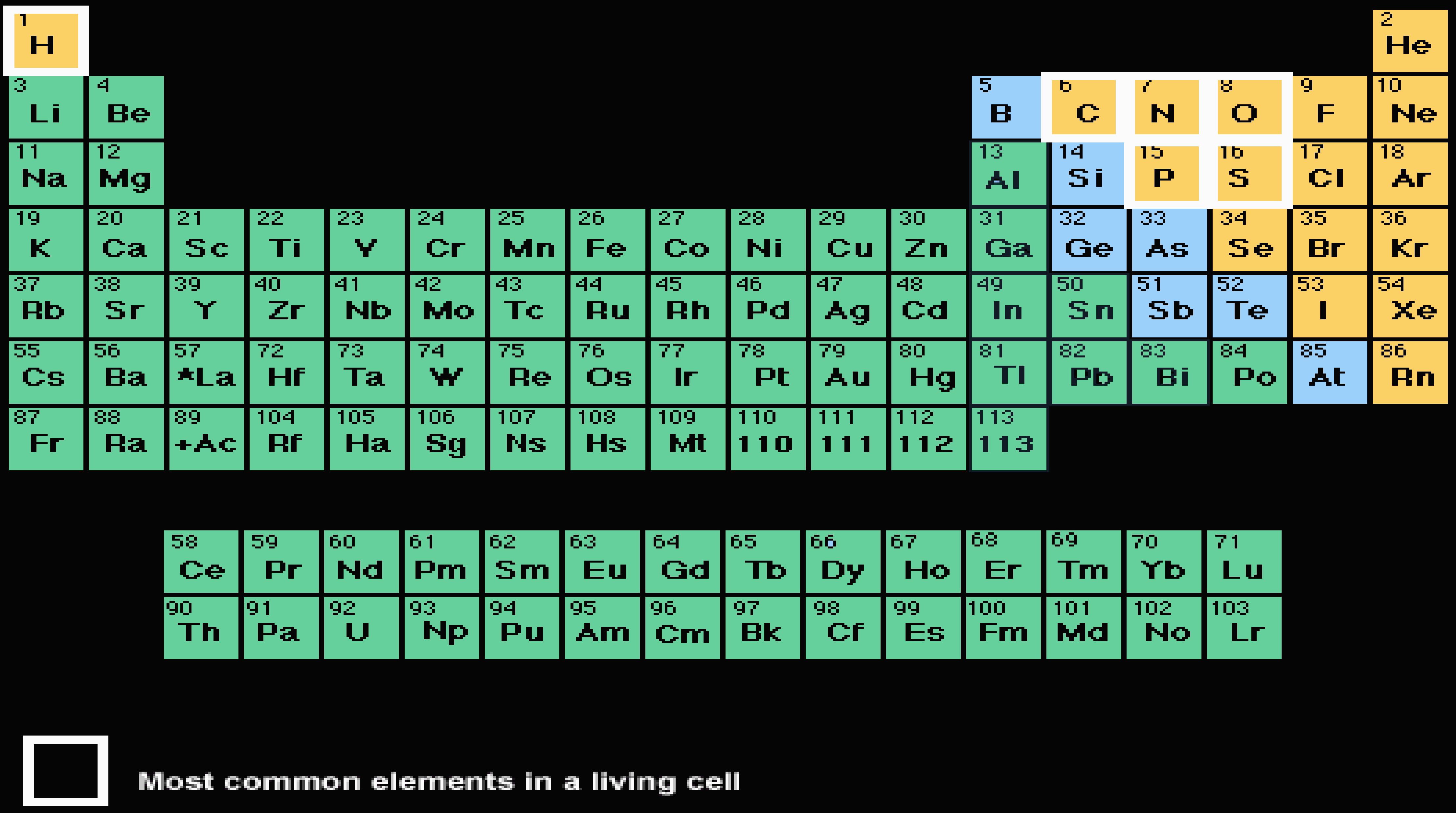
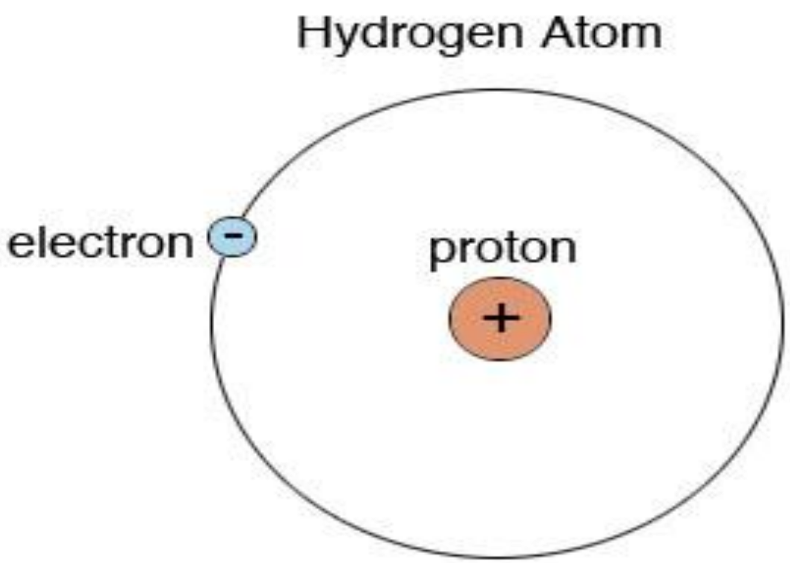
BIOLOGY FOR ENGNEERS

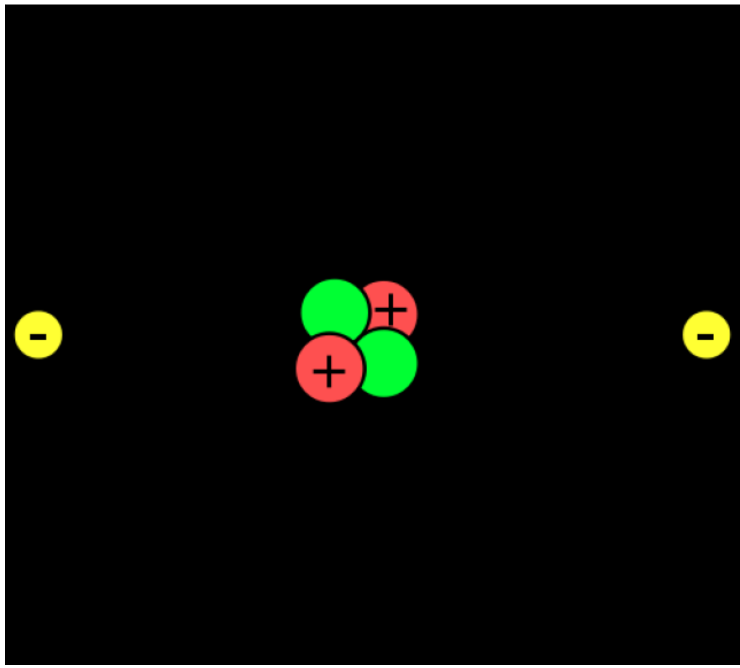
Need for BFE

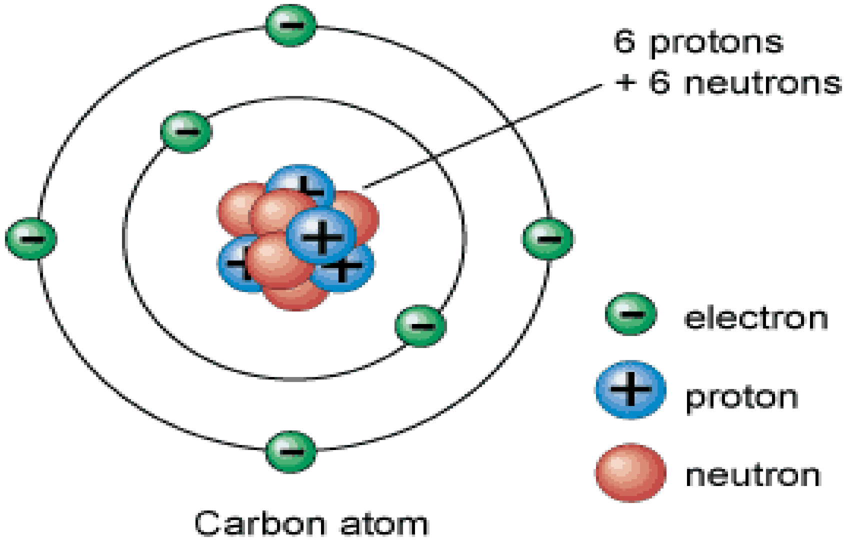
- It is well known that this is the century of biology in which significant advances in the understanding and application of biological systems are expected.
- The significant impact on the world is expected in terms of better healthcare, better processes, better products and an overall better quality of life.
- Thus, any person can be interested in knowing the fundamentals of biology to be able to understand, or participate in the biological revolution.
- For example, any engineer, irrespective of the parent discipline (mechanical, electrical, civil, chemical, metallurgical, etc.,) has a high probability of using the disciplinary skills toward designing/improving biological systems in the future.
- This course is designed to convey the essentials of cell and molecular biology to provide a frame-work for more specific understanding, and contribution by any interested person.

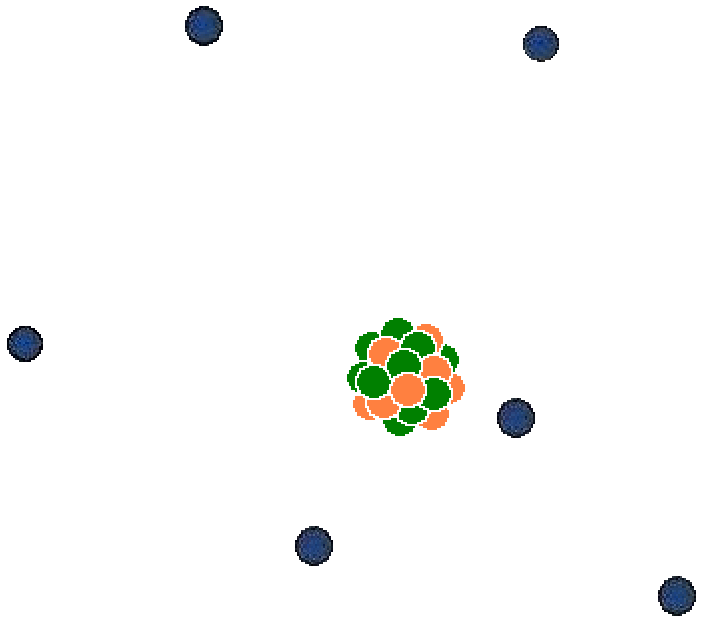
Elements


1 H
2 He
3 Li 4 Be 5 B 6 C 7 N 8 O 9 F 10 Ne
11 Na 12 Mg 13 Al 14 Si 15 P 16 S 17 Cl 18 Ar
19 K 20 Ca 21 Sc 22 Ti 23 V 24 Cr 25 Mn 26 Fe 27 Co 28 Ni 29 Cu 30 Zn 31 Ga 32 Ge 33 As 34 Se 35 Br 36 Kr
37 Rb 38 Sr 39 Y 40 Zr 41 Nb 42 Mo 43 Tc 44 Ru 45 Rh 46 Pd 47 Ag 48 Cd 49 In 50 Sn 51 Sb 52 Te 53 I 54 Xe
55 Cs 56 Ba 57 *La 72 Hf 73 Ta 74 W 75 Re 76 Os 77 Ir 78 Pt 79 Au 80 Hg 81 Tl 82 Pb 83 Bi 84 Po 85 At 86 Rn
87 Fr 88 Ra 89 +Ac 104 Rf 105 Ha 106 Sg 107 Ns 108 Hs 109 Mt 110 110 111 111 112 112 113 113
58 Ce 59 Pr 60 Nd 61 Pm 62 Sm 63 Eu 64 Gd 65 Tb 66 Dy 67 Ho 68 Er 69 Tm 70 Yb 71 Lu
90 Th 91 Pa 92 U 93 Np 94 Pu 95 Am 96 Cm 97 Bk 98 Cf 99 Es 100 Fm 101 Md 102 No 103 Lr
Most common elements in a living cell

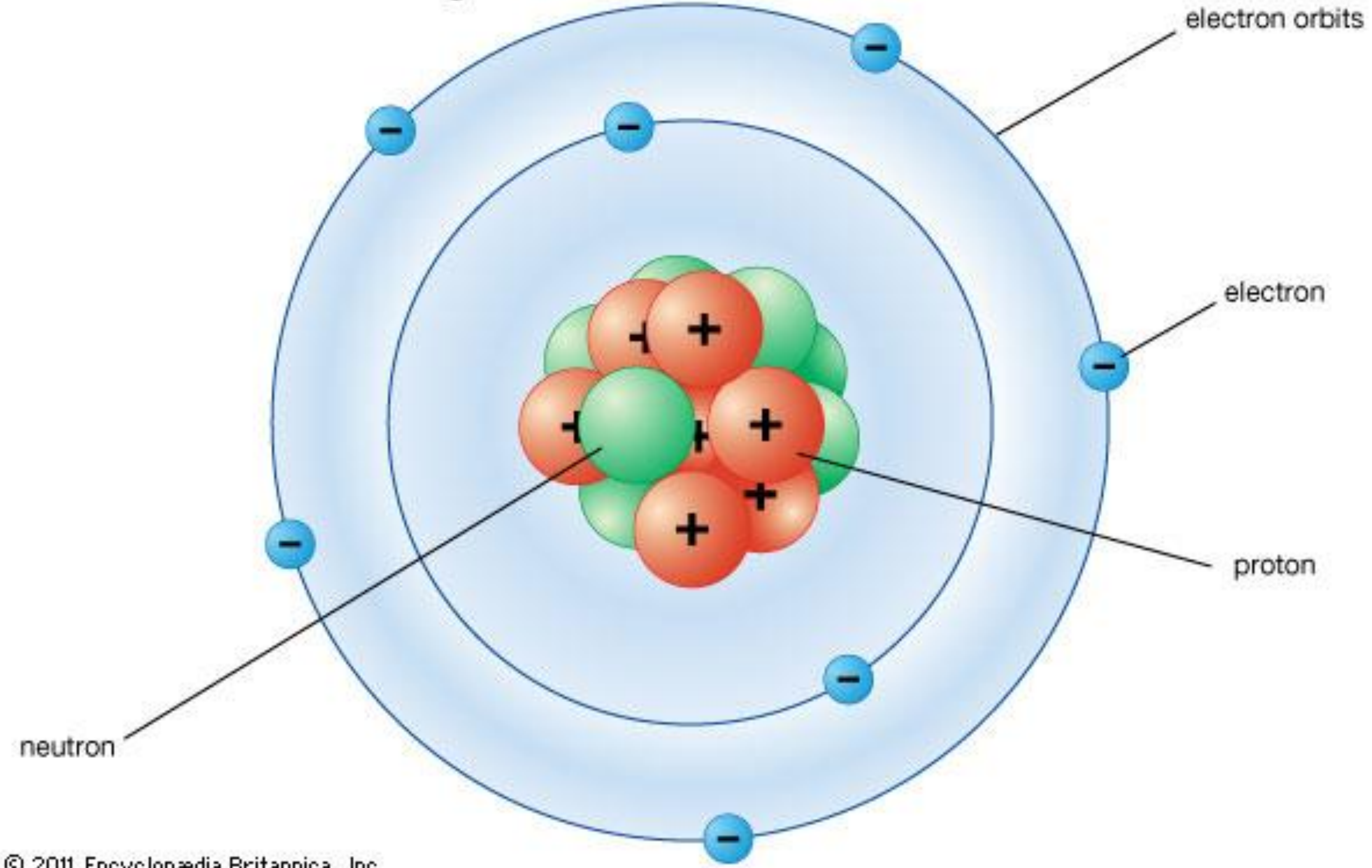

Hydrogen Atom
electron
-
proton
+




6 protons
+ 6 neutrons
electron
proton
neutron
Carbon atom



Bohr atomic model of a nitrogen atom



Periodic Table

- Alkali
- Alkaline
- Transition
- Lanthanoid
- Actinoid
- Poor
- Metalloid
- Nonmetal
- Halogen
- Noble gas
- Unknown

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo
	*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
	**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

2.2 The Periodic Table The periodic table groups the elements according to their physical and chemical properties. Elements 1–92 occur in nature; elements with atomic numbers above 92 were created in the laboratory.

The six elements highlighted in yellow make up 98% of the mass of most living organisms.

Elements in the same vertical columns have similar properties because they have the same number of electrons in their outermost shell.

Elements highlighted in orange are present in small amounts in many organisms.

1 H 1.0079																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.179
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.06	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.08	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.922	34 Se 78.96	35 Br 79.909	36 Kr 83.80
37 Rb 85.4778	38 Sr 87.62	39 Y 88.906	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc (99)	44 Ru 101.07	45 Rh 102.906	46 Pd 106.4	47 Ag 107.870	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.904	54 Xe 131.30
55 Cs 132.905	56 Ba 137.34	71 Lu 174.97	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 186.207	76 Os 190.2	77 Ir 192.2	78 Pt 195.08	79 Au 196.967	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.980	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.025	103 Lr (260)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (269)	109 Mt (268)	110 (269)	111 (272)	112 (277)	113	114 (285)	115 (289)	116	117	118 (293)

Masses in parentheses indicate unstable elements that decay rapidly to form other elements.

Elements without a chemical symbol are as yet unnamed.

Composition of life

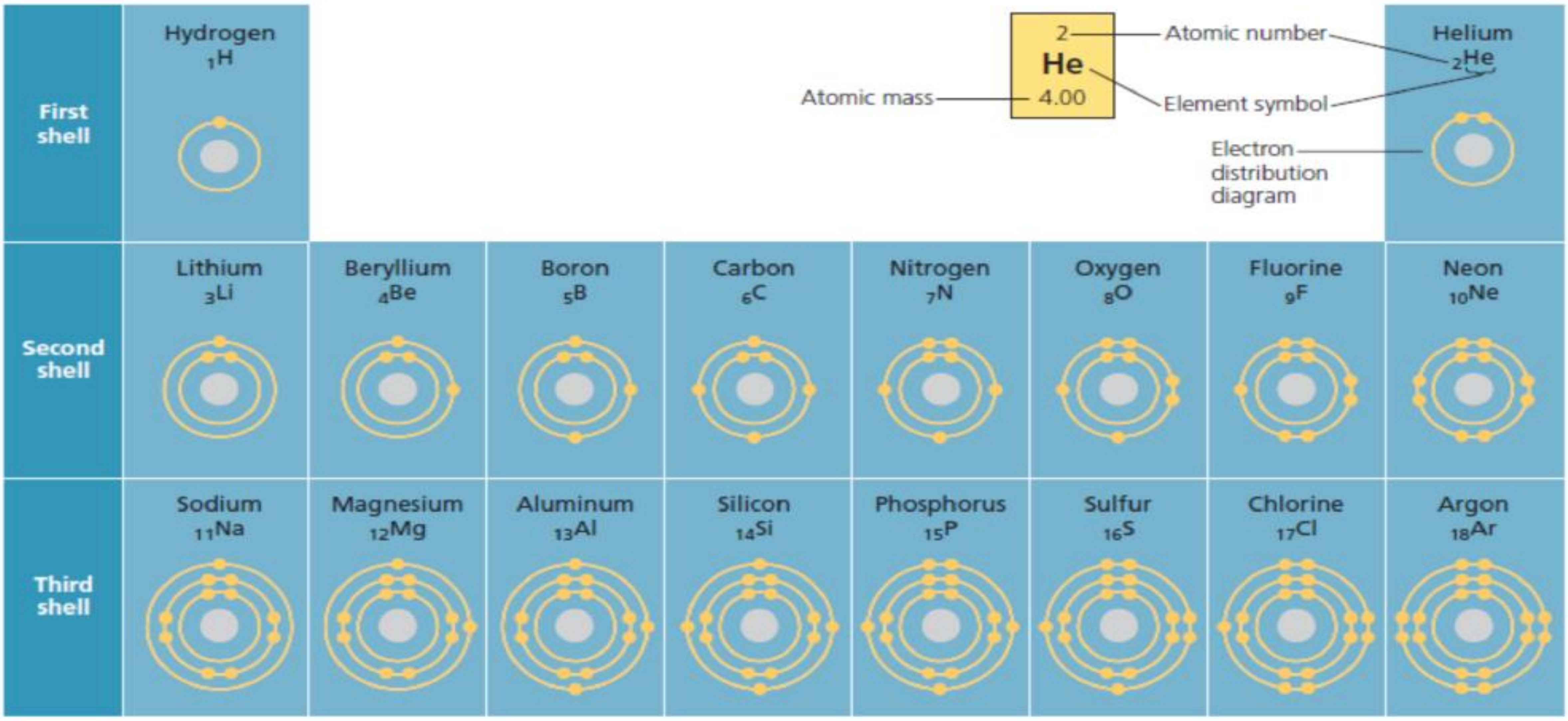
- Water: 80%
- Dry weight: 20%
  - **Proteins**: **50%**
  - **Carbohydrates**: **15%**
  - **Lipids and fats**: **10%**
  - **Nucleic acids**: **15%**

Two important properties of elements

- To understand the elements used in life:

- 1). Valency (unpaired electron in the outer orbital of the shell)

2). Electronegativity (This gives an opportunity for the element to combine with other element)



Circles indicate shells/ electron cloud; Yellow dots indicate electrons

Electronegativity

Electronegativity is a chemical property that describes the tendency of an atom to attract electrons (or electron density) towards itself.

An atom's electronegativity is affected by both its atomic number and the distance at which its valence electrons reside from the charged nucleus.

The higher the associated electronegativity number, the more an element or compound attracts electrons towards it.

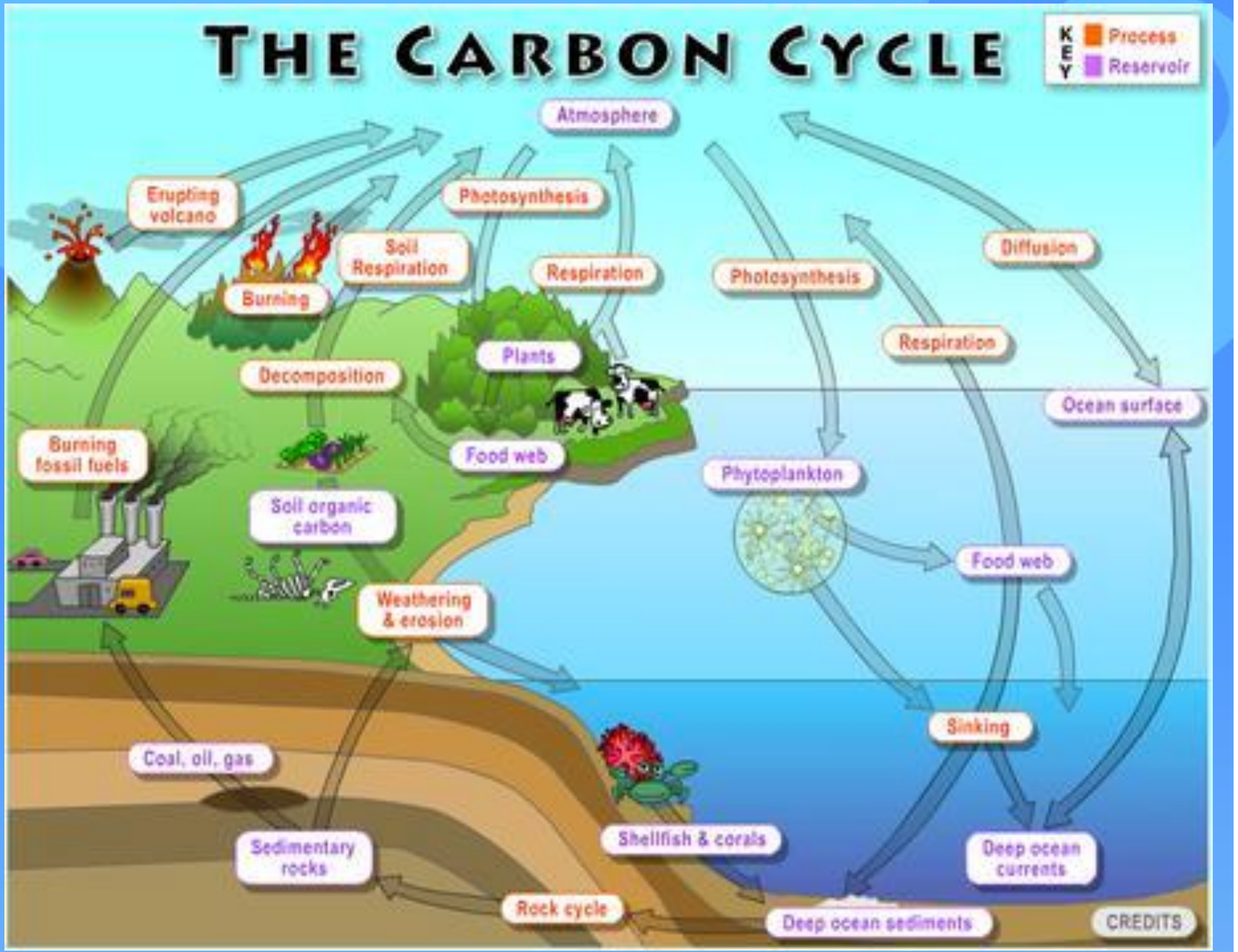
H 2,20																	He
Li 0,97	Be 1,47											B 2,01	C 2,50	N 3,07	O 3,50	F 4,17	Ne
Na 1,01	Mg 1,23											Al 1,47	Si 1,74	P 2,06	S 2,44	Cl 2,83	Ar
K 0,91	Ca 1,04	Sc 1,20	Ti 1,32	V 1,45	Cr 1,56	Mn 1,60	Fe 1,64	Co 1,70	Ni 1,75	Cu 1,75	Zn 1,66	Ga 1,82	Ge 2,02	As 2,20	Se 2,48	Br 2,74	Kr
Rb 0,89	Sr 0,99	Y 1,11	Zr 1,22	Nb 1,23	Mo 1,30	Tc 1,36	Ru 1,42	Rh 1,45	Pd 1,30	Ag 1,42	Cd 1,46	In 1,49	Sn 1,72	Sb 1,82	Te 2,01	I 2,21	Xe
Cs 0,86	Ba 0,97	La 1,10	Hf 1,23	Ta 1,33	W 1,40	Re 1,46	Os 1,52	Ir 1,55	Pt 1,44	Au 1,42	Hg 1,44	Tl 1,44	Pb 1,55	Bi 1,67	Po 1,76	At 1,96	Rn
Fr 0,86	Ra 0,97	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo

NUMBER	SYMBOL	ELEMENT	ELECTRONEGATIVITY
1	H	Hydrogen	2.20
2	He	Helium	no data
3	Li	Lithium	0.98
4	Be	Beryllium	1.57
5	B	Boron	2.04
6	C	Carbon	2.55
7	N	Nitrogen	3.04
8	O	Oxygen	3.44
9	F	Fluorine	3.98
10	Ne	Neon	no data
11	Na	Sodium	0.93
12	Mg	Magnesium	1.31
13	Al	Aluminum	1.61
14	Si	Silicon	1.90
15	P	Phosphorus	2.19

CARBON

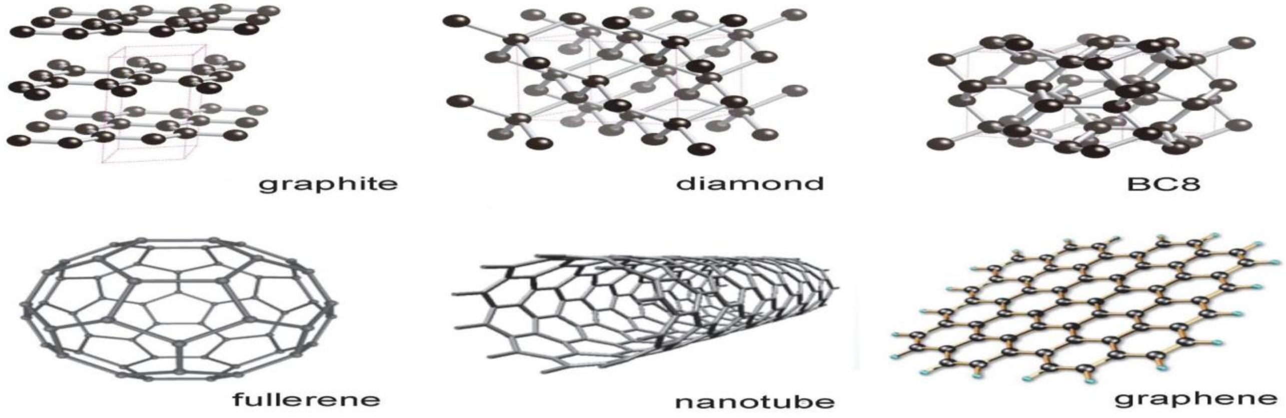
Why is carbon important to life?

Most living things on Earth are made of carbon. Living things need carbon in order to live, grow, and reproduce. Carbon is a finite resource that cycles through the Earth in many forms. This makes carbon available to living organisms and remains in balance with other chemical reactions in the atmosphere and in bodies of water like ponds and oceans.



Facts about Carbon

- Carbon is the most abundant element in the universe and is the building block of life on earth.
- Carbon circulates through the land, ocean, and atmosphere, creating what is known as the Carbon Cycle.
- All living things contain carbon in some form.
- Carbon is the primary component of macromolecules, including proteins, lipids, nucleic acids, and carbohydrates.
- Carbon's molecular structure allows it to bond in many different ways and with many different elements.



Types of Chemical Bonds

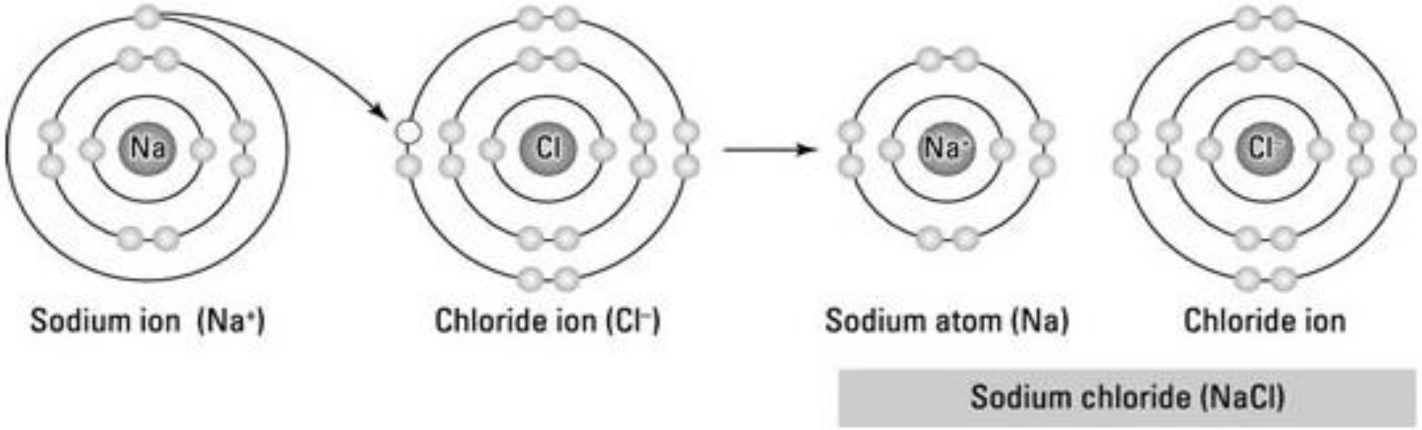
Atoms tend to arrange themselves in the most stable patterns possible

The force that holds atoms together is known as *molecules* is referred to as a *bond.*

Two main types and some secondary types of chemical bonds:

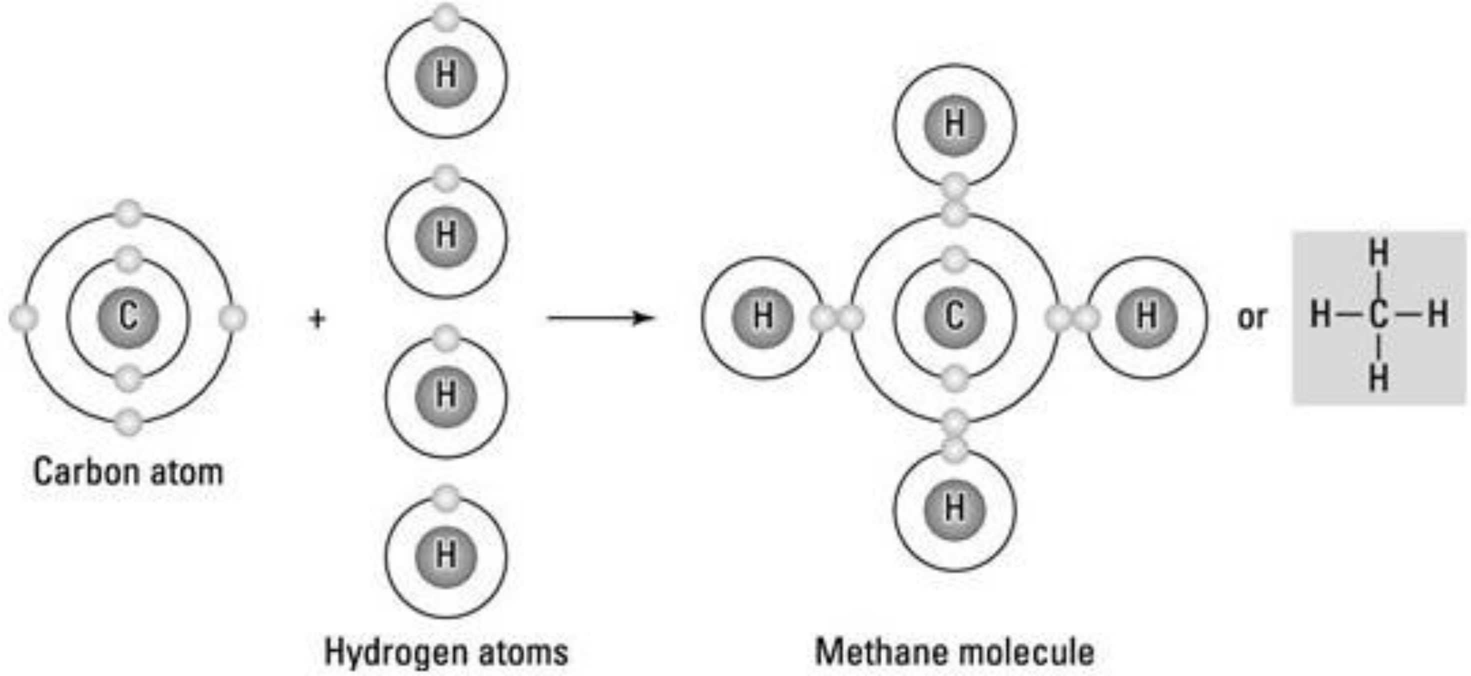
1. Ionic bond:

Involves a transfer of an electron, so one atom gains an electron while one atom loses an electron. One of the resulting ions carries a negative charge (anion), and the other ion carries a positive charge (cation). Because opposite charges attract, the atoms bond together to form a molecule.



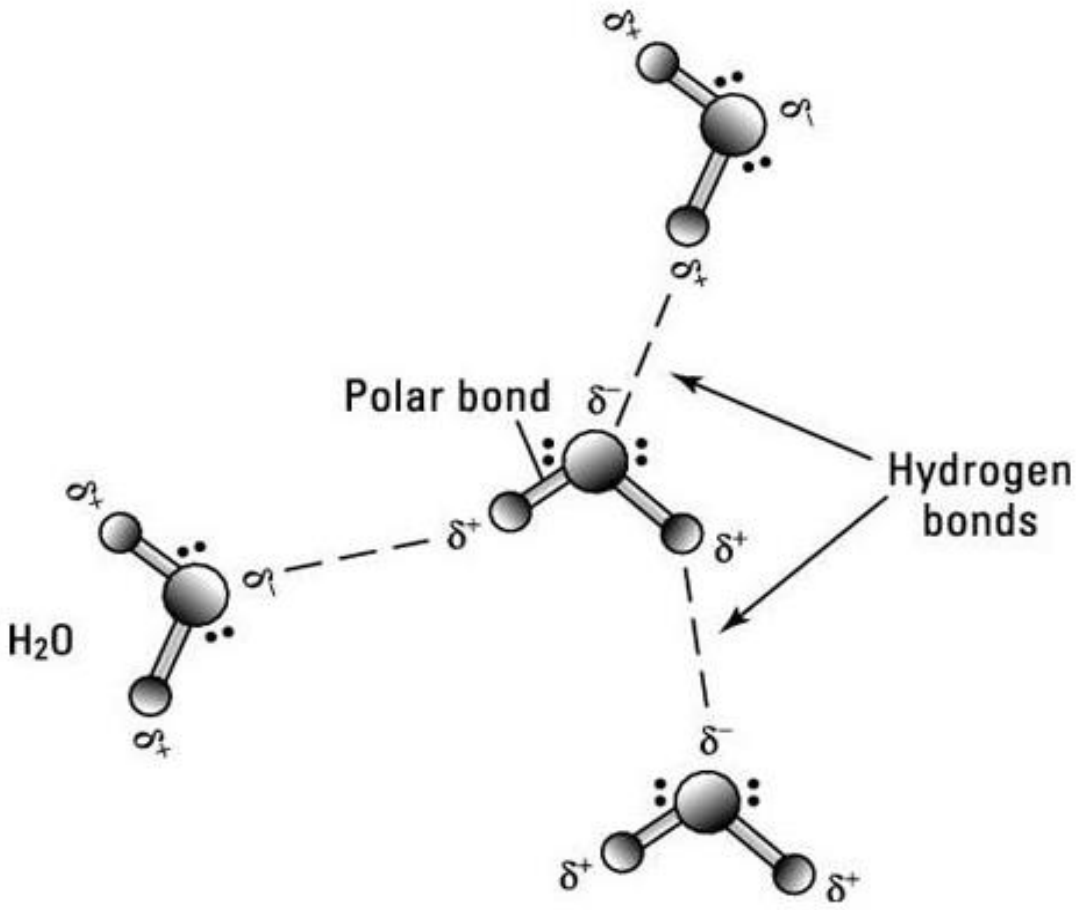
2. Covalent bond:

The most common bond in organic molecules, a covalent bond involves the sharing of electrons between two atoms. The pair of shared electrons forms a new orbit that extends around the nuclei of both atoms, producing a molecule. There are two secondary types of covalent bonds that are relevant to biology — polar bonds and hydrogen bonds.



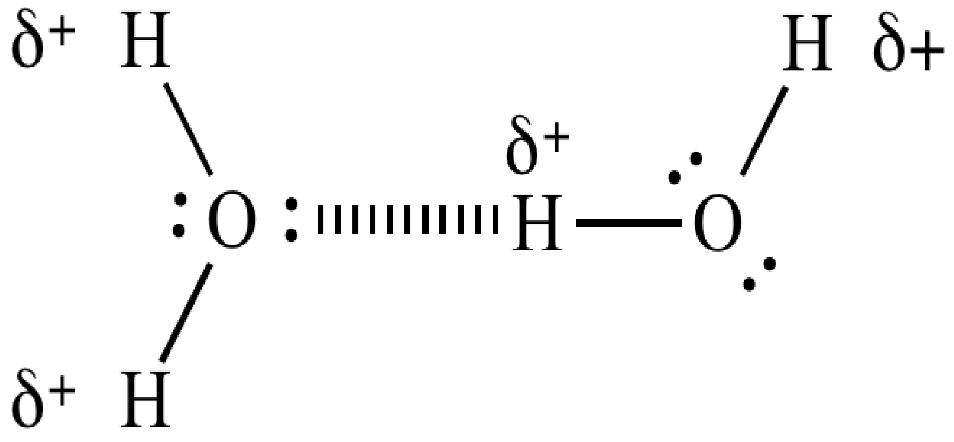
- **Polar bond**

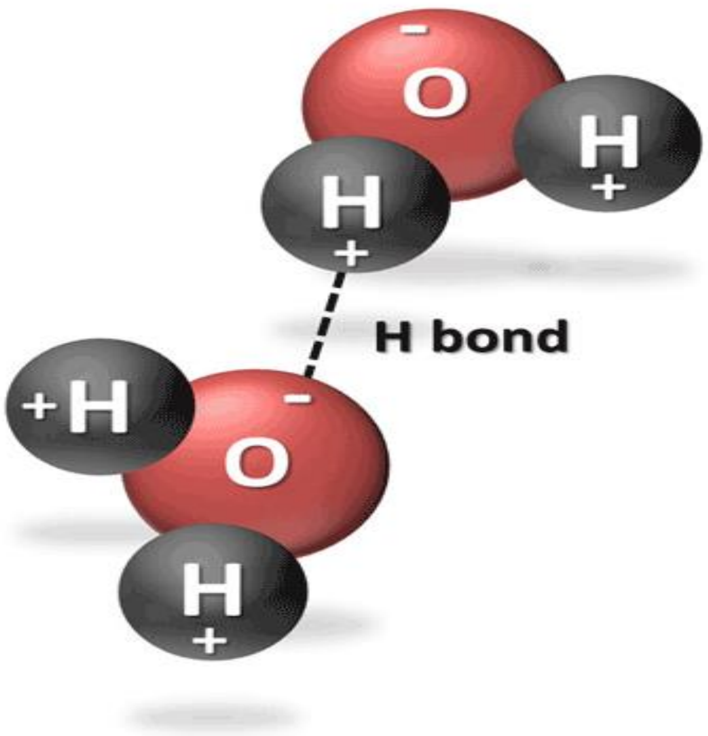
Two atoms connected by a covalent bond may exert different attractions for the electrons in the bond, producing an unevenly distributed charge. The result is known as a *polar bond*, an intermediate case between ionic and covalent bonding, with one end of the molecule slightly negatively charged and the other end slightly positively charged.

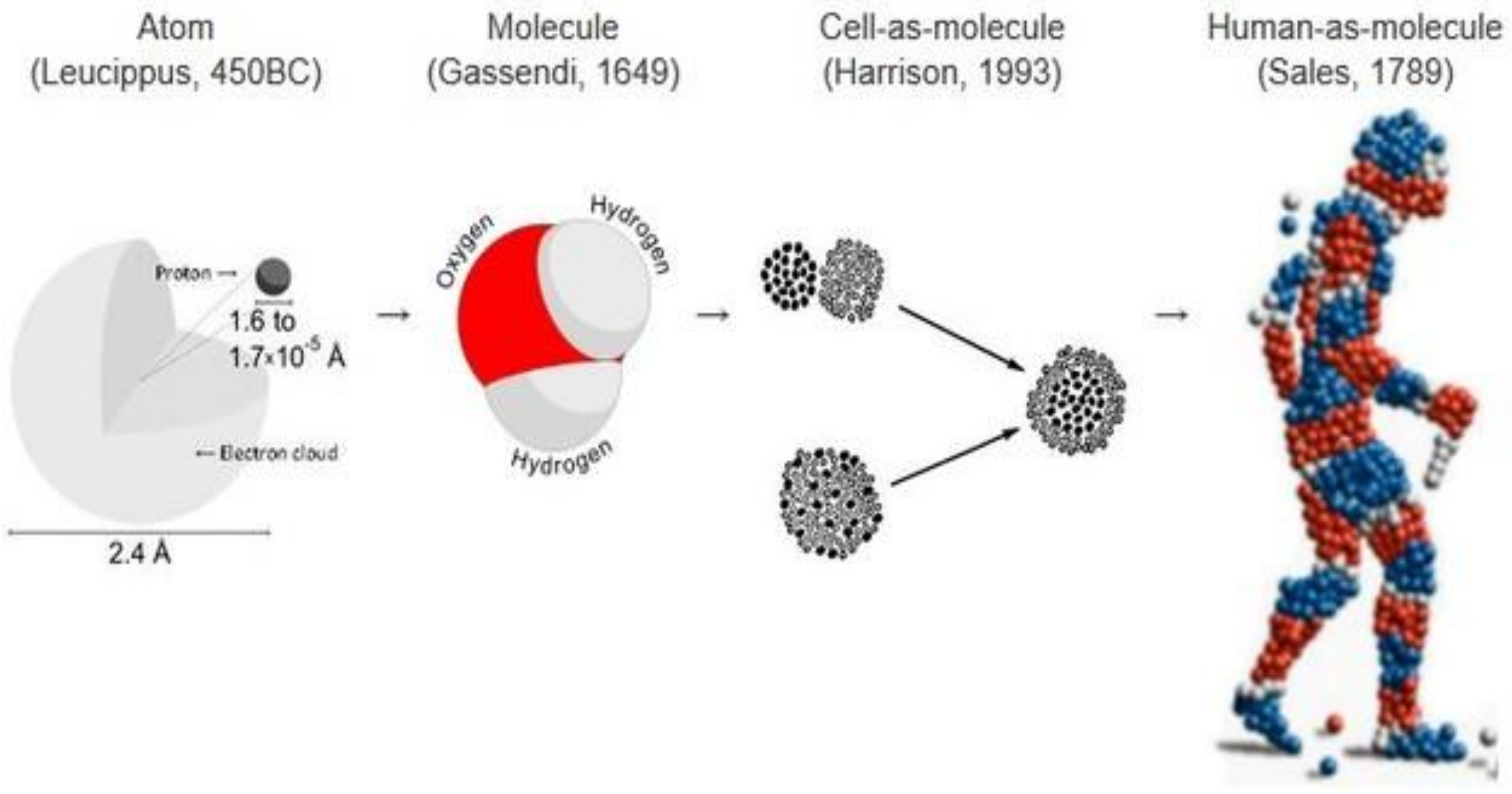


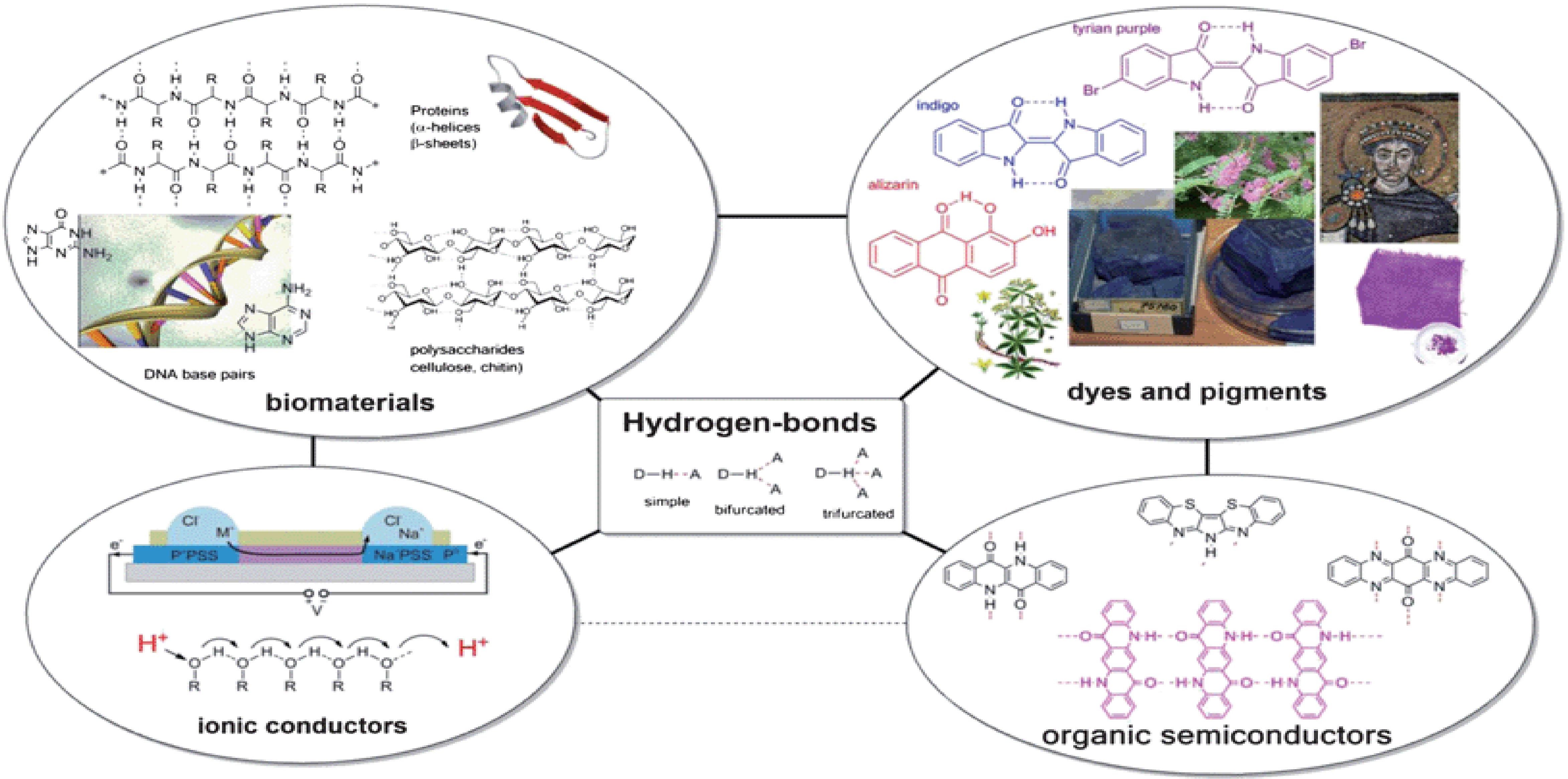
- **Hydrogen bond**

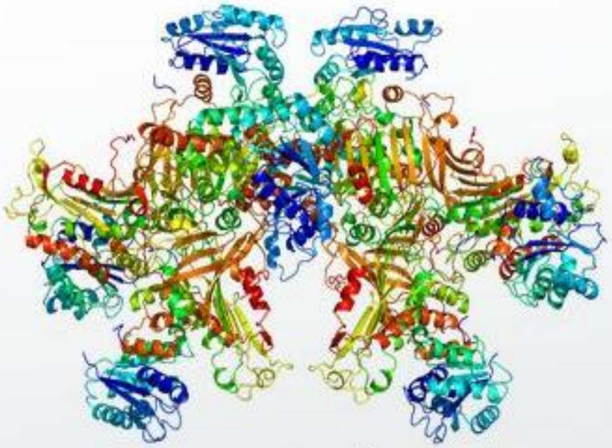
Two adjacent H_2O (water) molecules can form a linkage known as a *hydrogen bond*, where the (electronegative) hydrogen atom of one H_2O molecule is electrostatically attracted to the oxygen atom of an adjacent water molecule. Consequently, molecules of water join together transiently in a hydrogen-bonded lattice.



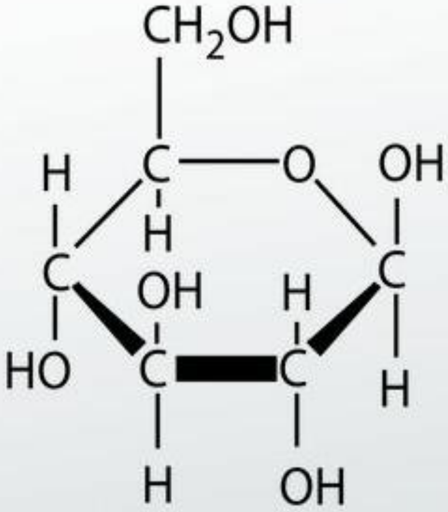



Atom
(Leucippus, 450BC)
Molecule
(Gassendi, 1649)
Cell-as-molecule
(Harrison, 1993)
Human-as-molecule
(Sales, 1789)
Proton
1.6 to
1.7×10⁻⁵ Å
Electron cloud
2.4 Å
Oxygen
Hydrogen
Hydrogen

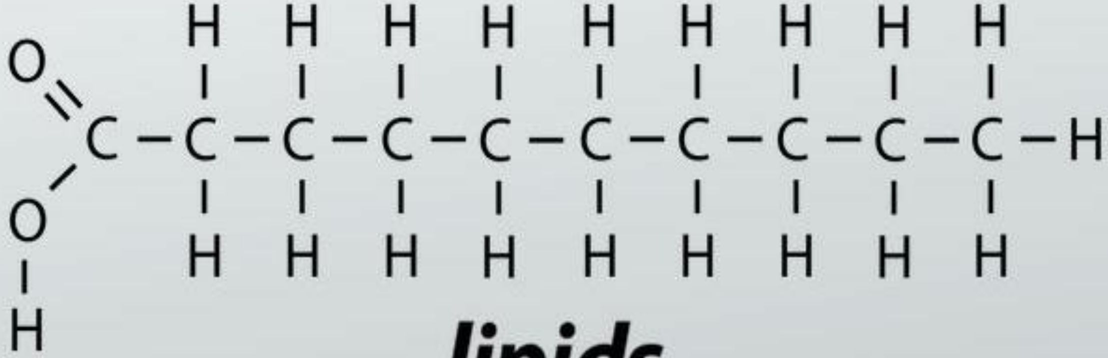

Hydrogen-bonds
D—H- -A
simple
bifurcated
trifurcated
Proteins
(α-helices
β-sheets)
DNA base pairs
polysaccharides
cellulose, chitin)
biomaterials
tyrian purple
indigo
alizarin
dyes and pigments
P⁺PSS⁻
Na⁺PSS⁻
ionic conductors
organic semiconductors



proteins

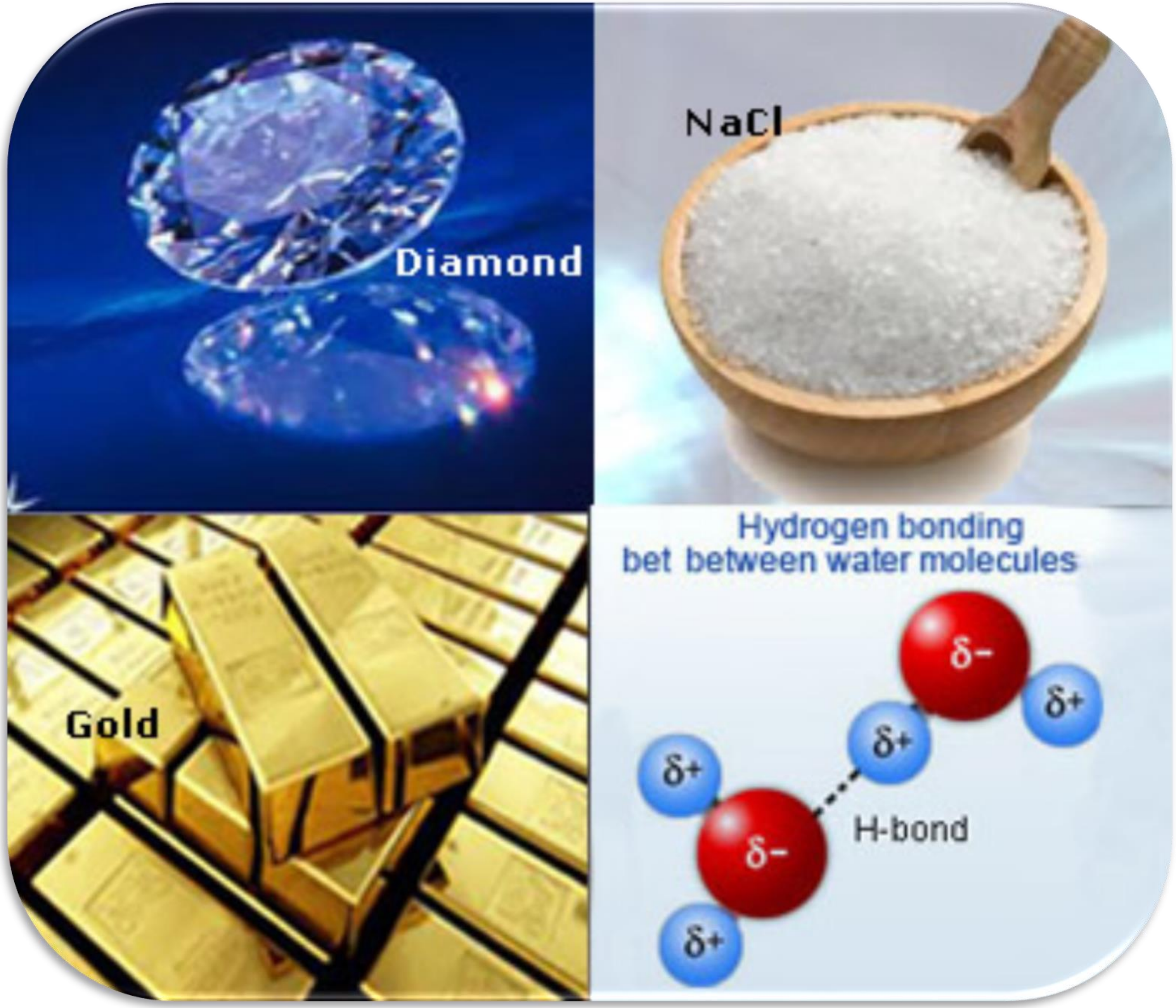


carbohydrates



lipids

nucleic acids


Diamond
NaCl
Gold
Hydrogen bonding
bet between water molecules
δ−
δ+
δ+
δ+
δ−
δ+
H-bond