Overview of Protein

• Body is made up of thousands of substances that are made of proteins

• Each protein has own unique structure and function
  – More than 300 different amino acids described
  – Twenty amino acids commonly found in human protein
  – Proteins = 50% of the dry weight of most cells

• Contains carbon, hydrogen, and oxygen
  – And at least one N in structures
  – N is in the form of an amino group \((\text{NH}_2)\)
  – Carboxyl group \((\text{COOH})\)
Overview of Protein

• Functions
  – Regulate metabolism
    • Enzymes
    • Hormones (insulin)
  – Contractile mechanism of muscles
  – Bone
    • Protein collagen forms a framework for deposition of calcium
  – Bloodstream
    • Hemoglobin
    • Plasma albumin
    • Fluid balance
  – Immune system
    • Immunoglobulins-fight infection
Amino Acid

R group                              Acid group
Nitrogen group                        C                OH
NH₂                  O
R                 C                        C                OH
H
"Generic" amino acid. The R signifies another chemical group that would be present.

Glutamic acid
Relationship of Essential and Non-essential Amino Acids

• Example:
  Phenylalanine $\rightarrow \rightarrow \rightarrow$ tyrosine
  (essential $\rightarrow$ non-essential)

• But in PKU diagnosed individuals:
  Phenylalanine $\rightarrow \rightarrow \rightarrow$ tyrosine
  (essential $\rightarrow$ NOW essential)
Amino Acids

- Essential
  - Body does not have pathway to synthesize
- Non-essential
  - Can be provided through metabolic pathways
Dietary Protein

• Animal proteins
  – High-quality
  – Complete – 9 essential amino acids

• Low-quality
  – Incomplete
  – Most plant (except soy)
  – Cannot meet all amino acid needs

• Greater variety and amount of plant proteins needed
Dietary Protein

• All-or-none principle in protein synthesis
  – If not all of the amino acids are present, protein synthesis does not occur

• Limiting amino acids
  – Essential amino acid in smallest supply

• Complementary proteins
  – Mixed diets – foods containing different amino acids are combined
Limiting Amino Acid

C is the limiting amino acid in this example
## Limiting Amino Acids in Plant Foods

**Table 6-2  Limiting Amino Acids in Plant Foods**

<table>
<thead>
<tr>
<th>Food</th>
<th>Limiting Amino Acids</th>
<th>Good Plant Source of the Limiting Amino Acids*</th>
<th>Traditional Food Combinations in Which the Proteins Complement Each Other in a Meal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legumes (beans)</td>
<td>Methionine</td>
<td>Grains, nuts, seeds</td>
<td>Red beans and rice</td>
</tr>
<tr>
<td>Grains</td>
<td>Lysine, threonine, tryptophan</td>
<td>Legumes</td>
<td>Rice and red beans; lentil curry and rice; corn tortillas and beans</td>
</tr>
<tr>
<td>Nuts and seeds</td>
<td>Lysine</td>
<td>Legumes</td>
<td>Soybeans and ground sesame seeds (miso); peanuts, rice, and black-eyed peas; green peas and sunflower seeds</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Methionine</td>
<td>Grains, nuts, seeds</td>
<td>Green beans and almonds</td>
</tr>
</tbody>
</table>

Note: As you might suspect from the information in Table 6-2, the amino acids most likely to be low in a diet are lysine, methionine, threonine, and tryptophan. If a diet is low in an amino acid, nutrition experts recommend finding a good food source to supply it. Finding the right combinations of amino acids, such as a dish of rice and beans, is recommended. Forget about amino-acid supplements—they can lead to problems, such as decreased absorption of other, similar amino acids. Amino acids as such also have a disagreeable odor and flavor and are also much more expensive than food protein. *Animal products in the diet serve the same purpose, such as when fish is consumed with rice, or cheese with macaroni.*
Complementary Protein

Food 1 | Food 2 | Combined
CC     | CCCCC | CAR
AAAA   | AA    | CAR
RRR    | RRR   | CAR
Protein Synthesis

• DNA contains coded instructions  
  – nucleus
• Copies of codes  
  – Transferred to the cytoplasm (via mRNA)  
  – Moves to ribosomes, message read, translated
• Amino acids added one at a time  
  – With aid of transfer RNA (tRNA)
• Requires energy
Protein Synthesis

1. DNA contains the information necessary to produce proteins.

2. Transcription of DNA results in mRNA, which is a copy of the information in DNA needed to make a protein.

3. The mRNA leaves the nucleus and goes to a ribosome.

4. Amino acids, the building blocks of proteins, are carried to the ribosome by tRNAs.

5. In the process of translation, the information contained in mRNA is used to determine the number, kinds, and arrangement of amino acids in the protein.
Protein Organization

• Polypeptide chain
  – Twists and bends to native conformation
  – Determined by side chains
  – Hydrophobic or hydrophilic

• Order of amino acids in a protein determines its ultimate shape

• Protein’s final shape determines its function in the body
Primary structure
This level of structure is determined by the sequence of amino acids that join to form a polypeptide.
Fig. 6.2
Denaturation of Proteins

(a) Denatured Protein

Heat / Acid

(b) Native Protein
Denaturation of Proteins

Heat/acid/alkaline/enzymes

Results in alteration of the protein’s three dimensional structure
Denaturation

• Alter biological activity
• Cooking can make substances available
  – Vitamin – biotin (cooked eggs)
• Stomach acid
• Foods are a means of obtaining amino acids
Animal Protein

• Contribution to our diet
  – ~70% of our protein intake
• Top 5 contributors of protein in U.S. diet:
  – Beef
  – Poultry
  – Milk
  – White bread
  – Cheese
• Worldwide, 35% comes from animal sources
Plant Protein

• Provides
  – Protein, minerals, and dietary fiber
• Contains no cholesterol
• Limited saturated fats
• High fiber
  – Time needed to adjust to the higher fiber load
Digestion of Protein

• Begins with cooking
  – Denatures proteins
  – Softens connective tissue

• Chewing food
  – Stimulates gastrin release from stomach
  – Gastrin stimulates production of stomach acid (HCl)

• Protein in stomach
  – Signals enzyme secretion (pepsinogen → pepsin)
  – Protein denatured by stomach acid
  – Pepsin – unravels polypeptide chains
Digestion of Protein in the Small Intestine

- Chyme moves to small intestine
  - Release of CCK (walls of intestine)
  - CCK travels through bloodstream to pancreas
- Pancreatic enzymes:
  - Trypsin - into the duodenum
- Peptones $\rightarrow$ peptides $\rightarrow$ amino acids
- Small peptides and amino acids
  - Di- and tripeptides
  - Ready for absorption
Protein Absorption

• Site of absorption
  – Microvilli surface and within absorptive cells
  – Amino acids absorbed into mucosa
    • Active transport (carriers specific for amino acid)

• Amino acids are sent to the liver
  – Via portal vein
Protein Turnover

• Breakdown and synthesis
• Responds to change, needs
• Process 250 g protein/day
• Amino acids can be recycled
• Dietary intake – 65-100 g/day
Metabolism of Amino Acids
Functions of Proteins

• Building blocks of body structures
  – Part of every cell

• Maintain fluid balance
  – Blood pressure-Needed to perfuse blood throughout tissues
  – Move fluid from capillary beds to extracellular spaces
  – Protein in bloodstream attracts fluid
(a) Arterial end of capillary bed

- Blood cells
- Fluid forced into tissue spaces by blood pressure generated by pumping action of heart

(b) Venous end of capillary bed

- Proteins
- Fluid drawn into bloodstream by the proteins as blood pressure declines in the capillary bed

(b) Blood pressure balanced by counteracting force of protein

- Normal tissue

(b) Blood pressure exceeds counteracting force of protein, trapping fluid in tissues.

- Swollen tissue (edema)
Functions of Proteins

• Contribute to acid/base balance
  – Proteins are most plentiful buffer
    • Buffers inside cells and plasma
    • More protein inside cells
      – \( \frac{3}{4} \) buffering occurs intracellularly
    • Helps buffer extracellular fluids
      – Can take several hours
Functions of Proteins

• Building blocks for hormones and enzymes
  – Hormones may be one type amino acid or many different kinds of amino acids
  – Enzymes are all or at least part proteins

• Immune function
  – Antibodies

• Gluconeogenesis
  – Used to make glucose

• Energy
RDA for Protein

- Promotes equilibrium

- 0.8 gm of protein / kg of healthy body weight

\[
\text{154 lb.} \quad = \quad 70 \text{ kg} \\
2.2 \text{ kg/lb.}
\]

\[
70 \text{ kg} \times 0.8 \text{ g protein} = 56 \text{ g protein} \\
\text{kg healthy body wt}
\]
RDA for Protein

• Increased by ~10-15 gm /day for pregnancy
• Endurance athletes
  – May need 1.2 – 1.7 gm/kg healthy weight
• Provide about 8-10% of total kcal
• Most of us eat more than the RDA for protein
• Excess protein cannot be stored as protein
Protein Balance

Situations in which protein balance is positive:
- Growth
- Pregnancy
- Recovery stage after illness, injury
- Athletic training**
- Increased secretion of certain hormones, such as insulin, growth hormone, and testosterone

Situations in which protein balance is negative:
- Inadequate intake of protein (fasting, intestinal tract diseases)
- Inadequate calorie intake
- Conditions such as fevers, burns, and infections
- Bed rest (for several days)
- Deficiency of essential amino acids (e.g., poor-quality protein consumed)
- Increased protein loss (as in some forms of kidney disease)
- Increased secretion of certain hormones, such as thyroid hormone and cortisol

*Based on losses of urea and other nitrogen-containing compounds in the urine, as well as protein itself lost from feces, skin, hair, nails, and other minor routes.

**Only when additional lean body mass is being gained. Nevertheless, the athlete is probably already eating enough protein to support this extra protein synthesis; protein supplements are not needed.
Vegetarian Diets

• Why become a vegetarian?
  – Philosophy, religion
  – Reduce risk of chronic diseases
    • Limits saturated fat and cholesterol

• Vegans
  – No use of animal products for any purpose

• Fruitarians
  – Fruits, nuts, honey, vegetable oils

• Lactovegetarians
  – Dairy products, plant foods

• Lactoovovegetarians
  – Dairy products, eggs, plant foods
Concerns for infants and children

- Deficiencies of iron, B-12, D, calcium
- High volume
- Low caloric density
- May not eat enough for caloric needs
The Vegetarian Diet Pyramid

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The Traditional Healthy Vegetarian Diet Pyramid

Daily beverage recommendations: 6 glasses of water

Alcohol in moderation

Weekly

Daily

At every meal

Daily Physical Activity
Is a High-Protein Diet Harmful?

- Low in plant foods (fiber), vitamins, phytochemicals
- High in saturated fat and cholesterol
- Excessive intake of processed red meat is linked with colon cancer
- Burden on the kidney
- May increase calcium loss in the urine
Calcium Loss

- Meat eating increases osteoporosis risk
  - Increase in sulfur ions from methionine-containing amino acids
  - Excess sulfur makes blood more acidic
  - Bone constituents used to neutralize acid load
  - Increases calcium in urine
Calcium Loss

• Excess amino acids pass through liver
• >50% converted to breakdown product
  – Urea
• 23% amino acids returned to general circulation
• Excessive urea acts as a diuretic
  – Eliminates water
  – Eliminates minerals
HIGH PROTEIN DIET ROBS BODY OF CALCIUM

<table>
<thead>
<tr>
<th>Amount of Protein Ate</th>
<th>Calcium Gain/Loss (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>48 gms. protein/day</td>
<td>Gain: 20</td>
</tr>
<tr>
<td>95 gms. protein/day</td>
<td>Loss: -20</td>
</tr>
<tr>
<td>142 gms. protein/day</td>
<td>Loss: -70</td>
</tr>
</tbody>
</table>
Calcium Loss

• Leads to increased risk of kidney stones
  – >61 g/day increases risk
  – Risk offset by
    • Eating foods high in potassium
    • Drinking plenty of water
High Protein

• Linked to cancer
  – Lymphoma – cancer of lymph glands
  – Strikes younger adults
  – ~ 23,000 deaths/year
  – USA joins Finland with highest incidence of lymphoma deaths/year
High Protein

- High blood pressure and diabetes
  - Destroy kidney’s filtering units – nephrons
- Diabetics
  - Kidney disease is one of the leading causes of
    - Disability
    - Death
  - 1 in 3 develop kidney failure
Kidney Failure

• Research study
  – Diabetics placed on low protein diet
    • 42 g/day
    • Stop kidney function deterioration
LOW PROTEIN DIET ARRESTS KIDNEY FAILURE IN DIABETICS

- Normal American diet
- One year of low protein diet

Kidney filtering ability ml/min.

Diet changed
One year after diet change

50

0

100
Malnutrition

• Protein-Energy Malnutrition

• Kwashiorkor
  – Third world countries
  – Little protein in diet
  – Symptoms
    • Flaky skin, fatty liver, reduced muscle mass
    • Edema in abdomen and legs*
  – Protein not available for fluid balance, immune function, proper growth
Malnutrition

• Marasmus
  – Protein and calorie deficiency
  – Seen in hospitalized patients
Protein Calorie Malnutrition

Moderate calorie deficit with severe protein deficit, especially in light of increased needs due to infections

Kwashiorkor
(edema with maintenance of some subcutaneous fat tissue)

Severe calorie and protein deficit

Marasmus
(skin and bones appearance with little or no subcutaneous fat tissue)