SciTREK Volunteer Handbook

Best Bread

Big Question:

How do you maximize the production of CO_2 in yeast?

October 2018

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**. 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 single-celled 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 = $C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O$ + 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. The discussion will go 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

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 Inactivated 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_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 ‘Bromothymol Blue’ which is pH sensitive. Weakly acidic and basic solutions are blue, whereas more strongly acidic solutions (pH < 3) are yellow. **Bromothymol 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 Bromothymol Blue. The indicator will change colors. To make is 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 shows that yeast is also producing CO_2 in the presence of sugar. This demo involves warming a 100 mL of diluted solution of bromothymol blue in a 125 mL Erlenmeyer flask to 37 °C on a hot plate in front of the class. The lead will then add 1 gram of sugar to the flask and allow it to dissolve before adding 1 gram of yeast. Once yeast has been added, swirl the flask and wait as the solution turns from blue to yellow. This experiment is

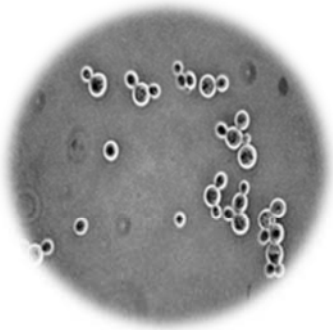
used to show the comparison between human's CO_2 production and the CO_2 production in yeast.

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 is yeast and what does it do?

Microscopy



Light Microscope
1000X Magnification

Electron Microscope
20000X Magnification

Observations:

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 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: Bromothymol Blue

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

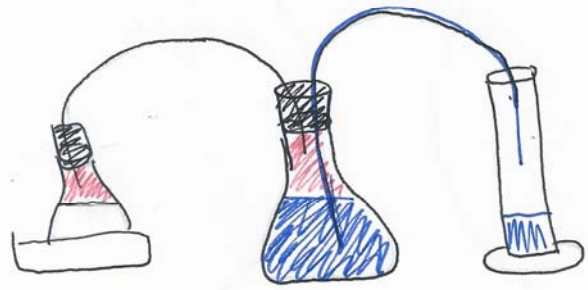


Figure 1. Water displacement apparatus to measure CO_2 output of yeast.

DAY 2 Literature Review

Volunteers will not be here on this day, it is an off-day activity for the students. 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 your research group 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.

After all groups have finished their control experiments the lead/teacher will write each groups data on the board and determine the class average. Students will write this average into their notebooks and compare it to their result, this is a good opportunity to discuss the possibility of outliers and how they can affect your data, if the students know that they made a mistake during their procedure (like letting the temperature drop or not having the stir bar spinning etc.) then their data should be removed from the average. Mention to these groups that another way of testing if their data was outlier is by reproducing the experiment, however this will not be done during this module because of time constraints.

Experiment Design #1

Challenge your group 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.

- 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.
- 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.
- 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 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 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	5mL

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

Class average: 7mL

Discussion Question:

Was your experimental result consistent with the classes average? Was your data an outlier?

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	17mL

1 Were you successful with your first trial? How do you know?

Yes, we collected more water in the graduated cylinder.

2 Which variable is directly responsible for your success? How do you know?

Either amount of sugar or stir speed was responsible because those were the two that were changed.

3 As a group, which variables would you like to explore further?

Stir speed is what we want to explore.

DAY 4 Procedure Practice

This is another off-day activity, the volunteers will not be here for this. The students will be tasked with writing their own procedures and correcting an inaccurate procedure of the CO2 experiment. The purpose of this is so that the students may have a better understanding of what is to be done on day 5.

DAY 5 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.

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 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. Each group should start day 6 by doing one more trial. If a group gets reasonably consistent results, they can test a different value (still same variable) on day 6.

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 5-6 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.

Reference Day 3 Control

Variable: Stir Speed

Data Table

	Temperature of water bath	Amount of Sugar	Amount of Yeast	Stir speed	Amount of water collected
Trial 1	37°C	1g	3g	4	25mL
Trial 2	37°C	1g	3g	4	27mL

Trials Average (mL): 26

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

Changing 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. Remember to repeat your experiment at least twice for reproducibility. **Goal: Figure out what value of your variable causes the yeast to produce the most CO_2. You will be using this information in the future to compete against other classes, so be sure to conduct your experiments carefully!!!**

Temperature at water bath	Amount of Sugar	Amount of Yeast	Stir speed	Amount of water collected	
37°C	1g	3g	5	32mL	Avg: 30mL
37°C	1g	3g	5	28mL	
37°C	1g	3g	6	43mL	Avg. 43mL
37°C	1g	3g	6	43mL	

DAY 6 Collecting More Data

Students run experiments on their own with their teacher and SciTrek Lead. Groups that obtained consistent results should proceed to try a different amount of the variable in question. They should try two different values of the same variable on this day – repeat trials only if your group got completely unexpected results, like 0 mL of water collected.

DAY 7 Graphing Practice

Students will practice graphing bar and line graphs. After they've gotten practice graphing with a few data sets the students will then attempt to graph their own data. The data should be presented with the changing variable on the X-axis, while the water collected is represented by the Y-axis. Students should have a title for their graphs. This is another off-day activity that the volunteers will not be there for. Students will present this data that they've collected and graphed on day 8.

DAY 8 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. Students should also write these optimized conditions in their notebook as well. 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.

DAY 8 Conclusions and Write Up

Conclusions

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

My results ~~share~~ showed that a higher stir causes the yeast to produce more CO_2. Other groups found that more sugar also causes the yeast to produce more CO_2.

Now that you have a hypothesis for what the best conditions to produce CO_2 with yeast are, try it for yourself. Make a table below with all your experimental values and take note of how much water you collect. Once each group has finished their experiment, your teacher will help you find the class average.

Temperature water bath	Amount of Sugar	Amount of Yeast	Stir speed	Sugar Type? Acidity? Salinity?	Amount of water collected
37°C	5g	3g	6	X	70mL

Optimized experiment class average: 74 mL

Discussion Question: Was your groups experimental value consistent with the class average? If not, what could have caused this error? Explain below.

The amount water my group collected was slightly below average, but we think it was caused by our temperature decreasing over the experiment.

DAY 9 Finish Power Point Presentation

Again, this is an off-day activity, volunteers will not be here. The students will be working together to finish their power point presentation. Their presentation should contain all of the information that they learned as well as their control, experimental, and optimal results.

DAY 10 Power Point Presentation

Groups will be presenting their power point presentation. The first 5 minutes should consist of the volunteers checking their groups presentation, after which the groups will present in front of the class. Each presentation should take about 5 minutes. There should be a 2-3 minute question period after each presentation. Volunteers are encouraged to start off the question process if none of the students do so themselves. Communicating your results with peers is an important aspect of how science works! So try and have fun 😊

SciTrek is an educational outreach program that is dedicated to allowing 2nd-8th grade students to experience the scientific process first hand. SciTrek partners with local schools to present student-centered inquiry-based modules that not only emphasize the process of science but also specific grade level content standards. Each module allows students to design, carryout, and present their experiments and findings.

For more information please feel free to visit us on the web at *http://www.chem.ucsb.edu/scitrek/* or contact us by e-mail at scitrekadmin@chem.ucsb.edu.

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