# Online Physiology 2130 – Digestive System

## Introduction

Dear Student,
Thank you for opening this resource for Physiology 2130, and welcome. This resource has been created by the Education Team at WebStraw. The Education Team consists of students that have previously taken and/or students that are currently taking Physiology 2130.

## Purpose

This resource focuses on key concepts that are important for students to understand to succeed within this course. This resource was created by students for other students. Our goal is to help students (1) further develop their understanding of course content and (2) achieve greater academic success. (3) Our resource is also open access meaning there are no financial or legal barriers to students who wish to access and use our resource.

## Instructions

These study resources consists of several parts. The first part includes a condensed review of the major takeaways from each physiology module. This is followed by a series of questions and fill in the blank worksheets that should be completed after you have gone through the module and course material, in order to verify your understanding.

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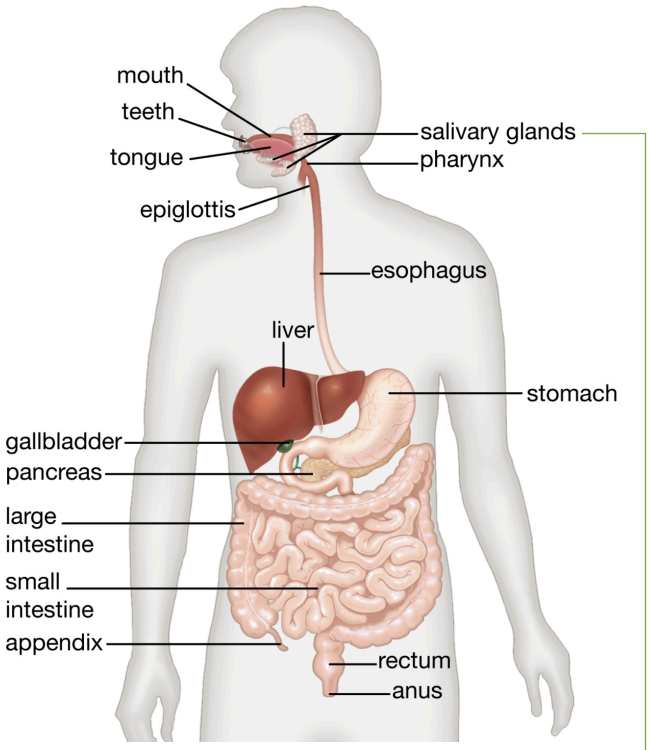
We wish you the best of luck on your exams!
The WebStraw Team

**Note to Instructors:** If this resource has been created for your course and you would like to collaborate with us, please email us at team@webstraw.ca

# Module 15 - Digestive System

| Biological Macromolecule | Building Blocks |
|---|---|
| Carbohydrates ↓ | Monosaccharides<br>Disaccharides<br>Polysaccharides |
| Proteins ↓ | Amino acids |
| Lipids | Fatty acids & glycerol |

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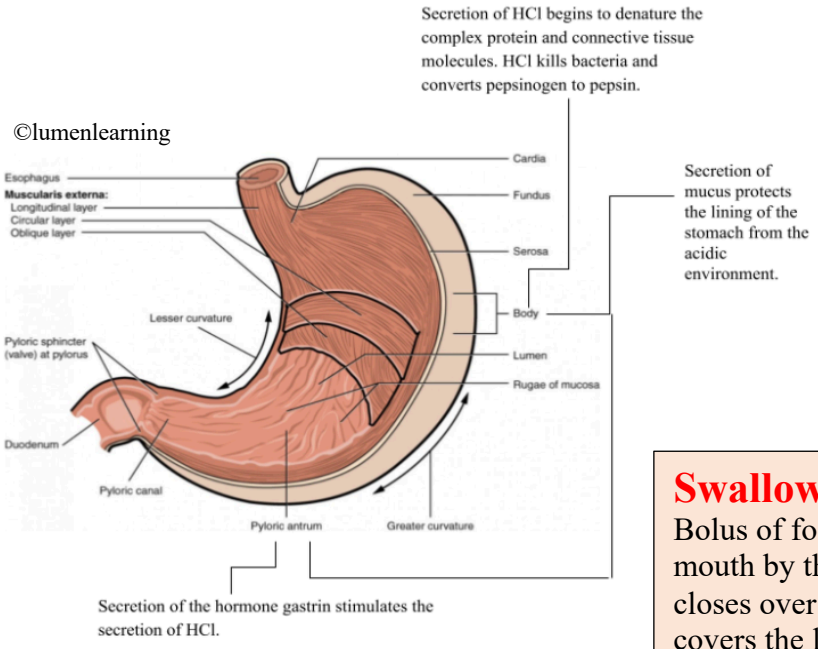
## Stomach

- Liquifies, mixes and stores the bolus of food
- Regulates amount of food entering the small intestine



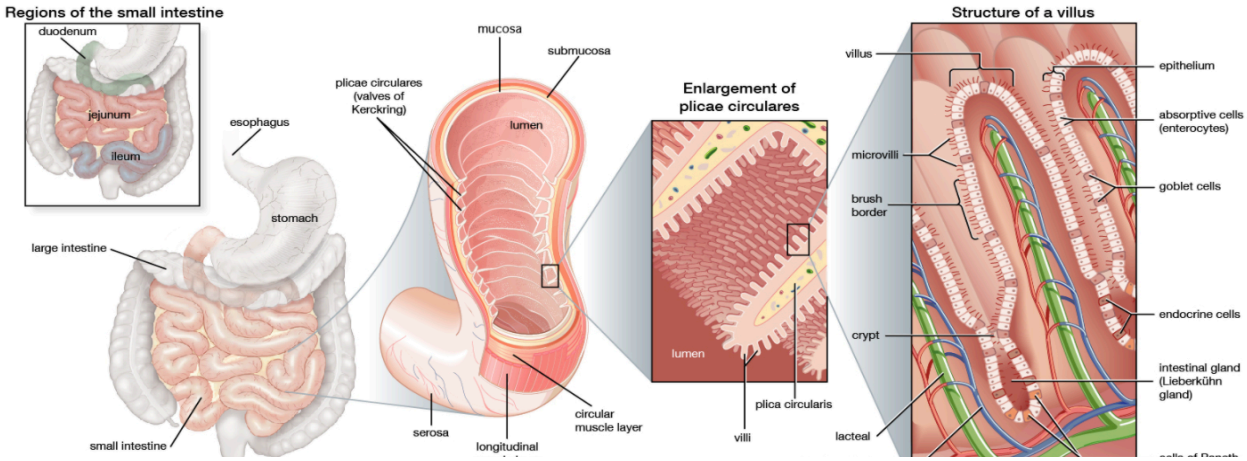

## Salivary Glands

- **Parotoid Gland**
  - Serosal, water secretion
- **Submandibular Gland**
  - Serosal and mucous secretion
- **Sublingual Gland**
  - Saliva (mostly mucous) secretion

## Swallowing

Bolus of food is lubricated with saliva → pushed to back of the mouth by the tongue → ***swallowing reflex*** initiates → uvula closes over the nasopharynx → ***larynx*** is lifted → ***epiglottis*** covers the larynx → bolus moves down the ***esophagus*** through the ***lower esophageal sphincter*** → into the stomach through a contraction **(peristalsis)**

## Small Intestine



## Types of Carbohydrates:

- **Monosaccharides -** single building block
- **Disaccharides -** two monosaccharides
- **Polysaccharides -** more than two units of monosaccharides

## Carbohydrate Absorption

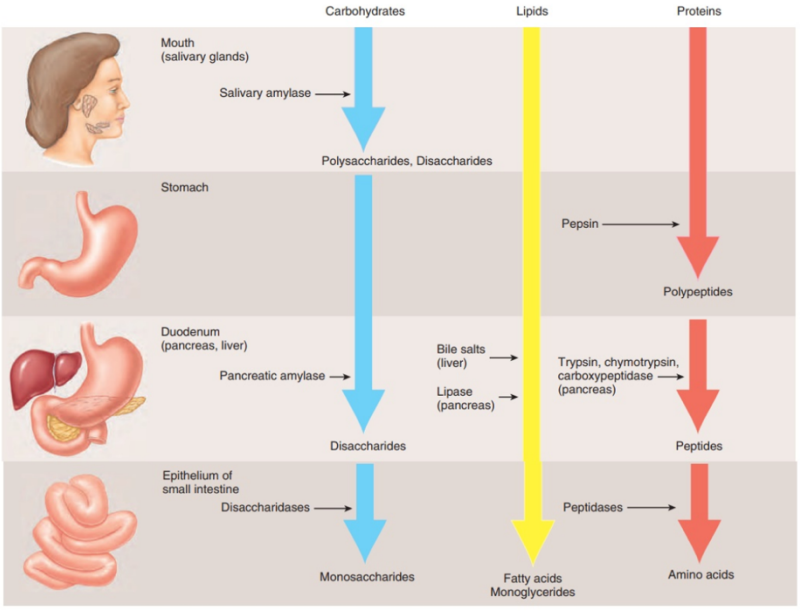
- Intestinal epithelial cells contain $Na^+/K^+$ pumps on their ***basal side***
  - Creating a concentration gradient for $Na^+$
- Concentration gradient strengthens the $Na^+$/glucose co-transporter (on the ***luminal side***)
- The co-transporter moves glucose **INTO** the cell as $Na^+$ moves in
- Glucose will then **DIFFUSE OUT** through the ***basal side*** by ***facilitated diffusion***

## Proteins

- Long chains of ***amino acids*** linked together
  - 11 ***nonessential*** amino acids
  - 9 ***essential*** amino acids

## Protein Absorption

- $Na^+$ moves **INTO** the intestinal epithelial cells, which powers a ***co-transporter*** that moves the amino acids **INTO** the cell
- Remaining peptides are absorbed by ***endocytosis***






## Carbohydrate Digestion

1. Begins in the mouth with **amylase** (salivary enzyme)
2. Amylase breaks up large polysaccharides into smaller polysaccharides and maltose
3. Due to the acidic environment, the digestion of carbohydrates ***stops*** in the stomach
   - Denaturation of salivary amylase occurs
4. After reaching the small intestine, digestion continues
   - Pancreas secretes amylase into the ***duodenum***
5. Pancreas secretes ***bicarbonate ions*** allowing neutralization in the stomach
   - Allows pancreatic amylase to perform digestion
6. Polysaccharides and disaccharides are digested to a monosaccharide with specific enzymes

## Protein Digestion

1. Beings in the stomach
2. HCl converts pepsinogen to pepsin (active enzyme form)
   - HCl helps uncoil long strands of protein
   - Pepsin digests them into polypeptides
3. Polypeptides pass through the pyloric sphincter into the small intestine
4. Secretion of bicarbonate (from the pancreas) neutralizes the chyme and allows ***pancreatic enzymes*** to continue digestion
   - Pepsin becomes inactivated due to neutral pH environment
5. ***Trypsin*** and ***chymotrypsin*** (from the pancreas) continue digestion in the small intestine
6. **Proteases** - digest proteins into amino acids
   - **Endopeptidases** - break the bonds between amino acids in **the *inner part*** of the protein
   - **Exopeptidases** - break the bonds between amino acids at the ***ends*** of the protein

## Fats and Lipids

- Triglycerides, phospholipids, cholesterol and long-fatty acids
    - Not water soluble

## Fat Digestion

- **Emulsification** - stomach churning; breaks up large fat drops into smaller ones
- **Bile** - is produced by the liver and stored in the gall bladder
    - Contains water, bile salts, fatty acids, and many ions
    - Bile salts keep the lipid droplets ***emulsified***
- Pancreas secretes ***colipase*** (protein) which allows ***lipase*** to access interior of fat droplets
- **Lipase** - digests the lipid interior, making them smaller
    - Attacks phospholipids leaving behind monoglycerides
    - Eventually, the droplets form small sphere-shaped structures called **micelles** which have a single layer of bile salts surrounding a small lipid droplet

## Water Absorption → 9 L/day

- 80% reabsorbed from water contained in:
    - Saliva
    - Digestive enzymes from the stomach and pancreas
    - Bile
    - Intestinal secretions
- 20% comes from drinking and food
- Amount reabsorbed in intestine varies
    - Duodenum + Jejunum: 44%
    - Ileum: 38%
    - Large intestine: 1.5%
- The remaining 100 mL is excreted in feces
- As glucose, amino acids, and lipids are absorbed, an osmotic gradient is built up
    - This causes water to enter cells by osmosis

## Large Intestine

- *Absorbs water and electrolytes to store and concentrate feces*
- Secretes mucus to protect its lining from chemical and mechanical damage and to lubricate the feces
- $K^+$ and bicarbonate are secreted into colon
- Small amount of digestion by bacteria happens
    - They produce gas (**flatus**) and Vitamin K

## Fat Absorption

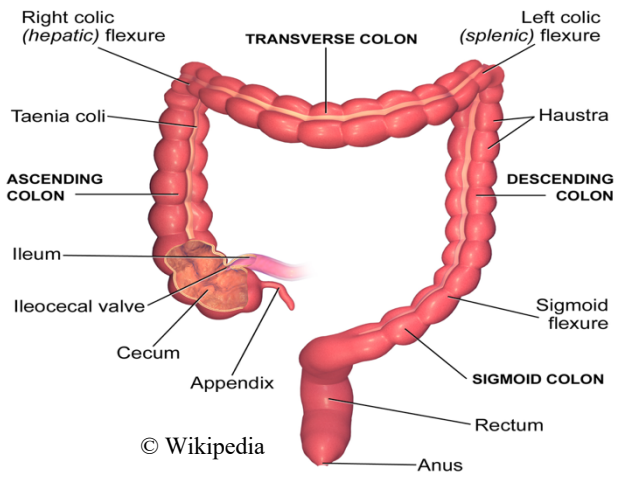
- Fatty acids and monoglycerides ***diffuse*** into the membrane of small intestinal epithelia
- Cholesterol is transported by an active transport system
- Leftover bile salts are reabsorbed by a transport system in the ileum
    - Returned to the liver and reused
- In the ***smooth ER***, monoglycerides and fatty acids combine with cholesterol to form ***chylomicrons***
    - Chylomicrons are packaged into secretory vesicles by Golgi apparatus
    - Chylomicrons enter lacteals and drain into circulatory system

## Vitamin Absorption

- Lipid-soluble vitamins diffuse directly through cell membrane
    - Vitamins A, D, E and K
- Water-soluble vitamins are absorbed into the cell by carrier-mediated mechanisms
    - Folic acid, niacin, and Vitamin B and C

## Ion absorption

- $Na^+/K^+$ pump on the basal side establishes a $Na^+$ concentration gradient (low inside, high outside)
    - $Na^+$ moves into the cell ***down*** its concentration gradient
- $K^+$ is passively absorbed
    - Its concentration increases in the lumen and creates a concentration gradient favoring the passive diffusion of $K^+$ into the cell



**Enteric Nervous System (ENS)**

- ANS alters activity of nerves in the enteric nervous system which affects the secretory cells, smooth muscle in the walls of the digestive tract, and endocrine cells
- Functions through 2 types of reflex loops
  - **Long loops**
  - **Short loops**

**Long Loops** – travel through the CNS

- Include input from higher brain centers
- Stimulated by ***sight* or *smell*** of food, which is detected by sensors
- Signals are sent through ***parasympathetic nervous system*** to the enteric nervous system to alter digestive function
  - Enzyme release and gastric motility

**Short Loops** – travel locally within digestive system

- Stimulated by ***stretching*** or ***chemical changes*** (pH, osmolarity) within the stomach
- ENS sensors in the stomach wall detect changes and initiate a reflex
- Reflex activates effector organs:
  - Secretory cells release enzymes
  - Smooth muscle alters gastric motility

## Gastrointestinal Motility

- Muscular contractions of the stomach and intestine mix the food and propel it through the digestive tract
- Specialized smooth muscle cells called **interstitial cells** surround the digestive tract and act like pacemaker cells
  - Cells spontaneously alter their membrane potentials, producing **basal electrical rhythms (BERs)** that travel down the digestive tract
  - Slow waves travel from smooth muscle cell-to-cell via gap junctions
- BER frequency varies:
  - Stomach: 3 waves/minute
  - Duodenum: 12 waves/minute
- Smooth muscles ***contract*** when the peak of the slow wave reaches threshold
  - This requires an ***additional mechanical, nervous or hormonal signal***

## Gastric Acid Secretion Phases

1. **Cephalic phase** – refers to the ***brain***
   - Stimulated by sight, smell, taste and chewing
   - Involves activation of the ENS through long loop
   - Trigger PNS to activate ENS causing parietal cells to release HCl and G cells to release gastrin
   - Stomach motility increases
2. **Gastric phase** – refers to the ***stomach***
   - Stimulated by presence of food in stomach (mechanical) and amino acids (chemical) from protein breakdown
   - Triggers short loop reflex → causing release of HCl, gastrin and pepsinogen
   - Increases gastric motility
3. **Intestinal phase** – refers to ***intestine***
   - Stimulated by glucose, fat, and acidic chyme in intestine
   - Decreases motility and inhibits secretions in stomach
   - Performed by ENS and secretin, CCK, and glucose-dependent insulinotropic peptide

## Intestinal Hormones *can regulate gastric motility and secretion of digestive enzymes*

- **Secretin** – released in response to presence of ***acid*** in intestine
  - Inhibits emptying from stomach
  - Causes release of pancreatic bicarbonate and bile from liver
- **Cholecystokinin (CKK)** – released in presence of ***fats***
  - Slows emptying from stomach
  - Stimulates pancreas to release digestive enzymes and causes ***gall bladder*** to contract which releases bile
- **Glucose-dependent insulinotropic peptide** – secreted in response to *glucose* and *amino acids*
  - Stimulates release of insulin from pancreas
  - May inhibit emptying from the stomach

## Gastric Hormones

- ***Gastrin*** is secreted by ***G cells*** located in the antrum of the stomach in response to the presence of:
  - Proteins
  - Mechanical stretching from food
  - Stimulation from PNS
- Primary function of gastrin: secretion of HCl which converts pepsinogen to pepsin, allowing it to begin digesting proteins

**Review Questions**

1. Which of the following mechanical and chemical stimuli does NOT activate digestive activity?
   1) pH of chyme
   2) End products of digestion
   3) Osmolarity
   4) Contraction of the GI tract

      a. 1 & 3 only
      b. 1, 2, & 3 only
      c. 2 & 4 only
      d. 4 only

2. During protein absorption, Na+ moves _____ the intestinal epithelial cells and the co-transporter moves the amino acids _____ the cell.
   a. Into; Into
   b. Into; Out
   c. Out; Out
   d. Out; Into

3. Which of the following regarding bile is incorrect?
   a. Bile is made in the liver and stored in the gall bladder
   b. Bile contains water, bile salts, fatty acids, and many ions
   c. Bile directly digests the lipid interior, making them smaller
   d. Bile salts keep the lipid droplets emulsified

4. Basal electrical rhythms (BERs):
   a. Are generated spontaneously by interstitial cells
   b. Always create muscle contractions as they always reach threshold
   c. Their frequency is the same throughout the digestive tract
   d. Do not require an additional stimulus to generate muscle contractions

5. Which of the following incorrectly pairs an enzyme with its required stimulus?
   a. Secretin; acid in the intestine
   b. Cholecystokinin (CCK); fats
   c. Gastrin; glucose
   d. Glucose-dependent insulinotropic peptide; glucose

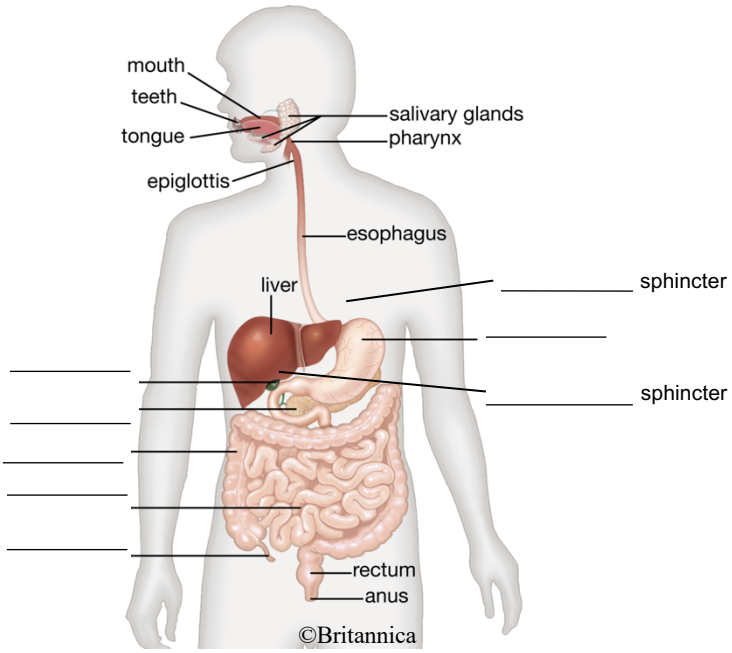
6. Which of the following does not occur in the large intestine?
   a. Absorption of water and electrolytes
   b. Concentration and storage of feces
   c. A small amount of digestion
   d. Release of CCK to excrete fats

**Answers:**
1.D 2. A 3.C 4.D 5.C 6.D

Fill in the blanks:

## Swallowing

_____ of food is lubricated with saliva → pushed to back of the mouth by the tongue → _____ initiates → uvula closes over the nasopharynx → _____ is lifted → _____ covers the larynx → bolus moves down the _____ through the _____sphincter → into the stomach through a contraction (_____)




## Carbohydrate Digestion

| Enzyme | Substrate | Origin | Site of Action |
|---|---|---|---|
| Salivary amylase | Oligosaccharides | Mouth | Mouth |
| Pancreatic amylase | | | |
| Brush border enzymes | | | |

## Protein Digestion

| Enzyme | Zymogen | Substrate | Origin | Site of Action |
|---|---|---|---|---|
| Pepsin | | | | |
| Pancreatic enzymes: _____, _____, _____ | _____, _____ | | | |
| Brush border enzymes | N/A | | | |

## Lipid Digestion

| Enzyme | Substrate | Origin | Site of Action |
|---|---|---|---|
| Lipase | | | |
| Colipase | **Action:** | | |
| Bile salts | **Action:** | | |

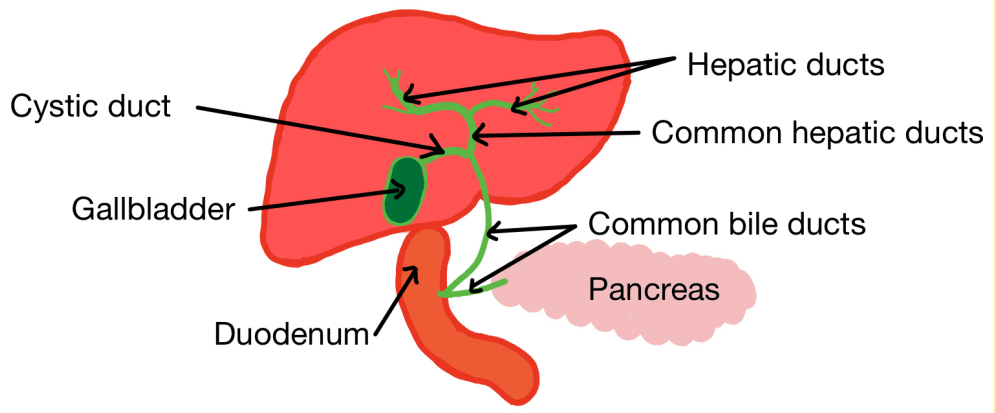
**Think About This: Why is liver cirrhosis associated with vitamin A deficiency?**
Liver cirrhosis results in the liver producing fewer bile salts, hindering the body's ability to digest lipids properly in the duodenum. This will result in malabsorption of Vitamin A, a lipid-soluble molecule.

Circle the correct answer:

| Salivary gland | Serosal | Mucosal |
|---|---|---|
| Parotid gland | Yes / No | Yes / No |
| Submandibular gland | Yes / No | Yes / No |
| Sublingual gland | Yes / No | Yes / No |

Creating ***mnemonics*** for certain pieces of information that are harder to remember is a good strategy for making information stick in your head. Creating a mnemonic that has a personal connection to you is even better! Start by finding two items that you want to pair and try to find a connection between the them.
**Example mnemonic:**
Chief cells secrete pepsinogen → The **chief** executive officer (CEO) created **pepsi**(nogen)

**Real-world example: Gallstones**
The gallbladder is responsible concentrating bile, so cholesterol-based gallstones often form there in people on a high-cholesterol diet. Gallstones can get lodged within the ductal system connecting the liver to the gallbladder and also the duodenum and pancreas. Bile, along with pancreatic secretions, enters the duodenum via the common bile duct. Thus, gallstones may block these secretions from entering the small intestine, hindering digestion. A cholecystectomy, or removal of the gallbladder, can be performed to treat chronic gallstones. Post-surgery, bile will be constantly secreted into the duodenum from the liver (even if there is no meal) since it cannot be stored in the gallbladder. Consequences of a cholecystectomy include constipation, cramping, and diarrhea. These effects are due to the fact that bile can no longer be concentrated by the gall bladder → poorer lipid digestion → undigested lipids travel to the large intestine and are fermented by bacteria.




**Module 15 Conceptual Questions**

1. Draw the pathway of a short loop reflex using the following: internal (GI) stimulus, sensors, local plexus, effectors, response. Give an example of a short loop reflex.

2. Draw the pathway of a long loop reflex using the following: internal (GI) stimulus, sensors, local plexus, external stimulus, CNS, effectors, response. Give an example of a long loop reflex.

Answer Key:

**Carbohydrate Digestion**

| Enzyme | Substrate | Origin | Site of Action |
|---|---|---|---|
| Salivary amylase | Oligosaccharides | Mouth | Mouth |
| Pancreatic amylase | Oligosaccharides | Pancreas | Small intestine |
| Brush border enzymes | Disaccharides | Small intestine | Small intestine |

**Protein Digestion**

| Enzyme | Zymogen | Substrate | Origin | Site of Action |
|---|---|---|---|---|
| Pepsin | Pepsinogen | Proteins | Stomach | Stomach |
| Pancreatic enzymes: trypsin, chymotrypsin | Trypsinogen, chymotrypsinogen | Large polypeptides | Pancreas | Small intestine |
| Brush border enzymes | N/A | Small peptides, Di/Tripeptides | Small intestine | Small intestine |

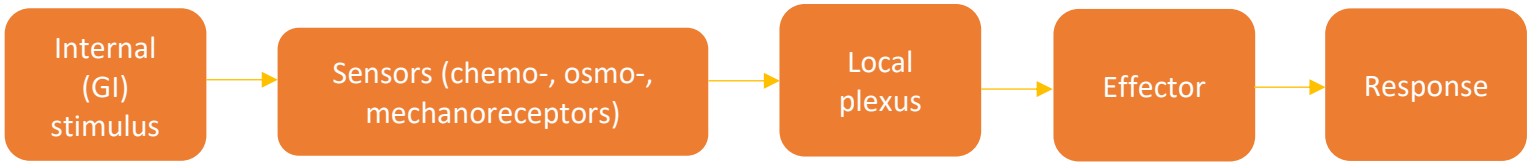
**Lipid Digestion**

| Enzyme | Substrate | Origin | Site of Action |
|---|---|---|---|
| Lipase | Triglycerides | Mouth, stomach, pancreas | Stomach/Small intestine |
| Colipase | **Action**: allows lipase to access interior of fat droplets | Pancreas | Small intestine |
| Bile salts | **Action:** emulsification of lipids | Liver | Small intestine |

Circle the correct answer:

| Salivary gland | Serosal | Mucosal |
|---|---|---|
| Parotid gland | **Yes** / No | Yes / **No** |
| Submandibular gland | **Yes** / No | **Yes** / No |
| Sublingual gland | Yes / **No** | **Yes** / No |

1.




2.