Amino Acids and Proteins

Introduction to Amino Acids and Protein Structure – A Complement to Chapter 18

1

Proteins are Biomolecules

Biomolecules:

- Proteins, carbohydrates, lipids and nucleic acids are examples of biomolecules.
- Many biomolecules are polymers containing hundreds of thousands of repeating units.
- Proteins are polymers that range in size from 10,000 g/mole to 150000 g/mole.

2

Topics Covered

Amino Acids and Proteins-An Introduction

- Introduction to the role of proteins
- Structure of Proteins
  - Primary, secondary, tertiary and quaternary structures
  - Importance of Protein Structure
- Properties of amino acids
  - Composition
  - Geometry-stereochemistry
  - Acid and base properties
  - Interactions between amino acids

3

Proteins

- Most people know that proteins are something they are supposed to eat, and some people have heard about essential amino acids and they know that these have something to do with proteins.


Nutrition Facts
Serving Size 1 bar (40g)
Servings Per Container 5
Amount Per Serving
Calories 140
Calories from Fat 35
% Daily Value*
Total Fat 4g 6%
Saturated Fat 1.5g 9%
Trans Fat 0g
Polyunsaturated Fat 0.5g
Monounsaturated Fat 1.5g
Cholesterol 0mg 0%
Sodium 90mg 4%
Total Carbohydrate 29g 10%
Dietary Fiber 9g 35%
Sugars 10g
Protein 2g
Vitamin A 2% • Vitamin C 0%
Calcium 10% • Iron 2%
*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:
Calories 2,000 2,500
Total Fat Less than 65g 80g
Sat Fat Less than 20g 25g
Cholesterol Less than 300mg 300mg
Sodium Less than 2,400mg 2,400mg
Total Carbohydrate 300g 375g
Dietary Fiber 25g 30g
INGREDIENTS: CARAMEL [CORN SYRUP, SUGAR, PARTIALLY HYDROGENATED SOYBEAN AND COTTONSEED OILS, SALT, SOY LECITHIN, ARTIFICIAL FLAVOR], PEANUTS, MILK CHOCOLATE [SUGAR, CHOCOLATE, COCOA BUTTER, SKIM MILK, LACTOSE, MILKFAT, SOY LECITHIN, ARTIFICIAL FLAVOR], NOUGAT [SUGAR, CORN SYRUP, PARTIALLY HYDROGENATED SOYBEAN OIL, EGG WHITES, SALT, ARTIFICIAL FLAVOR], HYDROGENATED PALM KERNEL AND PALM OILS, DEXTROSE, SKIM MILK, MILKFAT, LESS THAN 2% OF: EGG YOLKS, CORN SYRUP SOLIDS, MILK PROTEIN CONCENTRATE, SOY LECITHIN, ARTIFICIAL FLAVOR, SALT.
CONTAINS: SOY, MILK, ALMOND, PEANUT, SUNFLOWER AND WHEAT INGREDIENTS.

Proteins vs. DNA

- DNA, the instructions for our cells, gets a lot of attention, but DNA just tells an organism how to make proteins. Aside from a little bit of material that comes from our mothers, proteins are what made our bodies, and organize how our bodies function.

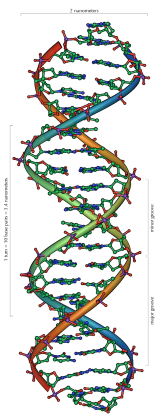


TABLE 18.2 Classification of Proteins by Function

TYPE	FUNCTION	EXAMPLE
Enzymes	Catalysts	*Amylase*—begins digestion of carbohydrates by hydrolysis
Hormones	Regulate body functions by carrying messages to receptors	*Insulin*—facilitates use of glucose for energy generation
Storage proteins	Make essential substances available when needed	*Myoglobin*—stores oxygen in muscles
Transport proteins	Carry substances through body fluids	*Serum albumin*—carries fatty acids in blood
Structural proteins	Provide mechanical shape and support	*Collagen*—provides structure to tendons and cartilage
Protective proteins	Defend the body against foreign matter	*Immunoglobulin*—aids in destruction of invading bacteria
Contractile proteins	Do mechanical work	*Myosin and actin*—govern muscle movement

6

Protein Structure:

Proteins are the polymers of **amino acids** and have four levels of structure:

- Primary
- Secondary structure
- Tertiary structure.
- Quaternary structure

We will deal with each one of them individually

Primary Structure

The primary structure of protein is sequence of its amino acids.

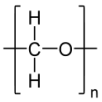
8

Polymers

This necklace is composed of beads, polymers are composed of monomers

Polymers are long chains of repeating chemical units. Though many biomolecules are polymers, polymers are also found in distinctly non-biological molecules.

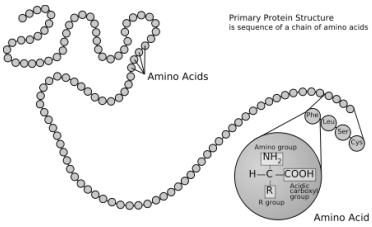
$-CH_2O-CH_2O-CH_2O-CH_2O-CH_2O-$



(Polyoxymethylene)

9

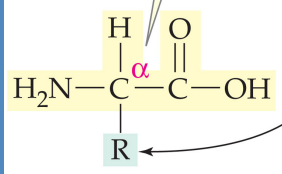
Proteins-Necklaces of Amino Acids



Amino acids are the monomers that make up proteins. The subunits in all proteins are similar and are linked by the same type of chemical bond.

10

The alpha carbon is the central carbon in an amino acid to which the amine, carboxyl and side chain R groups attach.

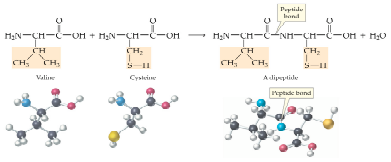


Side chain R group, different for each amino acid

Proline is the exception

Two or more amino acids can be linked together by a peptide bond.

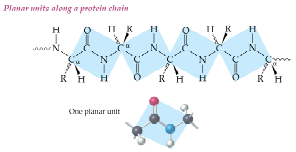
- **A dipeptide results from the linkage of two amino acids.**
- **A tripeptide results from the linkage of three amino acids.**
- **A polypeptide results from joining multiple amino acids.**
- **A protein typically contains more than 100 amino acids linked together..**



12

Amino Acid Chains

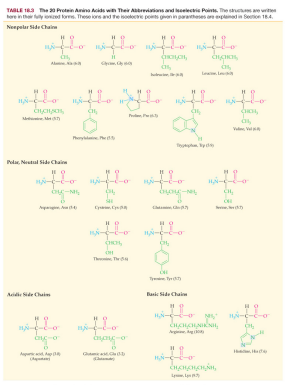
The carbon and nitrogen atoms lie along a zig- zag pattern along the backbone. Each α−carbon is tetrahedral, and each carboxyl carbon is planar.



Primary Protein Structure

- The primary structure of protein is sequence of its amino acids.
- The primary structure is very important.

  Even a single residue change in the sequence can change the biological activity. Sickle cell anemia is the result of a single amino acid change in the hemoglobin.
- In order to understand why a small change in the primary structure is so significant it is important to consider the amino acids that make up the primary structure.



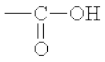
- Twenty amino acids are found in naturally occurring proteins.
- The side chains (-R groups) determine the characteristics of the amino acids.
- The functional groups (-COOH, $-NH_2$, $-CH_3$, -OH) on the side chains determine these characteristics.
- Amino acids are commonly grouped according to their characteristics.

Acidic and Basic Amino Acids

Neutral And Basic Amino Acids

- The amino acids are classified as **neutral, acidic and basic** depending on the nature of their side chain.
- All amino acids have an amine and carboxyl group, but only some have them in the –R groups.
- The main chain amine and carboxyl groups are not considered when amino acids are classified as acids or bases.

Amine
Functional Group

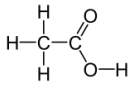


Carboxylic Acid
Functional Group

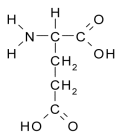
17

Acidic Amino Acids

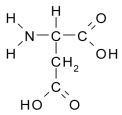
Carboxylic Acid
Functional Group



Acetic Acid



Glutamic Acid
Glu



Aspartic Acid
Asp

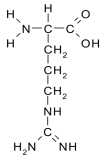
There are 2 amino acids with acidic side groups.

18

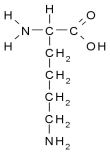
Basic Amino Acids

Amine
Functional Group

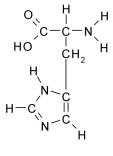
Ammonia



Arginine
Arg



Lysine
Lys



Histidine
His

There are 3 amino acids with basic side groups.

19

Polar and Nonpolar Amino Acids

20

Polar and Nonpolar –R groups

- Side groups are also classified according to their polarity.
- There are 9 amino acids with **nonpolar side chains.**
- There are 6 with **polar side chains** that are neither acid or basic.

21

Polar and Nonpolar –R groups

- The nonpolar amino acid side chains do not dissolve in the water. They are called hydrophobic, water fearing.
- The polar, acidic and basic side chains dissolve in water and are called hydrophilic, water loving.
- The polarity of amino acids is key in determining the tertiary and quaternary structure of proteins.

22

Polar/Nonpolar Review

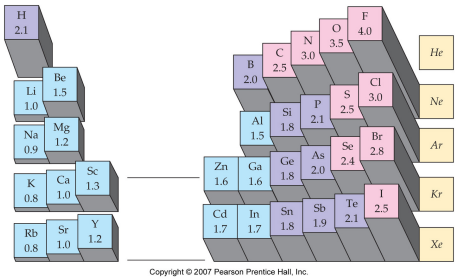
Polar and Nonpolar Review

- Polar molecules can dissolve in water.
- Nonpolar molecules do not dissolve in water.
- Water is polar. That polar side chains dissolve in water is a case of like dissolves like.
- If a nonpolar molecule dissolves in water the nonpolar molecule disrupts the structure of water--hydrogen bonding and δ^+-- δ^- alignment.

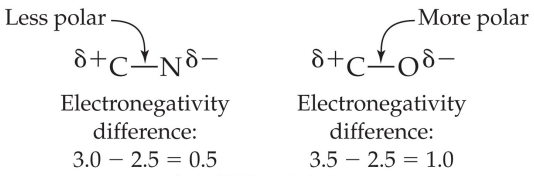
23

Polar/Nonpolar Review

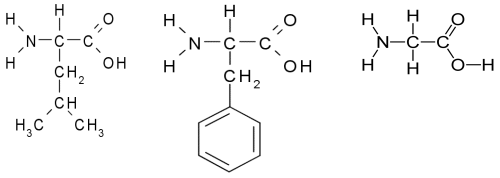
Differences in the electronegativity between atoms in a molecule determine if a covalent bond is polar or nonpolar.



Polar/Nonpolar Review



Nonpolar Amino Acids



Leucine
Leu

Phenylalanine
Phe

Glycine
Gly

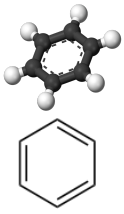
- There are 6 other amino acids that are usually classified as nonpolar.

26

Background

What the Ring Means

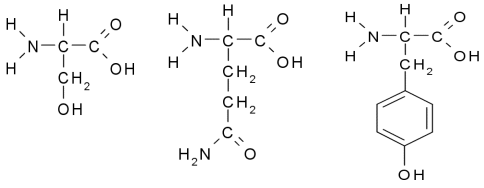
- The ring is called a phenyl functional group. It is quite nonpolar, and is flat.



- Each corner of the ring stands for a carbon, with a bond to a hydrogen atom.
- This shorthand is used because it is inconvenient to keep drawing the whole thing out and because this ring has special properties.
- Phenyl side groups resemble the molecule benzene, shown on the left, except that one or more of the carbons bond to something else other than a hydrogen atom.
- Phenyl groups are nonpolar when the atoms joined to them have an electronegativity close to that of carbon.

27

Polar Amino Acids



Serine
Ser

Glutamine
Gln

Tyrosine
Tyr

- There are 3 other polar amino acids + 5 acidic and basic amino acids that can behave as polar amino acids.

28

Summary of Amino Acid Polarity

Amino Acid	3-Letter	Side chain polarity
Alanine	Ala	nonpolar
Arginine	Arg	polar
Asparagine	Asn	polar
Aspartic acid	Asp	polar
Cysteine	Cys	nonpolar*
Glutamic Acid	Glu	polar
Glutamine	Gln	polar
Glycine	Gly	nonpolar
Histidine	His	polar
Isoleucine	Ile	nonpolar

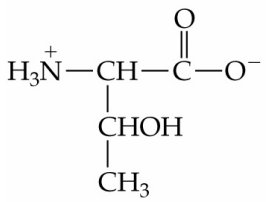
Amino Acid	3-Letter	Side chain polarity[80]
Leucine	Leu	nonpolar
Lysine	Lys	polar
Methionine	Met	nonpolar
Phenylalanine	Phe	nonpolar
Proline	Pro	nonpolar
Serine	Ser	polar
Threonine	Thr	polar
Tryptophan	Trp	nonpolar
Tyrosine	Tyr	polar
Valine	Val	nonpolar

Acid Base Nature of Amino Acids

Acid Base nature of Amino Acids

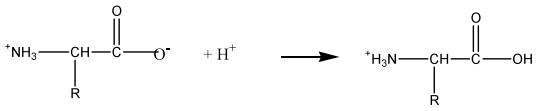
- All nonbonded Amino acids contain both an acidic group (-COOH) and a basic amino group (-NH_2).
- The presence of the acidic and the basic groups on the same can result in an intramolecular acid base reaction.
- The result is the transfer of the hydrogen from the –COOH group to the –NH_2 group to form a dipolar ion that has one positive charge and one negative charge and is electrically neutral. Dipolar ions are known as **zwitterions**.

- Because of the zwitterions nature, the amino acids have the properties of salts.
- They have high melting point, they are crystalline and are water soluble.

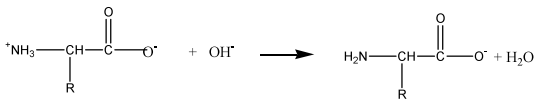


Threonine—zwitterion

- **In acidic solutions** the amino acids can gain one proton. Then they have a positive charge due to the -NH_3^+ end.



- **In basic solution** the acidic -NH_3^+ end gives the proton and leaves the negatively charged –COO^- group.



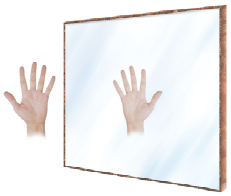
The charge on the amino acid depends on the amino acid and the pH of the medium.

The pH at which an amino acid has equal numbers of positive and negative charges is called isoelectric point pI. At this point the overall charge on the amino acid is zero.

Chirality of Amino Acids

Chiral (Ky-ral) molecules

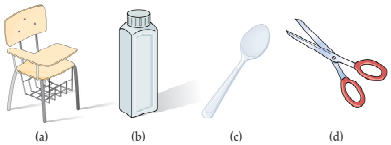
The objects that are mirror images of each other but they **can not be superimposed** on top of each other are called **chiral**, for example the mirror images of the hand.



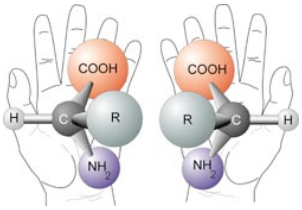
Achiral Objects

- The objects whose mirror images **can fit** on each other are called **achiral**, like the images of a chair.

Can you identify the chiral and achiral objects?



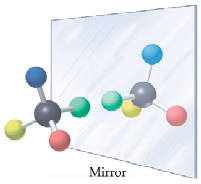
Amino Acids are Chiral



- All but one amino acids is chiral.
- Left hand amino acids are used in proteins.

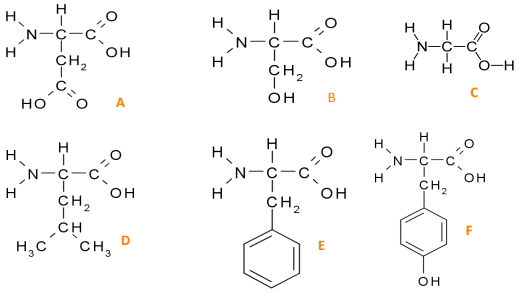
There Chiral Molecules in General

- There are many chiral molecules that are not biomolecules, though handedness of molecules tends to be important in biological systems
- A carbon atom attached to four different groups is a chiral carbon atom.



41

Which one of the amino acids is achiral?



42

Summary

In this presentation the primary structure of proteins has been discussed. This discussion considered the properties of amino acids, the monomers that make up protein chains. In the presentation following this secondary, tertiary, and quaternary structure will be discussed.