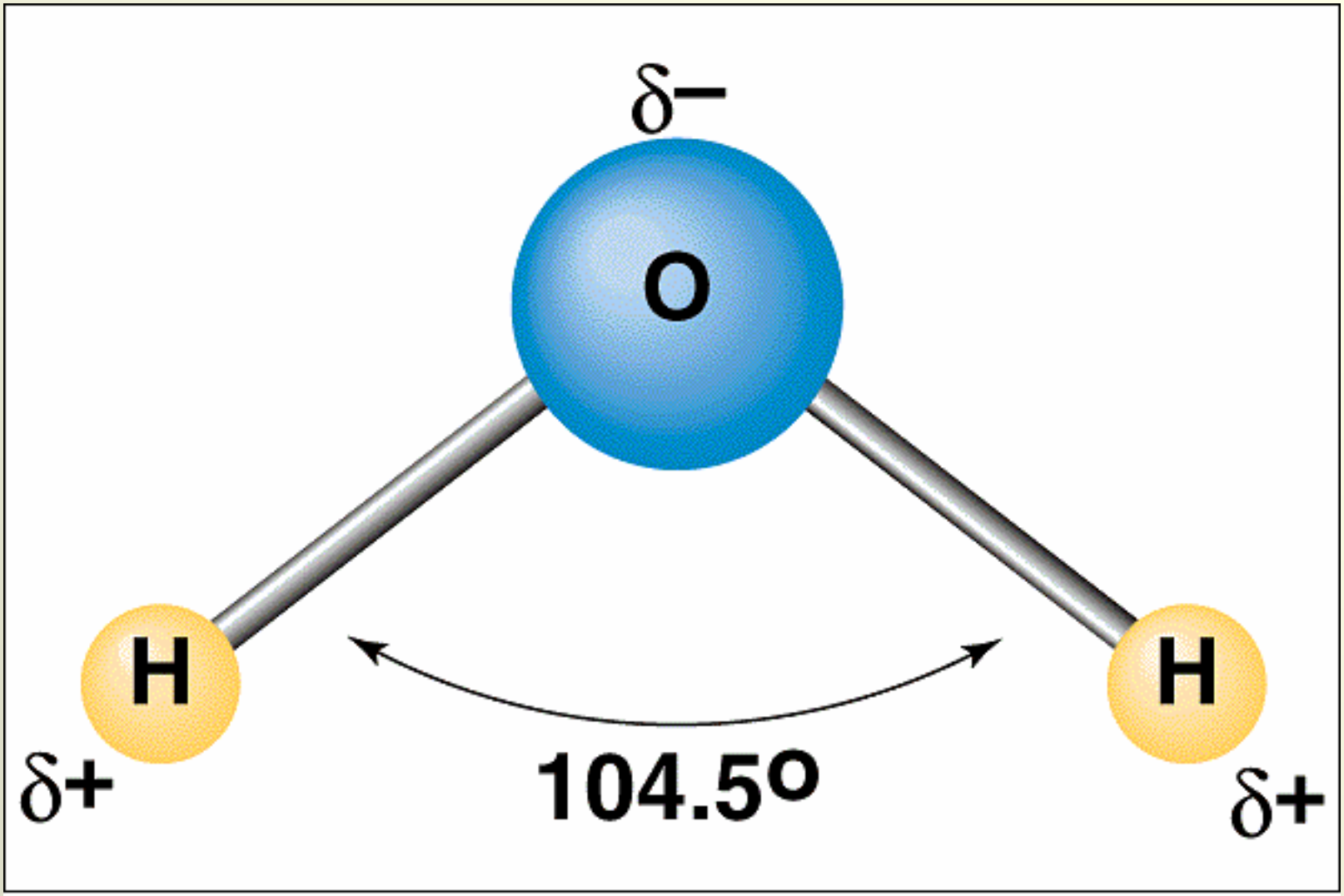
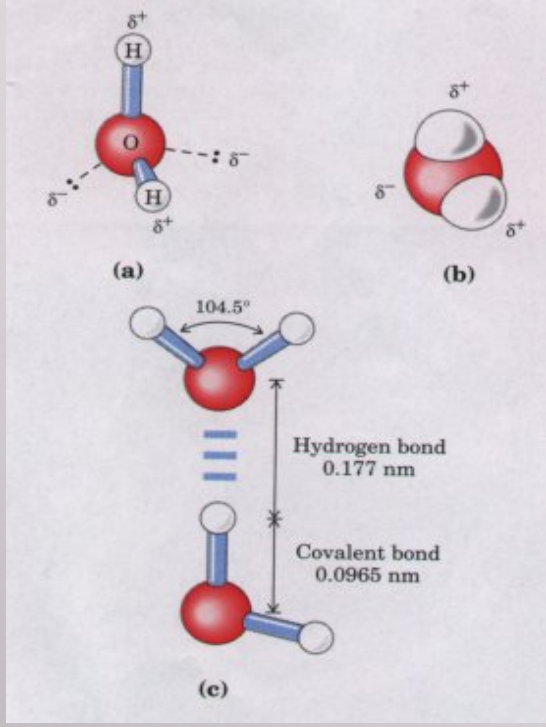
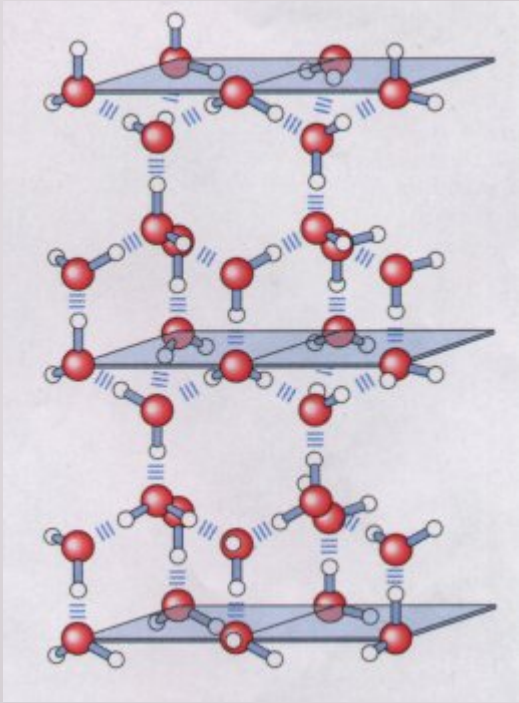


Table 4–1 Melting point, boiling point, and heat of vaporization of some common liquids

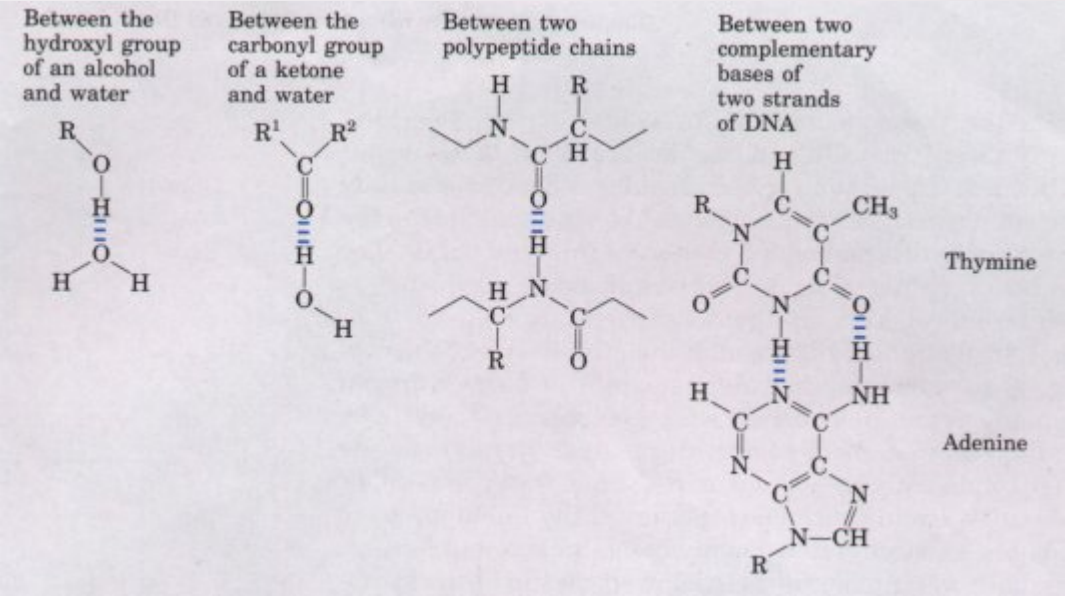
	Melting point (°C)	Boiling point (°C)	Heat of vaporization (J/g)*
Water	0	100	2,260
Methanol (CH_3OH)	−98	65	1,100
Ethanol (CH_3CH_2OH)	−117	78	854
Propanol ($CH_3CH_2CH_2OH$)	−127	97	687
Butanol ($CH_3(CH_2)_2CH_2OH$)	−90	117	590
Acetone (CH_3COCH_3)	−95	56	523
Hexane ($CH_3(CH_2)_4CH_3$)	−98	69	423
Benzene (C_6H_6)	6	80	394
Butane ($CH_3(CH_2)_2CH_3$)	−135	−0.5	381
Chloroform ($CHCl_3$)	−63	61	247

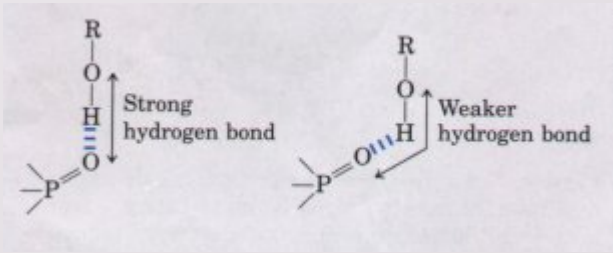
* The heat energy required to convert 1.0 g of a liquid at its boiling point, at atmospheric pressure, into its gaseous state at the same temperature. It is a direct measure of the energy required to overcome attractive forces between molecules in the liquid phase.

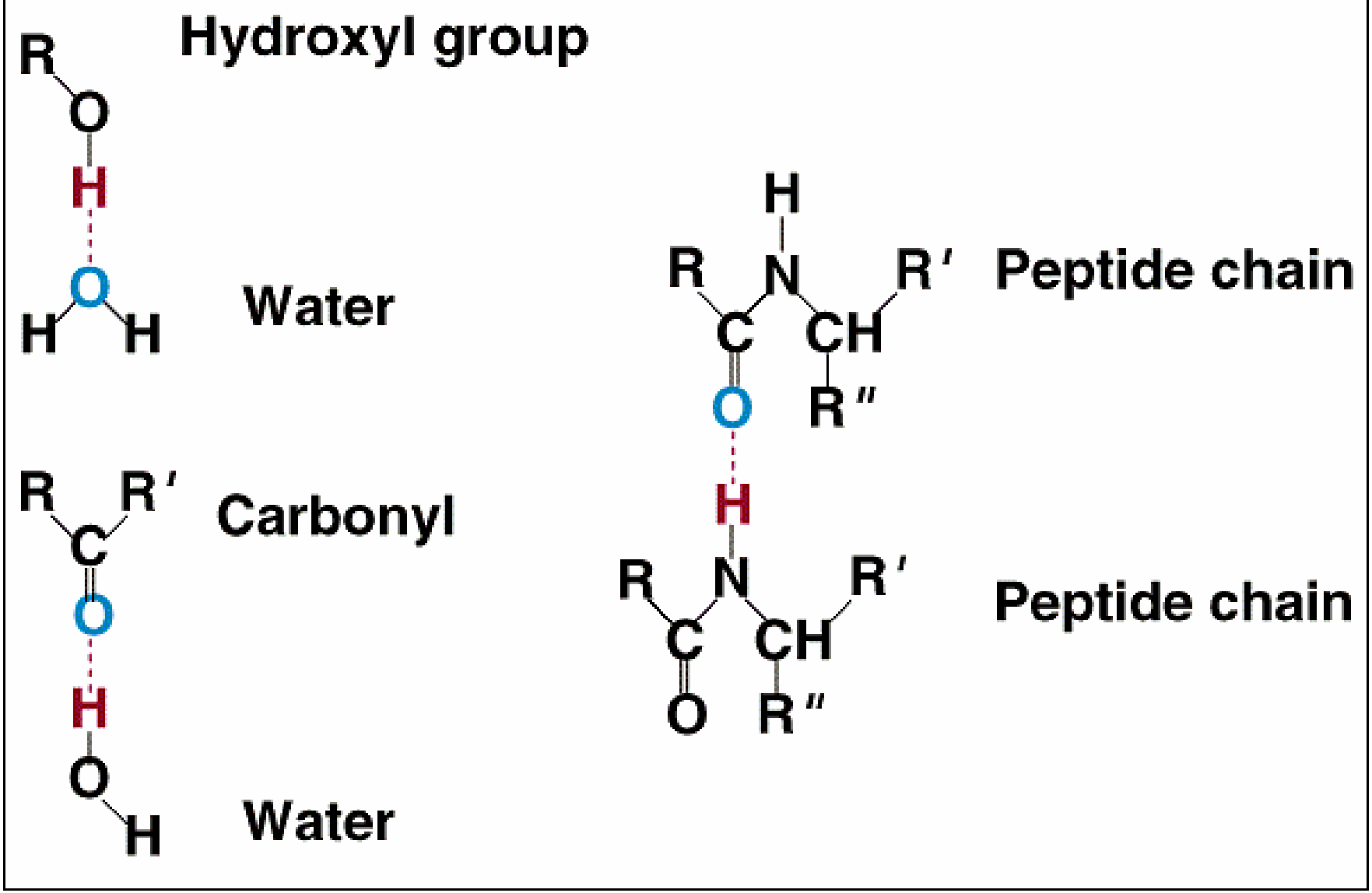




Hydrogen donor	Hydrogen acceptor
—O—H	O=C
—O—H	N
—O—H	O
N—H	O=C
N—H	O
N—H	N


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



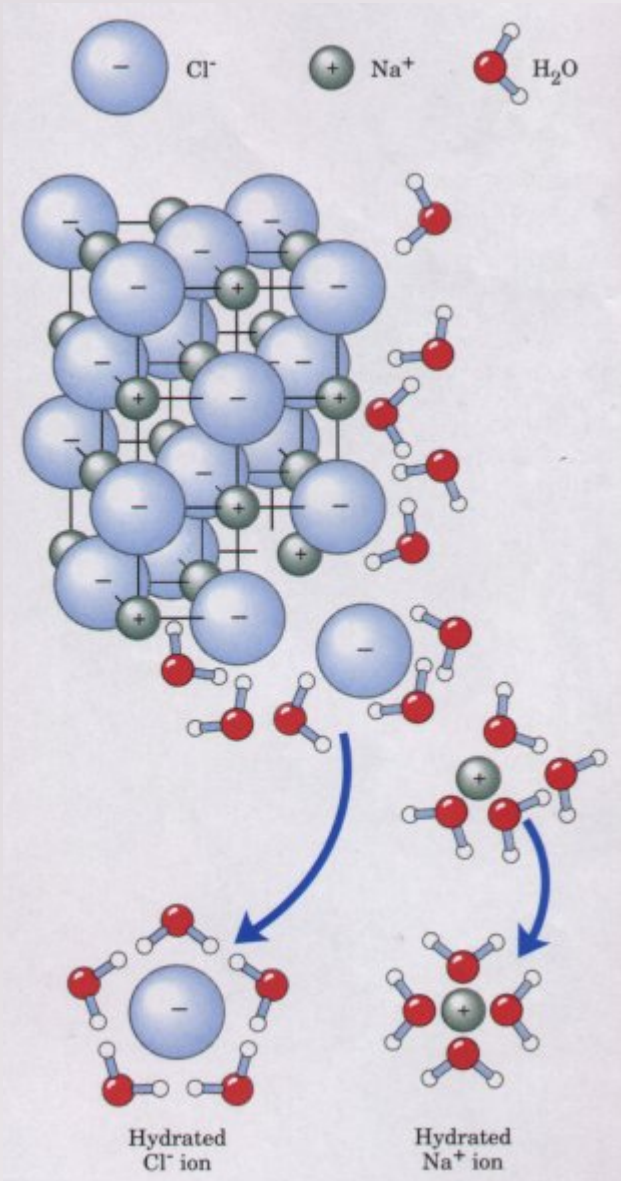

Cl⁻
Na⁺
H₂O
Hydrated Cl⁻ ion
Hydrated Na⁺ ion

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

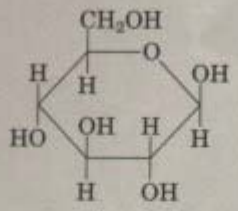
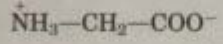
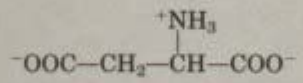
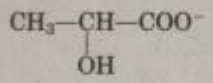
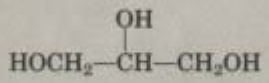
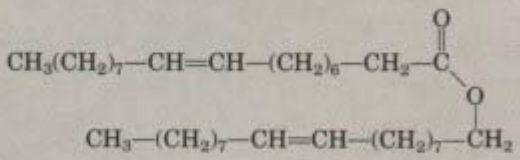
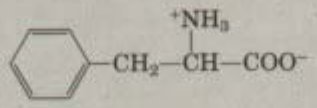
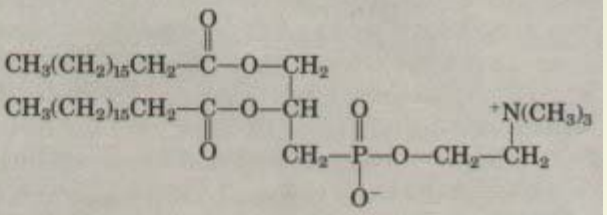
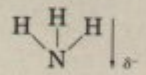
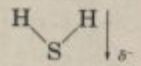
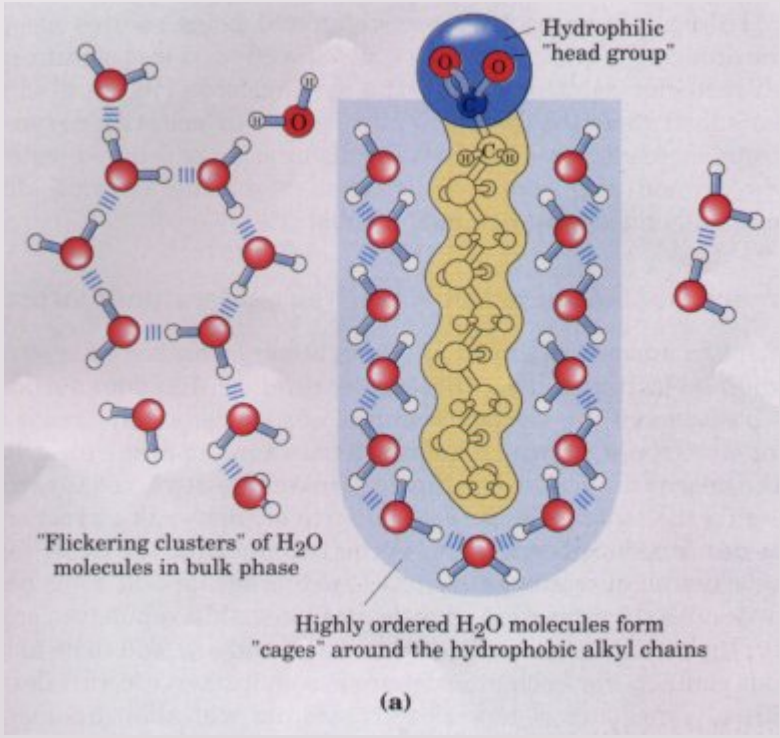
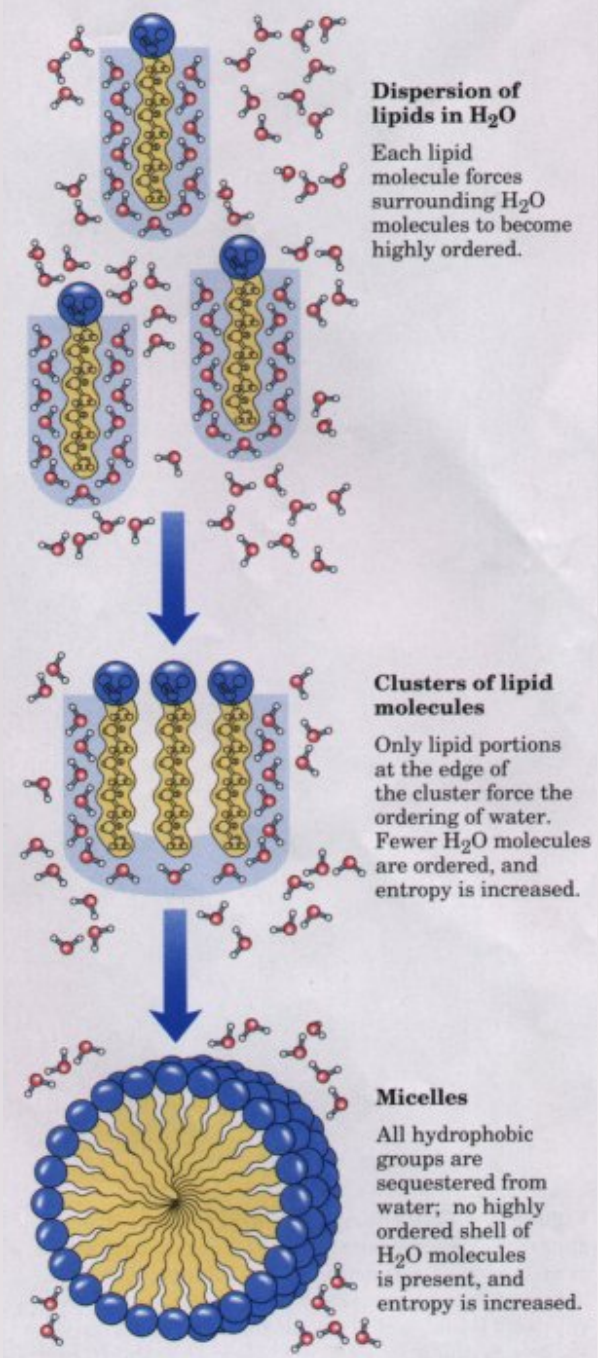
Biomolecule	Ionic form at pH 7
Polar	
Glucose	
Glycine	
Aspartic acid	
Lactic acid	
Glycerol	
Nonpolar	
Typical wax	
Amphipathic	
Phenylalanine	
Phosphatidyl-choline	

Table 4–3 Solubilities of some gases in water

Gas	Structure*	Polarity	Solubility in water (g/L)	Temperature (°C)
Nitrogen	N≡N	Nonpolar	0.018	40
Oxygen	O=O	Nonpolar	0.035	50
Carbon dioxide	$\overset{\delta^-}{\leftarrow}\quad\overset{\delta^-}{\rightarrow}$ O=C=O	Nonpolar	0.97	45
Ammonia		Polar	900	10
Hydrogen sulfide		Polar	1,860	40

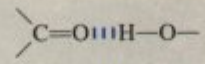
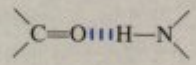
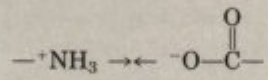
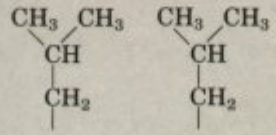

Hydrophilic
"head group"
"Flickering clusters" of H_2O
molecules in bulk phase
Highly ordered H_2O molecules form
"cages" around the hydrophobic alkyl chains

(a)


Dispersion of lipids in H_2O
Each lipid molecule forces surrounding H_2O molecules to become highly ordered.
Clusters of lipid molecules
Only lipid portions at the edge of the cluster force the ordering of water. Fewer H_2O molecules are ordered, and entropy is increased.
Micelles
All hydrophobic groups are sequestered from water; no highly ordered shell of H_2O molecules is present, and entropy is increased.

(b)

Table 4–4 Four weak interactions among biomolecules in aqueous solvent

Weak interaction		Stabilization energy (kJ/mol)
Hydrogen bonds		
Between neutral groups		8–21
Between peptide bonds		8–21
Ionic interactions		
Attraction		42
Repulsion		≈ −21
Hydrophobic interactions		4–8
van der Waals interactions	Any two atoms in close proximity	4

$H_2O \rightleftharpoons H^+ + OH^-$

$A + B \rightleftharpoons C + D$ $\qquad Keq = \frac{[C][D]}{[A][B]}$

$$Keq = \frac{[H^+][OH^-]}{[H_2O]}$$

$$Keq = \frac{[H^+][OH^-]}{55.5\ M}$$

$55.5M \times Keq = [H^+][OH^-] = Kw$

K_{eq} agua $= 1.8 \times 10^{-16}$ A 25ºC

$55.5M \times 1.8 \times 10^{-16} = [H^+][OH^-]$

$1.0 \times 10^{-14} = [H^+][OH^-] = K_w$

$K_w = [H^+][OH^-] = [H^+]^2$

$[H^+] = \sqrt{K_w} = \sqrt{1 \times 10^{-14}}$

$[H^+] = [OH^-] = 10^{-7}\ M$

$pH = \log \frac{1}{[H^+]} = -\log [H^+]$

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

* The expression pOH is sometimes used to describe the basicity, or OH^- concentration, of a solution; pOH is defined by the expression $pOH = -\log [OH^-]$, which is analogous to the expression for pH. Note that for all cases, pH + pOH = 14.

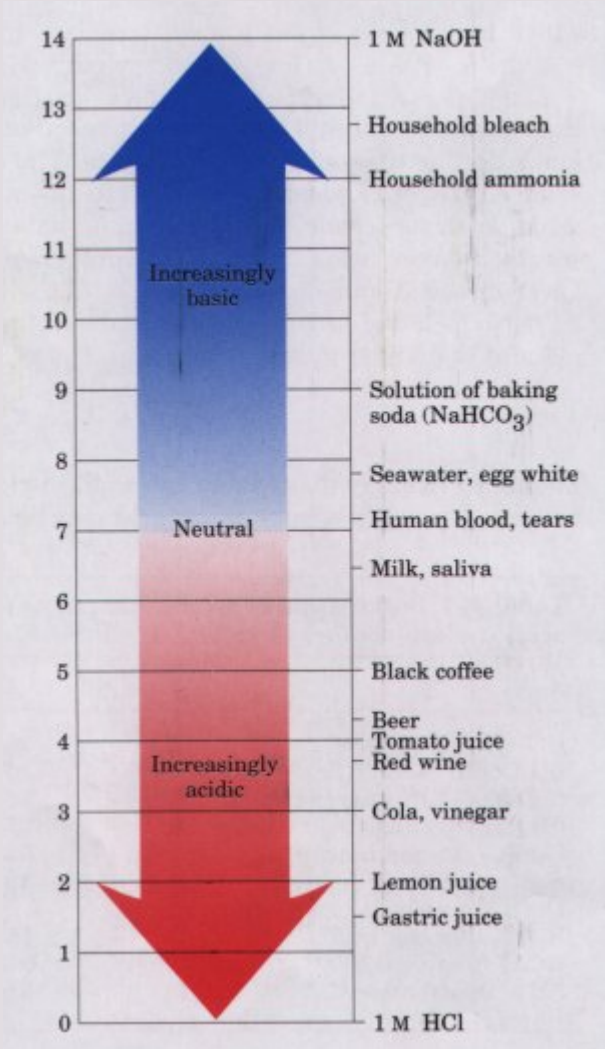
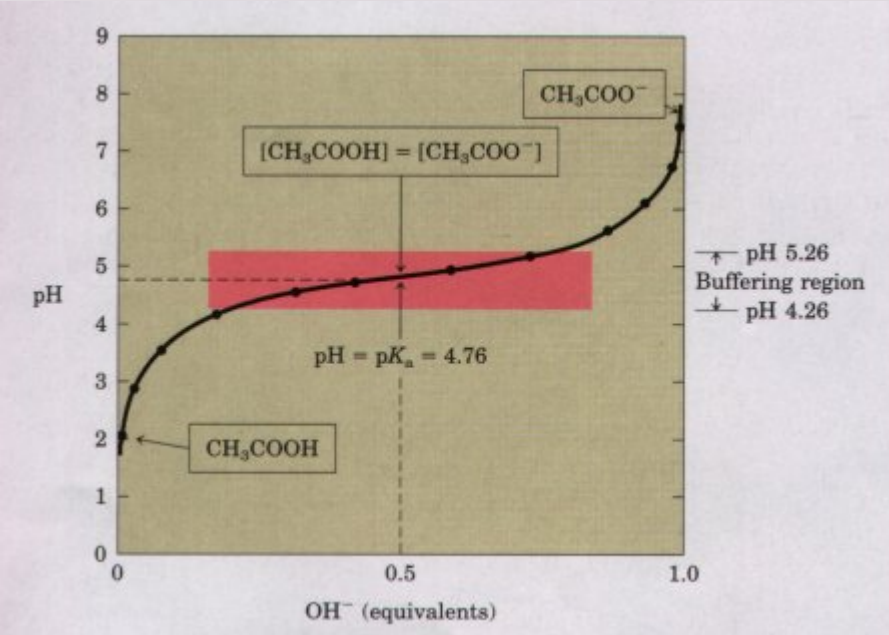
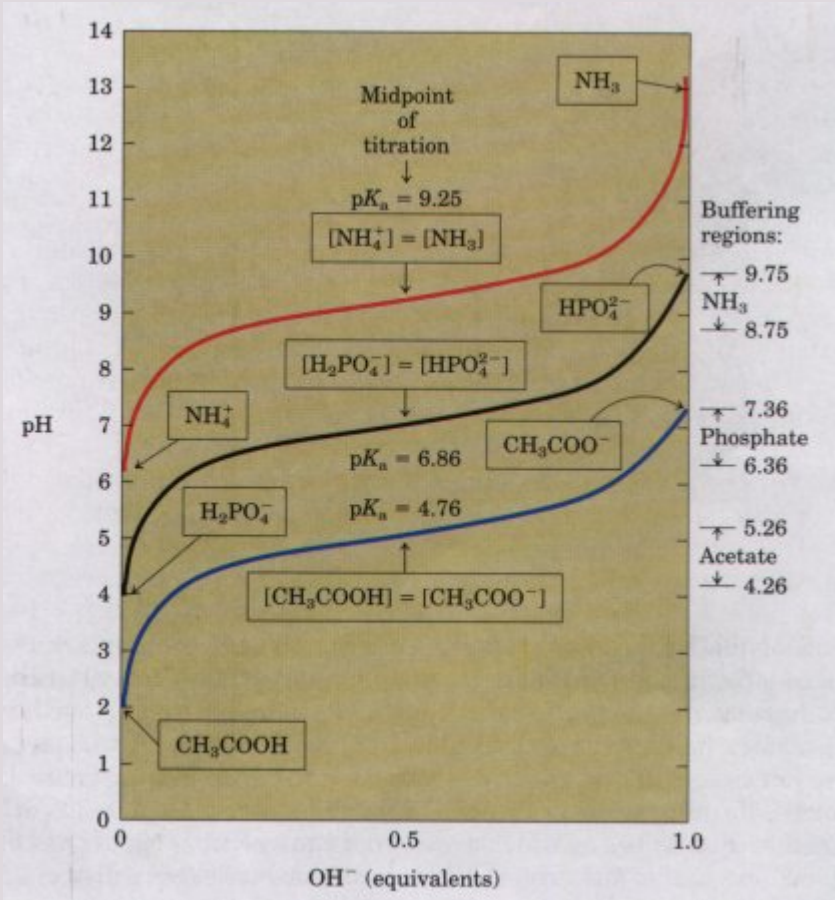
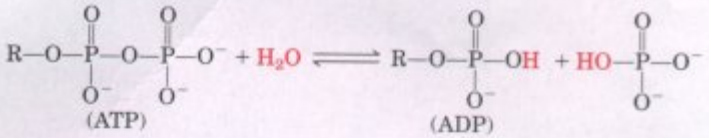

14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1 M NaOH
Household bleach
Household ammonia
Increasingly basic
Solution of baking soda ($NaHCO_3$)
Seawater, egg white
Human blood, tears
Neutral
Milk, saliva
Black coffee
Beer
Tomato juice
Red wine
Increasingly acidic
Cola, vinegar
Lemon juice
Gastric juice
1 M HCl

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)	1.78×10^{-4}	3.75
CH_3COOH (acetic acid)	1.74×10^{-5}	4.76
CH_3CH_2COOH (propionic acid)	1.35×10^{-5}	4.87
$CH_3CH(OH)COOH$ (lactic acid)	1.38×10^{-4}	3.86
H_3PO_4 (phosphoric acid)	7.25×10^{-3}	2.14
$H_2PO_4^-$ (dihydrogen phosphate)	1.38×10^{-7}	6.86
HPO_4^{2-} (monohydrogen phosphate)	3.98×10^{-13}	12.4
H_2CO_3 (carbonic acid)	1.70×10^{-4}	3.77
HCO_3^- (bicarbonate)	6.31×10^{-11}	10.2
NH_4^+ (ammonium)	5.62×10^{-10}	9.25

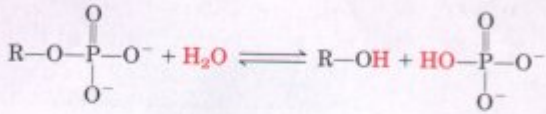

9
8
7
6
5
4
3
2
1
0
pH
0
0.5
1.0
OH⁻ (equivalents)
CH₃COO⁻
[CH₃COOH] = [CH₃COO⁻]
pH = pKa = 4.76
CH₃COOH
pH 5.26
Buffering region
pH 4.26


14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
pH
0
0.5
1.0
OH⁻ (equivalents)
Midpoint of titration
pKa = 9.25
[NH4+] = [NH3]
NH3
HPO4 2−
[H2PO4−] = [HPO4 2−]
NH4+
CH3COO−
pKa = 6.86
H2PO4−
pKa = 4.76
[CH3COOH] = [CH3COO−]
CH3COOH
Buffering regions:
9.75
NH3
8.75
7.36
Phosphate
6.36
5.26
Acetate
4.26



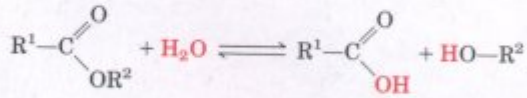
Phosphate anhydride

(a)



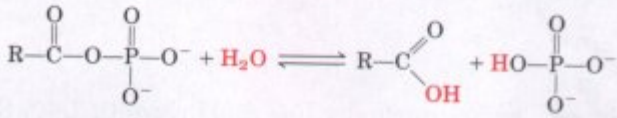
Phosphate ester

(b)



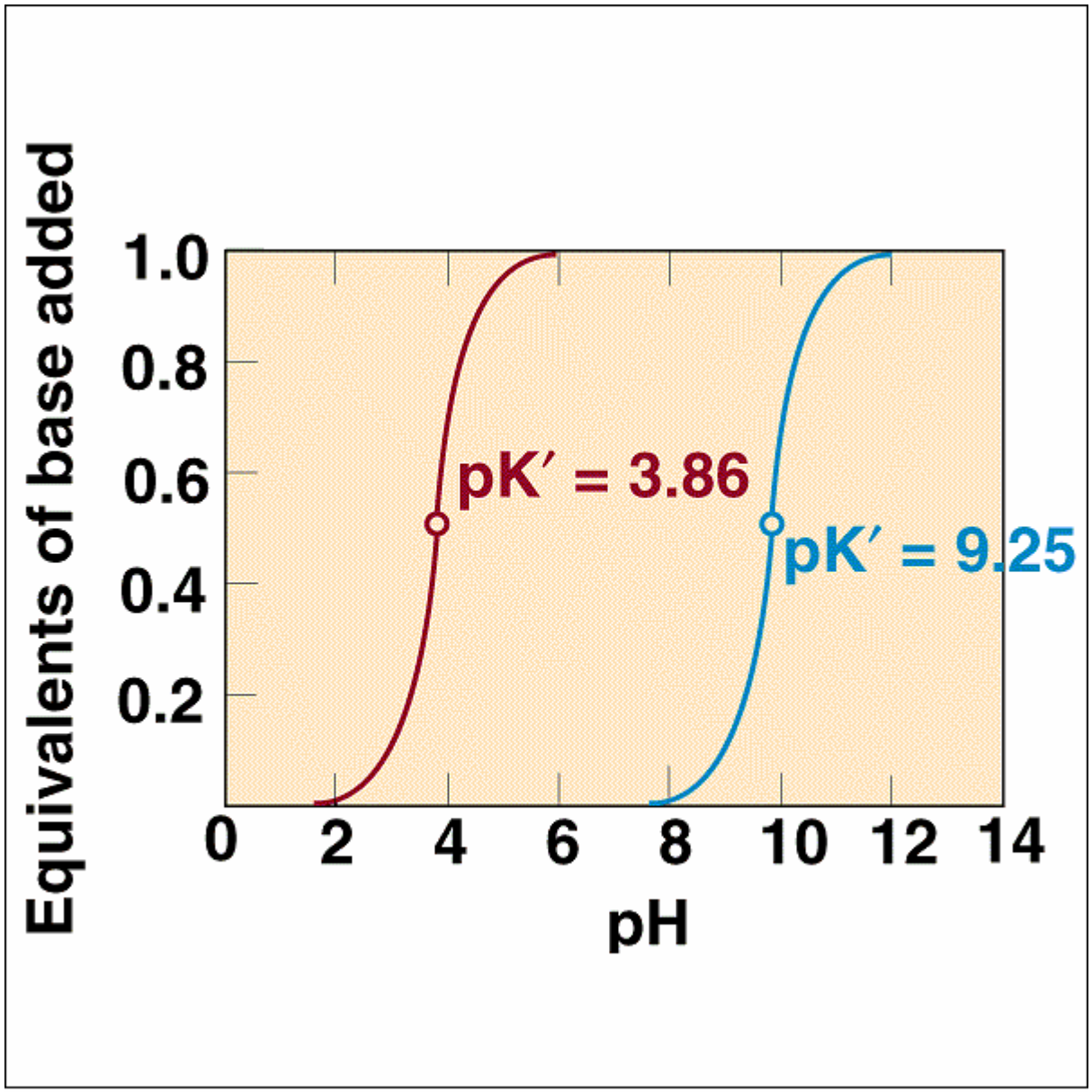
Carboxylate ester

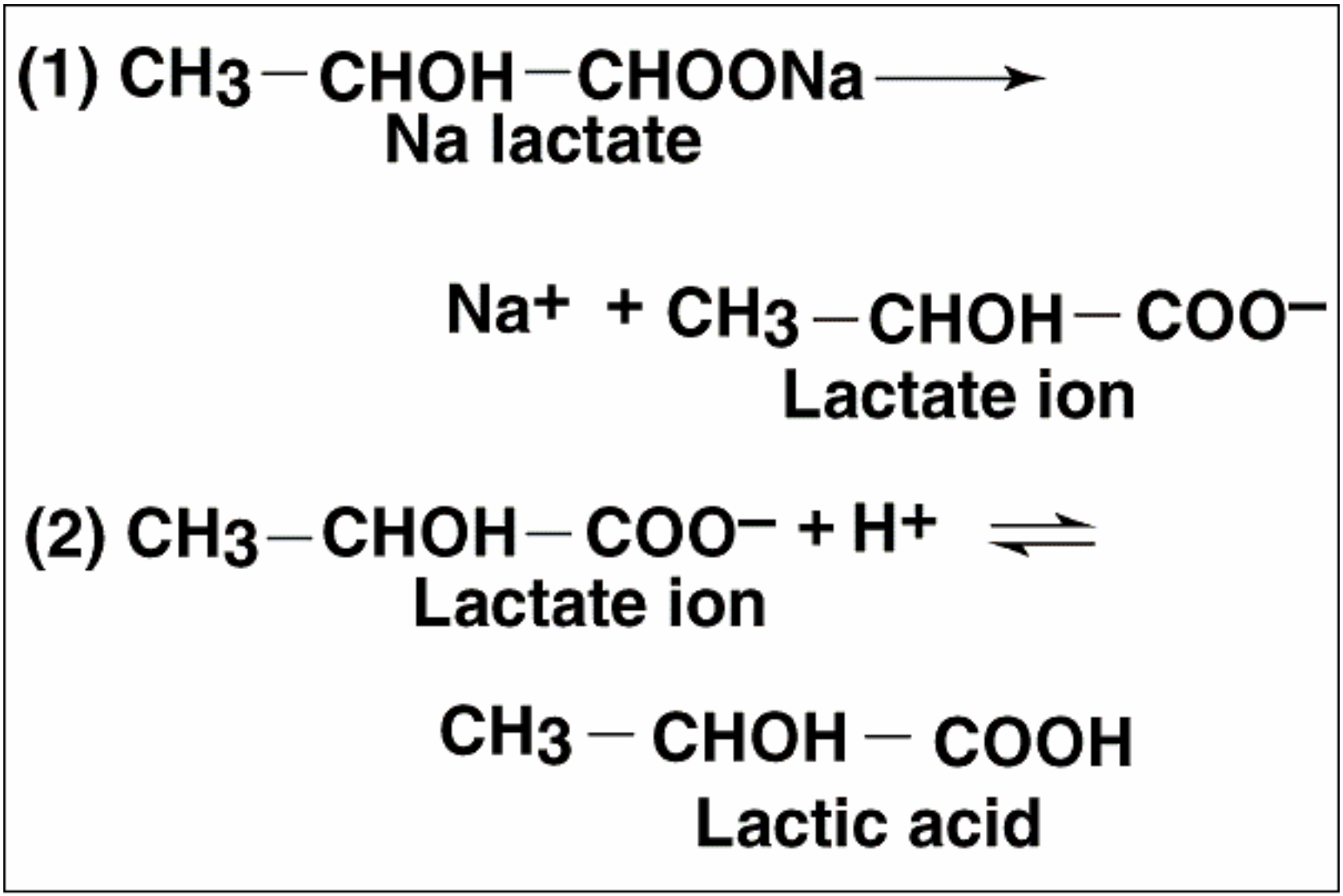
(c)

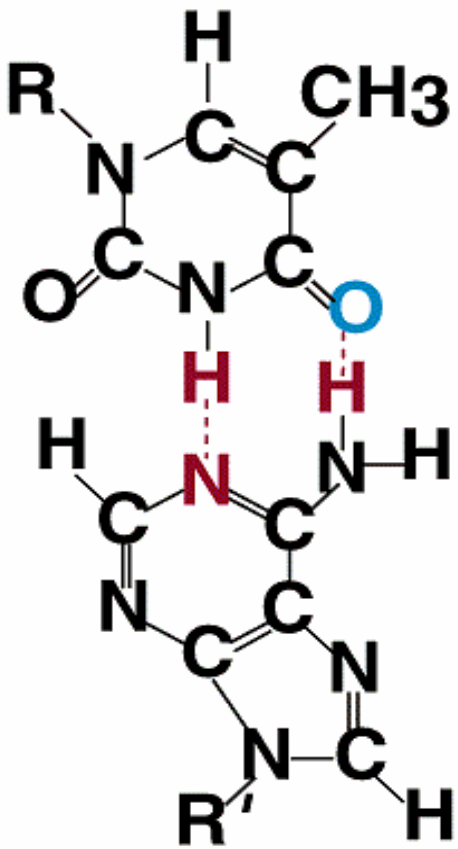


Acylphosphate anhydride

(d)







Thymine in DNA

Adenine in DNA