• Biochemistry is a dichotomous relationship between biology and organic chemistry.
• Biochemistry is actually the study of chemical reactions within the cell.
• Types of organisms:
  - Prokaryotes
  - Eukaryotes
• In addition to molecular structure and function and the relationship between these characteristics, biochemists also think about bioenergetics.
Introduction

Of the hundred plus chemical elements, only about 30 (29%) occur naturally in plants and animals.

- Elements in red are found in bulk form in living cells and are essential for life.
- Yellow are trace elements and likely essential.
- Elements in blue are present in some organisms.
Introduction

- Elemental composition of the universe.
- The earth's crust.
- The human body.

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**Comparison of Prokaryotic and Eukaryotic Cells**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Prokaryotic cell</th>
<th>Eukaryotic cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>Generally small (1-10 μm)</td>
<td>Generally large (5-100 μm)</td>
</tr>
<tr>
<td>Genome</td>
<td>DNA with one chromosome; genome is linear, not surrounded by chromosome</td>
<td>DNA composed of multiple chromosomes with nucleosomes; chromosomes in nucleus</td>
</tr>
<tr>
<td>Cell division</td>
<td>Fission or budding, no mitosis</td>
<td>Mitosis including mitotic spindle; centrioles in many species</td>
</tr>
<tr>
<td>Membrane-bounded organelles</td>
<td>Absent</td>
<td>Mitochondria, endoplasmic reticulum, Golgi apparatus, peroxisomes, (in animals), etc.</td>
</tr>
<tr>
<td>Nutrition</td>
<td>Absorption, some photosynthesis</td>
<td>Absorption, ingestion, photosynthesis in some species</td>
</tr>
<tr>
<td>Energy metabolism</td>
<td>Ribosomes; oxidative enzymes bound to plasma membrane</td>
<td>Oxidative enzymes postulated in mitochondria; more unified pattern of oxidative metabolism</td>
</tr>
<tr>
<td>Cytoskeleton</td>
<td>None</td>
<td>Complex with microtubules, intermediate filaments, actin filaments</td>
</tr>
<tr>
<td>Intercellular movement</td>
<td>None</td>
<td>Cytoskeleton: streaming, microtubules, microfilaments, intracellular transport</td>
</tr>
</tbody>
</table>
• Biochemistry began about 170 years ago.
  - Classify biomolecules
  - Intermediate metabolism, biochemist interest is in intermediates.

\[
\text{C}_6\text{H}_{12}\text{O}_6 \xrightarrow{\text{intermediate}} \text{CO}_2 + \text{H}_2\text{O}
\]

- Watson & Crick (DNA) Interaction between biomolecules.
  - "Super Chemistry"
  - Molecular Biology
- Study of control mechanisms
- Study of diseases at the molecular level

• Classifying biomolecules:
  - Approximately 2500 proteins are found in E. coli.
    - Cytochrome C is a protein involved in the metabolic process best known as the electron transport system.
    - General observation: Cytochrome C has been isolated from many different species to compare, contrast and characterize the protein.
  - Proteins are large macromolecules, which are made from individual or single units known as amino acids.
  - DNA & RNA are large macromolecules made from individual or single units known as nucleotides.
**Introduction**

- Water is the principle *ingredient* of the cell.
- **Most abundant** chemical compound in the biosphere.
- General *solvent* for most all living organisms.
- Continuous Phase – *Diffuses* through every cell and tissue.
- Serves in aiding to maintain structure of the macromolecules.
  - Water dictates how proteins fold (hydrophobic/hydrophilic)
  - Amino acid sequence determines shape and shape determines structure.
- Important in pH and buffers.

**Cell Size**

- If you were to magnify a cell 10,000 fold, how big would it appear? Assume you are viewing a “typical” eukaryotic cell with a cellular diameter of 50 microns.
  - The magnified cell would have a diameter of $50 \times 10^4 \mu m = 500 \times 10^3 \mu m = 500 \text{ mm.}$
Introduction

• Cell Concentration

• If the cell were muscle cell, how many molecules of actin could it hold assuming there are no other cellular components present? (Actin molecules are spherical with a diameter of 3.6 nm; assume the muscle cell is spherical, the volume of a sphere is $\frac{4}{3}\pi r^3$)

- The radius of a globular actin molecule is $3.6 \text{ nm}/2 = 1.8 \text{ nm}$; the volume of the molecule, in cubic meters is $\frac{4}{3}\pi(1.8 \times 10^{-9} \text{ m})^3 = 2.44 \times 10^{-26} \text{ m}^3$

- The total number of actin molecules that could fit inside the cell is found by dividing the muscle cell volume by the actin molecule volume. Cell volume = $\frac{4}{3}\pi(25 \times 10^{-6} \text{ m})^3 = 6.5 \times 10^{-14} \text{ m}^3$. Thus the number of actin molecules in the hypothetical muscle cell is:

$$(6.5 \times 10^{-14} \text{ m}^3)(2.44 \times 10^{-26} \text{ m}^3) = 2.66 \times 10^{12} \cong 2.7 \times 10^{12} \text{ molecules}$$

Introduction

General information in E. coli DNA

• The genetic information contained in DNA consists of linear sequences of successive coding units, known as codons. Each codon is a specific sequence of three nucleotides (three nucleotide pairs in double stranded DNA), and each codon code for a single amino acid unit in a protein.

• The molecular weight of an E. coli DNA molecule is about $3.1 \times 10^8$.

• The average molecular weight of a nucleotide pair is 660, and each nucleotide pair contributes 0.34 nm to the length of DNA.
General information in E. coli DNA

- Calculate the length of an *E. coli* DNA molecule. Compare the length of the DNA molecule with the cell dimensions. How does the DNA molecule fit into the cell?
- Assume that the average protein in *E. coli* consist of a chain of 400 amino acids. What is the maximum number of proteins that can be coded by an *E. coli* DNA molecule?
- The number of nucleotide pairs in the DNA molecule can be calculated by dividing the molecular weight of DNA by that of a single base pair.
  \[
  \frac{(3.1 \times 10^9)}{(0.66 \times 10^3)} = 4.7 \times 10^6 \text{ pairs.}
  \]
  \[
  (4.7 \times 10^6 \text{ pairs})(0.34 \text{ nm/pair}) \approx 1.6 \times 10^6 \text{ nm} = 1.6 \text{ mm}
  \]

Introduction

The length of an *E. coli* cell is 2.0 µm or 0.002 mm, which means that the DNA is 1.6 mm/0.002 mm or 800 times longer than the cell.

Since the DNA molecule has 4.7 × 10^6 nucleotide pairs, it must have 1/3 this number of triplet codons:

\[
(4.7 \times 10^6)/3 = 1.57 \times 10^6 \text{ codons.}
\]

If each protein has an average of 400 amino acids, each requiring one codon, the number of proteins that can be coded by *E. coli* DNA is:

\[
(1.57 \times 10^6)/400 = 3,930 \text{ proteins per cell}
\]
Introduction

Viruses

• Viruses cannot exist independently and are usually not considered a life-form.
• Viruses are deemed parasites since they are unable to carry out metabolism or reproduction without the help of a host cell.
• When viruses infect a cell, they take control of the cell’s metabolic machinery and force it to synthesize nucleic acids and proteins for new virus particles.
• Viruses are the cause of many plant and animal maladies and their presence in the world has resulted in much human suffering.
• However, enormous amount of biochemistry has been learned from studies of their actions.