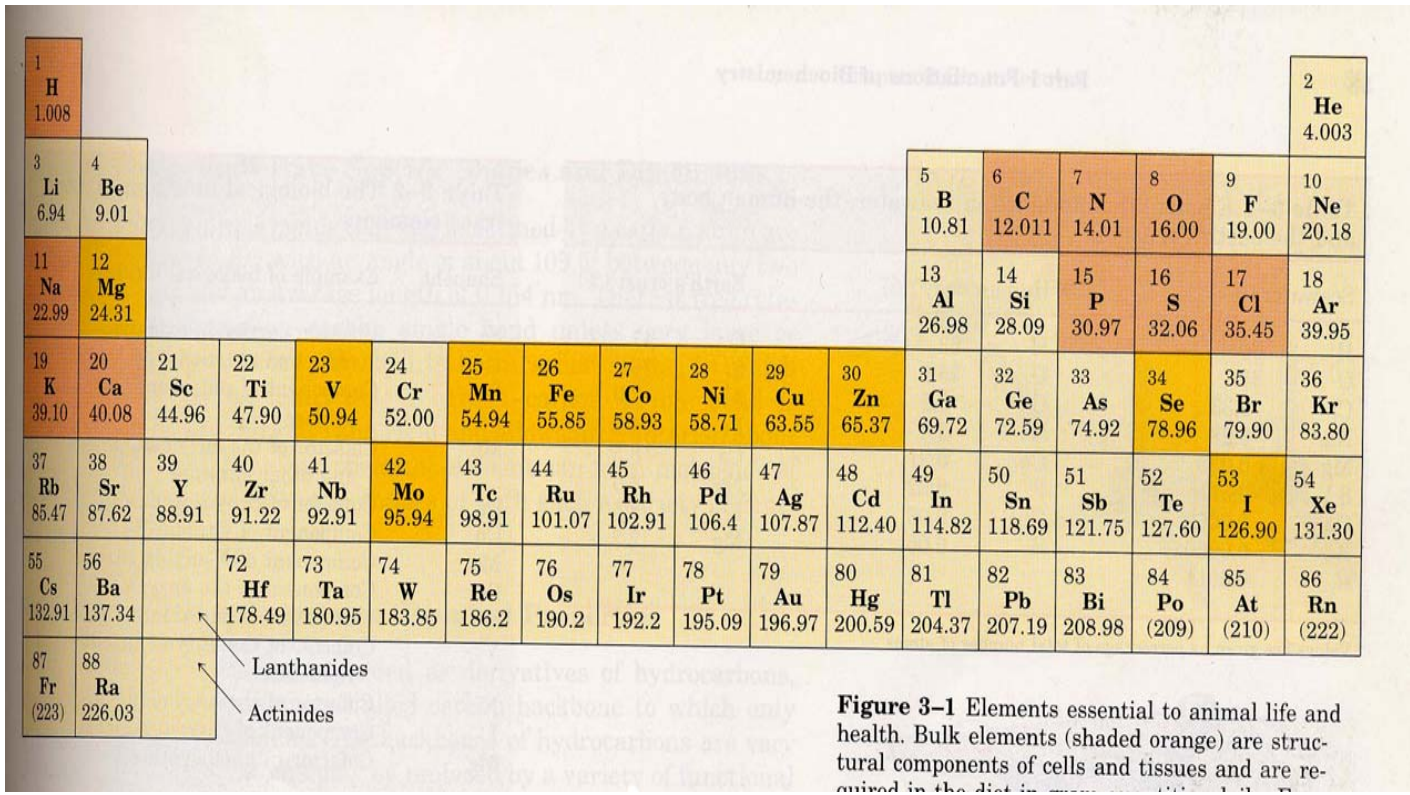
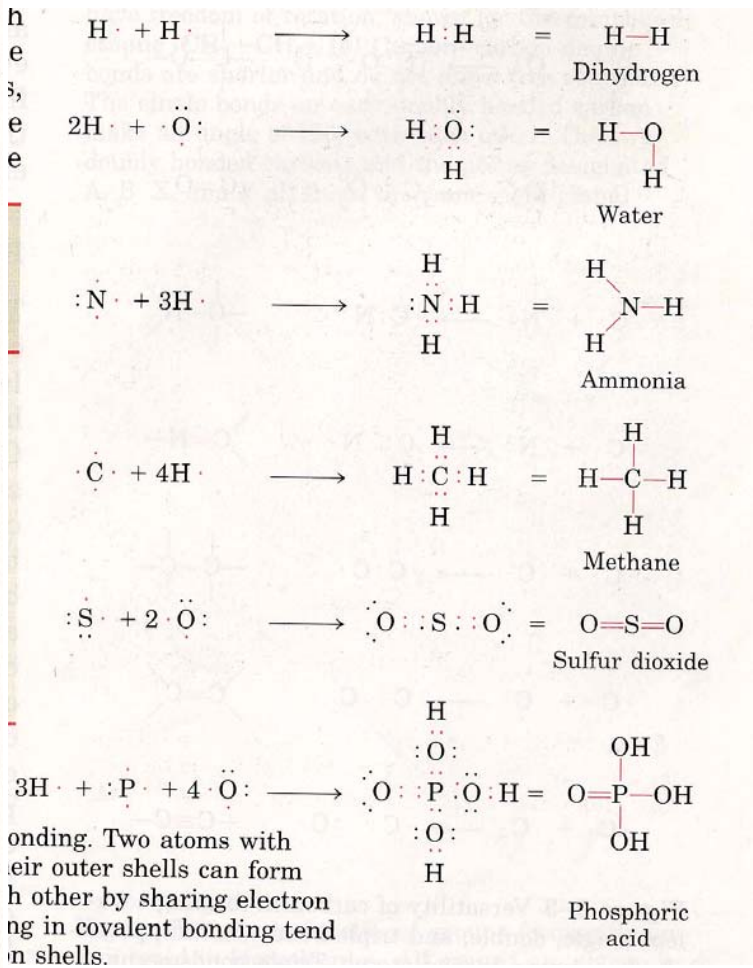


Figure 3–1 Elements essential to animal life and health. Bulk elements (shaded orange) are structural components of cells and tissues and are required in the diet in

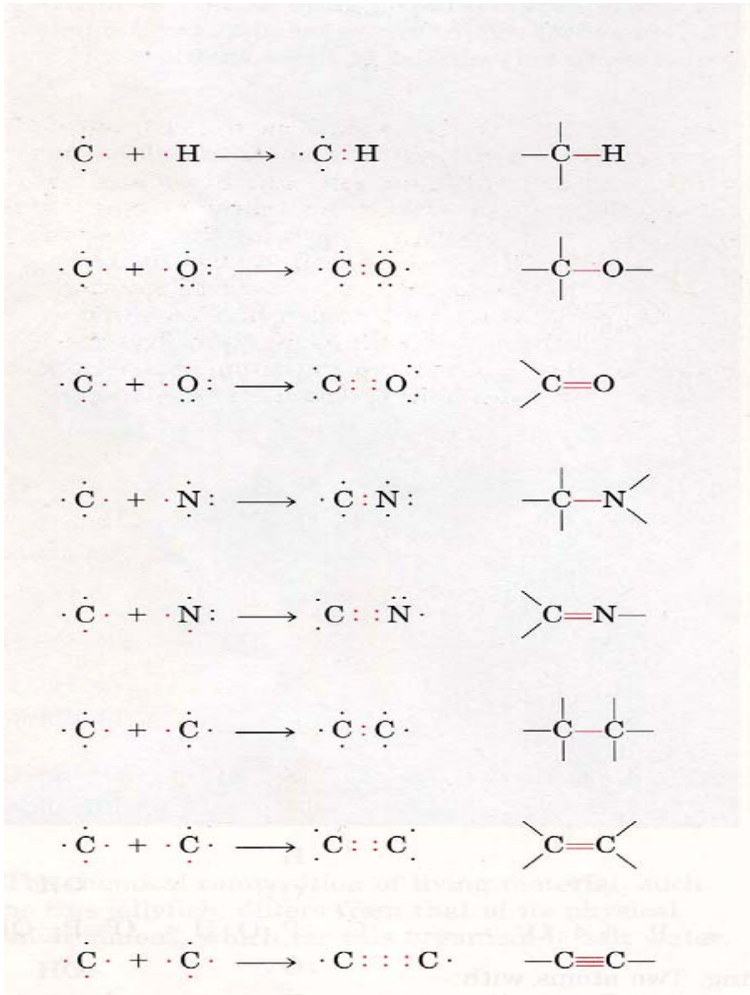
Atom	Number of unpaired electrons (in red)	Number of electrons in complete outer shell
H·	1	2
:Ö·	2	8
:N·	3	8
·C·	4	8
:S·	2	8
:P·	3	8

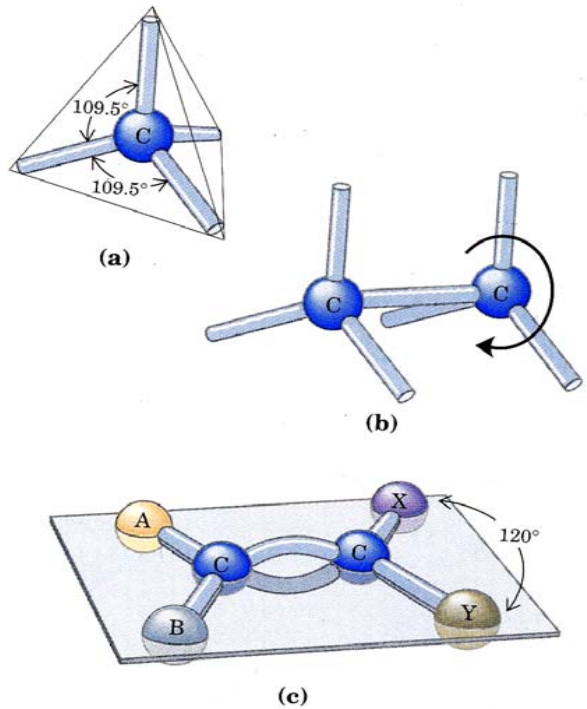


onding. Two atoms with
eir outer shells can form
h other by sharing electron
ng in covalent bonding tend
n shells.

Table 3–2 The biological functions of some trace elements

Element	Example of biological function
Fe	Electron carrier in oxidation–reduction reactions
Cu	Component of mitochondrial oxidase
Mn	Cofactor of the enzyme arginase and other enzymes
Zn	Cofactor of dehydrogenases
Co	Component of vitamin B_{12}
Mo	Component of N_2-fixing enzyme
Se	Component of the enzyme glutathione peroxidase
V	Cofactor of the enzyme nitrate reductase
Ni	Cofactor of the enzyme urease
I	Component of thyroid hormone
Mg	Cofactor in photosynthesis


· C · + · H ⟶ · C : H
— C — H
· C · + · O : ⟶ · C : O ·
— C — O —
· C · + · O : ⟶ C : : O
C = O
· C · + · N : ⟶ · C : N :
— C — N
· C · + · N : ⟶ C : : N ·
C = N —
· C · + · C · ⟶ · C : C ·
— C — C —
· C · + · C · ⟶ C : : C
C = C
· C · + · C · ⟶ · C : : : C ·
— C ≡ C —


109.5°
C
109.5°
(a)
C
C
(b)
A
X
C
C
120°
B
Y
(c)

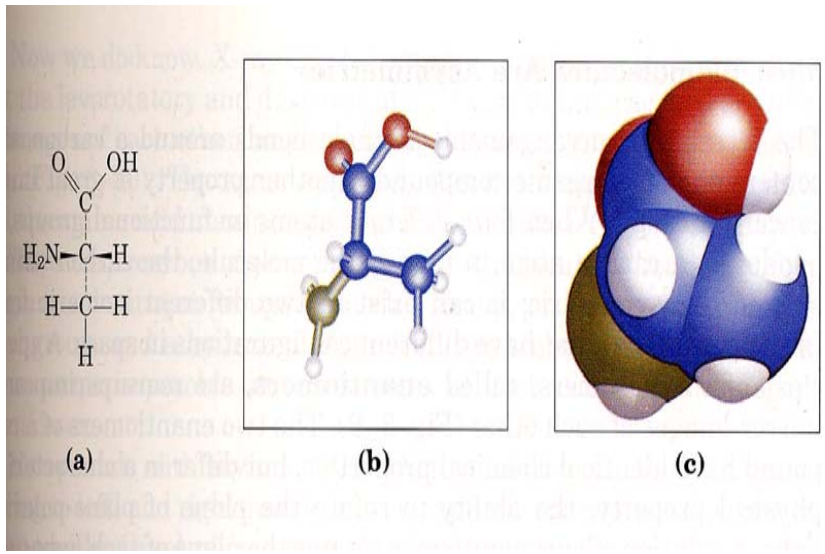
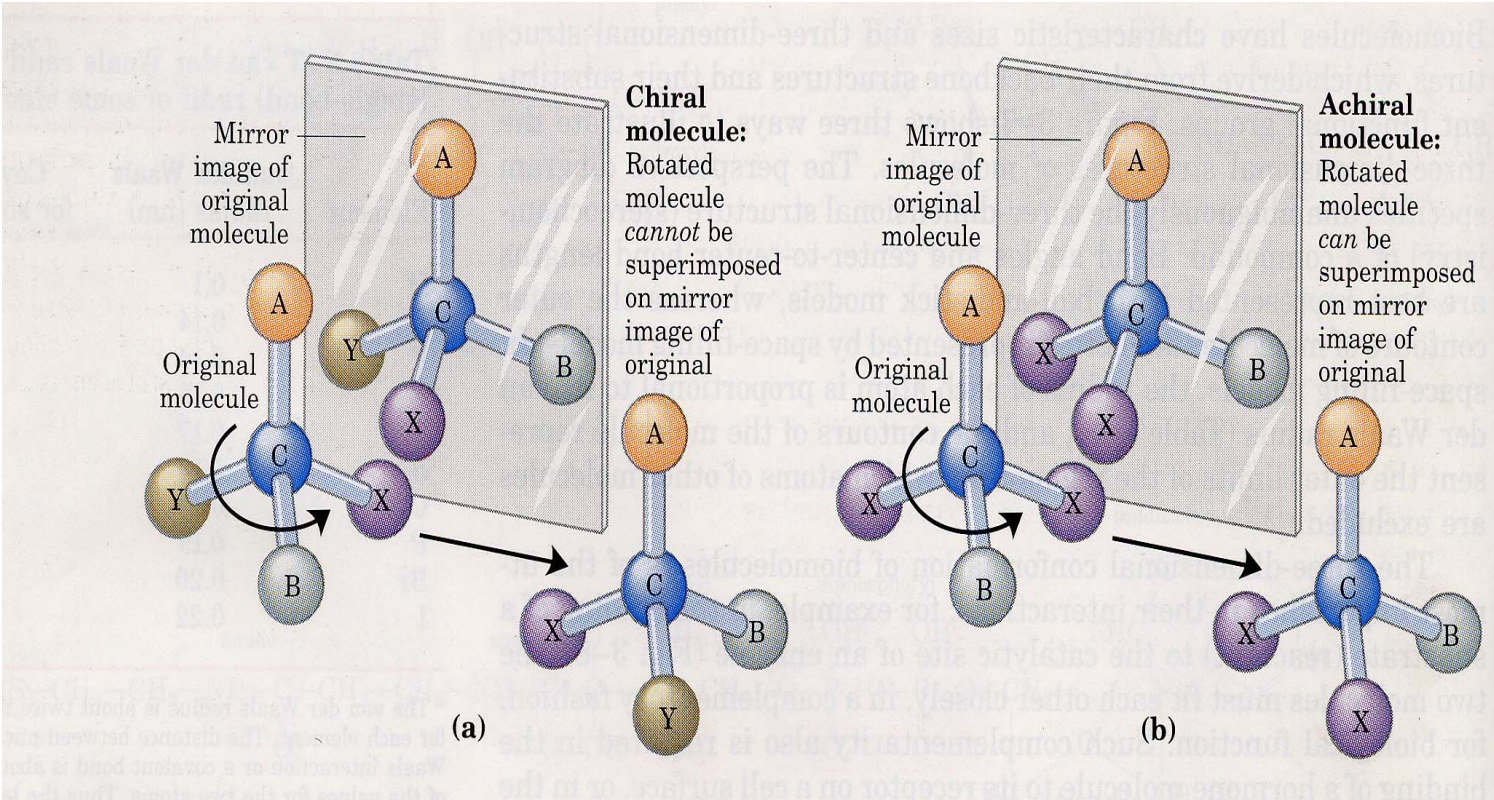
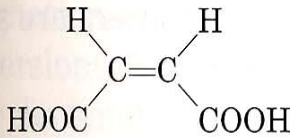

O
OH
C
H_2N–C–H
H–C–H
H
(a)
(b)
(c)

Table 3–3 van der Waals radii and covalent (single-bond) radii of some elements*

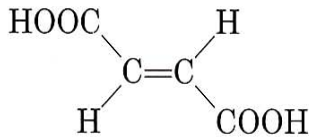
Element	van der Waals radius (nm)	Covalent radius for single bond (nm)
H	0.1	0.030
O	0.14	0.074
F	0.14	0.071
N	0.15	0.073
C	0.17	0.077
S	0.18	0.103
Cl	0.18	0.099
P	0.19	0.110
Br	0.20	0.114
I	0.22	0.133

* The van der Waals radius is about twice the covalent radius for each element. The distance between nuclei in a van der Waals interaction or a covalent bond is about equal to the sum of the values for the two atoms. Thus the length of a carbon–carbon single bond is about 0.077 + 0.077 = 0.154 nm.


Mirror image of original molecule
Original molecule
A
C
Y
X
B
Chiral molecule: Rotated molecule *cannot* be superimposed on mirror image of original
(a)
Mirror image of original molecule
Original molecule
Achiral molecule: Rotated molecule *can* be superimposed on mirror image of original
(b)

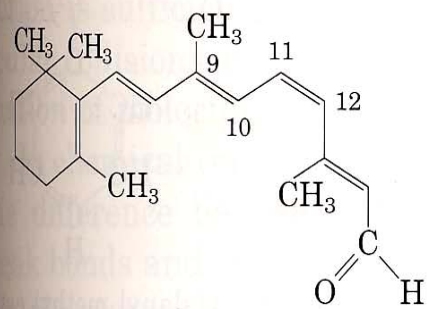


Maleic acid (cis)

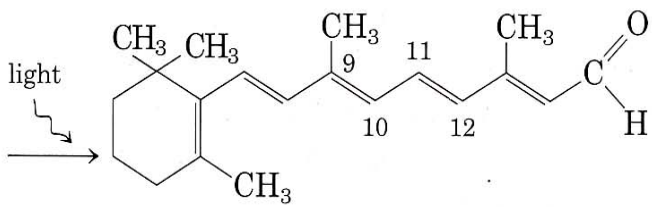


Fumaric acid (trans)

(a)

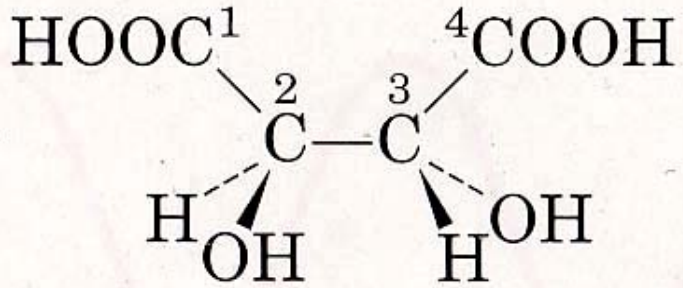


11-*cis*-Retinal

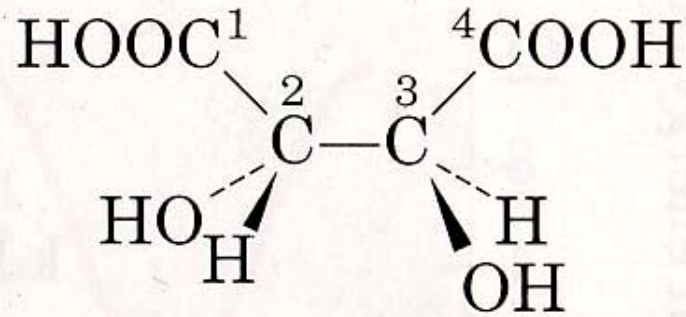


All-*trans*-Retinal

(b)



2*R*,3*R*-Tartaric acid
(dextrorotatory)



2*S*,3*S*-Tartaric acid
(levorotatory)

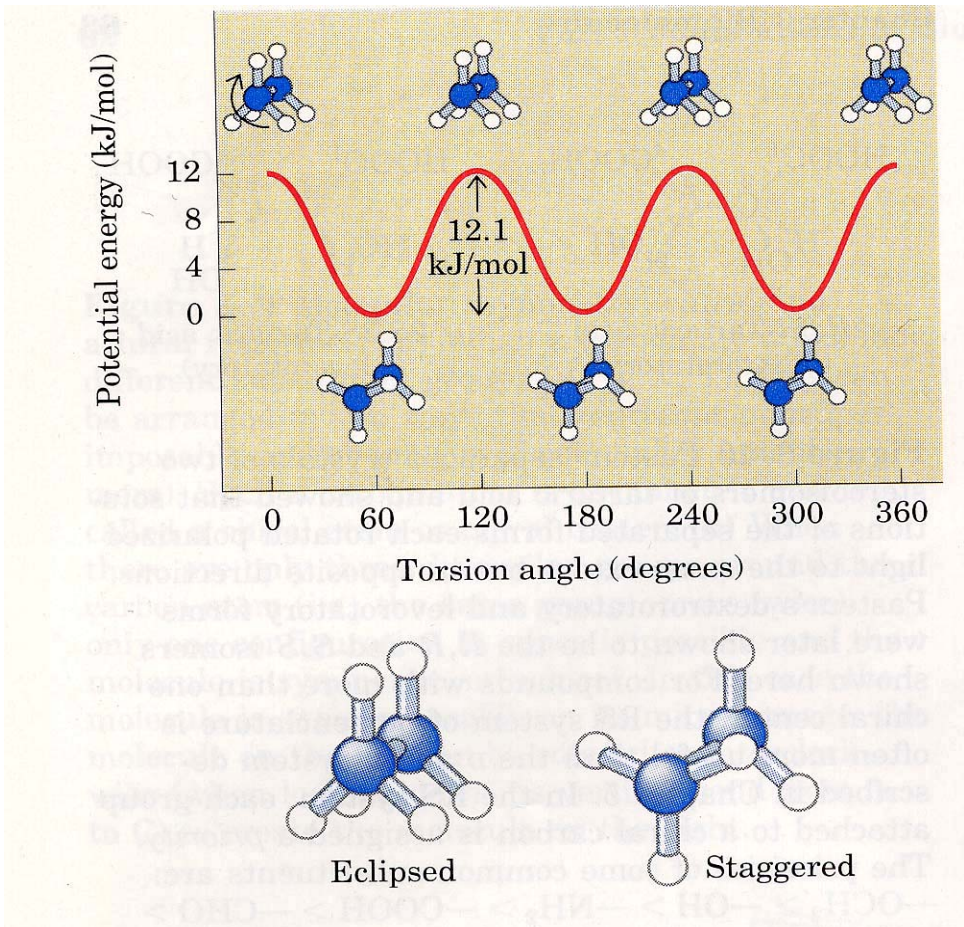

Potential energy (kJ/mol)
12
8
4
0
12.1
kJ/mol
0
60
120
180
240
300
360
Torsion angle (degrees)
Eclipsed
Staggered

Table 3–4 The electronegativities of some elements

Element	Electronegativity*
F	4.0
O	3.5
Cl	3.0
N	3.0
Br	2.8
S	2.5
C	2.5
I	2.5
Se	2.4
P	2.1
H	2.1
Cu	1.9
Fe	1.8
Co	1.8
Ni	1.8
Mo	1.8
Zn	1.6
Mn	1.5
Mg	1.2
Ca	1.0
Li	1.0
Na	0.9
K	0.8

* The higher the number, the more electronegative is the element.

Table 3–5 Strengths of bonds common in biomolecules

Type of bond	Bond dissociation energy (kJ/mol)	Type of bond	Bond dissociation energy (kJ/mol)
Single bonds		*Double bonds*	
O—H	461	C=O	712
H—H	435	C=N	615
P—O	419	C=C	611
C—H	414	P=O	502
N—H	389		
C—O	352	*Triple bonds*	
C—C	348	C≡C	816
S—H	339	N≡N	930
C—N	293		
C—S	260	*Noncovalent bonds or interactions*	
N—O	222	Hydrogen bonds	4–20
S—S	214	van der Waals interactions	
		Hydrophobic interactions	
		Ionic interactions	

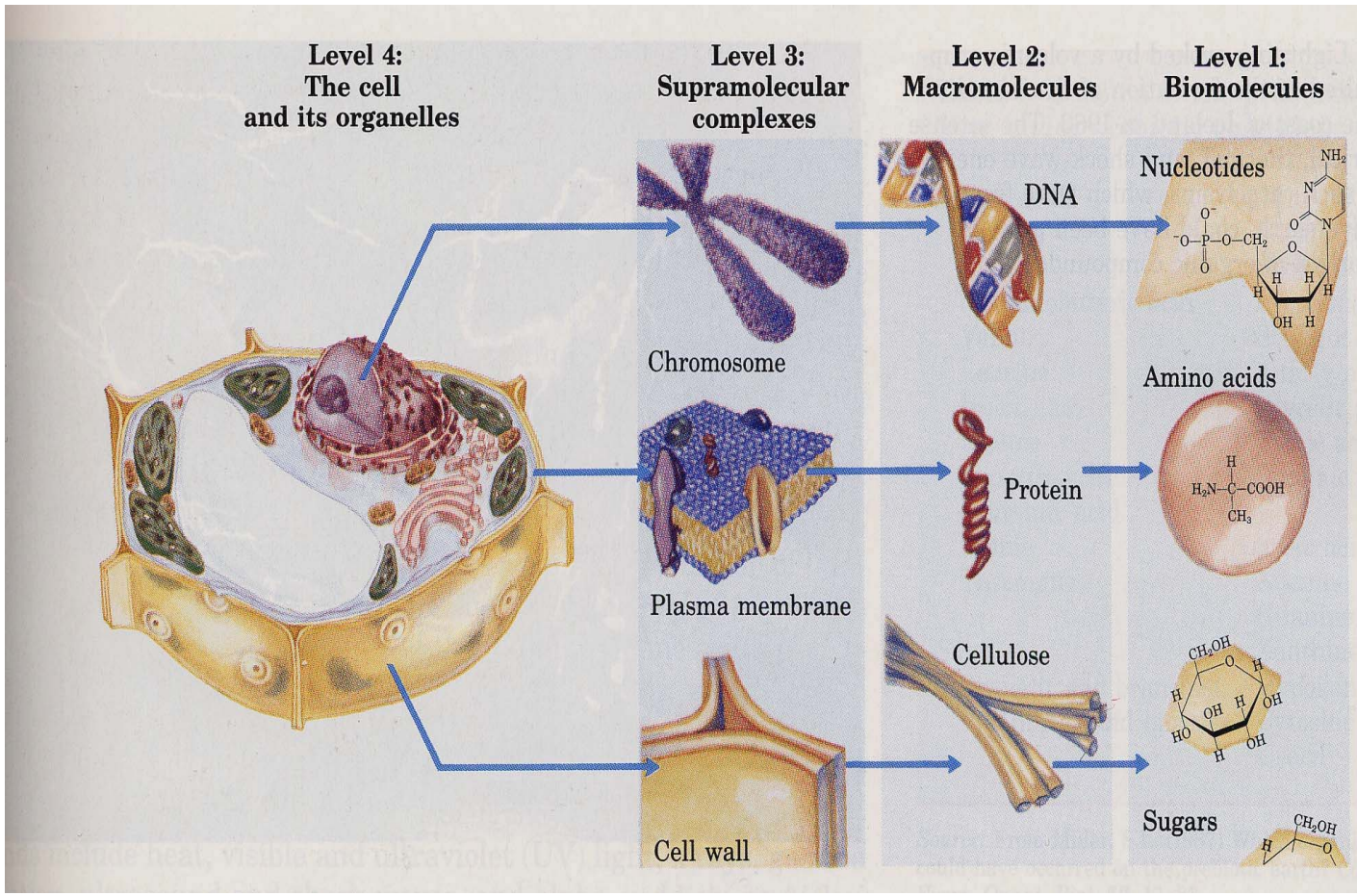

Level 4:
The cell
and its organelles
Level 3:
Supramolecular
complexes
Level 2:
Macromolecules
Level 1:
Biomolecules
Chromosome
DNA
Nucleotides
Amino acids
Protein
Plasma membrane
Cellulose
Cell wall
Sugars

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.

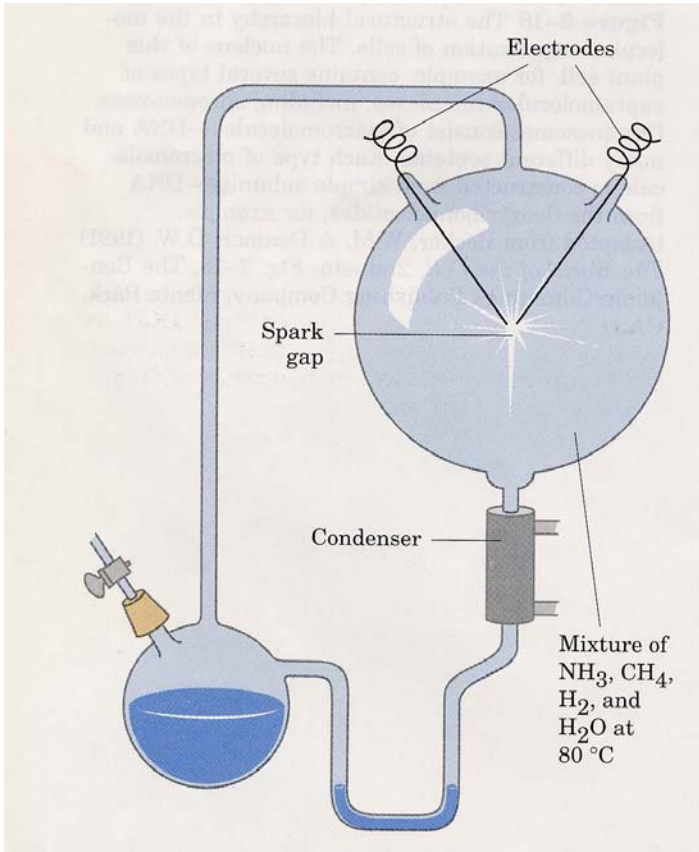

Electrodes
Spark gap
Condenser
Mixture of NH_3, CH_4, H_2, and H_2O at 80 °C

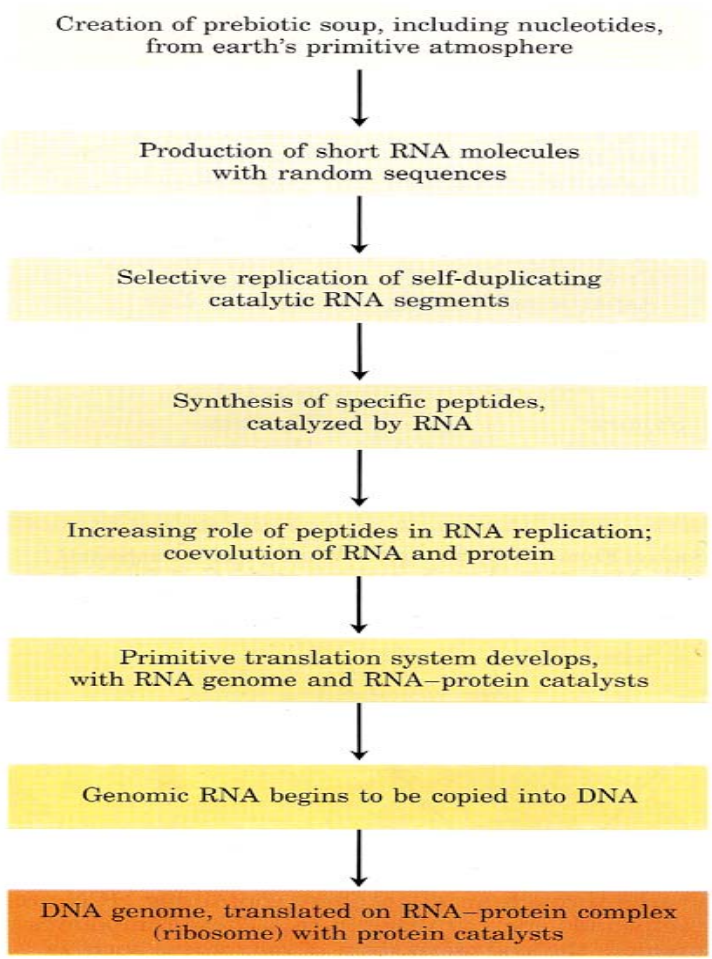
Table 3–8 Some of the products shown to form under prebiotic conditions

Amino acids
- Glycine
- Alanine
- α-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


Creation of prebiotic soup, including nucleotides, from earth's primitive atmosphere
Production of short RNA molecules with random sequences
Selective replication of self-duplicating catalytic RNA segments
Synthesis of specific peptides, catalyzed by RNA
Increasing role of peptides in RNA replication; coevolution of RNA and protein
Primitive translation system develops, with RNA genome and RNA–protein catalysts
Genomic RNA begins to be copied into DNA
DNA genome, translated on RNA–protein complex (ribosome) with protein catalysts