

- ## Proteins
- Most structurally & functionally diverse group of biomolecules
 - Functions:
 - ◆ involved in almost everything
 - enzymes
 - structure (keratin, collagen)
 - carriers & transport (membrane channels)
 - receptors & binding (defense)
 - contraction (actin & myosin)
 - signaling (hormones)

Proteins

- Structure:
 - ◆ monomer = **amino acids**
 - 20 different amino acids
 - ◆ polymer = **polypeptide**
 - protein can be 1 or more polypeptide chains folded & bonded together
 - large & complex molecules
 - complex 3-D shape

The diagram illustrates the formation of a polypeptide chain. Two amino acids, each with a central carbon atom bonded to a hydrogen atom (H), an R group, an amino group (H-N), and a carboxyl group (C=O-OH), are shown. A bond is formed between the amino group of one amino acid and the carboxyl group of another, releasing a water molecule (H₂O). The resulting polypeptide chain consists of two amino acid residues linked together.

Viva la difference!

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

The diagram shows the chemical structures of Estradiol and Testosterone. Both are steroid hormones with a four-ring core. Estradiol (female hormone) has a hydroxyl group at C3 and a phenolic A ring. Testosterone (male hormone) has a ketone group at C3 and a methyl group at C19. A small cartoon of a female lion and a male lion is shown to illustrate the difference in their sex characteristics.

- ## Types of functional groups
- 6 functional groups most important to chemistry of life:
 - ◆ hydroxyl
 - ◆ carbonyl
 - ◆ carboxyl
 - ◆ amino
 - ◆ sulfhydryl
 - ◆ phosphate
 - Affect reactivity
 - ◆ hydrophilic
 - ◆ increase solubility in water

Hydroxyl

... OH

- -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	$ \begin{array}{c} \text{H} & \text{H} \\ & \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ & \\ \text{H} & \text{H} \end{array} $ 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

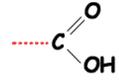


Table 4.1 Functional Groups of Organic Compounds

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

Amino

▪ -NH₂

♦ N attached to 2 H

- compounds with NH₂ = **amines**
 - ♦ amino acids
- NH₂ 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		Amines	 Glycine*

Sulfhydryl

▪ -SH

♦ S bonded to H

- compounds with SH = **thiols**
- SH groups stabilize the structure of proteins



Table 4.1 Functional Groups of Organic Compounds

Functional Group	Formula	Name of Compounds	Example
Sulfhydryl	-SH	Thiols	 Ethanethiol

Phosphate

▪ -PO₄

♦ P bound to 4 O

- connects to C through an O
- PO₄ are anions with 2 negative charges
- function of PO₄ is to transfer energy between organic molecules (ATP)

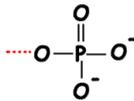


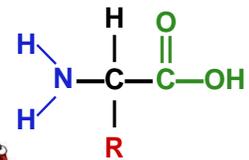
Table 4.1 Functional Groups of Organic Compounds

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

Amino acids

▪ Structure:

- ♦ central carbon
- ♦ amino group
- ♦ carboxyl group (acid)
- ♦ R group (side chain)
 - variable group
 - confers unique chemical properties of the amino acid

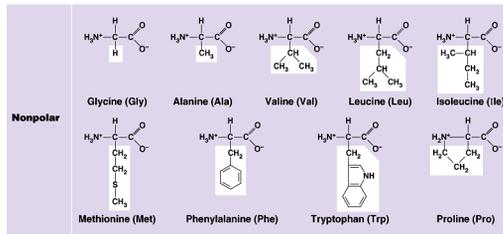


Oh yeah...
the inner nerd
is coming out
baby!



Nonpolar amino acids

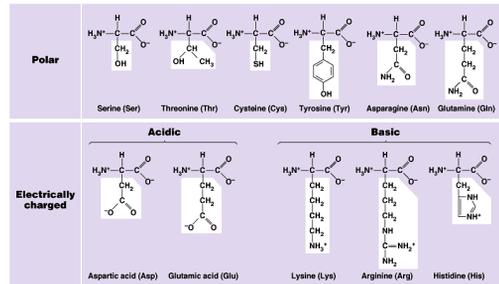
- nonpolar & hydrophobic



Why are these nonpolar & hydrophobic?

Polar amino acids

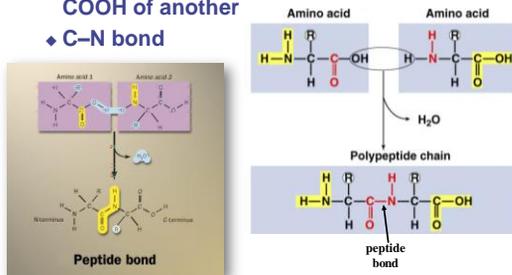
- polar or charged & hydrophilic



Why are these polar & hydrophilic?

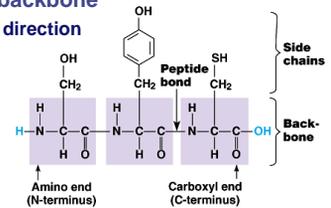
Building proteins

- Peptide bonds: dehydration synthesis
 - linking NH₂ of 1 amino acid to COOH of another
 - C-N bond



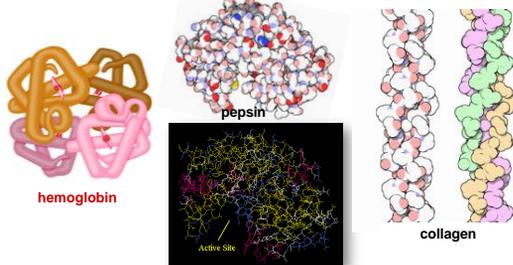
Building proteins

- Polypeptide chains
 - N-terminal = NH₂ end
 - C-terminal = COOH end
 - repeated sequence (N-C-C) is the polypeptide backbone
 - grow in one direction



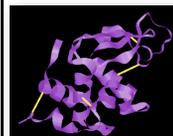
Protein structure & function

- function depends on structure
 - 3-D structure
 - twisted, folded, coiled into unique shape

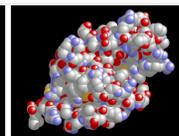


Protein structure & function

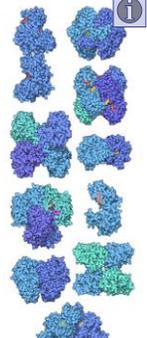
- function depends on structure
 - all starts with the order of amino acids
 - what determines that order of amino acids?



lysozyme: enzyme in tears & mucus that kills bacteria



the 10 glycolytic enzymes used to breakdown glucose to make ATP



Primary (1°) structure

- Order of amino acids in chain
 - amino acid sequence determined by DNA
 - slight change in amino acid sequence can affect protein's structure & it's function
 - even just one amino acid change can make all the difference!

Tell 'em about the Colonie Youth in a lineup!

Primary (1°) structure: Sickle cell anemia

(a) Normal red blood cells and the primary structure of normal hemoglobin

(b) Sickled red blood cells and the primary structure of sickle-cell hemoglobin

Just one "letter" change in the DNA causes a different amino acid to be positioned... Valine instead of Glutamine.

Secondary (2°) structure

- "Local folding"
 - folding along short sections of polypeptide
 - interaction between adjacent amino acids
 - H bonds between R groups
 - α-helix
 - β-pleated sheet

Tertiary (3°) structure

- "Global (whole molecule) folding"
 - determined by interactions between R groups
 - hydrophobic interactions
 - effect of water in cell
 - anchored by disulfide bridges (H & ionic bonds)

2° Hydrogen bonding

3° Electrostatic attraction

Hydrophobic interaction

Metal-Ion coordination

α-Helix

β-Sheet

Quaternary (4°) structure

- Joins together more than 1 polypeptide chain
 - only then is it a functional protein

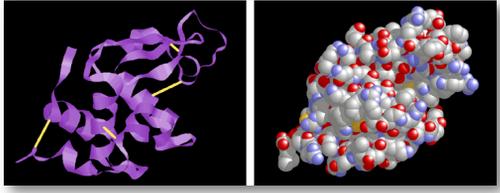
(a) Collagen

(b) Hemoglobin

Protein modeling

- Protein modeling
 - X-ray crystallography
 - extrapolation from known sequence
 - computer modelling

Cool "Molecules" app for your phone! Hey, there's a lot more than Angry Birds...



lysozyme

Protein structure (review)

1° **aa sequence** peptide bonds; determined by DNA

2° **backbone H bonds**

3° **R groups** hydrophobic interactions, disulfide bridges, ionic bonds

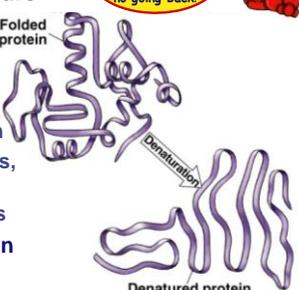
4° **multiple polypeptides** hydrophobic interactions, ionic bonds

(a) Primary structure
(b) Secondary structure
(c) Tertiary structure
(d) Quaternary structure

Denature a protein

- Disrupt 3° structure
 - pH
 - temperature
 - salt
- unravel or **denature** protein
- disrupts H bonds, ionic bonds & disulfide bridges
- Some proteins can return to their functional shape after denaturation, many cannot!

Think eggs... Once you cook 'em, there is no going back!



Folded protein

Denaturation

Denatured protein