# Fundamentals of Organic Chemistry

## CHEM 109

*For Students of Health Colleges*

**Credit hrs.: (2+1)**

*King Saud University*

College of Science, Chemistry Department



## CHAPTER 9. AMINO ACIDS, PEPTIDES AND PROTEINS

# Learning Objectives

## At the end of this chapter, students will able to:

- Predict the different type of amino acids.
- Recognize the basic properties (structure, physical and chemical properties) of amino acids.
- Predict whether the acid and amine groups in amino acids will be protonated at different pH values
- know how to prepare amino acids.
- Describe the primary, secondary, tertiary and quaternary structure of proteins

# Sources, Classification and Structure of Amino Acids



- **Proteins are naturally occurring polymers (polypeptides) composed of α-amino acids units joined one to another by amide (or peptide) bonds.**

  **Example,** animal hair and muscle, egg whites, and hemoglobin are all proteins.

- **Peptides** are oligomers of amino acids that play important roles in many biological processes.

  **Example,** the peptide hormone insulin controls our blood sugar levels.

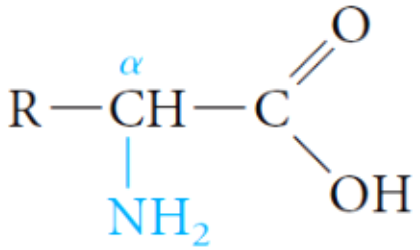
- **Peptides are classified to dipeptides, tripeptides, tetrapeptides, etc.. According to the number of amino acids in the chain.**

- **Proteins, peptides, and amino acids** are essential to the structure, function, and reproduction of living matter.

# Sources, Classification and Structure of Amino Acids



- **The amino acids** obtained from protein hydrolysis are α-amino acids.
- **The amino group** is on the **α -carbon atom**, the one adjacent to the carboxyl group.

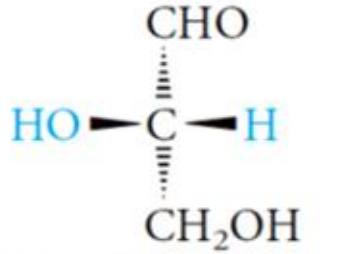



an α-amino acid

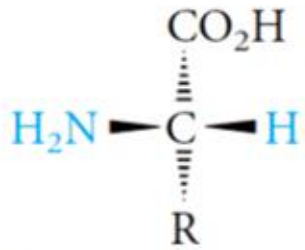
- With the exception of glycine, where R = H, a-amino acids have a stereogenic center (chiral carbon) at the α -carbon.
- All except glycine are therefore **optically active**.
- All natural amino acids **L-configuration** relative to glyceraldehyde.
- **Note that the Fischer convention**, used with carbohydrates, is also applied to amino acids.

# Sources, Classification and Structure of Amino Acids

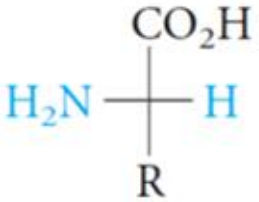




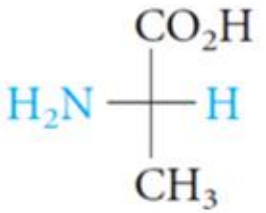

L-(−)-glyceraldehyde



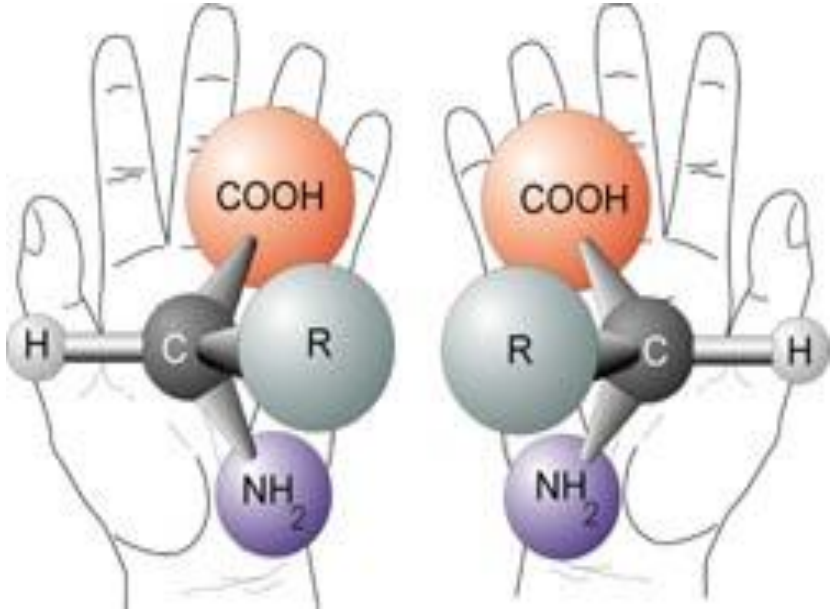

a naturally occurring L-amino acid




Fischer projection formula of an L-amino acid




L-(+)-alanine

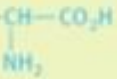
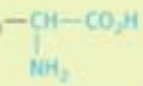
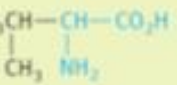
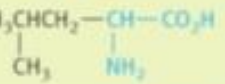
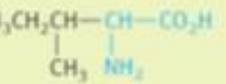
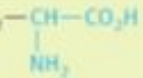
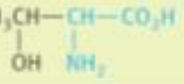


# Sources, Classification and Structure of Amino Acids



## List of the 20 α-amino acids commonly found in proteins.

**Table 17.1 Names and Formulas of the Common Amino Acids**

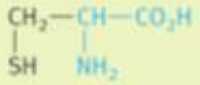
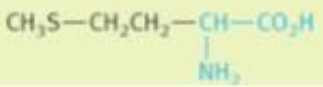
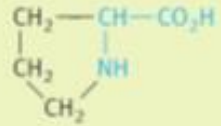
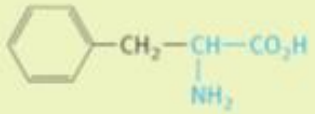
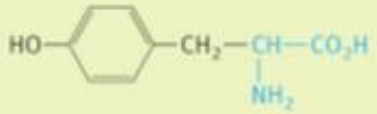
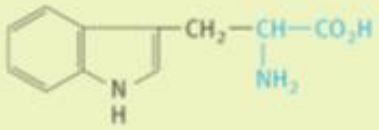
| Name | Three-letter abbreviation (isoelectric point) one-letter abbreviation | Formula | R |
|---|---|---|---|
| **A. One amino group and one carboxyl group** | | | |
| 1. glycine | Gly (6.0) G |  | |
| 2. alanine | Ala (6.0) A |  | |
| 3. valine | Val (6.0) V |  | R is hydrogen or an alkyl group. |
| 4. leucine | Leu (6.0) L |  | |
| 5. isoleucine | Ile (6.0) I |  | |
| 6. serine | Ser (5.7) S |  | |
| 7. threonine | Thr (5.6) T |  | R contains an alcohol function. |

*(continued)*

# Sources, Classification and Structure of Amino Acids



**Table 17.1 Names and Formulas of the Common Amino Acids**

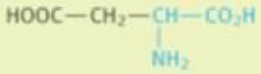
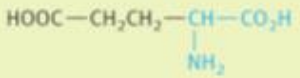
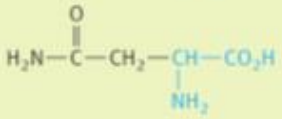
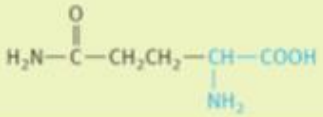
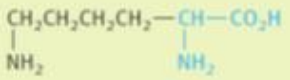
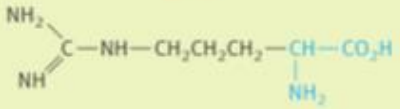
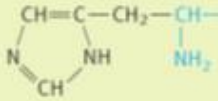
| Name | Three-letter abbreviation (isoelectric point) one-letter abbreviation | Formula | R |
|---|---|---|---|
| 8. cysteine | Cys (5.0) C |  | |
| 9. methionine | Met (5.7) M |  | R contains sulfur. |
| 10. proline | Pro (6.3) P |  | The amino group is secondary and part of a ring. |
| 11. phenylalanine | Phe (5.5) F |  | |
| 12. tyrosine | Tyr (5.7) Y |  | One hydrogen in alanine is replaced by an aromatic or heteroaromatic (indole) ring. |
| 13. tryptophan | Trp (5.9) W |  | |

*(continued)*

# Sources, Classification and Structure of Amino Acids



Table 17.1 (continued)

| Name | Three-letter abbreviation (isoelectric point) one-letter abbreviation | Formula | R |
|---|---|---|---|
| **B. One amino group and two carboxyl groups** | | | |
| 14. aspartic acid | Asp (3.0) D |  | |
| 15. glutamic acid | Glu (3.2) E |  | |
| 16. asparagine | Asn (5.4) N |  | |
| 17. glutamine | Gln (5.7) Q |  | |
| **C. One carboxyl group and two basic groups** | | | |
| 18. lysine | Lys (9.7) K |  | The second basic group is a primary amine, a guanidine, or an imidazole. |
| 19. arginine | Arg (10.8) R |  | |
| 20. histidine | His (7.6) H |  | |

# Sources, Classification and Structure of Amino Acids



- **The amino acids** are known by common names.
- Each also has a **three-letter abbreviation** based on this name, which is used when writing the formulas of peptides, and a one-letter abbreviation used to describe the amino acid sequence in a protein.

  For example; Glycine= Gly; Alanine = Ala; Valine = Val, etc..

- **The amino acids are classified into:**
  - **Essential amino acids**

    *Eight amino cannot be synthesized by adult humans and therefore must be included in the diet in the form of proteins.*

    e.g. Valine, Leucine, Isoleucine, Threonine, Methionine, Phenylalanine, Tryptophan, and Lysine.

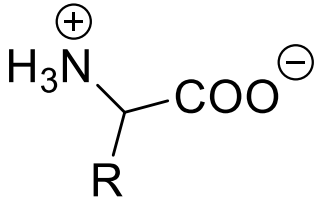
  - **Non-essential amino acids**

    *Twelve amino acids can be synthesized in the body from other foods.*

    e.g. Glycine, Alanine, Serine, Cysteine, Proline, Tyrosine, Aspartic acid, Glutamic acid, Asparagine, Glutamine, Arginine, and Histidine.

# Sources, Classification and Structure of Amino Acids

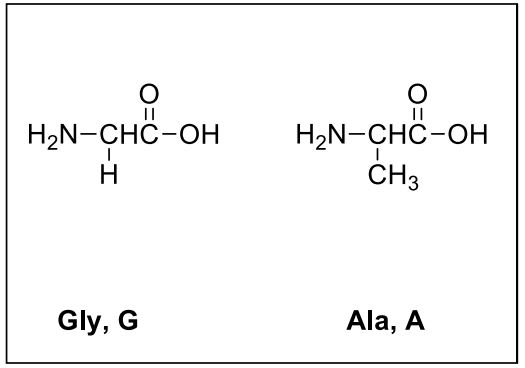
**Classification** - Amino acids are classified on the basis of the structure of R



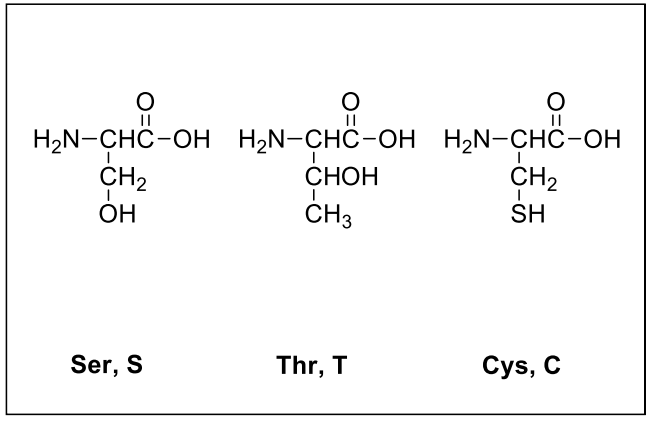

- **Aliphatic side chains non-polar amino acids:** such as Alanine, Valine, Leucine, etc **…..hydrophobic**
- **Polar side chains:** are containing HO-, SH- and amide groups, such as Serine, Cystein **---- hydrophilic**
- **Acidic:** are containing more than one COOH group, such as Aspartic, Glutamic------ **hydrophilic**
- **Basic:** are containing more than one N atom, Such as Lysine, Arginine------**hydrophilic**
- **Heterocyclic/Aromatic** – Such as Histidine----**hydrophilic or hydrophobic**

# Sources, Classification and Structure of Amino Acids

**Aliphatic side chains** – hydrophobic

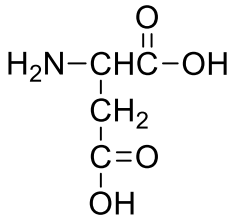



**Polar side chains** – text classifies as HO-, S-, and amide containing – hydrophilic

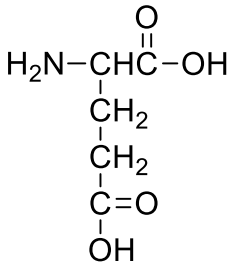


# Sources, Classification and Structure of Amino Acids

**Acidic** – hydrophilic

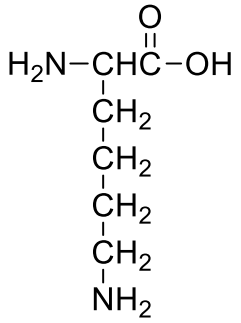


Asp, D

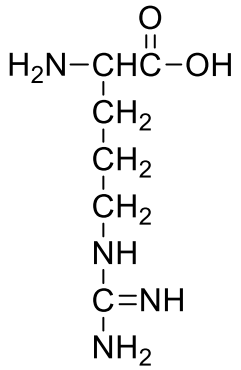


Glu, E

**Basic** – hydrophilic

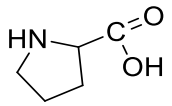


Lys, K

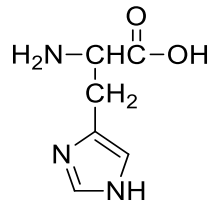


Arg, R

**Heterocyclic/Aromatic** – hydrophilic or hydrophobic



Pro, P



His, H

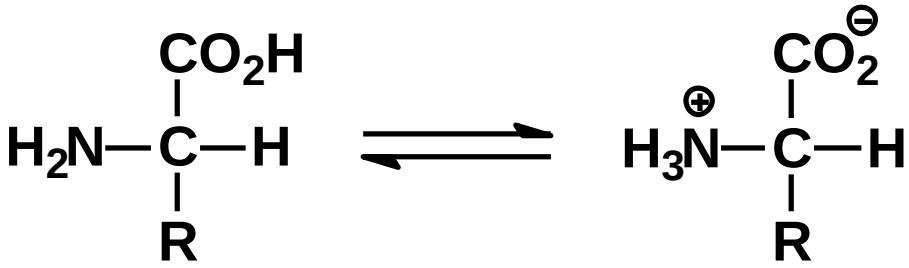
# The Acid–Base Properties of Amino Acids



- **Amino acids** are classified according to the side chain into:

  i) Neutral amino acids, such as Glycine, Alanine, Valine, etc..
  ii) Basic amino acids, such as Arginine, Lysine (they have extra amino group)
  iii) Acidic amino acid, such as Aspartic and Glutamice (they have extra carboxylic group)

- **Acid–Base Properties**
  - Since amino acids have both an acidic functionality and a basic functionality, we should expect the following equilibrium:



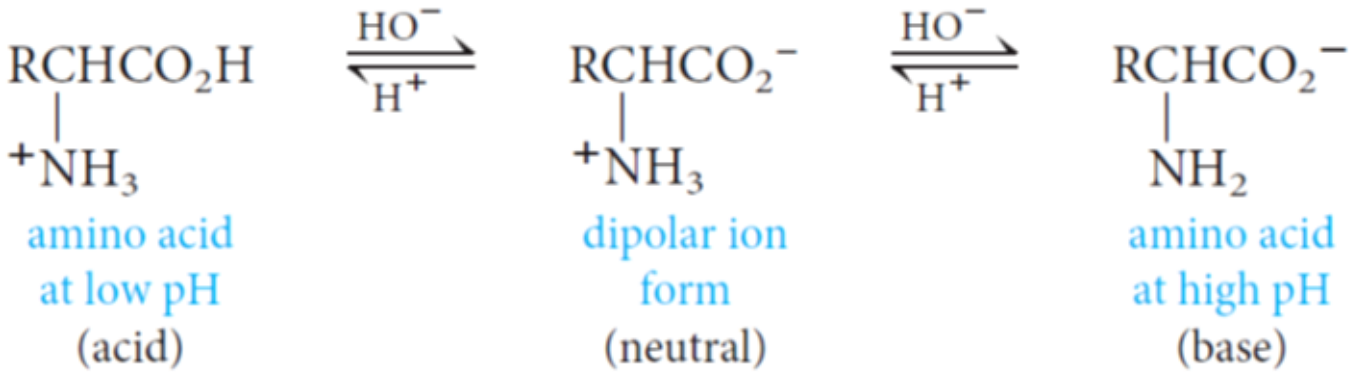

  - In fact, the equilibrium lies to the right  all amino acids are charged at any pH!
  - Such species that are overall neutral molecules but contain charged ends are called ***zwitterions***

# The Acid–Base Properties of Amino Acids



- The **amino group** is protonated and present as an ammonium ion, whereas the carboxyl group has lost its proton and is present as a carboxylate anion.
- This **dipolar structure** is consistent with the salt-like properties of amino acids, which have rather high melting points and relatively low solubility in organic solvents.
- **Amino acids are *amphoteric*.**

  *They can behave as acids and donate a proton to a strong base, or they can behave as bases and accept a proton from a strong acid.*

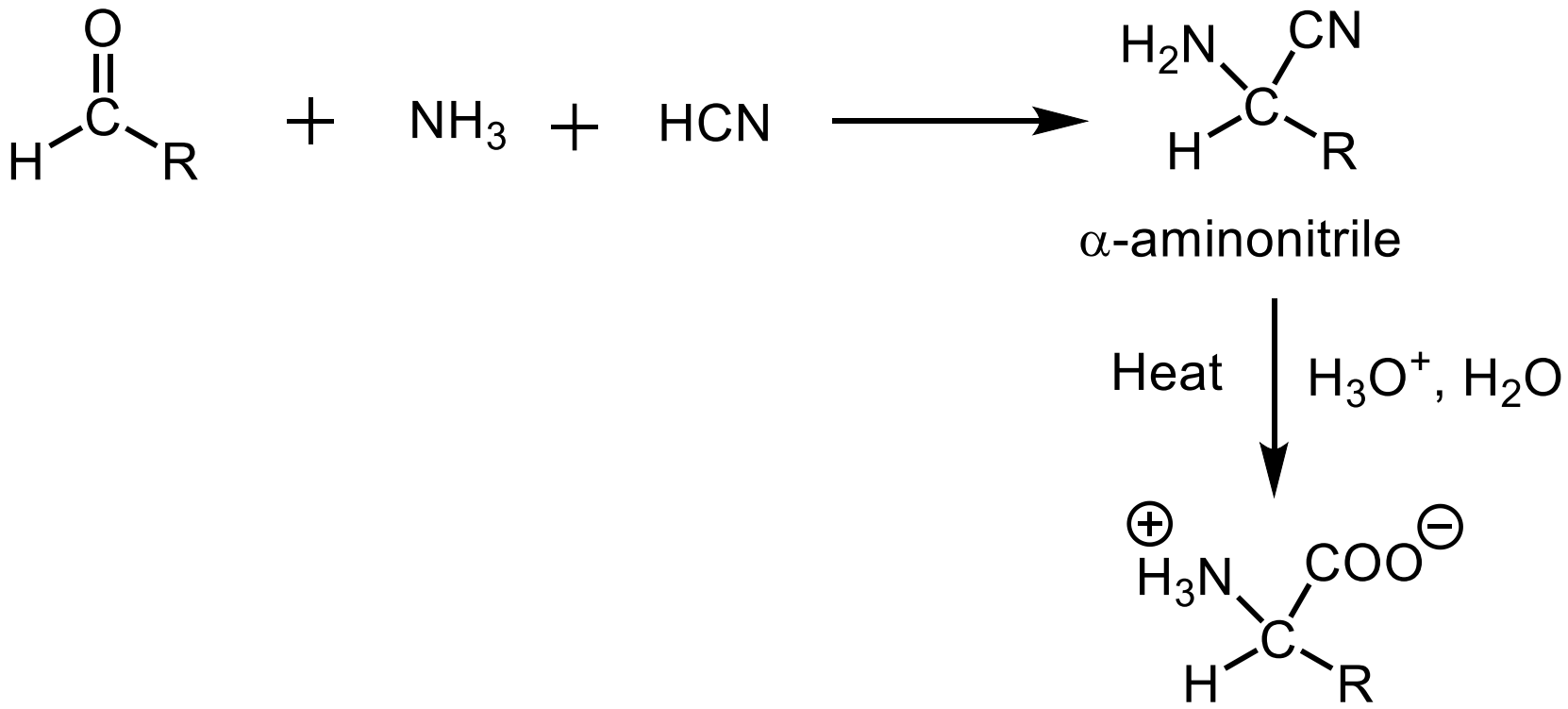



- The **isoelectric point (pI)**, the amino acid will be dipolar and have a net charge of zero.

# Synthesis of Amino Acids



**Strecker Synthesis:** **Recall reductive amination and Cyanohydrin formation.**

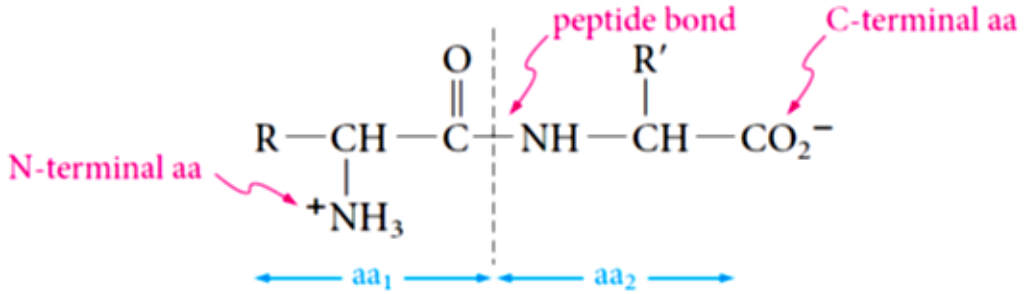


# 2) Formation of an amide linkage
## (The peptide bond: Proteins)

# Reactions of Amino Acids



- **Amino acids** are linked in **peptides and proteins** by an amide bond (***peptide bond***) between the carboxyl group of one amino acid and the α-amino group of another amino acid.
- A molecule containing only *two* amino acids (the shorthand aa is used for amino acid) joined in this way is a **dipeptide**:



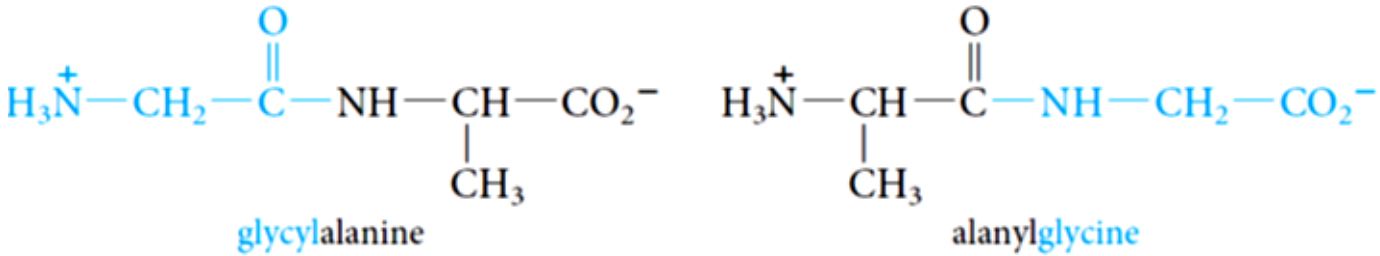

- By convention, the **peptide bond** is written with the amino acid having a free $^{+}NH_3$ group at the left and the amino acid with a free $CO_2^-$ group at the right.
- These amino acids are called, respectively, the **N-terminal amino** acid and the **C-terminal** amino acid.

# 2) Formation of an amide linkage
## (The peptide bond: Proteins)

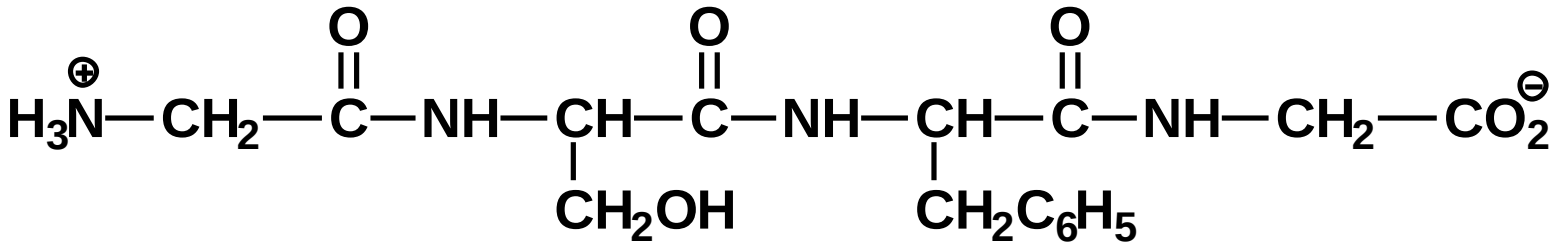
# Reactions of Amino Acids



- We often write the formulas for peptides in a kind of shorthand by simply linking the **three-letter abbreviations for each amino acid**, *starting with the N-terminal one at the left.*
- **For example;** glycylalanine is Gly—Ala, and alanylglycine is Ala—Gly.




**A tetrapeptide** **glycylserylphenylalanylglycine = gly-ser-phe-gly**



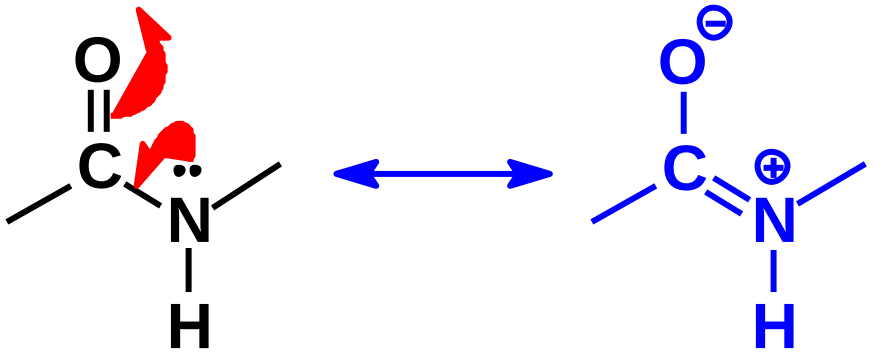
# The peptide bond: Proteins

## The Peptide (Amide) Bond

The amide nitrogen is $sp^2$ hybridized and the lone pair is conjugated with the carbonyl group

There is considerable C–N double-bond character

Rotation about the C–N bond is difficult



# Structure of Proteins



- **Proteins** are biopolymers composed of many amino acids connected to one another through amide (peptide) bonds.
- Some **proteins** are major components of structural tissue (muscle, skin, nails, and hair).
- Others transport molecules from one part of a living system to another.

- **The main features of peptide and protein structure.**
  - ***Primary structure;***

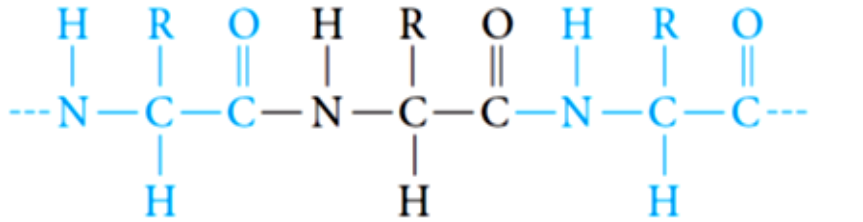
    *How many amino acids are present and what their sequence is in the peptide or protein chain.*
  - ***Secondary, tertiary, and quaternary structures;***

    *Three-dimensional aspects of peptide and protein structure, usually referred to as their.*

# The Primary Structure of Proteins



- The **backbone of proteins** is a repeating sequence of one nitrogen and two carbon atoms.



protein chain, showing amino acids linked by amide bonds

- **Peptides and proteins** can be hydrolyzed to their amino acid components by heating with 6 M HCl.
- An instrument called an **amino acid analyzer** is used to determine the amino acids mixture.

# Uses of Amino Acids

- Amino acids, often referred to as the building blocks of proteins, are compounds that play many critical roles in your body.
- They're needed for vital processes like the building of proteins and synthesis of hormones and neurotransmitters.
- Phenylalanine plays an integral role in the structure and function of proteins and enzymes and the production of other amino acids.
- Valine helps stimulate muscle growth and regeneration and is involved in energy production.
- Leucine helps to regulate blood sugar levels, stimulates wound healing and produces growth hormones.