Chemical Level of Organization

Matter and Energy
- Matter occupies space and has mass
- Energy is capacity to move mass
  - Potential vs. kinetic
  - Energy forms
    - radiant-moving waves
    - electrical-moving charged particles
    - heat-movement of atoms or molecules
    - chemical-bonding of atoms
    - mechanical-state of mass

Chemical Elements
- Elements are units of matter
- Body is 96% O, C, H & N
- Another 2.5% Ca & P
- Another 1.4% K, S, Na, Cl, Mg, I & Fe
- Another 0.1% trace elements

Atoms
- Units of matter (10⁻⁸ cm in diameter)
- Made up of protons (+), neutrons & electrons (-)
- Atomic number=# of protons
- Mass number=# of protons + neutrons
- Isotopes-same element with different # of neutrons (e.g. ¹²C & ¹⁴C)
  - Half-life
- Atomic weight=avg. mass # for all isotopes x a specific # of atoms (mole)

More than Atoms
- Formation of molecules or compounds
- Electron interactions with other electrons and protons are basis for chemical reactions
- Molecules held together by altered positions of electrons (bonds)
- Concept of electron shells and valence shell stability (2, 8 & 8)
- Structure of periodic table
- Electron donors vs. acceptors

Types of Chemical Bonds
- Ionic bonds-electron(s) transferred
  - Cations vs. anions
- Covalent bonds-sharing of electrons
  - Sharing more than one e⁻ - double or triple bonds
  - non-polar vs. polar bonds
• Hydrogen bonds-weak attractions usually with O or N
  – Power in numbers

**Chemical Reactions**
• Breaking or forming chemical bonds
• Reactions in body - metabolism
• Rate dependent on concentration, temperature, size, orientation
• Conservation of mass and energy
• Energy required or released
  – Endergonic vs. exergonic
• Anabolism vs. catabolism
• Oxidation-reduction reactions

**Inorganic Compounds**
• Many compounds dissociate
• Acids dissociate forming H⁺ ions
  – HCl → H⁺ + Cl⁻
• Bases dissociate forming OH⁻ ions
  – NaOH → Na⁺ + OH⁻
• Salts dissociate forming anions and cations

**Water, A Unique Inorganic**
• Largest chemical component of the body
• Important in many chemical reactions
  – Hydrolysis vs. dehydration
• High heat capacity
• High heat of vaporization
• Good lubricant
• Excellent solvent because of polar characteristics

**Acid/Base Balance**
• Biochemical reactions sensitive to pH
• Acidity vs. alkalinity
• pH is a measure of [H⁺]
  – pH=-log₁₀ [H⁺]
• Water (H₂O) dissociates to H⁺ & OH⁻
  – At STP, [H⁺]=0.0000001 moles/liter
  – Equals pH of 7
• Acid: pH<7 Base: pH>7

**Buffering Systems**
• Minimize changes in pH
  – Consist of a weak acid and weak base to bind excess OH⁻ and H⁺
Example: carbonic acid/bicarbonate buffering system
- \( H_2O + CO_2 \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^- \)

**Organic Compounds**
- Carbon
  - Form up to four covalent bonds with other atoms
  - Frequently composed of repeating subunits called monomers - polymers
  - Polymers created by dehydration reaction
  - Polymers broken down by hydrolysis
- Compounds include carbohydrates, lipids, proteins, nucleic acids & ATP

**Carbohydrates**
- Sugars, starches, glycogen and cellulose
- Structural importance for DNA & RNA
  - Deoxyribose and ribose
- Source of energy from simple sugars - mono and disaccharides
  - Mono - glucose, fructose, galactose
  - Di - sucrose (glucose + fructose), lactose (glucose + galactose)

**More Carbohydrates**
- Energy storage in the form of glycogen (in muscles and liver) - polysaccharides
- Smaller carbos are water soluble because of polar covalent bond between C & H and O

**Lipids**
- Triglycerides, phospholipids, steroids, vitamins A, D, E and K, fatty acids, lipoproteins, and eicosanoids
- Have few polar covalent bonds (less oxygen) and are thus hydrophobic

**Triglycerides**
- Most plentiful of lipids in body
- Provide protection, insulation and energy storage (2x more energy than carbos or proteins)
- Composed of glycerol and three fatty acids
- Can be converted from excess sugars and proteins in diet
- Saturated vs. unsaturated

**Phospholipids**
- Important structural component of cell membranes
- Similar to triglycerides with one fatty acid replaced with phosphate molecule
- Phosphate portion is polar, making molecule amphipathic
- Formation of phospholipid bilayer

**Other lipids**
- Steroids:
  - Sex hormones, vitamin D, cortisol, bile salts, and cholesterol
– Common structure are four carbon rings

**Eicosanoids:**
– Include prostaglandins which influence various physiological responses (e.g. hormone action, inflammatory response, regulation of body temp.) and leukotrienes which also influence inflammatory and allergic responses
– Derived from 20-carbon fatty acid

**Proteins - Importance**
• Connective tissue structures (e.g. collagen in bones and tendons)
• Regulate processes (e.g. hormone insulin)
• Immune response (e.g. antibodies)
• Contractile action of muscles
• Transport substances across membranes
• Enzymes

**Proteins - Structure**
• Sequential chain of amino acids
• Amino acids contain amino group, carboxylic acid group, and R-group
• R-group differentiates the 20 amino acids
• Amino acids bound by peptide bonds creating peptides (up to 10 AA) or polypeptides

**Proteins - More Structure**
• Primary structure: order of amino acids
• Secondary structure: alpha helix or pleated sheet created by H-bonds
• Tertiary structure: folded 3-D shape due to H, ionic, & covalent bonds, polar and non-polar attractions
• Quaternary structure: attractions between separate protein molecules

**Proteins - Activity**
• Activity affected by 3-D shape of protein
• Shape altered by temperature, pH, and electrolyte concentration
• Inactive protein called denatured

**Proteins - Enzymes**
• Control chemical reactions by
  – Increasing frequency of collisions
  – Lowering energy of activation
  – Proper orientation of colliding molecules
• Substrate specific - concept of active site
• Enzymes controlled by cells including number, activity, and presence of cofactors
• Usually end in -ase

**Nucleic Acids**
• Deoxyribonucleic acid (DNA): genetic code for production of enzymes
• Ribonucleic acid (RNA): relay genetic instructions to protein manufacturing process
• Composed of linked nucleotides (pentose sugar, phosphate group and nitrogenous base)

**DNA**
• Deoxyribose sugar
• Four nitrogenous bases including adenine & guanine (purines) and thymine & cytosine (pyrimidines)
• Made up of two strands forming double helix
• Opposing strands “complement” the other…purine for pyrimidine (A/T and C/G)

**RNA**
• Differences from DNA
  – Single stranded
  – Ribose sugar
  – Uracil replaces thymine
• Three types
  – Messenger RNA
  – Ribosomal RNA
  – Transfer RNA

**Adenosine Triphosphate**
• Or ATP
• Energy currency within cells
• Three phosphate groups linked to adenosine (5-carbon ribose plus adenine)
• ADP + phosphate group + energy $\leftrightarrow$ ATP