Introduction to Amino Acids and Proteins

Jianhan Chen
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Section Overview

• “Nitrogen Metabolism”
• Feb 26 – April 7 (spring break: March 17-21)
• Metabolisms of Amino acids (Chapter 21) & nucleotides (Chapter 23)
• Redacted versions of the PowerPoint slides will be available on KSOL under: \Course Content\Modules\Module II – Nitrogen Metabolism\Lecture Notes
  – Be prepared to take good notes during lectures
• Office hours: MF 1:30 – 2:30 PM, Chalmers 034
  – Or by appointment
Quizzes and Exam

• Quizzes: 10 point each
  – Three quizzes: Fridays of March 7, March 14, and March 28
  – Up to 10 minutes at the beginning of lectures
  – Cover materials since the first lecture (first quiz) or the previous quiz
  – Will reflect the emphasis of Section exam (below)

• Section final exam (70 points):
  – Monday of April 7: one hour
  – All materials of Section II
  – One A4 cheat sheet allowed

• No make-up: please plan your schedule accordingly

• Grading: overall course grade will be determined by adding the scores from the three sections and grading on a curve

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Introduction to Amino Acids and Proteins

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Proteins and Protein Functions

Hierarchical Organization of Proteins

Amino Acids

peptide bond

residue

Primary Sequence:

MTYKLILNGK TLKGETTTEA VDAATAEKVF KQYANDNGVD GEWTYDDATK TFTVTE

Peptides

α-helix

β-strand

Protein G B1 (3gb1) Myoglobin (1mbc) tRNA transferase (1mxi)

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Natural Amino Acids

- Nearly all polypeptides from animals and plants are constructed from the 20 standard α-amino acids
- All α-amino acids in L-configuration (except gly)
- Side chains vary
- Essential (10) vs non-essential ones
- Co-exist in two forms
  - Ionic (zwitterionic form) and unionized

\[
\begin{align*}
\text{Amino Acid} & \quad \text{Carboxyl} \\
\text{H₂N} & \quad \text{O} \\
\text{H₂O} & \quad \text{R} \\
\text{H₂N} & \quad \text{C} \\
\text{H₂} & \quad \text{R} \\
\end{align*}
\]

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α-Amino Acids

- An amino acid is an organic compound that contains both an amino (—NH₂) group and a carboxyl (—COOH) group bound to the same carbon (α carbon).
Classification of α-Amino Acids

Classification of standard amino acids

- **Nonpolar (neutral)**
  - (9)
  - Neutral
  - Acidic
  - Basic

- **Polar**
  - (6)
  - Acidic
  - (2)
  - Basic
  - (3)

A nonpolar amino acid is an amino acid that contains one amino group, one carboxyl group, and a nonpolar hydrophobic side chain.
Polar Neutral α-Amino Acids

A polar neutral amino acid contains a side chain that is polar but neutral at physiological pH (side chain can form H-bonds).

Polar Acidic α-Amino Acids

A polar acidic amino acid is an amino acid that contains one amino group and 2 carboxyl groups, the second carboxyl group being part of the side chain.
Polar Basic α-Amino Acids

A polar basic amino acid is an amino acid that contains ≥ 2 amino groups and one carboxyl group, the second amino group being part of the side chain.

Three-Letter and Single-Letter Codes

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>3-Letter</th>
<th>1-Letter</th>
<th>Amino Acid</th>
<th>3-Letter</th>
<th>1-Letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alanine</td>
<td>Ala</td>
<td>A</td>
<td>Leucine</td>
<td>Leu</td>
<td>L</td>
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<tr>
<td>Arginine</td>
<td>Arg</td>
<td>R</td>
<td>Lysine</td>
<td>Lys</td>
<td>K</td>
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<td>Asparagine</td>
<td>Asn</td>
<td>N</td>
<td>Methionine</td>
<td>Met</td>
<td>M</td>
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<tr>
<td>Aspartate</td>
<td>Asp</td>
<td>D</td>
<td>Phenylalanine</td>
<td>Phe</td>
<td>F</td>
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<td>Cys</td>
<td>C</td>
<td>Proline</td>
<td>Pro</td>
<td>P</td>
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<tr>
<td>Histidine</td>
<td>His</td>
<td>H</td>
<td>Serine</td>
<td>Ser</td>
<td>S</td>
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<tr>
<td>Isoleucine</td>
<td>Ile</td>
<td>I</td>
<td>Threonine</td>
<td>Thr</td>
<td>T</td>
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<tr>
<td>Glutamine</td>
<td>Gln</td>
<td>Q</td>
<td>Tryptophan</td>
<td>Trp</td>
<td>W</td>
</tr>
<tr>
<td>Glutamate</td>
<td>Glu</td>
<td>E</td>
<td>Tyrosine</td>
<td>Tyr</td>
<td>Y</td>
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<tr>
<td>Glycine</td>
<td>Gly</td>
<td>G</td>
<td>Valine</td>
<td>Val</td>
<td>V</td>
</tr>
</tbody>
</table>

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Chirality of α-Amino Acids

- α-carbon is a tetrahedral stereocenter (except glycine)
  - Pair of enantiomers
- Only L-α-amino acids exist in the proteins of animals and plants (with very few exceptions)
  - Amino acids refer to L-α-enantiomers

![Diagrams of amino acids and their structures]

Acid-Base Properties

\[
\begin{align*}
- \text{COOH} & \rightarrow -\text{COO}^- + \text{H}^+ \\
- \text{NH}_2 + \text{H}^+ & \rightarrow + \text{NH}_3
\end{align*}
\]

Isoelectric point (pI): zwitterion

![Diagram showing pH-dependent dissociation of acidic and basic groups, indicating the pH range for zwitterions]
**Electrophoresis**

- Analyze a mixture of $\alpha$-amino acids
- Identify substances in an electrical field by separation
  - Cations (1+) move to the negative electrode
  - Anions (1-) move to the positive electrode
  - Neutral $\alpha$-amino acids does not migrate

![Electrophoresis Diagram]

**$\alpha$-Amino Acids**

<table>
<thead>
<tr>
<th>Name</th>
<th>Abbreviations</th>
<th>Side group (R)</th>
<th>Isoelectric point (pI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NONPOLAR NEUTRAL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>glycine</td>
<td>Gly</td>
<td>$H^-$</td>
<td>5.97</td>
</tr>
<tr>
<td>alanine</td>
<td>Ala</td>
<td>$CH_3^-$</td>
<td>6.01</td>
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<tr>
<td>valine*</td>
<td>Val</td>
<td>$\text{ICH}_2\text{CH}_2^-$</td>
<td>5.96</td>
</tr>
<tr>
<td>leucine*</td>
<td>Leu</td>
<td>$\text{CH}_3\text{CH}_2$</td>
<td>5.98</td>
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<td>isoleucine*</td>
<td>Ile</td>
<td>$\text{CH}_3\text{CH}_2$</td>
<td>6.02</td>
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<td>$\text{HN}$</td>
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<tr>
<td>tryptophan*</td>
<td>Trp</td>
<td>W</td>
<td>5.88</td>
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α-Amino Acids

<table>
<thead>
<tr>
<th></th>
<th>Abbreviations</th>
<th>Side group (R)</th>
<th>Isoelectric point (pI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>polar neutral</td>
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<tr>
<td>cysteine</td>
<td>Cys C</td>
<td>HSCCH₂⁻</td>
<td>5.05</td>
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<tr>
<td>serine</td>
<td>Ser S</td>
<td>HOCH₂⁻</td>
<td>5.68</td>
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<td>Thr T</td>
<td>OH</td>
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<td>Asn N</td>
<td>H₂NCH₂⁻</td>
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<td>glutamine</td>
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<td>H₂NCH₂⁻</td>
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<tr>
<td>tyrosine</td>
<td>Tyr Y</td>
<td>HO—CH₂⁻</td>
<td>5.66</td>
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<td>polar acidic</td>
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<tr>
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<td>Asp D</td>
<td>O</td>
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<tr>
<td>glutamic acid</td>
<td>Glu E</td>
<td>HOCH₂⁻</td>
<td>3.22</td>
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<td>polar basic</td>
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<tr>
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<td>Lys K</td>
<td>H₂NCH₂CH₂CH₂⁻</td>
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<td>histidine*</td>
<td>His H</td>
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<td>7.59</td>
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</table>

Basic Chemical Reactions

- **Backbone:** common to all amino acids
  - Amines and carboxylic acids undergo dehydration to form amides
  - Peptides are polyamides formed by α-amino acids

- **Side chains:** amino acid specific
  - Often occurred as “post-translational” modifications (signaling, natural modification, oxidation/damage etc)
  - Disulfide bond formation: between cysteines, an important structural feature
Disulfide Bonds

The small protein insulin has two polypeptide chains connected by two interchain disulfide bonds. There is also one intrachain disulfide.

- The amino acid cysteine contains a thiol group, -SH. Pairs of cysteine residues often link two peptide chains or two parts of one peptide chain through disulfide bridges.
- Formation of disulfide is an oxidation reaction and the reverse involves disulfide reduction.

Summary

- Proteins: overview
- Amino acids
  - Chemical composition: backbone and side chain
  - Classification: side chain properties
  - Physical and chemical properties
    - zwitterionic form;
    - peptide bond formation
- Peptides and proteins: polyamides (heteropolymers of amino acids)
- Next two+ weeks: amino acid metabolism (Chapter 21)