CHAPTER 2

Digestion, Absorption, and Metabolism
The Human Body: 
Role of Nutrition

● Food: Change and Transformation

➢ Through a successive interrelated system, foods are transformed into simple substances that can be absorbed into the body and enter the metabolic pathways in the cell.
The Human Body: Role of Nutrition (Cont.)

- Importance for Health and Nutrition
  - Food is a mixture of chemical substances and nutrients
  - Nutrients released from food are unavailable to the body until they cross the intestinal wall and are transported to tissues for storage or immediate use
  - Allows homeostasis
The Gastrointestinal Tract

● Component Parts
  - Gastrointestinal tract (alimentary canal)
    - Long, hollow tube that begins at the mouth and ends at the anus
  - Specific parts of the tract: mouth, esophagus, stomach, small intestine, large intestine (or colon), and rectum
  - Organs that lie outside the tract: the pancreas, gallbladder, and liver
The Gastrointestinal Tract (Cont.)

- Four major functions in digestion and absorption:
  1. Receives food
  2. Releases nutrients from food
  3. Delivers nutrients into the blood
  4. Excretes nondigestible waste
The Gastrointestinal Tract (Cont.)

● Sensory Stimulation and Gastrointestinal Function
  ➢ Physiologic and psychological factors influence digestion
  ➢ Sensory stimulation—sight, smell, or proximity to food—brings about the secretion of digestive juices and muscle motility
Principles of Digestion

- Digestion: first step in preparing food for use by the body
- Two types of actions involved:
  1. Chemical
  2. Muscular
Gastrointestinal Secretions

● Food is digested chemically through the combined action of a number of secretions

● Secretions:
  ➢ Enzymes
  ➢ Hydrochloric acid and buffer ions
  ➢ Mucus
  ➢ Water and electrolytes

● Special cells in the mucosal lining of the gastrointestinal tract and in adjacent accessory organs produce these secretions
Digestion: Types of Muscles

- Muscle layers from the outer surface inward
  1. Serosa
  2. Longitudinal muscle layer
  3. Circular muscle layer
  4. Submucosa
  5. Mucosa
Muscular Actions in Digestion

- Muscles along the gastrointestinal tract:
  - Longitudinal muscles help propel food mass forward
  - Circular contractile muscles: rhythmic sweeping waves push food forward (peristalsis)
  - Sphincter muscles act as valves: pyloric, ileocecal, and anal (keep food moving forward)
  - Mucosal muscles: local constrictive contractions to chop and mix the food mass
  - Tonic and periodic rhythmic contractions
Nervous System Control

- Throughout the gastrointestinal tract, specific nerves regulate muscle action.
- An interrelated network of nerves within the gastrointestinal wall called the intramural nerve plexus extends from the esophagus to the anus.
Mouth and Esophagus

Taste and Smell

- Taste buds located on the tongue, roof of the mouth, and throat contain chemical receptors that respond to food and produce the five sensations of taste:
  - Salty, sweet, sour, bitter, umami
- Much of what we perceive as taste of a food may actually be its odor
- Taste is affected by genetic differences, chemotherapy, medications, zinc deficiency, radiation therapy, Parkinson’s disease, and dementia
- Dysgeusia and hypogeusia
Mouth and Esophagus (Cont.)

Mastication

- Biting and chewing starts to break down food
- 55 lb of muscular pressure is applied through the incisors, and 200 lb is applied through the molars
- Enlarges surface area for enzyme action
Mouth and Esophagus (Cont.)

Mastication (Cont.)

- Ability to chew is necessary to prepare fiber-containing foods, fruits, vegetables, and whole grains for digestion
- Diseases of the gums such as gingivitis that make chewing painful contribute to restricted food intake and malnutrition
Chemical Digestion in the Mouth

- Three pairs of salivary glands:
  1. Parotid
  2. Submaxillary
  3. Sublingual
- Saliva secretion ranges from 800 to 1500 mL/day
- Sensory stimuli influence secretions
Chemical Digestion in the Mouth (Cont.)

- Salivary secretions have three important functions:
  1. Salivary amylase begins the breakdown of starch
  2. Moisten the food particles so they bind together to form a bolus that moves easily down the esophagus
  3. Lubricate and cleanse the teeth and tissues of the mouth
     - Dry mouth—xerostomia
Swallowing

- Involves both the mouth and pharynx
- Tongue initiates a swallow by pressing the food upward and backward against the palate
- Swallowing proceeds as an involuntary reflex
- Swallowing occurs rapidly, taking less than 1 second
  - Larynx closes to prevent food from entering trachea
  - Soft palate rises to prevent food from entering nose
Mouth and Esophagus (Cont.)

- Esophagus is a muscular tube that connects the mouth and throat with the stomach
- Has the following three parts:
  1. Upper esophageal sphincter (UES)
  2. Esophageal body
  3. Lower esophageal sphincter (LES)
Mouth and Esophagus (Cont.)

- Entry into the Stomach
  - Gastroesophageal constrictor muscle relaxes to allow the food to pass and then contracts quickly to prevent regurgitation or reflux
  - Failure of this mechanism results in gastroesophageal reflux disease (GERD)
    - “Heartburn”
    - Damages the unprotected tissues of the esophagus
    - Obesity, overeating, physical inactivity, smoking, and certain medications contribute to this condition
Stomach

Motility

- Muscles in the stomach wall have three motor functions:
  1. Storage
  2. Mixing
  3. Controlled emptying
Stomach (Cont.)

Motility (Cont.)

- Muscle waves gradually increase their kneading and mixing action to move the mass of food and secretions toward the pyloric valve at the distal end of the stomach.
- The energy (kcaloric) density, volume, and composition of a meal influence the rate of stomach emptying.
Chemical Digestion

- Secretions produced in the stomach contain:
  - Acid
  - Mucus
  - Enzymes
Stomach (Cont.)

Control of Secretions

- Stimuli for the release of gastric secretions come from:
  1. Nerve stimuli
  2. Hormonal stimuli
Small Intestine

Intestinal Muscle Layers

- Coordination of intestinal motility is accomplished by three layers of muscle:
  1. The thin layer of smooth muscle in the mucosa (the muscularis mucosae) with fibers extending up into the villi
  2. The circular muscle layer
  3. The longitudinal muscle lying next to the outer serosa
Types of Intestinal Muscle Action

- Wall-stretch pressure from food or hormonal stimuli produces muscle action of the following two types:
  1. Propulsive movements
  2. Mixing movements
Small Intestine (Cont.)

Major Role of the Small Intestine

- Secretes many enzymes, each specific for one of the macronutrients—carbohydrate, fat, or protein
- Acts as a regulatory center that senses the nutrient content, pH, and osmolarity of its contents
Small Intestine (Cont.)

- Four types of digestive secretions complete this final stage of chemical breakdown:
  1. Enzymes
  2. Mucus
  3. Hormones
  4. Bile
- End products of digestion are then ready for absorption
Small Intestine (Cont.)

Surface Structures

● Three types of convolutions and projections greatly expand the area of the absorbing surface:
  1. Mucosal folds
  2. Villi
  3. Microvilli
Small Intestine (Cont.)

Surface Structures (Cont.)

- Increase the inner absorbing surface area about 1000 times over that of the outside serosa
- Produce a tremendously large surface to capture and absorb nutrients
Small Intestine (Cont.)

Mechanisms of Absorption

- Particular transport used depends on the nutrient and the prevailing electrochemical fluid pressure gradient
  - Passive diffusion and osmosis
  - Facilitated diffusion
  - Energy-dependent active transport
  - Engulfing pinocytosis
Small Intestine (Cont.)

Routes of Absorption

- Water-soluble monosaccharides and amino acids enter directly into the portal blood and travel to the liver and other tissues.
- Fats packaged in a bile complex (micelle) are carried into the cells of the intestinal wall, where they are processed into human lipid compounds and form a complex with protein as a carrier (lipoprotein).
Small Intestine (Cont.)

Routes of Absorption (Cont.)

- Chylomicrons flow into the lymph, empty into cisterna chyli of the lymphatic system, and enter venous blood at the left subclavian vein.
- Chylomicrons are rapidly cleared from the blood by lipoprotein lipase.
- Short-chain fatty acids are water soluble and can be absorbed directly into the blood with carbohydrate and protein breakdown products.
Colon

Role in Absorption

- Absorption of water is the main task of the colon
- Approximately 1 to 1.5 L is received from the ileum, and 95% of that is absorbed
- Most of the water in the chyme (350 to 400 mL) is absorbed in the first half of the colon
Colon (Cont.)

Role in Absorption (Cont.)

- Approximately 100 to 150 mL of water remains to form the feces
- Absorption of water in the colon is important in regulating water balance and eliminating fecal waste
- Amount of water absorbed affects constipation and diarrhea
Mineral Absorption

- Sodium and other electrolytes are absorbed from the colon
- Unabsorbed minerals are excreted in the feces
- Up to 90% of the calcium and iron in the food we eat is not absorbed
- The proportion of a mineral intake that is absorbed is important for nutrient balance
Colon (Cont.)

Vitamin Absorption

- Conditions in the gastrointestinal tract influence vitamin absorption
- When gastric acid is lower than normal, vitamin B$_{12}$ is not easily released from its animal protein source and is lost in the feces
- Colon bacteria synthesize vitamin K and biotin
Colon (Cont.)

Role of Intestinal Bacteria

- More than 1000 species of bacteria are found in the normal gastrointestinal tract
- The kinds of microflora differ according to dietary intake of fiber or other nondigestible carbohydrates, genetics, physical environment, immune responses, and antibiotic use
Colon (Cont.)

Role of Intestinal Bacteria (Cont.)

- Intestinal bacteria make up about one third of fecal weight
- Particular microflora produce bothersome gas or increase the risk of gastrointestinal disease
- Other species make positive contributions to health
Excessive Gas Production

Fermentation of Complex Carbohydrates

- Major contributors to gas production
- Certain polysaccharides in grains, fruits, and vegetables cannot be broken down by human digestive enzymes and absorbed
Excessive Gas Production (Cont.)

Fermentation of Complex Carbohydrates (Cont.)

- Intestinal bacteria act on these polysaccharides and produce $\text{CO}_2$, $\text{H}_2$, methane, and sometimes hydrogen sulfide
- Excessive gas has social implications
- Various over-the-counter products claim to reduce the formation of gas or eliminate gaseous odors, but all have limitations
Large Intestine (Colon)

Waste Elimination

- Approximately 4 hours after a meal is consumed, it enters the cecum
- Approximately 8 hours later it reaches the sigmoid colon
- Feces are usually stored in the descending colon
- Anal sphincters under voluntary control regulate elimination of feces
Chronic Gastrointestinal Distress

- Some people experience abdominal pain, bloating, early satiety, nausea, vomiting, or diarrhea on a regular basis
  - Dyspepsia
- Sometimes no specific biochemical or structural explanation can be found
- Other influences on gastrointestinal function:
  - Anxiety, emotional stress, depression, certain prescription medications, and chronic disease
Lactose Intolerance

- Affects 70% of the world’s population
- Most common in Asians, African Americans, and Hispanics
- Symptoms with 6 to 18 g lactose
  - (1 cup milk = 12 g lactose)
- Caused by deficiency of enzyme lactase
  - Undigested lactose absorbs water and is fermented by resident bacteria
- Symptoms worsen with irritable bowel syndrome, celiac disease, cystic fibrosis, or other damage to the intestinal mucosa
Lactose Intolerance (Cont.)

- Different from milk allergy
- To ensure adequate intakes of calcium and vitamin D:
  - Add dairy foods gradually
  - Include lactose-containing foods with a meal or snack
  - Choose dairy foods lower in lactose
Prebiotics

- Prebiotics are nondigestible carbohydrates that serve as substrates to support the proliferation of health-promoting bacteria

- Positive effects of prebiotics
  - Support immune function
  - Increase mineral absorption
  - Promote normal laxation
  - Protect against colon cancer
Probiotics

- Probiotics are nutritional supplements made up of living microorganisms
- Bifidobacteria and lactobacilli are bacteria commonly found in the gastrointestinal tract with positive effects on health
Probiotics (Cont.)

Several clinical applications of probiotics:

- Infectious diarrhea
- Infant allergies
- Inflammatory bowel disease
- Inhibition of *Helicobacter pylori*
- Gastrointestinal immune response
- Lactose intolerance
Metabolism

Carbohydrate Metabolism
- Glucose is an immediate energy source for all body cells
- Preferred energy source for brain and nervous system

Sources of Blood Glucose
- Carbohydrate sources
  1. Dietary starches and sugars
  2. Glycogen stored in liver and muscle
  3. Products of carbohydrate metabolism, such as lactic acid and pyruvic acid
Metabolism (Cont.)

Sources of Blood Glucose (Cont.)

- Noncarbohydrate sources
  - Protein and fat provide indirect sources of glucose
  - Formation of glucose from protein, glycerol, and carbohydrate metabolites is called *gluconeogenesis*
Metabolism (Cont.)

Blood Glucose

- Normal range of 70 to 140 mg/dL (3.9 to 7.8 mmol/L)
- When blood glucose levels begin to fall, stored glucose is released into the blood for use in meeting the energy needs of the brain and other cells
Blood glucose can be used for:

- Energy production
- Energy storage in the form of glycogen and fat
- Formation of other glucose products, such as the carbohydrates used in forming deoxyribonucleic acid (DNA) and ribonucleic acid (RNA)
Metabolism (Cont.)

Hormonal Controls for Carbohydrate

- Hormones directly and indirectly influence glucose metabolism and regulate blood glucose levels:
  - Blood glucose–lowering hormone: insulin
  - Insulin lowers blood glucose via glycogenesis, lipogenesis, and increased cell permeability
Metabolism (Cont.)

Hormonal Controls for Carbohydrate (Cont.)

- Blood glucose–raising hormones
  - Glucagon
  - Somatostatin
  - Steroid hormones
  - Epinephrine
  - Growth hormone (GH) and adrenocorticotropic hormone (ACTH)
  - Thyroxine
Metabolism (Cont.)

Lipid Metabolism

- Two organ tissues form a balanced axis of lipid metabolism
  - Liver
  - Adipose tissue
- Both participate in lipid synthesis and breakdown
Lipid Metabolism (Cont.)

- Lipoproteins
  - Produced in:
    - The intestinal wall after the initial absorption of dietary lipids
    - The liver for constant recirculation to and from cells
Hormonal Controls for Lipids

- Lipid and carbohydrate metabolism are interrelated
- Same hormones are involved:
  - GH, ACTH, and thyroid-stimulating hormone (TSH)
  - Cortisol and corticosterone
  - Epinephrine and norepinephrine
  - Insulin
  - Thyroxine
Protein Metabolism

Anabolism (Tissue Building)

- The process of anabolism builds tissue through the synthesis of new protein
- Directed by DNA “blueprint”
- Specific enzymes, coenzymes, GH, gonadotropins, and thyroxine control and stimulate the building of tissue protein
Catabolism (Tissue Breakdown)

- Breakdown of these amino acids yields two parts:
  - The nitrogen-containing group
  - The remaining nonnitrogen residue
Metabolic Interrelationships

- Each chemical reaction in the body is purposeful
- All reactions are interdependent
- Fill two essential needs
  - Produce energy
  - Support growth and maintenance of healthy tissue
- Controlling agents are cell enzymes, coenzymes, and special hormones