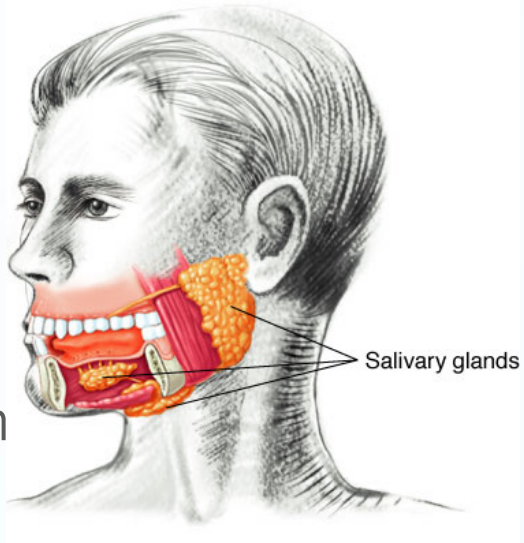
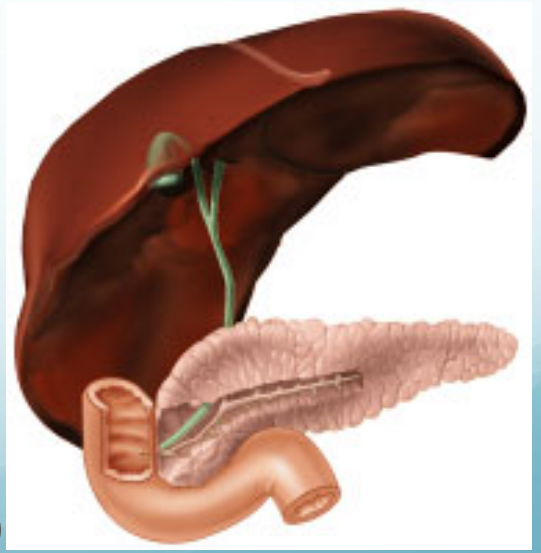
Assisting/Accessory Organs

1. **Salivary glands**
   - Moisten food
   - Supply enzymes



2. **Liver**
   - Produce bile (fat emulsifier)
   - "Detox center:" filters toxins in blood → kidn
   - "Chemical factory": >500 chemicals
     - Produce blood proteins, cholesterol, sugar
   - "Dynamic Warehouse": stores hormones, cholesterol, minerals, sugar, etc.

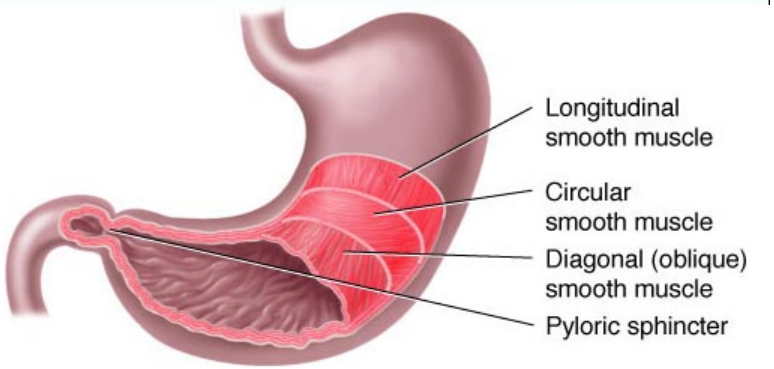
3. **Gallbladder**
   - Stores and excretes bile
   - **Bile's Enterohepatic circulation**:
     - Liver → Gallbladder → Intestine → Liver



4. **Pancreas**
   - Secretes bicarbonate, digestive enzymes
   - Secretes hormones (insulin and glucagon)

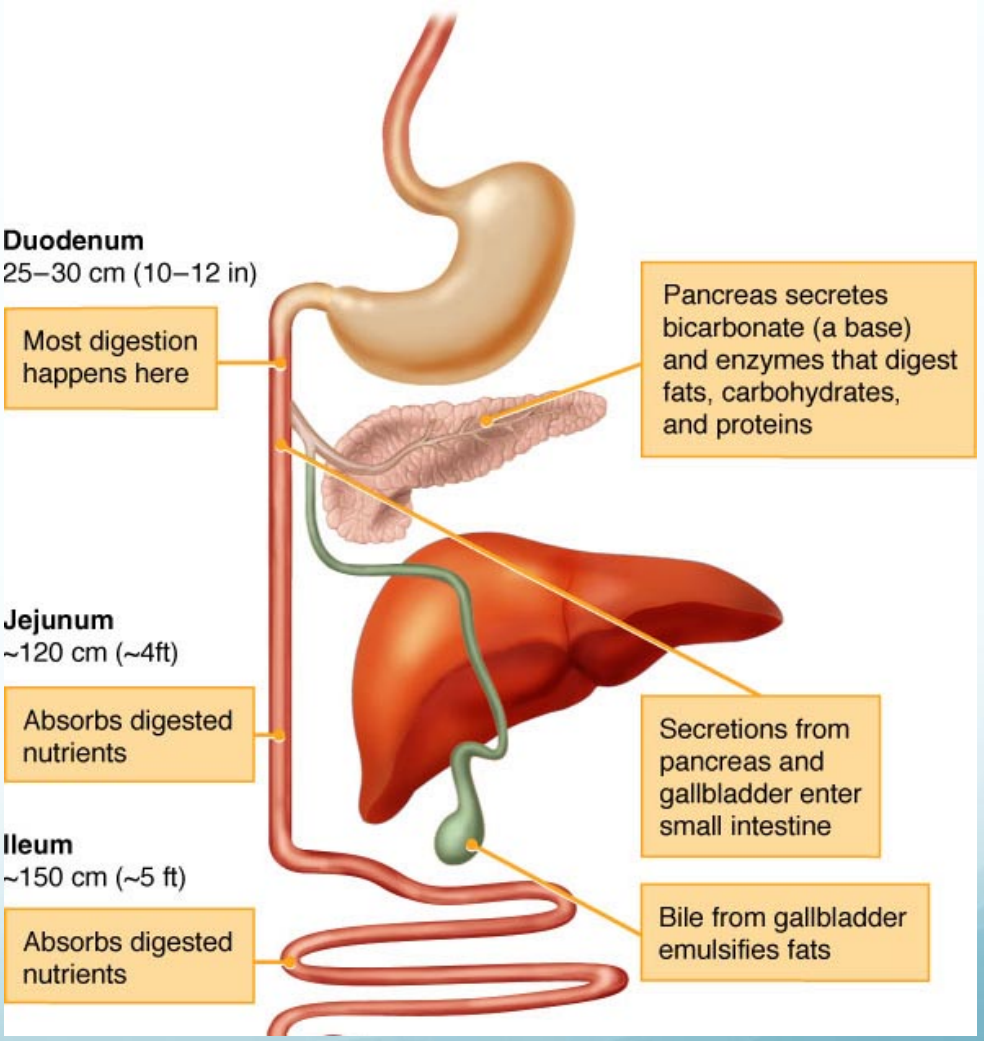
- Mouth
  - Enzymes
    - **Salivary amylase**
    - **Lingual lipase**
  - Saliva
    - Moistens food for swallowing → **bolus**
- Esophagus
  - Transports food to stomach
  - Esophageal sphincter (“cardiac sphincter”)
    - “Heartburn”

- Stomach Enzymes:
  - **Hydrochloric acid/gastric acid**
    1. kills bacteria
    2. prepares protein for digestion
       1. breaks down 3D structure of protein
       2. **Pepsinogen** (inactive) → Pepsin (active)
  - **Pepsin**: breaks down protein into smaller pieces
  - **Gastric lipase**: some fat digestion
  - **Gastrin** (hormone) stimulates gastric secretion and movement
  - **Intrinsic factor** is needed for vitamin B12 absorption.



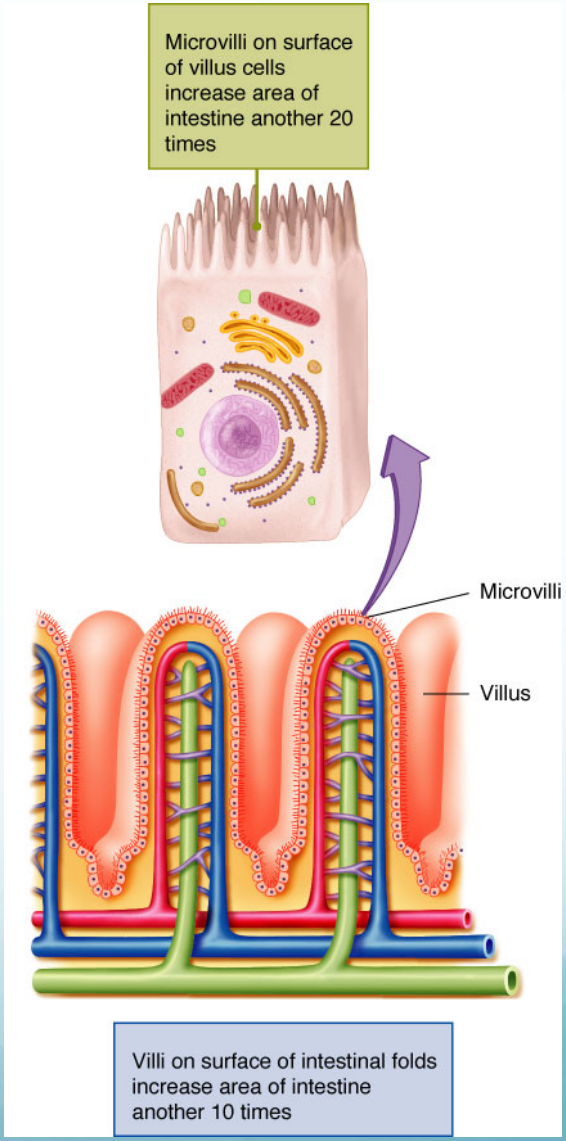
Putting It All Together: Digestion and Absorption

- Small intestine (~10ft)
  - **Pyloric Sphincter**
  - Sections of small intestine:
    - **Duodenum**
    - **Jejunum**
    - **Ileum**
  - Nutrient digestion
    - **Bicarbonate** neutralizes stomach acid
    - Pancreatic and intestinal enzymes to digest carbohydrates, lipids, and proteins.



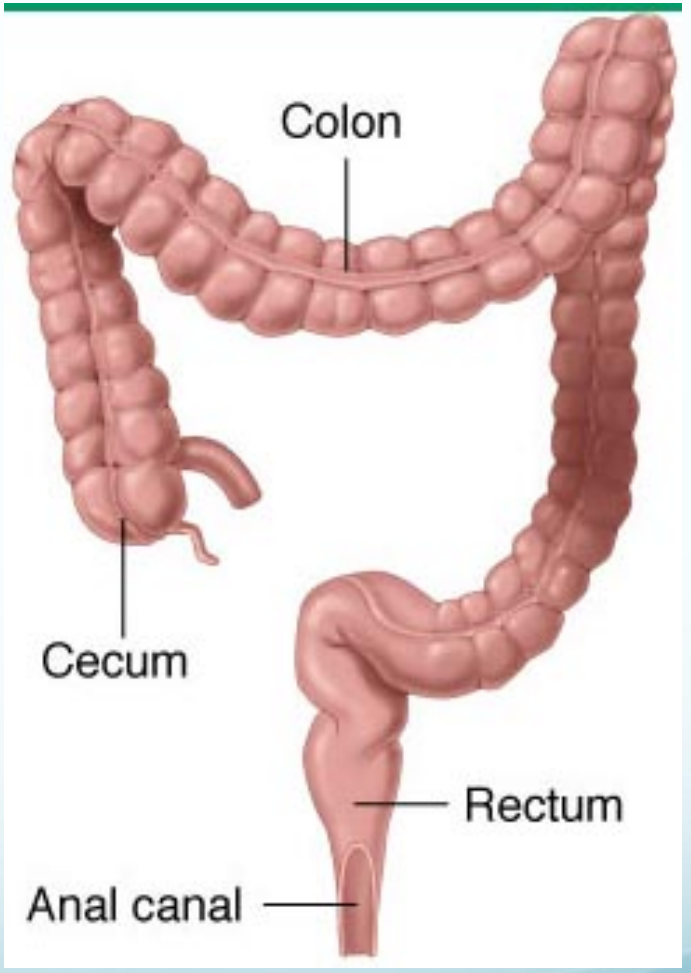
Putting It All Together: Digestion and Absorption

- Small intestine
  - Completes absorption:
    - **Folds, villi, microvilli** expand absorptive surface
      - 600x fold increase/tennis court!
    - Most nutrients absorbed here
    - Fat-soluble nutrients → lymphatic system **(lymphatic vessel in the intestinal villus)**
    - Water-soluble nutrients → **bloodstream**.



Putting It All Together: Digestion and Absorption

- Large Intestine
  - **Ileocecal valve**
  - Sections
    - Cecum, colon, rectum, and anal canal
  - Digestion
    - Peristaltic movement is slow, taking 18-24 hours for material to travel
    - Some bacterial activity (e.g. fiber digestion)

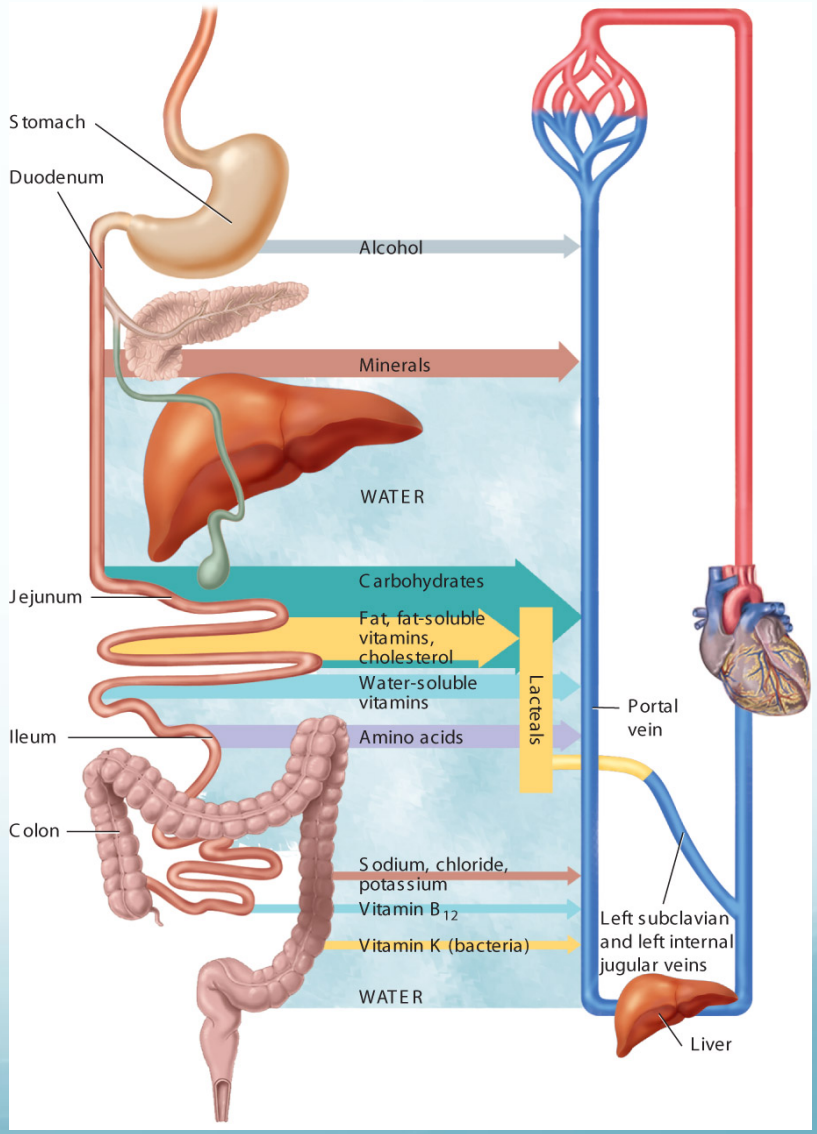


Beans, Beans, Beans!

- Beans are made up of oligosaccharides (e.g. *raffinose* and *stachyose*), a component of fiber.
- They are ignored until they are met by 700+ species of bacteria in your large intestine.
  - Bacteria digests these sugars → gases accumulate → **flatulence**

Putting It All Together: Digestion and Absorption

- Large Intestine:
  - Absorption
    - Water
    - Na, K, Cl
    - Vitamin K (produced by bacteria)
  - Elimination at anal sphincter
    - Feces: 60% solid (bacteria, dietary fiber, digestive secretions), 40% water



Circulation of Nutrients

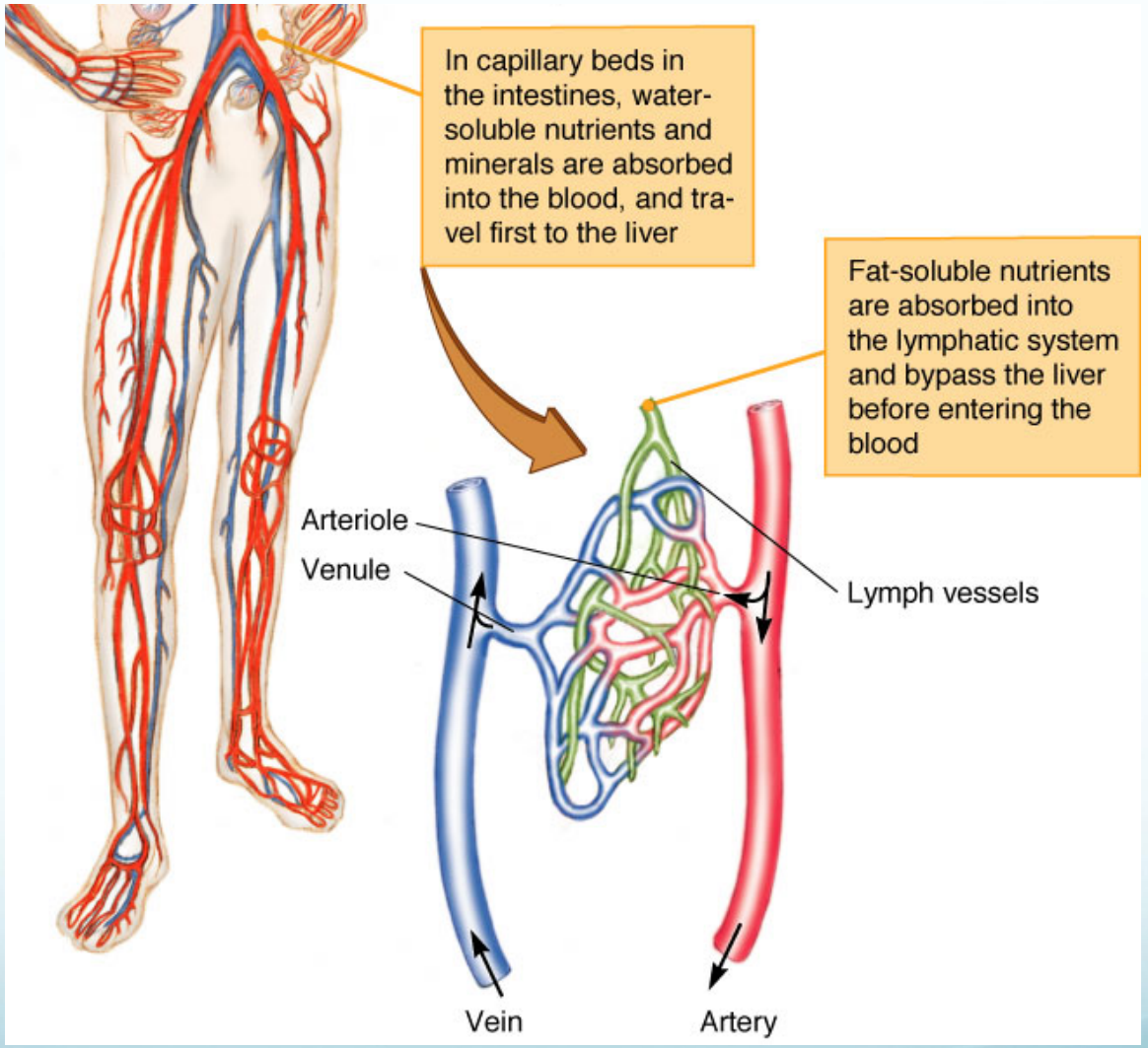
Vascular System

- Veins and arteries
- Water soluble nutrients are absorbed into the capillaries of the intestines.
- Blood carries nutrients through portal vein to the liver before dispensing them through the body.

Lymphatic system

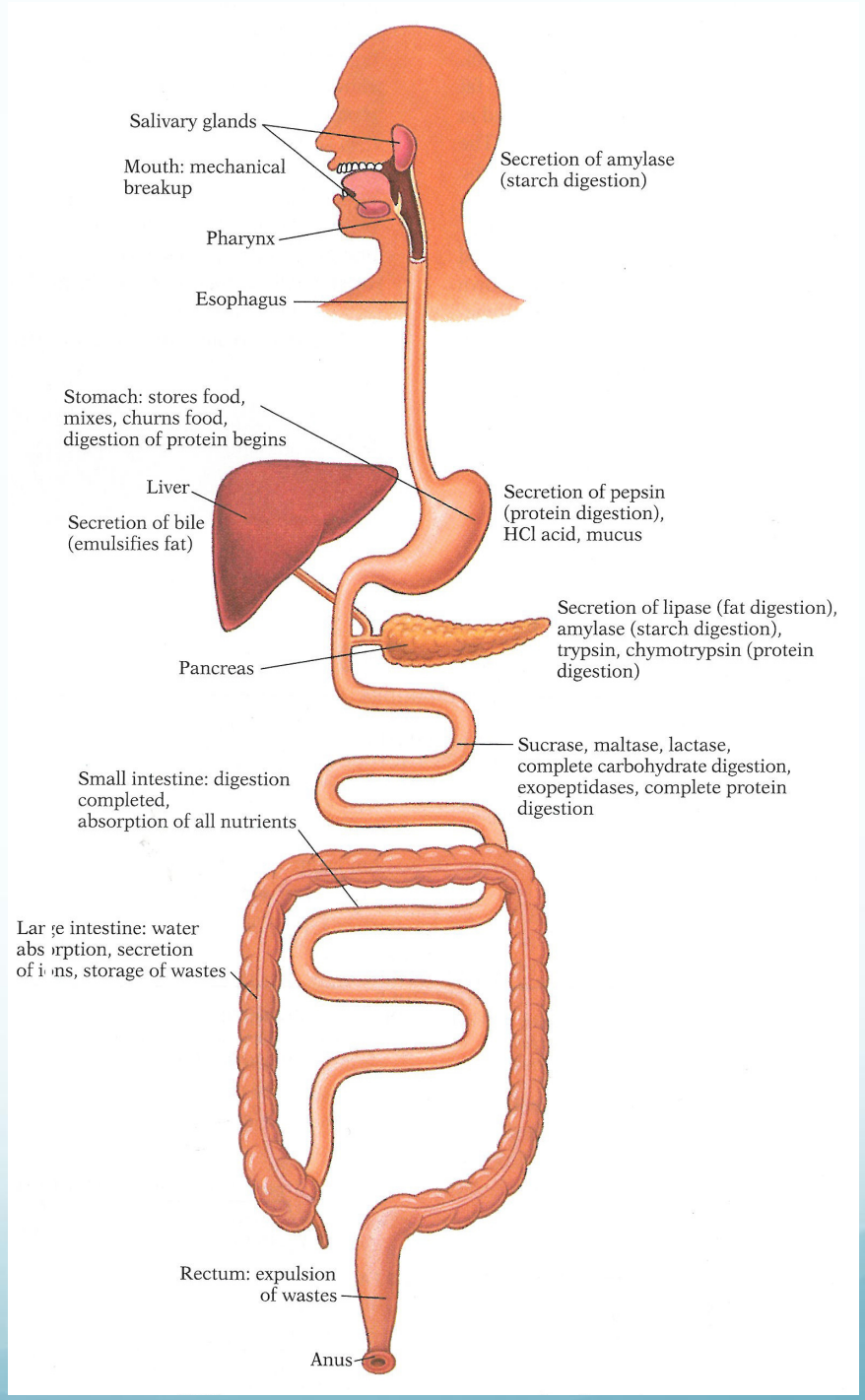
- Vessels that drain **lymph** (clear fluid formed in the spaces between cells)
- Fat soluble-vitamins are absorbed into lymph vessels in the intestine.
- Bypasses liver and delivers nutrients to veins in the neck → enter blood

Circulation of Nutrients



Circulation of Nutrients

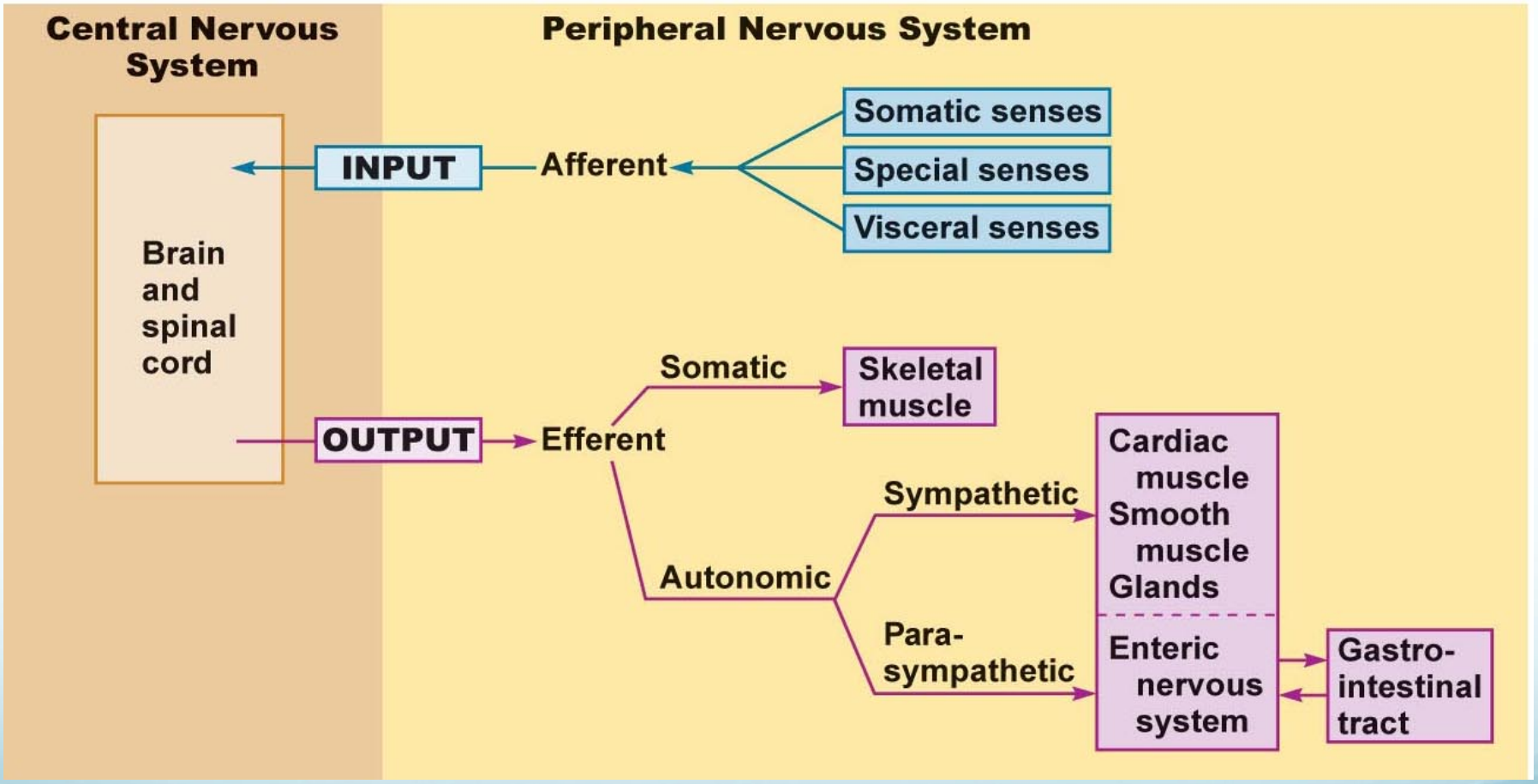
- Excretion and Elimination
  - Lungs
    - Excrete water and carbon dioxide (**metabolic wastes**)
  - Kidneys filter blood
    - Excrete **digestive wastes**
      - Urine: urea + salts + water
    - Maintain water and ion balance


Salivary glands
Mouth: mechanical breakup
Secretion of amylase (starch digestion)
Pharynx
Esophagus
Stomach: stores food, mixes, churns food, digestion of protein begins
Liver
Secretion of bile (emulsifies fat)
Secretion of pepsin (protein digestion), HCl acid, mucus
Secretion of lipase (fat digestion), amylase (starch digestion), trypsin, chymotrypsin (protein digestion)
Pancreas
Sucrase, maltase, lactase, complete carbohydrate digestion, exopeptidases, complete protein digestion
Small intestine: digestion completed, absorption of all nutrients
Large intestine: water absorption, secretion of ions, storage of wastes
Rectum: expulsion of wastes
Anus

Signaling Systems: Command, Control, Defense

- Nervous system
  - Nerves carry info back and forth between tissues and the brain using chemical signals known as **neurotransmitters**.
  - The **Central Nervous System (CNS)** regulates GI activity in 2 ways:
    1. **Enteric nervous system**: nerves located in the GI wall.
    2. **Autonomic nervous system**: part of CNS that controls organ function.
       - Responses to sight, smell, thought of food by enhancing GI movement and secretion

Signaling Systems: Command, Control, Defense

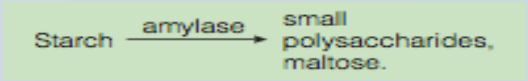
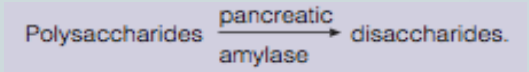
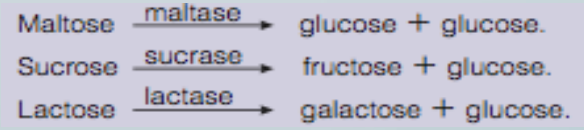
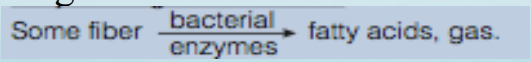


Signaling Systems: Command, Control, Defense

- Hormonal system
  - **Hormones**: chemical messengers that travel in the bloodstream
    1. Increases or decreases GI motility and secretions
    2. Influence your appetite by sending messages to your CNS.
- Thus, your CNS and hormones work together to coordinate movement and secretions of the GI tract.

Digestion and Absorption of Nutrients

Overview of Digestion & Absorption

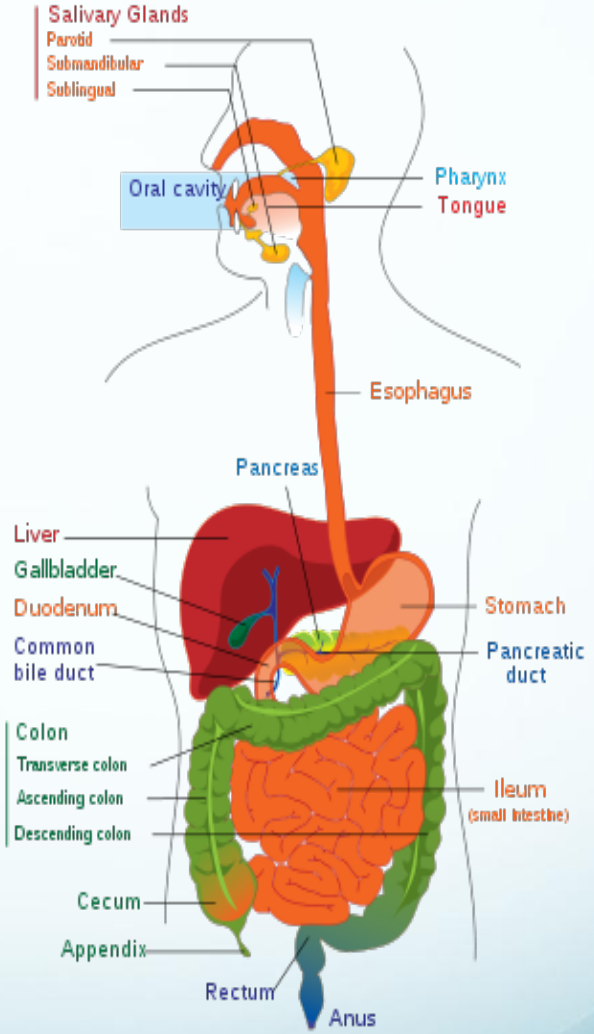
	Fiber	Carbohydrate
Mouth and salivary glands	The mechanical action of the mouth and teeth crushes and tears fiber in food and mixes it with saliva to moisten it for swallowing.	The salivary glands secrete saliva into the mouth to moisten the food. The salivary enzyme amylase begins digestion: 
Stomach	Fiber is unchanged.	Stomach acid inactivates salivary enzymes, halting starch digestion. To a small extent, stomach acid hydrolyzes maltose and sucrose
Small intestine	Fiber is unchanged.	The pancreas produces enzymes and releases them through the pancreatic duct duct into the small intestine:  Then enzymes on the surfaces of the small intestinal cells break disaccharides into monosaccharides, and the cells absorb them : 
Large intestine	Most fiber passes intact through the digestive tract to the large intestine. Here, bacterial enzymes digest some fiber:  Fiber holds water; regulates bowel activity; and binds cholesterol and some minerals, carrying them out of the body as it is excreted with feces	

Overview of Digestion & Absorption (Cont.)

	Fat	Protein
Mouth and salivary glands	The sublingual salivary gland in the base of the tongue secretes as salivary lipase. Some hard fats begin to melt as they reach body temperature.	Chewing and crushing moisten protein-rich foods and mix them with saliva to be swallowed.
Stomach	The acid-stable salivarylipase splits one bond of triglycerides to produce diglycerides and fatty acids. The stomach's churning action mixes fat with water and acid. A gastric lipase accesses and hydrolyzes a very small amount of fat.	Hydrochloric acid (HCL) uncoils protein strands and activates stomach enzymes: Protein $\xrightarrow[\text{HCl}]{\text{pepsin}}$ smaller polypeptides.
Small intestine	Bile flows in from the liver and gallbladder (via the common bile duct): Fat $\xrightarrow{\text{bile}}$ emulsified fat. Pancreatic lipase flows in from the pancreas (via the pancreatic duct): Emulsified fat $\xrightarrow{\text{pancreatic lipase}}$ monoglycerides, glycerol, fatty acids (absorbed).	Polypeptides $\xrightarrow[\text{and intestinal proteases}]{\text{pancreatic}}$ tripeptides, dipeptides, amino acids Then enzymes on the surface of the small intestinal cells hydrolyze these peptides and the cells absorb them. Peptides $\xrightarrow[\text{dipeptidases and tripeptidases}]{\text{intestinal}}$ amino acids (absorbed)
Large intestine	Some fat and cholesterol, trapped in fiber, exit in feces.	

Overview of Digestion & Absorption (Cont.)

	Vitamin	Water and Minerals
Mouth and salivary glands	No action.	The salivary glands add water to disperse and carry food.
Stomach	Intrinsic factor attaches to vitamin B12.	Stomach acid (HCl) acts on iron to reduce it, making it more absorbable. The stomach secretes enough watery fluid to turn a moist, chewed mass of solid food into liquid chyme.
Small intestine	Bile emulsifies fat-soluble vitamins and aids in their absorption with other fats. Water-soluble vitamins are absorbed.	The small intestine, pancreas, and liver add enough fluid so that approximately 2 gallons are secreted into the intestine in a day. Many minerals are absorbed. Vitamin D aids in the absorption of calcium.
Large intestine	Bacteria produce vitamin K,which is absorbed.	More minerals and most of the water are absorbed.



The Process of Digestion

- To digest food, five different body organs secrete digestive juices: the salivary glands, the stomach, the small intestine, the liver (via the gallbladder), and the pancreas.
- These secretions enter the GI tract at various points along the way, bringing an abundance of water and a variety of enzymes. Each of the juices has a turn to mix with the food and promote its breakdown to small units that can be absorbed into the body.

DIGESTION IN THE MOUTH

- Digestion of carbohydrate begins in the mouth, where the **salivary glands** secrete **saliva,** which contains water, salts, and enzymes (including salivary **amylase)** that break the bonds in the chains of starch.
- The enzymes in the mouth do not affect the fats, proteins, vitamins, minerals, and fiber that are present in the foods people eat.

The Process of Digestion (Cont.)

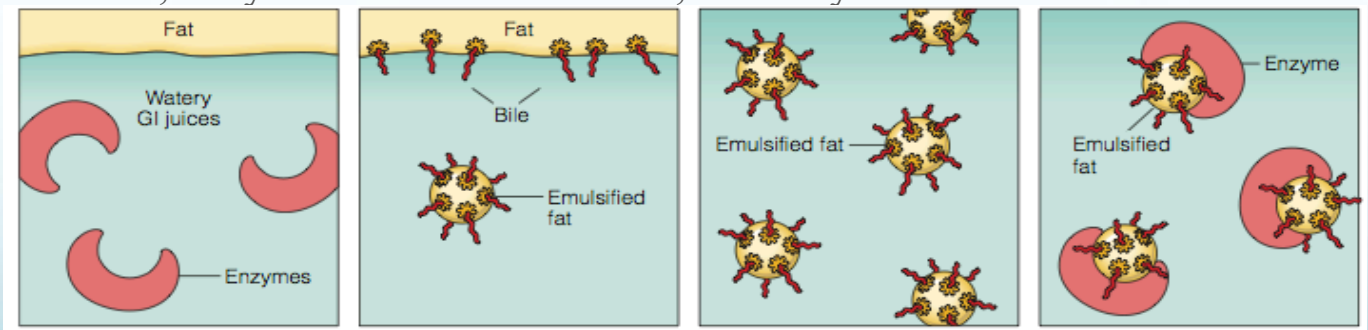
DIGESTION IN THE SMALL INTESTINE

- The pancreas and the liver contribute additional digestive juices through the duct leading into the duodenum, and the small intestine adds **intestinal juice.** These juices contain digestive enzymes, bicarbonate, and bile.

- The pancreatic juice also contains sodium **bicarbonate,** which neutralizes the acidic chyme as it enters the small intestine. From this point on, the contents of the digestive tract are neutral or slightly alkaline. The enzymes of both the intestine and the pancreas work best in this environment.

- **Bile** is secreted continuously by the **liver** and is concentrated and stored in the gallbladder.

- Bile is not an enzyme but an **emulsifier** that brings fats into suspension in water .After the fats are emulsified, enzymes can work on them, and they can be.



In the stomach, the fat and watery GI juices tend to separate. The enzymes are in the water and can't get at the fat.

When fat enters the small intestine, the gallbladder secretes bile. Bile has an affinity for both fat and water, so it can bring the fat into the water.

Bile's emulsifying action converts large fat globules into small droplets that repel each other.

After emulsification, the enzymes have easy access to the fat droplets.

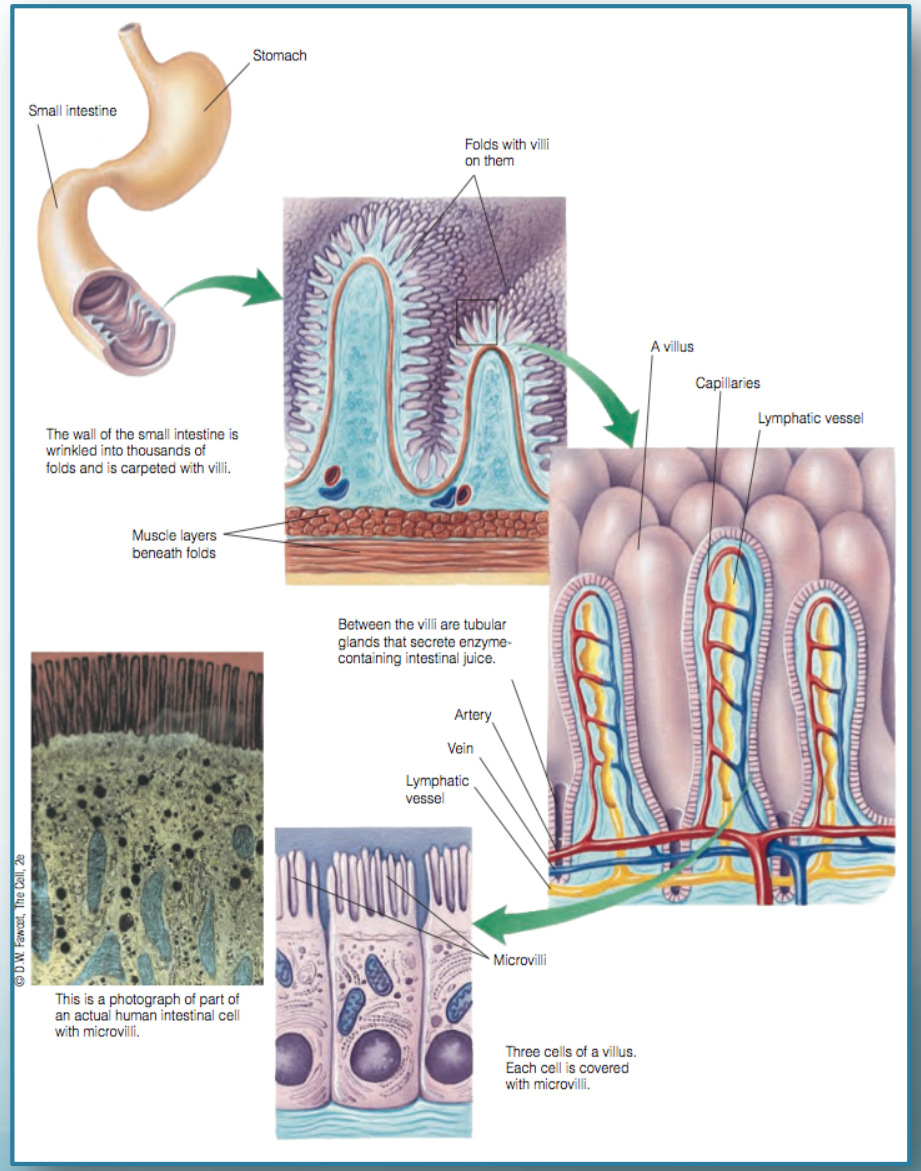
Like bile, detergents are emulsifiers and work the same way, which is why they are effective at removing grease spots from clothes. Molecule by molecule, the grease is dissolved out of the spot and suspended in water, where it can be rinsed away.

DIGESTION IN THE LARGE INTESTINE

- Undigested residues, such as some fibers, are not absorbed but continue through the digestive tract as a semisolid mass that stimulates the tract's muscles, helping them remain strong and able to perform peristalsis efficiently.
- Fiber also retains water, keeping the stools soft, and carries some bile acids, sterols, and fat out of the body.

The Absorptive System

- Most absorption takes place in the small intestine.
- Small intestine's inner surface looks smooth, but viewed through a microscope, it turns out to be wrinkled into hundreds of folds.
- Each fold is covered with thousands of fingerlike projections called **villi.**
- A single villus, magnified still more, turns out to be composed of several hundred cells, each covered with microscopic hairs called **microvilli.**



The Absorptive System (Cont.)

- Once a molecule has entered a cell in a villus, the next step is to transmit it the **bloodstream** and the **lymphatic system.**
- Both systems supply vessels to each villus. Through these vessels, the nutrients leave the cell and enter either the **lymph** or the blood. In either case, the nutrients end up in the blood.
- The water- soluble nutrients (and the smaller products of fat digestion) are released directly into the bloodstream by way of the capillaries, but the larger fats and the fat-soluble vitamins find direct access into the capillaries impossible because these nutrients are insoluble in water (and blood is mostly water). They require some packaging before they are released.
- The intestinal cells assemble the products of fat digestion into larger molecules called **triglycerides,** which then packaged for transport.
- They cluster together with special proteins to form **chylomicrons,** one kind of **lipoproteins**. Finally, the cells release the chylomicrons into the lymphatic system.

TRANSPORT OF LIPIDS: LIPOPROTEINS

- Within the circulatory system, lipids always travel from place to place bundled with protein, that is, as lipoproteins.
- VLDL, LDL, HDL , and chylomicrons transport newly absorbed lipids from the intestinal cells to the rest of the body.
- The liver can assemble different lipoproteins, which are known as **very-low-density lipoproteins (VLDL).** As the body's cells remove triglycerides from the VLDL, the proportions of their lipid and protein contents shift. As this occurs, VLDL become cholesterol-rich **low-density lipoproteins (LDL).**
- Cholesterol returning to the liver for metabolism or excretion from other parts of the body is packaged in lipoproteins known as **high-density lipoproteins (HDL).**