJ mol^{-1}

Hydrogen bonding

- Weak association between electronegative (acceptor) atom and hydrogen atom, connected to another atom covalently (donor atom)

Hydrogen in this case is still covalently bound to donor atom



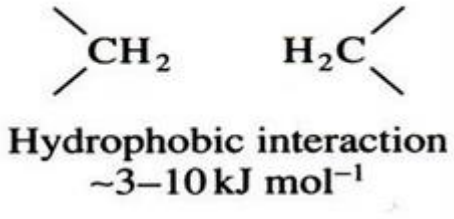


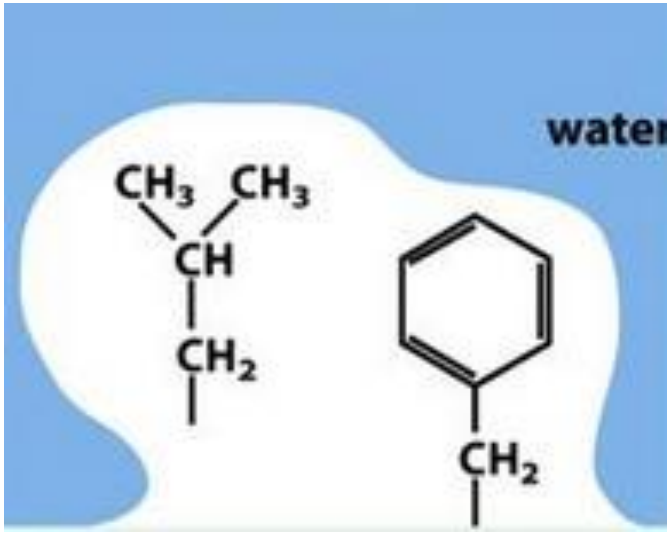
For example in water – hydrogen ia attracted to the pair of electrons on the outer shell of oxygen in the next water molecule

Hydrophobic interactions

- Weak association between nonpolar molecules to minimize their exposure to polar molecules (for example – water molecules)

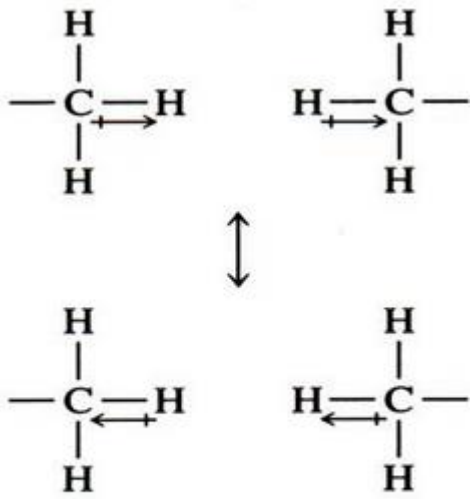
Hydrogen in this case is still covalently bound to donor atom





Van der Waals interactions

- Weak association between (transient) molecular dipoles.



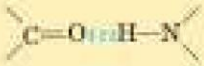
The electron density in one molecule forms transient dipole.
This dipole disturb the electron cloud of the other molecule therefore the second transient dipole is generated.
Two transient dipoles weakly interact

VDW interaction – very weak and rapidly weakens with a distance between molecules.

Both polar and nonpolar molecules can exibit VDW interactions (i.e. dipoles and induced dipoles)

VDW – responsible for example for nonpolar lipids to condense to liquid and solid states at respective temperature

TABLE 2-5 Four Types of Noncovalent ("Weak") Interactions among Biomolecules in Aqueous Solvent

Hydrogen bonds	
Between neutral groups	
Between peptide bonds	
Ionic interactions	
Attraction	
Repulsion	
Hydrophobic interactions	
van der Waals interactions	Any two atoms in close proximity

Weak interaction in biopolymers

Hydrogen bonds

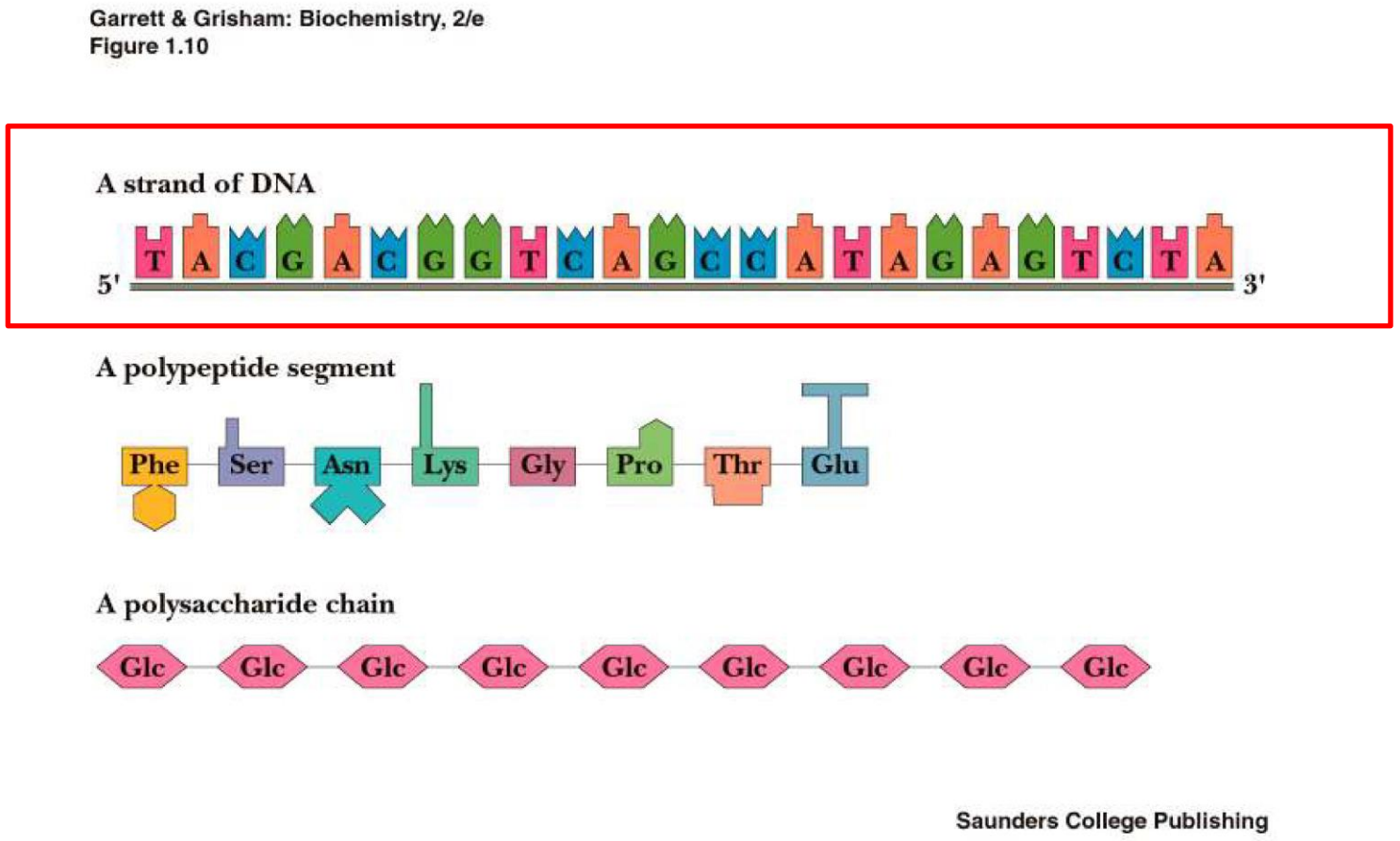
Ionic interactions (charged biomolecules)

Hydrophobic interaction (protein cores)

Covalent bonds
Hydrogen bonds
Ionic interaction
Hydrophobic bonds
Van der Waals interactions

Functional use of biopolymers/biomonomers in the fate of the cell

1. INFORMATION

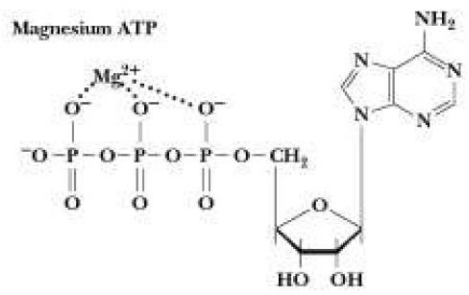


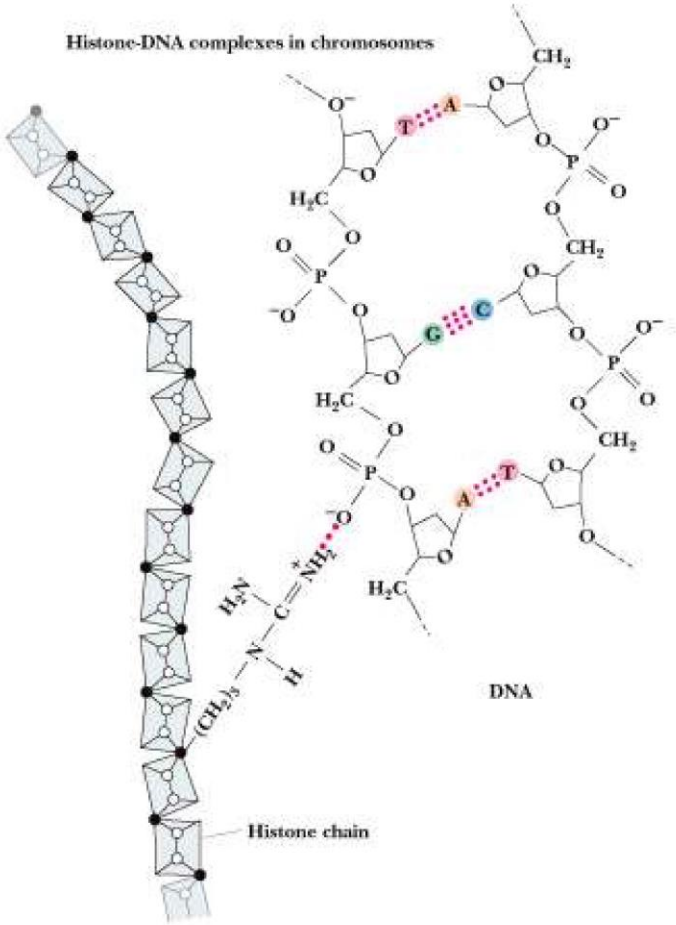
Variation in the structure of monomers can be used to “code” information.
Alternating interactions (weak) with monomers is the used to decode-transfer information.

2. STRUCTURE

Various structures of monomers, side chains taken together with weak non-geometrical bonding gives vast possibilities to form 3D structures

3. Biological function as a result of weak interaction





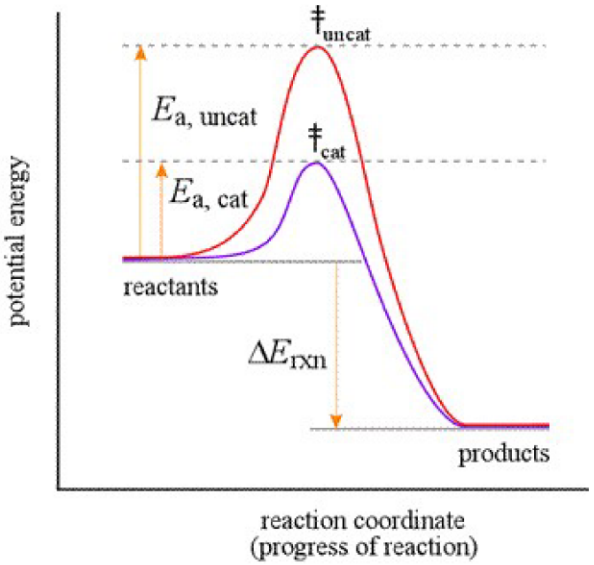
Various structures taken together with weak interactions that can be easily broken and formed results in variety of functions to be performed

1. informational source

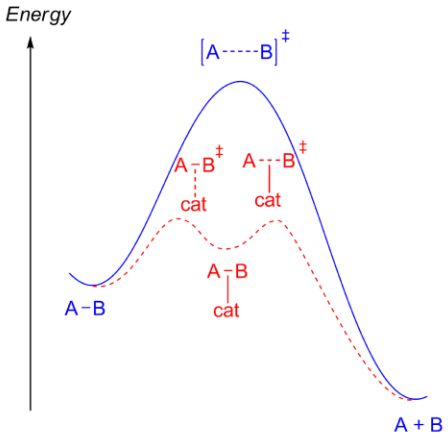
2. structure (cell wall/cellular skeleton)

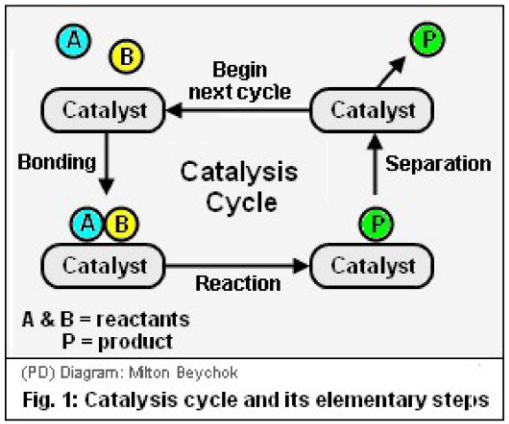
3. chemical transformation (enzymes)
   biological function

CHEMICAL REACTIONS - CATALYSIS



OR

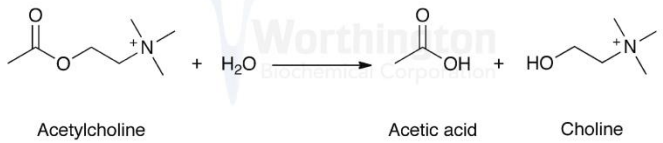




(PD) Diagram: Milton Beychok

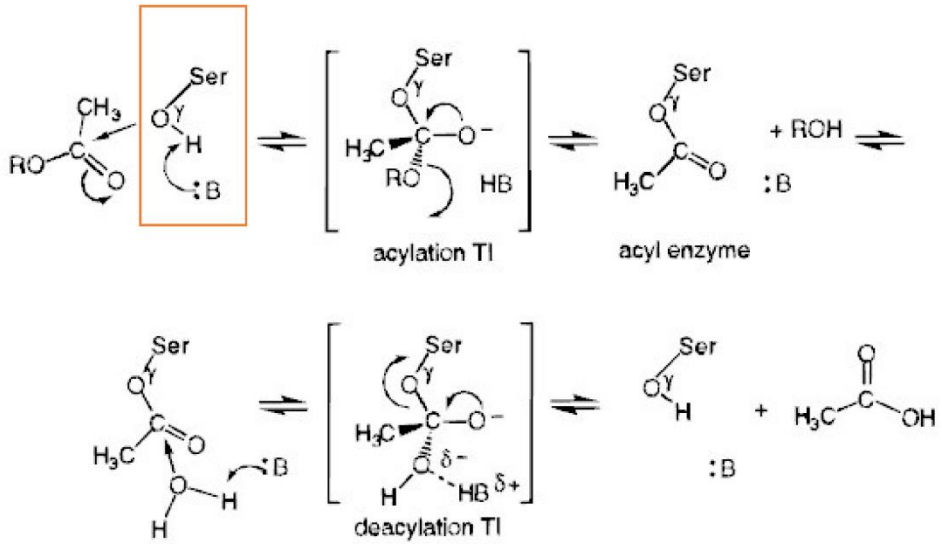
Fig. 1: Catalysis cycle and its elementary steps

BIOCATALYSIS – Enzymes/Rybozymes



Reaction

Enzyme – catalyst AcetylCholinesterase



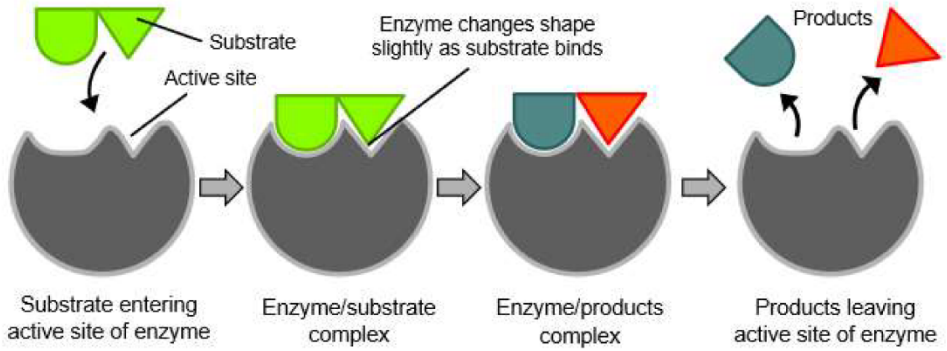
BIOCATALYSIS – Enzymes/Rybozymes

Enzymes FUNCTION in
- food digestion
- signaling in cell
- nervous system signal transfer
- muscle contraction
- genetic material replication
- molecular motors

Enzymes NATURE
- proteins + (cofactors)
- ribozymes

Enzymes FEATURES
- VERY high specificity
- VERY high speedup of reactions

As a result of enzyme structure



Literature biochemistry

1. Lehninger Principles of Biochemistry (Nelson D.L., Cox M.M.)
2. Principles and Techiniques of Biochemistry and Molecular Biology (Wilson K., Walker J.)

Biochemistry

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