

# Advanced Cell Biology. Lecture 3

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# Outline

Questions and answers

Chemistry of life

Chemical elements and atoms

Organic molecules

Basics of organic chemistry

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## Previous final question: the answer

Which organelle is present in most prokaryotic cells and absent in all eukaryotic?

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Which organelle is present in most prokaryotic cells and absent in all eukaryotic?

- ▶ Flagella<sub>1</sub>
- ▶ Tylacoid

# Chemistry of life

## Chemical elements and atoms

# Periodic table and atomic features

## IUPAC Periodic Table of the Elements

1																										18
1 <b>H</b> hydrogen 1.008																2 <b>He</b> helium 4.003										
3 <b>Li</b> lithium 6.941(2)	4 <b>Be</b> beryllium 9.012																13 <b>B</b> boron 10.81	14 <b>C</b> carbon 12.011	15 <b>N</b> nitrogen 14.01	16 <b>O</b> oxygen 16.00	17 <b>F</b> fluorine 19.00	18 <b>Ne</b> neon 20.18				
11 <b>Na</b> sodium 22.99	12 <b>Mg</b> magnesium 24.31																13 <b>Al</b> aluminium 26.98	14 <b>Si</b> silicon 28.09	15 <b>P</b> phosphorus 30.97	16 <b>S</b> sulfur 32.07	17 <b>Cl</b> chlorine 35.45	18 <b>Ar</b> argon 39.95				
19 <b>K</b> potassium 39.10	20 <b>Ca</b> calcium 40.08	21 <b>Sc</b> scandium 44.96	22 <b>Ti</b> titanium 47.87	23 <b>V</b> vanadium 50.94	24 <b>Cr</b> chromium 52.00	25 <b>Mn</b> manganese 54.94	26 <b>Fe</b> iron 55.85	27 <b>Co</b> cobalt 58.93	28 <b>Ni</b> nickel 58.69	29 <b>Cu</b> copper 63.55	30 <b>Zn</b> zinc 65.38(2)	31 <b>Ga</b> gallium 69.72	32 <b>Ge</b> germanium 72.64	33 <b>As</b> arsenic 74.92	34 <b>Se</b> selenium 78.96(3)	35 <b>Br</b> bromine 79.90	36 <b>Kr</b> krypton 83.80									
37 <b>Rb</b> rubidium 85.47	38 <b>Sr</b> strontium 87.62	39 <b>Y</b> yttrium 88.91	40 <b>Zr</b> zirconium 91.22	41 <b>Nb</b> niobium 92.91	42 <b>Mo</b> molybdenum 95.94(2)	43 <b>Tc</b> technetium 101.1	44 <b>Ru</b> ruthenium 101.07	45 <b>Rh</b> rhodium 102.9	46 <b>Pd</b> palladium 106.4	47 <b>Ag</b> silver 107.87	48 <b>Cd</b> cadmium 112.4	49 <b>In</b> indium 114.82	50 <b>Sn</b> tin 118.71	51 <b>Sb</b> antimony 121.76	52 <b>Te</b> tellurium 127.6	53 <b>I</b> iodine 126.91	54 <b>Xe</b> xenon 131.3									
55 <b>Cs</b> caesium 132.9	56 <b>Ba</b> barium 137.3	57-71 lanthanoids	72 <b>Hf</b> hafnium 178.5	73 <b>Ta</b> tantalum 180.9	74 <b>W</b> tungsten 183.85	75 <b>Re</b> rhenium 186.2	76 <b>Os</b> osmium 190.2	77 <b>Ir</b> iridium 192.22	78 <b>Pt</b> platinum 195.08	79 <b>Au</b> gold 197.0	80 <b>Hg</b> mercury 200.6	81 <b>Tl</b> thallium 204.4	82 <b>Pb</b> lead 207.2	83 <b>Bi</b> bismuth 209.0	84 <b>Po</b> polonium	85 <b>At</b> astatine	86 <b>Rn</b> radon									
87 <b>Fr</b> francium	88 <b>Ra</b> radium	89-103 actinoids	104 <b>Rf</b> rutherfordium	105 <b>Db</b> dubnium	106 <b>Sg</b> seaborgium	107 <b>Bh</b> bohrium	108 <b>Hs</b> hassium	109 <b>Mt</b> meitnerium	110 <b>Ds</b> darmstadtium	111 <b>Rg</b> roentgenium	112 <b>Cn</b> copernicium															



57 <b>La</b> lanthanum 138.9	58 <b>Ce</b> cerium 140.1	59 <b>Pr</b> praseodymium 140.9	60 <b>Nd</b> neodymium 144.2	61 <b>Pm</b> promethium	62 <b>Sm</b> samarium 150.4	63 <b>Eu</b> europium 152.0	64 <b>Gd</b> gadolinium 157.3	65 <b>Tb</b> terbium 158.9	66 <b>Dy</b> dysprosium 162.5	67 <b>Ho</b> holmium 164.9	68 <b>Er</b> erbium 167.3	69 <b>Tm</b> thulium 168.9	70 <b>Yb</b> ytterbium 173.1	71 <b>Lu</b> lutetium 175.0
89 <b>Ac</b> actinium	90 <b>Th</b> thorium 232.0	91 <b>Pa</b> protactinium 231.0	92 <b>U</b> uranium 238.0	93 <b>Np</b> neptunium	94 <b>Pu</b> plutonium	95 <b>Am</b> americium	96 <b>Cm</b> curium	97 <b>Bk</b> berkelium	98 <b>Cf</b> californium	99 <b>Es</b> einsteinium	100 <b>Fm</b> fermium	101 <b>Md</b> mendelevium	102 <b>No</b> nobelium	103 <b>Lr</b> lawrencium



## Terms of atomic chemistry and physics

- ▶ Number of protons, neutrons, electrons and periodic table
- ▶ Isotopes, radioactivity
- ▶ Atomic weight, molecular weight
- ▶ Mole, molar solution, Avogadro's number

## Primary elements

- ▶ Main three biogenic elements: carbon (C), hydrogen (H), oxygen (O)
- ▶ Slightly less important are nitrogen (N) and phosphorus (P)
- ▶ Potassium (K), sodium (Na), calcium (Ca), magnesium (Mg): as cations, e.g.y  $K^+$  or  $Ca^{2+}$
- ▶ Chlorine (Cl) and sulfur (S): used as anions

## Microelements

- ▶ Play a lesser roles and used in lesser amounts (< 0.9%)
- ▶ These are: iron (Fe), silicon (Si), iodine (I), fluorine (F), selenium (Se), vanadium (V), manganese (Mn), boron (B), molybdenum (Mo), copper (Cu), nickel (Ni), zinc (Zn) and chromium (Cr)

# All biogenic elements

1 <b>H</b> 1																	He
Li	Be											5 <b>B</b> 11	6 <b>C</b> 12	7 <b>N</b> 14	8 <b>O</b> 16	9 <b>F</b> 19	Ne
11 <b>Na</b> 23	12 <b>Mg</b> 24											Al	14 <b>Si</b> 28	15 <b>P</b> 31	16 <b>S</b> 32	17 <b>Cl</b> 35	Ar
19 <b>K</b> 39	20 <b>Ca</b> 40	Sc	Ti	23 <b>V</b> 51	24 <b>Cr</b> 52	25 <b>Mn</b> 55	26 <b>Fe</b> 56	27 <b>Co</b> 59	28 <b>Ni</b> 59	29 <b>Cu</b> 64	30 <b>Zn</b> 65	Ga	Ge	As	34 <b>Se</b> 79	Br	Kr
Rb	Sr	Y	Zr	Nb	42 <b>Mo</b> 96	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	53 <b>I</b> 127	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Ha													

## Ionic bonds

- ▶ Based on electrostatic attraction
- ▶ Requires electron transfer from one to another atom
- ▶ Molecules with ionic bonds are normally well dissolved in water

## Covalent bonds

- ▶ Based on electron sharing
- ▶ Depending on strength, may be polar and non-polar

## Hydrogen bonds

- ▶ Molecule-to-molecule bonds
- ▶ Normally occurs between molecules with polar covalent bonds and appropriate size

## Water and its importance

- ▶ Universal solvent
- ▶ Water molecules are cohesive (water attracts water)
- ▶ Water molecules are adhesive (water attracts other materials)
- ▶ Water has high surface tension (pond-skaters may skate on water)
- ▶ Water has high heat capacity (keeps warmth)
- ▶ Water is less dense than ice (water bodies are not completely frozen)



## Acids, bases and pH

- ▶ Molecules dissociates with hydrogen ion (or, in other model, hydronium ion) are acids
- ▶ Molecules dissociates with hydroxyl ion are bases
- ▶ Weak acids/bases have high frequency of reverse reaction
- ▶ pH represents the concentration of hydrogen ions, high pH (> 7) corresponds with bases, low pH (1–5) corresponds with acids

## Hydrophobic “bonds”

- ▶ Inside water solutions, hydrophobic (non-solvable) molecules often united in groups
- ▶ This process is often called “hydrophobic” bonds

# Organic molecules

## Basics of organic chemistry

## Carbon and carbon skeleton

- ▶ Carbon atom has a small size and 4 electrons in the outer layer
- ▶ Consequently, it can form 4 bonds per atom, double and triple bonds, and may even form long chains of same element
- ▶ Other elements with similar features: silicon (same Group IV!), nitrogen, sulfur

## Basic classes of organic molecules

- ▶ Hydrocarbons with single, double and triple bonds:  $C_nH_m$
- ▶ Aromatic hydrocarbons (arenes): benzene etc.
- ▶ Alcohols and phenols:  $R-OH$
- ▶ Ethers:  $R-O-R$
- ▶ Aldehydes:  $R-CHO$
- ▶ Ketones:  $R-CO-R$
- ▶ Carboxylic acids:  $R-COOH$
- ▶ Amines:  $R-NH_2$

## Basic groups of biochemical compounds

- ▶ Mono-, disaccharides (sugars) and polysaccharides: alcohols + ketones / aldehydes
- ▶ Fatty acids and lipids: hydrocarbons + carboxylic acids
- ▶ Amino acids and proteins: amines + carboxylic acids
- ▶ Nucleotides and nucleic acids: sugars + amines + phosphoric acid

## Final question (1 point)

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Name one chemical element which is NOT biogenic



## Summary

- ▶ There are five main biogenic elements: carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and phosphorus (P)
- ▶ Ionic and covalent bonds are inter-atomic, hydrogen and hydrophilic bonds are inter-molecular
- ▶ Organic chemistry is a chemistry of carbon

## For Further Reading



A. Shipunov.

*Advanced Cell Biology* [Electronic resource].

2011—onwards.

Mode of access: [http:](http://)

[//ashipunov.info/shipunov/school/biol\\_250](http://ashipunov.info/shipunov/school/biol_250)



B. Alberts et al.

*Essential Cell Biology*. 3rd edition.

Garland Science, 2009.

*Chapter 2: Chemical bonds; Molecules in cells, Panel 2-1.*