

Biochemistry

- The study of the chemistry of biological systems
- The study of the molecular basis of life

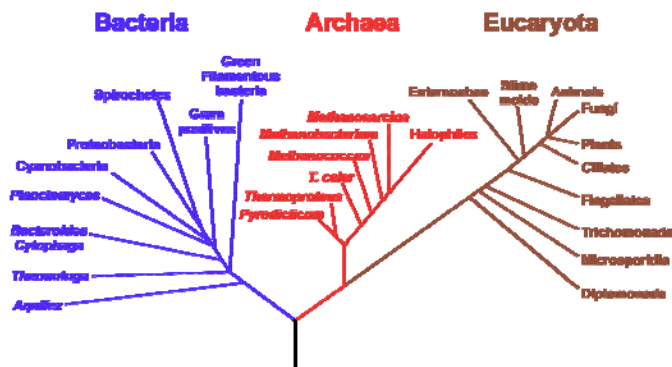
Why study biochemistry?

The chemical mechanisms of many central processes of life are now understood

- DNA (genes & now genomes)
- Flow of genetic information
- 3-D structures, mechanisms of proteins
- Central metabolic pathways
- Molecular machines-harvest energy, detect signals, process information

Common molecular patterns and principles underlie the diverse expressions of life

Phylogenetic Tree of Life



Credit: Eric Gaba, http://commons.wikimedia.org/wiki/Image:Phylogenetic_tree.svg

Biochemistry's impact on human health

- Molecular basis of genetic diseases
- Clinical diagnostics
- DNA probes
- Genetically engineered bacteria
- Rational design of new drugs
- agriculture

Biochemical concepts and techniques allow researchers to address problems in biology

- Fertilized egg → complex organism
- Molecular mechanism of memory
- Mental disorders
- Cell growth control

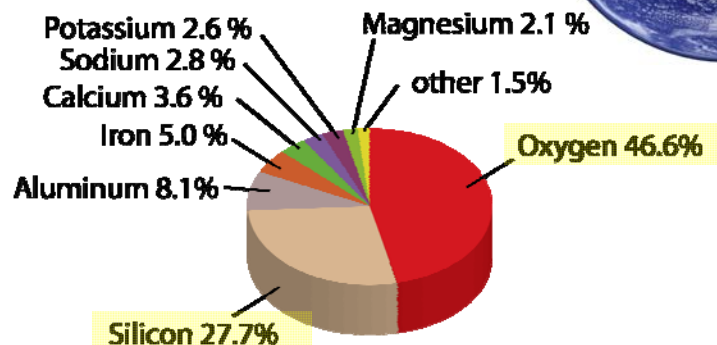
What distinguishes living organisms from inanimate objects?

- 1) Choice of elements
- 2) Structurally complex
- 3) Highly organized
- 4) Assemble limited # monomeric building blocks → macromolecules
- 5) Extract, transform, use energy
- 6) Not in equilibrium with environment
- 7) Faithfully reproduce themselves
- 8) Evolve via natural selection

Choice of elements for biological systems: what to base life on?



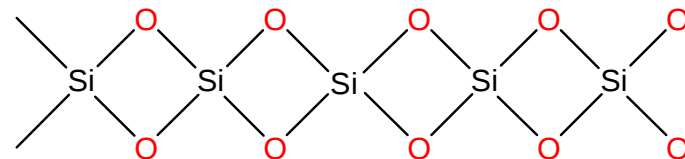
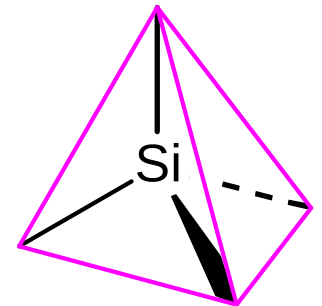
Elemental composition of earth's crust:



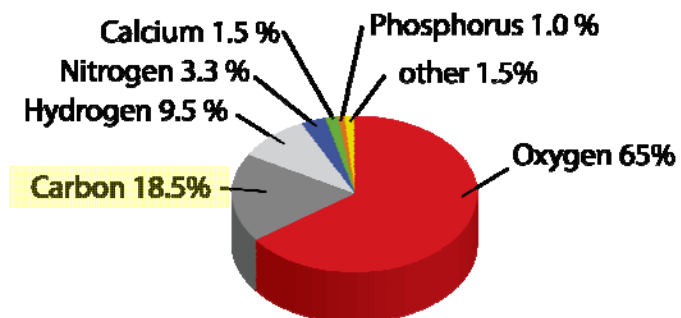
Silicon?

Limitations:

- Usually only single bonds
- Prefers O

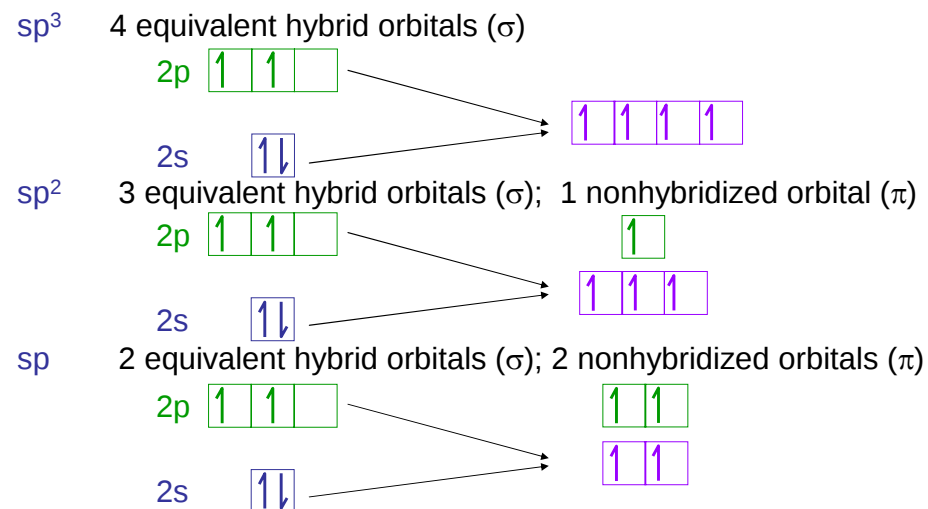
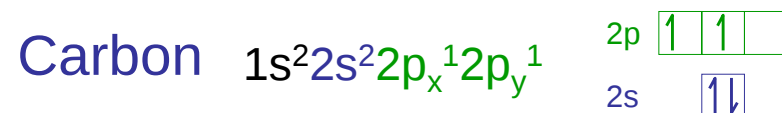


Elemental composition of the human body



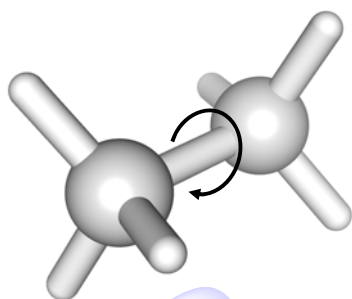
- All life forms are C-based and highly reduced

What's so great about carbon?

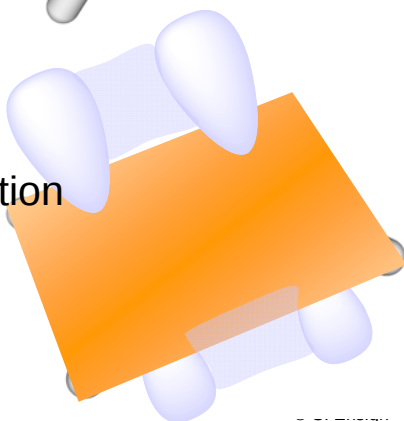


σ and π bonds

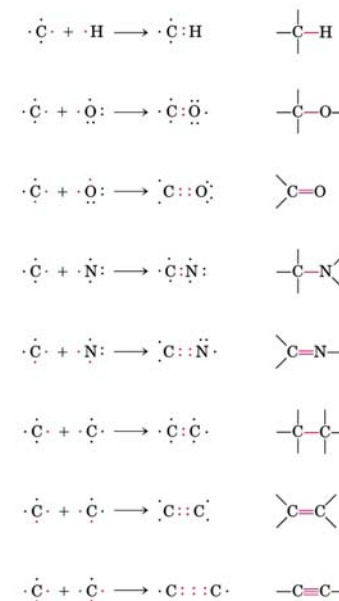
- σ bonds: free rotation



- π bonds: restricted rotation



$C + C, H, O, N, S, P$



Some important organic functional groups

Structure	Functional group	Biological example
$\text{R}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}^-$	Carboxylic acid	
$\text{R}-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$	Aldehyde	
$\text{R}-\text{OH}$	Alcohol	
$\text{R}_1-\overset{\text{O}}{\parallel}{\text{C}}-\text{R}_2$	Ketone	
$\text{R}_1-\text{O}-\text{R}_2$	Ether	
$\text{R}_1-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\text{R}_2$	Ester	
$\text{R}-\text{NH}_2$	Amine	
$\text{R}_1-\overset{\text{O}}{\parallel}{\text{C}}-\text{N}(\text{H})-\text{R}_2$	Amide	
$\text{R}-\text{SH}$	Thiol	
$\text{R}_1-\overset{\text{O}}{\parallel}{\text{C}}-\text{S}-\text{R}_2$	Thioester	

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Some important organic functional groups

Structure	Functional group	Biological example
$\text{R}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}^-$	Carboxylic acid	Fatty acid
$\text{R}-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$	Aldehyde	Sugars
$\text{R}-\text{OH}$	Alcohol	Sugars
$\text{R}_1-\overset{\text{O}}{\parallel}{\text{C}}-\text{R}_2$	Ketone	Nucleotides
$\text{R}_1-\text{O}-\text{R}_2$	Ether	Lactones (sugar rings)
$\text{R}_1-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\text{R}_2$	Ester	Lipids
$\text{R}-\text{NH}_2$	Amine	Amino acids
$\text{R}_1-\overset{\text{O}}{\parallel}{\text{C}}-\text{N}(\text{H})-\text{R}_2$	Amide	Proteins
$\text{R}-\text{SH}$	Thiol	Proteins
$\text{R}_1-\overset{\text{O}}{\parallel}{\text{C}}-\text{S}-\text{R}_2$	Thioester	Coenzymes

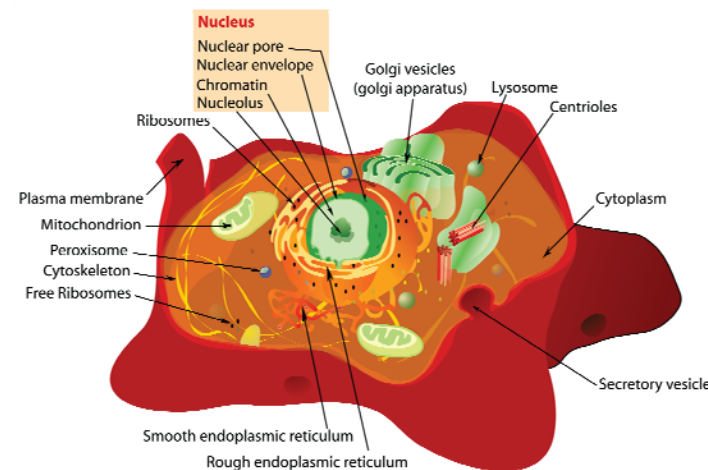
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Structural complexity of a eukaryotic cell



Credit: Mariana Ruiz, http://commons.wikimedia.org/wiki/Image:Animal_cell_structure_eng

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A typical biological system

- Division of labor
- Environmental sensors-
respond to stimuli
- Support- skeleton,
exoskeleton
- Anchoring devices



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Biological Building Blocks

monomer → macromolecule

Amino acids → Proteins

Nucleotides → Nucleic acids

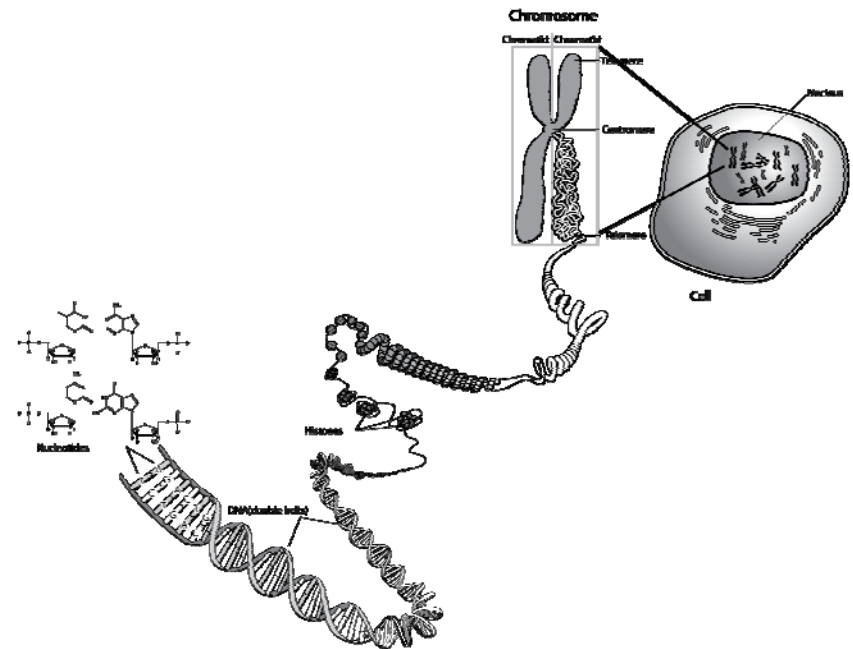
Fatty acids → Lipids

Monosaccharides → Polysaccharides

A limited number of different monomeric building blocks are used to build a wide variety of different macromolecules

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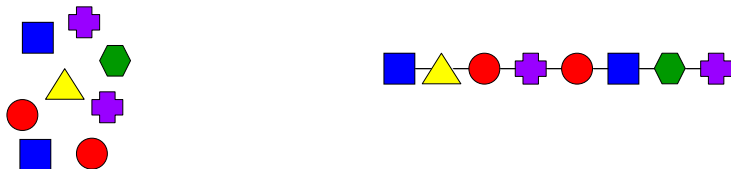


Modified from: <http://www.genome.gov/Pages/History/DIRM/PA/Glossary/Illustration/Pdf/chromosome.pdf>

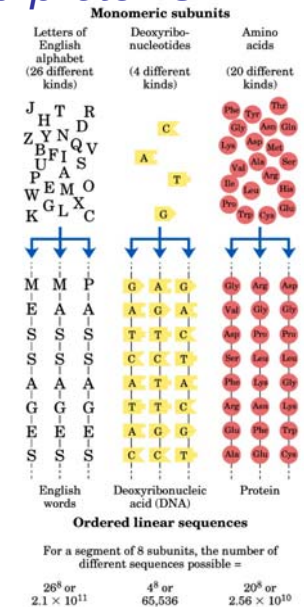
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Macromolecules are generally linear sequences of building blocks, folded into 3-dimensional structures



The languages of DNA and proteins

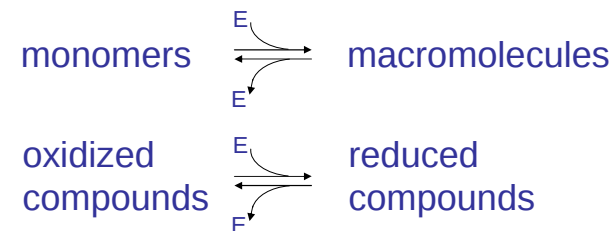


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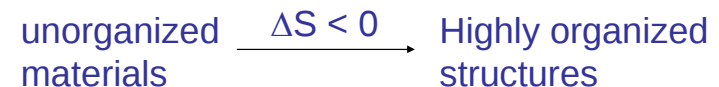
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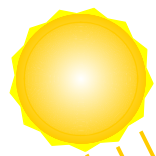
Energy

- 1st law: E of universe is constant
 - Biological systems transduce energy

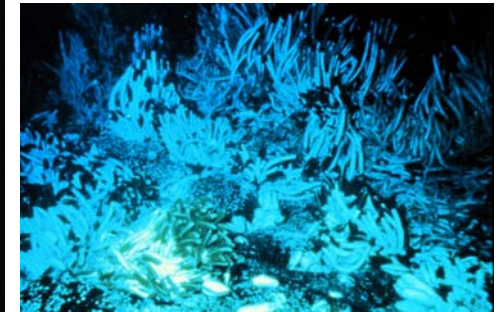
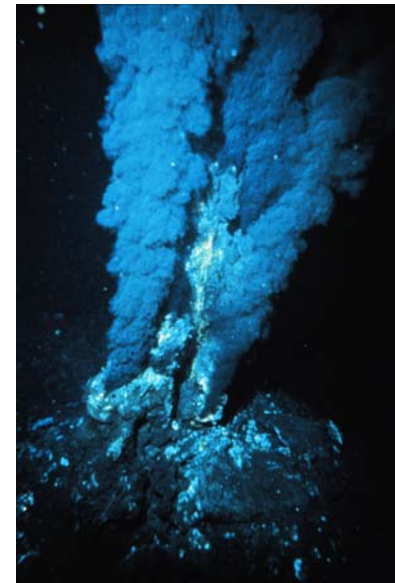
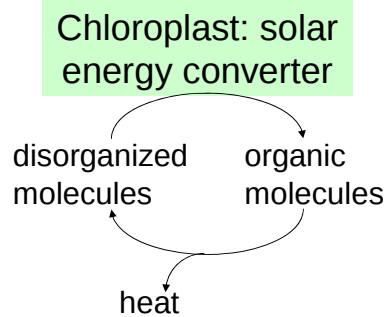


- 2nd law: Entropy of the universe is increasing
 - Do biological systems “defy” the 2nd law?



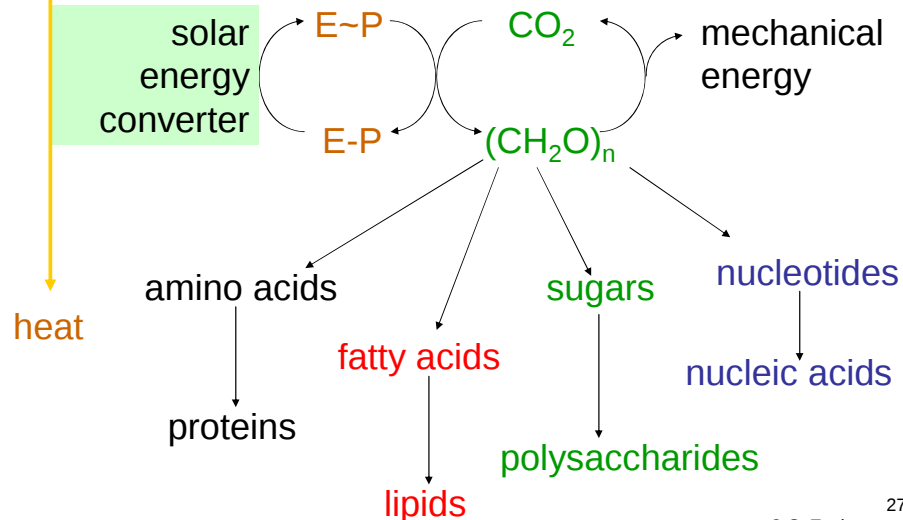


The sun: the direct or indirect source of energy for virtually all organisms



<http://www.photolib.noaa.gov/htmls/nur04507.htm>

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Get the most out of class

- Download and preview lecture overheads ahead of class
- Read text chapters before class.
- Review chemical principles to be covered as part of lecture if you are rusty (bonding, thermo, kinetics, acid-base equilibrium, functional groups, reactivity, etc).
- Form study groups
- Take advantage of office hours and weekly review session
- Work old exams (available through webCT)
- I only test on concepts covered in lectures!