Food is the material used by the body to keep it alive and help it grow, but it cannot be used in its original form. It must be broken down from larger molecules into smaller components that can be assimilated into the body in the form of nutrients — proteins, carbohydrates, lipids, vitamins, minerals, and water. The process that breaks food down into nutrients for the body to use is the digestive process.

The digestive process is actually two procedures that work in conjunction with one another — mechanical digestion (such as chewing) and chemical digestion (breakdown of large molecules). When food is chewed, larger pieces of food are broken into smaller pieces, increasing the surface area of each piece, easing chemical digestion. In the process of chemical digestion, the body produces digestive enzymes (protein molecules); these belong to the class of hydrolytic enzymes that act as catalysts in the chemical breakdown of food. Although enzymes initiate the chemical breakdown, the enzyme itself does not change during the reaction.

There are several different types of enzymes; each breaks down and isolates different nutrients. Some of these enzymes are most effective under certain environmental conditions, such as lower pH or higher temperature, where other enzymes might not function as well. Because of this, the body has an elaborate digestive system that causes food to pass through several types of environments, each of which contains enzymes optimized for that particular environment.

Both mechanical and chemical digestion begin when food is placed in the mouth. While the food is being chewed, the salivary glands produce saliva, which is a mixture of water, mucus, and salivary amylase (an enzyme that helps convert complex starch molecules to disaccharides which are more useful to the body). Saliva begins the breakdown of the food and also lubricates the food, making it easier to swallow and protecting the delicate tissues inside the body from abrasion.
Chewed and moistened food is then swallowed and forced through the pharynx into the esophagus. The food travels down the esophagus through a series of involuntary muscle contractions, into the stomach. This process is known as peristalsis. Once the food enters the stomach, a different set of digestive processes occur.

The stomach is a large, hollow cavity surrounded by several layers of muscle, that also participate in mechanical digestion by contracting and relaxing, churning the contents of the stomach. The inner lining of the stomach contains glands that release mucus, digestive enzymes, and hydrochloric acid. The stomach lining also secretes the chemical pepsinogen. In a very acidic environment, pepsinogen is converted to pepsin, a digestive enzyme that chemically splits large protein molecules into small amino acid chains known as peptides.

The mucus released by the stomach lining helps protect its delicate tissues from the very low pH created by the release of hydrochloric acid. The pH of the stomach becomes so low (pH 1.0 to 3.0) that the salivary amylase can no longer function as it did in the saliva (pH 6.0 to 7.5), preventing carbohydrate digestion from occurring in the stomach.

The action of the stomach muscles, along with the protein-reducing actions of the pepsin, turn the food into a semi-liquid material called chyme (kīm). The chyme is stored in the stomach and slowly released into the long (up to seven meters) small intestine, where it is exposed to a number of other digestive processes as it travels this great length.

When the chyme first enters the small intestine, it is still very acidic. The pH of the chyme is raised to a basic level by pancreatic fluid, consisting of digestive enzymes and sodium bicarbonate, produced by the pancreas. The pancreatic fluid’s digestive action is aided by bile, which is produced by the liver, stored in the gallbladder, and is eventually released into the small intestine when chyme is present. Bile, while not a true digestive enzyme, breaks large fat globules into smaller droplets, creating a larger surface area for the pancreatic fluid to act on.

At this point, the small intestine contains a mixture of chyme, bile, mucus, and pancreatic juices. The pancreatic juices contain the enzymes trypsin, amylase, and lipase. Amylase, in the basic environment of the small intestine, further breaks down the maltose produced by salivary amylase into the simple sugar glucose, which is more easily absorbed through the lining of the intestine. Lipase is a fat-digesting enzyme that acts on the small fat droplets created by the bile to produce glycerol and fatty acids. Trypsin is a protein-digesting enzyme that acts on the peptides created in the stomach to further reduce them into individual amino acids. Trypsin also breaks down any remaining large protein molecules that were not digested in the stomach.
As the resulting mixture of amino acids, glycerol, fatty acids, and simple sugars passes through the remainder of the small intestine, the individual nutrients are absorbed through the lining of the intestine and transferred into the circulatory system, which distributes them to various parts of the body. The remaining materials (those not digested and absorbed in the small intestine) are passed into the large intestine, where some minerals and most of the small amount of remaining water are absorbed. The material of little or no nutritional value to the body passes through the large intestine and is expelled as waste.
OBJECTIVES

- Understand the processes and steps involved in digestion
- Investigate the actions of three different digestive enzymes (amylases, proteases, and lipases)
- Identify the organ included in the digestive system
- Simulate environmental conditions found in various parts of the digestive tract
- Examine the effects of temperature on rate and degree of digestive enzyme activity
- Determine the optimum conditions for the digestion of various nutrients

MATERIALS

MATERIALS NEEDED PER GROUP

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Item Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Test tubes w/screwcaps</td>
</tr>
<tr>
<td>5</td>
<td>Pipets</td>
</tr>
<tr>
<td>6</td>
<td>pH test strips</td>
</tr>
<tr>
<td></td>
<td>pH indicator chart</td>
</tr>
<tr>
<td></td>
<td>Hard-boiled egg</td>
</tr>
</tbody>
</table>

SHARED MATERIALS

- Iodine solution
- Olive oil
- Hydrochloric acid, 1%
- Sodium hydroxide, 0.1%
- Starch solution, 1%
- Pancreatin solution, 2%
- Phenolphthalein solution
- Incubator
- Ice bath
- Pepsin solution, 1%
- Test tube racks
A. Digestion of Lipids and Effects of Temperature

1. Label one test tube “Room Temperature”; label a second test tube “37°C”.

2. Add 5 ml of distilled water to each test tube.

3. Add two drops of phenolphthalein solution to each test tube.

4. Add 20 drops of 0.1% sodium hydroxide solution to each test tube. The color of the solution in both test tubes should turn light pink.

   **Phenolphthalein is a pH indicator that turns pink at a pH of 8.0 or above.**

5. Add 5 ml of 2% pancreatin solution to each test tube. Cap both tubes and mix.

   **Pancreatin is a mixture of proteolytic, diastatic, and lipolytic enzymes.**

6. Remove the caps from both tubes, add 1 ml olive oil to each test tube, and loosely re-cap both tubes. Record the color of the solution and your observations of each tube in Table 1 in the Analysis section of the lab.

   **To examine the color of the solution in the tubes, hold the tubes up with a piece of white paper behind them.**

7. Place the “37°C” test tube in a 37°C incubator overnight. Leave the “Room Temperature” test tube at room temperature overnight.

8. The following day, observe the two test tubes. Record your observations in Table 1 in the Analysis section.

B. Digestion of Starch and Effects of Temperature

1. Label one test tube “5°C”, another “Room Temperature”, and a third “37°C”.

**DID YOU KNOW?**
Certain foods take longer to digest than others. Generally, carbohydrates require the least amount of time followed by proteins, and then fats. A mixture of two or three types requires even more time.
2. Add 5 ml of 1% starch solution to each test tube.

3. Add 1 ml of dilute iodine to each test tube.

Iodine is a starch indicator, which turns blue/black in the presence of starch.

4. Add 5 ml of the pancreatin solution to each test tube. Cap and mix each test tube, then loosen each cap slightly. Record your observations in Table 2 in the Analysis section.

5. Place the “5°C” test tube in an ice water bath. Place the “37°C” test tube in a 37°C incubator. Leave the “Room Temperature” test tube at room temperature.

6. At the end of the class period, tighten the caps on each tube, shake the test tubes, and compare the color of each solution. Record the color of each solution in Table 2 in the Analysis section.

C. Digestion of Proteins and Effect of pH

1. Obtain a hard-boiled egg and remove it from the shell. Remove the yolk and cut three 0.5 cm x 0.5 cm egg white cubes.

2. Label one test tube “1”, another “2”, and a third “3”.

3. Add 1 ml of distilled water to each test tube.

4. Add 3 ml of 1% pepsin to each test tube.

5. Add 1 ml of 1% hydrochloric acid to test tube 1.

6. Add 1 ml of distilled water to test tube 2.

7. Add 1 ml of 0.1% sodium hydroxide to test tube 3.

8. Place one cube of boiled egg white in each test tube.

9. Using a new pH test strip for each tube, test the pH of the solution in all three tubes and record your results in Table 3 in the Analysis section. Also record your initial observations of each tube in Table 3.

10. Loosely cap the test tubes and place them in a 37°C incubator overnight.

11. The following day, observe the egg white cubes in the test tubes for any changes and use three new pH test strips to determine the pH of the solution in each of the tubes. Record the pH and your observations in Table 3 in the Analysis section.
**WARD’S**  
Investigating Digestive Processes  
Lab Activity

**TABLE 1**

<table>
<thead>
<tr>
<th>Test Tube</th>
<th>Initial Observations</th>
<th>Final Observations</th>
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<tr>
<td>Room Temperature</td>
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**TABLE 2**

<table>
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<td>5°C</td>
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<td></td>
</tr>
<tr>
<td>Room Temperature</td>
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</tr>
<tr>
<td>37°C</td>
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</table>

**TABLE 3**

<table>
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<tr>
<th>Test Tube</th>
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<th>Initial Observations</th>
<th>Final pH</th>
<th>Final Observations</th>
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</tr>
<tr>
<td>2</td>
<td></td>
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<tr>
<td>3</td>
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</tbody>
</table>
1. Read the paragraph below and fill in the blanks with the most appropriate terms.

In part A of the experiment, you added the indicator __________________ to your test tubes and then added sodium hydroxide. The sodium hydroxide __________________ the pH, which was indicated by __________________ in the tubes. The next component, pancreatin, digested the ________________. After overnight incubation, the incubated sample contained a _______________ solution while the room temperature sample retained its light pink color. The color change in the incubated sample resulted from a _______________ of the pH, caused by the breakdown of the _______________ into _______________. The results from this experiment indicate that pancreatin is more effective at a _______________ temperature.

2. Given the results from part B of the experiment, examine the four graphs shown below. Can you determine which of the graphs best represents the results of your experiment? If not, can you eliminate any of them? Explain why.

![Graphs a, b, c, d](image-url)
3. In the question above, if you could not determine which graph best fits your experimental results, explain how you could alter the experiment in order to make this determination. If you have determined the best graph already, explain why.

4. Part C of the experiment demonstrated the effects of acidity on protein digestion. Given the results, where in the human body do you believe most protein digestion occurs?

5. Find a formula to convert Celsius to Fahrenheit. Using the formula, convert the following temperatures from Celsius to Fahrenheit. Be sure to show your work. Below your conversions, explain why all of the experiments involved a sample incubated at 37°C.

   5°C =
   16°C =
   26°C =
   37°C =
6. Found below is a diagram of the digestive system and a list of enzymes and pH ranges. Match the terms to the part of the diagram where you believe they belong (some terms may be used more than once).

stomach, bile, amylase, pH 2.0, trypsin, saliva, pH 6.5, small intestine, pepsin, mouth, lipase, hydrochloric acid
7. Examine the following statements and determine if they are true or false. If they are false, explain why.

‘Water is a nutrient for the human body.’

‘Mechanical digestion only occurs through the act of chewing.’

‘Salivary amylase operates best at a pH of 2.0.’

‘Digestive enzymes are a form of hydrolytic enzyme, an enzyme that utilizes water to break down a substrate.’

‘All protein digestion occurs in the stomach.’

8. Which of the following does not produce enzymes that aid in the process of digestion?

a. stomach
b. pancreas
c. liver
d. salivary glands
e. small intestine
9. You are Seymour Gutz, tour guide of the human body. You have recently been informed that you have to give a tour of the digestive system to some very important visitors. Write up a brief outline of your tour, where you will begin, what you will visit on the tour, and some important highlights you be pointing out on your journey.

10. Research the digestive system of another organism. Using a Venn diagram, compare and contrast the digestive system to that of a human. Be sure to include at least three similarities and three difference between the systems.