Part 1 - Amino Acids
Structure and Chemistry
Part 1 - Amino Acids
Structure and Chemistry

• Building Blocks of Proteins
Part 1 - Amino Acids
Structure and Chemistry

- Building Blocks of Proteins
- Essential Amino Acids
Part 1 - Amino Acids
Structure and Chemistry

• Building Blocks of Proteins
• Essential Amino Acids
• Basic Structure
Part 1 - Amino Acids
Structure and Chemistry

• Building Blocks of Proteins
• Essential Amino Acids
• Basic Structure
• Stereochemistry
Part 1 - Amino Acids
Structure and Chemistry

- Building Blocks of Proteins
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- Stereochemistry
- Side Chain Chemistry
Part 1 - Amino Acids
Structure and Chemistry

• Building Blocks of Proteins
• Essential Amino Acids
• Basic Structure
• Stereochemistry
• Side Chain Chemistry
• Properties
Part 1 - Amino Acids
Structure and Chemistry

• Building Blocks of Proteins
• Essential Amino Acids
• Basic Structure
• Stereochemistry
• Side Chain Chemistry
• Properties
• Ionization
Part 1 - Amino Acids
Structure and Chemistry

• Building Blocks of Proteins
• Essential Amino Acids
• Basic Structure
• Stereochemistry
• Side Chain Chemistry
• Properties
• Ionization
• Bonding
Amino Acids & Proteins
**Amino Acids & Proteins**

- Workhorses of cell
Amino Acids & Proteins

• Workhorses of cell
  – Catalysis
Amino Acids & Proteins

• Workhorses of cell
  – Catalysis
  – Signaling
Amino Acids & Proteins

• Workhorses of cell
  – Catalysis
  – Signaling
  – Structure
Amino Acids & Proteins

• Workhorses of cell
  – Catalysis
  – Signaling
  – Structure
  – Energy/Gradient Generation
Amino Acids & Proteins

• Workhorses of cell
  – Catalysis
  – Signaling
  – Structure
  – Energy/Gradient Generation

• Proteins comprised of 20-21 amino acids
### Amino Acids

#### Essential Amino Acids

- Histidine
- Isoleucine
- Leucine
- Lysine
- Methionine
- Phenylalanine
- Threonine
- Tryptophan
- Valine

#### Non-Essential Amino Acids

- Alanine
- Arginine
- Asparagine
- Aspartic acid
- Cysteine
- Glutamic acid
- Glutamine
- Glycine
- Proline
- Selenocysteine
- Serine
- Tyrosine

**Table 2.1 - Essential and non-essential amino acids**
Basics of Structure

Elements
Basics of Structure

Elements

Alpha Amino Acids
Basics of Structure

Elements

Alpha Amino Acids
Basics of Structure

Elements

Alpha Amino Acids
Basics of Structure
Elements

Alpha Amino Acids
Basics of Structure

Elements

Alpha Amino Acids

Differences in R Groups

Diagram of amino acid structure with labels:
- Alpha Carbon
- Alpha Carboxyl
- Alpha Amine
Basics of Structure

Elements

Alpha Amino Acids

Differences in R Groups

Examples
Basics of Structure
Elements
Alpha Amino Acids
Differences in R Groups
Examples

Alpha Carbon
Alpha Carboxyl
Alpha Amine

Cysteine
Basics of Structure

Elements

Alpha Amino Acids

Differences in R Groups

Examples

Cysteine
Basics of Structure

Elements

Alpha Amino Acids

Differences in R Groups

Examples

Alpha Carbon

Alpha Carboxyl

Alpha Amine

Asymmetric Center

Cysteine
Basics of Structure

Elements

Alpha Amino Acids

Differences in R Groups

Examples

Alpha Carbon

Alpha Carboxyl

Alpha Amine

Phenylalanine
Basics of Structure

Elements

Alpha Amino Acids

Differences in R Groups

Examples

Alpha Carbon

Alpha Carboxyl

Alpha Amine

Phenylalanine
Basics of Structure

- Elements
- Alpha Amino Acids
- Differences in R Groups
- Examples

Alpha Carbon

Alpha Carboxyl

Alpha Amine

Asymmetric Center

Phenylalanine

Examples:

Alpha Carboxyl

Alpha Carbon

Alpha Amine

R
Amino Acids
Stereochemistry

D and L Isomers
Amino Acids
Stereochemistry

D and L Isomers
Amino Acids
Stereochemistry

D and L Isomers

D-Glyceraldehyde
L-Glyceraldehyde
Amino Acids
Stereochemistry

D and L Isomers
Amino Acids
Stereochemistry

D and L Isomers

D-Glyceraldehyde

L-Glyceraldehyde

Asymmetric Carbon
Almost all biological amino acids are in the L-configuration.
## Categorizing Amino Acids

<table>
<thead>
<tr>
<th>Non-Polar</th>
<th>Carboxyl</th>
<th>Amine</th>
<th>Aromatic</th>
<th>Hydroxyl</th>
<th>Other</th>
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<tbody>
<tr>
<td>Alanine</td>
<td>Aspartic Acid</td>
<td>Arginine</td>
<td>Phenylalanine</td>
<td>Serine</td>
<td>Asparagine</td>
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<tr>
<td>Glycine</td>
<td>Glutamic Acid</td>
<td>Histidine</td>
<td>Tryptophan</td>
<td>Threonine</td>
<td>Cysteine</td>
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<tr>
<td>Isoleucine</td>
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<td>Lysine</td>
<td>Tyrosine</td>
<td>Tyrosine</td>
<td>Glutamine</td>
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<td></td>
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<td></td>
<td>Selenocysteine</td>
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<tr>
<td>Methionine</td>
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<td></td>
<td></td>
<td></td>
<td>Pyrrolysine</td>
</tr>
<tr>
<td>Proline</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Valine</td>
<td></td>
<td></td>
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<tr>
<td>Name</td>
<td>Charged R-group</td>
<td>Approximate R-group pKa</td>
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<tr>
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<tr>
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<td>8.2</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Tyrosine</td>
<td>-O⁻</td>
<td>10.5</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Amino Acids

Aromatic R-Groups

- **Tryptophan**
- **Tyrosine**
- **Phenylalanine**
Amino Acids
Aromatic R-Groups

- Tyrosine
- Phenylalanine
- Tryptophan

- Alpha Carbon
- Alpha Amine
- Alpha Carboxyl
Amino Acids

Aromatic R-Groups

Tyrosine

Phenylalanine

Tryptophan
Amino Acids
Aromatic R-Groups
Charges at Physiological pH

- **Tryptophan**
- **Tyrosine**
- **Phenylalanine**
Amino Acids
Aromatic R-Groups
Charges at Physiological pH

Tyrosine
Phenylalanine

Ionizes at high pH

Tryptophan
Amino Acids
Aliphatic R-Groups

Alanine
Glycine
Proline
Isoleucine

Leucine
Valine
Methionine
Amino Acids
Aliphatic R-Groups

Alanine
Glycine
Proline
Isoleucine

Leucine
Valine
Methionine
Amino Acids
Aliphatic R-Groups
Charges at Physiological pH
Amino Acids
Aliphatic R-Groups
Charges at Physiological pH

Alanine
Glycine
Proline
Isoleucine
Leucine
Valine
Methionine
Amino Acids
Aliphatic R-Groups
Charges at Physiological pH

Alanine
Glycine
Proline
Isoleucine
Leucine
Valine
Methionine
Amino Acids
Aliphatic R-Groups
Charges at Physiological pH

Alanine
Glycine
Proline
Isoleucine
Leucine
Valine
Methionine
Amino Acids
Aliphatic R-Groups
Charges at Physiological pH

- Alanine
- Glycine
- Proline
- Isoleucine
- Leucine
- Valine
- Methionine
Amino Acids
Aliphatic R-Groups
Charges at Physiological pH

Alanine
Glycine
Proline
Isoleucine
Leucine
Valine
Methionine
Amino Acids
Aliphatic R-Groups
Charges at Physiological pH

Alanine
Glycine
Proline
Isoleucine
Leucine
Valine
Methionine
Amino Acids
Aliphatic R-Groups
Charges at Physiological pH

- Alanine
- Glycine
- Proline
- Isoleucine
- Leucine
- Valine
- Methionine
Amino Acids
R-Group Carboxyls

Aspartic Acid
Glutamic Acid
Amino Acids
R-Group Carboxyls

Aspartic Acid

Glutamic Acid
Amino Acids

R-Group Carboxyls

Aspartic Acid

Glutamic Acid
Amino Acids
R-Group Carboxyls

Aspartic Acid

Glutamic Acid
Amino Acids
R-Group Carboxyls
Charges at physiological pH

Aspartic Acid

Glutamic Acid
Amino Acids
Hydroxyl R-Groups

Serine

Threonine

Tyrosine
Amino Acids
Hydroxyl R-Groups

Serine

Threonine

Tyrosine
Amino Acids
Hydroxyl R-Groups

Serine

Hydroxyl

Threonine

Hydroxyl

Tyrosine
Amino Acids

Hydroxyl R-Groups
Charges at Physiological pH

Serine

Threonine

Tyrosine

Ionizes at high pH
Amino Acids
Hydroxyl R-Groups
Charges at Physiological pH

Serine

Threonine

Tyrosine

Ionizes at high pH
Amino Acids
Sulfhydryl R-Group

Cysteine
Amino Acids
Sulfhydryl R-Group

Ionizes at about pH = 8

Cysteine
Amino Acids
Carboxamide R-Groups

Asparagine

Glutamine
Amino Acids

Carboxamide R-Groups

Asparagine

Glutamine
Amino Acids
Carboxamide R-Groups

Asparagine

Glutamine
Amino Acids

Carboxamide R-Groups

Asparagine

Glutamine
Amino Acids
Carboxamide R-Groups

Asparagine

Glutamine
Amino Acids
Ionizable Amine R-Groups

[Chemical structures of Lysine, Arginine, and Histidine are shown.]

- Arginine
- Lysine
- Histidine
Amino Acids
Ionizable Amine R-Groups

Arginine
Lysine
Histidine
Amino Acids
Ionizable Amine R-Groups
Charges at Physiological pH

Arginine

Lysine

Histidine
Rare Amino Acids

Pyrrolysine

Selenocysteine
Rare Amino Acids

Pyrrolysine

Selenocysteine
Rare Amino Acids

Pyrrolysine

Selenocysteine
Rare Amino Acids

Pyrrolysine

Selenocysteine
Rare Amino Acids

Pyrrolysine

Selenocysteine
Rare Amino Acids

Pyrrolysine

Selenocysteine
Rare Amino Acids

Pyrrolysine

Selenocysteine
Rare Amino Acids

Pyrrolysine

Selenocysteine
Rare Amino Acids

Pyrrolysine

Selenocysteine
Non-Protein Amino Acids
Non-Protein Amino Acids

Carnitine
Non-Protein Amino Acids

Carnitine

Also - Citrulline, Ornithine, others
Amino Acids
Ionization
Amino Acids

Ionization - by $\text{pKa}$ Values
Amino Acids
Ionization -by pKa Values
Amino Acids
Ionization - by pKa Values
Amino Acids

Ion Locations in Titration

Charge = -1

pK₁

pK₂

pK₃

pH

Equivalents of OH
Amino Acids

Ionization - by pKa Values
Amino Acids
Ionization - by pKa Values
Amino Acids
Ionization - by pKa Values

Charge = -2
Ionization Changes Charges Within Proteins
Ionization Changes Charges Within Proteins

Changes in Charge Change Activities
Ionization Changes Charges Within Proteins

Changes in Charge Change Activities

![Graph showing activity vs. pH for Pepsin and Trypsin](image)
Post-translational Modifications
Post-translational Modifications

- Hydroxyproline
- γ-Carboxyglutamate
- Carbohydrate-asparagine adduct
Post-translational Modifications

- Hydroxyproline
- γ-Carboxyglutamate
- Carbohydrate-asparagine adduct
Post-translational Modifications

- **Hydroxyproline**
- **γ-Carboxyglutamate**
- **Carbohydrate-asparagine adduct**
Post-translational Modifications
Phosphorylated Amino Acids
Phosphorylated Amino Acids

- Phosphoserine
- Phosphothreonine
- Phosphotyrosine
Phosphorylated Amino Acids

Phosphoserine

Phosphothreonine

Phosphotyrosine
Phosphorylated Amino Acids

- Phosphoserine
- Phosphothreonine
- Phosphotyrosine
Phosphorylated Amino Acids

Phosphoserine

Phosphothreonine

Phosphotyrosine
Breakdown of Amino Acids
Breakdown of Amino Acids

Legend

<table>
<thead>
<tr>
<th>Glucogenic</th>
<th>Ketogenic</th>
<th>Glucogenic/ketogenic</th>
</tr>
</thead>
</table>

Glucose → Phosphoenolpyruvate

Pyruvate → Acetyl-CoA

Asparagine Apartate

Alanine, Cysteine, Glycine, Serine, Threonine, Tryptophan

Tryptophan, Tyrosine, Phenylalanine, Threonine, Isoleucine, Lysine, Leucine, Arginine, Histidine, Proline, Glutamine

Glutamate → Citrate → Isocitrate → α-Ketoglutarate → Succinyl-CoA → Succinate → Fumarate → Malate → Oxaloacetate → Acetyl-CoA → Pyruvate → Glucose

Threonine, Isoleucine, Methionine, Valine
Peptide Bond Formation
Peptide Bond Formation

Amino acid (1)  Amino acid (2)

N-terminus  C-terminus

Peptide bond

Dipeptide

Water
Metabolic Melody
The Amino Alphabet Song
(to the tune of "The Alphabet Song")
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Lysine, arginine and his
Basic ones you should not miss
Ala, leu, val, ile, and met
Fill the aliphatic set
Proline bends and cys has 's'
Glycine's 'R' is the smallest
Then there's trp and tyr and phe
Structured aromatically

Asp and glu's side chains of R
Say to protons "au revoir"
Glutamine, asparagine
Bear carboxamide amines
Threonine and tiny ser
Have hydroxyl groups to share
These twen-TY amino A's
Can combine a zillion ways
Metabolic Melody
You’re Cysteine
To the tune of “You’re Sixteen”
Copyright © Kevin Ahern
You’re Cysteine
To the tune of “You’re Sixteen”
Copyright © Kevin Ahern

You’re in every protein
That I’ve ever seen
There’s no need to debate
You’re cysteine, a building block, and you’re great

You give the hair waves
It’s something we crave
Makes the food on my plate
You’re cysteine, a building block, and you’re great

Bridge
That sulfhydryl in your chain
Can oxidize, but I don’t complain
It gives support to all peptides
So proteins need to have disulfides
You’re in every protein
    That I’ve ever seen
There’s no need to debate
You’re cysteine, a building block, and you’re great

You give the hair waves
    It’s something we crave
Makes the food on my plate
You’re cysteine, a building block, and you’re great

Bridge
    That sulfhydryl in your chain
Can oxidize, but I don’t complain
It gives support to all peptides
So proteins need to have disulfides

You’re an acid it seems
    And have an amine
Please don’t ever mutate
You’re cysteine, a building block, and you’re great

You’re in my skin and in my bone
And even in my glutathione

Bridge
A U-G-U or U-G-C
In secret code at the cell's decree
You’re in every protein
    That I’ve ever seen
There’s no need to debate
You’re cysteine, a building block, and you’re great

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