



How Science Works

Volunteer Notebook

High School Biology

Module 1

Class Question:

*How do living organisms change
the physical properties of compounds?*

Scientist (Your Name): _____

Teacher's Name: _____

SciTrek Volunteer's Name: _____

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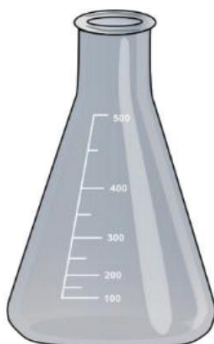
Key:
Answers
 Information for UC

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EXPERIMENTAL MATERIALS



Weighing Balance



**Erlenmeyer
Flask**



Beaker



**Graduated
Cylinder**



Timer



**Heat Plate
Tubes**



Test



Plastic Pipettes

REAGENTS

Benedict's - an indicator used to detect simple sugars in a sample

Biuret - an indicator used to detect protein in a sample

Iodine (Lugol's Test) - an indicator used to detect starch in a sample

DAY 1

The Building Blocks of Life

Introduction of SciTrek - 5 minutes

The SciTrek lead will give a short introduction about what SciTrek is and what we do. After the lead introduces themselves, he/she will ask you to do the same. State your name, your year, and a fun fact about yourself. This should take no more than 5 minutes. The students are going to watch a video on how BP (British Petroleum, one of the biggest energy companies) is using bananas to make jet fuel. Don't directly answer questions posed by students -- this video is meant to simply have an idea rolling in their minds that there is some process to convert one substance to another.

Link to video: https://twitter.com/bp_america/status/1087520154815250433?lang=en

Introduction to Macromolecules - 25 minutes

After introductions and vocabulary activity, the lead will explain to the students what macromolecules are using slides 4-6 on the powerpoint. The lead will then help the students answer the following questions with the help of the PowerPoint presentation. These questions are found in the student notebook, so remind students to write down the answers. The following strategies are recommended for leading the discussion: 1) ask for volunteers, 2) ask students to discuss in pairs or groups of 4-5 before answering, 3) if no one has an answer, use the answers below to guide your explanations to the class.

Compounds can be organic, inorganic, or both

Organic - compounds that contain both carbon and hydrogen atoms

Inorganic - compounds that DO NOT contain both carbon and hydrogen

There are four classes of organic compounds that are central to life on earth.

1. Carbohydrates 2. Lipids 3. Proteins 4. Nucleic Acids

Carbohydrates (Sugars and Starches) - compounds made of C, H, and O which give us energy. Carbohydrates can be **simple sugars** that give us quick energy, like fruit and white bread, or they can be **complex carbohydrates** that give us long-term energy, like starch found in potatoes, rice, corn. Carbohydrates can also be used for structural support in some organisms: cellulose is a carbohydrate that makes up the cell wall of plants (wood), and glycogen is a food storage compound in animals.

monomer: monosaccharide polymer: polysaccharide

Lipids (Fats, Oils, Waxes) - compounds made of C, H, and O which store energy. Some lipids have structural functions: Plant wax is a lipid that keeps plants from dehydrating, and cholesterol is a lipid found in membranes of cells and organelles (your cells have this). Lipids are mostly **nonpolar**, meaning they do not mix well with polar molecules. Lipids are not polymers; A common lipids called a triglyceride consists of 3 fatty acids and one molecule of glycerol.

Not really a monomer.. repeating unit(s): 3 fatty acids and glycerol

Not really a polymer: triglyceride

Proteins (long chains of amino acids) - compounds made of C, H, O, and N which carry out many functions and are an energy source. The monomers of proteins are called **amino acids**, and the bonds that hold amino acids together are called **peptide bonds**. Proteins are used to build and repair hair, nails, and muscle tissues. A special class of proteins, called **enzymes**, are used to speed up the rate of chemical reactions. Enzymes are used for digestion, respiration, reproduction, vision, movement, thought, and other various tasks.

monomer: amino acids polymer: proteins

Nucleic Acids (made up of nucleotides) - compounds made of C, H, O, and N. Subcategories include DNA and RNA. The monomers of nucleic acids are called **nucleotides** which are composed of a nitrogenous base, a 5-carbon sugar, and a phosphate group. Really important nucleic acids called DNA stores genetic information. Another important nucleic acid called RNA makes proteins.

monomer: nucleotides polymer: nucleic acids

Trading Card Activity - 15 minutes

The next activity the class will do is a trading card game in which they trade with their classmates to produce organisms. The objectives and rules are described below:

Objective: You and your group are working together as a plant cell. You have limited resources (element cards) that you need to build another organism (reproduce). Trade with the other cells in your class so that you have enough biomolecules to survive and reproduce.

Types of cards:

Stage 1 – elements - hydrogen, carbon, oxygen, nitrogen

Stage 2 – sugar

Stage 3 – lipids, carbohydrates, protein, DNA

Stage 4 – organism

Recipes:

<u>To make:</u>	<u>You need:</u>
Sugar	2 hydrogens + 1 carbon + 1 oxygen
Lipid	2 sugars
Carbohydrate	3 sugars
Protein	2 sugars + 2 nitrogens
DNA	2 sugars + 2 nitrogens
Organism	1 lipid + 1 carbohydrate + 1 protein + 1 DNA

Rules:

1. Shuffle the element cards.
2. Each group is provided 25 random element cards and an instruction card to begin (take out one nitrogen card to make 125 element cards total). During this time, the groups can sort out their cards.
3. With the cards given to each group, consult the formula on the instruction card to use your elements to construct your sugar molecules first.
4. After constructing sugar molecules, the groups can trade in their sugar molecules for larger molecules from a SciTrek volunteer (the volunteer will have the sugar and macromolecule cards)
5. Groups are allowed 45 seconds to discuss trading plans to trade any cards for other cards with another group (ex. Give up nitrogen for 2 hydrogens). Start a timer for 45 seconds.
6. Once the 45 seconds are up, have each group send one representative to the front of the room. The representatives will trade with each other for 1 minute, then return to their groups.
7. Repeat steps 5 and 6 until a group forms an organism. The first group to form an organism wins.
8. To push the game along if the trading dies down and no organisms are formed:
 - a. At 7 minutes, photosynthesis occurs! Give each group 2 sugar cards.
 - b. At 11 minutes, fertilization occurs! Give each group 2 nitrogen cards.

*(*A volunteer/lead should prepare a 70°C water bath at the front of the class during the game*)*

Questions after the Game - 15 minutes

1. Circle the following macromolecules that are considered “building blocks” of organisms.

Carbohydrates Proteins Lipids **LEGO** Nucleic Acids

2. Why does your body need carbohydrates and where can you find them?

Carbohydrates are an immediate source of fuel. The body uses carbs (through processes like glycolysis and respiration) to make a molecule called adenosine triphosphate [ATP], a major energy source. We get carbs by eating things like grains, rice, and bread. Without carbs, our bodies will have to break down fats and proteins for energy, which occurs when you are starving..

3. Why does your body need proteins and where can you find them?

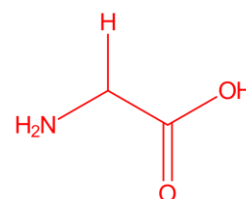
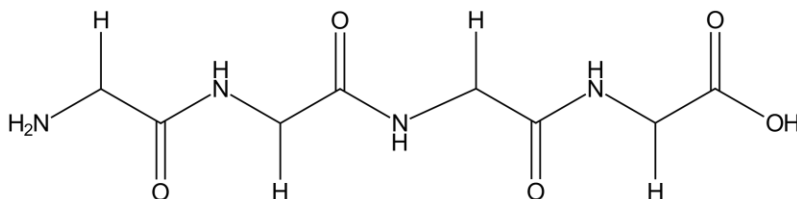
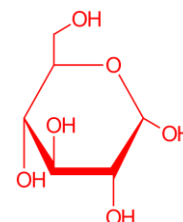
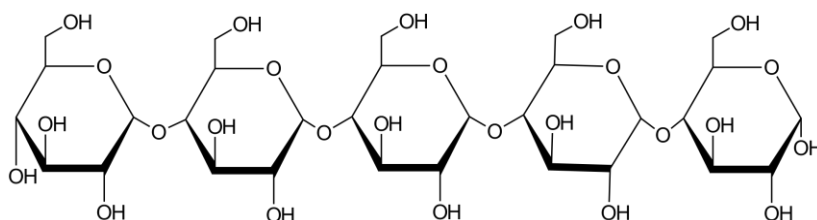
Proteins do a lot for the body. We need protein to build and repair the body's structures like our nails, hair, cartilage, and muscles. We also have a special case of proteins called enzymes, that help the body do chemical reactions like digesting food. Proteins are made from monomers called amino acids, and since the body can't make all the amino acids, we need to get them from

the food we eat. We get protein from milk, eggs, meat, some plant-sources, rice, corn, and beans.

4. Why does your body need fats and where can you find them?

Fats are essential for giving the body energy and supporting growth. They also insulate the body. We can get fats from avocados, cheese, dark chocolate, oily fish, nuts, and chia seeds.

5. It takes a lot more than one molecule each of carbohydrates, proteins, fats, and DNA to make an organism. What actually happens is that carbs and proteins will form long chains called **polymers** made of individual repeating units called **monomers**. Given the pictures of a carbohydrate chain and a protein chain respectively, box and redraw the repeating monomer unit.



If the students ask, not all lipids are polymers, and DNA they will discuss sometime later.

6. A SciTrek volunteer is having a hard time trying to get lipids to dissolve in water. Why would lipids and water typically not want to mix together: What might you add to help the lipids dissolve in water? Hint: why do you use shampoo to wash your hair? What are you trying to get rid of?

Lipids are nonpolar but water is polar, so the two will not mix without the help of additional molecules. You can add soap or detergents to help dissolve lipids in water.

DAY 2

Testing for Biomolecules

Caution: Concentrated acids should only be used by the lead and placed in a safe area when not in use. Affected areas should be washed with soap and water for 10 minutes.

It's going to be Legen- wait for it- Dairy

Testing for the Other Macromolecules-30 minutes

Congratulations! What you just did was used for a long time to determine protein amounts in dairy and other foods. It works with large samples but takes a bit of time. Modern methods used for example in the food industry make use of **spectrophotometry**, where the concentration can be determined using chemical indicators.

Gravimetric analysis is great and effective when you have a relatively large amount of sample, but if you look at the weigh scales we have, they only go up to two decimal points. What if I want to measure out something in milligrams or track a small change in carbohydrates, protein, or sugar content? Let me introduce you to my little friend.....

Lead plunks ThermoScientific Spectronic 15 in front of the class and everyone says ooo
SciTrek Lead: *slaps roof of spec* this bad boy can fit so many mgs of sugar over it.

How does the spectrophotometer work?

When light is passed through a sample, some of the light is absorbed by the sample, and the intensity of light that passes through will change. With higher concentrations of a substance that absorbs light of a particular wavelength, the absorbance of the sample increases. This phenomena can be used to quantify how much of a substance is present in the sample.

Demonstration: Bradford Reagent for Testing Protein Amount

The SciTrek lead will call attention to the chicken and butter that they have on the front desk. As the name of the test suggest, Bradford tests for proteins. This can be easily visualized by adding Bradford's reagent to protein heavy food (chicken and non-protein food (butter)).

A SciTrek volunteer will show the class 5 test tubes that contain varying concentrations of protein (%Protein: 0.01%, 0.001%, 0.0001%, 0.00001%, 0% (control)). Percents are given in mass per volume, meaning that 0.1% protein solution was made by adding 0.1g to 100mL water.

Test the class by asking what the purpose of the control is. What is in the color then? Why do we need a control?

100% water, the control solution turns clear with bluish tint with the addition of the Bradford Reagent. We need a control as a standard for comparison.

The chemical the students will be using in this test is Bradford reagent. It forms a complex with protein which gives off a blue color. The greater the concentration of protein, the darker blue the solution will be. **Students will observe the volunteer add 14 drops of Bradford to the samples.**

Is there a pattern of how the solution color changes with increasing protein concentration? Draw and color the series of solutions below.

Control = clear, 1/1000 protein = blue, 1/10000 protein = light turquoise, 1/100000 = turquoise, 1/1000000 = dark turquoise



Ask the students how they could use this series of solutions to figure out how much protein is in an unknown solution? We typically call a series of solutions a **gradient**. There's a different name that the students have learned before, a **calibration curve**.

You need to know the concentrations that were used in the gradient, then perform the Bradford's test on a sample and match the resulting color to the colors in your gradient.

Ask the students, what are some limitations to this test? What are some problems in determining the quantity of each solution?

Color of the sample will interfere with the color produced from the reagent. Small variations in concentration are difficult to observe. Hard to quantify the exact concentration, that is if you are eyeballing it.

Ah, but what if we had a way to do better than simply eyeballing the color? This one is for all you color-blind people out there. The lead will take samples of each solution into a cuvette and measure their absorbance at 610 nm. After getting a series of absorbances, the lead will make a table on the board that looks like this:

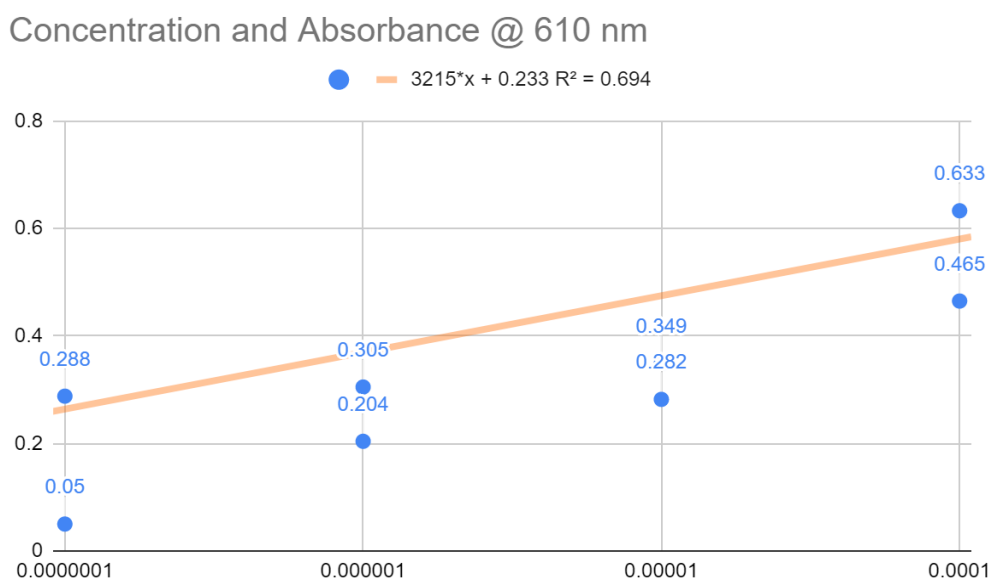
Concentration of Protein	Absorbance of Sample @ 610 nm
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Control	<u>0</u>
0.01%	<u>~0.465-0.633</u>
0.001%	<u>~0.282-0.349</u>
0.0001%	<u>~0.204-0.305</u>
0.00001%	<u>~0.050-0.288</u>

The students will see that there is a linear relationship between the concentration of the protein and the absorbance on the spectrophotometer. This is called a **standard curve** or **calibration curve**. The lead will start a presentation on how to use calibration curves to help determine the concentrations of unknown samples.

While this presentation is happening, Bradford is going to be added to the milk sample to determine its protein concentration. However, a problem that the students will run into is that when the Bradford reagent is added to the milk, it will immediately react with the milk, but it will be too opaque to get a good reading on the spec. And it will not mix well due to this reaction.

Here is what the best line of fit should be around:



Day 2 Waiting Activities- 20 minutes during Milk Filtration Process

Vocabulary Activity

Have students review concepts and vocabulary terms. Maybe have a quiz for the next day for review before Day 3. Explain how organic molecules and atoms (C, H, N, and O) are conserved to make different organic molecules and are reused in biological processes.

First, the class will be divided into 8 groups (One for each definition). Make a table with eight boxes on the whiteboard; each box will contain one of the terms found below. One volunteer should be assigned to each group. Each group will then be given a card with multiple ways to identify which term they are looking for and will try to match the definitions to the corresponding term. Cards will include definitions, pictures of the molecule, and real-life examples. After each group has decided which definition, picture, and an example for a term, they will compare their answers with other groups and ask each other why they believe their answers are correct, explain their reasoning, and have time to change their answers. After each group has finalized their answers, the lead and volunteers will go over the right definitions for each of the vocab terms, and students will write down the answers in their notebooks.

Together with your group, come up with a thorough but concise definition of the following vocabulary terms on the table. Use no more than ten words per definition.

Carbohydrates	<u>Compounds with the molecular formula $(CH_2O)_n$ composed of small subunits called monosaccharides or sugars</u>
Lipids	<u>Can be a fat or oil depending on whether they are solid or liquid at room temperature, respectively</u>
Macromolecules	<u>A macromolecule is a very large molecule made from smaller molecules</u>
Monomers	<u>Single subunits that can be strung together to make large molecules</u>
Nucleic Acids	<u>Biomolecules with subunits that are composed of a phosphate group, a sugar, and an identifying molecule.</u>
Polymers	<u>A chain made of monomers. The common polymers of life (biopolymers) are nucleic acids, proteins, and carbohydrates</u>
Proteins	<u>Polymers made of amino acids.</u>
Starch	<u>A large and complex type of carbohydrate. polymer of many sugars bonded together.</u>

Colorimetric Calibration Curve Activity

Today we are going to bring the unknown food samples to the students. The students will go around station-by-station to get hands-on practice doing the Benedict's (sugar), Biuret (protein), and Lugol's (starch) tests. They will take their solutions to the front and measure the absorbances on the spectrophotometer.

How to use the SpectroVis Plus Spectrophotometer

- 1. Download the SpectroVis Plus Spec software onto a device (computer, laptop, iphone even, requirement: must have a USB port)*
- 2. Plug the spectrophotometer into your device and open the downloaded software*
- 3. Once the program window appears, an option list should pop up. Under the "Absorbance" drop-down select "vs. Concentration (Beer's Law)". This will allow you to measure the absorbance of a sample at the wavelength of your choice.*
- 4. Wait for the spectrophotometer to warm up. This should take roughly five minutes. In the meantime, prepare a blank cuvette with H₂O, which the program will prompt you to insert for calibration when it is finished warming up. When the spectrophotometer is ready for the blank, put in the cuvette and press "finish calibration."*
- 5. A window called "Choose a Wavelength" will pop up. Type your desired wavelength to the nearest whole number and press enter. You are now ready to start measuring samples!*
- 6. Load your sample into the cuvette (must fill to at least above the V shape) and insert the cuvette into the spectrophotometer. Press "collect", wait a few seconds, then press "keep" to collect a data point. Type in the corresponding concentration and press "keep point" to save it. Press "stop" to collect. When you try to record a second data point, the software will ask if you want to make a new data set. DO NOT MAKE A NEW DATA SET. Hit append and continue recording data points.*
- 7. Repeat until you have created a graph.*

Test #1 – Benedict’s Reagent for Carbohydrates

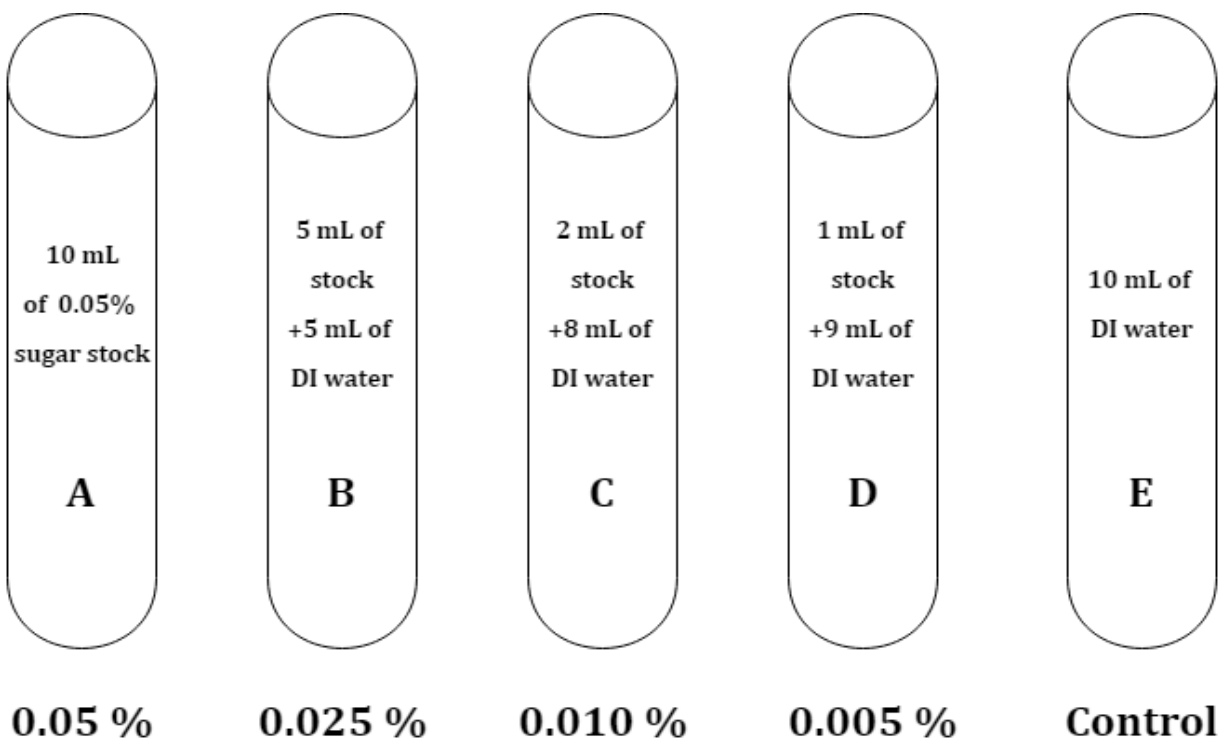
(Caution: Hot objects ~ test tubes and hot plate ~ can lead to painful burns. Be careful!)

The first station that the students will have set-up is the Benedict’s test, which tests for reducing sugars. This station will require a water bath on a hot plate (~100°C) and materials necessary for the experiment.

Materials

- Hot plate + beaker of hot water (~250mL H₂O @ boiling) + stir bar (prepared beforehand)
- Thermometer
- Benedict’s solution
- 0.05% dextrose solution prepared beforehand (100-fold dilution of 5% dextrose solution)
- DI water
- 10mL graduated cylinder + 50mL beaker
- Plastic pipettes
- Labeled test tube rack + 5 labeled test tubes (A, B, C, D, and E)
- Spectrophotometer + cord
- Laptop
- Cuvettes

Prepare a test tube rack labeled like the diagram on the previous page.



Percent Concentration of Sugar Solution

$$(\text{grams of sugar/mL of water}) \times 100\%$$

Calibration Curve Procedure:

Prepare the hot water bath beforehand (takes ~30 minutes to heat). Plug the spectrophotometer into your device and open the Vernier Spectrovis Plus software.

Choose the “vs. Concentration” option of data collection.

Wait 5 minutes for the spectrophotometer to warm up.

After waiting 5 minutes, insert a blank (a cuvette with pure water) when prompted and press “finish calibration” to blank the spectrophotometer. When prompted, input the desired wavelength (750 nm) for the Benedict’s assay.

1. To prepare the calibration curve, the students will start by adding 5 mL of H₂O into test tube **B**, 8 mL of H₂O into test tube **C**, and 9 mL of H₂O into test tube **D**. Add 10mL of H₂O to test tube **E**. Do not add water to test tube **A**.
1. Your table should have ~ 18 mL of 0.05% dextrose stock solution already set out in a labeled container.
2. Have the students take 10mL of the dextrose stock and add this to tube A.
3. Your students will take 5 mL stock and add it to test tube B. Have them mix by swirling.
4. The students will add 2 mL of stock to tube C and swirl to mix.
5. The students will add 1 mL of stock to tube D and mix.
6. Tube E will just have water.

7. After adding 1 mL of Benedict's solution to each of the test tubes, the students will then carefully lower them into the pre-prepared water bath. For ~ 3 minutes. Remind them to take caution so that they don't accidentally burn themselves.
8. Carefully remove the tubes (only grasp the top of each tube since the bottom may be hot) and replace them on their rack.
9. To measure the absorbance of each sample, have the students use a plastic pipette to fill a clean cuvette with sample until the sample volume reaches at least $\frac{2}{3}$ of the cuvette height. Take the cuvette from the student. Remove the blank and insert the sample. Press "collect" on your device screen and wait for a few seconds before pressing "keep." Type in the corresponding concentration of your sample in the table that pops up (the concentrations are the same as in the example table at the bottom of this section). Press "keep point" to save your data. Repeat this for each of the students' samples.
10. Have the students rename "Data Set __" with "Benedict's Calibration Curve" and your table number. They can click on the three dots in the upper right hand corner next to the table's title to change the table name. If they've labeled their table correctly, they'll be able to determine the corresponding absorbance values for each sample.
11. Have them clean out their cuvette by emptying it into a waste beaker, adding water to it, pipetting up and down to flush out any remaining sample, and empty out the cuvette into the waste beaker once more. Although this may be tedious, do not let them leave sample in their cuvettes since precipitate will get stuck inside it.
12. Have the students report their absorbances to the lead at the front of the classroom to plot your data.

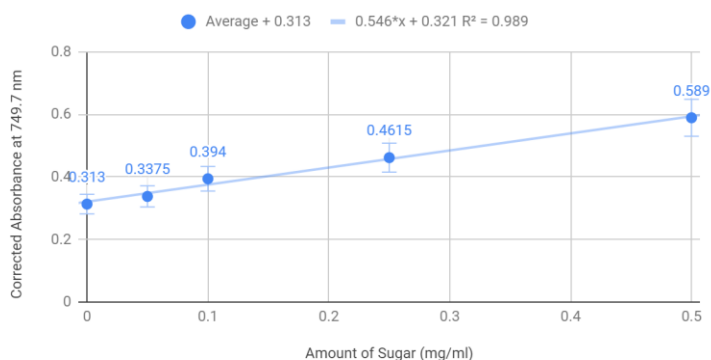
	Test tube A	Test tube B	Test tube C	Test tube D	Test tube E
Sugar Solution Volume	Solution A = 0.050% dextrose (most sugar)	Solution B = 0.025% dextrose	Solution C = 0.010% dextrose	Solution D = 0.005% dextrose	Solution E = 0% dextrose (least sugar)
Benedict's Amount	1 mL	1 mL	1 mL	1 mL	1 mL
Expected Observation	<u>Orange</u>	<u>Brownish Orange</u>	<u>Brown</u>	<u>Brownish Blue</u>	<u>Blue</u>

For those of you who are interested in the specifics behind the reagent, Benedict's reagent is made with copper (II) sulfate. When reacting with a reducing sugar, the copper(II) ions which

appear blue are reduced to copper(I) ions which appear red. This is the cause of the color transition you see above.

Concentration of Sugar	Absorbance of Sample @ 749.7 nm
0.050%	<u>~0.5890</u>
0.025%	<u>~0.4615</u>
0.010%	<u>~0.3940</u>
0.005%	<u>~0.3375</u>
Control	<u>~0.3130</u>
*stock solution is 0.05% dextrose (simple sugar)	

Benedict's Solution and 5% Dextrose Calibration Curve at 750 nm

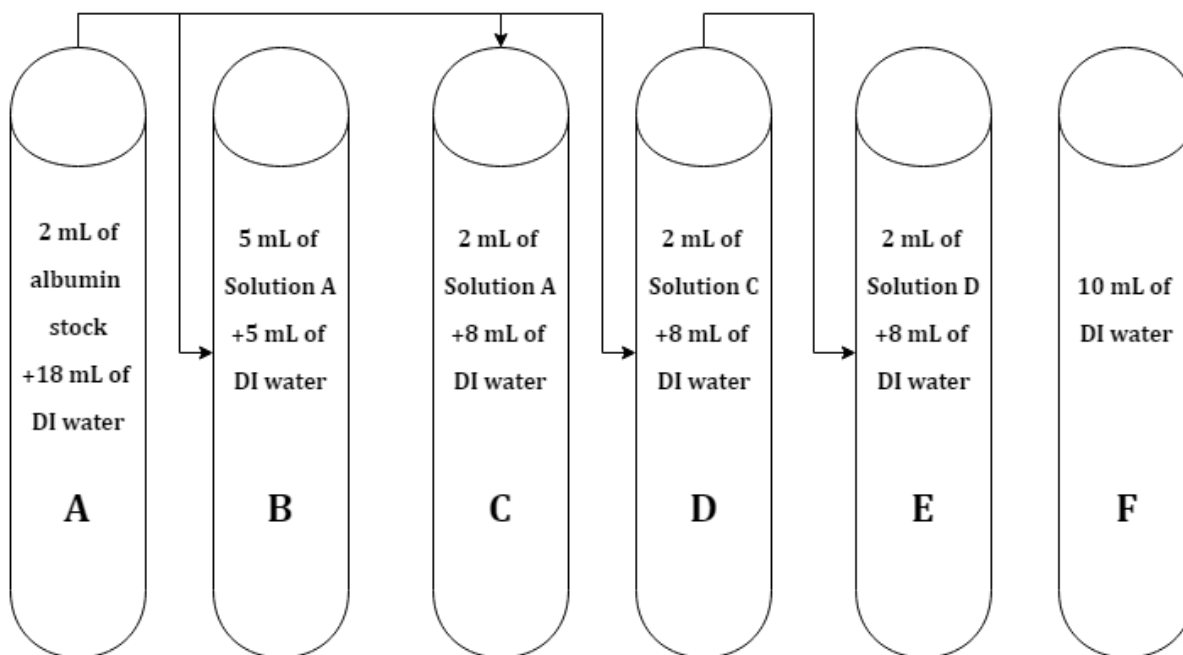


Test #2: Biuret Test for Proteins

The second test that the students will be doing uses Biuret solution, which tests for proteins. Show the class 6 test tubes that contain varying of albumin (Protein: (0 mg/ml (control), 0.16 mg/ml, 0.8 mg/ml, 4mg/ml, 10 mg/ml, 20 mg/ml). Add Biuret reagent to the samples and mix. Aid the class in answering the questions in their notebooks.

Materials:

- Labeled test tube rack, Biuret solution, Plastic pipettes, DI water
- Albumin solution (200 mg/ml)
- 6 labeled test tubes of varying albumin protein concentration (A, B, C, D, E, F)
- 10mL graduated cylinder
- Plastic pipette
- Spectrophotometer + cord
- Laptop
- Cuvettes



20 mg/mL 10 mg/mL 4 mg/mL 8 mg/mL 0.16 mg/mL Control

Concentration of Protein Solution
(grams of protein/mL of water)

Procedure for Biuret Assay and Calibration Curve:

1. To begin the calibration curve, first take 2 ml from the albumin solution using a pipette and add it to test tube A. Then add 18 mL of H₂O to test tube A. Mix solution in test tube by swirling.
2. Next, add 8 mL of H₂O each to test tubes C, D, and E.
3. Take 2 ml from test tube A and add to test tube C. Swirl solution.
4. After test tube C is mixed, take 2 ml from test tube C and add to test tube D. Swirl solution.
5. Take 2 mL from test tube D and add to test tube E then swirl.
6. For test tube B, take 5 mL from test tube A and add 5 mL of water. Swirl to mix
7. Add 10 mL of H₂O for test tube F. This will be your control test tube.
8. After the test tube solutions are prepared, add 8 drops of Biuret solution to each test tube and observe the change in color. Record observations of color in the chart.

The spectrophotometer should be plugged into your device and the Vernier Spectrovis Plus software should be open. Choose a New Experiment by clicking the File Menu on the upper left corner. Choose the "vs. Concentration" option of data collection. The spectrophotometer will take a few seconds to calibrate so in the meantime prepare a blank by filling a cuvette with

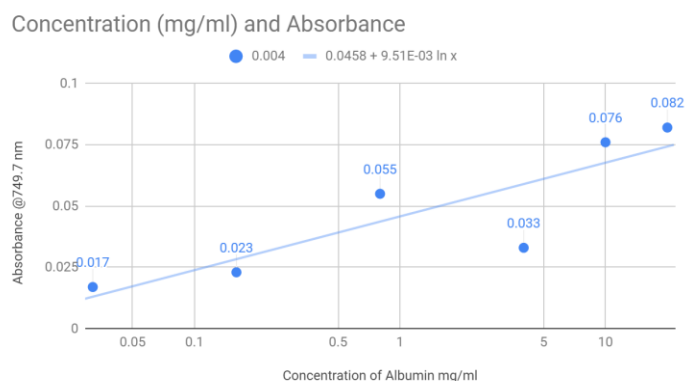
pure water. Insert the blank when prompted and press “finish calibration” to blank the spectrophotometer. When prompted, input the desired wavelength (590 nm) for the Biuret assay.

9. Get a clean pipette and pipette out a sample from test tube A into a clean plastic cuvette until the cuvette is filled $\frac{2}{3}$ of its total volume. Give cuvette with sample to your lead so the lead can insert your cuvette into the spectrophotometer at the wavelength 590 nm.
10. Click “Collect” to measure the absorbance of the sample. Wait for the Absorbance Value to stop changing after a few seconds and click “Keep.” Type in the concentration of the sample you’re testing. For example, if you’re testing test tube A, name the concentration as “20 mg/ml.” Label your tables well so you’ll be able to keep track of all the corresponding absorbance values for each sample.
11. Record the absorbance value for test tube A in your notebooks. After you saved the absorbance value and the concentration, click “Stop” to reset for measuring absorbance for another sample.
12. After your lead gives you back your cuvette, dump the sample into a waste beaker. Add water to the cuvette and pipette up and down to flush out any remaining sample. Rinse again with water to clean the cuvette.
13. Repeat steps 9-11 for each remaining test tube to get absorbance values for all your samples until you generated an Absorbance vs. Concentration graph from all the data points you recorded.
14. After getting absorbance values for all your test tube samples, report your data to the lead at the front to be plotted.

	Test tube A	Test tube B	Test tube C	Test tube D	Test tube E	Test tube F
Protein Concentration	20 mg/ml	10 mg/ml	4 mg/ml	0.8 mg/ml	0.16 mg/ml	0 mg/ml (control)
Biuret Amount	8 drops	8 drops	8 drops	8 drops	8 drops	8 drops
Expected Observation	<u>Light Pink</u> <u>Yellow over time</u>	<u>Pink-purple</u>	<u>Purple</u>	<u>Dark purple</u>	<u>Light blue</u>	<u>clear</u>

For those of you who are interested in the specifics of the reagent, proteins have a unique type of bond called a peptide bond. The copper(II) ions in the Biuret solution turns into copper(I) ions when there are peptide bonds in the solution, resulting in the color change.

Concentration of Protein (mg/ml)	Absorbance of Sample @ 590 nm
20	<u>~0.082</u>
10	<u>~0.076</u>
4	<u>~0.033</u>
0.8	<u>~0.055</u>
0.16	<u>~0.023</u>
Control	<u>0.0000~0.004</u>



Questions:

1. What happens to the color of the solution as the protein, sugar, complex carbohydrate concentration increases? (*Three different answers*)? How does this change in color affect absorbance?

As the concentration of the solution is increased, the color of the solution turns darker and the color intensifies. Because there is an increased concentration as the color darkens, the absorbance value goes higher because more light is absorbed through the solution.

2. Why do we need a control such as a sample of water?

The control can be used as a qualitative comparison to see if a sample contains starch, protein or reduced sugars.

3. Why is it important to only test one variable at a time?

It is important to only test one variable at a time so that if we see a change in our results, we can be absolutely sure of what caused the change. If multiple variables are changed, we cannot

be sure whether any one of the alterations caused the differing results or if a combination of those results was what caused the change.

4. What is the purpose of a spectrophotometer?

The spectrophotometer is included in this module to quantitatively measure the amount of change seen in each sample when each reagent is added. This allows for greater accuracy in measurements and more meaningful results. For instance, in the Benedict's test, we know that a green sample has more sugar in it than a blue sample, but if someone were to ask how much more sugar was in the green sample, the only way you would be able to tell them is by quantitatively measuring the sugar content in both samples. A spectrophotometer is one of the ways to do just that.

5. What type of interaction is the Biuret solution causing to the protein in the sample to make a color change? (Refer to the background information page about the Biuret reagent)

The copper ion from the Biuret solution interacts with the peptide bond in the protein to form a complex that gives off the purple color. As the protein concentration increases, the more peptide bonds the copper ion can interact with and the color deepens and has a higher absorbance value.

6. What is the purpose of making calibration curves? What are the steps to make one?

Calibration curves are used to help quantify the concentration or how much stuff is in a sample accurately. For instance, you make different amounts of samples with varying concentrations as your independent variable and measure the absorbance of each sample as your dependent variable. Then, plot the values or variables to get a linear relationship between your variables. The goal is to use this curve to help quantify the concentration of an unknown sample by using the known values for comparison.

Linear Regression: Making the Best of Everyone's Data (20 minutes)

By this point everyone should have some data points for all three tests. The students will share the data up on the board, and the lead will be transcribing the data into Google Sheets as the students are writing. The link to the Google Sheets used for this can be found here:

<https://docs.google.com/spreadsheets/d/1ns-Atrs80IqBD1PSMGio8S5Iy5vEfvGbDlrD7gxAcuA/edit#gid=1158093814>

Some students might get outlier data which can be discarded. The average of all the student's data points should form a line.

Similar to the previous exercise, copy down the combined class calibration curves to compare the concentration of sugar, protein, and fat to the spectroscopic absorbance on the grid below.

[illegible]

Below, please record all of the linear equations of the class average for each of the different macromolecule concentration curves. These equations will be very helpful for us in the future!

Class Average Equations	Simple Sugars	Complex Carbohydrates	Proteins
Equation			
R-squared value			

DAY 4

The Ripening Finale

Today is the final day. The students are provided little to no directions to see if they can use critical thinking to come up with their own procedure. It is very important that you have the students reference the previous day to help them understand what they are supposed to do in this scenario. The lead will have the graphs and the equations they received from yesterday's

concentration curves so hopefully they will connect the dots as to what they are supposed to be used for. If not, ask them questions that pertain to the purpose of these graphs.

In front of you are two synthetically made samples. Each sample contains three test tubes with different a different amount of sugar, protein, or complex carbohydrate. How would you go about testing the concentration of these molecules? Discuss with your group and come up with an accurate way to measure the concentration of you synthetic samples.

Record all data below:

Materials:

- Two synthetic samples
- 6 test tubes
- 6 pipettes
- 6 cuvettes
- 1 spectrophotometer
- 1 hot plate
- 1 beaker (400 mL)
- 1 stir bar
- 20 mL of each indicator
- 100 mL of DI water

Synthetic Sample #1

	Color	Absorbance Value	Concentration
Protein			
Sugar			
Complex Carb			

Identity of Unknown Solution: *The answers to these tables will vary between synthetic sample. We will have a cheat sheet that goes along with all the synthetics!*

Synthetic Sample #2

	Color	Absorbance Value	Concentration
Protein			
Sugar			
Complex Carb			

Identity of Unknown Synthetic: *The answers to these tables will vary between synthetic sample. We will have a cheat sheet that goes along with all the synthetics!*

As the student volunteer in this situation, it is important to make sure the students are referring to the giant screen at the front when they are trying to calculate their actual concentrations. It is very important that they finish the synthetic samples before they move on to the biological samples.

That didn't seem too difficult, right? Now let's take a look at a real biological sample that you have worked with before, and see if you can spot any differences in the macromolecule concentration as milk transitions to yogurt.

Materials:

- 2 biological samples
- 6 test tubes
- 6 cuvettes
- 6 pipettes
- 1 spectrophotometer
- 1 hot plate
- 1 beaker (400 mL)
- 100 mL of DI water

Milk: Dilution of 1/500

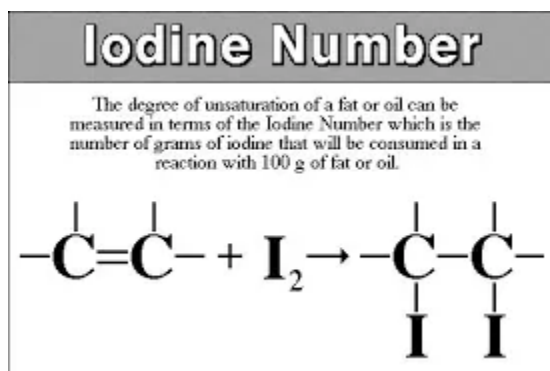
	Color	Absorbance Value	Concentration
Protein	<u>Purple</u>		<u>Same as yogurt</u>
Sugar	<u>Green</u>		<u>Higher than yogurt</u>
Complex Carb	<u>Yellow Orange</u>		<u>Negative response</u>

Yogurt: Dilution of 1/500

	Color	Absorbance Value	Concentration
Protein	<u>Purple</u>		<u>Same as milk</u>
Sugar	<u>Blue</u>		<u>Lower than milk</u>
Complex Carb	<u>Yellow Orange</u>		<u>Negative response</u>

Place to do Math!

In the biological samples, the only difference we should observe is in sugar, but one thing that is particular is the disappearance of the iodine as it is being added to both samples. If a student notices this and asks, use the following information below to explain to them what is going on:

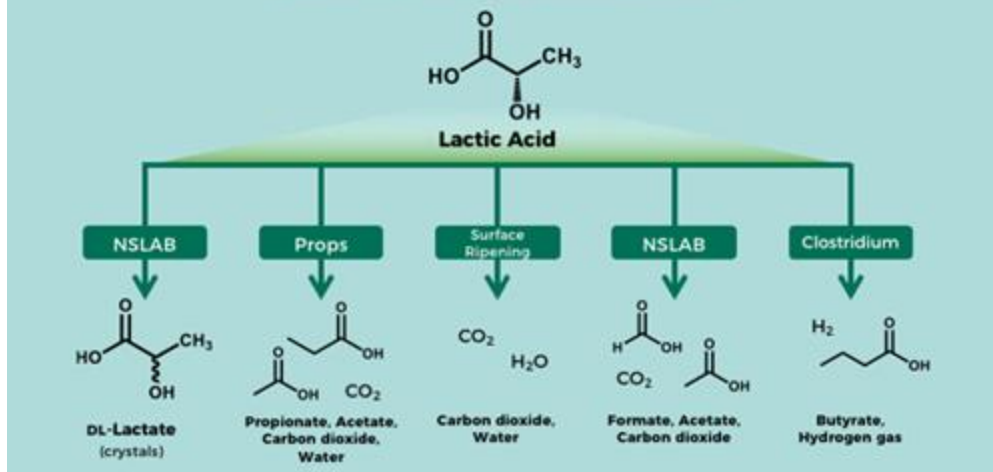


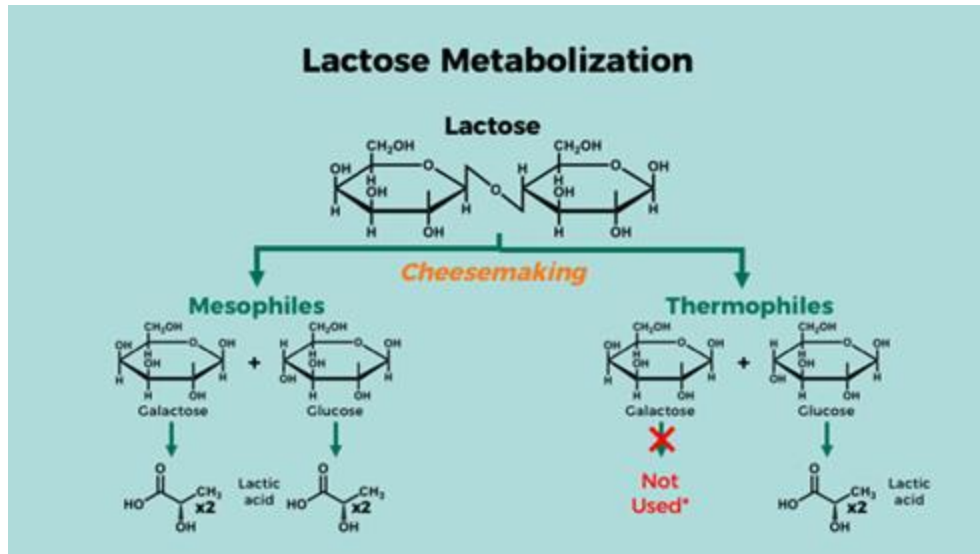
Milk and yogurt, no matter how fat free, will have some levels of unsaturated fats within them (fats with double bonds). As the yellow iodine is being added to the milk and yogurt, the color is disappearing because the unsaturated fat is consuming the iodine by sacrificing its double bond to grab the two iodine molecules.

Did you notice anything different between your two biological samples? If so, why do you think there was a difference in any of the three macromolecules? *Hint: What did we add to the milk on day 2 to force it to coagulate?* Summarize your findings and make a conclusion. Support your conclusion with numerical data from the data above

The protein amount should be the same. The complex carbohydrate test should yield a negative result, indicating that there are no complex carbohydrates within the milk or yogurt. There should be a noticeable difference in absorbance, and therefore, concentration in milk and yogurt. As milk is converted to yogurt, lactose (The main sugar found in milk) is converted to lactic acid by bacteria! The lactic acid causes a decrease in the pH of the biological sample which causes the proteins to coagulate. This can be seen when eating store bought yogurt. There is a small acid like taste that is covered by the sweet supplements most companies that make yogurt put in to hide it. Pure yogurt without any supplements actually does not taste too sweet.

Lactic Acid Metabolization





Wrapping it Up/Conclusion - 10 minutes

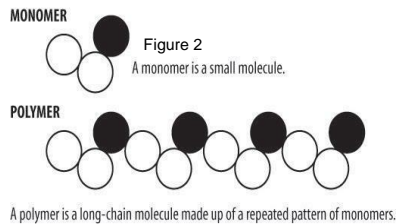
In the final 10 minutes of class, the lead and volunteers will pass out a small 3x5 2 question exit form to the students which will be the exit slip.

1. What was your favorite part about today's module?
2. What are the 4 main elements that make up biological macromolecules?

GLOSSARY

- **Macromolecules** - A macromolecule is a very large molecule made from smaller molecules.
- **Monomers** - Small molecules that can be strung together to make large molecules (polymers) (Figure 1)

Structure of Monomers and Polymers



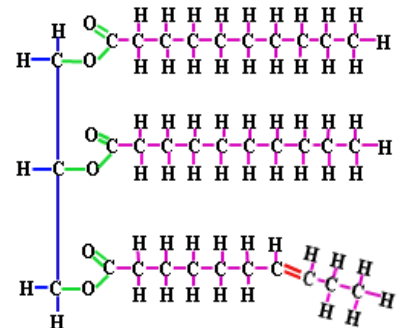
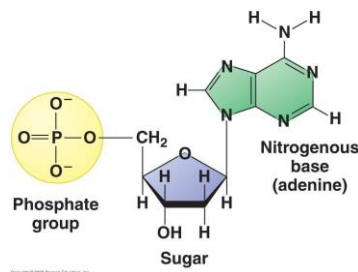
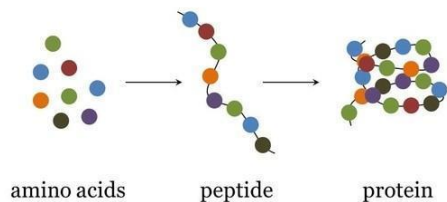
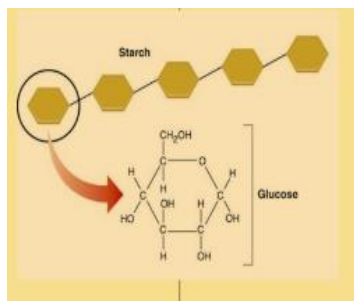
- **Polymers:** A chain made of monomers or small molecules

- **Carbohydrates:** Compounds made of small subunits called monosaccharides or sugars (ex. glucose). Carbs give us energy to do science! (Figure 2). Type of polymer. Ex. Starch

- **Proteins:** Polymers made of amino acids. (Proteins build and repair muscles; they're amazing!)

- **Lipids:** Can be a fat or oil depending on whether they are solid or liquid at room temperature, respectively. Lipids aren't polymers, but they can interact together to form cell membranes

- **Nucleic Acids:** Biomolecules with subunits that are composed of a phosphate group, a sugar, and base
Ex. DNA is responsible for genetic inheritance of traits.



Proteins

Nucleic
Acids

Lipids