Proteins are made from amino acids
- each has an amino group and carboxyl group
- each has unique side chain
  - some larger size-wise, charged, polar, non-polar, rings, etc.
  - R-group determines properties (behavior) of aa in protein

- 20 total amino acids needed by humans for protein synthesis
- **Essential**: MUST ingest! Body can’t make (or can’t make sufficient amounts)!
- **Nonessential**: not necessary to ingest in diet; body can make these
- **Conditionally essential**
  - under normal circumstances (i.e. healthy adult) body can make
  - under some circumstances, must ingest in diet to meet needs
    - e.g. tyrosine made from phenylalanine: if Phe intake low, need to make sure to ingest tyrosine in diet
    - other AAs become essential in times of severe stress or illness
Peptide bond formation

- to join individual aas to make a polypeptide necessary to make “peptide bond”
- carboxyl end of first joined to amino end of next
- condensation reaction (water released)
- expensive to cell! Each peptide bond “costs” 4 GTP!
• **Primary structure**: amino acid sequence
  • Protein structure
    • Chain of amino acids
      • Sequence of amino acids determines shape
      • Shape of protein determines function—remember enzymes!!!

• **Secondary structures** = alpha helix or beta sheet
• **tertiary** structure = 3D folding
• **quaternary** = arrangement / interaction of multiple polypeptide chains
Protein denaturation

- 3-D structure essential to protein function
- several factors can disrupt bonds holding protein in shape -> DENATURE
  - heat
  - pH (acids, bases)
  - oxidation
  - mechanical agitation
- denaturation = first step to digestion
  - digestive enzymes can access more easily
Protein functions

• **structural, mechanical**
  - tons of structural proteins - think connective tissues keratin, collagen (most abundant protein in mammals!)
  - mechanical - power muscle contraction, flagella

• **enzymes** - necessary for every useful biological reaction!
  - food contains enzymes, but our stomach acid denatures them

• **hormones** - chemical messengers acting at remote locations
  - e.g. insulin, glucagon

• **antibodies** - bind invaders, target them for destruction

• **fluid balance** - proteins in blood maintain correct level of fluid in vascular system
  - e.g. albumin, globulin
  - if not enough protein fluid leaks out of vessels into tissue - edema

• **acid-base balance** - proteins serve as buffers to keep overall pH at neutral (7)
  - in acidic environment, can pick up excess H+ ions to raise pH
  - in alkaline environment, can donate H+ to lower pH

• **channels, pumps** - regulate passage of molecules across membranes

• **transport** - can act as carriers e.g. lipoproteins carry lipids around, carry fat-soluble vitamins around e.g. Vit A
  - transferrin carries iron around
Proteins in the Diet

• Protein quality
  – Complete proteins
    • supply all essential amino acids
    • animal proteins, soy proteins
  – Incomplete proteins
    • low in one or more essential amino acids
    • most plant proteins
  – Complementary proteins
    • 2 incomplete proteins = complete protein

• Evaluating protein quality
  • Amino acid composition
  • Digestibility
  • Protein Digestibility-Corrected Amino Acid Score (PDCAAS)
    • Used to determine %DV
• Protein and amino acid supplements
  • Generally not needed with risks unknown

• Complete proteins a.k.a. high-quality
  • provide all the essential amino acids in proportions needed by body
  • also provide other (nonessential) amino acids as nitrogen source
  • animal foods provide complete protein (exception is gelatin)
  • only plant product that provides complete protein = soybeans

• Incomplete proteins a.k.a. low-quality
  • lack adequate amounts of one or more essential amino acid

• Complementary proteins
  • two protein sources that alone are incomplete but make a complete protein when eaten together
    • e.g. legumes + grains
    • e.g. legumes + nuts, seeds
  • mostly a concern for vegetarians

• proteins add structure, flavor, texture
• protein hydrolysates = proteins partially digested with enzymes; now are shorter polypeptides and some amino acids
  • often added as thickeners, stabilizers, flavoring
• amino acids also sometimes added as flavor enhancers
  • ex. Mono sodium glutamate - Comes from seaweed.
Recommended protein intake

Convert weight to kilograms
(pounds ÷ 2.2)
Multiply kg x 0.8 = protein RDA in g
About 15% caloric intake

average man = 58 g
average woman = 46 g
Americans’ average actual intake = 75 g daily!

Calculating recommended protein intake
• based on body weight
• weight in kg * 0.8
• NOTE: assumes not using protein for energy, using protein only for protein synthesis!
• energy intake should be no more than 15% from protein (higher than RDA usually)
• Recommended protein intake
  • Adult RDA = 0.8 grams/kilogram body weight
  • Infant RDA = ~ 1.5 grams/kilogram body weight
Protein Basics

Proteins in the Body

- Protein synthesis
  - Directed by cellular DNA
  - Amino acid pool maintained by ingestion of dietary proteins containing the essential amino acids and the synthesis of other amino acids from those.

Protein Digestion
- Stomach
  - Proteins are denatured by hydrochloric acid
  - Pepsin begins digestion
- Small intestine
  - Pancreatic and intestinal proteases and peptidases complete digestion
  - Amino acids absorbed into the bloodstream
- Protein excretion
  - Deamination of amino acids
  - Amino groups converted to urea for excretion
- Nitrogen balance
  - Nitrogen intake vs. nitrogen output
**Protein digestion**

**NOTE:** most proteases first secreted as proenzymes that are later cleaved/modified to their active form, otherwise would digest cells making enzyme

- no protein digestion in **mouth**

- **Stomach:**
  - HCl denatures proteins
  - pepsinogen = proenzyme, cleaved to pepsin by HCl
    - breaks down ~10 - 20% proteins

- **small intestine**
  - majority of protein digestion here
  - contribution by pancreatic enzymes
  - majority of digestion done by enzymes from microvilli
    - to tripeptides, dipeptides, some individual AAs
Protein absorption

- tripeptides and dipeptides and AAs absorbed into intestinal cells
- intestinal cells break into individual amino acids
- individual amino acids absorbed into bloodstream (~99% in this form)
- rare for peptides to be absorbed, never whole proteins - cause severe allergic reactions
- any undigested protein excreted in feces