13.1 Overview

- Digestive system – allows body to break down complex molecules into simple molecules
  - Some used for energy
  - Others used in cell and tissue development
- Two components
  - Digestive tract (or alimentary canal)
    - Mouth, esophagus, stomach, small intestine, large intestine, and rectum
  - Accessory digestive organs
    - Produce secretions that help digestive tract
      - Salivary glands, pancreas, liver, and gallbladder
Major Digestive Organs

- Mouth
- Salivary glands
- Pharynx
- Esophagus
- Liver
- Gallbladder
- Stomach
- Pancreas
- Small intestine
- Large intestine
Digestive Tract – Mouth and Pharynx

- **Mouth** – chemical and mechanical digestion
- **Lips (labia)** – contain sensory receptors that detect temperature and texture of food
  - Get their color from large amounts of blood vessels
- **Buccal or oral cavity** – cheeks
  - Where food is moistened in preparation for 1st steps of digestion
- **Palate** – forms roof of buccal cavity
  - **Hard palate** – anterior portion that covers maxillary and palatine bones
  - **Soft palate** – posterior to hard palate
    - Contains muscular arch called uvula, cone-shaped projection
- **Oropharynx** – posterior to buccal cavity
  - **Epiglottis** – separates respiratory system from the pharynx
- Tongue – bottom of buccal cavity – covered by lingual membrane
  - Taste buds on upper surface of lingual membrane
  - Lingual membrane covers four intrinsic muscles
    - Form bulk of tongue, attach to mucus membranes and other tongue muscles
    - Permit a variety of shapes that assist with speech and swallowing
    - Extrinsic muscles – originate outside of structure – attach to bony structures
- Lingual tonsils – lymphatic tissue
  - Anterior to epiglottis – help fight infection
    - When swollen, difficult to swallow
Sense of Tongue

Vallate papillae

Fungiform papillae

Filiform papillae

Bitter

Sour

Salt

Sweet

• Salivary glands – lie under facial skin and buccal cavity
  • Produce saliva – aids in digestion
    • Moistens food and starts chemical digestion
      • 3 major glands – parotid, sublingual, and submandibular

• 2 jaw bones and hard palate – responsible for mechanical breakdown of food – assist with speech
Salivary Glands

- Parotid gland
- Sublingual gland
- Submandibular gland
Cont, (teeth)

- Adult, or permanent teeth = 32
- Each jaw has 16 located in alveolar sockets
- Incisors – central (4) teeth – front, cutting teeth
- Canine, or cuspid – 4 – used to hold and tear food
- Bicuspid, or premolars -8- assist with breaking food into fine particles
- Molars –6(most) - specialized for grinding food into a fine mash
- Wisdom teeth, or 3rd molars – usually appear between 18 and 20 years
  - Removed if they cause crowding
Teeth

- Incisors
- Canine
- Premolars
- Molars
- Uvula
- Throat
- Tongue

- Canine
- Lateral incisor
- Central incisor
- First premolar
- Second premolar
- First molar
- Second molar
- Third molar
- (Wisdom tooth)
## Important Vitamins

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Food sources</th>
<th>Role</th>
<th>Effects of deficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin A (retinol)</td>
<td>butter, eggs, liver, carrots, green leafy vegetables, sweet potatoes</td>
<td>healthy eyes and skin, strong bones and teeth</td>
<td>infections of urinary and digestive systems, night blindness</td>
</tr>
<tr>
<td>Vitamin B₁ (thiamin)</td>
<td>most vegetables, nuts, whole grains, organ meats</td>
<td>nerve and heart function, carbohydrate metabolism</td>
<td>digestive disturbances, impaired senses</td>
</tr>
<tr>
<td>Vitamin B₂ (riboflavin)</td>
<td>fish, poultry, cheese, yeast, green vegetables</td>
<td>healthy skin, tissue repair, carbohydrate metabolism</td>
<td>blurred vision, cataracts, cracking of skin, lesions of intestinal lining</td>
</tr>
<tr>
<td>Vitamin B₃ (niacin)</td>
<td>whole grains, fish, poultry, tomatoes, legumes, potatoes</td>
<td>healthy skin, carbohydrate metabolism</td>
<td>mental disorders, diarrhea, inflamed skin</td>
</tr>
<tr>
<td>Vitamin B₁₂ (cobalamin)</td>
<td>meat, poultry, milk, dairy products</td>
<td>formation of red blood cells</td>
<td>reduced number of red blood cells</td>
</tr>
<tr>
<td>Vitamin C (ascorbic acid)</td>
<td>citrus fruits, strawberries, potatoes</td>
<td>healthy gums and teeth, wound healing</td>
<td>swollen and bleeding gums, loose teeth, slow-healing wounds</td>
</tr>
<tr>
<td>Vitamin D (cholecalciferol)</td>
<td>salmon, tuna, fish liver oils, fortified milk, cheese</td>
<td>calcium uptake by the gut, strong bones and teeth</td>
<td>bone deformities in children, loss of muscle tone</td>
</tr>
<tr>
<td>Vitamin E (tocopherol)</td>
<td>vegetable oils, nuts, seeds, olives, whole grains</td>
<td>protects against damage by free radicals</td>
<td>reduced number of red blood cells, nerve tissue damage in infants</td>
</tr>
<tr>
<td>Vitamin K (phylloquinone)</td>
<td>leafy green vegetables, liver, cauliflower</td>
<td>normal blood clotting</td>
<td>bleeding caused by prolonged clotting time</td>
</tr>
<tr>
<td>Mineral</td>
<td>Food sources</td>
<td>Role</td>
<td></td>
</tr>
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<tr>
<td>Sodium</td>
<td>table salt, processed foods, dairy products</td>
<td>water balance, nerve function</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>meats, many fruits and vegetables, beans</td>
<td>fluid balance, nerve and muscle function</td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>milk, dairy products, tofu, legumes, dark-green leafy vegetables, shellfish, bony fish</td>
<td>healthy bones and teeth, nerve and muscle function, blood clotting</td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td>red meat, whole and enriched grains, dark-green vegetables, peas, beans, eggs</td>
<td>bone growth, metabolism, muscle contraction, oxygen transport in blood</td>
<td></td>
</tr>
<tr>
<td>Iodine</td>
<td>iodized salt, seafood</td>
<td>thyroid hormones, normal cell function</td>
<td></td>
</tr>
</tbody>
</table>
• Esophagus
  • Base of pharynx, behind the epiglottis = esophagus
  • Muscular tube that carries food and liquids from pharynx to stomach
    • Passes through opening in diaphragm just above stomach
      • 4 tissue layers make up esophagus
        • Mucosa
        • Submucosa
        • Muscularis layer
        • Serosa(adventitia)
• 2 circular groups of muscles called sphincters close off esophagus the pharynx and the stomach
  • Upper sphincter – used during swallowing – closely associated with larynx
  • Cardiac sphincter – surrounds esophagus at entrance of stomach
    • Both are normally closed, except during swallowing
    • Prevent air from pharynx from regularly entering stomach
    • Also prevents a backflow, or reflux, of stomach contents that can damage esophagus and pharynx
Stomach

- Large, saclike organ at the distal end of esophagus
- 4 layers to withstand corrosive chemical digestion and strong muscular contractions
- Can store up to 3 pints of food
- Specialized cells secrete acid and protein digestive enzymes
Stomach, cont.

- 3 regions – each has a unique set of glands
  - Upper (cardiac)
    - Continually secrete mucus
  - Middle (fundic)
    - 4 types
      - Parietal cells – produce HCl
      - Chief cells – secrete digestive enzymes
      - Mucous neck cells – secrete mucus by stimulated by vagus nerve
      - Gastric stem cells – replace other fundic-gland cells
  - Lower (pyloric)
    - Produce mucus
Stomach anatomy

- Esophagus
- Fundus
- Lower esophageal sphincter
- Pyloric sphincter
- Cardia
- Lesser curvature
- Pyloric sphincter
- Duodenum
- Pyloric canal
- Greater curvature
- Body
Muscularis layer consists of 3 thick layers of smooth muscle

- **Oblique**
  - Directly underneath submucosa
  - Thin bands that permit stomach squeezing

- **Circular**
  - Composed of thick bands of muscles making up the middle layer
  - Produce a mixing effect

- **Longitudinal**
  - Outermost layer
  - Assist with mixing and moving digested food out of stomach
Small Intestine

- Long, narrow tube running from the pyloric region of stomach to large intestine
- Tightly looped back and forth within abdominal cavity
- 3 distinct sections
  - Duodenum
    - Receives partially digested food from the stomach
    - Where most digestion takes place
  - Jejunum
    - Where most nutrients are absorbed into the blood
  - Ileum
    - Where remaining nutrients are absorbed before entering large intestine
Small Intestine, cont.

- Villi – fingerlike projections char. Of mucosa in small intestine
  - Increase surface area for food digestion and absorption
- Lacteals – collections of lymphatic tissues
  - Carry absorbed foods, especially fats, to liver
- Microvilli – smaller projections on surface of villi
  - Enhance surface area
- Enterocytes – absorptive cells of the s.i.
  - Enteroendocrine cells – hormone producing cells of s.i.
    - Regulate digestion
- Paneth cells – maintain beneficial microorganisms
Small Intestine, cont.

- Muscularis layer has 2 layers
  - inner circular
    - Mixing food
  - Outer longitudinal layer
    - Transport food through length of small intestine
- Mesenteries – connects small intestine to peritoneum
- Ileocecal valve – where small intestine meets large intestine
  - Forms barrier that prevents bacteria from entering small intestine and prevents backflow into s.i.
Large Intestine

- A.k.a colon – larger in diameter, shorter in length than s.i.
- 5 anatomical regions:
  - Cecum
    - Small, contains ileocecal valance and appendix
      - Appendix – function unknown, common site of infection
        - Appendicitis
  - Ascending colon
    - Starts at ileocecal valve and runs to hepatic flexure (below liver)
  - Transverse colon
    - Runs parallel to diaphragm
    - Connects descending colon and splenic flexure (below spleen)
  - Descending colon
    - Vertical downward along left abdominal cavity
  - Sigmoid colon
    - S-shaped curve at the end of descending colon
Small and Large Intestine

- Duodenum
- Splenic flexure
- Hepatic flexure
- Descending colon
- Ascending colon
- Cecum
- Sigmoid colon
- Jejunum
- Rectum
- Ileum
- Anus
- Internal sphincter
- External sphincter
- Anal columns
Large intestine, cont.

- Main function = absorption of electrolytes, vitamins, and water
- Removes undigested materials from digestive tract
- Mucosa of l.i. is smooth and has no villi
- Has many types of bacteria, 1 type of yeast
  - Break down wastes, provide little benefit or harm to humans
Rectum

- Muscular storage area for undigested wastes
- Final portion of digestive tract
- Anal canal – region between digestive tract and region of skin around anus
- Anus – opening of rectum to the outside of body
- Anal sphincter – sphincter muscle of anus
13.3 Glandular Structures of the Digestive System

- Pancreas – posterior lies to the stomach
  - Attached by mesentery
  - Thin layer of CT forms capsule around pancreas
  - Glandular lobules
    - Each has blood vessels, nerves, and ducts
  - Has endocrine and exocrine functions

![Diagram of digestive system with pancreas highlighted]
Glandular structures, cont.

- Acini – clusters of exocrine cells
  - Contain enzymes
    - Inactive – zygomens
      - Becomes active when it enters digestive tract
  - Leads to pancreatic duct – collects pancreatic exocrine secretions
  - Common bile duct – secretions from liver and pancreas empty into duodenum
    - Bile – yellow-green fluid produced by the liver
      - Contains acids, cholesterol, glyceride fats, and salts
        - Aids in fat digestion
Liver

- Liver carries out the most complex functions of the digestive system
  - Divided into 4 lobes, surrounded by capsule of CT, which is covered by visceral peritoneum
    - Left and right lobe make up most of liver’s mass
    - Quadrate lobe
    - Caudate lobe
  - 2 blood vessels enter at region called hilum
    - Hepatic artery – provides blood for the liver cells
    - Hepatic portal vein – carries food from small intestine to liver
  - Hepatic vein – carries wastes from liver to inferior vena cava
Liver, cont.

- Composed of hepatocytes
  - Have 2+ nuclei
  - Lives about 5 months, slow at carrying out mitosis
    - Works slower during liver disease....
  - Current research shows healthy liver cells can regenerate when the liver is damaged
- Contains lymphatic vessels
Liver Functions

- Glycogen storage for regulating blood sugar
- Formation of urea
- Formation of blood proteins and clotting factors
- Synthesis of heparin, a blood coagulant
- Metabolism of cholesterol and fatty acids
- Formation of serum globulins
- Metabolism of vitamin D
- Removal of microorganisms from blood
- Breakdown of drugs and many poisons
- Breakdown of amino acids
- Destruction of bilirubin – causes jaundice (hepatitis)
- Storage of iron
Liver
Liver Cirrhosis
Gallbladder

• Small pear-shaped sac that stores and concentrates bile
• Underneath right lobe of liver
• Smooth muscles of gallbladder contract to release bile through cystic duct
  • Cystic duct joins common hepatic duct to form the common bile duct
• Gallstones – form when the bile contains too much bilirubin, cholesterol, or bile salts
  • Can cause considerable pain when they pass through ducts
Digestive Process

- Pregastric factors – conditions that affect food intake
  - Hunger and thirst
  - Any condition that determines the degree of hunger or thirst
- CNS has a hunger center in hypothalamus
  - Satiety center
- Abnormalities of these regions results in some types of eating disorders
• Ingestion – taking food into the body via mouth
• Parenteral nutrition – nutrition into body by bypassing the digestive tract
  • Can be injected into muscles or veins
    • Get crucial materials to body quickly
• Mastication – chewing!
  • First step in chemical digestion in mouth
  • Salivation wets the food to facilitate swallowing and to assist when chemical degradation of polymers
    • Amylase – enzyme that digests starch into glucose
Parenteral Nutrition

TPN

Subclavian vein

Superior vena cava

Clavicle

Heart
• Peristalsis – muscle contractions that push food and liquid
  • Permits you to swallow even when you are upside down…
    • Gives astronauts ability to swallow in outer space
• Reverse peristalsis – vomiting – forces food in opposite direction of flow
• Protease – enzyme that digests proteins
  • Secreted into stomach by stomach lining
• pH of stomach can vary from 1 to 3 during digestion
Three major hormones that control digestion (produced by stomach and small intestine):

- Cholecystokinin (CCK) – causes pancreas to produce enzymes
- Gastrin – stimulates acid production
- Secretin – causes pancreas to release digestive juices

Chyme – partially digested food in stomach

- Stimulates pyloric sphincter to relax
  - Permits food to enter the duodenum
    - Only alcohol and many strong drugs are absorbed in stomach
This diagram illustrates the average time food spends in each part of the digestive system along with the average pH.

Saliva
6.5 - 7.5 pH
up to 1 minute

Upper Stomach (fundie)
4.0 - 6.5 pH
30 - 60 mins

Lower Stomach
1.5 - 4.0 pH
1 - 3 hrs

Duodenum
7.0 - 8.5 pH
30 - 60 mins

Small Intestine
4.0 - 7.0 pH
1 - 5 hrs

Large Intestine
4.0 - 7.0 pH
10 hrs - several days
Digestive Process, cont.

- In duodenum, food is mixed with bile and pancreatic secretions
  - Bile acts to break down fat into smaller droplets called micelles
  - Breaks down carbs, lipids, nucleic acids, and proteins (the 4 major macromolecules)
- Enterokinase – enzyme that actives intestinal zygomens in small intestine
- Substances that haven’t digested in small intestine enter the large intestine
  - As a result of metabolic activities, produce gas
    - Flatulence – excessive gas production
Flatulence 😊

IN FLATULENCE
EMERGENCY
DO NOT
USE
ELEVATOR
USE STAIRWAY

DANGEROUS GASES
Feces – waste eliminated from the large intestine
  - Mostly composed of water
  - Solid matter = bacteria, carbohydrate polymers, dried digestive secretions, fat, intestinal cells, and protein
Roughage – assists the large intestine with peristalsis by providing something solid for muscles to push upon
Emptying rectum is under voluntary and involuntary control
13.4 Pathology

• Various origins
  • Psychological disorders, allergies, infections, genetic syndromes, & degenerative changes from toxins or trauma

• Lack of a certain enzyme
  • Food intolerance – inability to digest or absorb a certain food
    • Can produce intestinal irritation and painful gas
  • Celiac disease – inability to digest a certain protein in wheat
Pathology, cont.

- Gastric reflux, or acid reflux – backward flow of stomach contents into the esophagus
  - Due to weakening or incomplete closure of cardiac sphincter
    - Causes heartburn
- Dysphagia - A swallowing disorder
  - Associated with gastric reflux
- Diarrhea – frequent and water bowel movements
  - Many causes….
  - Can be fatal due to dehydration and electrolyte loss
Pathology, cont.

- Acute diarrhea – a short-term, rapid onset diarrhea
  - Lasts no more than 2 weeks
  - Many causes..

- Salmonella – bacteria that causes food poisoning
  - Causes severe diarrhea and etc.
  - Mostly found in poultry and foods made with ground beef

- Chronic diarrhea – a long-term, usually painful, diarrhea

- Inflammatory bowel disease (IBD) – disease that causes irritation to intestines
  - Aka irritable bowel syndrome
  - Peristalsis disorder with no known cause
Amoebic dysentery – inflammation of intestines caused by protistan called Endamoeba histolytica
  • Extreme abdominal cramping and regular bouts of diarrhea
    • Contracted from food or water contaminated with human feces

Colon polyps – occur in ~20% of adults in NA
  • Growths in large intestine
  • From people who smoke, eat high-fat diets, very little fiber, and are overweight
  • Can cause adenomatous polyps – lead to colon cancer
  • Screening for anyone 50+
Pathology, cont.

- Ulcer – erosion of digestive tract mucosa
  - Can form anywhere in digestive tract
    - Most common in stomach and duodenum
- Hernias – protrusion of an organ into surrounding tissues
- Hiatal hernia – protrusion of upper part of stomach into thorax
- Inguinal hernia – protrusion of small intestine into pelvic muscles
Pathology, cont.

- Hepatitis – liver disease, inflammation of liver
  - Caused by viruses that attack hepatocytes
  - Different types, designated by letters
- Cirrhosis – causes liver to become scarred and filled with fat
  - Caused by chronic drug and/or alcohol use, hepatitis, and various toxins
- Pancreatitis – inflammation of pancreas
- Diverticulosis – pouchlike pockets develop in the large intestine
LIVER