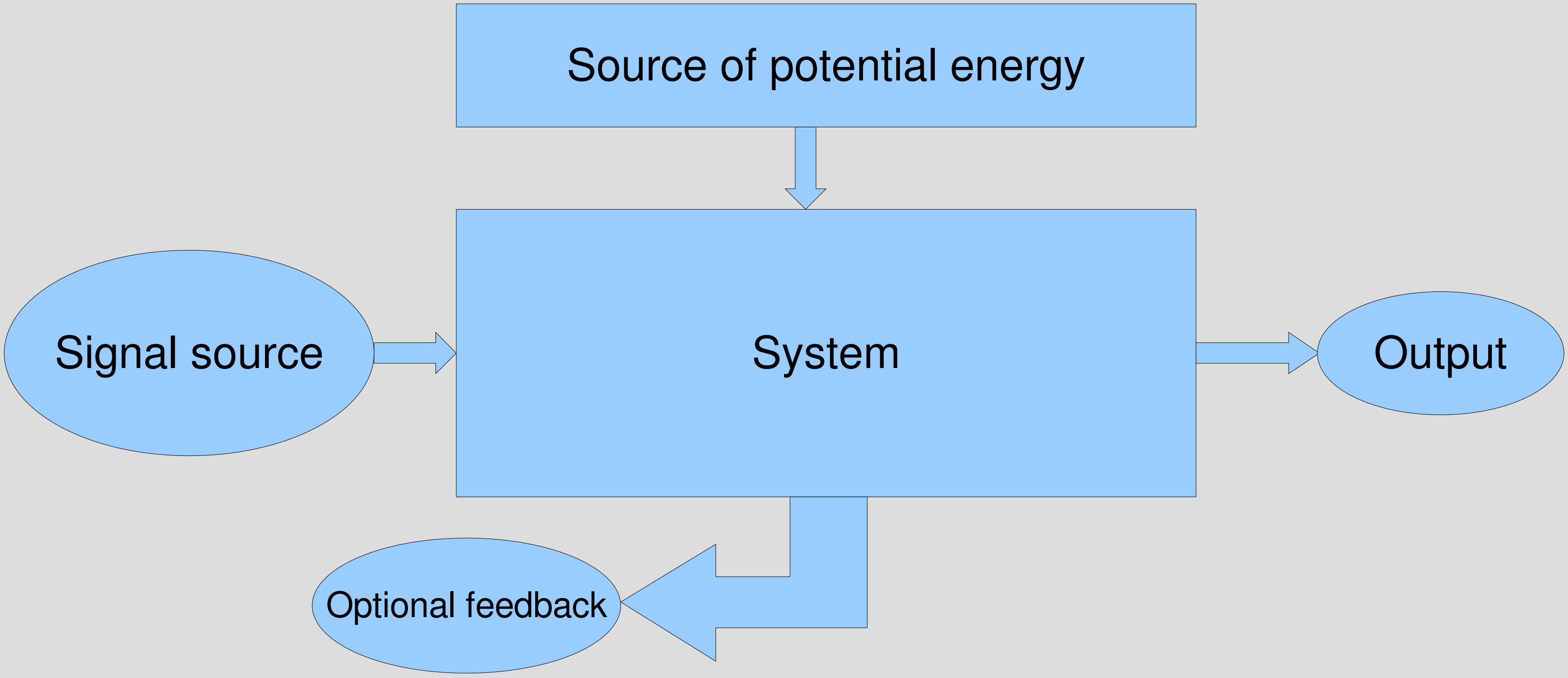
Biology from an EE perspective
Lecture 4

Will discuss:
Very broad functional similarities of systems
A recap of molecules and reactions
Highlight in what respects biomolecules different

Rakesh K Lal

Block diagram of an electrical system
!actually any engineered dynamic system!

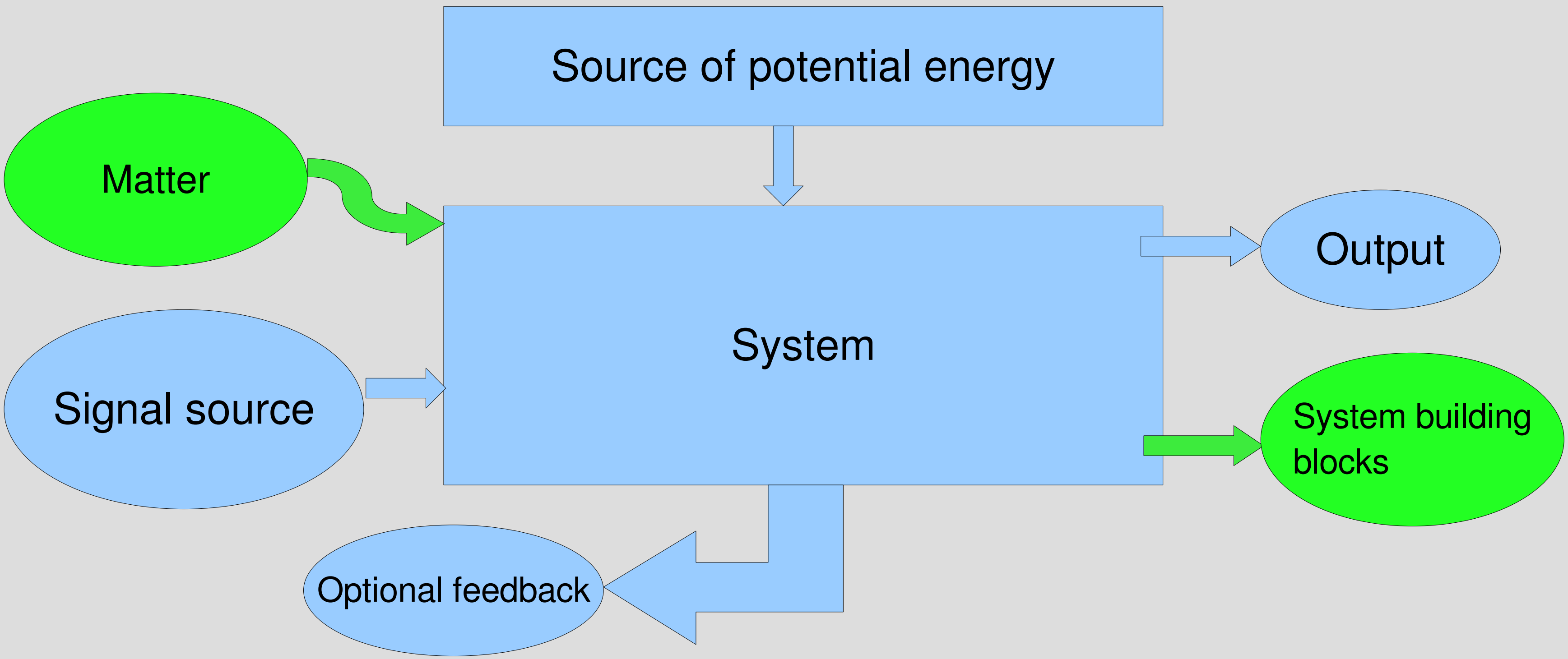
All dynamical systems are about energy conversion to perform a task



Quick comments on the block diagram

- Potential energy – thermal, hydrostatic, chemical, optical or electrical ... – converted normally to electrical
- The outputs could be processed signals, signals for feedback, or just electrical power
- In systems there is always a transformation/cascading down of potential energy to finally thermal energy
- In common electrical systems, the signal is invariably physical often electrical
- Though we don't normally address thermodynamic issues, there is an overall increase of entropy

Block diagram of a biological system



This architectural similarity at the higher levels permits similar system level approaches in analyses of biosystems

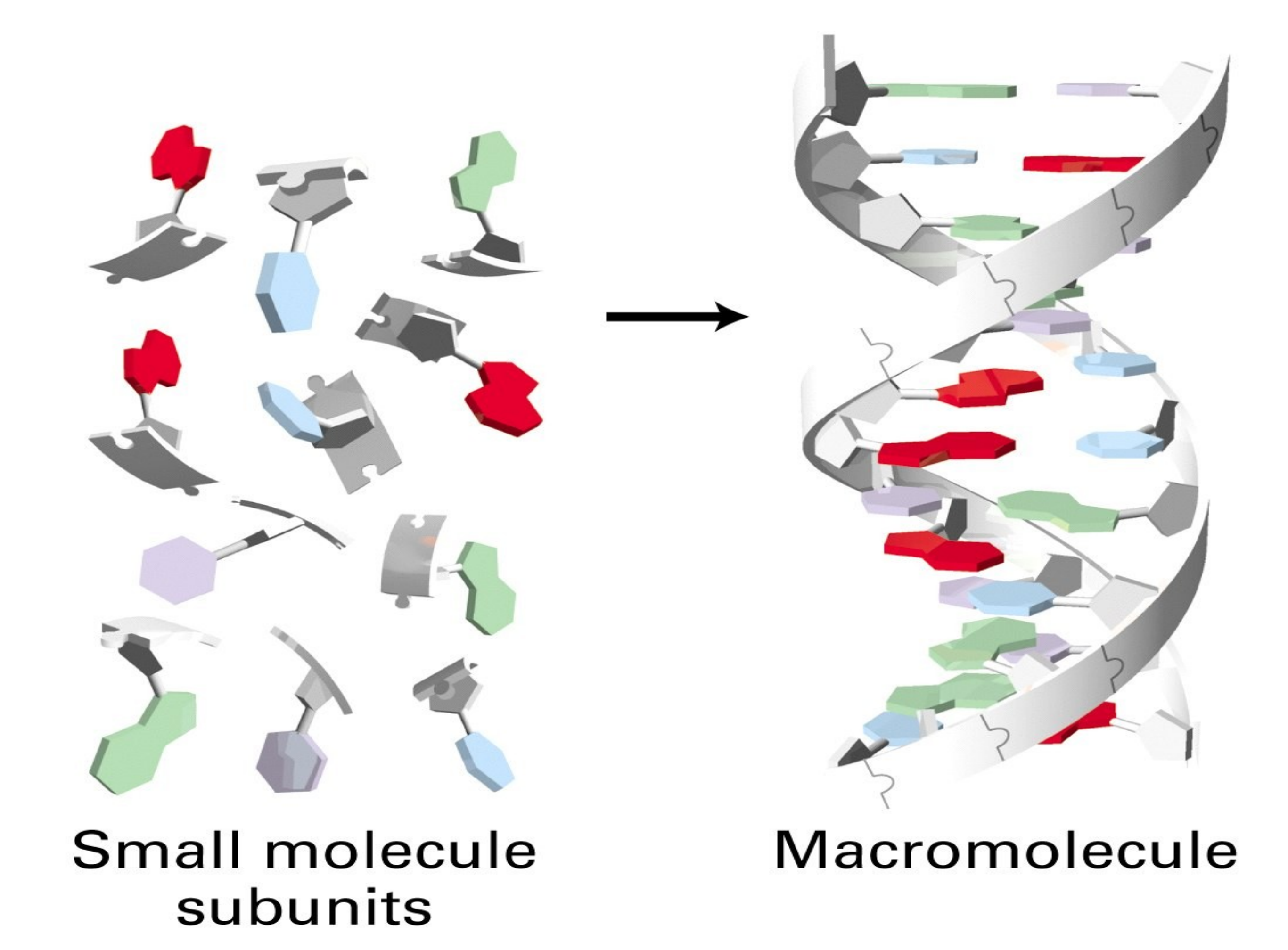
Some comments on the block diagram

- The source of potential energy is photo or chemical -- sometimes electric field could be a driving force of a subsytem but the primary energy sources are light or chemical
- The input signal can be of many kinds, most often it is chemical/biochemical
- The output signal is most often biochemical, but it could be electrical or mechanical or optical ..
- The *biggest difference* of living systems from engineered systems is the ability of the former to synthesize their own building blocks, including the machinery to build them, from the matter & energy they harvest from the environment

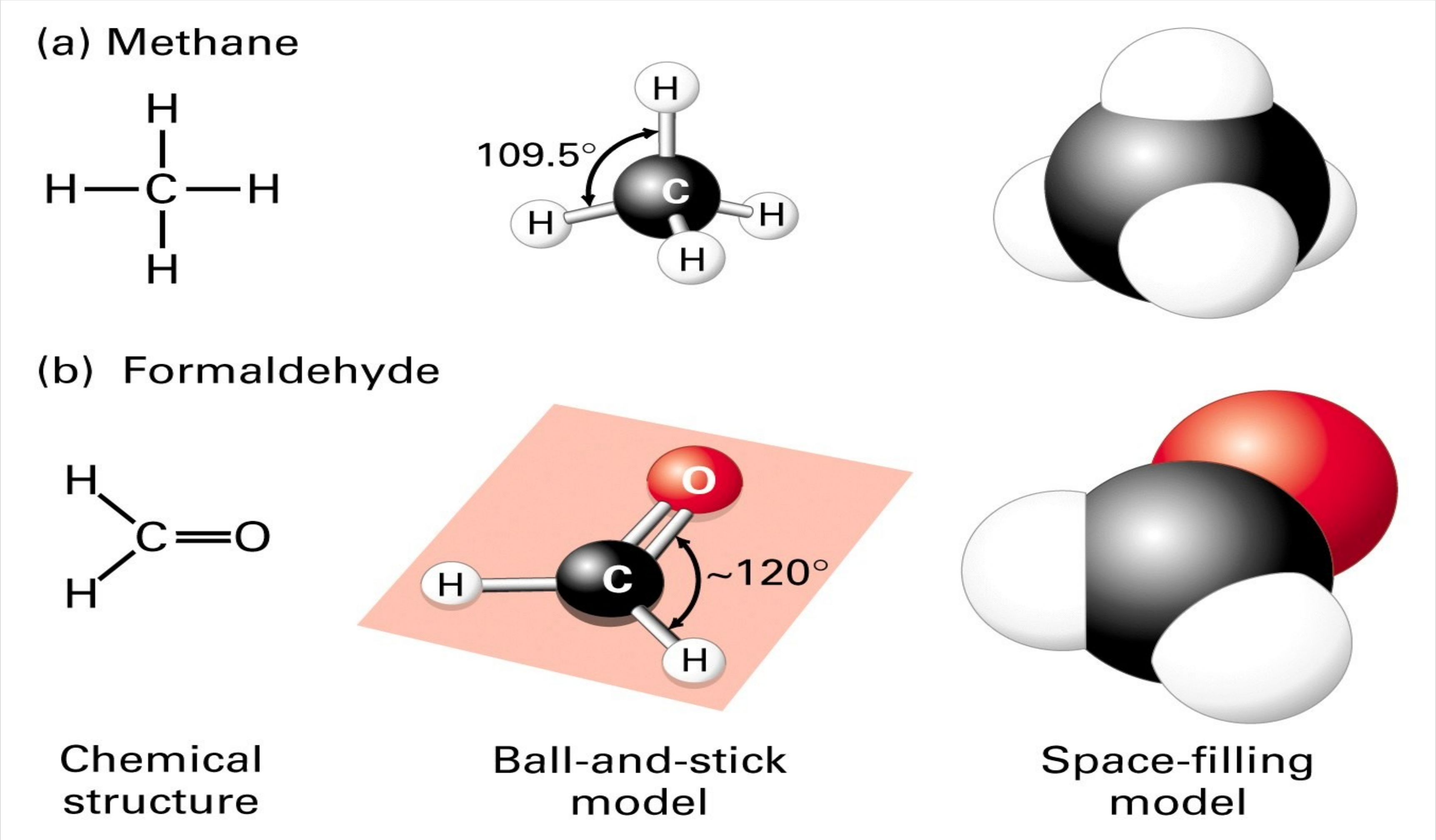
Recap of chemistry and stressing in what respects biochemistry is different

Let's recap some basic chemistry to understand how organisms transform chemical energy to signals or molecules that they need for their own synthesis

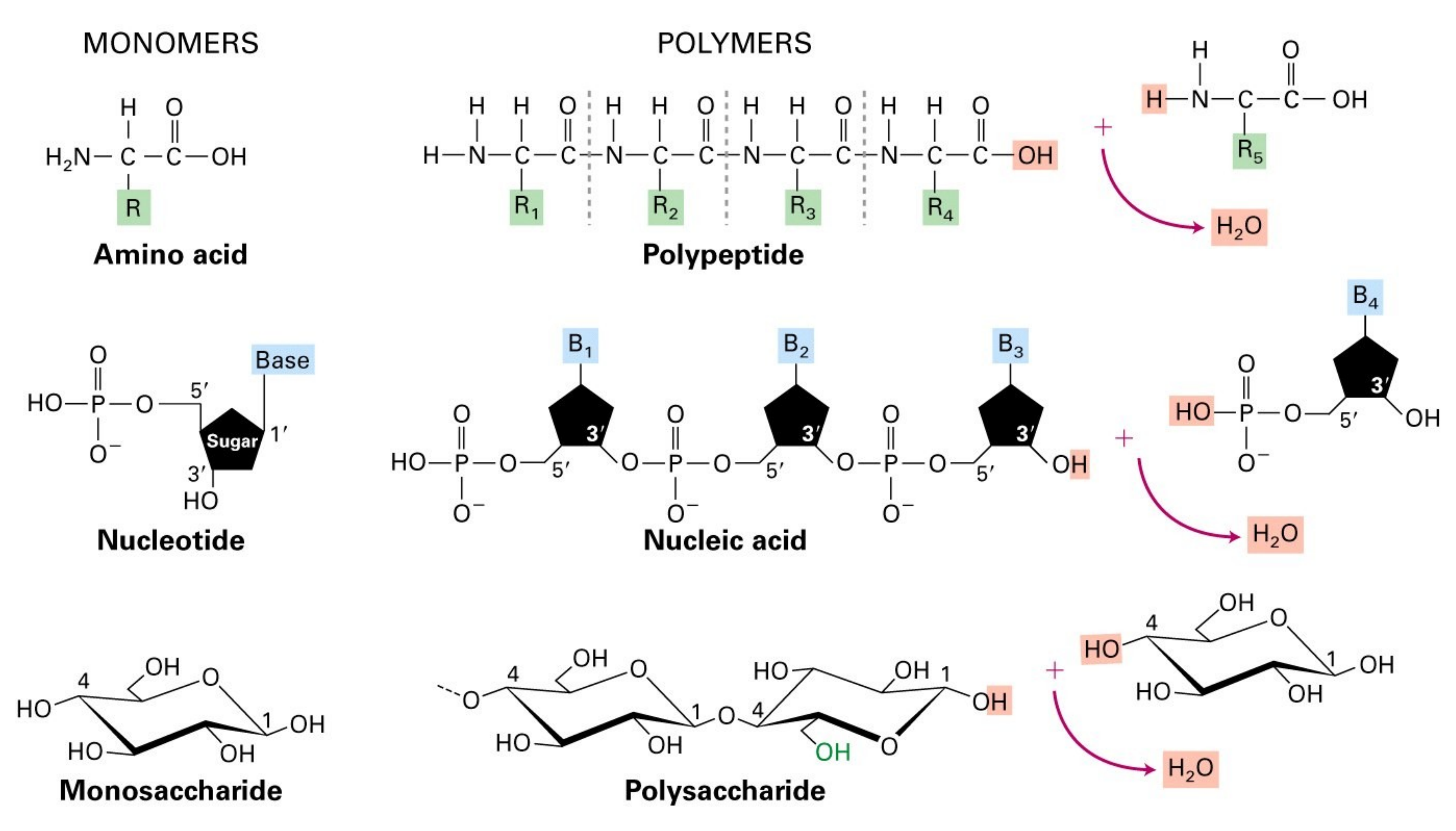
Organisms synthesize building blocks that can self-assemble or can be catalyzed to self assemble



Visual models of molecules important
-- they give hints on how reactions might happen

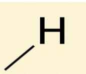
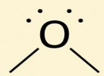
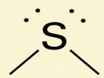
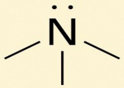
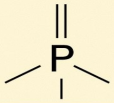
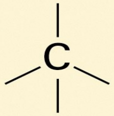


The building blocks



The important atoms in biomolecules

TABLE 2-1 Bonding Properties of Atoms Most Abundant in Biomolecules

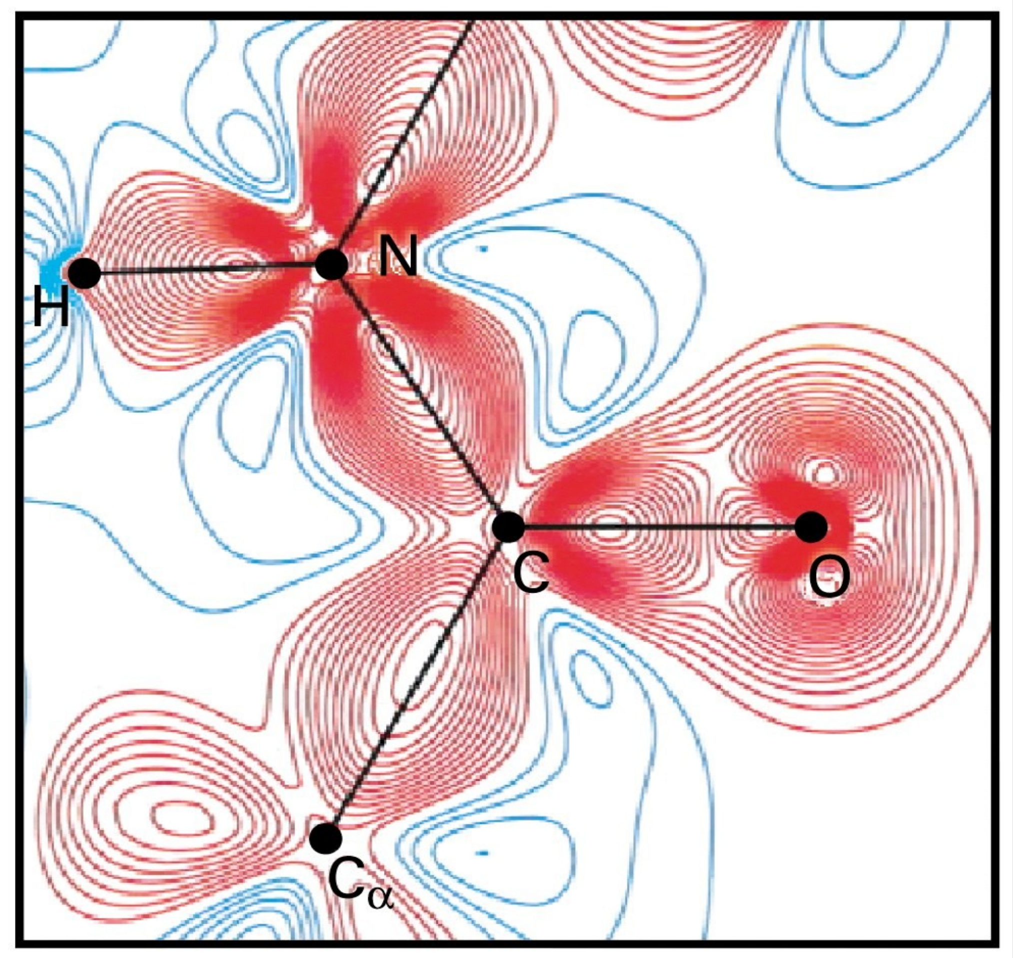
Atom and Outer Electrons	Usual Number of Covalent Bonds	Bond Geometry
H	1	
O	2	
S	2, 4, or 6	
N	3 or 4	
P	5	
C	4	

Chemical bonds between two atoms

- Covalent bond formed when the electronegativity of the atoms forming the bond similar:
  - Molecular orbital formed by a combination of atomic orbitals forming bonding and antibonding orbitals – electrons in bonding orbitals help to hold the two nuclei together & form a covalent bond
  - Bond non-polar
- Polar covalent bond formed when the electronegativity non-zero but less that 1.6
- Ionic bonds when the electronegativity difference is greater than 1.6 and the two atoms ionized and held together by electrostatic interaction rather than via sharing a molecular orbital

Non-polar & polar bonds

- In the presence of electronegativity difference the bonding electrons get localized and one gets a polar bond
- Polar bonds could result in a molecule having a dipole moment



Bonds between more than two atoms

- Aromatic bond: In rings of atoms with similar electronegativity in which single and double bonds alternate, an electron is not localized to one bond and all the molecular orbitals participating are said to form a bond
- Metallic bond: Delocalized valence electrons over the lattice help to bond the atoms forming the lattice

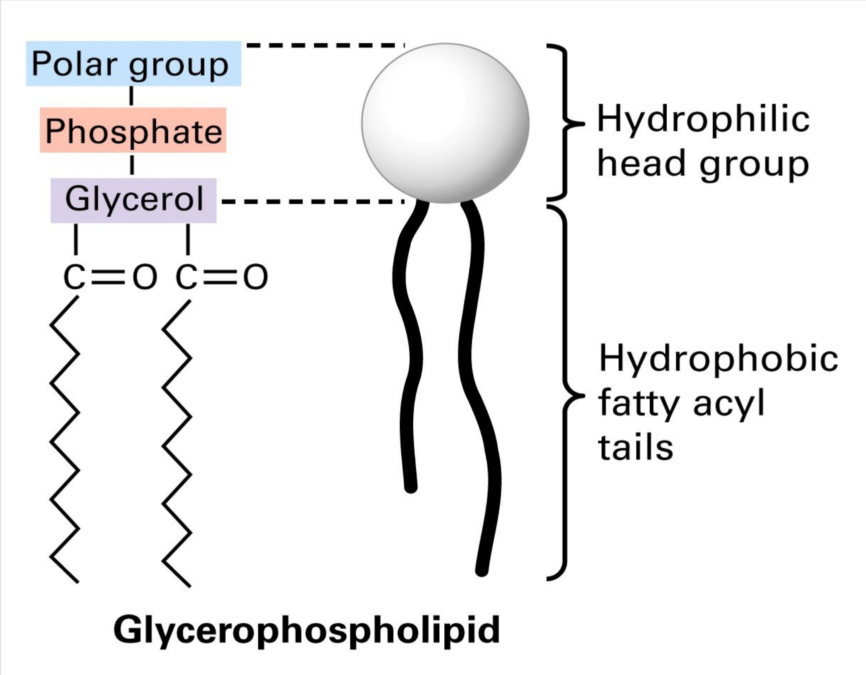
Intermolecular bonds/interactions

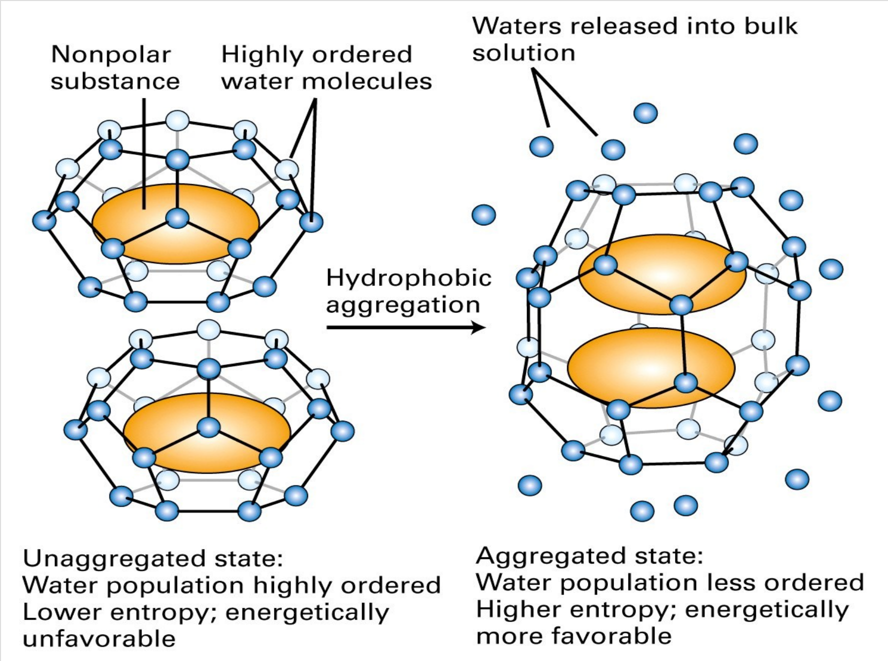
- Permanent dipole bond: Two polar molecules could bond to each other because of dipole-dipole interactions (weaker than ionic bonds)
- Van der Waals' force: Transient dipoles formed between two non-polar or a polar and a non-polar molecules could have a bonding effect
- Hydrogen bond: Occurs when the hydrogen is bonded to a small electronegative atom such as oxygen or nitrogen or fluorine – the resultant dipolar molecules share a hydrogen and form a bond

Visualization of van der Waals' force between nonpolar molecules due to transient polarization

Intermolecular bonds/interactions -2

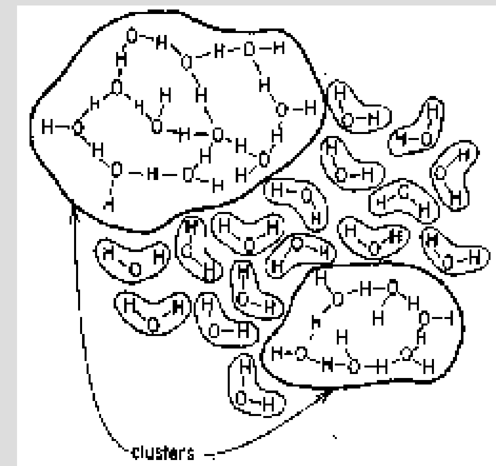
- Hydrophobic (nonpolar molecules) and hydrophilic (polar molecules) interactions

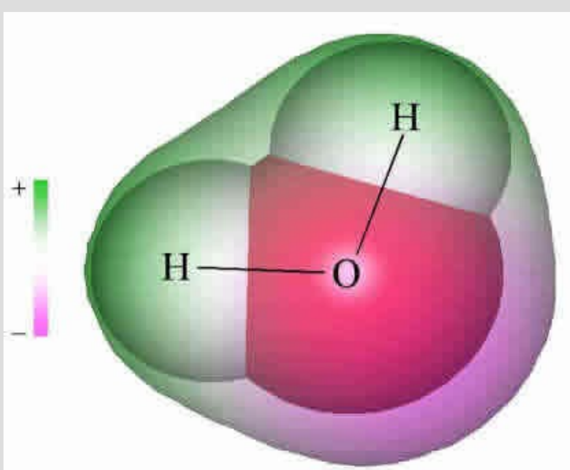


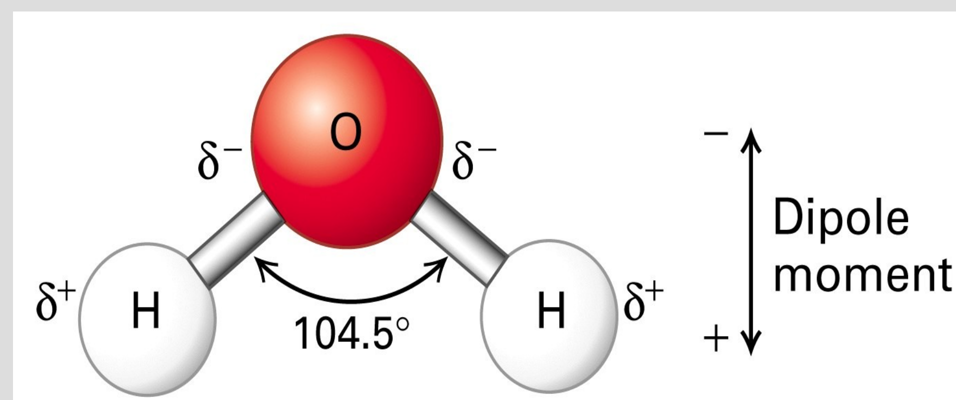


Water very important for life

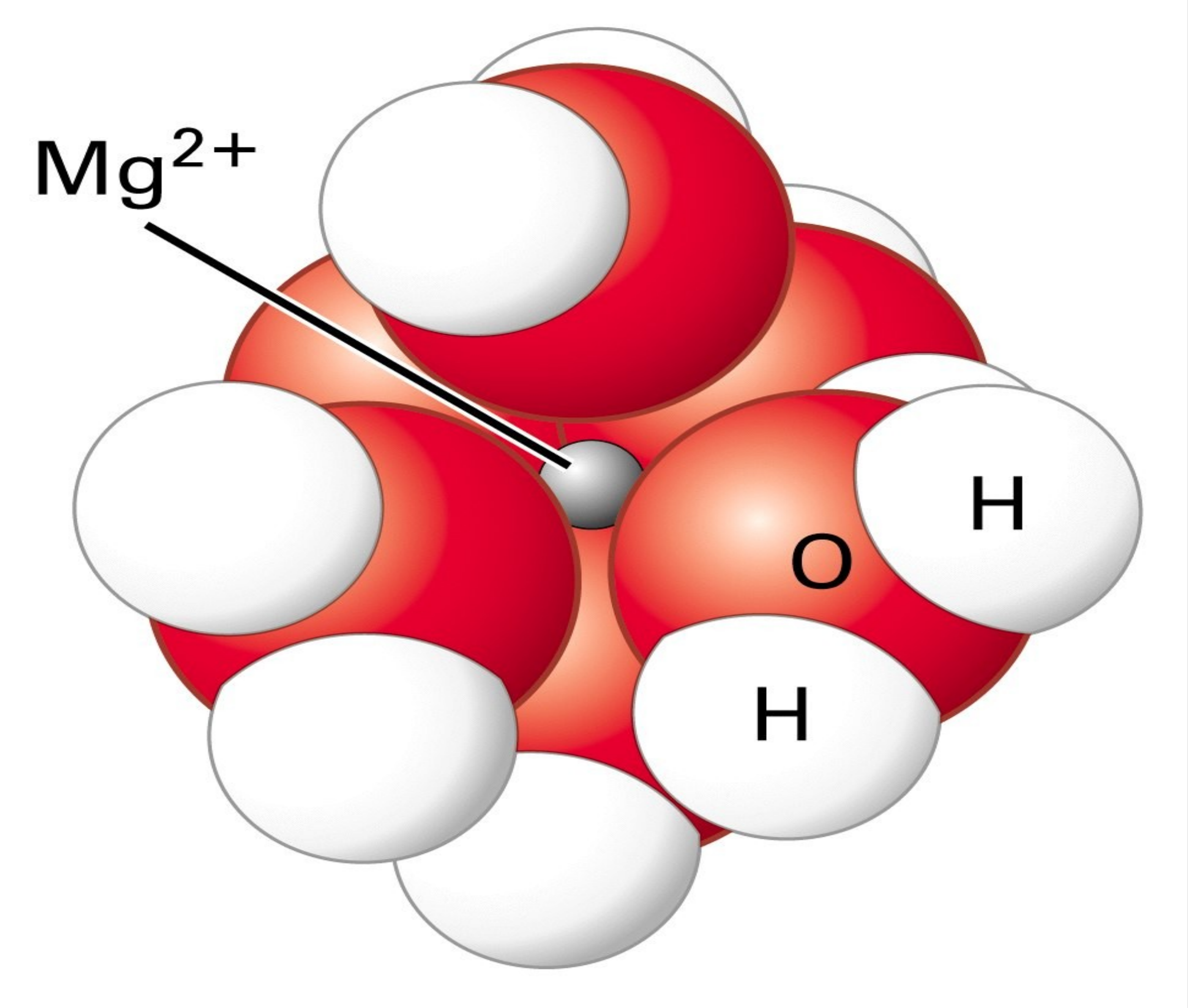
- H-bond higher BP
- Dissolves & solvates ions
- Creates hydrophobic interactions





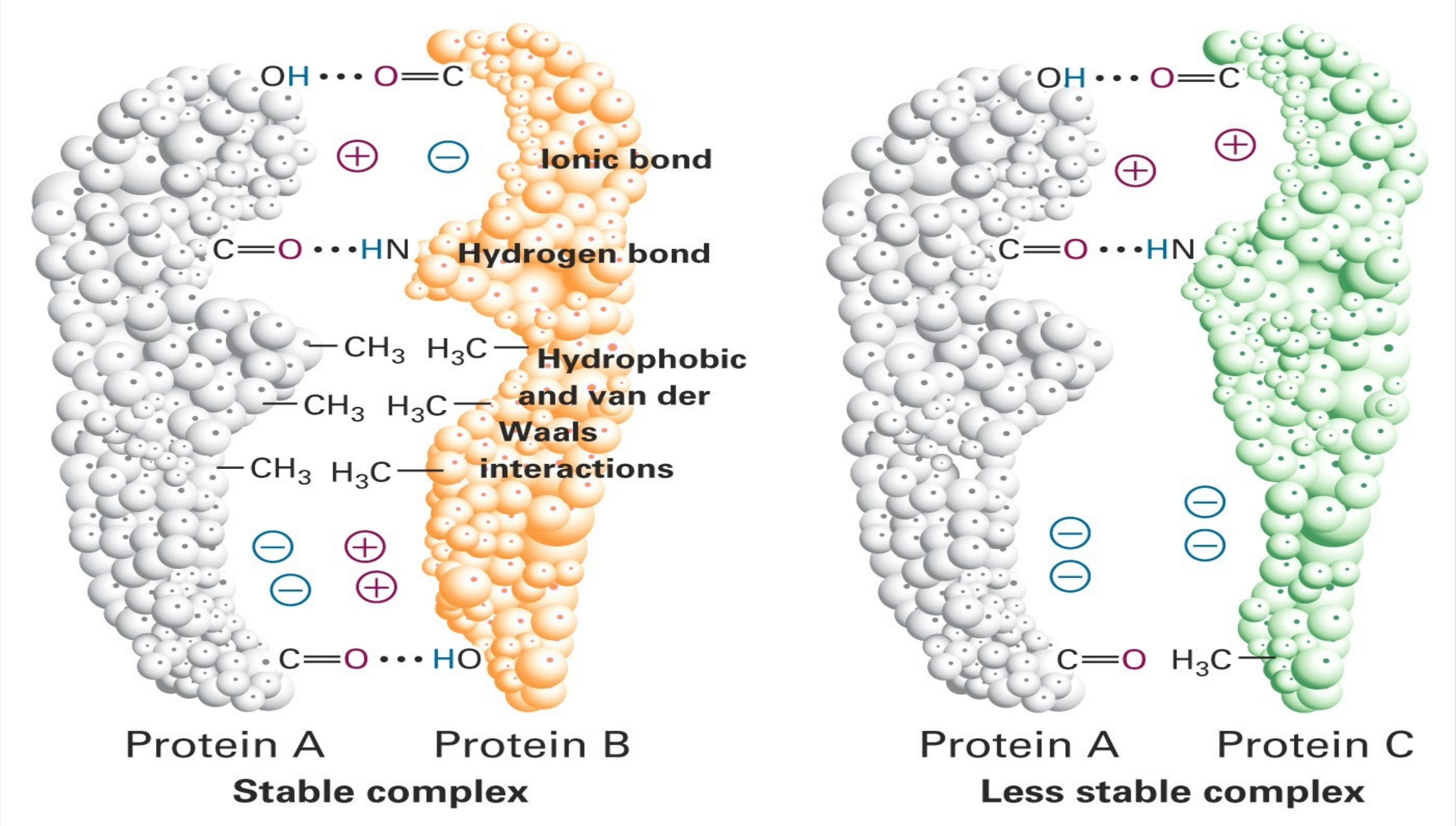


Solvation of ions

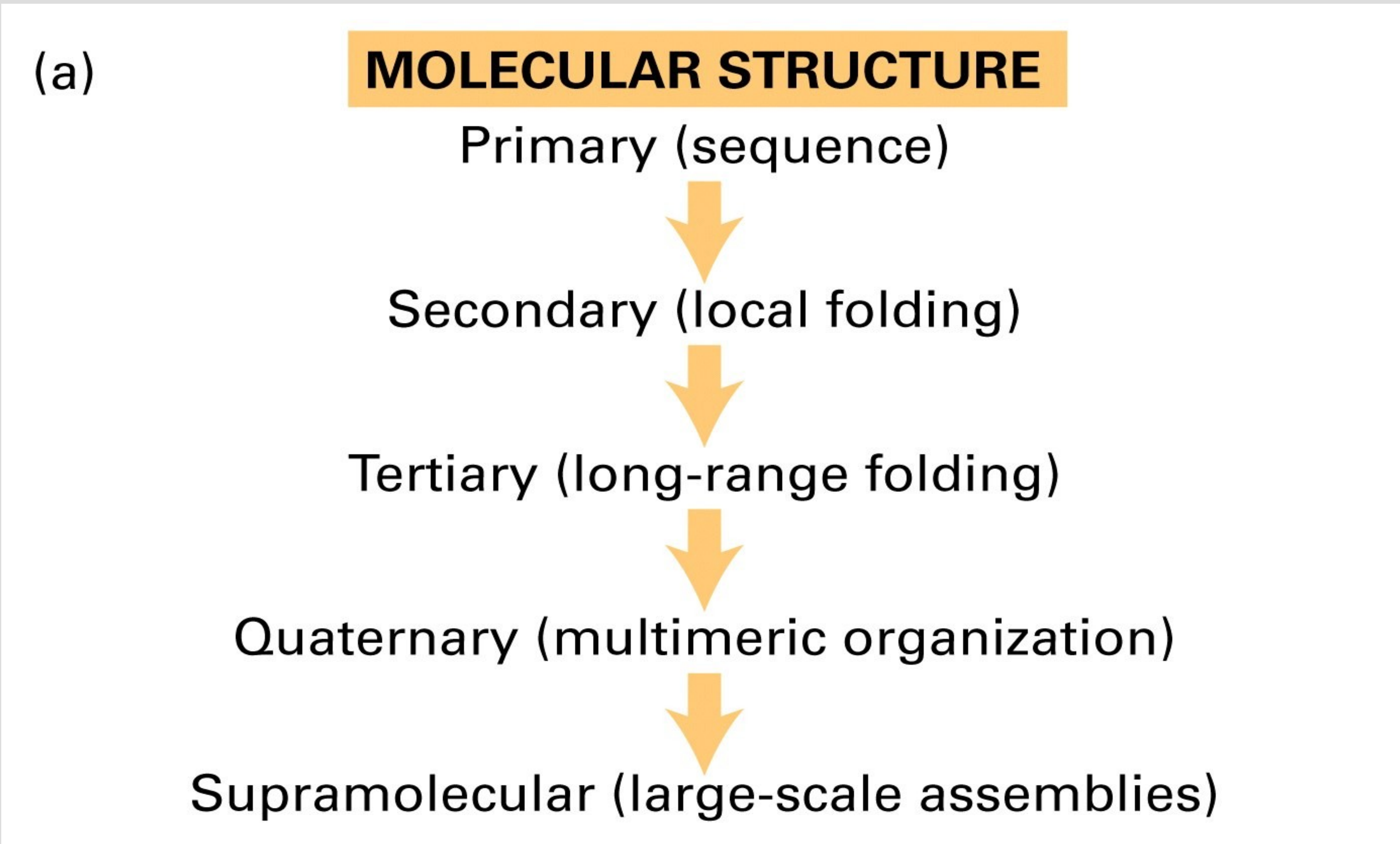


The solvation sheath allows
proteins
to manipulate ions in molecular
machineries

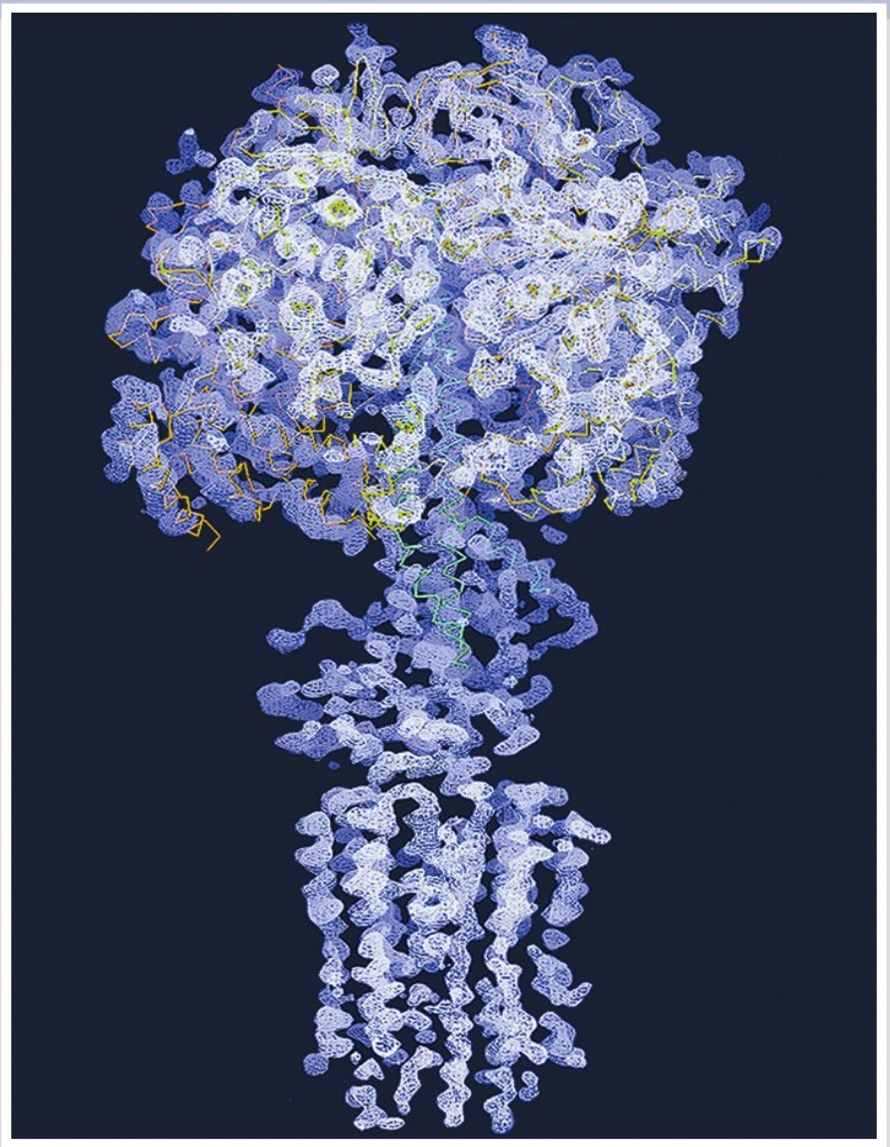
The weaker interactions very important for biomolecules and processes



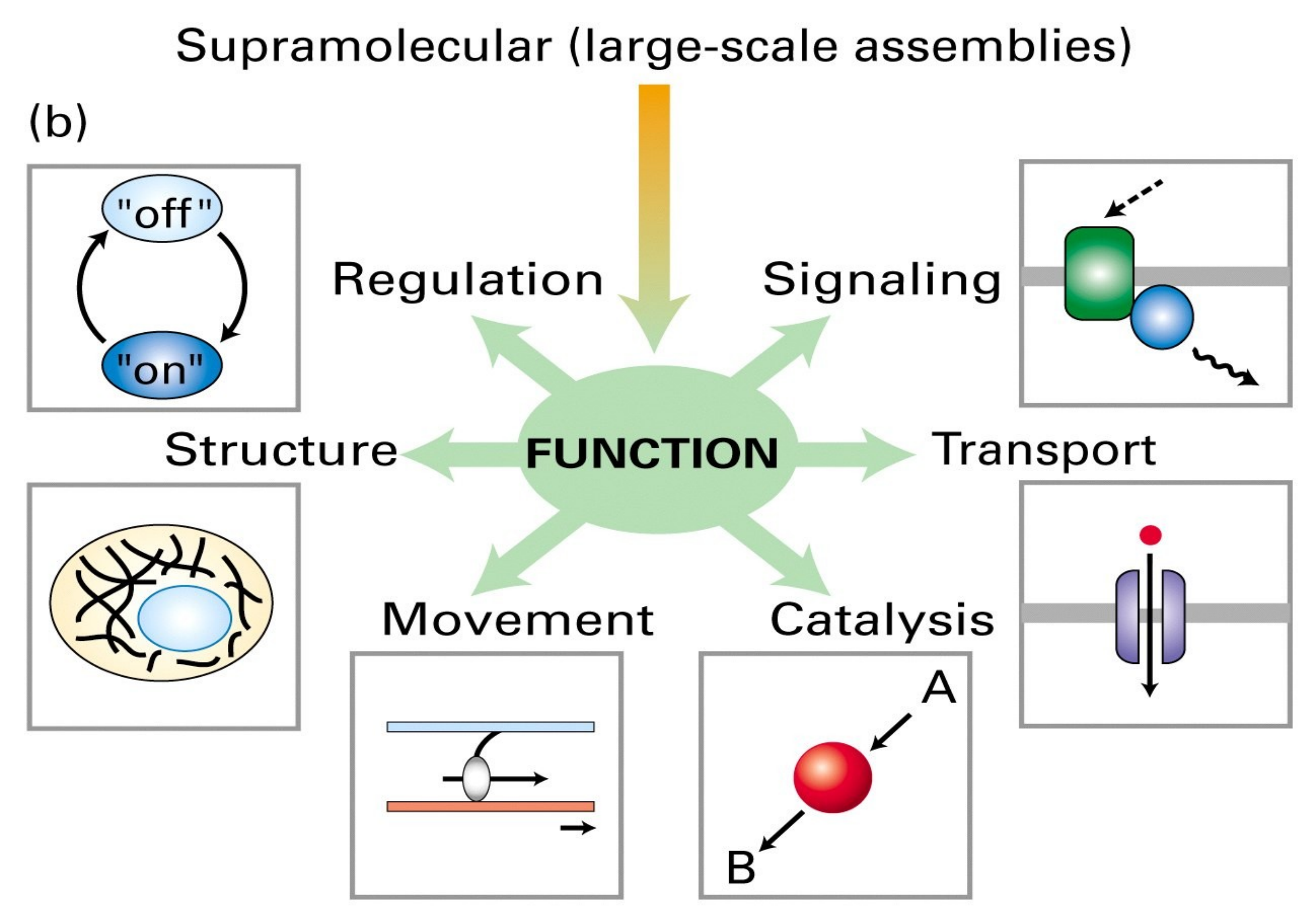
How do these weak interactions come in? Consider a protein



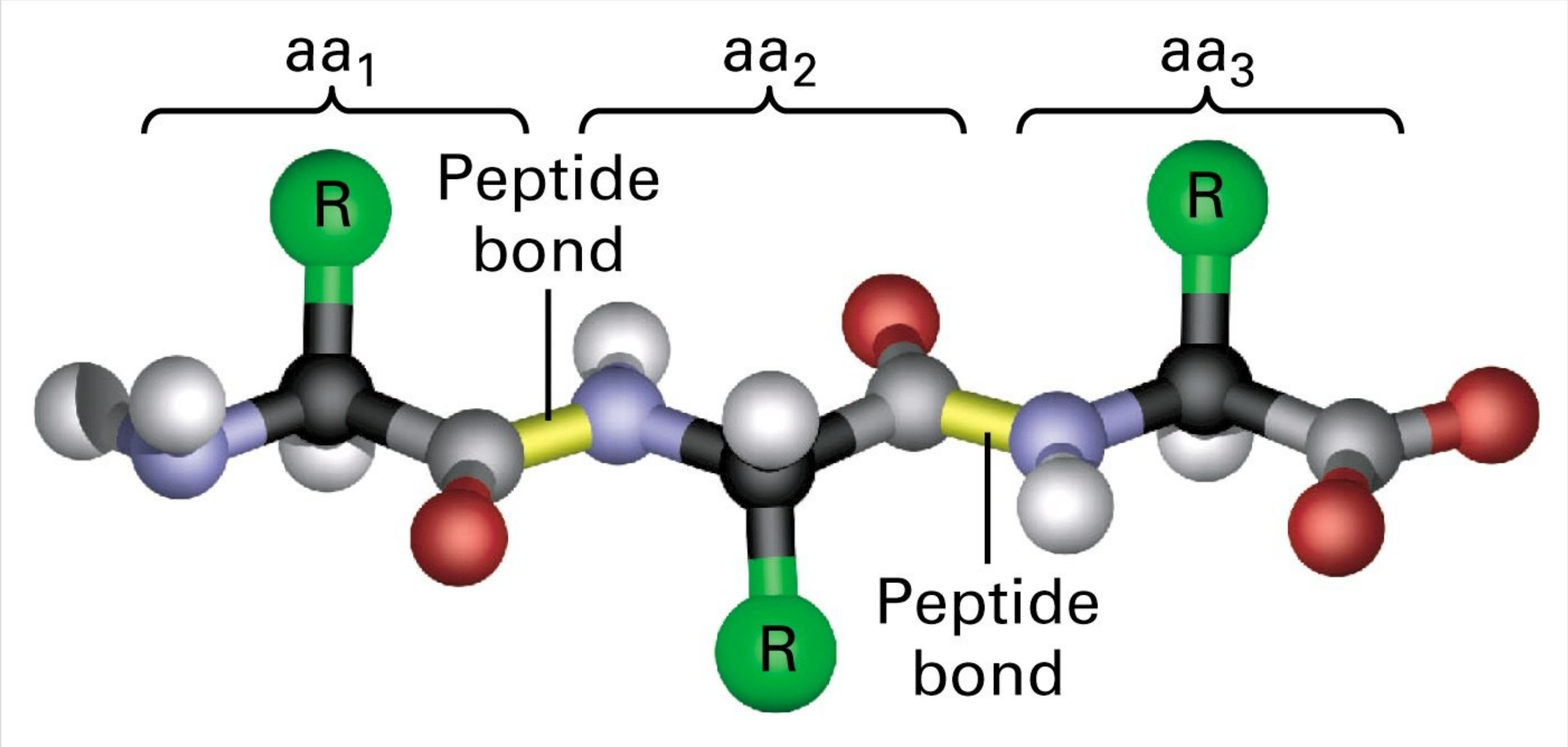
An example



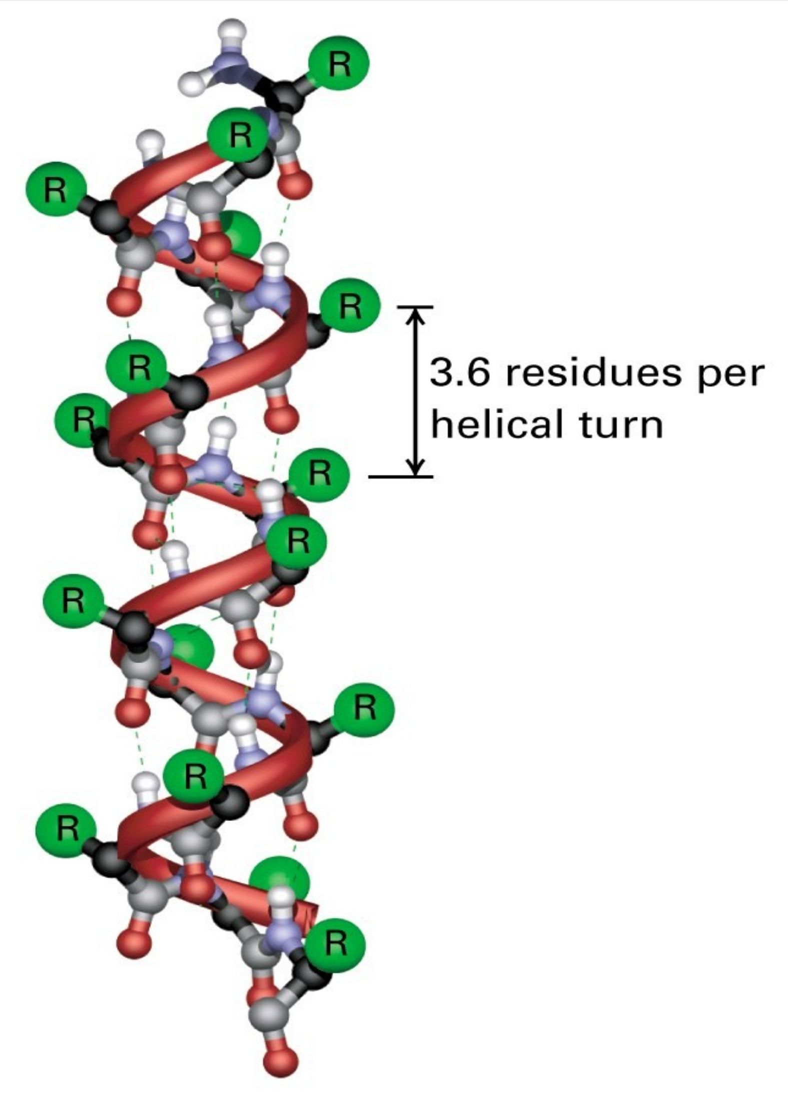
What do these supramolecules enable



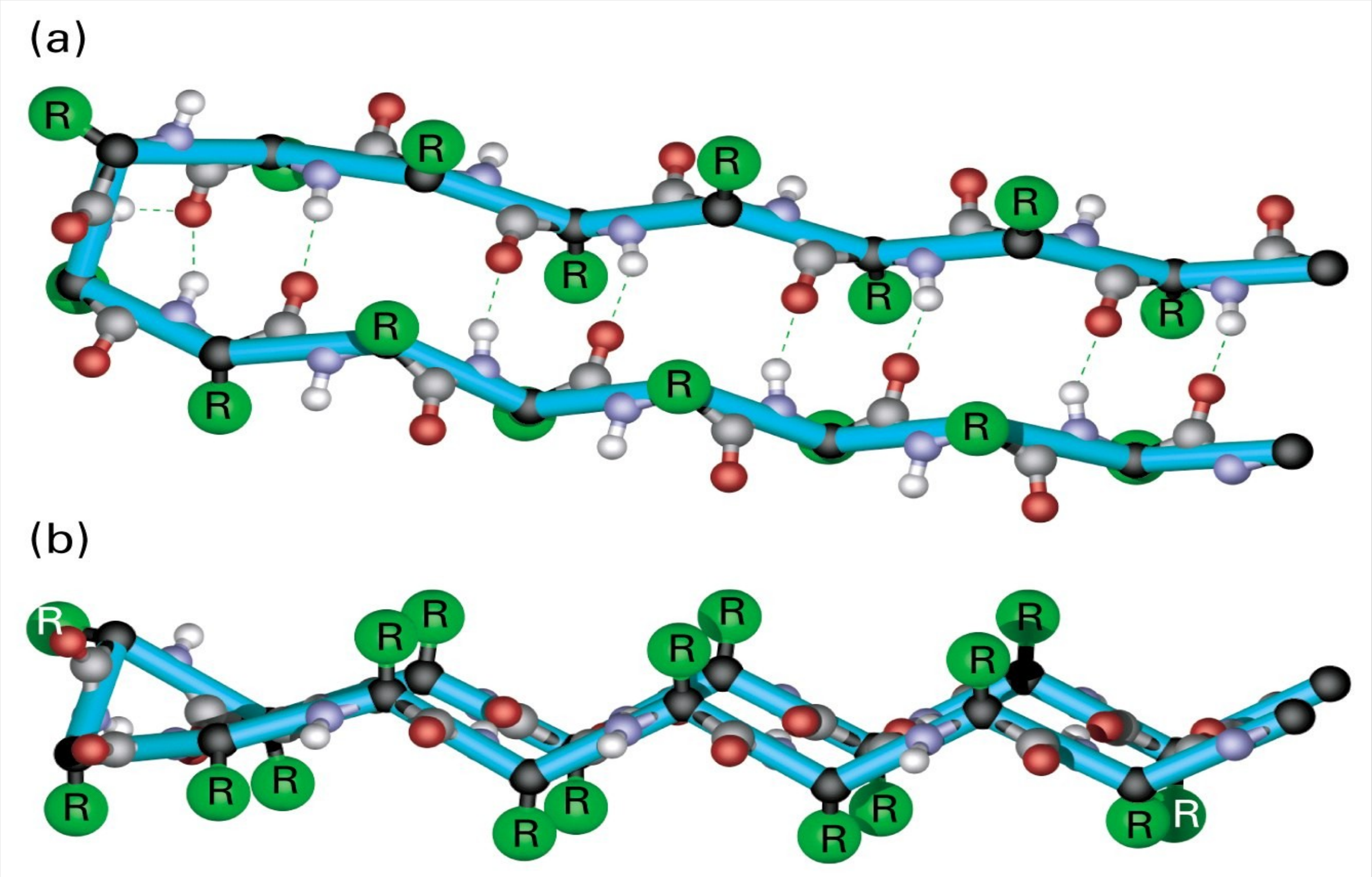
Peptide bond -1



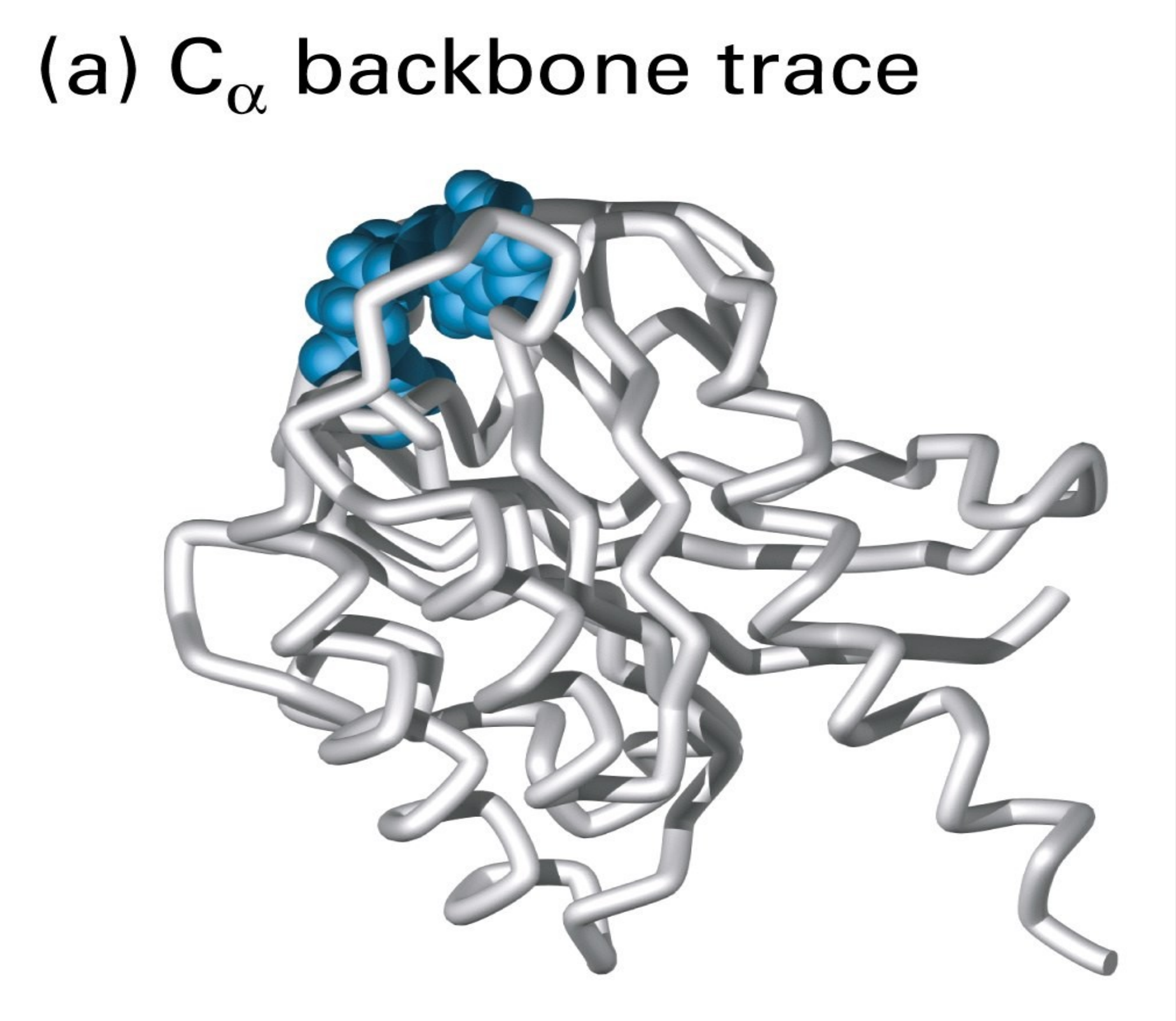
Peptide bond -2



Peptide bond -3

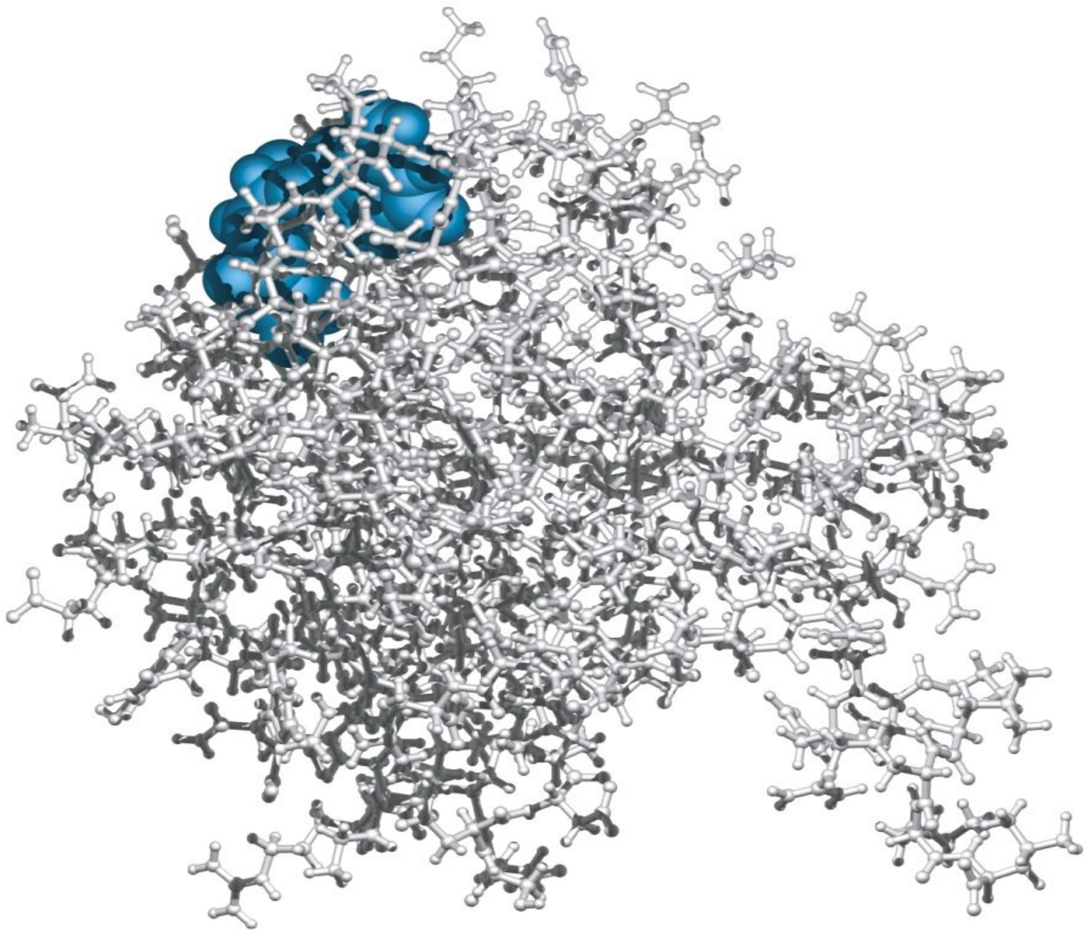


Peptide bond -representation

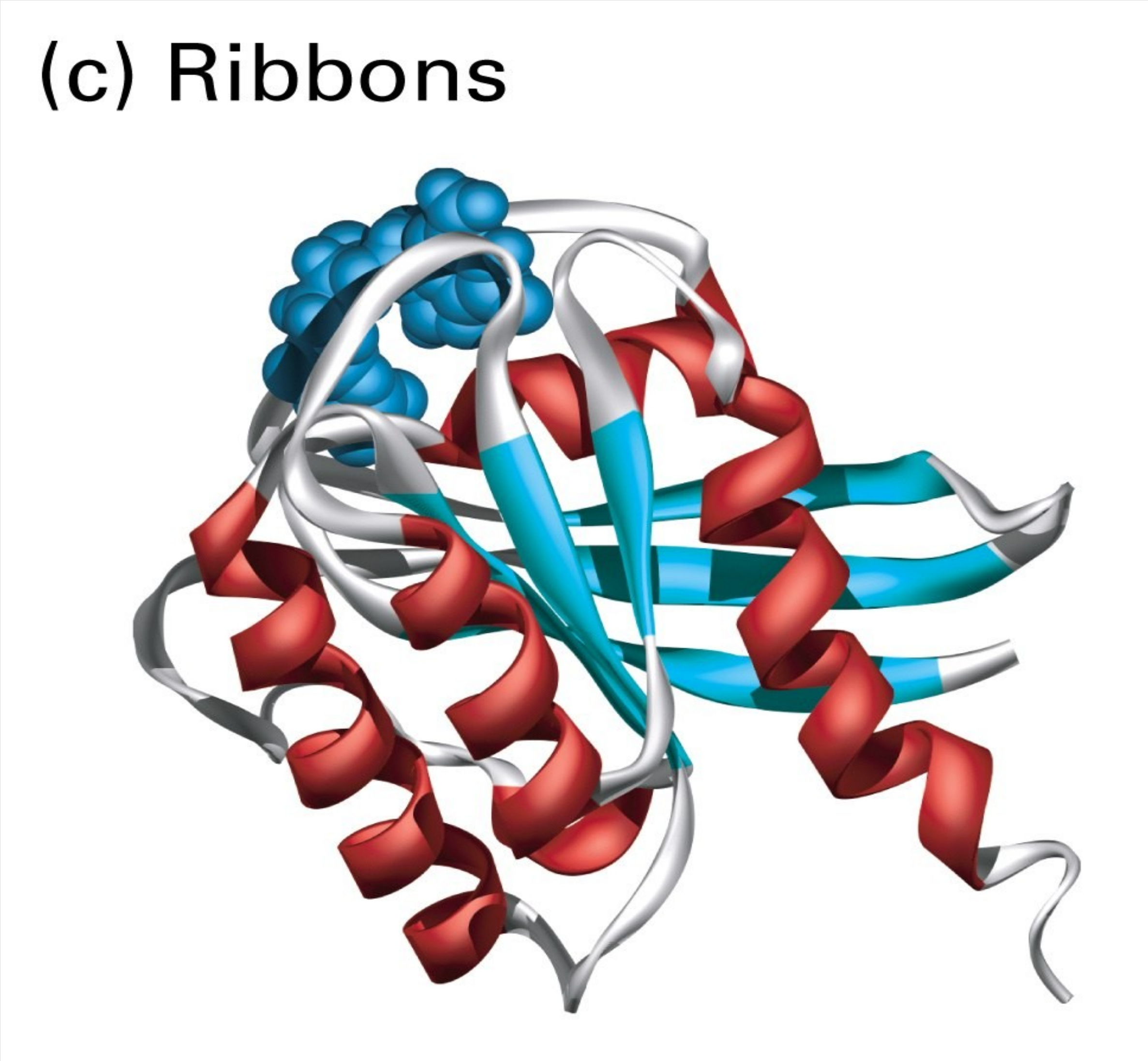


Representation -- Ball & stick model

(b) Ball and stick

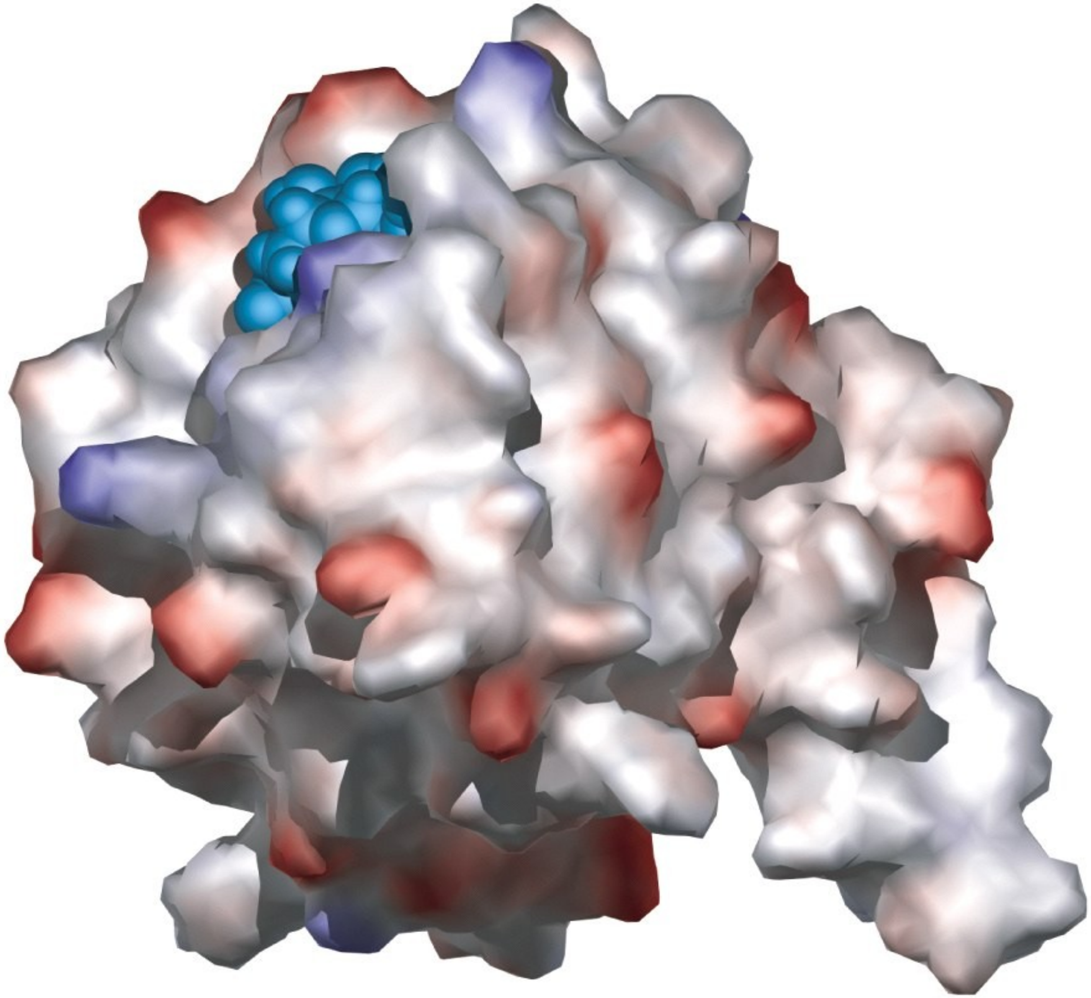


Ribbons

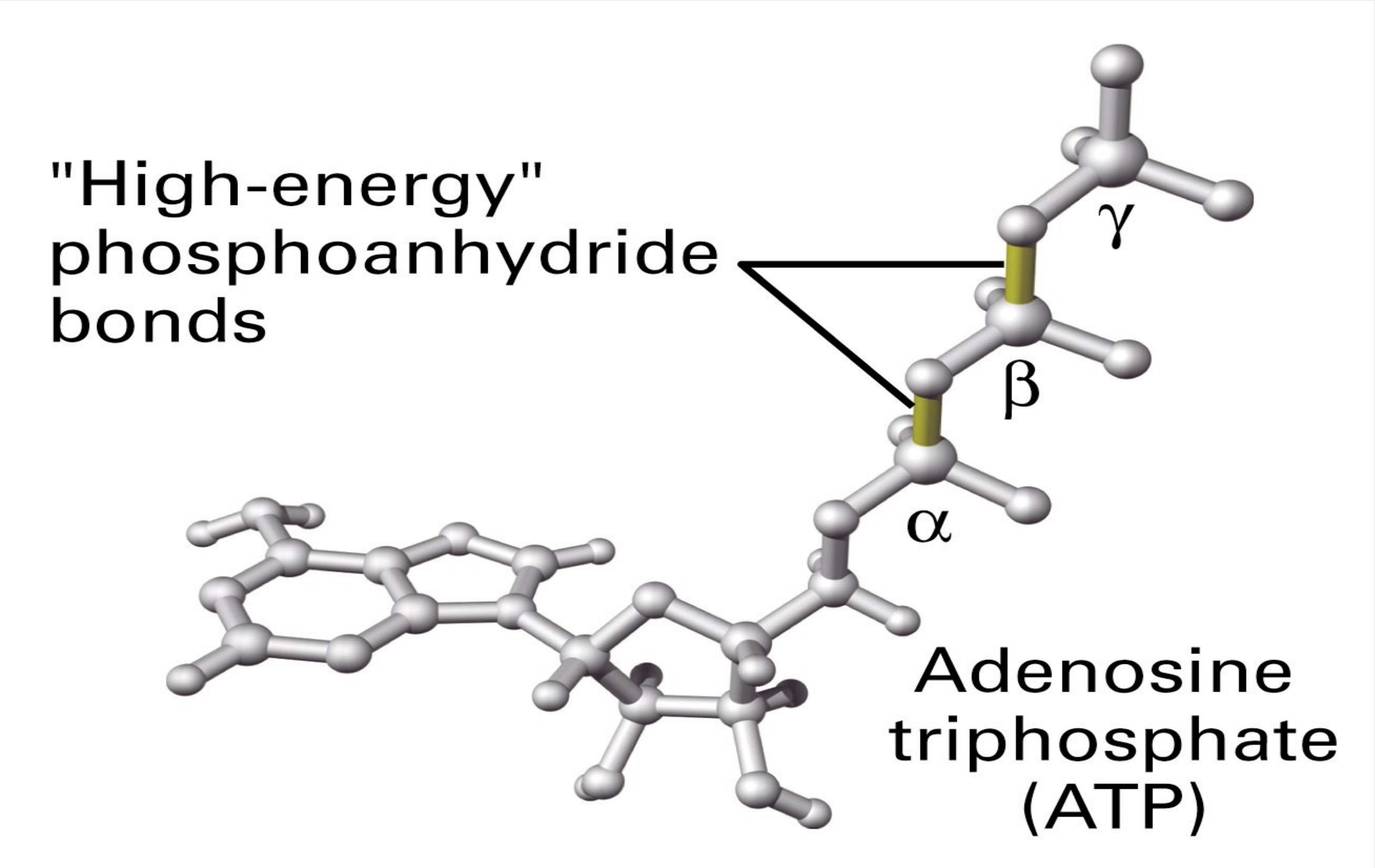


Solvated

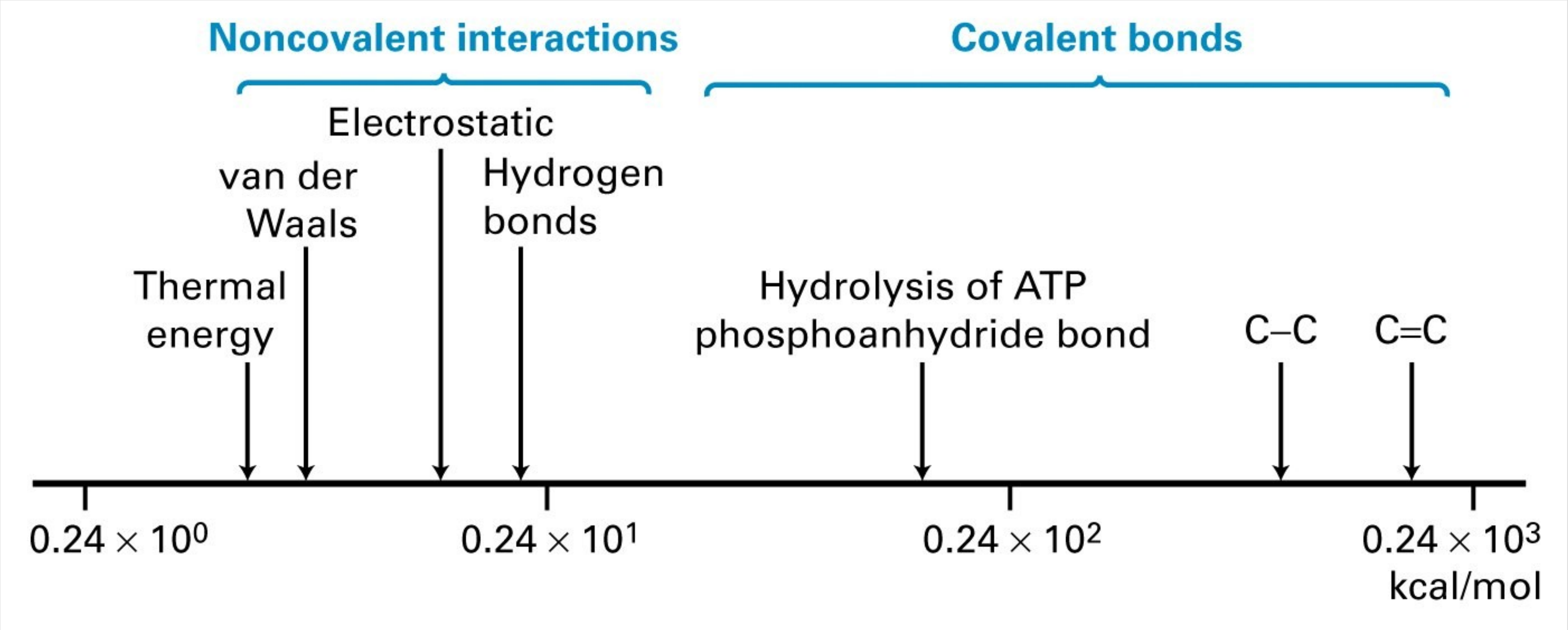
(d) Solvent-accessible surface



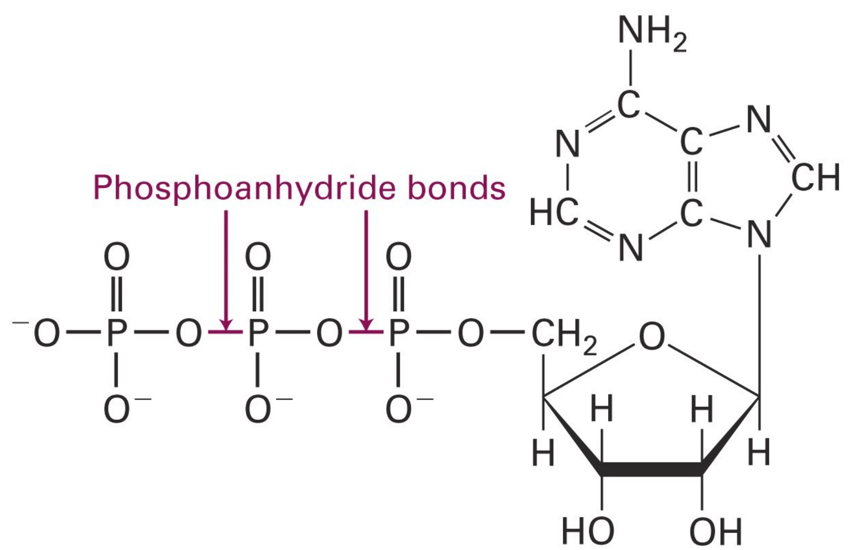
ATP is the primary energy carrier in biological systems



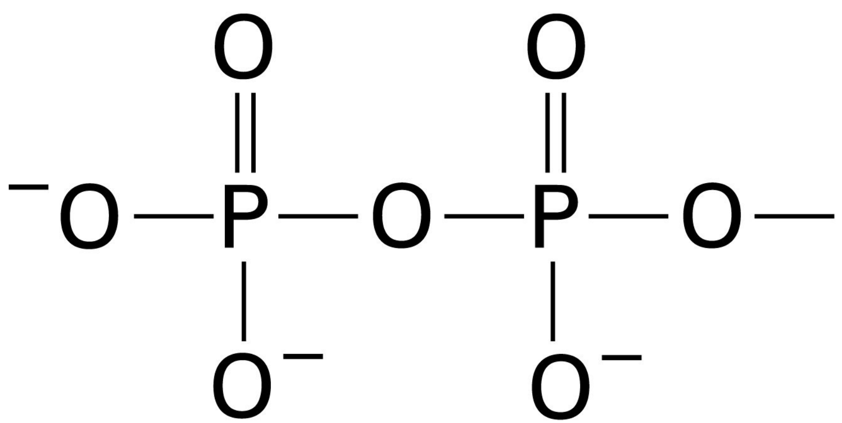
Energies of interactions



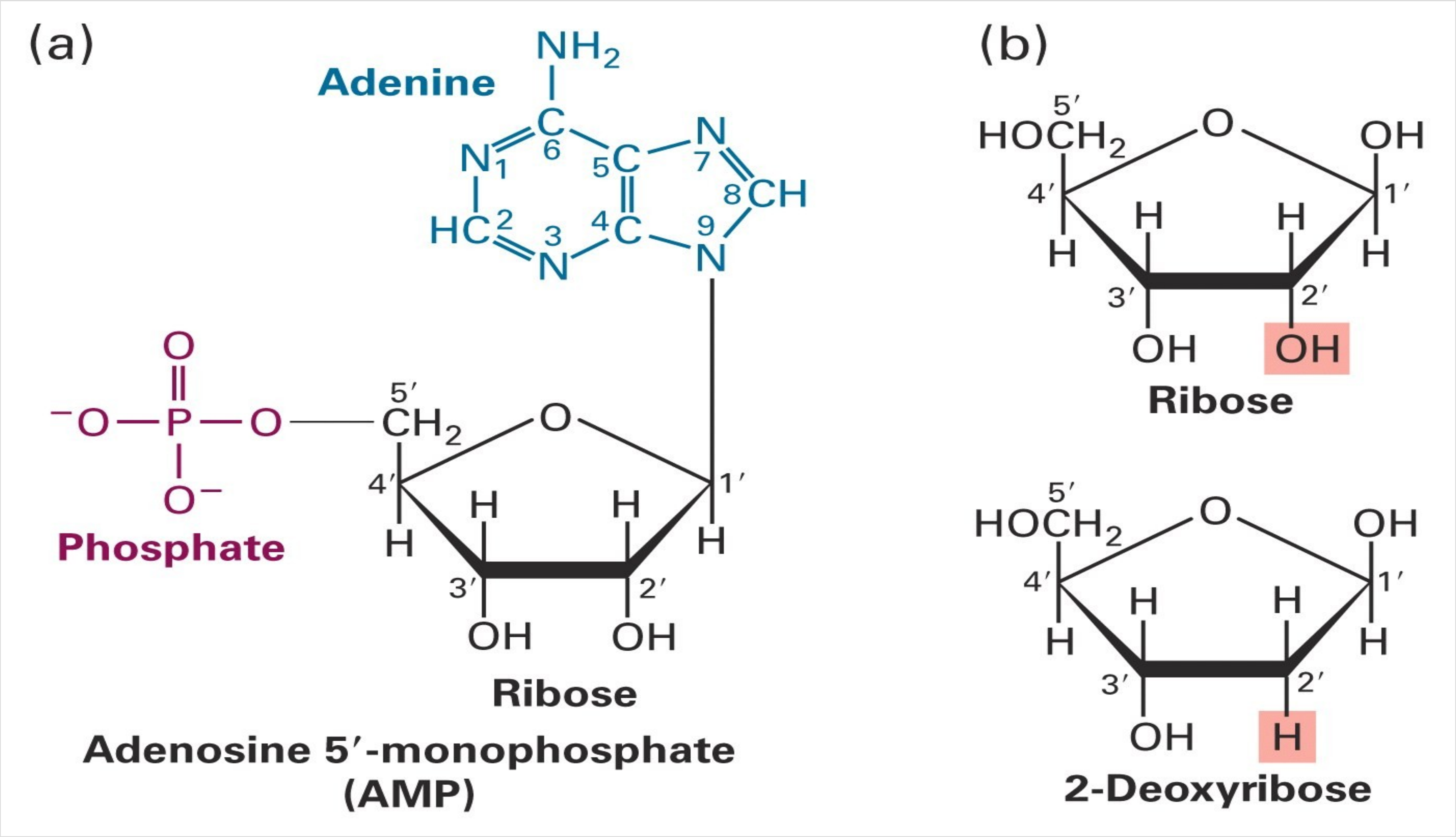
More on adenosine triphosphate



Adenosine triphosphate (ATP)



Pyrophosphate


(a)
Adenine
Phosphate
Ribose
Adenosine 5′-monophosphate
(AMP)
(b)
Ribose
2-Deoxyribose

Chemical reactions can be modeled by rate equations