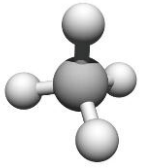
Chemistry of Life



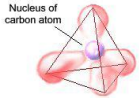
Building Blocks

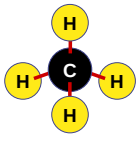
Why study Carbon?

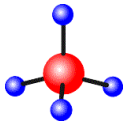
- All of life is built on carbon
- Cells
  - ~72% H_2O
  - ~25% carbon compounds
    - carbohydrates
    - lipids
    - proteins
    - nucleic acids
  - ~3% salts
    - Na, Cl, K…

Chemistry of Life

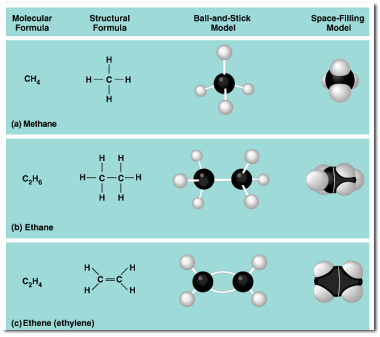
- Organic chemistry is the study of carbon compounds
- C atoms are versatile building blocks
  - bonding properties
  - 4 stable covalent bonds





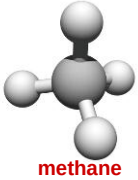


Complex molecules assembled like TinkerToys



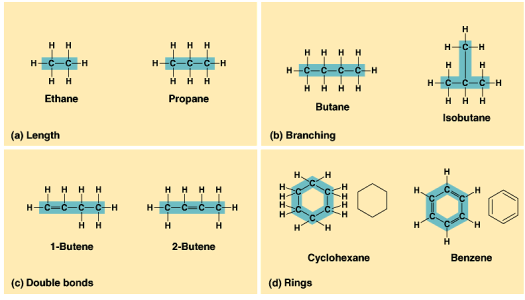
Hydrocarbons

- Combinations of C & H
  - non-polar
    - not soluble in H_2O
    - hydrophobic
  - stable
  - very little attraction between molecules
    - a gas at room temperature



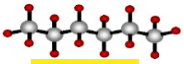
methane
(simplest HC)

Hydrocarbons can grow

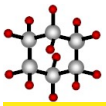


Isomers

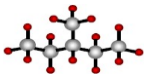
- Molecules with same molecular formula but different structures (shapes)
  - different chemical properties
  - different biological functions



6 carbons



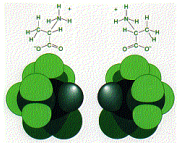
6 carbons

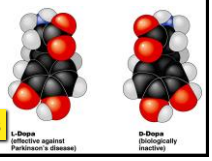


6 carbons

Form affects function

- Structural differences create important functional significance
  - amino acid alanine
    - L-alanine used in proteins
    - but not D-alanine
  - medicines
    - L-version active
    - but not D-version
  - sometimes with tragic results…





L-Dopa (effective against Parkinson's disease)

D-Dopa (biologically inactive)

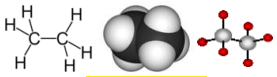
stereoisomers

Form affects function

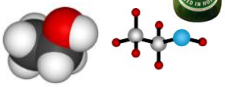
- Thalidomide
  - prescribed to pregnant women in 50s & 60s
  - reduced morning sickness, but…
  - stereoisomer caused severe birth defects

Diversity of molecules

- Substitute other atoms or groups around the carbon
  - ethane vs. ethanol
    - H replaced by a hydroxyl group (–OH)
    - nonpolar vs. polar
    - gas vs. liquid
    - biological effects!



ethane (C_2H_6)



ethanol (C_2H_5OH)

Functional groups

- Parts of organic molecules that are involved in chemical reactions
  - give organic molecules distinctive properties
    - hydroxyl
    - carbonyl
    - phosphate
    - amino
    - carboxyl
- Affect reactivity
  - makes hydrocarbons hydrophilic
  - increase solubility in water

Viva la difference!

- Basic structure of male & female hormones is identical
  - identical carbon skeleton
  - attachment of different functional groups
  - interact with different targets in the body
    - different effects

Female lion

Male lion

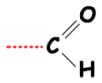
Hydroxyl

- –OH
  - organic compounds with OH = alcohols
  - names typically end in *-ol*
    - ethanol

Table 4.1 Functional Groups of Organic Compounds

Functional Group	Formula	Name of Compounds	Example
Hydroxyl	—OH	Alcohols	Ethanol (the drug of alcoholic beverages)

Carbonyl

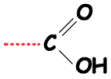


- C=O
  - O double bonded to C
    - if C=O at end molecule = aldehyde
    - if C=O in middle of molecule = ketone

Table 4.1 Functional Groups of Organic Compounds

Functional Group	Formula	Name of Compounds	Example
Carbonyl		Aldehydes	Propanal
		Ketones	Acetone

Carboxyl

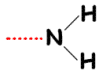


- –COOH
  - C double bonded to O & single bonded to OH group
    - compounds with COOH = acids
      - fatty acids
      - amino acids

Table 4.1 Functional Groups of Organic Compounds

Functional Group	Formula	Name of Compounds	Example
Carboxyl	(non-ionized) (ionized)	Carboxylic acids	Acetic acid* (the acid of vinegar)

Amino

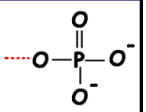


- -NH_2
  - N attached to 2 H
    - compounds with NH_2 = amines
      - amino acids
    - NH_2 acts as base
      - ammonia picks up H^+ from solution

Table 4.1 Functional Groups of Organic Compounds

Functional Group	Formula	Name of Compounds	Example
Amino	(non-ionized) (ionized)	Amines	Glycine*

Phosphate



- $–PO_4$
  - P bound to 4 O
    - connects to C through an O
    - lots of O = lots of negative charge
      - highly reactive
    - transfers energy between organic molecules
      - ATP, GTP, etc.

Table 4.1 Functional Groups of Organic Compounds

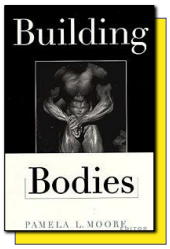
Functional Group	Formula	Name of Compounds	Example
Phosphate		Organic phosphates	Glycerol phosphate

Macromolecules

Building Blocks of Life

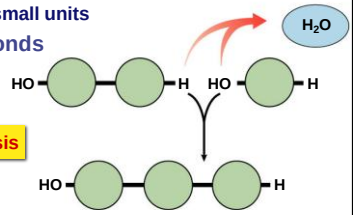
Macromolecules

- Smaller organic molecules join together to form larger molecules
  - macromolecules
- 4 major classes of macromolecules:
  - carbohydrates
  - lipids
  - proteins
  - nucleic acids



Polymers

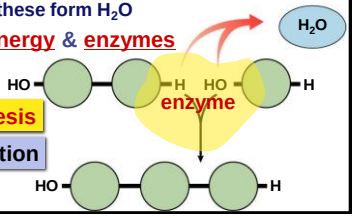
- Long molecules built by linking repeating building blocks in a chain
  - monomers
    - building blocks
    - repeated small units
  - covalent bonds



Dehydration synthesis

How to build a polymer

- Synthesis
  - joins monomers by "taking" H_2O out
    - one monomer donates OH^-
    - other monomer donates H^+
    - together these form H_2O
  - requires energy & enzymes

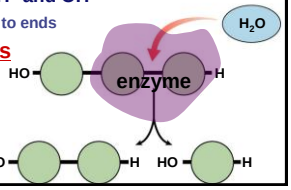


Dehydration synthesis

Condensation reaction

How to break down a polymer

- Digestion
  - use H_2O to breakdown polymers
    - reverse of dehydration synthesis
    - cleave off one monomer at a time
    - H_2O is split into H^+ and OH^-
      - H^+ & OH^- attach to ends
  - requires enzymes
  - releases energy



Hydrolysis

Digestion

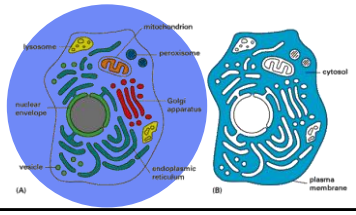
Chemistry of Life

Properties of Water

More about Water

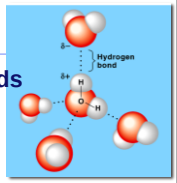
Why are we studying water?

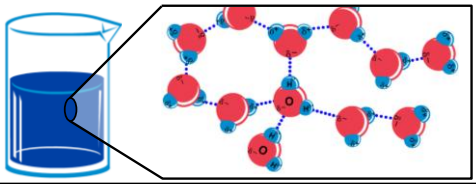
All life occurs in water
- inside & outside the cell



Chemistry of water

- H_2O molecules form H-bonds with each other
  - +H attracted to –O
  - creates a sticky molecule



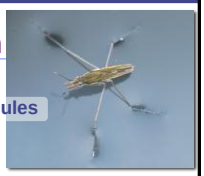


Elixir of Life

- Special properties of water
  1. cohesion & adhesion
     - surface tension, capillary action
  2. good solvent
     - many molecules dissolve in H_2O
     - hydrophilic vs. hydrophobic
  3. lower density as a solid
     - ice floats!
  4. high specific heat
     - water stores heat
  5. high heat of vaporization
     - heats & cools slowly

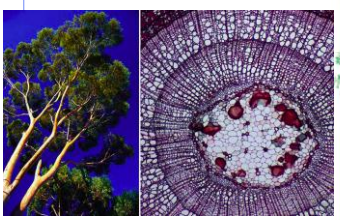
1. Cohesion & Adhesion

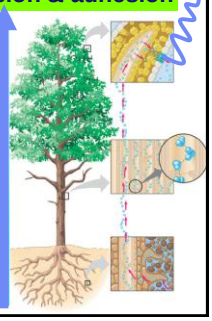
- Cohesion
  - H bonding between H_2O molecules
  - water is "sticky"
    - surface tension
    - drinking straw
- Adhesion
  - H bonding between H_2O & other substances
    - capillary action
    - meniscus
    - water climbs up paper towel or cloth



How does H_2O get to top of trees?

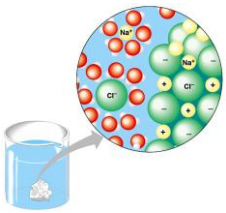
Transpiration is built on cohesion & adhesion

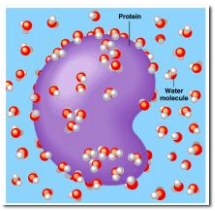




2. Water is the solvent of life

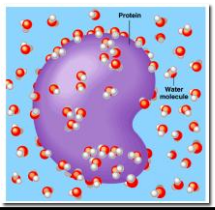
- Polarity makes H_2O a good solvent
  - polar H_2O molecules surround + & – ions
  - solvents dissolve solutes creating solutions

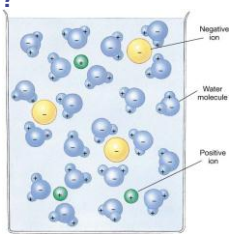




What dissolves in water?

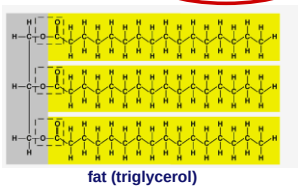
- Hydrophilic
  - substances have attraction to H_2O
  - polar or non-polar?





What doesn't dissolve in water?

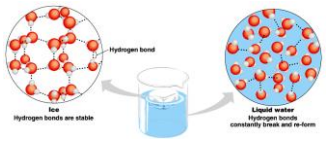
- Hydrophobic
  - substances that don't have an attraction to H_2O
  - polar or non-polar?



fat (triglycerol)

3. The special case of ice

- Most (all?) substances are more dense when they are solid, but not water…
- Ice floats!
  - H bonds form a crystal

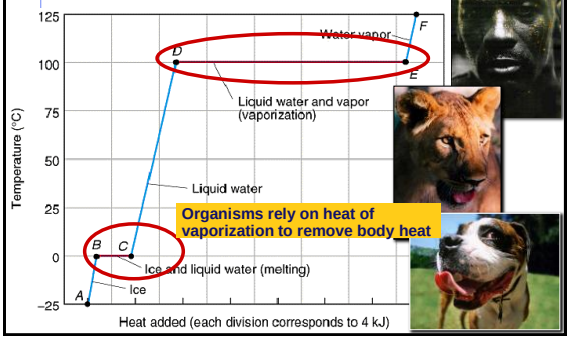


4. Specific heat

- H_2O resists changes in temperature
  - high specific heat
  - takes a lot to heat it up
  - takes a lot to cool it down
- H_2O moderates temperatures on Earth

5. Heat of vaporization

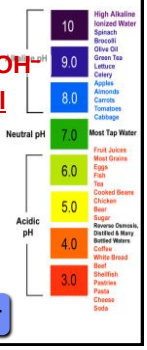
Evaporative cooling



Ionization of water & pH

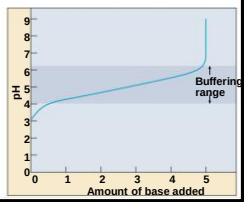
- Water ionizes
  - H^+ splits off from H_2O, leaving OH^-
    - if $[H^+] = [^-OH]$, water is neutral
    - if $[H^+] > [^-OH]$, water is acidic
    - if $[H^+] < [^-OH]$, water is basic
- pH scale
  - how acid or basic solution is
  - 1 → 7 → 14

$H_2O \rightarrow H^+ + OH^-$



Buffers & cellular regulation

- pH of cells must be kept ~7
  - pH affects shape of molecules
  - shape of molecules affect function
  - therefore pH affects cellular function
- Control pH by buffers
  - reservoir of H^+
    - donate H+ when $[H^+]$ falls
    - absorb H+ when $[H^+]$ rises




Any
Questions?