Foundations of Biochemistry – Dental Course

Text: Nelson & Cox-Lehninger
Principles of Biochemistry (5th ed 2008)
Objectives

1. Recognize that cells are composed of structural and functional units:
   a. Plasma membrane
   b. Cytoplasm
   c. Cytosol
   d. Ribosomes
   e. Small metabolites
   f. Coenzymes
   g. Nucleus
   h. Genome

2. Recognize that life consists of 3 domains:
   a. Archaebacteria
   b. Eubacteria
   c. Eukaryotes

3. Distinguish between components of Eukaryotes and Prokaryotes.
4. Classify organisms according to energy and carbon acquisition:
   a. Phototrophs
   b. Chemotrophs
   c. Autotrophs
   d. Heterotrophs
      i. Lithotrophs
      ii. Organotrophs

5. Identify common bonds in biomolecules and dissociation energies. Recognize the importance of sunlight as energy source for life.

6. Recognize common functional groups of biomolecules.

7. Identify molecular components in *E. coli* cell:
   a. By percentage weight.
   b. By number of different molecular species.
8. Recognize that complex molecules are often linear polymers of simple molecules.
   a. 3D structures
   b. Optical activity

   [Note Sections 1.3 Physical Foundation and Section 1.4 Genetic Foundation will be covered in depth at appropriate times during the course]

9. Recognize that heritable instructions allow evolution.
   a. Mutations
   b. A biotic production of biomolecules
   c. Landmarks in the evolution of life in earth.

10. Identify organisms in which Genomes have been sequenced.

11. Recognize importance of genomic comparisons in biology and medicine.

   [Form a discussion of benefits and/or risks of genomic research].
**Table 1.2**

**Biomolecular Dimensions**

The dimensions of mass* and length for biomolecules are given typically in daltons and nanometers,† respectively. One dalton (D) is the mass of one hydrogen atom, \(1.67 \times 10^{-24}\) g. One nanometer (nm) is \(10^{-9}\) m, or 10 Å (angstroms).

<table>
<thead>
<tr>
<th>Biomolecule</th>
<th>Length (long dimension, nm)</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>0.3</td>
<td>18</td>
</tr>
<tr>
<td>Alanine</td>
<td>0.5</td>
<td>89</td>
</tr>
<tr>
<td>Glucose</td>
<td>0.7</td>
<td>180</td>
</tr>
<tr>
<td>Phospholipid</td>
<td>3.5</td>
<td>750</td>
</tr>
<tr>
<td>Ribonuclease (a small protein)</td>
<td>4</td>
<td>12,600</td>
</tr>
<tr>
<td>Immunoglobulin G (IgG)</td>
<td>14</td>
<td>150,000</td>
</tr>
<tr>
<td>Myosin (a large muscle protein)</td>
<td>160</td>
<td>470,000</td>
</tr>
<tr>
<td>Ribosome (bacteria)</td>
<td>18</td>
<td>2,520,000</td>
</tr>
<tr>
<td>Bacteriophage φx174 (a very small bacterial virus)</td>
<td>25</td>
<td>4,700,000</td>
</tr>
<tr>
<td>Pyruvate dehydrogenase complex (a multienzyme complex)</td>
<td>60</td>
<td>7,000,000</td>
</tr>
<tr>
<td>Tobacco mosaic virus (a plant virus)</td>
<td>300</td>
<td>40,000,000</td>
</tr>
<tr>
<td>Mitochondrion (liver)</td>
<td>1,500</td>
<td>1.5</td>
</tr>
<tr>
<td><em>Escherichia coli</em> cell</td>
<td>2,000</td>
<td>2</td>
</tr>
<tr>
<td>Chloroplast (spinach leaf)</td>
<td>8,000</td>
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</tr>
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*Molecular mass is expressed in units of daltons (D) or kilodaltons (kD) in this book; alternatively, the dimensionless term *molecular weight*, symbolized by \(M_c\) and defined as the ratio of the mass of a molecule to 1 dalton of mass, is used.

†Prefixes used for powers of 10 are

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Exponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>10⁶</td>
<td>mega M</td>
<td>10⁻⁶</td>
</tr>
<tr>
<td>10³</td>
<td>kilo k</td>
<td>10⁻³</td>
</tr>
<tr>
<td>10⁻¹</td>
<td>deci d</td>
<td>10⁻⁹</td>
</tr>
<tr>
<td>10⁻²</td>
<td>centi c</td>
<td>10⁻¹²</td>
</tr>
<tr>
<td>10⁻¹⁵</td>
<td>femto f</td>
<td>10⁻¹⁵</td>
</tr>
<tr>
<td>Prefixes used for powers of 10 are</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>$10^6$</td>
<td>mega M</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>$10^3$</td>
<td>kilo k</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>$10^{-1}$</td>
<td>deci d</td>
<td>$10^{-9}$</td>
</tr>
<tr>
<td>$10^{-2}$</td>
<td>centi c</td>
<td>$10^{-12}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$10^{-15}$</td>
</tr>
</tbody>
</table>

Å  Angstrom = $10^{-8}$cm

Part per million (ppm) = 1mg/L
Comparative Sizes of Biomolecules, Viruses and Cells

- Water
- Amino Acids
- DNA helix
- Protein helix
- Enzyme
- Cu, Zn Superoxide Dismutase
Prokaryotic and Eukaryotic Cells

Red blood cell

White blood cell

E. coli bacterium
Examples of nanoparticles used in medicine

N. Eng J Med 363:25
(Dec 16, 2010)
### Table 1.2

**Biomolecular Dimensions**

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† Prefixes used for powers of 10 are

- $10^6$ mega M
- $10^3$ kilo k
- $10^{-3}$ milli m
- $10^{-6}$ micro µ
- $10^{-9}$ nano n
- $10^{-12}$ pico p
- $10^{-15}$ femto f

Electron microscope resolution

- 0.05nm or 0.5Å
What is the Fundamental Source of All Life on Earth?
ENERGY OUTPUT FROM SUN

- 3.8 x 10^{23} kw-hr energy per hr
- 170,000 TW strike earth (TW=trillion watts)
- One third of energy reflected back into space
- Current useable energy is ca 13 TW
- By 2050 ca 43 TW of energy will be needed
<table>
<thead>
<tr>
<th>Type of radiation</th>
<th>Gamma rays</th>
<th>X rays</th>
<th>UV</th>
<th>Infrared</th>
<th>Microwaves</th>
<th>Radio waves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>&lt;1 nm</td>
<td>100 nm</td>
<td></td>
<td>&lt;1 millimeter</td>
<td>1 meter</td>
<td>Thousands of meters</td>
</tr>
</tbody>
</table>

Visible light

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>380</th>
<th>430</th>
<th>500</th>
<th>560</th>
<th>600</th>
<th>650</th>
<th>750</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kJ/einstein)</td>
<td>300</td>
<td>240</td>
<td>200</td>
<td>170</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 19.6
Energy per mole of photons (einstein) as a function of wavelength, compared with energies of several chemical bonds. Light in the UV and visible range has enough energy to directly break chemical bonds, whereas light in the long-wavelength portion of infrared region of the spectrum only causes heat-producing molecular vibrations.
**TABLE 1–1**  Strengths of Bonds Common in Biomolecules

<table>
<thead>
<tr>
<th>Type of bond</th>
<th>Bond dissociation energy* (kJ/mol)</th>
<th>Type of bond</th>
<th>Bond dissociation energy (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single bonds</strong></td>
<td></td>
<td><strong>Double bonds</strong></td>
<td></td>
</tr>
<tr>
<td>O—H</td>
<td>470</td>
<td>C=O</td>
<td>712</td>
</tr>
<tr>
<td>H—H</td>
<td>435</td>
<td>C=N</td>
<td>615</td>
</tr>
<tr>
<td>P—O</td>
<td>419</td>
<td>C=C</td>
<td>611</td>
</tr>
<tr>
<td>C—H</td>
<td>414</td>
<td>P=O</td>
<td>502</td>
</tr>
<tr>
<td>N—H</td>
<td>389</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C—O</td>
<td>352</td>
<td>C≡C</td>
<td>816</td>
</tr>
<tr>
<td>C—C</td>
<td>348</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S—H</td>
<td>339</td>
<td>N≡N</td>
<td>930</td>
</tr>
<tr>
<td>C—N</td>
<td>293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C—S</td>
<td>260</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N—O</td>
<td>222</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S—S</td>
<td>214</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The greater the energy required for bond dissociation (breakage), the stronger the bond.*
Microbes co-inhabiting our bodies outnumber human cells by a factor of 10. They account for 90% of all protein-encoding cells. They protect us from pathogens, synthesize essential vitamins, enzymes for digestion and contribute to such human factors as obesity, food digestion and pill metabolism.

Imbalances of microbes can result in auto-immune diseases such as Crohn’s and skin disorders like eczema and psoriasis.
In the mouth, bacteria in saliva can be different from that on the teeth.

In fact, bacteria on one tooth may be different from the tooth next to it.
<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 nonhistone protein; genome in nucleoid, not</td>
<td>DNA complexed with histone and nonhistone proteins in chromosomes; chromosomes</td>
</tr>
<tr>
<td></td>
<td>surrounded by membrane</td>
<td>in nucleus with membranous envelope</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, chloroplasts (in plants, some algae), endoplasmic reticulum,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Golgi complexes, lysosomes (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>No mitochondria; oxidative enzymes bound to plasma</td>
<td>Oxidative enzymes packaged in mitochondria; more unified pattern of oxidative</td>
</tr>
<tr>
<td></td>
<td>membrane; great variation in metabolic pattern</td>
<td>metabolism</td>
</tr>
<tr>
<td>Cytoskeleton</td>
<td>None</td>
<td>Complex, with microtubules, intermediate filaments, actin filaments</td>
</tr>
<tr>
<td>Intracellular movement</td>
<td>None</td>
<td>Cytoplasmic streaming, endocytosis, phagocytosis, mitosis, vesicle transport</td>
</tr>
<tr>
<td>Organelle</td>
<td>Function</td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Mitochondrion</td>
<td>Citric acid cycle, oxidative phosphorylation, fatty acid oxidation, amino acid breakdown</td>
<td></td>
</tr>
<tr>
<td>Cytosol</td>
<td>Glycolysis, pentose phosphate pathway, fatty acid biosynthesis, many reactions of gluconeogenesis</td>
<td></td>
</tr>
<tr>
<td>Lysosomes</td>
<td>Enzymatic digestion of cell components and ingested matter</td>
<td></td>
</tr>
<tr>
<td>Nucleus</td>
<td>DNA replication and transcription, RNA processing</td>
<td></td>
</tr>
<tr>
<td>Golgi apparatus</td>
<td>Posttranslational processing of membrane and secretory proteins; formation of plasma membrane and secretory vesicles</td>
<td></td>
</tr>
<tr>
<td>Rough endoplasmic reticulum</td>
<td>Synthesis of membrane-bound and secretory proteins</td>
<td></td>
</tr>
<tr>
<td>Smooth endoplasmic reticulum</td>
<td>Lipid and steroid biosynthesis</td>
<td></td>
</tr>
<tr>
<td>Peroxisomes</td>
<td>Oxidative reactions catalyzed by amino acid oxidases and catalase; glyoxylate cycle reactions in plants</td>
<td></td>
</tr>
<tr>
<td>(glyoxysomes in plants)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percentage of total weight of cell</td>
<td>Approximate number of different molecular species</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Water</td>
<td>70</td>
<td>1</td>
</tr>
<tr>
<td>Proteins</td>
<td>15</td>
<td>3,000</td>
</tr>
<tr>
<td>Nucleic acids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DNA</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>RNA</td>
<td>6</td>
<td>&gt;3,000</td>
</tr>
<tr>
<td>Polysaccharides</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Lipids</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>Monomeric subunits and intermediates</td>
<td>2</td>
<td>500</td>
</tr>
<tr>
<td>Inorganic ions</td>
<td>1</td>
<td>20</td>
</tr>
</tbody>
</table>
All organisms

Phototrophs (energy from light)
  - Autotrophs (carbon from CO₂)
    - Examples:
      - Cyanobacteria
      - Plants
  - Heterotrophs (carbon from organic compounds)
    - Examples:
      - Purple bacteria
      - Green bacteria

Chemotrophs (energy from chemical compounds)
  - Heterotrophs (carbon from organic compounds)
    - Lithotrophs (energy from inorganic compounds)
      - Examples:
        - Sulfur bacteria
        - Hydrogen bacteria
    - Organotrophs (energy from organic compounds)
      - Examples:
        - Most prokaryotes
        - All nonphototrophic eukaryotes
(a) Animal cell

- Ribosomes are protein-synthesizing machines
- Peroxisomes destroy peroxides
- Cytoskeleton supports cell, aids in movement of organelles
- Lysosome degrades intracellular debris
- Transport vesicle shuttles lipids and proteins between ER, Golgi, and plasma membrane
- Golgi complex processes, packages, and targets proteins to other organelles or for export
- Smooth endoplasmic reticulum (SER) is site of lipid synthesis and drug metabolism
- Nucleolus is site of ribosomal RNA synthesis
- Rough endoplasmic reticulum (RER) is site of much protein synthesis
- Nucleus contains the genes (chromatin)
- Mitochondrion oxidizes fuels to produce ATP
- Nuclear envelope segregates chromatin (DNA + protein) from cytoplasm
- Plasma membrane separates cell from environment, regulates movement of materials into and out of cell
(b) Plant cell

Plasma membrane separates cell from environment, regulates movement of materials into and out of cell.

Rough endoplasmic reticulum (RER) is site of much protein synthesis.

Mitochondrion oxidizes fuels to produce ATP.

Nucleolus is site of ribosomal RNA synthesis.

Smooth endoplasmic reticulum (SER) is site of lipid synthesis and drug metabolism.

Nucleus contains the genes (chromatin).

Ribosomes

Cytoskeleton

Chloroplast harvests sunlight, produces ATP and carbohydrates.

Starch granule temporarily stores carbohydrate products of photosynthesis.

Thylakoids are site of light-driven ATP synthesis.

Cell wall provides shape and rigidity; protects cell from osmotic swelling.

Vacuole degrades and recycles macromolecules, stores metabolites.

Plasmodesma provides path between two plant cells.

Cell wall of adjacent cell

Glyoxysome contains enzymes of the glyoxylate cycle.
(a) Differential centrifugation

Tissue homogenate

Low-speed centrifugation (1,000 g, 10 min)

Supernatant subjected to medium-speed centrifugation (20,000 g, 20 min)

Supernatant subjected to high-speed centrifugation (80,000 g, 1 h)

Supernatant subjected to very high-speed centrifugation (150,000 g, 3 h)

Pellet contains whole cells, nuclei, cytoskeletons, plasma membranes

Pellet contains mitochondria, lysosomes, peroxisomes

Pellet contains microsomes (fragments of ER), small vesicles

Supernatant contains soluble proteins

Pellet contains ribosomes, large macromolecules
(b) Isopycnic (sucrose-density) centrifugation

Diagram showing the process:

1. **Centrifugation**
   - Sample
   - Sucrose gradient
   - Less dense component
   - More dense component

2. **Fractionation**
   - Tubes labeled 8 to 1
Level 4: The cell and its organelles

Level 3: Supramolecular complexes
- Chromosome
- Plasma membrane
- Cell wall

Level 2: Macromolecules
- DNA
- Protein
- Cellulose

Level 1: Monomeric units
- Nucleotides
- Amino acids
- Sugars
Six elements are the most essential for life: C, H, O, N, P, S. A microbe in California can substitute As for P as part of DNA.
Hg - Americans are walking around with more than 1,000 tons of mercury in their mouths.
Amalgam separators are available for between $750 and $3,000 which can trap about 95 – 99% of Hg in drain wash but most states do not require them.
Ultimate Disposal of Mercury in Teeth (what happens to fillings in cremated corpses?)

Crematoria in Europe must filter Hg released from dental amalgams; In the US the EPI does not regulate Hg emissions from smokestacks however about 6,600 #’s (3.3 tons) of Hg were released into the environment in 2005.

This problem may last until about 2055 when Hg fillings fall out of use.

Ref. Chem & Eng News  June 28, 2010   p 41
So if there may be a problem with amalgams, what other options are available?

Resin-based dental materials can be used but these commonly contain Bisphenol A (BPA) which can be intra-orally released from the biting surface of the teeth.

Children with higher cumulative exposure to BPA derivatives demonstrated impaired psychosocial behavior compared to children treated with amalgams. (Ref. Pediatrics 2011-3374)

Lesson: BE AWARE of RISK OF FILLING TYPE
BIOMOLECULES

KEY TERMS

Functional Groups: Groups of atoms added to carbon skeletons, which confer specific properties in the molecule.

Stereoisomers - order of bonding is the same but special relationship between atoms is different.

Geometric (cis-trans) - differ in arrangement of substituent groups around double bond.

Chiral Center - Asymmetric carbon atom - i.e. 4 different substituents.

Enantiomers - mirror images

Diastereomers - non-mirror images

Racemic mixtures - no optical rotation
Methyl

\[
\begin{array}{c}
\text{H} \\
\text{R} - \text{C} - \text{H} \\
\text{H} \\
\text{H}
\end{array}
\]

Ethyl

\[
\begin{array}{c}
\text{H} \\
\text{R} - \text{C} - \text{C} - \text{H} \\
\text{H} \\
\text{H} \\
\text{H}
\end{array}
\]

Phenyl

\[
\begin{array}{c}
\text{H} \\
\text{C} = \text{C} \\
\text{C} - \text{C} \\
\text{C} - \text{C} \\
\text{C} - \text{C} \\
\text{H} \\
\text{H} \\
\text{H}
\end{array}
\]
Sulfhydryl

\[ R\text{-}S\text{-}H \]

Disulfide

\[ R^1\text{-}S\text{-}S\text{-}R^2 \]

Thioester

\[ R^1\text{-}C\text{-}S\text{-}R^2 \]
Phosphoryl

\[ R-O-\text{PO}_2\text{OH} \]

Phosphoanhydride

\[ R^1-O-\text{PO}_2\text{O}-\text{PO}_2\text{O}-R^2 \]

Mixed anhydride (carboxylic acid and phosphoric acid; also called acyl phosphate)

\[ R-C-\text{O}-\text{PO}_2\text{OH} \]
Structural Isomers

\[ \text{CHO} \quad \text{CH}_2\text{OH} \]
\[ \text{H-C-OH} \quad \text{HO-C-H} \]
\[ \text{H-C-OH} \quad \text{H-C-OH} \]
\[ \text{HO-C-H} \quad \text{CH}_2\text{OH} \]
\[ \text{CH}_2\text{OH} \quad \text{CH}_2\text{OH} \]

\text{d-Glucose} \quad \text{d-Fructose}

Optical Isomers (enantiomers)

\[ \text{CHO} \quad \text{HO-C-H} \]
\[ \text{H-C-OH} \quad \text{CH}_2\text{OH} \]
\[ \text{CH}_2\text{OH} \quad \text{CH}_2\text{OH} \]

\text{d-Glyceraldehyde} \quad \text{l-Glyceraldehyde}
Maleic acid (cis)

Fumaric acid (trans)
11-cis-Retinal \[\xrightarrow{\text{light}}\] All-trans-Retinal
Chiral molecule: Rotated molecule *cannot* be superimposed on its mirror image.
Achiral molecule: Rotated molecule can be superimposed on its mirror image.

Mirror image of original molecule.
(2R,3R) - Tartaric acid (dextrorotatory)

(2S,3S) - Tartaric acid (levorotatory)
$\text{CHO}$

$\text{HO} \rightarrow \text{C} \rightarrow \text{H}$

$\text{CH}_2\text{OH}$

\text{L-Glyceraldehyde}$

$\equiv$

$\text{CHO}^{(2)}$

$\text{H}^{(4)}$

$\text{OH}^{(1)}$

$\text{CH}_2\text{OH}^{(3)}$

\text{(S)-Glyceraldehyde}$
(R)-Carvone (spearmint)

(S)-Carvone (caraway)
L-Aspartyl-L-phenylalanine methyl ester (aspartame) (sweet)

L-Aspartyl-D-phenylalanine methyl ester (bitter)
A diagram showing a device with the following components:

- **Electrodes**
- **Spark gap**
- **Condenser**

A mixture of \( \text{NH}_3, \text{CH}_4, \text{H}_2, \text{and} \text{H}_2\text{O} \) at 80°C is present in the setup.
<table>
<thead>
<tr>
<th>Carboxylic acids</th>
<th>Nucleic acid bases</th>
<th>Amino acids</th>
<th>Sugars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formic acid</td>
<td>Adenine</td>
<td>Glycine</td>
<td>Straight and branched pentoses</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>Guanine</td>
<td>Alanine</td>
<td>and hexoses</td>
</tr>
<tr>
<td>Propionic acid</td>
<td>Xanthine</td>
<td>α-Aminobutyric acid</td>
<td></td>
</tr>
<tr>
<td>Straight and branched fatty acids</td>
<td>Hypoxanthine</td>
<td>Valine</td>
<td></td>
</tr>
<tr>
<td>(C₄–C₁₀)</td>
<td>Cytosine</td>
<td>Leucine</td>
<td></td>
</tr>
<tr>
<td>Glycolic acid</td>
<td>Uracil</td>
<td>Isoleucine</td>
<td></td>
</tr>
<tr>
<td>Lactic acid</td>
<td></td>
<td>Proline</td>
<td></td>
</tr>
<tr>
<td>Succinic acid</td>
<td></td>
<td>Aspartic acid</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Glutamic acid</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Serine</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Threonine</td>
<td></td>
</tr>
</tbody>
</table>

Creation of prebiotic soup, including nucleotides, from components of Earth’s primitive atmosphere

Production of short RNA molecules with random sequences

Selective replication of self-duplicating catalytic RNA segments

Synthesis of specific peptides, catalyzed by RNA

Increasing role of peptides in RNA replication; coevolution of RNA and protein

Primitive translation system develops, with RNA genome and RNA-protein catalysts

Genomic RNA begins to be copied into DNA

DNA genome, translated on RNA-protein complex (ribosome) with protein catalysts
<table>
<thead>
<tr>
<th>Organism</th>
<th>Genome size (millions of nucleotide pairs)</th>
<th>Biological interest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mycoplasma pneumoniae</td>
<td>0.8</td>
<td>Causes pneumonia</td>
</tr>
<tr>
<td>Treponema pallidum</td>
<td>1.1</td>
<td>Causes syphilis</td>
</tr>
<tr>
<td>Borrelia burgdorferi</td>
<td>1.3</td>
<td>Causes Lyme disease</td>
</tr>
<tr>
<td>Helicobacter pylori</td>
<td>1.7</td>
<td>Causes gastric ulcers</td>
</tr>
<tr>
<td>Methanococcus jannaschii</td>
<td>1.7</td>
<td>Grows at 85 °C!</td>
</tr>
<tr>
<td>Haemophilus influenzae</td>
<td>1.8</td>
<td>Causes bacterial influenza</td>
</tr>
<tr>
<td>Methanobacterium thermo-autotrophicum</td>
<td>1.8</td>
<td>Member of the Archaea</td>
</tr>
<tr>
<td>Archaeoglobus fulgidus</td>
<td>2.2</td>
<td>High-temperature methanogen</td>
</tr>
<tr>
<td>Synechocystis sp.</td>
<td>3.6</td>
<td>Cyanobacterium</td>
</tr>
<tr>
<td>Bacillus subtilis</td>
<td>4.2</td>
<td>Common soil bacterium</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>4.6</td>
<td>Some strains cause toxic shock syndrome</td>
</tr>
<tr>
<td>Saccharomyces cerevisiae</td>
<td>12.1</td>
<td>Unicellular eukaryote</td>
</tr>
<tr>
<td>Plasmodium falciparum</td>
<td>23</td>
<td>Causes human malaria</td>
</tr>
<tr>
<td>Caenorhabditis elegans</td>
<td>97.1</td>
<td>Multicellular roundworm</td>
</tr>
<tr>
<td>Anopheles gambiae</td>
<td>278</td>
<td>Malaria vector</td>
</tr>
<tr>
<td>Mus musculus domesticus</td>
<td>$2.5 \times 10^3$</td>
<td>Laboratory mouse</td>
</tr>
<tr>
<td>Homo sapiens</td>
<td>$2.9 \times 10^3$</td>
<td>Human</td>
</tr>
</tbody>
</table>
Introduction to “-omics”

Def. The term –omics represents the rigorous study of various collections of molecules, biological processes or physiological and structures such as systems, represented most prominently by genomics.

The human genome encodes over 30,000 genes and generates more than 100,000 functionally distinct proteins. Most genes have small sequence differences (polymorphisms) that occur between individuals at about every 1,500 base pairs. SNPs make up about 90% of all human genetic variability.

Allele – any one of a number of alternate forms of the same gene
Genotype – the genetic material in the chromosome
Phenotype – properties of an organism that are produced by interaction with the environment
Dental care – related anxiety, fear of dental pain and avoidance of dental care may be influenced by genetic variations.

An example is naturally red haired persons who have a melanocortin-1 receptor gene variant which causes them to be resistant to subcutaneous local anesthetics (ie tooth-numbing drugs like novocaine).

Consequently, these persons experience troublesome episodes during dental procedures, develop a fear of dental care and avoid all future checkups.

(a possible solution is to use a relaxant such as valium during treatments)
Figure 4. Certain genetic polymorphisms can shift the balance of energy intake and energy expenditure and thereby influence bioenergetics and obesity. Higher energy intakes, a low polyunsaturated-to-saturated fat ratio, insulin resistance, and a sedentary lifestyle leading to obesity are risk factors for chronic diseases, such as heart disease, diabetes, and cancer, depicted when the scale is sloping downward. The right side of the scale portrays lifestyle including physical activity and a diet rich in whole grains, fruits, vegetables, and soy protein, which are associated with less risk for obesity and chronic disease. Gene-nutrient imbalances may explain the morbidity and mortality associated with obesity.
70-90% of risk for diseases is due to environmental exposures. The term **EXPOSOME** refers to the totality of environmental exposures from conception onward.
Unlock the secrets of your DNA today with 23andMe.

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Learn more: Overview Health & Traits Ancestry Sharing & Community 23andMe Research

New at 23andMe What People Are Saying What 23andMe Can Do For You
Genetic Tests Available

Abdominal aneurism
Alzheimer's disease
Arterial fibrillation
Brain aneurism
Breast cancer
Celiac disease
Crohn's disease
Deep vein thrombosis
Diabetes type 2
Glaucoma
Graves' disease
Heart attack
Hemochromatosis
Lactose intolerance
Lung cancer
Lupus
Macular degeneration
Melanoma
Multiple sclerosis
Obesity
Osteoarthritis
Prostate cancer
Psoriasis
Restless leg syndrome
Rheumatoid arthritis
Sarcoidosis
Stomach cancer (diffuse)

Cost $500 (2009)
Practice Exercises

CHAPTER 1
A 1% solution of NaF equals how many ppm’s?

a. 1
b. 10
c. 100
d. 1000
e. 10,000

1% = 1g/100 ml = 10g/L x 1000mg/g = 10,000mg/L
1 ppm = 1 mg/L so ans is 10,000 ppm (e)
1. A Eukaryotic cell is homogenized and centrifuged at 150,000 xg for 1 hour. The pellet will contain all of the following EXCEPT which one?

a. Organelles
b. Ribosomes
c. Enzymes
d. Mitochondria
e. Endoplasmic reticulum
2. The basic difference between prokaryotes and eukaryotes is:

- Presence of a nuclear envelope.
- Bacteria have a nucleid which has no membrane.
- Eukaryotes have a nucleus which has a double membrane.
3. Small cells have a (large, small) surface/volume ratio so $O_2$ diffusion is (easy, difficult).

- Small cells have a large surface/volume ratio so $O_2$ diffusion is easy.

- Large cells have a small surface/volume ratio so $O_2$ diffusion is difficult.
Anabolic activity takes place in which of the following? (hint check ALL that are correct)

A. Cytosol
B. Lysosomes
C. Mitochondria
D. RER
E. SER
4. An example of a level 3 supramolecular complex is:

a. DNA 
b. Cellulose 
c. **Plasma membrane** 
d. The cell 
e. Nucleotide
5. The plasma membrane is a barrier to free passage of:

a. $\text{Na}^+$
b. $\text{K}^+$
c. Polar molecules
d. Charged molecules
e. All of these
6. Both plant and animal cells contain:

   a. Thylakoid membrane
   b. Central vacuole
   c. Glyoxysomes
   d. Chloroplasts
   e. Rough endoplasmic reticulum
7. An element essential for life with the highest molecular weight is:

a. Chromium
b. Copper
c. **Iodine**
d. Iron
e. Selenium
8. Which of the following is characterized as an **essential trace** element?

   a. Aluminum
   b. Chlorine
   c. Hydrogen
   d. **Magnesium**
   e. Sodium
9. For a chiral carbon atom which substrate has (a) the highest, (b) the lowest priority?

a. -NH
b. -CHO
c. CH₂OH
d. -OH (highest)
e. -CH₃ (lowest)
10. The primitive atmosphere of earth contained all the following gases, EXCEPT which one?

a. H\textsubscript{2}O

b. O\textsubscript{2}

c. NH\textsubscript{3}

d. CH\textsubscript{4}

e. H\textsubscript{2}
11. Genome sequences have been obtained for all the following species, EXCEPT which one?

a. Fruit fly
b. Roundworm
c. Rice
d. Mouse
e. All of these have been sequenced