LIFE SCIENCE
MIDDLE SCHOOL

PASCO®
21st CENTURY SCIENCE

TEACHER GUIDE | PS-3850

Middle School Life Science
Teacher Guide

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Middle School Life Science

Teacher Guide
21^{st} Century Science

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Introduction

PASCO scientific's probeware and laboratory investigations move students from the low-level task of memorization of science facts to higher-level tasks of data analysis, concept construction, and application. For science to be learned at a deep level, it is essential to combine the teaching of abstract science concepts with "real-world" science investigations. Hands-on, technology-based, laboratory experiences serve to bridge the gap between the theoretical and the concrete, driving students toward a greater understanding of natural phenomenon. Students also gain important science process skills that include: developing and using models, carrying out investigations, interpreting data, and using mathematics.

At the foundation of teaching science are a set of science standards that clearly define the science content and concepts, the instructional approach, and connections among the science disciplines. The Next Generation Science Standards (2012)© are a good example of a robust set of science standards.

The Next Generation Science Standards (NGSS) position student inquiry at the forefront. The standards integrate and enhance science, technology, engineering, and math (STEM) concepts and teaching practices. Three components comprise these standards: Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts. The lab activities in PASCO's 21st Century Science Guides are all correlated to the NGSS (see http://pasco.com).

- The *Science and Engineering Practices* help students to develop a systematic approach to problem solving that builds in complexity from kindergarten to their final year in high school. The practices integrate organization, mathematics and interpretive skills so that students can make data-based arguments and decisions.
- *Disciplinary Core Ideas* are for the physical sciences, life sciences, and earth and space sciences. The standards are focused on a limited set of core ideas to allow for deep exploration of important concepts. The core ideas are an organizing structure to support acquiring new knowledge over time and to help students build capacity to develop a more flexible and coherent understanding of science.
- *Crosscutting Concepts* are the themes that connect all of the sciences, mathematics and engineering. As students advance through school, rather than experiencing science as discrete, disconnected topics, they are challenged to identify and practice concepts that cut across disciplines, such as "cause and effect". Practice with these concepts that have broad application helps enrich students' understanding of discipline-specific concepts.

PASCO's lab activities are designed so that students complete guided investigations that help them learn the scientific process and explore a core topic of science, and then are able to design and conduct extended inquiry investigations. The use of electronic sensors reduces the time for data collection, and increases the accuracy of results, providing more time in the classroom for independent investigations.

In addition to supporting the scientific inquiry process, the lab activities fulfill STEM education requirements by bringing together science, technology, engineering, and math. An integration of these areas promotes student understanding of each of these fields and develops their abilities to become self-reliant researchers and innovators. When faced with an idea or problem, students learn to develop, analyze, and evaluate possible solutions. Then collaborate with others to construct and test a procedure or product.

Information and computer tools are essential to modern lab activities and meeting the challenge of rigorous science standards, such as NGSS. The use of sensors, data analysis and graphing tools, models and simulations, and work with instruments, all support the science and engineering practices as implemented in a STEM-focused curriculum, and are explicitly cited in NGSS. PASCO's lab activities provide students with hands-on and minds-on learning experiences, making it possible for them to master the scientific process and the tools to conduct extended scientific investigations.

About the PASCO 21st Century Science Guides

This manual presents teacher-developed laboratory activities using current technologies to help you and your students explore topics, develop scientific inquiry skills, and prepare for state level standardized exams. Using electronic-sensor data collection, display and analysis devices in your classroom fulfills STEM requirements and provides several benefits. Sensor data collection allows students to:

- observe phenomena that occur too quickly or are too small, occur over too long a time span, or are beyond the range of observation by unaided human senses
- perform measurements with equipment that can be used repeatedly over the years
- collect accurate data with time and/or location stamps
- rapidly collect, graphically display, and analyze data so classroom time is used effectively
- practice using equipment and interpreting data produced by equipment that is similar to what they might use in their college courses and adult careers

The Data Collection System

"Data collection system" refers to PASCO's DataStudio®, the Xplorer GLX™, SPARKvue™, and SPARK Science Learning System™ and PASCO Capstone™. Each of these can be used to collect, display, and analyze data in the various lab activities.

Activities are designed so that any PASCO data collection system can be used to carry out the procedure. The DataStudio, Xplorer GLX, SPARKvue, or SPARK Science Learning System Tech Tips provide the steps on how to use the data collection system and are available on the storage device that came with your manual. For assistance in using PASCO Capstone, refer to its help system.

Getting Started with Your Data Collection System

To help you and your students become familiar with the many features of your data collection system, start with the tutorials and instructional videos that are available on PASCO's website (www.pasco.com).

Included on the storage device accompanying your manual is a Scientific Inquiry activity that acts as a tutorial for your data collection system. Each data collection system (except for PASCO Capstone) has its own custom Scientific Inquiry activity. The activity introduces students to the process of conducting science investigations, the scientific method, and introduces teachers and students to the commonly used features of their data collection system. Start with this activity to become familiar with the data collection system.

Teacher and Student Guide Contents

All the teacher and student materials are included on the storage device accompanying the Teacher Guide.

Lab Activity Components

Each activity has two components: Teacher Information and Student Inquiry Worksheets.

Teacher Information is in the Teacher Guide. It contains information on selecting, planning, and implementing a lab, as well as the complete student version with answer keys. Teacher Information includes all sections of a lab activity, including objectives, procedural overview, time requirements, and materials and equipment at-a-glance.

Student Inquiry Worksheets begin with a driving question, providing students with a consistent scientific format that starts with formulating a question to be answered in the process of conducting a scientific investigation.

This table identifies the sections in each of these two activity components.

TEACHER INFORMATION	**STUDENT INQUIRY WORKSHEET**
Objectives	Driving Questions
Procedural Overview	
Time Requirement	
Materials and Equipment	Materials and Equipment
For teacher demonstrations	
For each student or group	For each student or group
Concepts Students Should Already Know	
Related Labs in This Guide	
Using Your Data Collection System	
Background	
Pre-Lab Discussion and Activity	
Preparation and Tips	
Safety	Safety
Driving Question	
Thinking about the Question	Thinking about the Question
Sequencing Challenge	Sequencing Challenge
Investigating the Question	Investigating the Question
Part 1 – Making predictions	Part 1 – Making predictions
Part 2 or more – procedure	Part 2 or more – procedure
Sample Data	
Answering the Question	Answering the Question
Analysis Questions	Analysis Questions
Multiple Choice Questions	Multiple Choice Questions
True/False Questions	True/False Questions
Key Term Challenge	Key Term Challenge
Further Investigations	

Electronic Materials

The storage device accompanying this manual contains the following:

- Complete Teacher Guide and Student Guide with Student Inquiry Worksheets in PDF format.
- The Scientific Inquiry activity for SPARK™, SPARKvue™, Xplorer GLX®, and DataStudio® and the Student Inquiry Worksheets for the laboratory activities are in an editable Microsoft™ Word format. PASCO provides editable files of the student lab activities so that teachers can customize activities to their needs.
- Tech Tips for the SPARK, SPARKvue, Xplorer GLX, DataStudio, and individual sensor technologies in PDF format.
- User guides for SPARKvue and GLX.
- DataStudio and PASCO Capstone® Help is available in the software application itself.

International Baccalaureate Organization (IBO*) Support

IBO Diploma Program

The International Baccalaureate Organization (IBO) uses a specific science curriculum model that includes both theory and practical investigative work. While this lab guide was not produced by the IBO and does not include references to the internal assessment rubrics, it does provide a wealth of information that can be adapted easily to the IB classroom.

By the end of the IB Diploma Program students are expected to have completed a specified number of practical investigative hours and are assessed using the specified internal assessment criteria. Students should be able to design a lab based on an original idea, carry out the procedure, draw conclusions, and evaluate their own results. These scientific processes require an understanding of laboratory techniques and equipment as well as a high level of thinking.

Using these Labs with the IBO Programs

The student versions of the labs are provided in Microsoft Word and are fully editable. Teachers can modify the labs easily to fit a problem-based format.

For IB students, pick one part of the internal assessments rubrics to go over with the students. For example, review the design of the experiment and have students explain what the independent, dependent, and controlled variables are in the experiment. Ask students to design a similar experiment, but change the independent variable.

Delete certain sections. As students become familiar with the skills and processes needed to design their own labs, start deleting certain sections of the labs and have students complete those parts on their own. For example, when teaching students to write their own procedures, have the students complete one lab as it is in the lab guide. In the next lab, keep the Sequencing Challenge, but have students write a more elaborate procedure. Finally, remove both the Sequencing Challenge and the Procedure sections and have students write the entire procedure.

Encourage students to make their own data tables. Leave the procedure, but remove the data tables and require the students to create them on their own. In another lab, leave the driving question and procedure, but remove the analysis questions and have students write their own analysis, conclusion, and evaluation.

Use only the driving question. As students' progress through their understanding of the structure of an experiment, provide them with just the driving question and let them do the rest. Some of the driving questions are too specific (they give the students the independent variable), so revise them appropriately.

Extended inquiry. After students complete an activity in the lab guide, use the extended inquiry suggestions to have the students design their own procedure, or the data collection and processing, or both.

About Correlations to Science Standards

The lab activities in this manual are correlated to a number of standards, including United States National Science Education Standards, the Next Generation Science Standards, and all State Science Standards. See http://pasco.com for the correlations.

Global Number Formats and Standard Units

Throughout this guide, the International System of Units (SI) or metric units is used unless specific measurements, such as air pressure, are conventionally expressed otherwise. In some instances, such as weather parameters, it may be necessary to alter the units used to adapt the material to conventions typically used and widely understood by the students.

Reference

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

Master Materials and Equipment List

Italicized entries indicate items not available from PASCO. The quantity indicated is per student or group. NOTE: Some activities also require protective gear for each student (for example, safety goggles, gloves, apron, or lab coat).

Teachers can conduct some lab activities with sensors other than those listed here. For assistance with substituting compatible sensors for a lab activity, contact PASCO Teacher Support (800-772-8700 inside the United States or http://www.pasco.com/support).

Act	Title	Materials and Equipment	Qty
Life Science			
1	**Acid Rain and Seed Germination** Use a pH sensor to determine the effect of acid rain on the germination of bean seeds.		
	Teacher Demonstration	*Distilled water* *Permanent marker* *Plastic cups, 250-mL* Pipet *Small pieces of chalk, ~5 cm* *White vinegar* *Nail, galvanized*	~2.5 L 1 4 1 4 90 mL 1
	Student or Group	Data Collection System PASPORT pH Sensor *Bean seeds* *Distilled water* *Permanent waterproof marker* *Simulated acid rain samples, 100 mL* *Plastic cups, 250 mL* *Resealable small plastic bags* *Stirring rod or plastic spoon* *Ruler* *Paper towels*	1 1 15 100 mL 1 2 3 3 1 1 6

Act	Title	Materials and Equipment	Qty
2	**Acid's Effect on Teeth** Use a pH sensor as a means of quantitatively describing the acidity of various beverages.		
	Teacher Demonstration	*Beaker, glass, 400-mL or Mason jar, pint* *Vinegar, white* *Raw eggs in their shells* *Chicken thigh bones, cleaned* *Plastic wrap to cover the beakers, ~6 in. x 6 in. (optional)* *Water, distilled*	4 800 mL 2 2 4 200 mL
	Student or Group	Data Collection System PASPORT pH Sensor *Beaker, 250-mL* *Beakers, 100-mL or paper cups* *Graduated cylinder, 50-mL* *Vinegar, white* *Orange juice* *Soda pop (3 different kinds)* *Water, distilled* *Labeling materials (such as marking pen, tape)* *Wash bottle with distilled water*	1 1 1 4 1 50 mL 50 mL 50 mL each 50 mL Several 100 mL
3	**Air Pressure and the Lungs** Use an absolute pressure sensor to measure the change in air pressure within a model "chest cavity" while causing the syringe "diaphragm" to change its volume.	Data Collection System PASPORT Absolute Pressure Sensor Quick-release connector Tubing *1-hole rubber stopper, #6 (2)* *Syringe, 60 mL* *Balloon, at least 12" diameter* *Tape* *Marker*	1 1 1 1 1 1 1 1 1

Act	Title	Materials and Equipment	Qty
4	**Introduction to Acids and Bases** Use a pH sensor to measure the pH of several different household chemicals		
	Teacher Demonstration	Data Collection System PASPORT pH Sensor *Head of red cabbage,* *Large pot* *Hot plate or burner* Buffer solution pH 4 Buffer solution pH 10 *Distilled water* *Beakers, 1000-mL, or clean glass quart jars* *Isopropyl alcohol (70%) (optional)* *Household chemical products, including white vinegar (enough for 50 mL each per lab group)*	1 1 1 1 1 25 mL 25 mL 1 gallon 4 100 mL 4 different samples
	Student or Group	Data Collection System PASPORT pH Sensor *Red cabbage indicator* Pipet *Beakers, 250-mL* *Distilled water in wash bottle* *Household chemical samples, 50 mL each*	1 1 100 mL 1 5 200 mL 4
5	**Muscle Fatigue** Use a force sensor to investigate and observe changes in the muscular movement of bones during a prolonged period of sustained exertion.	Data Collection System PASPORT Force Sensor with rubber bumper attached	1 1
6	**Photosynthesis** Use a light sensor and absolute pressure sensor to measure the change in light and pressure in an aquatic ecosystem as an *Elodea* or other aquatic plant undergoes photosynthesis.	Data Collection System PASPORT Light Sensor PASPORT Absolute Pressure Sensor with quick release connector and plastic tubing PASPORT Sensor Extension Cable *Beaker, 400 to 600 mL* *Clear or translucent funnel* *Clay, modeling (golf ball-sized piece)* *Baking soda* *Elodea (sometimes called Anacharis)* *Measuring spoons* *Water, distilled*	1 1 1 1 1 1 1 1/4 tsp. 3 to 4 sprigs 1 set 400 mL

Act	Title	Materials and Equipment	Qty
7	**Recovery Heart Rate** Use a heart rate sensor to determine students' resting heart rate, their heart rate with exercise, and their recovery heart rate.		
	Teacher Demonstration	*Clock or timer with seconds displayed*	1
	Student or Group	Data Collection System PASPORT Heart Rate Sensor, hand-grip *Comfortable foot attire and exercise clothing* *Clock or timer with seconds displayed* *Damp paper towel (2)*	1 1 1 2
8	**Seasonal Pond Exploration** Use a pH sensor and temperature sensor to measure temperature and pH over the course of a day in a vernal pond.		
	Teacher Demonstration	Mobile Data Collection System PASPORT pH Sensor PASPORT Temperature Sensor* Buffer solution pH 4 Buffer solution pH 10	1 1 1 25 mL 25 mL
	Student or Group	Mobile Data Collection System PASPORT pH Sensor PASPORT Temperature Sensor* *Hand lens*	1 1 1 1
9	**Sunlight and Photosynthesis in Aquatic Plants** Use a pH sensor to collect pH data to demonstrate the relationship between photosynthesis and light.	Data Collection System PASPORT pH Sensor *Plastic bags, 500-mL or 16-oz, sealable* *Graduated cylinder, 250-mL* *Aquatic snails* *Aquatic plants such as Elodea* *Fluorescent lamp* *Aluminum foil, 15 in. x 15 in.* *Stream or pond water* *Marking pen*	1 2 2 1 2 2 1 2 500 mL 1
10	**Thermoregulation of Body Temperature** Use a fast response temperature sensor to observe that different parts of the body are at different temperatures and these differences are related to their distance from the heart.		
	Teacher Demonstration	Data Collection System PASPORT Fast Response Temperature Sensor	1 1
	Student or Group	Data Collection System PASPORT Fast Response Temperature Sensor *Chair (for ankle temperature reading)*	1 1 1

* Either the PASPORT Fast Response Temperature Sensor or the PASPORT Stainless Steel Temperature Sensor can be used for this activity.

Act	Title	Materials and Equipment	Qty
11	**Transpiration** Use a weather sensor to measure the change in humidity and temperature of a small potted plant over a 24-hour period.		
	Teacher Demonstration	Data Collection System PASPORT Weather Sensor PASPORT Sensor Extension Cable *Gallon size self-sealing bag* *Small potted plant* *Aluminum foil, 12 in. x 18 in.* *Tape*	1 1 1 1 1 1 1 roll
	Student or Group	Data Collection System PASPORT Weather Sensor PASPORT Sensor Extension Cable *Gallon size self-sealing bag, 1 or 2 depending on plant size* *Small potted plant* *Aluminum foil, 12 in. x 18 in.* *Water, tap (for moistening plant soil)* *Tape*	1 1 1 1 or 2 1 1 ~100 mL 1 roll
12	**Venous Blood Flow** Use a heart rate sensor to measure students' heart rate while standing, lying flat, and lying flat with both legs raised.		
	Teacher Demonstration	Data Collection System PASPORT Heart Rate Sensor, hand grip PASPORT Sensor Extension Cable	1 1 1
	Student or Group	Data Collection System PASPORT Heart Rate Sensor, hand grip PASPORT Sensor Extension Cable *Long, sturdy table or athletic board* *Pillows or thick books* Meter stick	1 1 1 1 2 1
13	**Yeast Growth** Use a temperature sensor and absolute pressure sensor to measure the change in pressure inside a flask of fermenting yeast cells at two different temperatures.	Data Collection System PASPORT Absolute Pressure Sensor PASPORT Temperature Sensor* PASPORT Sensor Extension Cable *Beaker, 200 mL* *Erlenmeyer flask, 250 mL,* Plastic tubing with quick-release and barbed connectors Balance *Rubber stopper with one hole* *Yeast* *Sugar* *Tap water* *Apron* *Glycerin*	1 1 1 1 1 2 1 1 per class 1 1 tsp 2 tsp ~200 mL 1 1 drop

* Either the PASPORT Fast Response Temperature Sensor or the PASPORT Stainless Steel Temperature Sensor can be used for this activity.

Calibration materials

If you want to calibrate various sensors, you will need the following:

pH Sensor

Item	Quantity	Where Used
Buffer solution, pH 4 Buffer solution, pH 10 Beaker, small Wash bottle with deionized or distilled water	25 mL 25 mL 3 1	13

Activity by PASCO Sensors

This list shows the sensors and other PASCO equipment used in the lab activities.

Items Available from PASCO	Qty	Activity Where Used
Data Collection System	1	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13
Mobile Data Collection System	1	8
PASPORT Absolute Pressure Sensor	1	3, 6, 13
PASPORT Fast Response Temperature Sensor	1	10
PASPORT Force Sensor	1	5
PASPORT Heart Rate Sensor	1	7, 12
PASPORT Light Sensor	1	6
PASPORT pH Sensor	1	1, 2, 4, 8, 9
PASPORT Temperature Sensor*	1	8, 9
PASPORT Weather Sensor	1	11
PASPORT Sensor Extension Cable	1	6, 11, 12, 13

* Either the PASPORT Fast Response Temperature Sensor or the PASPORT Stainless Steel Temperature Sensor can be used for this activity.

Normal Laboratory Safety Procedures

Overview

PASCO is concerned with your safety and because of that, we are providing a few guidelines and precautions to use when exploring the labs in our Middle School Science guide. This is a list of general guidelines only; it is by no means all-inclusive or exhaustive. Of course, common sense and standard laboratory safety practices should be followed.

Regarding chemical safety, some of the substances and chemicals referred to in this manual are regulated under various safety laws (local, state, national, or international). Always read and comply with the safety information available for each substance or chemical to determine its proper storage, use and disposal.

Since handling and disposal procedures vary, our safety precautions and disposal comments are generic. Depending on your lab, instruct students on proper disposal methods. Each of the lab activities also has a Safety section for procedures necessary for that activity.

General Lab Safety Procedures and Precautions

- Follow all standard laboratory procedures
- Absolutely no food, drink, or chewing gum is allowed in the lab.
- Wear protective equipment (for example, safety glasses, gloves, apron) when appropriate.
- Do not touch your face with gloved hands. If you need to sneeze or scratch, take off your gloves, wash your hands, and then take care of the situation.
- Wash your hands after handling samples, glassware, and equipment.
- Know the safety features of your lab such as eye-wash stations, first-aid equipment or emergency phone use.
- Insure that loose hair and clothing are secure when in the lab.
- Handle glassware with care.
- Insure you have adequate clear space around your lab equipment before starting an activity.
- Do not wear open-toe shoes in the laboratory.
- Allow heated objects and liquids to return to room temperature before moving.
- Never run or joke around in the laboratory.
- Do not perform unauthorized experiments.
- Students should work in teams of 2 or more in case of trouble and help is needed.
- Keep the work area neat and free from any unnecessary objects.

Water Related Safety Precautions and Procedures

- Keep water away from electrical outlets.
- Keep water away from all electronic equipment.

Chemical Related Safety Precautions and Procedures

- Consult the manufacturer's Material Safety Data Sheets (MSDS) for instructions on handling, storage, and disposing of chemicals. Your teacher should provide the MSDS documents of the chemicals you are using. Keep these instructions available in case of accidents.
- Many chemicals are hazardous to the environment and should not be disposed of down the drain. Always follow your teacher's instructions for disposing of chemicals.
- Sodium hydroxide, hydrochloric acid, and acetic acid are corrosive irritants. Avoid contact with your eyes and wash your hands after handling. In case of skin exposure, wash it off with plenty of water.
- Always add acids and bases to water, not the other way around, as the solutions may boil vigorously.
- Diluting acids and bases creates heat; be extra careful when handling freshly prepared solutions and glassware, as they may be very hot.
- Handle concentrated acids and bases in a fume hood; the fumes are caustic and toxic.
- Wear eye protection, lab apron, and protective gloves when handling acids. Splash-proof goggles are recommended. Either latex or nitrile gloves are suitable. Use nitrile gloves if you have latex allergy.
- Read labels on all chemicals and pay particular attention to hazard icons and safety warnings.
- When handling any bacterial species, follow aseptic techniques.
- Wash your hands before and after a laboratory session.
- If any solution comes in contact with skin or eyes, rinse immediately with a copious amount of running water for a minimum of 15 minutes.
- Follow the teacher's instructions for disposing of chemicals, handling substances.
- Check the label to verify it is the correct substance before using it.
- Never point the open end of a test tube containing a substance at yourself or others.
- Use a wafting motion when smelling chemicals.
- Do not return unused chemicals to their original container.
- Keep flammable chemicals from open flame.

Dangerous or Harmful Substance Related Lab Safety Precautions

- When handling any bacterial species, follow aseptic techniques.
- Always flame inoculating loops and spreaders before setting them down on the lab bench.
- Pipetting suspension cultures can create an aerosol. Keep your nose and mouth away from the tip of the pipet to avoid inhaling any aerosol
- Use caution when working with acids.
- Use appropriate caution with the matches, burning splint and foods, and other hot materials.
- Be careful using a knife or scalpel.

Outdoor Safety Precautions

- Practice appropriate caution around water bodies, steep terrain, and harmful plants or animals.
- Treat plants, animals and the environment with respect.
- Inspect all equipment for damage (cracks, defects, etc.).
- Require students to use a buddy system and specify the procedure to use in case of trouble.

Other Safety Precautions

- If water is boiled for an experiment involving heat, make sure it is never left unattended. Remember, too, that the hot plate will stay hot well after it is unplugged or turned off.
- Any injury must be reported immediately to the instructor, an accident report has to be completed by the student or a witness.
- If you are suffering from any allergy, illness, or are taking any medication, you must inform the instructor. This information could be very important in an emergency.
- Try to avoid wearing contact lenses. If a solution spills in your eye, the presence of a contact lens makes first aid difficult and can result in permanent damage. Also, organic solvents tend to dissolve in soft contact lenses, causing eye irritation. If contact lenses must be worn, use a style of goggles called “eye cup.”

Additional Resources

- Flinn Scientific
- The Laboratory Safety Institute (LSI)
- National Science Education Leadership Association (NSELA)/Safe Science Series

Rubric

Use this rubric for scoring students' accomplishments and performance in the different sections of this laboratory activity.

Category	4 points	3 points	2 points	1 point
Pre-Lab Preparation	Excellent participation in pre-lab discussion. All vocabulary terms, and equations, if applicable, are used correctly.	Good participation in pre-lab discussion. Most vocabulary terms, and equations, if applicable, are used correctly.	Good participation in pre-lab discussion. Some vocabulary terms, and equations, if applicable, are used correctly.	Limited participation in pre-lab discussion. Few vocabulary terms, and equations, if applicable, are used correctly.
Activity Set-up	All instructions are read, by all lab group members, prior to beginning set-up. Set-up reflects lab group needs and safety rules.	All instructions are read, by some lab group members, prior to beginning set-up. Set-up reflects lab group needs and safety rules.	Some instructions are read, by some lab group members, prior to beginning set-up. Set-up reflects lab group needs and safety rules.	Activity instructions can't be verified by any lab group members, prior to beginning set-up. Set-up does not reflect lab group needs and/or safety rules.
Data Collection	Data is collected for the specified amount of time in a reliable manner.	Data is collected for almost the specified amount of time, in a reliable manner.	Data is collected in a manner lacking reliability, safety, or specified amount of time.	Data is collected in such a way that it cannot be analyzed.
Lab Notebook or Record	Lab notebook includes a complete record of the activity, including properly drawn and labeled diagrams, data, observations, modifications, reasons for modifications, and some reflection about the strategies used and the results.	Lab notebook includes a nearly complete record of the activity, including properly drawn and labeled diagrams, data, observations, modifications, reasons for modifications, and some reflection about the strategies used and the results.	Lab notebook includes all but two records of the activity: properly drawn and labeled diagram(s), data, observations, modifications, reasons for modifications, and some reflection about the strategies used and the results.	Lab notebook lacks more than two records of the activity: properly drawn and labeled diagram(s), data, observations, modifications, reasons for modifications, and some reflection about the strategies used and the results.
Safety	Great care taken during activity to ensure that all lab members follow all safety rules.	One safety violation during the activity.	Two safety violations during the activity.	More than two safety violations during the activity.
Activity Clean-up	All members of lab group collaborate to complete all clean-up instructions in time allotted.	All clean-up is accomplished in time allotted, by majority of lab group members.	All clean-up is accomplished in time allotted, by minority of lab group members, OR all lab group members collaborate but exceed time limit.	Clean-up is not accomplished.

Lab Activities

1. Acid Rain and Seed Germination

How You Bean?

Objectives

Using the pH sensor and simulated rainwater from different sources, the students determine the effect of acid rain on the germination of bean seeds.

In this activity students will:

- Become familiar with the way pH levels can vary within rainfalls or surface water
- Measure the pH of different rain water samples
- Gain skills and confidence in using a scientific measurement tool, the pH sensor, as well as the graphing capability of a computer to represent and analyze data

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Making predictions, and Part 2 – Testing the pH of the water	50 minutes
■ Lab activities, Part 3 – Observing acid rain's effect on seed germination	20 minutes per day for a minimum of 3 days
■ Analysis	50 minutes

Activity at a Glance

Students gain experience conducting the following procedures:

- Setting up the equipment and work area to measure the pH of several different "rainwater" samples
- Measuring the growth of bean seeds over a period of 4 to 7 days to see the response to different levels of acid in their water
- Using math skills to average the lengths of roots

Materials and Equipment

For teacher demonstration:

- ☐ Distilled water, ~2.5L
- ☐ Permanent marker
- ☐ Plastic cups, 250-mL (4)
- ☐ Pipet
- ☐ Small pieces of chalk, ~5 cm (4)
- ☐ White vinegar, 90 mL
- ☐ Nail, galvanized

For each student or group:

- ☐ Data collection system
- ☐ pH sensor
- ☐ Bean seeds (15)
- ☐ Distilled water, 100 mL
- ☐ Permanent waterproof marker
- ☐ Simulated acid rain samples (2), 100 mL [1]
- ☐ Plastic cups, 250 mL (3)
- ☐ Resealable small plastic bags (3)
- ☐ Stirring rod or plastic spoon
- ☐ Ruler
- ☐ Paper towels

[1] To formulate simulated acid rain samples from white vinegar and distilled water, refer to the Preparation and Tips section.

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- The processes of photosynthesis and respiration
- Evaporation
- Plant structures and their functions
- Ecosystem stability and fragility

Related Labs in This Guide

Labs conceptually related to this one include:

- Acid Rain and Weathering
- Introduction to Acids and Bases
- Soil Characteristics

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system. Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)

- Connecting a sensor to your data collection system �(2.1)
- Calibrating the pH sensor �(3.6)
- Monitoring live data without recording �(6.1)
- Displaying data in a graph �(7.1.1)
- Adjusting the scale of a graph �(7.1.2)
- Saving your experiment �(11.1)

Background

Protecting our waterways requires constant monitoring of industrial effluent (a discharge of liquid waste, as from a factory, a nuclear plant, or from sewage). Metal finishing and metal plating plants tend to produce acidic wastewater, as does mining. Chemical plants often have very alkaline wastewater.

To guide the proper neutralization of such industrial waste and to monitor the final effluent quality, pH measurements are taken. Occasionally, an acidic stream can be combined with an alkaline stream to produce a final stream that is close to neutral. Measuring the pH helps assure the proper management of this cost saving technique.

The pH of a river or lake is important in maintaining a proper ecological balance. The pH of the water directly affects physiological functions and nutrient utilization by plant and animal life. Extremes in pH can reduce a lake to a lifeless, smelly bog.

Rainfall is normally slightly acidic, because it is exposed to the carbon dioxide in the atmosphere. The carbon dioxide dissolves in the rainwater and forms carbonic acid. Rainwater, therefore, might have a pH around 6. However, rainfall in some parts of the world has a pH of 5 or 4. The problem of acid rain is far reaching.

The sources of pollution are often located far from the affected area. For example, many factories burn fossil fuel with a high sulfur content. They produce exhaust that contains sulfur dioxide gas. This gas combines with water in the clouds to produce acid rain. This rain falls on areas downwind of the factory.

Factories in the Great Lakes region of the United States produce exhaust that causes acid rain to fall in the New England area. This acid rain is killing the lakes in this northeastern region of the United States.

Legislated efforts to reduce air pollution generate a great irony involving acid rain. Regulations to protect fouled neighborhoods near factories require manufacturers to build tall smokestacks. As a result, all areas downwind of the factories now are experiencing acid rain.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Share with the students that the term acid rain is used to describe overly acidic precipitation of any kind. This includes frost, dew, mist, fog, rain, sleet, and snow.

Direct students to “Thinking About the Question.”

After a few minutes, ask the groups to share some of their thoughts about the effect of varying strengths of acid on chalk with the class (the notes for this are located in the Preparation and Tips section, below). Share with the students your investigation with chalk and vinegar. Allow the students to look carefully at the results. Use the pH sensor to test the strength of each vinegar solution. Have the students document their observations for each level of pH. Ask the students to discuss within groups how acid rain could affect their environment. After a few minutes, ask the groups to share some of their ideas.

Direct students to “Investigating the Question.”

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- Three days before the discussion in class, set up four different reactions of chalk in white vinegar as follows:

1. Score four small pieces of chalk (each approximately 5 cm in length) with a nail. (Cutting lines in the chalk increases the surface area that can react with the vinegar.)
2. Label four small, plastic cups “A”, “B”, “C”, and “D” then fill each cup as follows:

   A – 50 mL distilled water(control)

   B – 20 mL vinegar and 30 mL distilled water

   C – 30 mL vinegar and 20 mL distilled water

   D – 40 mL vinegar and 10 mL distilled water

4. Allow the cups of chalk, water, and vinegar solution to sit undisturbed for three days.

- Prepare simulated "acid rain" for the students.

1. Add 5 mL of white vinegar to 1 L distilled water. Stir to mix. Use the pH sensor to check the pH of this solution. It should be about pH 4.
2. If the "acid rain" solution is above pH 4, use a pipet to add vinegar one milliliter at a time, stirring after each addition and checking the pH. Continue in this manner until the pH reaches a value of 4.
3. Label this container "Acid Rain Water Sample A."
4. Prepare a second 1 L sample of "acid rain" us the same method as above, but begin with 3 mL of white vinegar. This solution should be about pH 5.
5. Label this container "Acid Rain Water Sample B."

- Purchase seeds intended for growing. Bean seeds bought at a grocery store, for instance lima beans, may not sprout. Depending on your area, seeds for this experiment may need to be purchased during the spring or fall.

- Remind students to handle the roots as little as possible. Extensive handling will kill the roots. In addition, students should wash their hands before handling the seeds to minimize the introduction of contamination. Samples that become too contaminated will tend to mold quickly.

Safety

Add this important safety precaution to your normal laboratory procedures:

- Wear safety glasses and lab coats or aprons.

Driving Question

How does acid in rain affect the growth of seeds?

Thinking about the Question

Chalk is composed of calcium carbonate. Chalk is similar to a rock called limestone. Limestone is used in the construction of buildings, statues and monuments. Acid rain affects some stone and metal buildings and statues the same way that vinegar affects chalk.

How do you think that varying strengths of acid will affect pieces of chalk?

> Answers will vary. Students may say that the more acidic the solution, or the stronger the acid, the more damage the chalk will incur. Chalk that has been exposed to the strongest acid will show greater damage than chalk that has been exposed to weaker acid or distilled water without vinegar.

When factories burn coal or oil, many gases are given off, including sulfur dioxide. In the atmosphere, sulfur dioxide can react with water vapor to form sulfuric acid. Car exhaust contains nitrogen oxides, which can react in the atmosphere to form nitric acid. The acids are carried back to Earth with precipitation and they can even fall to the ground on dry days as dust-like particles. Acid rain can kill plants and fish, damage buildings and roads, and contaminate public water supplies.

In this activity, you will investigate the effect of simulated "acid rain" on the germination of seeds.

Sequencing Challenge

Note: This is an optional ancillary activity that may be omitted.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

3	2	4	5	1
Test and record the pH of each of the water samples.	Obtain and label samples of acid rain water and distilled water.	Moisten a paper towel with water from the sample; arrange 5 bean seeds in the towel so they will germinate.	Measure and average the length of the growing roots of the bean seeds over several days' time.	Make sure that each member of your lab group is aware of the safety rules and procedures for this lab.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

1. ☐ Your teacher has prepared some samples that simulate acid rain water. How do you think the pH of these samples will differ from the pH of distilled water? Record your prediction about the pH of the samples.

   We predict that the distilled water will have a pH of 7, and the pH of the acid rain samples will be lower than 7, maybe as low as a pH of 4.

2. ☐ Predict how watering bean seeds with acid rain will affect the growth these seeds.

   We predict that the more acidic the rain water is, the less the seeds will grow. Some seeds might not even grow at all, if their water is too acidic. Water that is just slightly acidic might allow the seeds to grow almost as well as distilled water would.

Part 2 – Testing the pH of the water

3. ☐ Collect the prepared acid rain water samples and distilled water in small plastic cups. Identify each sample of water according to its origin as follows: Label the cups "A", "B", and "C". Fill cups A, and B with 100 mL of each acid rain sample; fill cup C with 100 mL of distilled water.

4. ☐ Start a new experiment on the data collection system. �(1.2)

5. ☐ Connect a pH sensor to the data collection system using a sensor extension cable. �(2.1)

6. ☐ Display pH in a digits display. �(7.3.1)

7. ☐ Rinse the pH sensor with distilled water.

8. ☐ Why is the sensor rinsed with distilled water before testing each sample?

   Distilled water is used to keep the sensor from having cross contamination from the other samples. Distilled water does not contain any chemicals that might alter the pH sensor. Regular tap water would.

9. ☐ Monitor live data without recording. �(6.1)

10. ☐ Place the sensor into the first cup, and gently stir the solution with the sensor during data collection.

11. ☐ Wait until the pH reading stabilizes (up to 60 seconds).

12. ☐ Record the pH in Table 1 in the Answering the Question section below.

13. ☐ Remove the pH sensor from the cup.

14. ☐ Rinse the probe with distilled water, monitor and record a stabilized pH for the other two water samples, as you did for the first sample.

15. ☐ Stop data monitoring. �(6.1)

Part 3 – Observing acid rain's effect on seed germination

16. ☐ Use a waterproof marker to label where seeds one through five will go on a paper towel.

   Note: This will help with measuring the length of the roots later.

17. ☐ Slightly wet this paper towel with distilled water. Place 5 seeds near the numbers and fold the towel over the seeds several times so that it will fit into the small plastic bag.

18. ☐ Why should the towel just be damp and not sopping wet?

If the towel is too wet, it might drown the seeds, or cause them to mildew instead of germinate. The seeds need enough water to germinate, but not too much.

19. ☐ Place the towel inside a re-sealable bag and label it with a permanent marker as "Control." The bag should be left open to the air.

20. ☐ On another paper towel, use a permanent marker to label where seeds 1 to 5 will go. Slightly wet this paper towel with water from the acid rain water sample from cup A. Place 5 seeds near the numbers and fold the towel over the seeds several times so that it will fit into the small plastic bag. Make sure the towel is just damp.

21. ☐ Place the towel inside a re-sealable bag and label it with a permanent marker as "Acid Rain Sample A." The bag should be left open to the air.

22. ☐ Repeat this procedure for acid rain water sample B.

23. ☐ Place all of the bags in an indoor location where they will get sunlight through a window for at least 2 hours each day.

24. ☐ Measure the root length of each bean in each bag after 3 or 4 days. Average the root length for each bag. Record this data in Table 2 in the Answering the Question section below.

25. ☐ Measure the root length of each bean in each bag each day for the next 2 to 3 days.

Answering the Question

Analysis

Table 1: pH levels of distilled water and acid rain water samples

Sample	pH
Control	7.1
Acid Rain Water Sample A	4.2
Acid Rain Water Sample B	5.3

Table 2: Bean seed root length

Sample	Average Root Length Day 1 (mm)	Average Root Length, Day 2 (mm)	Average Root Length, Day 3 (mm)	Average Root Length, Day 4 (mm)
Control	8 mm	23 mm	32 mm	46 mm
Acid Rain Sample A	2 mm	4 mm	5 mm	5 mm
Acid Rain Sample B	4 mm	7mm	19 mm	22 mm

1. Look at the data in Table 1 above. What was the range of pH in your water samples (recall that the range of a set of data is the difference between the highest and lowest value)?

   Answers will vary based on samples.

2. Analyze your data from Table 2 above. How did the growth of the roots vary between the samples?

   Answers will vary based on samples. However, the roots in the lower pH should grow less than the roots in the higher pH.

4. How did your predictions compare to the actual growth of the roots?

   Answers will vary. One student group answered as follows: Our results after 4 days showed that the seeds germinated in distilled water grew the most, on average, of all the seeds we used. The seeds watered with the most acidic water, from Sample A, grew the least, which we predicted. The seeds watered with Sample B grew on average at a rate in between the control and the most acidic, which we also predicted.

5. Based on the evidence from your investigation, does acidic rain water promote the healthy growth and thriving of young plants? Explain your thinking.

   Answers will vary. One student group answered as follows: We do not think that acid rain helps young plants grow and stay healthy. Our bean seeds that we watered with the most acidic water sample grew the worst of our three samples. By the end of our experiment, they looked almost dead, and their roots were on average 5 mm long compared to 46 mm long roots, on average, for the seeds watered with distilled water.

6. Why is it considered good experimental design to average the growth of 5 seeds for one sample of water, rather than germinating one seed per sample of water?

It is good experimental design to have multiple seeds and average their growth in case one or more seeds does not germinate or has some other problem. When five are averaged, any unusual results have less of an impact on our experiment. This is similar to conducting multiple trials.

7. Imagine that you are a farmer planting a crop of beans to grow, harvest, and sell. As a farmer, you contribute to the nation's food supply and earn a living. Two days after you plant the crop, it rains, watering the new seeds in the process. You test the rain water and are alarmed at how low its pH is — your new crop has just been soaked with acid rain! Discuss some of the implications of this event, and write your thoughts in the space below.

Answers will vary. One student group answered as follows: If our entire crop of seeds had been watered with acid rain, many or most of the seeds would germinate slowly or maybe not at all. At best we might be able to harvest a poor crop, and at worst we might have no crop to harvest at all. Without a good crop, we could not get much money to live on, and we might not be able to afford the things we needed to buy. If all the bean crops in our area were affected by the acid rain, there would be fewer beans for everyone, and there would be a shortage that might also affect the prices by raising them.

Further Investigations

Research to find out where in the world where acid rain is a problem. Is this primarily an issue in the United States, or do other regions in the world have to contend with this problem?

Prepare a presentation for your class that illustrates the effects of acid rain on forests.

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

2. Acid's Effect on Teeth

Why do We Brush Our Teeth?

Objectives

Students use the pH scale to quantitatively describe how acidic a substance is and they connect the acidity of common beverages to the need for brushing one's teeth.

Procedural Overview

Students gain experience conducting the following procedures:

- Setting up the equipment and work area to measure the pH of several different liquids
- Measuring the pH of vinegar, orange juice, and a variety of soda pop beverages.

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Making predictions	50 minutes
■ Lab activity, Part 2 – Distilled Water, vinegar, and pH	25 minutes
■ Lab activity, Part 3 – Juice, soda pop, and pH	25 minutes
■ Analysis	50 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Beaker (4), glass, 400-mL or Mason jar, pint
- ☐ Vinegar, white, 800 mL
- ☐ Raw eggs in their shells (2)
- ☐ Chicken thigh bones, cleaned (2)
- ☐ Plastic wrap to cover the beakers (optional)
- ☐ Water, distilled, 200 mL

For each student or group:

- ☐ Data collection system
- ☐ pH sensor[1]
- ☐ Beaker, 250-mL
- ☐ Beakers (4), 100-mL or paper cups
- ☐ Graduated cylinder, 50-mL
- ☐ Vinegar, white, 50 mL
- ☐ Orange juice, 50 mL
- ☐ Soda pop, 50 mL (3 different kinds)
- ☐ Water, distilled, 50 mL
- ☐ Labeling materials (such as marking pen, tape)
- ☐ Wash bottle with distilled water, 100 mL

[1]To calibrate the pH sensor, use 10 mL each of the standard buffers, pH 4 and pH 10.

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- Elements and compounds
- The teeth and skeletal system, including calcium as a key component
- The pH scale from 0 to 14; neutral pH, acidic pH, alkaline pH

Related Labs in This Guide

Prerequisites:

- pH Factor

Labs conceptually related to this one include:

- Acid Rain and Seed Germination

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system � (1.2)
- Connecting a sensor to your data collection system � (2.1)
- Calibrating a pH sensor �(3.6)
- Changing the number of digits with which a variable is displayed � (5.4)
- Monitoring live data � (6.1)

Background

When certain types of compounds are added to water, they dissolve into their components, resulting in more hydrogen ions (H^+) than in pure water. For example, hydrogen chloride (HCl) dissolves in water and forms H^+ and Cl^- ions. When there are more H^+ ions in the water than in pure water, the water is called acidic. Since HCl causes water to become acidic, it is called an acid. Some acids are stronger than others. This means that some acids will break into ions more easily than others.

When some compounds are added to water and they dissolve into their components, the result is more hydroxide ions (OH^-) than in pure water. For example, sodium hydroxide (NaOH) ionizes into Na^+ and OH^- in solution. When there are more OH^- ions in a solution than there are in pure water, the solution is called basic. Since NaOH added to water causes the solution to become more basic, it is called a base. Some bases are stronger than others. This means that some bases will break into ions more readily than others.

Some compounds, such as ammonia (NH_3), do not contain OH^- ions, yet they are still able to make bases. NH_3, when dissolved in water, takes H^+ ions from water, making ammonium ions (NH_4^+). This leaves more OH^- ions than are in pure water, which makes the solution basic.

Some compounds, such as carbon dioxide and sulfur dioxide, do not contain hydrogen but still make acids. Carbon dioxide (CO_2) is a gas that reacts with water. In water, CO_2 becomes carbonic acid (H_2CO_3), which ionizes to H^+ and $(HCO_3)^-$. The result is the production of H^+ ions. This is why pure water exposed to air will eventually reach a pH of about 5.6. Sulfur dioxide (SO_2) reacts with water to form sulfurous acid (H_2SO_3). This also ionizes slightly, producing H^+ ions and $(HSO_3)^-$ ions. This is a weak acid because low concentrations of H^+ ions are made.

The actual concentration of H^+ ions (the number of H^+ ions in a certain volume of solution) in solutions, even in acid solutions, is usually very small. To avoid working with such small numbers, the pH scale was developed. The numbers of the pH scale are the negative logarithms of the hydrogen ion (H^+) concentration, which ends up with a pH scale for water from 0 to 14.

A solution with a pH of 0 has the most H^+ ions, while a solution with a pH of 14 has the fewest H^+ ions and the most OH^- ions. A solution with a pH of 7 is neutral. A solution with a pH value less than 7 is acidic and one with a pH value greater than 7 is basic.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

On the day of the activity, show students the "before and after" of the raw eggs and chicken bones you prepared (see the "Preparation and Tips" section). They should observe that the bone and shell have been dissolved by the vinegar. They should also observe that the egg is left without protection and the bone is now "rubbery" rather than strong.

Discuss with students the idea of a "control." The egg and chicken bone in water at a neutral pH are the controls because they serve to compare the effect of the acid on the egg and chicken bone and eliminate the possibility that the changes in the egg and chicken bone occurred because they were in a liquid.

Ask students how the egg shell and chicken bone are similar to teeth. If necessary, suggest that all contain calcium as part of their chemical composition.

Discuss with students that the calcium compound in the egg shell and bone reacts with the acid in vinegar. In the reaction, the calcium compound is dissolved. Direct students to "Thinking about the Question."

Ask the students to share with the class the various nutritious foods that contain acids. If the students have difficulty naming such foods, suggest citrus fruits. You may also suggest such foods as barbecue sauce, tomato sauces, or other foods containing vinegar. Ask the students to explain how to find the ingredients contained in packaged or prepared foods.

Direct students to "Investigating the Question."

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

1. At least two days prior to the activity, prepare a demonstration.

   a. In each of two large glass beakers or jars, place a raw egg (with the shell intact) and a cleaned chicken thigh bone. Add 200 mL of distilled water to each beaker. This egg and bone will serve as the controls.

   b. In each of two large glass beakers or jars, place the second raw egg, with the shell intact, and the second cleaned chicken thigh bone.

   c. Fill each of the second pair of beakers or jars with 200 mL of vinegar so that both objects are floating or immersed.

   Note: Distilled white vinegar works best.

   d. Place this demonstration in an area where students can observe it.

   e. Cover the beakers with clear plastic wrap if the smell of the vinegar is a problem.

   f. Carefully reposition the chicken bone and the egg twice a day so the vinegar is able to dissolve all of the egg shell, as well as remain in contact with all of the chicken bone.

2. Calibrate the pH sensors before students begin this activity. �(3.6) If you have previously shown students how to do this, consider allowing them time to calibrate the sensors.

3. Provide students with paper towels in case of spills or overflows.

4. Provide a variety of soda types. For example, sodas such as 7Up® and Sprite® are not as acidic as Pepsi® and Coke®.

Safety

Add these important safety precautions to your normal laboratory procedures:

- Wear safety glasses and lab coats or aprons.
- Consider the juice and soda as chemicals; they are not for drinking.

Driving Question

Why do we need to brush our teeth after we eat and drink?

Thinking about the Question

As you probably know, your teeth are made of the same material as your bones, which include such minerals as calcium and phosphorus. You may even have heard people claim that calcium helps build strong bones and teeth, and therefore a healthy diet should include calcium-rich foods. This is especially true for growing children.

Nature uses calcium to build strong or protective structures, including bones, teeth, and egg shells. Despite its strength, calcium is a substance that reacts easily with many types of acids.

Many of the foods you eat, such as oranges, green apples, pickles, and cranberries, taste sour, due to their acid content. Many of the beverages you drink, such as orange juice, lemonade, and soda pop, contain natural or added acids.

Some of the foods that are considered the most nutritious and healthful are those that contain vitamin C. Vitamin C is also known as ascorbic acid. In fact, ascorbic acid is sometimes added to foods that do not naturally contain it, such as breakfast cereal. Foods that have had this acid added often state on their labels, "Fortified with Vitamin C."

In this activity, you measure the acid present in various liquids by using a pH sensor and you use the pH scale to compare the results.

Discuss with your lab group members which foods you commonly eat that contain vitamin C.

> Student may say orange juice and other citrus fruits and fruit juices. They may not distinguish that some foods have high vitamin C content because it has been added. Students are less likely to mention foods such as red pepper or broccoli, which have more vitamin C than an orange.

How can you tell from the package if a food contains a particular ingredient, such as sugar or vinegar?

> Ingredients are listed on the food packaging. The order of the list is based on the amount of each ingredient there is in the food, by weight. The ingredient present in the greatest amount is listed first.

What are some of the results of not brushing one's teeth on a regular basis? Can permanent damage be caused to teeth if they are not regularly brushed?

> Answers may vary. One students group answered as follows: Not brushing teeth regularly can cause cavities, loss of teeth, gum disease, and bad breath. Permanent damage includes tooth decay and cavities.

Sequencing Challenge

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

4	3	1	2	5
Measure and record the pH of the three soda samples and the orange juice.	Arrange the orange juice and soda samples for measuring the pH.	Make certain that each member of your lab group is familiar with the safety rules and procedures for this activity.	Set up the data collection system and measure and record the pH of distilled water and vinegar.	Compare the acidity of all the samples.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

1. ☐ Using the terms such as "neutral," "acidic," "more acidic," and "most acidic," predict how your samples of beverages will compare to each other.

   Answers will vary. One student group answered as follows: Juice is very acidic and soda is not. Another student group answered: Orange juice is acidic, but we predict that sodas are more acidic. (Both orange juice and soda pop tend to be very acidic, typically in the 2.5 to 4.0 range.)

2. ☐ Put your predictions about the sample beverages in order from least acidic to most acidic.

   Answers will vary. One students group answered as follows: The pH of sodas will vary but we think orange juice will be less acidic than soda.

Part 2 – Distilled water, vinegar, and pH

3. ☐ Using a graduated cylinder, measure 50 mL of distilled water into a 100-mL beaker and measure 50 mL of vinegar into another 100-mL beaker.

4. ☐ Start a new experiment on the data collection system. �(1.2)

5. ☐ Connect a pH sensor to the data collection system. �(2.1)

6. ☐ Change the number of digits displayed to show one decimal place (tenths). �(5.4)

7. ☐ Remove the storage bottle from the pH sensor tip and set the bottle aside.

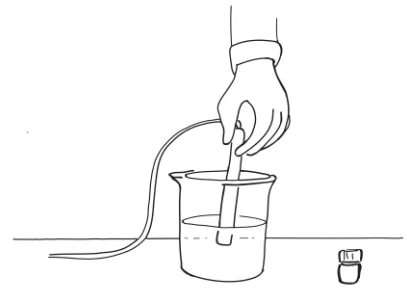
8. ☐ Rinse the tip of the pH sensor with distilled water over the empty beaker.

   Note: Use the 250-mL beaker to collect waste water.

9. ☐ Why is the sensor tip rinsed with distilled water before testing each sample? How might your results be affected if you did not rinse the sensor between trials?

   Distilled water is used to keep the probe from being contaminated by another sample, which could result in an incorrect pH reading. Distilled water does not contain any chemicals that might alter the pH sensor reading. (Regular tap water would.)

10. ☐ Monitor live data without recording. �(6.1)



11. ☐ For each sample, measure the pH as follows:

    a. Place the pH sensor into the beaker containing the sample.

    b. When the pH reading has stabilized, record the result in Table 1.

    c. Rinse the tip of the pH sensor with distilled water.

12. ☐ Put the pH sensor tip back into the storage bottle.

13. ☐ Was the pH of the vinegar higher or lower than the pH of the distilled water?

The pH for vinegar was much lower than the pH for the distilled water.

Part 3 – Juice, soda pop, and pH

14. ☐ Empty the beakers and rinse them with distilled water.

15. ☐ Obtain two more 100-mL beakers so you have a total of 4.

16. ☐ Determine a way to label the four beakers so you can identify the four solutions you will be measuring.

17. ☐ How did you label the beakers so you could identify their contents?

Answers will vary. One student group labeled the beakers with the names of the beverages. Another group labeled them "1" to "4" and created a reference table to identify them.

18. ☐ Record the names of the soda corresponding to the order they will be measured in Table 1.

19. ☐ Rinse the graduated cylinder with distilled water.

20. ☐ Use the graduated cylinder to measure 50 mL of each solution and pour them into the appropriately labeled beaker.

    Note: Rinse the graduated cylinder thoroughly before measuring the next solution. Give it a final rinse with distilled water if tap water was used.

21. ☐ Why would you rinse the graduated cylinder with distilled water if it was first rinsed with tap water?

Tap water may not be at a neutral pH. Rinsing with distilled water makes sure the pH of the sample is not altered.

22. ☐ Monitor live data without recording. �(6.1)

23. ☐ Remove the storage bottle from the pH sensor tip and set the bottle aside.

24. ☐ Starting with the orange juice, measure the pH of each sample as follows:

    a. Place the pH sensor into the beaker containing the sample.

    b. When the pH reading stabilizes (after about 30 seconds), record the result in Table 1.

    c. Rinse the tip of the pH sensor with distilled water.

25. ☐ Put the pH sensor tip back in the storage bottle.

26. ☐ Clean up according to your teacher's instructions.

Answering the Question

Analysis

Table 1: pH values of water, vinegar, orange juice and soda

Sample	pH	Rank (most acidic is 1)	Degree of Acidity (neutral, acidic, more acidic, most acidic)
Distilled water	7.1	6	Neutral
White vinegar	2.6	2	Most acidic
Orange juice	3.5	5	Acidic
Soda 1:	2.5	1	Most acidic
Soda 2:	2.9	4	More acidic
Soda 3:	2.8	3	More acidic

1. Fill in the "Rank" column in Table 1 to order the liquids you measured from most acidic (#1) to least acidic (#6).

Note: On the pH scale, "1" represents the most acidic, and "14" represents the most alkaline (also known as basic). A pH of 7 is neither acidic nor basic.

2. Which of the liquids you measured, if any, have a pH close to 7?

   The distilled water was the only liquid close to 7. It was 7.1.

3. Compare your predictions with the data you collected. Using the same descriptive words as in your predictions (neutral, acidic, more acidic, most acidic), use the data for each liquid to enter the description you now think is appropriate in the last column of Table 1.

   Answers will vary. One student group answered as follows: Our prediction that the sodas were more acidic than orange juice was wrong. One of the sodas is the most acidic.

   The pH of the samples can be described as follows: Distilled water is neutral: pH 7.1; Orange juice is acidic: pH 3.5, Sodas 2 and 3 are more acidic: pH 2.9 and pH 2.8; Soda 1 and white vinegar are most acidic: pH 2.5 and pH 2.6,

4. If the calcium materials that bones and teeth are made of were to be coated with an acidic substance, the calcium would begin to react and dissolve. According to your results, which beverages would be harmful to teeth?

   Students would likely *never* drink vinegar, but it is in things we eat, such as pickles and salad dressings, and it is the worst for teeth because it has a pH of 2.5. Of the things we do drink, sodas would be the most harmful to teeth. Orange juice would be harmful as well if it remained coated on teeth.

5. Using your results from this investigation as evidence, how would you convince someone to brush his or her teeth after drinking one of the beverages you sampled?

   Answers will vary. One student group answered as follows: You could say something like, "Even something really healthy for you, like orange juice, can be bad for your teeth because of its high acidity content. Look at how the egg shell and bone dissolved. Vinegar is not very different in acid content from soda. Do not let acidic liquids coat your teeth too long! "

6. Is it possible for nutritious foods or beverages to be harmful to your teeth if left in contact with them for a long period of time?

   Yes.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. Which of the following describes a substance with a pH of 2?

   A. Healthy food
   B. Acid
   C. Compound

2. Which of the following will determine how acidic a substance is?

   A. A pH sensor
   B. A base
   C. A neutral substance

3. What is the range of the pH scale?

   A. 2 to 15
   B. 7 to 14
   C. 0 to 14

4. Which number on the pH scale represents neutral?

   A. 0
   B. 14
   C. 7

5. Which pH number indicates an extremely acidic substance?

   A. 0
   B. 14
   C. 7

True or False

Enter a "T" if the statement is true or an "F" if it is false.

___T___ 6. Teeth contain the some of the same key chemicals as bones and egg shells.

___T___ 7. Foods that are healthy and necessary for good nutrition can be harmful to our teeth.

___F___ 8. Teeth exposed to acids for a long period of time will not suffer any harmful effects.

___T___ 9. Some acids, such as ascorbic acid (vitamin C), are added to food to make them more nutritious.

Key Term Challenge

Fill in the blanks from the randomly ordered words below. Note that not all of the words may be used:

hydrogen ions	hydroxide ions	pH	element
compound	more acidic	less acidic	neutral
acidic	basic	0	5
7	9	14	calcium
phosphorous	carbon dioxide		

1. The pH scale ranges from ___0___ to ___14___.

2. A ___pH___ value of 3 is considered ___acidic___, while a ___pH___ value of 10 is considered ___basic___ and a ___pH___ value of 7 is considered ___neutral___.

3. The ___element___ that makes bones and teeth strong is ___calcium___.

4. There are more ______hydrogen ions______ in an acid than in pure water and more ______hydroxide ions______ in a base than in pure water.

5. A liquid with a pH of 5 is______less acidic______ than a liquid with a pH of 1.

Further Investigations

Investigate the pH of "energy" beverages.

Investigate the pH of beverages that do not taste sour, such as milk, tea, or coffee.

Conduct Internet research to learn how sugar can undergo a chemical reaction during the digestive process and become an acid.

Conduct further research to learn how many different kinds of food acids there are.

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

3. Air Pressure and the Lungs

Take a Breath

Objectives

Students investigate how air pressure and changes in air pressure allow us to breathe.

By measuring changes in air pressure in a model human lung, students learn about the mechanics of breathing while they:

- Realize that substances have characteristic properties and that the air around us exerts pressure on everything (air pressure)
- Realize that unbalanced forces will cause changes in the direction of an object's motion
- Demonstrate the complementary nature of structure and function in the lungs

Procedural Overview

Students gain experience conducting the following procedures:

- Setting up the work area and equipment to measure the change in pressure over time in a closed system
- Building a model of a human lung within the chest cavity from materials provided
- Increasing the volume of the model "chest cavity" and observing the effect on a balloon "lung"
- Using the absolute pressure sensor to measure the change in air pressure within the model chest cavity while causing the syringe "diaphragm" to change its volume
- Using graphing and math skills to interpret and analyze data

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Make a model of your lung	25 minutes
■ Lab activity, Part 2 – How do you inhale and exhale?	25 minutes
■ Analysis	50 minutes

Materials and Equipment

For each student or group:

- ☐ Data collection system
- ☐ Absolute pressure sensor
- ☐ Metabolism chamber
- ☐ Quick-release connector[1]
- ☐ Tubing[1]
- ☐ 1-hole rubber stopper, #6 (2)
- ☐ Syringe, 60 mL
- ☐ Balloon, at least 12" diameter
- ☐ Tape
- ☐ Marker

[1] Included with the Absolute Pressure Sensor

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- Forces exerted by air results in pressure
- The role of air pressure around us, for example, wind, inflating tires, and vacuum cleaners
- Use of the pressure sensor, including how to make the various connections with tubing and connection accessories

Related Labs in This Guide

Labs conceptually related to this one include:

- Boyle's Law

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting a sensor to the data collection system �(2.1)
- Changing the sample rate �(5.1)
- Monitoring live data �(6.1)
- Recording a run of data �(6.2)
- Displaying data in a graph �(7.1.1)
- Adjusting the scale of a graph �(7.1.2)

Background

This activity shows how changes in air pressure are essential for breathing. Boyle's law states that P_1V_1 equals P_2V_2 when the temperature is constant (where P and V are pressure and volume for two specific states of the same amount of gas). This means that for a given amount of air at a fixed temperature, the product of the pressure and the volume is a constant. If pressure is increased, volume will decrease, and vice versa. For example reducing the volume by half will double the pressure.

This law is evident in the way the lungs function. When we breathe, we increase the size of our chest cavity by lowering our diaphragm and increasing the size of our rib cage. This pulls the lung walls out and increases the volume in the lungs, which lowers the air pressure in the lungs. Because the pressure in the lungs is less than the outside air pressure, air is drawn in from outside through our mouth or nose, creating an inhalation.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Question students about what they know about the types of situations where air pressure plays a role. Winds are the result of air flowing from high pressure to low pressure. Tires and balls use air pressure for inflation. Vacuum cleaners use air pressure for suction. From breathing to weather to transportation to cooking, air pressure is involved. Be aware, though, that because air pressure is largely invisible to our senses, it can be more difficult to comprehend than temperature, light intensity, or other more tangible phenomena occurring around us.

Initiate a discussion by asking students to think about what occurs during breathing. Are there changes in air pressure during the breathing process, and if so, what do you think they are? If you felt there were changes in air pressure and you wanted to test your hypothesis, how could you best do it?

Share with students that in scientific inquiry, certain situations are easier to test than others. In some cases, the most appropriate way to test something is to construct a physical model that is analogous to the real situation. After looking at what constitutes a model and why making and using models can be helpful, students create a model of the chest cavity and the lung with which to begin experimentation on how we use air pressure changes to breathe. Direct students to "Thinking About the Question."

Explain to the students as they start their investigation of the question that by recording pressures as volume changes, they can see that as the volume of a fixed amount of air increases, the pressure decreases proportionally. If the volume is reduced, the pressure increases proportionally. Direct students to "Investigating the Question."

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- Assemble the 1-hole rubber stopper and tubing portion of the apparatus for each student group. Use the accessories that are included with the absolute pressure sensor to connect approximately 25 cm of tubing to one stopper and 5 cm of tubing to another stopper. The lengths do not need to be exact; students need to be able to connect the absolute pressure sensor to the stopper in the top of the metabolism chamber and the 60-mL syringe to the stopper in the side of the metabolism chamber. A drop of glycerin may be helpful when inserting the connection fittings into the tubing or stoppers.

- Although only one balloon is necessary for each lab group, have some extra balloons in reserve in case a group breaks the one they have been given.
- The metabolism chamber bottles are lightweight and can easily tip over. Encourage students to hold the bottles steady as they manipulate the tubing, syringe, and other parts of the apparatus.
- If you do not have metabolism chambers, you can construct a similar type of apparatus using a rigid plastic juice bottle and cutting a round hole in one side to accept the rubber stopper.

Safety

Follow all standard lab safety procedures.

Driving Question

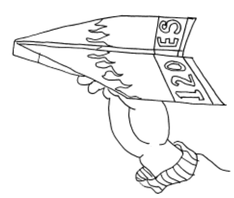
How do you inhale and exhale with your lungs?

Thinking about the Question

To investigate this question, you are going to use a model.

Have you ever made a paper airplane or played with a toy car or doll? These are models which in some way resemble their real counterparts. Have you ever used a flight simulator? Again, this is a model made to help people learn how to fly an aircraft. Often scientists make models, picking and choosing what aspects are most important to include in the model.

Look at the paper airplane below. How does this model resemble or behave like the real thing?



This model airplane and a real airplane can fly because they both depend on the same aerodynamic principles.

How does it differ from a real airplane?

Differences include size, shape (this plane has no distinct wings or tail), the length of time they can stay in the air, and the materials they are made of.

Look at the list below and add a check mark for each of the items that represent a model.

_X_ Matchbox car
___ Guitar
_X_ Soccer video game
___ Area of rectangle = length x width
___ Clock
___ Pen
___ Tree

Get together with the other members in your group and write a list of as many types of models as you can. Include your list below.

Examples of models include model trains, dolls, stuffed animals, a model of the solar system, a planetarium.

To investigate how you inhale and exhale you are going to make a model of a lung. With this model, you will be able to see the way one of your lungs works and you will measure air pressure changes to better understand how it works.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

5	1	3	4	2
Pull out the plunger of the syringe to increase the volume and inflate the model "lung."	Make certain that each lab group member is aware of the safety rules and procedures for this lab activity.	Hang the large balloon down inside the metabolism chamber; stretch its opening over the mouth of the chamber.	Insert the stopper attached to the syringe into the side of the metabolism chamber.	Label a large balloon with the word "Lung."

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Make a model of your lung

1. ☐ Use a marker to label a large balloon "Lung."

2. ☐ Place the large balloon down into the metabolism chamber bottle and carefully stretch the open end of the balloon over the mouth of the bottle.

3. ☐ Connect the 60-mL syringe to the rubber stopper with the shorter tubing.

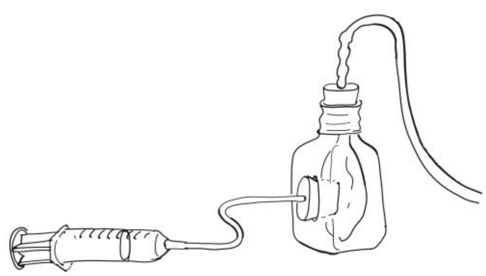
   Note: The plunger of the syringe should be pushed in all the way.

4. ☐ Connect the absolute pressure sensor to the longer piece of tubing.

5. ☐ Insert the rubber stopper connected to the syringe into the hole in the side of the metabolism chamber bottle.

6. ☐ Use a piece of tape to label the syringe "diaphragm."

7. ☐ Use another piece of tape to label the metabolism chamber bottle "Chest Cavity."



8. ☐ Start a new experiment on the data collection system. �(1.2)

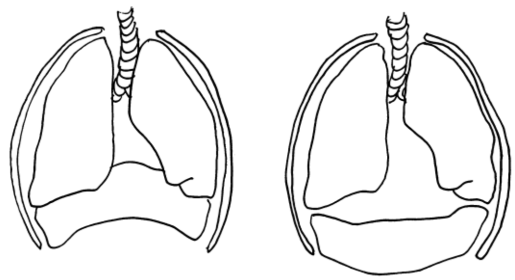
9. ☐ Connect the absolute pressure sensor to the data collection system. �(2.1)

10. ☐ Display Absolute Pressure on the y-axis of a graph with Time on the x-axis. �(7.1.1)

11. ☐ Change the sample rate to 2 samples per second. �(5.1)

Part 2 – How do you inhale and exhale

12. ☐ Take a deep breath using your diaphragm.



a. When you inhale, what happens to your diaphragm?

The diaphragm lowers.

b. What do you think happens to the volume of your lungs when you take a deep breath using your diaphragm?

The lungs expand; their volume increases.

13. ☐ Gently pull the plunger of the syringe until it reaches the maximum volume. What happens to the "lung" in the model when you pull the plunger on the syringe "diaphragm?" Why do you think this happens?

The balloon inflates, indicating the expansion of the lung. It happens because the air pressure is now less in the bottle, since the same amount of air has more space to fill.

14. ☐ Insert the rubber stopper connected to the absolute pressure sensor into the balloon to close the top of the metabolism chamber bottle, being very careful not to tear the balloon.

15. ☐ Now, without touching the "diaphragm" of your model, start data recording to measure the air pressure in the balloon or "lung." �(6.2) Write the pressure in the space provided.

Pressure in the balloon "lung": 101 kPa

16. ☐ After measuring the pressure, stop data recording. �(6.2)

17. ☐ Return your lung model to its initial condition.

a. Remove the stopper connected to the absolute pressure sensor from the bottle.

b. Depress the plunger of the syringe so it is at minimum volume.

18. ☐ Replace the stopper connected to the absolute pressure sensor in the mouth of the metabolism chamber bottle.

19. ☐ Begin data recording. �(6.2)

20. ☐ Measure the air pressure inside the "lung" as you slowly pull out on the syringe plunger "diaphragm," hold it at maximum volume for a few seconds, and then slowly depress the syringe plunger "diaphragm" back to its minimum volume.

21. ☐ Repeat this series of volume changes three times to make sure your results are consistent. Each time you move the plunger of the syringe observe the balloon "lung" very carefully for any changes in the volume of air inside the "lung." What have you just modeled with this series of changes in volume?

We modeled taking several breaths by breathing in and out.

22. ☐ Stop data recording. �(6.2)

23. ☐ Review your graph of absolute pressure versus time. Select which happens to the volume of air in the "lung" when the pressure in the "chest cavity" decreases?

_X_ When pressure decreases in the chest cavity the air volume in the lung increases.

____ When pressure decreases in the chest cavity the air volume in the lung decreases.

____ When pressure decreases in the chest cavity the air volume in the lung stays the same.

24. ☐ Using what you understand about air pressure, explain why the balloon inflates. Be prepared to share your answer with the class.

The balloon lung inflates because the pressure in the chest cavity is lower than the pressure in the balloon lung. The higher pressure in the balloon lung pushes out, causing the balloon to inflate.

25. ☐ If you wanted the "lung" balloon to inflate even more, what would you need to do to the air pressure in the "chest cavity"?

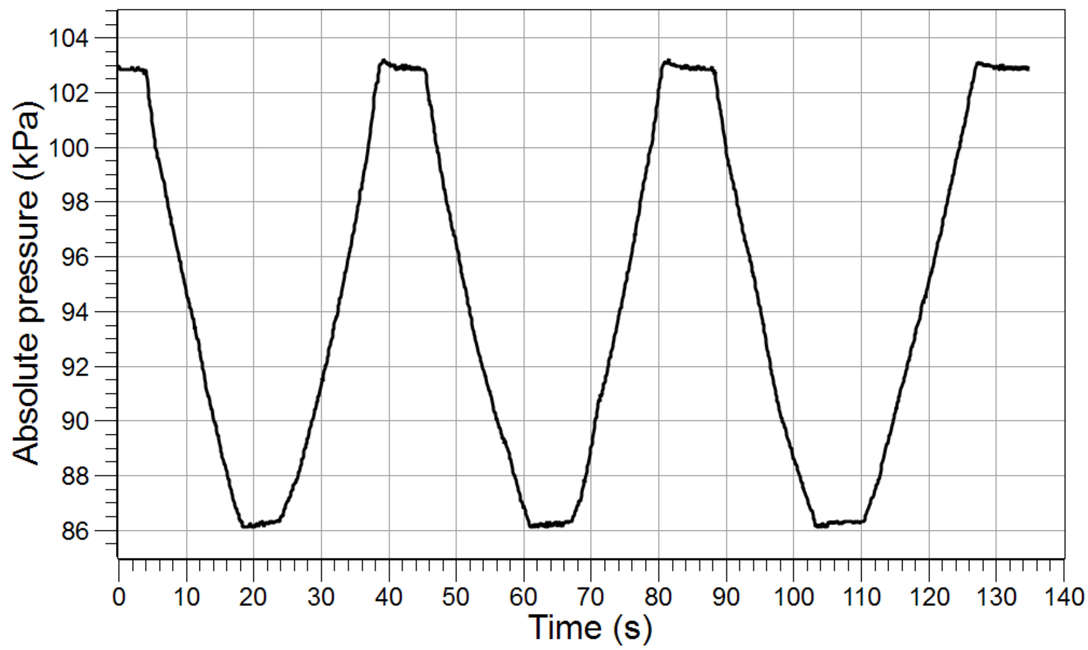
____ Raise it

_X_ Lower it further

26. ☐ Explain your choice above. Be prepared to share your answer with the class.

Answers will vary. One group answered as follows: You would need to lower the pressure in the chest cavity even further, since lowering it by about 60 mL caused the lung to inflate a certain amount. To actually do this, we would need a bigger syringe with a larger volume.

Sample Data



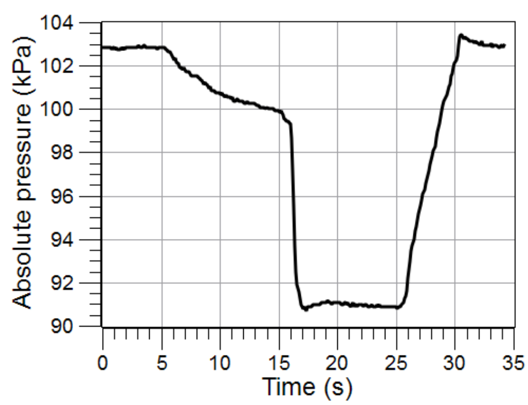
Answering the Question

Analysis

1. How did using a model help you better understand what is happening when you breathe?

   Answers will vary. One group answered as follows: By using a model of a chest cavity, a lung, and a diaphragm, we could visualize each part of the breathing process as it was taking place and see how the inflation of the balloon lung was directly related to the change in pressure in the chest cavity, which was caused by the diaphragm.

2. Using your chest cavity and lung model, someone created the following graph by measuring air pressure in the "chest cavity."



Select which of the following is a possible explanation for the graph.

____ The "diaphragm" plunger was pulled out quickly and then released.

__X_ The "diaphragm" plunger was pulled out slowly for about 11 seconds then pulled out further quickly and held for 9 seconds, and then depressed back in.

____ The "diaphragm" plunger was pulled out quickly, held, and then depressed over a period of 12 seconds.

3. What must happen inside the body in order for the lungs to take a breath? Use evidence from this lab activity to support your reasoning.

Answers will vary. One group answered as follows: In order for the lungs to take a breath, the air pressure in the cavity surrounding the lungs must drop. In our model, this was done by pulling out the plunger of a syringe. In a body, it happens when the diaphragm expands and lowers, making the volume of the chest cavity a little bigger. The volume of the air and its pressure are related. When the volume goes up, the pressure of the air goes down.

4. The forces exerted by the air on the lungs are either balanced forces or unbalanced forces. Review your pressure data again carefully. According to your graph, when are the forces acting on the model lung balanced? How can you tell?

We can tell from our graph when the model lung is not moving, because the line is flat. Since only unbalanced forces result in a change in motion, the time when the lung is not moving and the pressure is not changing must be when the forces are balanced.

5. Describe the forces acting on your own lungs when you hold your breath for a few seconds. Are the forces balanced or unbalanced?

The forces on our lungs are balanced when we hold our breath because they are not inflating or deflating. They are not moving, so the forces must be balanced.

6. Take a deep breath and then exhale the breath slowly. At what point in this deep breath is the pressure inside your chest cavity the lowest? How does this compare to the volume of air in your lungs?

The pressure inside the chest cavity is the lowest when the breath is at its deepest. The lungs are filled to their greatest volume at this point. The lowest pressure surrounding the lungs results in the highest volume of air in the lungs.

Key Term Challenge

Fill in the blanks from the randomly ordered words below:

diaphragm	model	chest cavity	rib cage
lungs	gas	pressure	kilopascals
decrease	greater	volume	

1. In the human body the ___lungs___ are found within the ___chest cavity___, which is protected by the bones of the ___rib cage___.

2. During breathing the ____diaphragm____ lowers to expand the volume of the chest cavity, which causes the____pressure____to____decrease____.

3. Scientists often use a ____model____ to represent specific aspects of something they are investigating.

4. For a given amount of ____gas____, the pressure will increase as the____volume____ decreases.

5. In the SI system of measurement ____kilopascals____, or kPa, is a unit of pressure.

6. The ____greater____ the volume of a fixed amount of gas, the lower its pressure will be, as long as it is held at a constant temperature.

Further Investigations

For a fixed amount of air, establish that PV = a constant. You can use a syringe connected to an air pressure sensor and take pressure readings at various volumes.

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

4. Introduction to Acids and Bases

pH Factor

Objectives

Working with common household chemicals, students develop an understanding of the pH scale. In this activity, students investigate and observe how red cabbage juice changes color in the presence of acids and bases and relate this visual indicator to the numbers of the pH scale.

Additionally, students will be able to:

- Recognize that substances often are placed in categories or groups if they react in similar ways, such as an acid or base
- Make explanations and predictions from evidence and drawing logical conclusions
- Gain skills and confidence in using a scientific measurement tool—the pH sensor—as well as the spreadsheet and graphing capability of a computer to represent and analyze data

Procedural Overview

Students gain experience conducting the following procedures:

- Setting up the equipment and work area to measure the pH of different household chemicals
- Measuring the pH of several different household chemicals
- Classifying chemicals as acid, neutral, or base

Time Requirement

Introductory discussion and lab activity,	50 minutes
Lab activity, Part 1 – Making predictions	50 minutes
Lab activity, Part 2 – Measuring the pH of household chemicals	25 minutes
Analysis	50 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Data collection system
- ☐ pH sensor
- ☐ Head of red cabbage
- ☐ Large pot
- ☐ Hot plate or burner
- ☐ Buffer solutions to calibrate pH sensors
- ☐ Distilled water, 1 gallon
- ☐ Beakers, 1000-mL (or clean glass quart jars) (4)
- ☐ Isopropyl alcohol (70%), 100 mL (optional)
- ☐ Household chemical products, including white vinegar, 50 mL each

For each student or group:

- ☐ Data collection system
- ☐ pH sensor
- ☐ Red cabbage indicator, 100 mL
- ☐ Pipet
- ☐ Beakers, 250-mL (5)
- ☐ Distilled water, 200 mL, in wash bottle
- ☐ Household chemical samples, 50 mL each (4)

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- The pH scale has a range of 0 to 14, with 7 being neutral.
- A substance with a pH below 7 is classified as an acid, while a substance with a pH above 7 is classified as a base.
- The lower the pH, the stronger the acid, and the higher the pH, the stronger the base.
- How to safely waft a chemical with the hand, to test for its odor.

Related Labs in This Guide

Labs conceptually related to this one include:

- Photosynthesis
- Acid Rain and Seed Germination
- Acid Rain and Weathering
- Acid's Effect on Teeth

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting a sensor to the data collection system �(2.1)
- Calibrating a pH sensor �(3.6)
- Changing the sample rate �(5.1)
- Recording a run of data �(6.2)
- Displaying data in a digits display �(7.3.1)
- Saving your experiment �(11.1)

Background

We are surrounded in life by acids and bases. Acids are found in numerous substances including soft drinks, salad dressing, the human body, rain water, and batteries. Acids taste sour, cause indicators to change color (turn litmus red), react with certain metals to form hydrogen gas, and react with bases to form a salt and water.

Bases can be found in soap, cleaning products, baking soda, and beer. Bases taste bitter, feel slippery or soapy, cause indicators to turn color (turn litmus blue), react with oil and grease, and react with acids to form a salt and water.

At the molecular level, an acid is able to donate a hydrogen ion (Brønsted-Lowry acid). The donated hydrogen ion can bond with any available water molecule to form a hydronium ion (H_3O^+). Acids are ranked based on how easily they give up their hydrogen ions. The terms "strong" and "weak" refer not to the concentration of the acid, but the degree to which the acid dissociates (separates into hydrogen ions and the conjugate base).

A strong acid is one that readily and completely dissociates. In a strong acid, every acid unit breaks into a hydrogen ion and the negative counter ion. For example, with hydrochloric acid every unit of HCl splits into H^+ and Cl^-.

In contrast, a weak acid is one that only partially dissociates. In a weak acid only a fraction of the available acid units break into hydrogen ions and the negative counter ions. For example in acetic acid of 100 $HC_2H_3O_2$ units, only one splits into H^+ and $C_2H_3O_2^-$ while the remaining 99 remain combined as $HC_2H_3O_2$.

A base is the complement of an acid. A base is a substance that accepts a hydrogen ion (Brønsted-Lowry base). The more readily a chemical substance bonds with hydrogen ions, the stronger the base.

The pH scale provides a numerical measure of the acid concentration of a chemical substance in solution. The term pH refers to the concentration of H_3O^+ in a solution of the substance. The pH scale is based on the observation that water has a slight tendency to autoionize into H^+ and hydroxide ions (OH^-). Because there is a one-to-one mole ratio, equal amounts of the H_3O^+ ion and the OH^- are formed.

The concentration of H_3O^+ ions and OH^- ions is inversely related. If the concentration of H_3O^+ ions increases, then the OH^- ion concentration must decrease and vice versa. The following table shows the two extremes after adding a strong acid or a strong base to water to make a 1.0 M solution.

The range of H_3O^+ ion concentrations will therefore generally be between 1 and 1 x 10^{-14}. Because of the extreme range of values, the pH scale simplifies these numbers by taking the negative logarithm of the H_3O^+ ion concentration to give a range from 0 to 14.

$$pH = -\log [H_3O^+]$$

When there are equal concentrations of H_3O^+ ions and OH^- ions, a solution is said to be neutral and has a pH value of 7. When there are greater amounts of H_3O^+ ions than OH^- ions the solution is acidic and has a pH less than 7. The lower the pH value the more acidic the solution. When there are fewer H_3O^+ ions than OH^- ions, the solution is basic and has a pH greater than 7. The higher the pH value the more alkaline (basic) the solution.

Although students will likely never have heard a log function, they need to understand the significance between substances with different pH values. For every one unit change of pH, there is a ten-fold change in acidity. That means a solution with a pH of 5 is 10 times more acidic than a solution with a pH of 6 and 100 times more acidic than a solution with a pH of 7. For this reason the pH value is often termed the pH "factor."

Indicators are substances that change color depending on the pH level. Some common pH indicators include phenolphthalein, which is colorless in acidic and neutral solutions, but turns pink in the presence of a base. Red litmus paper remains red in acidic and neutral substances, but turns blue in the presence of a base. Blue litmus paper remains blue in neutral and basic solutions, but changes to red in the presence of an acid. Universal indicators can change into a range of colors, depending on the pH of the solution. Red cabbage juice is one example of a universal pH indicator.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Gather and display the red cabbage juice indicator, distilled water, and two or three labeled samples each of acidic and basic household chemicals in clear cups or beakers. One chemical sample should be white vinegar. Also have available the pH sensor connected to the data collection system.

Explain to students that you will demonstrate a type of pH indicator that changes color in the presence of different pH factors. Demonstrate a color change by pouring some cabbage juice indicator into one of the basic chemical samples (for example, diluted ammonia, 1 tsp. baking soda dissolved in 100 mL of distilled water, or liquid soap). Ask students to predict whether this substance is acidic, basic, or neutral. Accept all predictions. Use the pH sensor to obtain a measurement of the pH of the substance, and display or write this on the board for students to see. Use the opportunity to demonstrate to students how to rinse the pH sensor with distilled water between measurements.

Ask students to predict whether distilled water is acidic, basic, or neutral. Accept all predictions. First use the pH sensor to obtain a measurement of the pH of the distilled water. Then pour some cabbage juice indicator into the sample of distilled water. Students should observe that the indicator does not change color, although it becomes less intense because it has been diluted by the water. Explain to students that distilled water is nearly neutral, and is therefore placed in the middle of the pH scale. Because of the dissolved carbon dioxide from the atmosphere, the pH of distilled water will probably not be exactly 7, but a little lower. Substances whose pH factors are greater than 7 are classified as bases, while those whose pH factors are less than 7 are classified as acids.

Next pour some cabbage juice indicator into one of the acidic chemical samples (not the vinegar – you will save this sample for last). Ask students to predict whether this substance is acidic, basic, or neutral. Accept all predictions. Again use the pH sensor to obtain a measurement of the pH of the substance, displaying the information for students.

After you have gone through these steps for all of the samples except the vinegar, ask students to organize the samples from lowest pH (most acidic) to highest pH (most basic). Ask them to predict where the vinegar sample will rank among the other samples already tested. Students should suggest that the vinegar will be acidic and will most likely have a very low pH factor. When students have had the opportunity to make their predictions, test the vinegar with cabbage juice indicator and the pH sensor. Ask students to describe how the color of the cabbage juice indicator is related to the numbers of the pH scale.

> Answers will vary. Students should suggest that acids tend to range in color from shades of lavender-purple for substances that are slightly acidic to bright magenta and red for substances that are more acidic. They should suggest that a pH of 6 would turn the indicator a pink or "pinkish" color, while a pH of 3 or 4 would turn the indicator a color closer to magenta or red. For basic substances, students should suggest that pH numbers closer to neutral result in the indicator turning a bluish-purple color, while those substances with higher pH numbers turn the indicator shades of blue, then blue-green. The highest pH numbers, corresponding to the most basic substances, result in the indicator turning green, greenish-yellow, and yellow.

Direct students to "Thinking About the Question."

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- Up to one day prior to this lab activity, prepare the red cabbage juice indicator as follows:

  1. Cut or tear a head of red cabbage into small pieces.
  2. Place the cabbage pieces into the pot with enough distilled water to cover them.
  3. Heat the pot of water and cabbage over medium heat until the water begins to steam. Continue heating the pot until the water has turned a deep, dark purple.
  4. Allow the cabbage to cool.
  5. Discard the pieces of cabbage and save the purple liquid.

Note: If you will be using the cabbage juice for more than one lab activity, it will keep under refrigeration for 2 to 3 days before spoiling. It can be preserved for up to two weeks by adding 50 mL of isopropyl alcohol per 2 liters of indicator solution and refrigerating. Note that alcohol-preserved indicator cannot be used for the Photosynthesis lab activity, as it will kill the *Elodea* plants used in that activity.

- Suggested household chemicals that are bases include ammonia solution, laundry or dish soap, shampoo, bubble solution, baking soda, Milk of Magnesia, and antacid tablets.

- Suggested household chemicals that are acids include vinegar, lemon juice, lime juice, grapefruit juice, apple juice, citric acid, and Witch Hazel.
- Household chemicals that are in tablet form need to be crushed and dissolved in distilled water to make a solution. Those that are in powder or granular form need to be dissolved in distilled water to make a solution.
- Display for students the various household chemicals whose pH factors they will be testing. Either list on the board the household chemicals used as samples, label each of the containers the student lab groups will be using to obtain their samples of household chemicals, or show the original containers.
- Remind students that it is unsafe to mix many household chemicals, and they should only test their samples individually. You may allow students to mix different samples if they check with you and obtain your permission.

Safety

Add this important safety precaution to your normal laboratory procedures:

- Students should wear goggles and an apron when working with glassware and chemicals.

Driving Question

What is the pH of some common household chemicals?

Thinking about the Question

Manufacturers of beauty products such as cleansers, soaps, and shampoo, often advertize that their products are "pH balanced," or made for the pH of one gender while still being effective for the other gender. You have probably heard of the pH scale before, and you may even know that it is used to classify substances by how acidic or how basic they are. You may have already learned that pure water is considered neutral on the pH scale, with a pH of 7.

Discuss with your lab group members what types of products are commonly found around the home that may be classified as acids or bases. Do any of the substances feel slippery or soapy or taste bitter? Do any taste any sour? Categorize each of the products you list according to how they are used — for example, are they household cleaners, cosmetics, medicine, or food?

> Answers will vary. Student suggestions should include some of the following: Laundry and dish detergents, hand soap, shampoo, and cosmetic cleansers are basic substances. Vinegar, citrus juices, tomato juice, sodas, and sour foods are acidic substances. Aspirin is a type of medicine that is acidic, while antacid tables are an example of medicine that is basic.

In humans, the blood typically has a pH of about 7.4, while saliva normally has a pH of between 6.0 and 7.4. Like most living organisms, our bodies are able to stay healthy only when their pH remains within a narrow range. Discuss with your lab group members why some household chemicals may be dangerous to humans and pets. Be prepared to share your ideas with the class.

> Answers will vary. Students should suggest that some cleaners in particular, are dangerous to touch or inhale. Oven cleaners and drain cleaners are extremely basic, and can cause caustic burns. Students may know from experience that soap and shampoo stings if it gets into the eyes of people or pets.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

2	1	3	5	4
Obtain and label four samples of household chemicals.	Make certain that each member of your lab group is familiar with the safety rules and procedures for this activity.	Remove the pH sensor electrode from the storage bottle of buffer solution, setting the bottle safely aside.	Using the wash bottle and empty beaker, rinse the electrode of the pH sensor after measuring the pH of a sample.	Record pH data for one of the samples of household chemicals.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

1. ☐ Observe each of your samples of household chemicals. Check with your teacher to see if you may safely smell any of the chemicals, and if so, carefully waft the sample toward your nose to check for odors. Note your observations in the space below:

   Answers will vary. One student group answered as follows: We observed that one of our samples looks like cloudy, whitish water and has a very bad smell, like window cleaner. Another of our samples smells like lemon and is light yellow. The third sample smells like pickles and is clear. The fourth sample is also cloudy but we could not detect any smell.

2. ☐ Based on your observations of your chemical samples, predict which are acids and which are bases.

   Answers will vary.

Part 2 – Measuring the pH of household chemicals

3. ☐ Start a new experiment on the data collection system. �(1.2)

4. ☐ Connect the pH sensor to the data collection system. �(2.2)

5. ☐ Display pH data in a digits display. �(7.3.1)

6. ☐ Remove the storage bottle from the pH sensor tip, and set the bottle aside.

7. ☐ Rinse the pH sensor with distilled water, over the empty beaker. This beaker will hold waste rinse-water.

8. ☐ Place the pH sensor into the first sample of household chemical.

9. ☐ Use the pipet to add several drops of red cabbage indicator solution to the sample. Record the color change, if any, in the data table at the end of this section.

10. ☐ Start data recording. �(6.2)

11. ☐ Wait until the reading has stabilized and then stop recording. �(6.2) Write the pH of this chemical sample in the data table at the end of this section.

12. ☐ Rinse the pH sensor with distilled water.

13. ☐ Place the pH sensor into the second sample of household chemical.

14. ☐ Use the pipet to add several drops of red cabbage indicator solution to the sample. Record the color change, if any, in the data table at the end of this section.

15. ☐ Start data recording. �(6.2)

16. ☐ Wait until the reading has stabilized and then stop recording. �(6.2) Write the pH of this chemical sample in the data table at the end of this section.

17. ☐ Rinse the pH sensor with distilled water.

18. ☐ Place the pH sensor into the third sample of household chemical.

19. ☐ Use the pipet to add several drops of red cabbage indicator solution to the sample. Record the color change, if any, in the data table at the end of this section.

20. ☐ Start data recording. �(6.2)

21. ☐ Wait until the reading has stabilized and then stop recording. �(6.2) Write the pH of this chemical sample in the data table at the end of this section.

22. ☐ Rinse the pH sensor with distilled water.

23. ☐ Place the pH sensor into the fourth sample of household chemical.

24. ☐ Use the pipet to add several drops of red cabbage indicator solution to the sample. Record the color change, if any, in the data table at the end of this section.

25. ☐ Start data recording. �(6.2)

26. ☐ Wait until the reading has stabilized and then stop recording. �(6.2) Write the pH of this chemical sample in the data table at the end of this section.

27. Put the pH sensor tip back into the storage bottle.

28. ☐ Dispose of your chemical samples and rinse water according to your teacher's instructions.

Table 1: pH measurements

Sample	pH	Indicator Color
1	4.8	Pinkish-red
2	9.7	Teal-green
3	3.2	Magenta-red
4	8.6	Bluish/teal-green

Answering the Question

Analysis

1. How do your results compare to your prediction? Are your results close to what you expected? Why or why not?

Answers will vary. One student group answered as follows: We predicted that the sample that smelled like window cleaner would be basic. It turned out to have a pH of 9.7, which made it the most basic of our samples. Our lemon-smelling sample was acidic, which we predicted, and had a pH of 4.8. Our sample that smelled like pickles is the most acidic because it has the lowest pH, 3.2. We predicted it would be acidic because pickles are usually sour. The last sample we tested had no smell, so we predicted it would be basic because we thought it might be some kind of soap. It turned out to be basic, and had a pH of 8.6.

2. Review your pH data. What was the range between the highest and lowest pH factors of your household chemical samples? How did you calculate this range?

Answers will vary. One student group answered as follows: We found the highest pH, which was 9.7, and the lowest pH, which was 3.2. Then we subtracted 3.2 from 9.7 and found the difference, which is 6.5. This is the range of our pH data.

3. Which household chemical substance tested had a pH closest to that of your skin (remember that human blood typically has a pH of about 7.4)? What was the pH of this sample? If you do not already know, ask what this household chemical is and include this information in your answer.

> Answers will vary based samples available to students. One student group answered as follows: The substance we tested that was closest in pH to our skin had a pH of 8.6. We found out that it is a type of soap, which is what we predicted it was.

4. The pH scale is organized by powers of ten. This means that a substance with a pH factor of 8 is ten times more basic than a neutral substance with a pH of 7. Likewise, a substance with a pH of 6 is ten times more acidic than the neutral substance. Did you test any samples that were more than 1000 times as acidic or as basic as distilled water? If so, which substances were they?

> Answers will vary based on samples available to students. One student group answered as follows: For a substance to be 1000 times more acidic or basic than pH 7, it would have to be 3 pH numbers different. If pH 8 is ten times more basic, then pH 9 is 100 times more basic and pH 10 is 1000 times more basic. We did not test anything that was that basic. Ammonia had our highest pH factor, 9.7. For our acids, the lowest pH was 3.2. A pH of 6 is ten times more acidic than distilled water, a pH of 5 is 100 times more acidic, and a pH of 4 is 1000 times more acidic. This means that our vinegar sample, with a pH of 3.2, was more than 1000 times as acidic as distilled water.

Key Term Challenge

Fill in the blanks from the randomly ordered words below. Not all words may be used; some words may be used more than once:

acids	bases	neutral	10
100	1000	distilled water	red cabbage
factor	sour	soap	7
5	Indicator solution	14	lemon juice

1. The pH scale goes from zero to 14, with a pH of ___7___ indicating that a substance is neither an acid nor a base.

2. A substance is considered ___neutral___ if it is neither acidic nor basic.

3. Rinsing the pH sensor with ___distilled water___ between measurements helps prevent contamination of a sample with substances from previous measurements.

4. Foods such as vinegar and citrus that have a ___sour___ taste are often classified as ___acids___ because they have pH numbers below ___7___ .

5. A chemical sample with a pH of 2 is ___100___ times more acidic than a substance with a pH of 4.

6. Each pH number is larger than the previous pH number by a ____factor_____ of ten.

7. A/an ____indicator solution________ changes color in the presence of acids or bases.

8. A mixture made of distilled water and ____lemon juice______ may have a pH factor of 4.5.

9. _____Red cabbage______ turns magenta in the presence of_____acids________ and turns green in the presence of _________bases_________.

10. A substance with a pH of _________14__________ would be unsafe for humans or animals to get on their skin.

Further Investigations

Can a basic solution be neutralized by adding an acid to it? Is it possible to neutralize an acidic solution? What happens to the pH of baking soda dissolved in water, when vinegar is added to it?

Conduct research to determine which foods are the most acidic and the most basic. Just how strong of an acid or a base do we commonly ingest? Are sour foods always acidic? Are bitter foods always basic?

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

5. Muscle Fatigue

A Workout For Your Thumb

Objectives

In this activity, students investigate and observe changes in the muscular movement of bones during a prolonged period of sustained exertion while they:

- Measure changes in force applied by their thumbs over a period of time
- Learn that the human organism has systems for digestion, respiration, reproduction, circulation, excretion, movement, control, coordination, and protection from disease, and that these systems interact with one another
- Learn that all organisms must be able to obtain and use resources, grow, reproduce, and maintain stable internal conditions while living in a constantly changing external environment
- Gain skills and confidence in using a scientific measurement tool, the force sensor, as well as the graphing capacity of a computer to represent and analyze data

Procedural Overview

Students gain experience conducting the following procedures:

- Setting up the equipment to measure force versus time
- Applying a push to the force sensor for 60 seconds without watching the force graph
- Applying a push to the force sensor for 60 seconds while watching the force graph
- Repeating the procedure for all lab group members
- Using math skills to interpret the force versus time data

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Making predictions	25 minutes
■ Lab activity, Part 2 – Measuring a sustained push on the force sensor	25 minutes
■ Lab activity, Part 3 – Applying a force while watching the graph	25 minutes
■ Analysis	25 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Data collection system
- ☐ Force sensor with rubber bumper attached

For each student or group:

- ☐ Data collection system
- ☐ Force sensor with rubber bumper attached

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- Muscle types include skeletal muscle, smooth muscle, and cardiac muscle.
- Skeletal muscles are connected to bones by tendons.
- Most skeletal muscles are arranged in opposing pairs; one muscle in the pair moves the bone in one direction, while the other muscle in the pair moves the bone in the opposite direction.
- Muscles move bones by pulling, not pushing, them.
- Muscles move bones by contraction and relaxation.

Related Labs in This Guide

Labs conceptually related to this one include:

- Recovery Heart Rate

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting a sensor to the data collection system �(2.1)
- Starting and stopping data recording �(6.2)
- Displaying data in a graph �(7.1.1)
- Adjusting the scale of a graph �(7.1.2)
- Saving your experiment �(11.1)

Background

The functional unit of muscle contraction is the sarcomere, which contains filaments of myosin and actin. Interactions between the myosin and actin are responsible for the contraction of the sarcomere. In a relaxed muscle, the filaments of myosin and actin overlap; during muscle contraction these filaments slide past one another, lengthening the distance along which they overlap. The result is an overall shortening of the sarcomere. This process can be pictured by holding your hands so your fingers are interspersed between each other, alternating left- and right-hand fingers. Your fingers overlap each other by a finger length. If the region of overlap increases, your hands become closer together. If the region of overlap decreases, your hands move farther apart. Hands closer together model a muscle contraction, while hands farther apart model a muscle relaxation.

At the cellular level, muscle contraction requires energy, which is provided by ATP. Muscle cells need this energy to allow the myosin and actin to interact and slide past one another. The sources of energy available to muscle cells include glucose, which is delivered by the blood; glycogen, which is stored within the muscle cells to be used as necessary if no glucose is available; and fat molecules, which contain more chemical potential energy than any other type of energy molecule available to cells.

Physiologically, muscle fatigue occurs when muscle use outpaces the ability of the body to provide the necessary energy and the supply of ATP is temporarily depleted. In this situation, muscles can remain in a state of continuous contraction, which manifests itself as a muscle cramp.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Initiate a discussion by asking students if they have ever had a muscle cramp while playing a sport such as soccer, or running a long distance, or while engaging in a physically strenuous activity such as ballet or other form of dance. Students may have seen athletes suffer muscle cramps during a sporting event they have attended or watched on TV. Ask students what happens during a muscle cramp. Can the athlete continue performing?

> During a muscle cramp, an athlete cannot continue performing. The muscle experiencing the cramp will not work properly, and is very painful. The result for the athlete is that she or he is momentarily disabled until the cramp is resolved.

Explain to students that the human body is a marvelously complex system with many requirements for its functioning. It contains many organ systems that each have their role and function to play. The skeletal system provides the human body with structure and supports and protects our internal organs. The muscular system also provides structure, as well as supporting and moving the core and limbs, and moving substances throughout the body.

Share with students that active muscles use a large amount of energy. The arteries must supply these muscles continuously with oxygen and nutrients. Because the muscles metabolize the oxygen and nutrients, they produce waste products; it is the function of the veins to carry away this metabolic waste.

Direct students to "Thinking About the Question".

Before directing students to “Investigating the Question”, demonstrate how to apply pressure with your index finger to the bumper on the force sensor.

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- Install the rubber bumpers on the force sensors. Store the hooks in the sensor envelopes, as they are small parts that can easily get lost.
- Remind students not to apply forces greater than 50 newtons to the force sensor, as damage to the sensor will result.
- Students in each lab group will need to take turns with the force sensor. It may be helpful for students to decide ahead of time what the order will be for taking turns.
- As groups are recording force data, circulate throughout the room and ensure that students apply force only with their index finger. As the students' hands become tired, it is natural for them to put more fingers on the bumper of the force sensor.

Safety

Follow all standard lab safety procedures.

Driving Question

What happens when muscles become fatigued?

Thinking about the Question

If you have ever had a muscle cramp, you know it can be very painful! A muscle cramp happens when the muscle involuntarily contracts and is not able to relax. The skeletal muscles in the legs and feet are commonly the location of cramps.

Before your muscles experience a cramp, they may have become fatigued. When a muscle is used past the point that enough energy is available to it, muscle fatigue occurs and the muscle cannot be voluntarily controlled any longer. If you experience muscle fatigue, your brain may send nerve signals to your muscles, but they will not be able to respond by contracting.

In this lab activity, you will use the muscles of your fingers to exert a continuous, steady force against the rubber bumper of the force sensor for a period of time that will be challenging to maintain. You will compare results within your lab group and with the rest of your class.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

2, 3	1	3, 2	5	4
Zero the force sensor in the direction it will be used for this investigation.	Make certain that each member of your lab group is aware of the safety rules and procedures for this lab activity.	Grasp the force sensor with your thumb through one of the finger-holds.	Apply a steady, even force to the black rubber bumper on the force sensor.	Begin data recording.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

1. ☐ Discuss with your partners how long you think it will take the muscles in the thumb of your dominant hand to become fatigued from pushing steadily against the force sensor.

   Predicted time for muscles to become fatigued: 2 minutes

2. ☐ Predict whether it will be easier to maintain a steady pushing force without being able to watch the force graph or while watching the force graph.

   Answers will vary. Either situation is possible depending on individual students' experiences.

Part 2 – Measuring a sustained push on the force sensor

3. ☐ Start a new experiment on the data collection system. �(1.2)

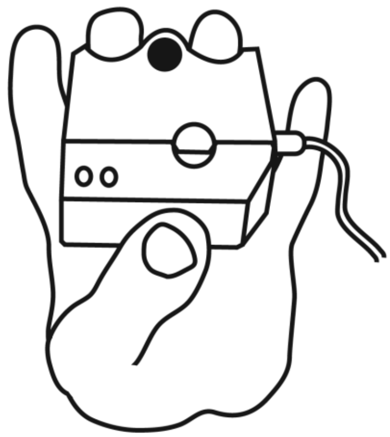
4. ☐ Connect a force sensor to the data collection system. �(2.1)

5. ☐ Display Force, with push positive, on the y-axis of a graph with Time on the x-axis. �(7.1.1)

6. ☐ Zero the force sensor. Why is it important to zero the force sensor in this experiment?

It is important to zero the sensor because it is influenced by the earth's gravitational field, and is sensitive enough to measure the pull of gravity on itself.

7. ☐ Hold the force sensor comfortably, so your fingers go through the finger-holds and your thumb is positioned above the black rubber bumper.



8. ☐ Start data recording. �(6.2)

9. ☐ Without looking at the graph of force versus time, begin applying a steady force with your thumb *only*, as strong as you can comfortably push without causing yourself discomfort or exceeding 50 newtons.

Note: Another member of your lab group should be watching the graph to tell you if you are exceeding 50 newtons of force.

10. ☐ After 60 seconds stop applying force.

11. ☐ Stop data recording. �(6.2)

12. ☐ Repeat the procedure for each member of your lab group. Remember not to look at the graph while you are applying the force to the force sensor.

13. ☐ Review your data. Adjust the scale of the graph in order to see specific data points. �(7.1.2) What do you notice about the forces exerted by each lab group member? Note your observations below:

Answers will vary. Students should observe that, with the axes re-scaled, it is apparent that the forces exerted by their thumbs were not uniform.

Part 3 – Applying a force while watching the graph

14. ☐ Hide the data runs from Part 2 of the activity. �(7.1.7) This will allow you to begin with a blank graph, but keep the data from Part 2 for later analysis.

15. ☐ Zero the force sensor.

16. ☐ Start data recording. �(6.2)

17. ☐ While watching the graph of force versus time, begin applying a steady force with your thumb *only*, as strong as you can comfortably push without causing yourself discomfort or exceeding 50 newtons.

Note: Be sure to use the same hand and finger as you did in the first trial of the activity.

18. ☐ After 60 seconds stop applying force.

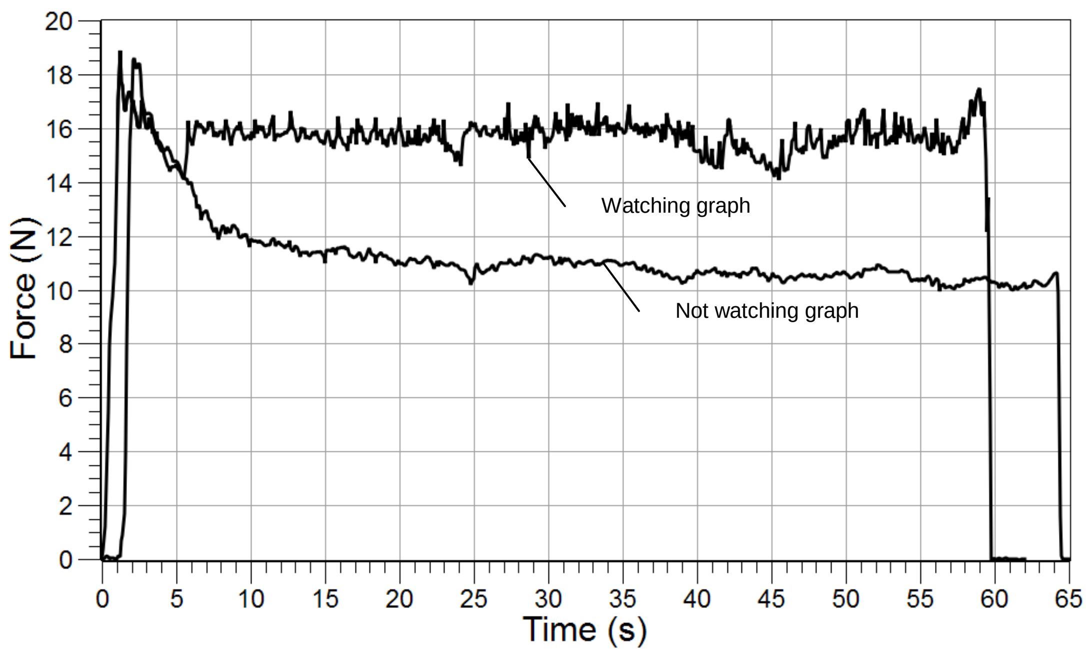
19. ☐ Stop data recording. �(6.2)

20. ☐ Repeat the procedure for each member of your lab group. Remember to look at the graph while you are applying the force to the force sensor.

21. ☐ Review your data. Adjust the scale of the graph in order to see specific data points. �(7.1.2)

22. ☐ Save your experiment according to your teacher's instructions. �(11.1)

Sample Data



Answering the Question

Analysis

1. Review the data for each lab group member, first for applying force without looking at the graph and then for looking at the graph. How did your predictions compare to the results you obtained?

Answers will vary. One group answered as follows: We each predicted that we could push on the force sensor steadily for at least two minutes. However, in our experiment we found that we could not apply the force for that long, and even while we thought we were applying a steady, even force, it was actually varying in strength by as much as almost 10 newtons. The closer each person got to the 60-second mark, the more variable the force became.

2. In the first trial, you were not able to see the graph of force versus time while you were applying the force. In the second trial, you were able to watch the graph. Did you observe any differences between the trials? If you did, what do you think accounts for the differences? Explain your thinking.

Answers will vary. One group answered as follows: Some people in our group had steadier, more even force data when they could not watch the graph and others had steadier, more even data when they could watch the graph. We think the people who had steadier data in the first trial were able to concentrate very well, and also maybe had tired finger muscles by the time they did their second trial. We think the people who had steadier data in the second trial were helped somehow by being able to see the graph and knowing when they were pressing too hard or soft on the force sensor, so they could adjust the strength of their pushing.

3. Describe what the arteries, veins, and skeletal muscles of your hand and fingers were doing while you were applying the steady force on the force sensor.

Answers will vary. Students should suggest that the arteries were supplying oxygen and nutrients to the muscles, the veins were carrying away waste products, and the muscles were contracting.

4. Muscles store energy for use after the supply of blood-delivered energy is completely used up. Each muscle cell contains an energy "reserve" of glycogen, a substance which must be broken down in order to be used by the muscle. What evidence do you have in your data to indicate that your muscles may have begun to use their energy reserves during this activity? Explain your thinking.

Answers will vary. One group answered as follows: In the second trial of our force data, we noticed that the graphs for some people got quite uneven toward the end of the 60 seconds. The unevenness leads us to believe that it was difficult for these people to keep pushing the rubber bumper and it got harder for them to do as time went on. In fact, on the second trial, one person could not keep pushing for the entire 60 seconds and stopped early. We think that these people's muscles may have run out of energy from the blood vessels and then maybe had to begin using their stored energy reserves.

5. Muscle fatigue is the inability of a muscle to contract, even when you want it to do so. Recall your experience of pushing on the force sensor. Discuss this with the members of your lab group. Was there a point at which you felt it was difficult to control the muscles in your index finger? Describe how the muscles in your finger and hand felt.

Answers will vary. One group answered as follows: We all found it very difficult to maintain the same amount of force on the force sensor throughout the 60 seconds, especially on the second trial. We found that our entire hand was getting tired and especially our index fingers. Our fingers began to waver a little and we could not keep them steady. No one's thumbs actually got a cramp in them, but it seemed imaginable that if we had kept on pushing the force sensor for very much longer, we would have got a cramp in our fingers or hands.

6. Why was it important to adjust the scale of the graph during your analysis of the data? At what scale does the force data appear to look steadiest? At what scale does the force data appear to look least steady?

Answers will vary. Students should suggest that at a greater scale the data appear steadiest and at a closer scale the data appear least steady. It is important to adjust the scale to be able to see the variations in the amount of force applied over time.

7. Review the data for each lab group member again. �(7.1.7) What was the maximum variation in force data for each lab group member? By how many newtons did the force vary from the greatest force applied to the least force applied during a particular run of data?

Answers will vary. One group answered as follows: In our group the maximum variation was 9.7 newtons between biggest and smallest force for one person. The other variations were 7.8 newtons, 6.5 newtons, and 6.2 newtons.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. Bones are moved by the________________________of skeletal muscles.

   A. Extension
   B. **Contraction**
   C. Metabolism

2. Muscle fatigue is:

   A. **The inability of a muscle to contract when you want it to do so**
   B. The inability of muscle cells to contain stored energy reserves
   C. The result of the circulatory system failing to carry off waste products

3. Force, in the SI system, is measured in:

   A. **Newtons**
   B. Kilograms
   C. BTUs

4. In order to function correctly, muscles need an adequate supply of:

   A. Work to be done
   B. Nerves
   C. **Energy**

5. A muscle cramp happens when the muscle:

   A. Involuntarily relaxes and cannot contract
   B. **Involuntarily contracts and cannot relax**
   C. Voluntarily contracts and cannot relax

6. Skeletal muscles are connected to bones by:

   A. Nerves
   B. **Tendons**
   C. Many different types of connective tissue

7. Which organ system in the human body is responsible for providing structure as well as supporting and protecting the organs?

   A. The muscular system
   B. The cardiovascular system
   C. **The skeletal system**

8. Which of the following are most likely to be susceptible to muscle fatigue?

   A. Tibia, femur, clavicle, cranium
   B. Aorta, femoral artery, capillaries, pulmonary artery
   C. **Triceps, biceps, deltoid, latissimus dorsi**

True or False

Enter a "T" if the statement is true or an "F" if it is false.

___T___ 1. Skeletal muscles can become fatigued when they need more energy than is available to them.

___F___ 2. Most of the time, muscle cramps are completely painless.

___T___ 3. Muscles need both oxygen and nutrients to function properly.

___T___ 4. Muscle fatigue can occur during prolonged periods of exertion.

___F___ 5. Once skeletal muscles become fatigued, they easily obey nerve signals from the brain to voluntarily contract.

Further Investigations

Design an experiment to investigate which of your fingers is able to exert a force for the longest amount of time before experiencing muscle fatigue. Are the fingers of your dominant hand stronger than those of your non-dominant hand? Which finger is weakest?

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

6. Photosynthesis

Dining By Light

Objectives

In this activity, students investigate the rate of photosynthesis in an aquatic plant using an absolute pressure sensor and a light sensor while they:

- Explain the process of photosynthesis
- Describe the factors that affect the rate of photosynthesis

Procedural Overview

Students gain experience conducting the following procedures:

- Setting up the equipment and work area to measure the change in light and pressure in an aquatic ecosystem as an *Elodea* or other aquatic plant undergoes photosynthesis.
- Measuring the changes in pressure, temperature, and light in the *Elodea's* environment throughout a cycle of light and dark.

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Equipment setup, Part 2 – Making predictions	50 minutes
■ Lab activity, Part 3 – Measuring the changes that indicate photosynthesis	24 hours
■ Analysis	50 minutes

Materials and Equipment

For each student or group:

- ☐ Data collection system
- ☐ Light sensor
- ☐ Absolute pressure sensor with quick release connector and plastic tubing
- ☐ Sensor extension cable
- ☐ Beaker, 400 to 600 mL
- ☐ Clear or translucent funnel[1]
- ☐ Clay, modeling (golf ball-sized piece)
- ☐ Baking soda, 1/4 tsp.
- ☐ *Elodea* (sometimes called *Anacharis*), 3 to 4 sprigs
- ☐ Measuring spoons
- ☐ Water, distilled, 400 mL

[1] The circumference of the funnel's outer rim should be approximately the same as the inside of the beaker, so as to fit inside the beaker

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- Processes of photosynthesis and respiration
- Identification of plant structures and understanding of their functions

Related Labs in This Guide

Labs conceptually related to this one include:

- Transpiration
- Bag an Ecosystem

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting multiple sensors to the data collection system �(2.2)
- Changing the sampling rate �(5.1)
- Adjusting the scale of a graph �(7.1.2)
- Displaying multiple variables on the y-axis of a graph �(7.1.10)
- Saving your experiment �(11.1)

Background

During photosynthesis, pigments in a plant's chloroplasts absorb light energy. In the chloroplasts, the light energy is used to split water molecules into hydrogen and oxygen gases. This happens during the light-dependent reaction. At this point, the oxygen is given off as a byproduct. The hydrogen combines with carbon dioxide to form glucose during the light-independent reaction. The chemical equation for this entire process is:

$$6\ CO_2 + 6\ H_2O + \text{light energy yields} \rightarrow C_6H_{12}O_6 + 6\ O_2$$

A plant uses glucose for food and to make cellulose for its cell walls. The excess glucose a plant makes is stored in the roots and is available as an energy source to other organisms that may eat it.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Ask students the following questions:

What is photosynthesis?

Photosynthesis is the process by which plants make food using water, carbon dioxide and light energy.

Where does photosynthesis take place?

Photosynthesis takes place in the chloroplasts in a plant's leaves.

What is a chemical reaction?

During a chemical reaction, one or more substances are changed into new substances with different properties.

What materials does a plant need for photosynthesis?

A plant needs carbon dioxide, water, and light energy to undergo photosynthesis.

What materials are produced during photosynthesis?

Plants produce glucose and oxygen during photosynthesis.

What are the two stages of the photosynthesis reaction?

In the light reaction, a plant takes light energy and splits water into hydrogen and oxygen. The oxygen is given off and the hydrogen is used during the dark reaction. During the dark reaction, the plant takes the hydrogen and combines it with carbon dioxide to produce glucose.

Direct the students to "Thinking About the Question." Discuss the answers to these questions as a whole group.

Direct the students to "Investigating the Question."

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- *Elodea* is an aquatic plant that is commonly used in fresh water aquariums and can be found at most pet stores. If it is not available, any aquatic plant that is small enough to fit underneath the funnel will do.
- If you plan to run the experiment over a 24-hour period, make provisions for plugging in the data collection systems. If you do not want to run the experiment overnight, place a box that is large enough to cover the entire apparatus over it to simulate nighttime.
- Connect the absolute pressure sensor to the quick release connector and the plastic tubing for each student or group. A drop of glycerin will help fit the tubing.
- Changes in the pressure will occur more quickly if the funnel is filled with water as much as possible

Safety

Add this important safety precaution to your normal laboratory procedures:

- Students should wear goggles and an apron when working with glassware.

Driving Question

What is photosynthesis?

Thinking about the Question

What is photosynthesis?

Photosynthesis is the process by which plants make food using water, carbon dioxide, and light energy.

When do plants carry out the process of photosynthesis? Is there a particular time of day where they are likely to be more actively involved in photosynthesizing than at other times? Is there any way to tell by looking at a plant that it is carrying out this process? Discuss these questions with your lab group members. Be prepared to share your thoughts with the rest of the class.

Students should suggest that plants are more apt to be photosynthesizing when there is light available, as light is the form of energy converted by plants to chemical energy. Students may suggest that there is no way to tell by looking at a plant whether or not it is photosynthesizing.

In this lab activity, you will measure the change in the pressure of a closed system as well as the amount of light available to the aquatic plant in the system to gather evidence of photosynthesis.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

2	1	5	3	4
Place 400 mL of distilled water and 1/4 teaspoon of baking soda in a beaker.	Make certain that each member of the lab group is aware of safety rules and procedures for this lab.	Use clay to seal the pressure sensor to the opening of the funnel.	Position a sprig of *Elodea* in distilled water in a beaker.	Invert and submerge a funnel in the beaker so it covers the *Elodea*.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Equipment setup

1. ☐ Start a new experiment on the data collection system. �(1.2)

2. ☐ Connect an absolute pressure sensor and a light sensor to the data collection system. �(2.2) Use a sensor extension cable to connect the absolute pressure sensor.

3. ☐ Display Absolute pressure and Light Intensity on the y-axis, with Time on the x-axis in a graph display. �(7.1.10)

4. ☐ Change the sampling rate to take one absolute pressure and light measurement every 30 minutes. �(5.1)

5. ☐ What is the reason for using the absolute pressure sensor in this experimental setup?

   Pressure is being used as an indication of the oxygen given off by a plant. The more oxygen the plant produces, the more oxygen molecules are present in the container which increases the pressure.

Part 2 – Making predictions

6. ☐ Record your prediction about what will happen to the pressure inside the container holding the aquatic plant during the period when it is light. Explain your reasoning.

   Answers will vary. One student group answered as follows: We predict that the pressure in the plant's container will increase when it is light because plants carry out photosynthesis in the presence of light. If the plant is photosynthesizing, we should see an increase in pressure due to the production of oxygen.

7. ☐ Record your prediction about what will happen to the pressure inside the container holding the aquatic plant during the period when it is dark. Explain your reasoning.

   Answers will vary. One student group answered as follows: We predict that the pressure in the plant's container will decrease when it is dark, because the plant will not carry out photosynthesis in the dark. Therefore, we should see a decrease in pressure due to the lack of production of oxygen.

Part 3 – Measuring the changes that indicate photosynthesis

8. ☐ Add 1/4 teaspoon of baking soda to 400 mL of distilled water in a beaker. What is the function of the baking soda?

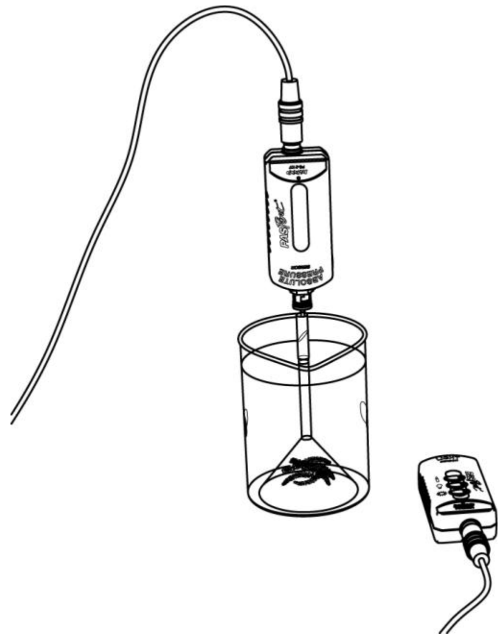
   The function of the baking soda is to provide the *Elodea* with carbon dioxide.

9. ☐ Place 3 or 4 sprigs of *Elodea* or other aquatic plant on the bottom of the beaker and set the beaker where it will receive direct sunlight.

10. ☐ Invert the funnel in the beaker and allow it to rest on the bottom of the beaker so it covers the plant, and the water fills up the funnel and stem of the funnel.

11. ☐ Connect the absolute pressure sensor tubing to the stem of the funnel. Create a seal between the plastic tubing and the funnel stem by wrapping some clay around the joint and pressing it firmly to seal it. Why do you think it is important to have a good seal between these parts of the apparatus?

The clay makes sure the seal is intact between the end of the funnel and the absolute pressure sensor tubing. This is important because leaks or gaps would prevent the pressure sensor from measuring changes in the pressure.



12. ☐ Place the light sensor so it is facing the window or other source of sunlight.

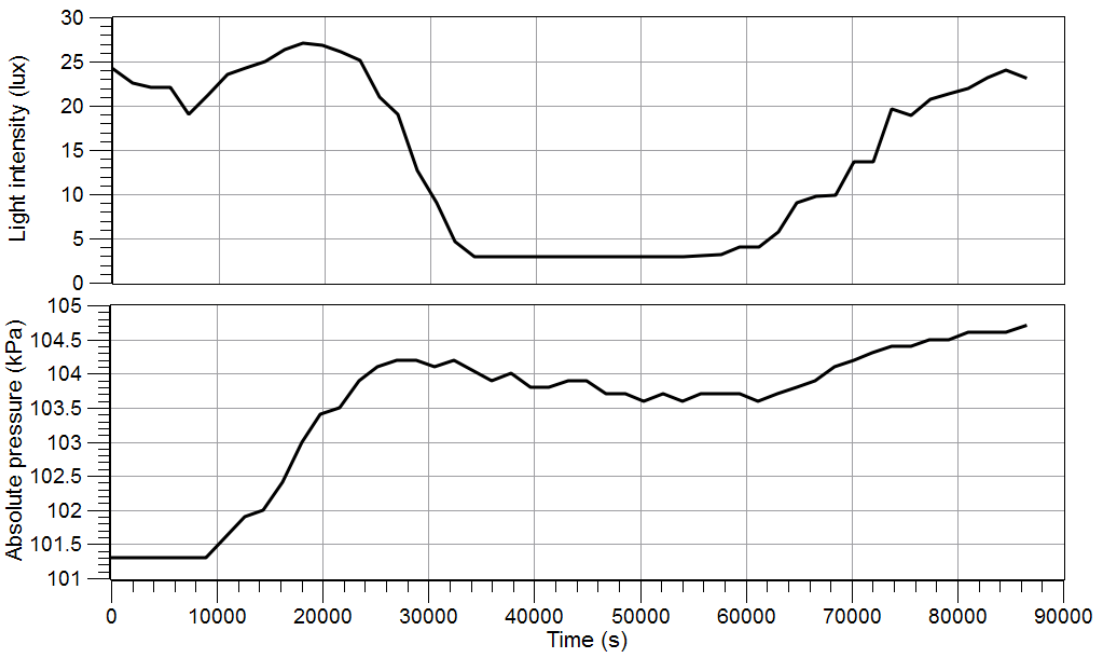
13. ☐ Start data recording. �(6.2)

14. ☐ Record data for at least a 24 hour period to see the effects of the plant being in the dark as well as the light.

15. ☐ At the end of the 24-hour time period, stop data recording. �(6.2)

16. ☐ Save your experiment according to your teacher's instructions.

Sample Data



Answering the Question

Analysis

1. Looking at your data, did the plant undergo photosynthesis during the night (dark)? Suggest reasons for this observation.

The plant did not undergo the photosynthesis reaction that changes water molecules into hydrogen and oxygen during the night. The pressure leveled off during the hours of darkness indicating that the plant was not giving off oxygen anymore.

2. How did your prediction compare to the actual pressure data recorded during the day (light)?

Answers will vary. One student group answered as follows: The pressure increased during the day hours as we predicted it would due to the production of oxygen gas. However, the change in pressure was not as much as we thought it would be.

3. How did your prediction compare to the actual relative pressure data during the night (dark)?

Answers will vary. One student group answered as follows: The pressure stopped increasing during the night hours, which we predicted would happen. It did not decrease as much as we thought it would.

4. What happened to the relative pressure during the dark? Suggest reasons for this observation.

The relative pressure leveled off during the dark. The plant no longer had light for carrying out photosynthesis so it was not giving off oxygen anymore. The system was sealed so the pressure did not decrease during this time.

5. Describe what occurs during the process of photosynthesis.

Plants create glucose as a part of a chemical reaction. They combine carbon dioxide and water using light energy to produce glucose and oxygen.

6. Review your data. You may need to adjust the scale of your graph. �(7.1.2) How fast did the aquatic plant undergo photosynthesis during the light? How fast did it undergo photosynthesis during the dark? Suggest reasons for this observation.

Answers will vary. One student group answered as follows: We noticed that as soon as the light intensity got to its lowest point, the pressure began to level off almost at the same time. The graph of light and the graph of pressure have very similar trends. This evidence suggests that the plant needed the light to photosynthesize, and as soon as the light was gone, it stopped the process almost immediately.

7. What are the two major factors that affect the rate of photosynthesis?

The biggest factors affecting the rate of photosynthesis are the amounts of water and light.

8. What would life be like if organisms did not undergo photosynthesis?

Animals, including humans, would not be able to survive since there would not be enough oxygen to breathe. Photosynthetic organisms capture the sun's energy and make that energy available to consumers. Without plants, consumers would eventually die off due to lack of food.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. Photosynthesis is a chemical reaction that:

   A. **Converts light energy to chemical energy**
   B. Converts chemical energy to light energy
   C. Converts heat energy to chemical energy
   D. Converts light energy to heat energy

2. In photosynthesis, energy is stored in the form of:

   A. **Glucose**
   B. Oxygen
   C. Water
   D. Carbon dioxide

3. Which of the following is NOT used in the overall reaction for photosynthesis?

   A. Carbon dioxide
   B. **Oxygen**
   C. Water
   D. Light

4. In a typical plant, all of the following factors are necessary for photosynthesis except:

   A. Chlorophyll
   B. **Sugar (glucose)**
   C. Water
   D. Carbon dioxide

5. In many plants, excess glucose is stored in:

   A. The stem
   B. **The roots**
   C. The leaves
   D. The flowers

6. Photosynthesis takes place in a plant's:

   A. Mitochondria
   B. Vacuoles
   C. Ribosomes
   D. **Chloroplasts**

Further Investigations

What effect would a higher intensity light have on the rate of photosynthesis?

What effect would a lower intensity light have on the rate of photosynthesis?

Design and conduct an investigation to see what wavelength of light produces the highest rate of photosynthesis. Check your design with your teacher before beginning the investigation.

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

7. Recovery Heart Rate

It's Fun to be Fit

Objectives

Students determine the effect of exercise on their heart rate and find their recovery heart rate, which is a measure of fitness.

Procedural Overview

Students gain experience conducting the following procedures:

- Using an exercise heart rate sensor to determine their resting heart rate, their heart rate with exercise, and their recovery heart rate
- Applying statistics (mean, median, and range) to data collected for the entire class and calculating the percentage change of their measured heart rates

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Making predictions	50 minutes
■ Lab activities, Parts 2a, 2b and 2c	50 minutes
■ Analysis	50 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Clock or timer with seconds displayed

For each student or group:

- ☐ Data collection system
- ☐ Hand-grip heart rate sensor
- ☐ Comfortable foot attire and exercise clothing
- ☐ Clock or timer with seconds displayed
- ☐ Damp paper towel (2)

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- Statistics (mean, median, and range)
- Circulatory system

Related Labs in This Guide

Labs conceptually related to this one include:

- Venous Blood Flow

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting a sensor to your data collection system �(2.1)
- Recording a run of data �(6.2)
- Displaying data in a graph �(7.1.1)
- Adjusting the scale of a graph �(7.1.2)
- Adding a note to the graph �(7.1.5)
- Finding the values of a point on a graph �(9.1)
- Viewing statistics of data �(9.4)
- Saving your experiment �(11.1)

Background

Heart rate is a term to describe the number of beats of the heart per unit of time. Usually it is calculated as the number of contractions (beats) of the heart in one minute and is generally expressed as "beats per minute" (bpm). When resting, the typical adult human heart beats at about 70 bpm in men and 78 bpm in women. Infants and children have higher heart rates.

Regular exercise affects the heart in two ways. Exercise increases the stroke volume, which means the heart pumps more blood with each beat. More blood flowing due to the increased stroke volume during exercise increases the muscle function. Exercise also lowers the resting heart rate.

Measuring the difference between the resting heart rate and the heart rate during exercise can give a relative indication of overall fitness level. Recovery heart rate is another measure of fitness. This refers to the heart's ability to return to a normal rhythm after being elevated during exercise. A fast return to the resting heart rate after exercise is another indicator of overall fitness.

There are various ways to determine the recovery heart rate. In this activity, the recovery heart rate is the heart rate measured 2 minutes after terminating exercise.

Pre-Lab Discussion and Activity

Measuring Heart Rate

Begin a discussion with students by asking them how they can tell how fast their hearts are beating. Since counting beats for an entire minute can be tedious, ask the students how they could determine beats per minute (bpm) more quickly. A convenient technique is to count for 15 seconds and multiply by 4.

Have students find their own heart rate. Explain to the students that it can be measured at different locations on their bodies. They can place the tips of their fingers on the carotid arteries of their neck (alongside the trachea), the temporal arteries at the sides of their head, or the radial arteries of their wrists and count the number of beats in 15 seconds.

Collecting Whole Class Data

After everyone has mastered the technique, do a whole class trial and have each student report their beats per minute as you record all results at the front of the room. If you have access to a computer, spreadsheet, and projector in the classroom, enter the values in a column of the spreadsheet and then use the spreadsheet software to sort the column of data. Normal pulse rate at rest is between 70 and 78 beats per minute. Initiate a discussion about the results.

Discuss Range, Median, and Mean

Probe for comments regarding the variation in the data. Introduce the terms range, median, and mean to the students. For range and median, it may be helpful to place the sample set of data on a number line (or use the sorted data on the spreadsheet). Locate the largest and smallest number and demonstrate finding the range by taking the difference between these two values. Explain that the median can be found by locating the exact middle of the data when it is placed in order as shown on the number line. (If there is an even number of data points, the average of the two in the middle is the median.)

Have the students find the sum of all of the numbers in the data set. Explain they can find the mean by dividing the sum by the number of data points in the set.

Effect of Exercise on Heart Rate

Ask what variables might change their individual heart rates. List their responses. At least one student will probably suggest that exercise is one possible variable. Suggest that they could investigate the effect of exercise on heart rate. Conduct a discussion on how that investigation should be designed. Depending on the prior experience of the class this might be done as a written group task or a whole class brainstorm.

The goal of the discussion should be to develop the understanding that if we want to find out the impact of exercise on heart rate all other variables must be held constant. It is best if this understanding is the result of their deliberations and testing. One option is to do an initial practice by having everyone run in place for one minute and immediately take their pulse.

Effect of Other Variables on Heart Rate

The results will probably vary more than they did on the initial trial at rest. This could lead to an exploration of possible other variables, such as how fast each child was running. One technique for controlling running speed might be to run to a predetermined rhythm. Direct the students to "Thinking about the Question". After a few minutes hold a class discussion for them to share their ideas about how daily physical and sports activity affects heart rate.

Note: Before students start the rest of the activity, demonstrate how to attach the heart rate clip to an earlobe or the web of skin between the thumb and index finger of one of your students and display collecting stable BPM data.

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- Tell students that if they feel pain or discomfort during the 3-minute exercise portion of this activity, they can stop exercising and continue with the next part of the procedure.
- Formulate a classroom management plan for this activity that will minimize potential disruption.
    - Inquire ahead of time (perhaps with the school nurse) whether any students should be excluded from participation due to medical or health issues.
    - Communicate behavior expectations clearly to students ahead of time.
    - Consider having groups of all girls or all boys.

Note: The exercise heart rate sensor is designed to provide accurate and reliable data for educational purposes. It is not intended for use as a medical instrument.

Safety

Add this important safety precaution to your normal laboratory procedures:

- Stop exercising if you become light headed or dizzy.

Driving Question

How does exercise affect your heart rate?

Thinking about the Question

Being physically fit means our bodies respond effectively to exercise. Repeated exercise strengthens heart muscle as it strengthens skeletal muscle. As a result, an athlete’s heart can pump more blood during each contraction. The more forceful beat allows longer exercise and faster recovery rates.

What is your daily level of physical and sports activity? Do you often become winded after climbing a set of stairs or running short distances? How long does it take for you to recover? Discuss with your lab group members the relationship between the level of your physical conditioning to your recovery rate after exercising. Do you feel that with daily exercise that you will decrease the amount of time needed to recover? Why?

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

2	1	5	3	4
Set up the data collection system with the heart rate sensor.	Make sure each lab group member is aware of safety rules and procedures for this lab.	Compare the different changes in your heart rate.	Measure your resting heart rate, running heart rate, and recovery heart rate.	Determine the length of time for your heart rate to return to the resting heart rate.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. Please make copies of these step-by-step instructions available for your students.

Part 1 – Making predictions

1. ☐ Write your predictions for the following:

   a. What do you think your resting heart rate will be while relaxing in a chair?

   Student answers will vary. Students should have a value close to what they collected while checking heart rate with their fingers. This should be around 70 to 75 beats per minute.

   b. How do you think your resting heart rate will change when you run?

   Student answers will vary. Students should predict a higher heart rate than the resting rate of 75 beats per minute. It could be in the range of 100 to 120 beats per minute.

   c. How long do you think it will take your heart rate to recover to its resting heart rate after exercising?

   Student answers will vary. Depending upon how well the students are conditioned, this could be from one to three minutes. Students will be using real data to compare their predictions.

Part 2a – Finding your resting heart rate

2. ☐ Start a new experiment on the data collection system. � (1.2)

3. ☐ Connect the hand-grip heart rate sensor to the data collection system. � (2.1)

4. ☐ Display Heart Rate in beats per minute (bpm) on the y-axis of a graph with Time in seconds (s) on the x-axis. � (7.1.1)

5. ☐ Adjust the scale of the graph to show all data. �(7.1.2)

Note: This activity is easier to do if one partner is in charge of recording data and keeping track of time while another partner is being measured.

Note: Once you begin to collect data, continue to collect data until the end of the experiment. Do not stop collecting data as you change activities.

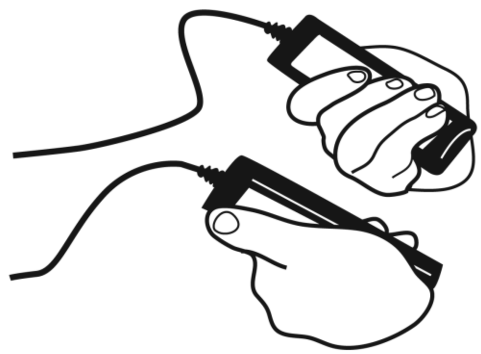
Note: During data collection, only one data point will be recorded every five seconds. It may take several seconds before the heart rate graph displays the actual heart rate value.

6. ☐ What is your control data point in this experiment?

The control is the average heart rate measured while at rest.

7. ☐ Grasp the hand grip sensors with both hands.

Note: Grasp the hand grips firmly but not too tightly in the palms of the hands so that one of the metallic sides of each grip is in the center of the palm. Measurements will be easier and more accurate if the hands are clean and dry.



8. ☐ Remind the person who is being monitored to stand relaxed and to remain as still as possible, and not to look at the data as it is recorded.

9. ☐ Why is the resting heart rate measured while standing still rather than sitting or lying down?

The heart rate is higher when standing still than it is when lying down or sitting, since the heart has to pump harder because of the effect of gravity. The running and recovery heart rates should be compared to the standing heart rate, since the effect of gravity will be the same for all of the measurements.

10. ☐ Start data recording. � (6.2)

11. ☐ Describe the graph for the first 60 seconds.

The graph does not change much. The readings are between 60 and 80 beats per minute.

Part 2b – Finding your running heart rate

12. ☐ After the 60 seconds is finished, the person being measured should run in place for three minutes (180 seconds) while data collection continues.

13. ☐ Describe your graph for this 180 second interval.

Depending on students' fitness, answer will vary. A likely heart rate is between 110 and 120 beats per minute.

Part 2c – Finding your recovery heart rate

14. ☐ The test subject should stop running and stand as still and relaxed as possible.

15. ☐ What is the unit of measurement that your data is being recorded in?

Beats per minute (bpm)

16. ☐ After 2 minutes of standing, describe the graph. This is the recovery heart rate. Record the value in Table 1.

Depending on fitness, answers will vary. A likely decrease would be to 80 or 90 beats per minute.

17. ☐ Continue collecting data until the test subject's heart rate returns to that person's initial resting heart rate. How long did this take? Record the time below.

Recovery time to return to the resting heart rate: 3.5 minutes

18. ☐ Stop data recording. � (6.2)

19. ☐ Add a note to the graph that says "recovery heart rate". � (7.1.5) It should point to the data point that occurred 2 minutes after the test subject stopped running.

20. ☐ If time allows, switch roles and repeat the procedure to allow another person in your group to be monitored.

21. ☐ Save your experiment � (11.1) and clean up according to your teacher's instructions.

Note: Wipe the hand-grip exercise sensor with a damp paper towel.

22. ☐ Use the tools on your data collection system to complete Table 1. � (9.1) (9.4)

Table 1: Heart rates

Condition	Heart Rate (bpm)
Resting heart rate (average)	76
Exercise heart rate (maximum)	123
Recovery heart rate (2 minutes after exercise stops)	71

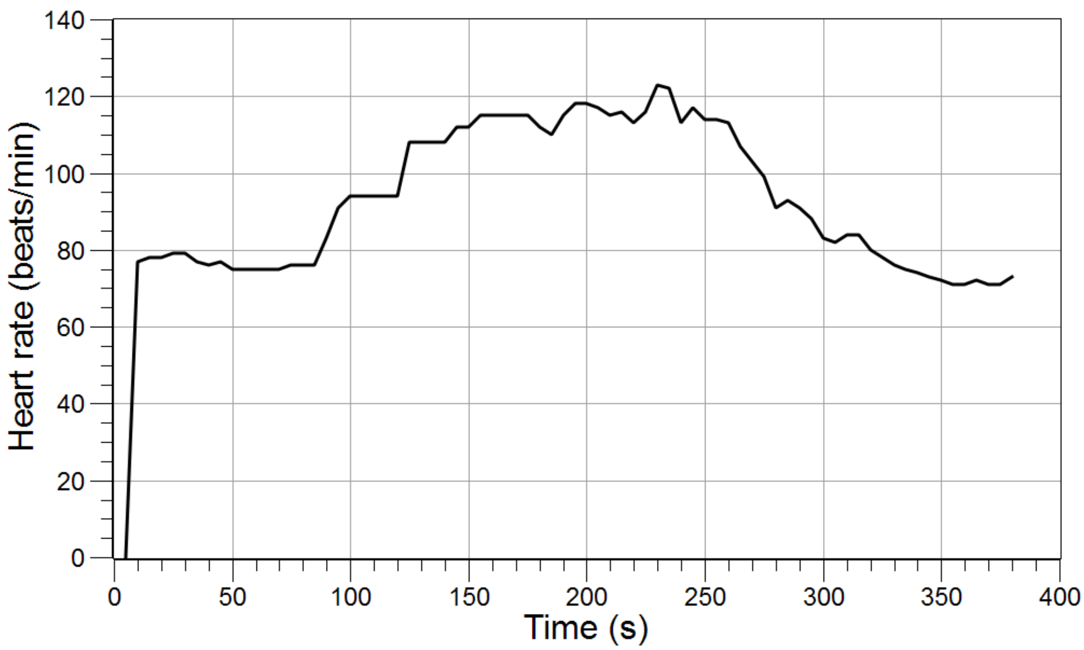
23. ☐ How does the resting heart rate compare with your prediction?

Student responses should be relatively close based on the previous measurements using their fingers to determine their heart rate.

24. ☐ How does your maximum exercise heart rate compare with your prediction?

Answers will vary about the comparison, but students should state that their prediction and the heart rate after exercising were both elevated significantly.

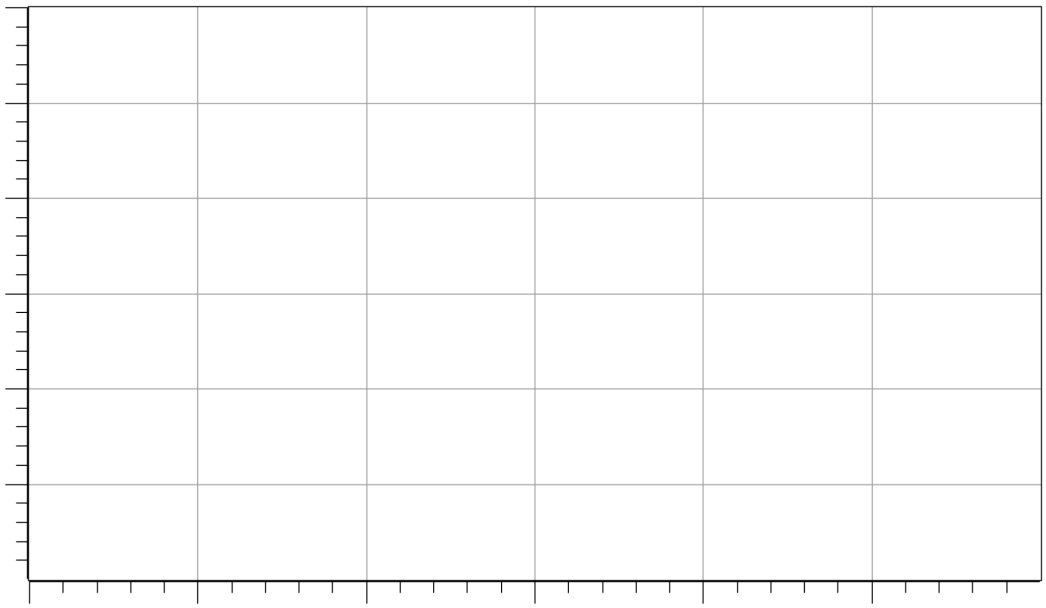
Sample Data



Answering the Question

Analysis

1. Sketch your graph of heart rate (bpm) versus time (s). Label the overall graph, the x-axis, the y-axis, and include a scale with units on the axes.



2. Observe your heart rate graph. How did the time compare between heart beats measured during rest and after exercise?

   Students should recognize that heart rate after exercising was more rapid compared to the resting heart rate. This means that time between beats for exercising heart rate was less.

3. Calculate the difference between your running heart rate and your resting heart rate. Show your calculations.

   Difference between maximum and resting heart rates: 47 beats per minute.

   123 bpm – 76 bpm = 47 bpm

4. What does this tell you about heart rate and exercise? Be prepared to share your answer with the class.

   Students should recognize that their heart rate increases significantly during exercise. They may also note that the rate of breathing increases during exercise. As one exercises, the heart needs to beat faster to provide the additional oxygen needed to support the increased demands on the body.

5. Calculate the percentage change in heart rate between the resting heart rate and maximum heart rate and between the resting heart rate and the recovery heart rate. The formula for calculating the percentage change is

$$\text{Percent Change} = \frac{|\text{Maximum or recovery heart rate} - \text{Resting heart rate}|}{\text{Resting heart rate}} \times 100$$

$$\text{Maximum heart rate percent change} = \frac{123\text{ bpm} - 76\text{ bpm}}{76\text{ bpm}} \times 100 = 61.8\%$$

$$\text{Recovery heart rate percent change} = \frac{|71\text{ bpm} - 76\text{ bpm}|}{76\text{ bpm}} \times 100 = 6.5\%$$

6. Using the graph, determine the length of time between your heart rate immediately after running and when your heart rate returned to resting rate level. This time period is called your recovery time.

Recovery time: 1.58 minutes

7. How did your actual recovery time compare to your prediction?

Depending on their conditioning, student answers may be higher or lower.

8. What does the maximum heart rate percent change and recovery heart rate percent change tell you about heart rate and exercise? Be prepared to share your answer with the class.

The greater the maximum heart rate percent change, the higher the exercise heart rate was. This might decrease with additional routine exercise.

The smaller the recovery heart rate percent change the quicker the heart rate returns to its normal rate, indicating that person may be used to routine exercise.

9. Interview your group members about their daily level of physical and sport activities. After sharing recovery times, write the relationship between the level of physical conditioning to recovery time.

Students should explain that recovery times are lower with students that experience regular physical conditioning and exercise. This will be especially evident with athletes.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. What is the average adult resting heart rate?

   A. Between 30 and 40 bpm
   B. **Between 72 and 78 bpm**
   C. Between 80 and 90 bpm

2. The range of a set of numbers is

   A. The sum of all the numbers divided by the number of the numbers
   B. **The difference between the greatest and smallest numbers of the set**
   C. The number in the middle of the set

3. The best place to measure your own pulse is

   A. On the radial arteries of your wrist
   B. On the carotid artery on your neck
   C. **Both of the above**

4. When a person is standing, the heart must do work against ___________in order to pump the blood.

   A. Veins
   B. Other muscles in the body
   C. **Gravity**

True or False

Enter a "T" if the statement is true or an "F" if it is false.

___T___1. The heart rate is typically higher when standing up than when lying down.

___F___2. Our bodies respond well to exercise when we are not physically fit.

___T___3. The amount of time it takes the heart to return to its resting heart rate after a period of exercise is related to a person's level of physical fitness.

___T___4. A more rapid heart rate allows the heart to provide more oxygen to the blood.

___T___5. Heart rate is recorded in units of bpm, or beats per minute.

___F___6. The heart, the veins, and the arteries are all part of the immune system.

Further Investigations

Complete a long-term study to improve your physical fitness. Interview your health teacher, science teacher, or personal physician to find out the exercises that help to improve cardiovascular circulation. Design and perform a daily exercise program for one month. If you have any physical restrictions, contact your personal physician to approve your plan. Record and compare your heart rate after exercise each day. Did your recovery time decrease after exercise as the month progressed? What other exercises would help to improve your cardiovascular condition?

Just as your heart rate can be elevated during exercise, humans and all mammals experience a depressed heart rate when chilled. Compare your rest and exercise heart rate to your heart rate after placing your hand in ice water. Note how your heart rate changes and how long it takes to return to your resting heart rate. How does your depressed recovery rate compare to your elevated recovery rate?

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

8. Seasonal Pond Exploration

Probing a Vernal Pool

Objectives

In this activity, students investigate conditions of a vernal pool (temporary pond). They collect data using the temperature and pH sensors, then compare and organize their information in simple tables or graphs to identify relationships found in a vernal pond.

Students investigate and observe life existing in a vernal pool while:

- Understanding that for ecosystems, the major source of energy is sunlight and that energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis
- Realizing that the number of organisms an ecosystem can support depends on the resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition
- Recognizing that substances often are placed in categories or groups if they react in similar ways, such as an acid or base
- Recognizing that heat can be transferred through a fluid
- Gaining skills and confidence in using scientific measurement tools—the temperature and pH sensors—as well as graphing capabilities of a computer to represent and analyze data

Procedural Overview

Students gain experience conducting the following procedures:

- Making and recording careful qualitative and quantitative observations and notes about a vernal pond
- Setting up equipment to measure temperature and pH over the course of a day in a vernal pond

Time Requirement

Introductory discussion and lab activity	25 minutes
Lab activity, Part 1 – Site assessment	50 minutes
Lab activity, Part 2 – Making predictions	25 minutes
Lab activity, Part 3 – Making measurements	Three 15 minute sessions on the same day
Analysis	50 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Mobile data collection system
- ☐ pH sensor
- ☐ Temperature sensor
- ☐ Buffer solutions to calibrate pH sensors

For each student or group:

- ☐ Mobile data collection system
- ☐ pH sensor
- ☐ Temperature sensor
- ☐ Hand lens

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- Vernal pools and ponds are seasonal, temporary bodies of water. They are unique ecosystems.
- The water cycle involves precipitation, evaporation, and condensation as it moves water through an ecosystem.
- The basics of using the data collection system in an outdoor or field environment.
- The pH scale and classification of substances as acidic, basic, or neutral.
- Identification of biotic and abiotic factors in the environment.
- Photosynthesis converts sunlight to energy in the cells of plants.

Related Labs in This Guide

Labs conceptually related to this one include:

- Exploring Environmental Temperatures
- Photosynthesis
- Water Cycle

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting multiple sensors to the data collection system �(2.2)

- Calibrating a pH sensor �(3.6)
- Changing the sample rate �(5.1)
- Recording a run of data �(6.2)
- Displaying data in a digits display�(7.3.1)
- Adjusting the scale of a graph �(7.1.2)
- Saving your experiment �(11.1)

Background

Organisms that live in vernal pools are adapted to survive in varied conditions. They must grow fast in the spring, reproduce, and leave their seeds in the ground. They have survival strategies that include migration and aestivation (summer dormancy). Having seeds, spores or cysts that come to life when the conditions are right is another adaptation that organisms that live in vernal pools have. This applies to non-plant creatures also, which leave eggs or pupae in the soil.

Watersheds are made up of all the land, lakes and tributaries drained by a particular stream or river. Watersheds range from a few acres drained by a tiny stream, to huge landmasses drained by major rivers like the Amazon, Nile and Mississippi. Studying the elements of watersheds is important because the water in a stream becomes a barometer of the health of its entire watershed. What occurs on land will eventually be reflected in the rivers, lakes, aquifers, and estuaries that drain the landscape.

Photosynthesis is the process used by plants and green algae to capture the energy of sunlight and use it to convert carbon dioxide (CO_2) and water to sugar and oxygen. The resulting sugar is energy rich and powers almost all life. When we or other organisms consume plants, we use this stored energy to power our own bodies.

Most organisms are adapted to specific pH ranges. Many organisms can only survive between a pH of 6 and 9. The pH of natural waters is also important because it controls chemical and biological processes. For example, pH determines whether nutrients and heavy metals are available to aquatic organisms. Very low pH values can dissolve metals that can harm fish and other organisms. Carbon dioxide makes water acid; its removal through photosynthesis can result in the water becoming less acid. This is why the pH in a vernal pool is usually highest in the daylight hours when photosynthesis occurs.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Ask students to identify changes that occur in a vernal pond throughout the year. Changes throughout the year include volume of water, the temperature of the water, the pH of the water, the oxygen concentration, the food availability, and the number of occupants.

Describe the vernal ponds that will be used for this activity. Have teams select their vernal pond for a site assessment. Discuss with them any special rules to which the students should adhere while at the site.

Direct students to "Thinking About the Question."

Explain to the students that a site assessment provides important information about the health of a body of water. When combined with the data obtained from sensors (temperature and pH), a site assessment provides a more complete picture of the system dynamics at the site.

Build in time for students to take a thorough look around and to record their observations before they start using their sensors. The data students collect with their sensors will not mean much if they do not have basic information about their site and the weather conditions. Furthermore, the observation period provides an excellent opportunity for students to develop and test their questions—a crucial part of the inquiry-based method.

Before directing students to "Investigating the Question", emphasize to the students that correct levels of temperature and pH are critical to life in water. Water temperature controls aquatic life cycles, such as reproduction and migration. Many animals and other organisms living in water depend on sufficient oxygen being dissolved in the water. Like most gasses, O_2 dissolves in cold water more readily than warm water. The pH determines whether organisms can function well or live at all. Most organisms are adapted to specific pH ranges. Many organisms can only survive between a pH of 6 and 9.

Finally, have the students review the graphical data from each measurement and select the temperature and pH for the morning, noon, and afternoon. Try to make the final reading as late as possible in the day. Allow time for the students to communicate and share their findings for different vernal pond sites.

Preparation and Tips

These are the appropriate preparations prior to the lab.

1. You should scout out vernal pools in advance to identify possible test sites. Check for any hazards including poison ivy, poison oak, steep banks, and potentially dangerous animals such as snakes, spiders, et cetera.
2. Since students need to take measurements throughout the same day, this may require a full-day field trip or sites within walking distance of the school. However, if such a trip is not possible, arrange to leave a data collection system at the site, collecting data throughout the day. If you do this, you will need to change the sampling rate to take a data measurement once per minute. �(5.1)
3. Before going to any body of water, discuss field trip procedures and guidelines. Explain the importance of not disturbing or polluting the ecosystem at the site.
4. Remind students to wear proper shoes and other appropriate clothing because they may need to wade into the water to obtain many of the readings.
5. Whatever the locations or locations, be prepared for the rain. Bring rain gear and protective plastic for your sensors and mobile data collection system.
6. Because you are collecting environmental data, it is important to calibrate the pH sensors �(3.6) before their use. You may want to add a pre-lab activity where you walk the students through calibration in the classroom. Either you or the students will need to calibrate the sensors in the field. If students will be using the Xplorer GLX as the mobile data collection system, and turn the GLX off and turn it back on, if they do not use a saved file, they will have to recalibrate each time.

Safety

Add these important safety precautions to your normal outdoor class procedures:

- Before going to any body of water, discuss field trip procedures and guidelines. Explain the importance of not disturbing or polluting the ecosystem at the site.
- Remind students to wear proper shoes and other appropriate clothing because they will need to wade into the water to obtain many of the readings. Parents should sign proper permission slips that are filed with the school administration.

Driving Question

How can life exist in a vernal pool?

Thinking about the Question

If you are walking or hiking on a spring day, you may see many wet places. Many of these wetlands are called vernal pools. Vernal pools are depressions that hold winter and spring rain, but remain dry for the rest of the year. These temporary ponds may seem inhospitable to life, but many plants, as well as amphibians and invertebrate animals, are adapted to this wet-dry cycle.

If you look closely you will see many arthropods, which include insects, spiders, and fairy shrimp.

Discuss with your partners the changes that occur in a vernal pond throughout the year.

> Student answers may vary, but some suggestions will be that the ponds dry out in the late spring, turn to mud, and are dried up by the summer. Where water once was, grasses and other plants may then grow. Students may point out that at the driest times of the year, it may not be obvious or even apparent that there was ever water in these ponds. As soon as the rains come again, the ponds convert back to holding water, and some of the grasses or other plants may be covered up or even die. During the winter, the pond may even freeze over.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

2	1	5	3	4
Locate a suitable vernal pond to study.	Make certain that each lab group member is aware of the safety rules and procedures for this lab.	Compare your observations and findings with others in your class.	Connect temperature and pH sensors to your data collection system.	Record the temperature and pH of the vernal pond's water at three times during the day.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Conducting a site assessment

1. ☐ Choose a vernal pool site according to your teacher's instructions.

2. ☐ Conduct a site assessment. Be sure to note any special conditions that occur at your site.

3. ☐ Record your site assessment of the vernal pond you investigated.

   Vernal Pond Site Assessment Student answers will vary. One student group answered as follows:

Name Dry Creek Pond

Country United States

State California

Town Roseville

Watershed American River

Date March 26, 2009

Weather:

Today's weather Partly sunny, temperature 8°C, no wind

Past two days Rainy and windy the past two days

What the water looks like:

What color is it? Brownish-clear

Is there an oily film on it? No film on it

Is there any algal growth? Some algae near the edges

Do you smell any chemicals? No smells of chemicals

What the vernal pond looks like:

Is it rocky? There is some gravel on the bottom.

Is it sandy? There is mostly sand and clay on the bottom

What habitats are available for animals and plants in the water? At the edge there are boulders, and there is lots of tall grass.

What the surrounding area looks like:

Are there shrubs, grass, softwood trees, or hardwood trees along the water? Grass, blackberry bushes, poison oak, and oak trees and pine trees

Is there any vegetation at all? There is a lot of vegetation.

Is the bank surrounding the vernal pond eroding? There is a little foot path where people or animals walk to the edge, where there is some erosion of the bank.

What does the land in the area get used for?

Cropland? ______________________________

Grazed pasture? _________________________

Housing? ______________________________

Industry? It is used for a city park, bike path, school grounds, and a green belt.

Part 2 – Making predictions

4. ☐ Predict how you think the temperature of your site will change throughout a day. Explain your reasoning. Be prepared to share your thoughts with the class.

   Answers will vary. One student group answered as follows: We predict a slightly cooler temperature in the water than in the air, especially in the morning. We predict that the air temperature will increase throughout the day, to maybe as much as 10 degrees Celsius warmer in the afternoon. We predict that the water temperature will not increase as much as the air temperature, but will warm up by some measureable amount.

5. ☐ Predict how you think the pH of your site will change throughout a day. Explain your reasoning. Be prepared to share your thoughts with the class.

   Answers will vary. One student group answered as follows: The vernal pool will be slightly basic due to the local bedrock.

Part 3 – Making measurements

6. ☐ Start a new experiment on the data collection system. �(1.2)

7. ☐ Connect the pH and temperature sensors to the data collection system. �(2.2)

8. ☐ Display pH and temperature in a digits display. �(7.3.1)

9. ☐ Change the number of digits with which pH data is displayed to two digits past the decimal point. �(5.4)

10. ☐ Change the sample rate to 1 sample per second. �(5.1)

11. ☐ Carefully place the pH and temperature sensors into the pool, making sure that the tip of each sensor is immersed in the water. Do not wade into the water unless your teacher has instructed you to do so.

12. ☐ Start data recording. �(6.1)

13. ☐ After the readings have stabilized, stop data recording. �(6.1)

14. ☐ Take pH and temperature measurements three times throughout the day, each time following the same procedure as you did in the previous steps.

15. ☐ As you measure the pond's temperature throughout the day, record these values below:

Morning: 8.43 °C

Noon: 9.58 °C

Afternoon: 10.45 °C

16. ☐ As you measure the pH throughout the day, record these values below:

Morning: 7.31

Noon: 7.34

Afternoon: 7.37

Answering the Question

Analysis

1. How do your results from Part 3 compare to your predictions in Part 2? Are your results close to what you expected? Why or why not?

Student answers will vary. One student group answered as follows: We predicted that the water in the pond would warm up, and it did. The temperature increased by just over 2 degrees Celsius from the morning to the late afternoon. It was sunny for most of the day today, which means that the sun's energy was absorbed by the pond's water. The pH was a little above 7, meaning that it is basic. The pH increased very slightly (by 6 one-hundredths).

2. How will conditions in the vernal pool be affected by a storm?

Student answers will vary. One group answered as follows: If it rains during the storm, the water level in the pond will increase. The water that drains into the pond from the surrounding area may add pollutants such as fertilizer, oil, or pollen that was on the ground or plants. If the rain is acidic, adding rain water would make the pond's water less basic. If the rain is neutral, it could still change the pH of the pond by diluting it. It would be good for the aquatic organisms to have rain to keep water in the pool, so they could have longer to grow and reproduce.

3. How will conditions change as the season progresses?

Student answers will vary. One group answered as follows: As summer approaches, the pool will dry up due to increasing temperatures. The warming temperatures will evaporate the water, and there will soon be just mud. Then, even the mud will dry up. By the time this happens, the tadpoles will have grown into frogs. A vernal pool is like an incubator for young tadpoles. Flowers will grow and blossom, because the soil is still moist where the pond was.

4. From information gathered at your vernal pool, what particular animal and plant life survive in specific conditions (for example, high pH, high temperature, et cetera.)?

Student answers will vary. One group answered as follows: As the temperature increases throughout the spring, the pool will dry up and the toads and frogs will leave their temporary home. There is algae that prefers certain times of the year, for example there is more algae in the water as it begins to warm up and evaporate. There is almost no algae in the winter just as the pond is freezing around the edges. Grass and flowers survive best when there is some moisture and the temperatures are warmer, but they die when it is too hot and the soil has dried out, or when it is too cold and the frost kills them.

5. The term "vernal" comes from the Latin word for the season of spring. What evidence from your investigation supports spring as an important season in the life cycle of this ecosystem?

Student answers will vary. One group answered as follows: In the spring, the most biotic factors can be found in our vernal pond. For example, we saw at least seven different types of arthropods, including some spiders, and some insects such as dragonflies and water striders. We saw tracks of a mammal in the mud leading up to the pond, which we think was a raccoon or a cat. We also saw some mollusks, which were snails and slugs. At the edge of the pond are three different kinds of flowers blooming at the same time, and the seeds of others that have already bloomed. The leaves of all the plants are green, so the plants are photosynthesizing and turning sunlight into energy.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. Which measurement describes a pond's level of acidity?

   A. Temperature
   B. **pH**
   C. Dissolved oxygen

2. The sun's energy is captured by plants and converted into chemical energy during the process known as:

   A. **Photosynthesis**
   B. Neutralization
   C. Transpiration

3. Which of the following is *not* an abiotic factor of a vernal pond?

   A. Amount of sunlight
   B. **Algae**
   C. Sand, gravel, and clay

4. A vernal pool that forms a habitat for many organisms is most likely to have a pH in the range of:

   A. pH 3 to pH 5
   B. pH 9 to pH 12
   C. **pH 6 to pH 8**

5. What is the original source of all of the energy available to the organisms that live in or near a vernal pond?

   A. The type of bedrock or soil that forms the pond
   B. The amount of dissolved oxygen in the water
   C. **The sun**

True or False

Enter a "T" if the statement is true or an "F" if it is false.

___T___ 1. Biotic factors in an ecosystem are those that are living.

___F___ 2. A vernal pond changes very little with the seasons.

___T___ 3. Vernal ponds are dependent upon rainfall for most of their water.

___F___ 4. Every species of organism that lives in a vernal pond is microscopic.

___T___ 5. It is possible for the pH in a vernal pond to be too high or low for all organisms to survive.

___F___ 6. One factor that has no effect on the ecosystem of a vernal pond is the temperature at the hottest part of the day.

___F___ 7. A storm would probably have no effect on the conditions in a vernal pond.

___T___ 8. Vernal ponds can be home to a variety of plants and animals.

Further Investigations

Complete a long-term study of a vernal pool throughout the spring or fall season. How do the plant life, animal life, and conditions differ from the beginning to the end of the season?

Locate a second vernal pool. How does the plant and animal life differ between pools? Compare temperature and pH in both pools. What accounts for any differences in the two pools?

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

9. Sunlight and Photosynthesis in Aquatic Plants

Bag an Ecosystem

Objectives

Students investigate the process of photosynthesis in an aquatic ecosystem. They use their pH data to demonstrate the relationship between photosynthesis and light. They also:

- Understand that for ecosystems, the major source of energy is sunlight and that energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis

Procedural Overview

Students gain experience conducting the following procedures:

- Collecting data using the pH sensor
- Organizing data in simple tables or graphs to identify pH patterns related to light
- Identifying dependent and independent variables

Time Requirement

Introductory discussion and lab activity, Part 1 – Making predictions	75 minutes
Lab activity, Part 2 – The effect of photosynthesis on the pH of an ecosystem	50 minutes (data is collected for 24 hours)
Analysis	50 minutes

Materials and Equipment

For each student or group:

- ☐ Data collection system
- ☐ pH sensor (2)[1]
- ☐ Plastic bags (2), 500-mL or 16-oz, sealable
- ☐ Graduated cylinder, 250-mL
- ☐ Aquatic snails (2)[2]
- ☐ Aquatic plants (2) such as *Elodea*
- ☐ Fluorescent lamp
- ☐ Aluminum foil, 15 in. x 15 in.
- ☐ Stream or pond water, 500 mL
- ☐ Marking pen

[1]To calibrate the pH sensor, use 10 mL each of the standard buffers, pH 4 and pH 10.

[2]If you can, obtain these from your local environment.

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- Photosynthesis is the conversion of light energy into chemical energy by living organisms.
- A chloroplast is a cell inside a green leaf where photosynthesis takes place.
- Sugar is a type of molecule that stores chemical energy.
- The pH scale has a range of 0 to 14, with 7 being neutral.
- A substance with a pH below 7 is classified as an acid, while a substance with a pH above 7 is classified as a base.
- The lower the pH, the stronger the acid, and the higher the pH, the stronger the base.

Related Labs in This Guide

Suggested Prerequisite:

- Introduction to Acids and Bases

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting multiple sensors to the data collection system �(2.2)
- Calibrating a pH sensor �(3.6)
- Changing the sample rate �(5.1)
- Monitoring live data without recording. �(6.1)
- Starting and stopping data recording �(6.2)
- Displaying data in a graph �(7.1.1)
- Adjusting the scale of a graph �(7.1.2)
- Displaying two data runs in a graph �(7.1.3)
- Saving your experiment �(11.1)

Background

In an aquatic environment, whether a pond or an ocean, photosynthesis in aquatic plants adds oxygen (O_2) to water. During photosynthesis, sunlight converts water (H_2O) and carbon dioxide (CO_2) into sugar: $C_6H_{12}O_6$. The sugar contains less oxygen per hydrogen and carbon atom than the initial water and carbon dioxide. This excess oxygen is returned to the water as oxygen gas (O_2). The rate at which oxygen is added to the water by photosynthesis depends on the amount of sunlight that reaches the plant. The process of photosynthesis can be written as

$$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

Oxygen is removed from water by plant and animal respiration (fish and other animals need oxygen to live). Aerobic bacteria require oxygen to decompose organic material. Plants require oxygen when they convert the sugar they have stored into energy to fuel their growth. The process for respiration is as follows:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

Cellular respiration occurs 24 hours a day in plants. However, under lighted conditions, photosynthesis also occurs and uses CO_2 faster than cellular respiration produces it. The net effect during lighted conditions is a decrease in the concentration of CO_2 in water. In the dark, however, the CO_2 concentration in the water increases, which then increases the concentration of carbonic acid in the water and lowers the pH.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Initiate a discussion with students about changes they may have noticed or would expect from day to day or during the day in an aquatic environment. They will probably discuss changes such as those in appearance due to changes in temperature and light.

Direct students to "Thinking about the Question." Ask students to share with the class the concept maps they create with their groups. Then draw a class concept map that includes the gas exchange between the plants and animals.

Based on the class concept map, ask the students to answer the following questions. What evidence have you observed that plants consume carbon dioxide? What evidence have you observed that animals produce carbon dioxide? What evidence have you observed that light affects how plants produce carbon dioxide? What does the pH of a solution indicate about the amount of dissolved carbon dioxide in the water?

At this point in the activity, students will likely have little, if any, evidence of these processes.

Discuss briefly the idea of independent and dependent variables. An independent variable is an experimental factor that scientists control and a dependent variable is a factor that changes based on a change in the independent variable. For this activity, the independent variable is the light (students control whether the plants are in the light or in the dark) and the dependent variable is the pH, which changes based on the presence or absence of light.

Direct students to "Investigating the Question."

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- Take a trip to a local pond and collect pond water. Look for *Elodea*, duck weed, or other aquatic plants with roots.
- Snails and aquatic plants are also easily obtainable from a local aquarium store, if not available in a local pond.
- Data is collected for 24 hours, so this activity might be best done as a demonstration that runs in the background while the class carries on with other work. Data is collected and displayed in a graph. Students can use this data the next day to complete the activity.
- Alternatively, students can be put into larger groups if necessary (2 pH sensors are needed per group) and collect their own data the next day in class. Be sure students place their "ecosystems" and lamps in a safe place.
- Calibrate the pH sensors for students ahead of time, unless the students know how to do this and there is sufficient time. �(3.6)

Safety

Add these important safety precautions to your normal laboratory procedures:

- Working with live snails requires respect and care in treatment. Once the activity is completed, return all organisms to their original environment or dispose of them humanely. Do not release into the wild any nonnative organisms.
- Wash your hands thoroughly after preparing the ecosystems.

Driving Question

How does light affect the pH of an aquatic ecosystem?

Thinking about the Question

Plants are unique among living things because they make their own food. Through the process of photosynthesis—which uses light, water, and carbon dioxide—plant and tree leaves make sugar, important for providing the energy needed for growth.

With your partners, quickly list a variety of different environments around your school and home, such as forests, wetlands, deserts, and oceans. These can be large (like an ocean, forest, or meadow) or small (like a backyard or neighborhood park) in scope. Then make a list of environmental components that affect the conditions of an environment, like climate, native wildlife, and the presence or absence of water. How do these interact (for example, what animals are present in a dry environment? How do they survive?)

Choose one of the local environments on your list and discuss with your partners any relationships and interactions you have observed among the environmental components. Create a diagram that illustrates these relationships.

Answers will vary depending on the environment selected.

In this activity, you observe the relationship between a plant, animal, and light in an aquatic environment. By placing a small aquatic plant and snail in a plastic bag filled with pond water, you can measure the pH to determine the change in the rate of photosynthesis. The live snail produces carbon dioxide, which is dissolved in the water in the form of carbonic acid. The plant needs the carbon dioxide for photosynthesis. However, photosynthesis only occurs in plants if ample light is available. During the night or at lower light levels, unused carbon dioxide increases in aquatic ecosystems and as a result, the pH decreases.

Discuss with your partners how light affects the pH of an aquatic system. Be prepared to share your thoughts with the class.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

5	4	3	2	1
Determine what the data indicates about the photosynthesis activity of the plant in each ecosystem.	Put one bag under a fluorescent lamp and cover the other so no light gets to the plant. Measure the pH for 24 hours.	Set up the data collection system and insert a pH sensor in each of the “ecosystem” bags.	Create two identical models of an ecosystem with pond water, an aquatic plant, and a snail.	Make sure each lab group member is aware of safety rules and procedures for this lab.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

1. ☐ Each of two plastic bags will contain a snail, a small aquatic plant, and pond water. One will be in placed in the light, the other will be covered so it is in the dark.

   Based on what you know about photosynthesis, predict which plastic bag will have the greatest acid content (lowest pH) after 24 hours.

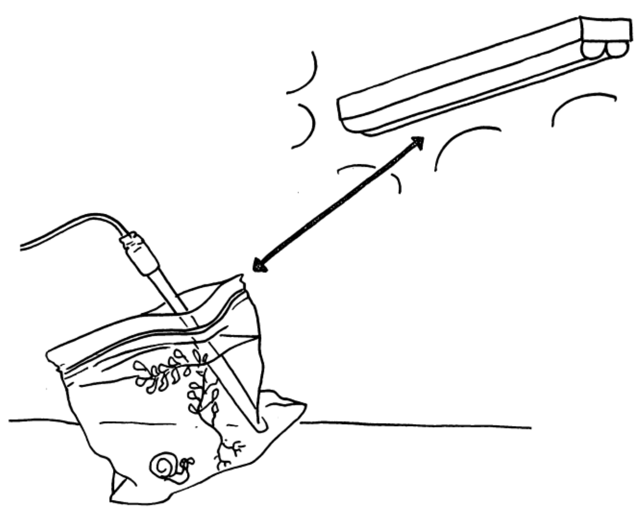
   The pH of the bag kept in the dark will have the greatest acid content and lowest pH.

Part 2 –The effect of photosynthesis on the pH of an ecosystem

2. ☐ Use the graduated cylinder to measure 250 mL of pond water and carefully pour the water into the plastic bag.

   Note: Position the bag securely so the water can't spill.

3. ☐ Place a snail and a small aquatic plant (about the same size) with its roots into each small plastic bag filled with the pond water.



4. ☐ As this experiment is studying photosynthesis, why is there a snail in the bag as well as the plant?

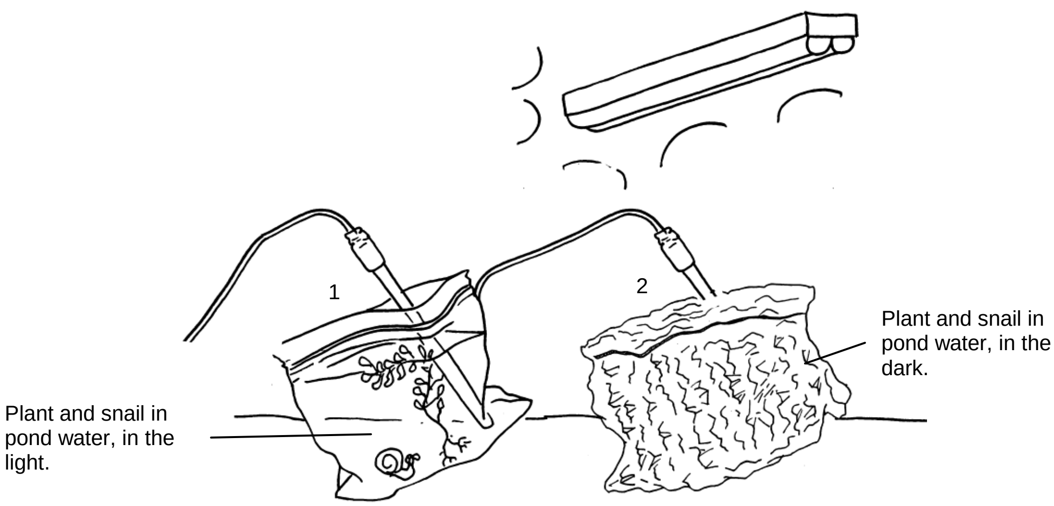
   Plants need CO_2 for photosynthesis and the snail provides CO_2. This makes sure the plant doesn't run out of CO_2.

5. ☐ Label the ecosystem (plastic bag) in the light "#1" and the ecosystem in the dark "#2".

6. ☐ Insert the pH sensor in each bag so the tip is immersed in the water.

7. ☐ Place one bag within a half meter of a fluorescent lamp that has been turned on.

8. ☐ Wrap the other bag in aluminum foil so no light reaches the plant.



9. ☐ Start a new experiment on the data collection system. �(1.2)

10. ☐ Connect two pH sensors to the data collection system. �(2.2)

11. ☐ Display pH on the y-axis and Time on the x-axis. �(7.1.1)

12. ☐ Adjust the scale of the graph to show all data. �(7.1.2)

13. ☐ Display both data runs. �(7.1.3)

14. ☐ Monitor live data without recording. �(6.1)

15. ☐ Record the initial pH of each ecosystem in Table 1.

16. ☐ Describe your aquatic ecosystems.

For this example, in both bags, the plants are dark green. In ecosystem #1 the snail is moving around. Ecosystem #2 is covered, so there's no way to know what the snail is doing. The pH of each bag at the start had a similar pH of 6.56 (bag #1) and 6.57 (bag #2).

17. ☐ Set the sample rate to one per hour. �(5.1)

18. ☐ Start data recording. �(6.2)

19. ☐ Measure the pH of your aquatic ecosystems for 24 hours.

20. ☐ After 24 hours, stop data recording. �(6.2)

21. ☐ Record the pH values of each ecosystem in Table 1.

Table 1: pH comparison of pond water in ecosystems with and without light

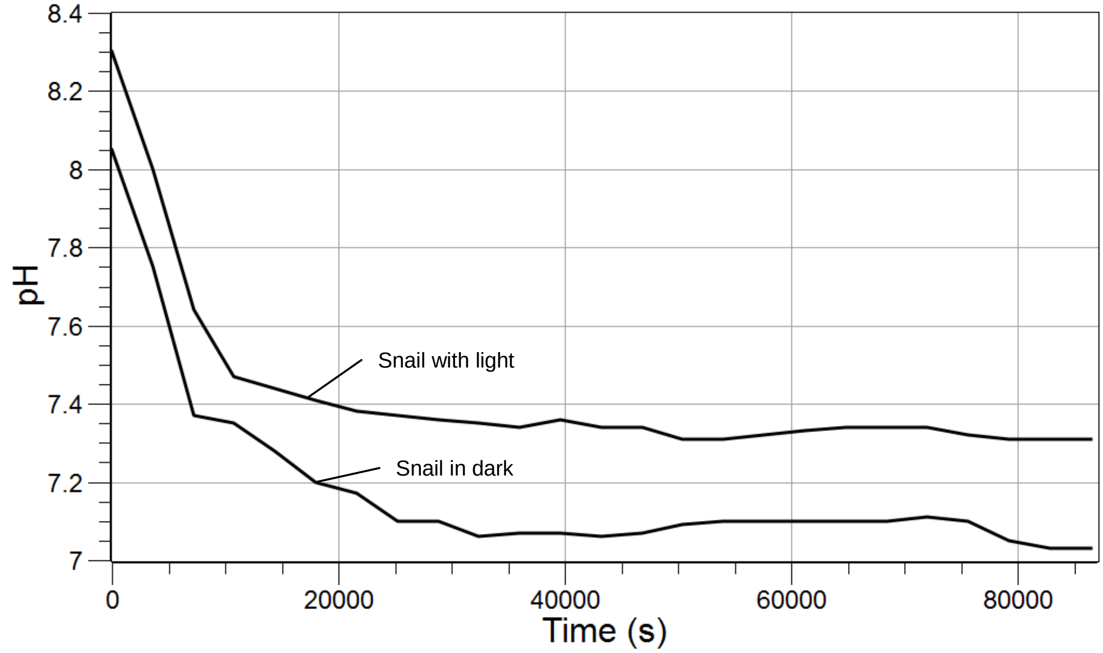
Hour	pH (ecosystem in the light, #1)	pH (ecosystem in the dark, #2)	Hour	pH (ecosystem in the light, #1)	pH (ecosystem in the dark, #2)
Initial	8.31	8.05	13	7.34	7.07
1	8.00	7.75	14	7.31	7.09
2	7.64	7.37	15	7.31	7.09
3	7.45	7.32	16	7.32	7.10
4	7.44	7.28	17	7.33	7.10
5	7.40	7.19	18	7.34	7.10
6	7.38	7.17	19	7.34	7.10
7	7.37	7.10	20	7.34	7.11
8	7.36	7.09	21	7.32	7.10
9	7.35	7.06	22	7.31	7.05
10	7.34	7.07	23	7.31	7.03
11	7.35	7.07	24	7.31	7.03
12	7.34	7.06			

22. ☐ How did the pH of the two ecosystems vary over time?

The one in the dark had a lower pH after 24 hours than the one in the light.

23. ☐ Save your experiment �(11.1) and clean up according to your teacher's instructions.

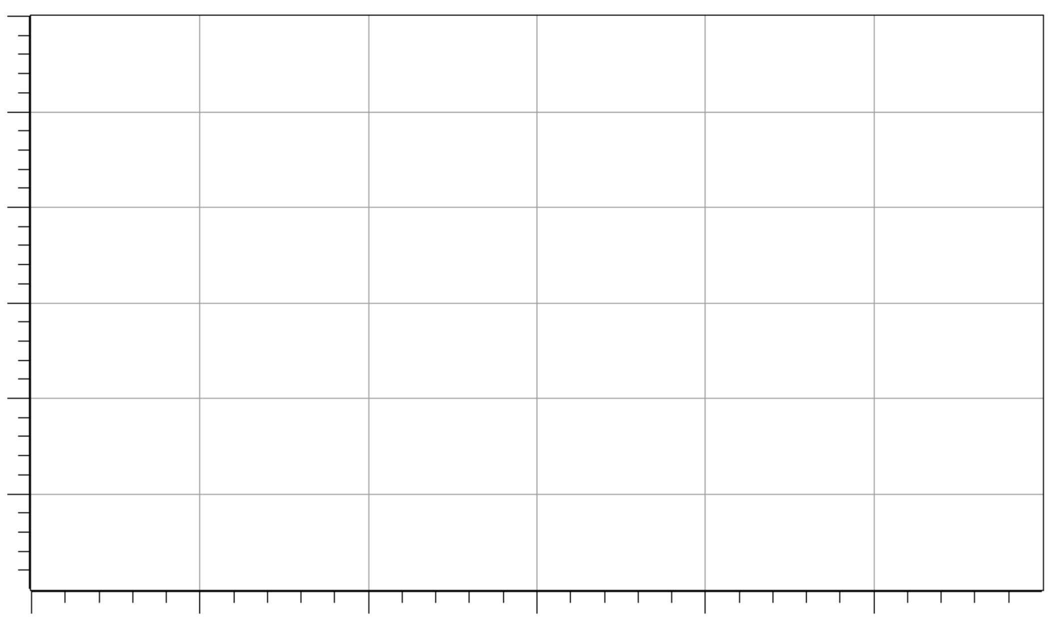
Sample Data



Answering the Question

Analysis

1. Label the axes and sketch the curves of the pH versus Time graph.



2. How do your results compare to your predictions? Are your results close to what you expected? Why or why not?

Answers will vary. According to one student group: "The pH increased slightly in the bag with the light. The pH decreased in the bag without the light. The change was not as great as I expected. I am sure that the change would be greater if more plants and snails were in the ecosystems."

3. How do you explain any differences in pH? How does it relate to the photosynthesis?

The difference in pH is due to the plant photosynthesis that occurs in the light, which uses up the carbon dioxide. When there is no light, photosynthesis doesn't occur, so the plant will not use up the carbon dioxide. The CO_2 remains dissolved in the water and forms carbonic acid, lowering the pH.

4. Would the results have been the same if different plants were used (for example, *Elodea*, duck weed, et cetera)?

There should be a similar pattern.

5. If an independent variable is an experimental factor that scientists control and a dependent variable is a factor that changes based on a change in the independent variable, then for this activity, what is the independent variable and what is the dependent variable?

The independent variable is light and the dependent variable, which changes based on the presence or absence of light, is pH.

6. Describes what happens during photosynthesis.

Green plants use sunlight to synthesize food from carbon dioxide and water.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. The primary source of energy for life on the earth is:

   A. Water
   B. The sun
   C. Oil

2. The CO_2 used for photosynthesis

   A. Is necessary to provide food for most animals
   B. Eventually results in the growth of trees and plants
   C. Both of the above

3. Characteristics of an animal that would survive in a desert environment are:

   A. Bright colors, loud vocalizations, and its diet is heavy with fruits
   B. Burrows into a den during the day and plugs it to keep out the hot, drying air
   C. Feeds on leaves, flowers, berries, buds, twigs and other types of vegetation

True or False

Enter a "T" if the statement is true or an "F" if it is false.

___T___ 1. Photosynthesis is the conversion of light energy into chemical energy by living organisms.

___F___ 2. Carbon dioxide is removed from water by plant and animal respiration.

___F___ 3. The water of your ecosystem was more acidic when it was in the dark because photosynthesis produced carbon dioxide in the dark.

___F___ 4. Another way you could carry out this activity to provide evidence of photosynthesis is to measure the amount of oxygen dissolved in the water with a dissolved oxygen sensor. During photosynthesis, the level of dissolved oxygen would increase. In this case, oxygen would be the independent variable and light would be the dependent variable.

Key Term Challenge

Fill in the blanks from the randomly ordered words below:

oxygen	sunlight	photosynthesis	dependent
carbon dioxide	more	less	characteristic
ecosystem	independent	energy	water

1. A biological community of interacting organisms and their physical environment is called a(an) ___ecosystem___.

2. For most ecosystems, the major source of energy is ___sunlight___.

3. Photosynthesis requires light and ___carbon dioxide___ and ___water___ and generates ___oxygen___ as a byproduct. The snail requires ___oxygen___ and gives off ___carbon dioxide___ as a byproduct.

4. The water was ___more___ acidic when the snail and plant ecosystem was in the dark.

Further Investigations

How would the pH change if the plastic bag had more snails or plants?

Keep one of your “ecosystems” (plastic bags) outside. Measure the pH every hour throughout a 24-hour period. Is there evidence of photosynthesis?

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

10. Thermoregulation of Body Temperature

Cold Nose, Warm Ears

Objectives

Students observe that different parts of the body are at different temperatures and these differences are related to their distance from the heart. They also understand that the hypothalamus regulates and maintains the body temperature within a small range.

Procedural Overview

Students gain experience conducting the following procedures:

- Setting up the equipment and work area to measure the temperature of several different locations on their bodies
- Looking for a pattern in the temperature measurements of the different parts of their body

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Making predictions	50 minutes
■ Lab activity, Part 2 – Measuring temperatures around the body	25 minutes
■ Analysis	25 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Data collection system
- ☐ Fast-response temperature sensor

For each student or group:

- ☐ Data collection system
- ☐ Fast-response temperature sensor
- ☐ Chair (for ankle temperature reading)

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- The SI (international system) units for temperature is degrees Celsius: The typical body temperature (measured orally) of 37 degrees Celsius is also expressed as 98.6 degrees Fahrenheit.

Related Labs in This Guide

There are no labs in this guide conceptually related to this lab.

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting a sensor to your data collection system �(2.1)
- Changing the sample rate �(5.1)
- Monitoring data without recording �(6.1)
- Displaying data in a digits display �(7.3.1)

Background

The human body has the capability of regulating its core temperature via several feedback mechanisms. But all parts of the body are not at the same temperature.

The core temperature of the body is the temperature in the deep organs, such as the liver or the heart. Body temperature is commonly measured orally, rectally, or under the arm. While the core temperature may be 40.6 °C (105 °F), under the tongue it is 37 °C (98.6 °F); rectal temperature is usually higher—up to 0.56 °C (1.0 °F) higher than the oral temperature, and axillary temperature (under the arm) is likely to be 0.28 °C (0.5 °F) lower than the temperature obtained by mouth. For this activity, the temperature obtained under the arm will be considered as the core temperature.

People commonly refer to the temperature measured orally as the typical body temperature. As Table 1 shows, the temperature of the body varies, depending on where it is measured.

Table 1: Typical temperatures of different parts of the human body

Body Area	Temperature (°C)	Temperature (°F)
Body organs	40.6	105
Mouth	37.0	98.6
Armpit	36.5	97.7
Forehead	34.5	94.1
Hand	33.0	91.4
Fingers	32.0	89.6

Even though the temperatures vary around the body, the core temperature stays within a tight range through thermoregulation. Thermoregulation is the ability of an organism to keep its body temperature within certain boundaries, even when the surrounding temperature is very different. This process is one aspect of homeostasis: a dynamic state of stability between an animal's internal environment and its external environment. The hypothalamus, located in the brain, not only regulates the body temperature, but controls hunger, thirst, fatigue, and anger.

When a rise in body temperature occurs, the hypothalamus directs blood vessels in the skin to expand in diameter (dilate). This increases heat loss by shifting warm blood to the skin. The opposite condition, when body temperature decreases below normal levels, is known as hypothermia. With a drop in body temperature, the hypothalamus inside the brain directs blood vessels in the skin to narrow in diameter (constrict). This reduces heat loss by shifting warm blood to the interior of the body.

Pre-Lab Discussion and Activity

Engage students in the following discussion, questions, and demonstration:

The goal of this discussion should be to develop the understanding that the body maintains its core body temperature within a small temperature range. By the end of the activity, students should understand that temperatures at different locations of the body vary considerably due to the way heat is produced and lost. The circulation of blood tends to maintain an average temperature for the internal body parts.

Ask students if they know what their body temperature should be under normal conditions.

> Many students will be familiar with 37 °C (98.6 °F) as a typical number. This is the normal temperature obtained orally.

Place the sensor on the foreheads of several student volunteers. Demonstrate how to touch the temperature sensor to the skin without warming the sensor with your fingers (see the Preparation and Tips section). Announce the temperatures to the class. Temperatures taken on the forehead tends to be lower than the typical core body temperature, which is about 40.6 °C (105 °F).

Ask the class why each student's temperature varied so little from one another.

> Although the body temperature is relatively constant, it varies slightly due to biochemical (metabolic) reactions within the body and also varies with the time of day. Students may know that their body has the ability to keep its temperature within certain limits, even when the temperature of the surrounding environment is different.

Ask the class if the temperature of the forehead is lower than they expected. Ask what variables might affect the temperature of different parts of the body.

> Someone may suggest heat loss. Others may suggest that the distance from the heart matters.

Explain that an elevated temperature, above the normal body temperature, is designated as a fever. A condition where the body is unable to maintain a normal temperature and the temperature increases above 40.6 °C (105 °F) is referred to as heatstroke (some marathon runners experience this). The opposite condition, when body temperature decreases significantly below normal levels, is known as hypothermia.

Direct the students to "Thinking about the Question." After a few minutes, hold a class discussion for them to share their ideas about why the temperature varies around their bodies.

Suggest that the class investigate the temperatures of different parts of their bodies. Discuss the relationship of the heart and blood circulation to these temperatures, including how far body parts are from the heart. Depending on the prior experience of the class this might be done as a written group task or a whole class brainstorm.

Before directing students to "Investigating the Question," remind them how to touch the temperature sensor to their skin without warming the sensor with their fingers.

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- When measuring their temperature, students should not be in the direct path of a heater or air conditioner.
- Show students where to place the sensor and make sure they avoid placing their fingers on the sensor. Doing so could affect the reliability of the measurements.
- For this activity it is appropriate to group girls with girls and boys with boys, in case help is needed to hold the temperature sensor on the different places temperature is to be measured on their bodies.

Safety

Add this important safety precaution to your normal laboratory procedures:

- This sensor should be placed only on those areas specified in this activity.

Driving Question

How does temperature vary on different parts of your body?

Thinking about the Question

Discuss with your lab group members why the temperature varies on different parts of your body. Be prepared to share your thoughts with the class.

Student answers will vary. Students may think that changes occur based on how much clothing is covering parts of their bodies. Students may think about the circulatory system and relate temperature to the distance from the heart.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

5	1	2	3	4
Determine if there is a pattern of the temperature measurements you have taken.	Make sure each lab group member is aware of safety rules and procedures for this lab.	Set up the data collection system with the fast-response temperature sensor.	Take temperature measurements of your earlobe, nose, fingertip, and ankle.	After taking the various body temperatures, take the temperature that will be used as your core body temperature.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

1. ☐ Predict which location will be the warmest: earlobe, tip of the index finger, nose, or ankle.

   Students will often list their nose or finger as the warmest.

2. ☐ Why do you think different parts of your body are at different temperatures?

   Student answers will vary. One group might say it is based on the distance from the heart.

Part 2 – Measuring temperatures around the body

3. ☐ Start a new experiment on the data collection system. � (1.2)

4. ☐ Connect a fast-response temperature sensor to the data collection system. �(2.1)

5. ☐ Display temperature in a digits display. �(7.3.1)

6. ☐ Change the sample rate to one sample per second. �(5.1)

Note: You will be using the sensor to make several measurements. Avoid placing your fingers on the sensor. Doing so could affect the accuracy of the measurements.

7. ☐ Monitor live data without recording �(6.1)

8. ☐ Carefully place the end of the temperature sensor on the front of your earlobe.

9. ☐ After holding it in place for 30 seconds, record the temperature in Table 1.

10. ☐ Repeat these two measurement steps for the tip of your index finger, your nose, and ankle. After holding the temperature sensor at each location for 30 seconds, record each temperature in Table 1.

    Note: Sit in a chair before taking the ankle measurement.

Part 3 – Measuring your core temperature

11. ☐ Carefully place the end of the temperature sensor under your armpit, below your shirt or blouse and directly on the skin.

    Note: Although this temperature is not as close to your core temperature measurements that other areas might be, the temperature in your armpit will be considered the core temperature of your body for this experiment.

12. ☐ Why do you need to obtain your core temperature?

    The core temperature is the warmest temperature in your body. Measuring the core temperature provides a way to observe how the temperature varies at other points of the body.

13. ☐ Hold the sensor in place by pressing your arm against your side.

14. ☐ After holding the sensor in place for 30 seconds, record the temperature in Table 1.

15. ☐ Clean up according to your teacher's instructions.

Table 1: Body temperature at different locations

Body Area	Temperature (°C)
Earlobe	33.0
Tip of index finger	32.0
Nose	34.0
Ankle	29.5
Armpit	37.0

Answering the Question

Analysis

1. How did your predictions of temperatures around your body compare to their actual temperature values?

   Answers will vary. The actual values may be hard for students to come up with, but their predictions should show a pattern.

2. Explain any differences in your body temperature as taken at different locations. Be prepared to share your answer with the class.

   Answers should relate to the distance from the heart that the temperature is taken.

3. Do you think your body regulates its temperature? If so, how?

   Students should be aware that their body temperature is regulated by the hypothalamus in the brain, which can regulate the temperature in several ways, including (1) signaling blood vessels in the skin to dilate to help lose heat or to constrict to help retain heat, (2) triggering shivering or sweating or (3) increasing heat production through chemical reactions.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. What is the typical human body temperature measured orally?

   A. 98.6 °C
   B. 50 °C
   C. 37 °C

2. The____________________________is the temperature of the blood flowing through internal organs of the body.

 A. Regulated temperature
 B. Constant temperature
 C. Core temperature

3. Which part of the body is responsible for controlling body temperature?

 A. The spinal column
 B. The hypothalamus
 C. The circulatory system

4. The condition in which body temperature drops below normal is known as:

 A. Hypothermia
 B. Heat stroke
 C. Dilation

Key Term Challenge

Fill in the blanks from the randomly ordered words below.

thermoregulation	hypothalamus	temperature	environment
core	thyroid	homeostasis	hypothermia
fever	heatstroke	thermometer	earlobe

1. ____Homeostasis_____ is a type of balance between an animal's internal conditions and its surroundings.

2. Hunger, body temperature, anger, thirst, and fatigue are all regulated by the ______hypothalamus_______.

3. An organism's ability to maintain its body temperature, even when the temperature of its surroundings varies greatly, is known as _______thermoregulation______.

4. An organism's _______environment_________ includes such things as climate, soil, and other living things in its surroundings.

Further Investigations

Monitor the temperature of different parts of your body under different weather or external temperature conditions. How does the core temperature adjust to changes in environmental conditions?

Monitor the temperature of different parts of your body after exercising. How quickly does your body adjust to stress? How can you tell?

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

11. Transpiration

When Water Leaves

Objectives

In this activity, students investigate transpiration in a land plant. Students use a weather sensor to record data on a plant's environmental conditions inside a closed system while they:

- Define transpiration and explain where it occurs
- Describe how a plant can control the rate of transpiration
- Explain how different environmental conditions affects the rate of transpiration
- Describe the movement of water through a plant

Procedural Overview

Students gain experience conducting the following procedures:

- Setting up the equipment and work area to measure the change in humidity and temperature Watering a small potted plant and then wrapping the pot and soil surface in aluminum foil to prevent moisture loss
- Enclosing the potted plant and weather sensor in a sealed plastic bag
- Measuring humidity and temperature over a 24-hour period
- Using math skills to interpret and analyze data

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Making predictions	25 minutes
■ Lab activity, Part 2 – Temperature and humidity in light and dark conditions	25 minutes for set-up + 24 hours of data collection

Materials and Equipment

For teacher demonstration:

- ☐ Data collection system
- ☐ Weather sensor
- ☐ Sensor extension cable
- ☐ Gallon size self-sealing bag
- ☐ Small potted plant
- ☐ Aluminum foil
- ☐ Tape

For each student or group:

- ☐ Data collection system
- ☐ Weather sensor
- ☐ Sensor extension cable
- ☐ Gallon size self-sealing bag, 1 or 2 depending on plant size
- ☐ Small potted plant
- ☐ Aluminum foil
- ☐ Water, tap (for moistening plant soil)
- ☐ Tape

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- The processes of photosynthesis and respiration
- How water moves through evaporation and osmosis
- Be able to identify plant structures and explain their functions

Related Labs in This Guide

Labs conceptually related to this one include:

- Exploring Environmental Temperatures

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting a sensor to the data collection system �(2.1)
- Recording a run of data �(6.2)
- Changing the sampling rate �(5.1)
- Adjusting the scale of a graph �(7.1.2)
- Displaying multiple variables on the y-axis of a graph �(7.1.10)
- Saving your experiment �(11.1)

Background

Transpiration is the evaporation of water from plant leaves. Plants may lose gallons of water a day due to transpiration. This process occurs through stomata. Stomata are openings on the plant's leaves; most are on the leaves' lower surfaces. The function of a stoma (plural stomata) is to allow gas exchange – oxygen out and carbon dioxide into the plant. Not only does oxygen and carbon dioxide move through these openings, but water vapor does as well. Two guard cells surround the stoma, which control its opening and closing.

The majority of the water that is absorbed by the plant's roots leaves the plant due to transpiration. There is a column of water that extends from the roots of the plant, through the xylem, to the leaves. Water molecules are cohesive (stick together) due to hydrogen bonding. This allows the column of water to be moved up through the plant as transpiration occurs.

Plants can slow down the rate of transpiration by closing the stomata, developing a thick cuticle (waxy covering on the leaf) or leaf hairs. Leaf hairs increase the boundary layer that surrounds a plant. The boundary layer is an area of still air that surrounds the leaf surface. The larger the boundary layer, the slower transpiration will occur.

Environmental conditions also play a role in the rate of transpiration. Among these conditions are relative humidity, temperature, soil water content, light, and wind. Relative humidity is the measure of water vapor in the air compared to the amount the air could hold at a certain temperature. The higher the relative humidity, the more moisture is in the air, which would slow the rate of transpiration. As temperature increases, the amount of water the air can hold increases. So the warmer the temperature, the faster transpiration will occur. The water for transpiration comes from the water in the soil. The more water in the soil, the faster transpiration can occur. If the soil contains little water, the plant will start to wilt since the water lost to transpiration is not being replaced. Transpiration usually occurs during the day when light is available for photosynthesis to occur. Wind can increase the rate of transpiration by decreasing the size of the boundary layer around a leaf which would allow more water vapor to be released.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Ask students the following questions:

What is transpiration?

> Transpiration is the evaporation of water from plant leaves.

Where does transpiration occur?

> Transpiration occurs through stomata. Stomata are openings on the plant's leaves, most are on the lower surface.

What is the path water takes as it moves through a plant?

> Water is taken in from the soil through the root hairs, moves into the xylem, up the stem and out through the leaves.

What factors affect the rate of transpiration?

> Factors that affect the rate of transpiration are the amount of sunlight, the temperature, the amount of moisture in the air, the wind speed, and the amount of water in the soil.

Would you expect all plant species to have the same transpiration rate under similar environmental conditions? Why or why not?

Accept all reasonable answers.

What would the cuticle thickness be in cool, moist climates? In hot, dry climates? In direct sunlight?

Cuticles in cool, moist climates tend to be thinner than the cuticles in hot, dry climates. Hot, dry climates would have increased transpiration so the thick cuticle would slow down this rate. Leaves in direct sunlight would also have a high rate of transpiration so a thick cuticle would help slow transpiration down.

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- Prepare an example set-up of the weather sensor, with sensor extension cable connected, sealed in the plastic bag with the potted plant. Show students how to apply tape around the opening where the sensor extension cable comes out, to seal it.
- Small potted plants such as coleus, basil, or vegetable starts (tomato, squash, pumpkin, corn or others with large leaf areas), are available at most nurseries.
- Have students water their plants just enough to moisten the soil.
- Make sure students wrap the entire pot and soil surface with aluminum foil to prevent evaporation of the soil moisture into the plastic bag. This will add to the relative humidity inside the bag.
- Students will need to be able to leave their set-up in place for 24 hours of data collection.

Safety

Add this important safety precaution to your normal laboratory procedures:

- Students should wear an apron to protect clothing.

Driving Question

What happens to a living plant throughout the day and night?

Thinking about the Question

How are plants like every other living thing?

Plants need food, they respire, they reproduce, and they grow.

What measurement can we use to determine if the plant is undergoing transpiration?

Relative humidity can be used to determine if the plant is undergoing transpiration; this measures the amount of water vapor in the air.

Will there be a difference in how much a plant transpires during the day and how much it transpires at night?

Since plants undergo photosynthesis during the day, the stomata are open to allow for gas exchange and more transpiration. Also, the temperatures tend to be higher during the day which would increase the rate of transpiration. Most stomata are closed during the night and the temperature is lower so the rate of transpiration will be decreased.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

3	1	2	5	4
Cover the pot and the soil entirely with a sheet of aluminum foil to prevent loss of soil moisture.	Make sure each lab group member is aware of the safety rules and procedures for this activity.	Obtain a small potted plant and water it so its soil is moist.	Use tape to seal the bag around the weather sensor extension cable.	Place the potted plant and a weather sensor into a plastic sealable bag.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1– Making predictions

1. ☐ What do you think will happen to the relative humidity around a plant during a period of light? Record your prediction:

   Answers will vary. One group answered as follows: We predict that the plant will carry out more life processes during the daylight hours, which includes transpiration. Since we predict it will transpire more during the day, we predict that the relative humidity will be higher during the day.

2. ☐ What do you believe will happen to the relative humidity around a plant during a period of dark? Record your prediction:

   Answers will vary. One group answered as follows: We predict that the plant will shut down or slow down many of its life processes during the dark, including transpiration. Since it will transpire less at night, we predict that the relative humidity will be lower during the night.

Part 2 – Temperature and humidity in light and dark conditions

3. ☐ Start a new experiment on the data collection system. �(1.2)

4. ☐ Connect a weather sensor to the data collection system. �(2.1)

5. Display both Relative humidity and Temperature on the y-axis of a graph with Time on the x-axis. �(7.1.10) What is relative humidity and why are we measuring it in this activity?

   Relative humidity is the amount of water vapor in the air compared to the amount of water vapor the air could actually hold at the same temperature. We are measuring it because it will tell us if the plant is losing water into the air through transpiration.

6. ☐ Change the sampling rate to take a relative humidity measurement once every two minutes. �(5.1)

7. ☐ Acquire a small plant from your teacher.

8. ☐ Wrap aluminum foil around the base of the plant so that all of the soil is covered. Why do you need to wrap the base of the plant?

   We need to wrap the base of the plant so the soil's water does not evaporate, but can be taken up only by the plant's roots.

9. ☐ Place the wrapped plant into the gallon size self-sealing bag.

10. ☐ Put the weather sensor in the bag with the plant. Seal the bag and tape around the opening, as necessary.

    Note: If the plant is larger than one bag, place a second one over the top of the plant.

11. ☐ Place the plant in a sunny location.

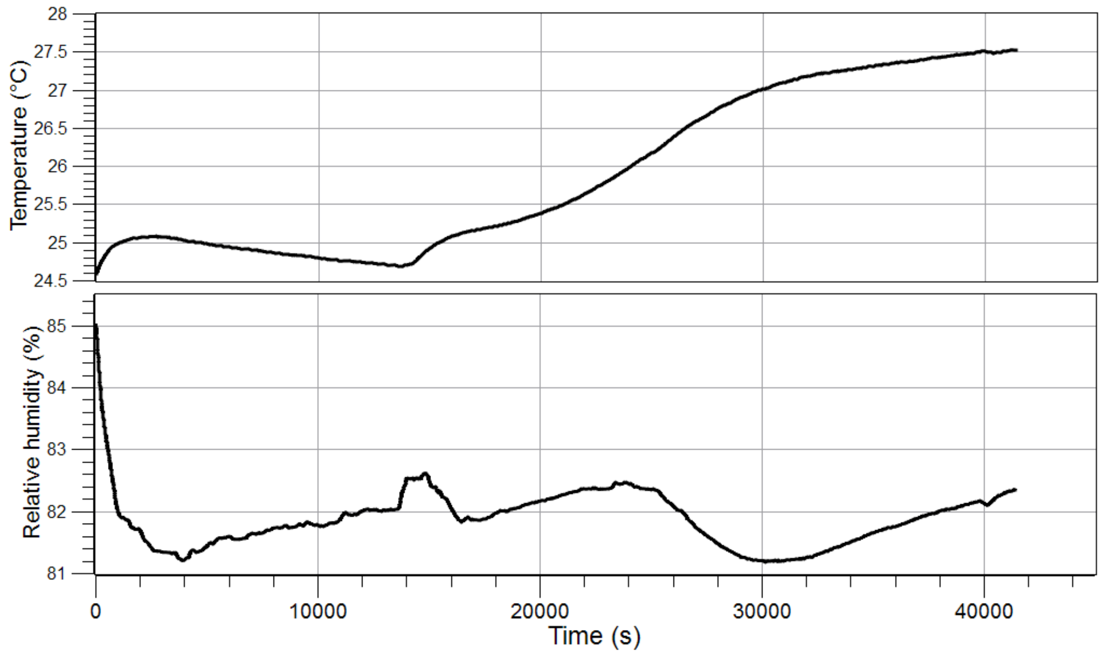
12. ☐ Start data recording. �(6.2)

13. ☐ Record data for at least one 24 hour period.

14. ☐ Stop data recording at the end of the 24 hours. �(6.2)

15. ☐ Save your experiment according to your teacher's instructions. �(11.1)

Sample Data



Answering the Question

Analysis

1. Review your data. You may need to adjust the scale of your graph to see all of the data. �(7.1.2) did the plant undergo transpiration more during the day or during the night? Suggest reasons for this observation.

   The relative humidity should rise during the day and drop off at night. This would indicate that transpiration was higher during the day.

2. How did your prediction compare to the actual rate of transpiration during the day?

   Answers will vary. One group answered as follows: Our temperature and relative humidity data shows that the plant did transpire more when it was light.

3. How did your prediction compare to the actual rate of transpiration during the night?

   Answers will vary. One group answered as follows: Our temperature and relative humidity data shows that the plant generally transpired less when it was dark.

4. How do the plants avoid losing too much water through transpiration?

   Plants can slow down the rate of transpiration by closing the stomata, developing a thick cuticle (waxy covering on the leaf) or leaf hairs.

5. What environmental conditions control water loss in plants?

   Environmental conditions can affect the rate of transpiration. Among these conditions are the relative humidity, temperature, soil water, light, and wind.

6. Would the transpiration rate in a conifer leaf (needle) be higher or lower than a deciduous (regular) leaf? Explain.

The conifer leaf has a smaller surface area and therefore would have a lower rate of transpiration than a leaf of a deciduous plant.

Multiple Choice

Circle the best answer or completion to each of the question or incomplete statements below.

1. The cuticles on leaves that are in the sun will be __________ compared to the cuticles on leaves that are in the shade.

   A. Thinner
   B. Thicker
   C. The same
   D. Cannot determine

2. Which of the following describes the fate of most of the water taken up by a plant?

   A. It is used as a solvent.
   B. It is used as a hydrogen source in photosynthesis.
   C. It is lost during transpiration.
   D. It makes cell elongation possible.

3. Where in a plant does transpiration take place?

   A. All parts of the plant
   B. Leaves
   C. Stem
   D. Only the aerial parts

4. Most of transpiration takes place through:

   A. Stomata
   B. Epidermis
   C. Stem
   D. Cuticle

5. All of the following can affect transpiration except:

   A. Humidity
   B. Temperature
   C. Air Movement
   D. Leaf Color

6. Most stomata are located in the lower epidermis. This is to:

   A. Increase photosynthesis
   B. Reduce respiration
   C. Reduce water loss
   D. Increase transpiration

True or False

Enter a "T" if the statement is true or an "F" if it is false.

___F___ 1. Transpiration is the exchange of oxygen for carbon dioxide gas by a plant.

___T___ 2. All organisms must be able to maintain stable internal conditions while living in a constantly changing external environment.

___F___ 3. Plants can transpire from cells in their roots.

___T___ 4. Plants are able to regulate the amount of water they lose to the environment.

___F___ 5. A plant may transpire more on a calm day than on a windy day.

___T___ 6. Water is taken in from the soil through the root hairs, moves into the xylem, up the stem and out through the leaves.

___T___ 7. The processes of photosynthesis and transpiration both occur in a plant's leaves.

Further Investigations

What would be the effect of covering the top or bottom surface of the leaves with petroleum jelly?

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

12. Venous Blood Flow

What's the Circulatory Story?

Objectives

Students understand how their heart rate changes when they change their physical position.

Procedural Overview

Students gain experience conducting the following procedures:

- Measuring their heart rate while standing, lying flat, and lying flat with one leg raised

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Making predictions	25 minutes
■ Part 2 – Finding your reclining heart rate	25 minutes
■ Part 3 – Finding your standing heart rate	10 minutes
■ Part 4 – Finding your raised leg heart rate	10 minutes
■ Analysis	25 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Data collection system
- ☐ Heart rate sensor, hand grip
- ☐ Sensor extension cable

For each student or group:

- ☐ Data collection system
- ☐ Heart rate sensor, hand grip
- ☐ Sensor extension cable
- ☐ Long, sturdy table or athletic board
- ☐ Pillows or thick books (2)
- ☐ Meter stick

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- Circulatory system

Related Labs in This Guide

Labs conceptually related to this one include:

- Recovery Heart Rate

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting a sensor to the data collection system �(2.1)
- Starting and stopping data recording �(6.2)
- Displaying data in a graph �(7.1.1)
- Displaying data in a table �(7.2.1)
- Naming a data run �(8.2)
- View statistics of data �(9.4)
- Saving your experiment �(11.1)

Background

When a person stands after sitting, gravity pulls blood from the head to the feet. This lowers the blood pressure in the upper half of the body and in the aorta and carotid arteries. The pressoreceptors that are stimulated by changes in blood pressure in the arteries then signal the medulla to speed the heartbeat. The faster the heart beats the faster the body returns blood pressure to its normal level. While standing, the average person's heartbeat and pulse rate increases 10 to 30 beats per minute.

In a standing position, the gravity-induced pressure in the legs and feet forces fluids through capillary walls into space outside the capillaries. Heat further increases the loss of fluids by causing the blood vessels to dilate, making them more permeable. For these reasons and because the force of gravity pulls blood from the brain, people who stand for a long time in the heat may faint.

When a person remains still while standing, blood accumulates in the veins of the feet. Without muscular contractions, the blood cannot move toward the heart and the veins swell. When stepping in place, muscle movement will compress the veins, forcing the accumulated blood through the one-way valves of the veins and eventually to the heart. Because much of the blood they contained has been squeezed out of them by the muscular contractions, the veins appear collapsed immediately after stopping the stepping movements. But blood begins to accumulate in the veins after the movement stops, and then begin again to swell.

Pre-Lab Discussion and Activity

Monitoring Heart Rate

Help your students find their own heart rate by placing the tips of their fingers on the carotid arteries of their neck (alongside the trachea), the temporal arteries at the sides of their head, or the radial arteries of their wrists and count the number of beats in 15 seconds. After everyone has mastered the technique, do a whole class trial and have each student report their beats per minute (bpm) as you record all results at the front of the room. (Note: A normal pulse rate at rest is between 70 and 75 beats per minute.)

Monitoring Blood Circulation

Ask students to explain how blood circulates in a body. Can they trace the flow of blood through their bodies? Discuss William Harvey's investigation performed in the early 1600s that traced for the first time blood circulation from the heart to the arteries to the veins and back to the heart. Prior to his work, blood was thought to move much like a tide through your body, shifting back and forth in the blood vessels.

Request a volunteer with prominent veins in his or her hands. Have the volunteer stand with hands hanging downward for one minute. This will provide time for the veins to fill with blood. Now have them raise one arm slowly to about eye level. At what level do the veins on the raised hand collapse? Measure the approximate vertical distance from the heart to the place at which the veins collapse. Generally this distance is about 10 centimeters which is the equivalent of the venous pressure.

Effect of Gravity on Blood Flow

Ask the students how gravity affects the flow of blood through their bodies. Will their bodies experience a different venous flow while standing than when exercising or lying down? Direct the students to "Thinking about the Question." After a few minutes, ask the groups to share some of their ideas with the class.

Again, after asking for a volunteer, have the volunteer stand in bare feet for a minute. Do the feet have prominent veins showing after one minute? What is preventing the blood from moving readily toward the heart? Take ten quick steps in place and then stand still again. Did the veins collapse? Why? Do the veins quickly refill with blood? If the legs are not moving, the feet hold much of the blood in the veins, making them swell and the venous pressure to significantly increase. The movement of the legs during exercise forces the blood through the one-way valves, reducing the venous pressure in the legs and feet.

Using the Heart Rate Sensor

Demonstrate the heart rate sensor to the students. Explain that the ear clip registers and records the flow of blood through your body as they change positions. This sensor shines a small incandescent lamp through your earlobe and measures the change in light that is transmitted to record your pulse rate. Direct the students to "Investigating the Question."

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- Demonstrate how to hold the hand grips of the heart rate sensor, pointing out to students not to squeeze too hard or grip too loosely. Show students the flashing green light on the sensor box that indicates the device is obtaining heart rate data. Remind students that it may take as long as 10 to 20 seconds before a non-zero value for the heart rate appears on the graph.

- Make sure students know that heart rate varies over time and differs for different people and circumstances.

Safety

Follow all standard laboratory procedures.

Driving Question

How does changing your body level and position alter your heart rate?

Thinking about the Question

Discuss with your partners the relationship between the position of a body and the flow of blood through the body. Be prepared to share your thoughts with the class.

> Student answers will vary. Students should be thinking about the effect of gravity on blood flow. If the heart is at the same level as the rest of the body, such as in a reclined position, less work is needed to pump the blood around the body.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

2	1	5	3	4
Set up the data collection system and attach the heart rate sensor.	Make sure each lab group member is aware of safety rules and procedures for this lab.	Determine why your heart rate was higher or lower (if it did change) in the different positions.	Lie flat on a table and measure your heart rate. Then stand up and measure your heart rate.	Lie down again and raise your legs about 30 degrees from the flat surface and measure your heart rate.

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Making predictions

1. ☐ Discuss with your partners what you think a person's resting heart rate will be while lying flat on a table (or an athletic board). Record your prediction below.

   Predicted reclining heart rate: _________ bpm

   Answers will vary.

2. ☐ Discuss with your partners what you think the person's heart rate will change to when they stand. Record your prediction below.

   Predicted standing heart rate: _________ bpm

   Answers will vary.

3. ☐ Discuss with your partners what you think the person's heart rate will change to when they raise their legs while lying down. Record your prediction below:

   Predicted raised legs heart rate: _________ bpm

   Answers will vary.

Part 2 – Finding your reclining heart rate

4. ☐ Start a new experiment on the data collection system. �(1.2)

5. ☐ Use the sensor extension cable to connect a heart rate sensor to the data collection system. �(2.1)

6. ☐ Display your data in a graph with Heart Rate on the y-axis and Time on the x-axis. �(7.1.1)

7. ☐ Have your partner lie down and relax. Your partner should not have recently exercised.

8. ☐ Attach the heart rate sensor on the tip of his or her ear.

9. ☐ Start data recording. �(6.2)

10. ☐ When you have captured a good trace for 30 seconds, stop data recording. �(6.2)

11. ☐ Find the mean heart rate. �(9.4)

12. ☐ Record the mean heart rate below.

    Reclining heart rate: ___73___ bpm

    Heart rates will vary; generally students will have a heart rate of 70 to 75 beats per minute (bpm).

13. ☐ Name the data run "Reclining". �(8.2)

Part 3 – Finding your standing heart rate

14. ☐ Have your partner stand up. Be sure the heart rate sensor is still attached to their earlobe

15. ☐ Start data recording. �(6.2)

16. ☐ When you have captured a good trace for 30 seconds, stop data recording. �(6.2)

17. ☐ Find the mean heart rate. �(9.4)

18. ☐ Record the mean heart rate below.

    Standing heart rate: ___88___ bpm

    Student rates will vary; generally students will have an elevated heart rate of 80 to 100 bpm.

19. ☐ Name the data run "Standing". �(8.2)

Part 4 – Finding your raised leg heart rate

20. ☐ Have your partner lie down and relax again. Have your partner raise his or her legs at an angle of 30 degrees by resting them on two pillows or two books or both. Be sure the heart rate sensor is still attached to their earlobe.

    Note: To make a 30 degree angle, raise your partner's legs to a height that is about half the length of his or her legs.

21. ☐ Start data recording. �(6.2)

22. ☐ When you have captured a good trace for 30 seconds, stop data recording. �(6.2)

23. ☐ Find the mean heart rate. �(9.4)

24. ☐ Record the mean heart rate below.

    Raised legs heart rate: ____68____ bpm

Student rates will vary; generally students will have an elevated-legs heart rate of 60 to 70 bpm.

25. ☐ Why have you been recording the mean heart rate rather than the final heart rate measured?

Taking the average (mean) is a more accurate indication of the heart rate, which may vary over time. It also allows for variations due to the detection method of the heart rate sensor.

26. ☐ Name the data run "Raised legs". �(8.2)

27. ☐ Save your experiment �(11.1) and clean up according to your teacher's instructions.

Answering the Question

Analysis

1. Review each of your four saved heart rate data sets. If it is helpful, you can display the heart rates in a table. �(7.2.1) How did the heart rate of each position differ and what caused the difference?

Student answers will vary. The reclining position of the body will represent the base heart rate. The standing heart rate will be greater due to work against gravity. The heart rate will be slightly less while reclining with the legs raised due to shifting blood flow from the legs to the heart and easing the work needed to circulate the blood through the rest of the body.

2. Review your predictions between the position of a person's head and the flow of blood through the body. Did the data you collected verify your assumption?

Student answers will vary, based on the predictions.

3. Using your resting heart rate, calculate the number of heart beats of a person 15 years old.

Beats per minute:	70
Beats per hour:	4200
Beats per day:	100,800
Beats per year:	36,792,000
Beats per 15 years:	551,880,000

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. When going from lying down to standing, your heart rate will likely:

   A. Decrease
   B. Increase
   C. Stay the same

2. When changing from lying flat to supporting your legs about a foot from the table or floor you are laying on, your heart rate will likely:

   A. Decrease
   B. Increase
   C. Stay the same

3. The human organism has systems for digestion, respiration, reproduction, circulation, excretion, movement, control, and coordination and for protection from disease. The heart and blood vessels make up the:

   A. Digestive system
   B. Immune system
   C. Circulatory system

4. A primary difference between an organism's veins and arteries is:

   A. Veins are always smaller than arteries because they play a less important role in helping organisms to maintain stable internal conditions
   B. Veins return de-oxygenated blood to the heart while arteries bring oxygen-rich blood to the cells
   C. Arteries return de-oxygenated blood to the heart while veins bring oxygen-rich blood to the cells

5. One way in which a person's veins can become damaged is by:

   A. Exercising regularly
   B. Eating a healthy diet
   C. Smoking

Key Term Challenge

Fill in the blanks from the randomly ordered words below:

blood	heart rate	beats per minute	70
pulse	standing	resting	90

1. ____Heart rate____ is a term used to describe the number of beats of the heart per unit of time.

2. Usually heart rate is calculated as the number of contractions (beats) in one minute, so it is usually expressed as ____beats per minute____.

3. When resting, the typical adult human heart beats at about ____70____ bpm.

4. The ____pulse____ provides one way of measuring the heart rate.

Further Investigations

Design and perform an investigation: What is the effect of exercise and increased skin temperature (due to exercise) on your heart rate for the different positions used in this activity? Use the temperature sensor to test your skin temperature. Do you think you will have the same results with this elevated temperature as you did at your normal body temperature?

When you are restricted to your seat on a long airplane flight (at least 2 hours), what is the effect on your venous blood flow? Design and perform an investigation that tests your theory. Repeat the investigation while exercising in your seat throughout the entire investigation. Based on your results, would you suggest exercising during a long flight? Why?

Is there a significant difference between the heart rates of boys and girls?

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.

13. Yeast Growth

Fermentation in a Flask

Objectives

In this activity, students investigate fermentation by yeast cells using an absolute pressure sensor.

Additionally, students will be able to:

- Explain the fermentation process
- Describe the role of yeast cells during fermentation

Procedural Overview

Students gain experience conducting the following procedures

- Setting up the equipment and work area to measure the change in pressure in a flask as yeast cells undergo the fermentation process
- Measuring the change in pressure inside a flask of fermenting yeast cells at two different temperatures
- Comparing results with classmates to draw conclusions about the effect of temperature on the rate of fermentation of yeast

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Equipment setup and Part 2 – Making predictions	30 minutes
■ Lab activity, Part 3 – Fermenting yeast	30 minutes
■ Analysis	25 minutes

Materials and Equipment

For each student or group:

- ☐ Data collection system
- ☐ Absolute pressure sensor
- ☐ Temperature sensor
- ☐ Sensor extension cable
- ☐ Beaker, 200 mL
- ☐ Erlenmeyer flask , 250 mL (2)
- ☐ Plastic tubing with quick-release and barbed connectors[1]
- ☐ Balance
- ☐ Stopper with one hole
- ☐ Yeast, 1 tsp.
- ☐ Sugar, 2 tsp
- ☐ Tap water
- ☐ Glycerin, 1 drop

[1]Included with PASPORT Absolute Pressure Sensor

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- Yeasts are single-celled sac fungi.
- Yeast cells use sugar as food during the fermentation process, producing carbon dioxide and alcohol as wastes.
- The carbon dioxide that is given off causes bread dough to rise because the gas is trapped within the dough.
- Photosynthesis and respiration are processes that occur in living organisms.
- The slope of a graph represents the rate of change; the steeper the slope the greater the rate of change.

Related Labs in This Guide

Labs conceptually related to this one include:

- Transpiration
- Photosynthesis
- Boyle's Law

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system (identified by the number following the symbol: "�"). Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system �(1.2)
- Connecting multiple sensors to the data collection system �(2.2)
- Monitoring live data without recording �(6.1)
- Starting and stopping data recording �(6.2)
- Displaying data in a graph �(7.1.1)
- Adjusting the scale of a graph �(7.1.2)
- Displaying data in a digits display �(7.1.3)
- Saving your experiment �(11.1)

Background

150 years ago, no one knew how important the single celled sac fungi called *yeasts* are to humankind. We now know that yeast cells are involved in common medical conditions and are promising genetic research tools. They are also responsible for turning grape juice into wine; converting sugar, water, and hops into beer; and causing bread dough to rise. However, prior to the discovery of yeast as living things, people thought that magic was responsible.

Beer makers had known since ancient times that they needed to stir the wort (the sugar, hops, and water) with a special stick that they handed down from generation to generation in order to get the proper fermenting action. Bread makers also had known since ancient times that they had to preserve a culture that they carefully kept fresh with regular additions of sugar, and wine makers have known for millennia that when they crushed the grapes and let the juice sit in vats with the skins for awhile, it would ferment and turn into wine.

Louis Pasteur was the scientific genius who discovered that these processes were caused by yeast cells. When the French government called on him to figure out why the wine and beer industries were literally going sour, he used classic microbiological methods to determine that rogue bacteria had invaded the beer and wine and were preventing the yeast cells from growing and doing their job. He invented the pasteurization process to kill the bacteria, and then he inoculated the sterile solutions with the proper kinds of yeast cells, and voilà! Everyone was back in business.

Yeasts are versatile organisms. Unlike most other organisms that obtain their cellular energy either through *aerobic respiration* (requiring gaseous oxygen) or through *anaerobic respiration* (requiring the absence of oxygen), yeast cells respire in either condition, depending upon the availability of gaseous oxygen.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Ask the students, "What causes bread to rise?"

Yeast in the bread dough causes it to rise.

Ask the students, "What is yeast?"

Yeast is a living organism that is single celled, called a sac fungus.

Ask the students, "How does yeast cause bread to rise?"

These cells use the sugar in the dough as food during the fermentation process, producing carbon dioxide and alcohol as wastes. The carbon dioxide that is given off is what causes the dough to rise because the gas is trapped.

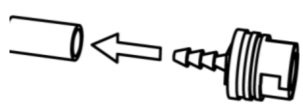
Direct the students to "Thinking About the Question." Discuss the answers to these questions as a whole group and come to a consensus.

Now direct the students to "Investigating the Question."

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- It can take as long as ten minutes for the yeasts to begin producing enough carbon dioxide for the pressure to show an increase.
- Make sure the Erlenmeyer flasks are clean, so that no residual chemicals are present that might prevent the growth of the yeast cells.
- If students will be doing multiple trials, they can start setting up for the second trial while the data is being collected in the first trial to save time in class.
- Make sure each pressure sensor's tubing has the quick-connector attached at one end.



- To ensure that a wide variety of temperatures are used, you may want to set out a series of containers of water that each vary in temperature between 5 and 10 degrees Celsius. Otherwise, monitor students as they obtain their tap water. Remind students that yeasts cannot survive extremely hot water, so caution them not to use water warmer than 50 degrees Celsius (about 130 degrees Fahrenheit).

Safety

Add this important safety precaution to your normal laboratory procedures:

- Students should wear goggles and an apron when working with glassware.

Driving Question

What affects the growth of a yeast cell?

Thinking about the Question

You are the brand new owner of a bakery. The faster you can produce your doughnuts and bread, the more money you will make. You need to determine what the optimal conditions are for getting the doughnuts and bread to rise. What causes the yeast in the dough to produce carbon dioxide?

> These cells use the sugar in the dough as food during the fermentation process, producing carbon dioxide and alcohol as wastes.

What can you test to determine the optimal conditions?

> Amount of yeast, amount of sugar, temperature

Would increasing the amount of yeast or sugar used in the dough be cost effective?

> No, increasing the amount of yeast or sugar would increase the costs of product so you would have less profit.

Which, temperature or amount of sugar, do you think would have the greatest effect on carbon dioxide production? Explain your reasoning.

> Students should suggest that giving the yeast a warmer environment will be more conducive to rapid rising, while providing more sugar does not change the rate at which the yeasts would be able to metabolize it.

How can you set up a test to verify which will have the greatest effect, using the materials in the equipment list?

> Students should suggest that by using a pressure sensor, the increase in the amount of carbon dioxide can be measured. Since carbon dioxide is a gas, increasing the number of gas molecules present in the closed flask will result in an increase in pressure. The greater the rate of pressure increase, the greater the rate of production of carbon dioxide gas by the fermenting yeast organisms.

Consider that it can take the yeast organisms a minimum of ten minutes to begin metabolizing the sugar, and will take as long as 25 minutes for them to produce enough carbon dioxide gas to cause the bread dough to rise. How can your entire class work together to test several different conditions at the same time? What variables will need to be controlled during this investigation?

> Students should suggest that each lab group can test a different temperature of water. Each temperature can be considered a separate trial, with the results being combined into one class data table. Variables that will need to be controlled are the volume of water, the amount of sugar, the volume and type of flask, the amount of yeast, and the stirring or mixing of the yeast and sugar-water used by each group. Although students may not consider the plastic tubing as a part of the volume of the flask, the length of the tubing is a factor in the total volume of the system. Therefore, the length of each piece of tubing should be as similar as possible.

Sequencing Challenge

Note: This is an optional ancillary activity.

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

2	1	5	3	4
Measure the temperature of the water to which you will add the yeast.	Make certain that each member of your lab group is aware of the safety rules and procedures for this activity.	Place the stopper firmly into the flask to seal it tightly so that any change in pressure can be accurately measured.	Add yeast to tap water.	Record pressure data in the flask with water, yeast, and sugar,

Investigating the Question

Note: When students see the symbol "�" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Equipment set up

1. ☐ Start a new experiment on the data collection system. �(1.2)

2. ☐ Connect an absolute pressure sensor and temperature sensor to the data collection system. �(2.2)

   Note: Use the sensor extension cable to connect the absolute pressure sensor.

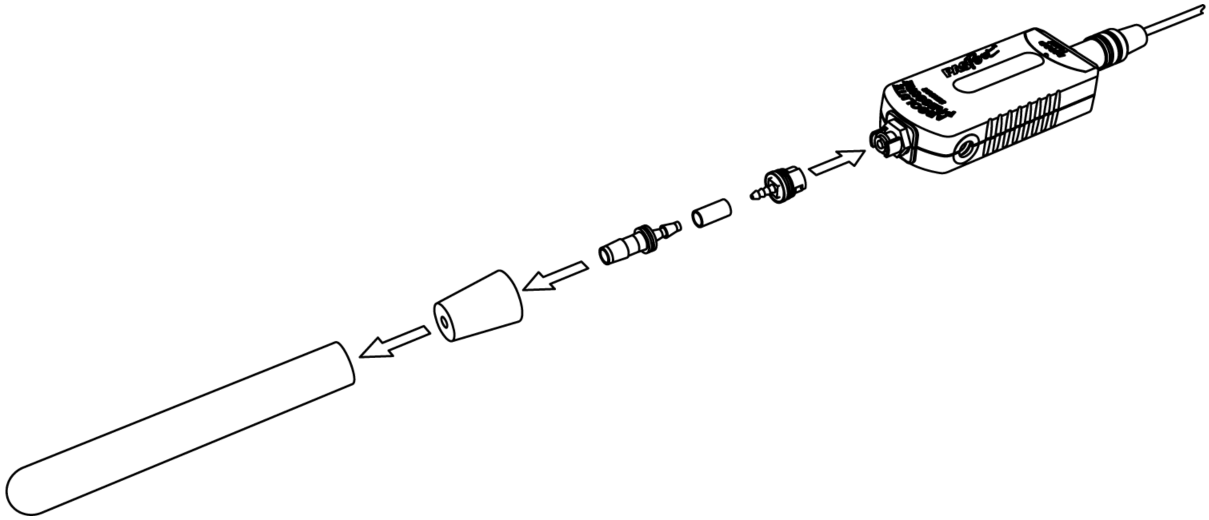
3. ☐ Display Absolute pressure on the y-axis of a graph with Time on the x-axis. �(7.1.1)

4. ☐ Display temperature in a digits display. �(7.3.1)

5. ☐ Change the sampling rate to take one absolute pressure and temperature measurement each second. �(5.1)

6. ☐ Assemble the pressure sensor tubing by inserting the barbed tubing connector through the hole of the stopper. Use glycerin if necessary, to help get the tubing through the hole.

7. ☐ Connect the quick-connect end of the tubing to the pressure sensor. Ask your teacher to verify that you have connected the apparatus correctly if you are unsure. Set the pressure sensor, the tubing, and the stopper assembly aside until Part 3 of the activity.



Part 2 – Making predictions

8. ☐ Record your prediction about what will happen to the pressure for two different temperatures of water.

We predict that the warmer water will cause the yeast to ferment more rapidly than the cooler water.

9. ☐ Record your prediction for which temperature used in class will be the one to produce optimal results.

Answers will vary. One student group answered as follows: We predict that the best temperature for the yeast to ferment at will be about the middle temperature among all the ones tested. For example, the coldest water probably will not be best, and the hottest water probably will not be best. Once we compare our class results, we predict that we will find the best temperature to be a medium temperature.

Part 3 – Fermenting yeast

10. ☐ Add 5 g (or 1 teaspoon) of sugar to 75 mL of water in an Erlenmeyer flask. What is the function of the sugar?

The sugar is the food for the yeast. As the yeasts metabolize the sugar, they give off carbon dioxide.

11. ☐ Monitor the temperature of the sugar water without recording. �(6.1) Write down this temperature to label the data run later.

Sugar water temperature: ___23.9___ °C

12. ☐ Add 2 g (or 1/2 teaspoon) of yeast to the flask. Carefully swirl the flask just enough to mix the yeast, sugar, and water.

13. ☐ Place the stopper into the opening of the flask and seal it tightly.

14. ☐ Start data recording. �(6.2) Continue recording for ten minutes. Observe the yeast in the flask and the pressure graph. Note your observations in the space below:

For the first several minutes, we didn't see any changes. Then the yeast began to get foamy and thicker. The layer of yeast that was floating at the top of the water got thicker as time went on. We also saw the pressure begin to increase.

15. ☐ After 10 minutes, stop recording pressure data. �(6.2)

16. ☐ Prepare the second sample. Pour 75 mL of water at a different temperature into the second Erlenmeyer flask.

17. ☐ Add 5 g (or 1 teaspoon) of sugar to the 75 mL of water in the second Erlenmeyer flask.

18. ☐ Monitor the temperature of the second sample of sugar water without recording. �(6.1) Write down this temperature to label the data run later.

Sugar water temperature: 44.6 °C

19. ☐ Add 2 g (or 1/2 teaspoon) of yeast to the flask. Carefully swirl the flask just enough to mix the yeast, sugar, and water.

20. ☐ Place the stopper into the opening of the flask and seal it tightly.

21. ☐ Start data recording �(6.2) on the same graph. You will now have two data runs in your graph display.

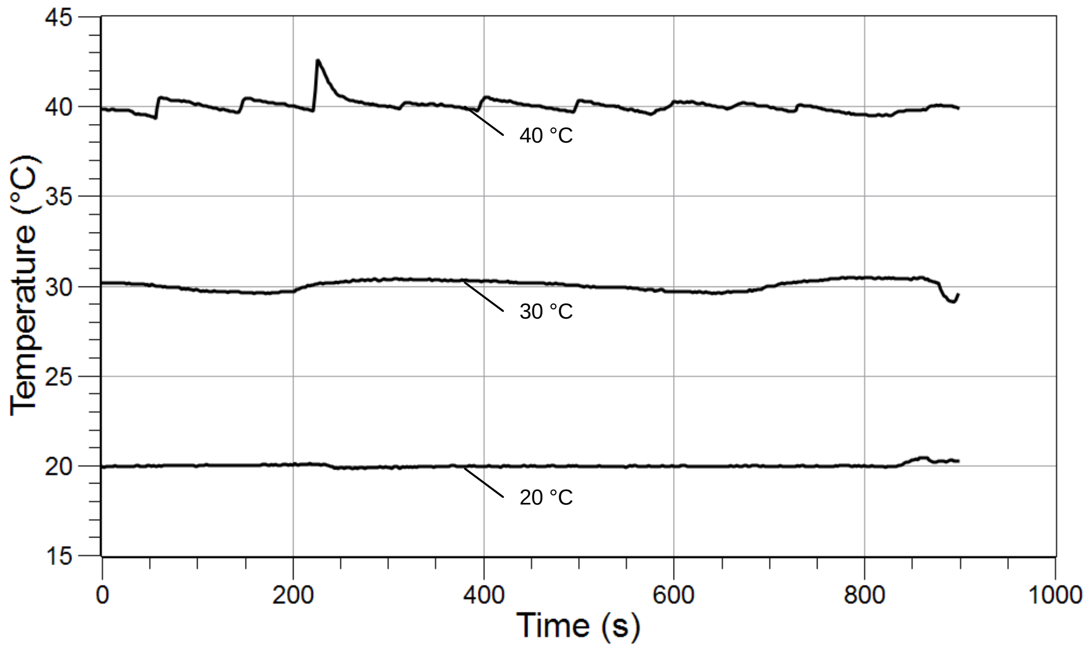
22. ☐ Continue recording pressure data in the second flask for ten minutes. Observe the yeast in the flask and the pressure graph. Note your observations in the space below:

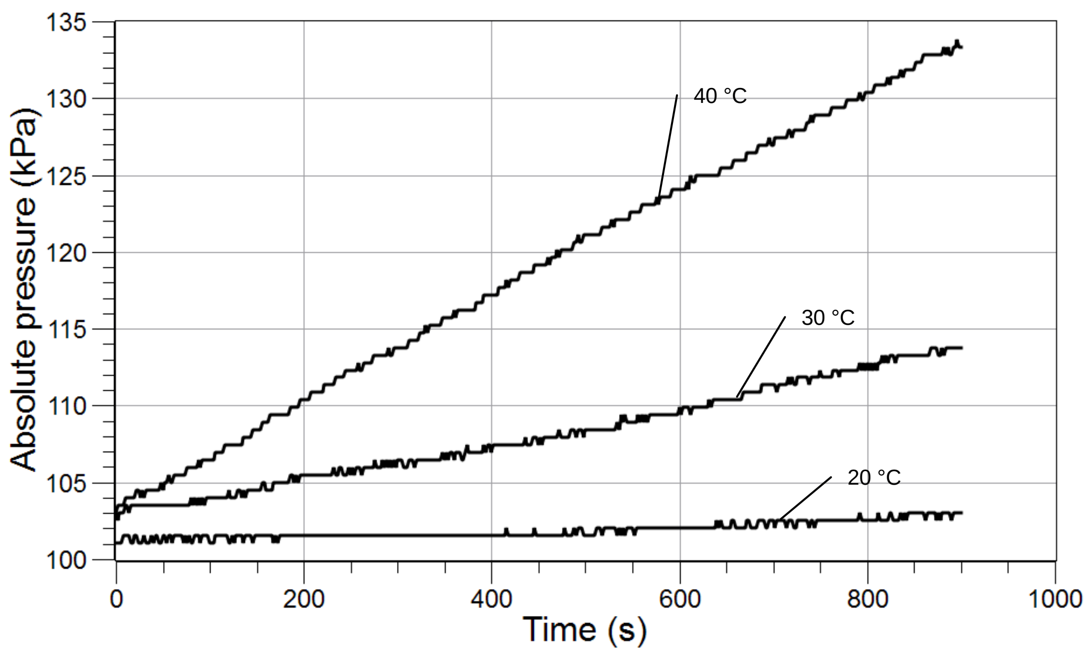
In the warmer water we saw the yeast begin to get foamy much sooner. We also noticed that the pressure began increasing sooner, and that the line on the graph seems slanted more steeply.

23. ☐ After your second yeast sample has been fermenting for ten minutes, stop recording pressure data. �(6.2)

24. ☐ Follow your teacher's instructions for saving your experiment �(11.1) and cleaning up your work area.

Sample Data





Answering the Question

Analysis

1. Review your data for absolute pressure. You may need to adjust the scale of your graph to see all of your data. �(7.1.2) In your graph of absolute pressure versus time, what does the slope of the line represent?

   The slope is the rate at which carbon dioxide is being produced.

2. What is the significance of one line of absolute pressure data appearing steeper than the other?

The steeper the line, the faster carbon dioxide is being produced.

3. Compare the different temperatures of water used by each of the lab groups. List the temperatures used, in order from coolest to warmest.

The temperatures of water used by our class were: 19.7°C, 23.9°C, 27.3°C, 32.7°C, 36.1°C, 39.1°C, 42.5°C, 44.6°C, 47.9°C, 48.2°C, 49.4°C, 50.3°C

4. Is there a temperature from which the rate of carbon dioxide production no longer increases? How do you know?

Above about 42.5 ˚C, the rate of carbon dioxide production is about the same. When we compared our pressure graphs with other lab groups, no one had a steeper slope for the pressure than the groups that used water that was 42.5°C.

5. Looking at your predictions, were you correct? Why or why not.

We predicted that the yeast would do best at a medium temperature of all the ones used by our class. The coolest water was 19.7°C, and the warmest water was 50.3°C. It turned out that the yeast fermentation produced carbon dioxide gas fastest at about 42.5°C, which was in the mid-range of our temperatures, but closer to the warmest water than to the coolest water.

6. Based on your data, what would be the most cost effective way to increase your bakery's production?

The most cost effective way to increase my bakery's production is to use water at 42.5°C when mixing the dough.

7. Describe the fermentation process.

In fermentation, the yeast cell gets its energy by breaking down sugar into an alcohol called ethanol and two carbon dioxide molecules.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. In the SI system pressure is measured in units called

   A. Newtons
   B. Pascals
   C. Kelvins

2. We used the ________________ to measure the increase in a gas in a closed flask.

   A. Pressure sensor
   B. Dissolved oxygen sensor
   C. Temperature sensor

3. Yeasts are organisms that

   A. Photosynthesize in the presence of sunlight.
   B. Produce oxygen as a waste product.
   C. Each consist of a single cell

4. Suppose that you wanted to provide some yeast with an ideal environment in which to cause bread to rise as quickly as possible. Rank the following in order from least to most important for success:

   A. Enough sugar, a large enough container, adequate ventilation
   B. Adequate ventilation, enough sugar, plenty of time
   C. Adequate container, enough sugar, optimum temperature

5. A type of anaerobic respiration in which yeast feeds on sugar and gives off alcohol and carbon dioxide gas as waste products is known as:

   A. Fermentation
   B. Photosynthesis
   C. Pressurization

Key Term Challenge

Fill in the blanks from the randomly ordered words below. Not every word may be used.

aerobic respiration	anaerobic respiration	asexual	budding
fermentation	fungus	yeast	gas

1. A single-celled fungi in the phylum Ascomycota that reproduce by budding is called __yeast__.

2. ____Aerobic respiration____ is the oxidation of food molecules such as glucose to water and CO_2 requiring the presence of free oxygen

3. ____Budding____ is a form of asexual reproduction in which new individuals develop from a portion of the parent.

4. The oxidation of food molecules such as glucose to water and CO_2 without requiring the presence of free oxygen is called ____anaerobic respiration____.

5. ____Fungus____is the kingdom of non-photosynthetic organisms that reproduce by spores and absorb nutrients through their cell walls.

6. ___Asexual___ reproduction takes place without the formation of gametes. The production of clones of an organism such as by budding or fission.

7. On Earth, carbon dioxide exists mainly in the ___gas___ phase of matter.

Further Investigations

What effect would more sugar have on the rate of carbon dioxide production?

What affect would more yeast have on the rate of carbon dioxide production?

How long does it take for a given amount of yeast to stop producing further carbon dioxide gas? How could you tell from a graph that CO_2 production had stopped?

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.