SciTREK Teacher/Lead Handbook

Best Bread

November 2016

Student ____

UCSB Team Leader ____

Teacher ______________________ Period __________

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Overview & Background Information

This module is designed to give students experience in designing experiments. In particular, the students should 1) recognize the function of a control experiment, 2) recognize the merits of only focusing on one variable at a time, and 3) understand the importance of running several trials within the experiment.

The context of this module is optimizing yeast activation and growth using a given protocol of collecting CO_2 produced. Students will work in research groups of 6-7 students and you will be their **Advisor**. Each group will break into 3 mini research groups so that each student can get more involved. As their Advisor, you will lead, teach, assess verbally, facilitate and help the students complete and present their experiments.

As their Advisor, you should know as much about yeast and baking bread as possible. Yeast are a type of singlecelled eukaryotic organism that are members of the fungi kingdom. Eukaryotes are distinct from prokaryotes (e.g. bacteria) in that eukaryotes have organelles (membrane-bound compartments within cells, e.g. nucleus, mitochondria, etc.) and linear DNA. Prokaryotes have circular DNA and are typically about ten times smaller than eukaryotes. Eukaryotic cells are 10-100 microns in diameter; a human hair is about 100 microns (10^{-6} meters) wide. All cells (prokaryotic and eukaryotic) have cell membranes and use DNA to replicate.

All cells need to harness energy in order to grow and replicate. The chemical reactions that take place in order to sustain a cell are broadly termed metabolism, or, synonymously, respiration. Proteins called enzymes help carry out (catalyze) the metabolic reactions inside cells.

Aerobic Respiration (requires oxygen, O_2)

- Reactants = sugar (generally speaking, an energy-rich, carbon-containing compound; specifically, glucose) and oxygen
- Products = carbon dioxide (CO_2), water, chemical energy in the form of ATP (adenosine triphosphate) o Overall reaction = $C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O$ + energy
  o The rate of respiration is proportional to the amount of available food (sugar), the amount of yeast cells, the temperature, and the rate at which reactants meet each other (i.e. the stirring rate).

Bread Baking Basics

1. "Activate" the yeast. In order for the yeast to become active, they need to be warmed up and given a food source. This is achieved by putting the yeast in warm water with some sugar. You know it's activated once it starts bubbling.
2. Mix in flour and salt (and seasonings if you're fancy); stir.
3. Knead the dough.
4. Let the dough rise (i.e., let the yeast produce the desired amount of CO_2). This is achieved by putting the dough in a container and letting it sit in a warm (just above room temperature) place.
5. After allowing the dough to rise the desired amount, put it in a suitable pan and bake it in the oven. The yeast will continue to respire for the first few minutes, making the bread rise even more. Pretty soon, however, it will become too hot and the yeast will die.
6. Continue baking so that the starches are broken down into simple sugars and the proteins are broken down into amino acids.
7. Remove the bread before it burns; eat when cooled.

To learn more than you would ever want to know about baking bread visit:
www.seriouseats.com/2014/10/breadmaking-101-the-science-of-baking-bread-and-how-to-do-it-righ.html

DAY 1 Microscopy, Indicator Dye

Intodruction

First, the SciTrek program will be introduced. The lead of the period will introduce themselves, then the volunteers will follow. State your name, what year you are in school, and what you are studying.

The lead will then give an introduction to yeast. They will go through if yeast is a eukaryote or a prokaryote and what that means to us. The discussion will go somewhat as follows:
"Is yeast more like us or the bacteria that causes you to have an ear infection."
It is more like us. Yeast have organelles like us, which help us to learn more about ourselves.
"What is yeast used for"
Bread, Beer, etc.

Then we will relate yeast to us, through cellular respiration.
"So when we breath in oxygen, what do we breath out?"
Carbon Dioxide.

"And in order to breath in oxygen, what do we need. What allows us to go running or to go out and play sports?"
Food which gives us energy.
"Right, so just like us, yeast need energy, which allows them to take in oxygen and breath out carbon dioxide."

At this point, the students will split into small groups, where they will start to explore yeast further.

Yeast Under a Microscope

The intent of this section is to provide context and engage the students. Most students do not understand what yeast cells are.

Since finding the yeast under a microscope is very difficult and will take the students a long time to find a single cell, we will instead give them printed out pictures of each of the microscopic images. They will paste those pictures in their notebooks and make observations about them.

Observe Activated and Unactivated Yeast

You will set up two yeast samples for your entire group: one beaker with sugar and one without. The one with sugar will be properly "activated" and should produce bubbles after a few minutes, while the beaker without a food source should remain essentially unchanged. Allow the beakers to sit for 10 minutes or so while you proceed with the next demo.

The instructions for this activity are in their notebooks and should be easy to follow.

Indicator for CO_2 – Class Activity
Bubbling Blue CO_2 Indicator

This is a fun way to show that indeed CO_2 is being produced by the yeast. The indicator being used here is 'Bromophenol Blue' which is pH sensitive. Weakly acidic and basic solutions are blue, whereas more strongly acidic solutions (pH < 3) are yellow. **Bromophenol Blue is a mild skin irritant and slightly harmful if digested**. The students will not be handling the indicator, however it is important that they know about the different materials they are seeing. Before starting this demo, tell your students what an indicator is. They probably will not understand that an indicator changes color with the pH of a solution, so instead tell them that the indicator changes color when it comes in contact with CO_2. Remind them of the discussion that we had earlier about what we breathed in and out. In order to make sure this demo is as safe as possible, the volunteers will be performing it. We don't want any students to accidently ingest the indicator. The volunteers will use a straw to bubble CO_2 (their breath) into water with the Bromophenol Blue. The indicator will change colors. To make is more inderesting for the students, have them count how long it takes their lead to change the color of the water. Make it a race for the volunteers.

Like stated before, this demo gets the students thinking about how yeast are similar to us. They are able to see that we, like yeast, breath out carbon dioxide. This is also a demo to get the students' excited. One big emphasis of SciTrek is to get the students excited about science. Sometimes that happens through a simple demo.

The second part of this demo is the dry ice section. Students should be familiar with dry ice and what it is. Dry ice is CO_2, or what we breath out that has been frozen. Unlike water, carbon dioxide needs to be at an extremely low temperature to freeze. This means that when dry ice is in room temperature, it will start to do something called "sublimation." This means that instead of doing a normal phase change (solid -> liquid -> gas), it will instead go from solid -> gas. This can be seen as the lead takes the dry ice out of the cooler. Gas will be seen coming off the chunck of dry ice. Since the dry ice is frozen at a very low temperature, it can be very dangerous if touch with your bare hands. It is so cold, that touching dry ice can cause burns. Because of this, only the lead will be allowed to touch the dry ice when they have special gloves on. The students will be allowed to look at it, but we don't want any of them touching it.

A small piece of the dry ice will then be placed in a 1L graduated cyclinder that has been filled with bromophenol blue and water. When the small piece of dry ice is placed in the cyclinder, it will go to the bottom of the cylinder and cause a color change. Since the dry ice is in water that is around room temperature, it will quickly sumblime and go from a solid to a gas. This can be seen through the large amounts of bubbles that will be coming from the dry ice. The bromophenol blue will begin to change color in response to the carbon dioxide. You will see the change in color from the bottom of the cylinder to the top, as the carbon dioxide gas from the dry ice travels to the top of the graduated cylinder.

Assemble & Discuss the Experimental Apparatus

The students will then split up into their small groups with their volutneers. The volunteers will show them the picture of the experimental set up and challenge them to recreate the setup. Let them work together to try to figure out what their experiment will look like. If they are able to do it themselves this time, it will be easier for them to figure out later on. Call out individual students and see if they can name each piece of equipment as you put it together. Don't forget to explain how it works. This is important, because the students will be working with this basic set up for the rest of the module and need to be able to assemble it on their own. By the time you finish setting up and explaining how it works, students will probably have started their sketches of the apparatus. Don't be afraid to point to parts of students' sketches and ask what that part is called. If they forgot already, give them a friendly reminder. This is a great chance to teach and reinforce scientific vocabulary.

DAY 1 What are yeast and what do they do?

Microscopy

A. Light Microscope

Magnification: ________________

B. Scanning Electron Microscope

Magnification: ________________

Activating Yeast

Instructions: Weigh out 3 grams of yeast into two separate beakers. Add 1 gram of sugar to one of the beakers (label this one "beaker 1" and the one without sugar "beaker 2), and then add 50 mL of warm (37 °C) water to each of the beakers. Swirl the beakers and then let them sit for 10 minutes. Record your observations below.

Beaker 1	The beaker is slightly warm. There is a layer of bubbles that are CO_2 bubbles that the yeast has produced.
Beaker 2	The beaker is not warm. There is no CO_2 production.

CO_2 Indicator

Instructions: Follow the directions on the "Bubbling Blue" demo sheet. Record your observations below.

Name of indicator dye: Bromophenol Blue

Observations: The liquid goes from blue to yellow as more CO_2 comes into contact with the liquid.

Assemble the Device!

Instructions: With your advisor, assemble the experimental set up that you will be using this week. Sketch it in the space below. Color in red where the CO_2 will build up; color in blue where water will be pushed out to be measured.

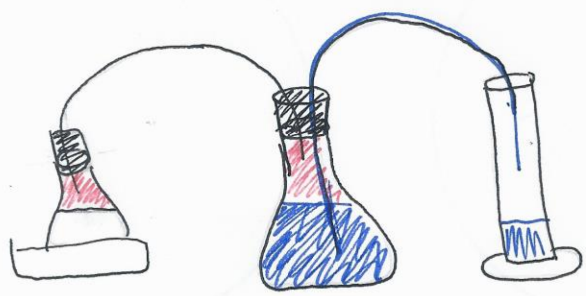


Figure 1. Water displacement apparatus to measure CO_2 output of yeast.

DAY 2 Literature Search

The students will read some articles and use the internet to investigate yeast. They will brainstorm some ideas for ways to increase the amount of CO_2 that yeast produce. Make sure you also understand the different variables that will affect the yeast so that you can answer their questions. The lead and volunteers will not be there for this activity, so this is up to the teachers to make sure that they know what different variables may affect how much CO_2 yeast produces.

Some teachers elect not to have the students perform the literature search, and instead just go through the different variables that affect CO_2 growth. While this is an option, we strongly urge against it. Learning how to do accurate research is an important part of the scientific process and this is a good time for students to practice this skill.

DAY 3 Control; Maximize CO_2

Using the information that they gathered the previous day, students will design their own experiments. The lead will first remind students what they did the previous day that the volunteers were there. They will do a quick run through of what yeast is, and how they are similar and different from us. It is always important to make sure that the students are

reminded of what they did with SciTrek the previous day. These students have many classes each day they are in school, and it is beneficial to them to give them a quick refresher of what was done before.
“Hey everyone, welcome back. So can anyone remind me of what we are going to be studying for the next few days.”
Yeast
“Right, and are yeast more like us, or more like bacteria.” More like us
“Correct. And just like us yeast breathe in what?” Oxygen.
“And we both breathe out…” Carbon dioxide.

After the lead has this discussion, they will quickly go into the literature search that was done the previous day.
“Alright, so yesterday you did a literature search with your teacher and you went through some different thinks that may affect how much carbon dioxide is released. What types of things did you come up with?”
Stir speed, temperature, amount of sugar, type of sugar (food), amount of yeast, time.
The lead will then go through each
Stir speed: “So if I run around a lot, I’m going to be breathing heavier right? Just like us, stir speed affects how much carbon dioxide yeast releases.”
Temperature: “What is your normal body temperature?” 98.6 degrees farenheit. “Right, and when you get sick, you may get a temperature. That is your body trying to fight off any infection. So just like us, yeast have a temperature that allows them to function perfectly.”
Amount of Sugar: “Just like us, yeast need food to survive. In this experiment, we are giving them that food in the form of sugar.”
Type of food: “After you eat something really greasy and fatty, do you ever feel tired? That can happen to yeast to. Yeast work best if they have a certain type of food.”
Amount of yeast: “If you have a lot of yeast, there will be more carbon dioxide released, right?”
Time: “Eventually, the yeast will run out of food, but if you allow to yeast to produce carbon dioxide for the longest time possible, then you will have more carbon dioxide.”

Control Run

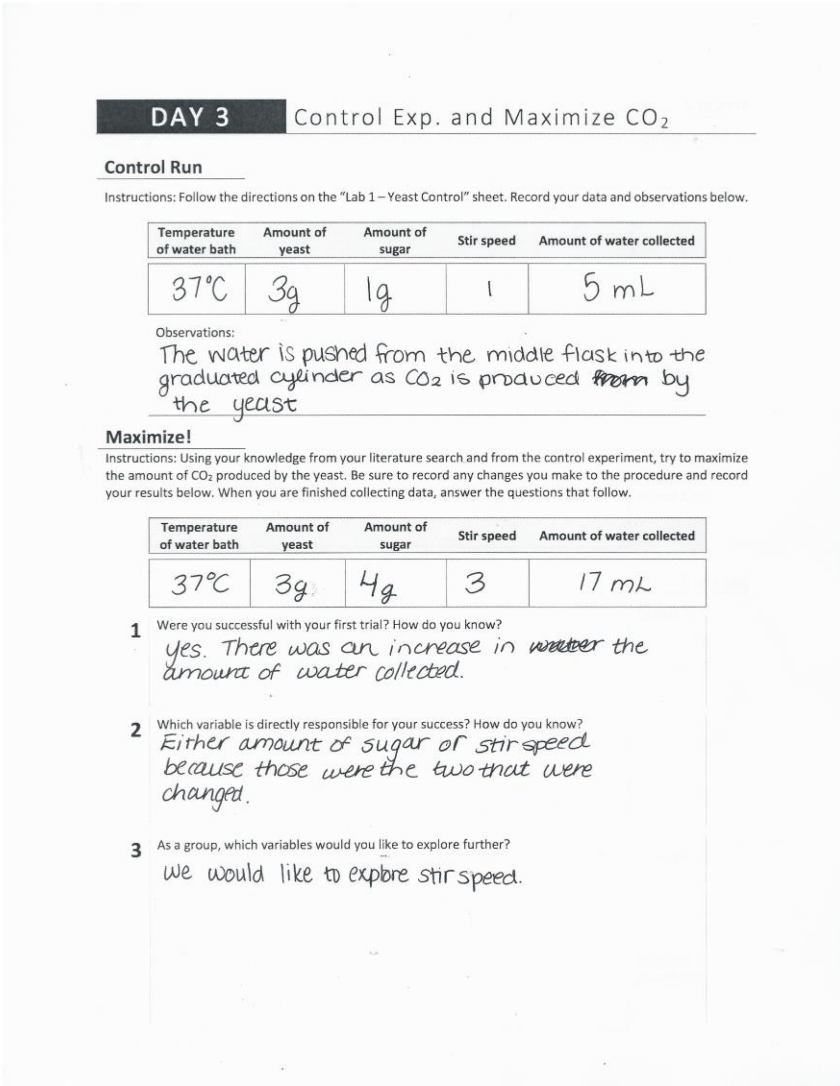
Help each of your mini research groups to assemble and run the control experiment. Follow the protocol carefully. Have the students fill out the data table in their handbook to record control run conditions. Ask the students why doing a control experiment is important.
A control experiment is important so you know how effective your experiment actually was. If you don’t have anything to compare it to, how are you supposed to know if your experiment was successful.
One part of running this experiment that becomes complicated in the classroom is the temperature of the water bath. We want the temperature to be constant throughout the experiment, so it is usually the lead’s responsibility to walk around with a beaker of hot water

and give each group a little more if their temperature drops. This becomes difficult when the lead needs to run a group as well. In this case, the volunteers should make sure they have a beaker of hot water at their tables. These beakers should be very hot, so you won't have to add much to the water bath to increase the temperature. Because of this hot temperature, the students should not pour the hot water and the volunteer or lead should always be using a fire proof glove to protect their hand.

Experiment Design #1

Challenge your mini groups to maximize the amount of CO_2 produced. Have them brainstorm all the variables that they can explore. Let them try a run with as many variables changed as they want. It will make you cringe, but we need them to try multiple variables at the same time in order to make our point when trying to unravel their results.
At first, allow them to choose as many variables as they want. At first they will want to change anything in the flask and see what happens. After they do this for their first experiment, they won't know what has exactly caused the change in carbon dioxide production. This will help guide their thinking. After they realize they don't know exactly what affected the carbon dioxide production, ask them to choose one variable they hope will cause the most carbon dioxide production and have them change just that variable.

- Be sure to save time at the end to talk to your whole group. Discuss each of their results (3 mini groups will be reporting out). Facilitate a discussion around how to best interpret the results – lead them to understand that testing only one variable at a time is the best way to work on optimizing the system.
- You can record their results on a white board or piece of paper to help the students visualize their results.
- Review with your group the concepts learned from the multiple variable experiment. As a group, decide on a variable or variables they think worth pursuing to optimize CO_2 production. The amount of yeast must remain constant, i.e. the same amount as the control.
- The students can explore any variable besides the following: amount of yeast, time, and amount of liquid.



DAY 3 Control Exp. and Maximize CO_2

Control Run

Instructions: Follow the directions on the "Lab 1 – Yeast Control" sheet. Record your data and observations below.

Temperature of water bath	Amount of yeast	Amount of sugar	Stir speed	Amount of water collected
37°C	3g	1g	1	5 mL

Observations:
The water is pushed from the middle flask into the graduated cylinder as CO_2 is produced ~~from~~ by the yeast

Maximize!

Instructions: Using your knowledge from your literature search and from the control experiment, try to maximize the amount of CO_2 produced by the yeast. Be sure to record any changes you make to the procedure and record your results below. When you are finished collecting data, answer the questions that follow.

Temperature of water bath	Amount of yeast	Amount of sugar	Stir speed	Amount of water collected
37°C	3g	4g	3	17 mL

1 Were you successful with your first trial? How do you know?
yes. There was an increase in ~~water~~ the amount of water collected.

2 Which variable is directly responsible for your success? How do you know?
Either amount of sugar or stir speed because those were the two that were changed.

3 As a group, which variables would you like to explore further?
we would like to explore stir speed.

DAY 4 Refining the Experiment

Review concepts from the last meeting, such as what the purpose of a control is, how many variables should change in a single experiment, etc. Go over the variables that the group as a whole wants to explore.

Variable List

The following is a list of potential variables that the students can explore:

- o Sugar amount
- o Sugar type
- o Stir speed
- o Water bath temperature
- o Salinity
- o Acidity/Alkalinity

Each experiment must leave the amount of yeast, the total solution volume, and the reaction time constant, but all other variables are free to be changed as much or as little as possible. As an advisor, help the students organize their data tables. They can be fashioned after the ones used for Day 2, but make sure that they record the new quantity for the variable that they are testing. However, they will only have time for 2 experiments per day, and we would also like them to repeat their trials to check for consistency. On this day, have each mini group run the same experiment twice. Students will probably be anxious to try a new value for their variable, so remind them how important repeatability is in science. If students get very different results for the same experimental conditions, talk to them about possible sources of error. These mini groups should start day 5 by doing one more trial. If a mini group gets reasonably consistent results, they can test a different value (still same variable) on day 5.

While the students are conducting their experiments, constantly review equipment vocabulary, assess verbally whether they understand the process that is occurring, and why they are collecting data on water volume and not gas. They should also be comfortable enough to assemble and run the experiments on their own the next day.

Don’t let students start another trial if you don’t think they will finish in time. When students are finished have them start cleaning up.

DAY 4 - 6 What variables affect CO_2 Production?

Prove It!

Instructions: Work with your Advisor to design an experiment to determine how your chosen variable affects the amount of CO_2 that your yeast can produce. Create a data table for your experiment below.

Variable: Stir Speed

Data Table

Temp of Water Bath	Amount of Yeast	Amount of Sugar	Stir Speed	Amount of Water Collected
37°C	3g	1g	4	25 mL

1 What affect did changing your variable have on the CO_2 production of the yeast?

~~The changing~~ changing the stir speed increased CO_2 production

Use the space below and on the next page to conduct additional trials and experiments to explore your variable, then answer the questions that follow

Temp of Water Bath	Amount of Yeast	Amount of Sugar	Stir Speed	Amount of Water Collected
37°C	3g	1g	5	32 mL
37°C	3g	1g	6	43 mL

DAY 5 Collecting More Data

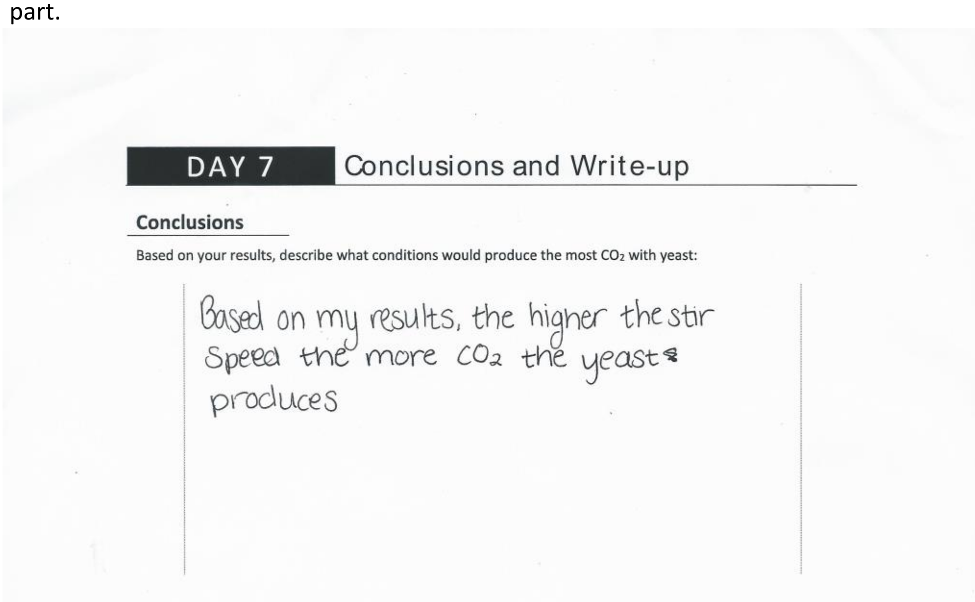
Students run experiments on their own with teacher and SciTrek Lead. Mini groups that obtained consistent results should proceed to try a different amount of the variable in question. They should try 2 different values on this day – we won't have time to do repeat trials.

Overall, we want them to have three trials for the variable they are pursing; that way they will have enough to get an average from their experiment.

DAY 6 Finish Data Collection; Begin Poster

Start by having each group share with the others what the optimal value of their variable was. If the group did not find an optimal value (e.g. results are totally inconsistent) help them make an educated guess. Suppose that a group finds that more of a certain variable increases the output of CO_2, and they don't find an upper limit (a point where adding more of the variable actually decreases CO_2 production). They do not have to pick the value with their best results. They could pick a higher value. Caution them to not go very much beyond their highest value, since they can't be sure that the trend will hold. Write down the group's combination of optimized conditions on a white board or piece of paper. Have each group run an experiment with all optimized variables. Because each group is doing the same experiment, we can teach them about uncertainty and error when doing science. Small variability in results is a normal part of science! If results of the same experiment are very different from each other, then it is likely that one of them is not correct. The teacher may go through finding the optimized class experiment on the day before the SciTrek volunteers come in. That is okay. The class with the best optimized carbon dioxide output out of all the classes will be the winner.

After analyzing your group's results, help them get started on their posters. Each student will work on a particular part of the poster, and they will eventually share their poster as a whole with the rest of the class. Help the students decide who does each part, and make sure that each student knows what to do for his/her part.



DAY 7 Conclusions and Write-up

Conclusions

Based on your results, describe what conditions would produce the most CO_2 with yeast:

Based on my results, the higher the stir Speed the more CO_2 the yeast produces