Digestion & Absorption of the Food Nutrients

HNF 610: Nutrition & Fitness
Dr. Melissa Olfert
Nutrient Digestion and Absorption

- Hydrolysis reactions
  - Catabolic
  - Separate water molecules into $H^+$ and $OH^-$
- Condensation reactions
  - Anabolic
  - Join $H^+$ and $OH^-$ to form a water molecule
Hydrolysis

Sucrose → Water → Glucose + Fructose

Peptide bond

Dipeptide → Water → Amino acid + Amino acid
Condensation

Glucose + Glucose \rightarrow \text{Maltose} \quad \text{New bond created}

Amino acid + Amino acid \rightarrow \text{Dipeptide} \quad \text{Water}
Enzymes

- Accelerate chemical reactions
- No change occurs in the enzyme itself
- Decrease activation energy
- A substrate is any substance acted upon by an enzyme
- Coenzymes facilitate enzyme action
Passive Transport

- Simple diffusion
- Facilitated diffusion
- Osmosis
- Filtration
Osmolality

- Concentration of particles in a solution
  - Isotonic
  - Hypertonic
  - Hypotonic
A. Isotonic solution

- cell size and shape do not change

B. Hypertonic solution

- cell shrinks in size

C. Hypotonic solution

- cell expands and can burst

Copyright © 2009 Wolters Kluwer Health | Lippincott Williams & Wilkins
Active Transport

- Sodium-potassium pump
- Coupled transport
- Bulk transport
  - Exocytosis
  - Endocytosis
Acid–Base Concentration

• Acid: any substance that dissociates (ionizes) in solution and releases hydrogen ions (H\(^+\))
• Base: any substance that picks up or accepts H\(^+\) to form hydroxide ions (OH\(^-\)) in water solutions
• pH: provides a quantitative measure of the acidity or alkalinity (basicity) of a liquid solution
Buffers

- Chemical buffers
  - Consist of a weak acid and a base or salt of that acid
  - Example: bicarbonate

- Ventilatory buffer
  - Increases or decreases in pulmonary ventilation

- Renal buffer
  - Kidneys excrete $\text{H}^+$ to maintain acid–base stability of body fluids
The Gastrointestinal (GI) Tract

- The GI tract includes the esophagus, gallbladder, liver, stomach, pancreas, small intestine, large intestine, rectum, and anus
- It is surrounded by a connective tissue mesentery that weaves around and supports the intestinal organs.
- This membrane contains a diffuse network of capillaries that transports absorbed nutrients via the hepatic-portal vein to the liver
  - The liver processes the nutrients
The Mouth and Esophagus

- **Mouth**
  - Chewing or mechanical digestion alters food in the mouth.
  - Easier to swallow
  - Increases the accessibility to enzymes

- **Esophagus**
  - Connects the pharynx to the stomach
Peristalsis and Sphincters

- Peristalsis involves progressive, recurring waves of smooth muscle contractions that compress and squeeze the GI tract
- Sphincters control the passage of food
  - Act as valves that regulate passage or flow of material through the GI tract
  - Respond to stimuli from nerves, hormones, and hormone-like substances and an increase in pressure
The Stomach

- Temporary holding tank for partially digested food before moving it into the small intestine
- The stomach’s contents mix with chemical substances to produce chyme, a mixture of food and digestive juices.
- Parietal cells secrete hydrochloric acid stimulated by gastrin and acetylcholine released by the vagus nerve.
- Food mixes as hydrochloric acid and enzymes continue the breakdown process.
The Small Intestine

- Consists of three sections: the duodenum, the jejunum, and the ileum.
- Most digestion occurs in the small intestine.
- Absorption takes place through millions of villi.
  - Most absorption through the villi occurs by active transport that uses a carrier molecule and expends ATP energy.
- Lacteals absorb most digested lipids.
Intestinal Contractions

- 1-3 days for foods to leave the GI tract
- Segmentation: intermittent oscillating contractions and relaxations of the intestinal wall’s circular smooth muscle
  - Gives digestive juices time to mix with food
- Gallbladder and pancreas secrete digestive juices.
The Large Intestine

- This terminal portion of the GI tract, also known as the colon or bowel, contains no villi.
- Its major anatomic sections include the ascending colon, transverse colon, descending colon, sigmoid colon, rectum, and anal canal.
- Bacteria ferment the remaining undigested food residue.
- Serves as a storage area for undigested food residue (feces)
- Where absorption of water and electrolytes occurs
Digestive Process

- Controlled by the autonomic nervous system: involuntary control
- Digestion hydrolyzes complex molecules into simpler substances for absorption.
- Self-regulating processes within the digestive tract largely control the liquidity, mixing, and transit time of the digestive mixture.
Hormones Control Digestion

- Four hormones regulate digestion.
  - Gastrin
  - Secretin
  - Cholecystokinin (CCK)
  - Gastric inhibitory peptide
Carbohydrate Digestion and Absorption

- Salivary amylase degrades starch to simpler disaccharides.
- Pancreatic amylase continues carbohydrate hydrolysis.
- Enzymes on the brush border complete the final stage of carbohydrate digestion to monosaccharides
  - Maltase
  - Sucrase
  - Lactase
Lipid Digestion and Absorption

- Lingual lipase begins lipid digestion in the mouth.
  - Short-chain and medium-chain saturated fatty acids
- Gastric lipase continues lipid breakdown in the stomach.
  - Triacylglycerols
- Majority of lipid breakdown occurs in the small intestine.
Lipids Digestion and Absorption (cont.)

- Major lipid breakdown occurs by the emulsifying action of bile and the hydrolytic action of pancreatic lipase.
- Cholecystokinin (CCK) is released from the wall of the duodenum.
- Gastric inhibitory peptide and secretin are released in response to a high lipid content in the stomach.
Medium-Chain Triacylglycerols

- Medium-chain triacylglycerols rapidly absorb into the portal vein.
- Bound to glycerol and medium-chain free fatty acids
- Bypass the lymphatic system and enter the bloodstream rapidly
- Supplements have clinical application for patients with tissue-wasting disease or with intestinal malabsorption difficulties.
Long-Chain Fatty Acids

- Long-chain fatty acids are absorbed by the intestinal mucosa. They reform into triacylglycerols and then form chylomicrons.
- Chylomicrons move slowly through the lymphatic system and empty into the venous blood of the systemic circulation.
- Lipoprotein lipase is an enzyme that allows chylomicrons to hydrolyze to free fatty acids and glycerol.
Protein Digestion and Absorption

- Pepsin initiates protein digestion in the stomach.
- Gastrin stimulates secretion of gastric hydrochloric acid, performing many functions.
  - Activates pepsin
  - Stimulates the release of hydrochloric acid
  - Kills pathogenic organisms
  - Improves absorption of iron and calcium
  - Inactivates hormones of plant and animal origin
  - Denatures food proteins, making them more vulnerable to enzyme action
Protein Digestion and Absorption (cont.)

- The final steps in protein digestion occur under the action of the enzyme trypsin.
  - The peptide fragments further dismantle into tripeptides, dipeptides, and single amino acids.
- Amino acids also join with sodium for active absorption through the small intestine into the portal vein and on to the liver.
Amino Acids in the Liver

- Once amino acids reach the liver, one of three events occurs:
  - Conversion to glucose (glucogenic amino acids)
  - Conversion to fat (ketogenic amino acids)
  - Direct release into the bloodstream as plasma proteins, such as albumin, or as free amino acids
Vitamins

- Vitamin absorption occurs mainly by the passive process of diffusion in the jejunum and ileum.
- Fat-soluble vitamins are absorbed with dietary lipids.
- Once absorbed, chylomicrons and lipoproteins transport these vitamins to the liver and fatty tissues.
Vitamins

- Water-soluble vitamins diffuse into the blood, except for vitamin $B_{12}$. 
  - This vitamin combines with intrinsic factor produced by the stomach, which the intestine absorbs by endocytosis.
- Water-soluble vitamins pass into the urine when their concentration in plasma exceeds the renal capacity for reabsorption.
Minerals

- Both extrinsic (dietary) and intrinsic (cellular) factors control the eventual fate of ingested minerals.
- The body does not absorb minerals very well.
- Mineral availability in the body depends on its chemical form.
- Gender influences mineral absorption.
  - Males absorb calcium better than females.
Water Absorption

- Major absorption of ingested water and water contained in foods occurs by the passive process of osmosis in the small intestine.
- Intestinal tract absorbs about 9 L of water each day.
  - 72% absorbed in the proximal small intestine
  - 20% absorbed from the distal segment of the small intestine
  - 8% absorbed from the large intestine