What Do You Think?

The pH of the hydrochloric acid in the stomach is about 2. That’s strong enough to burn your skin. Thankfully, your stomach has a layer that protects it from this strong acid.

- What do you think happens to food like a hamburger or potatoes when they are in the stomach?

Record your ideas about this question in your *Active Chemistry* log. Be prepared to discuss your responses with your small group and the class.

Investigate

1. Prepare four artificial “stomachs.” Place a plastic sandwich bag inside a 250-mL beaker. Fold down the top of the bag over the lip of the beaker. Use either a piece of string or a rubber band to secure the bag to the beaker.
2. Prepare “food” for the “stomachs.”
   Get four equal pieces of potato, four equal pieces of hard-boiled egg white, four equal pieces of beef jerky, and four equal pieces of raw cabbage.

   To each of four of the sticks, tie a piece of potato and a piece of egg white. To each of the other four sticks tie a piece of beef jerky and a piece of raw cabbage.

3. Lay one stick across the mouth of the beaker so that the two food samples dangle below into the liquid. Now lay another stick, with the other two foods, crisscross to the first stick. All four food samples should now be submerged in the “stomach” fluid.

4. Prepare the other three “stomachs” in the same manner.

5. Cover each of the artificial stomachs with a strip of plastic wrap.

6. Observe each of the foods in each of the stomachs after 15 minutes, 24 hours, 48 hours, and 72 hours. Your teacher may have prepared some of these in advance.

   a) Record all of your observations.
   b) What have you decided goes on in each “stomach?” What kind of digestion appears to be taking place? Record in your Active Chemistry log your predictions and interpretations.
DIGESTION IN THE STOMACH

Observing Human Digestion in the Stomach

In 1822, a young army doctor, Dr. William Beaumont, was the first person actually to see digestion in a live stomach. On June 6, 1822, a French-Canadian man named Alexis St. Martin was shot in the stomach. Dr. Beaumont arrived 30 minutes after the accident. He treated the wound, but he could not fully close the hole in the man’s stomach. The hole remained “large enough that Beaumont could insert his entire forefinger into the stomach cavity.”

A year from the time of the accident, the hole was still about 2.5 inches in circumference and had to be continually closed with a compress and bandage.

In 1825 Dr. Beaumont began his experiments with St. Martin, “...becoming the first person to observe human digestion as it occurs in the stomach.” He tied pieces of food to a silk string and dangled the food through the hole into St. Martin’s stomach. Some of the kinds of food he tested were beef, pork, and raw cabbage. In 1831 he experimented with a much wider range of foods. He took samples from St. Martin’s stomach that had spent various times in the stomach and examined the progressive stages of digestion.

Alexis St. Martin lived 58 years after the accident and died at the age of 86. Because you will not be able to find volunteers like St. Martin, you carried out your investigation in artificial plastic bag stomachs.

Pepsin Helps in the Digestion of Protein

There are numerous differences between a real stomach and the artificial ones you used in this activity. The environment of the stomach is not calm and contented as your artificial stomachs might lead you to believe. When food is present, the stomach is in constant motion. The stomach continually squeezes the food as it undergoes peristalsis. This is the involuntary muscle contraction that moves food around in the stomach and intestines. If you were clinging to a morsel of food...
inside the stomach, the ride would be pretty violent. In addition, the environment would be very acidic. From cells embedded in the entire surface of the stomach, hydrochloric acid is secreted into the mix.

From this activity you learned that hydrochloric acid alone will not digest the vehicle in which you are riding through the alimentary canal. You have seen that digestion requires both hydrochloric acid and pepsin. Only foods containing proteins (i.e., beef jerky and egg white) seemed to be affected.

Recall from Activity 1, that the enzyme amylase was needed to hydrolyze the starch. Similarly, **pepsin** is an enzyme that helps hydrolyze proteins within the stomach. Amylase is specific to starch and pepsin is specific to proteins.

What exactly is a protein? **Proteins** are very large chain-like molecules made out of carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur. Just as a bicycle chain is made up of many links, a protein is made up of many smaller molecules called **amino acids**. Foods such as meat, peanuts, cheese, and eggs contain proteins that must be broken down. Digestion of proteins is the chemical attack of these long-chain molecules.

**Enzymes as Catalysts**

Pepsin is an enzyme that acts as a catalyst for the hydrolysis of proteins. A **catalyst** is a reagent that speeds the rate of a chemical reaction without getting used up in the process. **Enzymes** themselves are proteins, and are highly specific catalysts. Often, their only job is to catalyze one particular reaction and nothing else. They work best at a particular pH and temperature. Specific conditions vary for different enzymes, but most of them work best at around 40ºC. That’s very close to normal body temperature of 37ºC.

The graph shows you enzyme activity (how well it works) vs. temperature. At temperatures above 45ºC enzymes become denatured, or their shape changes and they are no longer effective.

You could draw a similar looking graph for pH vs. enzyme activity, as pH can also denature enzymes (proteins) and make them ineffective.

The enzymes that get secreted in the stomach are called gastric enzymes. Pepsin is the main gastric enzyme. It is active only in the acid environment of the stomach.
(pH 1.5–2.5 or less); it is ineffective in the intestine (~pH 7, neutral). Pepsin in the stomach works best at pH = 2. Amylase in the mouth works best at pH = 7.

**Other Functions of the Stomach**

Contrary to what many people believe, very little digestion goes on in the stomach. As you have seen in your artificial stomachs and as Dr. Beaumont learned from observing his patient, food is only digested to a small degree in the stomach. The stomach does perform other important functions, however. When food first enters the stomach, it is thoroughly mixed through peristalsis, the mechanical contraction of stomach muscles.

The gastric juice present in the stomach turns the food into a mushy substance called “chyme,” preparing it to move down the digestive tract. If a person eats food that has lots of bacteria, or if the stomach gets irritated by a virus or other germ, the stomach may say, “Hey, this food’s not going any further!” At this point, the muscles of the stomach squeeze themselves together to push the food out the way it came—back out through the esophagus and mouth. Vomiting is an important line of defense. It can remove dangerous food and prevent more serious problems that could show up further down the line.

**Unusual Uses for Pepsin**

Pepsin is used commercially in some cheese-making, in the leather industry to remove hair and residual tissue from hides, and in the recovery of silver from discarded photographic films by digesting the gelatin layer that holds the silver.

**Checking Up**

1. What important function does peristalsis perform?
2. What smaller units combine to make up proteins?
3. What are two of the requirements that must be present to start the digestion of protein in the stomach?
4. Which type of food seems to be the only kind that can undergo digestion in the stomach?
5. What causes food to be vomited?

**What Do You Think Now?**

At the beginning of this activity you were asked:

- What do you think happens to food like a hamburger or potatoes when they are in the stomach?

How have your predictions about the fate of a hamburger and potato changed as a result of your investigation?
Reflecting on the Activity and the Challenge

In this activity, you saw evidence that the enzyme pepsin, along with hydrochloric acid in the stomach, begins the digestion of proteins. You may have also gotten some hints concerning which types of foods would be relatively safe to choose as your vehicle through this portion of the alimentary canal. Remember that the skit for your portion of the ride down the alimentary canal has to be from the point of view of what might be happening at the molecular level. What might you incorporate into your skit from what you have learned about the stomach in this activity? Seat belts might be in order!

Chem Essential Questions

What does it mean?
Chemistry explains a macroscopic phenomenon (what you observe) with a description of what happens at the nanoscopic level (atoms and molecules) using symbolic structures as a way to communicate. Complete the chart below in your Active Chemistry log.

<table>
<thead>
<tr>
<th>MACRO</th>
<th>NANO</th>
<th>SYMBOLIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Describe the disintegration of the foods in the different “stomachs” over time.</td>
<td>What does an enzyme do at the molecular level to aid in digestion?</td>
<td>Data is often shown in graphical form. Explain the meaning of the graph showing enzyme activity vs. temperature.</td>
</tr>
</tbody>
</table>

How do you know?
What evidence do you have that the only “stomach” that promoted digestion was the one containing the enzyme pepsin and hydrochloric acid, and that the only type of food that went through the digestion process was food containing protein.

Why do you believe?
Contrary to what many would predict, hydrochloric acid cannot digest food without the enzyme. Apparently pepsin does not promote the digestion of carbohydrates, at least not with the low pH found in the stomach. With the evidence from Activity 1, it appears that enzymes are highly important in digesting food. Can the enzymes in the mouth digest the proteins in meat?

Why should you care?
Enzymes pose a major danger for riders traveling down the alimentary canal. Even though an enzyme is very specific with which substances it will react, there are many different enzymes in the alimentary canal. This might need to be addressed in your Chapter Challenge in some manner.
1. Which foods seem to undergo digestion in the artificial stomachs?
2. Which set of conditions allowed the digestion to begin?
3. After 72 hours, had the foods been digested? Does it take more than 72 hours to digest these same foods inside you? Explain the difference in time required for digestion in this artificial setting compared to what goes on inside your stomach.
4. The chemical breakdown of a protein is called ___________. In this process, the _______ of the protein is broken.
5. Make a sketch of a graph that represents enzyme activity vs. pH. Be sure to label your axes and make the pH axis to scale.
6. Preparing for the Chapter Challenge

   The stomach is not a calm, motionless, plastic bag filled with liquid. When food is observed or smelled, as it enters the mouth and stomach, signals from the brain are sent to get the stomach ready for its part in digestion. Develop a working model that you can use to demonstrate with real food what kind of action (both chemical and physical) would be going on in the stomach.

Inquiring Further

1. Stomach stapling

   Even though the stomach is important, could a person survive if a part or all of the stomach were removed? What would the effect be if a physician surgically stapled a patient’s stomach to decrease the stomach’s size? Research stomach stapling and report to your class what you learn.

2. Carbohydrates and proteins

   How does the structure of a protein differ from a carbohydrate?

3. pH dependency of pepsin and amylase

   Design and carry out an experiment investigating the pH dependency of pepsin or amylase. That is, at what pH do these enzymes show the most activity? Be sure to identify your independent and dependent variables, and include the use of a control. This exercise could help you with your Chapter Challenge as you need to identify the chemical perils that your food particle may encounter.