Teacher Preparation Notes for
A Scientific Investigation – What types of food contain starch and protein?[1]

In the first part of this activity, students answer analysis and discussion questions as they learn about the structure and functions of starch and proteins. They use this information to explain why certain parts of plants or animals contain a substantial amount of starch or protein. Then, students carry out key components of a scientific investigation, including:

- generating hypotheses
- designing and carrying out experiments to test their hypotheses
- if needed, using experimental results to revise their hypotheses.

The Student Handout provides information and questions to guide students in designing the first experiment, which evaluates two indicator solutions to see whether either of them can be used to test for starch or for protein. Based on their results, students formulate hypotheses concerning which types of food contain starch and which types of food contain protein (some or all foods derived from animals or plants or both). Next, students use their hypotheses to make predictions about the starch and protein content of several types of food, and they test their predictions in a second experiment. Students evaluate whether their results support their hypotheses and, if needed, they propose revised hypotheses.

Before beginning this activity, students should have a basic understanding of biological molecules.

You will probably want to complete your class discussion of pages 1-4 before one or two 50-minute laboratory periods.

Learning Goals

In accord with the Next Generation Science Standards[2]:

- This activity helps to prepare students for the Performance Expectation: HS-LS1-6. "Construct and revise an explanation based on evidence for how carbon, hydrogen and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules."
- Students learn the Disciplinary Core Idea: LS1.C: Organization for Matter and Energy Flow in Organisms – "The sugar molecules thus formed contain carbon, hydrogen, and oxygen; their carbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells."
- Students engage in the Science Practices of
  - "Planning and Carrying Out Investigations: Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on the types, how much, and accuracy of data needed to produce reliable measurements…"
  - "Analyzing and interpreting data" – Students should be able to:
    - "Analyze data systematically, either to look for salient patterns or to test whether data are consistent with an initial hypothesis."
    - "Evaluate the strength of the conclusion that can be inferred from any data set…"

[1] By Dr. Ingrid Waldron, Department of Biology, University of Pennsylvania, 2024. These Teacher Preparation Notes and the related Student Handout are available at https://serendipstudio.org/sci_edu/waldron/#starch.

[2] Quotations are from https://www.nextgenscience.org/resources/framework-k%E2%80%9312-science-education and https://www.nextgenscience.org/sites/default/files/HS%20LS%20topics%20combined%206.13.13.pdf.

- “Constructing Explanations: Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena…”
    - “Engaging in an Argument from Evidence: Construct, use and/or present … written argument or counter-arguments based on data and evidence.”
- This activity can help students to understand the Crosscutting Concept, Energy and Matter.
- This activity helps students to understand the Nature of Science, including:
    - Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings.
    - Science knowledge is based on empirical evidence.

Additional Content Learning Goals

- Starch is a polymer of glucose. The function of starch is glucose storage.
- Proteins are polymers of 21 different types of amino acids. The many different types of proteins serve a variety of functions, e.g. enzymes, structure and movement.
- The molecules in food are useful for the plant or animal from which the food was derived.
- In plants, photosynthesis combines CO_2 and H_2O to make the sugar, glucose. Glucose provides precursor molecules to make other types of plant molecules. For example, molecules derived from glucose plus N atoms in ions from the soil are used to make amino acids. The monomers (amino acids or glucose) are joined together to make the polymers (proteins or starch).
- An indicator is a substance that changes color in the presence of a particular type of organic compound.
- To evaluate the specificity of an indicator, it is important to include negative controls.
- Accurate, consistent methods and replication of experiments are needed to produce reliable experimental results.
- Inductive reasoning can provide useful generalizations based on specific observations, but the results of inductive reasoning should be treated with caution, since additional observations may show exceptions to a generalization.
- To test a hypothesis, scientists use deductive reasoning to predict specific experimental results expected on the basis of the hypothesis.
- Experiments to test a hypothesis often produce results that require scientists to modify their original hypothesis.
- Substantial amounts of starch are found in some foods derived from plants. Substantial amounts of protein are found in some foods derived from animals and some foods derived from plants.

Supplies

- Indicator Solution 1 = Iodine-Potassium Iodide Solution (~12 mL per class; available from http://www.carolina.com/; if not in an opaque container, should be stored in the dark)
- Indicator Solution 2 = Biuret reagent (~50 mL per class; available from http://www.carolina.com/; Biuret reagent should be fresh since old Biuret reagent is less sensitive as a protein indicator.)[3]

[3] To dispose of significant amounts of Biuret solution, do not pour into sink drains or sewers, but instead contact a permitted waste disposer. It appears that the tiny amounts of Biuret solution added to each sample can safely be disposed of by placing the tested samples in the regular trash. Additional safety information is available at http://www.carolina.com/pdf/msds/BIURETGHS.pdf and http://www.carolina.com/pdf/msds/iodinetincghs.pdf.

- Dropper bottles for the indicator solutions (bare minimum of two, one for each indicator solution; ideally, as many as the number of student groups in your largest class, so each pair of student groups can share a pair of dropper bottles)
- Containers for testing such as small plastic or Styrofoam cups (28 if you have containers that will be washed after each laboratory class and reused; if containers will not be washed and reused, 48 per class; white containers or transparent containers placed on a white background make it easier to see the color change in the indicator solutions; *small paper cups should not* be used because at least some brands test positive for starch even when you use a sample of pure water)
- Markers for labeling the containers
- Stirrers (e.g. plastic knives and/or spoons; at least 2 per student group in your largest class; 6 per student group, if you do not want students to have to wash stirrers during their experiments)
- Gloves (minimum of 1 per student per day) (Goggles can also help keep students safe.)
- If you want your students to measure the exact amounts of each sample given on pages 5 and 7 of the Student Handout, you can use milliliter pipettes to measure the amounts of water and oil and a scale to measure the amounts of the solid samples and egg white. However, the tests for starch and protein work well with estimated amounts of samples, and your students can use measuring spoons to measure the amounts of samples. When you buy a set of measuring spoons, we recommend that you look for a set that includes 1/8 teaspoon measure. (In many sets, ¼ teaspoon is the smallest measure.) If you have your students use measuring spoons, you should substitute the teaspoon amounts for the gram amounts in the Student Handout.[4]
- Samples for pages 4-6 of the Student Handout – amount needed per class (It will be good to have extra of each of these, e.g. to accommodate the group assignments proposed on the bottom of page 8 of these Teacher Preparation Notes.)
  - Corn starch (~1.2 g or ~ ½ teaspoon; can be found in the baking needs aisle)
  - Potato starch (~1.2 g or ~ ½ teaspoon; can be found in the baking needs aisle)
  - Egg white from a whole egg (~3.2 g or ~1 teaspoon) or powdered egg whites (~1.2 g or ~ ½ teaspoon; follow the directions to dissolve in water)
  - Unsweetened Gelatin (~0.4 g or < ~¼ teaspoon)
  - Sucrose = "table sugar" (~1.2 g or ~ ½ teaspoon)
  - Vegetable oil (~4 mL or ~0.8 teaspoon)
- Samples for pages 7-8 of the Student Handout – amount needed per class (It will be good to have a little extra of each of these.)
  - Beans (~8 canned beans; we have had good success with white cannellini beans which are easy to mash and have a light color, so the color change of Biuret solution is more visible)
  - Almond paste (~2.5 g or ½ teaspoon; can be found in the baking needs aisle)
  - Marmalade (~6 g or ~1 teaspoon; since Part 2 of the activity analyzes the starch and protein content of foods derived from plants vs. animals, you will want to check the label to make sure your marmalade does *not* contain gelatin)

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[4] Substitute wording for instruction A on page 5 of the Student Handout:

A. For either type of starch or sucrose, dissolve 1/8 teaspoon in ½ teaspoon of water. For gelatin, dissolve less than 1/16 teaspoon in ½ teaspoon of water. For liquid egg white or oil, use ¼ teaspoon as your sample.

Amounts to substitute in the table in question 19 on page 7 of the Student Handout:

- 1/8 teaspoon of almond paste, mixed with slightly less than 1/8 teaspoon of water
- ¼ teaspoon of marmalade, mixed with 1/8 teaspoon of water
- ¼ teaspoon of butter and of yogurt.

- Butter (~4 g or ~1 teaspoon)
- Yogurt (~4 g or ~1 teaspoon; you should check the ingredients list to make sure to purchase a brand of yogurt that does *not* contain starch or gelatin)

- Water (tap water should be fine; ~40 mL or ~9 teaspoons per class for pages 5-6 and ~10 mL or ~2 teaspoons per class for pages 7-8 + water for washing unless you have enough containers and stirrers so students do not need to wash them)

Suggestions for Implementation and Background Information

To maximize student participation and learning, I recommend that you have students work on groups of related questions individually or in pairs before having a class discussion of their answers.

In the Student Handout, numbers in bold indicate questions for the students to answer and letters in bold indicate steps in the experimental procedure for the students to do. Each

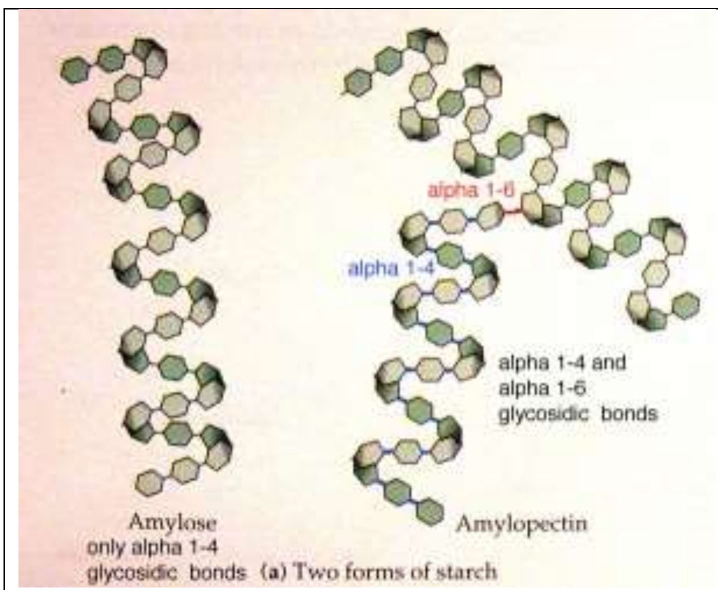
➢ indicates a safety precaution.

You can use the Word document for the Student Handout to prepare a revised version that may be more suitable for your students. If you use the Word document, please check the format by viewing the PDF.

A key is available upon request to Ingrid Waldron (iwaldron@upenn.edu). The following paragraphs provide additional instructional suggestions and background information – some for inclusion in your class discussions and some to provide you with relevant background that may be useful for your understanding and/or for responding to student questions.

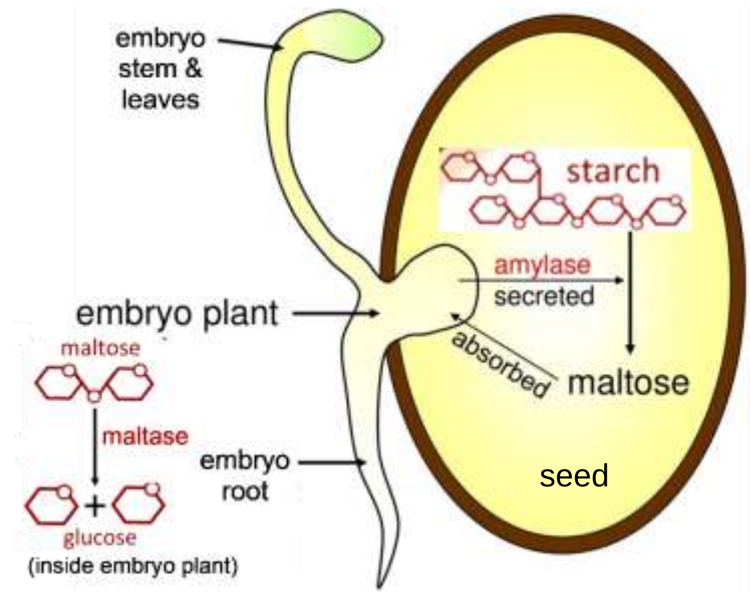
Question 1 is designed to get students thinking about the driving question for this activity. As you discuss the student answers to this question, you may want to mention that we are only concerned with foods that have a substantial amount of starch or protein. I recommend that you not reveal which student answers are correct at this time, but rather position them as hypotheses that will be tested during this investigation. You will return to student answers to this question at the end of the activity.

The figure on page 1 of the Student Handout shows an example of the branched form of starch. This figure shows examples of both forms of starch. The linear helix constitutes about 20-25% of starch by weight, and the branched helix constitutes about 75-80% of starch.



(http://www.precisionnutrition.com/wordpress/wp-content/uploads/2011/07/amylose-300x249.jpg)

This figure shows a more complete version of the lower figure on page 1 of the Student Handout. You may want to ask your students what types of food are derived from seeds. The Student Handout does not discuss differences between different kinds of seeds. Grains (e.g., wheat or rice), corn kernels,[5] beans and other legumes tend to have more starch, whereas nuts tend to have more oil.



(modified from https://slideplayer.com/slide/13124647/79/images/7/Enzymes+are+used+in+seed+germination.jpg)

Additional information about the uses of glucose is available on the top of page 3 of the Student Handout and on page 7 of these Teacher Preparation Notes.

When you discuss student answers to question 2b, you may want to point out that starch is a carbohydrate, reflecting the fact that it contains carbon, hydrogen and oxygen atoms.

The classic understanding that human proteins contain only 20 different types of amino acids has been updated with the discovery that selenocysteine is incorporated in some human proteins. Question 4a should help your students understand the name, amino acid. Each amino acid contains nitrogen, in addition to carbon, hydrogen and oxygen. If appropriate for your students, you may want to add that some amino acids also contain sulfur or selenium.

Scientists have estimated that there are roughly 100,000 different types of proteins in the human body. Protein functions include:

- movement (including cilia, flagella, muscles, and transport within the cell (e.g. motor proteins), across cell membranes (e.g. ion channels), and in the blood (e.g. hemoglobin))
- structure (e.g. cytoskeleton; see https://www.nature.com/scitable/ebooks/essentials-of-cell-biology-14749010/118240354/)
- enzymes[6]
- chemical messengers (e.g. hormones)
- defense against infection (e.g. antibodies).

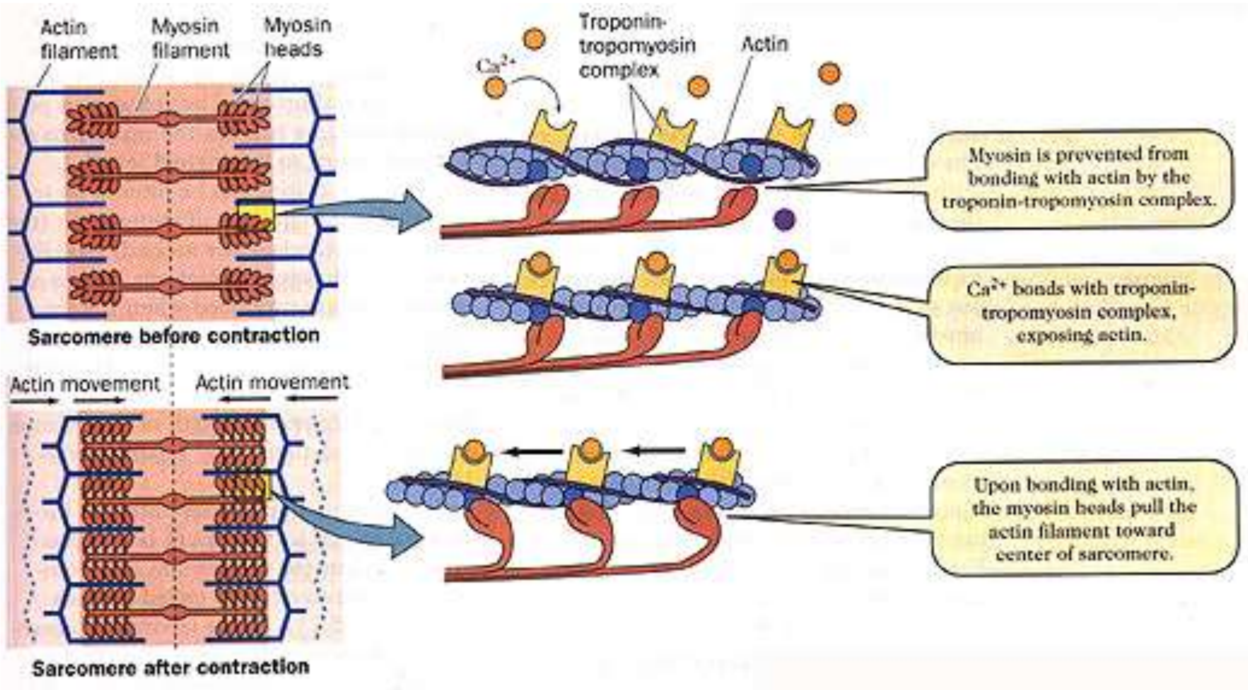
If your students are not familiar with the functions of proteins, you may want to use part or all of "Introduction to the Functions of Proteins and DNA" (https://serendipstudio.org/exchange/bioactivities/proteins). For more information about protein functions, see https://medlineplus.gov/genetics/understanding/howgeneswork/protein/ and https://www.ncbi.nlm.nih.gov/books/NBK26911/. For more information about the composition

[5] We generally eat immature corn kernels that have quite a bit of sugar, which is converted to starch as the corn kernels mature.

[6] You may want to augment your students' understanding of enzymes by using the hands-on activity, "Enzymes Help Us Digest Food" (https://serendipstudio.org/sci_edu/waldron/#enzymes).

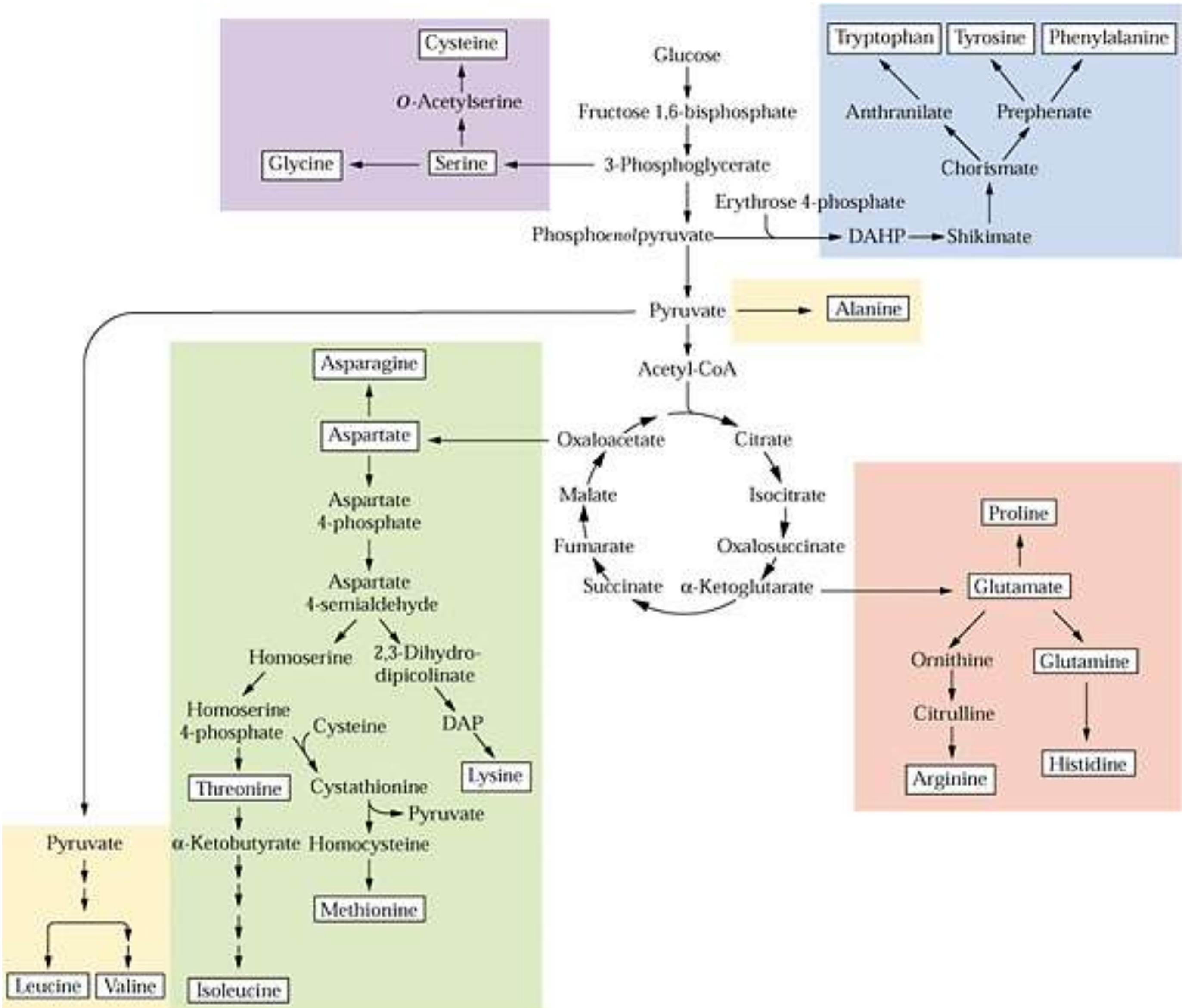
of meat, see https://amazingribs.com/technique-and-science/cooking-science/basic-meat-science/.

If students ask how proteins result in muscle contraction, you may want to show them this figure and tell them that myosin and actin are proteins, and the bending of the myosin heads pulls the actin filaments in, which shortens the sarcomeres, which contracts the muscle.



(https://www.physioweb.org/IMAGES/actin_myosin.jpg)

The flowchart on the top of page 3 of the Student Handout describes the different uses of the glucose molecules produced by photosynthesis. Some are used as one input for cellular respiration, which produces ATP, which supplies the energy needed for many biological processes;[7] some are used to make starch;[8] and some are used to provide carbon backbones for the synthesis of other plant molecules. The figure below shows how molecules produced during cellular respiration of glucose are used to synthesize amino acids.

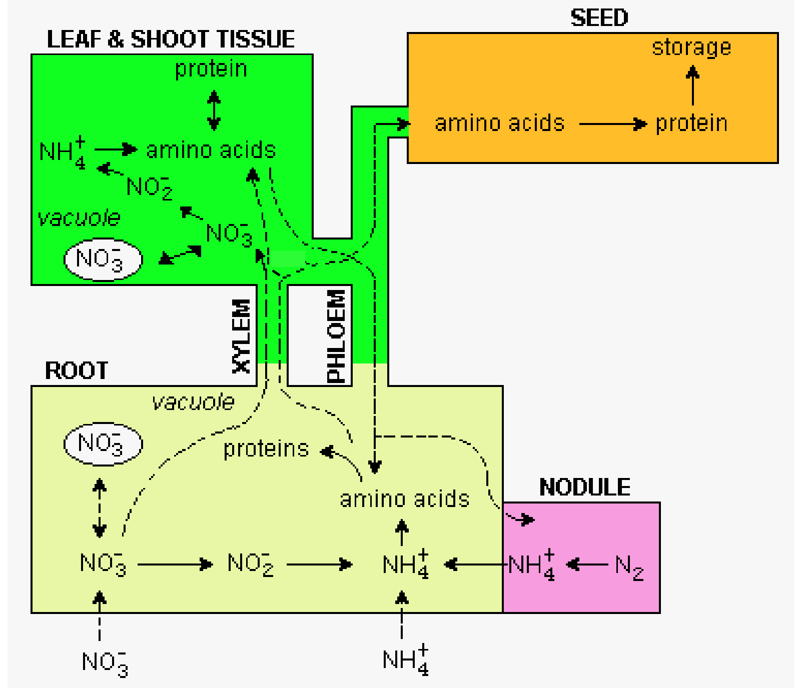


(http://www.uky.edu/~dhild/biochem/24/lect24.html)

[7] For information about cellular respiration, see "Cellular Respiration and Photosynthesis – Important Concepts, Common Misconceptions, and Learning Activities" (http://serendipstudio.org/exchange/bioactivities/cellrespiration); this document includes background information, plus suggested learning activities for your students.

[8] During the daytime, much of the sugar produced by photosynthesis is converted to starch. At night, when photosynthesis is not occurring, starch is broken down and used for cellular respiration.

The nitrogen needed for amino acid synthesis is taken up by the roots. NO_3^- is converted to NH_4^+ for incorporation in amino acids. This figure summarizes nitrogen metabolism in plants.



(http://www.uky.edu/~dhild/biochem/24/lect24.html)

After question 7, you may want to add this question.

7b. Many seeds contain quite a bit of protein. How is this protein useful for the embryo plant that develops from the seed?

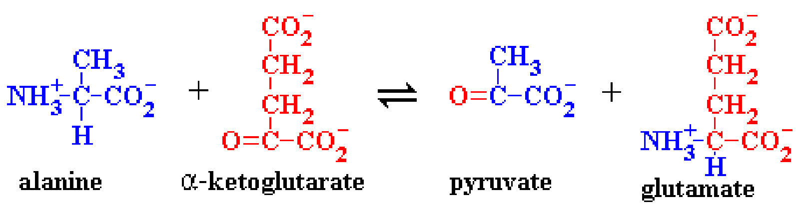
Enzymes in the seed digest the stored protein to amino acids which the embryo plant absorbs and uses to synthesize proteins (e.g. for growth).

If you want to provide additional scaffolding for question 9 for your students, you could use the following.

9. Which samples should be tested to evaluate whether either indicator solution is a good test for starch or a good test for protein? Complete this table.

Samples	Should these samples be included when you evaluate whether an indicator solution is a good test for **starch**? Explain your reasoning.	Should these samples be included when you evaluate whether an indicator solution is a good test for **protein**? Explain your reasoning.
Corn starch and potato starch		
Egg whites and gelatin		
Sucrose and vegetable oil		

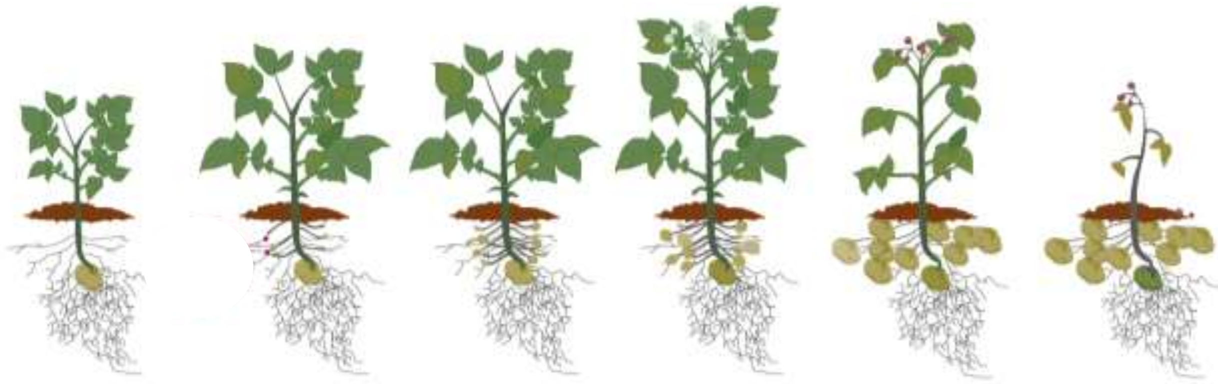
Plants, bacteria and Archaea can synthesize all of the amino acids they need. In contrast, humans must consume at least nine "essential" amino acids. (Sources disagree about the number of essential amino acids, because a person may need more types of amino acids in his/her diet, depending on his/her rate of growth and whether intake of certain other amino acids is low.) Humans can produce the other needed amino acids from the essential amino acids by a process called transamination (illustrated in the figure below). Transamination also plays an important role in the synthesis of amino acids in plants and prokaryotes.



(http://www.chemistry.uoguelph.ca/educmat/chm452/gif/ala_kg.gif)

To synthesize a protein, a cell needs to use information from a gene in the DNA to specify the sequence of amino acids. To teach your students about the processes of transcription and translation, I recommend the hands-on, minds-on activity on this topic (available at https://serendipstudio.org/sci_edu/waldron/#trans) or the analysis and discussion activity (available at https://serendipstudio.org/exchange/bioactivities/trans).

How can we test for starch and protein?
If your students ask how the starch in potatoes is useful for potato plants, you can explain that the starch in potatoes serves as glucose storage for the vegetative reproduction of potato plants. As shown in the figure below, a potato plant can sprout from a potato, after which the potato plant can produce multiple new potatoes. In the next growing season, each new potato can sprout one or more new potato plants. Compared to agricultural potato plants, wild potato plants make smaller new potatoes which are spread over a larger area; this facilitates vegetative reproduction.



(https://i.pinimg.com/originals/dd/ea/79/ddea79c9088a253f27ce12c79edb94c0.gif)

To test whether each indicator solution is a good indicator for starch (or for protein), students should evaluate color change when the indicator is added to:

- more than one type of starch (or more than one type of protein)
- negative controls, including water, sugar and oil.

The negative controls are important to establish that an indicator solution shows color change only for starch (or only for protein). The expected results are as follows.

- In the presence of starch, iodine will change color from yellow-brown to blue-black.
- In the presence of protein, Biuret reagent will turn from blue to purple.

Biuret reagent is less reliable than the iodine indicator. It is important to use fresh Biuret reagent. I recommend that you double check your Biuret reagent with a protein sample before your laboratory class. Also, you may want to show your students the color change for each of the indicator solutions before they begin their testing, so they will know what to look for. This will be helpful, for example, so students do not confuse the slight color change when egg whites are mixed with iodine with the reaction that occurs if starch is present.

Question 10 discusses the advantages of replication of each test. You may want to introduce the concept of false positives (which could occur if there were contamination) and false negatives (which could result from insufficient amounts of sample and/or indicator solution). If there are any differences between replicate tests, the test should be repeated with optimum methodology to resolve the conflict. You can point out to your students that an important and necessary part of scientific research is to refine and standardize methods in order to get consistent and reliable results.

See page 3 of these Teacher Preparation Notes for information about alternative ways that your students can measure the amount of each sample.

To accomplish the goals of having negative controls and replicating results, the experimental design should have duplicate tests with each indicator for each sample for a total of 24 tests = 6 samples x 2 indicator solutions x 2 replicates. I suggest that you have your students work in groups of 2-4. I recommend that you have each replicate test done by different groups (so whatever experimental error one group might make won't affect the replicate test). To increase student interest, you may want to have each student group test a starch sample, a protein sample, and one of the negative controls with each indicator. For example, if you have 4 student groups, you could use the plan shown in the table below.

Group	Samples to be Tested with Each Indicator Solution
1	corn starch, egg whites, sucrose
2	potato starch, egg whites, vegetable oil
3	corn starch, gelatin, vegetable oil
4	potato starch, gelatin, sucrose

If you have more than 4 student groups and you have three replicates for at least one sample, you will probably want to substitute the following table for the table currently shown in question 12. You may want to display the question 12 table on the board, so each student group can enter their data.

Sample	Did indicator solution 1 change color?			Did indicator solution 2 change color?		
	Replicate 1	Replicate 2	Replicate 3	Replicate 1	Replicate 2	Replicate 3
Corn Starch						
Potato starch						
Egg whites						
Gelatin						
Sucrose						
Vegetable oil						

In discussing question 15, you will want to include the limitations of inductive reasoning, especially when only a limited number of samples have been tested. To be more certain of conclusions concerning whether either of these indicator solutions can be used to test for starch or for protein, it would be desirable to test each indicator solution on a wider variety of samples, including additional types of starch and protein and additional types of negative controls, including glucose and amino acids (the monomers of starch and protein, respectively).

One important limitation of the indicator solution tests for starch or protein is that these tests are not sensitive enough to detect small amounts of starch or protein. The level of protein is high enough to be easily detected in concentrated sources of protein such as egg whites, beans, or milk (where the protein provides nutrition for the growing chick, plant seedling, or baby mammal, respectively). However, this indicator test will not detect the low levels of protein found in foods such as most fruits. You may want to mention that for intermediate levels of protein or starch, these indicators may give ambiguous results; you can discuss how scientific results are sometimes ambiguous, and scientists try to improve their methodology (e.g. develop quantitative methods) and repeat the experiment to clarify any ambiguity.

What types of food contain starch? What types of foods contain protein?

In this part, students:

- first use the data from the previous section to generate hypotheses about what types of food contain starch and protein,
- then carry out an experiment to test these hypotheses,
- interpret the results to see whether they support their hypotheses,
- and, if their initial hypotheses were not supported or only partially supported, formulate new revised hypotheses.

You will probably want to point out to your students that this is how real scientists work as they develop progressively better understanding of a research question.

Student hypotheses in response to question 18 will probably vary. This provides the opportunity to mention that this type of disagreement also happens in "real science" when different scientists have different interpretations of the same evidence; typically, these disagreements are resolved by obtaining additional evidence. At this point, all student hypotheses should be accepted as legitimate hypotheses to be tested by further experimentation, provided the hypotheses are compatible with the results summarized in question 17 which should show that:

- Some, but not all, foods derived from plants contain starch.
- At least some foods derived from animals do *not* contain starch.
- At least some foods derived from animals contain protein.
- At least some foods derived from plants do *not* contain protein.

Some of the student hypotheses may provide the opportunity to discuss how people formulate hypotheses based on both the results of the current experiment and also prior knowledge; this can be a useful part of the scientific process and contribute to cumulative improvements in our understanding of scientific questions.

You may want to point out that generating the hypotheses to answer question 18 requires inductive reasoning (generalizing from specific examples to more general hypotheses, which has the risk of overgeneralizing). In contrast, making the predictions in question 19 requires deductive reasoning (reasoning from general hypotheses to specific predictions, often used to test hypotheses).

To test their hypotheses, student groups will need to do replicate tests for each of the samples listed in question 20 with each of the indicator solutions. Thus, you will want a total of 20 tests = 5 samples x 2 indicator solutions x 2 replicates.

Comparing the results for protein summarized in questions 17 versus 19 demonstrates the risk of overgeneralizing from a limited set of observations. In the first set of samples, none of the foods derived from plants and all of the foods derived from animals have significant amounts of protein. In contrast, in the second set of samples, beans and almond paste have a significant amount of protein, whereas butter has almost no protein (so little that it is not detectable with our test).

Professional nutritional analysis provides the following values for starch and protein content for the food samples in this activity (% by weight; – indicates missing data).

Food	Starch	Protein
Corn starch	~91%	0%
Potato starch	–	–
Liquid egg whites	0%	11%
Powdered egg whites	–	81%
Gelatin, unsweetened	0%	86%
Sucrose	0%	0%
Vegetable oil (corn oil)	0%	0%
White beans (canned)	–	7%
Kidney beans (canned)	9%	5%
Almond paste	0%	10%
Marmalade	0%	0%
Butter	0%	1%
Low-fat vanilla yogurt*	0%	5%

(Most data from www.nutritiondata.com, accessed in 2012)

*These figures apply to brands like Stonyfield which do not add starch; read the ingredients list in the label to purchase a type of yogurt which does not have starch added.

Questions 22-23 asks students to compare their hypotheses (from their answers to question 18) to their new data (in their answers to question 19). This would also be a good time to revisit the hypotheses in student answers to question 1.

The following information is relevant to your class discussion of student answers to questions 22-23. Only plants produce starch, but starch is not present in significant amounts in some foods derived from plants, because the food is derived from a part of the plant that has little or no starch and/or because preparation of the food product has removed starch that was initially present. If an animal consumes food with more calories than needed for cellular respiration, glucose molecules may be stored in glycogen (a polymer of glucose that can release glucose rapidly during intense exercise), or molecules absorbed from the digestive system may be converted to lipids. (More energy is available from a given weight of lipid stores than from the same weight of starch or glycogen stores; this is an advantage for mobile organisms like animals.)

Additional Resources for Teaching about the Scientific Method

A wealth of resources for teaching and understanding the scientific process are provided in "Understanding Science – How science really works", available at https://undsci.berkeley.edu/

"Battling Bad Science" is an entertaining talk about the errors and deceptions behind misleading nutritional or medical advice, available at https://www.ted.com/talks/ben_goldacre_battling_bad_science?subtitle=en (the first 7.5 minutes are the most relevant).

Additional Hands-on Activities in Which Students Design Experiments and Interpret the Results: Activities that are explicitly aligned with the Next Generation Science Standards are indicated by (NGSS).

"Enzymes Help Us Digest Food"
https://serendipstudio.org/sci_edu/waldron/#enzymes
In this hands-on, minds-on activity, students investigate the biological causes of Maria's symptoms and Jayden's symptoms. To explore the causes of these symptoms, students carry out two experiments, interpret the results, and answer additional analysis and discussion questions. Students learn about enzyme function and enzyme specificity as they figure out that Maria's symptoms are due to lactase deficiency (which can result in lactose intolerance) and Jayden's symptoms are due to sucrase deficiency. In the final section, students are challenged to generalize their understanding of enzymes to interpret a video of an experiment with saliva, starch and iodine. This activity can be used in an introductory unit on biological molecules or later during a discussion of enzymes. (NGSS)

“Homeostasis and Negative Feedback – Concepts and Breathing Experiments”
https://serendipstudio.org/exchange/waldron/breathing
This minds-on, hands-on activity begins with analysis and discussion questions that develop student understanding of homeostasis, negative feedback, and positive feedback. Then, students carry out a breathing experiment and develop a negative feedback interpretation of observed changes in breathing; questions about cellular respiration and the circulatory and respiratory systems help the students to develop their negative feedback model. In an optional final section, each student group formulates a question or hypothesis concerning homeostasis and changes in breathing; they design a relevant experimental investigation, carry it out, and interpret the results. Information provided in the Teacher Preparation Notes can be used to facilitate student investigations of exercise, breath-holding, changes in rate vs. depth of breathing, or the effects of CO_2 vs. O_2 levels. (NGSS)

Discussion Activities for Learning about the Process of Science
"Carbohydrate Consumption, Athletic Performance and Health – Using Science Process Skills to Understand the Evidence"
https://serendipstudio.org/exchange/bioactivities/sciproc
This analysis and discussion activity is designed to develop students' understanding of the scientific process by having them design an experiment to test a hypothesis, compare their experimental design with the design of a research study that tested the same hypothesis, evaluate research evidence concerning two hypothesized effects of carbohydrate consumption, evaluate the pros and cons of experimental vs. observational research studies, and finally use what they have learned to revise a standard diagram of the scientific method to make it more accurate, complete and realistic.

"Vitamins and Health – Why Experts Disagree", available at
https://serendipstudio.org/exchange/bioactivities/vitamins
In this analysis and discussion activity, research concerning the health effects of vitamin E is used as a case study to help students understand why different research studies may find seemingly opposite results. Students learn useful approaches for evaluating and synthesizing conflicting research results, with a major focus on understanding the strengths and weaknesses of different types of studies (laboratory experiments, observational studies, and clinical trials). Students also learn that the results of any single study should be interpreted with caution, since

results of similar studies vary (due to random variation and differences in specific study characteristics).

Sources for Figures in Student Handout

- Starch from http://www.nutrientsreview.com/wp-content/uploads/2014/09/Starch.jpg
- Sprouting seed, modified from https://slideplayer.com/slide/13124647/79/images/7/Enzymes+are+used+in+seed+germination.jpg and https://i-biology.net/ahl/09-plant-science/
- Amino acids from http://www.carlagoldenwellness.com/wp-content/uploads/2015/07/a4657743.jpg and http://bio100.class.uic.edu/lectures/aminoacids01.jpg
- Protein from https://www.ebi.ac.uk/training/online/courses/protein-classification-intro-ebi-resources/wp-content/uploads/sites/96/2020/07/figure1.png
- Muscle and meat, modified from https://amazingribs.com/technique-and-science/cooking-science/basic-meat-science/
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