Chapter 15
The Digestive System
Diet provides essential nutrients and macromolecules

- 3 major macromolecules are carbohydrates, fats, and proteins.
- Carbohydrates are polymers of simple monosaccharides.
- Fats are polymers of glycerol and fatty acids.
- Proteins are polymers of amino acids.
Vitamins and Minerals

- Vitamins are organic molecules required in the diet.
  - Fat soluble: Vitamin A, D, E and K
  - Water soluble: Vitamin B, C
- Minerals are inorganic molecules.
  - Iron, calcium, phosphorous, Fluoride, zinc, copper, and several others.
- Vitamin and mineral deficiencies can cause severe disorders in the body
Food must be processed to obtain macromolecules and nutrients

The 4 main mechanisms of food processing are:

- **Ingestion**: eating (taking in food)
- **Digestion**: physical and chemical breakdown of food into the smallest absorbable molecules
- **Absorption**: the intake of food molecules by cells.
- **Elimination**: the passing out of undigested matter.
Food Processing (cont.)

- **Extracellular Digestion:**
  - In a gastrovascular cavity in simple animals
  - In an alimentary canal in more complex organisms

- **Intracellular Digestion:**
  - Occurs inside the cell, once the cell engulfs food particles
  - Is performed by the cell’s lysosomes
Food Processing (cont.)

- Alimentary canals are also called complete digestive tracts
- "one way movement" of food: a specific opening for ingestion and another for elimination
  - Makes for orderly progression of breakdown
  - Allows for more than 1 meal to enter the tract a time
Human Digestive Tract

The organs and functions of that make up the human alimentary canal and accessory structures.
The Oral Cavity (Mouth)

- Is bounded externally by lips and cheeks
  - Vestibule—the space between the lips, cheeks, & gums

- The tongue—composed of skeletal muscle
  - Is moved by muscles exterior to the tongue
  - Papillae—rough projections on the tongue
    - Allow food handling
    - Contain sensory receptors (taste buds)
    - Lingual frenulum—fold of mucous membrane underside the tongue
      - Difficulty speaking if too short ("tongue-tied")

- Roof of the Mouth
  - Anterior hard palate—maxilla and palatine bones
  - Posterior soft palate—muscle and glandular tissue
    - Uvula—finger-shaped projection
The Oral Cavity

- Incisors
- Soft palate
- Uvula
- Tonsil
- Tongue

Map of Taste Receptors:
- Bitter
- Sour
- Salt
- Sweet

Accessory parotid gland

Opening of submandibular (Wharton's) duct

Parotid gland

Sublingual gland

Submandibular (Wharton's) duct

Body of mandible

Submandibular gland
(a) Oral cavity, sagittal section

- Nasal cavity
- Hard palate
- Soft palate
- Pharyngeal tonsil
- Entrance to auditory tube
- Nasopharynx
- Uvula
- Palatine tonsil
- Fauces
- Palatopharyngeal arch
- Oropharynx
- Lingual tonsil
- Epiglottis
- Palatoglossal arch
- Opening of parotid duct
- Upper lip
- Cheek
- Lower lip
- Gingiva
- Vestibule
- Body of tongue
- Mandible
- Root of tongue
- Hyoid bone
(b) Oral cavity, anterior view
The Oral Cavity (Mouth)

- **Teeth**—Begin the mechanical digestion by chewing food – increasing surface area.
- **Salivary glands**—produce saliva
- **Tonsils**—immune function
Salivary Glands (3 Pairs)

- **Parotid**—anterior and inferior to the ears
  - Send saliva to the mouth via ducts
    - Between the cheek and the masseter
    - Ducts open on the inner surface of the cheek at the 2\textsuperscript{nd} upper molars
    - Swell during mumps (viral infection)
- **Sublingual**—underneath the tongue
- **Submandibular**—floor of the mouth, inside the surface of the lower jaw
  - Ducts for both open underneath the tongue
(a) Lateral view with left mandibular body and ramus removed
Composition & Functions of Saliva

Mucus, water, bicarbonate

Functions

1. protects mouth while chewing
2. lubricates food for swallowing
3. helps prevent tooth decay
4. kills many bacteria before swallowing
5. Chemical digestion of carbohydrates by Salivary amylase (starch $\rightarrow$ maltose)
The Pharynx

- The connection between our oral cavity and the esophagus
  - Nasopharynx, Oropharynx, Laryngopharynx
- The windpipe (trachea) also is located anterior to the pharynx and the esophagus
- A flap of cartilage called the *epiglottis* closes the opening of the trachea when we swallow, which prevents things from entering the lungs or choking.

**Swallowing–2 phases**

- Voluntary
- Reflex– once food is pushed into the oropharynx
3 parts of the pharynx

- Nasopharynx – respiratory function
- Oropharynx – respiratory and digestive function. Common pathway for food and air
- Laryngopharynx – digestive function only
The Swallowing Process

(a) **BUCCAL PHASE**
- Hard palate
- Tongue
- Epiglottis
- Trachea
- Soft palate
- Esophagus
- Bolus

(b) **PHARYNGEAL PHASE**
- Hard palate
- Tongue
- Epiglottis
- Trachea
- Soft palate
- Esophagus
- Bolus
The Swallowing Process

ESOPHAGEAL PHASE

(e) Peristalsis

(f) Thoracic cavity

(g) Esophagus

(h) Stomach

Diaphragm
Teeth

- 2 sets
  - **Deciduous** (20)
    - Ages 6 mo. – 2 ½ years
  - **Permanent** (32)
    - Ages 6 years – 25 years (3rd molars)
- Held in sockets
- **Gingiva** surrounds the base of the teeth
Deciduous Teeth

Central incisors (7.5 mo)
Lateral incisor (9 mo)
Cuspid (18 mo)
Primary 1st molar (14 mo)
Primary 2nd molar (24 mo)
Primary 1st molar (12 mo)
Cuspid (16 mo)
Lateral incisor (7 mo)
Central incisors (6 mo)

Upper jaw

(d) The primary teeth

Lower jaw
Adult Teeth

Mesial surface
Distal surface

Central incisors (7–8 yr)
Lateral incisor (8–9 yr)
Cuspid (11–12 yr)
1st Premolar (10–11 yr)
2nd Premolar (10–12 yr)
1st Molar (6–7 yr)
2nd Molar (12–13 yr)
3rd Molar (17–21 yr)
Bicuspsids (premolars)

Occlusal surfaces

Upper dental arch
Hard palate

Lower dental arch

3rd Molar (17–21 yr)
2nd Molar (11–13 yr)
1st Molar (6–7 yr)
2nd Premolar (11–12 yr)
1st Premolar (10–12 yr)
Cuspid (9–10 yr)
Lateral incisor (7–8 yr)
Central incisors (6–7 yr)

(c) Adult teeth, upper and lower jaws
Structure of a Tooth

- **Crown**
  - Part you see above the gum

- **Root**
  - 1 – 3 projections embedded in socket

- **Neck**
  - Junction between crown and root
Composition of a Tooth

- **Dentin**
  - Primary substance in tooth
  - Encloses pulp cavity
    - In crown
    - Root canals – narrow extensions of pulp cavity

- **Enamel – covers crown**
  - Hardest substance in the body
  - Protects tooth from wear of chewing
  - Barrier against acids that dissolve dentin

- **Cementum – covers root**

- **Tooth decay**

- **Wisdom teeth**
A Tooth

(a) Tooth, sectional view

- Pulp cavity
- Enamel
- Dentin
- Gingiva
- Gingival sulcus
- Cementum
- Periodontal ligament (membrane)
- Root canal
- Alveolar bone
- Apical foramen
- Branches of alveolar vessels and nerve
The Esophagus (food pipe)

- The *esophagus* is a muscular tube that transports the bolus from the mouth to the stomach.
- Stratified squamous epithelium
- Rhythmic muscular contractions, known as *peristalsis* push the food in one direction...Down.
- No digestion occurs here.
Step 1: Contraction of circular muscles behind bolus

Step 2: Contraction of longitudinal muscles ahead of bolus

Step 3: Contraction in circular muscle layer forces bolus forward

(a) Peristalsis

(b) Segmentation
The Esophagus cont...

- Lower Esophageal Sphincter (gastroesophageal) constriction between the esophagus and the stomach
  - Sphincters—muscles that encircle tubes
  - Relaxation—allows bolus to enter the stomach
  - Constriction—prevents acid backup from the stomach
- Heartburn—acid reflux from the stomach
- Vomiting—propelling of stomach contents by contraction of abdominal and stomach muscles
Layers of the Digestive Tract
(Deep → Superficial)

1. **Mucosa (mucous membrane layer):**
   - A layer of epithelium
   - Glandular cells (enzyme secretion)
   - Goblet cells (mucous secretion)

2. **Submucosa:**
   - Loose connective tissue with blood vessels, lymphatics, and nerves beneath it
   - Peyer’s patches—lymph nodules—immune function

3. **Muscularis (smooth muscle layer):**
   - Inner circular and outer longitudinal layer
   - Oblique—only in the stomach

4. **Serosa (serous membrane layer):**
   - Very thin outermost layer of squamous epi
   - Secretes serous fluid
   - Adventitia—only in the esophagus, loose CT
Layers of the Digestive Tract
Layers of the Digestive Tract
Peritoneum (Serous membrane)

- Parietal peritoneum: lines the abdominal wall
- Visceral peritoneum: covers the organs
  - **Mesentary**: double layer of visceral peritoneum in between the organs
  - **Greater omentum**: hangs down anteriorly
    - Fat cushion for insulation
    - Macrophages
    - Contains infections
  - **Lesser omentum**: between the stomach and the liver
External Anatomy of the Stomach
Anatomy of the Stomach
The Stomach
The Stomach

- Performs 2 major functions: Storage and Digestion

- Can hold up to 4 liters (1 gallon) of food (entire meal)

- Creates *Gastric Juice*, which begins protein digestion.

- Stomach walls churn the food to further increase surface area and to mix the gastric juice in with the food.
The Stomach

- **4 Regions:**
  - **Cardiac**—near the heart, surrounds the lower esophageal sphincter
  - **Fundic**—superior expansion, temporarily holds food
  - **Body**—main region
  - **Pyloric**—narrow to become pyloric canal, leads to the pyloric sphincter

- **Rugae**—stomach folds with allow the diameter of the stomach to expand
Smooth Muscle Layers of the Stomach

Three muscle layers:
- longitudinal
- circular
- oblique

Functions:
- move food along
- churn and mix food with gastric juices
- Break food down
Stomach mucosa

- Simple columnar epithelium
- Has millions of gastric pits leading to gastric glands
Stomach Glands and Functions

- 4 Cell types in gastric glands. Gastric juice is made from its 3 types of cells:
  - Mucus Cells
  - Chief Cells
  - Parietal Cells

- Enteroendocrine cells

  Secrete mucus to line the stomach wall
  Secrete Pepsinogen
  Secrete HCl and Intrinsic factor
  Secrete gastrin
Stomach (cont.)

- **Mucous cells**: produce mucus
  - Protects stomach from digesting itself
  - Stomach pH=2
  - **Ulcer**—open sore (most common cause *H. Pylori*)

- **Chief cells**: secrete pepsinogen (*inactive enzyme*)

- **Parietal cells**: produce HCL + Intrisic factor (IF)
  - HCl + Pepsinogen $\rightarrow$ Pepsin (active)
    - *Pepsin* chemically digests proteins into smaller proteins (polypeptides)
  - **IF** binds to VitB12 preventing pernicious anemia (failure of RBC development)
Stomach cont..

- **Enteroendocrine Cells:** produce gastrin
  - Gastrin (hormone) regulate stomach wall contractions and secretions

- The food (bolus) mixed with the stomach secretions is called *Chyme*.
  - *(Acidic)* _Chyme_ is released into the small intestine in small amounts through the *Pyloric Sphincter*
  - *Alcohol and water* get absorbed in the stomach, but food does not
  - Gastric emptying takes 2–6 hours
Small Intestine

- 6 meters long
- Nearly all digestion and nutrient absorption occurs here.
- 3 main sections:
  - Duodenum
  - Jejunum
  - Ileum
Duodenum

- The 1st 25 cm of the small intestine.

- The acid chyme from the stomach mixes with the digestive juices from the liver, pancreas, gall bladder and the small intestine walls.

- Most of the digestion (breakdown) of the chyme is completed by the time it reaches the end of the Duodenum.
Jejunum and Ileum

- Remaining sections of the S.I.
- Majority of food molecule absorption
- Lined with finger-like projections called Villi.
- Villi are further lined themselves with Microvilli
Mucosa—simple columnar epi

Serve to increase the rate of absorption by vastly increasing the surface area.

Each Villi has surrounding capillaries and a central *lacteal*
- a small lymphatic vessel
The capillaries absorb simple sugars, which are transported to the liver through the *Hepatic Portal Vein*.

Amino acids are also absorbed & transported through the body via the capillaries.

Fats are absorbed through the lacteals and travel through the lymphatic system.
A Villus
Histology of the Small Intestine

(a) Gross anatomy of the intestinal wall

(b) Intestinal villi and intestinal crypts

- Plica circulares
- Villi
- Mucosa
- Muscularis mucosae
- Submucosa
- Muscularis externa
- Serosa
- Lacteal
- Lymphoid nodule
- Intestinal gland
- Lymphatic vessel
- Submucosal plexus
- Circular layer of smooth muscle
- Myenteric plexus
- Longitudinal layer of smooth muscle
- Submucosal artery and vein
Large Intestine

- Involved in water recovery from the digestive juices left behind.
- Houses beneficial Bacteria that produce several vitamins.
The Large Intestine

- Hepatic portal vein
- Superior mesenteric vein
- Inferior vena cava
- Aorta
- Splenic vein
- Superior mesenteric artery
- Inferior mesenteric vein
- Right colic (hepatic) flexure
- Transverse colon
- Left colic (splenic) flexure
- Taenia coli
- Greater omentum (cut)
- Left colic vein
- Inferior mesenteric artery
- Descending colon
- Left colic artery
- Haustra
- Sigmoid arteries (red) and veins (blue)
- Sigmoid flexure
- Cecum
- Vermiform appendix
- Rectum
Histology of the Large Intestine

(a) Colon wall, sectional view

(b) Colon (LM x 104)
The useless end product of the digestive process is **feces**.

Feces contains masses of bacteria, cellulose and undigested food materials.

Feces is stored at the terminal portion of the L.I. called the **rectum**.

Two rings of muscle called **Sphincters** control the elimination of feces from the body via the **anus**.
There are occasional interruptions in proper Large Intestine function:

- *Constipation* occurs when peristalsis slows and most of the water is removed from the feces, which becomes impacted.

- *Diarrhea* occurs when water is not reabsorbed, either due to bacterial infection or some other irritant.
Small Intestine and the Accessory Organs

- Accessory organs of the digestive system:
  - Teeth, tongue, salivary glands, liver, gallbladder, pancreas

- Accessory organs are essential to digestion, yet they are not actually part of the Alimentary Canal

- Three accessory organs associated with the small intestine:
  - Pancreas
  - Liver
  - Gall Bladder
Gastrin – produced by the enteroendocrine cells in the stomach when you eat a meal high in protein.
   - Causes stomach wall to contract and gastric juices to be secreted.

Secretin – produced by cells of duodenum when it receives acidic chyme from stomach
   - Causes pancreas to release bicarbonate (strong base) into the duodenum (to raise the pH).

CCK (cholecystokinin) – produced by cells of duodenum when it receives partially digested fats and protein from the stomach
   - Causes pancreas to release pancreatic juice into the duodenum (to complete breakdown of fat & protein)
**Pancreas**

- **Head**: the broad end that fits into the C-shaped duodenum
- **Tail**: the narrow end
- **Pancreatic duct**: carries pancreatic enzymes to the duodenum
- **Opening of the duct**: hepatopancreatic ampulla
The Pancreas—notice where it’s positioned

- The pancreatic duct is where the pancreatic juice leaves pancreas into the duodenum.
Acinus (Acini)—secrete pancreatic enzymes – trypsin, nuclease, lipase, amylase

Islet cells—secrete endocrine hormones (insulin and glucoagon to regulate blood sugar)
Pancreatic Secretions (Exocrine)

- **Digestive enzymes**: help with the chemical digestion of food in the small intestine
  - Pancreatic Amylase: disaccharides into monosaccharides
  - Proteases & Trypsin: small polypeptides into amino acids
  - Pancreatic Lipase: fat droplets (emulsified in bile salts) → glycerol & fatty acids
  - Nuclease: Nucleic acids into nucleotides
  - Bicarbonate: a base that neutralizes the highly acidic chyme

All of these tiny molecules will be absorbed into the capillaries & lacteal inside the villi

http://www.zerobio.com/secretin_flash.htm
Liver Location and Overview

- Large & triangle shaped
- Right side of the body
- Below the diaphragm
- Is divided into lobes
- Right lobe is larger
The Liver – anterior

- Right lobe
- Coronary ligament
- Left lobe
- Falciform ligament
- Round ligament (ligamentum teres)
- Gallbladder

(c) Anterior (parietal) surface
The Liver – posterior

- Left lobe
- Caudate lobe
- Left hepatic vein
- Inferior vena cava
- Right lobe
- Coronary ligament
- Hepatic portal vein
- Hepatic artery
- Quadrat lobe
- Common bile duct
- Gallbladder
- Hilus (porta hepatis)

(d) Posterior (visceral) surface
Histology and Blood Supply of the Liver

(a) Lobar organization

- Hepatocytes
- Kupffer cells
- Sinusoid
- Bile canaliculi
- Hepatic artery
- Bile duct
- Hepatic portal vein
- Central vein
- Interlobular septum
- Bile ductules
- Portal area
Functions of the Liver

- Hepatocytes – liver cells produce bile
  - Composition
    - Water
    - Bile salts
    - Cholesterol
    - Pigments
      - **Bilirubin** – principal pigment.
      - **Jaundice** – caused by excessive amounts of bilirubin/blocked ducts – causes yellowing of skin/eyes.
  - Digestive function
    - Emulsification of fats – makes them more manageable for lipase to completely break them down.
  - Stores carbohydrates as glycogen
  - Filtering unit of the body
Gall Bladder

- Stores and concentrates bile made by the liver
- Contracts and squeezes bile into the *Duodenum* of the small intestine, as needed.
1. Cystic duct from gall bladder

2. Hepatic ducts from Liver

These 2 ducts form the common bile duct that lead to the duodenum (pathway for bile)
The Gallbladder – *find those ducts again*
Enzymes in summary....

- **Salivary Amylase** – made by salivary glands and breaks up carbs into disaccharides
- **Pepsin** – made in stomach and breaks up proteins into small polypeptides
- **Trypsin, Amylase, Nuclease, Lipase** – made in Pancreas and delivered to Small intestine.
  - **Trypsin** – breaks polypeptides into amino acids
  - **Amylase** – breaks disaccharides into monosaccharides
  - **Nuclease** – breaks nucleic acids into nucleotides
  - **Lipase** – breaks emulsified fats into fatty acids and glycerol
Hormones in summary...

- See slide 59 again 😊
Essential nutrients are minerals that are needed by the body, yet cannot be made by the organism.

Missing out on one or more essential nutrient is known as *malnourished*.

*Undernourishment* is caused by insufficient calories.
Vitamins and Minerals

- Organic molecules required in the diet.

- There are 2 varieties: fat soluble and water soluble

- Fat soluble examples are: Vitamin A, D, E and K. Excess of these are stored in fat and could cause accumulations that becomes toxic.

- Water soluble examples are: Vitamin C, B complex. Excess of these are excreted in urine.
Minerals are inorganic molecules.

Examples include: Iron, calcium, phosphorous, Fluoride, zinc, copper, and several others.

They have several different bodily functions ranging from muscle contraction to nervous system performance.
Vitamin and mineral deficiencies can cause severe disorders in the body.

Examples include: *Kwashiorkor, Scurvy, Rickets, and Goiter.*
Kwashior Kor

- Caused by inadequate Protein intake
- The protuberant abdomen is caused by the body’s inability to absorb fluids, due to depleted necessary blood proteins
Essential Nutrient Deficiency Symptoms (cont.)

- **Scurvy**

  - Caused by Vitamin C deficiency.

  - Results in degeneration of blood vessels which causes spongy gums. Tooth loss is common in advanced stages
Essential Nutrient Deficiency Symptoms (cont.)

- Rickets
- Caused by Vitamin D deficiency
- Causes bone softening and deformity
Essential Nutrient Deficiency

Symptoms (cont.)

- Goiter – thyroid gland that has grown to an abnormally large size
- Iodine deficiency