

What's Your Limit?

Modified from: NASA's Astromaterials Research and Exploration Science educational package
Fingerprints of Life? (<http://ares.jsc.nasa.gov/Education/Websites/AstrobiologyEducation/>)
It's Just Right activity (<http://ares.jsc.nasa.gov/Education/Websites/AstrobiologyEducation/Data/justright.pdf>)

Overview

Organisms on Earth live in a wide range of environment. They live in hot boiling springs as well as in the ice of Antarctica. The microbes that live in these extreme environments are called extremophiles. Scientists are studying microbes that can live in Earth's extreme environments to have a better understanding of places where life might have existed elsewhere in our solar system.

In this activity, the students design and implement an experiment to test the extremes at which *Saccharomyces cerevisiae*, one-celled organisms that are known as baker's yeast, can metabolize, as measured by the production of carbon dioxide. The students work in groups to test the limits of temperature, salinity, and acidity.

Students:

- Experiment with gas production of yeast at different temperatures, salinities, and alkalinities – or other extreme conditions that the students brainstorm!
- Take, record, and plot data from an experiment
- Discuss extreme environments on Earth and other planets

Materials

<u>For each team of 3 to 4 students:</u> <ul style="list-style-type: none">• 6 half-liter clear soda or water bottles with narrow mouths• 6 8 to 10 inch balloons• 6 packages of dry bakers yeast• 140 cc (2/3 cup) sugar• Measuring spoons• Beaker or metric measuring cup• Funnel• Cloth measuring tape or string and a metric ruler• Magic marker with a "soft" or blunt point• Magnifying glass• Access to warm and cold water• Timer or clock• Safety goggles	<u>Temperature Extremes Teams</u> <ul style="list-style-type: none">• 3 hot plates• 3 large pots for heating water• 6 thermometers• Ice
	<u>Salinity Extremes Team</u> <ul style="list-style-type: none">• 1 hot plate for warming solutions• 1 large pot for heating water• 70 cc (1/3 cup) salt• Metric scale that can weigh in units of tenths of grams• 6 thermometers
	<u>Alkalinity Extremes Teams</u> <ul style="list-style-type: none">• 1 hot plate for warming solutions• 1 large pot for heating water• 6 thermometers• 700 ml (3 cups) vinegar• Ammonia• pH paper from 0 to 14

Preparation

Carefully review the notes for the individual teams and take note of the cautions mentioned.

Introduction

Invite the students to discuss what is meant by an "extremophile" and "extreme environment."

Challenge them to create an experiment that will test the range of temperature or salinity, or alkalinity (or other!) in which *Saccharomyces cerevisiae* – baker's yeast – can metabolize. They will monitor the amount of carbon dioxide, a product of metabolism, generated by the yeast. Metabolism refers to the physical and chemical processes that make energy available to an organism. Metabolism is affected by environmental conditions. When the rate of these life-sustaining reactions drops beneath a critical level, the organism will die.

Activity Design Notes

There are many possible ways to design these experiments; teams should be encouraged to brainstorm an experimental design and present it to the class before they proceed (see individual team notes below).

The teams will prepare their half-liter test bottles in the same manner:

- 10 cc (2 teaspoons) of yeast
- 20 cc (4 teaspoons) of sugar

The students will then add:

- Water of the appropriate temperature to the bath
- 200 ml (1 cup) of fluid (water at different temperatures and alkalinities) into the bottle containing the yeast

Once they put their fluid in the container, they need to immediately secure the balloon neck on the bottle top so that a seal is formed. Be sure the balloon completely covers the whole neck of the bottle. If possible, the balloon should be deflated as it is being attached.

The students should take measurements of the balloon width (at the widest location) as soon as the bottle is sealed and every five minutes thereafter for 30 to 40 minutes. They may want to gently mark where they take their measurements on the balloon surface so that they measure in the same location each time.

Have the students use the Data and Observation Collection Sheets to record their findings. When they have completed their experiments, have them respond to the questions on the sheets.

As a class, discuss the findings of the teams. Using their data, what is the range of tolerance for *Saccharomyces cerevisiae*. What is the highest temperature under which the yeast survived

and continued to metabolize and produce gas? Salinity? Acidity? What is the lowest temperature that the yeast tolerated and continued to metabolize? Salinity? Alkalinity?

Did teams who tested the same environmental characteristics get similar results? Why or why not? (Experimental design may vary, yielding different results). How might they redesign their experiments to get more accurate results?

What questions do they continue to have? Would it be possible to narrow the range of extremes with a different experimental design? What would it look like?

If there is time, allow the teams to repeat their experiments to narrow the range

Notes: Temperature Extremes Teams

Caution: Experimental design may involve hot plates and very hot water.

This should be supervised by an adult at all times.

- This team's design may include adding water of different temperatures, from ice water to very hot water, directly to the containers.
- In the trial runs, there was no metabolic activity above 80 C (hence there is no need to use boiling water) and none below 5 C; encourage the students to restrict their experimentation to more specifically identify the range of extremes at which yeast survive.
- The temperatures should be maintained if possible for the duration of the experiment (e.g., the yeast on ice should be stored in an ice bath or cooler; yeast in warmer temperatures should be kept in warm baths).

Notes: Salinity Extremes Team

- This team's design may include adding varying amounts of salt to the dry mixtures of yeast, and then adding the water.
- The salt can be measured using the scale, to allow students to calculate salinity.

	Grams of Salt per Liter of Water	Grams of Salt per 200 Milliliters of Water
Fresh Water	<5 g	<1 g
Brackish Water	5 to 30 g	1 to 6 g
Salt Water	30-50 g	6 to 10 g
Brine	>50 g	>10 g

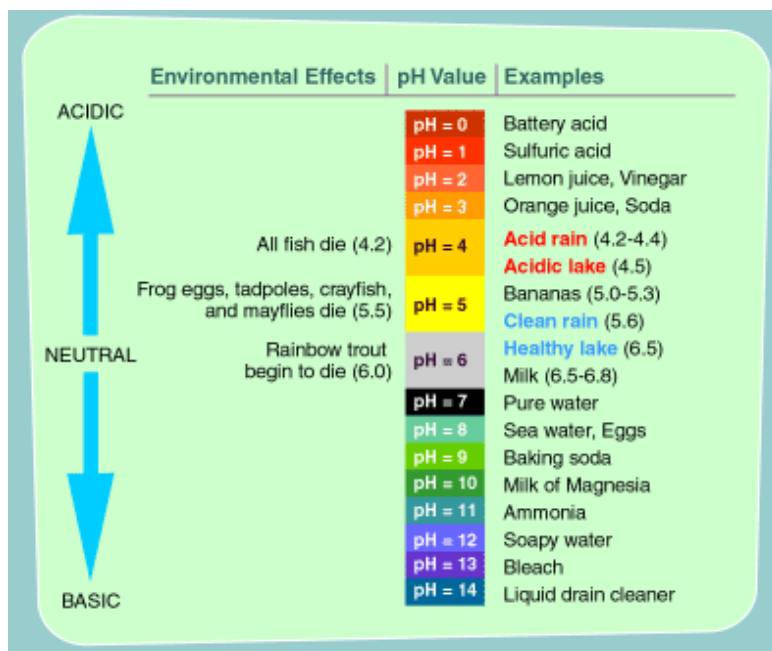
- The water for all containers should be the same warm temperature (~50 degrees C) and the temperature should be maintained. The bottles can be placed in the large pot of warm water. The hot plate can be used to maintain the temperature (a low setting typically is sufficient).

Notes: Alkalinity Extremes Team

Caution: Experimental design in this activity involves ammonia and must be monitored by an adult at all times.

Various other alkaline and acidic solutions could be substituted in this experiment, however, they are extremely dangerous and should not be used in the classroom.

- This team's design may include adding water of different alkalinities, from very acidic vinegar, to alkaline water.
- Vinegar has a pH of 2; water a pH of 7, and ammonia has a pH of 12. Approximately 2 ml of vinegar added to 200 ml of water results in a solution with a pH of 4. Approximately 2 ml of ammonia added to 200 ml of water results in a pH of 9. This experiment offers a "teachable moment" to explore what pH means.
- In the trial runs, there was no metabolic activity using undiluted vinegar or ammonia; there is no reason to use undiluted ammonia; indeed only a small amount of ammonia is needed to create solutions with a pH of 11 or 10. Encourage the students to restrict their experimentation to more specifically identify the range of extremes at which yeast survive.
- The pH of the fluid should be measured prior to adding it to the container.
- The vinegar, water, or other fluid for all containers should be the same warm temperature (~50 degrees C), and the temperature should be maintained using the water bath. **It is recommended that the ammonia and vinegar solutions be warmed (never above 50 degrees C) in a water bath; this must be done in a well ventilated area, although trials produced very little vapor.** The bottles can be placed in the large pot of warm water. The hot plate can be used to maintain the temperature (a low setting typically is sufficient).



http://www.epa.gov/acidrain/education/site_students/images/phscale.gif

What's Your Limit?

Data and Observation Collection Sheets

Team Members:

Experiment Variable: Temperature / Salinity / Alkalinity / Other

	Bottle 1 Balloon Diameter	Bottle 2 Balloon Diameter	Bottle 3 Balloon Diameter	Bottle 4 Balloon Diameter	Bottle 5 Balloon Diameter	Bottle 6 Balloon Diameter
Environmental Condition (T, Salinity, pH)						
Time						
Start!						
5 minutes						
10 minutes						
15 minutes						
20 minutes						
25 minutes						
30 minutes						
35 minutes						
40 minutes						

After 20 minutes, how did the appearance of the yeast change in each container?

Using the data collected, predict the range of tolerance for *Saccharomyces cerevisiae*. What is the most extreme high condition under which the yeast survived and continued to metabolize and produce gas? What is the lowest condition that the yeast tolerated and continued to metabolize?

How would your team redesign the experiment to get more accurate results?