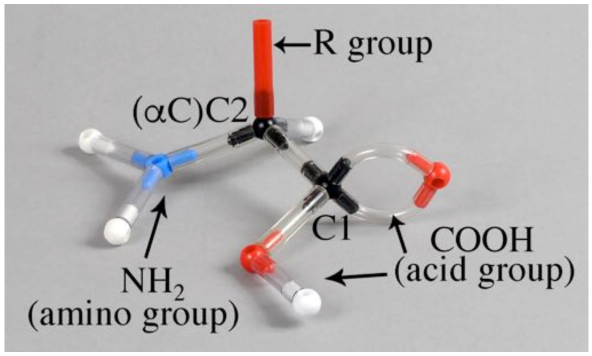
Super Models



Amino Acids (Large Set)
Molecular Model Kit

Recommended for ages 10-adult

⚠ **Caution:** Atom centers and vinyl tubing are a choking hazard. Do not eat or chew model parts.

Kit Contents:

52 white 1-peg hydrogen atom centers
2 white 2-peg hydrogen atom centers
2 blue 4-peg nitrogen atom centers
9 blue 3-peg nitrogen atom centers
14 red 2-peg oxygen atom centers
2 red 3-peg oxygen atom centers
3 yellow 2-peg sulfur atom centers
22 black 4-peg carbon atom centers
7 black 3-peg carbon atom centers
90 clear, 1.25″single bonds
14 clear, 4 cm bonds (for double bonds)
5 white, 2″ single bonds (for H bonds)
1 red, 1.25″ bond for R group

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GENERAL INFORMATION

I. FUNCTIONS:

Amino acids (aa's) are very important in the structures and functions of all living things. Over 500 types of aa's exist, however, there are only 20 standard aa's which are put together in a variety of combinations to form extracellular and intracellular proteins. In turn, proteins provide organisms with structural materials and enzymes (metabolic catalysts). The standard aa's are also called proteinogenic aa's.

Some individual aa's are used, as is, without being incorporated into proteins, or the aa is modified for a certain function.

In addition, there are a large number of types of less common aa's which exist independently of proteins and provide non-structural functions.

The vast majority of the aa's found in nature are in the L form, but note that D aa's are also found (the meaning of L and D will be covered later).

Bacterial cell walls contain D aa's. Even humans have two; one of these is utilized by the brain where it is important in memory and learning: it is D serine. The other is D aspartic acid.

Some amino acids are used for energy, but Only sparingly. Some are converted into Chemical messengers such as dopamine, Epinephrine and norepinephrine, serotonin, thyroxin, phenethylamine, GABA (gamma amino butyric acid), etc.

GABA is not an alpha amino acid; it has the amino group three carbons away from the acid end of the molecule. GABA reduces the sensitivity of nerve cells in the brain and spinal cord.

Cells use the amino acid, tyrosine as a starting material to make the brown pigment melanin.

Aspartame, a sugar substitute, is a dipeptide (a combination of two aa's) made of aspartic acid and phenylalanine. People who do not metabolize phenylalanine normally must not consume foods with aspartame. A warning to PKU individuals is placed on every product with the artificial sweetener indicating it should not be consumed. PKU is phenylketone urea, the disease which prevents PKU people from converting phenylalanine into tyrosine. If phenylalanine builds up in the blood, it will very quickly destroy the central nervous system. PKU individuals often have very light skin as a result of not producing tyrosine.

The histamine which causes so much discomfort to people with allergies is a modified form of histidine from which the acid group is removed.

Glycine and lysine are important in the cellular production of the porphyrin rings of heme (in hemoglobin and cytochromes) and chlorophylls in plants.

Within cells, aa's are bonded together to form chains. The joining of two aa's produces a dipeptide, three aa's bond to make a tripeptide. Longer chains up to about 10 aa's are oligopeptides, and the longest chains are called polypeptides.

II. KINDS OF AMINO ACIDS:

Humans are capable of making 11 aa's, called non-essential, while 9 which are essential must be supplied in our diets.

Non-essential:	**Essential:**
Alanine	Histidine
Arginine	Isoleucine
Asparagine	Leucine
Aspartic acid	Lysine
Cysteine	Methionine
Glutamic acid	Phenylalanine
Glutamine	Threonine
Glycine	Tryptophan
Proline	Valine
Serine	
Tyrosine	

III. AMINO ACID STRUCTURE:

All standard aa's are the L alpha (α) type (to be explained below), and they are found in the proteins of all living things.

All of the common aa's share the same four parts; 1) an acid group, -COOH, 2) an alpha (α) carbon which is bonded to the carbon of the acid group, 3) an amine group $-NH_2$ which is bonded to the α carbon and 4) a residual group (R), which is either a hydrogen atom or some other group of atoms. The residual group makes one aa different from another.

The general formula for all aa's is, then, as you can see in Fig. 1. Note that carbons which are in chains can be named numerically as C1, C2, etc. However, in some naming systems, such as the one used for aa's, the carbon atoms following C1 are designated by Greek letters, alpha (α), beta (β), gamma (γ), and so on.

Make a model to coincide with Fig. 1, observe the α carbon and the four different groups attached to it.

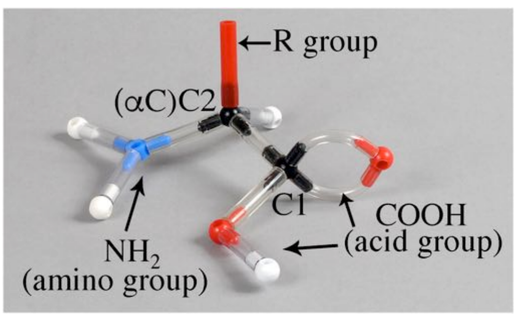


Fig. 1 General formula for all L α amino acids. The red tube represents an R group.

One of the more interesting properties of all aa's is their chirality (handedness, or asymmetry). aa handedness arises due to the alpha carbon atom having four different atoms and/or groups of atoms attached to it. Observe, in Fig. 2, that the alpha carbon (C2) has four different groups bonded to it, 1) a CH_3 group, 2) an amino group, 3) a hydrogen atom, and 4) an acid group.

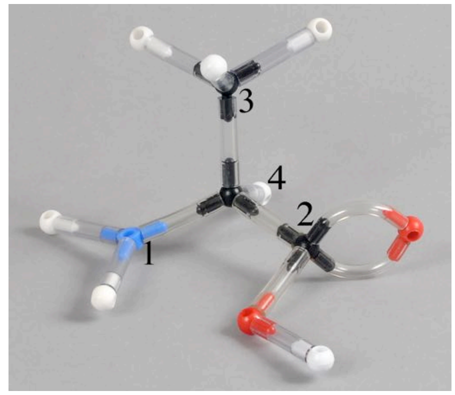


Fig. 2 Alanine with four groups, numbered 1 through 4, bonded to the α Carbon.

Make a model to look like Fig. 2. By replacing the red tube with CH_3, we have made the general formula into the formula for the aa, alanine. This model could be left handed or it could be right handed. Let's use the biochemists' method to determine the model's handedness.

IV. DETERMINING THE STEREO-CHEMISTRY OF AMINO ACIDS:

Step 1. Make sure that the atom with the lowest atomic weight on the alpha carbon is pointing away from you. In all of the amino acids it will be a hydrogen atom (at. wt. 1). The model photos have been positioned that way for convenience.

Step 2. Find the atomic weight of each other atom immediately bonded to the alpha carbon. The CH_3 group has a carbon atom (at. wt. 12) with three hydrogen atoms attached. Next, we see the nitrogen atom (at. wt. 14), and the last atom is carbon (at. wt. 12) with two oxygen atoms attached.

Step 3. Assign values from 1 to 4 to the Atoms based on their atomic weights. The lower the weight, the higher the value. Here, N = 1, H = 4. But it looks like a tie between the two carbon atoms; both are 12. We will have to break the tie. The carbon of CH_3 is bonded to three hydrogen atoms, and the carbon of the acid group is bonded to two higher atomic weight oxygen atoms. The acid-carbon atom of the acid group breaks the tie, and gets awarded a 2, while the CH_3 group carbon gets a 3.

Step 4. We already placed H = 4 in back, so now we trace a path from 1 to 2 to 3. The path travels counter clockwise, so we have discovered that this is an L amino acid.

V. DIAGRAMMING AMINO ACIDS:

There are two simplified methods of showing the structures of aa's. One is the wedge diagram which uses solid wedges to indicate the atoms coming toward the observer and dashed wedges meaning the atoms going away from the observer.

The second way to show the arrangement of the atoms is called a Fisher projection. A Fisher projection is the equivalent of a wedge diagram, and both assume the presence of the α carbon atom in the center where wedges or lines cross. Fig. 3, below, is a model of (L) α–alanine, and the wedge and Fisher drawings are in Fig. 4.

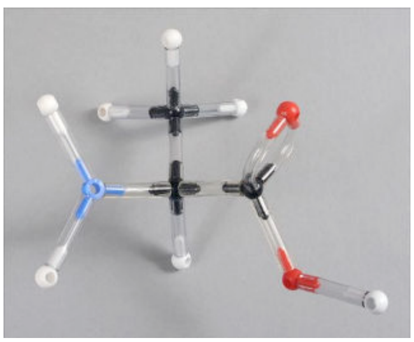


Fig. 3 A model of (L) α–alanine.

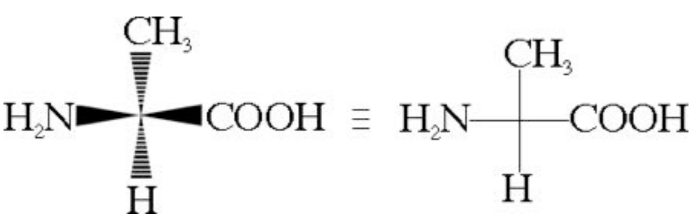


Fig. 4 Wedge and Fisher drawings of (L) α–alanine

Now imagine that the L-aa is facing a mirror and you can observe the aa's reflection. With some study of the diagram, (Fig. 5) below, you will see that the mirror image of the L-aa looks like the D-aa.

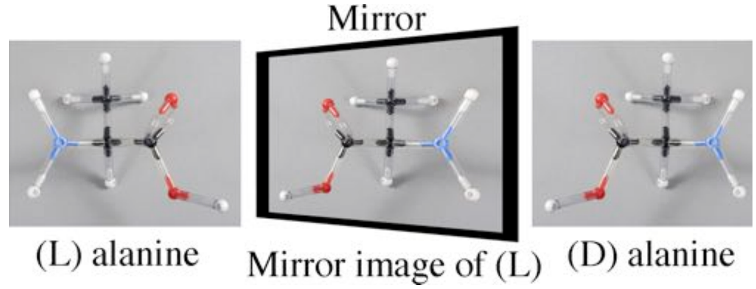


Fig. 5 L form on the left, D form on the right. Mirror image of L looks like D.

This demonstration is just what we observe when the reflection of your left hand (which looks like your right hand) is placed palm down on your left hand. The positions of thumbs and fingers do not coincide exactly.

Notice that when the alpha carbon of the D-aa is placed next to the alpha carbon of the L-aa, the hydrogen, and CH_3 groups coincide (green lines), but the amine and the acid groups (red lines) do not appear in the same positions in both aa's. Therefore, the molecules have "handedness," and they are different compounds. Molecules that have the same chemical formula, but different arrangements of the same kinds of atoms are called isomers. Because these isomers have the same kinds of atoms bonded to the same kinds of atoms, but in a different order, they are called stereoisomers.

Stereoisomers that are mirror images of one another, but not superimposable, as in Fig. 6, are known as enantiomers. D and L alanine are enantiomers of each other. See Fig. 6.

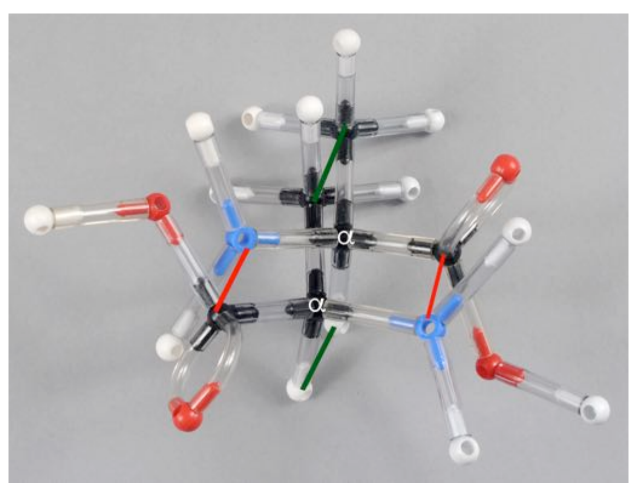


Fig. 6 D and L α–alanine overlapping.

A D enantiomer can be changed to an L, and an L aa changed to a D just by switching any **two** groups of atoms bonded to the alpha carbon.

VI. BONDING AMINO ACIDS TOGETHER:

It is customary to put the nitrogen end (N terminus) of an aa on the left side of the aa chain and the acid end (C terminus, C is for carboxyl group) on the right side.

The following diagrams show how phenylalanine at the N terminus can form a peptide bond with alanine at the C terminus. Phenylalanine is on the left, and alanine is on the right of Fig. 7.

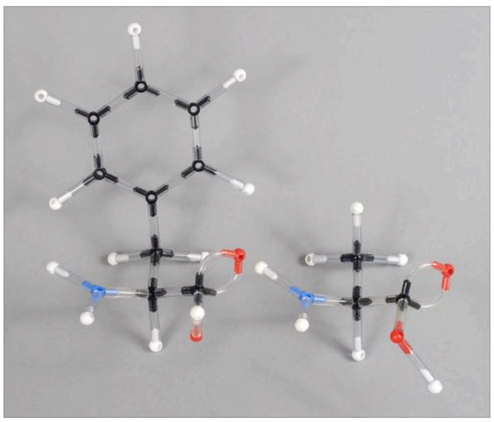


Fig. 7 Two aa's before bonding.

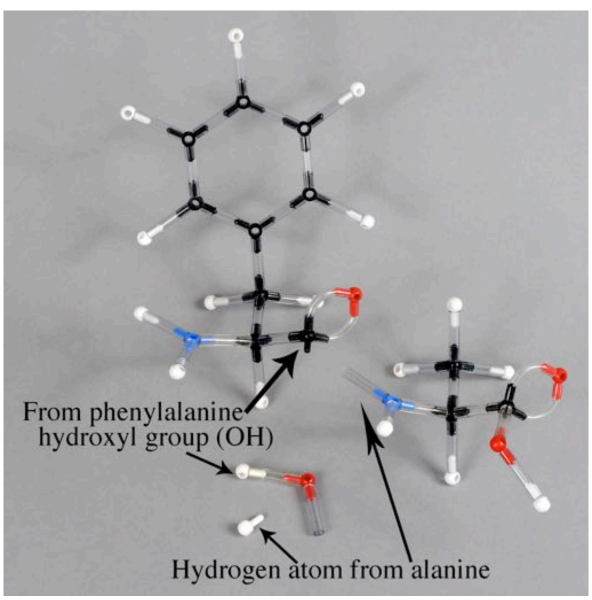


Fig. 8 Two aa's ready to make a peptide bond.

In Fig. 9, the two aa's have joined to form a peptide bond, and a molecule of water has formed. Because this reaction generated a water molecule the process is called a dehydration synthesis. We should note here that during digestion, the peptide bond can be broken by adding water back. That is known as hydrolysis (hydro for water, lysis means to break).

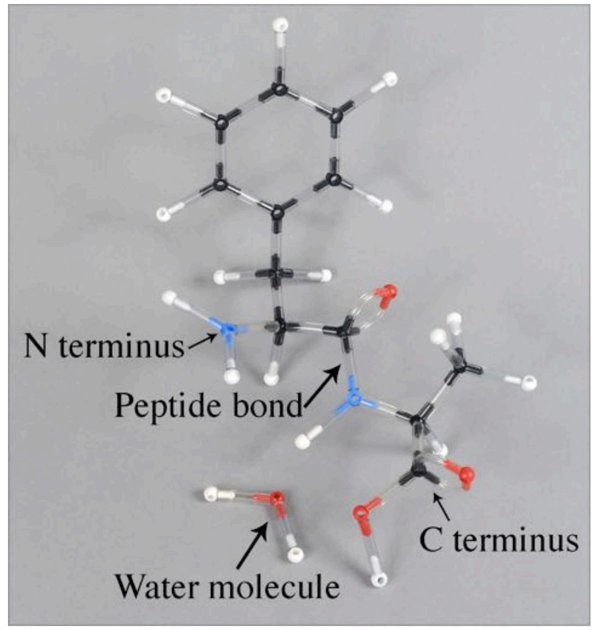


Fig. 9 A completed peptide bond.

A non-branching chain of aa's connected to each other through peptide bonds constitutes the primary (1°) structure of a polypeptide (a long strand of aa's): See Fig. 10.

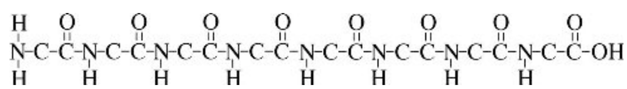


Fig. 10 1° structure of a polypeptide without R groups.

Several types of protein secondary (2°) structures are possible. One of these is called an α helix in which the aa's are twisted around a central axis with a right handed turn. In Fig. 11, below, carbon and nitrogen atoms lie on the ribbon. The α hydrogen atoms and the R groups are located on the outside surface of the ribbon, pointing away from the surface. Hydrogen bonding between oxygen atoms of acid groups and hydrogen atoms from nitrogen atoms in the amino groups hold the coil together. The hydrogen are drawn as three short, horizontal lines between oxygen and hydrogen. Hydrogen bonds are due to hydrogen atoms being shared between oxygen and nitrogen atoms.

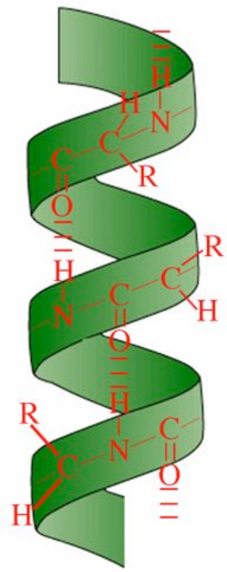


Fig. 11 A simplified picture of the α helix.

An easy way to demonstrate an α helix is to put the pattern from Fig 10 on a strip of paper, and then twist the paper into a roll so that oxygens and hydrogens line up appropriately. See Fig. 12 below.

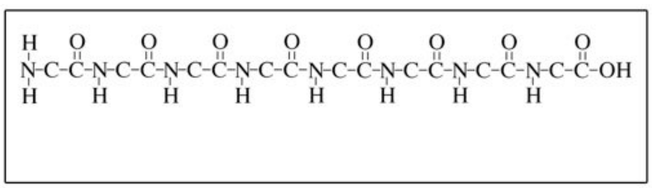


Fig. 12 Preparing a paper model of an α helix.

Two other common 2° structures are the beta (β) pleated sheets. There are two kinds; parallel and antiparallel. A β pleated sheet, like an α helix, is formed by intra-molecular hydrogen bonding. A small region of a pleated sheet in which the dashed lines represent hydrogen bonds is shown below in Fig. 13.

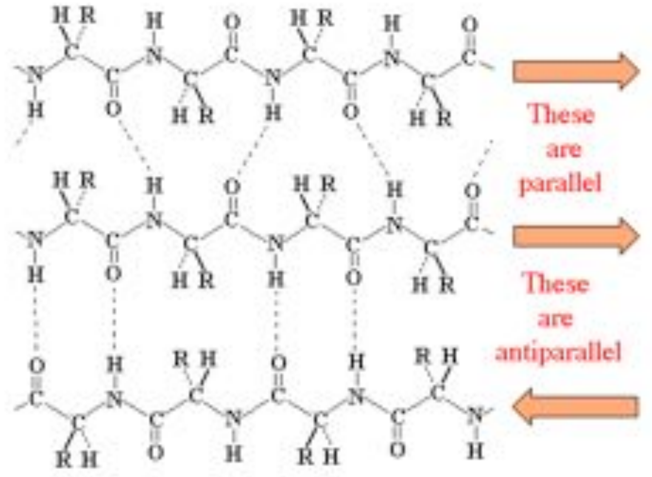


Fig. 13 Top and middle-parallel, middle and bottom-antiparallel β pleated sheets.

An α helix which folds upon itself produces a tertiary (3°) structure, and when two or more of these folded polypeptides bond to each other, the quaternary (4°) structure results.

LABORATORY EXERCISES:

I. HOW TO MAKE MOLECULAR MODELS:

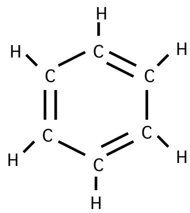
When making a double bond, connect two pegs of one atom to two pegs of the other atom using two of the long, thin tubes as you see below in Fig. 14.

Fig. 14 How to make a double bond.

In drawings of molecular diagrams of carbon chemicals, a carbon atom is assumed to exist where two lines intersect. In addition, carbon should have four bonds (lines) drawn to it. Fewer than four lines means that the absent bonds should be filled with hydrogen atoms.

Nitrogen should have three bonds, oxygen needs two bonds, and hydrogen will have one. When a hydrogen atom is found in a hydrogen bond, the atom has two bonds.

The molecular diagram-  means



This structure, with its alternating double bonds can be assembled by using six black, three-peg carbon atoms and six white, one-peg hydrogen atoms. It is called a benzene ring, or when bonded to another carbon, it is named a phenyl group (Fig. 15).

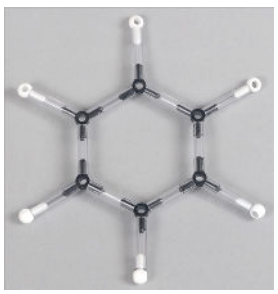
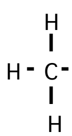
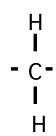


Fig. 15. A benzene ring

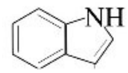
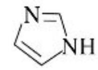
Remove one hydrogen atom to bond the ring to another atom.

When structural diagrams include shorthand symbols such as H_3C- (methyl), or -CH_2- (methylene), it is understood that the symbols mean:

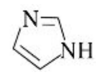
 and 

Refer back to Fig. 3 and to Fig. 4 before proceeding. When constructing aa's, make sure to orient the four groups around the α carbon correctly in order to avoid the possibility of making a D-, when you want to make an L- aa and vice-a-versa.

Use the following as a guide for placement of atom centers.

Use the three-peg-black atoms  where you see a double bonded carbon in an aa formula, e.g.  as in tyrosine or  as in tryptophan. An exception to this rule is in making this part,  of histidine where you should use 3 four-peg-black atoms  and four long, thin bonding tubes. Also, use the four-peg-black atoms for all other carbon atoms shown.

Use the two-peg yellow  atoms for both sulfur containing aa's.

The nitrogen with a double bond in this part of histidine,  is the only place to use a four-peg-blue atom . In all other aa's use the three-peg-blue atoms .

When a structural formula calls for inserting an atom of oxygen, use the two-peg-red atom . However, when demonstration a hydrogen bond, a three-peg-red atom  will have to be used instead.

II. DISTINGUISHING BETWEEN L- AND D- AMINO ACIDS:

Make a model of L-glycine (refer to the table of the 20 Common Amino Acids), and then make its mirror image. Now place the α carbon of one aa next to the alpha carbon of the other aa, and try to make the four groups on one α carbon align with the same four types of groups on the other aa.

Make a model of L-alanine and its mirror image, D-alanine. Again attempt to make the four groups on one alpha carbon align with the same four types of groups on the other aa.

Answer the questions in Part 1 of the Student Assessment: L- and D-Amino Acids.

III. MAKING A PEPTIDE BOND:

Using the L-alanine and L-glycine, you will make a dipeptide. Remove an -OH from the -COOH of L-alanine and one H- atom from the -NH_2 of L-glycine. Using a long, white tube, connect the exposed peg of the carbon from the L-alanine to the peg of the nitrogen on the L-glycine. Finally, bond the –OH to the H- atom.

Answer the questions in Part 2 of the Student Assessment: The Peptide Bond.

IV. MAKING AN OLIGOPEPTIDE:

Construct five L-aa's. Remove the oxygen with both thin tubes and one hydrogen attached from the -COOH of any four aa's. The one you leave unaltered will be the C terminus. Remove one H- atom from the -NH_2 of every aa except one (the aa left with the hydrogen atom should not be the one that is the C terminus aa). The aa you leave as is will be the N terminus. Using the long, white tubes, connect the peg of the carbon atom of one -CO to a peg of the nitrogen on another aa. Repeat until all aa's are joined in a straight chain. Put the water molecules together.

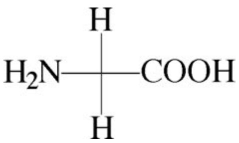
Answer the questions in Part 3 of the Student Assessment: Oligopeptides.

Secondary structure of a polypeptide:

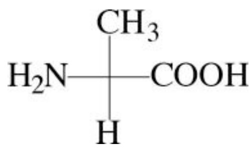
Replace the -H on the nitrogen of the first aa with a two peg hydrogen. Replace the double bonded oxygen of the fifth aa with a three peg oxygen. Twist the bonds of the model so that there are about 3.6 turns between the first and the fifth aa's. Connect the 2 peg hydrogen atom with the 3 peg oxygen atom using a long, white tube.

Answer the questions in Part 4 of the Student Assessment:The Alpha Helix.

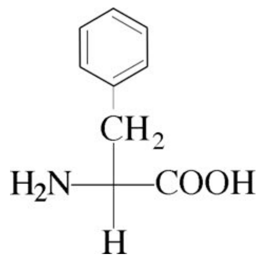
TABLE OF COMMON 20 AMINO ACIDS



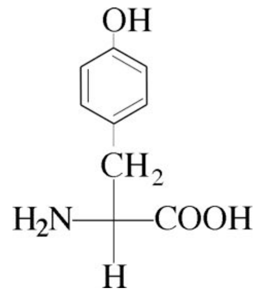
Glycine



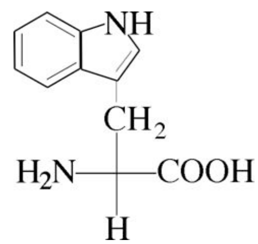
Alanine



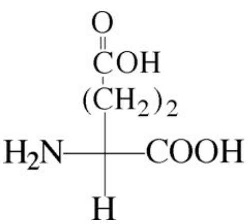
Phenylalanine



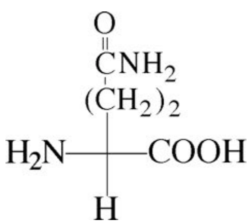
Tyrosine



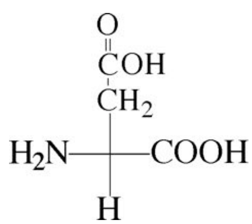
Tryptophan



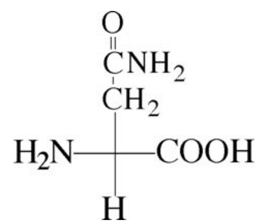
Glutamic acid



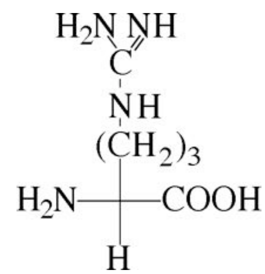
Glutamine



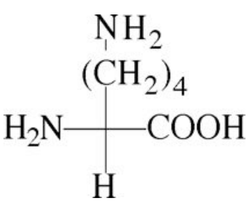
Aspartic acid



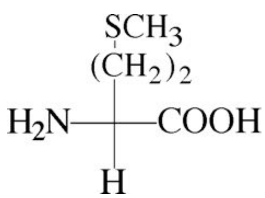
Asparagine



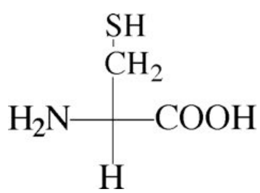
Arginine



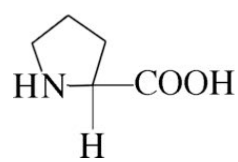
Lysine



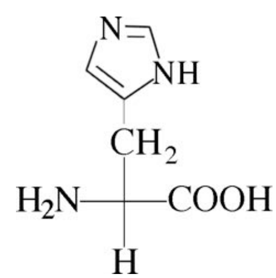
Methionine



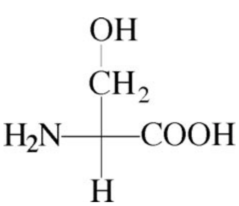
Cysteine



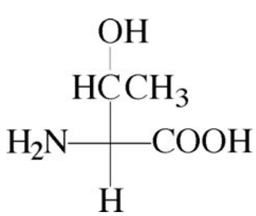
Proline



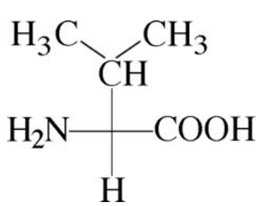
Histidine



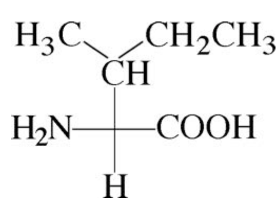
Serine



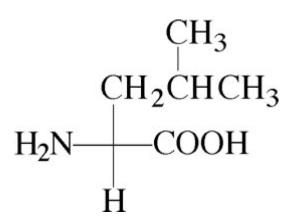
Threonine



Valine



Isoleucine



Leucine

Student Assessment

NAME_________________ CLASS_____ DATE________

PART 1-L and D Amino Acids

1. Are all of the parts of the L-glycine in register with the same kinds of parts in the mirror image?_____
2. Is the arrangement of parts of L- and a D- form of alanine the same?_____
3. How can you determine if a model of alanine is L- or D-?____
____
4. What does an amino group look like?_________________
5. What does an acid group look like?___________________
6. What is an alpha carbon?___________________________________
7. What does a hydroxyl group look like?_____________
8. What is an N terminus?_____________________________________
9. What is a C terminus?______________________________________
10. Complete the following table, and have it checked by your instructor.

Amino Acid Name	L Strucural Formula	D Strucural Formula	Model Checked
Glycine			
Alanine			

PART 2-The Peptide Bond

1. What is the term for the molecule created by forming one peptide bond?________________
2. When two amino acids are joined, another product is formed. What is it?_______________
3. What is the name of the bond that the white tube represents?___________________________
4. Have your model checked by your instructor.______________

PART 3-Oligopeptides

1. What is an oligopeptide?____
2. How many water molecules were made along with the oligopeptide?_________
3. What is the name of the bond that the white tube represents?___________________________
4. Have your model checked by your instructor.______________
5. Is the oligopeptide a 1^{o}, 2^{o}, 3^{o}, or 4^{o} structure?____________
6. What are three examples of secondary protein structures? ________________________
   ______________________________, and ______________________________

PART 4-The Alpha Helix

1. What is an alpha helix?____
2. What type of bond holds the alpha helix in its particular shape?_________________________
3. If a polypeptide is 35 aa's long, how many hydrogen bonds would be in the molecule?___________
4. Have your model checked by your instructor.______________

Answers to Student Assessment.

PART 1-L and D Amino Acids

1. No.
2. No.
3. Determine atomic weight values. Place the number four atom so it points away from observer. Trace an arc from number one to number two to number three groups. If the motion is clockwise, the molecule is D, if counterclockwise, the molecule L.
4. NH_2.
5. COOH.
6. The first carbon away from the acid carbon.
7. OH.
8. The left end of an amino acid (or dipeptide, etc.) with an NH_2.
9. The right end of an amino acid (or dipeptide, etc.) with a COOH.
10. Teacher checks models.

PART 2-The Peptide Bond

1. Dipeptide.
2. H_2O.
3. Hydrogen bond.
4. Teacher checks models.

PART 3-Oligopeptides

1. Four or more amino acids bonded together, up to about 10.
2. Four.
3. Hydrogen.
4. Teacher checks models.
5. 1° (primary).
6. Alpha helix, parallel pleated sheet, antiparallel pleated sheet.

PART 4-The Alpha Helix

1. It is the secondary protein structure that results from the twisting of a polypeptide into a right handed spiral held in that shape by hydrogen bonds.
2. Hydrogen.
3. Seven (35/5); one H bond for every five aa's.
4. Teacher checks models.