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Proteins and Amino Acids

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Johns Hopkins University
Section A

Definitions
Amino Acids

\[
\begin{align*}
\text{H} & \quad \text{C} \quad \text{COOH} \\
\text{NH}_2 & \quad \text{R} \\
\text{H} & \quad \text{C} \quad \text{COOH} \\
\text{NH}_2 & \quad \text{R}
\end{align*}
\]
Peptides

\[
\begin{align*}
\text{NH}_2 & \quad \text{C} & \quad \text{CO} \quad \text{NH} & \quad \text{C} & \quad \text{COOH} \\
\text{H} & \quad & \quad \text{H} & \quad & \quad \\
\text{R} & \quad & \quad \text{R} & \quad & \quad 
\end{align*}
\]
### Human Amino Acid Requirements

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>Amino Acid</th>
<th>Amino Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valine</td>
<td>Lysine</td>
<td>Glycine</td>
</tr>
<tr>
<td>Leucine</td>
<td>Threonine</td>
<td>Glutamine</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>Cysteine</td>
<td>Alanine</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>Arginine</td>
<td>Glutamic acid</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>Proline</td>
<td></td>
</tr>
<tr>
<td>Methionine</td>
<td>Histidinie</td>
<td></td>
</tr>
</tbody>
</table>
# Amino Acids Broken Down

**General Formula:**

- **ALPHATIC AMINO ACIDS**
  - Glycine
  - Alanine
  - *Valine
  - *Leucine
  - *Isoleucine
  - Serine
  - *Threonine
  - Cysteine
  - Cystine
  - *Methionine

- **AROMATIC and HETERO-CYCLIC AMINO ACIDS:**
  - Phenylalanine
  - Tyrosine
  - *Tryptophan

- **BASIC AMINO ACIDS**
  - *Histidine
  - *Lysine
  - Arginine

- **ACIDIC AMINO ACIDS and their AMIDES**
  - Aspartic Acid
  - Asparagine
  - Glutamic Acid
  - Glutamine

- **Proline**
Other Uses for Amino Acids

- Glutamic acid: Neurotransmitter
- Tyrosine: Catecholamines
- Tryptophan: Serotonin, niacin
- Glycine: Purines, pyrimidines
- Cysteine: Glutathion, taurine
- Methionine: Choline, creatine
Section B

Protein and Amino Acid Metabolism
Whole-Body Amino Acid Metabolism

Dietary amino acids → Free amino acid pool → Oxidation

Protein turnover

10
Protein Turnover

Intake: 90g

Fecal N: 10g  Urinary N: 75g  Other losses: 5g

Liver

Synthesis

Muscle 75
Viscera 127
Plasma 48

Kidney

Muscle 75
Viscera 127
Plasma 48

250g
### Some Common Food Proteins

<table>
<thead>
<tr>
<th>Protein</th>
<th>Source</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casein</td>
<td>Milk</td>
<td>34000</td>
</tr>
<tr>
<td>ß-lactoglobulin</td>
<td>Milk</td>
<td>35000</td>
</tr>
<tr>
<td>Ovalbumin</td>
<td>Eggs</td>
<td>44000</td>
</tr>
<tr>
<td>Gluten</td>
<td>Wheat</td>
<td>39000</td>
</tr>
<tr>
<td>Myosin</td>
<td>Meat</td>
<td>850000</td>
</tr>
</tbody>
</table>
Nitrogen Balance

- Humans cannot store excess amino acids not used for protein synthesis; they must be degraded and the N eliminated in the urine.
- In adults, dietary N requirements are determined by the need to replace obligatory losses.
- Once the true requirement is met, the N balance will tend to remain close to zero.
N Balance

IN — OUT = 0

Diet — Fecal — Urinary — Insensitive
N Balance

Balance (gm N/day)

gm Protein N in diet (whole egg)

N equilibrium

Actual requirement

Theoretical requirement
Section C

Protein Quality and Recommendations
Protein Quality

- Quality
- Digestibility
- Biological value
Protein Quality

- **Quality**—Content of essential amino acids relative to a reference protein
Protein Quality

- **Quality**—Content of essential amino acids relative to a reference protein
- **Digestibility**—Percent of ingested protein that is absorbed
Protein Quality

- **Quality**—Content of essential amino acids relative to a reference protein
- **Digestibility**—Percent of ingested protein that is absorbed
- **Biological value**—Percent of absorbed dietary protein that is retained in the body; also, rate of growth per g of protein consumed
## Digestibility of Some Proteins

<table>
<thead>
<tr>
<th></th>
<th>True Digestibility</th>
<th>% of Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg</td>
<td>97</td>
<td>100</td>
</tr>
<tr>
<td>Milk</td>
<td>95</td>
<td>100</td>
</tr>
<tr>
<td>Meat</td>
<td>94</td>
<td>100</td>
</tr>
<tr>
<td>Maize</td>
<td>85</td>
<td>89</td>
</tr>
<tr>
<td>Rice (polished)</td>
<td>88</td>
<td>93</td>
</tr>
<tr>
<td>Beans</td>
<td>78</td>
<td>82</td>
</tr>
</tbody>
</table>
## Amino Acid Content of Some Food Proteins

<table>
<thead>
<tr>
<th>Protein</th>
<th>S-AA</th>
<th>Lys</th>
<th>Trp</th>
<th>Leu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ideal</td>
<td>3.5</td>
<td>5.5</td>
<td>1.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Egg</td>
<td>5.5</td>
<td>6.4</td>
<td>1.6</td>
<td>8.8</td>
</tr>
<tr>
<td>Milk</td>
<td>3.3</td>
<td>7.8</td>
<td>1.4</td>
<td>9.8</td>
</tr>
<tr>
<td>Beef</td>
<td>3.8</td>
<td>8.7</td>
<td>1.2</td>
<td>8.2</td>
</tr>
<tr>
<td>Beans</td>
<td>2.6</td>
<td>6.4</td>
<td>1.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Corn</td>
<td>3.2</td>
<td>2.9</td>
<td>0.6</td>
<td>3.0</td>
</tr>
<tr>
<td>Protein</td>
<td>1.5</td>
<td>6.1</td>
<td>0.9</td>
<td>7.0</td>
</tr>
</tbody>
</table>
Protein Content of Some Foods

<table>
<thead>
<tr>
<th>Food</th>
<th>g/100g of Food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava</td>
<td>1.5</td>
</tr>
<tr>
<td>Potato</td>
<td>2.0</td>
</tr>
<tr>
<td>Cow’s milk</td>
<td>3.3</td>
</tr>
<tr>
<td>Rice</td>
<td>7.0</td>
</tr>
<tr>
<td>Eggs</td>
<td>13.0</td>
</tr>
<tr>
<td>Lean beef</td>
<td>19.0</td>
</tr>
</tbody>
</table>
Protein Requirements

- The lowest level of dietary protein intake that balances N losses when . . .
  - Stable energy balance
  - Modest level of physical activity
  - Adequate for physiological conditions
Determination of Dietary Protein Requirements

- **Rationale**
  - Amount that maintains N balance at different levels of energy intake

- **Method**
  - N balance data in adults

- **Assumptions**
  - Miscellaneous losses—8 mg N/day
  - Acknowledges that protein BV is dependent on level of energy intake
## Protein Requirements

<table>
<thead>
<tr>
<th>Energy (kcal/ kg Body Weight)*</th>
<th>Mean Requirement of Dietary Protein for Zero N Balance (G Protein/ Kg Body Weight)</th>
<th>Safe Allowance of Protein (Mean Requirement ÷ 2 Standard Deviations)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Grams Protein/ Kg Body Weight</td>
</tr>
<tr>
<td>40</td>
<td>0.78</td>
<td>1.02</td>
</tr>
<tr>
<td>45</td>
<td>0.56</td>
<td>0.74</td>
</tr>
<tr>
<td>48</td>
<td>0.51</td>
<td>0.62</td>
</tr>
<tr>
<td>57</td>
<td>0.42</td>
<td>0.50</td>
</tr>
<tr>
<td>Recommended dietary allowance</td>
<td>0.80</td>
<td>0.80</td>
</tr>
</tbody>
</table>
High and Low Limits of Protein Intake

- Adaptation to a low protein intake
  - Is there a body protein reserve?
  - Limits of adaptation: Accommodation
High and Low Limits of Protein Intake

- **Adaptation to a low protein intake**
  - Is there a body protein reserve?
  - Limits of adaptation: Accommodation

- **Adaptation to a high protein intake**
  - Is excess protein intake harmful?
  - Does a high-protein diet enhances performance?