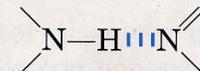
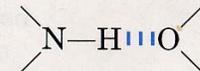
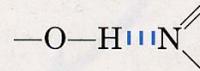


**Table 4–1 Melting point, boiling point, and heat of vaporization of some common liquids**

	Melting point (°C)	Boiling point (°C)	Heat of vaporization (J/g)*
Water	0	100	2,260
Methanol (CH <sub>3</sub> OH)	-98	65	1,100
Ethanol (CH <sub>3</sub> CH <sub>2</sub> OH)	-117	78	854
Propanol (CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub> OH)	-127	97	687
Butanol (CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> CH <sub>2</sub> OH)	-90	117	590
Acetone (CH <sub>3</sub> COCH <sub>3</sub> )	-95	56	523
Hexane (CH <sub>3</sub> (CH <sub>2</sub> ) <sub>4</sub> CH <sub>3</sub> )	-98	69	423
Benzene (C <sub>6</sub> H <sub>6</sub> )	6	80	394
Butane (CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> CH <sub>3</sub> )	-135	-0.5	381
Chloroform (CHCl <sub>3</sub> )	-63	61	247

Hydrogen  
donor

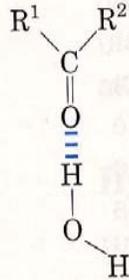
Hydrogen  
acceptor



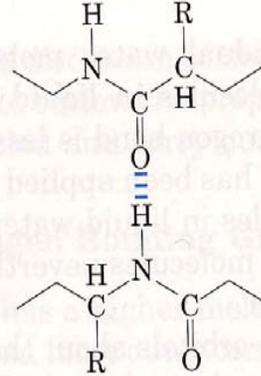
Between the hydroxyl group of an alcohol and water



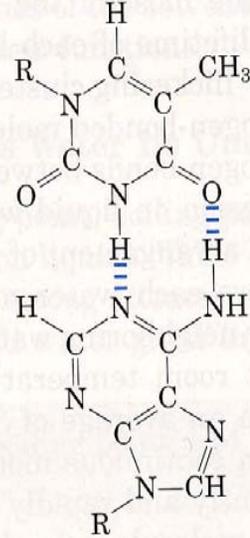
Between the carbonyl group of a ketone and water



Between two polypeptide chains

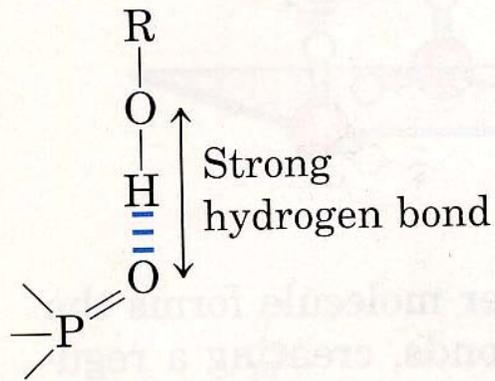


Between two complementary bases of two strands of DNA

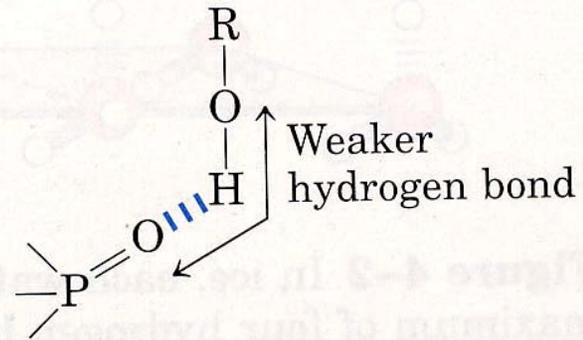


Thymine

Adenine



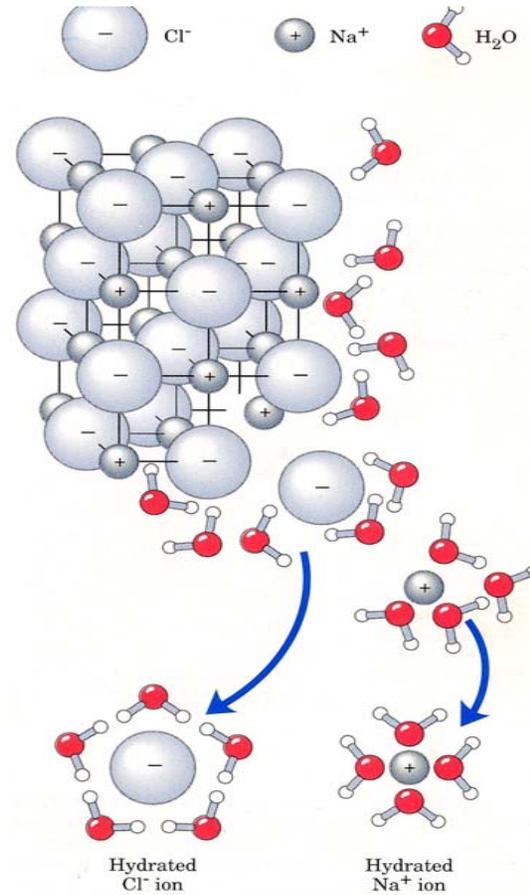
Strong hydrogen bond



Weaker hydrogen bond

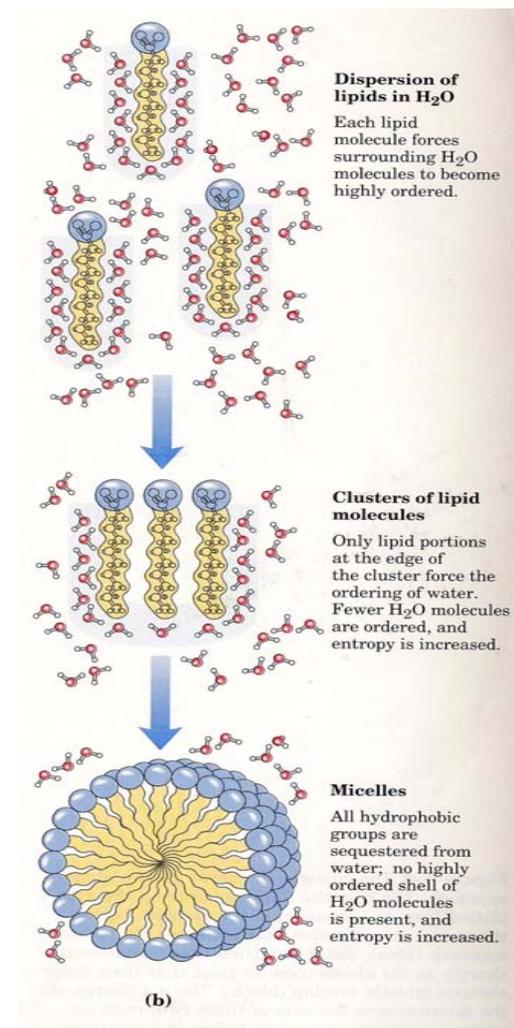
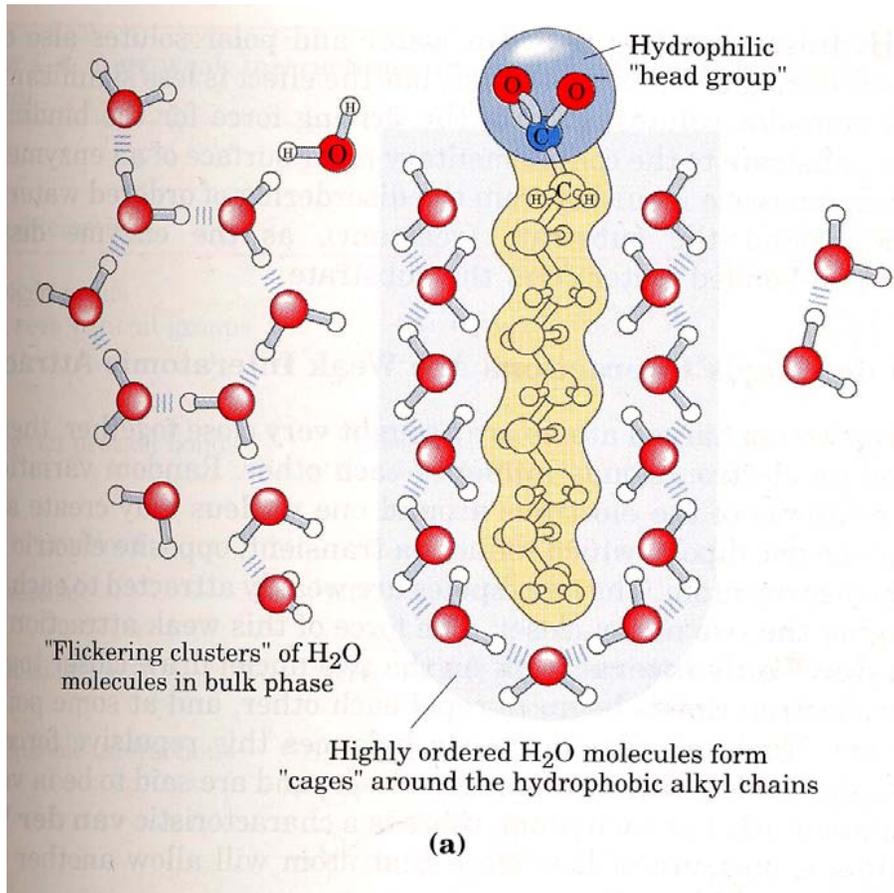
**Table 4-2** Some examples of polar, nonpolar, and amphipathic biomolecules

Biomolecule	Ionic form at pH 7
<i>Polar</i>	
Glucose	
Glycine	$^+ \text{NH}_3 - \text{CH}_2 - \text{COO}^-$
Aspartic acid	$^+ \text{NH}_3 - \text{CH}(\text{COO}^-) - \text{CH}_2 - \text{COO}^-$
Lactic acid	$\text{CH}_3 - \text{CH}(\text{OH}) - \text{COO}^-$
Glycerol	$\text{HOCH}_2 - \text{CH}(\text{OH}) - \text{CH}_2\text{OH}$
<i>Nonpolar</i>	
Typical wax	$\text{CH}_3(\text{CH}_2)_7 - \text{CH} = \text{CH} - (\text{CH}_2)_6 - \text{CH}_2 - \text{C}(=\text{O}) - \text{O} - \text{CH}_2(\text{CH}_2)_7 - \text{CH} = \text{CH} - \text{CH}_3$
<i>Amphipathic</i>	
Phenylalanine	$\text{C}_6\text{H}_5 - \text{CH}_2 - \text{CH}(\text{COO}^-) - \text{NH}_3^+$
Phosphatidylcholine	$\text{CH}_3(\text{CH}_2)_{15} - \text{CH}_2 - \text{C}(=\text{O}) - \text{O} - \text{CH}_2 - \text{C}(=\text{O}) - \text{O} - \text{CH}(\text{CH}_2 - \text{P}(=\text{O})(\text{O}^-) - \text{O} - \text{CH}_2 - \text{CH}_2 - \text{N}^+(\text{CH}_3)_3)$



**Table 4-3 Solubilities of some gases in water**

Gas	Structure*	Polarity	Solubility in water (g/L)	Temperat (°C)
Nitrogen	$\text{N}\equiv\text{N}$	Nonpolar	0.018	40
Oxygen	$\text{O}=\text{O}$	Nonpolar	0.035	50
Carbon dioxide	$\overset{\delta^-}{\leftarrow} \quad \overset{\delta^-}{\rightarrow}$ $\text{O}=\text{C}=\text{O}$	Nonpolar	0.97	45
Ammonia	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \diagdown \quad   \quad / \\ \text{N} \\ \downarrow \delta^- \end{array}$	Polar	900	10
Hydrogen sulfide	$\begin{array}{c} \text{H} \quad \quad \text{H} \\ \diagdown \quad / \\ \text{S} \\ \downarrow \delta^- \end{array}$	Polar	1,860	40

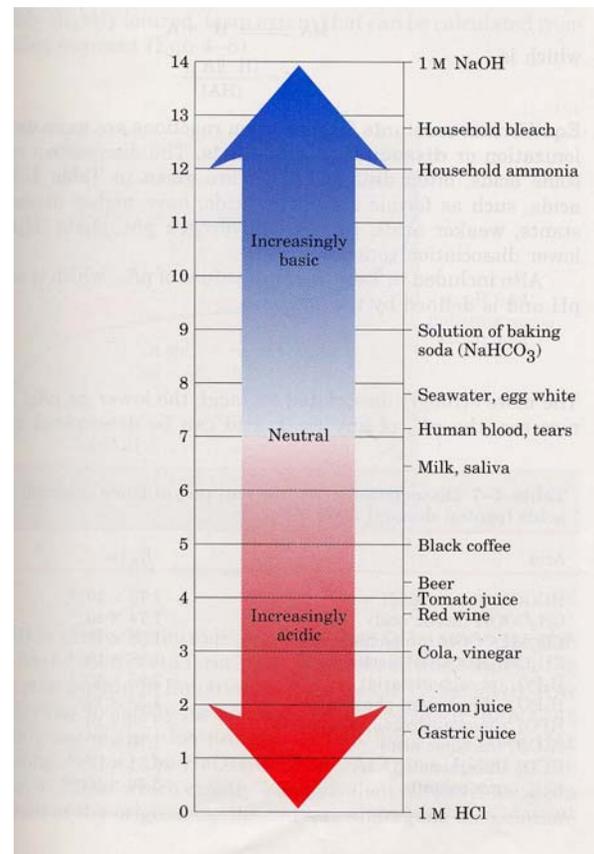


**Table 4-4** Four weak interactions among biomolecules in aqueous solvent

Weak interaction		Stabilization energy (kJ/mol)
Hydrogen bonds		
Between neutral groups	$\diagup \text{C}=\text{O} \cdots \text{H}-\text{O}-\diagdown$	8-21
Between peptide bonds	$\diagup \text{C}=\text{O} \cdots \text{H}-\text{N} \diagdown$	8-21
Ionic interactions		
Attraction	$-\text{NH}_3^+ \longleftrightarrow -\text{O}-\overset{\text{O}}{\parallel}{\text{C}}-$	42
Repulsion	$-\text{NH}_3^+ \longleftrightarrow \text{H}_3\text{N}^+-$	$\approx -21$
Hydrophobic interactions	$\begin{array}{c} \text{CH}_3 \quad \text{CH}_3 \\ \diagdown \quad \diagup \\ \text{CH} \\   \\ \text{CH}_2 \end{array} \quad \begin{array}{c} \text{CH}_3 \quad \text{CH}_3 \\ \diagdown \quad \diagup \\ \text{CH} \\   \\ \text{CH}_2 \end{array}$	4-8
van der Waals interactions	Any two atoms in close proximity	4

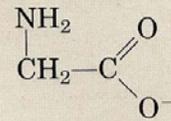
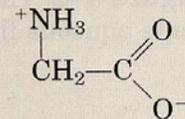
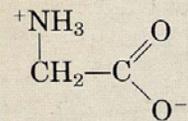
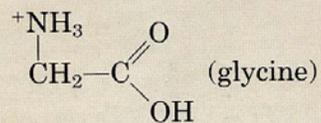
**Table 4-5 The pH scale**

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



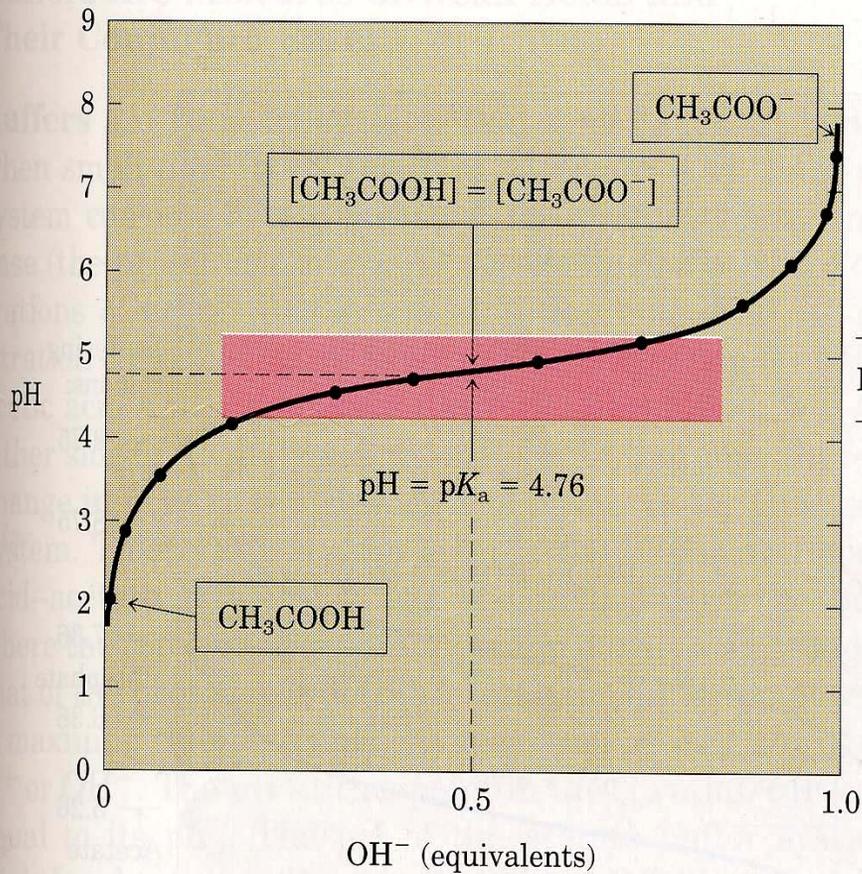
**Table 4-6 Some conjugate acid-base pairs\***

Proton donor	Proton acceptor
$\text{CH}_3\text{COOH}$ (acetic acid)	$\text{CH}_3\text{COO}^-$
$\text{H}_3\text{PO}_4$ (phosphoric acid)	$\text{H}_2\text{PO}_4^-$
$\text{H}_2\text{PO}_4^-$ (dihydrogen phosphate)	$\text{HPO}_4^{2-}$
$\text{HPO}_4^{2-}$ (hydrogen phosphate)	$\text{PO}_4^{3-}$
$\text{NH}_4^+$ (ammonium)	$\text{NH}_3$
$\text{H}_2\text{CO}_3$ (carbonic acid)	$\text{HCO}_3^-$
$\text{HCO}_3^-$ (bicarbonate)	$\text{CO}_3^{2-}$

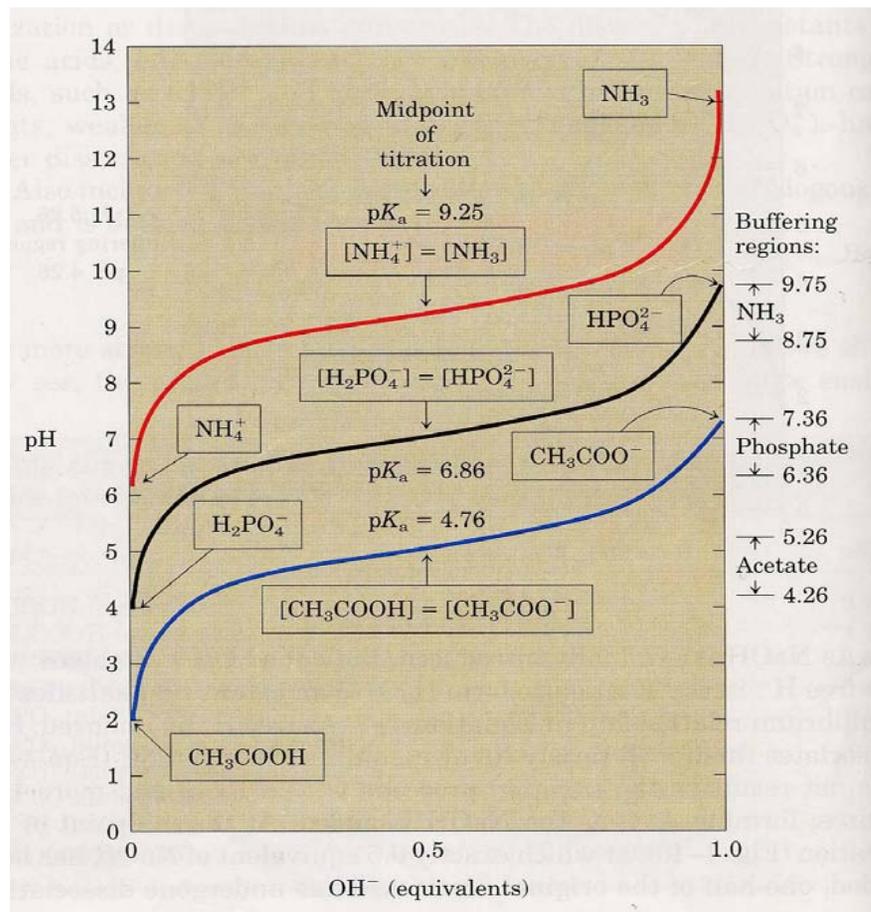


**Table 4–7** Dissociation constant and  $pK_a$  of some common weak acids (proton donors) at 25 °C

Acid	$K_a$ (M)	$pK_a$
HCOOH (formic acid)	$1.78 \times 10^{-4}$	3.75
CH <sub>3</sub> COOH (acetic acid)	$1.74 \times 10^{-5}$	4.76
CH <sub>3</sub> CH <sub>2</sub> COOH (propionic acid)	$1.35 \times 10^{-5}$	4.87
CH <sub>3</sub> CH(OH)COOH (lactic acid)	$1.38 \times 10^{-4}$	3.86
H <sub>3</sub> PO <sub>4</sub> (phosphoric acid)	$7.25 \times 10^{-3}$	2.14
H <sub>2</sub> PO <sub>4</sub> <sup>-</sup> (dihydrogen phosphate)	$1.38 \times 10^{-7}$	6.86
HPO <sub>4</sub> <sup>2-</sup> (monohydrogen phosphate)	$3.98 \times 10^{-13}$	12.4
H <sub>2</sub> CO <sub>3</sub> (carbonic acid)	$1.70 \times 10^{-4}$	3.77
HCO <sub>3</sub> <sup>-</sup> (bicarbonate)	$6.31 \times 10^{-11}$	10.2
NH <sub>4</sub> <sup>+</sup> (ammonium)	$5.62 \times 10^{-10}$	9.25



↑ pH 5.26  
Buffering region  
↓ pH 4.26

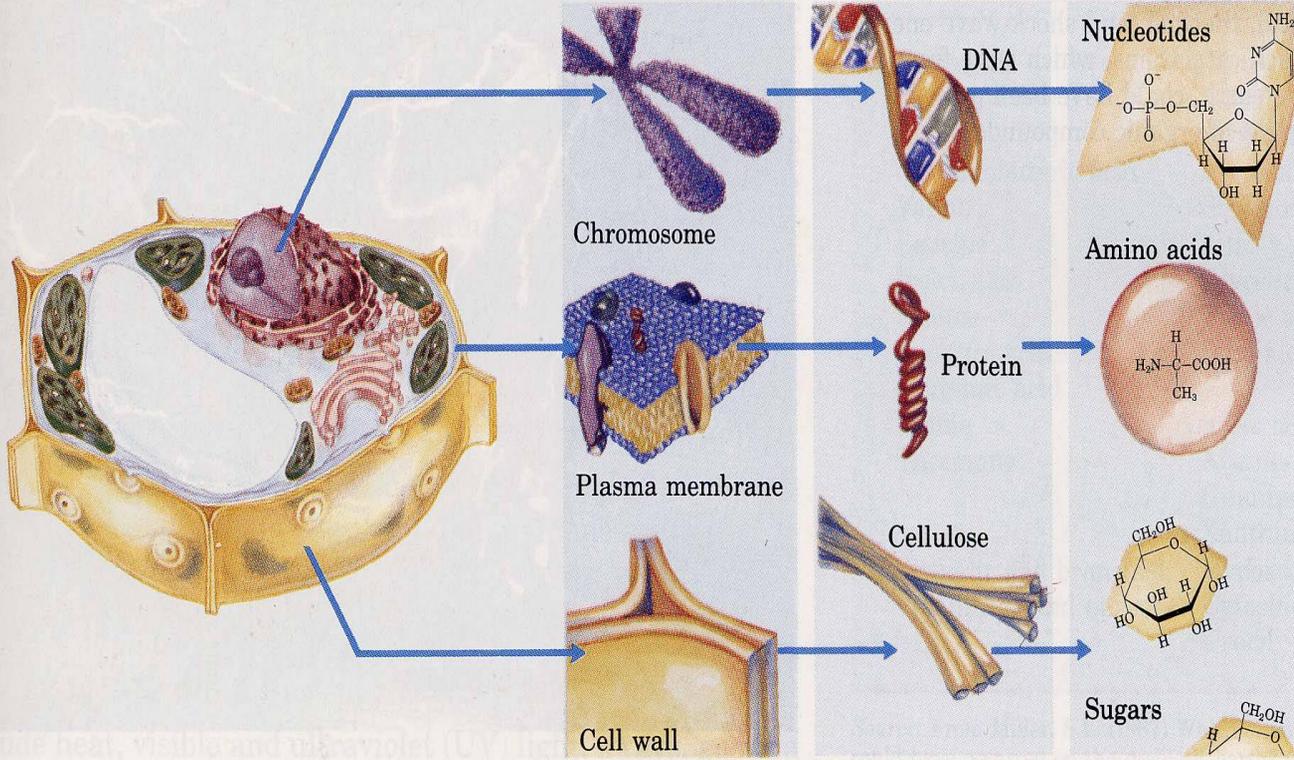


**Level 4:  
The cell  
and its organelles**

**Level 3:  
Supramolecular  
complexes**

**Level 2:  
Macromolecules**

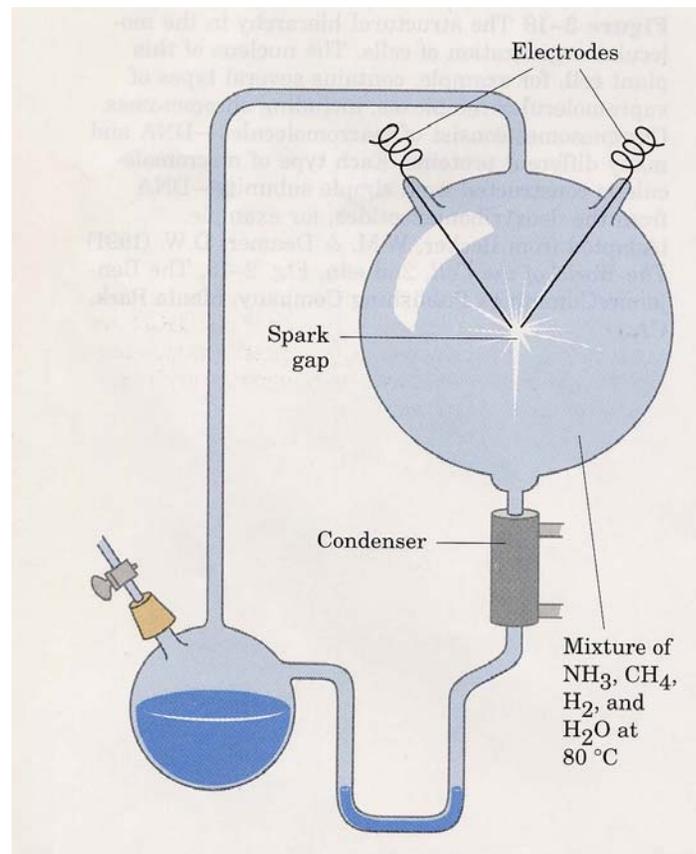
**Level 1:  
Biomolecules**



**Table 3-1 Elemental abundance in seawater, the human body, and the earth's crust\***

Seawater (%)		Human body (%)		Earth's crust (%)	
H	66	H	63	O	47
O	33	O	25.5	Si	28
Cl	0.33	C	9.5	Al	7.9
Na	0.28	N	1.4	Fe	4.5
Mg	0.033	Ca	0.31	Ca	3.5
S	0.017	P	0.22	Na	2.5
Ca	0.0062	Cl	0.08	K	2.5
K	0.0060	K	0.06	Mg	2.2
C	0.0014				

\* Values are given as percentage of total number of atoms.



**Table 3-8** Some of the products shown to form under prebiotic conditions

*Amino acids*

Glycine  
Alanine  
 $\alpha$ -Aminobutyric acid  
Valine  
Leucine  
Isoleucine  
Proline  
Aspartic acid  
Glutamic acid  
Serine  
Threonine

*Sugars*

Straight and branched  
pentoses and hexoses

*Carboxylic acids*

Formic acid  
Acetic acid  
Propionic acid  
Straight and branched  
fatty acids ( $C_4-C_{10}$ )  
Glycolic acid  
Lactic acid  
Succinic acid

*Nucleic acid bases*

Adenine  
Guanine  
Xanthine  
Hypoxanthine  
Cytosine  
Uracil

