Chapter 9

Composition of the Human Body

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The composition of the human body can be analyzed in several different ways. Such an analysis can be performed in terms of the percentage distribution of chemical elements dispersed in a human being or considering molecular components, such as the amounts of water, protein, fats(or lipids), hydroxyapatite, and carbohydrates, among others. In terms of cell types, the human body contains hundreds of different cell structures, but remarkably, the largest number of cells contained in a healthy human being (though not the largest mass) are not human cells, but bacteria that live in the gastrointestinal tract [1, 2, 3, 4, 5, 6].

9.1 Chemical Elements

Considering the chemical composition of the human body, it is possible to state that almost 99% of the entire mass of a standard human being is composed of only six distinct chemical elements: oxygen, carbon, hydrogen, nitrogen, calcium, and phosphor. Considering the 1% of the remaining mass, it is possible to state that 0.85% corresponds to five other elements: potassium, sulfur, sodium, chlorine, and magnesium. All other elements added together do not reach the mass of magnesium, the least abundant of the 11 elements mentioned in this list (Table 9.1) [7, 8, 9].

9.2 Complete Percentage Distribution

Regarding the complete chemical composition of the human body, it is usually considered that 61 different chemical elements are present [10, 11, 12, 13]. Some of the elements listed in the above table are not recognized as essential nutrients, although they are components of the human body [14, 15, 16]. Others, although essential, can be harmful when present in large amounts [17, 18, 19, 20, 21].

Table 9.1: Main elements in a healthy human body.

Element	Symbol	% dispersed in the human body	Atomic percentage
Oxygen	O	65.0	24.0
Carbon	C	18.5	12.0
Hydrogen	H	9.5	62.0
Nitrogen	N	3.2	1.1
Calcium	Ca	1.5	0.22
Phosphor	P	1.0	0.22
Potassium	K	0.4	0.03
Sulfur	S	0.3	0.038
Sodium	Na	0.2	0.037
Chlorine	Cl	0.2	0.024
Magnesium	Mg	0.1	0.015
Boron	B		
Chromium	Cr		
Cobalt	Co		
Copper	Cu		
Fluorine	F		
Iodine	I		
Iron	Fe	<1.0	<0.3
Manganese	Mn		
Molybdenum	Mo		
Selenium	Se		
Silicon	Si		
Tin	Sn		
Vanadium	V		
Zinc	Zn		

On average, a 70 kg adult body contains about 7×10^{27} atoms [22, 23, 24, 25, 26], distributed among numerous chemical elements [27, 28, 29]. The 61 most abundant elements are shown in table 9.2 [30, 31, 32, 33, 34].

Table 9.2: Elements in a human body ordered by abundance.

Element	% total mass	Essential biological role	Toxic effects
Oxygen	61.35	Yes	Oxidation and free radicals
Carbon	22.83	Yes	
Hydrogen	9.98	Yes	Acidosis
Nitrogen	2.57	Yes	
Calcium	1.42	Yes	Hypercalcemia
Phosphor	1.11	Yes	Hyperphosphatemia
Potassium	0.19	Yes	Hyperkalemia
Sulfur	0.19	Yes	
Sodium	0.14	Yes	Hypernatremia
Chlorine	0.14	Yes	Hyperchloremia
Magnesium	0.03	Yes	Hypermagnesemia
Iron	0.006	Yes	Hemochromatosis
Fluorine	0.0037	Perhaps	Bone/dental fluorosis and intoxication
Zinc	0.0033	Yes	Intoxication
Silicon	0.0014	Probably	
Galium	0.001	No	Poisoning
Rubidium	0.0009	No	Potassium replacement
Strontium	0.0005	No	Calcium replacement
Bromine	0.0004	Perhaps	Intoxication
Lead	0.0001	No	Poisoning/intoxication
Copper	Trace element	Yes	Intoxication
Aluminium	Trace element	No	Poisoning/intoxication
Cadmium	Trace element	No	Poisoning/intoxication
Cerium	Trace element	No	
Barium	Trace element	No	Poisoning
Tin	Trace element	No	
Iodine	Trace element	Yes	Iodine-induced hyperthyroidism
Titanium	Trace element	No	
Boron	Trace element	Probably	
Selenium	Trace element	Yes	Intoxication
Nickel	Trace element	No	Intoxication
Chrome	Trace element	Yes	
Manganese	Trace element	Yes	Manganism
Arsenic	Trace element	No	Poisoning/intoxication
Lithium	Trace element	Yes	Intoxication

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Element	% total mass	Essential biological role	Toxic effects
Ruthenium	Trace element	No	
Mercury	Trace element	No	Poisoning/intoxication
Cesium	Trace element	No	
Molybdenum	Trace element	Yes	
Germanium	Trace element	No	
Cobalt	Trace element	Yes	
Antimony	Trace element	No	Intoxication
Silver	Trace element	No	Argyria
Niobium	Trace element	No	
Zirconium	Trace element	No	
Lanthanum	Trace element	No	
Tellurium	Trace element	No	
Yttrium	Trace element	No	
Bismuth	Trace element	No	
Thallium	Trace element	No	Poisoning/intoxication
Indian	Trace element	No	
Gold	Trace element	No	Possible genotoxicity
Scandium	Trace element	No	
Tantalum	Trace element	No	
Tungsten	Trace element	No	
Vanadium	Trace element	Probably	
Thorium	Trace element	No	Radioactivity poisoning/intoxication
Uranium	Trace element	No	Radioactivity poisoning
Samarium	Trace element	No	
Beryllium	Trace element	No	Poisoning
Radio	Trace element	No	Radioactivity poisoning

9.2.1 Trace Elements

Not all elements present in the human body found in trace amounts play essential roles in life. Science believes that some of these elements are simple secondary contaminants with no biological function (e.g., cesium and titanium), while others are considered active toxics, which can be harmful depending on the amount (e.g., cadmium and mercury) [35, 36, 37, 38, 39]. In some cases, this function can be altered according to the amount present in the body. Arsenic, for example, is considered toxic, but it is speculated that it plays some biological role when present in tiny amounts in the body [40, 41, 42, 43, 44].

9.2.2 Presence of Unusual Chemical Elements

Among the components present in the composition of the human body, the existence of some unusual chemical elements is observed, although most of them are present in trace amounts [45, 46]. However, metals usually considered rare and of great commercial value, such as

silver, titanium, and gold, can be detected by instrumental analysis [47]. In the case of gold, for example, it is estimated that there are about 0.2 milligrams of metal in the body of each human being, and most of these gold atoms are found in circulation in the blood flow [48]. Although they have no known biological role, some studies indicate that gold and silver can impact the development of some cells in the human nervous system [49, 50].

Additionally, elements known to have high radioactivity are shown to be present in infinitesimal amounts, including beryllium, radium, thorium, and uranium [51]. Several radioactive isotopes of other chemical elements are also found circulating in human organisms [52], such as potassium-40,carbon-14, rubidium-87, and tritium [53]. However, the reduced amount of these elements normally present in humans eliminates any reason for concern about possible impacts or health risks arising from their levels of radioactivity [51, 54].

9.2.3 Molecular Substances

In relation to molecules most commonly present in the human body, it is possible to highlight the following substances [55, 56, 57]:

- Water;
- Proteins, including those present in muscles, hair, and connective tissues, among others;
- Lipids;
- Hydroxyapatite;
- Carbohydrates;
- Enzymes;
- DNA and RNA;
- Inorganic ionic compounds;
- Gases concentrated in organs of the respiratory and digestive systems and also dissolved in other components, such as blood, lymph, tissues, and body fluids;
- Numerous other small molecules, such as amino acids, fatty acids, nucleobases, nucleotides, vitamins, and coenzymes;
- Free radicals.

From a molecular point of view, the average composition of a typical cell of the human body, with a dimension of 20 micrometers can be summarized in table 9.3:

Table 9.3: Molecular composition of a human body.

Molecule	% total mass	% total molecules
Water	65.0	98.73
Proteins	20	0.011
Lipids	12	0.475
RNA	1.0	3×10^{-5}
DNA	0.1	3×10^{-11}
Other organic elements	0.4	0.044
Other inorganic elements	1.5	0.74

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