Chapter 1:

Picture Perfect

INSTRUCTOR'S GUIDE

As with all the cases in this book, please read the preface if you have not already done so. In the preface you will find suggestions for using Investigative Case Based Learning (ICBL) in different instructional situations such as starting a new lecture topic, assessing what students already know, setting a context for lab activities, and so on. The preface also describes ways to use cases in a variety of classroom settings and suggests multiple ways to assess learning with cases.

Picture Perfect accompanies Unit One: The Chemistry of Life in *Campbell Biology*, 9th edition. The case emphasizes material covered in Chapter 5: The Structure and Function of Large Biological Molecules. Students begin the investigative case by reading a narrative about a museum conservator preserving a 19th-century cotton dress stained with starch. There are three strands (or themes) in the case:

- The use of scientific thinking in preservation work
- The structure and function of polysaccharides, with an emphasis on starch and cellulose
- The introduction of amylase as an enzyme that catalyzes the hydrolysis of starch

Students should complete the Case Analysis immediately following the reading of the case. We strongly suggest that students work in groups to complete the Case Analysis. Actively listening to and challenging the ideas of others can help learners become aware of their own misconceptions, yet also value their own and others' prior knowledge.

Five investigations accompany *Picture Perfect*. Three are "core" investigations relating directly to the facts of the case, and two are additional investigations that extend the case to other applications. Table IG1.1 describes what students will gain from each investigation. See the Case Book website for an additional investigation on plants used as food starch globally.

Table IG1.1 Picture Perfect Case Overview.

Investigation	Learning Goals	Inquiry Skills Used
	Core Investigations	
I. Critical Reading	Students read parts of Chapter 5 covering an introduction to macromolecules, carbohydrates, and proteins. They also read selected sections in Chapter 8 about enzyme function. Emphasis is on carbohydrate chemistry and enzymes specific to starch.	• identifying information relevant to a question • making observations and constructing an evidence-based argument • relating structure to function
II. Analyze and Design an Experiment A. Analyzing an Experiment	Using data generated by simulation software in the *Chapter 41, Investigation: What Role Does Amylase Play in Digestion?* found on the Campbell Biology website or CD-ROM, students analyze the experimental setup and interpret outcomes. The use of iodine to test for starch and Benedict's solution to test for simple sugars is featured.	• analyzing experimental setups and data • explaining outcomes of experiments
B. Designing an Experiment	Students use the same experimental methods employed in II.A. to test a variable of their choice. They design experimental and control treatments and predict results. Students could use the website software to run their experiment (optional).	• writing questions • writing hypotheses • identifying variables • designing treatments • predicting results
III. Off the Wall: Starch Degradation Investigation	Students study a realistic situation in which an individual needs to test methods of removing wallpaper paste.	• interpreting visual data • making decisions • applying concepts of experimental design and starch chemistry
	Additional Investigations	
IV. Structure and Function of Starch A. Kinds of Starch	Students examine micrographs of starch granules from different plants. They infer the kind of starch Rob removed from the dress in the case.	• making observations • using evidence to solve problems
B. Using Starches in Food	Students learn the stages in starch gelatinization and apply their knowledge to common errors in preparing gravy and mashed potatoes.	• reading graphs • applying structure-function thinking to common problems
C. How Structural Properties of Native and Modified Starches Affect Their Function	Students learn how amylose affects the properties of native and modified starches, and how these differences are used in manufacturing starch-based products.	Students apply the concepts of starch structure and function to determine the best types of starch to use in the production of different foods.

V. Open-Ended Investigations	Students transfer their knowledge of starch to a new example.	• locating and managing information • identifying how their knowledge applies

Table IG1.2 contains several resources related to *Campbell Biology*, 9th edition, that will help your students further their understanding of this case. Note that chapter readings and activities are listed in order of importance.

Table IG1.2 Campbell-Related Resources.

Resource	Chapter/Activity	Topics Covered/Activity Titles
Critical Reading from *Campbell Biology*, 9th edition	Chapter 5: Structure and Function of Large Biological Molecules	Formation and breakdown of macromolecules; carbohydrates and proteins (Concepts 5.1–5.3)
	Chapter 8: An Introduction to Metabolism	Substrate specificity of enzymes; effects of local conditions on enzyme activity (Concept 8.4)
Related readings from *Campbell Biology*, 9e	Chapter 2: The Chemical Context of Life	Hydrogen bonds; molecular shape and function (Concept 2.3)
	Chapter 4: Carbon and the Molecular Diversity of Life	Carbon skeleton variation and molecular diversity (Concept 4.2)
Campbell website/ CD-ROM	Chapter 5 **Activities**	Models of Glucose Carbohydrates
	Chapter 8 **Activity**	How Enzymes Work
	Chapter 2 **Activity**	Hydrogen Bonds
	Chapter 41 **Investigation**	What Role Does Amylase Play in Starch Digestion?
	Chapter 2 **Investigation**	How Are Space Rocks Analyzed for Signs of Life?
	Chapter 3 **Activity**	The Polarity of Water
Morgan/Carter *Investigating Biology*, 7e	Lab Topic 4	Enzymes: A helpful introduction to enzyme function. In Exercise 4.3, students test the influence of concentration, pH, and temperature on amylase activity.

Case Narrative

Students were asked to underline terms or phrases in the introductory narrative that they think are important to understanding the case. Suggested terms and phrases that students might have chosen are in bold type.

As she drove back to the museum, Bryn considered the box and the tiny dress it contained. It had been worn by a child in a **19th-century portrait** of a local family already owned by the museum. Discovered in a trunk **in an unheated barn** by descendants, the dress was in **surprisingly good condition**.

Once she arrived, Bryn went to the curators' workroom to give the dress to Rob, the museum's **textile conservator.** Seeing Rob working intently, she quietly knocked on the half-open door. He put down his tools and looked up.

"Rob," she said excitedly. "Here it is! The dress I told you about from the painting! The donor was about to have it cleaned, but I'm so glad he called here first."

"You're not kidding. **It's easy to ruin old fabrics,**" Rob said as he accepted the box with the tissue-wrapped dress. After **putting on gloves**, he unwrapped the old dress carefully and **laid it flat** on a **clean table** to examine it. He saw that the cotton dress was **slightly yellowed** and there was a **small, stiff stain** near the neckline. He wondered if that spot might prove troublesome. "This is terrific, Bryn. I'll do my magic, and with luck these discolorations and spots should disappear."

Bryn laughed, knowing that Rob's work had nothing to do with **magic or luck.** As she left the workroom, Rob grabbed an *Object Description and Restoration* form and began to **fill it out in pencil.** Next he gently brushed the dress. Using a metal probe, he **scraped the stain** at the neckline and placed the **sample on a microscope slide.** Rob examined the slide with the microscope, noticing **several granules** mixed in with a few longer fibers. He was not surprised to see **long cellulose fibers, which he knew to be cotton.** The granules, though, which were smooth and oval-shaped with a diameter of about 75 μm (micrometers), came from the stain itself. He added a drop of a weak, yellowish **iodine solution** to the slide. The **granules turned dark blue.** Under *Treatment Plan* he wrote "Neckline stain: **use amylase cleaning solution"—**an **enzymatic solution specific for removing starch.**

Suggested Answers for Case Analysis

1. **Recognize potential issues and major topics in the case.** What is this case about? Underline terms or phrases that seem to be important to understanding this case. Then list **3 or 4** biology-related topics or issues in the case.

   Biology-related topics or issues: how museum textile conservators work, starch and its removal, cellulose, enzymes.

2. **What specific questions do you have about these topics?** By yourself, or better yet, in a group, make a list of what you already know about this case in the "What Do I Know?" column. List questions you would like to learn more about in the "What Do I Need to Know?" column.

   There are many possible answers, depending on the experiences of your students. Below are some likely responses:

What Do I Know?	What Do I Need to Know?
• *Iodine turns starch granules blue.* • *In plants starch forms granules.* • *In plants cellulose forms long fibers.* • *Enzymes can clean stains.* • *Fabrics (such as cotton) can last for a long time in poor storage conditions.*	• *What do the granules and fibers look like?* • *What does starch look like?* • *How does one become a textile conservator?* • *How does amylase work?*

3. Put a check mark by **1–3** questions or issues in the "What Do I Need to Know?" list that you think are most important to explore.

   You should expect a range of responses. Most students will use the contextual clues of being in a biology class and beginning the chemistry unit to identify chemistry-related questions.

4. **What kinds of references or resources would help you answer or explore these questions?** Identify two different resources and explain what information each resource is likely to give that will help you answer the question(s). Choose specific resources.

   Accept any reasonable resource (e.g., text, other book, Internet sites, data tables, and so on) that could be related to this case. The answer "the Web" is too vague. Students should explain the type of site they are looking for or search terms they might use.

Suggested Answers for Core Investigations

I. Critical Reading

To complete this investigation, you should have already read Concepts 5.1–5.3 in Chapter 5. In Concept 8.4, you should also read the text under the headings "Substrate Specificity of Enzymes" and "Effects of Local Conditions on Enzyme Activity." Then answer the following questions.

1. In the case narrative, Rob learned that the stain near the neckline of the dress contained starch. What specific types of macromolecule are starch and cellulose?

   Starch and cellulose are polysaccharides (carbohydrates).

2. What monomer is found in starch and cellulose?

   glucose

3. Contrast the structure and function of starch with those of cellulose in plant cells.

   Starch is a storage carbohydrate made of glucose monomers that are used for cellular fuel. The glucose monomers in amylose are joined by 1–4 linkages. Amylopectin, a branched polymer, has 1–4 linkages at its straight points and 1–6 linkages at branch points. All the glucose monomers in starch are in the a configuration.

   Cellulose is a building material found in plant cell walls. It is also made of glucose monomers, but its glycosidic linkages are different from those of starch. The glucose monomers of cellulose are all in the b configuration, making every other glucose monomer upside down in relation to the others. The molecules can form hydrogen bonds with other parallel cellulose molecules. This property allows for the formation of the strong fibers found in plant cell walls.

4. What is an enzyme?

   Enzymes are proteins that regulate metabolism by acting as catalysts (chemical agents that selectively speed up chemical reactions in the cell without being consumed by the reaction). Enzymes recognize and bind only to their specific substrates (the substances a particular enzyme works on).

5. To remove the stain from the dress, Rob treated the stain with a cleaner containing the hydrolytic enzyme *amylase*. Explain what happens to starch at the molecular level when it is acted upon by amylase. You may wish to sketch the structure of starch to show how this enzyme works (see Figure 5.7 in your text).

   As a hydrolytic enzyme, amylase breaks apart starch by adding a water molecule and breaking apart the 1–4 glycosidic linkages. A hydrogen atom is added to one monomer and an OH molecule to the other monomer involved in a single bond. Expect students' drawings to resemble Figure 5.5a, Dehydration synthesis of maltose in reverse.

6. Under the right conditions, amylase breaks down amylose efficiently; however, the enzyme is not very effective in breaking down amylopectin. Examine Figure 5.6 and read the related text in your textbook. Use your observations to propose a hypothesis for why amylase breaks down amylose much more effectively than amylopectin.

   Amylose is a starch made of glucose molecules bound together in 1–4 glycosidic linkages. Amylopectin has these same linkages, but it also has 1–6 glycosidic linkages, which are not broken down by amylase. Therefore, amylopectin is only partially degraded by amylase.

7. Explain why Rob did not have to worry that the amylase cleaning solution would damage the dress.

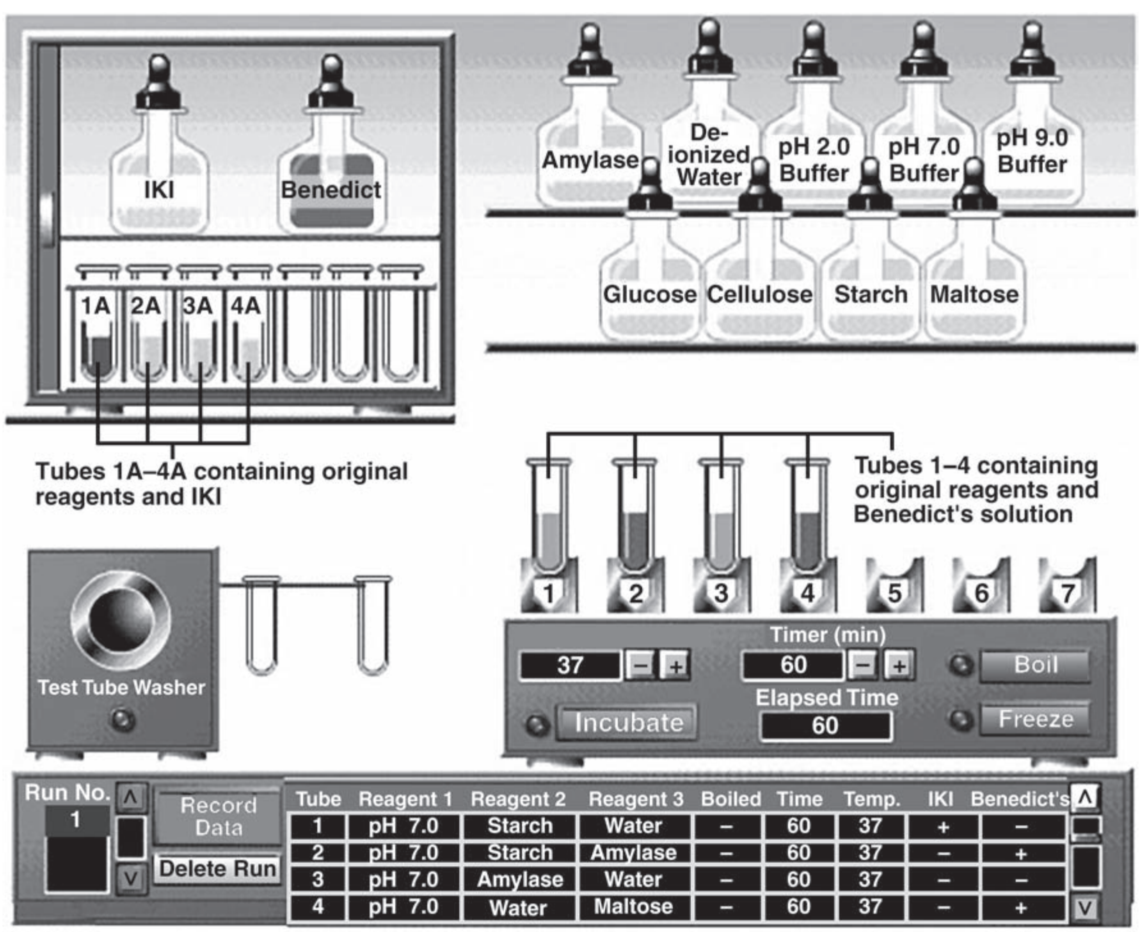
   Amylase is specific for a configuration, 1–4 glycosidic linkages. Cellulose consists of b linkages; therefore, it is not a substrate of amylase. Rob knew that the dress was made of cotton, which consists mainly of cellulose, and would not be affected by amylase.

II. Analyze and Design an Experiment

To further investigate starch and its components, first you will analyze an experiment. Then you will design your own. The experiment you will analyze was performed using the software in the *Chapter 41, Investigation: What Role Does Amylase Play in Digestion?* found on the Campbell website (http://www.masteringbio.com) and CD-ROM. However, you can complete the exercise with the information provided in this workbook.

A. Analyze an Experiment. In the following controlled experiment, we used both iodine solution (IKI) and Benedict's solution as indicators to test the effect of amylase on starch. As you may recall, Rob used the indicator iodine to test the dress stain for the presence of starch.

The Experiment: Four test tubes were set up. To find out which substances were placed in each tube, see the table in the bottom section of Figure 1.2. The tubes were then incubated at 37°C for 60 minutes (none were boiled). Half of the contents in tubes 1–4 were poured into tubes 1A–4A. The contents of tubes 1A–4A were tested with IKI. The remaining contents in tubes 1–4 were tested with Benedict's solution. The next set of questions asks you to analyze the results of both tests.



Tube	Reagent 1	Reagent 2	Reagent 3	Boiled	Time	Temp.	IKI	Benedict's
1	pH 7.0	Starch	Water	–	60	37	+	–
2	pH 7.0	Starch	Amylase	–	60	37	–	+
3	pH 7.0	Amylase	Water	–	60	37	–	–
4	pH 7.0	Water	Maltose	–	60	37	–	+

Figure 1.2 Experimental setup and results.

1. Review Figure 1.2 and note which of the reagents were used in each of the four test tubes. In Table 1.1, check off the reagents found in each tube.

   Students should have placed check marks in the areas indicated in Table IG1.3.

Table IG1.3 Answers to Student Table 1.1.

Reagent	Test Tube			
	1	2	3	4
Starch	√	√		
Amylase		√	√	
Buffer pH 7.0	√	√	√	√
Maltose				√
Water	√		√	√

2. Note the test-tube results for the use of IKI. The color change in the contents of each test tube is also shown in the test-tube rack at the upper left corner of the figure. A dark shade indicates a positive iodine reaction (the actual color is dark blue) and a light shade indicates a negative reaction (the actual color is yellow). Because Rob used iodine in this case, you know that iodine is a test for starch. Why, then, was the iodine test negative for test tube 2A?

   While test tube 2A did contain starch, amylase was also added to the tube. Amylase broke down the starch during the incubation period; therefore, when iodine is added to the tube there is no starch left for it to react with.

3. What is the purpose of adding iodine to test tubes 1A and 3A?

   Iodine is added to test tube 1A to test the effectiveness of the iodine solution. Because the tube is known to contain starch, the contents of the tube should turn a dark blue. If the color does not change, there may be something wrong with the iodine solution. Test tube 3A is a control to show that a combination of iodine and amylase does not lead to a blue solution. The color should remain light yellow.

4. Now examine the results for the Benedict's solution test. Color changes are shown in the rack containing tubes 1–4 at the middle right. A dark shade indicates a positive test (the actual color is reddish brown). A light shade indicates a negative test (the actual color is blue). Do you think Benedict's solution is a test for starch, amylase, or maltose? Explain.

   Benedict's solution must be a test for maltose. The tests with starch alone and amylase alone produced a negative result. The test with maltose alone and with starch and amylase produced positive results. The Benedict's solution test reveals that amylase does break down starch into maltose.

B. Design Your Own Experiment

1. Using *either* the iodine test or the Benedict's test, design an experiment to examine other factors in the action of amylase on starch. Your experiment should test only *one* of the following variables: pH, incubation temperature, incubation time, boiling, or freezing.

When evaluating a student's experiment, make sure the student has varied only one reagent or one experimental condition. If the student tests pH level, then incubation time and temperature should be the same for all tubes. If the student varies an environmental condition, then the tubes must contain the same reagents.

a. What question will you investigate in your experiment?

A student should state a question that relates the variables being changed to the outcome of the test. For example, does a change in pH level affect how well amylase breaks down starch?

b. Restate the question as a hypothesis (see Chapter 1 in your textbook for an explanation of forming hypotheses):

If ____,

then ____.

The question should be restated as an "If . . . then" statement. Usually a hypothesis is written as "If the variable I am changing goes up (or down), then the result of the test will go up (or down)." An example of a possible hypothesis could be "If the pH is raised as high as possible, then the enzyme will fail to break down starch."

2. In Table 1.2, describe your experimental treatment in test tube 1. Although it is likely that you will have more than one control tube, describe just one of your controls for test tube 2.

Table 1.2 Test Tube Contents and Conditions.

Reagents	**Test Tube 1 (experimental)**	**Test Tube 2 (control)**
Starch		
Amylase		
pH		
Experimental conditions		
Incubation time		
Incubation temperature		
Boiling		
Freezing		

The students should fill in the table with the reagents and experimental conditions that will be used in their experimental and control tubes. For the example described in 1.b., test tube 1 would be identical to test tube 2 except for the pH of the buffer.

3. In Table 1.3, indicate the results you would expect if your hypothesis were supported (use "+" and "−" for the test indicator that you chose).

Table 1.3 Predicted Results, Supporting Hypothesis.

Tests	Test Tube 1	Test Tube 2
Benedict's		
IKI		

Predicted results will vary based on the students' proposed experiments.

4. In Table 1.4, indicate the results you would expect if your hypothesis were *not* supported (use "+" and "−" for the test indicator that you chose).

Table 1.4 Predicted Results, Not Supporting Hypothesis.

Tests	Test Tube 1	Test Tube 2
Benedict's		
IKI		

Predicted results will vary based on the students' proposed experiments.

5. *Optional.* Conduct the experiment you designed using the software provided in the *Chapter 41, Investigation: What Role Does Amylase Play in Digestion?* found on the Campbell website (http://www.maseringbio.com) or CD-ROM. Turn in a screen capture of the table showing your results. *Note:* Experiments involving IKI tests of cellulose will not give the correct results due to a bug in the software.

   Students could use the software program in the Chapter 41, Investigation: What Role Does Amylase Play in Digestion? to run a simulation of their own experiment.

III. Off the Wall: Starch Degradation Investigation

Hildy planned to surprise her parents by remodeling their living room while they were away for the weekend. First she had to remove the wallpaper so that she could paint. When she started scraping at the edge of the dry wallpaper, only a few small pieces came off. "What's up with this wallpaper?" Hildy asked herself. "It's just not coming off!"

Hildy got a spray bottle and filled it with warm water. She sprayed the walls to moisten large areas. After several minutes, she scraped at the wallpaper again. Larger pieces came off this time, but big patches of hardened paste remained. Hildy couldn't spend the whole weekend scraping! She rummaged around the house and found some alcohol and some vinegar.

Unsure of what these substances would do to the walls, she also went out and bought two different types of commercial wallpaper remover. "I wonder which of these will work the best?" she thought.

To test which one would work best, she chose a section of the wall behind the couch and applied the five substances to a 10-cm^2 section of the wall. She labeled each patch to remember which substance had been applied to each square. After 20 minutes, she noted how much wallpaper she could remove with one scrape from each patch. See the results of her experiment in Figure 1.3.

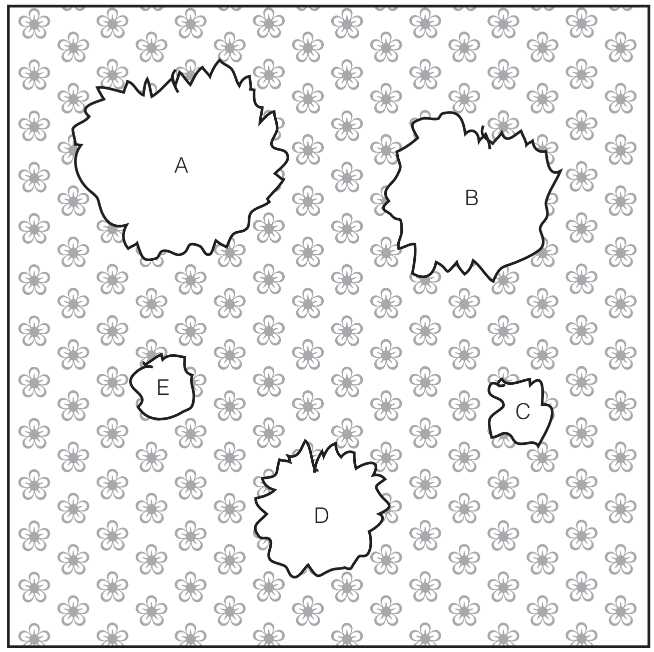


Figure 1.3 The above figure shows a section of Hildy's parents' living room wall after her experiment. The table below is a key containing her results.

Label on Wallpaper	Substance	Approximate % of Wallpaper and Paste Removed
A	remover with 0.5% amylase	100
B	remover with 0.1% amylase	75
C	rubbing alcohol	10
D	vinegar	50
E	water	10

1. Which substance worked best? What does this tell you about the composition of wallpaper paste?

   Substance A, the product with the highest percentage of amylase, allowed the most removal of wallpaper and paste. Wallpaper paste must contain starch.

2. Describe how the most effective substance worked to remove the paste.

   Amylase breaks down the starch in the wallpaper paste by breaking down the 1–4 glycosidic linkages.

3. Considering that vinegar is an acid, explain the results seen with the vinegar.

   Because vinegar is an acid, it slightly hydrolyzes starch, which results in a small clear area.

4. Why was it important that Hildy also test the effect of water alone on the wallpaper paste?

   Hildy needed to test the effect of water alone because it is the solvent for the other potential removers. She used water as the control in her experiment to show that water alone cannot break down starch to the same extent as some of the other products.

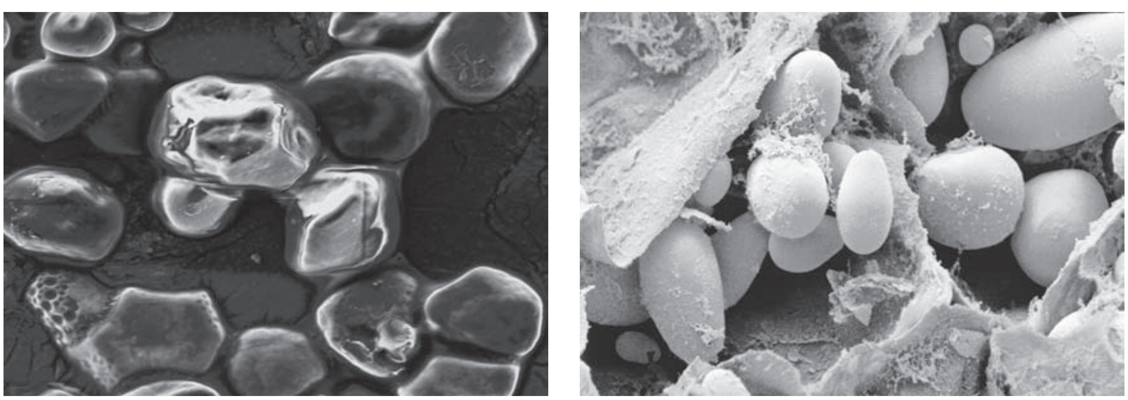
Suggested Answers for Additional Investigations

IV. Structure and Function of Starches

A. Kinds of Starch. Starches are a significant part of the typical human diet, making up 40–80% of total energy intake. Some plants store more starch than others. Humans have discovered many varieties of starchy plants that satisfy our hunger and taste buds, such as corn, cassava, and potatoes, originally from South America; sweet potatoes and yams, from tropical Africa and South America; chickpeas, from Turkey; plantains, originally from India; rice, originally from Asia; soybeans, originally from China; and wheat, from the Middle East.

Plants store starch as highly condensed granules that do not dissolve easily in water. The composition and size of these granules vary in different types of plants.

1. Contrast the microscopic starch granules of corn with those of potato, shown in Figure 1.4.



(a) Starch granules in corn (5–25 μm) (b) Potato starch (15–100 μm)

Figure 1.4 Note the variations in the size and shape of starch granules.

Corn granules (5–25 μm) generally are smaller than potato granules (15–100 μm). Corn granules are angular and irregularly shaped, while potato granules are smooth and sphere- or oval-shaped.

2. Now that you have learned more about the different types of starch granules, can you infer the type of granules that Rob scraped from the old dress? Explain your response.

   Rob most likely scraped off potato starch. The smooth, mostly oval granules were described as being approximately 75 μm in diameter.

B. Using Starches in Food: Understanding Structure for Commercial Application. Although the enzymes in our digestive system are capable of breaking apart starch granules, cooking starchy foods causes the starches to gelatinize, which enhances texture and taste and improves digestion. *Gelatinization* is the process in which granules of starch swell, break up, and disperse in water. Suspensions of various thicknesses are formed during this process.

Figure 1.5 on the next page shows a cornstarch granule before and after gelatinization. (Cornstarch is often used as a thickening agent in food products such as gravies and sauces.) Starch granules have complex structures. The granule surface consists of many amylopectin and some amylose molecules associating tightly with each other due to hydrogen bonding. Water does not easily penetrate the granule. Tiny channels lead from the surface into an amorphous center where less tightly bound amylose and amylopectin molecules are found.

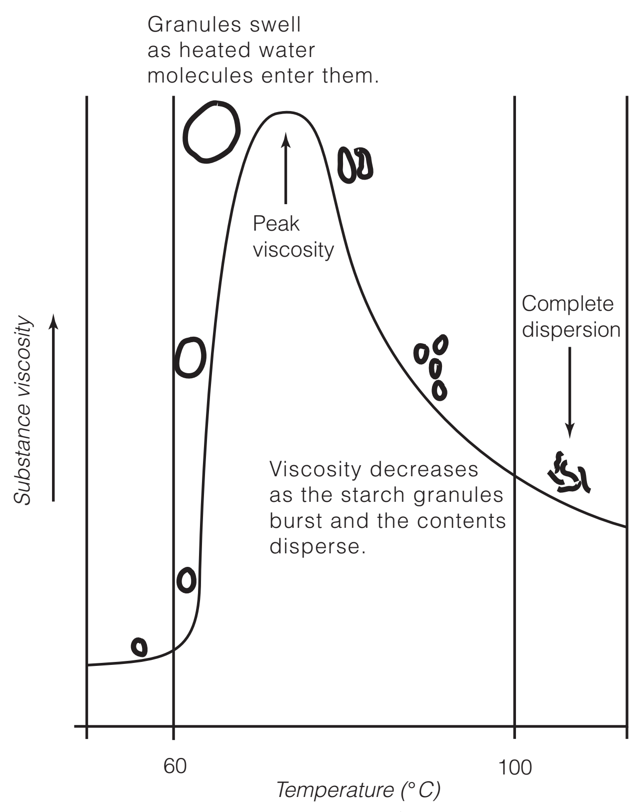


Figure 1.5 Gelatinization and disruption of starch molecules.

When starch granules are immersed in water, two things happen. Water moves slowly through the channels and forms hydrogen bonds with the amylose and amylopectin components in the center of the granules. At the same time, hydrogen bonding among the amylose and amylopectin molecules on adjacent granules causes clumping. Stirring the suspension prevents the granules from forming dense clumps. If understirred, the cornstarch mixture will be lumpy.

When exposed to heat, water molecules move more rapidly. The rapid movement allows more water molecules to enter the granules, causing the granules in the suspension to swell. The cornstarch and water mixture noticeably thickens (increases in viscosity). Because amylose molecules are unbranched, they can easily move through the channels and will leach out of the granules more quickly than amylopectin. If the gel sits and cools at this stage, the amylose molecules will begin to realign by hydrogen bonding, causing the granules to adhere to each other and to the container. The cornstarch may thicken unevenly and the resulting mixture will be difficult to pour.

On the other hand, continued heating of the gelatinized starch transfers more energy to the water molecules, allowing them to further destabilize hydrogen bonds between starch molecules. The granules continue to swell, and more starch molecules leak into the surrounding liquid. Heating past the boiling point causes swollen granules to break into fragments and release all of the starch molecules into the water. At this point, the mixture thins (decreases in viscosity). Stirring the mixture will hasten the thinning process, leading to a runny cornstarch mixture.

Investigation: What Went Wrong?

Gravy and mashed potatoes are two foods prepared in many U.S. homes, but they are tricky to make successfully. Examine the recipes below for gravy and mashed potatoes and answer the following questions using your knowledge of the gelatinization process. (*Hint:* The secret to making gravy and mashed potatoes is maintaining an even distribution of granular structure without fragmenting the individual granules.)

Turkey Gravy	**Mashed Potatoes**
1. In a large saucepan, over medium heat, bring 1 cup of turkey broth and pan juices to a boil. 2. Meanwhile, blend until smooth 2 tablespoons of cornstarch in 1 cup of cold water. 3. Slowly add the cornstarch mixture to the boiling broth. 4. Stir intermittently until the gravy thickens. 5. Season to taste with salt and pepper. 6. Remove from heat and serve immediately.	1. Place a large pot of cold water on the stove. 2. Peel each potato, cut into cubes of about 3/4-inch square, and put in the pot. 3. Do not allow the water to boil too rapidly; check for doneness after 15 minutes. 4. Mash the potatoes while they are hot. Do not overmash. Never use a food processor. 5. Mix in butter and milk. Do not let potatoes cool.

1. As you begin to prepare turkey gravy, you carefully blend 2 tablespoons of cornstarch into a cup of cold water. You add the mixture to the turkey broth, but then you forget to stir it. Your gravy turns out lumpy. How did the mistake ruin the gravy?

The cornstarch was allowed to stand after the granules swelled, forming a gel. Amylose molecules leaked out from the center of the granules, causing the granules to adhere to each other and form lumps.

2. To make mashed potatoes, you boil the potatoes for 25 minutes. The potato chunks begin to disintegrate as you drain them. When you add the butter and milk, the potatoes are thin and gluey—similar to wallpaper paste before it dries. What went wrong?

Overheating broke the potato granules into fragments. The starch molecules are dispersed in the water, with a corresponding decrease in viscosity. The potatoes are therefore thin and watery.

C. Structural Properties of Native and Modified Starches in Commercial Products. Starch has a number of properties that make it useful to manufacturers of prepared foods and other commercial products such as glues. Cornstarch products, such as corn syrup, are among the most common ingredients listed on the food labels of cookies, puddings, frozen dinners, and crackers.

Naturally occurring starches (native starches) may be used in dry form as ingredients for foods (about 75% of wheat flour is starch) or as dry lubricants (baby powder), but most are added to water to create gels and solutions. Two widely used types of native cornstarch, *dent* and *waxy,* vary in their amylose content, which makes them useful for different purposes.

Dent cornstarch comes from the most frequently planted type of corn in the United States. Dent cornstarch usually contains about 80% amylopectin and 20% amylose. Starch products made with dent corn tend to adhere to surfaces and form more rigid layers as they are cooked or allowed to dry. For example, dent cornstarch is used in the production of wallpaper paste. Amylose causes the wallpaper to stick to the wall through hydrogen bonding with cellulose and then to stiffen as it dries. The harder outer coating of jelly beans is also made from dent starch.

Waxy cornstarch is produced by a type of corn plant that does not produce amylose. Waxy starch consists entirely of amylopectin molecules. When this cornstarch is dissolved in a solution, it tends to be more stable than the dent cornstarch. The resulting product pours easily. For example, hot chocolate mixes contain waxy cornstarch.

Manufacturers often chemically modify native cornstarch to form additional bonds that cross-link amylose molecules or cross-link amylose and amylopectin molecules. These modified starches have different chemical properties than the native starches.

- Cross-linked waxy starches like Consista® and Rezista® absorb water but retain their granular structure, producing more stable mixtures with higher viscosity than that found in native starches. Products requiring a thicker consistency, such as gravy in canned stew, often contain modified waxy starch.
- Amylomaize, another modified starch, contains 70% amylose and 30% amylopectin. Manufacturers use amylomaize to make inexpensive and biodegradable packaging foam with good cushioning and resiliency properties. For starch to act like polystyrene (a plastic), its polymer molecules have to align closely through hydrogen bonds. Linear molecules perform better in this way than branched molecules; therefore, the high amylose content of amylomaize makes it work well.

Read the following product description and determine which starch would be the best choice for a manufacturer. (*Note:* The cost of dent starch is low, waxy starch is more expensive, and chemically modified waxy starches are the most expensive. Although cost is always an important factor in manufacturing decisions, for this exercise consider only the characteristics of the different types of starch.)

A. Dent starch
B. Waxy starch
C. Modified waxy starch
D. Amylomaize

1. **Instant cheesecake mix.** Manufacturers need a starch that will maintain a creamy consistency and will neither liquefy nor harden at room temperature. Explain your choice.

   The best choice is C. Modified waxy starch is the best choice because it retains granular structure, producing more stable mixtures with higher viscosity due to cross-linking.

2. **Soups.** Manufacturers need a starch that allows their product to be pourable but does not thicken too much as it cools. Explain your choice.

   The best choice is B. Waxy starch is the best choice because it contains only amylopectin. This results in a more stable product that will retain the ability to flow easily when poured.

3. **Batter and breading.** Manufacturers need a starch that will adhere to chicken and then become crunchy as the chicken is cooked. Explain your choice.

   The best choice is A. Dent starch is the best choice because amylose molecules are present, enabling the starch product to stick to the chicken through hydrogen bonding and then stiffen.

V. Open-Ended Investigations

A. Why is starch used in paper making? Consider the structure of starch molecules in your answer.

Starch is used throughout the paper-making process. In the wet phases, starch is added to the slumy to improve paper dry strength. Also involved in printability, charge control, and biochem oxygen demand reduction. Starch is also used as a surface application where it increaces strength, improves printability, and increases resistance to grease. Surface starch also acts as a binder, and increased amounts enable a smoother writing surface.

B. See the Case Book website for access to ideas for open-ended student investigations (short- or long-term, group or individual), simulations, and other information on extending your students' learning in this unit.

References

Corn Products U.S. www.cornproductsus.com/MISHRA_STARCH.pdf

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