Sample answer to Digestive System XC Assignment (by a former student)

**Mouth:**

- The mouth is the first portion of the alimentary canal.
- It receives food & begins digestion by mechanically breaking up solid particles into smaller pieces by chewing with teeth which increases the surface area of the food particles, enabling digestive enzymes to interact more effectively with nutrient molecules.
- The 3 major salivary gland pairs are the parotid, submandibular and sublingual. They produce saliva. Many minor salivary glands are scattered throughout the mucosa of the tongue, palate and cheeks. They continuously secrete fluid to keep the mouth moist.
- Parasympathetic impulses result in a large volume of watery saliva to be produced when a person sees, smells, tastes or thinks about pleasant food.
- The tongue mixes food particles with saliva during chewing and moves food toward the pharynx during swallowing.
- Mucous glands secrete mucous which binds food particles and acts as a lubricant for swallowing.
- Saliva contains salivary amylase – an enzyme that splits starch & glycogen molecules into disaccharides – the 1st step in the chemical digestion of carbohydrates.
- Saliva also contains some lipase to begin digestion of fats.

**Swallowing:**

- After the food is chewed and mixed with saliva the tongue rolls the mix into a mass and forces it into the pharynx. (Voluntary)

**Pharynx:**

- The mix reaches the pharynx and stimulates sensory receptors that trigger the swallowing reflex.
  1. soft palate (including uvula) raises. (prevents food from entering nasal cavity)
  2. hyoid bone & larynx elevated, epiglottis closes off the top of the trachea (so food doesn’t go into trachea)
3. tongue pressed against soft palate and uvula, sealing off oral cavity from pharynx

4. longitudinal muscles in pharyngeal wall contract, pulling pharynx up toward food

5. lower portion of the inferior constrictor muscles relax, opening esophagus

6. superior constrictor muscles contract, stimulating a peristaltic wave to begin in other pharyngeal muscles. This wave forces the food into the esophagus.

- Food passes through oropharynx, posterior to mouth and laryngopharynx (from oropharynx down to esophagus).

**Esophagus:**

- The esophagus is a passageway for food to the stomach. Mucous glands scattered throughout the submucosa of the esophagus moisten and lubricate the inner lining of the tube.

- Peristalsis transports food in the esophagus to the stomach

- Just superior to the point where the esophagus joins the stomach circular muscle fibers have increased sympathetic muscle tone forming the lower esophageal sphincter or cardiac sphincter. Usually contracted to close the entrance to the stomach.

- When peristaltic waves reach the stomach, muscle fibers of the lower esophageal sphincter relax briefly to allow swallowed food to enter.

**Stomach:**

- During the Cephalic Phase of gastric secretion Acetylcholine released in nerve endings in response to parasympathetic impulses arriving on vagus nerves stimulate gastric secretion (abundant gastric juice) at the taste, smell, sight or thought of food.

- The second phase or Gastric Phase begins when the food enters the stomach. The presence of food and the distension of the stomach wall triggers the stomach to release the hormone gastrin which stimulates production of more gastric juice. More food enters, more gastrin is produced and pH begins to rise from dilution of stomach acid.

- The stomach is lined with gastric glands:

  1. Chief cells that secret the digestive proenzyme, pepsinogen.
2. Parietal cells that release Hydrochloric acid solution.

   \textbf{Alkaline tide}: hydrogen ions are removed from the blood and an equivalent number of alkaline bicarbonate ions released into the blood after a meal. The blood concentration of bicarbonate ions increases so the urine excretes the extra.

3. Mucous cells (goblet cells)

   - The mix of the products of these glands is called gastric juice.

   - Gastric juice is made continuously but the rate varies and is controlled neurally and hormonally.

   - Parasympathetic and the hormone gastrin promote release of histamine from gastric mucosal cells which stimulates additional gastric secretion.

   - The stomach is coated by mucous from the mucous cells.

   - The chief cells secrete pepsinogen which, when comes into contact with hydrochloric acid from the parietal, cells turns into pepsin.

   - Pepsin begins digestion of nearly all types of protein (breaking them down).

   - Gastric juice contains small amounts of the enzyme gastric lipase and its action is weak due to the low pH of gastric juice but it acts mainly on butterfat.

   - Intrinsic factor in gastric juice from the parietal cells is required for vitamin B_{12} absorption in the small intestine.

   - The stomach mixes the food with gastric juice and creates chyme. Peristaltic waves move chyme toward the pyloric sphincter.

   - The stomach is not adept at absorption, it only absorbs some water, certain salts, certain lipid soluble drugs and alcohol.

   - Fatty foods may stay in the stomach for 3 – 6 hours.

   - Food high in protein move quickly.

   - Carbohydrates move even more rapidly than fats or proteins.

   - Peristaltic waves relax the pyloric sphincter which admits some chyme into the duodenum.
**Small Intestine:**

- The small intestine is so effective in absorbing digestive products, water and electrolytes that very little absorbable material reaches organ's distal end.

- The 3<sup>rd</sup> phase of gastric secretion (Intestinal Phase) begins when food leaves the stomach and enters the small intestine.
  
  o When food first contacts the intestinal wall it stimulates intestinal cells to release the hormone, intestinal gastrin that enhances gastric gland secretion. As more food moves into the small intestine a sympathetic reflex triggered by acid in the upper part of the small intestine inhibits secretion of gastric juice from the stomach wall. At the same time proteins and fats in this region of the intestine stimulate release of the peptide hormone cholecystokinin (CCK) from the intestinal wall which decreases gastric motility. Fats in the intestine stimulate the release of intestinal somatostatin from the intestinal cells which inhibit the release of gastric juice.

- When food first enters the small intestine it also increases the mucous secretion in the small intestine in response to mechanical stimulation and the presence of irritants (gastric juice).

- Distension of the intestinal wall activates nerve plexuses and stimulates parasympathetic reflexes that also trigger small intestine secretions.

- As chyme fills the duodenum the intestinal wall stretches stimulating sensory receptors which trigger the enterogastric reflex which causes fewer parasympathetic impulses arriving at the stomach inhibiting peristalsis and intestinal filling slows.

- If chyme is fatty the intestinal wall releases cholecystokinin which further inhibits peristalsis.

- In response to the acid in chyme, the hormone secretin is released into the blood from the duodenal mucous membrane. It stimulates the pancreas to secrete a large quantity of fluid which contains few, if any, digestive enzymes but a high concentration of bicarbonate ions to neutralize the acid in the chyme.

**Pancreatic Juice:**

During the cephalic and gastric phase of gastric secretion parasympathetic impulses stimulate the pancreas to release enzymes. The nervous and endocrine system regulate the release of Pancreatic Juice which contains:

- Pancreatic amylase which splits molecules of starch or glycogen into disaccharides.

- Pancreatic lipase which breaks triglycerides into fatty acids and monoglycerides
- Trypsinogen, chymotrypsin, and carboxypeptidase which split bonds between particular combinations of amino acids in proteins.

- Trypsinogen, chymotrypsin, and carboxypeptidase are secreted in inactive form and are activated by other enzymes after they reach the small intestine.

Trypsinogen activated to trypsin when it comes in contact with enterokinase which is secreted from the mucosa of the small intestine. Trypsin activates chymotrypsin and carboxypeptidase.

- Also contains two types of nucleases; enzymes that breakdown nucleic acid molecules into nucleotides plus high concentration bicarbonate ions make juice alkaline to help enzymes and neutralize acidic chyme.

- Proteins and fats in chyme in duodenum stimulate the release of CCK from the intestinal wall which reaches the pancreas by way of the bloodstream. CCK stimulates the pancreas to release a high concentration of digestive enzymes.

- The pancreatic duct joins with the bile duct from the liver and gallbladder and the pancreatic juice and bile go into the duodenum through the hepatopancreatic sphincter, which is relaxed by the action of CCK.

**Liver/Bile Production:**

- uses carbohydrates to help maintain normal concentration of blood glucose:

- liver’s effects on lipid metabolism:
  - oxidizing fatty acids at a high rate
  - synthesizing lipoproteins, phospholipids and cholesterol; and converting portions of carbohydrate and protein molecules into fat molecules
  - blood transports fats synthesized in the liver to adipose tissue for storage

- Livers role in protein metabolism
  - Deaminates amino acids; forming urea
  - Synthesizing plasma proteins and converting certain amino acids to other amino acid

- Liver stores glycogen, iron, vitamins A, D, B₁₂
  - Extra iron combines with protein becomes ferritin, stored until blood iron concentration falls then release
- Secretes Bile containing an abundant supply of bile salts (made with cholesterol)
  - Aid digestive enzyme

**Gall bladder/Bile:**

- The gall bladder releases stored bile into the duodenum through the hepatopancreatic sphincter when stimulated by CCK from the small intestine (in response to proteins and fats in the small intestine).
- Bile salts from the bile aid digestive enzymes causing emulsification of fats (breaking globules into droplets) which increases the total surface area of the fatty substances and results in droplets. The droplets mix with water. Lipases can then digest the fat molecules more effectively.
- Bile salts enhance absorption of fatty acids and cholesterol by forming complexes (micelles) that are very soluble in chyme and that epithelial cells can more easily absorb.
- Fat soluble vitamins A,D,E and K are also absorbed in the presence of bile salts.

**Small Intestine:**

- Lined by intestinal villi and microvilli which are most numerous in the duodenum and proximal portion of the jejunum and the presence of Plicae circulares the surface area of the intestinal lining is greatly enlarged for aiding in the absorption of digestive products.
- Blood capillaries and lacteals carry away absorbed nutrients and impulses transmitted by the nerve fibers can stimulate or inhibit the activities of the villus.
- Epithelial cells of the intestinal mucosa have digestive enzymes embedded in the membranes of the microvilli on their luminal surfaces. These enzymes break down food just before absorption takes place:
  - Peptidases split peptides into their constituent amino acids
  - Sucrase, maltase and lactase split the disaccharides sucrose, maltose and lactose into monosaccharides glucose, fructose and galactose.
  - Intestinal lipase splits fats into fatty acids and glycerol.
- Carbohydrate digestion begins in the mouth and is completed in the small intestine by enzymes from the intestinal mucosa and pancreas. The resulting monosaccharides are absorbed by facilitated diffusion or active transport into the villi and enter blood capillaries.
- Protein digestion begins in the stomach as a result of pepsin activity and completed in the small intestine by enzymes from the intestinal mucosa and pancreas. Large protein molecules ultimately broken down into amino acids which are absorbed into the villi by active transport and enter circulation.

- Fat molecules digested almost entirely by enzymes from the intestinal mucosa and pancreas resulting fatty acid molecules absorbed in following steps:
  
  o Fatty acid molecules dissolve in epithelial cell membranes of the villi and diffuse through them
  
  o Endoplasmic reticula of the cells use the fatty acids to resynthesize fat molecules similar to those previously digested.
  
  o These fats collect in clusters that become encased in protein
  
  o Resulting large molecules of lipoproteins are called chylomicrons and they make their way to lacteals of the villi
  
  o Periodic contractions of smooth muscles in the villi help empty the lacteals into the cysterna chili an expansion of the thoracic duct. Lymph carries chylomicrons to the blood stream

- Chylomicrons and blood transport dietary fats to muscle and adipose cells.

- VLDL molecules (produced in liver) transport tryglycerides synthesized from excess dietary carbohydrates. As VLDL molecules reach adipose cells, the enzyme lipoprotein lipase, catalyzes reactions that unload their triglycerides converting VLDL to LDL molecules. Because most triglycerides were removed LDL’s have higher cholesterol content then the original VLDL molecules.

- Cells in peripheral tissues remove LDL from plasma by receptor-mediated endocytosis, obtaining a supply of cholesterol.

- HDL removes cholesterol from tissues and delivers to liver; Liver disposes of it by secreting into bile or uses it to make bile salts.

- Intestine reabsorbs much of the cholesterol and bile salts in the bile which are transported back to the liver and the cycle repeats. During each cycle some escapes re-absorption and reaches the large intestine and is eliminated with the feces.

- Electrolytes are usually absorbed by active transport and water by osmosis.
**Small Intestine Movement:**

- Mixing and peristalsis are enhanced by the parasympathetic nervous system and inhibited by the sympathetic nervous system.

- Segmentation (major mixing movement) cuts chyme into segments and moves it back and forth also slows movement of chyme through small intestine.

- Peristaltic waves propel the chyme through the small intestine- they are weak and slow chyme takes 3 – 10 hours to travel the length of the small intestine.

- Reflexes involving parasympathetic impulses to the small intestine sometimes originate in the stomach. Food filling the stomach initiates the gastroenteric reflex which increases peristaltic activity in the small intestine. When the duodenum fills with chyme, stretching its wall, a reflex speeds the movement through the small intestine.

- At the distal end of the small intestine is the ileocecal sphincter joining the small intestine to the large intestine’s cecum. Eating a meal illicits the gastroileal reflex that increases peristalsis in the ileum and relaxes the sphincter forcing some of the small intestine contents into the cecum.

**Large Intestine:**

- Chyme entering has few nutrients remaining, contains water, electrolytes, mucus and bacteria.

- Large Intestine absorbs ingested water and electrolytes remaining.

- Electrolytes absorbed by active transport.

- Water follows passively entering mucosa by osmosis.

- 90 % water entering large intestine is absorbed, little sodium or water lost in feces.

- Reabsorbs and recycles water and remnants of digestive secretions.

- Forms and stores feces.

- Intestinal flora break down some molecules that escape actions of human digestive enzymes.

- Bacteria synthesize vitamins, such as K, B_{12}, thiamine and riboflavin which intestinal mucosa absorbs.

- Bacterial actions may produce flatus.
- Food travels through the cecum, ascending, transverse, descending and sigmoid colon, the anal canal and past the internal anal sphincter (smooth muscle under involuntary control) and external anal sphincter muscle (skeletal muscle) under voluntary control.

- Mechanical stimulation from chyme and parasympathetic impulses control the rate of mucous secretion (mucous only significant secretion in large intestine)

- Mucous protects the canal from abrasion and also holds fecal matter together & helps control pH of the large intestine contents.

- Slower Movement (mixing and peristalsis) then in small intestine. Mixing movements, called haustral churning, break fecal matter into segments and turn so all portions are exposed to the intestinal mucosa (to help absorption)

- Peristaltic waves only occur 2 to 3 times a day. These peristaltic waves are called mass movements. Large sections of the intestinal wall contracts vigorously forcing contents toward rectum (usually following a meal) as a result of the gastrocolic reflex.

The defecation reflex is triggered by feces entering the rectum. As it fills the rectum its wall is distended and the defecation reflex is triggered stimulating peristaltic waves in the descending colon. As a result of this reflex, the rectal wall contracts, the internal anal sphincter is relaxed, and the external anal sphincter contacts.

- When it is appropriate to defecate a person initiates defecation by holding a deep breath and contracting the abdominal wall muscles which increase internal abdominal pressure and forces feces into the rectum.

- At same time, other reflexes involving the sacral region of the spinal cord strengthen the peristaltic waves, lower the diaphragm, close the glottis, and contract the abdominal wall muscles. These actions additionally increase abdominal pressure and squeeze the rectum. The external anal sphincter is signaled to relax and feces are forced to the outside.