SECTION 10 - DIGESTION AND NUTRITION

EXERCISE 10.1 HISTOLOGY OF THE GASTROINTESTINAL TRACT, LIVER, AND PANCREAS

Approximate Time for Completion: 1-2 hours

Introduction

This exercise is designed to introduce students to the histology of the gastrointestinal tract, liver, and pancreas. Students will understand and recall the functions of these systems much better if they study and can visualize the structure of these tissues. This exercise may be combined with exercise 10.2 whose procedures require long incubation periods.

Materials

1. Microscopes
2. Prepared tissue slides of the digestive system

Textbook Correlations: Chapter 18 – Esophagus and Stomach, Small Intestine, Large Intestine, Liver, Gallbladder, and Pancreas

Answers to Questions

1. (a) parietal cells
   (b) chief cells
   (c) enterochromaffin-like cells
2. epithelium; lamina propria; muscularis mucosa
3. microvilli
4. villi; plicae circulares
5. hepatic portal vein
6. sinusoids
7. acini; (pancreatic) islets of Langerhans
8. Brunner's glands
9. The surface area of the small intestine is increased by the presence of plicae circulares, villi, and microvilli (brush border).
10. Pancreatic juice is a blend of water, bicarbonate, and a variety of digestive enzymes, including trypsin, lipase, and amylase. Bicarbonate buffers the acidic contents from the stomach, trypsin hydrolyzes polypeptides to amino acids, dipeptides, and tripeptides, and pancreatic amylase digests starch to maltose, maltriose, and oligosaccharides.
11. The liver is composed of a plate-like arrangement of hepatocytes in which each plate is only one cell thick. Blood travels in sinusoids between these plates allowing intimate interaction between the blood and the hepatocytes. Because of this intimate contact and because the sinusoids are lined by phagocytic Kupffer cells, the liver can modify the chemical composition of the blood. In contrast, bile travels between the hepatic plates in separate vessels called canaliculi and so is kept separated from the blood.
12. The epithelial cells that face the lumen of the small intestine produce many digestive enzymes. These enzymes are fixed within the microvilli along the membrane surface of these epithelial cells and work to digest polymers into monomers as food passes by. These fixed "brush border" epithelial enzymes also activate many of the inactive pancreatic juice enzymes as they enter the duodenum, thereby enhancing the digestive activity.

13. No. Grinding up the pancreas will release hormones from the islets of Langerhans (endocrine) but also will release many powerful digestive enzymes (exocrine) into the homogenate. Since insulin is a protein hormone (and a small one), the digestive action of the released trypsin, chymotrypsin, carboxypeptidase, and others polypeptidases would fragment any insulin molecules into products unrecognizable as the hormone.

EXERCISE 10.2 DIGESTION OF CARBOHYDRATE, PROTEIN, AND FAT

Approximate Time for Completion: 2-3 hours

Introduction

This exercise is designed to demonstrate the activity of selected digestive system enzymes on carbohydrate (starch), protein (albumin), and fat (oil). The enzymes observed are amylase (saliva), pepsin (stomach), and lipase (pancreas). Students will also see how pH and temperature affect enzyme activity. Reviewing principles of enzyme activity at this time would be very helpful to students.

Materials

1. Water bath (set at 37°C), Bunsen burners, test tubes, droppers, test-tube clamp, graduated cylinders
2. Starch solution: dissolve 1.0 g/100 ml over heat
3. Iodine (Lugol's reagent): dissolve 1.0 g iodine and 2.0 g potassium iodide in 300 ml of water
4. Benedict's reagent: dissolve 50.0 g sodium carbonate, 85.0 g sodium citrate, and 8.5 g copper sulfate in 5.0 liters of water
5. As an alternative to saliva, α-amylase (type VI-B from porcine or human pancreas) may be used. Dilute to a concentration of about 300 units per ml, equivalent to saliva. Amylase may be purchased as a solid with 500,000 units of activity (order A-3176) from Sigma Chemical Company at (800) 325-3010.
6. Freezer or ice bath; white of hard-boiled eggs
7. Pepsin (5 g/dl), 2 N HCl, 10 N NaOH
8. pH meter or short-range pH paper
9. Pancreatin solution (1 g/dl), bile salts, cream or vegetable oil

Textbook Correlations: Chapter 18 – Digestion and Absorption of Carbohydrates, Lipids, and Proteins

Answers to Questions

1. amylase
2. pepsin; 2.0
3. lipids
4. liver hepatocytes; gallbladder
5. emulsify lipids
6. chylomicrons
7. Following incubation, tubes 1 and 4 in exercise "A" contained the most starch and tube 2 contained the most reducing sugar. Salivary amylase therefore, functions best at a neutral pH and is at least partially destroyed by boiling.
8. Following incubation, the most digestion of egg albumin (protein) in exercise "B" occurred in tube 2. This shows that the enzyme pepsin has both a pH optimum (acidic) and a temperature optimum (37ºC).
9. Hydrochloric acid (HCl) stimulated the digestive action of pepsin whereas HCl inhibited the digestive action of salivary amylase. This is due to the difference in chemical composition and structure that determines the pH optima of these two enzymes. Pepsin is adapted to work best in the acidic environment of gastric juice, whereas salivary amylase is adapted to work optimally at the nearly neutral pH of saliva.

10. Following incubation in exercise "C," test tube 3 displayed the most rapid fall in pH. This tube contained not only the substrate molecules (fat or oil) but also contained emulsifying agents (bile salts), and digestive enzymes (pancreatin) that together hydrolyzed the oil into fatty acid molecules. The increase in the number of fatty acid molecules lowers the pH of the solution.

11. Dietary triglycerides (fat) are first emulsified by bile salts and then hydrolyzed by lipase into free fatty acids and monoglycerides. Once fatty acids and monoglycerides enter the intestinal epithelial cells they are reassembled into triglycerides and packaged as chylomicrons. These chylomicrons are then secreted into the central lacteals and enter the lymphatic drainage for return to the blood via the thoracic duct. Dietary carbohydrates and proteins by contrast, are digested by hydrolysis into simple sugars and amino acids that are absorbed through the intestinal epithelial cells without reassembly. These smaller molecules are then secreted directly into the blood of the hepatic portal vein and taken to the liver for processing or systemic distribution.

12. The stomach doesn't normally digest itself because of the protective effects of mucus, the tight junctions between adjacent epithelial cells, and the rapid rate of cell division that acts to replace damaged epithelial cells. Gastric juice does not normally digest the duodenum because the acidic gastric juice is rapidly neutralized by the arrival of alkaline juice from the pancreas, and to a lesser extent by the alkaline bile arriving from the liver.

13. In part "A," if the tests for both starch (substrate) and reducing sugar (product) are positive at the end of a one hour incubation, one can conclude that the starch was partially digested. If the incubation had proceeded for two hours and the test for starch was negative, one can conclude that all starch was digested by the enzyme amylase.

14. While chewing on the bite of bread, amylase from saliva acts on the bread starch forming reducing sugars. After swallowing the bite however, the acidic gastric juice would inactivate salivary amylase. This was observed in tube 3, where the addition of HCl severely reduced the activity of amylase (less starch digestion).

15. As shown in part "B" tube 3, freezing inhibits the action of enzymes. With regard to foods, the enzymes that are especially important are those enzymes that hydrolyze protein. Food that is frozen keeps longer because the enzymes in organisms that promote decomposition (bacteria and fungi) at room temperature are inhibited under freezing conditions.

16. When gallstones block the excretion of bile from the liver, bilirubin will accumulate in the blood because it cannot be adequately excreted through the bile. The subsequent rise in tissue bilirubin levels causes jaundice. Furthermore, if the secretion of bile into the intestine is blocked, normal fat digestion and absorption will be impaired. This could reduce the absorption of fat-soluble nutrients and vitamins including vitamin K. A deficiency in vitamin K will impair the normal formation and action of plasma clotting factors; thereby accounting for the prolonged clotting time.

EXERCISE 10.3 NUTRIENT ASSESSMENT, BMR, AND BODY COMPOSITION

Approximate Time For Completion: 3 days at home; plus discussion and analysis of data

Introduction

This exercise is designed to introduce students to methods of measuring caloric intake and expenditure, and the effects of caloric balance on body weight and composition. This exercise requires students to measure both their caloric intake and expenditure over three days, and then examine how this affected their body weight. It may be easiest to assign students to perform this exercise individually, and then analyze their results during the laboratory period. Alternatively, this exercise can be used as a take-home project or expanded into an individual research project with nutrition references as required reading.

Materials

1. Home scale or physicians height-weight scale
2. Tape measure, fat calipers (if available)
3. Calorie counting reference: such as the U.S. Department of Agriculture Handbook, cookbooks, or popular diet books
4. Alternatively, the caloric value of foods, and the caloric expenditure of exercise, can be obtained from the web. Once good source is www.caloriecontrol.org. Another is www.nal.usda.gov/fnic/foodcomp/. You must have Adobe Acrobat (which can be downloaded here) to view this information.

Textbook Correlations: Chapter 19 – Nutritional Requirement, Regulatory Functions of Adipose Tissue

Answers to Questions

1. catabolism
2. about 9; about 4
3. carbohydrates
4. fat-soluble
5. basal metabolic rate
6. body mass index (BMI)
7. Anabolism is the part of metabolism in which larger, energy-reserve molecules are produced; catabolism is the part that breaks down larger molecules into smaller ones to release energy. You can tilt your body towards anabolism by eating. After eating, the secretion of insulin is increased while the secretion of glucagon is decreased.
8. The basal metabolic rate (BMR) is the minimum rate of caloric expenditure by the body shortly after awakening and at least 12 hours after the last meal. Physical activity increases metabolism and thus burns more calories to maintain or decrease body weight. Physical activity usually raises the total energy expenditure by at least 30%.
9. In the normal person, diets high in complex carbohydrates are healthier. This is because complex carbohydrates contain starch that is a lower calorie source of energy to meet the metabolic needs of the body. Fats have more than twice the calories per gram at nine. Furthermore, complex carbohydrates include dietary fibers, minerals, and vitamins such as those found in fruits, vegetables, legumes, and whole-grain cereals. Dietary fiber has been associated with improving overall health by promoting normal stool elimination, enhancing satiety, and lowering plasma cholesterol levels.
10. Since one pound of fat is equivalent to 3,500 kilocalories, twenty pounds of fat is equivalent to 70,000 kilocalories. This is 7,000 kilocalories per month for 10 months. Dividing 7,000 kilocalories per month by four weeks per month gives 1,750 kilocalories per week. The student must thus eat 1,750 kilocalories per week less than is consumed by metabolism or increase metabolic expenditure by the same amount to lose 20 pounds by graduation.
11. Dividing 1,750 kilocalories per week by seven days per week gives 250 kilocalories per day. Yes, this is certainly a practical weight loss program, as 250 kilocalories per day might be saved by merely substituting low-fat food for their equivalents (for example, baked potato instead of french fries, nonfat milk for whole milk, and others), or by eliminating a high-calorie snack (such as a candy bar, or chocolate malt, and others).
12. Dividing 250 kilocalories per day by 9 kilocalories per gram of fat gives about 28g of fat. Yes, this is a practical weight loss program for the average American student. Assuming that the average American diet is approximately 2,500 calories per day and approximately 36% of these calories are derived from fat (900 calories), the average intake of fat per day is 100 grams. A decrease of 28g of fat would be well tolerated (for example, a bowl of ice cream, the double cheese on a cheeseburger, and others). Note that even a 2,000-calorie per day intake at 36% fat (720 calories) represents 80 grams of fat per day and is still a prudent approach to weight loss without compromising the intake of fat-soluble nutrients and vitamins. The key definition to this problem is in the clinical significance section, part B.