

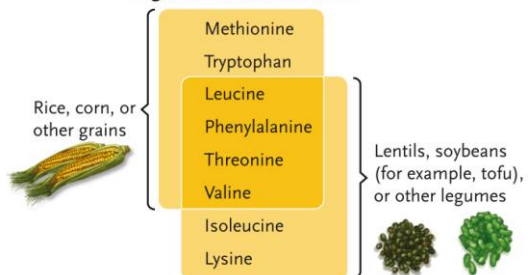
The Digestive System

Chapter 45

Human Nutritional Requirements (Adults)

- 8 essential amino acids
- 13 vitamins
 - Water-soluble vitamins
 - Fat-soluble vitamins
- A large number of essential minerals
 - Macronutrients
 - Micronutrients
 - Trace elements

Eight essential amino acids



Fat-Soluble Vitamins

TABLE 45.1 Vitamins: Sources, Functions, and Effects of Deficiencies in Humans

Vitamin	Common Sources	Main Functions	Selected Effects of Chronic Deficiency
Fat-Soluble Vitamins			
A (retinol)	Yellow fruits, yellow or green leafy vegetables; also in fortified milk, egg yolk, fish liver	Used in synthesis of visual pigments; and in growth of bone and teeth; maintains epithelial tissues	Dry, scaly skin; lowered resistance to infections; night blindness
D (calciferol)	Fish liver oil, egg yolk, fortified milk; manufactured when body exposed to sunshine	Promotes bone growth and mineralization; enhances calcium absorption from gut	Bone deformities (rickets) in children; bone softening in adults
E (tocopherol)	Whole grains, leafy green vegetables, vegetable oils	Antioxidant; helps maintain cell membrane and red blood cells	Lysis of red blood cells; nerve damage
K (naphthoquinone)	Intestinal bacteria; also in green leafy vegetables, cabbage	Promotes synthesis of blood-clotting protein by liver	Abnormal blood clotting, severe bleeding (hemorrhaging)

Water-Soluble Vitamins

Water-Soluble Vitamins

B ₁ (thiamine)	Whole grains, green leafy vegetables, legumes, lean meat, eggs, nuts	Connective tissue formation; needed for folate utilization; coenzyme for folate utilization; coenzyme forming part of enzyme in oxidative reactions	Mental confusion; tingling sensations; muscular wasting; poor coordination; pain; vomiting; rapid heart rate; enlarged heart; congestive heart failure
B ₂ (riboflavin)	Whole grains, poultry, fish, egg white, milk, lean meat	Coenzyme	Skin lesions
Niacin	Green leafy vegetables, potatoes, peanuts, poultry, fish, pork, beef	Coenzyme of oxidative phosphorylation	Sensitivity to light; damage to skin, gut, and nervous system, leading to, respectively, dermatitis, diarrhea, and dementia
B ₆ (pyridoxine)	Spinach, whole grains, tomatoes, potatoes, meat	Coenzyme in amino acid and fatty acid metabolism	Skin, muscle, and nerve damage
Pantothenic acid	In many foods (meat, yeast, egg yolk especially)	Coenzyme in carbohydrate and fat oxidation; required for fatty acid and steroid synthesis	Fatigue; tingling in hands; headaches, nausea
Folic acid	Dark green vegetables, whole grains, yeast, lean meat; intestinal bacteria produce some folate	Coenzyme in nucleic acid and amino acid metabolism; promotes red blood cell formation	Anemia; inflamed tongue; diarrhea; impaired growth; mental disorders; neural tube defects and low birth weight in newborns
B ₁₂ (cobalamin)	Poultry, fish, eggs, red meat, dairy foods (not butter)	Coenzyme in nucleic acid metabolism; necessary for red blood cell formation	Anemia; nerve damage that causes tingling of hands and feet, loss of balance, depression, and, in severe cases, dementia
Biotin	Legumes, egg yolk; colon bacteria produce some	Coenzyme in fat and glycogen formation and amino acid metabolism	Scaly skin (dermatitis); sore tongue; brittle hair; depression; weakness
C (ascorbic acid)	Fruits and vegetables, especially citrus, berries, cantaloupe, cabbage, broccoli, green pepper	Vital for collagen synthesis; antioxidant	Scurvy (weakness, anemia, gum disease, and skin problems); delayed wound healing; impaired immunity

Major Minerals

TABLE 45.2 Major Minerals: Sources, Functions, and Effects of Deficiencies in Humans

Mineral	Sources	Functions	Selected Effects of Deficiency
Calcium (Ca)	Dairy products, leafy green vegetables, legumes, whole grains, nuts	Bone and tooth formation; blood clotting; neural and muscle action	Stunted growth; diminished bone mass (osteoporosis)
Chlorine (Cl)	Table salt, meat, eggs, dairy products	HCl formation in stomach; contributes to body's acid-base balance; necessary for neural function and water balance	Muscle cramps; impaired growth; poor appetite
Chromium (Cr)	Meat, liver, cheese, whole grains, brewer's yeast, peanuts	Rules in carbohydrate metabolism	Impaired response to insulin; increased risk of type 2 diabetes mellitus
Cobalt (Co)	Meat, liver, fish, milk	Constituent of vitamin B ₁₂ (required for red blood cell maturation)	Same as for vitamin B ₁₂ (see Table 45.1)
Copper (Cu)	Nuts, legumes, seafood, drinking water, whole grains	Used in synthesis of melanin, hemoglobin, and some electron transfer system components in mitochondria	Anemia; changes in bone and blood vessels
Fluorine (F)	Fluoridated water, tea, seafood	Bone and tooth maintenance	Tooth decay
Iodine (I)	Marine fish, shellfish, iodized salt	Thyroid hormone formation	Goiter (enlarged thyroid), with metabolic disorders

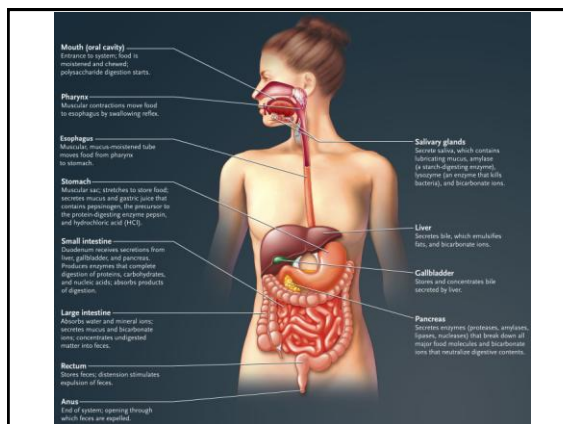
Major Minerals

Iron (Fe)	Liver, whole grains, green leafy vegetables, legumes, nuts, eggs, lean meat, molasses, dried fruit, shellfish	Component of hemoglobin, cytochrome, and myoglobin	Anemia
Magnesium (Mg)	Whole grains, green vegetables, legumes, nuts, dairy products	Required for action of many enzymes; roles in muscle and nerve function	Weak, sore muscles; impaired neural function
Manganese (Mn)²⁺	Whole grains, nuts, legumes, many fruits	Activates many enzymes, including ones with roles in synthesis of urea and fatty acids	Abnormal bone and cartilage
Molybdenum (Mo)²⁺	Dairy products, whole grains, green vegetables, legumes	Component of some enzymes	Impaired nitrogen excretion
Phosphorus (P)	Whole grains, legumes, poultry, red meat, dairy products	Component of bones and teeth, nucleic acids, ATP, and phospholipids	Muscular weakness; loss of minerals from bone
Potassium (K)	Meat, milk, many fruits, vegetables	Muscle and neural function; roles in protein synthesis	Muscular weakness
Selenium (Se)²⁺	Meat, seafood, cereal grains, poultry, garlic	Constituent of several enzymes; antioxidant	Muscle pain
Sodium (Na)	Table salt, dairy products, meat, eggs	Acid-base balance; water balance; roles in muscle and neural function	Muscle cramps
Sulfur (S)	Meat, eggs, dairy products	Component of body proteins	Same as protein deficiencies
Zinc (Zn)²⁺	Whole grains, legumes, nuts, meat, seafood	Component of digestive enzymes and transcription factors; roles in normal growth, wound healing, sperm formation, taste and smell	Impaired growth, scaly skin, impaired immune function

²⁺Required in trace amounts in diet

Mammalian Digestive System

- Structures common to all mammals
 - Mouth, pharynx, esophagus, stomach, intestine, anus
- Sphincters
 - Rings of smooth muscle form valves between major regions of the digestive tract



4 Major Layers of the Vertebrate Gut

1. Mucosa

- Lines inside of gut
- Epithelial and glandular cells

2. Submucosa

- Elastic connective tissue, neuron network, blood and lymph vessels

4 Major Layers of the Vertebrate Gut

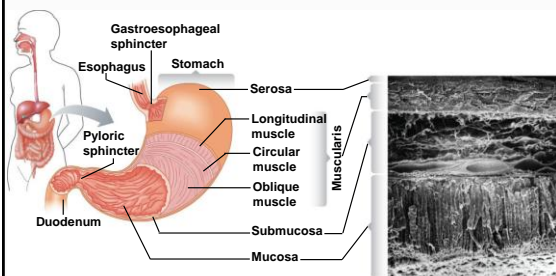
3. Muscularis

- Circular layer
- Longitudinal layer
- Oblique layer (**stomach only**)

4. Serosa

- Lubricating connective tissue
- Continuous with **mesentery**

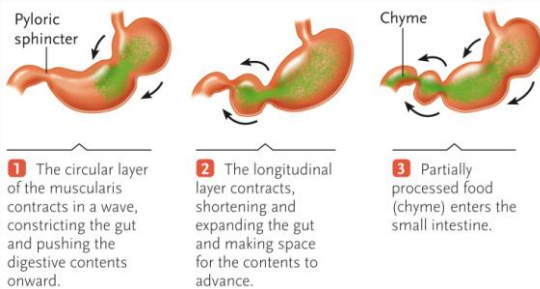
Layers of the Vertebrate Gut Wall



Peristalsis

- Coordinated contractions of **circular and longitudinal muscles**
- **Smooth muscle - involuntary**
- Produce **peristaltic waves** that move digestive contents from mouth to anus

Peristalsis

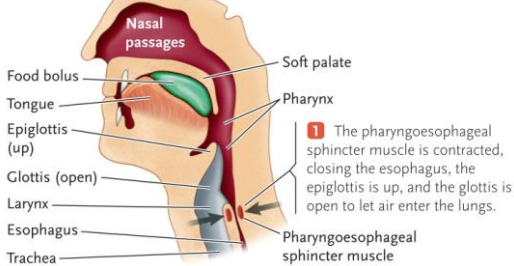


The Digestive Process (1)

- Digestion begins in the mouth
 - Teeth break food into smaller bits
- **Salivary glands** in the mouth secrete saliva
 - **Salivary amylase** digests starch
 - **Carbohydrate digestion begins!**
- Food mass (**bolus**) is swallowed
 - Through pharynx and esophagus to stomach
 - **Epiglottis** blocks trachea

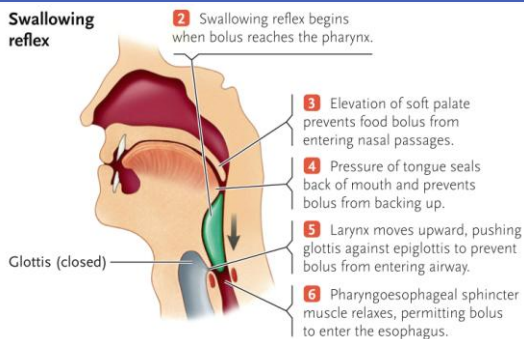
Swallowing Reflex

Individual not swallowing



Swallowing Reflex

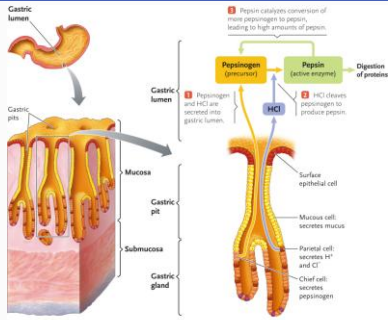
Swallowing reflex



The Digestive Process (2)

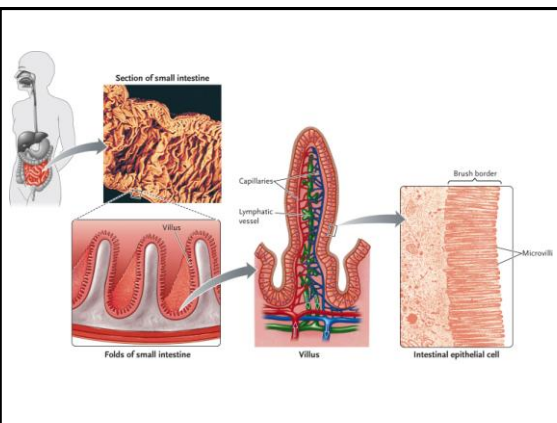
- Stomach secretes gastric juice
 - Hydrochloric acid
 - Protein-digesting enzyme pepsin (pepsinogen)
 - Mucus
- Stomach churns acid contents into chyme
 - Released in pulses into small intestine

Secretions of the Stomach Lining



The Digestive Process (3)

- Absorption of nutrients begins in the small intestine
- Specializations to optimize absorption
 - Intestinal villi
 - Microvilli



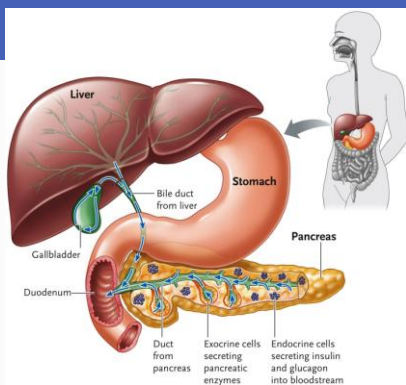
The Digestive Process (4)

- In the **duodenum**, digestive juices from the **pancreas** and **liver** add enzymes and digestive aids to the food mass
- Pancreatic juice
 - Digestive enzymes
 - Bicarbonate ions (neutralize acidity)

The Digestive Process (5)

- Liver secretion (**bile**) emulsifies fats
 - **Bile salts**
 - Cholesterol
 - **Bilirubin**
 - Additional bicarbonate ions
- **Gallbladder** stores **bile**

Liver, Pancreas, and Gallbladder



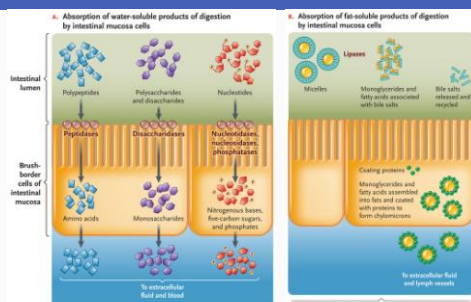
The Digestive Process (6)

- **Small intestine secretes enzymes that complete most digestion**
- Mucosal cells of the **small intestine absorb the molecular subunits**

Digestive Enzymes

	Carbohydrates	Proteins	Fats	Nucleic acids
Mouth	Polysaccharides ↓ Salivary amylase Smaller polysaccharides, disaccharides			
Stomach		Proteins ↓ Pepsin Peptides		
Lumen of small intestine	Polysaccharides ↓ Pancreatic amylase Disaccharides	Proteins ↓ Trypsin, chymotrypsin Peptides ↓ Large peptides ↓ Carboxypeptidase Amino acids	Triglycerides and other lipids ↓ Lipase Fatty acids, monoglycerides	DNA, RNA ↓ Pancreatic nucleases Nucleotides
Epithelial cells (brush border) of small intestine	Disaccharides (maltose, sucrose, lactose) ↓ Disaccharidases Monosaccharides (for example, glucose)	Large peptides ↓ Amino-peptidase Amino acids Dipeptides ↓ Dipeptidase Amino acids		Nucleotides ↓ Nucleotidases, nucleosidases, phosphatases Nitrogenous bases, five-carbon sugars, and phosphates

Intestinal Absorption



Other Liver Functions

- Absorbed nutrients are delivered to the liver
 - [Hepatic portal vein](#)
 - Excess glucose is converted into glycogen
 - Fats and some amino acids are converted into plasma proteins or sugars
- Liver synthesizes cholesterol from lipids, carbohydrates, and other substances

The Digestive Process (7)

- Large intestine
 - [Cecum, appendix, colon, rectum](#)
 - Absorbs water and mineral ions from digestive contents
- At end of large intestine, undigested remnants ([feces](#)) are expelled from the anus

Human Large Intestine

