Amino Acid Structure

Side group varies

Amino group

Acid group
Carbohydrates and lipids are composed of carbon, hydrogen and oxygen molecules.

Proteins also contain carbon, hydrogen and oxygen molecules, BUT in addition, they also contain nitrogen, a key element that distinguishes protein from other macronutrients.

The simple sugar (monosaccharide) is the building block for carbohydrates. The fatty acid is the building block for lipids. The amino acid is the building block for protein.
Examples of Amino Acids

- Glycine
- Alanine
- Aspartic acid
- Phenylalanine
Protein

- Side groups on amino acids make each one unique
- Side groups make proteins more complex than either carbohydrates or lipids
- When amino acids are linked together to form long chains or polypeptides/proteins (primary structure of protein) the side groups act to attract or repel other side groups in the chain causing the protein to fold or bend in a characteristic (secondary & tertiary structures)
The Chemist’s View of Proteins

- Proteins
  - Protein Shapes
    - Hydrophilic side groups are attracted to water.
    - Hydrophobic side groups repel water.
    - Coiled and twisted chains help to provide stability.
The Structure of Hemoglobin

Four highly folded polypeptide chains form the globular hemoglobin protein.

Iron

Heme, the nonprotein portion of hemoglobin, holds iron.

The amino acid sequence determines the shape of the polypeptide chain.
Essential Amino Acids: cannot be made by the body, must be supplied by the diet
- Histidine
- Isoleucine
- Leucine
- Lycine
- Methionine
- Phenylalanine
- Threonine
- Tryptophan
- Valine
Non-essential amino acids: can be created by the body
- Alanine, arginine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine, tyrosine

Conditionally essential amino acids
- Tyrosine may become essential if the diet fails to supply adequate phenylalanine (a precursor for tyrosine). This can happen for individuals being treated for the inborn error of metabolism, phenylketonuria
Body proteins are unique for each human being.

Uniqueness of a protein is determined by the amino acid sequence & genetics.

DNA is used as a template to make a strand of messenger RNA to deliver the amino acid sequence code for protein synthesis (transcription) to cellular apparatus for protein synthesis (translation).
Protein Synthesis

1. The DNA serves as a template to make strands of messenger RNA (mRNA). Each mRNA strand contains the instructions for making some protein the cell needs.

2. The mRNA leaves the nucleus through the nuclear membrane. DNA remains inside the nucleus.

3. The mRNA attaches itself to the protein-making machinery of the cell, the ribosomes.

4. Another form of RNA, transfer RNA (tRNA), collects amino acids from the cell fluid. Each tRNA carries its amino acids to the mRNA, which dictates the sequence in which the amino acids will be attached to form the protein strand. Thus the mRNA ensures the amino acids are lined up in the correct sequence.

5. As the amino acids are lined up in the right sequence, and the ribosome moves along the mRNA, an enzyme bonds one amino acid after another to the growing protein strand. The tRNA are freed to return for more amino acids. When all the amino acids have been attached, the completed protein is released.

6. Finally, the mRNA and ribosome separate. It takes many words to describe these events, but in the cell, 40 to 100 amino acids can be added to a growing protein strand in only a second. Furthermore several ribosomes can simultaneously work on the same mRNA to make many copies of the protein.

© 2007 Thomson Higher Education

© 2009 Cengage - Wadsworth
Sequencing errors can cause altered proteins to be made.

- An example is sickle-cell anemia where an incorrect amino acid sequence interferes with the cell’s ability to carry oxygen.
Sickle-shaped blood cell  Normal red blood cell

Amino acid sequence of normal hemoglobin:
Val - His - Leu - Thr - Pro - Glu - Glu

Amino acid sequence of sickle-cell hemoglobin:
Val - His - Leu - Thr - Pro - Val - Glu
Cells synthesize proteins according to the genetic information provided by the DNA in the nucleus in each cell

- DNA determines the sequence of amino acids in a given protein (primary protein structure)

Cells possess genes for making many proteins but only “express” the genes for the proteins needed by the cell

Epigenetics – study of factors that activate or silence gene expression without changing the genetic sequence itself.
Protein Functions in the Body

- Building Materials for Growth
- Maintenance of all body tissues, e.g.,
  - A matrix of collagen is filled with minerals to provide strength to bones and teeth.
  - Replaces tissues including the skin, hair, nails, and GI tract lining
  - Replaced red blood cells every 120 days
Protein Functions in the Body

- Enzymes are proteins that facilitate anabolic (building up) and catabolic (breaking down) chemical reactions.

- Hormones regulate body processes and some hormones are proteins. An example is insulin.
Protein Functions in the Body

Regulators of Fluid Balance
- Plasma proteins attract water
- Maintain the volume of body fluids to prevent edema which is excessive fluid
- Maintain the composition of body fluids
Protein Functions in the Body

- The chemical structure of amino acids & protein makes them **amphoteric**
  - Amphoteric = capable of acting as both an acid and a base; capable of neutralizing either bases of acids
  - Amino acids have an acid end (−COOH) and a basic end (−NH₂).

![Amphoteric Amino Acid Diagram]
Protein Functions in the Body

- Acid–Base Regulators
  - Act as buffers by keeping solutions acidic or alkaline
    - Acids release hydrogen ions in a solution.
    - Bases accept hydrogen ions in a solution.
  - Acidosis is high levels of acid in the blood and body fluids.
  - Alkalosis is high levels of alkalinity in the blood and body fluids.
Protein Functions in the Body

- Transporters
  - Carry lipids, vitamins, minerals and oxygen in the body
  - Act as pumps in cell membranes, transferring compounds from one side of the cell membrane to the other
An Example of a Transport Protein

Key:
- Sodium
- Potassium

The transport protein picks up sodium from inside the cell.

The protein changes shape and releases sodium outside the cell.

The transport protein picks up potassium from outside the cell.

The protein changes shape and releases potassium inside the cell.

© 2007 Thomson Higher Education
Protein Functions in the Body

Antibodies
- Fight antigens, such as bacteria and viruses, that invade the body
- Provide immunity to fight an antigen more quickly the second time exposure occurs
Other Roles

- Blood clotting by producing fibrin which forms a solid clot
- Vision by creating light-sensitive pigments in the retina
- Source of energy and glucose if needed
  - Protein-sparing roles of carbohydrates and fats
Protein turnover is the continual making and breaking down of protein.

Amino acid pool is the supply of amino acids that are available.

Amino acids from food are called exogenous.

Amino acids from within the body are called endogenous.
Nitrogen Balance

- Zero nitrogen balance (normal adult state)
  - Nitrogen equilibrium,
  - When input equals output.

- Positive nitrogen balance (growth)
  - Nitrogen consumed is greater than nitrogen excreted.

- Negative nitrogen balance (wasting, malnutrition)
  - Nitrogen excreted is greater than nitrogen consumed.
Proteins in the Body

- Amino Acids can be used by the body
  - To make proteins or nonessential amino acids
  - To make other compounds, e.g.,
    - Neurotransmitters are made from the amino acid tyrosine.
    - Tyrosine can be made into the melanin pigment or thyroxine.
    - Tryptophan makes niacin (one of the B-complex vitamins) and serotonin.
Proteins in the Body

- Amino Acids can be used to make Fat
  - Excess protein is deaminated and converted into fat.
  - Nitrogen is excreted.
- Amino Acids can be used to make glucose (gluconeogenesis)
  - There is no readily available storage form of protein.
  - The body breaks down tissue protein for energy if needed
Deamination of Amino Acids

- Removal of the amino or nitrogen-containing group
- Ammonia is released into the bloodstream.
- Ammonia is converted into urea by the liver.
- Kidneys filter urea out of the blood.
The quality of protein is measured by its:
- amino acid content,
- digestibility, and
- ability to support growth.

A diet inadequate in any of the essential amino acids limits protein synthesis.
Protein in Foods

- **Digestibility**
  - amount of amino acids absorbed from a given intake.

- **Digestibility of a protein depends on**
  - Source of protein
  - Other foods consumed with it
  - Most animal proteins are 90–99% digestible
  - Protein in soy & legumes is over 90% digestible
  - Plant proteins range from 70–90% digestible
Proteins in Food

- Reference protein
  - Standard against which the quality (usually essential amino acid content) of other proteins are measured

- Limiting amino acid:
  - an essential amino acid present in a protein in less than the amount needed to support protein synthesis

- Complementary protein
  - Two or more dietary proteins whose amino acid assortments complement each other such that the essential amino acids missing in one are supplied by the other, e.g. grains + legumes
Dietary Guidelines 2010

Ten Tips

◦ Vary your protein choices
◦ Choose seafood twice a week
◦ Make meat & poultry lean or low fat
◦ Have an egg
◦ Eat plant protein foods more often
◦ Choose unsalted nuts or seeds (watch portions)
◦ Try grilling, broiling, roasting, or baking or slow cooking to keep it tasty & healthy
◦ Think small when it comes to portions
◦ Check the sodium
Protein–Energy Malnutrition (PEM)
- Also called protein–kCalorie malnutrition (PCM)

Classifying PEM
- Chronic PEM and acute PEM
- Maramus, kwashiorkor, or a combination of the two
Protein Energy Malnutrition

- PEM
  - Marasmus
    - Infancy, 6 to 18 months of age
    - Severe deprivation or impaired absorption of protein, energy, vitamins and minerals
    - Develops slowly
Protein Energy Malnutrition

- PEM
  - Marasmus
    - Severe weight loss and muscle wasting, including the heart
    - < 60% weight–for–age
    - Anxiety and apathy
    - Good appetite is possible
    - Hair and skin problems
Protein Energy Malnutrition

- PEM
  - Kwashiorkor
    - Older infants and young children, 18 months to 2 years of age
    - Inadequate protein intake, infections
    - Rapid onset
    - Some muscle wasting, some fat retention
**Protein Energy Malnutrition**

- **PEM**
  - **Kwashiorkor**
    - Growth is 60–80% weight-for-age
    - Edema and fatty liver
    - Apathy, misery, irritability and sadness
    - Loss of appetite
    - Hair and skin problems
Protein Energy Malnutrition

- PEM
  - Marasmus–Kwashiorkor Mix
    - Both malnutrition and infections
    - Edema of kwashiorkor
    - Wasting of marasmus
Protein Energy Malnutrition

PEM

- Infections
  - Lack of antibodies to fight infections
  - Fever
  - Fluid imbalances and dysentery
  - Anemia
  - Heart failure and possible death
Protein Energy Malnutrition

- PEM
  - Rehabilitation
    - Nutrition intervention must be cautious, slowly increasing protein.
    - Programs involving local people work better.
Health Effects of Protein

- Heart Disease
  - Foods high in animal protein also tend to be high in saturated fat.
  - Elevated Homocysteine (an amino acid) levels increase cardiac risks.
  - Arginine (an amino acid) may protect against cardiac risks.
Protein & Health

- Health Effects of Protein
  - Cancer
    - A high intake of animal protein is associated with some cancers.
    - Is the problem high protein intake or high fat intake?
  - Adult Bone Loss (Osteoporosis)
    - High protein intake associated with increased calcium excretion.
    - Inadequate protein intake affects bone health also.
Protein & Health

Health Effects of Protein

- Weight Control
  - High-protein foods are often high-fat foods.
  - Protein at each meal provides satiety.
  - Adequate protein, moderate fat and sufficient carbohydrate better support weight loss.
Health Effects of Protein

- Kidney Disease
  - High protein intake increases the work of the kidneys.
  - Does not seem to cause kidney disease
Recommended Intakes of Protein

- **Assumptions**
  - People are healthy.
  - Protein is mixed quality.
  - The body will use protein efficiently.

- **RDA for protein (adults)**
  - $0.8 \text{ grams} \times \text{body wt (kg)}$

- **AMDR (Acceptable Macronutrient Distribution Range)**
  - 10–35% energy intake
Recommended Intakes of Protein

- **Adequate Energy**
  - Must consider energy intake
    - If energy intake is not adequate, protein consumed will be used for energy not other protein functions
    - Adequate carbohydrate & fat intake *spare* protein for other body functions
  - Must consider total grams of protein

- **Protein in abundance is common in the U.S. and Canada.**