Lecture Outline: The Digestive System and Nutrient Classes

I. **Overview of the Digestive System**

A. **Primary Functions**

1. **Processing of food**
2. **Immune function/Protection**
    a. Structures form a boundary between the body and the outside environment
    b. Protects against incoming pathogens

B. **Major Parts of the Digestive System**

1. **Alimentary Canal (Digestive Tract)**
    a. Continuous tube from the mouth to the anus
    b. Interior of the alimentary canal is considered **outside the body**
    c. "Element" means nourishment
2. **Accessory Organs**
    a. Not part of the alimentary canal; food does not pass through them
    b. Are connected to the alimentary canal
    c. Examples:
        (1) **Liver**: Largest organ of the digestive system and largest gland in the body
        (2) **Gallbladder**: Stores and concentrates bile produced by the liver

(3) **Pancreas**: Secretes pancreatic juice containing digestive enzymes and bicarbonate ions

(4) **Salivary Glands**: Produce saliva with digestive enzymes and antibacterial components

II. **Anatomy of the Alimentary Canal: Sequence of Structures**

A. **Mouth (Oral Cavity)**

1. First part of the alimentary canal; where digestion starts
2. Includes the tongue (for eating and speech)
3. Includes teeth (for mechanical digestion)
4. Roof of the mouth (palate):
    a. Hard palate (bony)
    b. Soft palate (pliable)
5. Gingiva (gums) surround the teeth

B. **Pharynx (Throat)**

1. Common passageway for air, food, and drink
2. Parts of the pharynx involved in food passage:
    a. Oropharynx (next to oral cavity)
    b. Laryngopharynx (next to larynx/voice box, leads to esophagus)
3. Nasopharynx is for air only
4. Uvula hangs at the back of the throat
5. Epiglottis closes off the trachea (airway) during swallowing to prevent food entry

C. **Esophagus (Eating Tube)**

1. Transports food and drink from the pharynx to the stomach
2. Collapsible tube (unlike the trachea)

D. **Stomach**

1. Mostly a **storage device** for food (now called **chyme**)
2. Does not do much chemical digestion, but performs significant mechanical digestion through churning
3. Regions:
    a. Cardiac region (entry from esophagus)
    b. Fundus (blind end)
    c. Body (main region)
    d. Pyloric region (exit to small intestine)
    e. Antrum (narrowing region near pylorus)
4. Internal features:
    a. **Rugae**: Folds in the lining that allow for stomach expansion
    b. **Gastric pits**: Tunnels in the lining containing secretory cells

E. **Small Intestine**

1. Where by far **most of the digestion and absorption takes place**
2. Very long and windy tube
3. Three parts (in order of material flow):
    a. **Duodenum** (first part, hairpin loop housing the pancreas)
    b. **Jejunum**
    c. **Ileum** (last part, connects to large intestine via the iliocecal valve)
4. Features for increased surface area (for absorption):
    a. **Plicae circularis (circular folds)**: Macroscopic folds in the lining
    b. **Villi**: Finger-like projections on the circular folds, each containing blood vessels and lacteals

c. **Microvilli**: Folds on the plasma membrane of individual cells lining the villi (form the "brush border")

F. **Large Intestine**

1. Receives residue (feces) from the small intestine (nutrients already absorbed)
2. Primarily absorbs **water** from feces, making them drier and solid
3. Parts (in order of material flow):
   a. **Cecum** (first part, receives material from ileum)
   b. **Appendix (vermiform appendix)**: Small projection from cecum, may house beneficial bacteria
   c. **Ascending Colon**
   d. **Transverse Colon**
   e. **Descending Colon**
   f. **Sigmoid Colon** (S-shaped)
   g. **Rectum** (straight part)
   h. **Anal Canal**
   i. **Anus** (final opening)
4. Internal features:
   a. **Haustra**: Pouch-like segments along its surface
   b. **Peyer's patches**: Lymphatic tissue for protection

III. **Layers of the Alimentary Canal Wall (Concentric Arrangement)**

A. **Mucosa**

1. Innermost layer, in direct contact with material (food, chyme, feces)
2. A mucous membrane, produces mucus for lubrication
3. Contains a thin smooth muscle layer

B. **Submucosa**

1. Underneath the mucosa
2. Composed mostly of connective tissue
3. Rich supply of blood vessels (arteries, veins) and lymphatic vessels for nutrient absorption

C. **Muscularis (Muscularis Externa)**

1. Composed primarily of **smooth muscle**
2. Typically has at least two layers:
    a. **Longitudinal muscle layer**: Shortens the tube, bunches it up
    b. **Circular muscle layer**: Narrows the diameter, squeezes contents
3. **Stomach has a third oblique layer**, allowing for churning and more movement

D. **Serosa or Adventitia** (outermost layer)

1. **Serosa**: A serous membrane (visceral layer of peritoneum), found where the alimentary canal is surrounded by the peritoneum (e.g., small intestine)
2. **Adventitia**: A connective tissue layer, found where the alimentary canal is not surrounded by peritoneum (e.g., mouth, esophagus)

E. **Enteric Nerves**: Networks of neurons (myenteric nerve plexuses) control smooth muscle movements

IV. **Accessory Organs and Their Contributions**

A. **Salivary Glands**

1. Produce saliva which contains:
    a. Water
    b. Mucus (forms food bolus, lubricant)

c. Digestive enzymes (e.g., salivary amylase for starch digestion)

d. Antibacterial components

2. Types: Parotid, Sublingual, Submandibular

B. **Liver**

1. Produces **bile** via hepatocytes
2. Bile is a complex mixture containing a **lipid that acts as a detergent**
3. Bile's function: **Emulsifies fats** (breaks large fat droplets into smaller ones), aiding digestion

C. **Gallbladder**

1. Stores and concentrates bile
2. Releases bile into the duodenum when needed

D. **Pancreas**

1. Both an endocrine gland (produces insulin, glucagon for blood sugar regulation) and an exocrine gland (digestive function)
2. Exocrine secretion: **Pancreatic juice**, delivered to duodenum via pancreatic duct
3. Pancreatic juice contains:
   a. **Bicarbonate ion**: Neutralizes acidic chyme from the stomach, creating optimal pH for small intestine enzymes
   b. **Pancreatic enzymes**: Digest carbohydrates, proteins, and fats
4. Hepatopancreatic ampulla: Common duct where bile and pancreatic ducts join before emptying into the duodenum

V. **Major Processes of Food Processing**

A. **Ingestion**: Taking food into the oral cavity (eating)

B. **Mechanical Breakdown (Mechanical Digestion)**

1. **Mastication (chewing)** in the mouth (teeth)
2. **Churning** in the stomach (three muscle layers)
3. **Segmentation** in the small intestine (mixes chyme)

C. **Propulsion**: Moving material through the alimentary canal in one direction
   1. **Deglutition (swallowing)**: Involves muscular movements of the tongue and pharynx
   2. **Peristalsis**: Wave-like contractions of smooth muscle that propel contents along the esophagus, stomach, small intestine, and large intestine

D. **Chemical Digestion**: Breaking down larger molecules into smaller ones using enzymes
   1. **Carbohydrate Digestion**
      a. Starts in the **mouth**: Salivary amylase breaks starch into smaller saccharides (destroyed by stomach acid)
      b. Continues in the **small intestine**: Pancreatic amylase continues breakdown, and brush border enzymes (e.g., lactase, sucrase) break disaccharides into monosaccharides
      c. Final products (monosaccharides) are absorbed
   2. **Protein Digestion**
      a. Starts in the **stomach**: Pepsin (activated from pepsinogen by HCl) breaks proteins into smaller polypeptides
      b. Continues in the **small intestine**: Pancreatic proteases (e.g., trypsin) and brush border enzymes break peptides into individual amino acids
      c. Final products (amino acids) are absorbed
   3. **Fat (Triglyceride) Digestion**

a. **Emulsification**: Bile from the liver emulsifies large fat droplets into smaller ones (prepares for digestion)
b. **Digestion**: Lipases (from pancreatic juice) break fats into glycerol and fatty acids or monoglycerides
c. Final products (glycerol, fatty acids, monoglycerides) are absorbed

E. **Absorption**: Small, digested molecules (nutrients) finally enter the body from the alimentary canal lumen
1. Mostly occurs in the **small intestine** for nutrients
a. Monosaccharides and amino acids absorbed directly into **blood capillaries** in villi (then to liver via hepatic portal system)
b. Fatty acids absorbed into **lacteals** (specialized lymphatic vessels in villi), eventually entering the bloodstream via the lymphatic system
c. Glycerol absorbed into blood capillaries
2. Mostly occurs in the **large intestine** for water
a. Reclaims useful water, preventing dehydration
b. Helps form feces into a solid form
3. Minimal absorption in mouth, esophagus, and stomach

F. **Defecation**: Elimination of undigested and unabsorbed waste (feces) from the body

VI. **Regulation of Digestion**

A. **Muscular Regulation**
1. **Sphincters**: Rings of muscle that control the passage of material
a. Upper esophageal sphincter
b. Cardiac (cardioesophageal) sphincter (between

esophagus and stomach)

c. Pyloric sphincter (between stomach and small intestine)

d. Hepatopancreatic ampulla sphincter

e. Anal sphincter

2. **Stomach churning (Retropulsion)**: Back-and-forth movement of chyme within the stomach when sphincters are closed

B. **Hormonal Regulation (e.g., from enteroendocrine cells in small intestine)**

1. **Cholecystokinin (CCK)**: Stimulates gallbladder contraction (bile release) and pancreatic enzyme secretion
2. **Secretin**: Stimulates liver bile release, pancreatic bicarbonate ion secretion, and stomach motility

C. **Nervous Regulation**

1. **Enteric nerves**: Local control over gut muscles
2. **Vagal stimulation (Vagus nerve)**: Provides nervous input to digestive organs

VII. **Nutrient Utilization and Homeostasis**

A. **Nutrient Classes and Building Blocks**

1. **Proteins**: Polymers of amino acids (9 essential amino acids must be obtained from diet)
2. **Carbohydrates**: Polysaccharides (starch, glycogen), disaccharides, and monosaccharides (e.g., glucose, major fuel)
3. **Fats (Triglycerides)**: Composed of glycerol and three fatty acids (efficient energy storage)

B. **Cellular Respiration**

1. Biochemical pathway in mitochondria that extracts chemical

energy from digested subunits (monosaccharides, fatty acids, amino acids)

2. Converts energy into **ATP molecules** (temporary energy storage)
3. Produces carbon dioxide and water as byproducts

C. **Glucose Homeostasis (Blood Sugar Balance)**

1. Maintained by the **pancreas** (endocrine function)
2. **Rising Blood Glucose (after absorption)**:
    a. Pancreas senses high glucose
    b. Releases **Insulin**
    c. Insulin causes liver (and muscles) to take up glucose and convert it into **glycogen (glycogenesis)** for storage
    d. Lowers blood glucose back to normal
3. **Falling Blood Glucose (hours after eating)**:
    a. Pancreas senses low glucose
    b. Releases **Glucagon**
    c. Glucagon causes liver to break down glycogen into glucose (**glycogenolysis**)
    d. Releases glucose into the blood, raising levels back to normal (critical for brain function)

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