



Human Digestion & Absorption

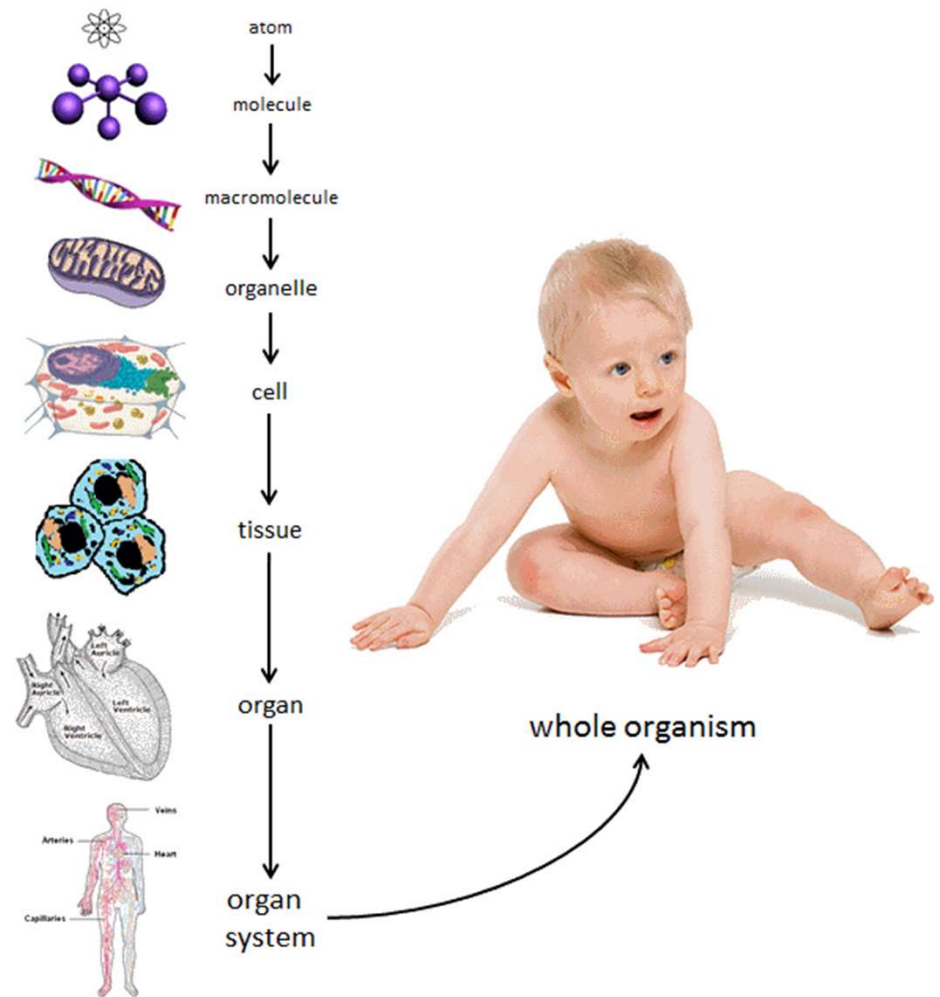
Module 3

Learning Objectives

- Describe the organizational hierarchy of the human body.
- Understand the structure and functions of organs involved in digestive transport.
- Explain how digestive enzymes and other secretions function in the digestive tract
- Outline the basic anatomy and functions of digestive system organs.
- Explain the processes of food transport, nutrition absorption, and how nutrients enter the circulatory system.
- Describe the function of key enzymes and hormones required for digestion and absorption.
- Identify major nutrition-related gastrointestinal disorders and typical approaches to prevention and treatment.

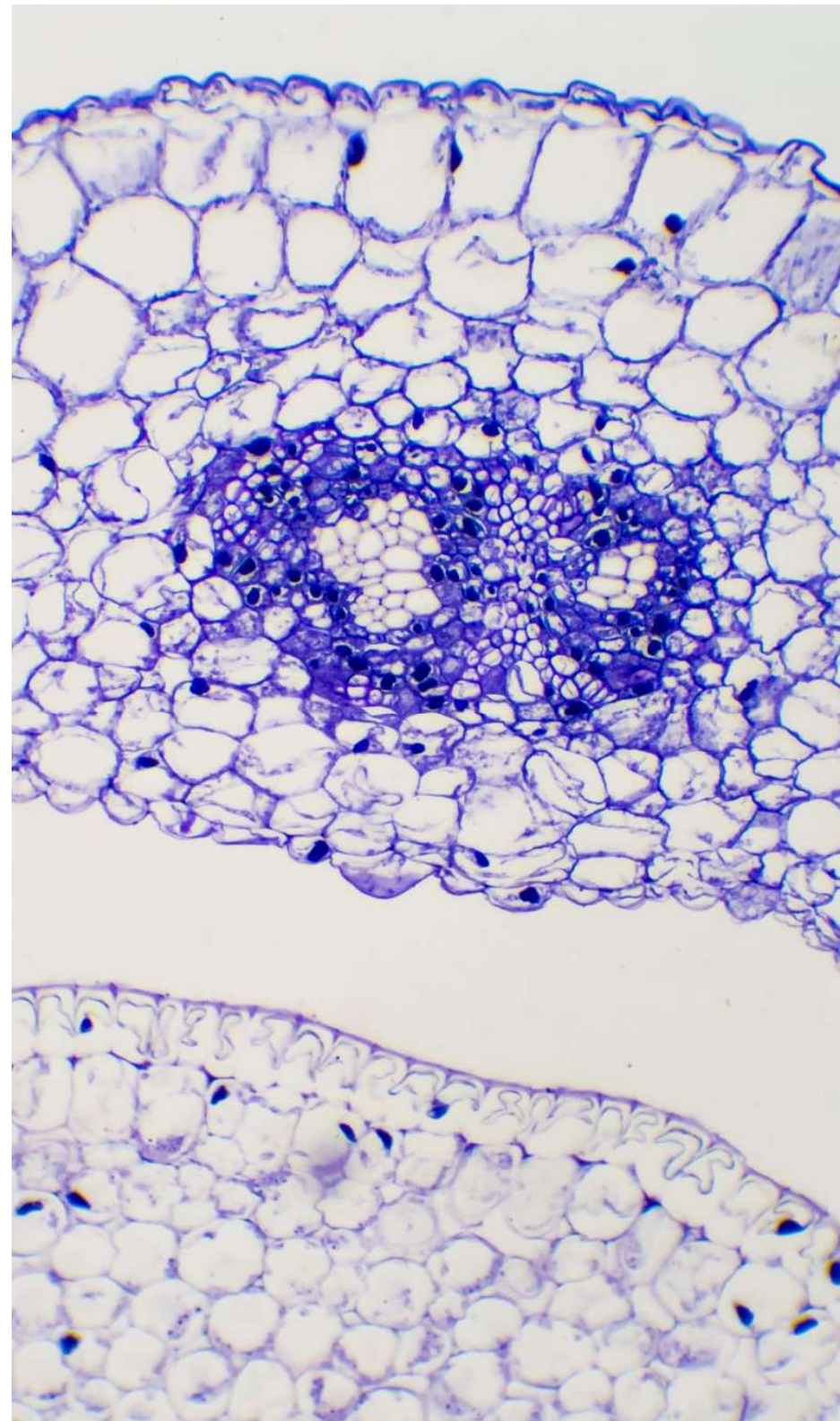
Human Body Hierarchy

- Trillions of cells in the human body
 - Ability to grow, and absorb nutrients and other substances
- The cellular processes require energy
 - From carbohydrates proteins, and fats
- Produce adenosine triphosphate or ATP through energy metabolism
- Without that energy, cellular processes cease, and you cannot survive



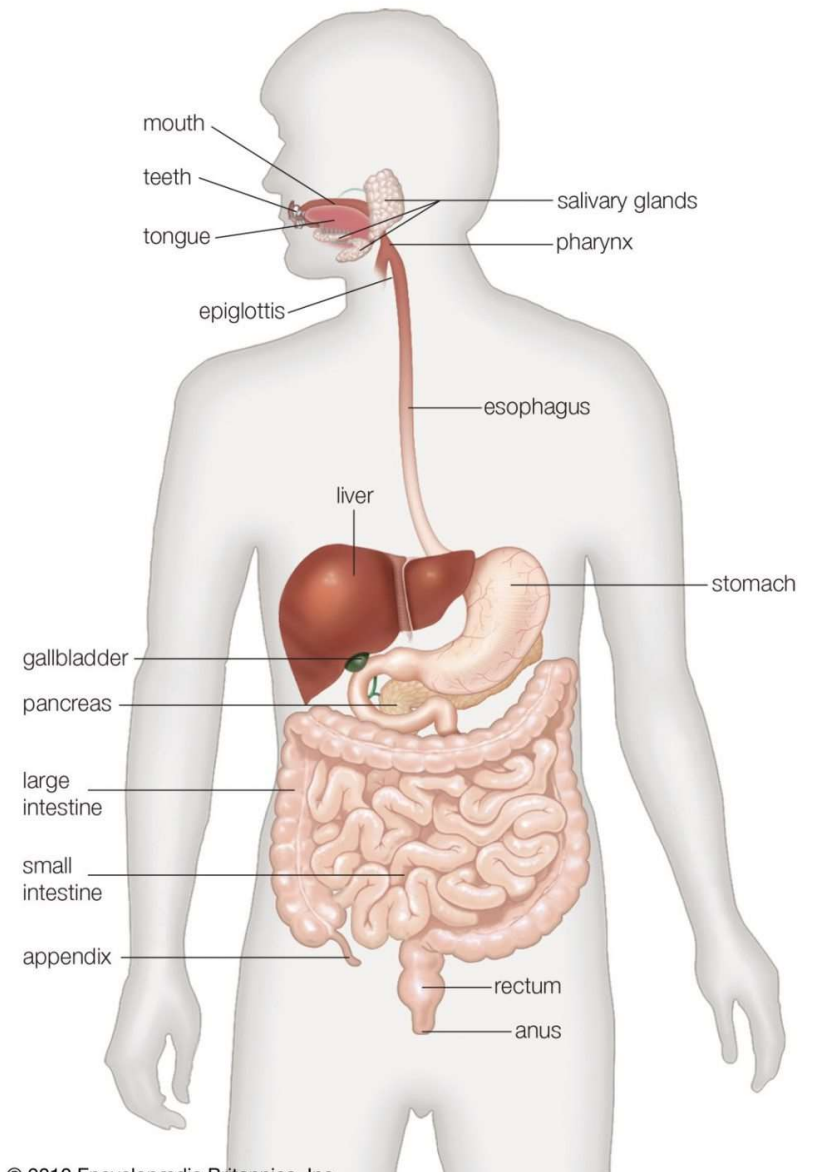
Body Organization

- Cells form tissues
- Tissues form organs
- Organs form systems, such as digestive system
- Getting adequate supply of nutrients to the body's cells begins with healthy diet. Cells need...
 - A continuous supply of energy from CHO, fats, and/or protein for cell turnover
 - Water
 - Building supplies – protein and/or minerals
 - Chemical regulators – vitamins
 - Cells need a constant supply of oxygen



Digestive System

- Consists of gastrointestinal tract, accessory structures liver, gallbladder, pancreas
- Performs mechanical and chemical digestion, absorption of nutrients, elimination of wastes
- Houses bulk of immune system







Sadness:

a "gut-wrenching" experience may give you stomach cramps



Fear:

makes you "feel nauseous"



Love:

"butterflies" in your stomach



Stress:

Digestive Symptoms: heartburn, abdominal cramps, or loose stools, weight loss or gain

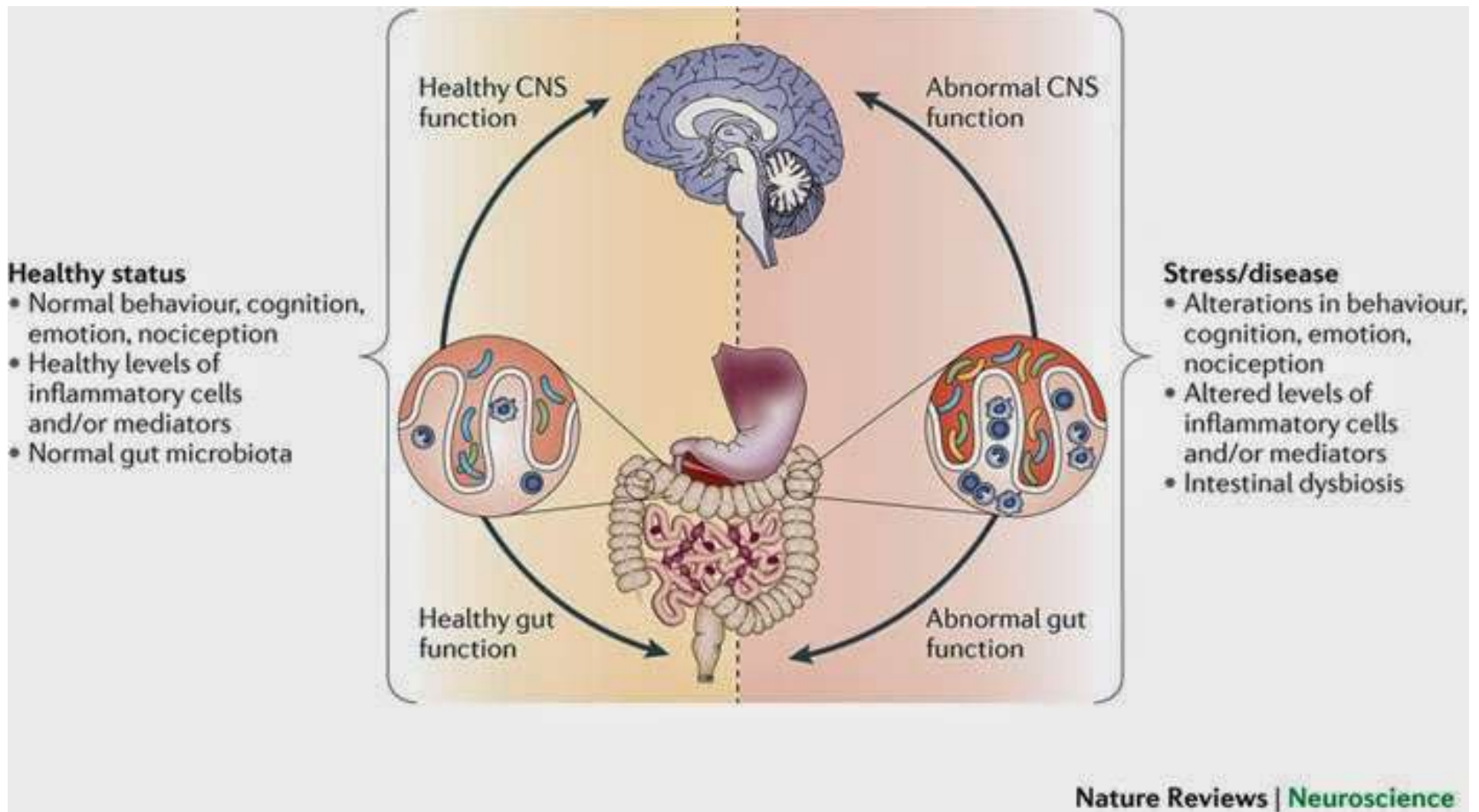


Depression:

Physical symptoms such as headaches and gastrointestinal problems get overlooked

**The
gastrointestinal
tract is sensitive to
emotion, stress,
anxiety and
depression.**

The Gut Brain Axis: Bidirectional Communication



Digestive System - Terms

- **Gastrointestinal (GI) tract:** sites in the body for digestion and absorption of nutrients; consists of mouth, esophagus, stomach, small intestine, large intestine, rectum, and anus
- **Motility:** movement of food through the GI tract
- **Digestion:** process by which large ingested molecules are mechanically and chemically broken down producing basic nutrients that can be absorbed across the wall of the GI tract
- **Absorption:** process by which substances are taken up from GI tract and enter bloodstream or lymph system

Table 4-2 Overview of GI Tract Digestion and Absorption Functions

Organs	Digestive Functions
Mouth and salivary glands	Prepare food for swallowing: chewing, moistening with saliva Detect taste molecules Start digestion of starch with amylase enzyme Start digestion of fat with lingual lipase
Esophagus	Moves food to stomach by peristaltic waves initiated by swallowing
Stomach	Secretes gastric juice containing acid, enzymes, and hormones Mixes food with gastric juice, converting it to liquid chyme Starts digestion of protein and fat Kills microorganisms with acid Secretes intrinsic factor, a protein required for vitamin B-12 absorption Slowly releases chyme to the small intestine
Liver	Produces bile to aid fat digestion and absorption
Gallbladder	Stores and concentrates bile and releases it to the small intestine
Pancreas	Secretes pancreatic juice containing digestive enzymes and bicarbonate into the small intestine
Small intestine	Mixes chyme with bile and pancreatic juice to complete digestion Secretes hormones that help regulate digestive processes Secretes digestive enzymes Absorbs nutrients and other compounds in foods

Sphincter	Function
1 Lower esophageal sphincter	Prevent backflow (reflux) of stomach contents into the esophagus
2 Pyloric sphincter	Control the flow of stomach contents into the small intestine
3 Hepatopancreatic sphincter	Control the flow of bile and pancreatic juice from the common bile and pancreatic ducts into the small intestine
4 Ileocecal valve	Prevent the contents of the large intestine from reentering the small intestine
5 Anal sphincters	Prevent defecation until person desires to do so

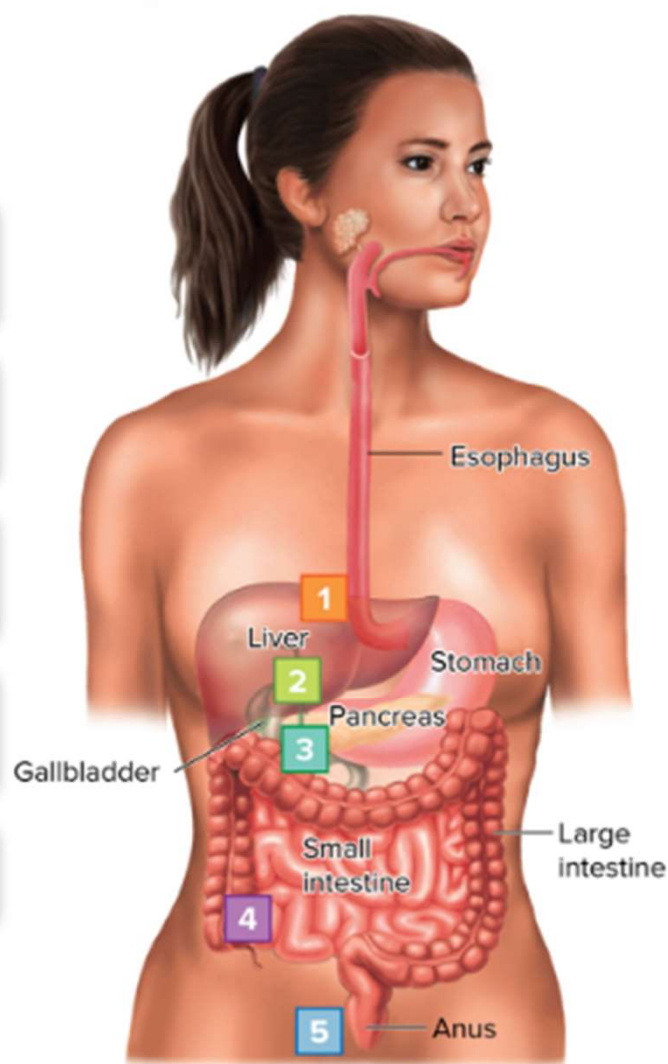


Figure 4-4 Sphincters of the GI tract. These circular muscles control the flow of contents through the GI tract. They open and close in response to stimuli from nerves, hormones, hormonelike compounds, and pressure that builds up around the sphincters.

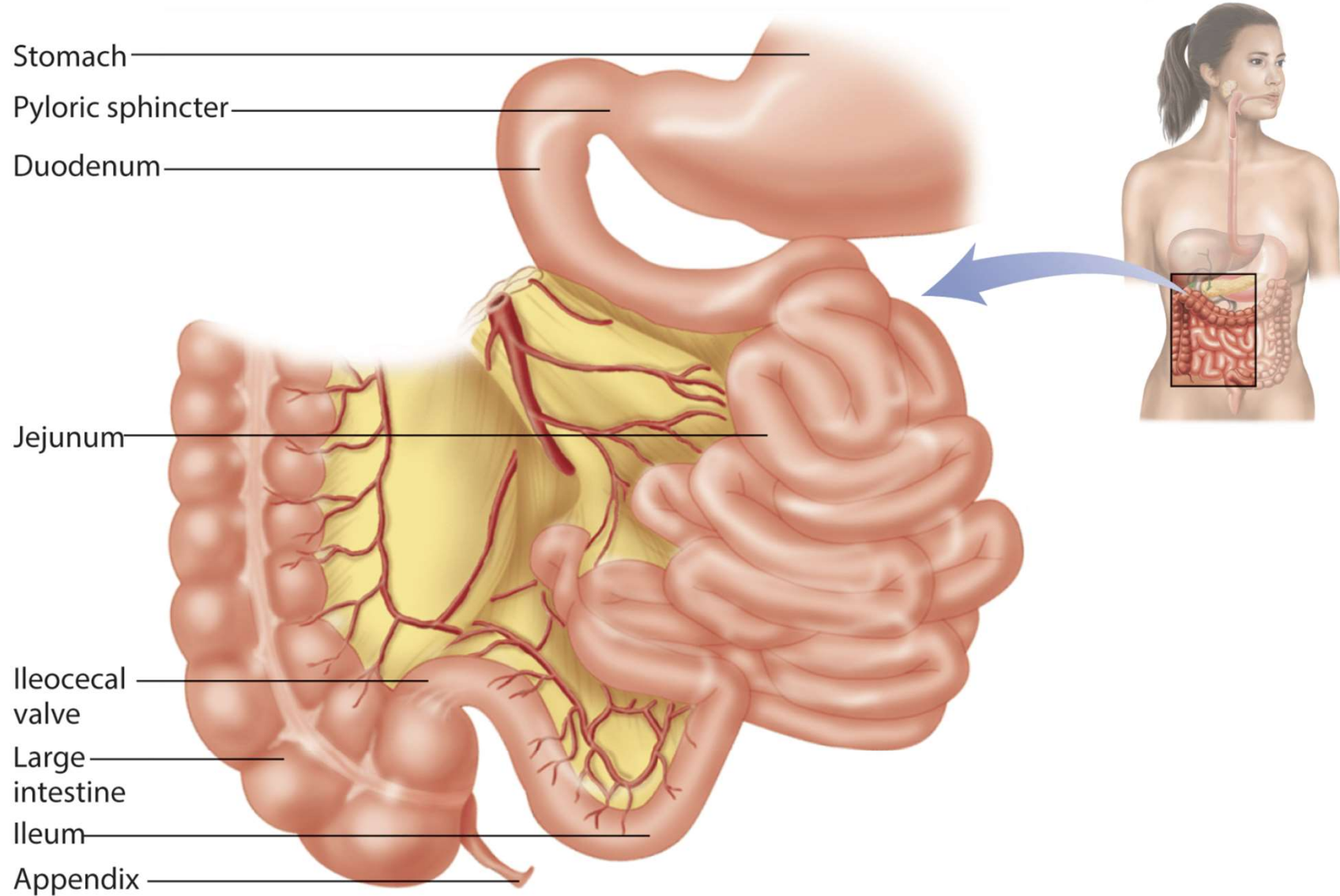


Figure 4-12 The small intestine and beginning of the large intestine. The 3 parts of the small intestine are the duodenum, jejunum, and ileum. Notice the smaller diameter of the small intestine, compared with the large intestine.

MIXING, SEGMENTATION & PERISTALSIS

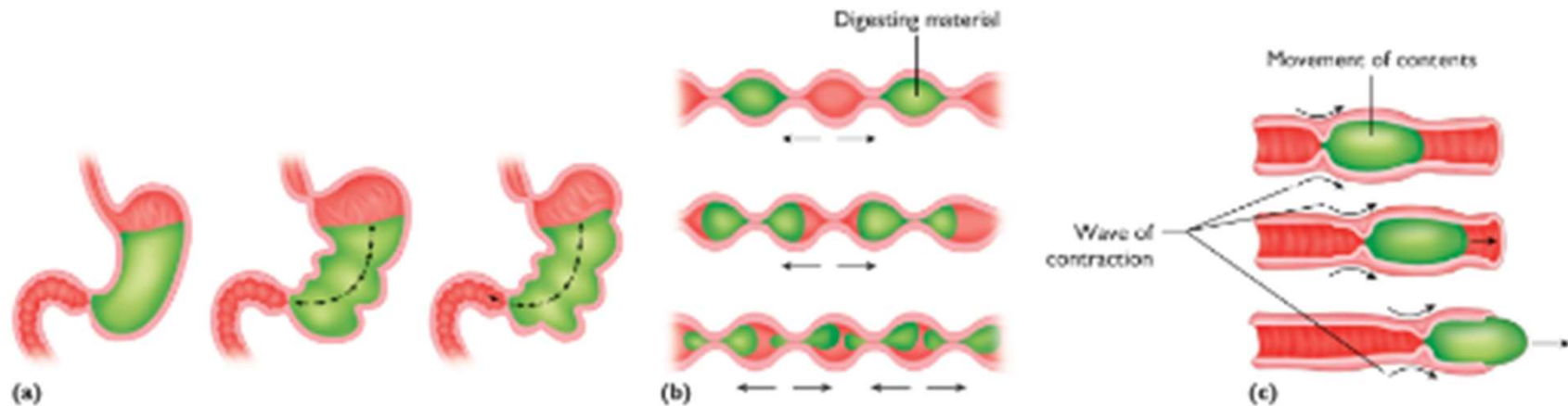



Figure 4-5 Mixing, segmentation, and peristalsis. (a) Strong contractions of the stomach muscles mix food and digestive juices. (b) Segmentation, a back-and-forth action in the small intestine, breaks apart contents of the small intestine into increasingly smaller pieces and mixes them with digestive juices. (c) Peristalsis, rhythmic waves of contraction and relaxation, moves the contents through the intestinal tract toward the anus.

Table 4-4 Major Regulatory Hormones of the GI Tract*

Hormone	Released By	Functions
Ghrelin	Stomach	Increases appetite and food intake
Gastrin	Stomach and duodenum in response to food reaching the stomach	Triggers the stomach to release HCl and pepsinogen; stimulates gastric and intestinal motility
Cholecystokinin (CCK)	Small intestine in response to dietary fat in chyme	Stimulates release of pancreatic enzymes and bile from the gallbladder
Secretin	Small intestine in response to acidic chyme Small intestine as digestion progresses	Stimulates release of pancreatic bicarbonate
Motilin	Small intestine in response to gastric distension and dietary fat	Regulates motility of the gastrointestinal tract
Glucose-dependent insulinitropic peptide (GIP)	Small intestine in response to glucose, amino acids, and fat	Inhibits gastric acid secretion, stimulates insulin release
Peptide YY	Ileum and large intestine in response to fat in the large intestine	Inhibits gastric and pancreatic secretions
Somatostatin	Stomach, small intestine, and pancreas	Inhibits release of GI hormones; slows gastric emptying, GI motility, and blood flow to the intestine

Many other hormones, synthesized throughout the GI tract and in the brain and pancreas, contribute to the regulation of digestion and absorption. Some of these hormones are listed in  **Table 4-4**.

Digestive Tract Secretions

Table 4-3 Important Secretions of the Digestive System

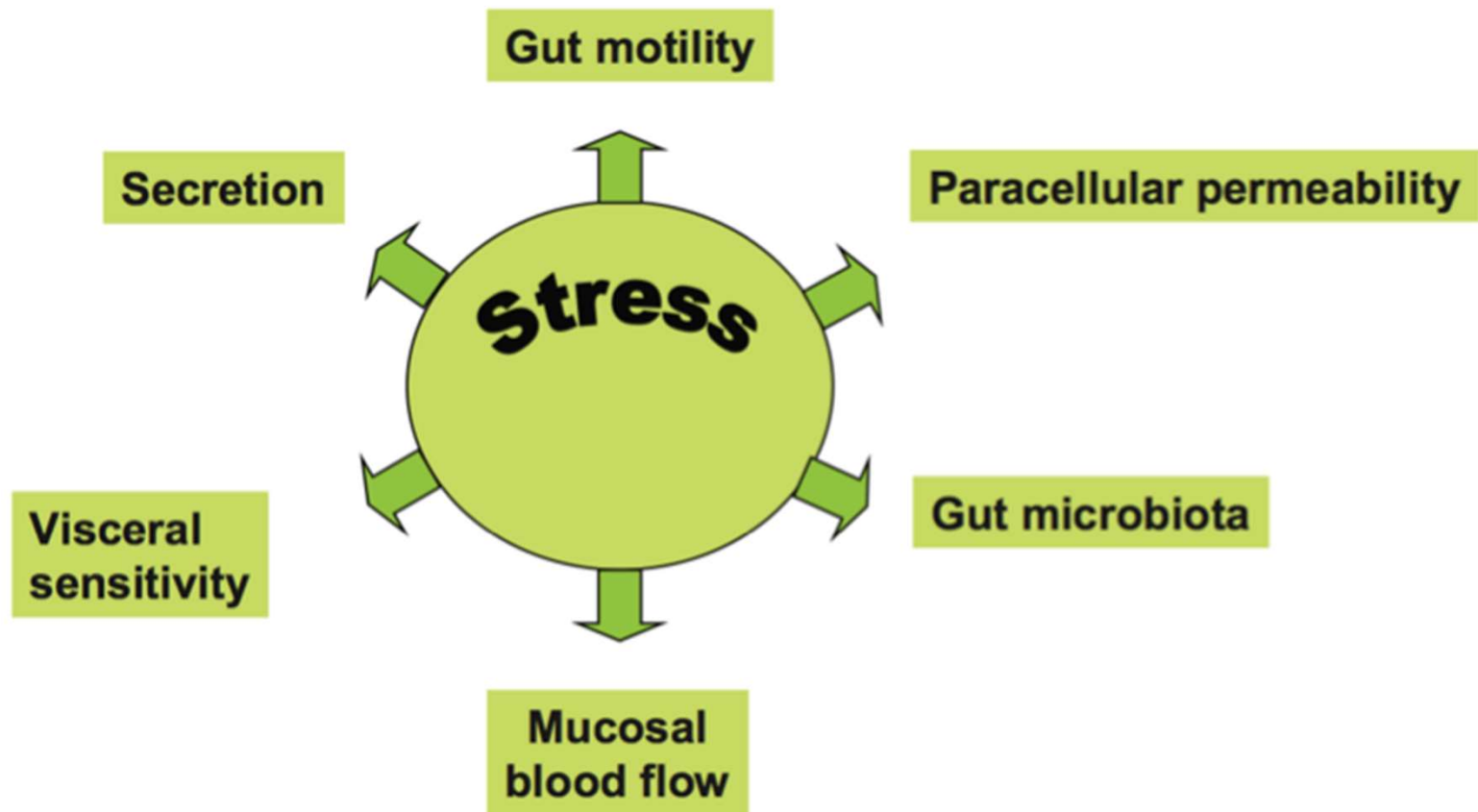
Secretion	Sites of Production	Functions
Saliva	Mouth	Dissolves taste-forming compounds; contains many compounds that aid swallowing, digestion, and protection of teeth
Mucus	Mouth, stomach, small and large intestines	Protects GI tract cells, lubricates digesting food
Enzymes (amylases, lipases, proteases)	Mouth, stomach, small intestine, pancreas	Break down carbohydrates, fats, and protein into forms small enough for absorption
Acid (HCl)	Stomach	Promotes digestion of protein, destroys microorganisms, increases solubility of minerals
Bile	Liver (stored in gallbladder)	Aids in fat digestion (emulsifies fat)
Bicarbonate	Pancreas, small intestine	Neutralizes stomach acid when it reaches small intestine
Hormones	Stomach, small intestine, pancreas	Regulate food intake, digestion, and absorption

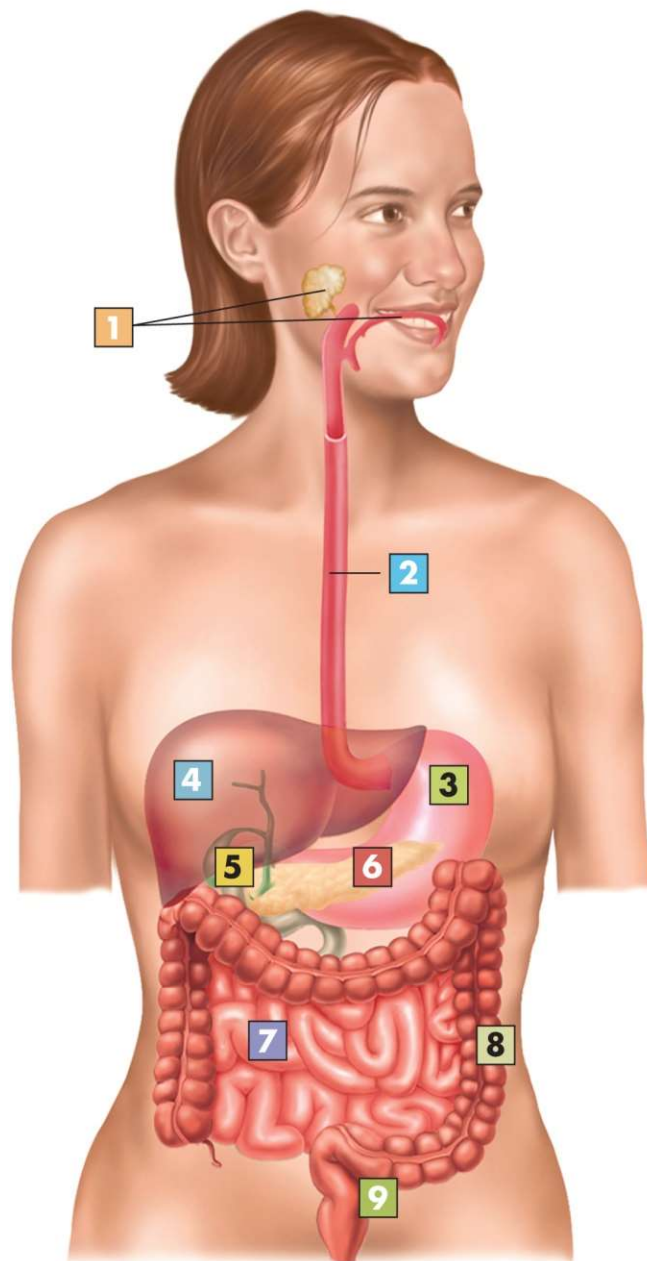
- The naming system for many enzymes is quite simple. The first part of the enzyme name usually indicates the target, followed by the suffix *-ase*. For instance, sucrase is the enzyme that digests the sugar sucrose; similarly, lactase digests lactose.

Digestive System

	Parasympathetic <i>Body at rest</i>	Sympathetic <i>Emergency situations</i>
Eyes	Constricts pupils	Dilates pupils
Heart	Beat more slowly	Beats faster and stronger
Lungs	Constricts airways	Relaxes airways, which lets you breathe more deeply
Digestion	Stimulates digestion	Inhibits digestion
Muscles	Reduces blood flow to skeletal muscles	Increases blood flow to skeletal muscles

- The autonomic (**parasympathetic**) nervous system is a control system that acts largely unconsciously and regulates heart rate, digestion, respiratory rate, pupillary response, urination etc.
- Stress initiates **sympathetic** nervous system



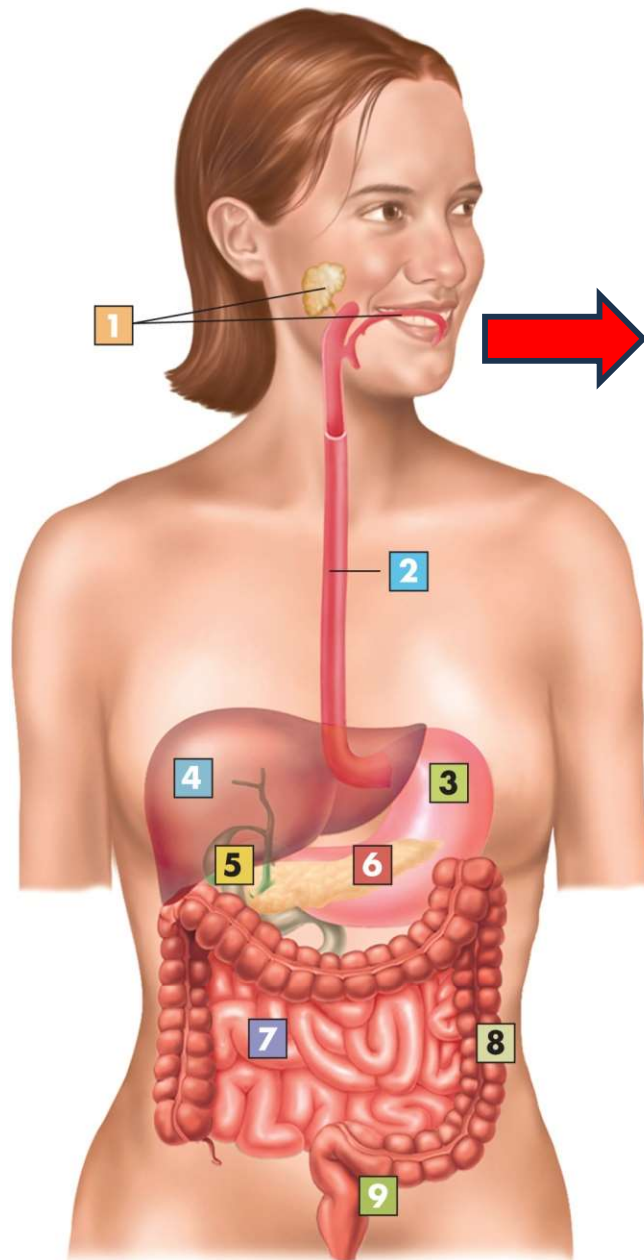


Organ	Digestive Functions
1 Mouth and salivary glands	Chew food Perceive taste Moisten food with saliva Lubricate food with mucus Release small amount of starch-digesting (amylase) and fat-digesting (lipase) enzymes Initiate swallowing reflex
2 Esophagus	Lubricate with mucus Move food to stomach by peristaltic waves (swallowing)
3 Stomach	Store, mix, dissolve, and continue digestion of food Dissolve food particles with secretions Kill microorganisms with acid Release protein-digesting (pepsin) and fat-digesting (lipase) enzymes Lubricate and protect stomach surface with mucus Regulate emptying of dissolved food into small intestine Produce intrinsic factor for vitamin B-12 absorption
4 Liver	Produce bile to aid fat digestion and absorption
5 Gallbladder	Store, concentrate, and later release bile into the small intestine
6 Pancreas	Secrete sodium bicarbonate and enzymes for digesting carbohydrate (amylase), fat (lipase), and protein (trypsin and chymotrypsin)
7 Small intestine	Mix and propel contents Lubricate with mucus Digest and absorb most substances using enzymes made by the pancreas (see above) and small intestinal cells (lactase, sucrase, maltase, peptidases)
8 Large intestine	Mix and propel contents Absorb sodium, potassium, and water House bacteria Lubricate with mucus Synthesize some vitamins and short-chain fatty acids Form feces
9 Rectum	Hold feces and expel via the anus, which is the opening to the outside of the body

Mouth

- Digestion begins here!
- Besides chewing food to reduce it to smaller particles, also senses taste of foods
- Tongue's taste buds identifies food flavor
 - Sweet, sour, salty, bitter, and umami (savory)
 - Sense of smell greatly contributes to taste
- Saliva
 - Digestive enzymes
 - Mucous

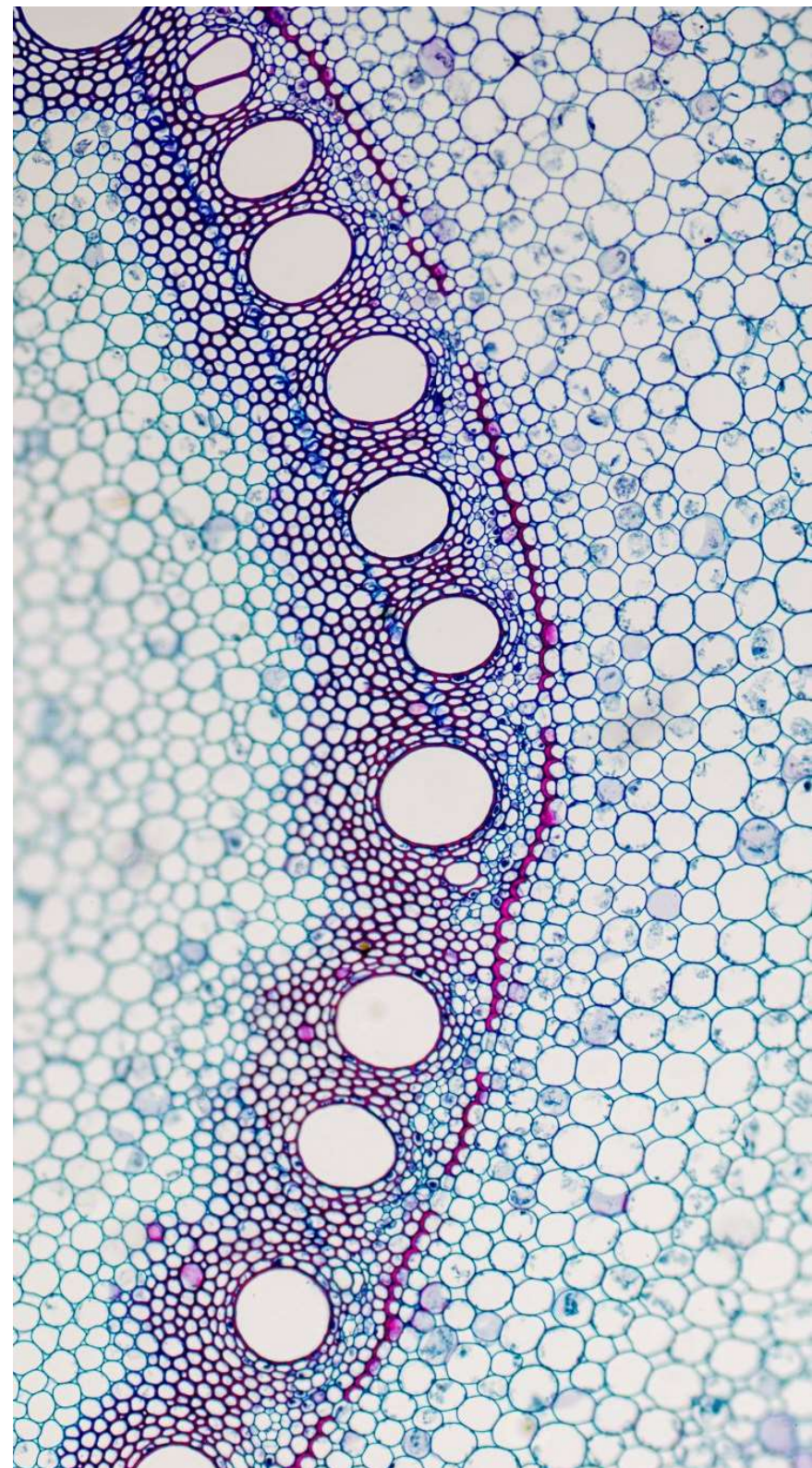


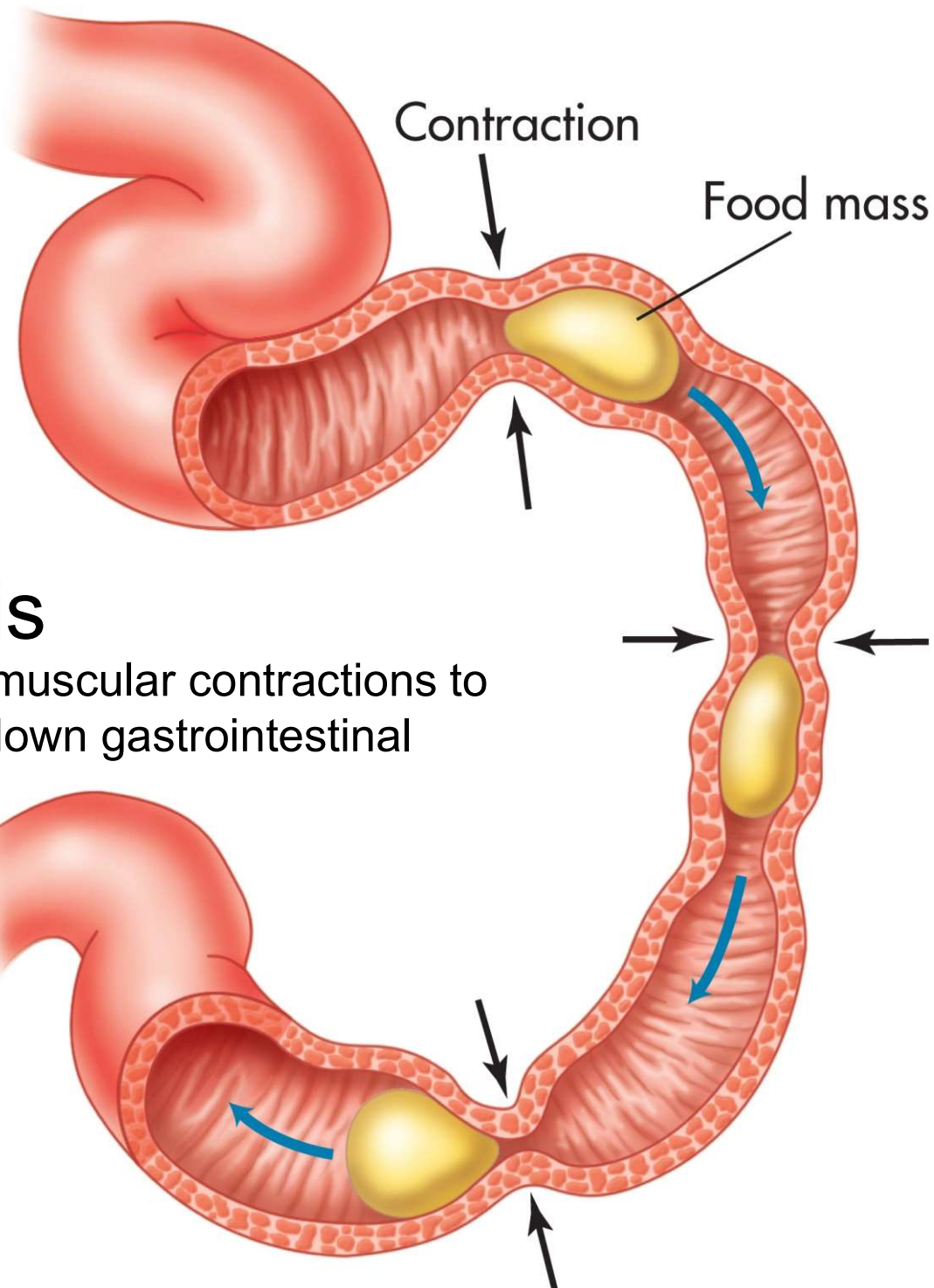


Organ	Digestive Functions
1 Mouth and salivary glands	<ul style="list-style-type: none"> Chew food Perceive taste Moisten food with saliva Lubricate food with mucus Release small amount of starch-digesting (amylase) and fat-digesting (lipase) enzymes Initiate swallowing reflex
2 Esophagus	<ul style="list-style-type: none"> Lubricate with mucus Move food to stomach by peristaltic waves (swallowing)
3 Stomach	<ul style="list-style-type: none"> Store, mix, dissolve, and continue digestion of food Dissolve food particles with secretions Kill microorganisms with acid Release protein-digesting (pepsin) and fat-digesting (lipase) enzymes Lubricate and protect stomach surface with mucus Regulate emptying of dissolved food into small intestine Produce intrinsic factor for vitamin B-12 absorption
4 Liver	<ul style="list-style-type: none"> Produce bile to aid fat digestion and absorption
5 Gallbladder	<ul style="list-style-type: none"> Store, concentrate, and later release bile into the small intestine
6 Pancreas	<ul style="list-style-type: none"> Secrete sodium bicarbonate and enzymes for digesting carbohydrate (amylase), fat (lipase), and protein (trypsin and chymotrypsin)
7 Small intestine	<ul style="list-style-type: none"> Mix and propel contents Lubricate with mucus Digest and absorb most substances using enzymes made by the pancreas (see above) and small intestinal cells (lactase, sucrase, maltase, peptidases)
8 Large intestine	<ul style="list-style-type: none"> Mix and propel contents Absorb sodium, potassium, and water House bacteria Lubricate with mucus Synthesize some vitamins and short-chain fatty acids Form feces
9 Rectum	<ul style="list-style-type: none"> Hold feces and expel via the anus, which is the opening to the outside of the body

Upper GI Tract Physiology

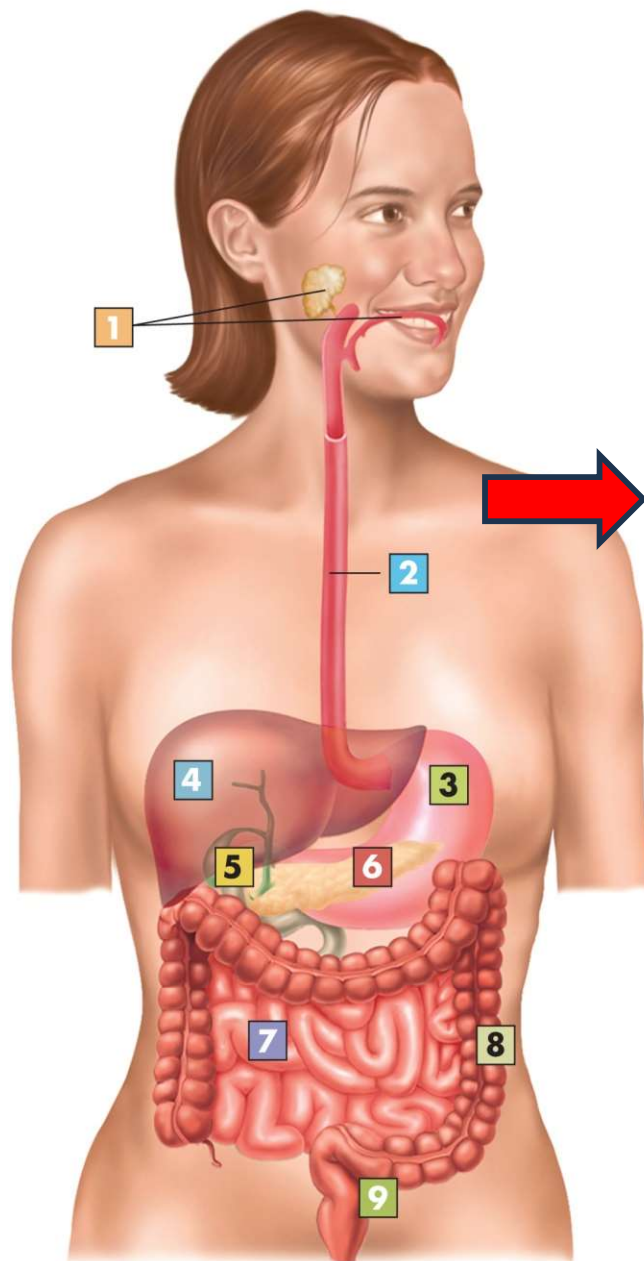
- **Lower esophageal sphincter**
 - Circular muscle constricts opening of esophagus to stomach
 - *What happens if this is not working?*
- **Chyme**
 - mixture of stomach secretions partially digested food
- **Pyloric sphincter**
 - ring of smooth muscle between stomach and small intestine





Peristalsis

coordinated muscular contractions to propel food down gastrointestinal tract



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4 Liver	<ul style="list-style-type: none"> Produce bile to aid fat digestion and absorption
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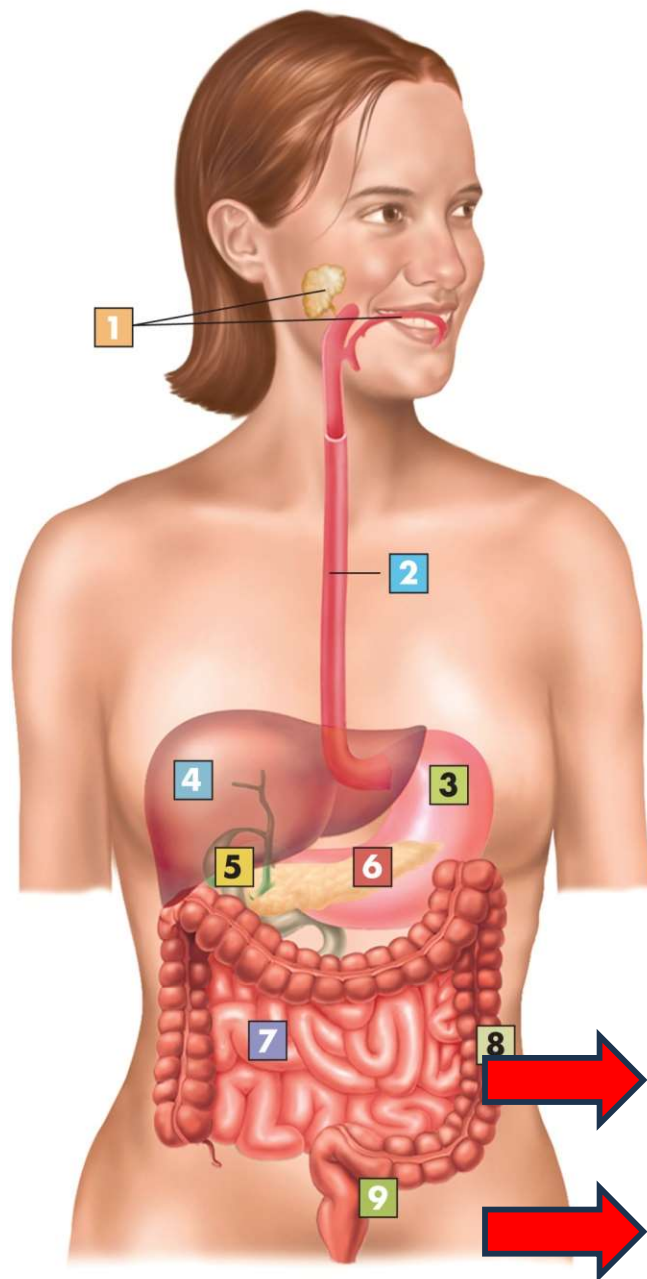
Stomach, Upper GI

- Hold up to 4 cups up to several hours
 - Size varies individually, can be altered by surgery
- Concentration of stomach acid (HCL) increases as food enters
- **Chyme** leaves stomach 1 teaspoon at a time
 - Enters small intestine through pyloric sphincter
- Minimal absorption of nutrients
- Intrinsic factor
 - Absorption of B12



Stomach Acid

- Hydrochloric Acid (HCL) is a very strong acid
- Thick layer of mucus protects stomach from acid
- What does HCL do?
 - Destroys activity of protein
 - Activates digestive enzymes – pepsin, gastric lipase
 - Partially digests dietary protein
 - Assists in calcium absorption
 - Makes dietary minerals soluble for absorption



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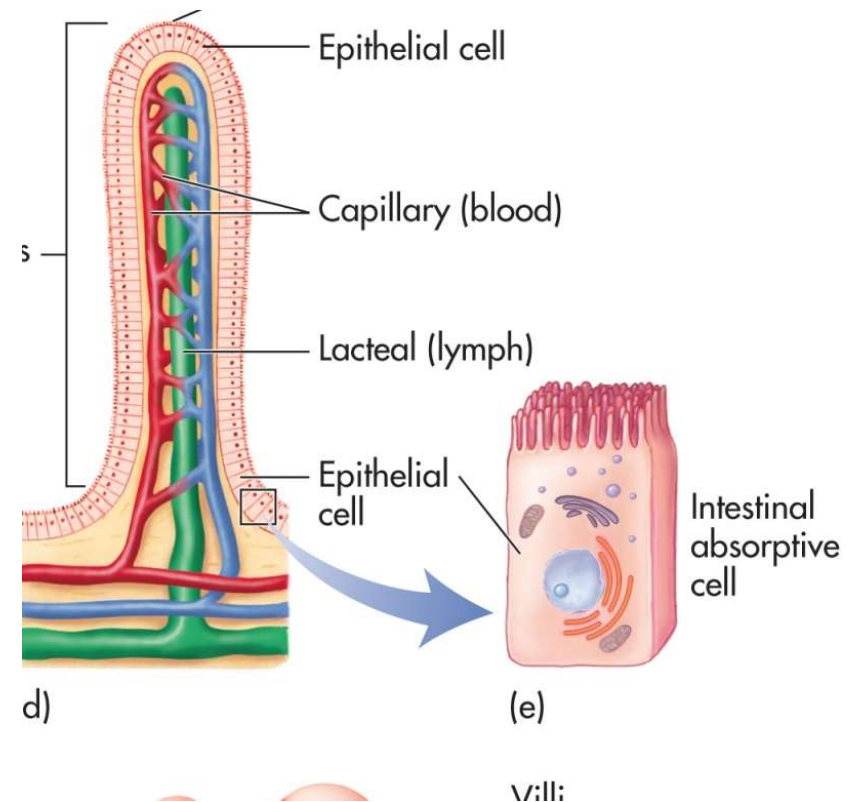
Accessory organs

Small Intestine

- **Duodenum**
 - First segment that receives chyme from stomach and digestive juices from **pancreas and gallbladder**
 - Primary site of digestion
 - 10 inches in length
- **Jejunum**
 - middle segment approximately 4 feet in length
- **Ileum**
 - last segment approximately 5 feet in length

Small Intestine

- **Villi**
 - fingerlike protrusions that participate in digestion and absorption of food
- **Absorptive cells**
 - intestinal cells that line villi and participate in nutrient absorption
- **Microvilli**
 - extensive folds on the mucosal surface of the absorptive cells
 - increase its surface area 600 times



Accessory Organs

- **Liver**
 - Releases number of unwanted substances that travel with bile to gallbladder
- **Gallbladder**
 - organ attached to underside of liver; bile storage, concentration, and secretion
 - *What happens when gallbladder removed?*
- **Bile**
 - released through common bile duct into the first segment of small intestine essential for digestion and absorption of fat

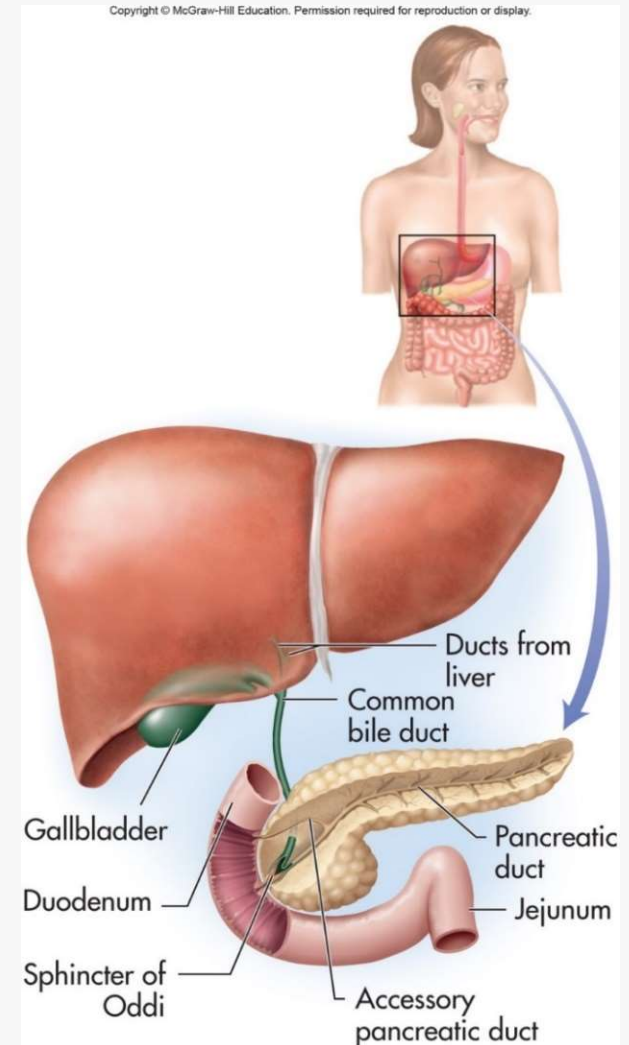


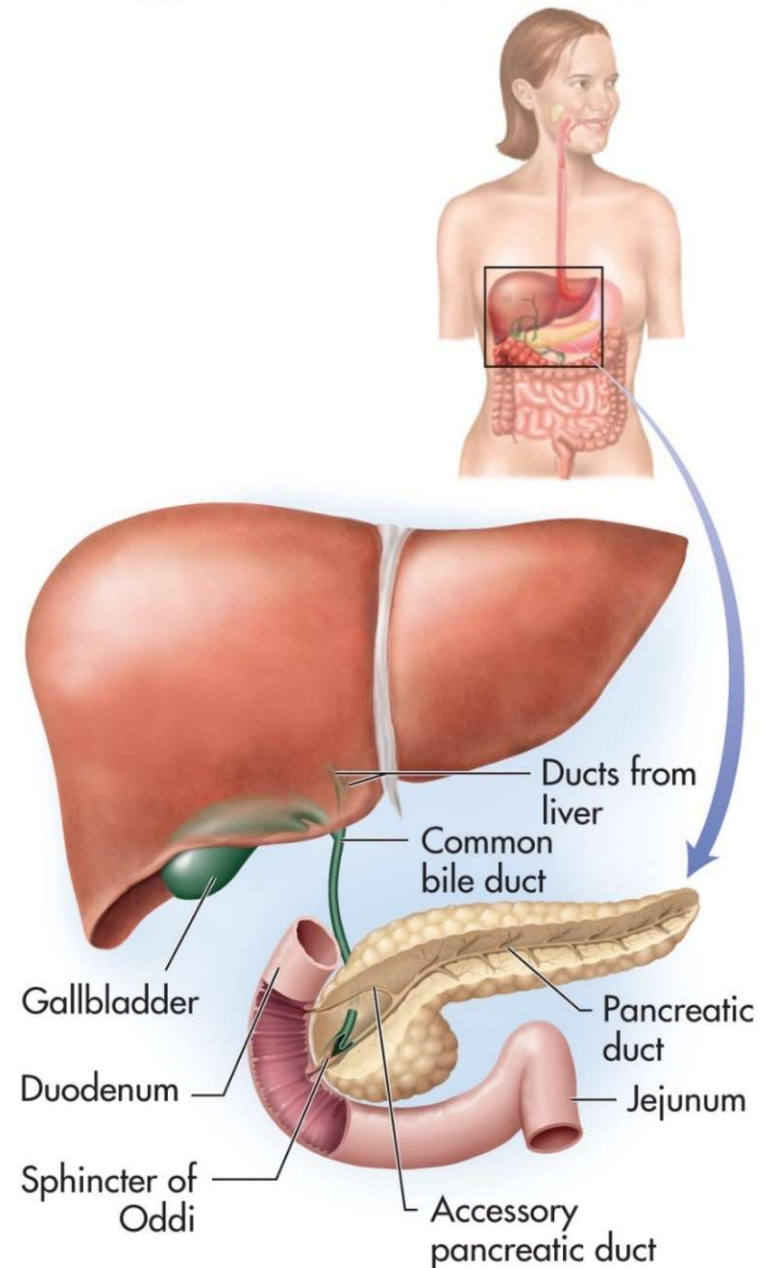
Table 4-4 Major Regulatory Hormones of the GI Tract*

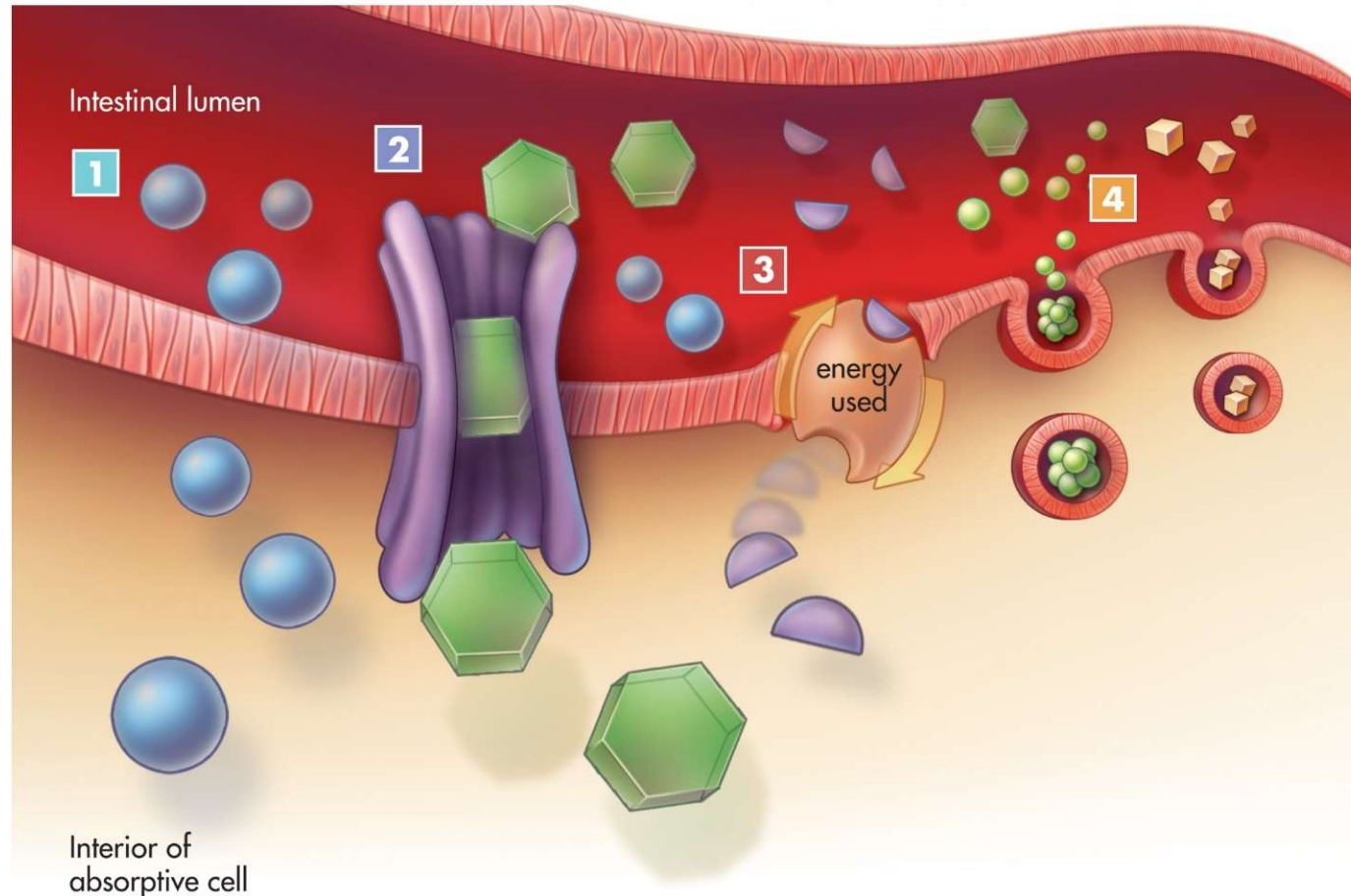
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Many other hormones, synthesized throughout the GI tract and in the brain and pancreas, contribute to the regulation of digestion and absorption. Some of these hormones are listed in [Table 4-4](#).

Pancreas

- Has both endocrine and digestive functions
- Manufactures hormones - insulin and glucagon
- Produces “pancreatic juice,” mixture of water, bicarbonate, and variety of digestive enzymes
- Amylase, lipase

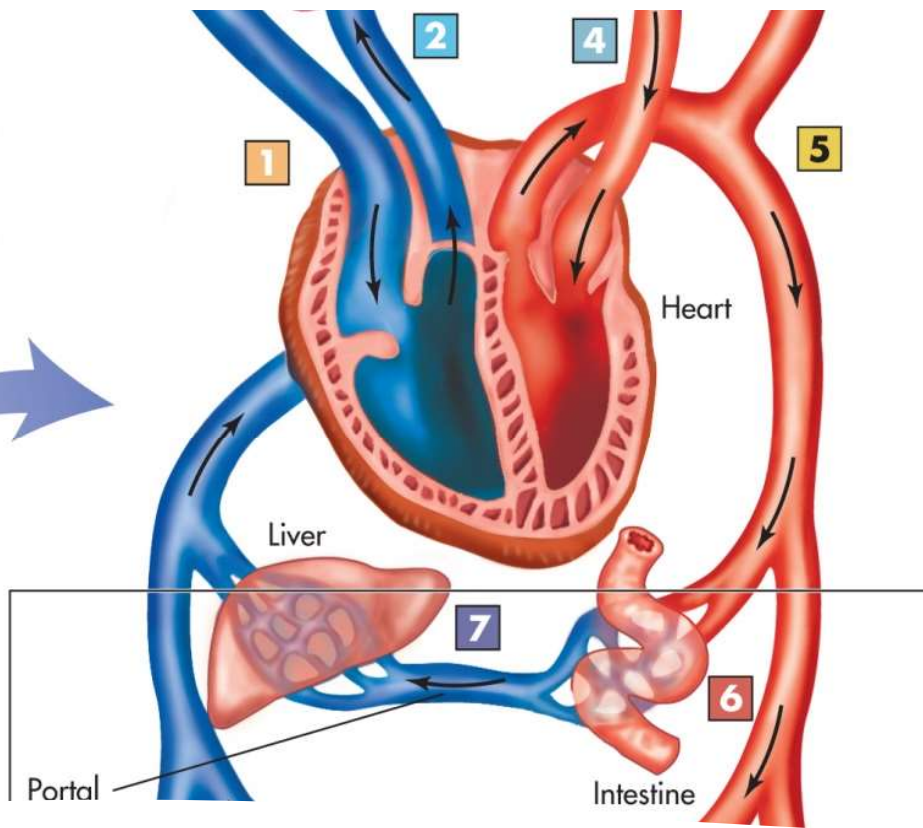
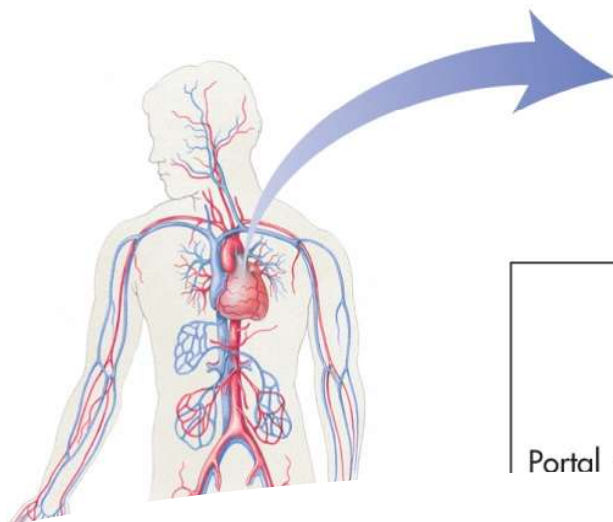




Small Intestine Nutrient Absorption

- 1. Passive diffusion:** diffusion of nutrients across the absorptive cell membranes
- 2. Facilitated diffusion:** uses a carrier protein to move nutrients **down** a concentration gradient (<https://youtu.be/IX-kLh34KcQ>)
- 3. Active absorption:** involves a carrier protein as well as energy to move nutrients (against a concentration gradient) into absorptive cells
- 4. Phagocytosis and pinocytosis:** forms of active transport in which absorptive cell membrane forms an indentation that engulfs a nutrient to bring it into cell

3 Gas exchange takes place in the lungs. Blood picks up oxygen and releases carbon dioxide.



5 Oxygenated blood from the left side of the heart is destined for body cells.

6 Blood reaching the small intestine supplies oxygen and nutrients to intestinal cells; also picks up nutrients from digestion of food.

7 Nutrient-rich venous blood leaves the small intestine and travels via a portal vein to liver.

8 When blood reaches the kidney, waste products, excess nutrients, and water are removed.

Hepatic Portal Circulation

- Part of the cardiovascular system
- **Hepatic portal circulation**
 - Portion of circulatory system using large vein (**portal vein**) to carry nutrient-rich blood from capillaries in intestines and portions of the stomach to liver

Hepatic Portal Circulation

1 Right side of the heart accepts oxygen-depleted venous blood that has already circulated to body cells.

2 Blood is pumped out of right side of the heart to lungs.

3 Gas exchange takes place in the lungs. Blood picks up oxygen and releases carbon dioxide.

4 Left side of the heart receives oxygen-rich blood from the lungs.

5 Oxygenated blood from the left side of the heart is destined for body cells.

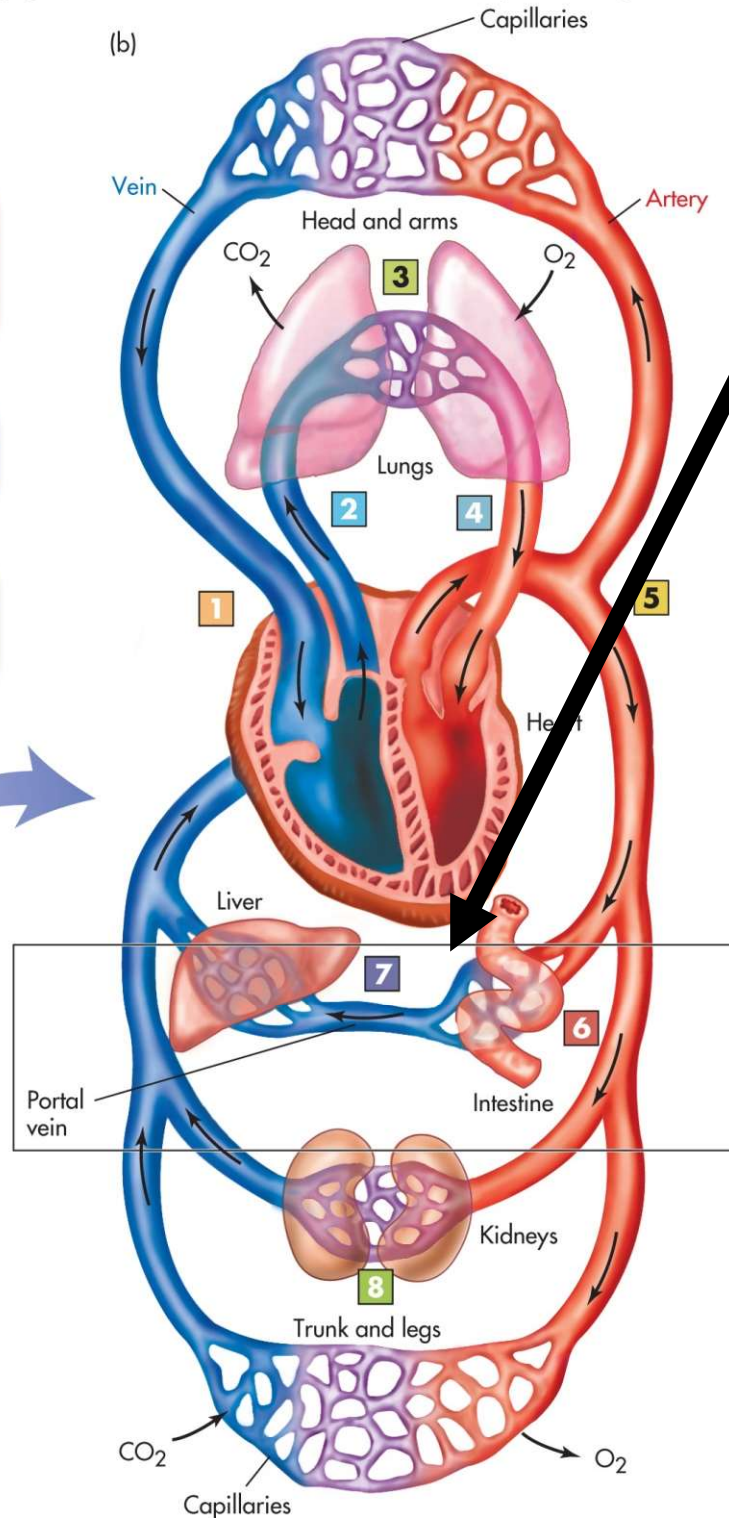
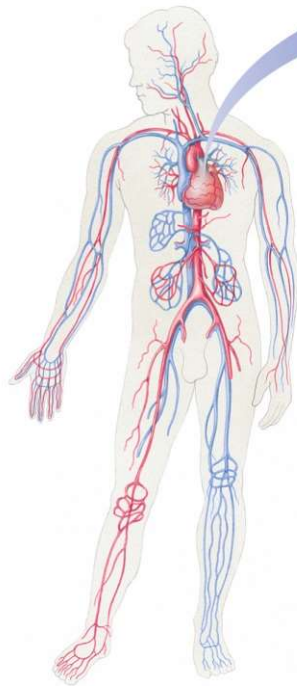
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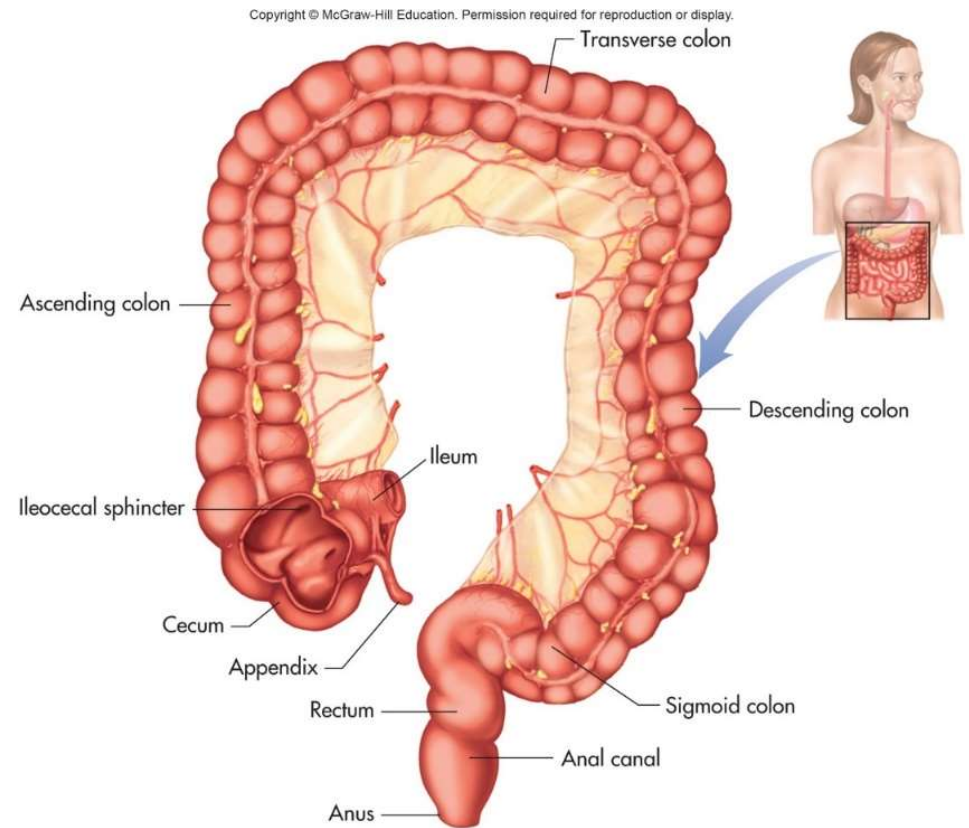
Portion of circulatory system using large vein (**portal vein**) to carry nutrient-rich blood from capillaries in intestines and portions of the stomach to liver

(a)



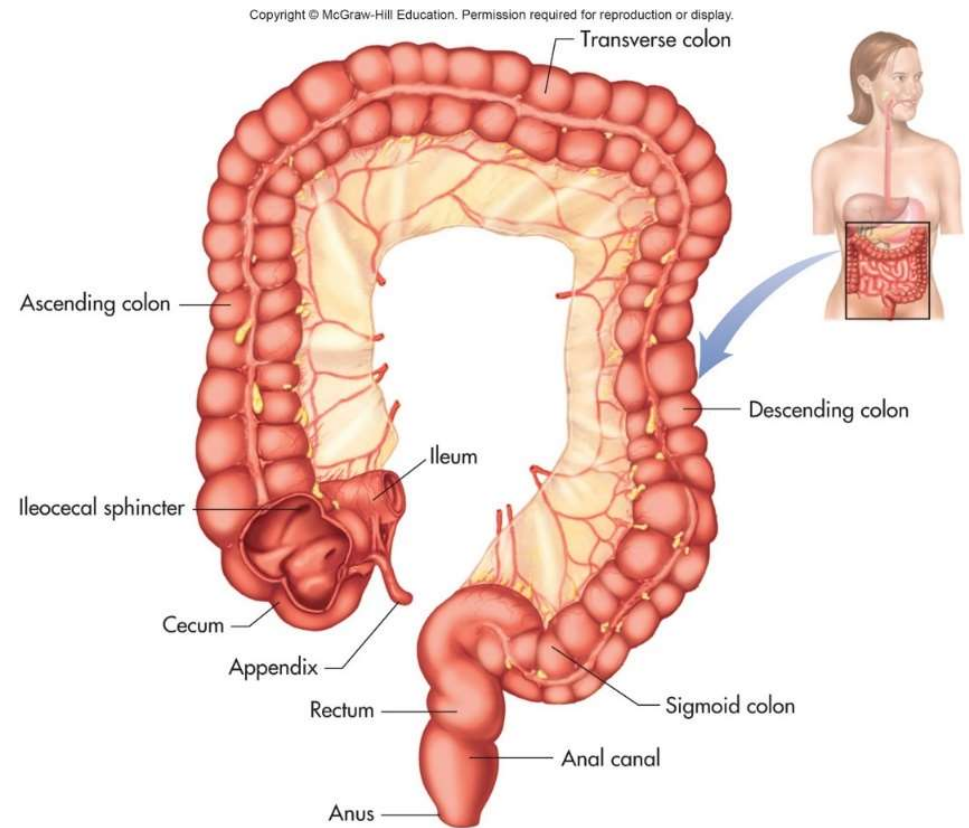
Large Intestine

- About 5% CHO, protein, fat escapes digestion from small intestine
- Large intestine; Absorption of water, some minerals, vitamins
- Houses gut microbiota that keep the GI tract healthy and absorbs water and electrolytes such as Na and K⁺ and forms and expels feces



Large Intestine

- **Feces**
 - some water and undigested fiber, tough connective tissues (from animal foods); bacteria, dead intestinal cells

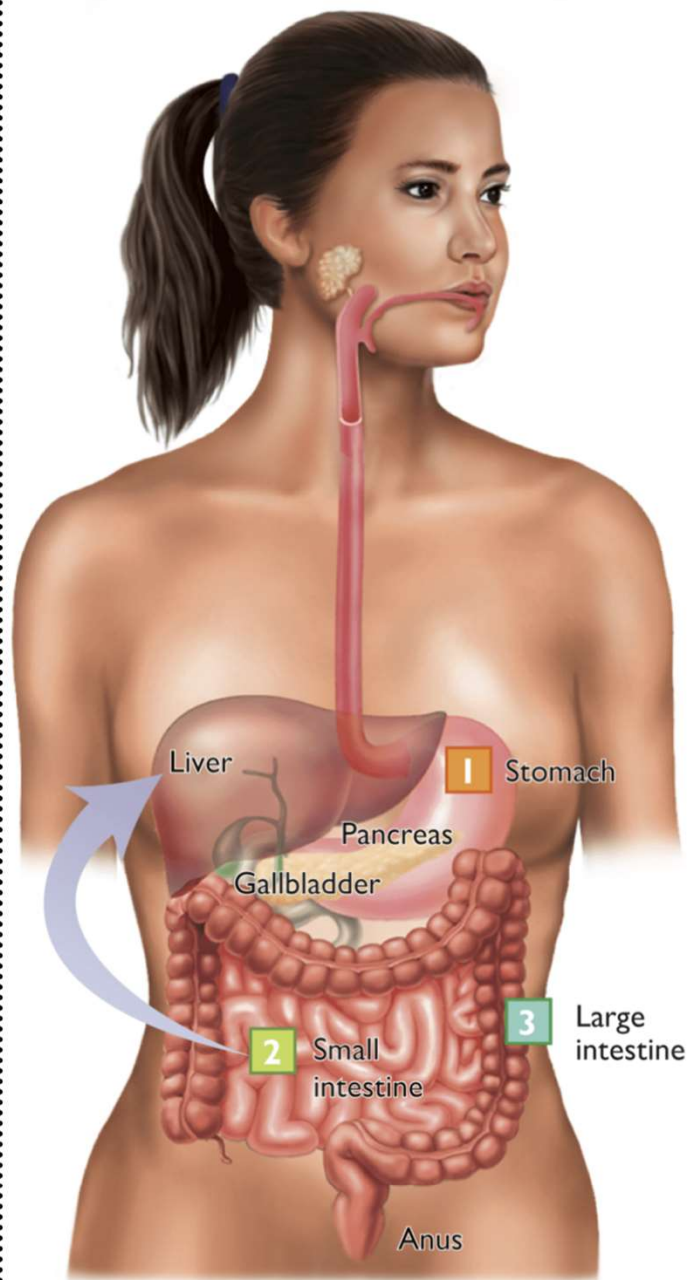


Gut Microbiota

- 100 trillion microbial cells (more than 10x number of cells in body)
- Contribute to health and immune function
 - Protect against infection by pathogens
 - Produce antimicrobial substances
 - Crowd out pathogens
 - Contribute to mucosal barrier health
 - Vitamin synthesis (vitamin K, biotin)
 - Modulates inflammation
- Dysbiosis
- Fecal transplants
- Many factors influence gut microbiota (Fig 4-20, pg 145)

Large Intestine – Keeping gut bacteria healthy

- **Probiotics**
 - Live microorganisms that provide health benefits
 - can be found in fermented foods (yogurt, miso) or as dietary supplement.
- **Prebiotics**
 - Non-digestible food ingredients that promote growth of beneficial bacterial in large intestine
 - Feed probiotics
 - Inulin, resistant starch
 - SCFA



Organ	Primary Nutrients Absorbed
1 Stomach	Alcohol (20% of total) Water (minor amount)
2 Small intestine	Calcium, magnesium, iron, and other minerals Glucose Amino acids Fats Vitamins Water (70 to 90% of total) Alcohol (80% of total) Bile acids
3 Large intestine	Sodium Potassium Some fatty acids Vitamin K and biotin (synthesized by microorganisms in the large intestine) Gases Water (10 to 30% of total)

Figure 4-16 Major sites of absorption along the GI tract. Note that some synthesis and absorption of vitamin K and biotin take place in the large intestine.

Nutrient Storage Capabilities



- Human body must maintain reserves of nutrients, storage capacity varies
 - Fat is stored in adipose tissue
 - Glucose: short-term storage in muscle and liver
 - Blood maintains small reserve of **glucose** and **amino acids**
 - Vitamin and minerals, storage varies
- Balanced diet safest means to acquiring nutrients needed for optimal health
 - Food first, supplements only when necessary
 - Nutrient density is imperative

Nutrition and Genetics

- Genetic variation can directly affect proteins encoded by our genes result in different:
 - nutrient requirements among individuals
 - effects of environmental factors (such as our diet) on our genes and proteins they make



The Emerging Field of Nutritional Genomics

- **Nutrigenetics**
 - effects of genes on nutritional health, such as variations in nutrient requirements and responsiveness to dietary modifications
 - MTHFR mutation
- **Nutrigenomics**
 - food impacts health through its interaction with our genes and its subsequent effect on gene expression.
 - Ex. Food turning on and off genes that code for proteins linked to prostate cancer
 - nutrients in foods are dietary signals that are detected by the cellular sensor systems that can regulate gene and protein expressions