

# Chem 452 - Lecture 2

## Protein Structure

### Part 2

**Question of the Day:** Most proteins are made from a repertoire of 20 different amino acids. A small protein contains around 100 amino acids strung together in a polypeptide chain. How many different possible chains, containing 100 amino acids each, can be made when there are 20 different options for each of the amino acid in a chain?

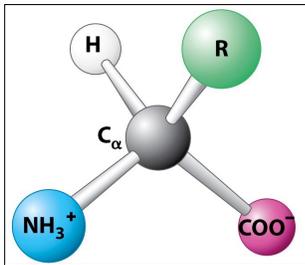
### The Amino Acids

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

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### The Amino Acids

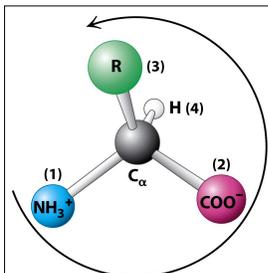
- + What they share in common



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### The Amino Acids

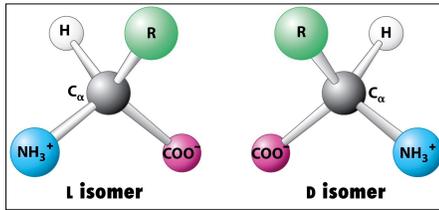
- + What they share in common



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## The Amino Acids

† What they share in common



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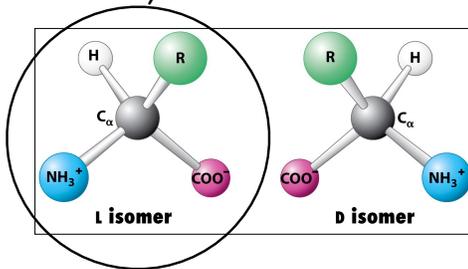
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## The Amino Acids

† What they share in common



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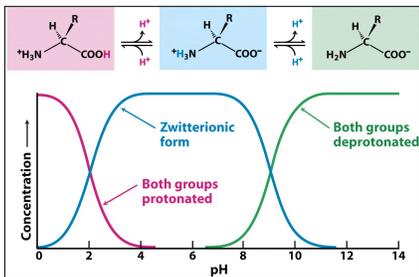
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## The Amino Acids

† What they share in common



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## The Amino Acids

† What they share in common

† The common regions of each amino acid is what is used to join them together to form a polymer of amino acids.

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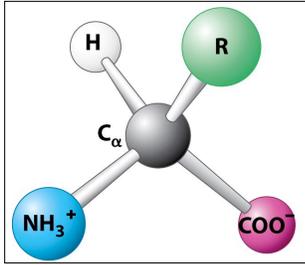
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## The Amino Acid Side Chains

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



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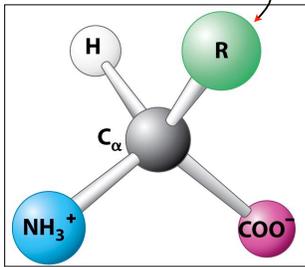
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## The Amino Acid Side Chains

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



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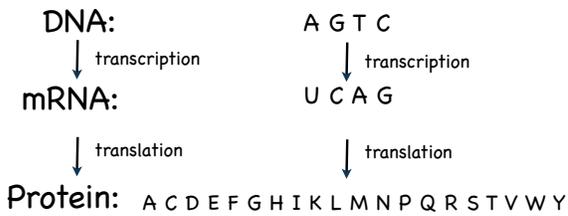
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## Genomics

- † The genetic code (1960's)



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## 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

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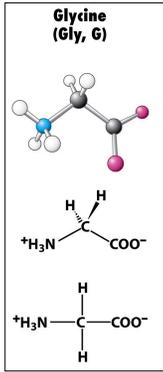
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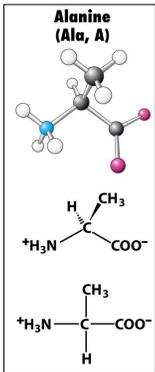
## The Amino Acid Side Chains



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

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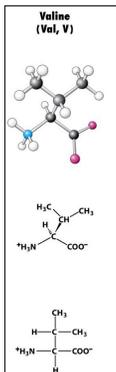
## The Amino Acid Side Chains



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

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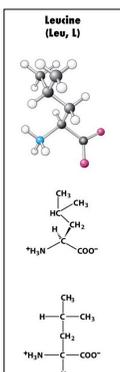
## The Amino Acid Side Chains



- † Non-polar
- † Side chain
  - † Isopropyl group (Aliphatic)
- † Size
  - † Medium
- † Note
  - † Branched at  $\beta$ -carbon

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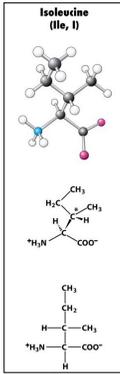
## The Amino Acid Side Chains



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

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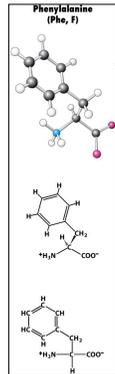
## The Amino Acid Side Chains



- † Non-polar
- † Side chain
  - † sec-Butyl group (Aliphatic)
- † Size
  - † Large
- † Note
  - † Branched at  $\beta$ -carbon

Chem 452, Lecture 2 - Protein Structure 15

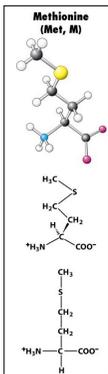
## The Amino Acid Side Chains



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

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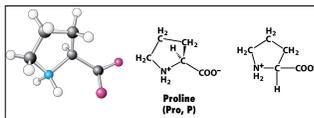
## The Amino Acid Side Chains



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

Chem 452, Lecture 2 - Protein Structure 17

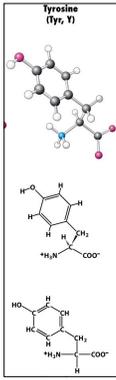
## The Amino Acid Side Chains



- † Non-polar
- † Side chain
  - † Pyrrolidine, which includes the  $\alpha$ -amino group
- † Size
  - † Medium
- † Note
  - † Conformationally, the most restricted

Chem 452, Lecture 2 - Protein Structure 18

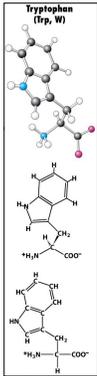
## The Amino Acid Side Chains



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

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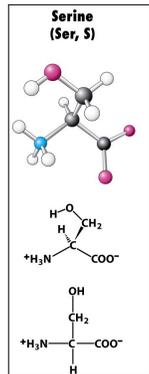
## The Amino Acid Side Chains



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

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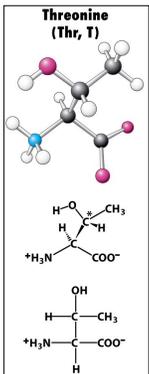
## The Amino Acid Side Chains



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

Chem 452, Lecture 2 - Protein Structure 21

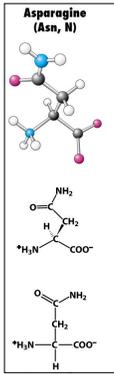
## The Amino Acid Side Chains



- † Polar neutral
- † Side chain
  - † Hydroxyethyl group (Alcohol)
- † Size
  - † Medium
- † Note
  - † Branched at  $\beta$ -carbon

Chem 452, Lecture 2 - Protein Structure 22

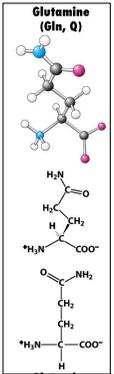
## The Amino Acid Side Chains



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

Chem 452, Lecture 2 - Protein Structure 23

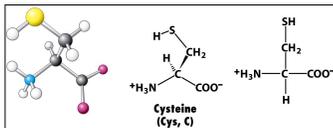
## The Amino Acid Side Chains



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

Chem 452, Lecture 2 - Protein Structure 24

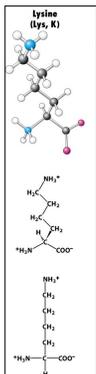
## The Amino Acid Side Chains



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

Chem 452, Lecture 2 - Protein Structure 25

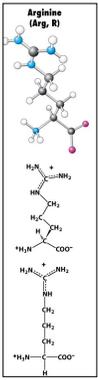
## The Amino Acid Side Chains



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

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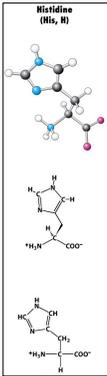
## The Amino Acid Side Chains



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

Chem 452, Lecture 2 - Protein Structure 27

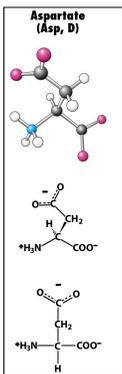
## The Amino Acid Side Chains



- + 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

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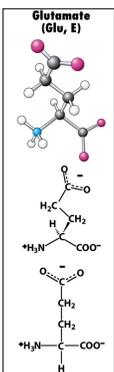
## The Amino Acid Side Chains



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

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## 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.

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## The Amino Acid Side Chains

- + The acid and basic groups

## The Amino Acid Side Chains

- + The

Group	Acid	Base	Typical pK <sub>a</sub> *
Terminal α-carboxyl group			3.1
Aspartic acid 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

\*pK<sub>a</sub> values depend on temperature, ionic strength, and the microenvironment of the ionizable group.

## The Amino Acid Side Chains

- + The

at pH 7

Group	Acid	Base	Typical pK <sub>a</sub> *
Terminal α-carboxyl group			3.1
Aspartic acid 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

\*pK<sub>a</sub> 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

## Next up

### + Protein primary structure

**Question of the Day:** Most proteins are made from a repertoire of 20 different amino acids. A small protein contains around 100 amino acids strung together in a polypeptide chain. How many different possible chains, containing 100 amino acids each, can be made when there are 20 different options for each of the amino acid in a chain?

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