Cellular Respiration

Contents

Objectives

- Review the process of cellular respiration
- Be able to explain how alcoholic fermentation can be measured
- Investigate the ability of organisms to utilize carbohydrates other than glucose in cellular respiration
- Be able to explain how aerobic respiration can be measured
- Explain the affects of excessive heat on this metabolic process

Introduction

Two essential biological processes for life on Earth are photosynthesis and respiration. This series of reactions converts light energy from the sun into chemical energy, largely in the form of the molecule ATP, which can then be used to power the cell's other life processes.

During this conversion, energy is temporarily stored in the chemical bonds of the carbohydrate glucose (which can be converted to other storage molecules for transport or storage). The net result is that these processes are essentially the opposite of one another with the one significant difference being the form of energy; light vs. chemical bonds in ATP. This is illustrated by comparing the overall reactions of each.

Overall Reactions in Photosynthesis

$$6CO_2 + 12H_20 + \text{light} \rightarrow \text{glucose} + 6O_2 + 6H_2O$$

Overall Reactions in Aerobic Respiration

$$\text{glucose} + 6O_2 + 6H_2O \rightarrow 6CO_2 + 12H_20 + \text{ATP}$$

Some organisms do not use oxygen, either because it is not present in their environment or it is toxic to their cells. These organisms utilize alternate pathways to break down glucose. One such pathway is fermentation.

In this process glucose is broken down in the absence of oxygen yielding some ATP (but not as much as in aerobic respiration), as well as alcohols or acids. In addition, in some organisms, carbon dioxide (a gas) is produced as a by-product of the reaction.

The first two activities in this lab examine aspects of anaerobic respiration by measuring carbon dioxide production. The third activity tests rates of aerobic respiration in peas.

Activity 8.1
Fermentation of Carbohydrates

In anaerobic conditions, yeast and some bacteria use the alcoholic fermentation metabolic pathway to produce the high energy molecule ATP. During this process, glucose is broken down to produce ethyl alcohol, carbon dioxide and ATP. To monitor alcoholic fermentation activity you will measure the production of carbon dioxide in this simulation.

Besides glucose, other carbohydrates may also be used by these organisms for alcoholic fermentation. If the organism has the necessary enzymes to convert a carbohydrate into glucose, that carbohydrate can be used as an energy source. For example, sucrose can be broken down into glucose and fructose. Then, other enzymes can convert the fructose into more glucose molecules.

As with nearly all chemical reactions in living systems, the reactions of alcoholic fermentation are catalyzed by enzymes. Environmental conditions that alter this enzymatic activity will either increase or decrease the rate of fermentation in the organism.

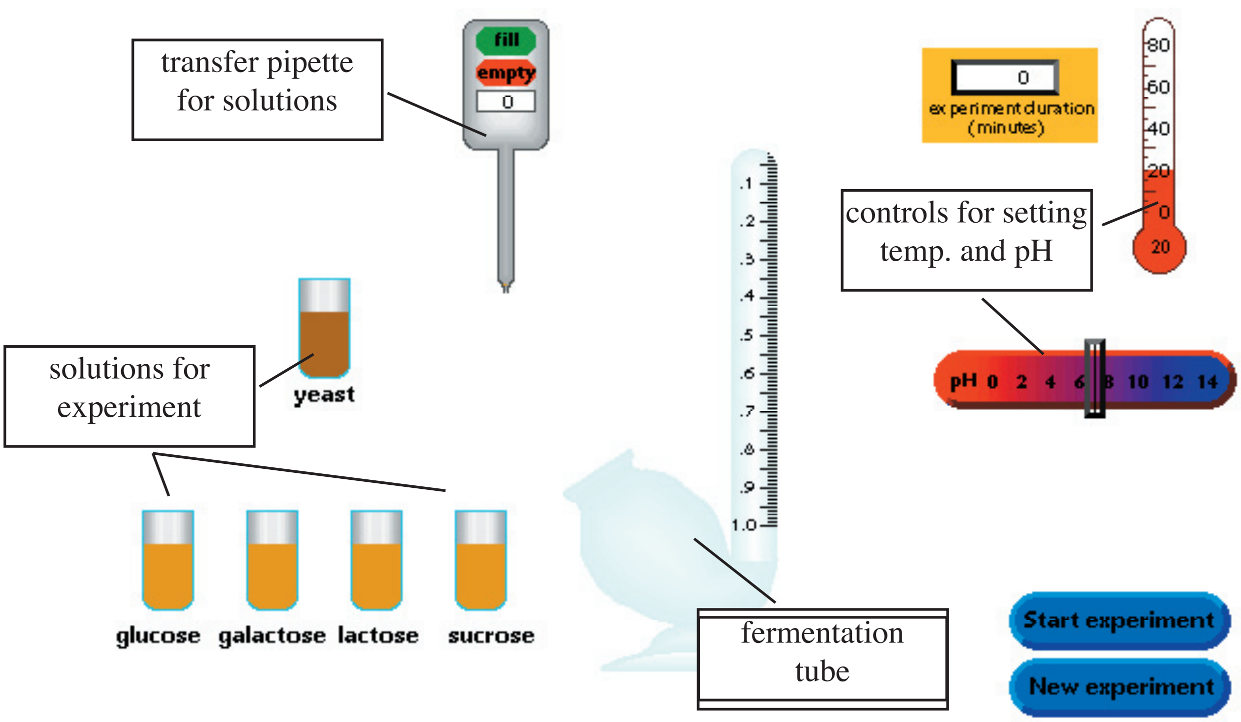
In the BiologyOne DVD, open the Cellular Respiration simulation. In the simulation screen you will see a yeast solution, four carbohydrate solutions, a pipette to transfer solutions, the fermentation tube, and controls for setting temperature and pH.

In your first experiment, leave the temperature set at 20 degrees and the pH at 7.

1. Transfer 40 ml of the glucose solution to the fermentation tube. Place the tip of the pipette in the solution to be transferred and click on the fill button until the appropriate volume has been taken up. Then drag the pipette so that the tip is over the location you want to receive the solution. Click on the empty button to release the fluid from the pipette.

2. Next, transfer 1 ml of the yeast solution to the fermentation tube.

Simulation for Anaerobic Respiration



3. You are going to measure how many minutes (on the simulation timer) it takes for this mixture of glucose and yeast to produce a volume of 1.0 in the fermentation tube. When ready, click on the Start Experiment button. The tube will rotate and if any carbon dioxide is produced, it will form a gas bubble in the top of the tube.

4. When the gas volume in the tube reaches the 1.0 level, note the number of minutes that have passed. Record this in the Results Section.

5. Repeat the above experiment, being sure to maintain the same conditions, for the other three carbohydrates, galactose, lactose, and sucrose. If no carbon dioxide is produced after 30 minutes (on the simulation timer), terminate that experiment. Record your observations in the Results Section.

Activity 8.2
Temperature and pH Effects

Experiment 1:
This first experiment investigates the effect of temperature on the rate of alcoholic fermentation in yeast.

1. Set the temperature to 0 degrees (units are centigrade) and the pH to 7.

2. Transfer 40 ml of glucose to the fermentation tube. Then add 1 ml of the yeast solution to the fermentation tube.

3. Click on the Start experiment button to begin the experiment.

4. Record the length of time it takes for the gas volume in the tube to reach the 1.0 level. If no carbon dioxide is produced after 30 minutes (on the simulation timer), terminate that experiment. Record your observations in the Results Section.

5. Repeat the above experimental steps to measure the carbon dioxide production for temperatures from 0 to 80 degrees C at 10 degree intervals.

What temperature is optimal for alcoholic fermentation in yeast?

Experiment 2:
The second experiment in this section test the effect of pH on the rate of alcoholic fermentation in yeast.

1. Set the temperature to 20 degrees C and the pH to 2.

2. Transfer 40 ml of glucose to the fermentation tube. Then add 1 ml of the yeast solution to the fermentation tube. When ready, click on the Start button to begin the experiment.

4. Record the length of time it takes for the gas volume in the tube to reach the 1.0 level. If no carbon dioxide is produced after 30 minutes (on the simulation timer), terminate that experiment. Record your observations in the Results Section.

5. Repeat the above experimental steps to measure the carbon dioxide production for pH values of 4, 6, 8 and 10.

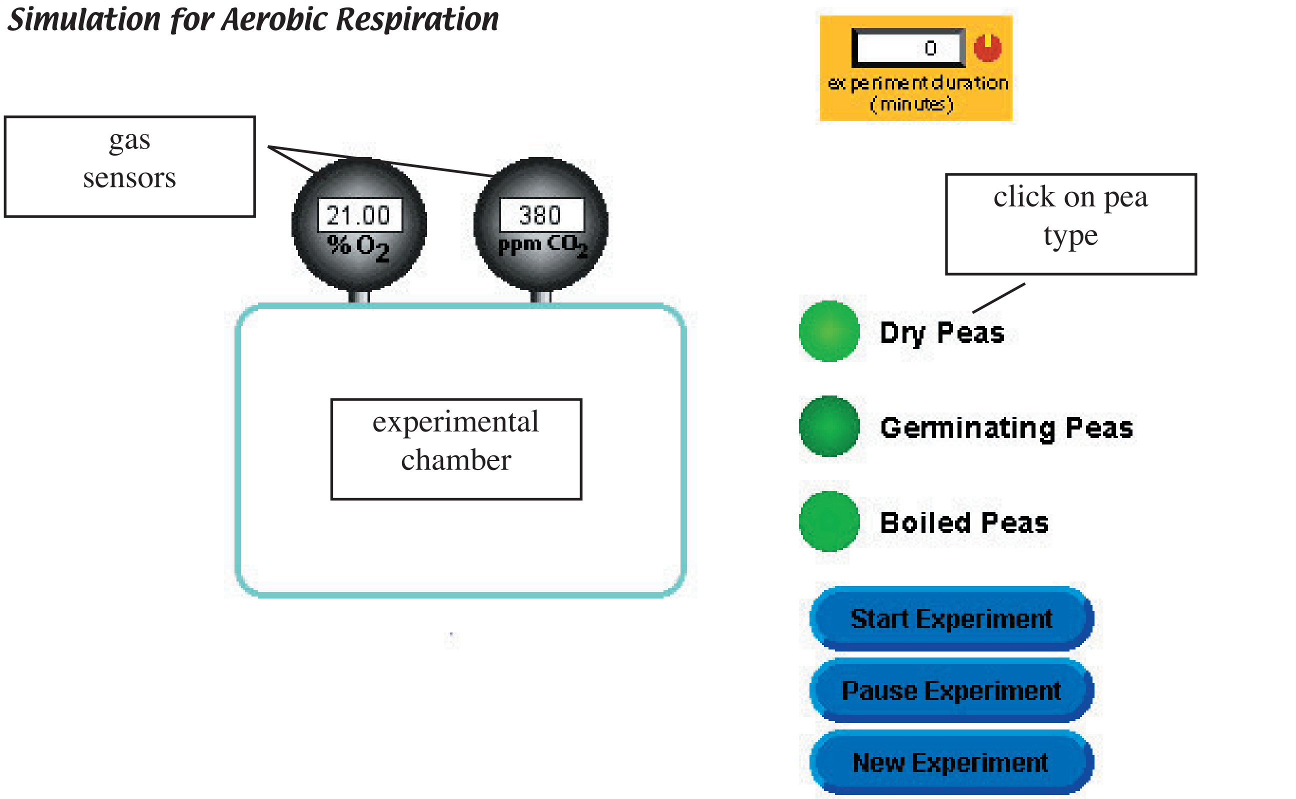
What pH is optimal for alcoholic fermentation in yeast?

While alcoholic fermentation will provide enough energy for some organisms, most organisms need to obtain more energy from glucose to survive. These organisms utilize oxygen to produce water at the end of the process known as aerobic respiration. Here, glucose (or other carbohydrates) is completely broken down producing energy (ATP), carbon dioxide and water. Aerobic respiration produces approximately 18 times more ATP than anaerobic fermentation for every glucose molecule.

Easy ways to measure rates of aerobic respiration are to monitor the production of carbon dioxide or the uptake of oxygen.

On the simulation screen you will see a chamber equipped with sensors to measure percent oxygen and ppm (parts per million) carbon dioxide. This simulation measures respiration in pea seeds. To the right of the experimental chamber are three types of pea seeds. The top seed is a dry, dormant pea seed. The middle seed is a actively ger-

Simulation for Aerobic Respiration



minating pea seed. The bottom pea seed is one that was germinating but was exposed to boiling water for 1 minute.

1. Click on the middle germinating pea seed to place it into the experimental chamber. Record the initial gas concentration values in the Results Section.

2. Click on the Start Experiment button to begin taking measurements. The timer in the upper right will begin to run.

3. At 5 minutes (simulation time), pause the experiment by clicking the Pause Experiment button. Record the gas concentration values in the Results Section.

4. Restart the experiment by clicking on the Start Experiment button. Pause again at every 5 minutes until you reach a total experimental time of 30 minutes (simulation time). Record the gas concentration values each time you pause.

Plot your data on the graph in the Results Section and answer the questions.

Repeat this experiment with the dry peas ad the boiled peas.

Lab Exercise 8 Name ______________________

Results Section

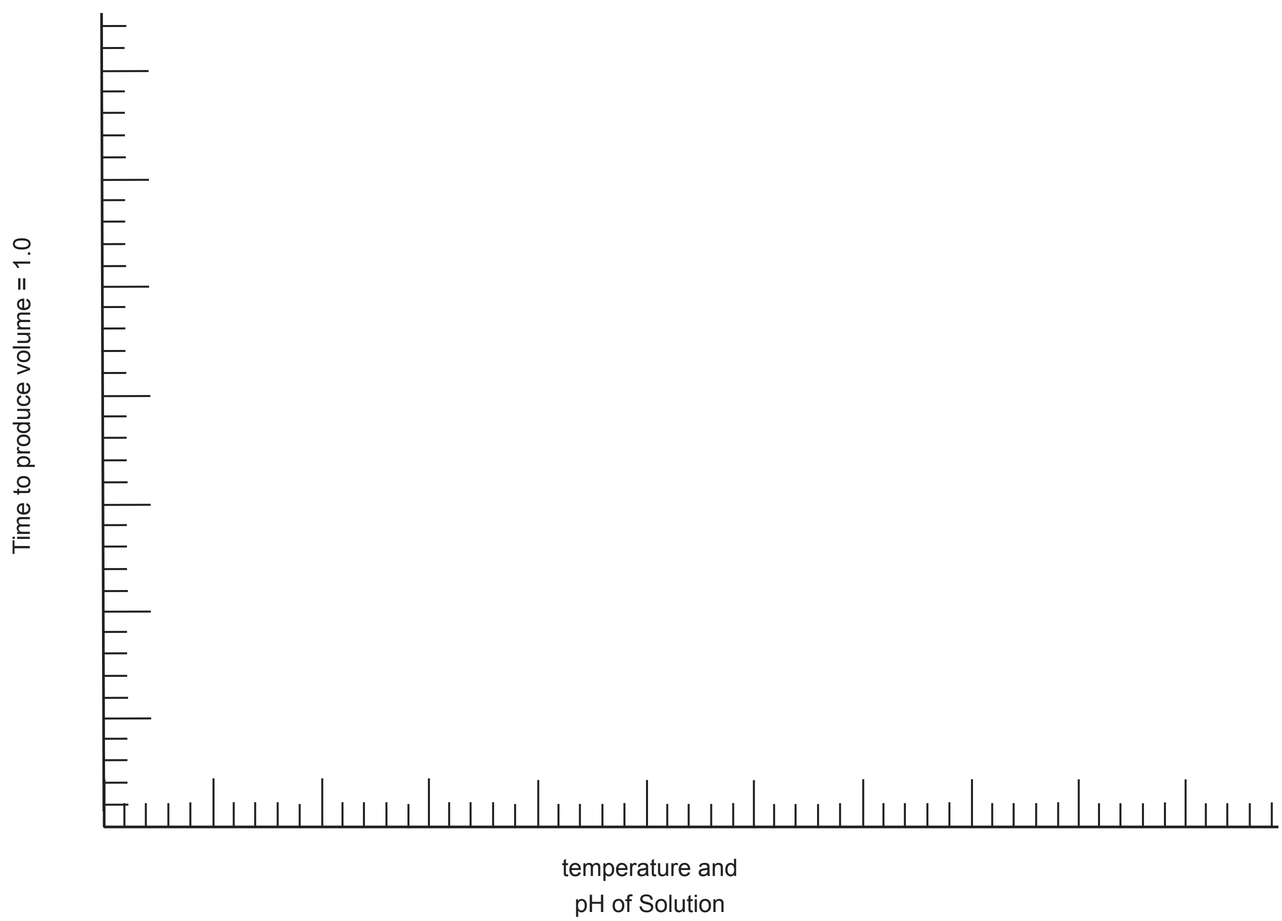
Activity 8.1
Fermentation of Carbohydrates

Carbohydrate	Time to produce volume = 1.0
glucose	
galactose	
lactose	
sucrose	

Activity 8.2
Temperature and pH Effects

Temperature	Time to produce volume = 1.0
0	
10	
20	
30	
40	
50	
60	
70	
80	

pH	Time to produce volume = 1.0
2	
4	
6	
8	
10	



Activity 8.3
Aerobic Respiration

germinating peas

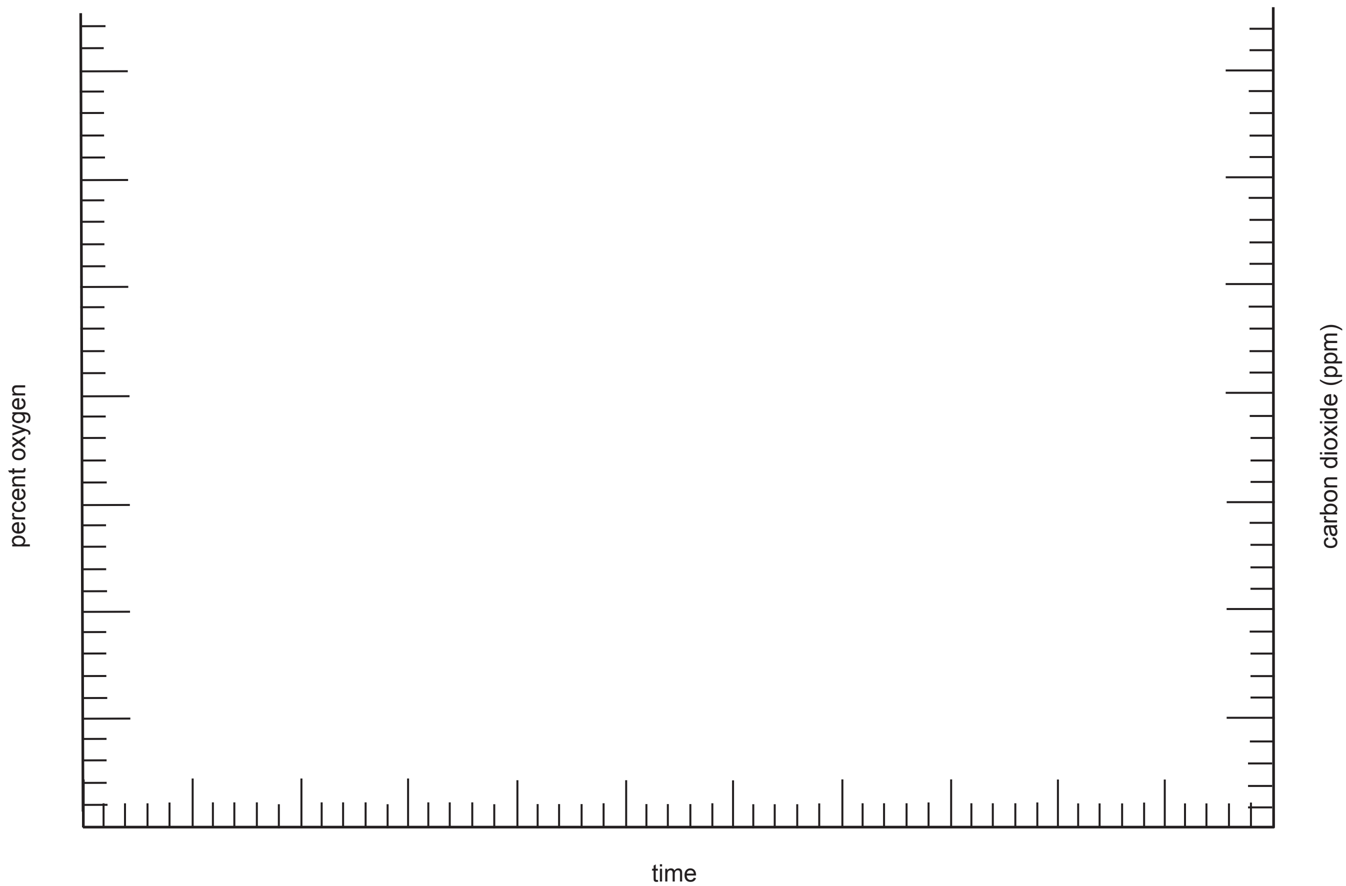
time	% O_2	CO_2 ppm
5		
10		
15		
20		
25		
30		

dry peas

time	% O_2	CO_2 ppm
5		
10		
15		
20		
25		
30		

boiled peas

time	% O_2	CO_2 ppm
5		
10		
15		
20		
25		
30		



What has (or has not) happened to cause the results for the dry and boiled peas to be different from the germinating peas?