Proteins

Suggested Problems Chapter 20: 3, 7, 21, 25, 37, 41, 42, 48, 50

Functions of Proteins

- __________
- __________
- __________
- __________
- __________
- __________
- __________
- __________
- __________

Amino Acids

- Amine derivatives of carboxylic acids
- α-amino acids
- Monomer units of proteins
  - So proteins are __________
- General structure
  \[
  \begin{array}{c}
  \text{H} \text{N} \text{C} \text{O} \\
  \text{R} \\
  \end{array}
  \]
Common Amino acids

- 20 common amino acids used in body
- Classified by the R-group
  - Nonpolar
  - Polar – neutral
  - Acidic
  - Basic

20 Protein-Derived AA

Nonpolar side chains (at pH 7.0)
- Alanine (Ala, A)
- Glycine (Gly, G)
- Isoleucine (Ile, I)
- Leucine (Leu, L)
- Methionine (Met, M)
- Phenylalanine (Phe, F)
- Proline (Pro, P)
- Tryptophan (Trp, W)
- Valine (Val, V)

Polar side chains (at pH 7.0)
- Asparagine (Asn, N)
- Glutamine (Gln, Q)
- Cysteine (Cys, C)
- Serine (Ser, S)
- Tyrosine (Tyr, Y)
- Threonine (Thr, T)
20 Protein-Derived AA

- Acidic and basic side chains (at pH 7.0)

Ionization of Side chains

- At physiological pH, the amino acids are zwitterions because they have both positive and negative charges.
- The α-carboxyl group
  - Acid – donates H+ to make __________
  - Charge -

- A-amino group
  - Base – accepts H+ to make __________
  - Charge -

Essential Amino Acids

- Amino acids are built in the body from intermediates in the cycle of sugar and fat metabolism
- Amino acids that require a lot of energy to make are categorized as essential
- Amino acids made in a few steps are categorized as nonessential
- Essential amino acids must be obtained from our diet

<table>
<thead>
<tr>
<th>Essential Amino Acids</th>
</tr>
</thead>
<tbody>
<tr>
<td>arginine</td>
</tr>
<tr>
<td>Methionine</td>
</tr>
<tr>
<td>Histidine</td>
</tr>
<tr>
<td>Phenylalanine</td>
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<tr>
<td>Isoleucine</td>
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<tr>
<td>Threonine</td>
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<tr>
<td>Leucine</td>
</tr>
<tr>
<td>Tryptophan</td>
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<tr>
<td>Lysine</td>
</tr>
<tr>
<td>Valine</td>
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</tbody>
</table>
Amino acids in the diet

- Animals contain complete protein
  - Protein from animal sources contain sufficient amounts of the essential amino acids
- Plant protein is incomplete
  - Different types of plants (vegetables) contain varying amounts of the essential amino acids

<table>
<thead>
<tr>
<th>Amino acid deficiency in selected vegetables and grains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice, wheat, oats</td>
</tr>
<tr>
<td>Corn</td>
</tr>
<tr>
<td>Beans</td>
</tr>
<tr>
<td>Peas</td>
</tr>
<tr>
<td>Almonds</td>
</tr>
<tr>
<td>Soy</td>
</tr>
</tbody>
</table>

Reactions of amino acids

- Oxidation of cysteine
  - Contains thiol group
  - Oxidize two cysteines to disulfide bond
  - Holds different protein chains together
  - Hold different parts of one protein chain together

\[
\begin{align*}
2 \text{H}_2\text{N-CH}_2\text{COOH} & \rightarrow \text{H}_2\text{N-CH}_2\text{COO}^- + \text{H}_2\text{O} \\
\text{Cysteine} & \rightarrow \text{a disulfide bond} \\
\end{align*}
\]

Condensation of amino acids

- The carboxylic acid of one amino acid reacts with the amine of another amino acid to form an __________.
  - Peptide bond – amide bond between two amino acids
  - Dipeptide – two amino acids
  - Polypeptide – contains many amino acids

\[
\begin{align*}
\text{Alanine (Ala)} + \text{Serine (Ser)} & \rightarrow \text{Alanylserine (Ala-Ser)} \\
\text{peptide bond} & \end{align*}
\]
The order or sequence of amino acids in a peptide chain is known as primary structure. Crucial to properties and function:

- Aspartame: Aspartic acid-phenylalanine-ester.
- If the order is reversed, the sweet taste is lost.
- Remember, molecules have to fit into their receptor slots to work.
- Insulin – first protein sequenced.
- Similar in different species.

Peptide sequence
(first level of protein structure)

Polypeptides - Examples
peptide hormones

- Oxytocin: Stimulates smooth muscle contraction.
- Vasopressin: Antidiuretic – adjusts water absorption in kidneys.
- Structures differ by only 2 amino acids.
- The shape is even the same.
- The difference in function is due to a difference in primary structure!

Two different peptides

\[ \text{Cys-S-S-Cys-Pro-Gly-NH}_2 \]
\[ \text{Tyr Asn PhGln} \]
\[ \text{Vasopressin} \]

\[ \text{Cys-S-S-Cys-Pro-Leu-NH}_2 \]
\[ \text{Tyr Asn Ile Gln} \]
\[ \text{Oxytocin} \]

What other kind of bond is shown besides the peptide bond? This bond is not part of the primary structure.
Proteins

- Polymer of over 50 amino acids with a function
  - Can be one polypeptide chain
    - Myoglobin – one folded chain
  - More than one chain held together by interactions between side chains
    - Hemoglobin – 4 chains folded separately and held together

Polypeptide chains

The next level of structure: Folding

- Fold according to interactions along chain or between chains
  - H-bonds
  - Polar interactions
  - Ionic interactions
  - Disulfide bridges
  - Nonpolar interactions
- The folding is crucial to the activity of the protein!

Types of folding

H-bonding (the second level of structure)

- These interactions are between close amino acids
- "Springy" peptides
  - Coiled shape – hair and wool
  - Chains not completely extended so flexible
  - Some coils are more extended than others
Folding due to H-bonding

- Extended peptides
  - Chains are extended
  - Less flexible
  - Arranged side-by-side
  - Silk
- Most proteins contain some of both structures
- These can be considered the first level of folding.

Types of folding – overall shapes (the third level of structure)

- Fibrous – long straight chains
  - Insoluble
  - Structural
  - Collagen, keratin, fibrin, silk
- Globular – folded into spherical, “ globs”
  - Colloids in cells and blood
  - Worker proteins of cells
  - Myoglobin and hemoglobin
  - Enzymes are globular

Amino Acids in proteins

- First, classify each amino acid below as polar or non polar, or charged
- Knowing that fibrous proteins are insoluble while globular proteins are generally soluble, determine whether the amino acids would be most abundant in a collagen molecule or on the surface of hemoglobin.

- Proline
- Serine
- Alanine
Collagen

- Fibrous protein made of bundles of tropocollagen ropes
- Each tropocollagen rope is made of 3 coiled chains coiled together to form a triple helix
- H-bonds hold chains together
  - Vitamin C necessary for H-bonds

Collagen

- Major protein of connective tissue
- Different types of collagen
  - Tendons – strong, stiff
  - Skin – loosely woven, expansion in all directions

Collagen disorders

- Scurvy – Vitamin C deficiency
  - Fewer H-bonds to hold chains together – skin lesions, weakened blood vessels
- Aging – cross links form b/w ropes
  - Brittle bones and tendons
  - Less elastic skin – wrinkles
- Ehlers- Danlos syndrome – genetic disorder
  - Easily displace joints
  - Skin tears easily
  - Vessels can rupture easily
myoglobin

- Carries oxygen to muscles
- Single polypeptide chain
  - Folded into globular structure
- Heme group – contains iron (Fe)
  - Not part of the protein
  - Helps bind oxygen
- One binding site for oxygen

Hemoglobin

- Carrier of oxygen in blood
- 4 globular chains interacting
  - Proper interaction of the 4 subunits is crucial to effective binding and release of oxygen
- Each subunit (chain) has Heme group
- 4 oxygen binding sites

Sickle Cell anemia

- Defective hemoglobin caused by mutation at one amino acid on two of the four chains
  - Valine replaces glutamic acid
  - The nonpolar a.a. don’t like to interact with aqueous environment, so the molecules dump together
  - Form long hemoglobin fibers – cause sickle shape inside RBC
  - Elongated cells clog capillaries
  - Loss of RBC – anemia
  - Can cause swelling, inflammation, pain, and cell death
## Sickle Cell anemia

- Sickling occurs most in absence of oxygen
- If oxygen is bound to Hb, it helps keep the molecule “round”
- “Crisis” triggers – high altitudes, exercise
- Must have both mutated genes to have Sickle-cell anemia
- Sickle cell trait – has one mutated gene
  - Protection against malaria
  - Not enough abnormal Hb to cause sickle crisis.

## Denaturation of Proteins

- Disruption of interactions that fold the protein
  - Loss of shape – loss of function
  - Usually causes protein to come out of solution
    - precipitate

## Methods of Denaturation

- Heat – gives energy to break H-bonds and other interactions
  - Cooking denatures proteins
- Acid-Base – affects charges on amino acids
- Heavy metal ions – break disulfide bonds
  - Used to kill bacteria
  - Also toxic to humans – heavy metal poisoning treated with raw eggs
- Organic compounds – alcohols H-bond with protein
  - Used as disinfectant – coagulate proteins in bacteria
Pineapple in the jello mold?

- You may have seen the warning not to use fresh pineapple in gelatin recipes (if you ever want them to congeal!).
  - Gelatin is a protein.
  - What may the problem be?

- Canned pineapple, (which has been heated) does not prevent congealing.
  - Explain

- You can experiment with this at home (although, don’t mess with Aunt Sally’s jello mold for the big dinner…….)

Denaturation vs. hydrolysis

- What level(s) of protein structure were affected by denaturation?
- Were peptide bonds broken?

Hydrolysis

- Breaking peptide bonds requires a hydrolysis reaction
- What level of structure is affected?
- Digestion of proteins is similar to digestion of lipids and sugars
- What is needed for hydrolysis?
- What are the products?
Protein digestion

- Denatured by HCl in stomach
- Intestines – enzymes hydrolyze peptide bonds
- Amino acids absorbed through intestine walls into blood
- Sometimes used for energy
- Used to make nitrogen containing compounds
- Waste nitrogen – excreted as urea

Protein digestion

- Where in your body is the primary structure of ingested proteins affected?

- Glycosidic bonds in sugars are broken in your mouth. Why are proteins not digested in the mouth?