Session 2

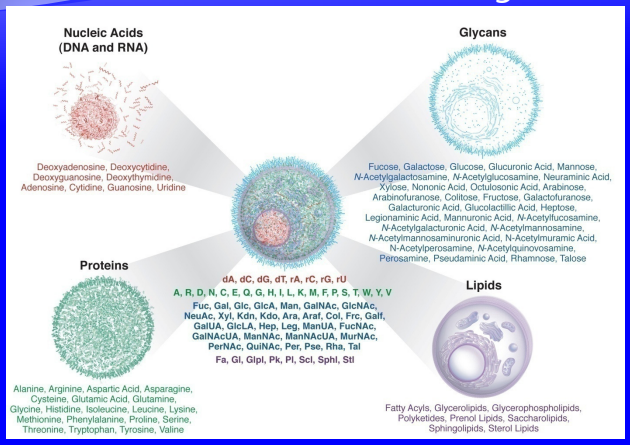
BUILDING BLOCKS

Fundamental Units of Organisms

- All life is from 68 molecular building blocks

Nucleic Acids
8 nucleosides

Proteins
20 amino acids



Glycans
32+ sugars

Lipids
8 types

"From the construction, modification, and interaction of these components, the cell develops and functions." –James Marth

J. Marth "A Unified Vision of the Building Blocks of Life" *Nature Cell Biology*, 2008,10(9):1015-16

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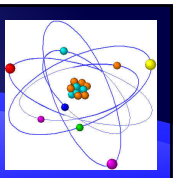
Atoms

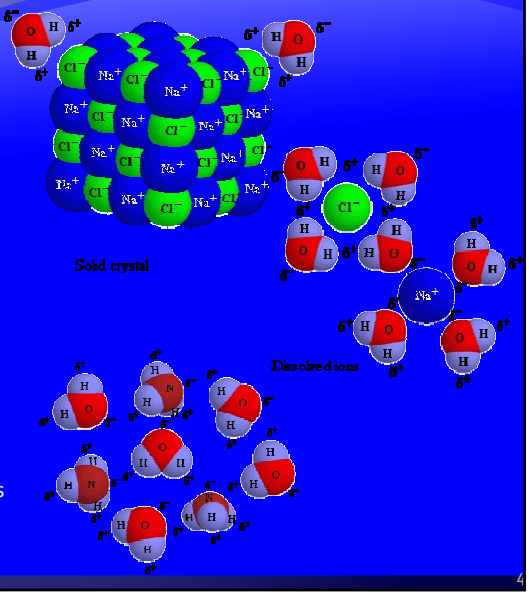


- Six basic elements
  - Hydrogen (H), Carbon (C), Nitrogen (N), Oxygen (O), Phosphorous (P), Sulfur (S)
- Valence electrons determine the bonding
- Electronegativity determines the polarity
- Composition is similar between living organisms

Atoms	H	C	N	O	P	S
Valency	1	4	5	6	5	6
Electronegativity	2.1	2.5	3.0	3.5	2.1	2.5
H. Sapien (%)	9.3	19.4	0.8	62.8	0.6	0.6
Bacteria (%)	9.9	12.14	3.0	73.7	0.6	0.3
Earth (%)	0.9	0.2	0.9	50	0.12	0.12

Molecules

- Covalent bonds
  - Shared electrons
  - Single (C-C), Double (C=C) , and rarely Triple (C≡C)
  - Bond angles determined by unshared electron pairs
- Ionic bonds
  - Electrostatics
- Hydrogen bonds
  - Electrons sharing is stronger around electronegative atoms
  - e.g., O = 3.5 vs H = 2.1
  - Water is polar because of its slightly negative oxygen and slightly positive hydrogen atoms
  - Ethanol, acetone, and long chains of hydrocarbons are nonpolar
  - e.g., C = 2.5 vs H = 2.1



Chemical Reactions

- Products and Reactants
  - $C_6H_{12}O_6 + 6\,O_2 \rightarrow 6\,CO_2 + 6\,H_2O$ + Energy
- Catalysts (Enzymes)
  - Energetically favorable if Gibbs free energy $\Delta G \leq 0$
  - Catalysts are intermediaries to help lower activation energy
    - Without enzyme

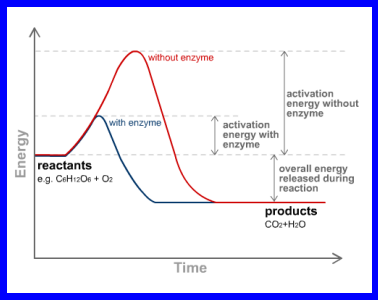
      A-B + C → A + B-C
    - With enzyme

      A-B + C + E → A-B-E + C

      → A + B-E + C

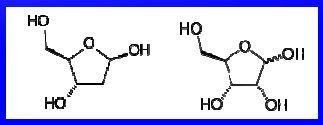
      → A + B-E-C

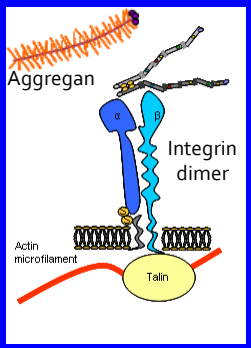
      → A + B-C + E



Glycans

- "Carbohydrates" – hydrated carbons, (C, H, O)
- Integral Building Blocks
  - Nucleic Acids
    - Deoxyribose - DNA
    - Ribose - RNA
  - Protein
    - Glycoproteins – transmembrane proteins, e.g. integrins
    - Proteoglycans – protein core with polysaccharide chains, e.g. ECM's aggregan
  - Lipids
    - Glycolipids – located in extracellular layer of the cell membrane

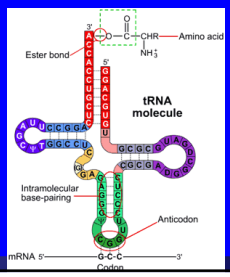


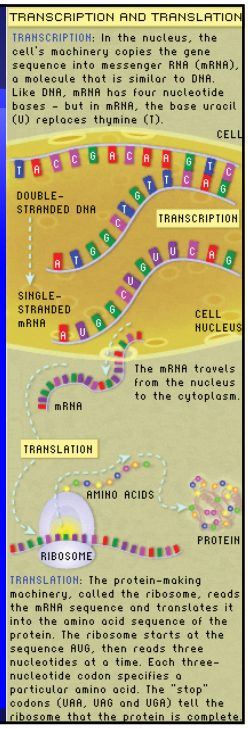


Nucleic Acids

[covered in hw 1]

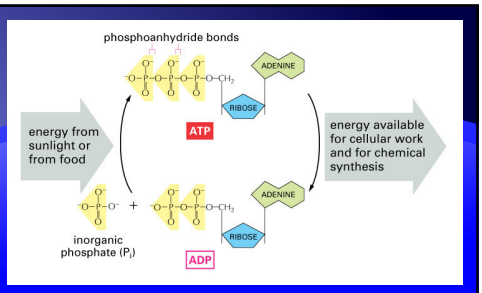
- DNA – genetic code
  - Adenine, Guanine, Cytosine, Thymine
- RNA – translation into proteins
  - Adenine, Guanine, Cytosine, Uracil
  - Messenger RNA (mRNA)
  - Transfer RNA (tRNA)





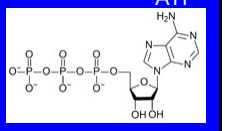
ATP & GTP

[not covered in hw 1]



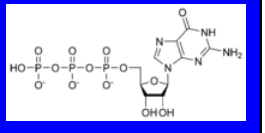
- ATP – energy currency
  - Adenosine triphosphate
  - ATP + H_2O → ADP + PO_4^{3-} + 7.3 kcal/mol
  - Actin & Myosin

ATP



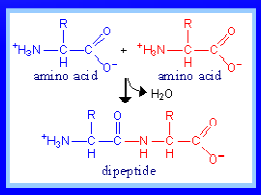
- GTP - regulatory
  - Guanosine triphosphate
  - G-protein Signal Transduction
  - Microtubules

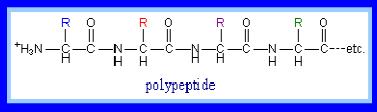
GTP



Proteins

- Individual amino acids are translated into long chains called polypeptides
- Peptide bond: carboxyl + amino → CO–NH + H_2O

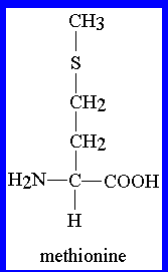




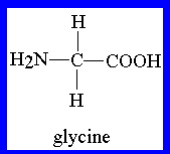
- Each amino acid in a polypeptide is called a residue (R)
- Residue sequence read from N-terminal to C-terminal
- Final sequence will "fold up" into a 3-dimensional structure
- Substitution of just one residue can change a protein's structure-function relationship

Amino Acids

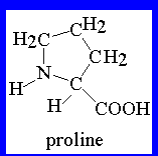
- Central carbon plus amino group ($-NH_2$), carboxyl group (-COOH), hydrogen atom (-H), and distinct side chain (20 in total)
- Side chains determine shape and function



Met, M
Start of all proteins



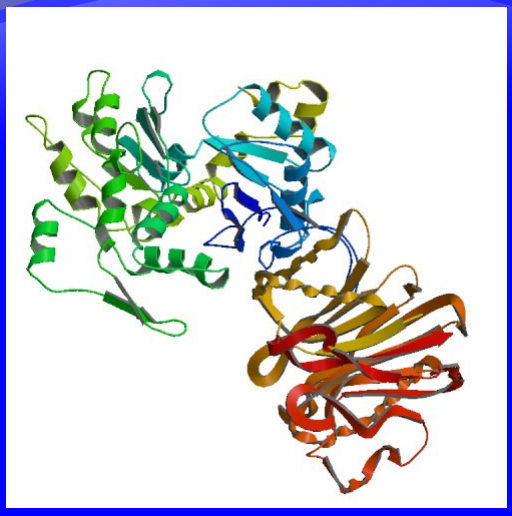
Gly, G
Simplest
Hydrophobic



Pro, P
Forms a rigid kink

Amino Acid Sequence

MCEEETTALVCDNGSGLCKAG
FAGDDAPRAVFPSIVGRPRHQ
GVMVGMGQDSYVGDEAQSK
RGILTLKYPIEHGIITNWDDME
KIWHHSFYNELRVAPEEHPTLL
TEAPINPKANREKMTQIMFET
FNVPAMYVAIQAVLSLYASGRT
TGIVLDSGDGVTHNVPIYEGYA
LPHAIMRLDLAGRDLTDYLMKI
LTERGYSFVTTAEREIVRDIKEK
LCYVALDFENEMATAASSSSL
EKSYELPDGQVITIGNERFRCP
ETLFQPSFIGMESAGIHETTYN
SIMKCDIDIRKDLYANNVLSGG
TTMYPGIADRMQKEITALAPS
TMKIKIIAPPERKYSVWIGGSIL
ASLSTFQQMWISKPEYDEAGP
SIVHRKCF



SMOOTH MUSCLE ACTIN (ACTG2)

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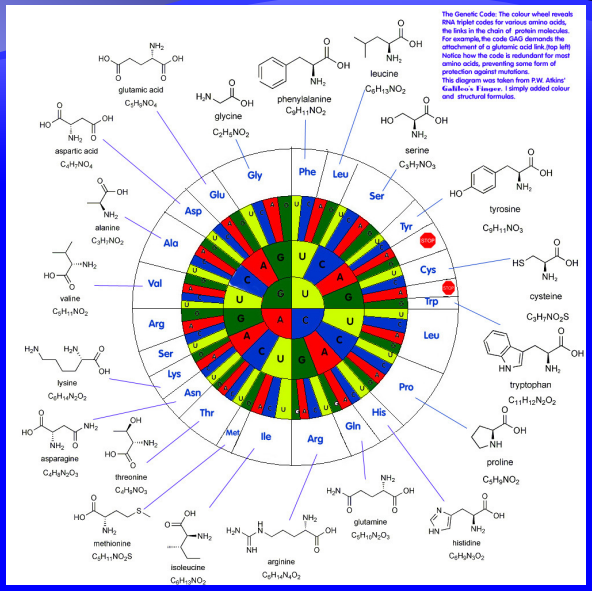
Translation

- Start with Methionine (AUG)
- Build codon by codon
- End with UAA, UAG, UGA



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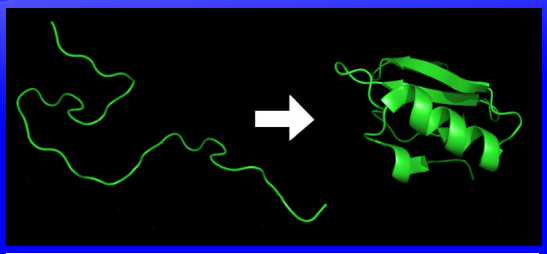
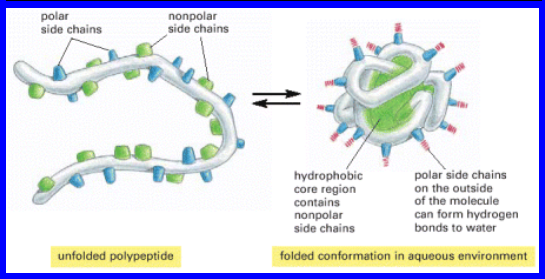
Protein Folding

- In aqueous cytoplasm, hydrophobic residues form the inner core of the protein
- Denaturing is a loss of protein structure through solvents, salts, pH, or heat





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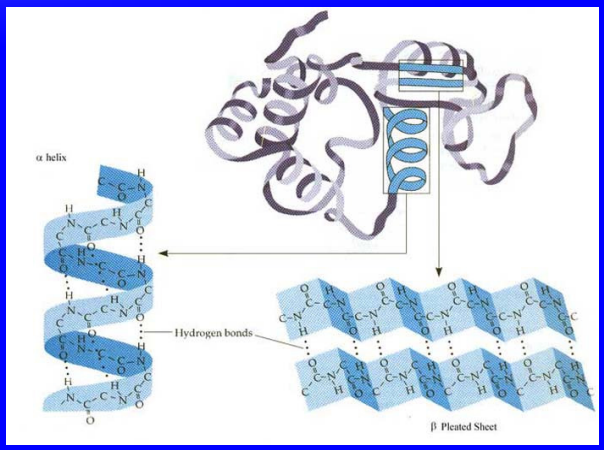
Protein Structure

- Primary – amino acid sequence
- Secondary – sub-structures through hydrogen bonds
  - Alpha helix
  - Beta sheet
- Tertiary – overall shape of a single protein unit
- Quaternary – union of more than one protein units



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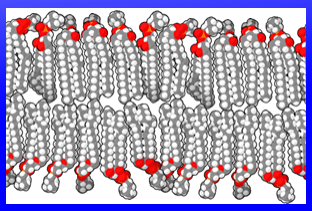
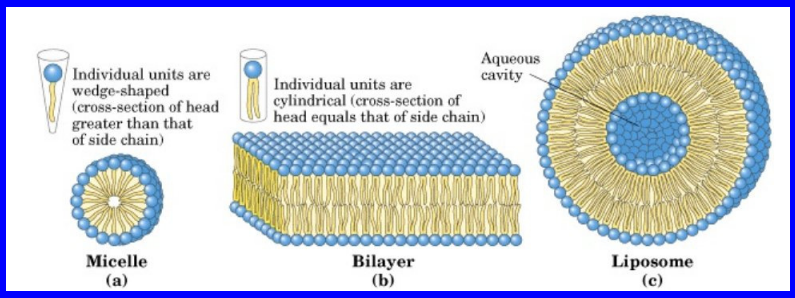
Lipids

- Phospholipids have nonpolar hydrocarbon chains ("tails") and polar, negatively charged phosphate groups ("head")
- In water, phospholipids cluster together to form bi-layer surfaces that shield the nonpolar tails.
- In air-water, tails point out and you have soap bubbles
- Layers held together by van der Waals forces





Questions?