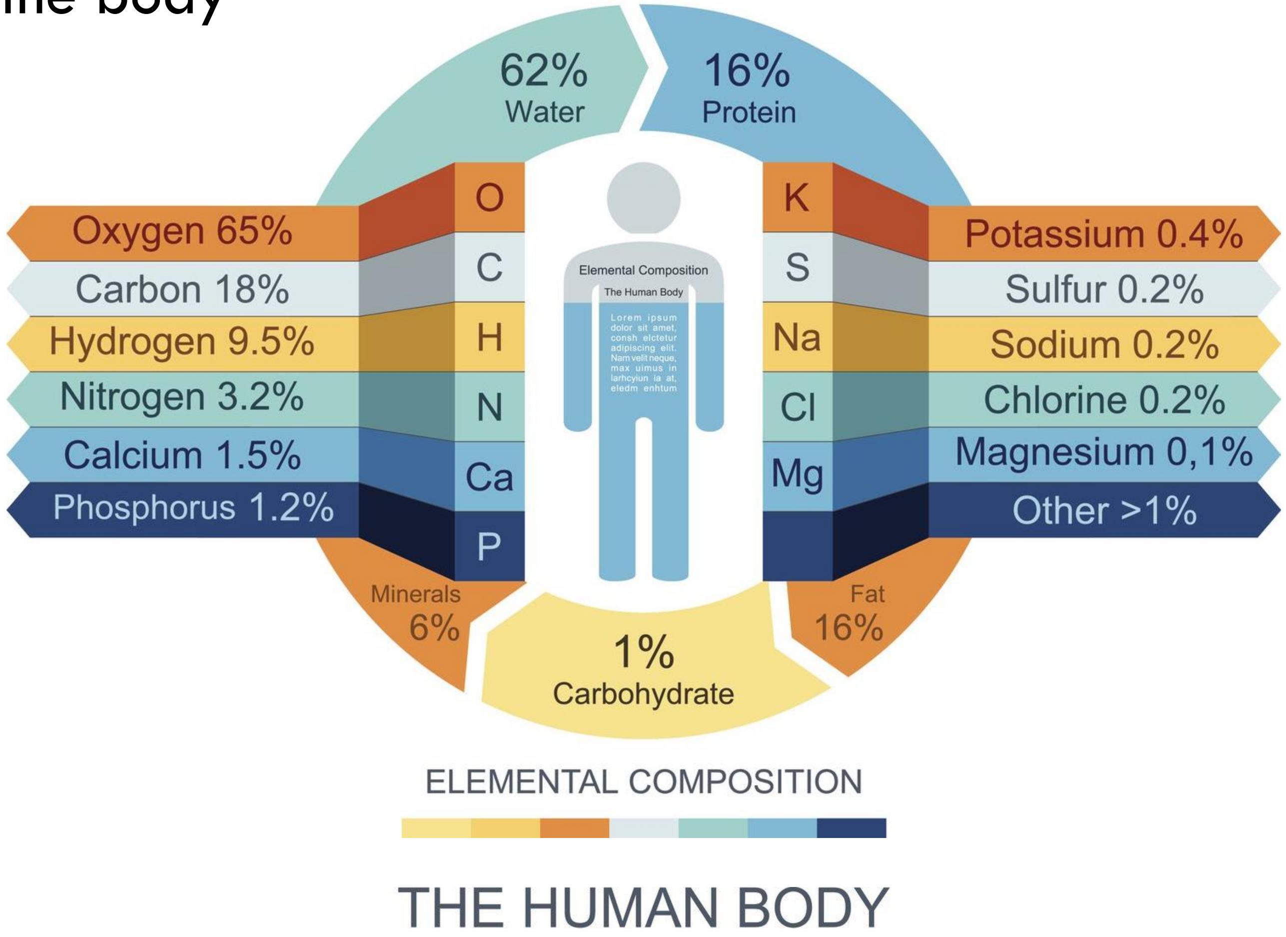
NTR 306: Fundamentals of Nutrition

Chapter 6: Proteins

Main Roles of Proteins

1) <u>Growth and Maintenance</u>

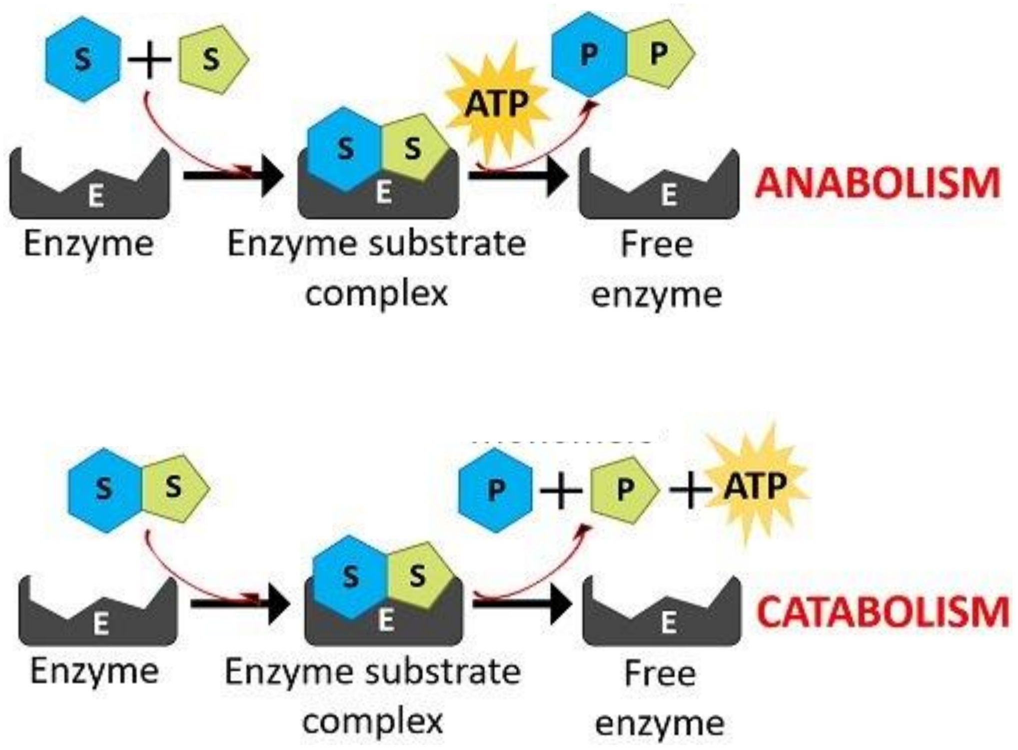
- Major structural component of all cells in the body
  - Skeletal muscle
  - Bones/Ligaments/Tendons/Cartilage
  - GI tract
  - Heart/Kidneys/Liver
  - Skin
- Allows for movement and function
- Replacement of dead/damaged cells
  - Skin cells, turnover 30 days
  - GI tract cells, turnover 2-3 days



Main Roles of Proteins

2) Enzymes

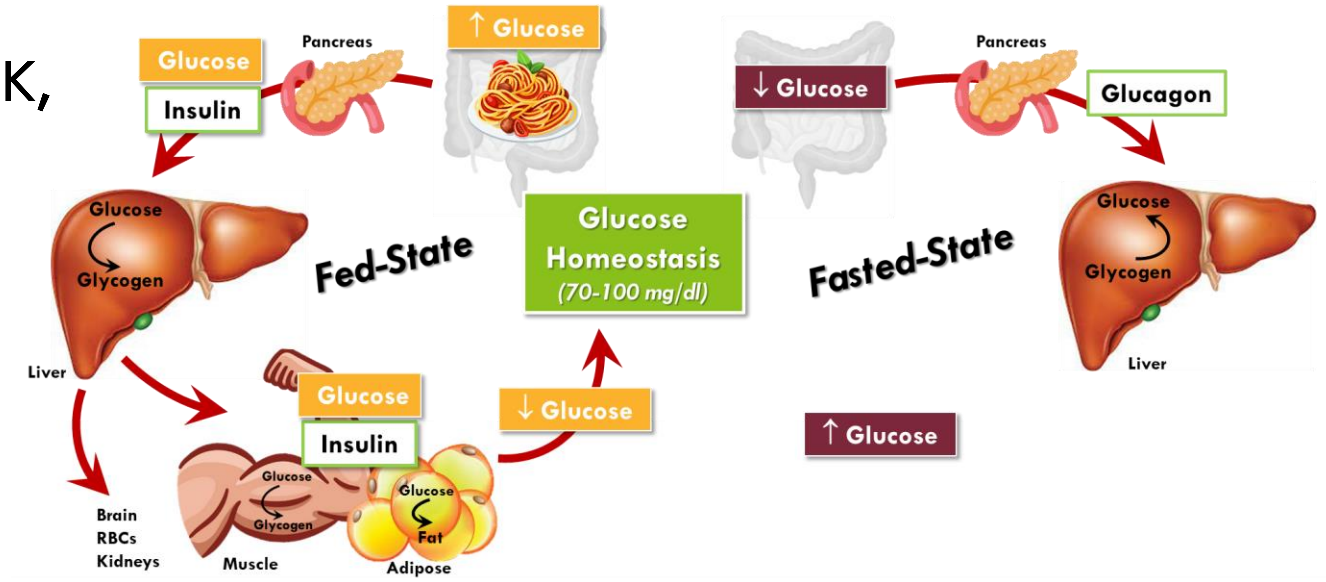
- Enzymes = catalysts
  - Facilitate reactions
  - They remain intact
- Build up (anabolic) substances
- Break down (catabolic) substances
- Transform substances



Main Roles of Proteins

3) <u>Hormones (some)</u>

- Messenger molecules
- Transported in blood from glands to target tissues
- Elicit responses in target tissues to maintain homeostasis
- Examples: insulin, glucagon, ghrelin, CCK, thyroid hormones, growth hormone



Main Roles of Proteins

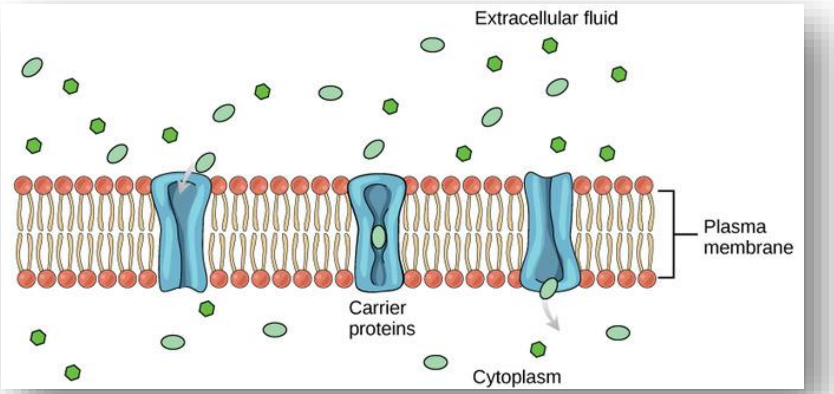
4) Regulators of fluid balance

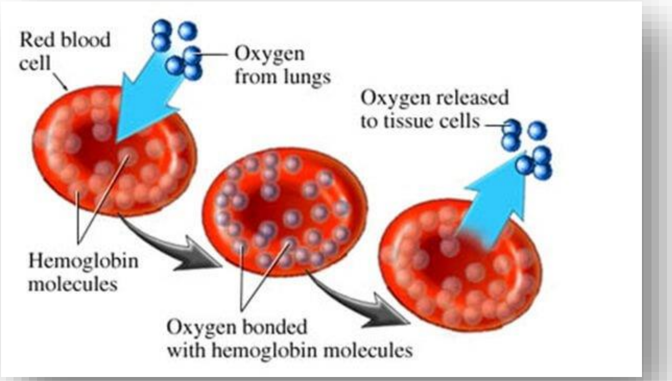
5) Acid-base regulators

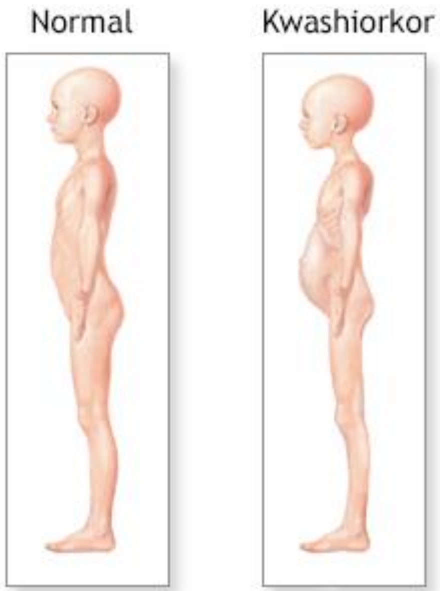
- Proteins = buffers that maintain acid-base balance in body

6) Transporters

- Cell membrane "pumps"
- Carry nutrients/other molecules (e.g., hemoglobin)





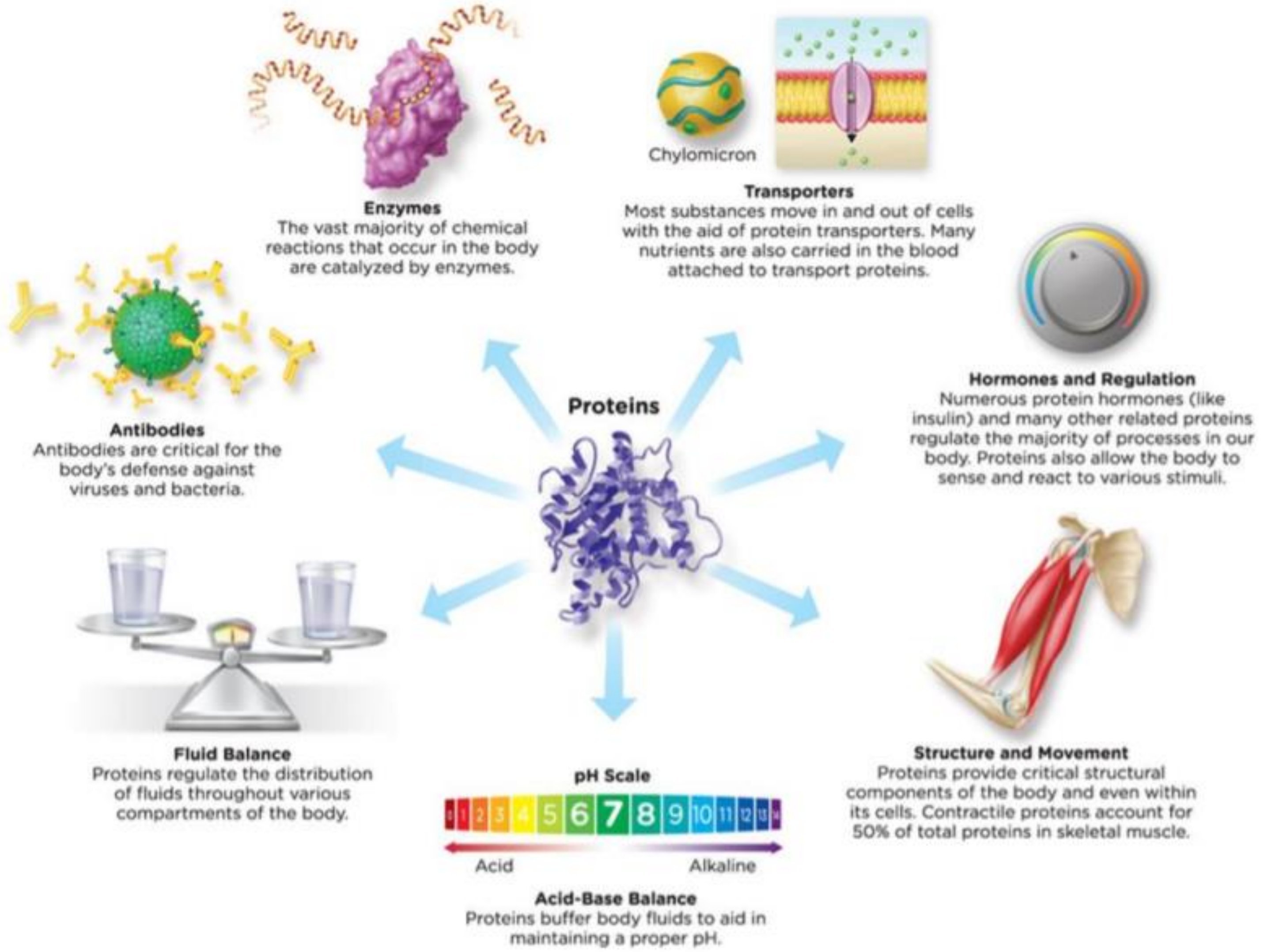


Main Roles of Proteins

7) Antibodies
   - Defend body against disease
   - Body detects antigens (invaders) and makes antibodies (protein molecules that combat specific antigens)

8) Energy/Glucose
   - Starvation or insufficient CHOs: PRO → Amino Acids → Energy
   - Priority: Help maintain blood glucose (which may cost lean body tissue)

Roles of Proteins – Summary

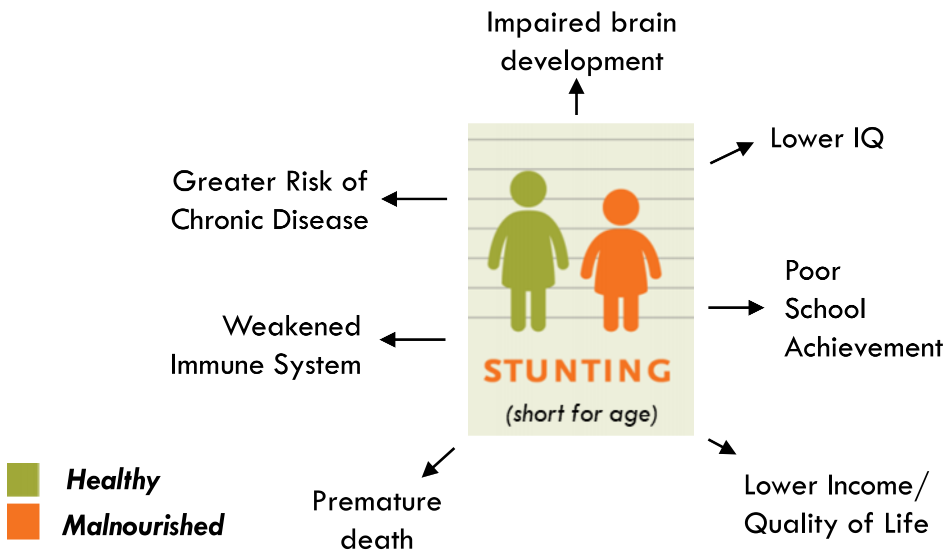


Nutrition for a Changing World; 2016

PRO Deficiency

- PRO Deficiency:
  - Too little total protein
  - Missing essential amino acids (building blocks of protein)
- Significant impact at every life stage, but especially in young people
  - Reduced growth
  - Reduced physical function
  - Reduced cognition
  - Mood disorders
  - Hunger
  - Impaired immune function
  - Skin, hair, nail problems

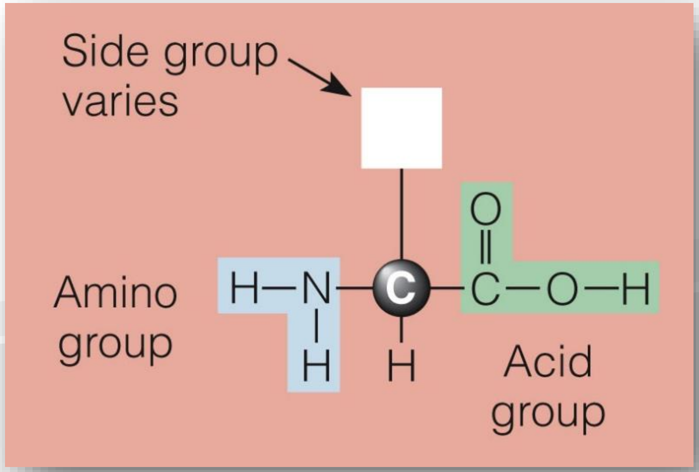
- **Stunting**: Most common sign of *protein* malnutrition in infants/children



Chemist's View of Proteins

- Amino Acids (AAs) = building blocks of protein
- Amino acid atoms:
  - Carbon (C), hydrogen (H), oxygen (O) - just like carbohydrates and lipids!
  - PLUS: nitrogen (N): ***amino* = nitrogen-containing**
- Amino acid structure:
  - Central carbon (C) with four bonds
  - One hydrogen (H)
  - Amino group (NH_2)
  - Acid group (COOH)
  - Unique side group for each amino acid

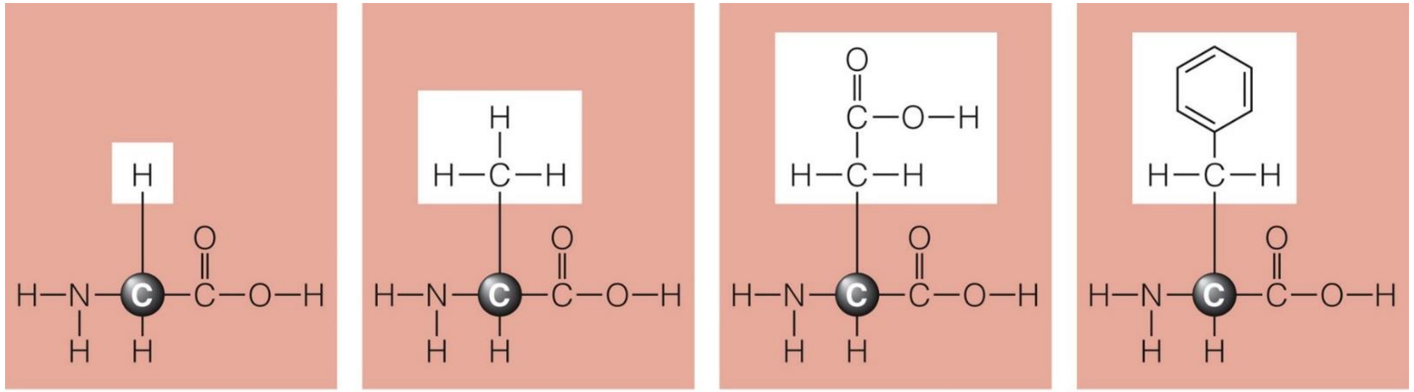
Amino Acid



Whitney & Rolfes, Understanding Nutrition (15th ed.)

Chemist's View of Proteins

- Twenty different amino acids
  - Similar chemical structure
  - Different characteristics (side groups): size, shape, electrical charge
  - Examples:



Glycine Alanine Aspartic acid Phenylalanine

Whitney & Rolfes, Understanding Nutrition (15th ed.)

Chemist's View of Proteins

- Essential amino acids
  - Body needs but cannot make
  - '*Essential*' to get these from diet

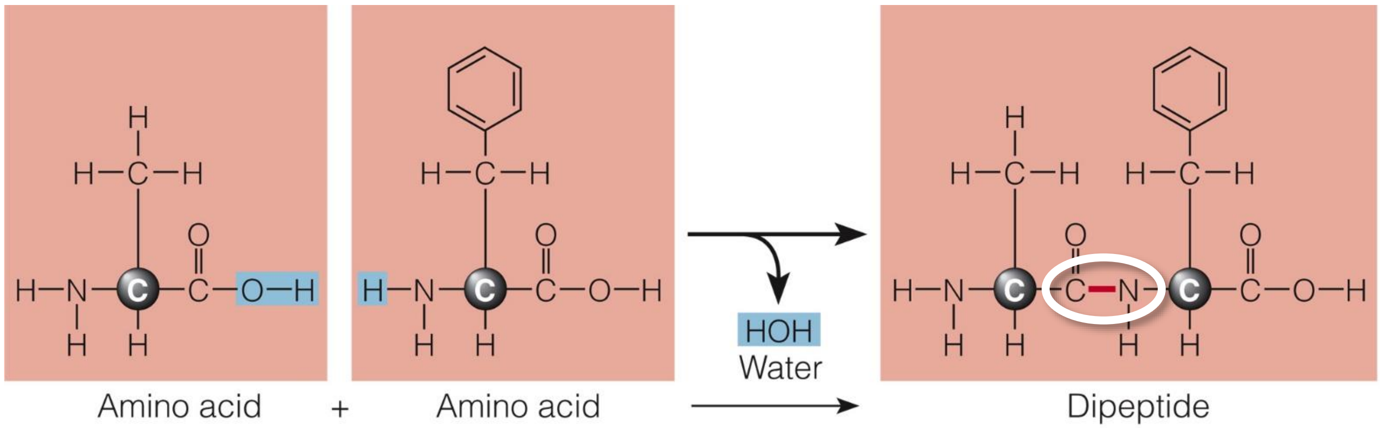
9 Essential AAs	
Leucine	Phenylalanine
Isoleucine	Threonine
Valine	Tryptophan
Lysine	Histidine
Methionine	

- Nonessential amino acids
  - Body needs but can synthesize (make)
  - Not needed from diet

11 Non-essential AAs	
Alanine	Glutamic acid
Arginine	Glutamine
Asparagine	Glycine
Aspartic acid	Proline
Cysteine	Serine
	Tyrosine

Chemist's View of Proteins

- Peptide bonds connect amino acids to form proteins (condensation)



An OH group from the acid end of one amino acid and an H atom from the amino group of another join to form a molecule of water.

A peptide bond (highlighted in red) forms between the two amino acids, creating a dipeptide.

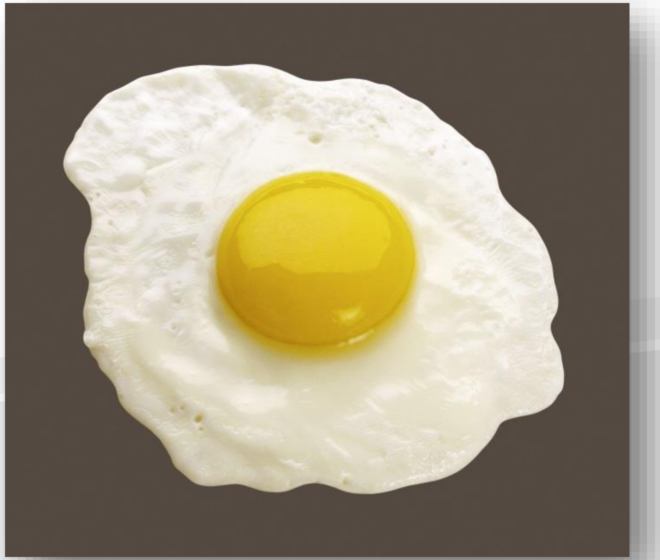
- 2 AAs bonded: dipeptide
- 3 AAs bonded: tripeptide
- 4+ AAs bonded: polypeptide

- Most proteins contain dozens to hundreds of amino acids

Whitney & Rolfes, Understanding Nutrition (15th ed.)

Chemist's View of Proteins

- Breaking down proteins: **denaturation**
  - Exposure to heat, acid, other conditions
  - Disruption of polypeptide bonds
  - Protein structures lose shape, stability and functionality
  - Irreversible (at certain point)
  - Examples:
    - Cooking eggs (heat)
    - Curdling milk (acid)
    - Digesting proteins in stomach (acid)



Whitney & Rolfes, Understanding Nutrition (15th ed.)

Instapoll

Where does most protein digestion occur?

- Mouth
- Stomach
- Small Intestine
- Large Intestine
- Colon

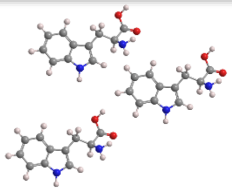
PRO Digestion & Absorption

<u>Ultimate goal</u>: Break foods into smaller molecules for use by the body

Digestion:

Proteins → → → AAs

→→→

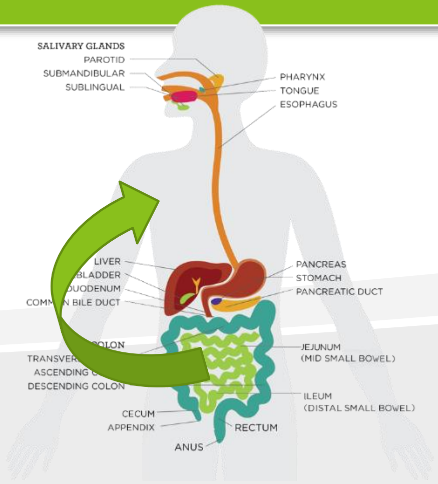


Long polypeptide chains

AAs

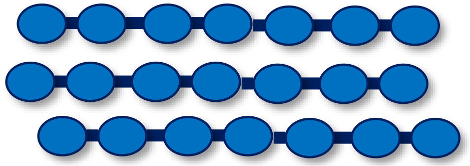
Absorption:

AAs (digestive tract) → blood → body



PRO Digestion - Mouth

- None!



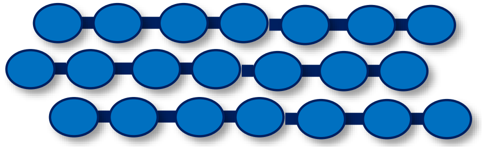
Proteins

Polypeptides
(large)

→

End Product

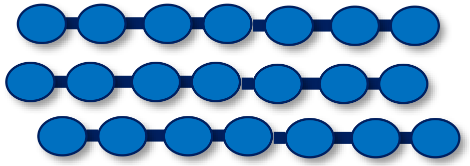
Polypeptides
(large)



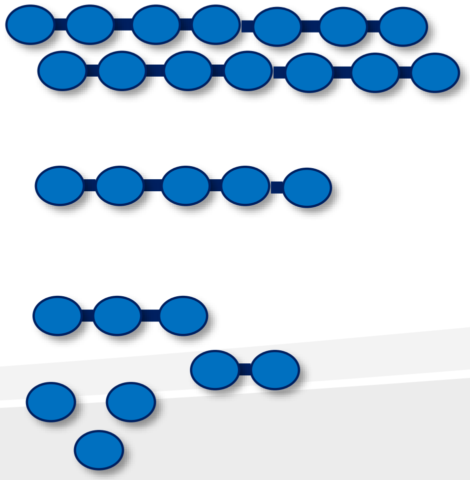
PRO Digestion - Stomach

- Small amount of digestion (~10-15%)
- Hydrochloric acid (HCl): denatures proteins *and* converts pepsinogen (**inactive** gastric enzyme) → pepsin (**active** gastric enzyme)

Pepsinogen (inactive) $\xrightarrow{HCl}$ *Pepsin (active)*

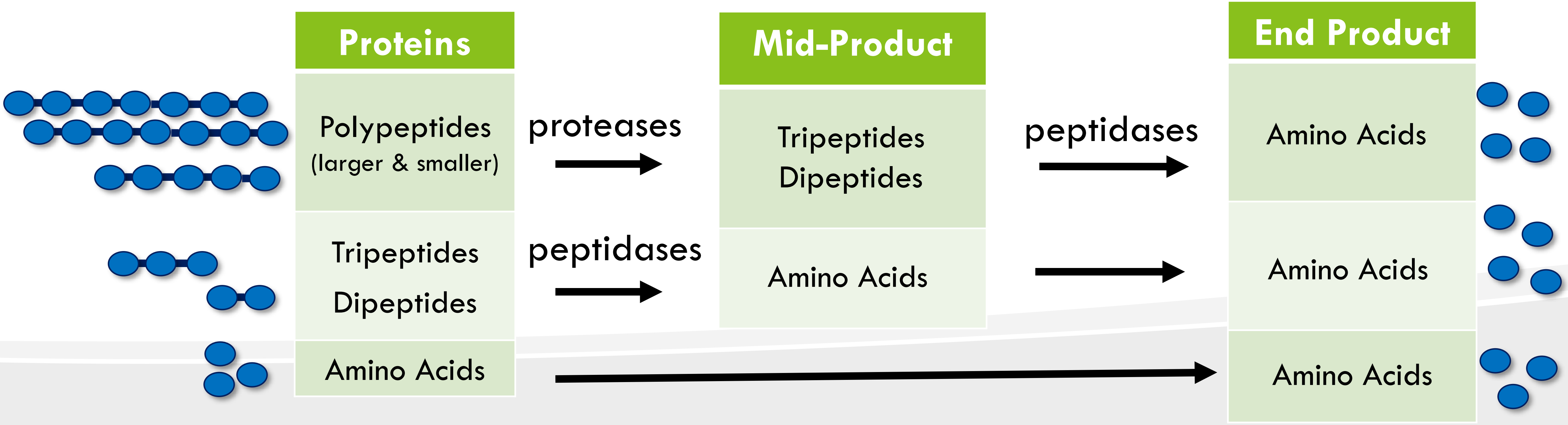


Proteins		End Product
Polypeptides (large)	Pepsin →	Polypeptides (large)
		Polypeptides (smaller)
		Tri & Dipeptides Amino Acids (some)



PRO Digestion - Small Intestine

- Most protein digestion occurs here (85-90%)
  - Pancreas and Small Intestine → proteases and peptidases
    - Note: There are a lot of these (10+)
    - Ultimately break down protein → AAs & smaller chain peptides



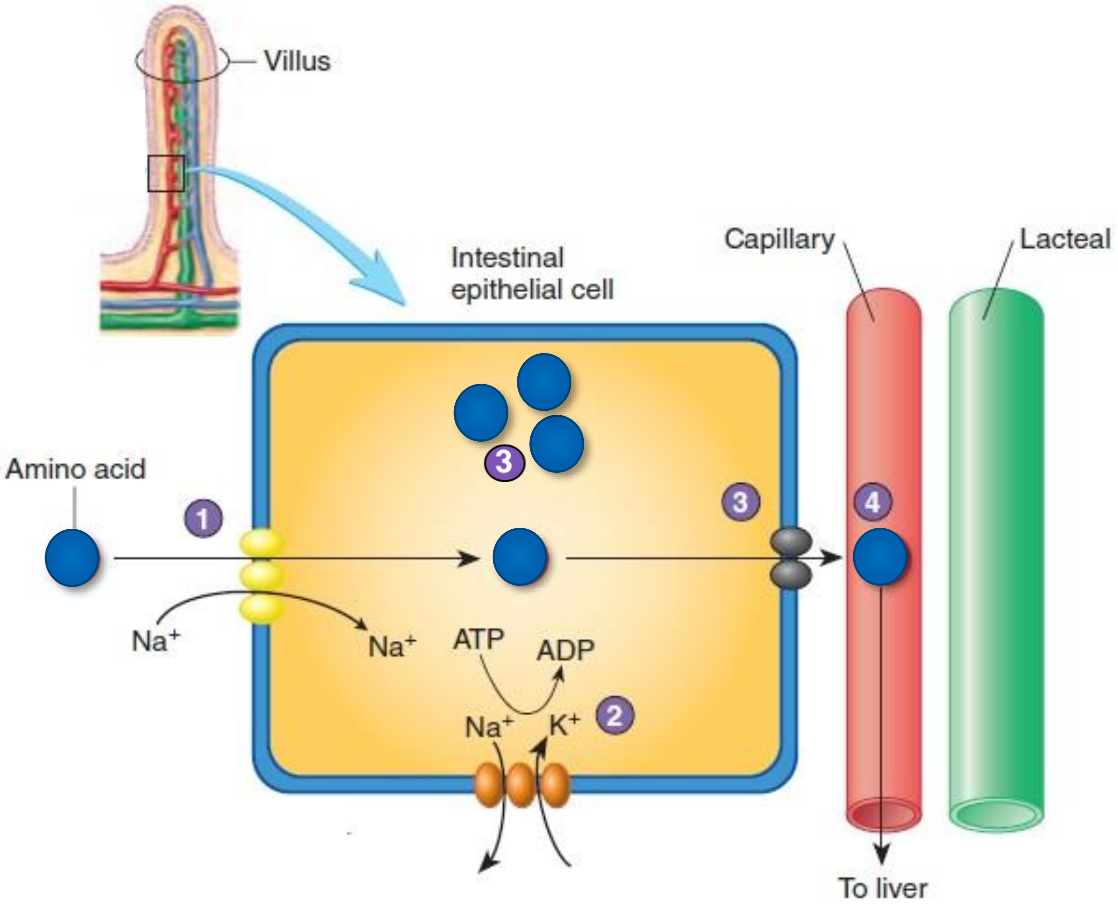
PRO Digestion - Large Intestine

- None!

Protein Absorption

<u>Amino Acid (AA) transport</u>:

1. AAs are absorbed by transport with Na^+ into cells
   2. Transport requires ATP (energy)
3. AAs either stay and are used there OR move out of the cells by facilitated diffusion
4. AAs enter the intestinal villi capillaries and are carried through the hepatic portal vein to the liver



Protein Metabolism

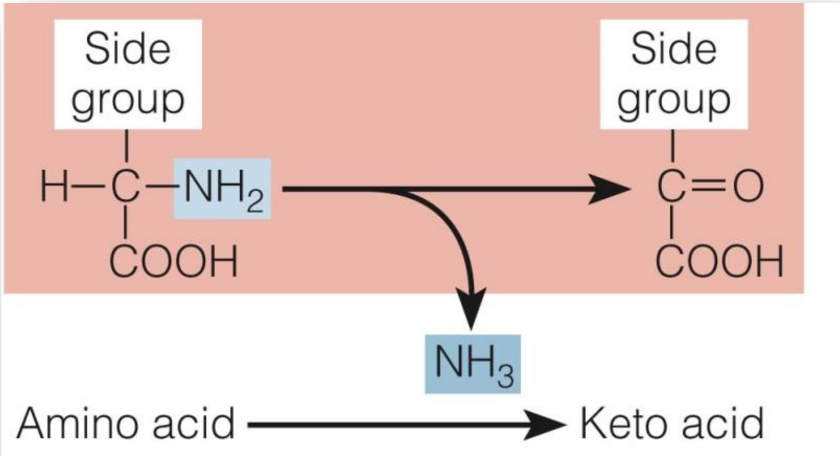
- Fed State: abundance/surplus of amino acids (e.g., after meals)
  - Provide AAs for functional needs (including muscle)
  - Supplies 10-15% of the body's daily energy needs
  - Excess AAs:
    - No "storage space" in the body
    - ✓ Converted to glucose → stored as glycogen
    - ✓ Converted to ketones → stored as fat

Protein Metabolism

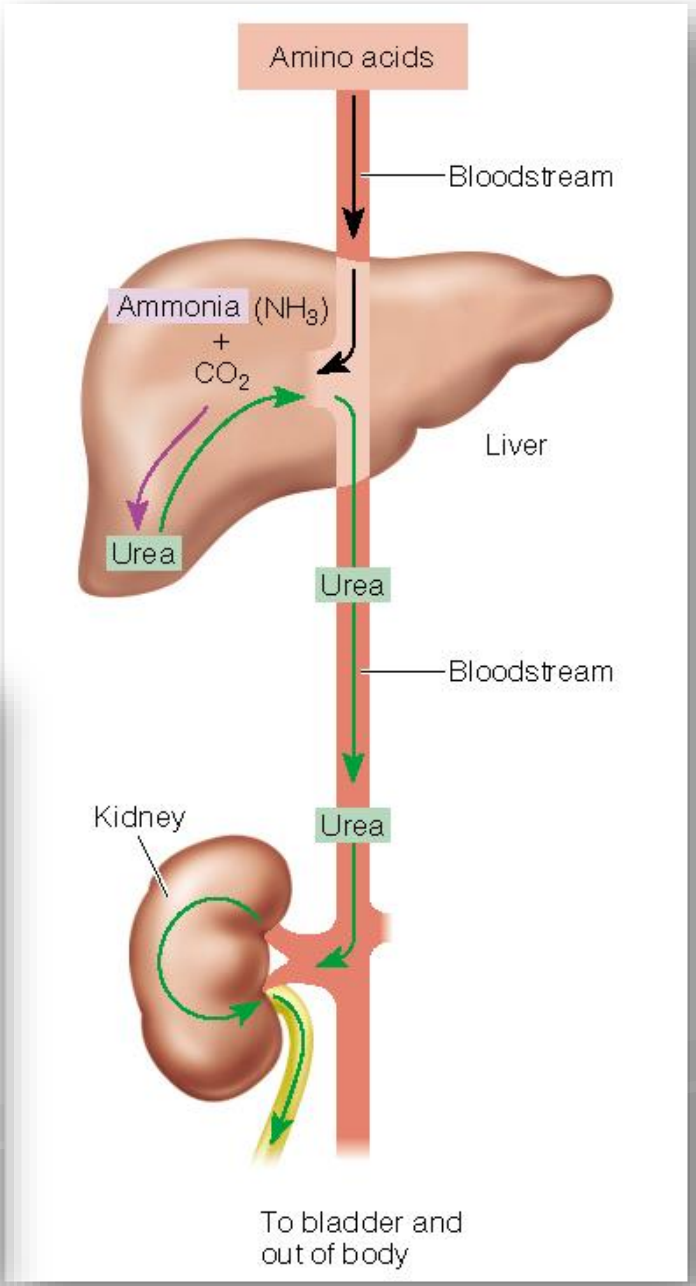
- Fasted State: low availability (e.g., between meals, overnight)
  - Body protein broken down to provide amino acids for:
    - ✓ Functional needs, *excluding muscle*
    - ✓ Creation of glucose for energy
    - ✓ Creation of ketones for energy

Protein Metabolism

- **Biproducts of protein/AA breakdown**
  - Also called **deamination**
  - Produces ammonia:
    - ✓ Toxic (must be eliminated)
    - ✓ Liver adds CO_2 and converts ammonia to urea (non-toxic)
    - ✓ Kidneys filter urea out of blood and into urine



The deamination of an amino acid produces ammonia (NH_3) and a keto acid.



Protein Excess: Kidney + Liver Function

- Increased dietary protein = increased ammonia + urea production
  - ↑ liver function (converting ammonia to urea)
  - ↑ kidney function (excreting urea from body)
  - Adequate hydration = critical to urea elimination (keep urea in solution)
  - High protein diet: water consumption is critical to avoid dehydration
- Indicator of liver disease: elevated blood ammonia
- Indicator of kidney disease: elevated blood urea

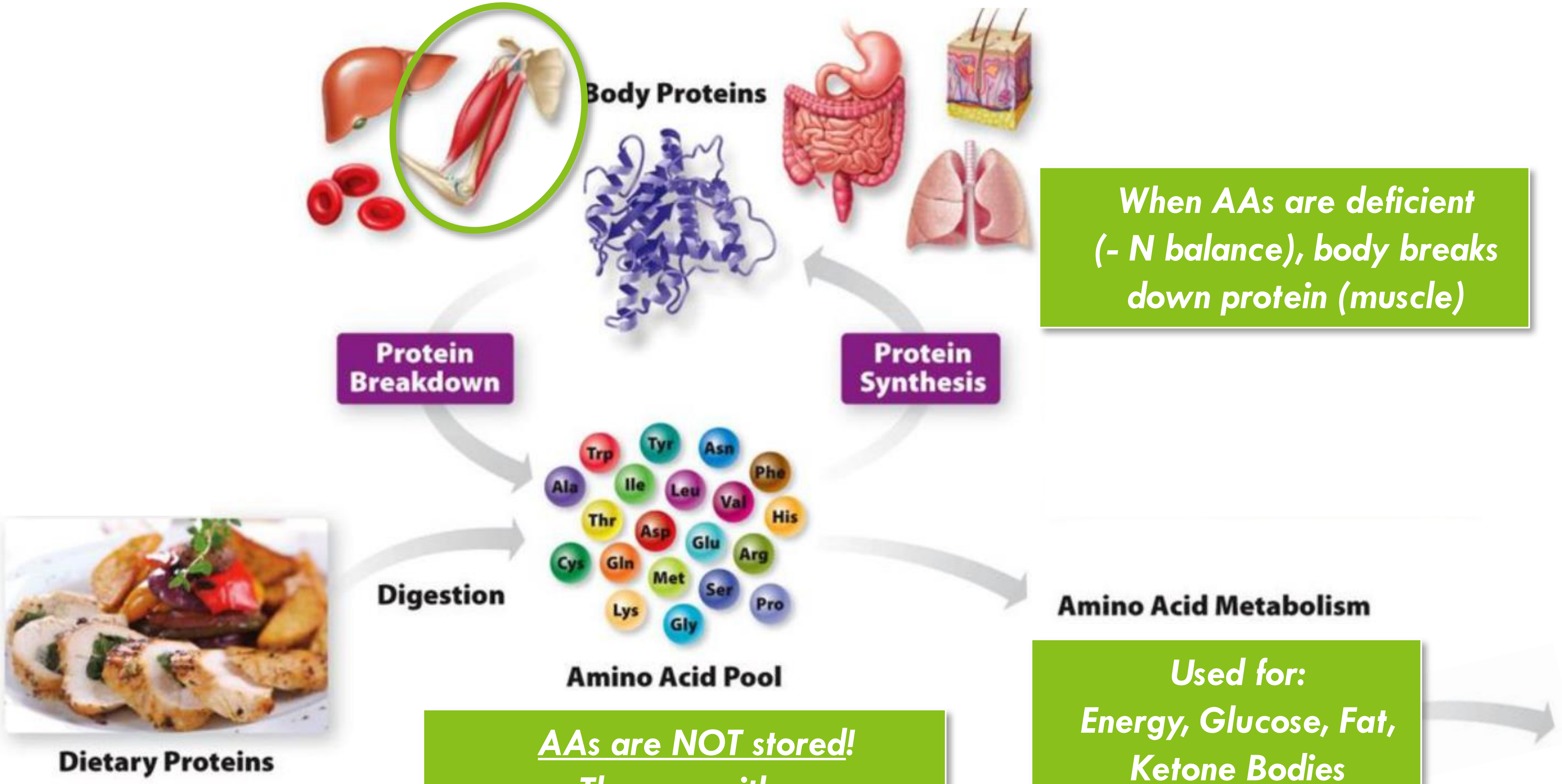
Protein Turnover

- **Protein turnover:** Continual production and destruction of proteins in cells
  - Releases amino acids
- **Amino acid pool:** *released* amino acids mix with *dietary* amino acids
  - Pattern of amino acids in pool = fairly constant, despite varying rates of protein intake and breakdown
  - Used for protein production
  - Used for energy or glucose (if deaminated)
  - Can also be stored as fat

Nitrogen Balance

- Nitrogen balance accompanies protein turnover
  - Balance: N in = N out
- **Balance** occurs when protein synthesis = protein breakdown AND when protein intake from food = N excretion (urine, feces, sweat)
- **Positive N status:** synthesis of new proteins exceeds breakdown; blood, bone, skin, and muscle cells are built
  - From increased dietary protein
  - Growing infants, children, pregnant women, recovering from injury, building muscle
- **Negative N status:** protein breakdown exceeds synthesis; muscle and other proteins are broken down for glucose or energy (muscle wasting)
  - Starvation, severe stress or injury (burns, infections, fever)

Protein Turnover



When AAs are deficient (- N balance), body breaks down protein (muscle)

<u>AAs are NOT stored!</u>
They are either:
used (then lost)
converted to something else

Used for:
Energy, Glucose, Fat, Ketone Bodies

AAs (N) Losses

Nutrition for a Changing World; 2016 Infographic 8.7

Protein – DRIs

- RDA set to prevent negative N balance (to meet growth, development, and maintenance needs)
  - AMDR (lower range) set to include whole-body requirements
- No UL → Protein isn't toxic
  - AMDR (upper range) → set based on what's 'left over' after carbohydrates and fat

Total PROs DRIs (19-30yo)			
	RDA	AMDR	UL
Males	0.8 g/kg body weight/d	10-35%	N/A
Females	0.8 g/kg body weight/d	10-35%	N/A

Assumptions: Healthy; adequate energy intake; protein is high quality; & protein is consumed with sufficient carbohydrates and fat

Protein amounts within AMDR for a 2000 kcal diet:

2000 kcal x 0.10 = 200 kcal / 4 kcal/g = 50 g/d
2000 kcal x 0.35 = 700 kcal/ 4 kcal/g = 175 g/d

Protein – DRIs

- RDA set to prevent negative N balance (to meet growth, development, and maintenance needs)
  - AMDR (lower range) set to include whole-body requirements
- No UL → Protein isn't toxic
  - AMDR (upper range) → set based on what's 'left over' after carbohydrates and fat

Total PROs DRIs (19-30yo)			
	RDA	AMDR	UL
Males	0.8 g/kg body weight/d	10-35%	N/A
Females			

<u>Assumptions</u>: Healthy; adequate energy intake; protein is high quality; & protein is consumed with sufficient carbohydrates and fat

Habitual Intakes (19-30yo)			
	Per gram Amounts		%
Males	1.0 g/kg body weight/d	98 g/d	15%
Females		71 g/d	

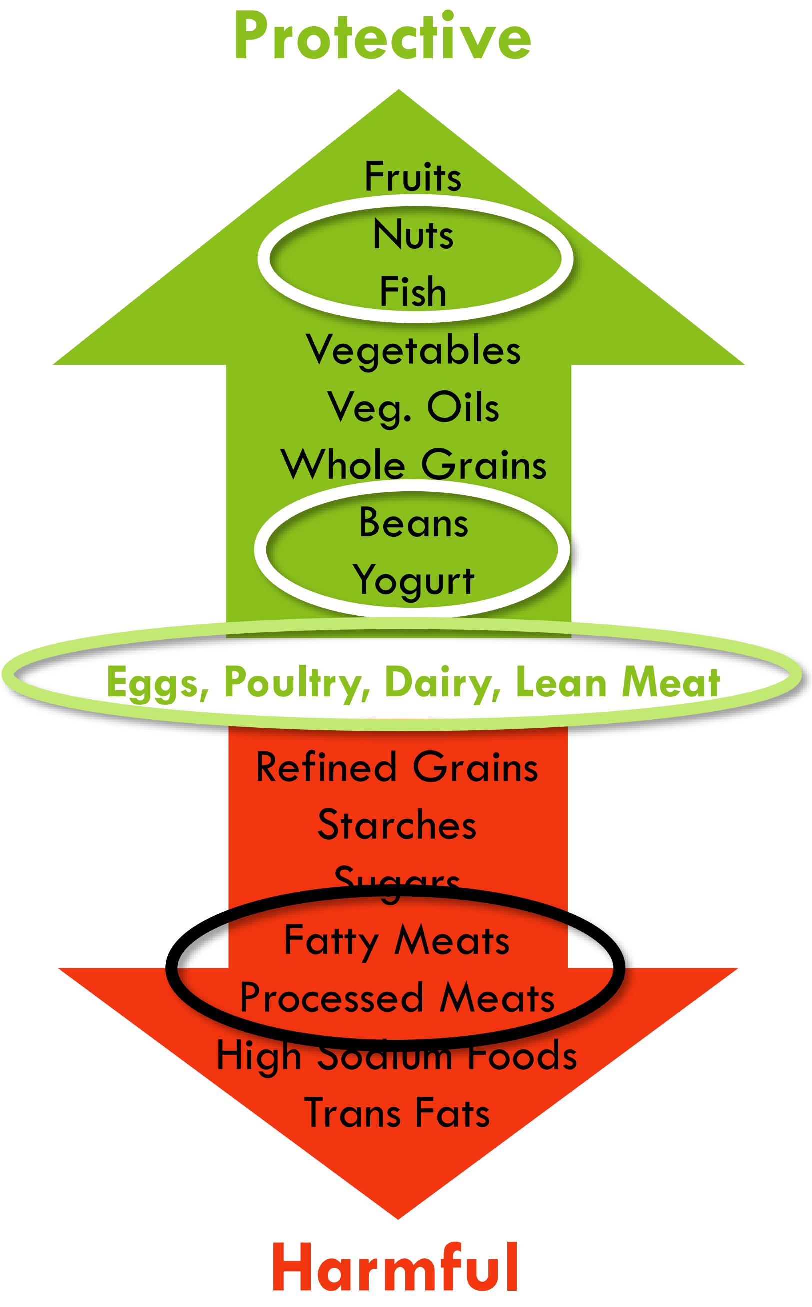
Protein - DGAs

- Consume a *variety* of protein-rich foods across food groups:
  - Seafood
  - Lean meats (including red meat), lean poultry, eggs
  - Legumes, nuts, seeds, soy
- Consume in moderation:
  - Fatty and/or processed meats

Protein Excess: Health Risk

- <u>Cardiometabolic Risks</u>
  - No causal role of ↑ protein & CVD risk
  - No causal role of ↑ protein & Type 2 Diabetes risk
  - Many protein-rich foods are protective against CVD
- <u>Cancer Risks</u>
  - No causal role of ↑ protein & cancer

Processed & Fatty Meat Consumption is associated with CVD & Cancer Risks



Instapoll

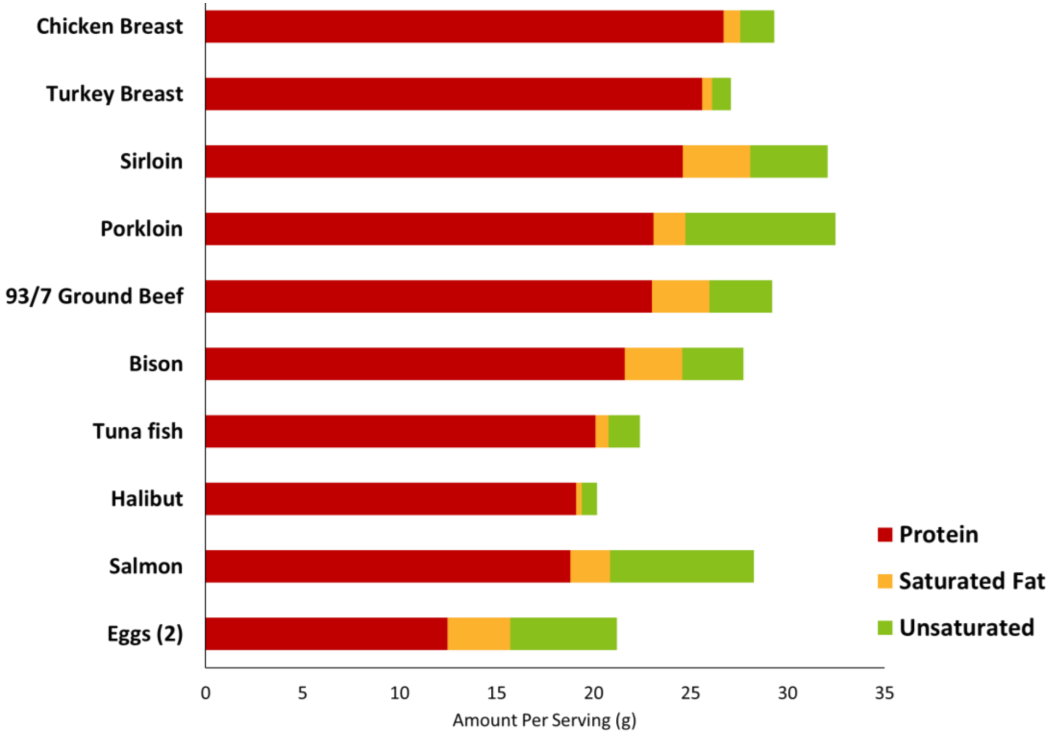
What is it about meat that increases health risks?

- Protein content
- Saturated fat content
- Accompanying foods (i.e., fries, refined grains, etc.)
- How meat is processed or cooked

Protein Foods - DGAs

Food Groups/Subgroups	CALORIE Level (within the Healthy US Dietary Pattern)											
	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200
Protein Foods (oz eq/day)	2	3	4	5	5	5 ½	6	6 ½	6 ½	7	7	7

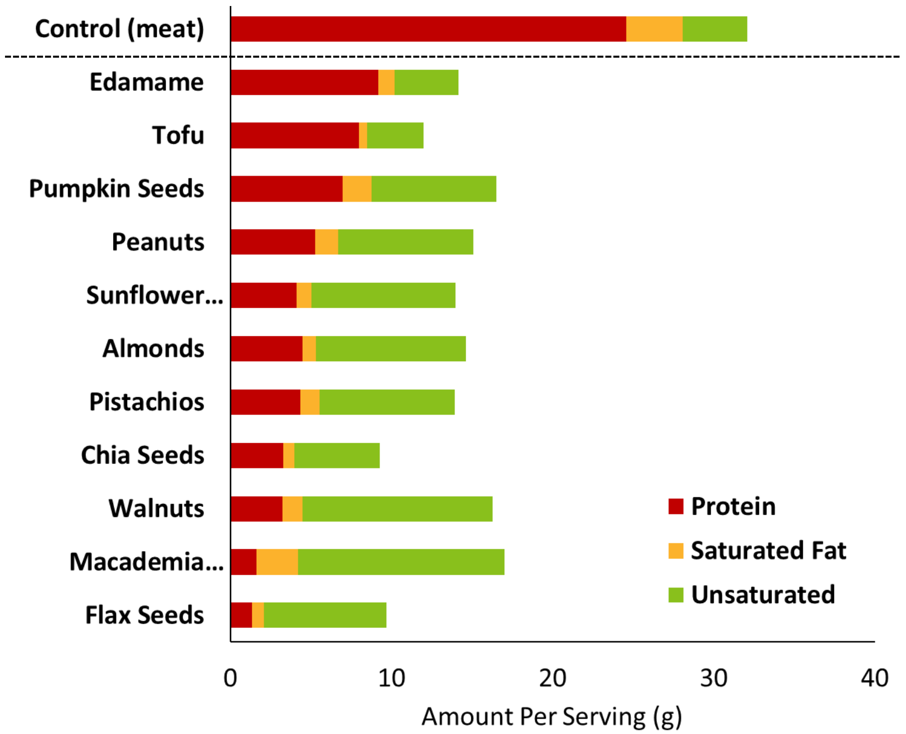
- Meats, poultry, eggs, and seafood
  - Most are protein-rich and low-fat:
    - ✓ 80-90% kcals from protein
    - ✓ 10-20% kcals from fat
  - Be mindful of cooked oils, etc.
  - Many have polyunsaturated fat



Protein Foods - DGAs

Food Groups/Subgroups	CALORIE Level (within the Healthy US Dietary Pattern)											
	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200
Protein Foods (oz eq/day)	2	3	4	5	5	5 ½	6	6 ½	6 ½	7	7	7

- Nuts and seeds
  - Most are protein-rich and fat-rich:
    - ✓ 80% kcals from fat
    - ✓ 10% kcals from carbohydrates
    - ✓ 10% kcals form protein
  - Be mindful of sugar and salt content
- Soy Products: Protein > Fat



Dairy - DGAs

Food Groups/Subgroups	CALORIE Level (within the Healthy US Dietary Pattern)											
	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200
Dairy (cup eq/day)	2	2 ½	2 ½	3	3	3	3	3	3	3	3	3

- Low-fat (1%) or fat-free milk, yogurt, and cheese (or soy alternatives):
  - Milk: (per serving, 1 cup)

	Energy	Sat. Fat	Protein	Added Sugar
Low-fat (1%)	100	1.5	8	0
Fat Free (Skim)	80	0	8	0
Lactose Free, Ultra-filtered, Skim	80	0	13	0
Soymilk (unsweetened)	80	0	7	0

  - Yogurt (per serving, 5.3 oz)

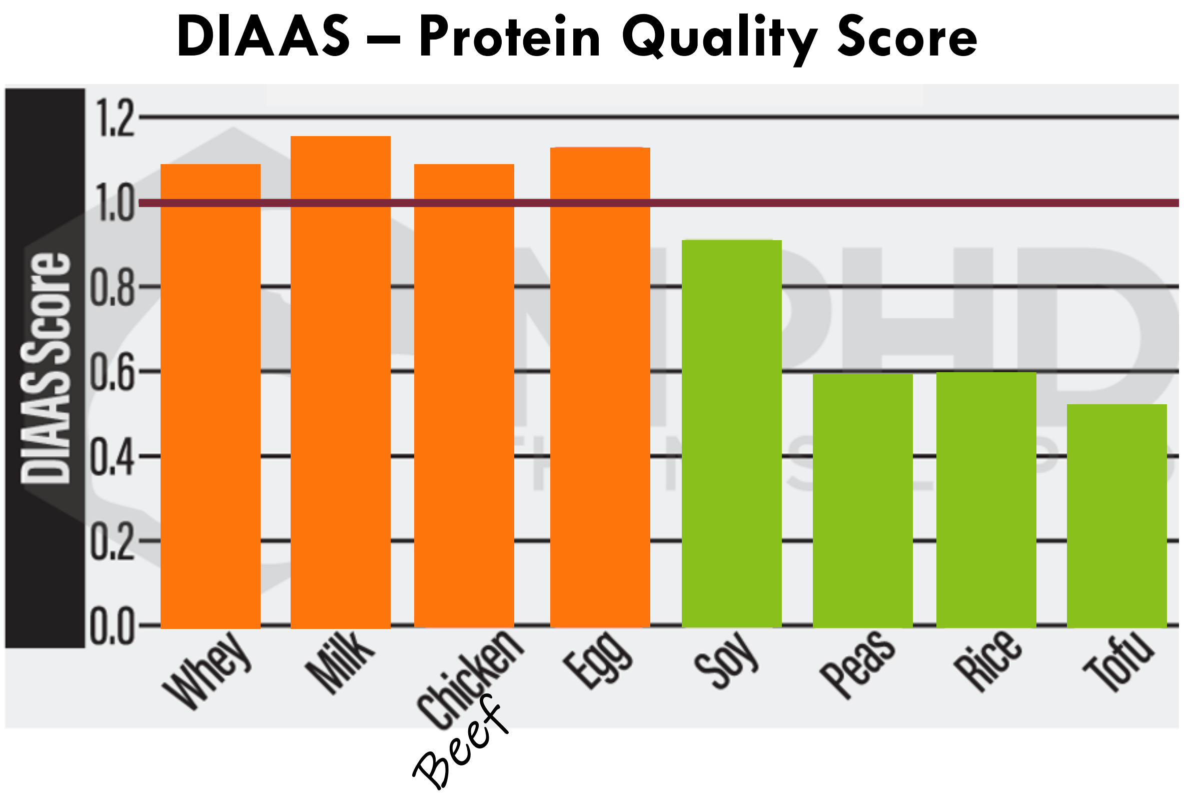
	Energy	Sat. Fat	Protein	Added Sugar
Fat Free Greek, Plain	80	0	16	0
Fat Free Greek, Strawberry	140	0	14	13
Fat Free (Regular), Strawberry	80	0	5	11
Soy (non-dairy), Strawberry	130	0	6	11

Protein Quality

1. Digestibility
   - Proteins must be digested before they can provide AAs to the body
   - Digestibility depends on the *source* AND *other foods eaten with protein*
     - ✓ *Animal proteins: 90-99% digestible*
     - ✓ *Plant proteins: 70-90% digestible*
2. Amino Acid Composition
   - For protein synthesis, dietary protein must supply all 9 essential AAs in required proportions
     - ✓ *Animal proteins: generally provide the most complete array of amino acids; are sometimes referred as Complete Proteins*
     - ✓ *Plant proteins: tend to be limiting in one or more essential amino acids; can be referred as 'Incomplete Proteins'*

Protein Quality

- Not all animal proteins are the same quality
- Not all plant proteins are the same quality



Complementary Proteins

- Low-quality proteins combined with each other to provide adequate levels of essential amino acids
- Protein quality of the combined foods is greater than either food alone
- Plant protein = lower quality than animal protein, and less protein by weight (per measure of food)
  - Vegetarians improve protein in diet by combining foods
  - Not necessary at every meal, but throughout a day
- Goal: eat foods you enjoy, while being mindful of protein!

Whitney & Rolfes, Understanding Nutrition (15th ed.)