Biochemistry (Chapter 1: A Brief History of Biochemistry)

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1 author:

Hikmet Geckil
Inonu University

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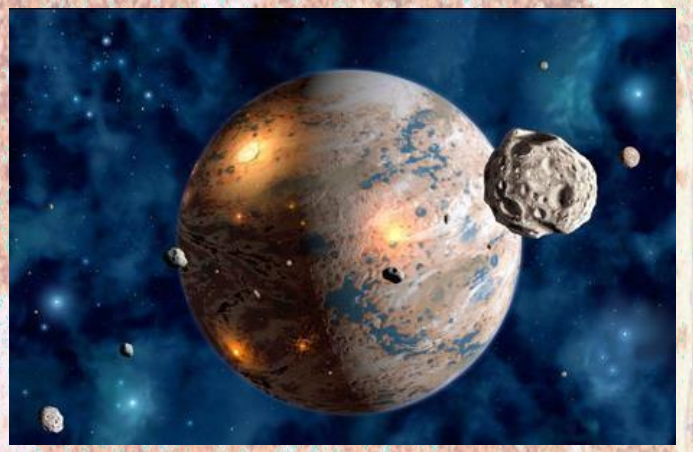
Biochemistry

Chapter 1: A Brief History of Biochemistry

Hikmet Geçkil, Professor
Department of Molecular Biology and Genetics
Inonu University

A Brief History of Earth & Life



- Earth was formed about 5 billion years ago, when our solar system (formed 15 billion yeras ago) took shape around the sun.

A current model for the origin of life on earth: The Bubble Hypothesis

- The origin of life is still a mystery, but there are some theories that speculate how inorganic matter was transformed into the organic matter that created life.

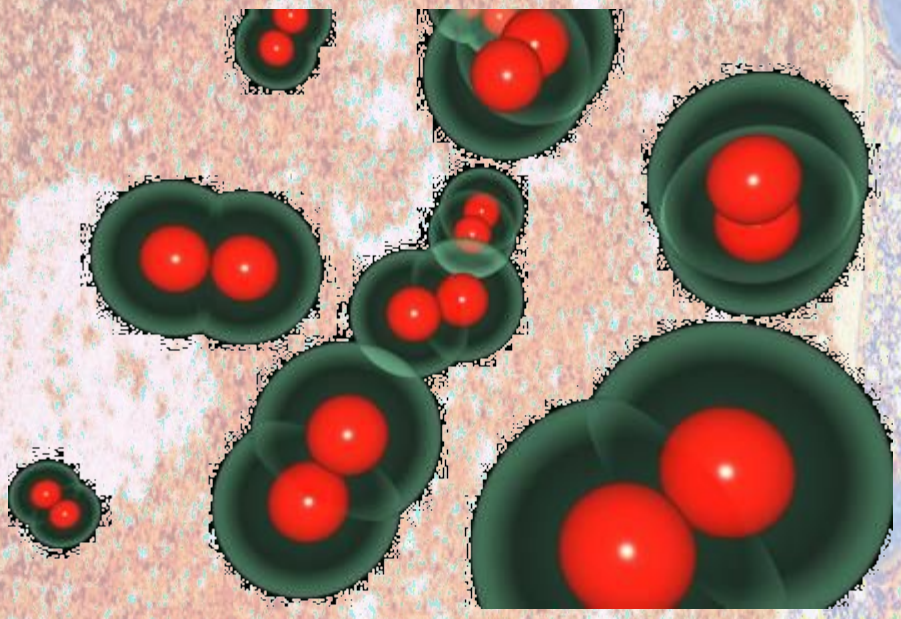
- In 1992 it was proposed that bubbles in the sea were the key to helping create complex organic matter that eventually became life.

- The first cells are thought to have arisen from aggregations of molecules that were more stable and, therefore, persisted longer.

- It has been suggested that RNA may have arisen before cells and subsequently became packaged within a membrane (RNA world).

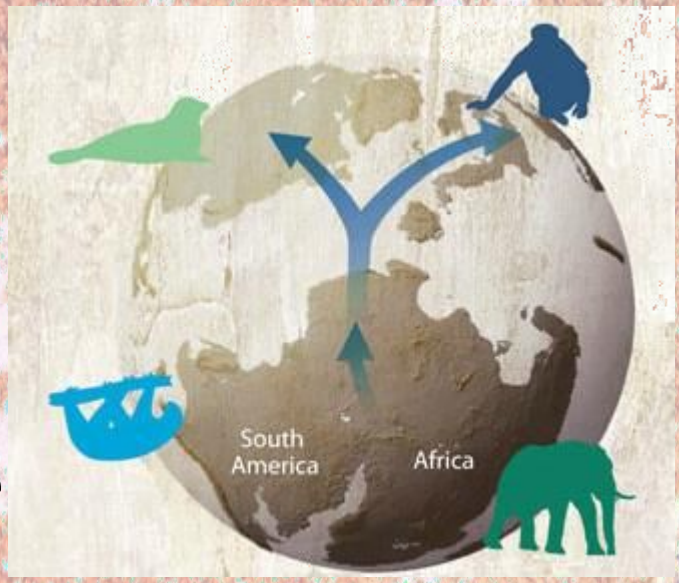
- Bacteria were the only life-forms on earth for about 1 billion years. First methane utilizers, then anaerobic photosynthesizers, and eventually O_2-forming photosynthesizers.

- Oxygen levels rise about 2.5 billion years ago, which is thought to have been created by photosynthesis by cyanobacteria living in the sea.



- The oxygen-rich ozone layer was also established, shielding the Earth's surface from harmful solar radiation.

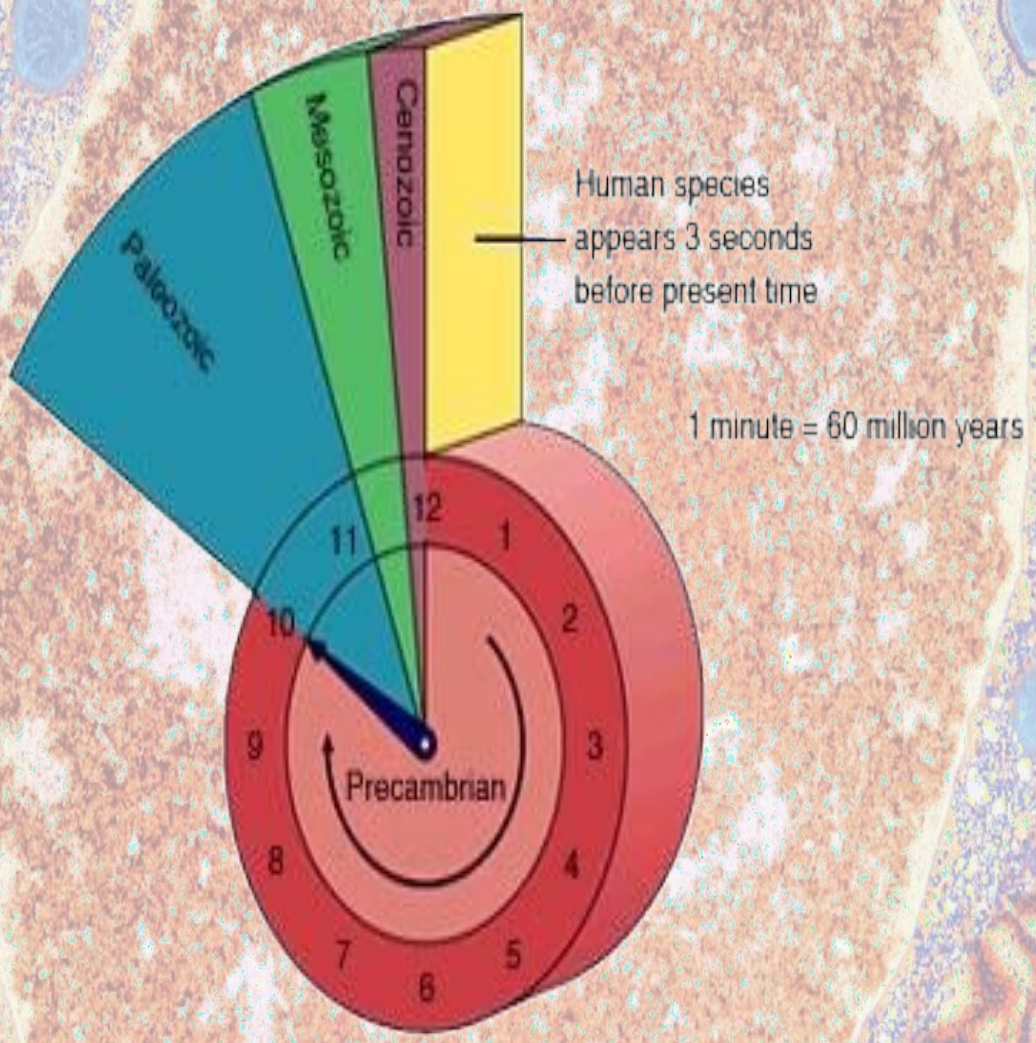
- This further provided our planet for appearence of and inhabitation by other organisms including us.



- Fossils indicate our own species, Homo sapiens, arose in eastern Africa some 190,000 years ago.

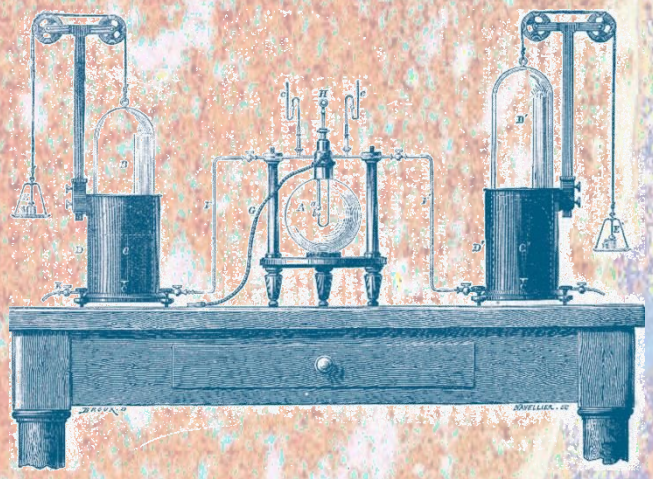
- First venturing beyond Africa about 70,000 years ago.

- The first eukaryotes can be seen in the fossil record about 1.5 billion years ago. All organisms other than bacteria are their descendants.



A Brief History of Biochemistry

- 1780s Antoine Lavoisier proposed that the combustion of a candle is similar to the respiration of animals, as both need O_2.

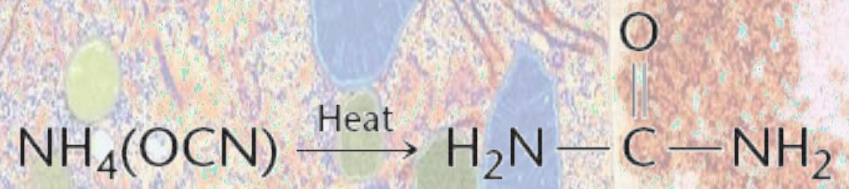


- For the first time a physiological process was explained with reference to a nonliving mechanism.

- Until the early 1800s “vitalism” was a common belief: the compounds found in living organisms (i.e., organic molecules) can only be produced by living organisms and could not be produced in the laboratory.

- Now an obsolete scientific doctrine, vitalists argued that it was the presence of a “vital force” (life force or spirit) that distinguished the living organic world from the inanimate inorganic world.

- Friedrich Wöhler disproved this belief (i.e., vitalism) in 1828 by synthesizing **urea**, an organic molecule and a waste product of animal metabolism, from ammonium cyanate, an inorganic molecule obtained from mineral (i.e., nonliving) sources.



- Many science historians this in vitro synthesis of urea by Wöhler as the starting point of Biochemistry.

▲ **Friedrich Wöhler (1800–1882).** Wöhler was one of the founders of biochemistry. By synthesizing urea, Wöhler showed that compounds found in living organisms could be made in the laboratory from inorganic substances.

- However, many consider Eduard Buchner's first demonstration of alcoholic **fermentation** in 1893 in cell-free yeast extracts as the starting point for the birth of biochemistry.

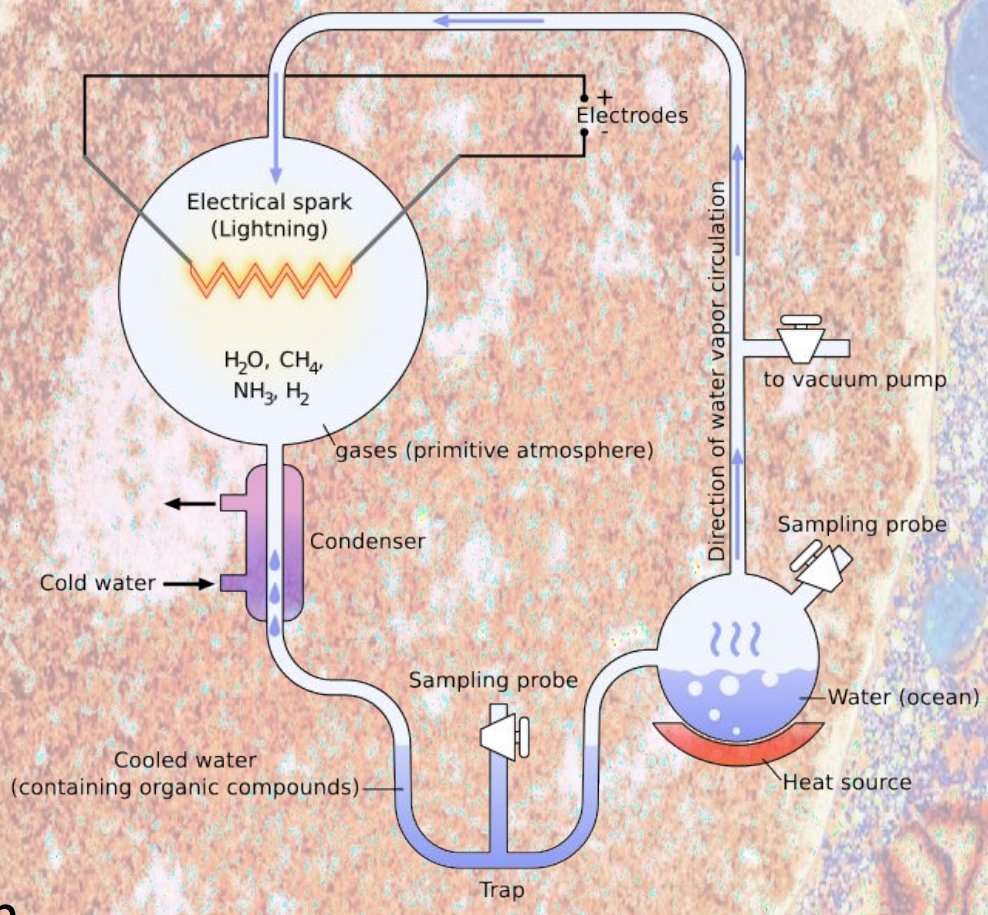
- This was another blow to the vitalistic thinking, showing that the presence of living yeast cells were not needed for fermentation. Previously, scientists believed that only living cells could catalyze such complex biological reactions.

▲ **Eduard Buchner (1860–1917).** Buchner was awarded the Nobel Prize in Chemistry in 1907 "for his biochemical researches and his discovery of cell-free fermentation."

Miller-Urey Experiment

- Experiments recreating the atmosphere of primitive earth, with the energy sources and temperatures have led to the spontaneous formation of amino acids and other biologically significant molecules.

- The Miller-Urey experiment showed that a variety of organic molecules, including the amino acids could form in an early, reducing atmosphere.



Thus,

- Living things obey the standard laws of physics and chemistry.

- And, no “vitalistic” force is required to explain life at the molecular level.

- 1810s-1830s: A major substance from animals and plants was identified, composed of C, H, O, and N. The term “Protein”, meaning the most important thing, was first used in 1838.

- 1850s-1890s: Carbohydrates, lipids, and nucleic acids were recognized.

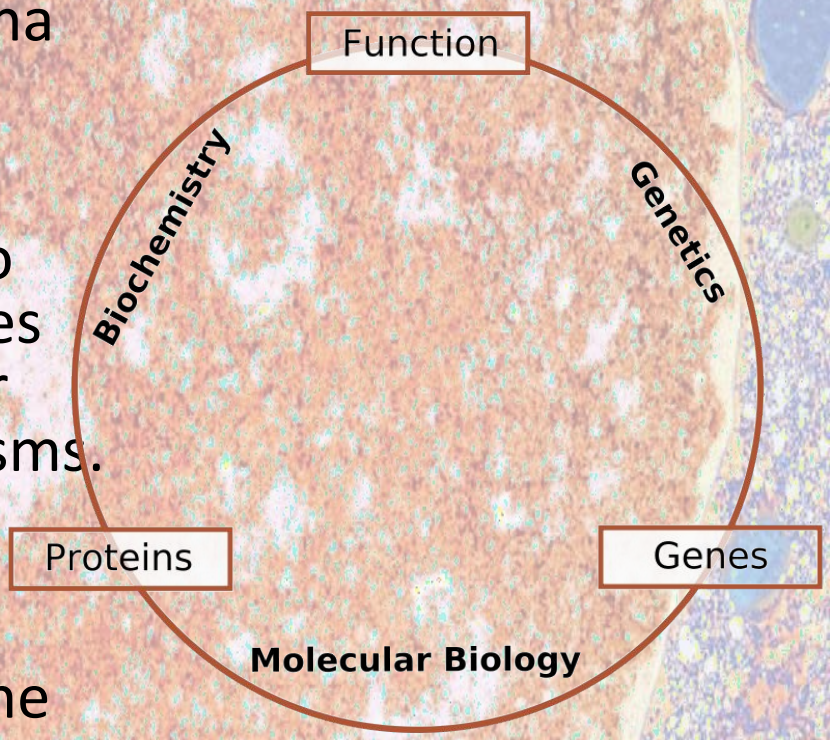
- The term “biochemistry” was coined in the 1870s. (the term Biology in 1800)

What is Biochemistry?

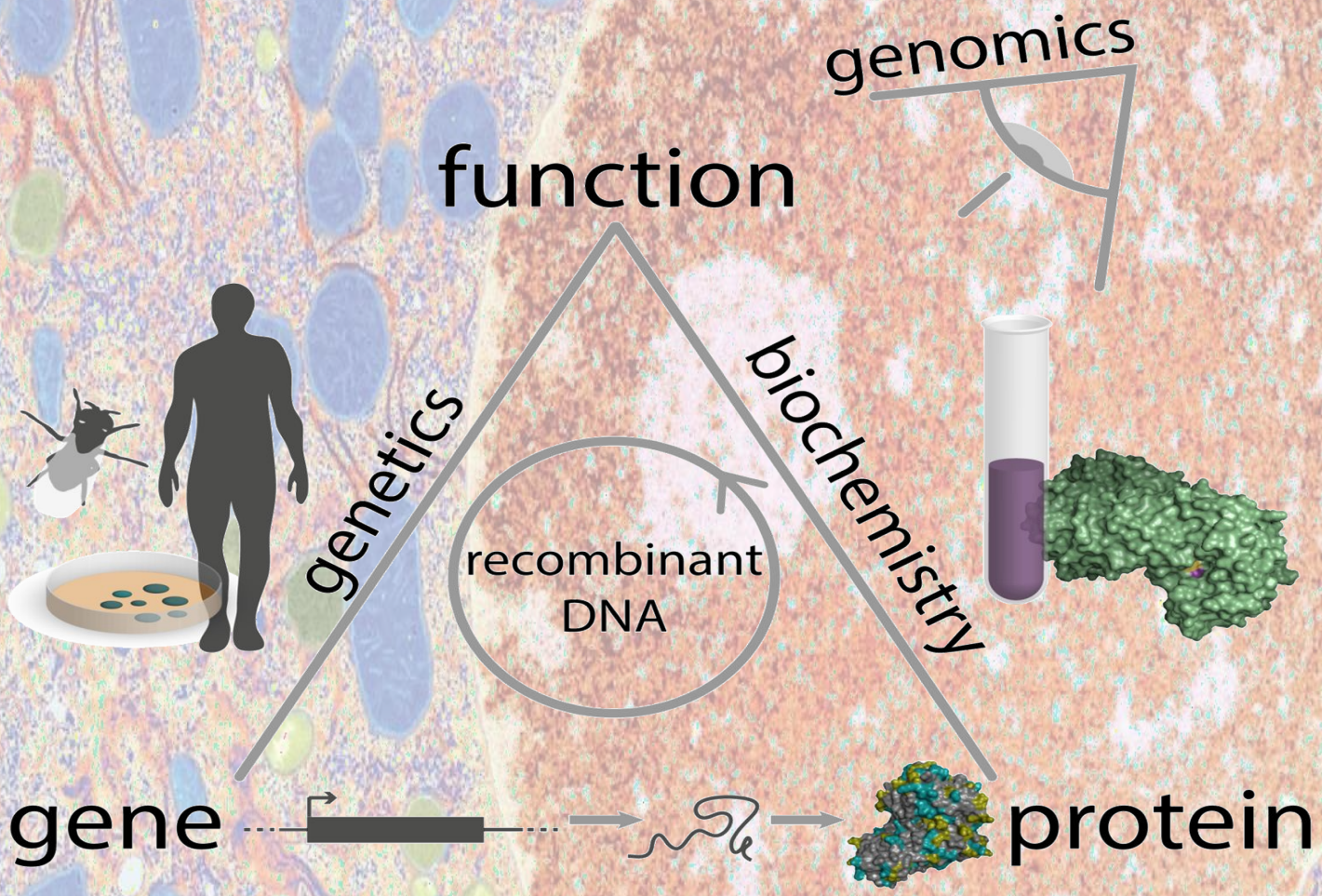
- The study of the molecular basis of life or understanding life phenomena in chemical terms

- The main focus of biochemistry is to understand how biological molecules give rise to the processes that occur within living cells and whole organisms.

- Biochemistry is closely related to molecular biology, the study of the molecular mechanisms by which genetic information encoded in DNA is able to result in the processes of life.



How Biochemistry relates to others



The Chemical Basis of "Life"

- We now know that, "life itself" is constructed from non-living matter (i.e., atoms and elements)

- Living organisms have about 20 elements (compared to 94 elements occuring naturally)

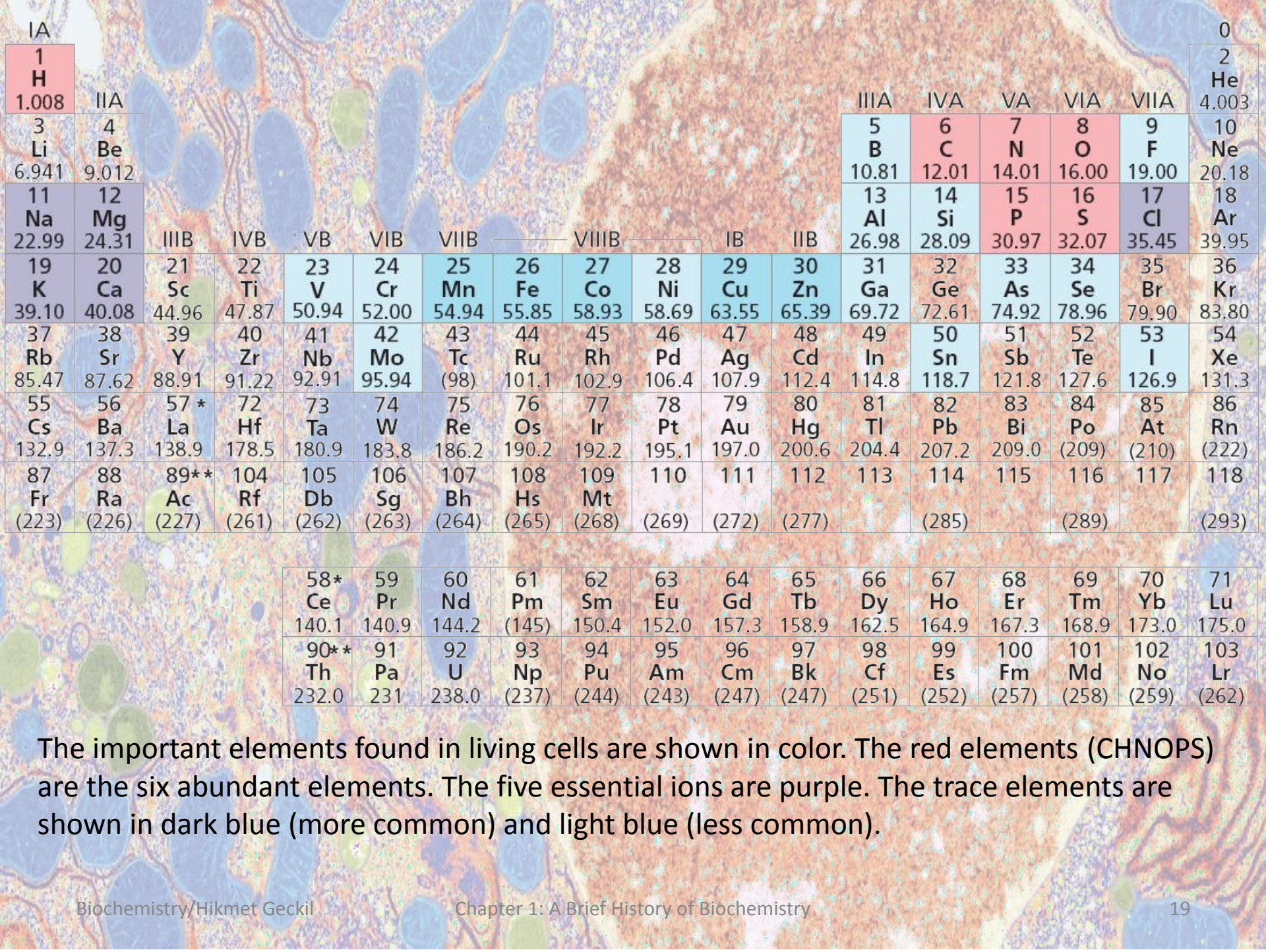
- Carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur (CHONPS) account for more than 97% of the weight of most organisms

- The relative amounts (and sometime species) of these elements may vary among organisms.

- Water is a major component of cells and accounts for the high percentage (by weight) of oxygen.

- Carbon is much more abundant in living organisms than in the rest of the universe.

- Some elements, such as silicon, aluminum, and iron, are very common in the Earth's crust but are present only in trace amounts in cells.



The important elements found in living cells are shown in color. The red elements (CHNOPS) are the six abundant elements. The five essential ions are purple. The trace elements are shown in dark blue (more common) and light blue (less common).

Paradox !

- Living organisms and cells are made from non living elements.
- Only cells can produce cells (Cell Theory).
- How the first cell came into being?
- This is on of the greatest scientific questions yet to be answered to explain *the origin of life*.

"Remarkable chemical unity under the biological diversity"

- Remarkable uniformity of organisms of at the molecular and cellular level.
- The common use of DNA and the genetic code by all organisms
- Construction of all organisms from similar molecular components (nucleotides, amino acids, other building blocks and larger molecules)
- Same or similar bosynthetic pathways
- *This uniformity reveals that all organisms on Earth have arisen from a common ancestor*.

Two major breakthroughs in the history of biochemistry are especially notable

1. ***The discovery of the roles of enzymes as catalysts***

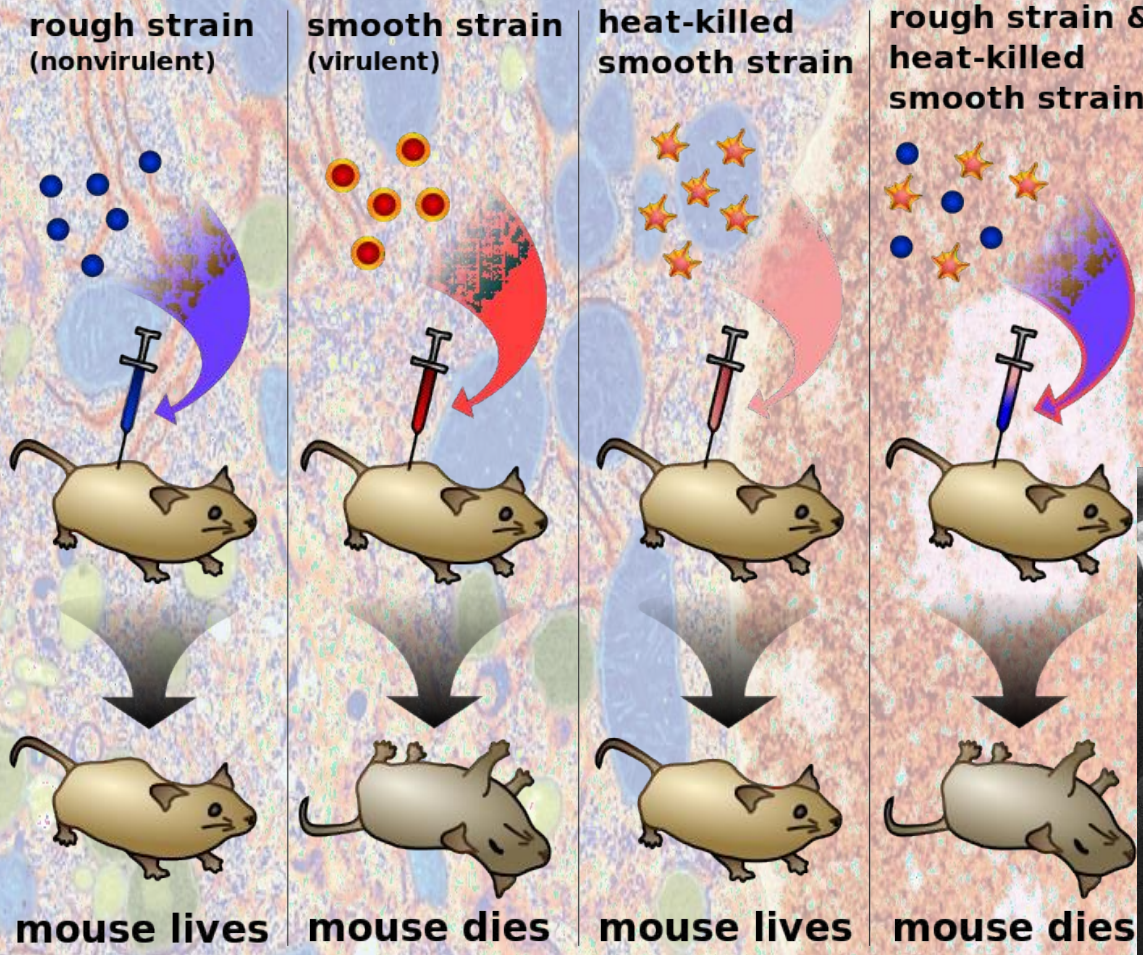
   - The experiments of Buchner showing that extracts of yeast cells could catalyze the fermentation of the sugar glucose to alcohol and carbon dioxide.

   - James Sumner showed that Enzymes are proteins (1920s-1930s).

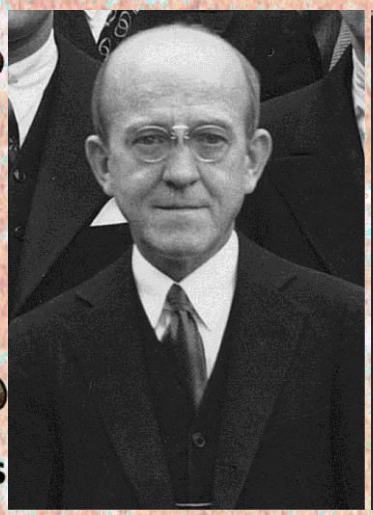
2. The role of nucleic acids as information-carrying molecules

- DNA is the genetic material (1940s)
- Three-dimensional structure of DNA (i.e., DNA double-helix) (1950s)
- Genetic code (1960s)
- Biological infromation flow (i.e., Central Dogma of molecular biology) (1970s)
- Manipulation of DNA (i.e., Genetic Engineering) (1970s)
- Catalytic activity RNA (Ribozyme) (1980s)
- Causes of cancer (1990s)
- Genomic Era (2000s)
- Brain research (2010s)

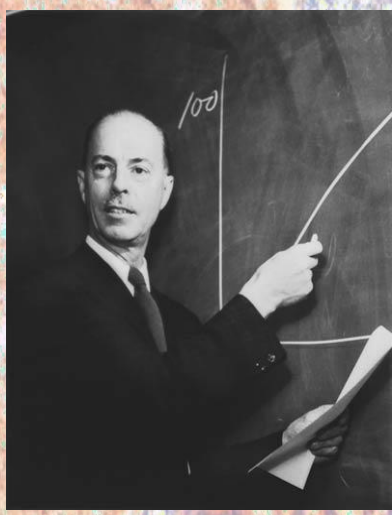
1940s-1950s: Frederick Griffith's transformation experiment and DNA carries the genetic information



Frederick Griffith

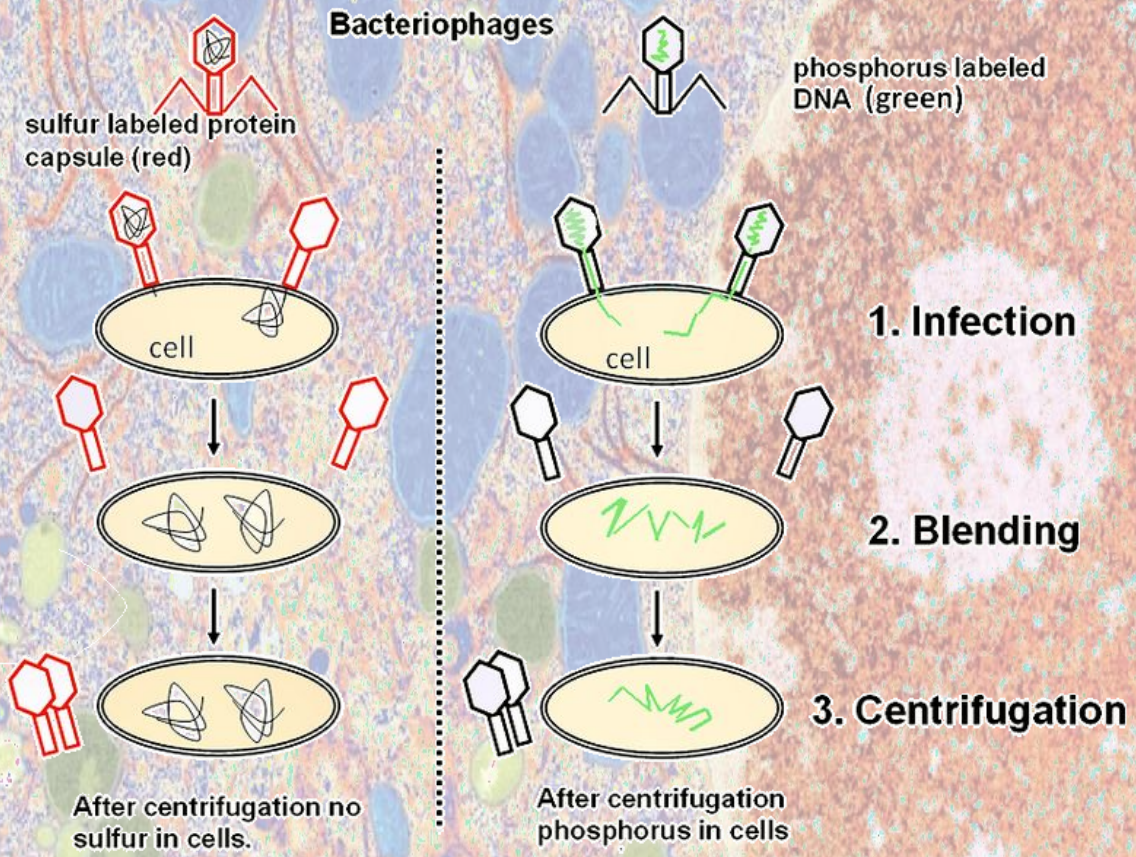


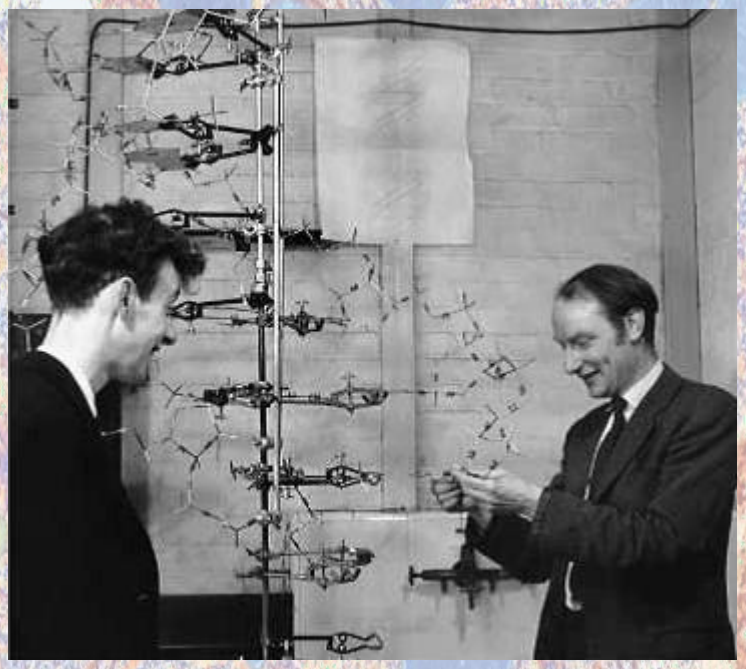
Oswald Avery



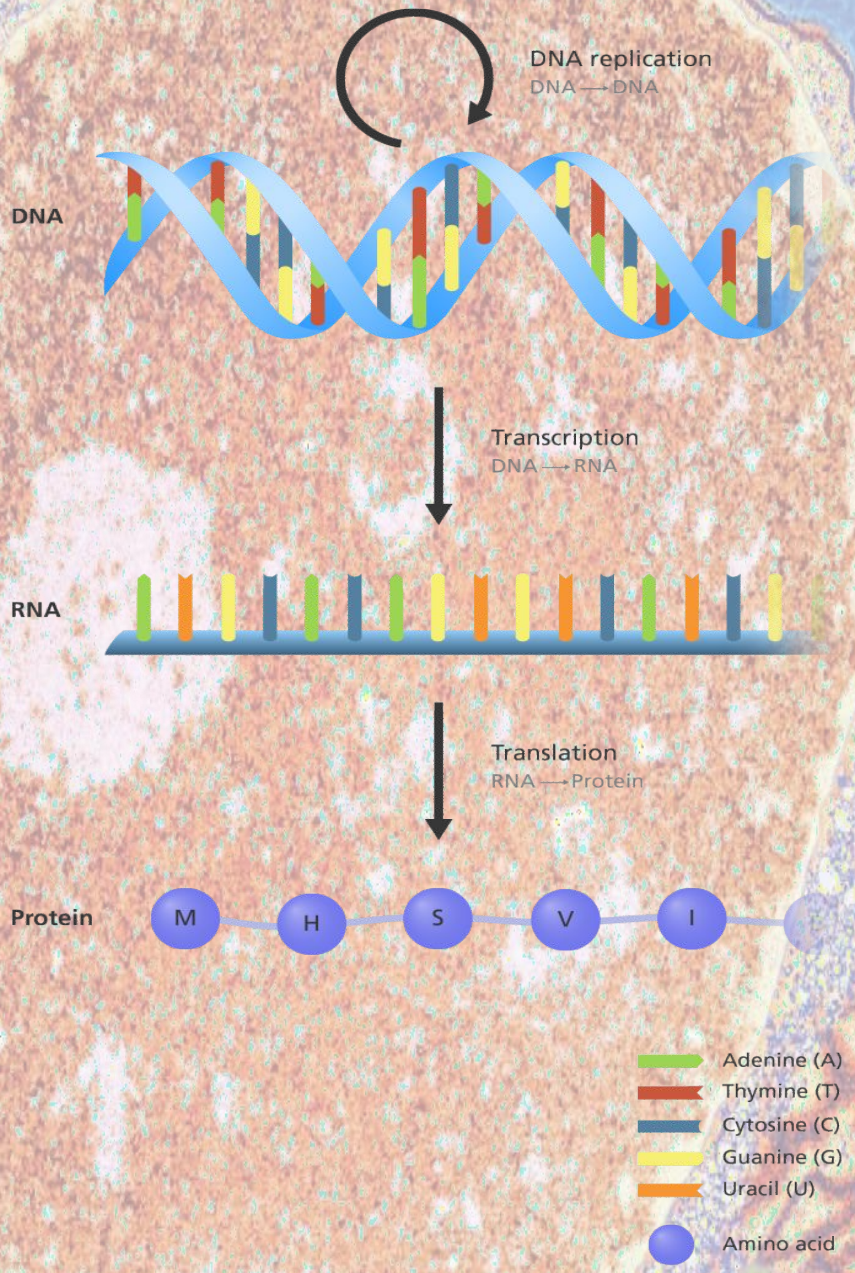
Colin MacLeod

Martha Chase and Alfred Hershey's blender experiment

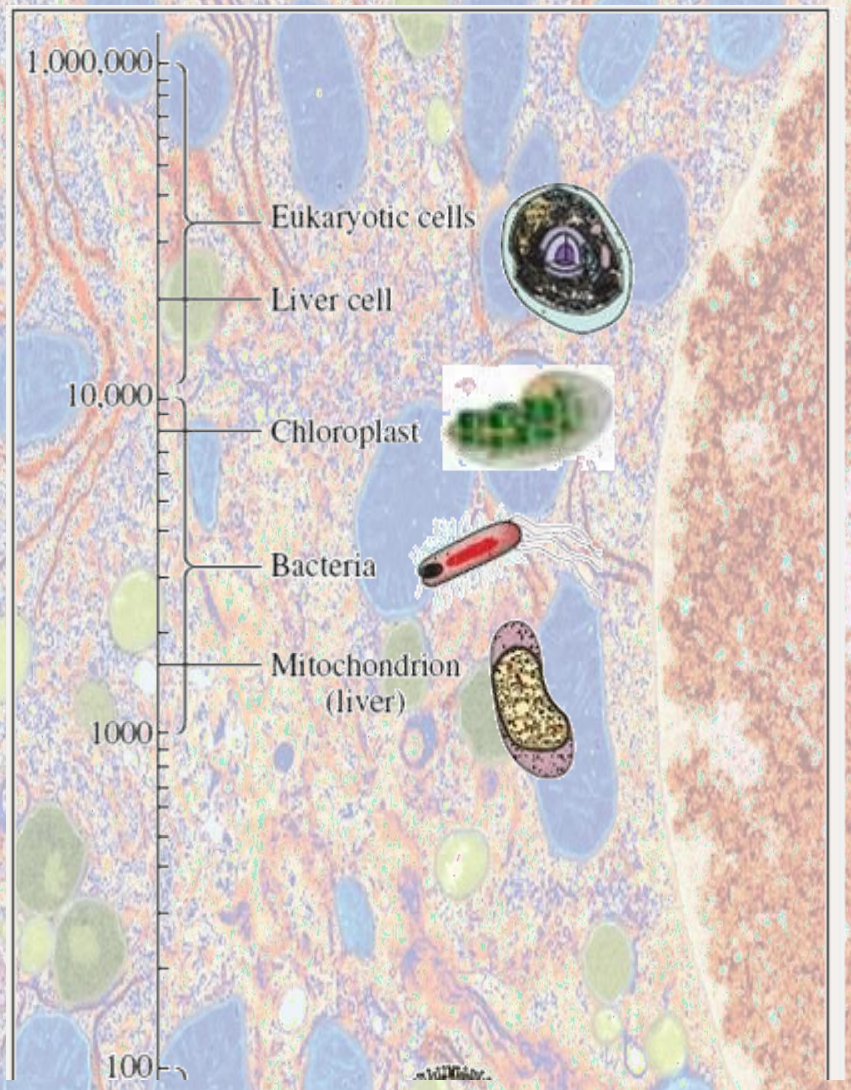


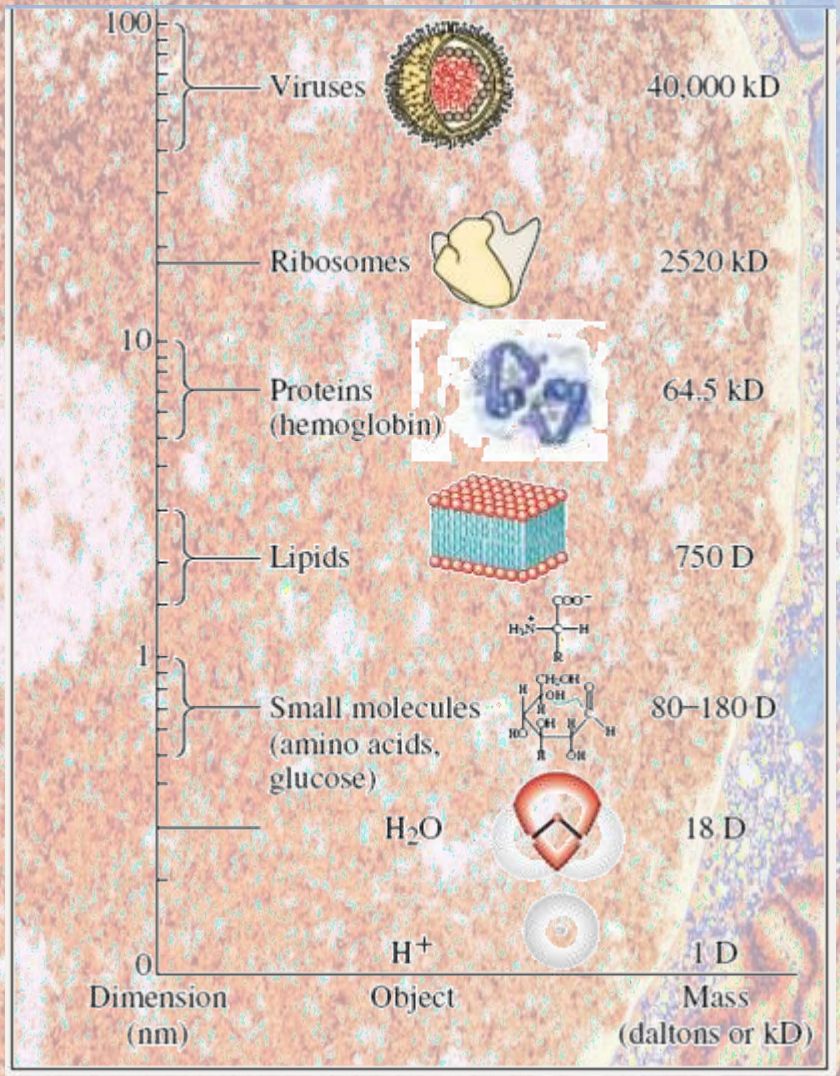


James Watson and Francis Crick with their DNA model



Scale of things in Biochemistry





What does bioochemistry study?

- Biochemistry studies all the processes within a living cell.

- With their all molecular compounds and contents, understanding how all these processes contribute to health and disease of living cells or organisms are major focus of Biochemistry.

- Throughout the course, you will learn the structure and function of
  - large (carbohydrates, lipids, proteins, and nucleic acids)
  - and small (building blocks, vitamins) molecules

- And how these molecules are metabolized (biosynthesis and breakdown) and their regulation play vital role in the well-being of a cell and organism.

References

- Principles of Biochemistry by Moran et.
- Lehninger Principles of Biochemistry
- Wikipedia