Biochemistry and Biomolecules

Today

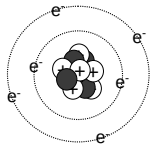
- A little chemistry refresher
- Classes of Biomolecules
- Integrated into Physiology

Chemistry Refresher

- Chemistry:
  - the science concerned with the composition, behavior, structure, and properties of matter, as well as the changes it undergoes during chemical reactions
- Biochemistry:
  - how chemistry works in biological models
    - i.e. protein assemblages

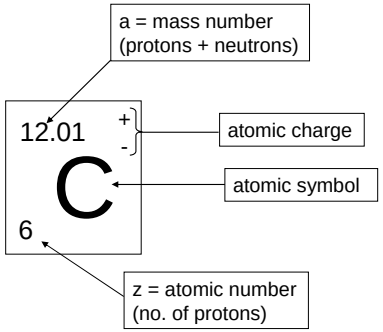
Chemistry Refresher

- Composition of Matter = Atom
  - the configuration of the atom will determine the properties of matter
  - atoms are composed of
    - positively charged core (nucleus) composed of
      - protons (charged)
      - neutrons (neutral)
    - negatively charged electrons
      - number of which is determined by the nuclear charge
      - arranged in electron shells
      - determines “activeness” or reactivity of the atom



Chemistry Refresher

- atomic notation

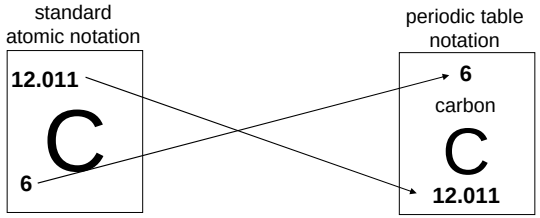


Chemistry Refresher

- Atomic number
  - The number of protons = the number of electrons
  - Number of electrons in the outer shell determines stability and atoms ability to
    - gain additional electrons
    - lose electrons
  - This gain/loss of electrons is accomplished by donating, accepting or sharing electrons

Chemistry Refresher

- Periodic Table
  - contains a listing of all of the elements
    - notation is slightly different from the standard atomic notation

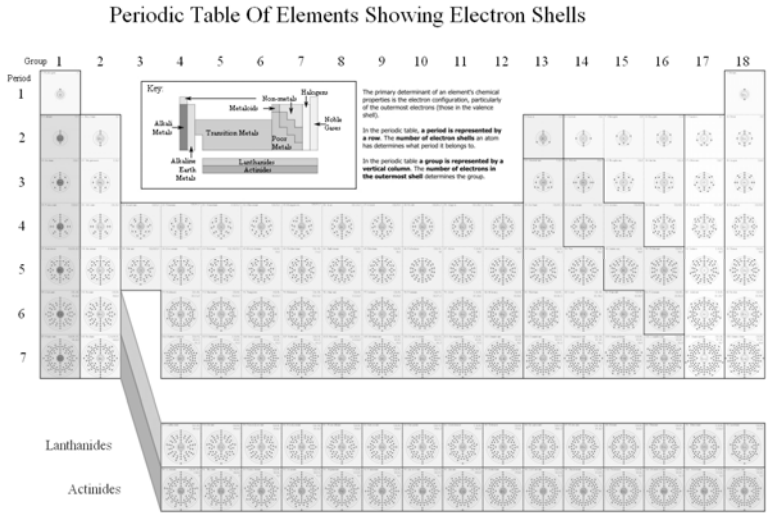


Chemistry Refresher

- Periodic Table Period & Group Trends
  - Periods (horizontal)
    - Number indicates the number of electron shells
      - Period 1 = one electron shell (H & He only)
    - Left to right
      - atomic radius decreases
      - atomic ionization energy increases (becomes more difficult to remove an electron)
      - Electron affinity increases (with the exception of the noble gases on the far right)
  - Groups (vertical)
    - From top to bottom
      - the atomic radius increases
      - The atomic ionization energy decreases (electrons that are farther away from the nucleus are less tightly held)
      - Electronegativity decreases from top to bottom

Chemistry Refresher

- Periodic Table Periods & Groups
  - Groups (vertical)
    - Determined by the number of valence shell electrons
      - Valence shell is just the outermost electron shell
    - From top to bottom
      - the atomic radius increases
      - The atomic ionization energy decreases (electrons that are farther away from the nucleus are less tightly held)
      - Electronegativity decreases from top to bottom



Chemistry Refresher

- So… valence shell electrons are critical!
- Stability is desired and achieved by
  - Donating & Accepting electrons
    - forms ionic bonds
  - Sharing electrons
    - forms covalent bonds
  - Electrostatic forces
    - weaker hydrogen bonds and van der waals interactions

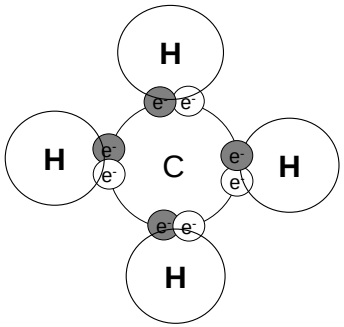
Chemistry Refresher

- Ionic Bonding
  - One atom donates electrons and the other receives them forming charged ions
  - Charged ions are electrostatically attracted to each other and so form a bond.
  - Example: NaCl
    - Sodium has 1 electron in its outer shell
    - Chlorine has 7 electrons in its outer shell
    - Upon contact, sodium gives up its one electron and
      - Na becomes a positively charged ion
      - Cl becomes a negatively charged ion
      - and….

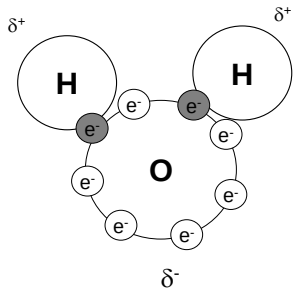
Chemistry Refresher

- Covalent Bonding
  - Electrons are shared
    - For each pair that is shared a single bond is formed
    - For each two pair that are shared a double bond is formed
    - For each three pair that are shared a triple bond is formed
  - Covalent bonds can form
    - Non-polar bonds (when electrons are shared equally)
      - Ex. Methane (CH_4)
    - Polar bonds (when electrons are shared unequally)
      - Ex. Water (H_2O)
    - Extensive bonding can result in larger molecules that have both polar and non-polar regions = amphipathic molecules
      - Ex. Phospholipids

Chemistry Refresher

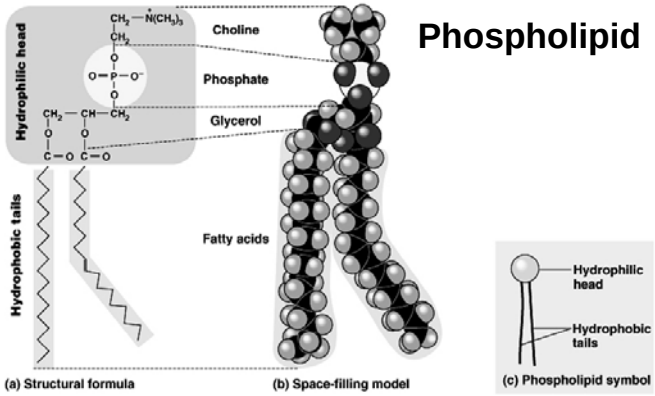


Non-Polar Molecule (Methane – CH_4)



Polar Molecule (Water – H_2O)

Chemistry Refresher



Phospholipid

Amphipathic Molecule

Chemistry Refresher

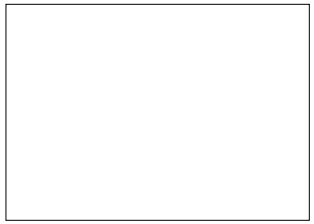
- Other important interactions
  - Hydrogen bond
    - A covalently bound hydrogen interacts with a nearby electronegative atom of O,N or Fl
    - Weaker than covalent bonds
    - Why is it important?
      - Aids in protein configuration (secondary, tertiary & quaternary)
      - Creates surface tension of water
  - Van der Waals interaction
    - Weak attractive or repulsive electrostatic forces between molecules or parts of molecules
    - Weaker than hydrogen bonds but still responsible for aiding in protein configuration

Biomolecules

- Any organic molecule that is produced, used or functioning in a biological organism
- Have in common
  - All have at least: carbon, hydrogen, oxygen
  - Also commonly found are nitrogen, phosphorous
- What don't they have in common?
  - Shape!
  - Why?
    - Different order, amount, bonding…
- Classes of Biomolecules
  - Nucleosides (nucleotides)
  - Saccharides (carbohydrates)
  - Amino Acids (proteins)
  - Lipids

Biomolecules

- Carbohydrates
  - General formula = $(CH_2O)_n$
  - Simple surgars
    - monomer units = monosaccharides (n = 6)
      - fructose
      - glucose
      - Galactose
    - Dimer units = disaccharides (n=12)
      - Sucrose
      - Maltose
      - Lactose
    - Multiple units = polysaccharides
      - Glycogen – we produce
      - Starch – we consume and use
      - Cellulose – we consume & …

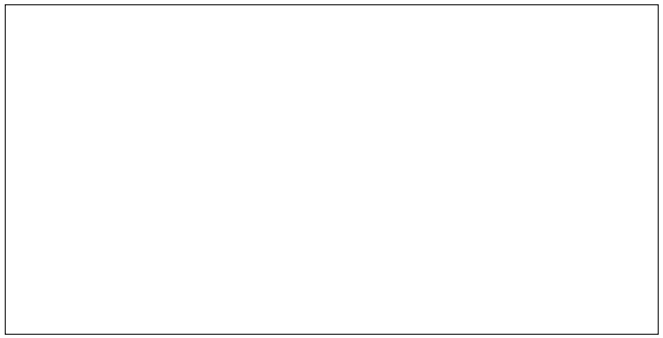


Biomolecules

- How does a monomer become a dimer or polymer?
  - Dehydration synthesis (condensation reaction)

Biomolecules

- How does a polymer get broken down?
  - Through hydrolysis reactions

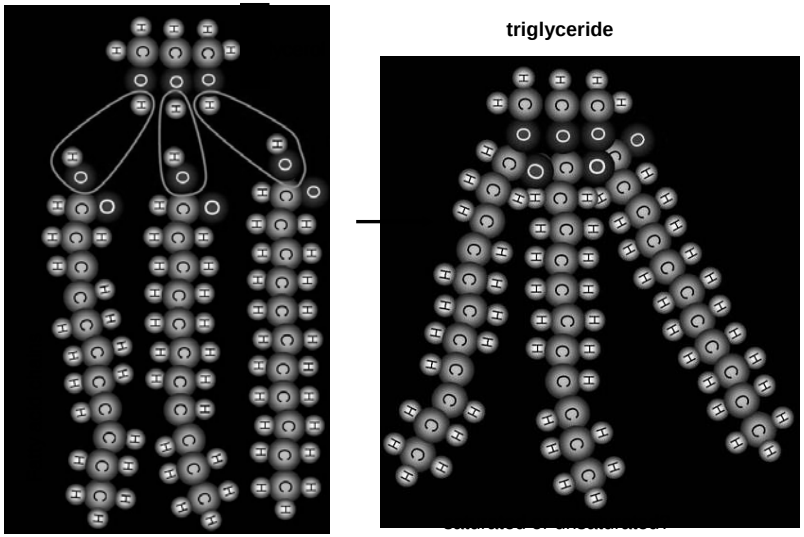


Biomolecules

- The functional importance of carbohydrates
  - Good for storage of energy (glycogen)
  - Used in production of ATP
  - Provides dietary fiber (cellulose)
  - Used in conjunction with lipids and proteins in membrane physiology
  - Ribose forms (along with phosphate) the backbone of DNA

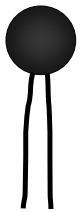
Biomolecules

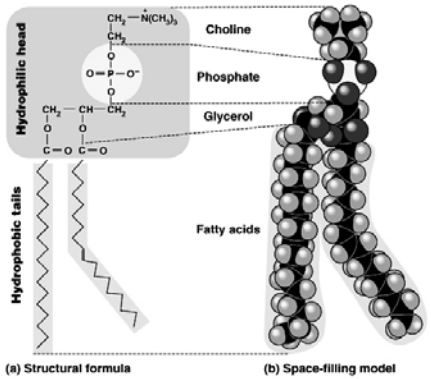
- Lipids (fats)
  - Consist of
    - glycerol backbone (3 carbons)
    - Hydrocarbon tails
      - Number of tails
        - » 1 = monoglycerides
        - » 2 = diglycerides
        - » 3 = triglycerides (90% of lipids in this form in us)
      - Determine nature of lipid by the bonding present
        - » No double bonds = saturated
        - » Double bonds = unsaturated (mono or poly)
      - Significance?



Biomolecules

- Phospholipids – major lipid-related molecule
  - Major component of cell membrane
  - One fatty acid is replaced by a polar phosphate group which creates
    - a hydrophillic "head" region
    - a hydrophobic "tail" region





Biomolecules

- Other Lipid-Related Molecules
  - Eicosanoids
    - Four important families of compounds derived from eicosanoids:
      - Prostaglandins – wide range of functions (cell growth to pain)
      - Prostacyclins – antagonistic to thromboxane, vasodilator
      - Leukotrienes – sustain inflammatory reactions in allergies & asthma
      - Thromboxanes – involved in platelet plug formation
    - Derived from omega-3 and omega-6 essential fatty acids
    - Levels determine health in these main areas
      - Cardiovascular
      - Arthritis
      - Triglyceride levels
      - Blood pressure

Biomolecules

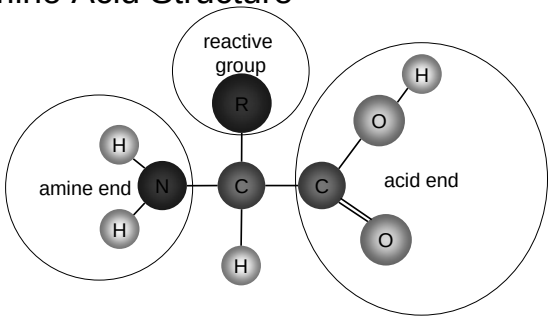
- Other Lipid-Related Molecules
  - Steroids
    - Created from cholesterol in human physiology
    - Four linked carbon rings with a carbon tail
    - Wide range of function from cell membranes to human growth

Biomolecules

- Proteins
  - Proteins are polymers of amino acids
  - Extremely versatile due to the different R (reactive) groups that allow for
    - 20 different amino acids
      - 11 are “non-essential”
      - 9 are “essential”
    - Unlimited arrangement of amino acids
    - Unlimited shapes due to molecular forces between molecules and steric strain (Van der Waals repulsion) due to the structural makeup of the R groups as well as di-sulfide bonds and hydrogen bonds

Biomolecules

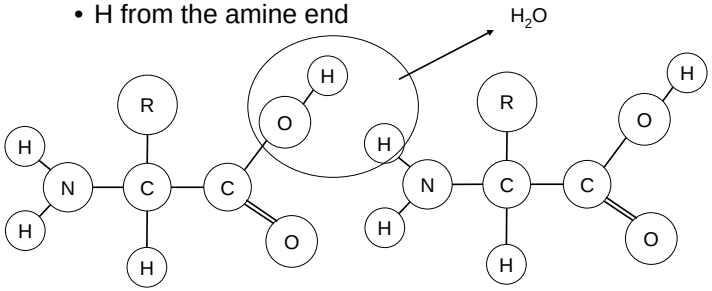
- Amino Acid Structure



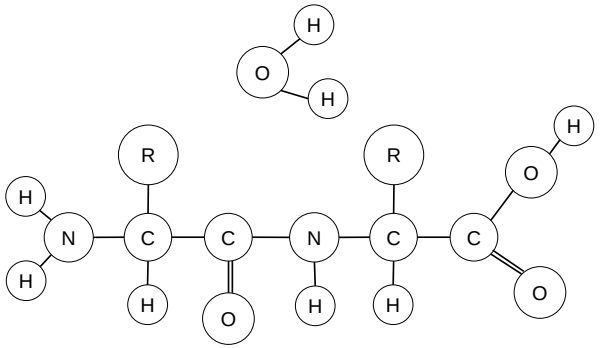
How is a protein made from an amino acid?

Biomolecules

- Protein Production
  - Amino acids joined together by dehydration synthesis, forming a peptide bond
    - OH from the acid end
    - H from the amine end

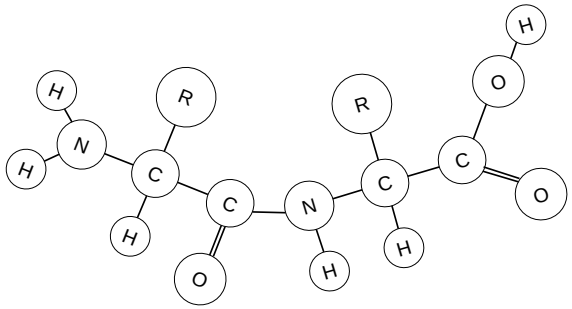


Dipeptide + Water



Bending of Amino Acids

- Depending on the R groups, the amino acids may bend toward or away from each other

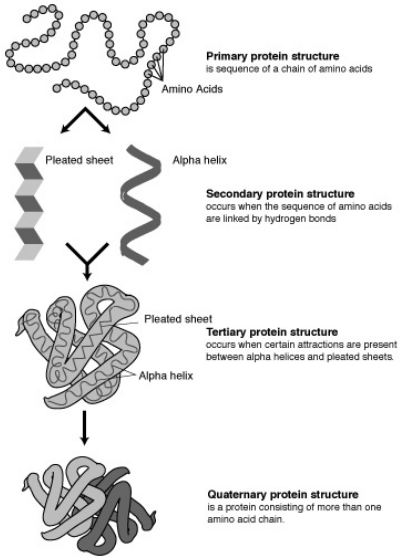


Biomolecules

- Protein Production Sequence
  - Initial chain of amino acids from translation is the primary protein
  - Folding or bending into sheets, or helices forms secondary proteins
  - Configuring into a globular three dimensional shape is a tertiary protein
  - More than one tertiary protein combining forms a quaternary protein

Biomolecules

- Sequence of protein formation



Biomolecules

- Proteins – why do we care?
  - Found in all cells
    - Acting as transporters, movers, enzymes, regulators
      - Within and on the cell
    - Establishes membrane potential
    - Provides cytoskeletal materials
    - Some gets exported from the cell to support extracellular matrix
  - Functions in cell to cell adhesion/communication
  - Mediate extracellular reactions
  - Act as signal molecules and hormones/neurotransmitters
  - Provide movement and structure
  - Provide raw material for new protein production
  - Defense in immunoglobulin production

Biomolecules

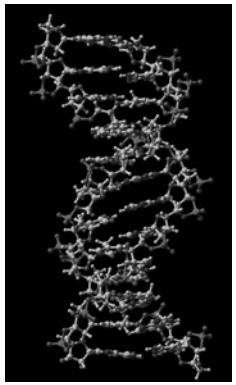
- Proteins can form bonds with other biomolecules
  - Lipoproteins
  - glycoproteins

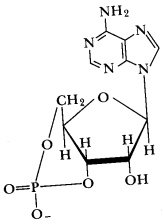
Biomolecules

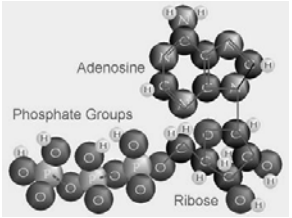
- Nucleotides
  - Composed of
    - Phosphate group (s)
    - 5 carbon sugars
      - May be ribose or deoxyribose
    - Nitrogenous base
      - One of two types of carbon-nitrogen ring structure
        1. Purines – double ring (guanine & adenine)
        2. Pyrimidines – single ring (cytosine, thymine & uracil)

Biomolecules

- Nucleotides form
  - – Informational structures
    - DNA and RNA
  - – Energy Structures
    - ATP, ADP, FAD, NAD, GTP, GDP
  - – Messengers
    - Cyclic AMP
    - Cyclic GMP







Biochemistry

- Biomolecule reactions
  - – We already know bonding, dehydration and hydrolysis reactions
- Need to know:
  - – Reaction directions, rates & enzyme function
  - – Solutions
  - – pH & buffers

Lab Next Week!

Integrated Physiology

- Biomolecules give us an understanding of why particular structures are capable of doing what they do!
- They play a role in every aspect of physiology.