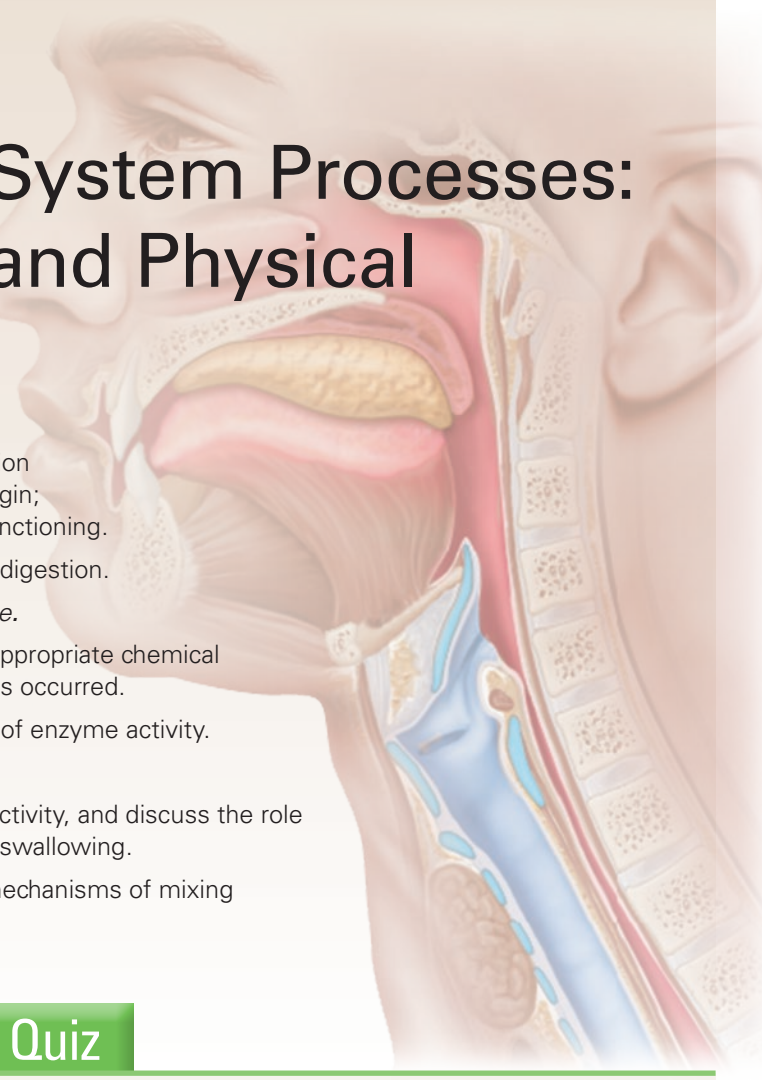
EXERCISE

39 Digestive System Processes: Chemical and Physical



Objectives

- ☐ List the digestive system enzymes involved in the digestion of proteins, fats, and carbohydrates; state their site of origin; and summarize the conditions promoting their optimal functioning.
- ☐ Name the end products of protein, fat, and carbohydrate digestion.
- ☐ Define *enzyme, catalyst, control, substrate,* and *hydrolase.*
- ☐ Describe the different types of enzyme assays, and the appropriate chemical tests to determine if digestion of a particular foodstuff has occurred.
- ☐ Discuss the role of temperature and pH in the regulation of enzyme activity.
- ☐ State the function of bile in the digestive process.
- ☐ Explain why swallowing is both a voluntary and a reflex activity, and discuss the role of the tongue, larynx, and gastroesophageal sphincter in swallowing.
- ☐ Compare and contrast segmentation and peristalsis as mechanisms of mixing and propulsion in digestive tract organs.

Materials

Part I: Enzyme Action

General Supply Area

- Hot plates
- 250-ml beakers
- Boiling chips
- Test tubes and test tube rack
- Wax markers
- Water bath set at 37°C (if not available, incubate at room temperature and double the time)
- Ice water bath
- Chart on board for recording class results

Activity 1: Starch Digestion

- Dropper bottle of distilled water

Text continues on next page. →

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Pre-Lab Quiz

1. Circle the correct underlined term. Enzymes are catalysts / substrates that increase the rate of chemical reactions without becoming a part of the product.
2. Circle True or False. Breakdown products of fats are absorbed by the lymphatic system and are then transported into the systemic circulation by lymph.
3. A(n) _____ is a specimen or standard against which all experimental samples are compared.
   a. assay **b.** control **c.** substrate **d.** trial
4. One enzyme that you will be studying today, produced by the salivary glands and secreted into the mouth, hydrolyzes starch to maltose. It is _____.
5. Circle True or False. When you use iodine to test for starch, a color change to blue-black indicates a positive starch test.
6. If Benedict's test in the starch assay produces a _____ precipitate, then your test will be recorded as positive for maltose.
   a. blue to black **b.** green to orange **c.** white
7. The enzyme _____, produced by the pancreas, is responsible for breaking down proteins.
   a. amylase **b.** kinase **c.** lipase **d.** trypsin
8. Circle the correct underlined term. The enzyme pancreatic lipase / pepsin hydrolyzes neutral fats to their component monoglycerides and fatty acids.
9. Circle True or False. Both smooth and skeletal muscles are involved in the propulsion of foodstuffs along the alimentray canal.
10. _____ movements are local contractions that mix foodstuffs with digestive juices and increase the rate of absorption.
    a. Deglutition **b.** Elimination **c.** Peristaltic **d.** Segmental

- Dropper bottles of the following:
  1% alpha-amylase solution*
  1% boiled starch solution, freshly prepared†
  1% maltose solution
  Lugol's iodine solution (IKI)
  Benedict's solution
- Spot plate

Activity 2: Protein Digestion

- Dropper bottles of 1% trypsin and 0.01% BAPNA solution

Activity 3: Bile Action and Fat Digestion

- Dropper bottles of 1% pancreatin solution, litmus cream (fresh cream to which powdered litmus is added to achieve a deep blue color), 0.1 *N* HCl, and vegetable oil
- Bile salts (sodium taurocholate)
- Parafilm® (small squares to cover the test tubes)

Part II: Physical Processes

Activity 5: Observing Digestive Movements

- Water pitcher
- Paper cups
- Stethoscope
- Alcohol swab
- Disposable autoclave bag
- Watch, clock, or timer

Activity 6: Video Viewing

- Television and VCR or DVD player for independent viewing of video by student
- *Interactive Physiology*®, Digestive System

PEx PhysioEx™ 9.1 Computer Simulation
Ex. 8 on p. PEx-119

** The alpha-amylase must be a low-maltose preparation for good results.*

† Prepare by adding 1 g starch to 100 ml distilled water; boil and cool; add a pinch of salt (NaCl). Prepare fresh daily.

The food we eat must be processed so that its nutrients can reach the cells of our body. First the food is mechanically broken down into small particles, and then the particles are chemically (enzymatically) digested into the molecules that can be absorbed. Food digestion is a prerequisite to food absorption. (You have already studied mechanisms of passive and active absorption in Exercise 5 and/or PhysioEx Exercise 1. Before proceeding, review that material.)

Digestion of Foodstuffs: Enzymatic Action

Enzymes are large protein molecules produced by body cells. They are biological **catalysts,** meaning that they increase the rate of a chemical reaction without themselves becoming part of the product. The digestive enzymes are hydrolytic enzymes, or **hydrolases.** Their **substrates,** or the molecules on which they act, are organic food molecules which they break down by adding water to the molecular bonds, thus cleaving the bonds between the chemical building blocks, or monomers.

Each enzyme hydrolyzes only one or a small group of substrate molecules, and specific environmental conditions are necessary for it to function optimally. Since digestive enzymes actually function outside the body cells in the digestive tract, their hydrolytic activity can also be studied in a test tube.

Figure 39.1 is a flowchart depicting the progressive digestion of carbohydrates, proteins, fats, and nucleic acids. It summarizes the specific enzymes involved, their site of formation, and their site of action. Acquaint yourself with the flowchart before beginning this experiment, and refer to it as necessary during the laboratory session.

General Instructions for Activities 1–3

Work in groups of four, with each group taking responsibility for setting up and conducting one of the following experiments. In each activity, you are directed to boil the contents of one or more test tubes. To do this, obtain a 250-ml beaker, boiling chips, and a hot plate from the general supply area. Place a few boiling chips into the beaker, add about 125 ml of water, and bring to a boil. Place the test tube for each specimen in the water for the number of minutes specified in the directions. You will also be using a 37°C bath and an ice water bath for parts of these experiments.

Upon completion of the experiments, each group should communicate its results to the rest of the class by recording them in a chart on the board. Each assay contains one or more **controls,** the specimens against which experimental samples are compared. All members of the class should observe the controls as well as the experimental results and be able to explain the tests used and the results observed and anticipated for each experiment.

Prepare for lab: Watch the Pre-Lab Video
MasteringA&P®>Study Area > Pre-Lab Videos

Activity 1

Assessing Starch Digestion by Salivary Amylase

1. From the general supply area, obtain a test tube rack, 10 test tubes, and a wax marking pencil. From the Activity 1 supply area, obtain a dropper bottle of distilled water and dropper bottles of maltose, amylase, and starch solutions.

2. In this experiment you will investigate the hydrolysis of starch to maltose by **salivary amylase.** You will need to be able to identify the presence of starch and maltose, the breakdown product of starch, to determine to what extent the enzymatic activity has occurred. Thus controls must be prepared to provide a known standard against which comparisons can be made. Starch decreases and sugar increases as hydrolysis occurs, according to the following formula:

$$\text{Starch} + \text{water} \xrightarrow{\text{amylase}} \text{maltose}$$

Text continues on p. 602. ➔

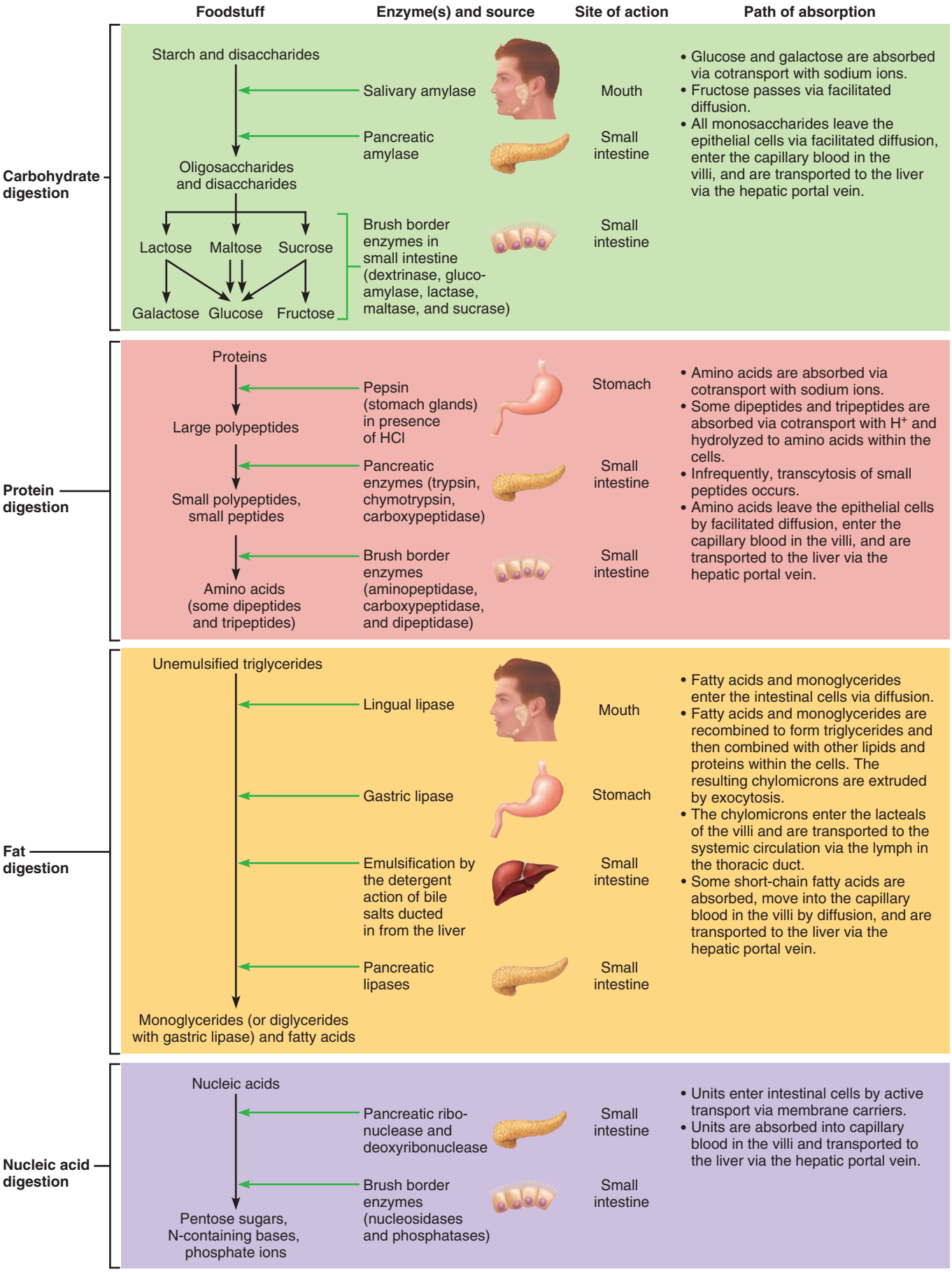


Figure 39.1 **Flowchart of digestion and absorption of foodstuffs.**

Two students should prepare the controls (tubes 1A to 3A) while the other two prepare the experimental samples (tubes 4A to 6A).

- Mark each tube with a wax pencil and load the tubes as indicated in the **Activity 1 chart** below, using 3 drops (gtt) of each indicated substance.
- Place tubes in the incubation conditions listed in the **Activity 1 chart** below for approximately 1 hour. Shake the rack gently from time to time to keep the contents evenly mixed.
- At the end of the hour, perform the amylase assay described below.
- While these tubes are incubating, proceed to Physical Processes: Mechanisms of Food Propulsion and Mixing (p. 606). Be sure to monitor the time so as to complete this activity as needed.

Amylase Assay

1. After one hour, obtain a spot plate and dropper bottles of Lugol's iodine solution (for the IKI, or iodine, test) and Benedict's solution from the Activity 1 supply area. Set up your boiling water bath using a hot plate, boiling chips, and a 250-ml beaker.

2. While the water is heating, mark six depressions of the spot plate 1A–6A (*A* for amylase) for sample identification.

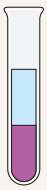
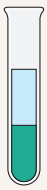
3. Using a pipet, transfer a drop of the sample from each of the tubes 1A–6A into the appropriately numbered spot. Into each sample drop, place a drop of Lugol's iodine (IKI) solution. A blue-black color indicates the presence of starch and is referred to as a **positive starch test.** If starch is not present, the mixture will not turn blue, which is referred to as a **negative starch test.** Record your results (+ for positive, – for negative) in the Activity 1 chart and on the board.

4. Into the remaining mixture in each tube, place 3 drops of Benedict's solution. Put each tube into the beaker of boiling water for about 5 minutes. If a green-to-orange precipitate forms, maltose is present; this is a **positive sugar test.** A **negative sugar test** is indicated by no color change. Record your results in the Activity 1 chart and on the board.

WHY THIS MATTERS | **Lactose Intolerance**

Lactose is a disaccharide found in milk and, to a lesser extent, in other dairy products. Lactose is hydrolyzed into glucose and galactose by the enzyme lactase. Infants usually produce lactase, but many individuals become lactose intolerant (lactase nonpersistent) as they mature. When lactose-intolerant individuals ingest dairy products, the bacteria in their colon react with lactose, producing gas, which causes bloating, flatulence, abdominal cramps, and diarrhea. Individuals who continue to produce lactase into adulthood are lactase-persistent and are able to metabolize lactose normally. Ingestion of probiotic bacteria has been found to reduce the symptoms of lactose intolerance, possibly because probiotic bacteria that produce their own lactase replace the gas-producing bacterial flora in the colon. ■

Activity 1: Salivary Amylase Digestion of Starch

Tube no.	1A	2A	3A	4A	5A	6A
Additives (3 gtt ea)	 amylase, water	 starch, water	 maltose, water	 amylase  boiled amylase, starch (Boil amylase 4 min, then add starch →)	 amylase, starch	 amylase, starch
Incubation condition	37°C	37°C	37°C	37°C	37°C	0°C
IKI test (color change)						
Result: (+) or (−)						
Benedict's test (color change)						
Result: (+) or (−)						

Additive key:

= Amylase = Starch = Maltose = Water

Protein Digestion by Trypsin

Trypsin, an enzyme produced by the pancreas, hydrolyzes proteins to small peptides. BAPNA (*N*-alpha-benzoyl-L-arginine-*p*-nitroanilide) is a synthetic trypsin substrate consisting of a dye covalently bound to an amino acid. Trypsin hydrolysis of BAPNA cleaves the dye molecule from the amino acid, causing the solution to change from colorless to bright yellow. The color change from clear to yellow is direct evidence of hydrolysis by trypsin.

Activity 2

Assessing Protein Digestion by Trypsin

1. From the general supply area, obtain five test tubes and a test tube rack, and from the Activity 2 supply area get a dropper bottle of trypsin and one of BAPNA. Bring these items to your bench.

2. Two students should prepare the controls (tubes 1T and 2T) while the other two prepare the experimental samples (tubes 3T to 5T).

- Mark each tube with a wax pencil, and load the tubes as indicated in the **Activity 2 chart**, using 3 drops (gtt) of each indicated substance.
- Place all tubes in a rack in the appropriate water bath for approximately 1 hour. Shake the rack occasionally to keep the contents well mixed.
- At the end of the hour, examine the tubes for the results of the trypsin assay (detailed below).

Trypsin Assay

Since BAPNA is a synthetic color-producing substrate, the presence of yellow color indicates a **positive hydrolysis test;** the dye molecule has been cleaved from the amino acid. If the sample mixture remains clear, a **negative hydrolysis test** has occurred.

Record the results in the Activity 2 chart and on the board.

Activity 2: Trypsin Digestion of Protein

Tube no.	1T	2T	3T	4T	5T
Additives (3 gtt ea)	trypsin, water	BAPNA, water	trypsin → Boil trypsin 4 min, then add BAPNA. → boiled trypsin, BAPNA	trypsin, BAPNA	trypsin, BAPNA
Incubation condition	37°C	37°C	37°C	37°C	0°C
Color change					
Result: (+) or (−)					

Additive key:

= Trypsin = BAPNA = Water

Pancreatic Lipase Digestion of Fats and the Action of Bile

The treatment that fats and oils go through during digestion in the small intestine is a bit more complicated than that of carbohydrates or proteins—pretreatment with bile to physically emulsify the fats is required. Hence, two sets of reactions occur.

First:

$$\text{Fats/oils} \xrightarrow[\text{(emulsification)}]{\text{bile}} \text{minute fat/oil droplets}$$

Then:

$$\text{Fat/oil droplets} \xrightarrow[\text{(digestion)}]{\text{lipase}} \text{monoglycerides and fatty acids}$$

The term **pancreatin** describes the enzymatic product of the pancreas, which includes enzymes that digest proteins, carbohydrates, nucleic acids, and fats. It is used here to investigate the properties of **pancreatic lipase,** which hydrolyzes fats and oils to their component monoglycerides and two fatty acids.

Since fatty acids are organic acids, they acidify solutions, decreasing the pH. An easy way to recognize that digestion is ongoing or completed is to test pH. You will be using a pH indicator called *litmus blue* to follow these changes; it changes from blue to pink as the test tube contents become acidic.

Activity 3

Demonstrating the Emulsification Action of Bile and Assessing Fat Digestion by Lipase

1. From the general supply area, obtain nine test tubes and a test tube rack, plus one dropper bottle of each of the solutions in the Activity 3 supply area.

2. Although *bile,* a secretory product of the liver, is not an enzyme, it is important to fat digestion because of its emulsifying action. It physically breaks down large fat particles into smaller ones. Emulsified fats provide a larger surface area for enzymatic activity. To demonstrate the action of bile on fats, prepare two test tubes and mark them 1E and 2E (*E* for emulsified fats).

- To tube 1E, add 20 drops of water and 4 drops of vegetable oil.
- To tube 2E, add 20 drops of water, 4 drops of vegetable oil, and a pinch of bile salts.
- Cover each tube with a small square of Parafilm, shake vigorously, and allow the tubes to stand at room temperature.

After 10 to 15 minutes, observe both tubes. If emulsification has not occurred, the oil will be floating on the surface of the water. If emulsification has occurred, the fat droplets will be suspended throughout the water, forming an emulsion.

In which tube has emulsification occurred? _____

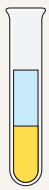
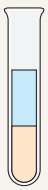
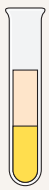
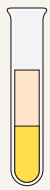
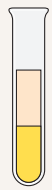
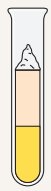
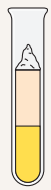
3. Two students should prepare the controls (1L and 2L, *L* for lipase) while the other two students in the group set up the experimental samples (3L to 5L, 4B, and 5B, where *B* is for bile), as illustrated in the **Activity 3 chart**.

- Mark each tube with a wax pencil and load the tubes using 5 drops (gtt) of each indicated solution.
- Place a pinch of bile salts in tubes 4B and 5B.
- Cover each tube with a small square of Parafilm, and shake to mix the contents of the tube.
- Remove the Parafilm, and place all tubes in a rack in the appropriate water bath for approximately 1 hour. Shake the test tube rack from time to time to keep the contents well mixed.
- At the end of the hour, perform the lipase assay below.

Lipase Assay

Fresh cream provides the fat substrate for this assay; add litmus powder to it to make litmus cream. The basis of this assay is a pH change that is detected by the litmus powder indicator. Alkaline or neutral solutions containing litmus are blue but will turn reddish in the presence of acid. If digestion occurs, the fatty acids produced will turn the litmus cream from blue to pink. Because the effect of

Activity 3: Pancreatic Lipase Digestion of Fats

Tube no.	1L	2L	3L	4L	5L	4B	5B
Additives (5 gtt ea)	 pancreatin, water	 litmus cream, water	 Boil pancreatin 4 min, then add litmus cream. →  pancreatin / boiled pancreatin, litmus cream	 pancreatin, litmus cream	 pancreatin, litmus cream	 pancreatin, litmus cream, bile salts	 pancreatin, litmus cream, bile salts
Incubation condition	37°C	37°C	37°C	37°C	0°C	37°C	0°C
Color change							
Result: (+) or (−)							

Additive key:

= Pancreatin = Litmus cream = Water = Pinch bile salts

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hydrolysis by lipase is directly seen, additional assay reagents are not necessary.

1. To prepare a color control, add 0.1 *N* HCl drop by drop to tubes 1L and 2L (covering the tubes with a square of Parafilm after each addition and shaking to mix) until the cream turns pink.
2. Record the color of the tubes in the Activity 3 chart and on the board.

Activity 4

Reporting Results and Conclusions

1. Share your results with the class as directed in the General Instructions (p. 600).
2. Suggest additional experiments, and carry out experiments if time permits.
3. Prepare a lab report for the experiments on digestion. (See Getting Started, on MasteringA&P.)

Group Challenge

Odd Enzyme Out

The following boxes each contain four digestive enzymes. One of the listed enzymes does not share a characteristic that the other three do. Working in groups of three, discuss the characteristics of the enzymes in each group. On a separate piece of paper, one student will record the characteristics for each enzyme for the group. Discuss the possible candidates for the "odd enzyme". Once the group has come to a consensus, circle the enzyme that doesn't belong with the others, and explain why it is singled out. Sometimes there may be multiple reasons why the enzyme doesn't belong with the others. Include as many as you can think of, but make sure it does not have the key characteristic shared by the other three.

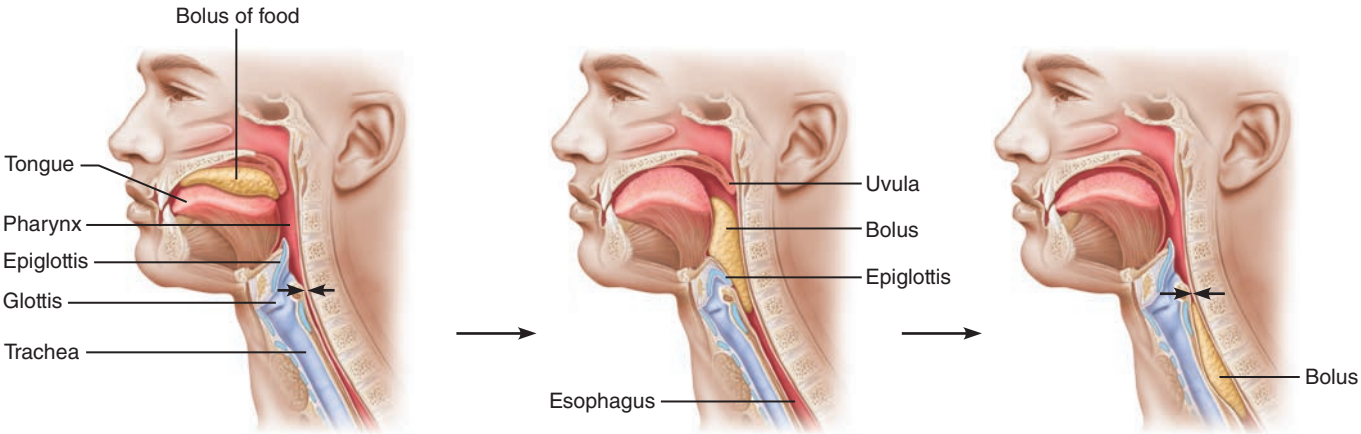
1. Which is the "odd enzyme"?	**Why is it the odd one out?**
Trypsin Carboxypeptidase Pepsin Chymotrypsin	
2. Which is the "odd enzyme"?	**Why is it the odd one out?**
Lactase Pepsin Aminopeptidase Trypsin	
3. Which is the "odd enzyme"?	**Why is it the odd one out?**
Maltase Pancreatic lipase Nucleosidase Dipeptidase	
4. Which is the "odd enzyme"?	**Why is it the odd one out?**
Sucrase Dextrinase Glucoamylase Chymotrypsin	

Physical Processes: Mechanisms of Food Propulsion and Mixing

Although enzyme activity is a very important part of the overall digestion process, foods must also be processed physically (by chewing and churning) and moved by mechanical means along the tract if digestion and absorption are to be completed. Muscles are involved in producing the movements of foodstuffs along the gastrointestinal tract. Although we tend to think only of smooth muscles when visceral activities are involved, both skeletal and smooth muscles are involved in the physical processes. This fact is demonstrated by the simple activities that follow.

Deglutition (Swallowing)

Swallowing, or **deglutition,** is largely the result of skeletal muscle activity and occurs in two phases: *buccal* (mouth) and *pharyngeal-esophageal.* The buccal phase (**Figure 39.2** step ①) is voluntarily controlled and initiated by the tongue. Once begun, the process continues involuntarily in the pharynx and esophagus through peristalsis, resulting in the delivery of the swallowed contents to the stomach (Figure 39.2 steps ②–③).



① During the buccal phase, the upper esophageal sphincter is contracted. The tongue presses against the hard palate, forcing the food bolus into the oropharynx.

② The pharyngeal-esophageal phase begins as the uvula and larynx rise to prevent food from entering respiratory passageways. The tongue blocks off the mouth. The upper esophageal sphincter relaxes, allowing food to enter the esophagus.

③ The constrictor muscles of the pharynx contract, forcing food into the esophagus inferiorly. The upper esophageal sphincter contracts (closes) after food enters.

Figure 39.2 Swallowing. The process of swallowing consists of voluntary (buccal) (step ①) and involuntary (pharyngeal-esophageal) phases (steps ②–③).

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Activity 5

Observing Movements and Sounds of the Digestive System

1. Obtain a pitcher of water, a stethoscope, a paper cup, an alcohol swab, and an autoclave bag in preparation for making the following observations.

2. While swallowing a mouthful of water, consciously note the movement of your tongue during the process. Record your observations.

_____

_____

_____

3. Repeat the swallowing process while your laboratory partner watches the externally visible movements of your larynx. (This movement is more obvious in a male, since males have a larger Adam's apple.) Record your observations.

_____

_____

What do these movements accomplish? _____

_____

_____

4. Before donning the stethoscope, your lab partner should clean the earpieces with an alcohol swab. Then, he or she should place the diaphragm of the stethoscope over your abdominal wall, approximately 2.5 cm (1 inch) below the xiphoid process and slightly to the left, to listen for sounds as you again take two or three swallows of water. There should be two audible sounds—one when the water splashes against the gastroesophageal sphincter,

and the second when the peristaltic wave of the esophagus arrives at the sphincter and the sphincter opens, allowing water to gurgle into the stomach. Determine, as accurately as possible, the time interval between these two sounds and record it below.

Interval between arrival of water at the sphincter and the

opening of the sphincter: _____ sec

This interval gives a fair indication of the time it takes for the peristaltic wave to travel down the 25 cm (10 inches) of the esophagus. (Actually the time interval is slightly less than it seems, because pressure causes the sphincter to relax before the peristaltic wave reaches it.)

Dispose of the used paper cup in the autoclave bag.

Segmentation and Peristalsis

Although several types of movements occur in the digestive tract organs, peristalsis and segmentation are most important as mixing and propulsive mechanisms (**Figure 39.3**).

Peristaltic movements are the major means of propelling food through most of the alimentary canal. Essentially, they are waves of contraction followed by waves of relaxation that squeeze foodstuffs through the alimentary canal, and they are superimposed on segmental movements.

Segmental movements are local constrictions of the organ wall that occur rhythmically. They serve mainly to mix the foodstuffs with digestive juices and to increase the rate of absorption by continually moving different portions of the chyme over adjacent regions of the intestinal wall. However, segmentation is also an important means of food propulsion in the small intestine, and slow segmenting movements called haustral contractions are frequently seen in the large intestine.

Activity 6

Viewing Segmental and Peristaltic Movements

If a video showing some of the propulsive movements is available, go to a viewing station to view it before leaving the laboratory. Alternatively, use the *Interactive Physiology*® module on the Digestive System to observe gut motility.

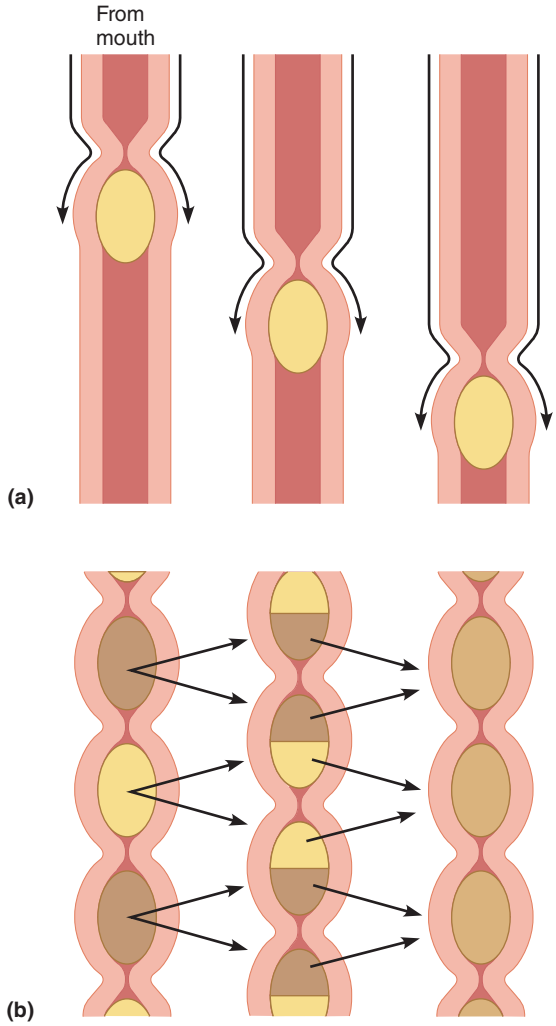

Figure 39.3 Peristaltic and segmental movements of the digestive tract. (a) Peristalsis: neighboring segments of the intestine alternately contract and relax, moving food along the tract. **(b)** Segmentation: single segments of intestine alternately contract and relax. Because inactive segments exist between active segments, food mixing occurs to a greater degree than food movement. Peristalsis is superimposed on segmentation movements.

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EXERCISE 39

REVIEW SHEET

Digestive System Processes: Chemical and Physical

Name _____ Lab Time/Date _____

Digestion of Foodstuffs: Enzymatic Action

1. Match the following definitions with the proper choices from the key.

Key: a. catalyst b. control c. enzyme d. substrate

_____ 1. substance on which a catalyst works

_____ 2. biologic catalyst; protein in nature

_____ 3. increases the rate of a chemical reaction without becoming part of the product

_____ 4. provides a standard of comparison for test results

2. List the three characteristics of enzymes. _____

_____

_____

3. The enzymes of the digestive system are classified as hydrolases. What does this mean?

_____

_____

4. Fill in the following chart about the various digestive system enzymes encountered in this exercise.

Enzyme	Organ producing it	Site of action	Substrate(s)	Optimal pH
Salivary amylase				
Trypsin				
Lipase (pancreatic)				

5. Name the end products of digestion for the following types of foods.

proteins: _____ carbohydrates: _____

fats: _____ and _____

WHY THIS MATTERS **6.** How does the substrate for amylase differ from the substrate for lactase? _____

_____

How are the substrates similar? _____

7. Where does lactose hydrolysis occur for lactase-persistent individuals? _____

Where does lactose hydrolysis occur for lactose-intolerant individuals who have consumed probiotic bacterial microflora? _____

8. You used several indicators or tests in the laboratory to determine the presence or absence of certain substances. Choose the correct test or indicator from the key to correspond to the condition described below.

Key: a. Lugol's iodine (IKI) b. Benedict's solution c. litmus d. BAPNA

_____ 1. used to test for protein hydrolysis, which was indicated by a yellow color

_____ 2. used to test for the presence of starch, which was indicated by a blue-black color

_____ 3. used to test for the presence of fatty acids, which was evidenced by a color change from blue to pink

_____ 4. used to test for the presence of reducing sugars (maltose, glucose) as indicated by a blue to green or orange color change

9. What conclusions can you draw when an experimental sample gives both a positive starch test and a positive maltose test after incubation? _____

Why was 37°C the optimal incubation temperature? _____

Why did very little, if any, starch digestion occur in test tube 4A? _____

_____

When starch was incubated with amylase at 0°C, did you see any starch digestion? _____

Why or why not? _____

_____

Assume you have said to a group of your peers that amylase is capable of starch hydrolysis to maltose. If you had not done control tube 1A, what objection to your statement could be raised? _____

_____

What if you had not done tube 2A? _____

10. In the exercise concerning trypsin function, why was an enzyme assay such as Benedict's or Lugol's iodine (IKI), which test for the presence of a reaction product, not necessary? _____

Why was tube 1T necessary? _____

Why was tube 2T necessary? _____

Trypsin is a protease similar to pepsin, the protein-digesting enzyme in the stomach. Would trypsin work well in the stomach? _____ Why? _____

11. In the procedure concerning pancreatic lipase digestion of fats and the action of bile salts, how did the appearance of tubes 1E and 2E differ? _____

_____

Explain the reason for the difference. _____

_____

Why did the litmus indicator change from blue to pink during fat hydrolysis? _____

_____

Why is bile not considered an enzyme? _____

How did the tubes containing bile compare with those not containing bile? _____

What role does bile play in fat digestion? _____

_____

12. The three-dimensional structure of a functional protein is altered by intense heat or nonphysiological pH even though peptide bonds may not break. Such inactivation is called denaturation, and denatured enzymes are nonfunctional. Explain why.

_____

_____

What specific experimental conditions resulted in denatured enzymes? _____

_____

13. Pancreatic and intestinal enzymes operate optimally at a pH that is slightly alkaline, yet the chyme entering the duodenum from the stomach is very acid. How is the proper pH for the functioning of the pancreatic-intestinal enzymes ensured?

_____

_____

14. Assume you have been chewing a piece of bread for 5 or 6 minutes. How would you expect its taste to change during this interval? _____

Why? _____

15. Note the mechanism of absorption (passive or active transport) of the following food breakdown products, and indicate by a check mark (✓) whether the absorption would result in their movement into the blood capillaries or the lymphatic capillaries (lacteals).

Substance	Mechanism of absorption	Blood	Lymph
Monosaccharides			
Fatty acids and monoglycerides			
Amino acids			
Water			
Na^+, Cl^-, Ca^{2+}			

16. People on a strict diet to lose weight begin to metabolize stored fats at an accelerated rate. How does this condition affect blood pH? _____

17. Using a flowchart, trace the pathway of a ham sandwich (ham = protein and fat; bread = starch) from the mouth to the site of absorption of its breakdown products, noting where digestion occurs and what specific enzymes are involved.

18. Some of the digestive organs have groups of secretory cells that liberate hormones into the blood. These exert an effect on the digestive process by acting on other cells or structures and causing them to release digestive enzymes, expel bile, or increase the motility of the digestive tract. For each hormone below, note the organ producing the hormone and its effects on the digestive process. Include the target organs affected.

Hormone	Produced by	Target organ(s) and effects
Secretin		
Gastrin		
Cholecystokinin		

Physical Processes: Mechanisms of Food Propulsion and Mixing

19. Complete the following statements.

Swallowing, or _1_, occurs in two phases—the _2_ and _3_. One of these phases, the _4_ phase, is voluntary. During the voluntary phase, the _5_ is used to push the food into the back of the throat. During swallowing, the _6_ rises to ensure that its passageway is covered by the epiglottis so that the ingested substances don't enter the respiratory passageways. It is possible to swallow water while standing on your head because the water is carried along the esophagus involuntarily by the process of _7_. The pressure exerted by the foodstuffs on the _8_ sphincter causes it to open, allowing the foodstuffs to enter the stomach.

The two major types of propulsive movements that occur in the small intestine are _9_ and _10_. One of these movements, _11_, acts to continually mix the foods and to increase the absorption rate by moving different parts of the chyme mass over the intestinal mucosa, but it has less of a role in moving foods along the digestive tract.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____