Protein and Amino Acids, Chap. 6

Module 6 Oct. 8, 2020
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Today's Learning Objectives

- Discuss why some amino acids are essential, nonessential, or conditionally essential to the human body, and state what happens when essential amino acids are lacking.
- Compare the digestion of protein and transport of amino acids in the body with that of lipids.
- Discuss the various roles of proteins and amino acids in the body.

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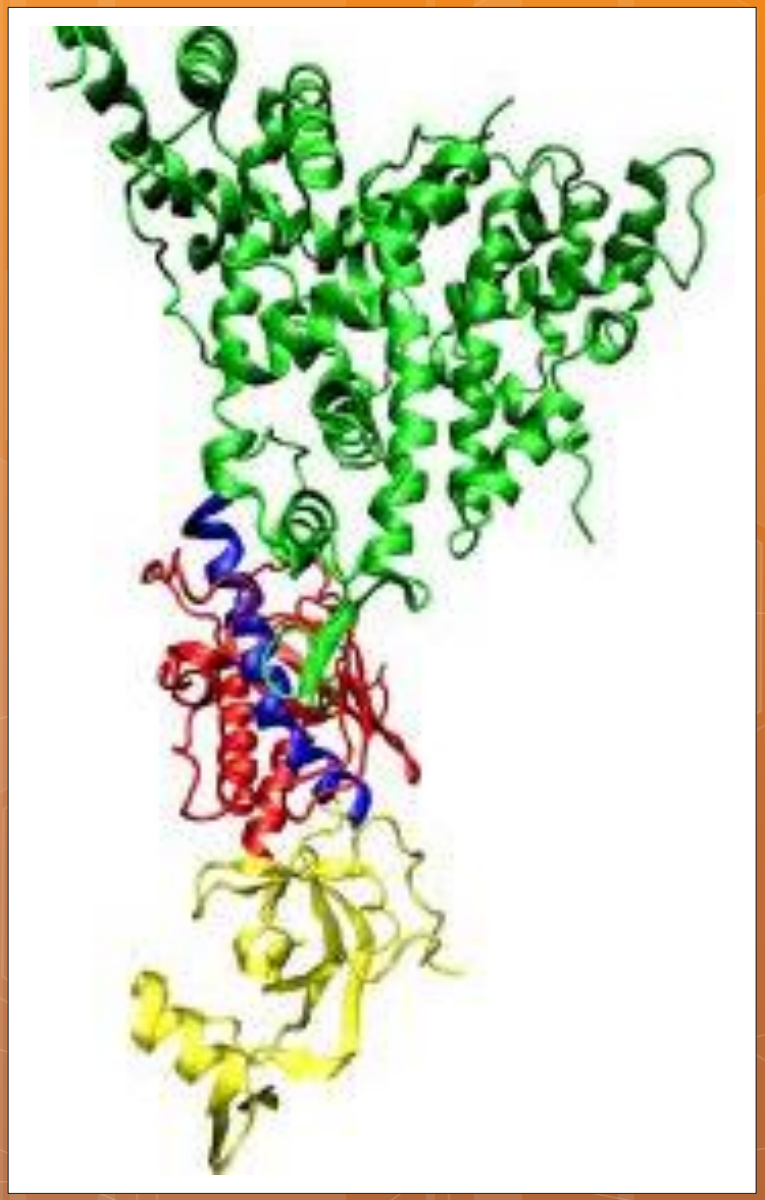
Module 6 OUTLINE

- Protein
- Roles in the body
- Requirements and dietary sources
- Protein and Health
- More specific recommendations
- Vegetarianism/Veganism



Protein Structure

Protein Structure

Amino Acids

- Building blocks of protein
- Made up of: Carbon, Hydrogen, Oxygen **Nitrogen**, Sometimes Sulphur

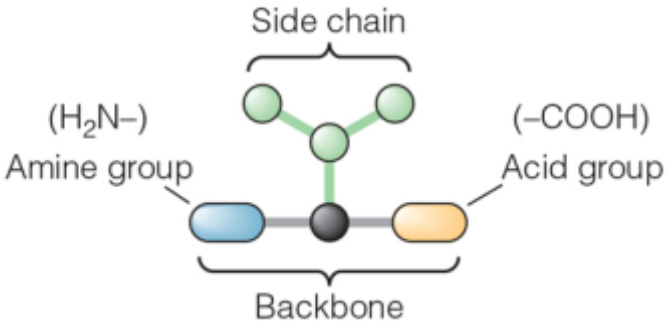
Structure:

- Carbon atom with amine group and acid group
- Unique side chain

Figure 6–1

An Amino Acid

The "backbone" is the same for all amino acids. The side chain differs from one amino acid to the next. The nitrogen is in the amine group.



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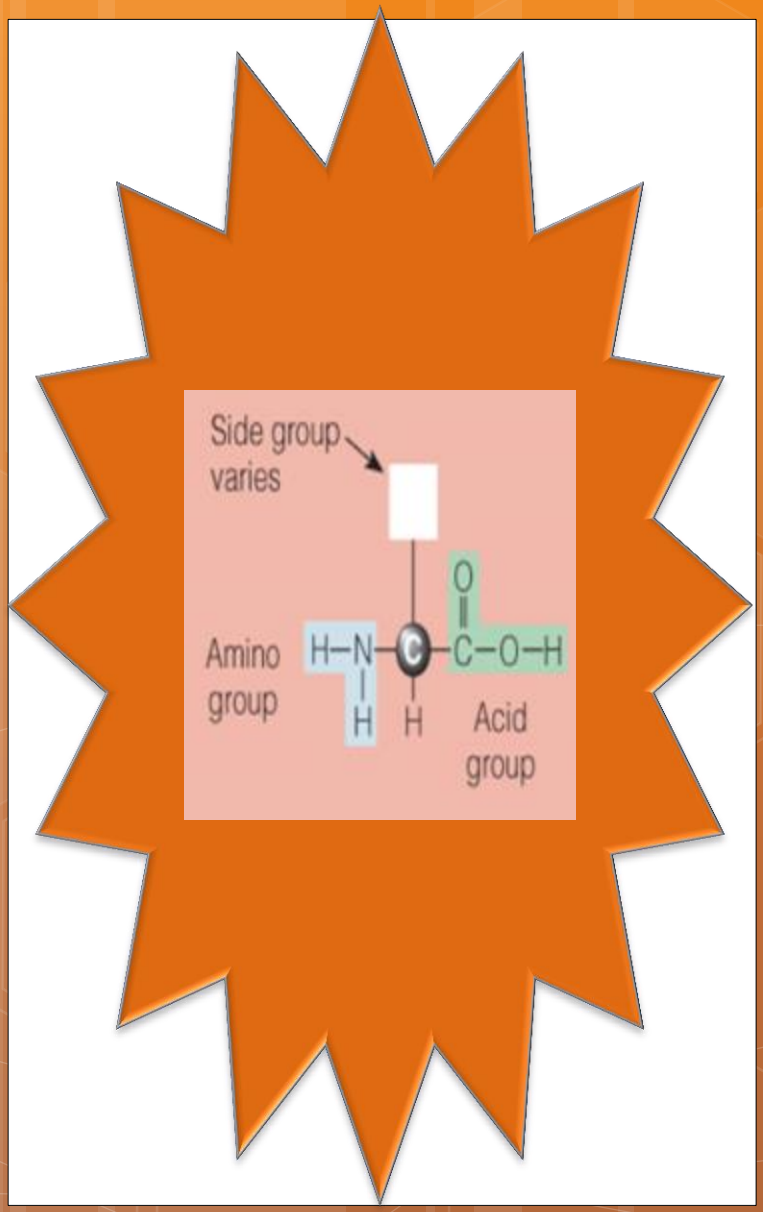


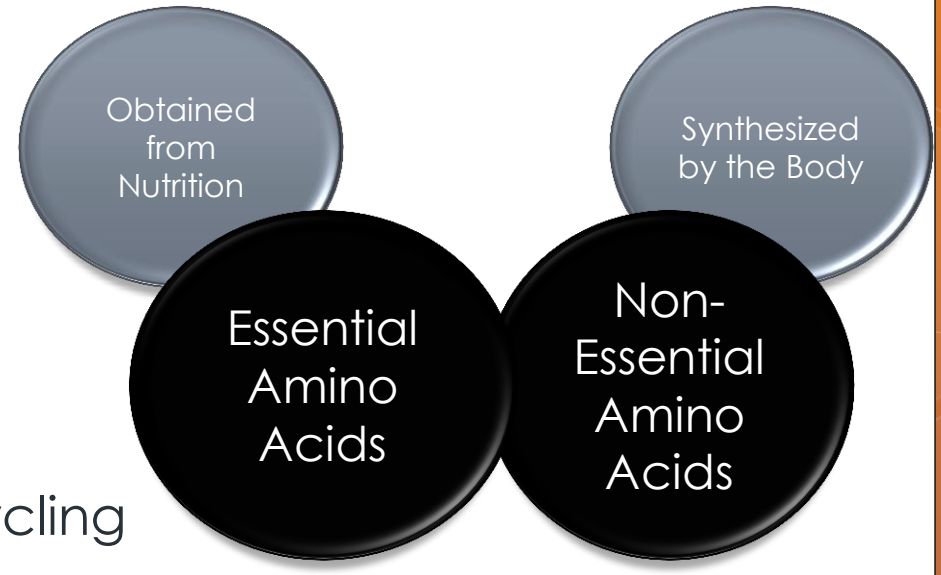
True or False?

Essential amino acids are not synthesized in the body..

20 Amino Acids (AA)

2-3 groups

- Essential:
  - Not made by the body
  - Obtained from foods
- Non-essential:
  - Made by the body, recycling
- Conditionally essential
  - Special situations- needs to be eaten.. PKU

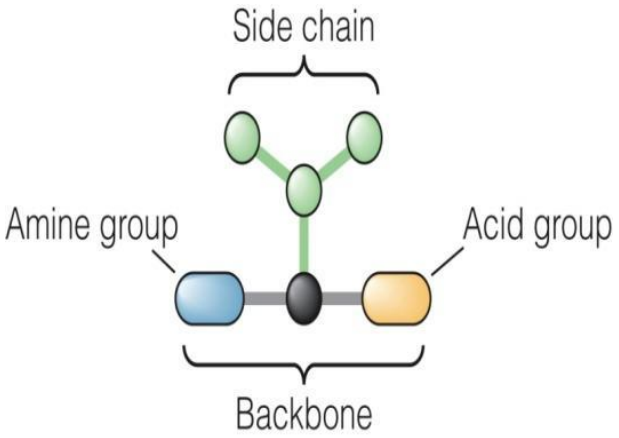


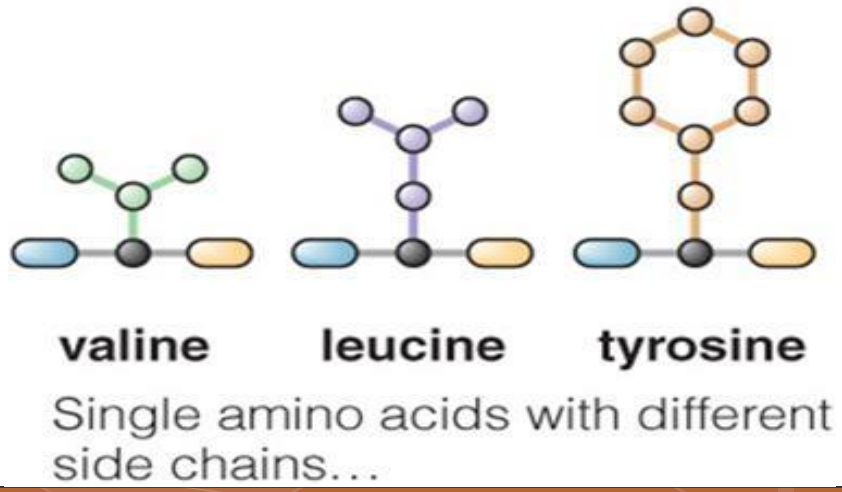
Amino Acids (AA)

Non Essential Amino Acids	Essential Amino Acids
Alanine	Histidine
Aspartic Acid	Isoleucine
Glutamic Acid	Leucine
Arginine	Lysine
Asparagine	Methionine
Cysteine	Phenylalanine
Glutamine	Threonine
Glycine	Tryptophan
Proline	Valine
Serine	
Tyrosine	

Amino Acid Structure

- AMINE group + ACID group = backbone
- Unique side chains extend out from backbone
  - Differ in size and shape
  - Determine its function





Single amino acids with different side chains…

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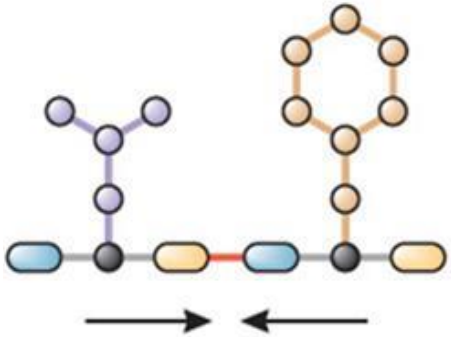
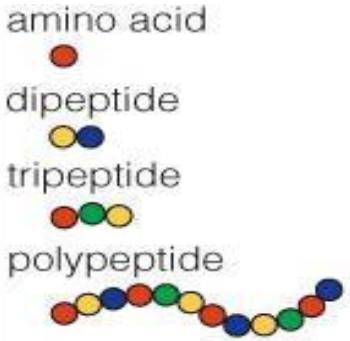
Protein Structure and Synthesis

- How do amino acids build proteins?

  Amino Acid + Amino Acid → Peptide bond



- Amino acids link via these peptide bonds until the strand contains several dozen to as many as 300 amino acids



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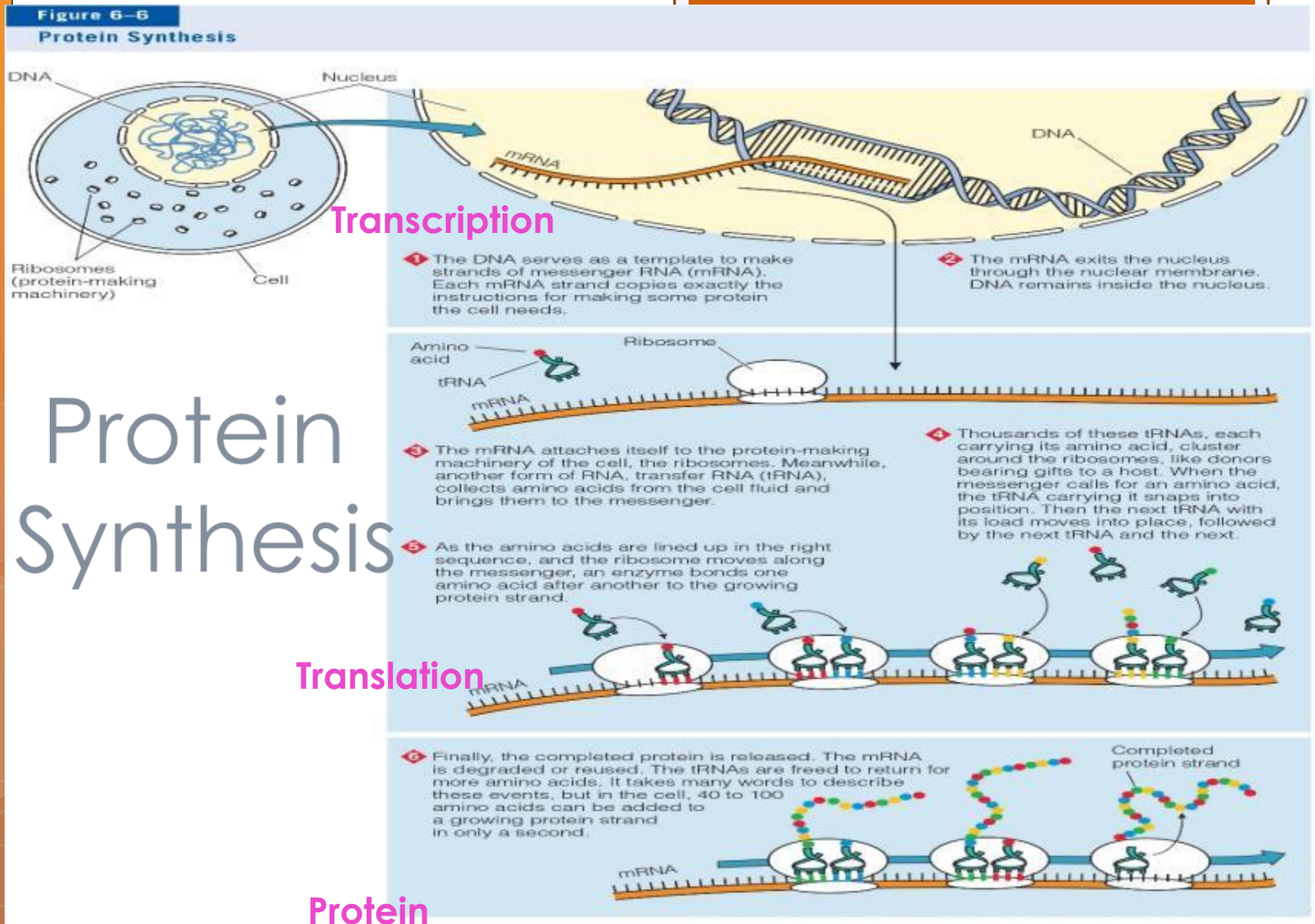
Protein Synthesis



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How Do Amino Acids Build Proteins?

- For a protein to become functional:
  - Several strands may cluster together into a functioning unit, or;
  - A metal ion (mineral) or a vitamin may join to the unit and activate it

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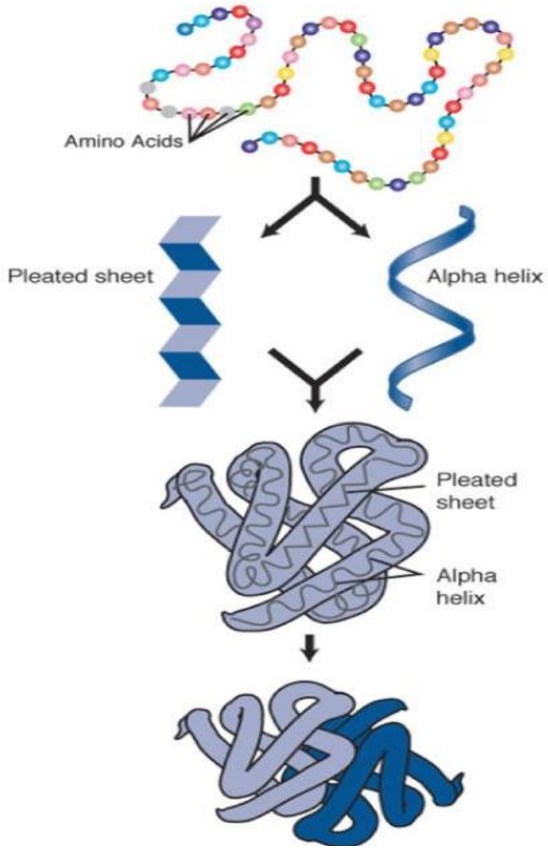
Protein Structure

Protein shapes enable the performance of different tasks in the body



- Primary
- Secondary
- Tertiary
- Quaternary

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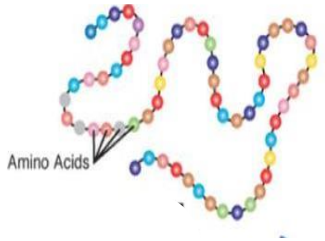
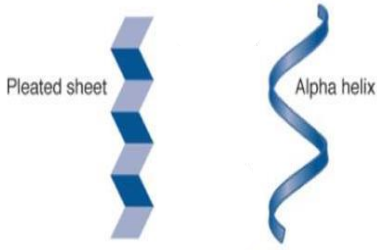
Protein Structure

- Protein strand of amino acids does not remain straight
  - Primary Structure



- The amino acids at different places along the strand are chemically attracted to each other causing the strand to coil
  - Secondary Structures…
    - Alpha Helix
    - Beta Pleated Sheet



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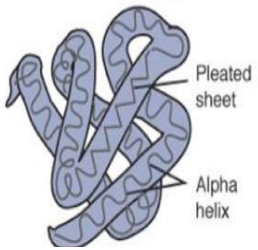
Protein Structure

- Places within this coil are either attracted or repelled by other sections causing the coil to fold one way or the other
  - Tertiary Structure

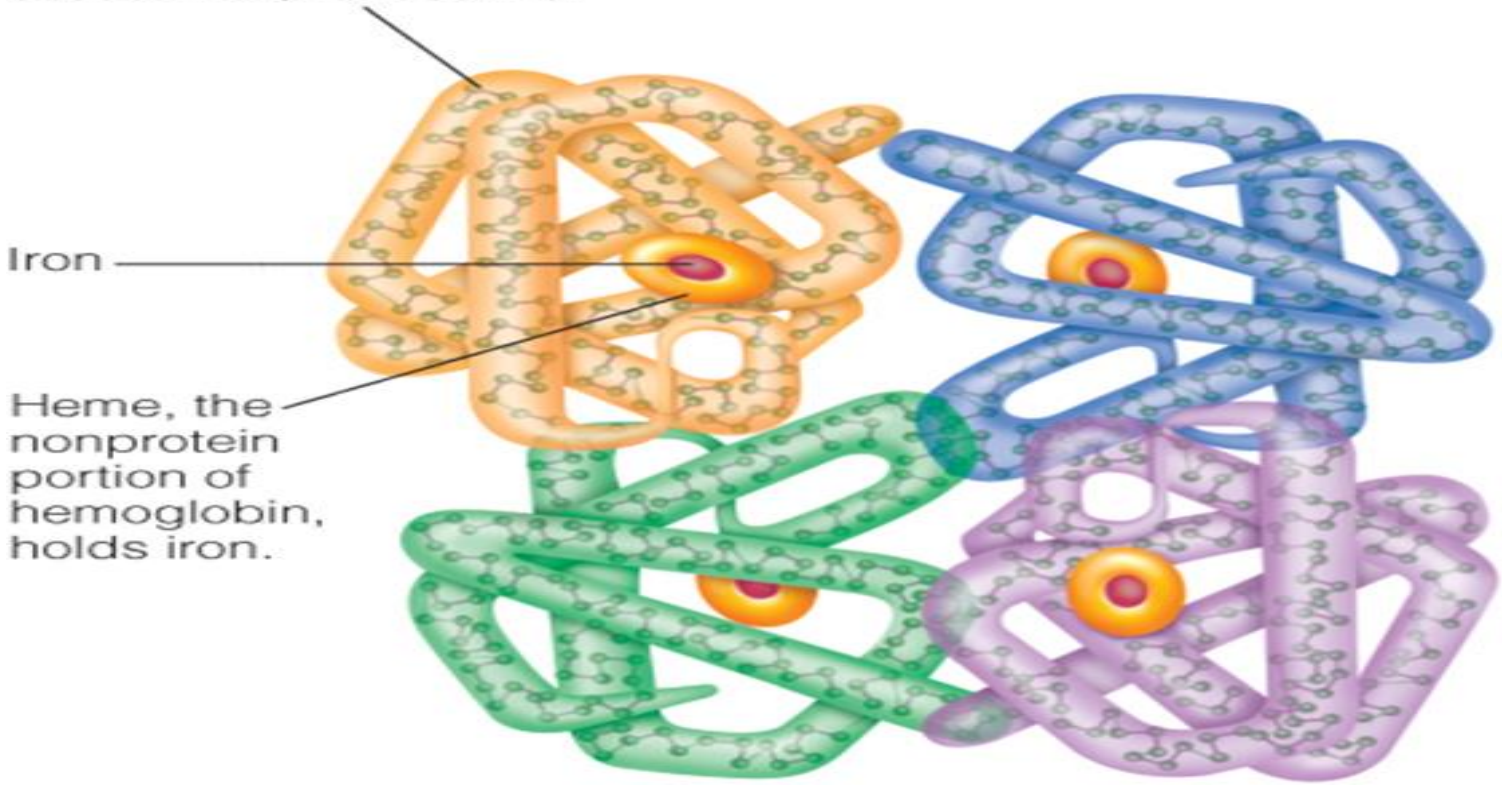
    Examples:
    - Globular Structure
    - Fibrous Structure



- Several strands may cluster together into a functioning unit or a metal ion/vitamin may join to activate it
  - Quaternary Structure

The Structure of Hemoglobin

The shape of each polypeptide chain is determined by an amino acid sequence (primary structure) that twists into a helix (secondary structure) and bends itself into a ball shape (tertiary structure). Together, the four polypeptide chains make the globular hemoglobin protein (quaternary structure).



Inherited Amino Acid Sequence

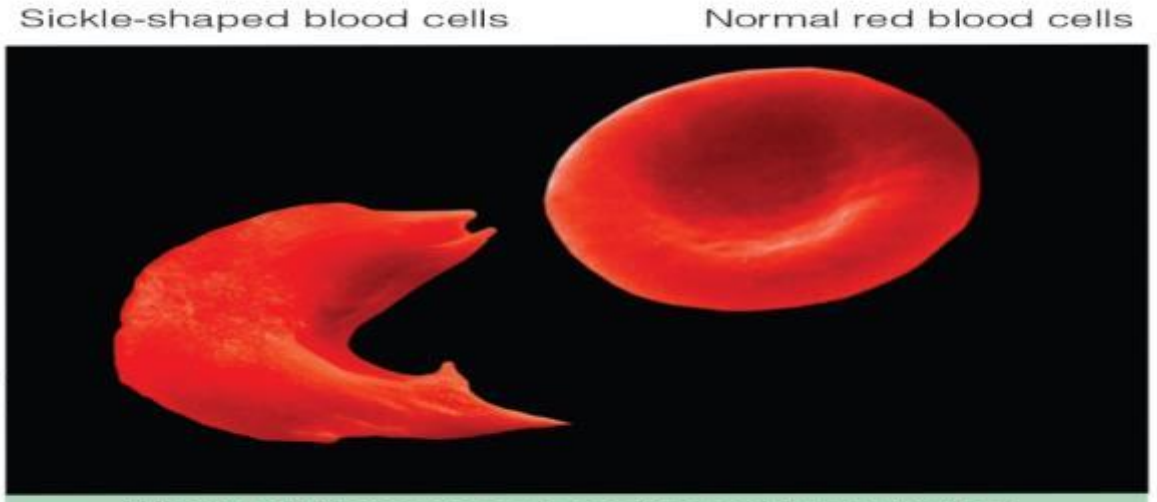
- Different AA combinations create different proteins
  - >80,000 types
- Each protein has a standard amino acid sequence specified by heredity

Normal Red Blood Cells & Sickle Cells

Inherited variations of aa sequences can negatively impact the **function** of the protein produced ….health issues

FIGURE 6–5
Normal Red Blood Cells and Sickle Cells

Normal red blood cells are disk shaped. In sickle-cell anemia, one amino acid in the protein strands of hemoglobin takes the place of another, causing some of the red blood cells to change shape and lose function.



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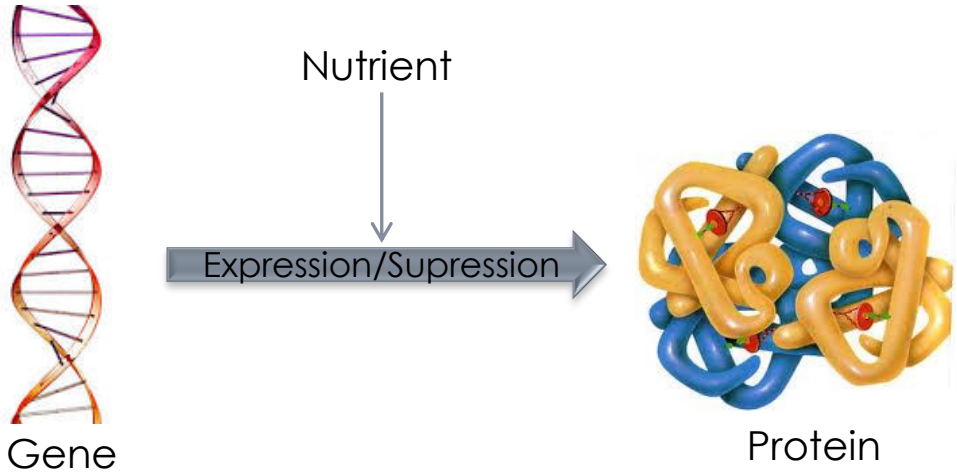
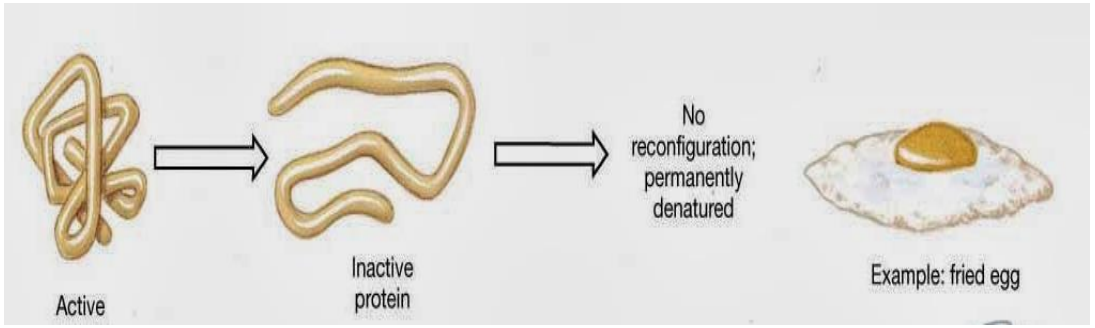
Nutrients and Gene Expression

- When a cell makes a protein → the gene for that protein has been "expressed"
- Nutrients influence this expression and the resulting proteins act as environmental signals
  - Example: iron abundance stimulates hemoglobin synthesis

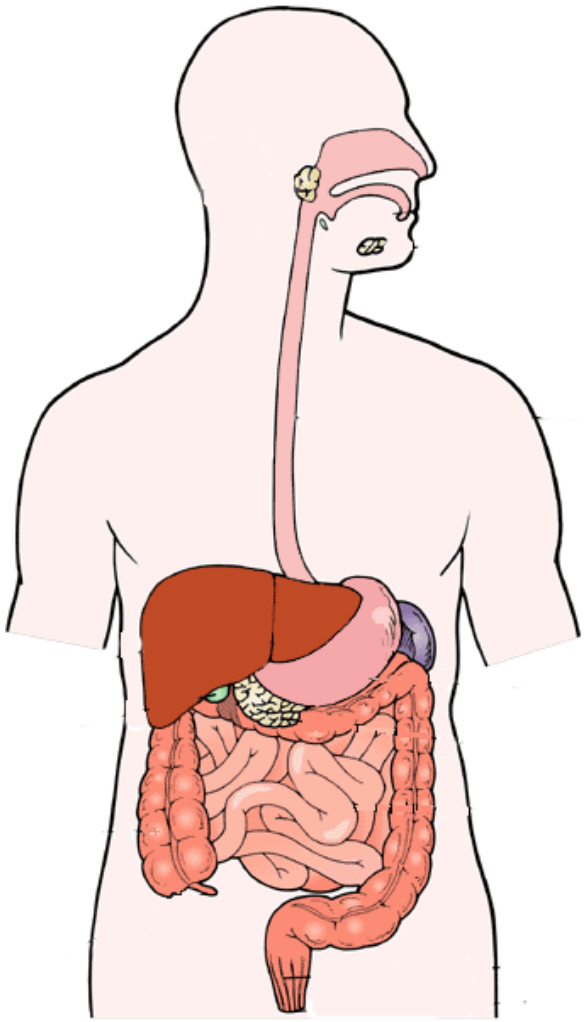


Protein Denaturation

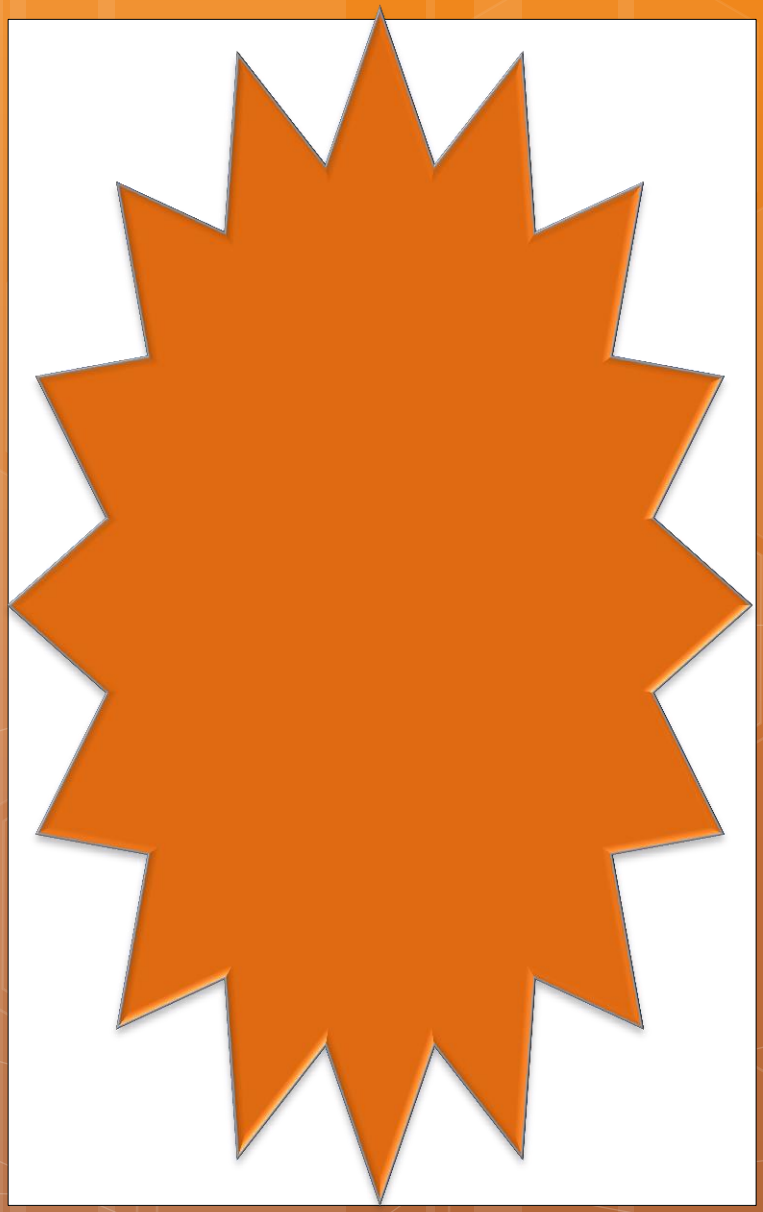
- Irreversible change in protein structure/shape
- Caused by:
  - Digestion
  - Radiation
  - Heat
  - Acid/Base
  - Heavy metal salts



- Denaturation is the first step of destruction



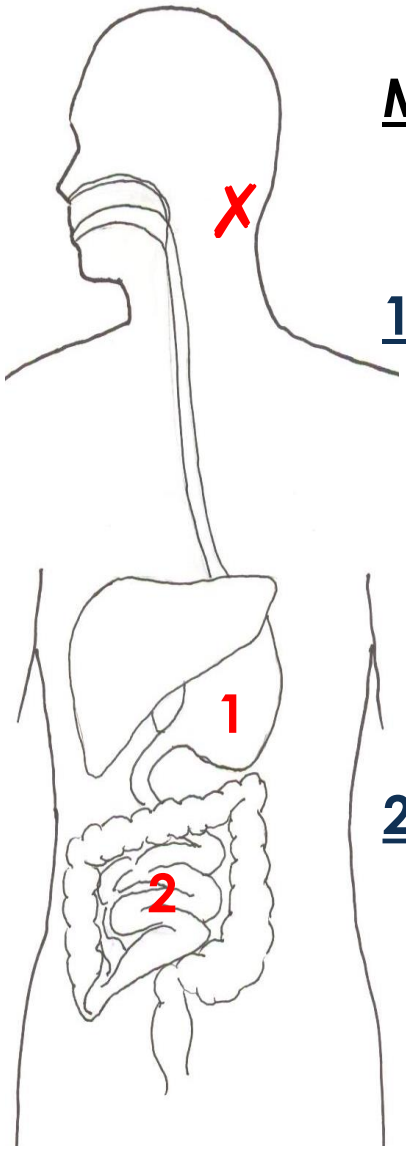
Digestion, Absorption and Transportation of Protein



True or False?

Protein digestion begins in the small intestine..

Digestion



Mouth:

- No protein digestion happens in the mouth

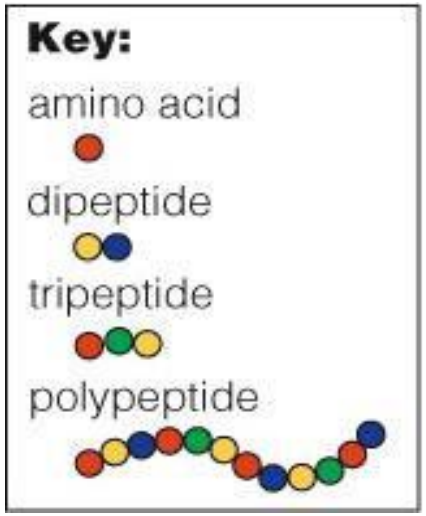
1. Stomach

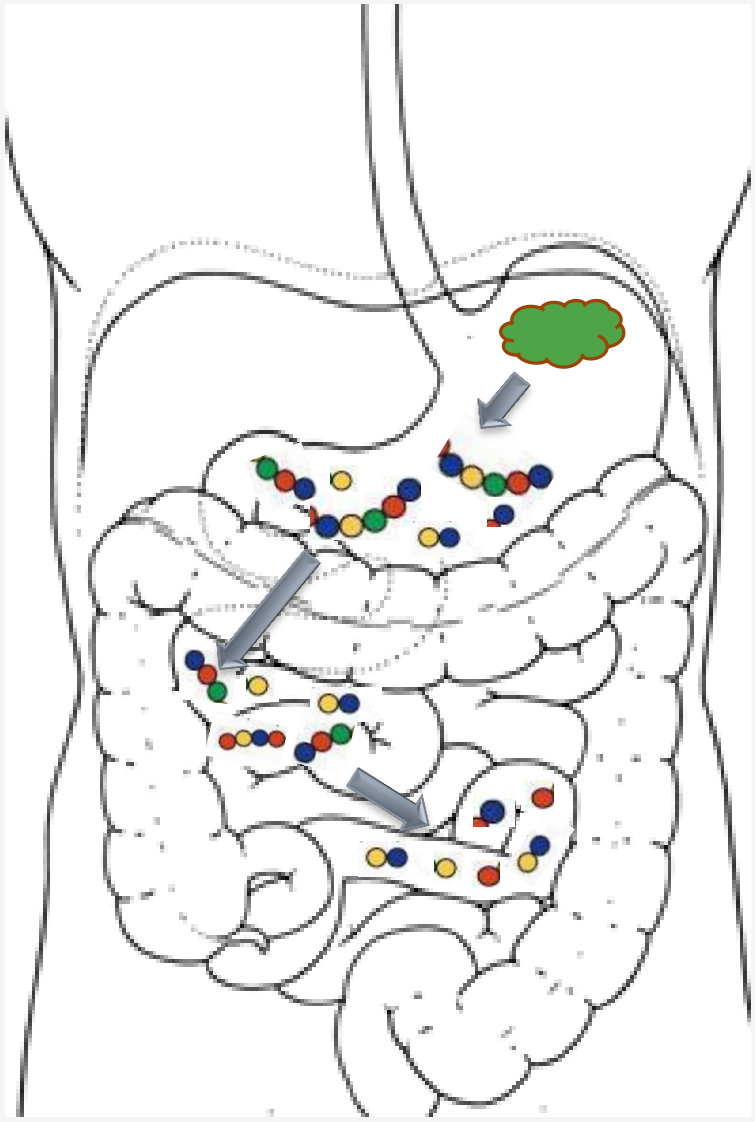
- Protein is denatured by strong acid
- Unfolds/uncoils the strands giving the digestive enzymes access to break the peptide bonds
- Results in single amino acids and larger molecules (peptides)

2. Small Intestine

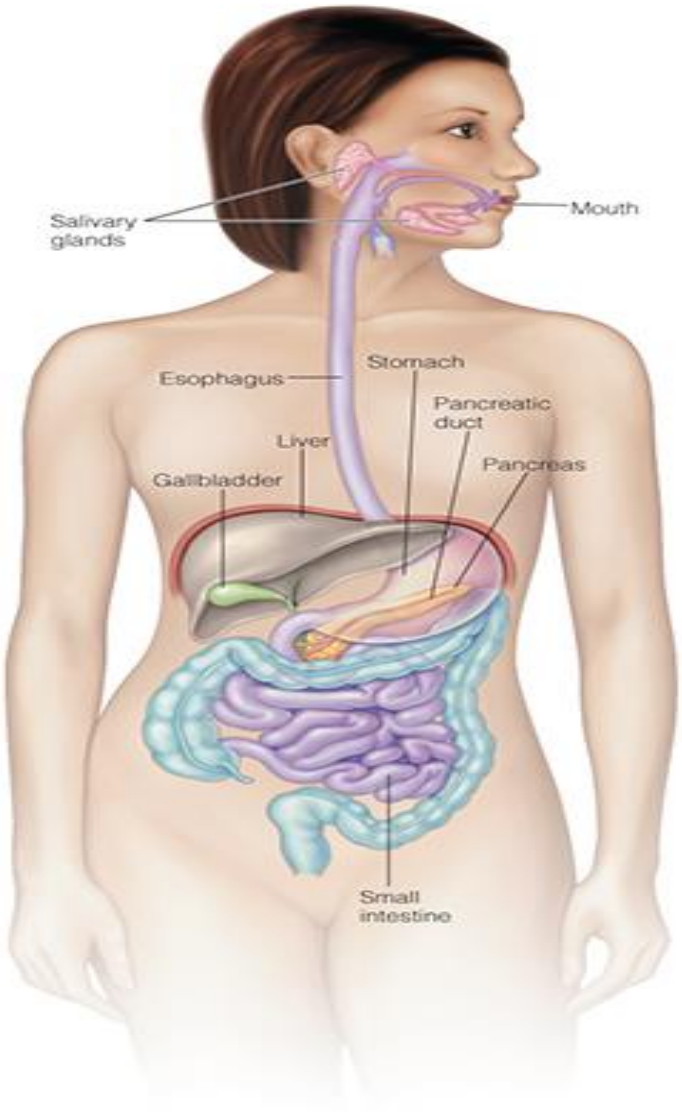
- Further breakdown of larger peptides
  - Polypeptides → single amino acids, dipeptides or tripeptides

Protein Digestion





Protein Digestion in the GI Tract



PROTEIN

Mouth and salivary glands

Chewing and crushing moisten protein-rich foods and mix them with saliva to be swallowed

Stomach

Hydrochloric acid (HCl) uncoils protein strands and activates stomach enzymes:

Protein —(Pepsin, HCl)→ Smaller polypeptides

Small intestine and pancreas

Pancreatic and small intestinal enzymes split polypeptides further:

Poly-peptides —(Pancreatic and intestinal proteases)→ Tripeptides, dipeptides, amino acids

Then enzymes on the surface of the small intestinal cells hydrolyze these peptides and the cells absorb them:

Peptides —(Intestinal tripeptidases and dipeptidases)→ Amino acids (absorbed)

HYDROCHLORIC ACID AND THE DIGESTIVE ENZYMES

In the stomach:

Hydrochloric acid (HCl)
- Denatures protein structure
- Activates pepsinogen to pepsin

Pepsin
- Cleaves proteins to smaller polypeptides and some free amino acids
- Inhibits pepsinogen synthesis

In the small intestine:

Enteropeptidase
- Converts pancreatic trypsinogen to trypsin

Trypsin
- Inhibits trypsinogen synthesis
- Cleaves peptide bonds next to the amino acids lysine and arginine
- Converts pancreatic procarboxypeptidases to carboxypeptidases
- Converts pancreatic chymotrypsinogen to chymotrypsin

Chymotrypsin
- Cleaves peptide bonds next to the amino acids phenylalanine, tyrosine, tryptophan, methionine, asparagine, and histidine

Carboxypeptidases
- Cleave amino acids from the acid (carboxyl) ends of polypeptides

Elastase and collagenase
- Cleave polypeptides into smaller polypeptides and tripeptides

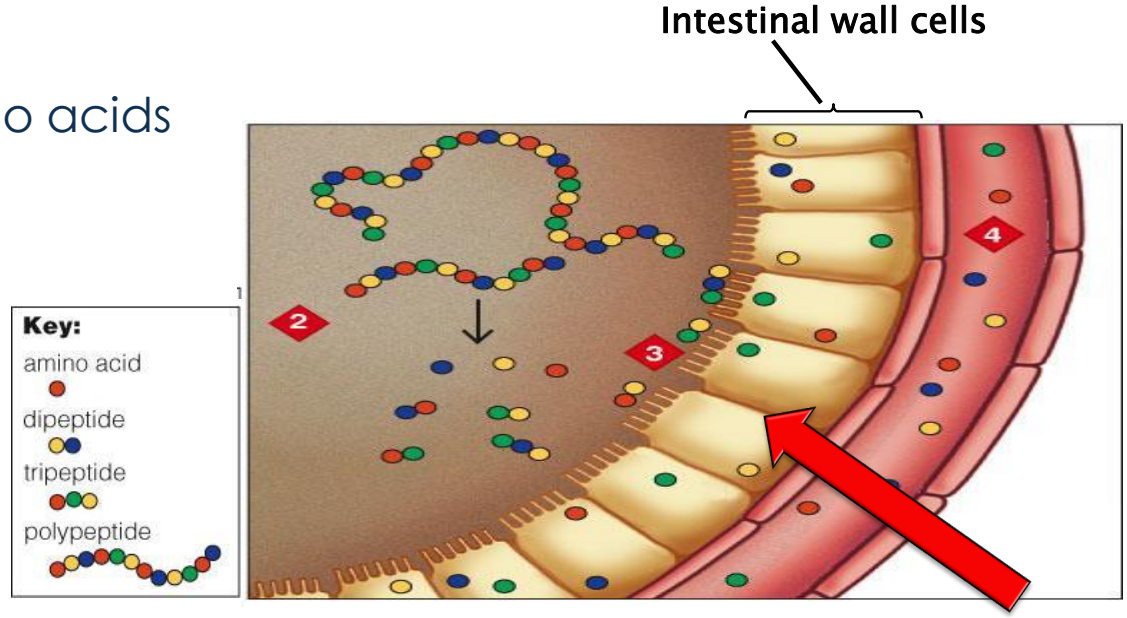
Intestinal tripeptidases
- Cleave tripeptides to dipeptides and amino acids

Intestinal dipeptidases
- Cleave dipeptides to amino acids

Intestinal aminopeptidases
- Cleave amino acids from the amino ends of small polypeptides (oligopeptides)

Protein Absorption

- Absorbed into the cells along the <u>wall of the small intestine</u>
  - Absorbed as:
    - Single amino acids
    - Dipeptides
    - Tripeptides



- The cells of the small intestine possess separate sites for absorbing different types of amino acids
  - Competition

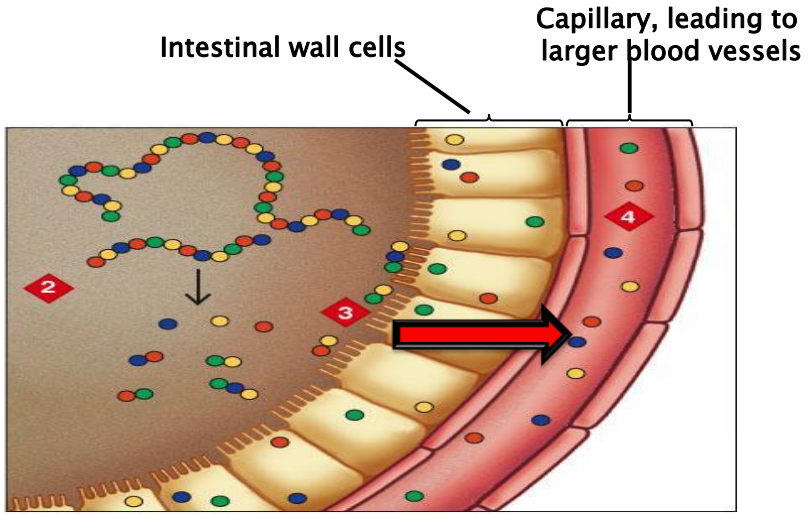
Nutrition: Concept & Controversies, 5th edition, Sizer & Whitney

Protein Absorption and Transport

- Once absorbed through the intestinal cell wall amino acids are released into the <u>bloodstream</u>

- Carried to the liver:
  - Used there

    OR
  - Released into the blood to be taken up by other cells



- Cells can then link the amino acids together to make new proteins or use them as energy
- The body <u>does not store excess</u> amino acids

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Protein absorption check:

1. During absorption, amino acids are transported by specific carriers to _____ cells.

2. Amino acids unused by these cells are transported to the ____.

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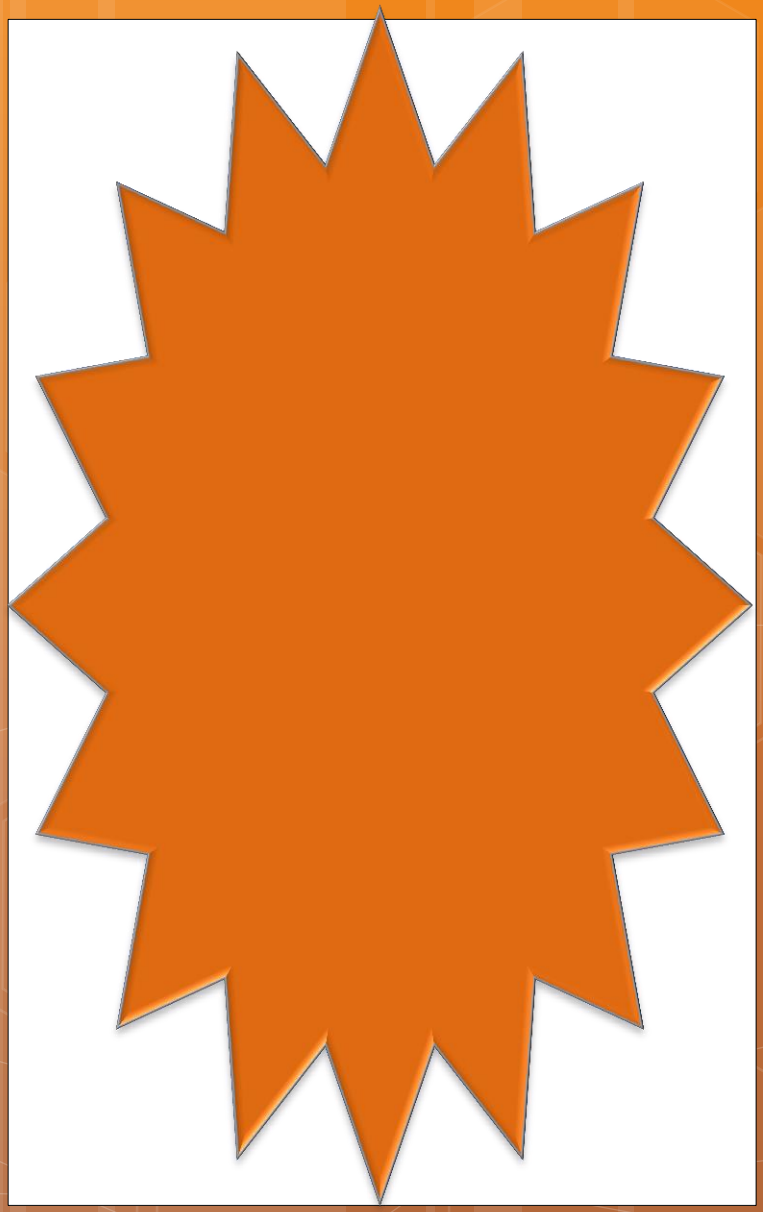


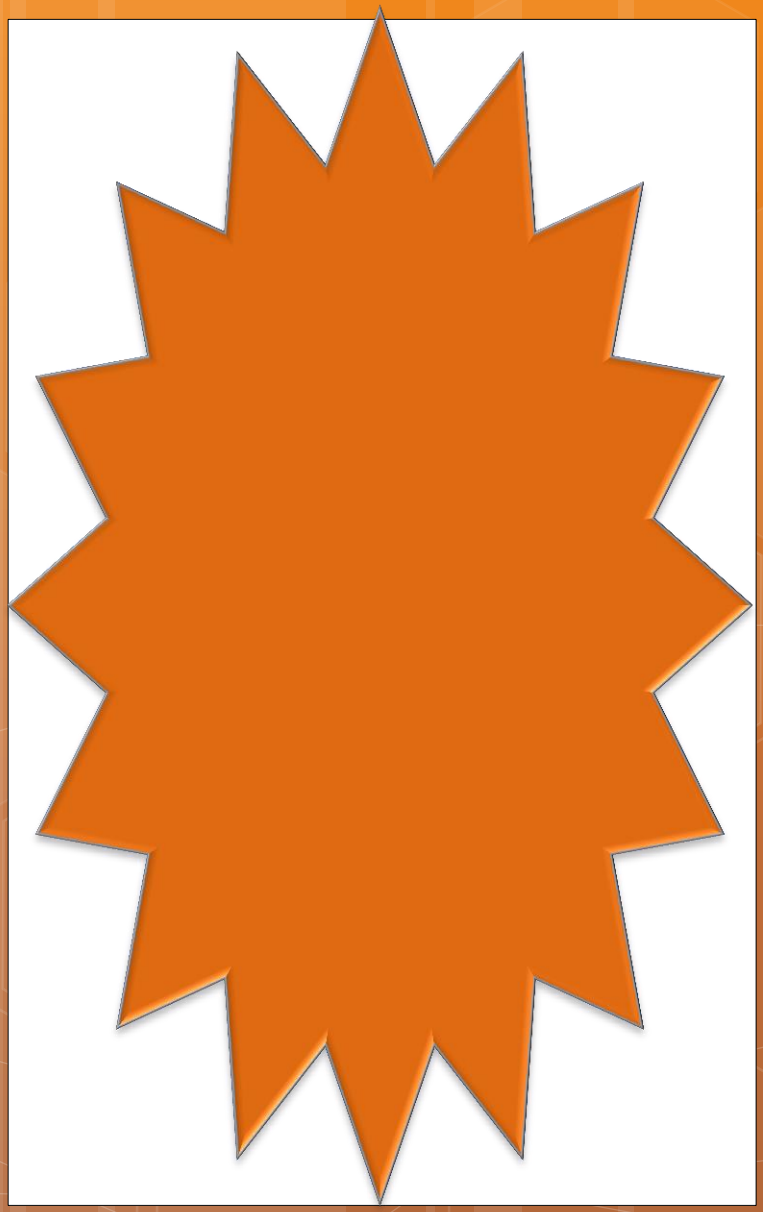
True or False?

"Predigested" amino acid supplements are handled better by the body compared to whole proteins.

Roles in the body

Roles of Protein in the body

1. **Structure**, Support of Growth and Maintenance
2. Building Enzymes and Hormones
3. Building Antibodies
4. Maintaining Fluid and Electrolyte Balance
5. Maintaining Acid-Base Balance
6. Blood clotting,…
7. Source of Energy

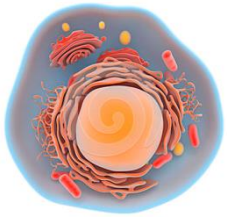


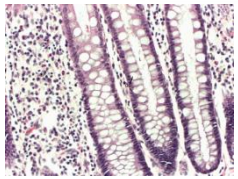
True or False?

Proteins support the formation of hair, skin and nail cells..

1. Structure: Supporting Growth and Maintenance

- Amino acids must be continuously available
  - Red blood cells
  - Internal cell structures
  - Muscles
  - Intestinal cells
  - Skin, hair, nails

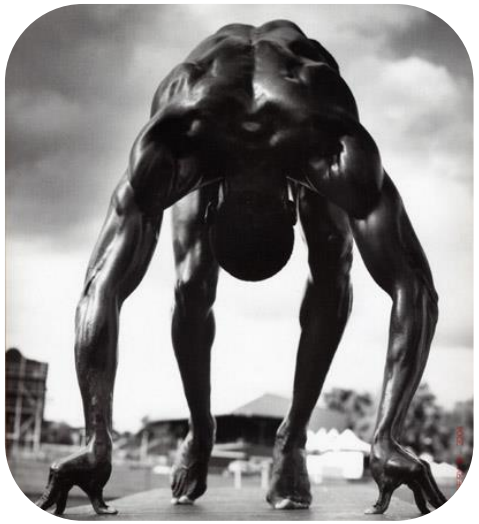





  - All constantly being replaced

- Structure and movement of body

1. Supporting Growth & Maintenance



Important for:

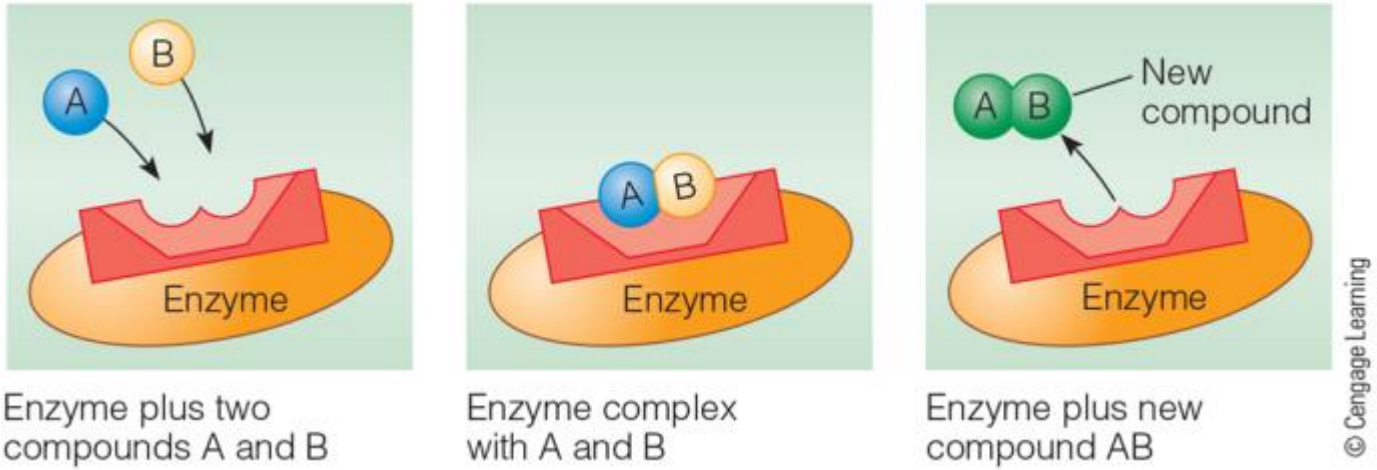
- Embryo
- Growing children
- Athletes
- Hemorrhage
- Healing
- Much more…

- **Protein turnover**
  - Process of breakdown, recovery and synthesis
  - Protein turnover ~ 300 - 400 g/day =20% of resting E needs
- Amino acid, Nitrogen recycling

2. Building Enzymes and Hormones and other compounds

Enzymes: Speed up chemical reactions in cells

- Catalyst



Enzyme plus two compounds A and B

Enzyme complex with A and B

Enzyme plus new compound AB

2. Building Enzymes & Hormones and other compounds- con't

- Hormones:
  - Messenger molecules released by various glands in response to changes
  - Hormones then elicit the response necessary to restore normal conditions
    - Insulin
    - Glucagon
    - Serotonin(via tryptophan)
- Other compounds
  - Tyrosine used synthesize the chemical messengers epinephrine and norepinephrine (neurotransmitters)
  - Tyrosine is also converted into hormone thyroxine

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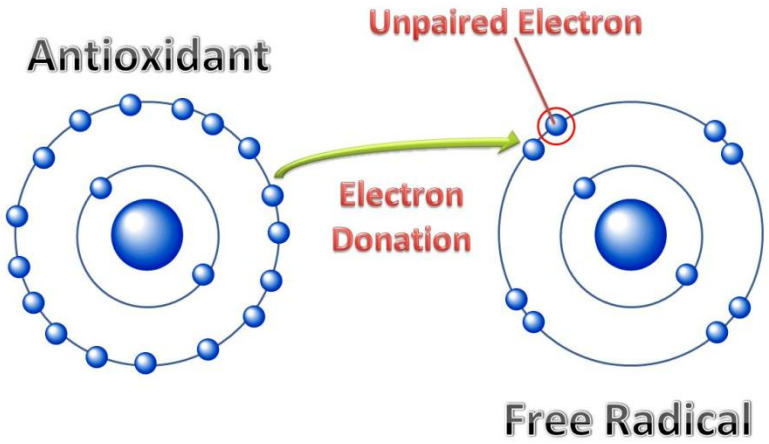
Roles of Protein in the body con't

3. Building Antibodies by Immune system

- Detect and attack foreign 'invaders'
  - Bacteria, virus, toxins, etc.
- Immunity
  - Very specific
  - Memory



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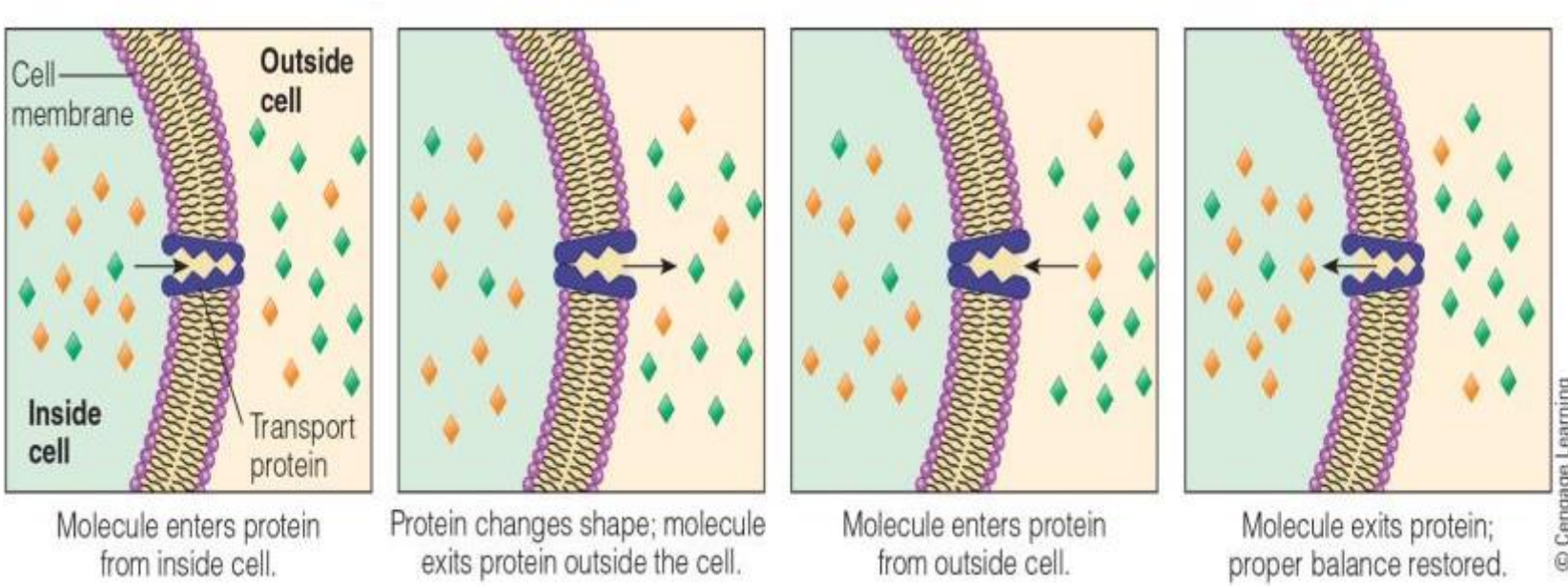
Roles of Protein in the body cntd.

4. Maintain Fluid and Electrolyte Balance

- Regulates the quantity of fluids and dissolved particles in the compartments of the body
  - Water, sodium, potassium
- By maintaining stores of internal proteins and some minerals, cells retain the fluid they need
- Transport proteins in membranes of cells continuously transfer substances into and out of cells

Edema

Proteins Transport Substances into and out of Cells



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Roles of Protein in the body cntd.

5. Maintaining Acid-Base balance

- Blood proteins act as buffers to maintain a normal pH level
- Blood pH is one of the most **rigidly** controlled conditions in the body
- Protect against acidosis (excess acid) and alkalosis (excess base)
  - can cause coma or death

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Roles of Protein in the body cntd.

6. Clotting of Blood

- Proteins are important for blood clotting and wound healing
- To prevent dangerous blood loss, special blood proteins respond to an injury by clotting the blood

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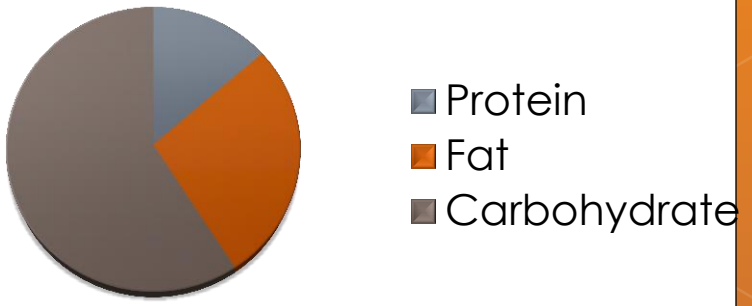
7. Source of glucose & energy

- **4** kcal/g
- Provides **~15%** of the daily energy need



- *Provides energy if needed (inadequate energy or carbohydrate intake)*
  - Example: starvation
- Amino acids → Glucose
  - Maintain supply of Glc needed by brain
  - Blood > muscles > liver > other organs
    - Amine group is stripped & may be incorporated by the liver into urea
- **No storage compound for protein for an oversupply of amino acids**

The Fate of an Amino Acid

Amino acids are "wasted" when:

i. Energy is lacking

ii. Protein is overabundant

iii. An amino acid is oversupplied in supplement form

iv. The quality of the diet's protein is too low

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Questions?