

1 ☐ The Chemistry of Cells

- Chapter 2, Karp

2 ☐ Things you should know

- Covalent bonds
- Ionic bonds
- pH
- Ionization

3 ☐ Water is a Polar Molecule

- Highly asymmetric and polar (charge is asymmetric) molecule- O (-side) on one side H (+side) on the other
- The H^+ can interact with negatively polarized (or charged) groups on other molecules like the O^- from water
- Hydrogen bond- a weak non-covalent bond (polar interaction) between a hydrogen atom and another atom
- Hydrogen bonding underlies water's unique chemical and biological properties
- Water molecules are hydrogen bonded to each other -Water has a structure to it!

4 ☐ Polarity of Water and Hydrogen Bonds (panel 2-7)

5 ☐ Solubility and Hydrogen bonding

- What does it mean for something to dissolve or “be in solution”?
- It means to interact with water or to become coated with water-
 - Molecules in solution are coated with a layer of tightly attached water- it requires significant energy to strip this “water of hydration” away.
- Like dissolves like-
 - Water dissolves polar and charged molecules because it is polar
 - non-polar molecules dissolve in non-polar liquids (like oil)
- Insoluble- cannot interact with water
 - it is energetically unfavorable for some molecules to be in water (they do not hydrogen bond to water) so they interact with each other instead

6 ☐ Dissolving in Water (2-2)

7 ☐ Dissolving glucose (2.8)

8 ☐ Water as a reactant

- Water can also take part in chemical reactions
- Hydrolysis- splitting water
- Condensation- formation of water from H^+ and O_2

9 ☐ Non-covalent interactions

- Weak interactions-the energy of the bond is much less than a covalent bond.
- Must be stronger than thermal energy at the temperature in question to be relevant
- In macromolecules it is the sum of lots of small non-covalent interactions that matters

10 ☐ Alberts Fig 3-3

11 ☐ Types of Non-covalent Bonds- Charge interactions

- 1. Ionic Bonds- interaction between oppositely charged ions-weaker than covalent, stronger than polar
 - Positive and negative charges attract strongly
 - Individual ions (Ca^{++} , Mg^{++})
 - Ionized atoms in a macromolecule (PO_4^- , or NH_3^+)
- 2. Hydrogen bonds- Interaction of oppositely polarized (but not charged) molecules. Always involves a hydrogen atom.
 - This is the same as hydrogen bonding in water, but it can also occur between water and other molecules and between two molecules without water.
 - Hydrogens attached to N or O are usually polar and hydrogen bond to other molecules
 - Hydrogens attached to carbons are usually not polar and so do not hydrogen bond (important for hydrophobic lipids)

12 ☐ Non-covalent bonds (2.3)

13 ☐ Hydrogen bonds in biological molecules(2.4)

14 ☐ Non-covalent bonds (cont.)

- 3. Van der Waals forces-
 - Very weak polar interactions
 - Only happen when molecules are very close together and often induced by being close

- Only come into effect when large surfaces of macromolecules come into contact

15  **Van der Waals forces (2.6)**

16  **Non-covalent interaction (not bonds)**


- **Hydrophobic interactions**

- Molecules that do not interact with water (non-polar) interact with each other to minimize the surface in contact with water
- This is not a force of interaction!
- It comes from the interaction of water with itself being stronger than the interaction with the molecule. The desire of water to be with itself forces the hydrophobic molecule to associate with others of its kind instead of water.

17  **Hydrophobic interactions (Fig. 2.5)**

18  **pH**

- This is another property of water and molecules in it!
- It is critical for polar/ionic interactions.
- The pK (the pH at which they ionize) of functional groups in cellular molecules is no accident.
 - NH_2 at physiological pH acquires a hydrogen ion to become NH_3^+
 - PO_4^{2-} and COO^- lose a hydrogen to become negatively charged
- There is a delicate balance of ionization of these groups in cells (proteins)
 - slight shifts in pH can alter the shape of proteins (intramolecular ionic interactions) or the interactions of proteins with other molecules (intermolecular ionic interactions)

19  **Ionization of amino acids (2.27)**

20  **Diffusion**

- Diffusion ultimately limits the rate of all biological processes
 - Nothing can happen faster than diffusion allows
 - But there is no “rate of diffusion”
- However, we can use cellular energy to bias the direction

of diffusion

21 ☐ Diffusion is a random walk

22 ☐ Diffusion

- Mean square displacement ($x^2=6Dt$ or $v=6D/x$)
- To go 10x farther takes 100x as long
- There is no “rate of diffusion”- the rate varies with time
- D=diffusion constant- controls rate
- D is a function of mass, temperature, solvent viscosity
- There is no directionality to diffusion at the molecular level

23 ☐ Diffusion in Cells

- Small molecules in the cytoplasm diffuse
- Many macromolecules are relatively fixed in place and don't diffuse much
- Some molecules are diffusing in a 2 dimensional sheet of the membrane
- Some molecules are moved around by molecular motors rather than diffusion
 - This eliminates the problem of random movement and time but requires a system to give directionality-cytoskeleton!

24 ☐ Diffusion in Cells

● Substance	Mw	D (cm ² /sec)	time to diffuse 1μ	diffuse 10μm
● bacterium		5x10 ⁻⁹	1 sec	100sec
● TMV	4x10 ⁷	3x10 ⁻⁸	0.1 sec	10 sec
● albumin 7x10 ⁴	6x10 ⁻⁷		10 msec	1 sec
● sucrose 3x10 ²	5x10 ⁻⁶		1msec	100msec

25 ☐ The molecular events inside cells are hard to imagine

- An enzyme can perform a reaction at upwards of 1000 to 500,000/sec.
 - This is because molecules vibrate around at very fast rates

→ But remember diffusion says it is random movement- to move a significant distance takes time

- **There is no inertia inside cells- viscosity is the major factor-everything is coated with sticky water and has to push its way through water that is very viscous- thick because it is stuck to itself**

26 ☐ **Life inside a cell is hard to imagine**

- **Imagine living in a world in which the following scenario is entirely plausible. You pour cream into your morning coffee; the cream remains in a blob in mid-coffee. So you stir the cup three times counterclockwise, spreading out the cream. Then, after distilling the daily disasters from the newspaper, you resume stirring but absentmindedly do so clockwise. After three circuits of the spoon, the blob of cream reappears, separated from the coffee, and you mutter maledictions about the nuisance of mixing liquids. The mental outlook improves not a bit when the drain in the sink plugs up, bailing out the contents is unavoidable. No small bucket is handy, but fortunately a colander works almost as well to transfer the water to an adjacent tub. Mildly mollified, you go off in your motor boat, pointing the propeller, a spiral cylinder in the front out into the main channel. It just takes far too much fuel to move along the shore. In mid-passage, the motor quits and the boat immediately stops. Having neglected to fastened your seat belt, you tumble over the bow but at least have the presence of mind to get quickly back into the boat. So only a little water needs to be scraped off.” S. Vogel pg 241 Life in moving fluids’**