Chapter 6
Protein: Amino Acids
The Chemist’s View of Proteins

Amino Acids

**Essential amino acids**, also called indispensable amino acids, must be supplied by the foods people consume.

Essential amino acids include histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine.

**Nonessential amino acids**, also called dispensable amino acids, are ones the body can create.

Nonessential amino acids include alanine, arginine, asparagines, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine, and tyrosine

The Chemist’s View of Proteins

**Conditionally essential amino acids** refer to amino acids that are normally nonessential but essential under certain conditions.

Ex: phenylalanine → tyrosine

The Chemist’s View of Proteins

**Proteins**

Amino acid chains are linked by peptide bonds in condensation reactions.

* Dipeptides have two amino acids bonded together.
* Tripeptides have three amino acids bonded together.
* Polypeptides have more than two amino acids bonded together.

**Amino acid sequences**

are all different

which allows for a wide variety of possible sequences.

**Primary structure** — Amino Acid Sequence

**Secondary structure** — electrical attractions

**Tertiary structure** — hydrophilic & hydrophobic

**Twists and folds**

**Quaternary structure** — two or more polypeptides

The Coiling and Folding of a Protein Molecule

**Protein shape and function**
The Chemist’s View of Proteins
Proteins
Protein Functions
Some carry and store materials - hemoglobin
Some provide strength - muscle fibers
Some require minerals for activation (example: hemoglobin and the mineral iron).
Protein denaturation is the disruption of the stability of the protein
The protein uncoils, it loses its shape, and loses its ability to function.
Proteins can be denatured by heat and acid (stomach acid)
After a certain point, denaturation cannot be reversed - cooked egg
Proteins- Review
Amino Acid Chains
- Dipeptide polypeptide
Amino acid sequences
- Specific for each protein
Protein shapes
Polypeptide chains twist depending on their amino acid sequence
Protein functions-unique shape allows them to perform their function
Protein denaturization-heat, acid disturb their stability and cause them to denature; they uncoil and lose their shape and function
Protein Digestion in the GI Tract
Protein Digestion
Protein Synthesis
Human body contains an estimated 30,000 different kinds of proteins.
Each protein is determined based on their amino acid sequence which is determined by genes.
The instructions for making every protein in the body are transmitted by the DNA in the nucleus of every cell
Protein Synthesis
Delivering the Instructions
Protein Synthesis
Lining Up the Amino Acids
Protein Synthesis
Sequence Errors
Protein Syntheses
- Nutrients and Gene Expression -
Cells regulate gene expression to make the type of protein needed for that cell, in the amounts and rates it needs them
Nearly all body cells have the genes to make all proteins
Each cell makes only the protein it needs
Proteins in the Body
Roles of Proteins
Building Materials for **Growth and Maintenance**
Building blocks for most body structures, id, collagen
Replaces tissues including the skin, hair, nails, and GI tract lining, muscles, organs

**Hormones**
Messenger molecules and some hormones are proteins
Regulate body processes. An example is insulin.

**Enzymes**
Proteins that facilitate the building of substance
Proteins that break down substances

Roles of Proteins

**Regulators of Fluid Balance**
In critical illness or malnutrition, proteins leak out of the blood vessel and into the tissues
Fluid accumulates and causes swelling, or edema

Roles of Proteins

**Acid-Base Regulators**
Proteins have a negative charge; they attract positive hydrogen ions
By accepting and releasing hydrogen, they control acid-base balance

Roles of Proteins

**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

Roles of Proteins

**Antibodies**
Defend against disease
Fight bacteria and viruses, that invade the body
Provide immunity to fight an antigen more quickly the second time exposure occurs

Roles of Proteins

**Source of energy and glucose if needed**
Will be sacrificed in times of starvation

Other Roles

**Blood clotting**

**Vision**
Roles of Proteins
Hormones
Antibodies
Fluid and electrolyte balance
Acid-base balance
Proteins regulate body processes. (Some hormones are made of protein.)
Proteins inactivate foreign invaders and protect the body against diseases.
Proteins help maintain the volume and composition of body fluids
Proteins help maintain the acid-base balance of body fluids by acting as buffers.
Roles of Proteins
Transportation
Energy
Proteins transport substances such as lipids, vitamins, minerals and oxygen, around the body
Proteins provide some fuel for the body’s energy needs.
Protein Metabolism

**Protein Turnover:**
Proteins are continually made and broken down.
Amino acids from body proteins mix with dietary protein to form an “amino acid pool” available in cells and blood
Remade into new protein.
Constant process
Protein Metabolism

**Nitrogen Balance:**
Intake from food (amino acids) balances with nitrogen excretion in feces, urine and sweat
Nitrogen in = Nitrogen out.
Nitrogen in > nitrogen out = Positive nitrogen balance
Growing infants, children, pregnant women
They are retaining protein in new tissue as they add blood, bone, muscle
Nitrogen out > Nitrogen in = Negative nitrogen balance
Starvation, burns, infections, fever
Protein Metabolism

Using Amino Acids to Make Proteins or Nonessential Amino Acids –
Cells can assemble amino acids into the protein needed
Can use essential amino acids to make non-essential amino acids
Using Amino Acids to Make Other Compounds
Neurotransmitters are made from the amino acid tyrosine.
Tyrosine can be made into the melanin pigment or thyroxin.
Tryptophan makes niacin and serotonin.
Protein Metabolism
Using Amino Acids for Energy and Glucose
We do not store protein.
When glucose or fat are not available:
Breaks down protein tissue for energy
Starvation causes loss of lean body tissue as well as loss of fat
Adequate supply of carbohydrate and fat spares body protein tissue
Preview of Protein Metabolism
Making fat
Energy and protein exceed needs
Carbohydrate intake is adequate
Can contribute to weight gain
Proteins in the Body
A Preview of Protein Metabolism
Deamination of Amino Acids
When amino acids are broken down- nitrogen-containing amino groups are removed- deamination
Ammonia is released into the bloodstream.
Ammonia is converted into urea by the liver.
Kidneys filter urea out of the blood and it is excreted in urine
Preview of Protein Metabolism
Protein Metabolism
Deaminating Amino Acids: removing the nitrogen containing groups

\[ \text{N} \quad \text{NH}_3 \quad \text{liver} \quad \text{urea} \quad \text{kidneys filter out} \]

\[ \text{urine} \]

Protein in Food
Protein Quality
Two Factors
Digestibility- amount of amino acids absorbed
Other foods consumed
Animal vs. plant proteins
Animal protein is 90-99%
Soy and Legumes is 90%
Plant protein is 70-90%
Amino acid composition
To make a protein, the cell must have all the need amino acids available
Essential amino acid consumption must be adequate
Protein In Food

Protein Quality

**Amino Acid Composition - Limiting AA:**
- The liver can make nonessential amino acids from the essential amino acids available
- If the diet supplies too little of any of the essential amino acids, it is called a *limiting amino acid*.

*Lysine, methionine, threonine, tryptophan*
- If the diet supplies too little of an essential AA, protein synthesis will be limited.

Protein in Foods

Protein Quality

**Reference protein**

**Essential AA requirements of preschool-age children**

**High-Quality Proteins**

- Contain all the essential amino acids in the amounts required
- Animal foods contain all the essential amino acids - meats, fish, poultry, eggs, yogurt, milk
- Plant foods tend to be missing one or more essential amino acids.

Protein Quality

**Complementary proteins**

- Two or more dietary proteins whose amino acid assortments complement each other such that the essential amino acids missing are supplied by the other.

Health Effects of Recommended Intakes of Protein

**Protein-Energy Malnutrition (PEM)**

- Deficient in protein, energy, or both
- Most often strikes children
- Affects 1 in 4 children worldwide (25%)
- Most of the 33,000 children who die each day are malnourished

**Poor growth in children**

- In adults, wasting and weight loss occur

**Protein-Energy Malnutrition**

- Acute PEM: recent food deprivation
- Thin for their height
- Chronic PEM: long term food deprivation
- Short for their age

**Protein Malnutrition**

- Most prevalent in Africa, Central America, South America, Middle East, East and Southeast Asia
- In the US - the homeless, poverty, elderly, drug and alcohol addiction
- Prevalent in AIDS, tuberculosis, anorexia
Health Effects and Recommended Intakes of Protein

Marasmus (chronic PEM)
Severe deprivation or impaired absorption of protein, energy, vitamins and minerals
6 to 18 months of age
Develops slowly
Severe weight loss and muscle wasting, including the heart
Impairs brain development and learning ability
Slows metabolism and lowers body temperature
< 60% weight-for-age
Anxiety and apathy
Hair and skin problems
No edema or fatty liver
Good appetite is possible

Protein-Energy Malnutrition (PEM)
Health Effects and Recommended Intakes of Protein

PEM
Kwashiorkor (acute PEM)
Rapid onset - sudden recent food deprivation - acute
Older infants and young children, 1-3 years
Inadequate protein intake or infections
Some weight loss
Some muscle wasting, some fat retention
Growth is 60-80% weight-for-age
Edema and fatty liver
Apathy, misery, irritability and sadness
Loss of appetite
Hair and skin problems
Malnourished Children in India
St. Luke’s Hospital in Kenya
A malnourished child is weighed in Bolosso Sorie, Ethiopia. International Medical Corps’ nutritional programs have seen an enormous spike in the number of malnourished children just in the past few months alone.

Marasmus-Kwashiorkor Mix
Both malnutrition and infections
Edema of kwashiorkor
Wasting of marasmus
Health Effects and Recommended Intakes of Protein

PEM
Infections
Lack of antibodies to fight infections
Fever
Fluid imbalances and dysentery
Anemia
Heart failure and possible death
Rehabilitation
Nutrition intervention must be cautious, slowly increasing protein.
Programs involving local people work better.

Health Effects and Recommended Intakes of Protein
Health Effects of Protein
Heart Disease
Foods high in animal protein also tend to be high in saturated fat.
Homocysteine levels increase cardiac risks.
Cigarettes, alcohol, coffee
Arginine may protect against cardiac risks.

Health Effects and Recommended Intakes of Protein
Health Effects of Protein
Cancer
A high intake of animal protein is associated with some cancers.
Red meat, processed meat-cancer

Adult Bone Loss (Osteoporosis)
High protein intake associated with increased calcium excretion.
Inadequate protein intake affects bone health also.

Health Effects and Recommended Intakes of Protein
Health Effects of Protein
Weight Control
Protein at each meal provides satiety.
Adequate protein, moderate fat and sufficient carbohydrate better support weight loss.

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

Recommended Intakes of Protein
General recommendation is 10-35% of kcalories
In a 2000 kcal diet-
200-700 kcal or 50-175 grams of protein

Protein RDA
- .8 grams per kg of healthy body weight
- Increases for infants, children, pregnant women
- Athletes need 1.2-1.7 grams per kg per day
Recommended Intakes of Protein
Adequate Energy
Protein in abundance
   1 ounce of protein = 7 grams
   8 ounces of protein = 56 grams
Protein in Foods
Protein and Amino Acid Supplements
Muscle work builds protein-not protein supplements
Food energy spares body protein-carbohydrate and fat
Protein supplements
Whey protein may increase protein synthesis when combined with strength training
Do not enhance athletic performance
Excess will be stored as fat
Protein and Amino Acids Supplements
Single amino acids do not occur naturally in food
Expensive
Less completely digested
Single amino acids can be harmful
Excess of one can lead to deficiency of another
May cause diarrhea
Lysine and Tryptophan
Possible Uses
Lysine-May suppress herpes in some individuals
   Up to 3 grams appears safe
Tryptophan-may be effective for sleep, pain
   Experimental
      1500 people developed eosinophilia-myalgia syndrome (muscle pain, high fever, 3 dozen deaths)
FDA issued recall of manufactured tryptophan due to impurities in the supplements
Inappropriate Protein Supplement Use
All women of childbearing age
Pregnant and lactating women
Infants, children and adolescents
Elderly people
People with inborn errors of metabolism
Smokers
People on low protein diets (kidney, liver disease)
Chronic or acute mental or physical illness
End of Chapter 6