Volunteer Handbook

Best Bread

November 2016

Student

________________________________________________________________________

UCSB Team Leader

________________________________________________________________________

Teacher

_____________________________  Period  _____________
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)

- Overall reaction = $C_6H_{12}O_6 + 6 O_2 \rightarrow 6 CO_2 + 6 H_2O + energy$

- 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

Working with Your Small Group

In each group, there will usually be one to two students who are content with not participating in these discussions. Make sure that when you work with your group you are engaging each student. One good way to do this is to assign responsibilities. Have one person do the reading of the instructions, one person monitor the temperature, one person measure the yeast, etc. This is a good way to make sure that everyone is staying engaged.

DAY 1 Microscopy, Indicator Dye

Introduction

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.
“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

When you first get into your groups, introduce yourselves again to the students. Then have them go around and introduce themselves. Make sure you learn their names. You are the person in charge of making sure these students are learning the material and it is important that you make the effort to get to know them.

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

Point out the magnification of light microscopes compared to electron microscopes. Light microscopes use photons, whereas electron microscopes use electrons (negatively charged particles). Gauge your students’ knowledge by asking if they know what an electron is.

The students will not actually be looking at yeast under the microscope, but will instead be given pictures of yeast under the microscope and asked to make observations about them. Have them write their observations of the two different images down next to the pictures. Make sure they note the different magnifications.

Observe Activated and Unactivated Yeast

The students will then weigh out two yeast samples for the 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. The students should weigh out 3 grams of yeast twice. Make sure they don’t get caught up in trying to get exactly three grams of yeast. Measurements don’t have to be accurate for this section. Then have them weigh out 1 gram of sugar and add it to the first beaker. Label this beaker “Beaker 1” and the one without sugar “Beaker 2.” Then have them measure out 50 mL of warm water and add it to the two beakers. The warm water will be in the back of the classroom on a heater. You should pour the water and have the students tell you when to stop. We don’t want them to burn themselves. Allow the beakers to sit for 10 minutes or so while you proceed with the next demo.

After the yeast has sufficiently activated have the students make observations about the two beakers. One should have foam on top of the yeast. Compare this foam to the foam on top of their soda. When they go to the soda machine at a restaurant, sometimes you get a bunch of bubbles on top of your soda and you have to wait for them to go down before you can put more in. What are those bubbles? Carbon Dioxide. Just like on their soda, these bubbles are made of carbon dioxide that the yeast has produced.

**Indicator for CO\textsubscript{2} – Class Activity**

**Bubbling Blue CO\textsubscript{2} Indicator**

This is a fun way to show that indeed CO\textsubscript{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\textsubscript{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\textsubscript{2} (their breath) into water with the Bromophenol Blue. The indicator will change colors. To make it more interesting 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\textsubscript{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 chunk of dry ice. Since the dry ice is frozen at a very low temperature, it can be very dangerous if touched 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 cyllinder 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 sublime 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 get back in their small groups and work through assembling the experiment. First have them all look at the laminated image that was in their group box. 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. Don’t tell them how to set it up, have them work through trial and error. If they have one piece that is wrong, tell them that they are close and what piece is incorrect, but don’t tell them why. Allow them to work through it on their own. By doing this, they are much more likely to know how to set it up for the rest of the module. Also make sure they are referring to everything using the proper scientific terms. One part of the scientific process is using science vocabulary. 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. As they wrap up their sketches ask the students where the indicator should be placed in order to test whether CO2 is being produced.
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 CO₂ bubbles that the yeast has produced.

Beaker 2
The beaker is not warm. There is no CO₂ production.

CO₂ 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 CO₂ comes into contact with the liquid.
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.

DAY 3  Control; Maximize CO$_2$

Using the information that they gathered the previous day, students will design their own experiments. When they first get into their class, the lead will have a discussion with them about what they learned last time we were in the classroom, and what they learned when they did research about yeast. They will discuss what variables makes the yeast produce more carbon dioxide, and what we will be keeping constant.

Some of the variables that can be tested are:

- Sugar Amount
- Sugar Type
- Stir Speed
- Water bath temperature
- Salinity
- Acidity/Alkalinity

The following have to be held as controls:
- Time of reaction
- Amount of liquid in reaction
- Amount of yeast

**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. They should know that if you don’t have a control group, you won’t have anything to compare your final results to. For example if you do an experiment without doing a control experiment, and you get 34mL of carbon dioxide production, you may think that you got a positive result, but you cannot be sure. You then do a control experiment and find that you have 50 mL of carbon dioxide production. What you thought was a positive result is now a negative result. Make sure the students understand this. Also make sure the students are taking notes of their observations of the control experiment.

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 CO2 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.
0 Be sure to save time at the end to talk to your whole group. Discuss each of their results. 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.

0 When the students test more than one variable at a time, question them as to what caused their increase or decrease in carbon dioxide production. They either won’t be able to name on thing in particular or they will. If they can’t name a particular reason, this is a good indication that they should instead try to focus on one variable as opposed to many. If they can name the one thing that they believe caused the increase in carbon dioxide production, have them test that out by itself and see if they are right.

0 You can record their results on a white board or piece of paper to help the students visualize their results.

0 Review with your group the concepts learned from the multiple variable experiment. As a group, decide on a variable they think worth pursuing to optimize CO2 production. The amount of yeast must remain constant, i.e. the same amount as the control.
DAY 3  Control Exp. and Maximize CO₂

Control Run

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

<table>
<thead>
<tr>
<th>Temperature of water bath</th>
<th>Amount of yeast</th>
<th>Amount of sugar</th>
<th>Stir speed</th>
<th>Amount of water collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>37°C</td>
<td>3 g</td>
<td>1 g</td>
<td>1</td>
<td>5 mL</td>
</tr>
</tbody>
</table>

Observations:
The water is pushed from the middle flask into the graduated cylinder as CO₂ 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 CO₂ 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.

<table>
<thead>
<tr>
<th>Temperature of water bath</th>
<th>Amount of yeast</th>
<th>Amount of sugar</th>
<th>Stir speed</th>
<th>Amount of water collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>37°C</td>
<td>3 g</td>
<td>4 g</td>
<td>3</td>
<td>17 mL</td>
</tr>
</tbody>
</table>

1. Were you successful with your first trial? How do you know?
   yes. There was an increase in whether 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 variable(s) that the group as a whole wants to explore. As a group comes to a consensus on which variable each mini group will test.

Variable List

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

- Sugar amount
- Sugar type
- Stir speed
- Water bath temperature
- Salinity
- 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. It would be ideal if each mini group can test three different values for the variable that they are responsible for. 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 CO₂ Production?

Prove It!

Instructions: Work with your Advisor to design an experiment to determine how your chosen variable affects the amount of CO₂ that your yeast can produce. Create a data table for your experiment below.

Variable: Stir Speed

<table>
<thead>
<tr>
<th>Temp of Water Bath</th>
<th>Amount of Yeast</th>
<th>Amount of Sugar</th>
<th>Stir Speed</th>
<th>Amount of Water Collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>37°C</td>
<td>3g</td>
<td>1g</td>
<td>4</td>
<td>25 mL</td>
</tr>
</tbody>
</table>

1. What affect did changing your variable have on the CO₂ production of the yeast?
   Due to changing the stir speed increased CO₂ 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.

<table>
<thead>
<tr>
<th>Temp of Water Bath</th>
<th>Amount of Yeast</th>
<th>Amount of Sugar</th>
<th>Stir Speed</th>
<th>Amount of Water Collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>37°C</td>
<td>3g</td>
<td>1g</td>
<td>5</td>
<td>32 mL</td>
</tr>
<tr>
<td>37°C</td>
<td>3g</td>
<td>1g</td>
<td>6</td>
<td>43 mL</td>
</tr>
</tbody>
</table>
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 3 trials that they can find an average for.

DAY 6  Finish Data Collection; Begin Poster

Start by having each group share with the class 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 class’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.

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.
Conclusions

Based on your results, describe what conditions would produce the most CO₂ with yeast:

Based on my results, the higher the stir speed the more CO₂ the yeast produces.