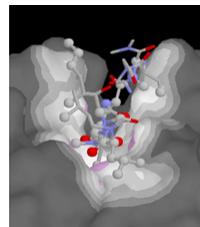


Welcome to BCMB / BIOL / CHEM 3100 Introductory Biochemistry

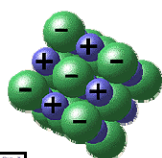


www.sussex.ac.uk

Please pick up handouts

(duplicate sets at both ends of the front desk).

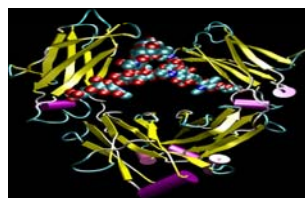
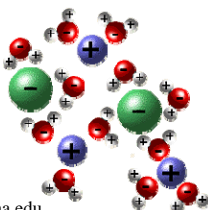
NaCl crystal structure



Arizona State
University
ASU

www.biology.arizona.edu

NaCl in water



INSTRUCTORS FOR THIS COURSE

1st half of course:

Dr. Debra Mohnen
Department of Biochemistry and Molecular Biology
Complex Carbohydrate Research Center, Room 2044 ←
315 Riverbend Rd.
Phone: 706-542-4458
email: dmohnen@ccrc.uga.edu

2nd half of course:

Dr. Daniel DerVartanian
Department of Biochemistry and Molecular Biology
A218 Life Sciences
Phone: 706-542-4620
email: dervar@bmb.uga.edu

**INTRODUCTORY BIOCHEMISTRY
BCMB/BIOL/CHEM 3100
Fall Semester 2010**

**10:10-11:00 AM, Mon. Wed. & Fri,
Room C127 - Life Sciences**

**Breakout Session: 5:00-5:50 PM,
Tues. Room C127 – Life Sciences**

See Syllabus for important information about the course

- **Partial Class Notes will be available on the website at least one day prior to lecture**
- **Class website (see syllabus for website)**
- **Grading: 100% from 4 exams**
- **You are strongly encouraged to form study groups**
- **Any handouts/exams not picked in the breakout session, will be available in the BCMB office**

Tips for doing well in BCMB/BIOL/CHEM3100

- **Read the chapter BEFORE CLASS**
Skim chapter (look at figures!)
Read in detail
Reread and integrate information with major concepts
- **Keep up!**
- **Work at the material every day**
- **Form study groups and meet regularly**
- **Complete homework by the due date and bring it to the breakout session.**
- **Bring calculator to all exams and breakout sessions. You may NOT use pencils, blue or red ink for the exam.**

Partial Class Notes for BCMB 3100 - Chapter 1

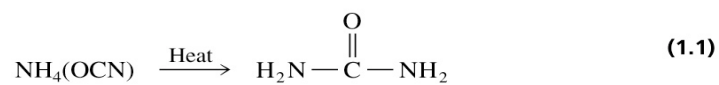
BCMB 3100 - Lecture 1

- **History of BIOCHEMISTRY**
- Important functional groups
- Four types of macromolecules in living organisms

HISTORY OF BIOCHEMISTRY

1800's: vitalism

1828 - Friedrich Wöhler -



1862 - Louis Pasteur -

1897 - Eduard & Hans Buchner - DEATH OF VITALISM.

1890 - Emil Fisher - lock-&-key model

1891 - configuration of D-glucose

Early 1900s - 1st biochemistry departments established.

1926 - James B. Sumner –

1930s - Linus Pauling & Robert Corey - x-ray

**1950s - 3D structure of 1st proteins by x-ray
crystallography**

1953 - James Watson & Francis Crick –

Current biochemical generalization regarding living things

1.

2.

3.

4. The Central Dogma of life information flow:

BCMB 3100 - Chapter 1

- History of BIOCHEMISTRY
- Important functional groups
- Four types of macromolecules in living organisms

Fig 1.2 (a) General formulas - Page 5
Organic compounds

Fig 1.2(b) General Formulas - Page 5
Functional groups

Fig 1.2 (c) General Formulas -Page 5
Linkages

BCMB 3100 - Chapter 1

- History of BIOCHEMISTRY
- Important functional groups
- Four types of macromolecules in living organisms

There are four types of molecules in living cells:

The basic macromolecular compartments of living things are _____

_____ cells contain no nucleus or intracellular membranes and are usually unicellular

_____ cells contains membrane-bound organelles: nucleus, ER, Golgi, mitochondria, lysosomes, peroxisomes, chloroplasts

Biochemists concentrate on certain “model” organisms for their studies.

Prokaryote: E. coli

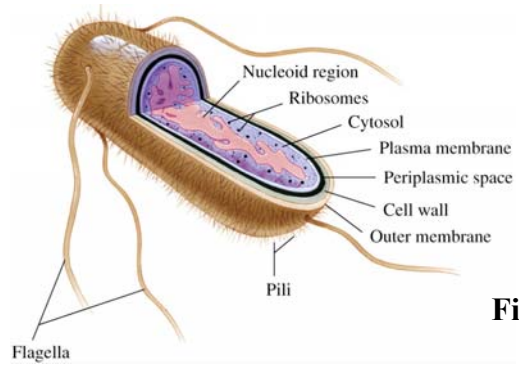


Fig. 1.14

Eukaryote: humans, mice, rats, yeast, arabidopsis, drosophila

Eukaryotic cell (animal)

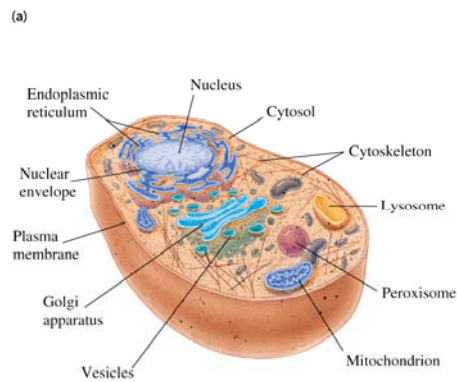


Fig 1.15 (a)

Eukaryotic cell (plant)

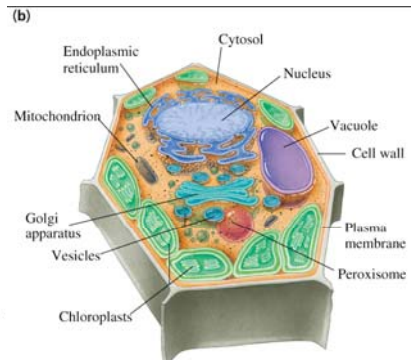
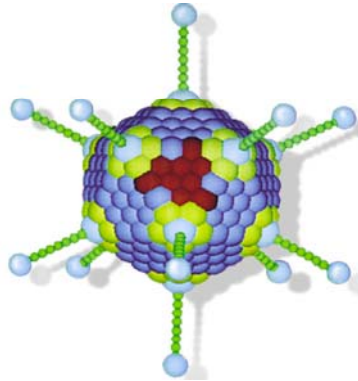


Fig 1.15(b)

Viruses



- Adenovirus: Viruses consist of a nucleic acid molecule surrounded by a protein coat

Be sure to see text (Chapter 1) for:

***SI for size units & terminology
(Tables 1.1 & 1.2, pg 25)**

Note: one angstrom (Å) = 0.1 nm !!!

***subcellular organization**

***types of organic compounds, linkages and
functional groups (Fig 1.2, pg 5)**

BCMB 3100 - Chapter 2

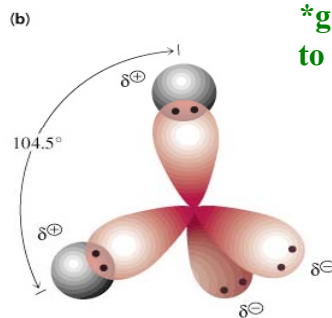
WATER

- Properties of the solvent of life: water
- Four types of noncovalent interactions
- Review of acid-base concepts, pKa



Fig. 2.1(a) Space-filling structure of water (Page 27)

***water is a polar molecule with asymmetric charge distribution**

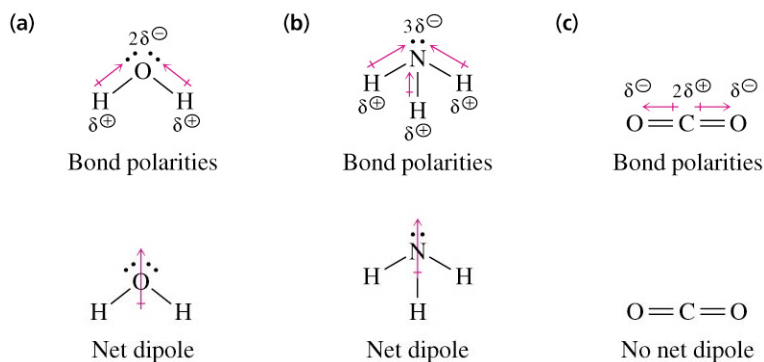


***geometry is tetrahedral due to shape of outer e- orbital of oxygen**

Fig. 2.1 (b) Covalent bond angle of water

Fig. 2.2 Polarity of Small Molecules

- Water and ammonia each have a permanent dipole while CO_2 does not



Water molecules have a high affinity for each other

- Water is _____
- water forms hydrogen bonds _____
- attraction between slightly negative O and slightly positive H
- H bonds are directional (more stable when linear)

Fig. 2.3 Hydrogen bonding between two water molecules

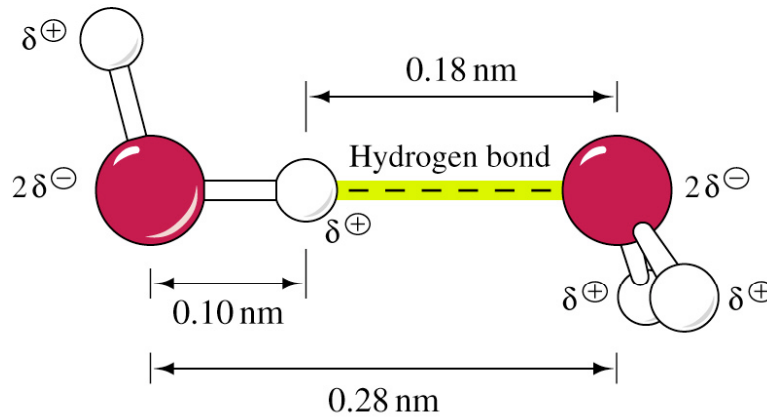
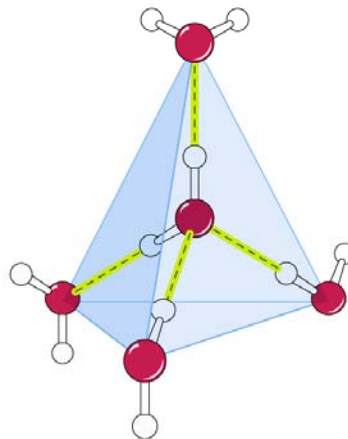


Fig. 2.4 Hydrogen bonding by a water molecule

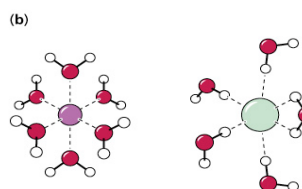
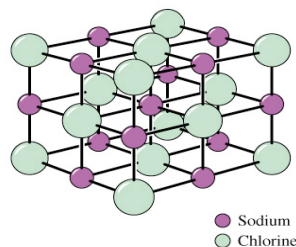
- A water molecule can form up to four hydrogen bonds
- Hydrogen bonds shown in yellow (dashed lines)
- Water is partly ordered, H-bonds continually form & break, average 3.4 H-bonds in water



Water is an excellent solvent for polar molecules

Fig. 2.6 Dissolution of NaCl in water

(a) NaCl crystal



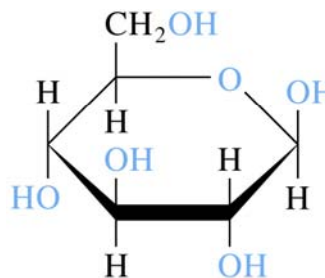
* life depends on the ability of water to dissolve polar molecules. A high [] of these molecules can coexist with water

*Molecules that dissolve readily in water are called

_____.

Glucose is an **example of a very soluble molecule** since it has five hydroxyl groups and a ring oxygen which can hydrogen bond with water

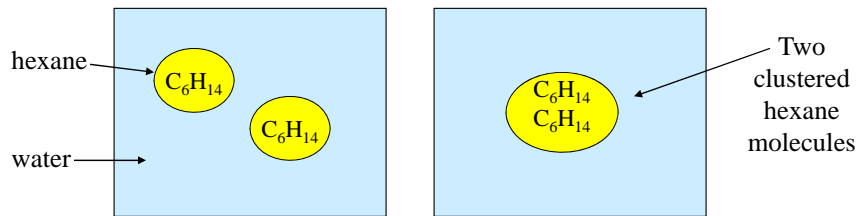
Fig. 2.7 Structure of glucose



***Some polar interactions, however, are essential. Biological systems have created water free microenvironments where polar interactions have maximal strength**

***Molecules that are nonpolar (e.g. hydrocarbons) do not dissolve in water. They are called _____**

***Nonpolar molecules or groups tend to cluster together in water = _____**



Nonpolar solute molecules are driven together in water NOT because they have a high affinity for each other BUT _____

_____.

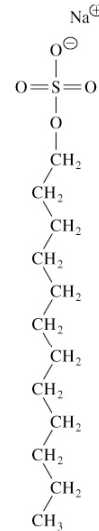
Water that surrounds nonpolar molecules is more restricted in its interaction with other water molecules.

Thus, there is a net gain in entropy when the nonpolar groups aggregate and water is freed from an ordered state.

Amphiphilic: molecules that are both hydrophilic and hydrophobic

Fig. 2.8 Sodium dodecyl sulfate (SDS)

- A synthetic detergent
- A 12-carbon tail
- Polar sulfate group



Thought of the Day

We are in the early stages of a “Freshwater Crisis” (Scientific American, August 2008)

Today one out of six people (> 1 billion) have inadequate access to water.

By 2050, as much as $\frac{3}{4}$ of the earth’s population could face scarcities of water.

What is minimum amount of water each person requires per year for drinking, hygiene and growing food?

Water is minimum amount of drinking water each person requires per year?

BCMB 3100 – Chapter 2

- Properties of the solvent of life: water
- **Four types of noncovalent interactions**
- Review of acid-base concepts, pKa

**There are four types of noncovalent bonds
(reversible molecular interactions)**

- *
*
*
*

Charge-charge interactions -

* **Charge-charge interaction** : also called ionic bond, salt linkage, salt bridge, ion pair, electrostatic attraction

* **In an optimal electrostatic attraction, distance between oppositely charge groups is _____**
(compare to 1.54Å in C-C bond)

Electrostatic bond: potentially strongest noncovalent interaction: _____

Hydrogen bonds:

* **Hydrogen donor:** atom to which H is more tightly associated. O-H, N-H

* **Hydrogen acceptor:** atom to which H is less tightly associated. O or N The acceptor has partial negative charge that attracts H atom.

* **Distance** between 2 electronegative atoms involved in hydrogen bond = _____

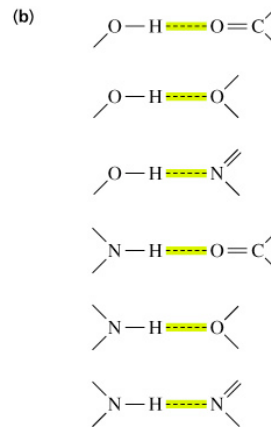
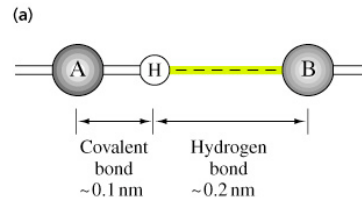
* **Hydrogen bond energy** ranges from _____

* **Hydrogen bonds** are _____

Fig. 2.10

(a) Hydrogen bonding between A-H and B

(b) Some biologically important H-bonds

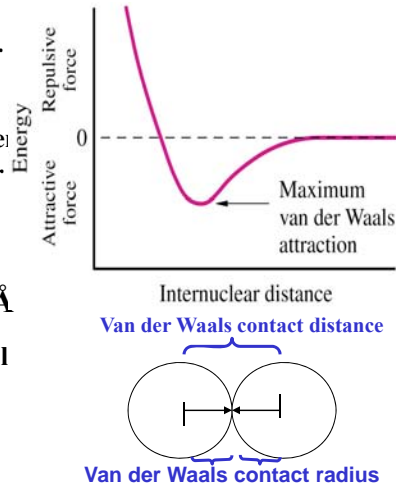


Van der Waals bonds: non-specific attractive force important when any two atoms are _____.
Most important when numerous atoms in one molecule come close to atoms in another molecule

- * _____ than electrostatic & H-bonds
- * the distribution of electric charge around an atom changes with time
- * Thus, at any instant charge distribution is asymmetric. This asymmetry around one atom encourages similar asymmetry in electric distribution around neighboring atoms, leads to attraction
- * Attraction is distance dependent: most strong at _____

Fig. 2.12 Effect of internuclear separation on van der Waals forces

- Strongly repulsive at short internuclear distances, very weak at long internuclear distances
- Van der Waals attraction is maximal when two atoms are separated by their van der Waals radii
- Van der Waals contact radius: 1.2-2.0Å
- Van der Waals contact distance : 2.4-4.0Å
- Van der Waals bond energy: 0.4-4 kJ/mol (~1 kcal/mol). Only slightly larger than the average thermal energy of molecules at RT (0.6 kcal/mol)



Hydrophobic attractions

* weak interactions: _____

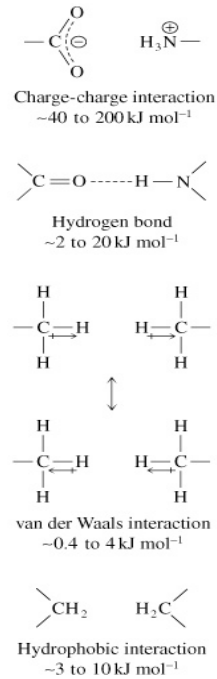
*Interactions between nonpolar molecules due to tendency of water to bond strongly to itself

* _____

_____ for folding of macromolecules, binding of substrates to enzymes, & formation of membranes

Fig. 2.13 Noncovalent interactions in biomolecules

- Charge-charge interactions
- Hydrogen bonds
- Van der Waals interactions
- Hydrophobic interactions



Water is a weak NUCLEOPHILE

- * : electron rich group due to a negative charge or to unshared pairs of electrons
- * **Nucleophiles tend to** **to positively charged or electron deficient groups known as electrophiles**
- * **Most common biological nucleophiles contain**
- * **makes hydrolysis (cleavage of a bond such as anhydrides or peptide bonds by water) a potential problem**
- * **Nonbeneficial hydrolysis in organisms is prevented by:**
 - biopolymer stability at physiological pH
 - inactive or inaccessible storage of hydrolases
 - two step biosynthetic reactions using nucleophiles other than water
 - shielding water sensitive intermediates in enzyme active site

BCMB 3100 – Chapter 2

- Properties of the solvent of life: water
- Four types of noncovalent interactions
- Review of acid-base concepts, pKa

Review of Acid-Base Concepts Ionization of Water (1)

Water dissociates into hydronium (H_3O^+) and hydroxyl (OH^-) ions $\text{H}_2\text{O} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{OH}^-$

(write H^+ rather than H_3O^+ for simplicity)



Equilibrium constant (K_{eq})

$$K_{\text{eq}} = [\text{H}^+] [\text{OH}^-] / [\text{H}_2\text{O}]$$

$$[\text{H}_2\text{O}] = 55.5\text{M} \quad K_{\text{eq}_{\text{water}}} = 1.8 \times 10^{-16} \text{M}$$

Ionization of Water (2)



Since [water] (i.e. 55.5M) changes little by ionization, the equilibrium constant of water (K_w) can be simplified :

$$K_{eq} = \frac{[\text{H}^+][\text{OH}^-]}{[\text{H}_2\text{O}]}$$
$$1.8 \times 10^{-16} \text{ M} = \frac{[\text{H}^+][\text{OH}^-]}{55.5 \text{ M}}$$

$$K_w = [\text{H}^+][\text{OH}^-] \quad (\text{Kw} = \text{ion product of water})$$

At 25°C, K_w is $1.0 \times 10^{-14} \text{ M}^2$

Definition of Acid & Base

Acid = proton donor

Base = proton acceptor

Conjugate Acid

Conjugate Base

acid

H^+ + base

acetic acid

H^+ + acetate

$\text{CH}_3\text{-COOH}$

H^+ + $\text{CH}_3\text{-COO}^-$

ammonium ion

H^+ + ammonium

NH_4^+

H^+ + HN_3

The above are conjugate acid-base pairs

The pH of a solution is a measure of the concentration of H^+

2.8 The pH Scale

- **pH** is defined as the negative logarithm of the concentration of H^+

$$pH = -\log [H^{\oplus}] = \log \frac{1}{[H^{\oplus}]} \quad (2.9)$$

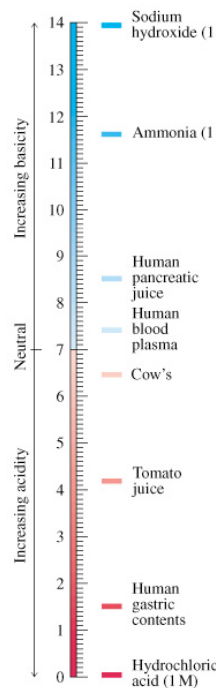
Table 2.3
Acid-Base
behavior in Water

Note: Since the ion product for water (K_w) is constant (i.e. $1.0 \times 10^{-14} M^2$), the product of $[H^+]$ and $[OH^-]$ is always $1.0 \times 10^{-14} M^2$, thus as an acid is dissolved in water, the $[OH^-]$ decreases and vice versa.

pH	$[H^{\oplus}]$ (M)	$[OH^{\ominus}]$ (M)
0	1	10^{-14}
1	10^{-1}	10^{-13}
2	10^{-2}	10^{-12}
3	10^{-3}	10^{-11}
4	10^{-4}	10^{-10}
5	10^{-5}	10^{-9}
6	10^{-6}	10^{-8}
7	10^{-7}	10^{-7}
8	10^{-8}	10^{-6}
9	10^{-9}	10^{-5}
10	10^{-10}	10^{-4}
11	10^{-11}	10^{-3}
12	10^{-12}	10^{-2}
13	10^{-13}	10^{-1}
14	10^{-14}	1

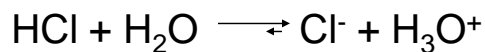
Fig 2.15 pH values for some fluids

- Lower values are acidic fluids
- Higher values are basic fluids



2.9 Acid Dissociation Constants of Weak Acids

- Strong acids and bases dissociate completely in water

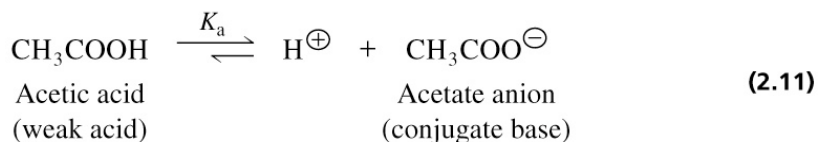


- Cl^- is the **conjugate base** of HCl
- H_3O^+ is the **conjugate acid** of H_2O

2.9 Acid Dissociation Constants of Weak Acids

Acetic acid is a weak acid

- Weak acids and bases do not dissociate completely in H₂O



$$\text{Equilibrium constant} = K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}$$

The Henderson-Hasselbalch Equation

- Defines the pH of a solution in terms of:
(1) The pK_a of the weak acid

pK_a is pH at which an acid is half dissociated
pK_a is a measure of acid strength

- (2) Concentrations of the weak acid (HA) and conjugate base (A⁻)

$$\text{pH} = \text{p}K_a + \log \frac{[\text{A}^\ominus]}{[\text{HA}]}$$

Table 2.4

TABLE 2.4 Dissociation constants and pK_a values of weak acids in aqueous solutions at 25° C

Acid	K_a (M)	pK_a
HCOOH (Formic acid)	1.77×10^{-4}	3.8
CH ₃ COOH (Acetic acid)	1.76×10^{-5}	4.8
CH ₃ CHOHCOOH (Lactic acid)	1.37×10^{-4}	3.9
H ₃ PO ₄ (Phosphoric acid)	7.52×10^{-3}	2.2
H ₂ PO ₄ [⊖] (Dihydrogen phosphate ion)	6.23×10^{-8}	7.2
HPO ₄ [⊖] (Monohydrogen phosphate ion)	2.20×10^{-13}	12.7
H ₂ CO ₃ (Carbonic acid)	4.30×10^{-7}	6.4
HCO ₃ [⊖] (Bicarbonate ion)	5.61×10^{-11}	10.2
NH ₄ [⊕] (Ammonium ion)	5.62×10^{-10}	9.2
CH ₃ NH ₃ [⊕] (Methylammonium ion)	2.70×10^{-11}	10.7

$$\text{Equilibrium constant} = K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}$$

Buffering Power: An acid-base conjugate pair resists changes in pH of a solution (i.e. it acts as a buffer). A weak acid has most effective buffering capability in +/- one pH unit of its pK_a .

Fig. 2.16 Titration curve of acetic acid (CH₃COOH)

- Titration curves are used to determine pK_a values

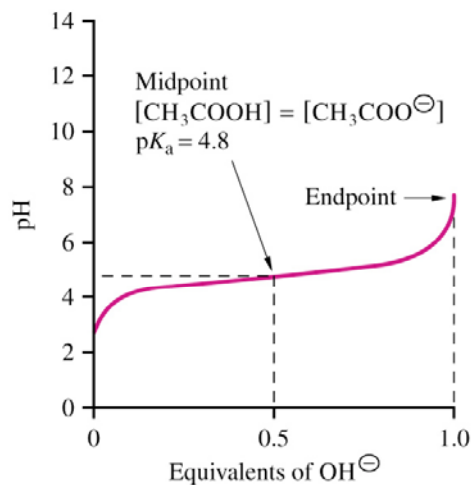
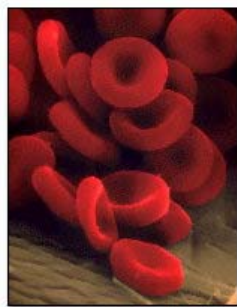
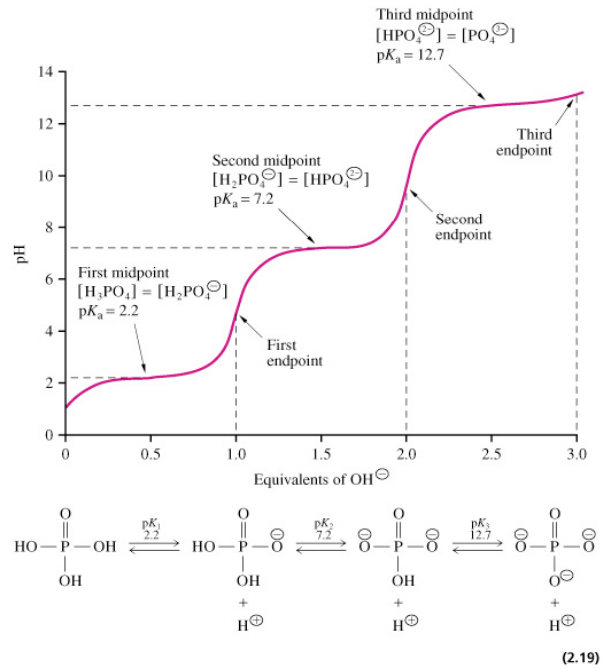
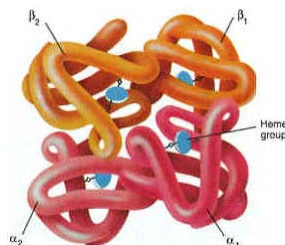
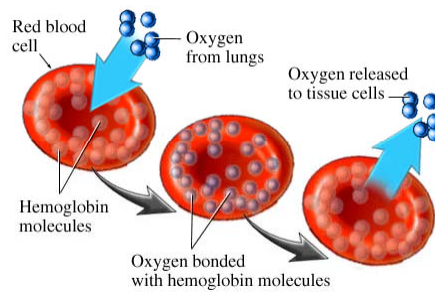


Fig. 2.18

Titration curve for phosphoric acid (H_3PO_4)



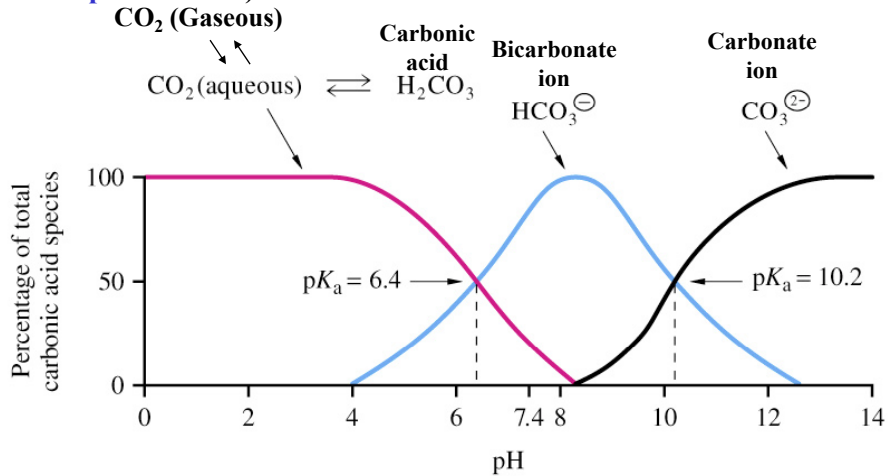
Copyright Dennis Kunkel, University of Hawaii



The pH of the blood is regulated primarily by the CO_2 -carbonic acid-bicarbonate buffer system.

Human Blood plasma is ~pH 7.4

Bicarbonate Buffer System for Blood. Fig. 2.19 Percentages of carbonic acid and its conjugate bases as a function of pH (pH of blood plasma ~ 7.4)



Proteins (hemoglobin) & inorganic phosphate also contribute to intracellular buffering

Fig. 2.20

Regulation of the pH of blood in mammals

