BIOCH 755: Biochemistry I  Fall 2015

Quiz on Friday:
Need to know ALL amino acids and their basic properties
No multiple choices question: all Q&As

3. Amino Acids (Chapter 4)

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Which of the following is NOT made of protein?

A. rhino horn
B. human toe nails
C. sheep wool
D. bacterial cell walls
E. jello

Proteins and Protein Functions

Programmed Cell Death

First map of human protein interactions. (Ulrich Stelzl et al./ Copyright: MDC)
Hierarchical Organization of Proteins

4.1 Amino Acid (Chemical) Structure

Key Concepts 4.1
- The 20 standard amino acids share a common structure but differ in their side chains.
- Peptide bonds link amino acid residues in a polypeptide.
- Some amino acid side chains contain ionizable groups whose pK values may vary.

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

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).
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

[Diagram of α-carbon and amino acids]

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

[Diagram of dehydration and peptide bond formation]

- 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

[Diagram of classification of α-amino acids]

Classification of α-Amino Acids

Classification of standard amino acids

- Nonpolar (neutral)
  - Neutral
  - Acidic
  - Basic

- Polar

[Diagram showing the distribution of amino acids by pH and their properties]
A nonpolar amino acid is an amino acid that contains one amino group, one carboxyl group, and a nonpolar hydrophobic side chain.

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

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.

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>
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<tbody>
<tr>
<td>Alanine</td>
<td>Ala</td>
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<tr>
<td>Arginine</td>
<td>Arg</td>
<td>R</td>
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<td>Asparagine</td>
<td>Asn</td>
<td>N</td>
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<tr>
<td>Aspartate</td>
<td>Asp</td>
<td>D</td>
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<tr>
<td>Cysteine</td>
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<td>C</td>
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<tr>
<td>Histidine</td>
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<td>H</td>
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<td>Isoleucine</td>
<td>Ile</td>
<td>I</td>
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<td>Glutamine</td>
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<td>Q</td>
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<td>Glycine</td>
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<td>F</td>
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<td>P</td>
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<td>Tryptophan</td>
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<td>W</td>
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<tr>
<td>Valine</td>
<td>Val</td>
<td>V</td>
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#### Disulfide Bonds

- 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.

#### Isoelectric Point

- The pH at which the net charge is zero.
- For amino acids: \( pI = (pKi + pKj)/2 \)
  - \( K_i \) and \( K_j \) are the dissociation constants of two charged species
- Slight side chain dependence; also dependent on structure

#### Electrophoresis

- Analyze a mixture of α-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 α-amino acids does not migrate

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>Isoelectric point</th>
</tr>
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<tbody>
<tr>
<td>alanine</td>
<td>6.11</td>
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<tr>
<td>arginine</td>
<td>10.76</td>
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<tr>
<td>asparagine</td>
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<td>aspartic acid</td>
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<td>threonine</td>
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<tr>
<td>tryptophan</td>
<td>5.88</td>
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</table>
4.3 Amino Acid Derivatives

- Post-translational modifications
  - The side chains of amino acid residues in proteins are often modified.
  - Adding small groups: Hydroxylation, methylation, acetylation, corboxylation, phosphorylation
  - Attaching large tails: lipids, carbohydrates etc
- A key signaling and regulatory mechanism

Green Fluorescent Protein

The light emitting group: Ser-Tyr-Gly under go spontaneous cyclization and oxidation and form conjugated double bond system!

Biological Active Amino Acid Derivatives

- Complex pathways of amino acid metabolic transformations
- Beyond AA synthesis and energy generation

Neurotransmitters
Summary

- Proteins: overview
- Amino acids
  - Chemical composition: backbone and side chain
  - Classification: side chain properties
  - Physical and chemical properties
    - zwitterionic form;
    - peptide bond formation
  - Post-translational modification
  - Derivatives
- Coming up: Peptides and proteins

Glycine has no R group

A. True
B. False

What is the name of the amino acid shown below?

A. Asp
B. Arg
C. Lys
D. Met
E. Leu

Which of the amino acids shown below is SER?

A. 
B. 
C. 
D. 

A. 
B. 
C. 
D. 

Which amino acid is this?

A. Phe  
B. His  
C. Tyr  
D. Trp

Which of the following pairs of amino acids might form a salt bridge?

A. Thr, Glu  
B. Tyr, Ser  
C. Glu, Asp  
D. Lys, Arg  
E. Lys, Asp

Which of the following amino acid side chains is polar and uncharged?

A. Glu  
B. Trp  
C. Tyr  
D. Phe  
E. Ile

How many charged functional groups are present on the peptide below at physiological pH?

A. 1  
B. 2  
C. 3  
D. 4  
E. 5

Arg-Asp-Cys-Tyr-Gln-Val-Glu
Which of the following groups of amino acid side chains is MOST LIKELY to be positioned into the active site of an enzyme that binds glucose as a substrate?

A. Gln, Asn, Ser  
B. Val, Leu, Ile  
C. Trp, Phe, Ile  
D. Val, Glu, Lys  
E. Cys, Met, Pro

Which of the following amino acids has a side chain that can form covalent cross-links in proteins?

A. Ser  
B. Met  
C. Trp  
D. Cys  
E. Thr

Which of the following statements regarding amino acids is/are false?

A. Thr and Cys may be phosphorylated.  
B. The side chain of the amino acid histidine usually acts as a base at pH 7.0.  
C. Arg contains four nitrogens.  
D. A and B  
E. All of the above statements are false.

Which of the following statements regarding amino acids is/are false?

A. Ala, Val, Leu and Ile play an important role in establishing and maintaining the 3-D structures of proteins.  
B. Every amino acid has at least two pKa values.  
C. When the pH of a solution is below the pKa value of an ionizable group, the unprotonated form of that group predominates.  
D. Statements A and B are false.  
E. All of the above statements are false.
Which of the following does NOT contain a carboxamide functional group?
A. The amino acid Asn.
B. The amino acid Asp.
C. The dipeptide Gln-His.
D. All of these contain a carboxamide group.
E. None of these contain a carboxamide group.

How many chiral carbons does Thr contain?
A. 0
B. 1
C. 2
D. 3

Which of the following net charge best represents aspartate at pH 12?
A. -2
B. -1
C. 0
D. +1
E. +2

There are several amino acid side chains that are always charged at physiological pH. These are:
A. Gln, Asn, Lys, and Arg.
B. Glu, Asp, Lys, and Arg.
C. Lys, His, and Arg.
D. Glu, Asp, Lys, Arg, and His.
Which L amino acid has the $R$- configuration for $\text{C}_\alpha$?

A. C  
B. A  
C. R  
D. T  
E. S

Which of the following amino acids could form a hydrogen-bonding interaction between their sidechains?

A. Q and A  
B. Q and V  
C. Q and F  
D. Q and I  
E. Q and W

How many charged R groups are present on the peptide below at physiological pH?

A. 1  
B. 2  
C. 3  
D. 4  
E. 5  
Asn-Asp-Cys-Tyr-Lys-Val-Glu

What is the net charge of the peptide below at physiological pH?

A. -2  
B. -1  
C. 0  
D. +1  
E. +2  
Ala-Arg-Asn-Asp-Glu-Ser-Gly