# Chem 452 - Lecture 2
# Protein Structure
# 110921

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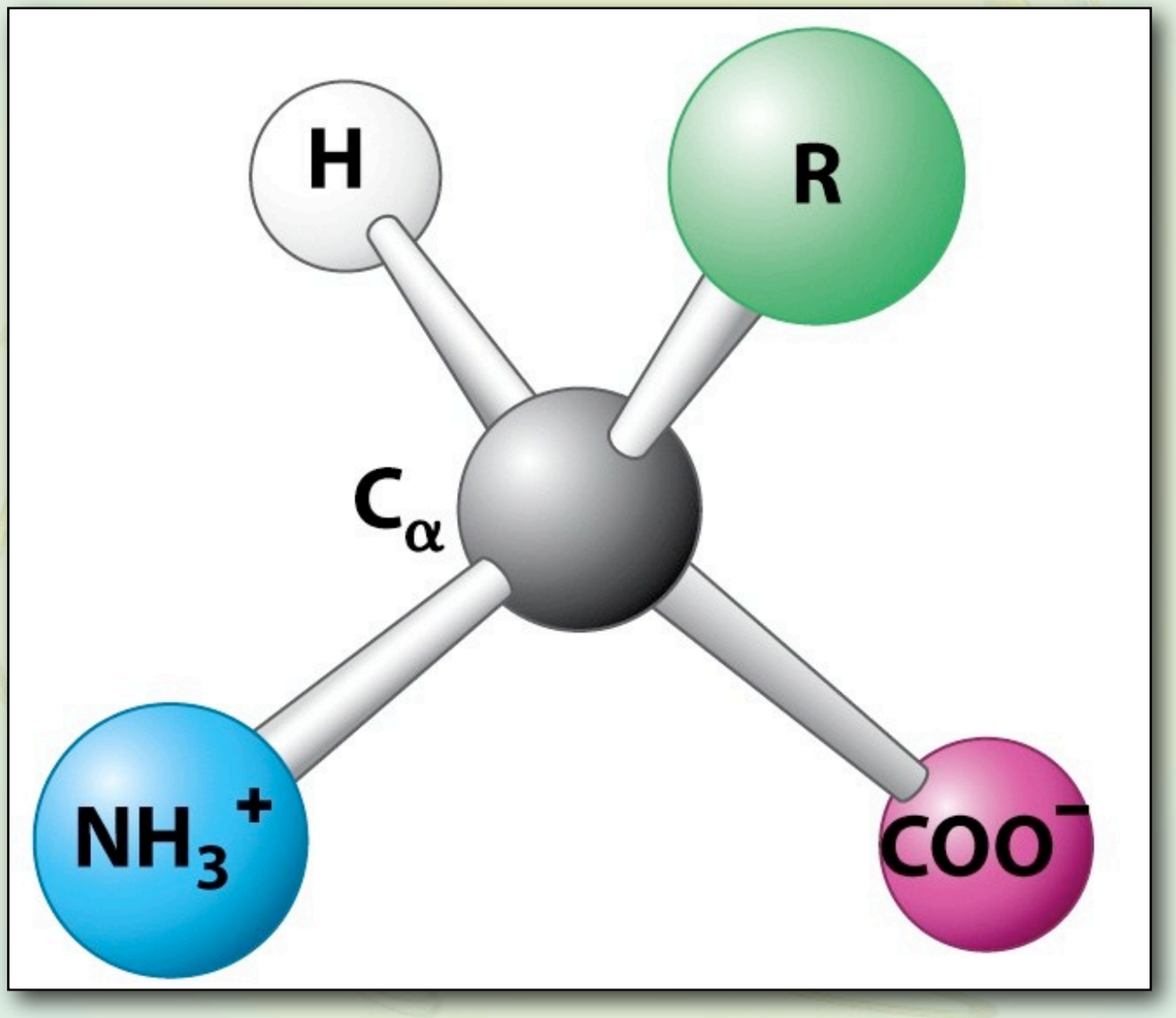
Proteins are the workhorses of a living cell and involve themselves in nearly all of the activities that take place in a cell. Their wide range of structures are manifested by the wide range of 3-dimensional structures that they are able to possess. Proteins are linear polymers of amino acids, whose sequence is determined by the sequence of DNA base pairs in their corresponding gene. The connection between this linear sequence of amino acids for a protein and its 3-dimensional structure will be the focus of this lecture.

# The Amino Acids

- Proteins are polymers of amino acids
- There are 20 naturally occurring amino acids that are the building blocks used to make proteins.

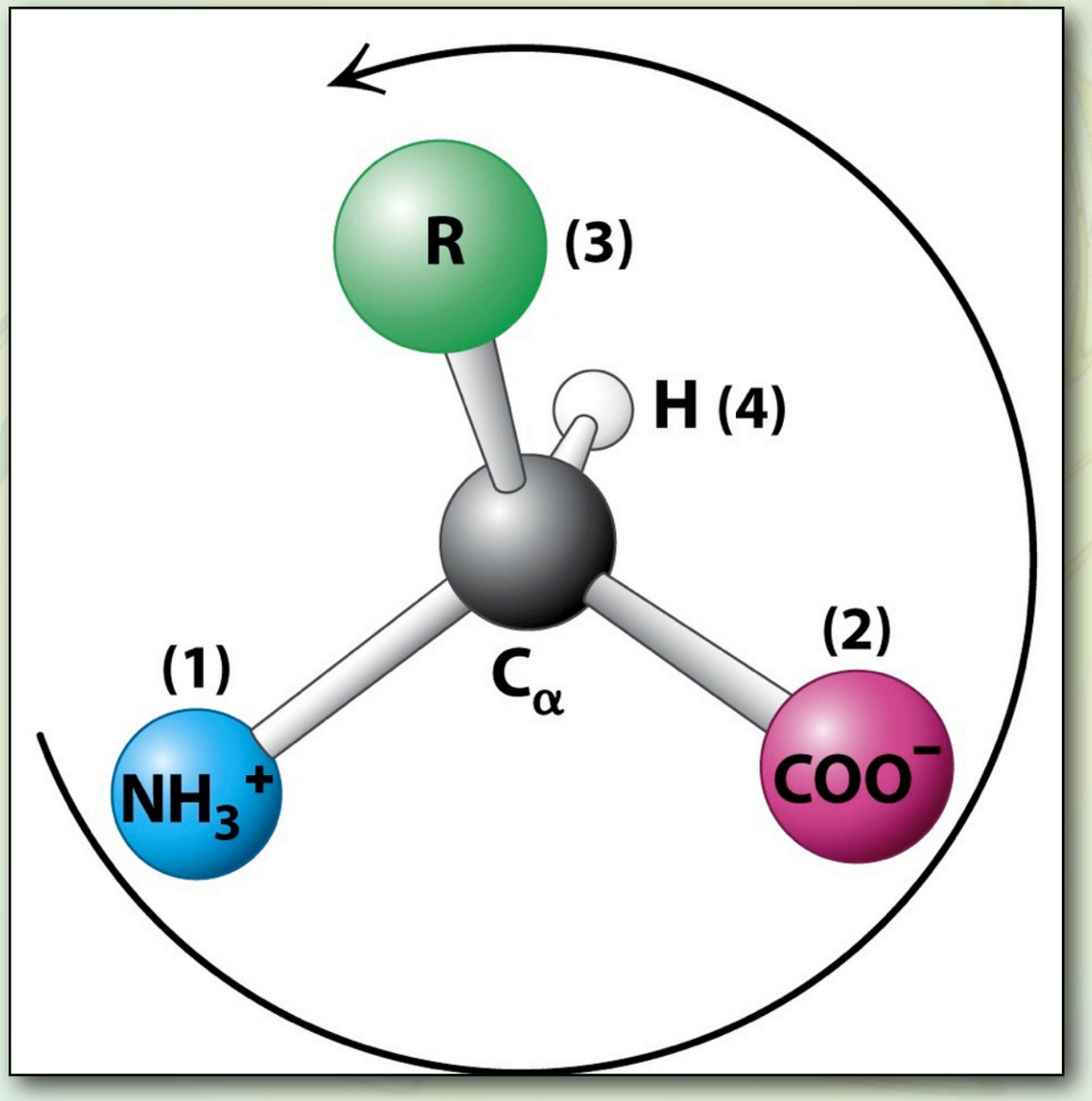
# The Amino Acids

- What they share in common



# The Amino Acids

- What they share in common



# The Amino Acids

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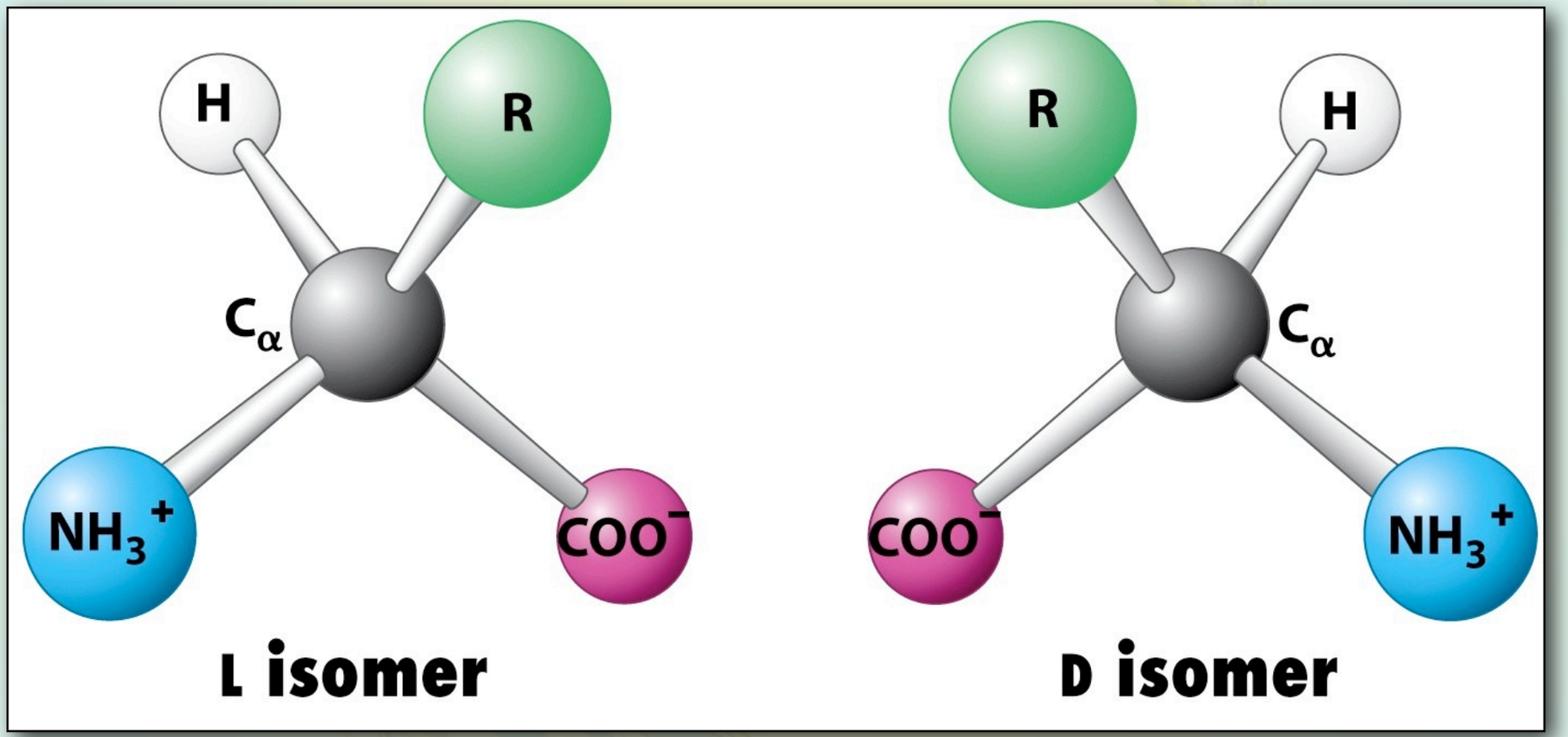

# The Amino Acids

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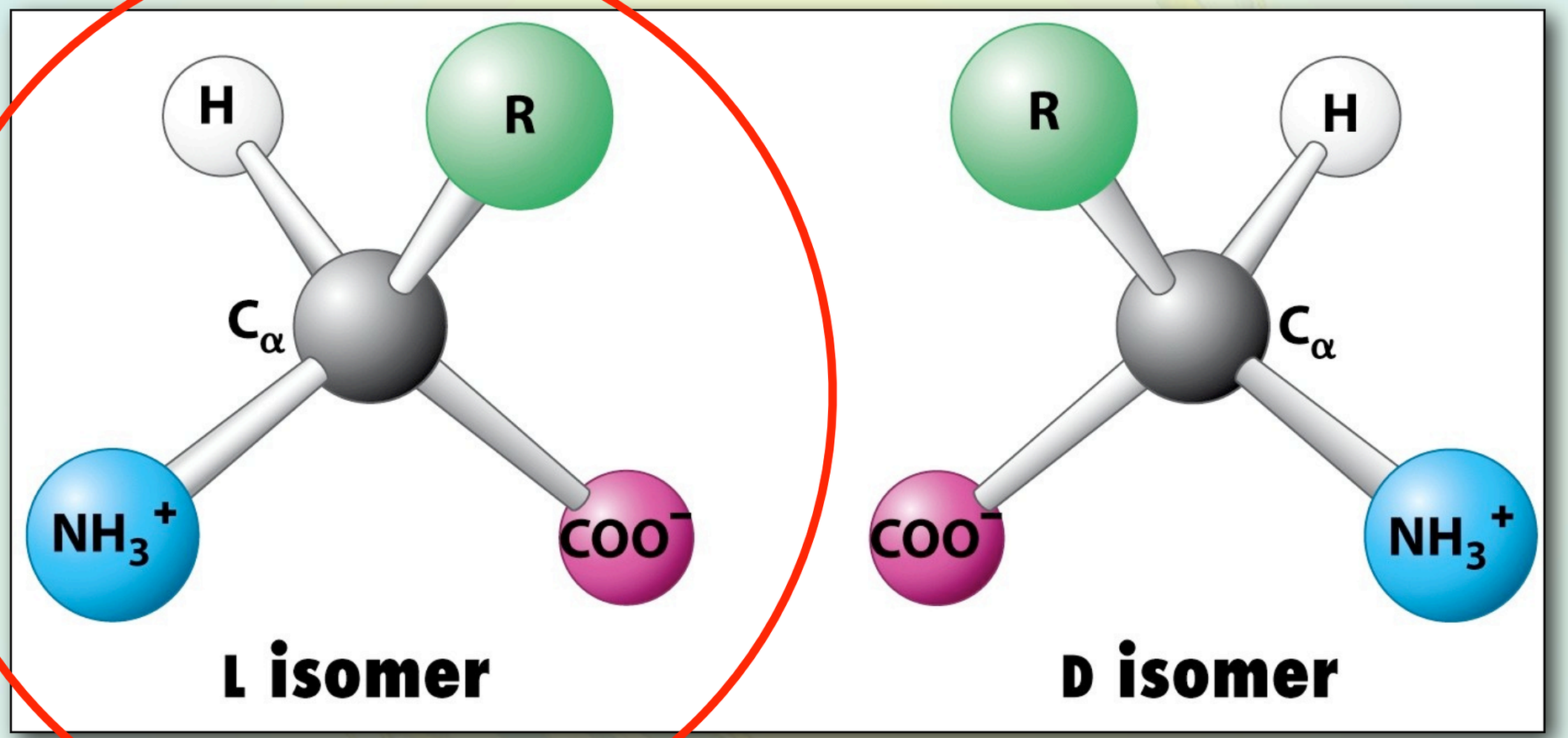
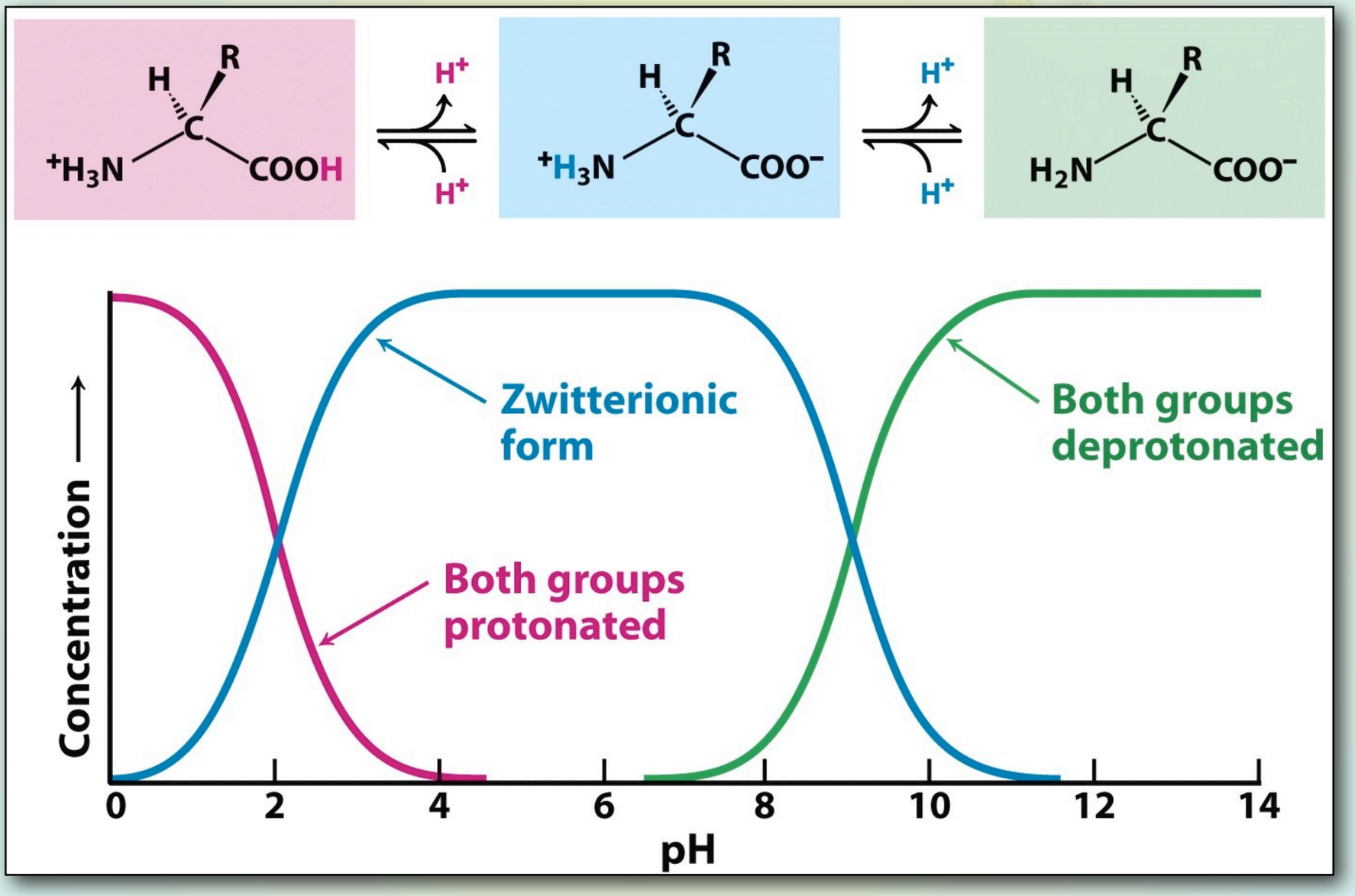


# The Amino Acids

- What they share in common

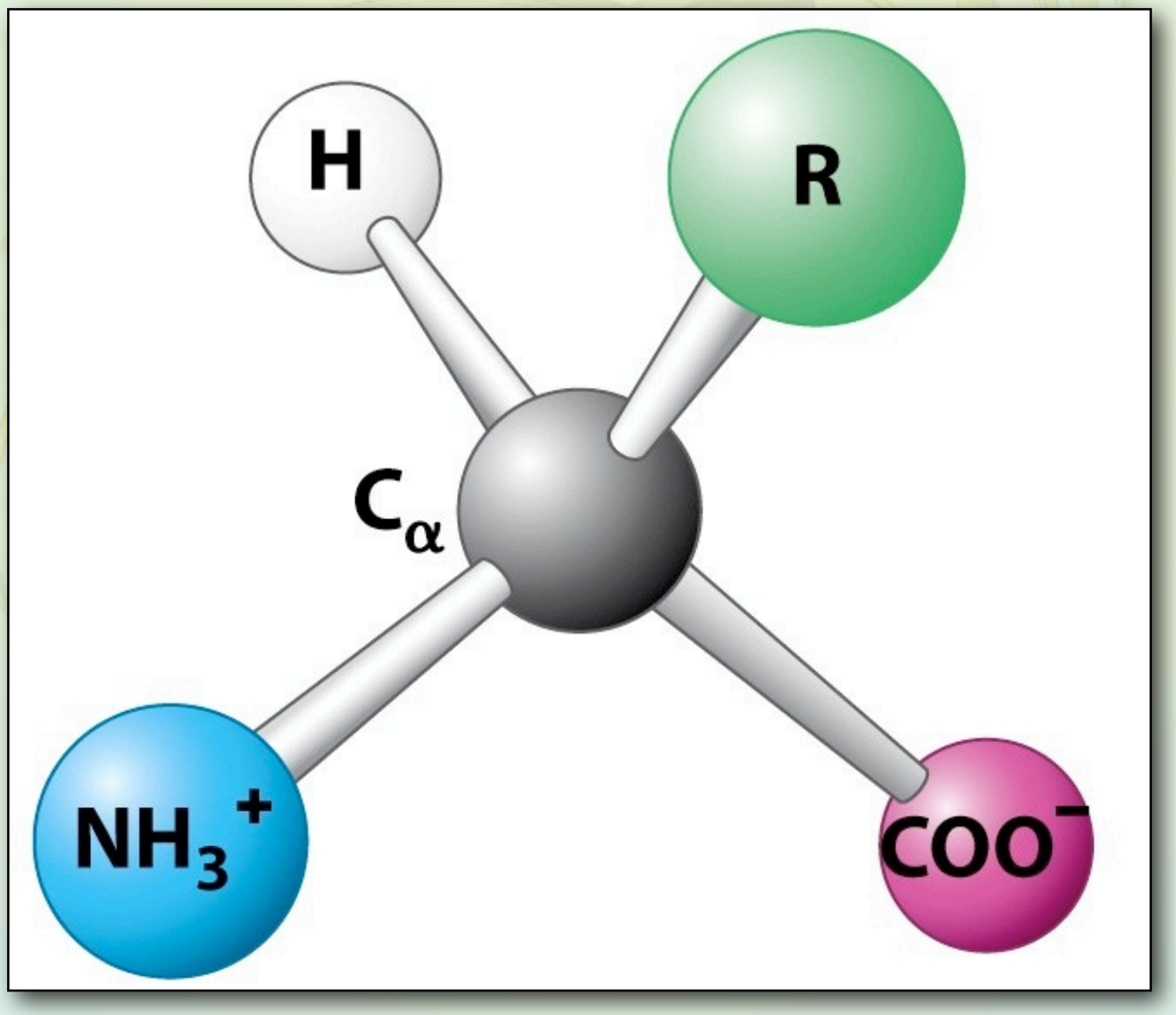


# The Amino Acids

- What they share in common
- The common regions of each amino acid is what joins together to form a polymer of amino acids.

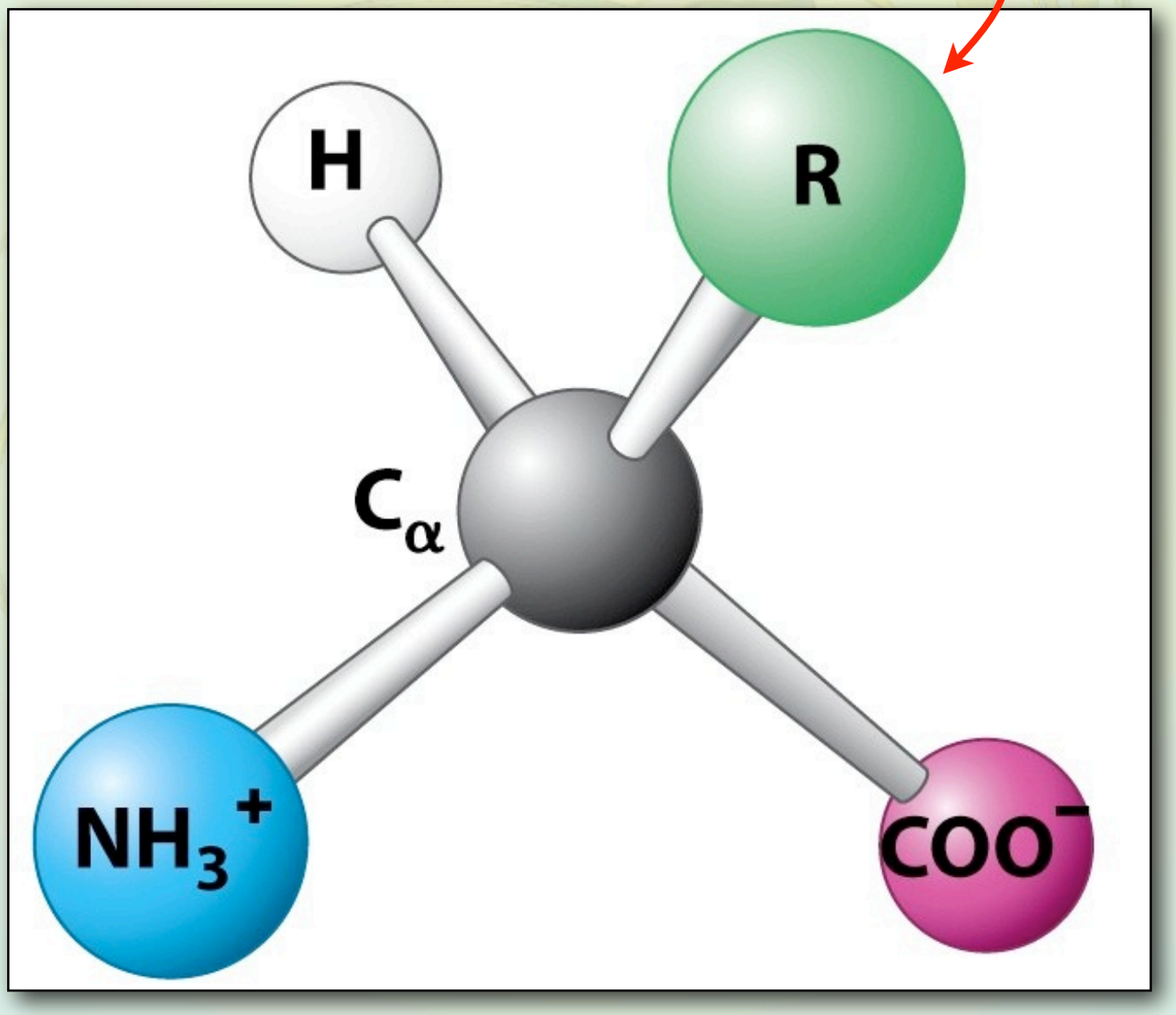
# The Amino Acid Side Chains

- The 20 amino acids are distinguished by their side chains.



# The Amino Acid Side Chains

- The 20 amino acids are distinguished by their side chains.



# Genomics

- The genetic code (1960's)

DNA: A G T C

↓ transcription

mRNA: U C A G

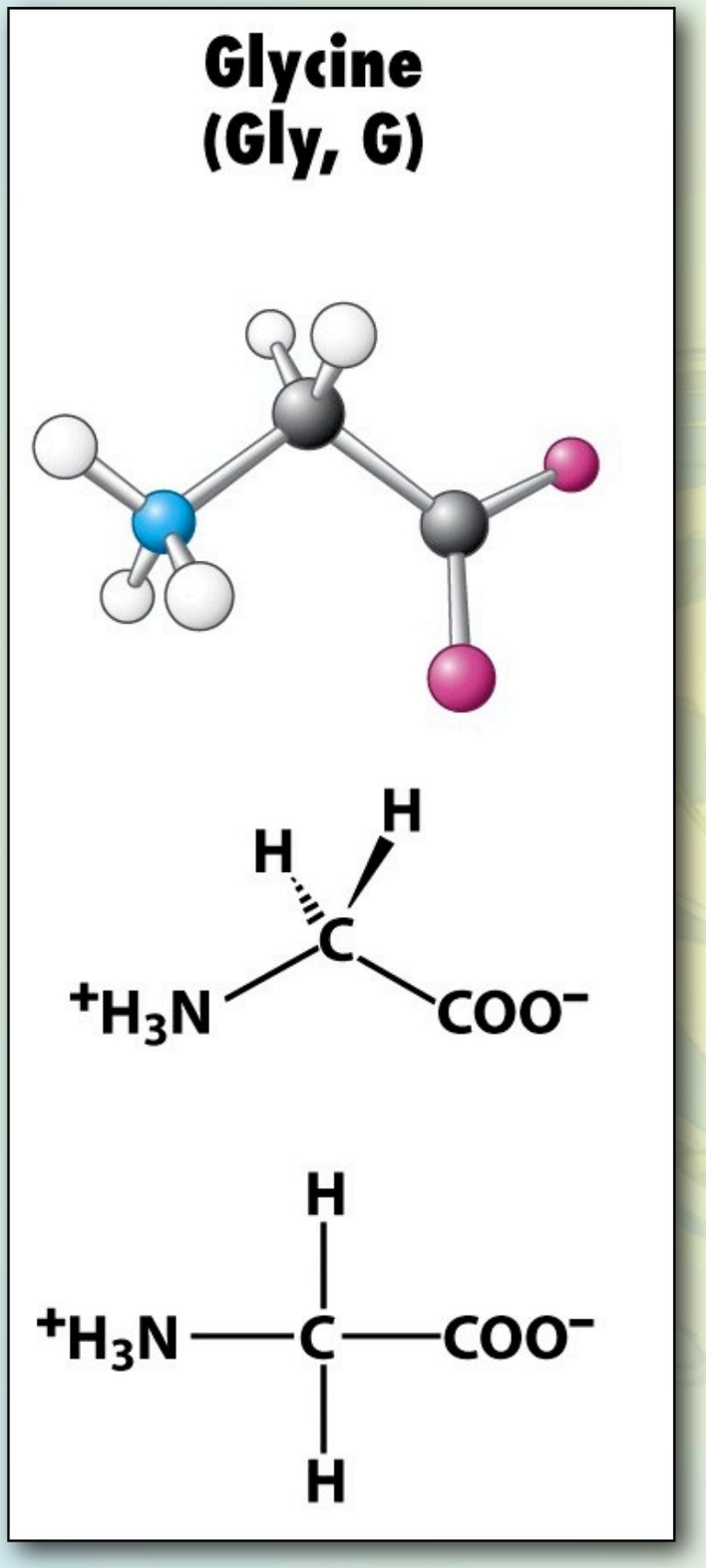
↓ translation

Protein: A C D E F G H I K L M N P Q R S T V W Y

# The Amino Acid Side Chains

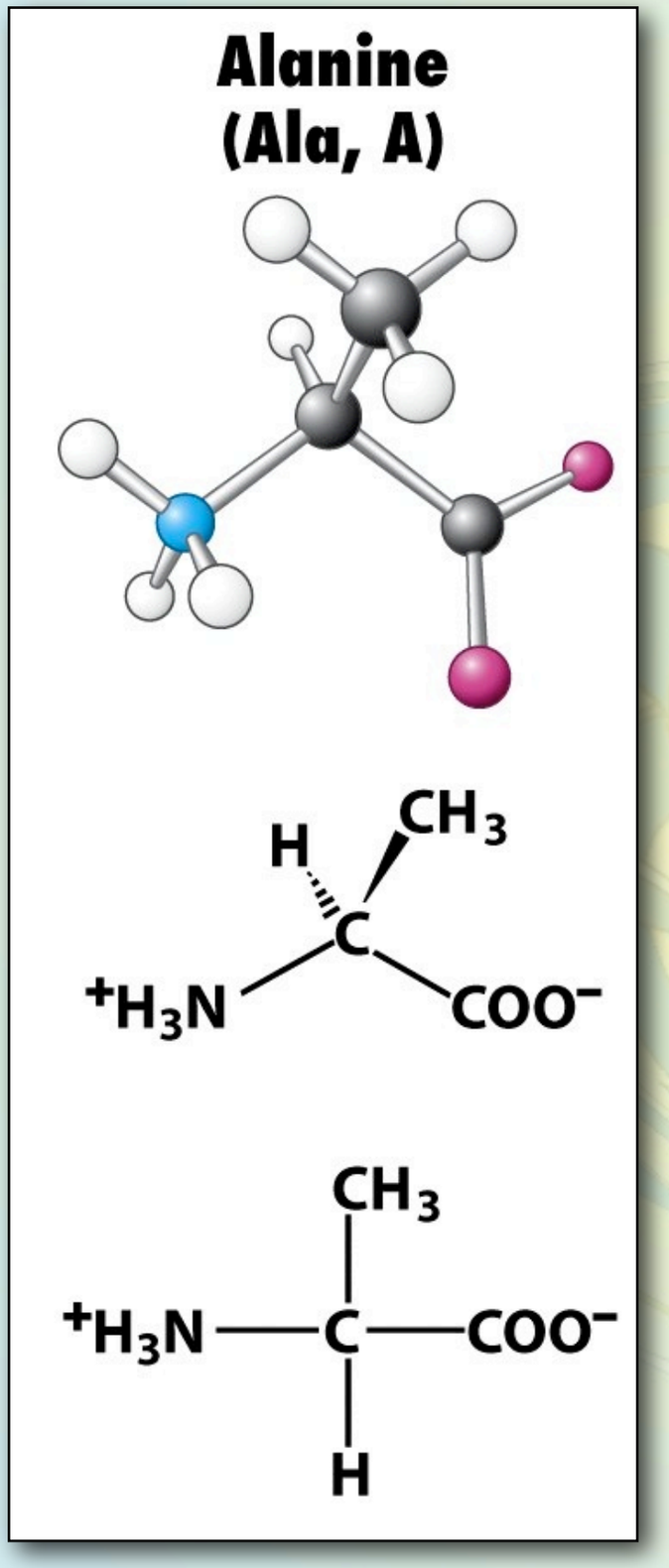
- The side chains display differences in
  - Physical properties
    - Non-polar (hydrophobic)
    - Polar (hydrophillic)
      - Polar Charged (acids and bases)
      - Polar neutral (hydrogen bonders)
  - Chemical properties
    - Acids
    - Bases
    - Nucleophiles

# The Amino Acid Side Chains



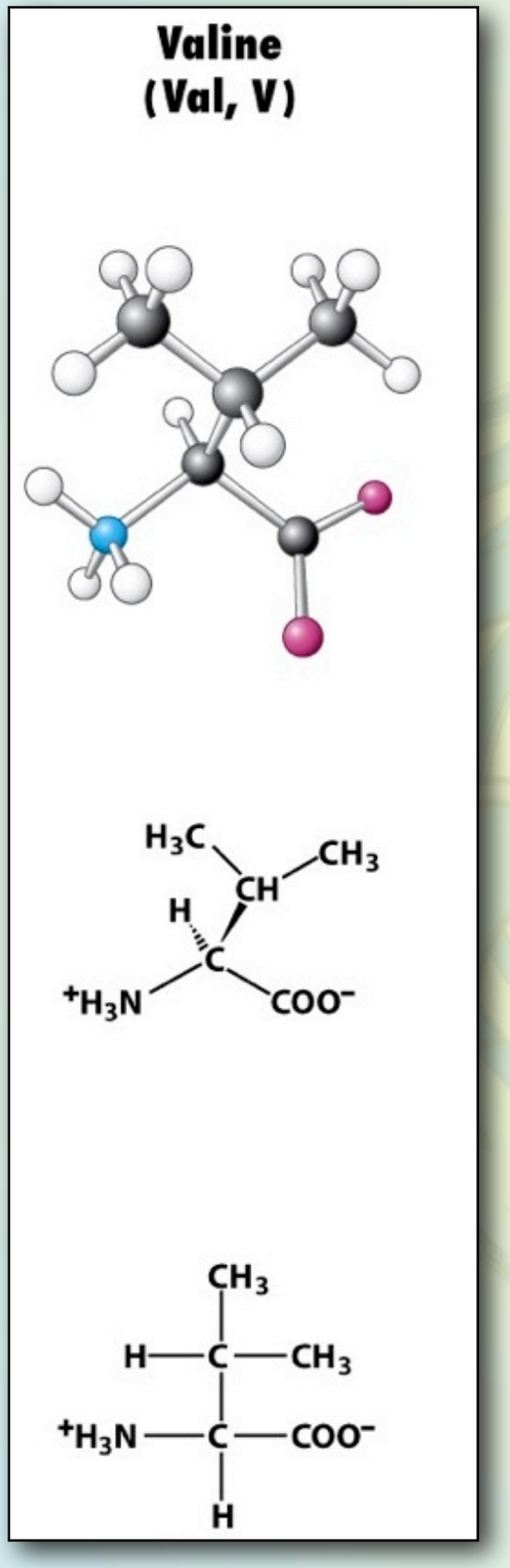

- Non-polar
- Side chain
  - Hydrogen
- Size
  - Small
- Note
  - Conformationally, the most flexible

# The Amino Acid Side Chains



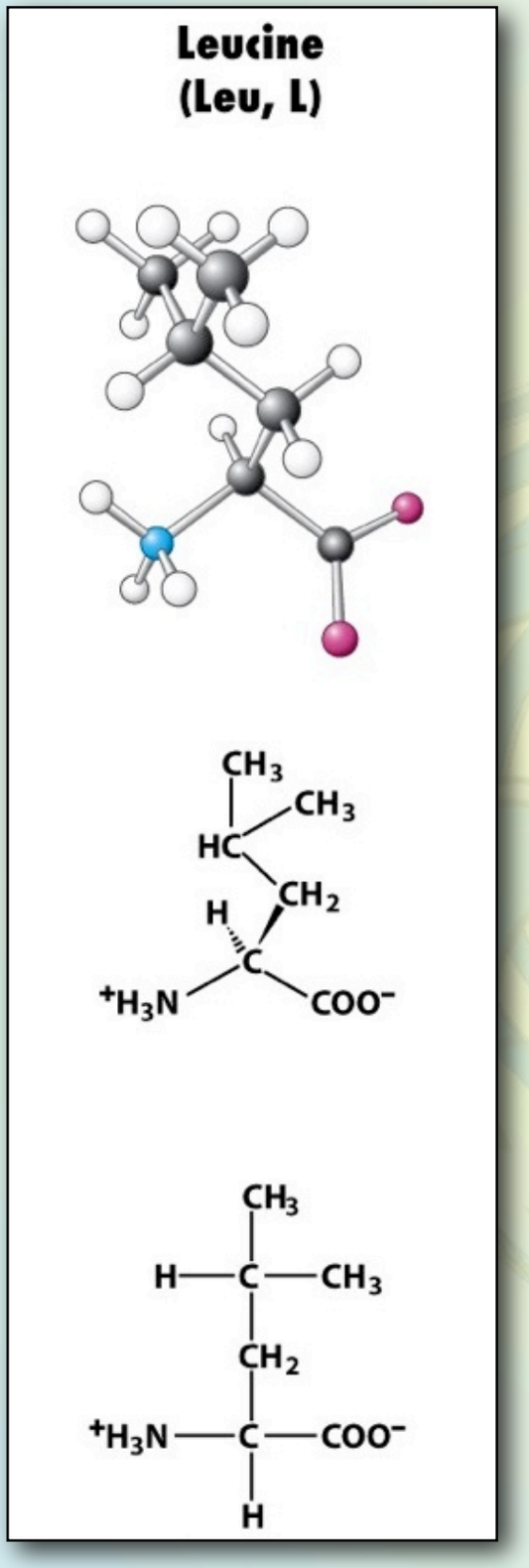

- Non-polar
- Side chain
  - Methyl group (Aliphatic)
- Size
  - small

# The Amino Acid Side Chains



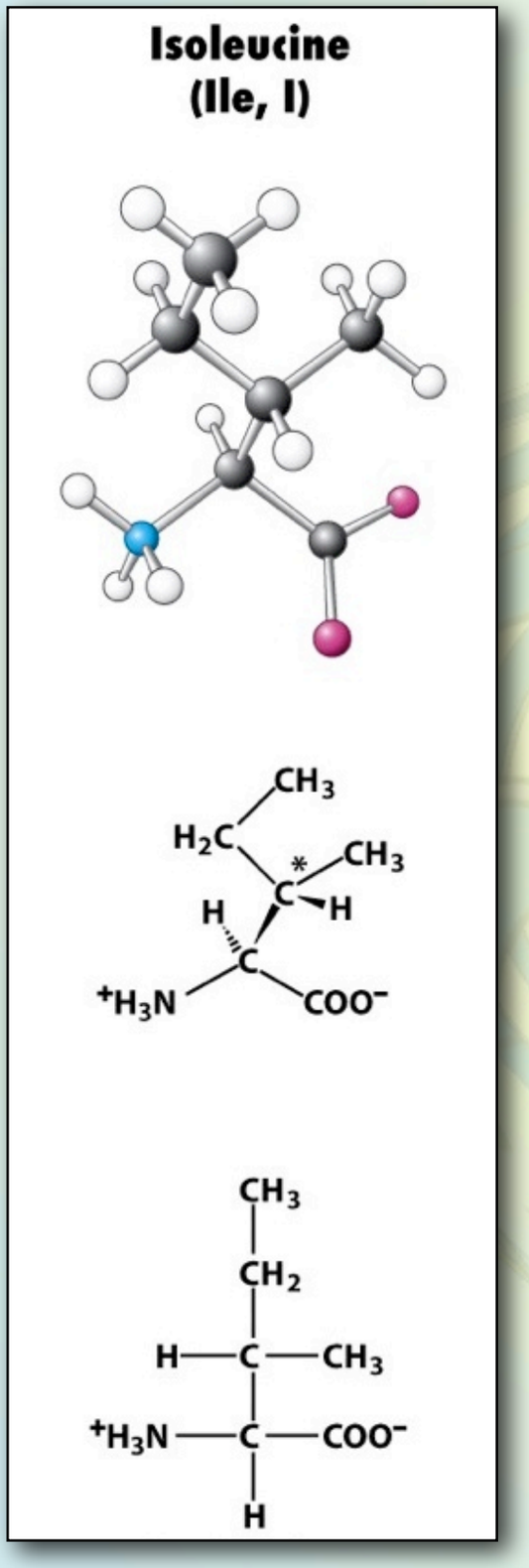

- Non-polar
- Side chain
  - Isopropyl group (Aliphatic)
- Size
  - Medium
- Note
  - Branched at β-carbon

# The Amino Acid Side Chains



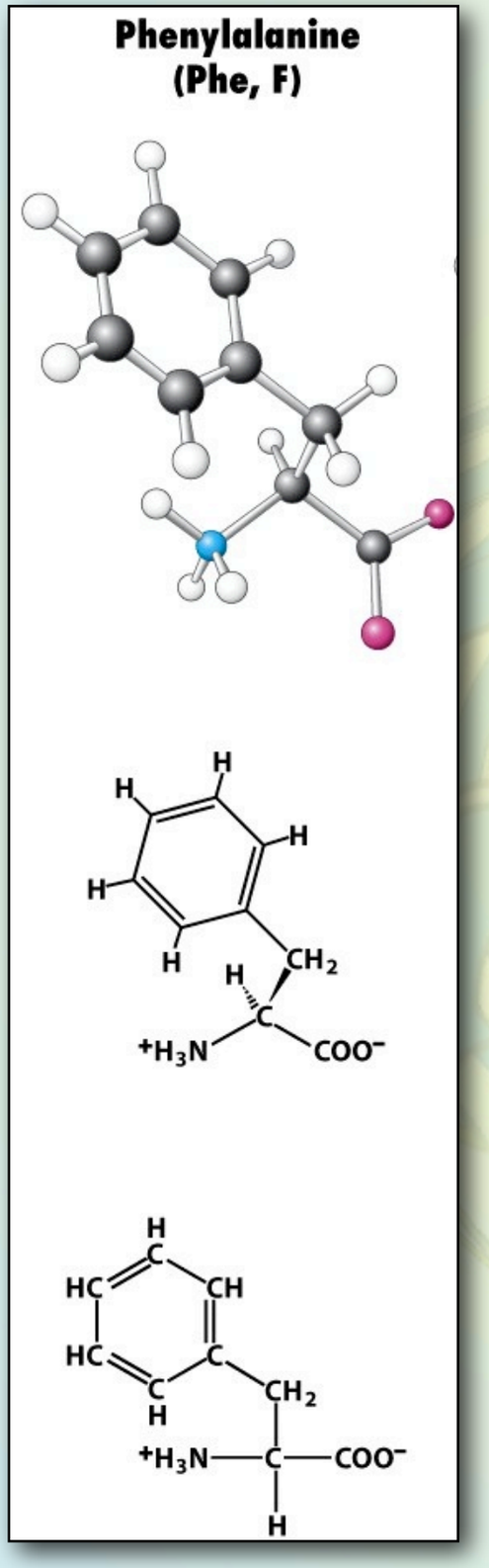

- Non-polar
- Side chain
  - Isobutyl group (Aliphatic)
- Size
  - Large

# The Amino Acid Side Chains



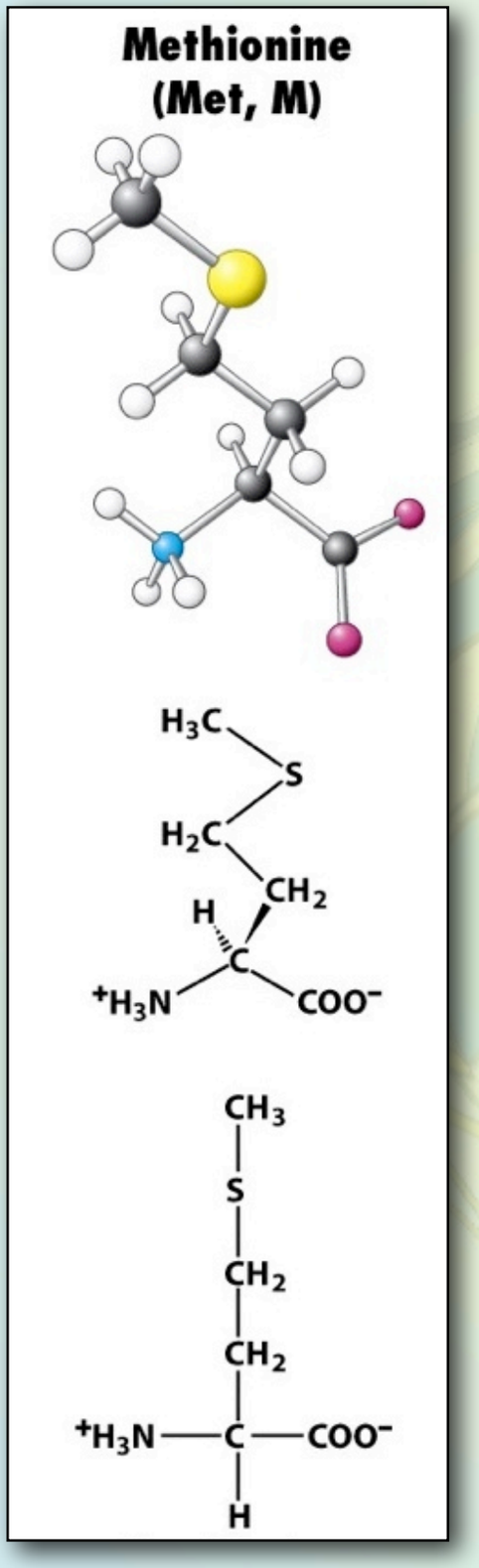

- Non-polar
- Side chain
  - sec-Butyl group (Aliphatic)
- Size
  - Large
- Note
  - Branched at β-carbon

# The Amino Acid Side Chains



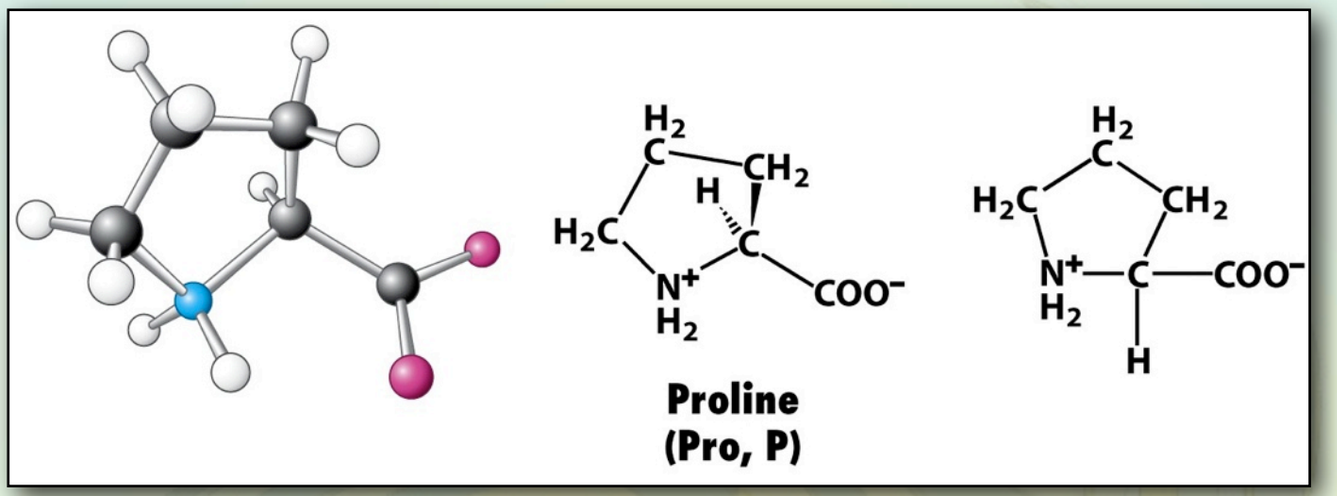

- Non-polar
- Side chain
  - Phenyl group (Aromatic)
- Size
  - Large

# The Amino Acid Side Chains



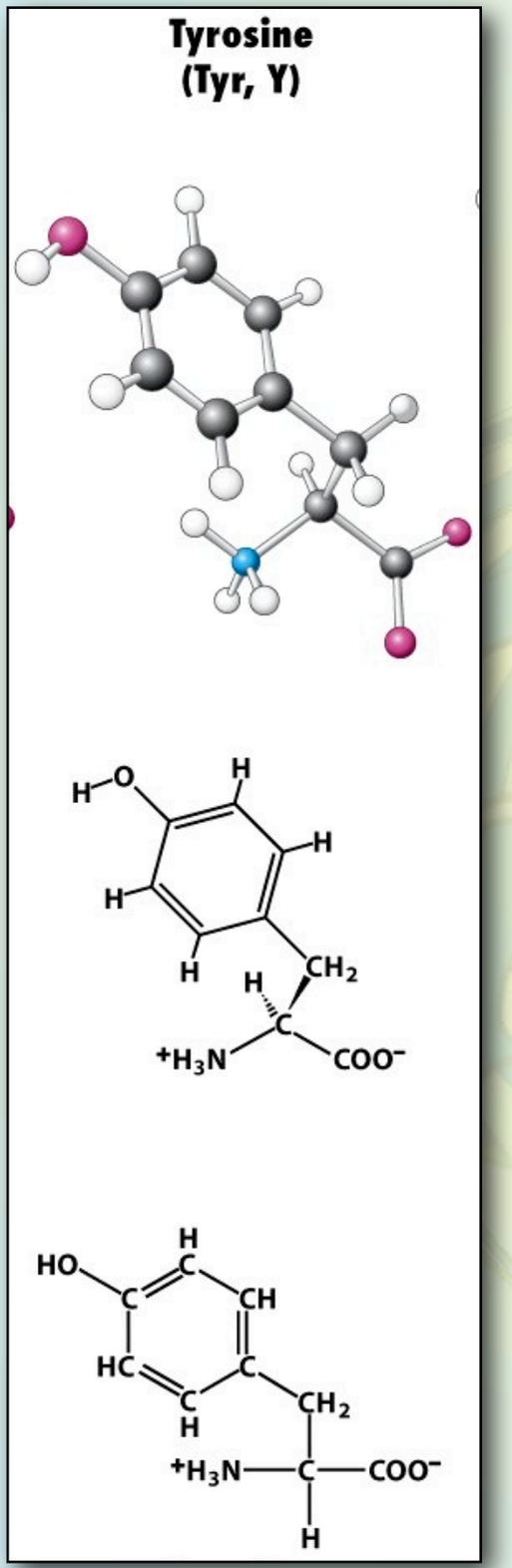

- Non-polar
- Side chain
  - Methyl Ethyl thioether group
- Size
  - Large
- Note
  - Sulfur containing

# The Amino Acid Side Chains



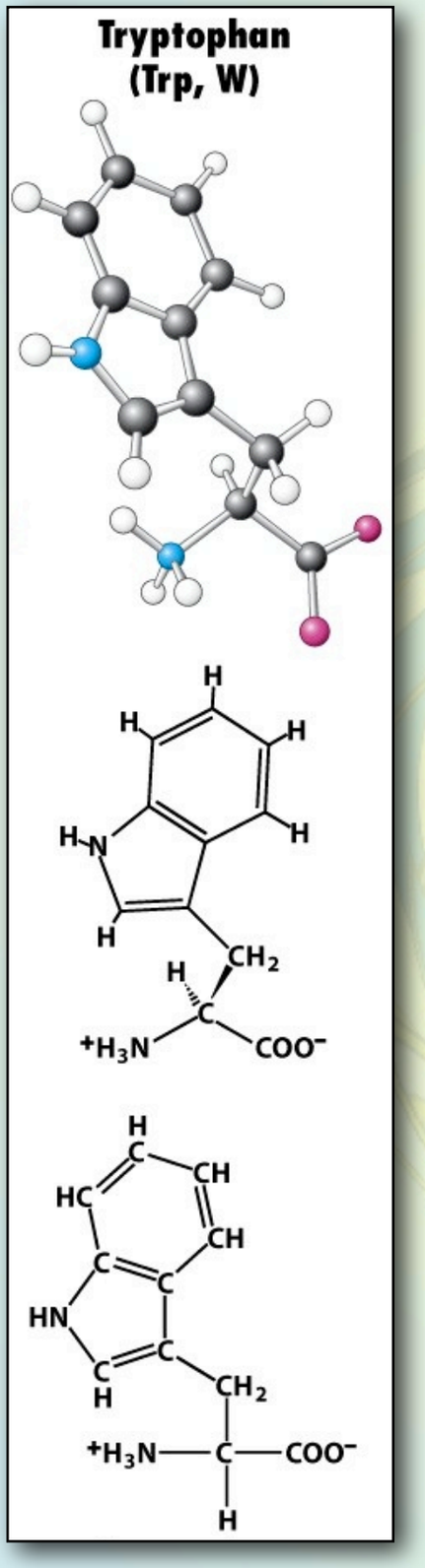

- Non-polar
- Side chain
  - Pyrrolidine, which includes the α-amino group
- Size
  - Medium
- Note
  - Conformationally, the most restricted

# The Amino Acid Side Chains



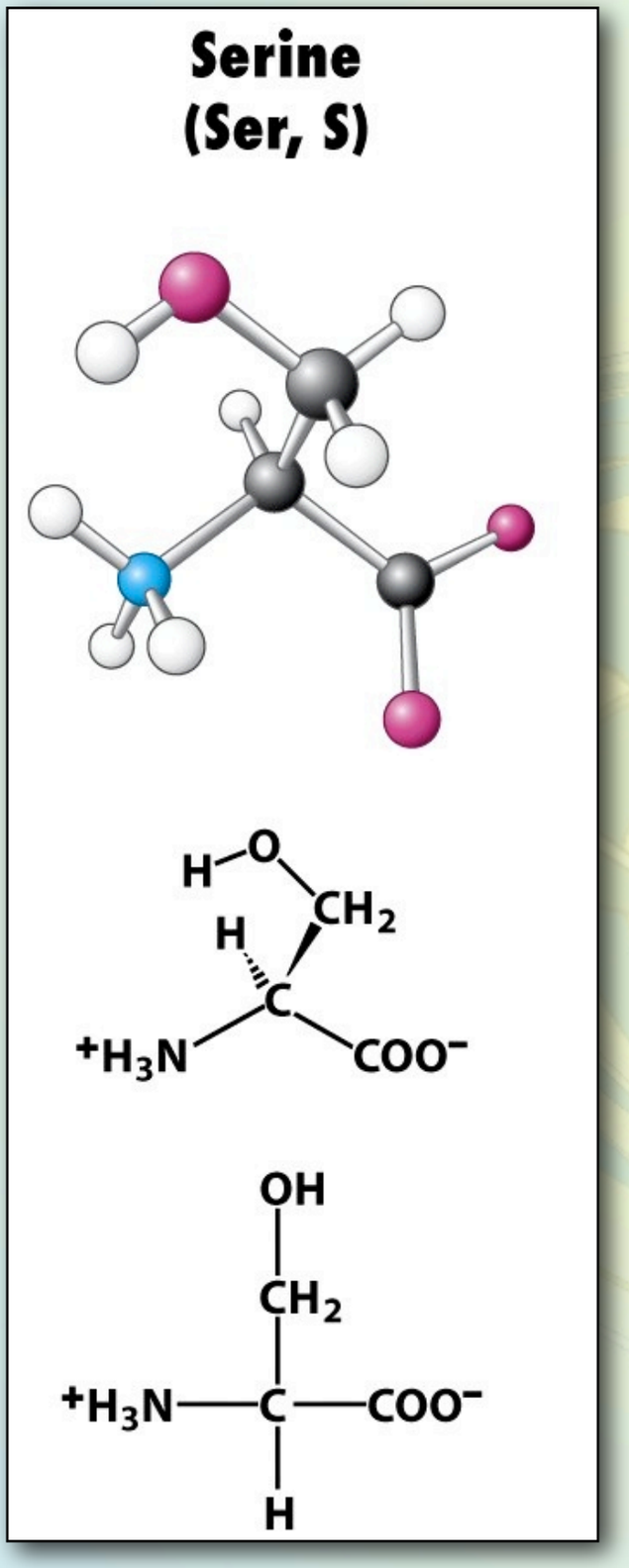

- Non-polar
- Side chain
  - Phenol group (Aromatic)
- Size
  - Large
- Note
  - The polar phenolic hydroxyl group is reactive and is ionize above pH 10

# The Amino Acid Side Chains



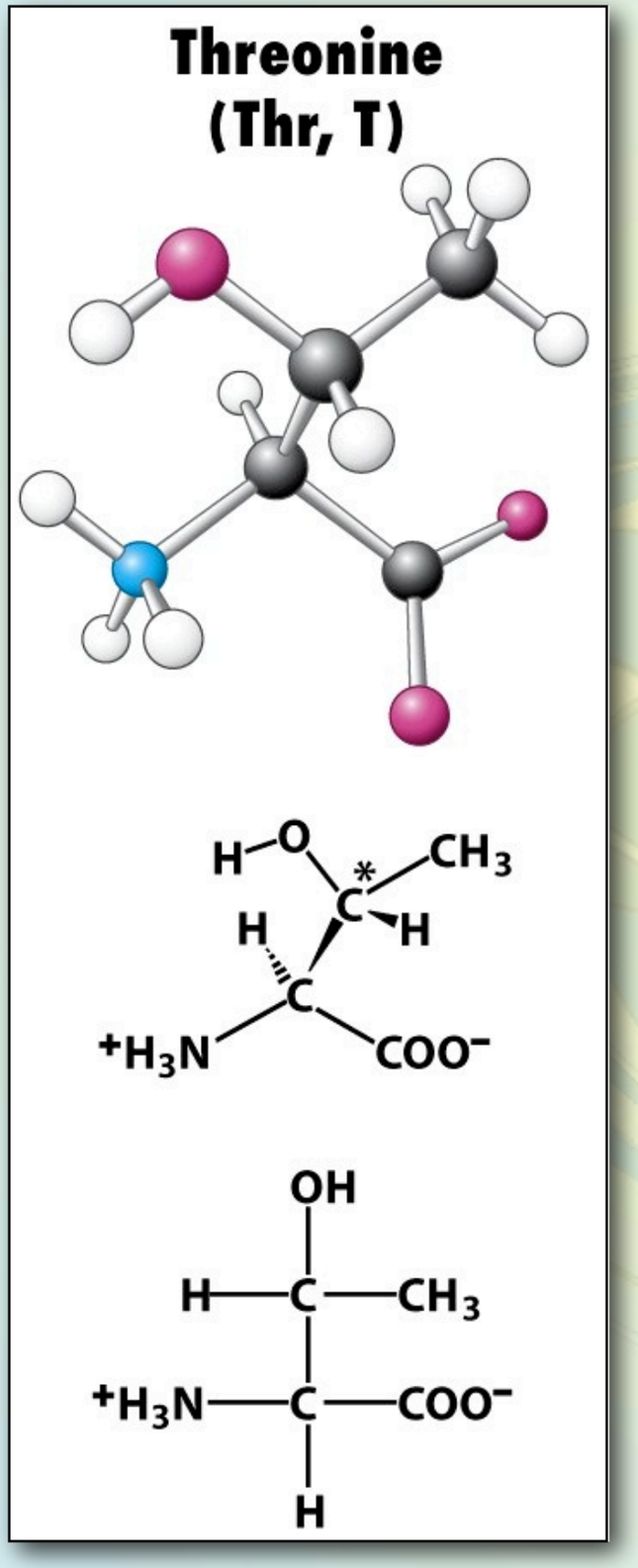

- Non-polar
- Side chain
  - Indole group (Aromatic)
- Size
  - Large
- Note
  - Largest amino acid side chain

# The Amino Acid Side Chains



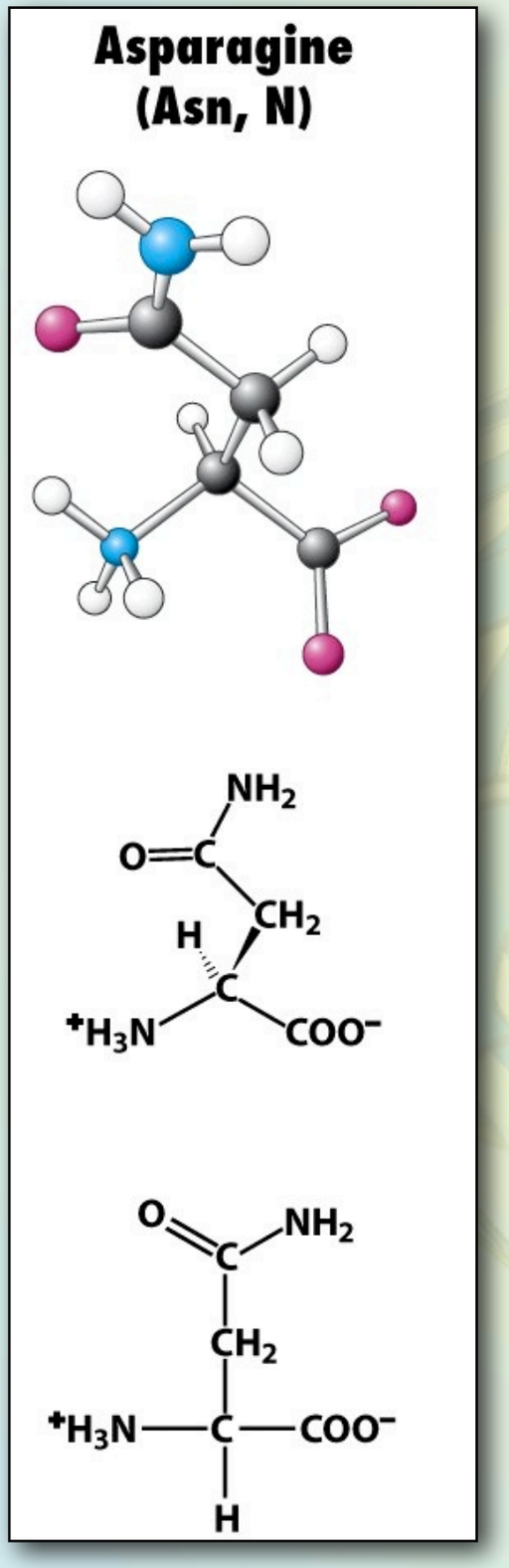

- Polar neutral
- Side chain
  - Hydroxymethyl group (Alcohol)
- Size
  - Small
- Note
  - Hydroxyl group can be reactive

# The Amino Acid Side Chains



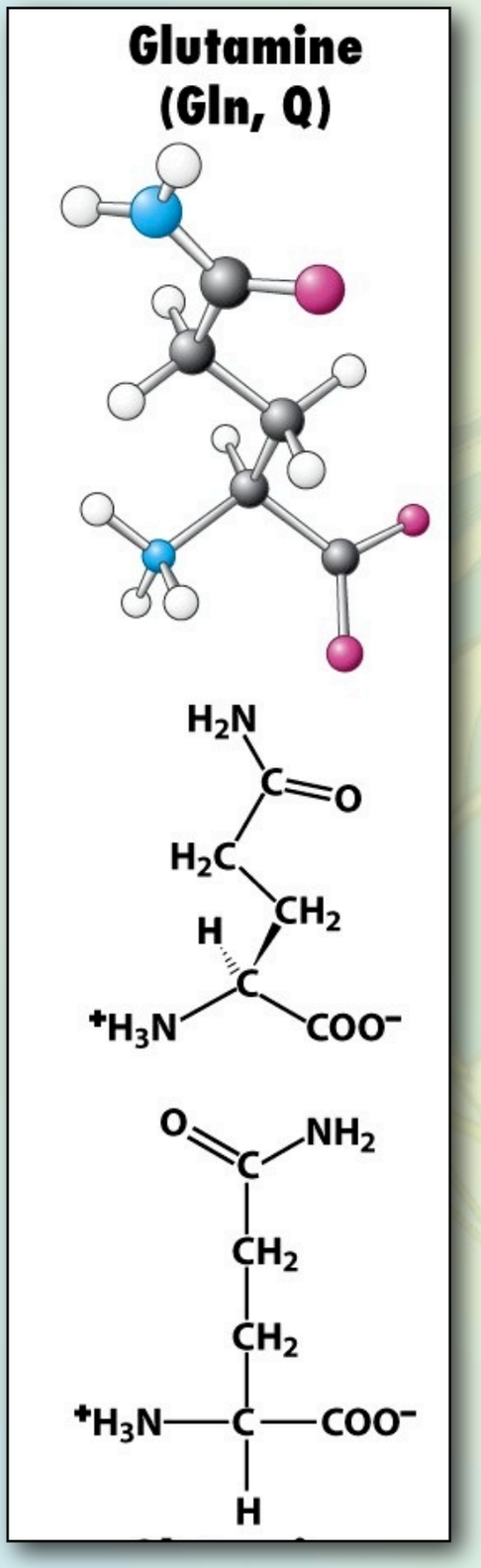

- Polar neutral
- Side chain
  - Hydroxyethyl group (Alcohol)
- Size
  - Medium
- Note
  - Branched at β-carbon

# The Amino Acid Side Chains



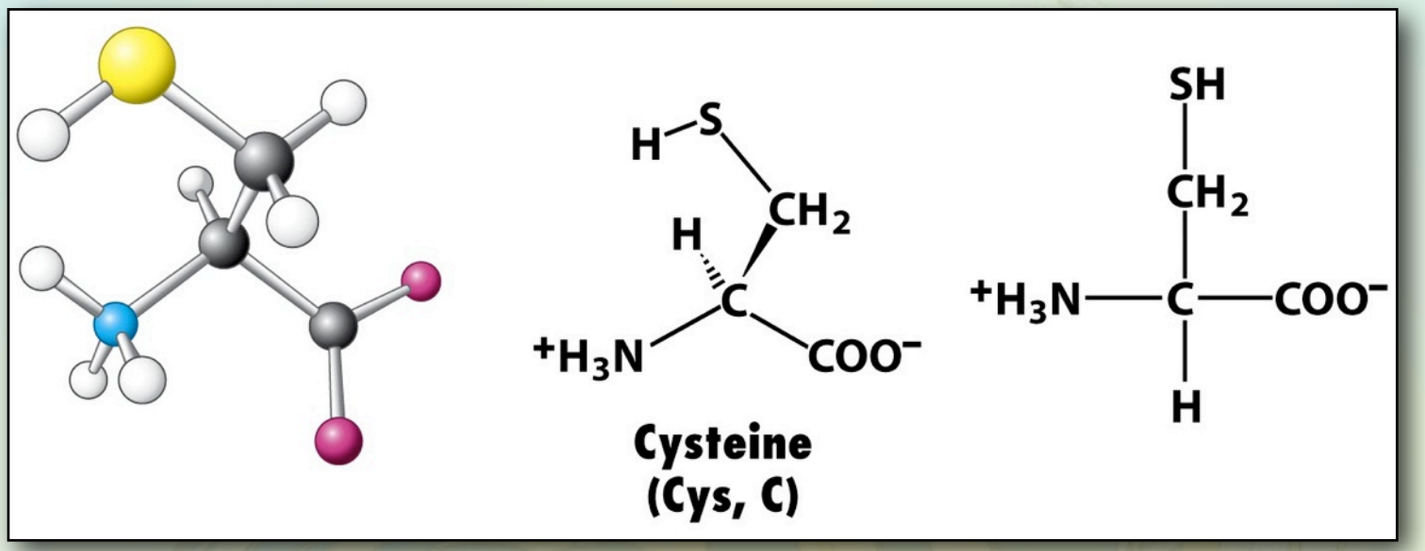

- Polar neutral
- Side chain
  - Amidomethyl group (Primary amide)
- Size
  - Medium
- Note
  - Excellent hydrogen bonder

# The Amino Acid Side Chains



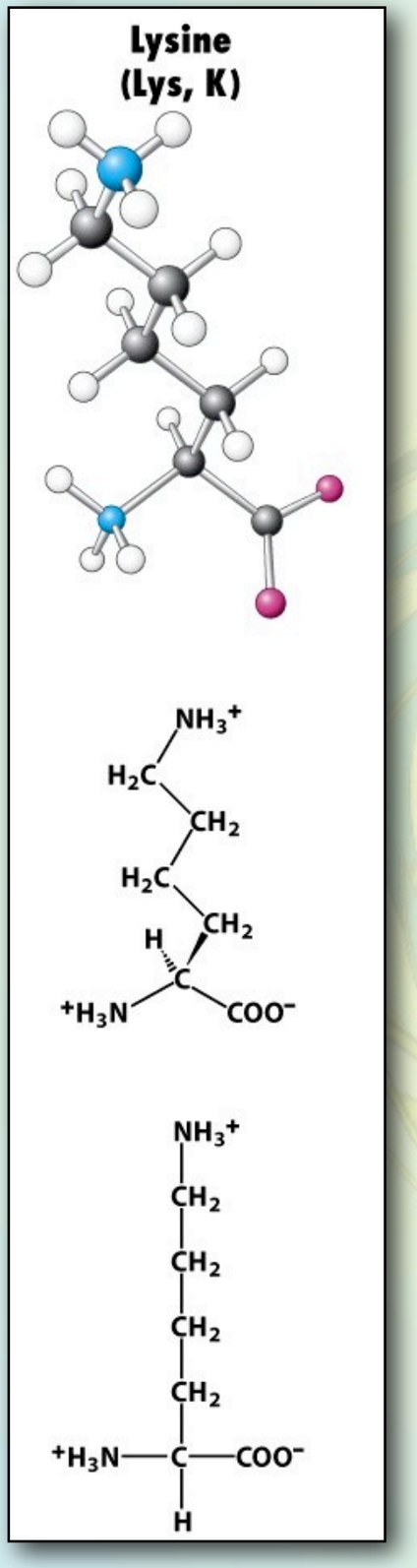

- Polar neutral
- Side chain
  - Amidomethyl group (Primary amide)
- Size
  - Large
- Note
  - Excellent hydrogen bonder

# The Amino Acid Side Chains



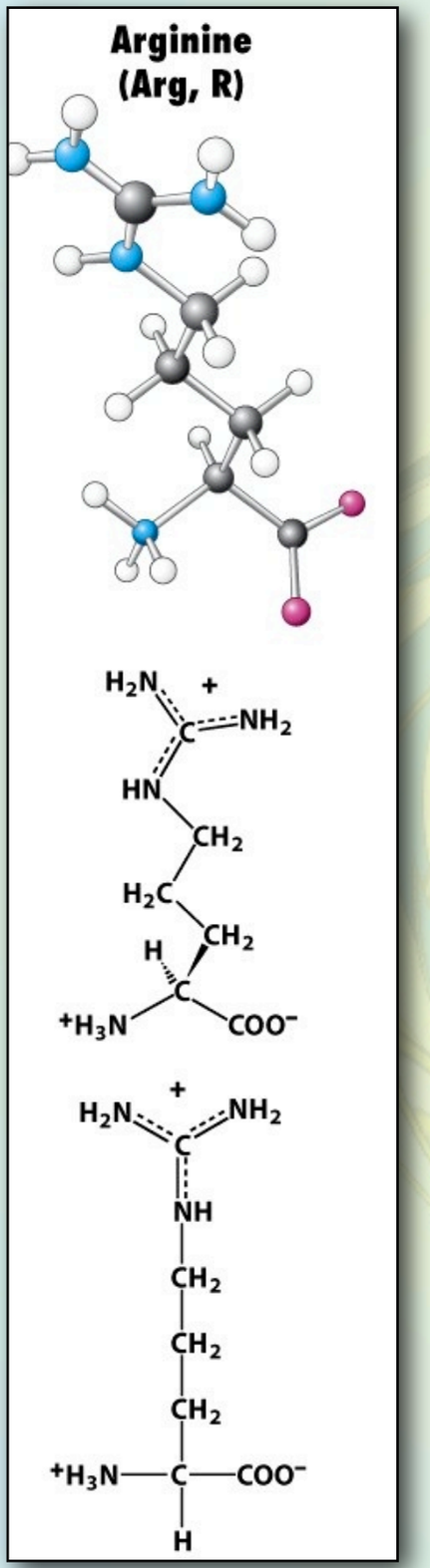

- Non-polar
- Side chain
  - Mercaptomethyl group (Thiol)
- Size
  - Medium
- Note
  - Thiol group is very reactive and is ionized above pH 8

# The Amino Acid Side Chains



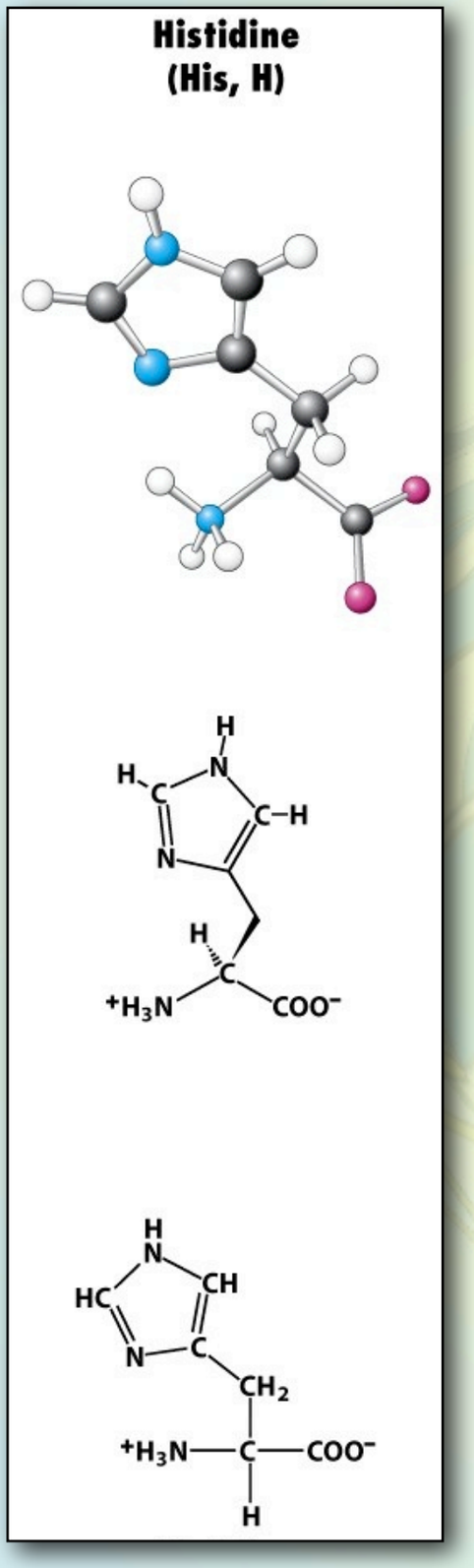

- Polar charged
- Side chain
  - Aminobutyl group (Base)
- Size
  - Large
- Note
  - Amino group is a base and positively charged below pH 10.

# The Amino Acid Side Chains



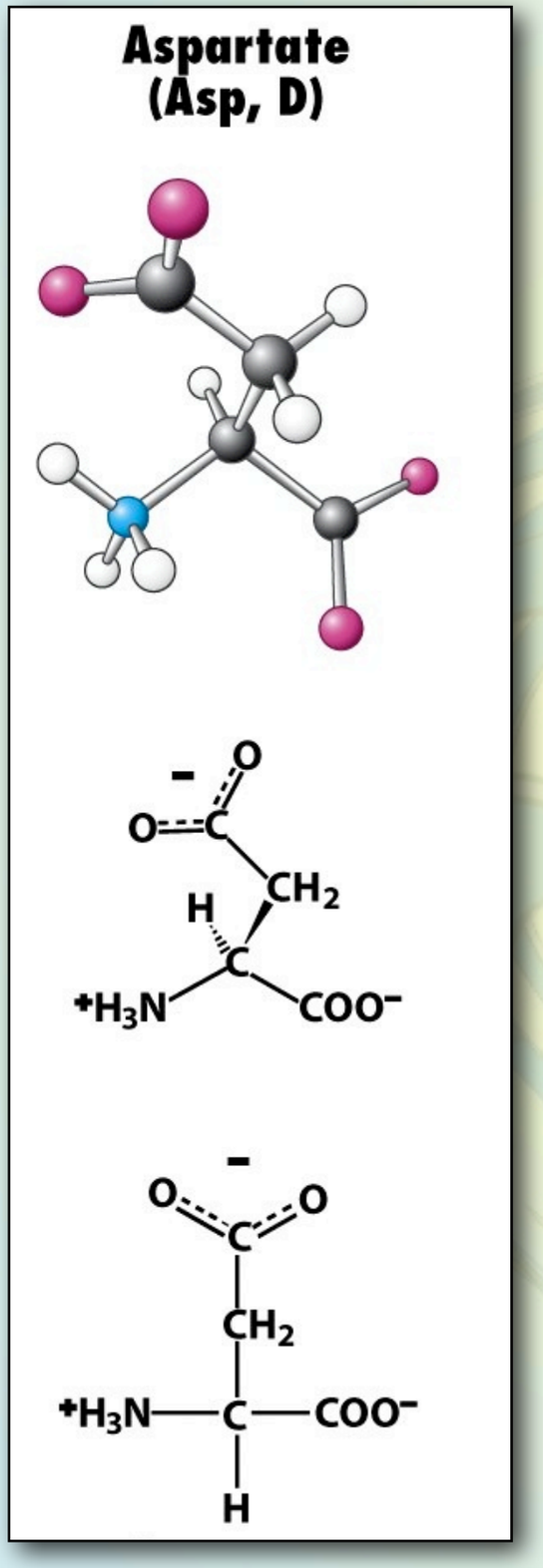

- Polar charged
- Side chain
  - Guanidinopropyl group (Base)
- Size
  - Large
- Note
  - Guanidium group is a base and charged below pH 12

# The Amino Acid Side Chains



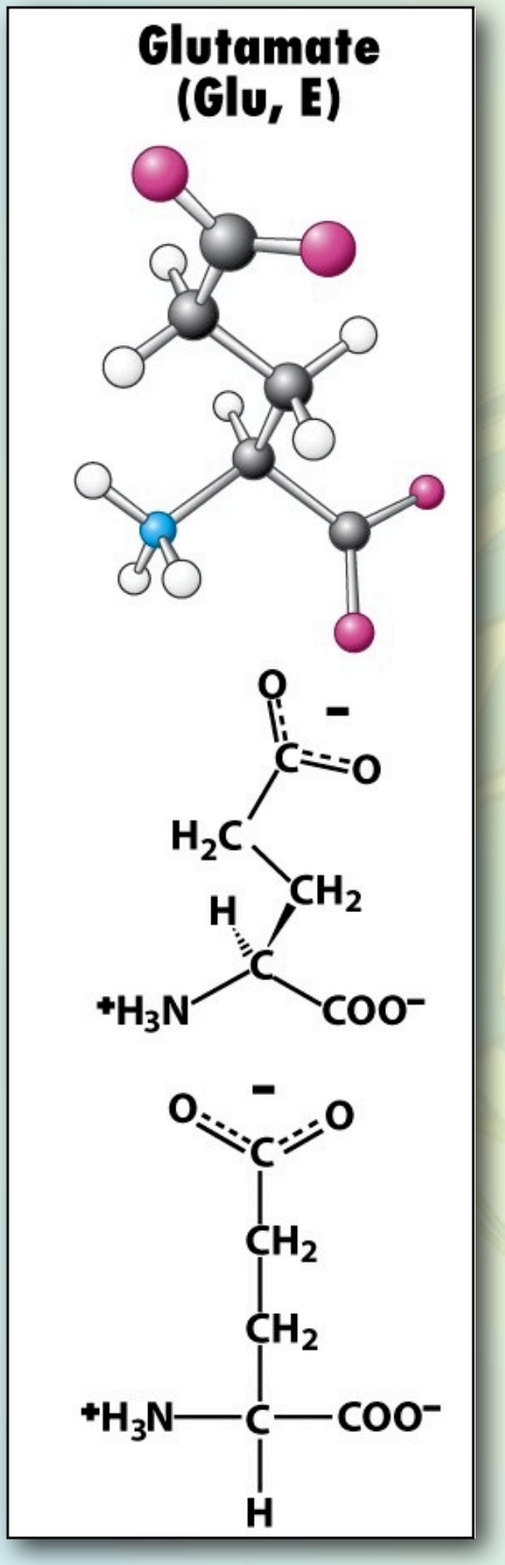

- Polar charged
- Side chain
  - Imidazole group (Base)
- Size
  - Large
- Note
  - Imidazole group is a base with a pK near 7, making it a good acid/base catalyst

# The Amino Acid Side Chains




- Polar charged
- Side chain
  - Carboxymethyl group (Acid)
- Size
  - Medium
- Note
  - Carboxylic acid group is an acid and negatively charged above pH 4.

# The Amino Acid Side Chains




- Polar charged
- Side chain
  - Carboxyethyl group (Acid)
- Size
  - Large
- Note
  - Carboxylic acid group is an acid and negatively charged above pH 4.

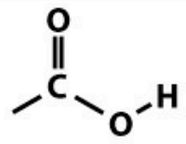
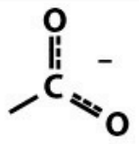
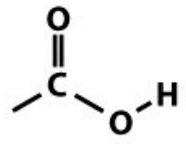
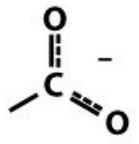
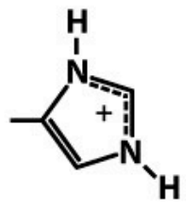
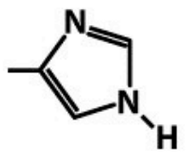
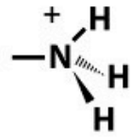
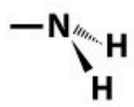
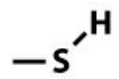
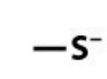
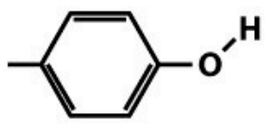
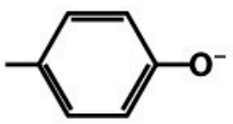
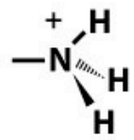
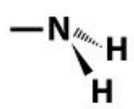
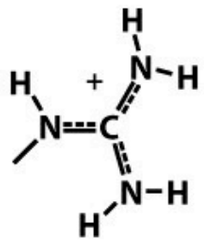
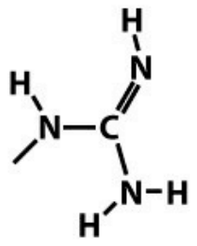
# The Amino Acid Side Chains

- The acid and basic groups

# The Amino Acid Side Chains

- The

**TABLE 2.1 Typical p$K_a$ values of ionizable groups in proteins**

| Group | Acid | | Base | Typical p$K_a$* |
|---|---|---|---|---|
| Terminal α-carboxyl group |  | ⇌ |  | 3.1 |
| Aspartic acid<br>Glutamic acid |  | ⇌ |  | 4.1 |
| Histidine |  | ⇌ |  | 6.0 |
| Terminal α-amino group |  | ⇌ |  | 8.0 |
| Cysteine |  | ⇌ |  | 8.3 |
| Tyrosine |  | ⇌ |  | 10.9 |
| Lysine |  | ⇌ |  | 10.8 |
| Arginine |  | ⇌ |  | 12.5 |

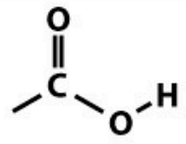
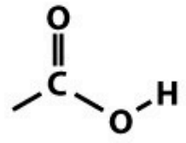
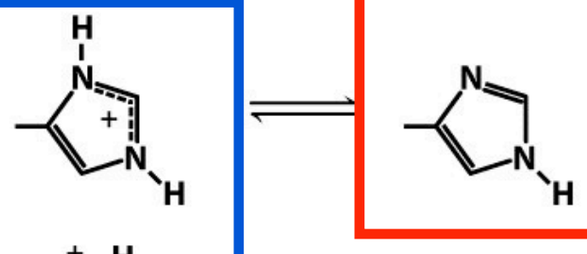
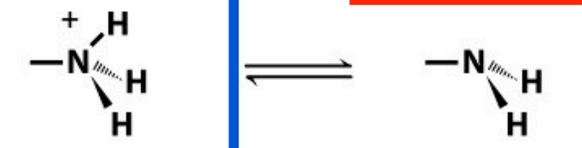
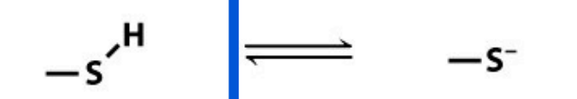
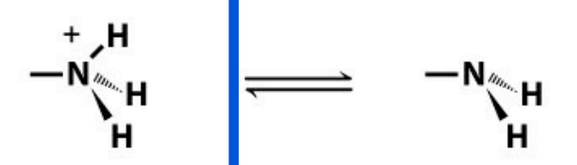
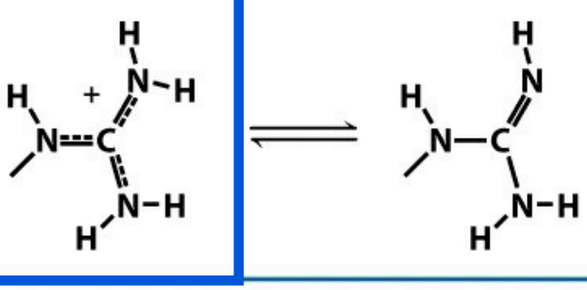
*p$K_a$ values depend on temperature, ionic strength, and the microenvironment of the ionizable group.

# The Amino Acid Side Chains

- The

at pH 7

**TABLE 2.1 Typical p$K_a$ values of ionizable groups in proteins**

| Group | Acid ⇌ Base | Typical p$K_a$* |
|---|---|---|
| Terminal α-carboxyl group |  | 3.1 |
| Aspartic acid<br>Glutamic acid |  | 4.1 |
| Histidine |  | 6.0 |
| Terminal α-amino group |  | 8.0 |
| Cysteine |  | 8.3 |
| Tyrosine |  | 10.9 |
| Lysine |  | 10.8 |
| Arginine |  | 12.5 |

*p$K_a$ values depend on temperature, ionic strength, and the microenvironment of the ionizable group.

# Next up

- Protein primary structure
- Protein secondary structure
- Protein tertiary structure
- Protein quaternary structure