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THE SCIENCE OF THE HEART AND CIRCULATION

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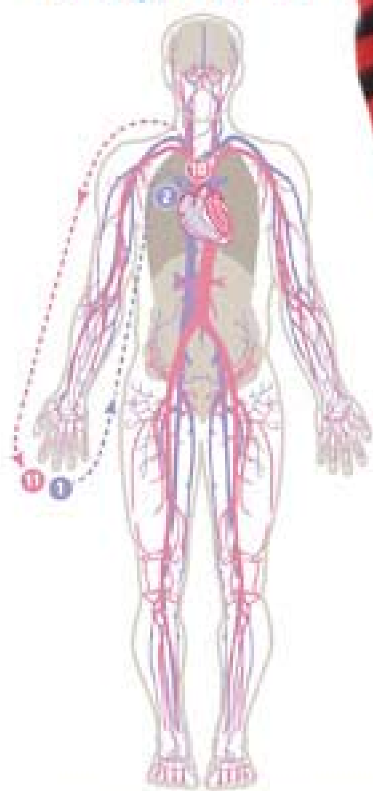

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TEACHER'S GUIDE

Barbara Z. Tharp, M.S., Deanne B. Erdmann, M.S., Marsha L. Matyas, Ph.D., Ronald L. McNeel, Dr.P.H., and Nancy P. Moreno, Ph.D.

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by

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Nancy P. Moreno, Ph.D.

RESOURCES

This publication is available in PDF format at www.nsbri.org and in the Teacher Resources section at www.BioEdOnline.org.

For online presentations of each activity and downloadable slide sets for classroom use, visit www.BioEdOnline.org or www.k8science.org.

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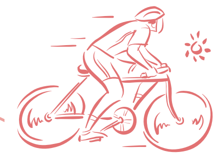

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Education is an important part of the National Space Biomedical Research Institute (NSBRI), which is teaming with some of the nation's finest biomedical researchers to create new strategies for safe human exploration and development of space.

Scientists supported by NSBRI are studying the heart and circulatory system to benefit not only NASA and space travelers, but also people right here on Earth.

For more information about all NSBRI research areas, visit the NSBRI Web site at www.nsbri.org.

TEAMING WITH BENEFITS

by Jeffrey P. Sutton, M.D., Ph.D., Director, National Space Biomedical Research Institute (NSBRI)

Dr. Jeffrey P. Sutton

Space is a challenging environment for the human body. With long-duration missions, the physical and psychological stresses and risks to astronauts are significant. Finding answers to these health concerns is at the heart of the National Space Biomedical Research Institute's program. In turn, the Institute's research is helping to enhance medical care on Earth.

The NSBRI, a unique partnership between NASA and the academic and industrial communities, is advancing biomedical research with the goal of ensuring a safe and productive long-term human presence in space. By developing new approaches and countermeasures to prevent, minimize and reverse critical risks to health, the Institute plays an essential, enabling role for NASA. The NSBRI bridges the research, technological and clinical expertise of the biomedical community with the scientific, engineering and operational expertise of NASA.

With nearly 60 science, technology and education projects, the NSBRI engages investigators at leading institutions across the nation to conduct goal-directed, peer-reviewed research in a team approach. Key working relationships have been established with end users, including astronauts and flight surgeons at Johnson Space Center, NASA scientists and engineers, other federal agencies, industry and international partners. The value of these collaborations and revolutionary research advances that result from them is enormous and unprecedented, with substantial benefits for both the space program and the American people.

Through our strategic plan, the NSBRI takes a leadership role in countermeasure development and space life sciences education. The results-oriented research and development program is integrated and implemented using focused teams, with scientific and management directives that are innovative and dynamic. An active Board of Directors, External Advisory Council, Board of Scientific Counselors, User Panel, Industry Forum and academic Consortium help guide the Institute in achieving its goals and objectives.

It will become necessary to perform more investigations in the unique environment of space. The vision of using extended exposure to microgravity as a laboratory for discovery and exploration builds upon the legacy of NASA and our quest to push the frontier of human understanding about nature and ourselves.

The NSBRI is maturing in an era of unparalleled scientific and technological advancement and opportunity. We are excited by the challenges confronting us, and by our collective ability to enhance human health and well-being in space, and on Earth.

NSBRI RESEARCH AREAS

CARDIOVASCULAR PROBLEMS

The amount of blood in the body is reduced when astronauts are in microgravity. The heart grows smaller and weaker, which makes astronauts feel dizzy and weak when they return to Earth. Heart failure and diabetes, experienced by many people on Earth, lead to similar problems.

HUMAN FACTORS AND PERFORMANCE

Many factors can impact an astronaut's ability to work well in space or on the lunar surface. NSBRI is studying ways to improve daily living and keep crewmembers healthy, productive and safe during exploration missions. Efforts focus on reducing performance errors, improving nutrition, examining ways to improve sleep and scheduling of work shifts, and studying how specific types of lighting in the craft and habitat can improve alertness and performance.

MUSCLE AND BONE LOSS

When muscles and bones do not have to work against gravity, they weaken and begin to waste away. Special exercises and other strategies to help astronauts' bones and muscles stay strong in space also may help older and bedridden people, who experience similar problems on Earth, as well as people whose work requires intense physical exertion, like firefighters and construction workers.

NEUROBEHAVIORAL AND STRESS FACTORS

To ensure astronaut readiness for spaceflight, preflight prevention programs are being developed to avoid as many risks as possible to individual and group behavioral health during flight and post flight. People on Earth can benefit from relevant assessment tests, monitoring and intervention.

RADIATION EFFECTS AND CANCER

Exploration missions will expose astronauts to greater levels and more varied types of radiation. Radiation exposure can lead to many health problems, including acute effects such as nausea, vomiting, fatigue, skin injury and changes to white blood cell counts and the immune system. Longer-term effects include damage to the eyes, gastrointestinal system, lungs and central nervous system, and increased cancer risk. Learning how to keep astronauts safe from radiation may improve cancer treatments for people on Earth.

SENSORIMOTOR AND BALANCE ISSUES

During their first days in space, astronauts can become dizzy and nauseous. Eventually they adjust, but once they return to Earth, they have a hard time walking and standing upright. Finding ways to counteract these effects could benefit millions of Americans with balance disorders.

SMART MEDICAL SYSTEMS AND TECHNOLOGY

Since astronauts on long-duration missions will not be able to return quickly to Earth, new methods of remote medical diagnosis and treatment are necessary. These systems must be small, low-power, noninvasive and versatile. Portable medical care systems that monitor, diagnose and treat major illness and trauma during flight will have immediate benefits to medical care on Earth.

For current, in-depth information on NSBRI's cutting-edge research and innovative technologies, visit www.nsbri.org.

OVERVIEW

To evaluate their current understanding of the heart and circulatory system, students will complete a pre-assessment. Students also will develop group concept maps. At the conclusion of this unit, students will repeat the assessment and compare their prior knowledge about the heart to what they have learned (see Answer Key, sidebar, p. 2).

ACTIVITY 1

PRE- AND POST-ASSESSMENT

This unit introduces students to the circulatory system in humans and other mammals. Using examples from current research on human space travel, it engages students in authentic questions and investigations. Students will learn that the circulatory system distributes materials to and from all regions of the body, and that it plays a role in regulating body temperature by transferring heat from warmer regions of the body to cooler ones, and vice versa. Circulation in mammals relies on the following components.

- **The heart** serves as a pump.
- **Blood** carries oxygen, carbon dioxide, nutrients, vitamins, minerals, waste products, water and other substances.
- **Blood vessels** serve as the "roadways" or "pipes" for delivery and pick-up.

Throughout the unit, students will work in groups to build concept maps that provide a visual representation of the groups' progress in understanding and linking concepts (see "Concept Maps," sidebar, p. 3). But first, students will complete a pre-assessment, which will prompt them to ask questions regarding a new topic, and provide an opportunity for you to gauge students' existing knowledge.

Students will repeat this assessment at the end of the unit as a post-assessment.

PRE-ASSESSMENT

TIME

10 minutes for setup; 45 minutes to conduct activity

MATERIALS

Each group will need:

- Markers and writing materials
- Pad of sticky notes
- Poster board or large sheet of paper

Continued

SCIENCE EDUCATION CONTENT STANDARDS*

GRADES 5–8

INQUIRY

- Identify questions that can be answered through scientific investigations.
- Think critically and logically to make the relationships between evidence and explanations.
- Recognize and analyze alternative explanations and predictions.
- Communicate scientific procedures and explanations.

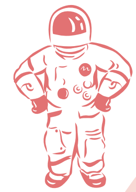
LIFE SCIENCE

- Living systems at all levels of organization demonstrate the complementary nature of structure and function.
- The human organism has systems for digestion, respiration, reproduction, circulation, excretion, movement, control and coordination, and for protection from disease. These systems interact with one another.

SCIENCE, HEALTH & MATH SKILLS

- Graphing

* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.



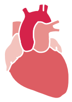
AstroBlogs!

Unit Extension: To enrich students' experiences throughout the unit, and to provide more opportunities for students to write about what they are learning, create a "blog wall" in the classroom, where students can post their comments and ideas. AstroBlog entries for some activities are provided at the back of this guide (see pp. 42–44).

Image Citations

Source URLs are available at the front of this guide.

USING COOPERATIVE GROUPS IN THE CLASSROOM



Cooperative learning is a systematic way for students to work together in groups of two to four. It provides organized group interaction and enables students to share ideas and to learn from one another. Students in such an environment are more likely to take responsibility for their own learning. Cooperative groups enable the teacher to conduct hands-on investigations with fewer materials.

Organization is essential for cooperative learning to occur in a hands-on science classroom. Materials must be managed, investigations conducted, results recorded, and clean-up directed and carried out. Each student must have a specific role, or chaos may result.

The Teaming Up! model* provides an efficient system for cooperative learning. Four "jobs" entail specific duties. Students wear job badges that describe their duties. Tasks are rotated within each group for different activities so that each student has a chance to experience all roles. For groups with fewer than four students, job assignments can be combined.

Once a cooperative model for learning is established in the classroom, students are able to conduct science activities in an organized and effective manner. The job titles and responsibilities are as follow.

Principal Investigator
- Reads the directions
- Asks questions of the instructor/teacher
- Checks the work

Maintenance Director
- Directs carrying out of safety rules
- Directs the cleanup
- Asks others to help

Reporter
- Records observations and results
- Shares results with group or class
- Tells the teacher when the investigation is complete

Materials Manager
- Picks up the materials
- Directs use of equipment
- Returns the materials

* Jones, R.M. 1990. Teaming Up! LaPorte, Texas: ITGROUP.

Each student will need:
- Copy of assessment sheet (p. 4)

SETUP & MANAGEMENT

The pre-assessment should be administered as an individual student activity prior to beginning the group activities (see Procedure, Items 1 and 2).

At the conclusion of the unit, you will conduct a post-assessment using a clean copy of the assessment sheet and the completed pre-assessments.

Unless noted, each activity in this guide is designed for students working in groups of four (see "Using Cooperative Groups in the Classroom," above).

PROCEDURE

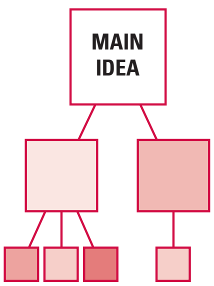
1. Explain to students that they will be learning about the heart and circulatory system. Tell them that first, they will take a pre-assessment to help them identify what they already know and what they might want to learn about this topic.
2. Distribute the pre-assessment to students. Have them complete the form individually, and then collect the assessments. (Save for use during the post-assessment.)
3. Instruct students to write any questions they have about topics covered on the assessment on a "sticky note." Then have students place their notes in a "parking lot" (a part of a bulletin board reserved just for student questions).
4. Use student questions to begin a discussion about the unit. This is a good time to identify any misconceptions the students may have. Explain to students that their questions will be answered as they learn more over the course of the unit.
5. Next, have students organize into groups of four to begin building their concept maps. Have student groups discuss what they know about their hearts and circulatory systems. Ask each group to begin a concept map

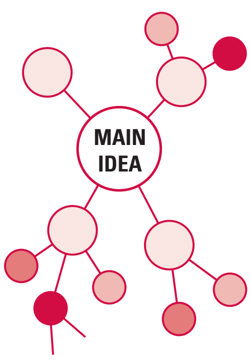
Pre- and Post-Assessment Answer Key

1.	c	9.	d
2.	a	10.	b
3.	b	11.	d
4.	a	12.	a
5.	a	13.	b
6.	c	14.	c
7.	b	15.	d
8.	b		

Concept Maps

Concept maps are web-like representations of knowledge, concepts and ideas. Concepts are expressed as words or phrases. They are connected by lines or arrows, and by linking words that describe relationships between two concepts.





Shown above are two different approaches to creating concepts maps. Students may use sticky notes to position and reposition concepts on their maps as they learn.

Computer-based graphics software also may be used to create concept maps.

or other form of graphic organizer that represents its collective knowledge and questions. Tell students that while they may not have much information now, they will be adding to their concept maps throughout the unit. You may want to describe concept maps as a way for students to "picture" what they are learning, including relationships among concepts and other pertinent information. Then suggest some ways for groups to begin. Concept maps may be computer generated or built on large poster paper or poster board. Students may prefer to use sticky notes on their concept maps, so that ideas and concepts can be rearranged as students' knowledge increases. Display the concept maps around the room.

Photo courtesy of NASA.

Astronaut Carl E. Walz, Flight Engineer, NASA International Space Station (ISS) Expedition 4, performs cardiopulmonary resuscitation on an improvised "human chest" dummy while onboard the space station. Astronauts not only need to keep themselves healthy; they also must be prepared to serve as health care providers for their fellow astronauts.

POST-ASSESSMENT

To be conducted at the end of this unit.

TIME

Two 45-minute sessions (2 days)

MATERIALS

Each group will need:

- Group concept maps (ongoing)

Each student will need:

- Clean copy of Assessment sheet (p. 4)
- Copy of previously completed pre-assessment (hold for distribution, see Session Two, Item 2)

PROCEDURE

Session One

1. After completing this unit, have students work in their original groups to review their concept maps. Each group should discuss the additions made to its concept map and decide which findings were most important.
2. Review each group's concept map for accuracy and help students to correct any misconceptions. Discuss any remaining questions placed on the board ("parking lot") over the course of the unit. Ask for volunteers or assign student teams to research unanswered questions. Provide time for student groups to change, add to or correct their concept maps.
3. Have each group, or a spokesperson from each group, present the group's concept map. The presentation should explain the group's approach to organizing material and concepts that it found particularly interesting or challenging. The presentations may be used as formative or summative assessments.

Session Two

1. Distribute copies of the post-assessment for each student to complete.
2. After students have finished, have them compare their answers on both pre- and post-assessments to see how much they have learned during the unit. Discuss any remaining student questions and collect the assessments, which can become part of students' portfolios or science notebooks.

Activity: Assessment

What Do You Know?

Name

Circle the best response to questions 1 through 15.

1. The heart is located
   a. on the left side of the chest.
   b. on the right side of the chest.
   c. near the center of the chest.
   d. in the abdomen.

2. During exercise, heart rate increases to
   a. supply muscles with more oxygen.
   b. improve breathing.
   c. aid digestion.
   d. supply the lungs with more oxygen.

3. What is the advantage of having a heart with four chambers?
   a. There is extra capacity when needed.
   b. Blood can be pumped separately to the lungs and to the rest of the body.
   c. There is a chamber to supply blood to each of the four limbs (arms and legs).
   d. It is twice as large as a heart with two chambers.

4. Once it leaves the heart, blood flows from
   a. arteries to capillaries to veins.
   b. veins to arteries to capillaries.
   c. capillaries to arteries to veins.
   d. none of the above.

5. Why do some blood vessels have thicker walls than others?
   a. To handle blood at a higher pressure.
   b. To carry thicker blood.
   c. To force blood into the heart.
   d. To handle blood at a lower pressure.

6. Under normal standing conditions on Earth, blood is pulled toward the
   a. arms.
   b. heart.
   c. legs.
   d. head.

7. Blood pressure is a measurement of the force of blood against the walls of the
   a. heart.
   b. arteries.
   c. veins.
   d. capillaries.

8. In outerspace, where gravity is not felt, the heart must work
   a. harder than on Earth.
   b. not as hard as on Earth.
   c. about the same as on Earth.
   d. about the same as on the Moon.

9. Blood pressure usually is reported as two measurements, such as "120 over 80." What does the second measurement describe?
   a. Pressure that is calculated based on a person's age.
   b. Pressure while the heart is contracting.
   c. Pressure that is typical for a person with hypertension.
   d. Pressure while the heart is relaxing.

10. Animals without a circulatory system rely on this process to transport nutrients and waste.
    a. Transfusion
    b. Diffusion
    c. Perfusion
    d. Respiration

11. When astronauts return from space, they often experience temporary changes in the circulatory system, which can cause
    a. loss of hearing.
    b. heart murmurs.
    c. spikes in blood pressure.
    d. dizziness.

12. Pulse results from
    a. a surge of pressure through an artery.
    b. filling of a chamber of the heart.
    c. valves found in veins.
    d. the heart relaxing.

13. The role of each atrium is to
    a. pump blood out of the heart.
    b. receive blood coming into the heart.
    c. serve as a doorway between chambers.
    d. connect the heart to the lungs.

14. What might you do if you wanted to lower your resting heart rate?
    a. Take frequent naps.
    b. Eat carbohydrates.
    c. Get more exercise.
    d. Get at least eight hours of sleep every night.

15. About how much blood circulates around the body of a typical adult each minute?
    a. 100 mL
    b. 500 mL
    c. 1,000 mL
    d. 5,000 mL

OVERVIEW

The circulatory system efficiently moves large volumes of blood through the body. It includes a large and complex array of different sized vessels that carry blood away from, and then back to the heart.

Students will work in teams to simulate the volume of blood moved through the circulatory system by transferring liquid into—and through—a series of containers.

ACTIVITY 2

A SYSTEM OF TRANSPORT

Every living organism—even single-celled organisms—must interact with its environment to exchange gases (oxygen and carbon dioxide), obtain nutrients and eliminate wastes. In general, larger and more complicated organisms (such as humans) have more sophisticated, efficient systems to transport needed materials to and remove waste from cells where exchanges occur. In this activity, students will simulate movement of blood through the circulatory system and learn about the challenges of moving large quantities of liquid a little at a time.

The circulatory system in most adult humans circulates approximately 5.0 liters (5,000 mL) of blood around the body every minute. In newborns, half this amount of blood is pumped. And approximately 4.1–4.3 liters of blood circulates each minute in children and adolescents. With each contraction, an adult heart pumps about 60–130 mL of blood out from the left chamber (also called left ventricle) into the artery that leads to the body. In children and adolescents, the amount pumped is about 40 mL per contraction.

Humans have a closed circulatory system. This means that whole blood, for the most part, stays inside the blood vessels and heart, and does not mix with other body fluids. A good example of a closed system is the water treatment facility in your town. The facility sends clean water to your home through pipes. If the pipes are working properly, the water does not leak out. After you use the water, you pour it down the drain. From there, it travels through a different set of pipes back to the water treatment plant, where it gets cleaned again for re-use.

Continued

SCIENCE EDUCATION CONTENT STANDARDS*
GRADES 5–8

PHYSICAL SCIENCE
Motion and forces
- The motion of an object can be described by its position, direction of motion, and speed. Motion can be measured and represented on a graph.

LIFE SCIENCE
Structure and function of living systems
- Living systems at all levels of organization demonstrate the complementary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms and ecosystems.

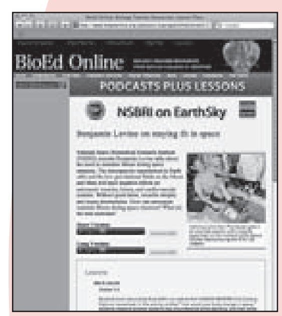
SCIENCE, HEALTH & MATH SKILLS
- Measuring
- Creating a model
- Comparing
- Questioning
- Calculating
- Drawing conclusions

* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

Miles of Vessels

The average child has more than 60,000 miles of blood vessels. Adults have almost 100,000 miles of vessels!

Teacher Resources



Downloadable activities in PDF format, annotated slide sets for classroom use, and other resources are available free at www.BioEdOnline.org or www.k8science.org.

In much the same way, the human circulatory system moves blood to all parts of the body through the blood vessels (pipes or tubes). The pump that drives the blood through these vessels is the heart. Like water in pipes, whole blood stays inside the blood vessels. And just as large water mains divide into smaller and smaller pipes (like those under your sink), the large blood vessels attached to the heart divide into smaller and smaller vessels, so that each cell in the body is near to or touching tiny blood vessels. On the way back to the heart, blood vessels merge together into larger veins. Like water in a treatment facility, blood gets cleaned during each round-trip, and is made ready to use again and again.

The circulatory system is the "transportation system" for the body, and blood serves as the transport vehicle. Just as trucks deliver food, clothes, and other goods to houses and stores, blood circulates around the body, carrying and delivering the oxygen and nutrients needed by each cell. And like trucks that carry garbage away from our homes, the blood in our bodies picks up waste products (carbon dioxide and cellular waste) from cells, and takes wastes to organs that eliminate them from the body. As blood travels through some organs, it also makes special drop-offs and pick-ups.

- At the lungs, blood drops off carbon dioxide (waste), water and heat, and picks up oxygen.
- At the kidneys, blood drops off waste products, excess water, salts and vitamins.
- At the intestines, blood picks up nutrients, minerals, water and some vitamins.
- At other organs and glands, blood picks up hormones that help regulate body functions.

TIME

10 minutes for setup; 45 minutes to conduct activity

MATERIALS

Teacher (see Setup)

- Marker or labels for tubs
- Timer or clock

Each group of six students will need:

- 6 tubs or buckets labeled A–F (5-liter capacity each)
- 4 flexible plastic cups (soft plastic that can be cut with scissors)
- 2 15-mL tablespoons for measuring
- Graduated cylinder (100-mL or higher)
- Pad of sticky notes
- Pair of scissors
- Paper towels
- Roll of masking tape

Each student will need:

- Copy of student sheet (p. 9)

SAFETY

Clean up spilled water promptly to avoid slippery floors. Always follow all district and school laboratory safety procedures. It is a good idea for students to wash their hands with soap and water before and after any science activity.

SETUP & MANAGEMENT

Have students conduct the activity in teams of six. For easier management, have two teams carry out the activity simultaneously, possibly as a relay race.

For each team, label each of six large (at least five-liter) containers with a letter, A through F. Place five liters of water in container "A." Leave the remaining containers empty.

Before students begin the activity, write "5,000 mL" on a large sticky note and place it on the board. This number represents the five liters of blood pumped through the average adult circulatory system in one minute. But do not mention its significance until students post their group numbers (see Procedure, Item 10).

Note: It may be advisable to review metric units for measuring volume.

PROCEDURE

1. Divide students into teams of six. Then have team members count off

The Circulatory System

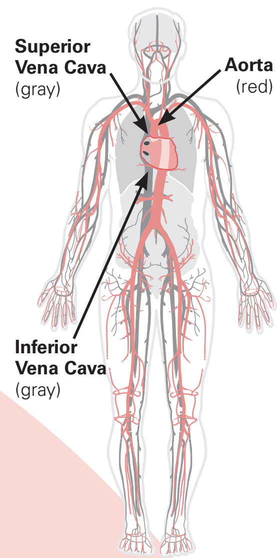


Fig. 1. The Circulatory System is the "transportation system" for the body, and blood serves as the transport vehicle.

Veins (shown in gray) take blood to the heart. Arteries (shown in red) take blood away from the heart.

The Liter

The liter (L) is the basic unit of volume in the metric system.

One liter represents the capacity of a 10-centimeter cube. One liter is approximately 1.75 pints.

1 milliliter (mL) = 0.001 L

1,000 mL = 1L

1 teaspoon (t) = 5 mL

1 tablespoon (T) = 15 mL

The Aorta

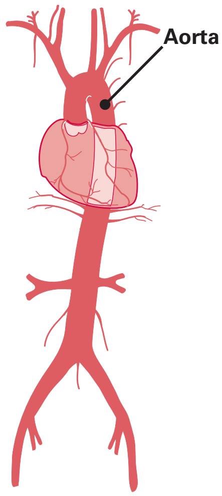


Fig. 2. There is no larger artery in the body than the aorta. It carries blood and nutrients away from the heart (see Fig. 1, p. 6).

The Vena Cavas

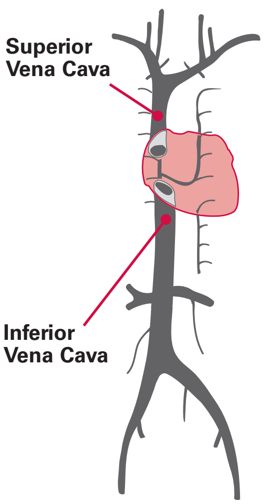


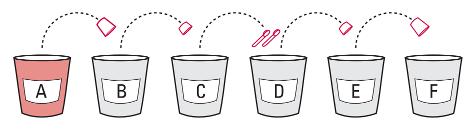
Fig. 3. The vena cavas are the two largest veins in the body. The superior vena cava brings blood from the arms and head to an opening at the top of the heart. The inferior vena cava brings blood from the legs and trunk to an opening in the bottom of the heart (see Fig. 1, p. 6).

STUDENT ACTIVITY: PATHWAY MODELED

Student Number	Location	Volume (mL) Per Move	Pathway Modeled
1	A to B	60	One contraction or "beat" from the heart to large arteries
2	B to C	30	From large arteries to small arteries
3 and 4 (students work in parallel; each has a tablespoon)	C to D	15 (1T)	From small arteries through capillaries into small veins
5	D to E	30	From small veins into large veins
6 =	E to F	60	From large veins back to the heart

from one through six. Each number designates a different role on the team.

2. Ask the Materials Manager and a helper from each group to pick up student worksheets, container "A" with five liters of water, other containers marked as B–F, a beaker or graduated cylinder, four plastic cups, scissors, two tablespoons, masking tape and several paper towels.
3. Have students calibrate four plastic cups as measuring tools, as follows.
   - Using the graduated cylinder, fill two cups with 60 mL of water and two cups with 30 mL of water.
   - Wrap a piece of tape around each cup, with the top edge of the tape lined up with the level of the water.
   - Empty all cups and cut off the top of each at the upper edge of the masking tape.
4. Explain to students that they will be participating in a "water relay race" by following a specific set of procedures. Each six-member relay team will work together to move five liters of water from container "A" all the way to container "F." Each team member may move water only by using the measuring cup or tablespoon assigned to him or her. Teams may not skip any steps. Review the assignment for each team using the "Move It" student page.
5. Set a time limit (three minutes is suggested) and tell student groups that they will measure the amount of water they are able to move to container "F" before the set time expires. Set up a system of tubs (A–F) arranged in a line to demonstrate a few steps in the procedure and ask if there are any questions.



6. Have students set up their relay systems, two groups at a time. Before they begin, check each team's setup. Start the activity with both groups simultaneously. All team members should stop when time is called.
7. Each team should record on a sticky note the number of mL of water in container "F" (total volume moved during the relay). Each team's note should be placed on the board in numerical order, before or after the 5,000 mL note that you had earlier placed on the board.
8. When all teams have posted their results, ask, *What do you think was modeled by the water relay race?* Take time to consider all responses. [The relay models the amount of blood pumped

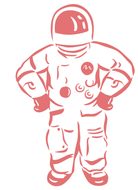
Continued

around the body (cardiac output) for an average adult, per minute.]

9. Next, refer to the numbers posted by each group. Ask, *Why is the number, 5,000, on the board?* Discuss and explain that this number represents the 5,000 mL (or five liters) of blood that typically are pumped from the heart through the body of an adult each minute.
10. Ask, *Which part of your team's system modeled the amount of blood that leaves the heart with each contraction?* [transfer of 60 mL of liquid into Container A] Sixty mL represents a typical amount of blood exiting the heart into the body (varies between 60 and 130 mL in adults). In the model, what other parts of the circulatory system were represented? Use a simplified illustration of the circulatory system (photocopy and make a transparency of the diagram on p. 6, or download a PowerPoint® slide of the circulatory system from www.BioEdOnline.org to explain how, after blood is pumped from the heart into the body, it travels through a series of vessels, called arteries.

    Arteries become progressively smaller further away from the heart. The smallest vessels, called capillaries, are thinner than a hair. They allow the transfer of nutrients, oxygen, waste and carbon dioxide between blood and individual cells. In most of the body, nutrients and oxygen are transferred from blood into cells, while waste and carbon dioxide move from cells into blood, which carries them away to be eliminated from the body.

    Vessels that convey blood back to the heart, called veins, become progressively larger in diameter until they reach the vena cavas, through which blood enters the heart. Ask, *Is your team's system a good model of the circulatory system? What are the shortcomings? How might we make it better?*
11. Have student groups create a literary representation of arteries, veins and capillaries to help them remember the function of each vessel. The representations can take the form of a poem, acronym, acrostic, rebus or other mnemonic. All representations should convey the following concepts: arteries carry blood away from the heart and have a larger diameter than capillaries; capillaries are very narrow and very numerous, which permits the transfer of materials—such as nutrients, oxygen, carbon dioxide and waste—to cells; veins are comparable in size to arteries and bring blood back to the heart.
12. Have students display their representations around the classroom. Ask, *Why do you need to know about your blood vessels? Have you ever heard or seen an advertisement about health problems related to blood vessels?* [for example, high blood pressure or blood clots]
13. Have student groups add information to their concept maps, including answers to any questions posed earlier.



AstroBlogs!

An AstroBlog entry for Activity 2 can be found on page 42.

Memory Aids

Acronym: A word formed from the combination of the initial letters of a phrase or name (such as LASER, derived from "light amplification by stimulated emission of radiation").

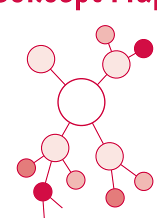
Acrostic: A series of lines or verses in which certain letters, usually the first of each line, spell out a word or phrase when read in sequence (such as the poem below, which is an acrostic for "vein").

Veritable tube that
Efficiently
Is designed to carry
Notable wastes from cells

Mnemonic: Any memory aid, such as a rhyme or acronym.

Rebus: A representation of words through pictures or symbols.

Update Concept Maps



ACTIVITY 2
MOVE IT!

During a relay race, members of each team take turns swimming or running parts of a circuit or course. In this activity, you and your team members will complete a water relay. Each team member will play a different role.

1. Within your team, count off from one through six. Each team member will have a specific job, based on his or her number (see chart below).

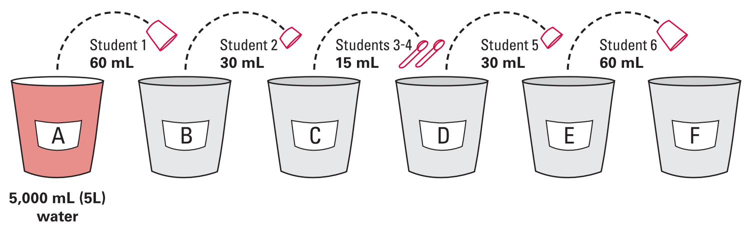
2. Gather six tubs or buckets, labeled A–F, a graduated cylinder, four plastic cups, two tablespoons, paper towels, a roll of masking tape and a pair of scissors.

3. Follow the instructions below to create and calibrate four special measurement cups.

    A. Fill a graduated cylinder with 60 mL of water and pour the water into one plastic cup.
    B. Wrap a long piece of tape around the outside of the cup, making sure that the top edge of the tape is level with the top of the water. Pour out the water.
    C. Cut off the extra plastic that is above the top edge of the tape. Label the cup "60 mL."
    D. Repeat to make another 60-mL cup and two 30-mL cups.*

    *To make two 30-mL cups, follow the instructions above, but begin 30 mL of water instead.

4. Find an empty area on the floor. Place the six tubs or buckets on the ground in a straight line, one next to the other. Make sure the tubs or buckets are labeled A–F.



5. Fill container A with five liters of water. Your team will work together to move water from tub A to tub F, with each student using his or her assigned cup or spoon to move only the specified amount from one tub to the next. All team members will be working at the same time.

6. Wait for your teacher's instruction to begin. Try not to spill any water.

7. After the teacher has called time to end the relay, measure the total amount of water in tub F. Record the number in the table below.

Team Member	Location	mL to Move
1	A to B	60
2	B to C	30
3 and 4	C to D	15 (Team members 3 and 4 each use a tablespoon to move water from container C to container D.)
5	D to E	30
6	E to F	60

	Water mL
Starting Amount in Tub A	**5,000 mL**
Amount in Tub F at End of Relay	**mL**

8. What do you think the water relay race was modeling?

OVERVIEW

Students will observe the dispersion of a drop of food coloring in water, draw conclusions about the movement of dissolved substances, and develop explanations about the importance of organisms' internal transport systems.

ACTIVITY 3

WHY CIRCULATE?

Have you ever made lemonade and forgotten to stir the mixture? The sweetener and flavoring eventually become distributed within the liquid, but the process, called diffusion, takes time. Diffusion is the random movement of molecules or particles in solution. They bounce against each other, generally moving from regions of higher concentration (where there is more of the dissolved substance) to regions of lower concentration (where there is less of the dissolved substance). Eventually, the mixture becomes evenly distributed. This is the process by which the sweetener and lemonade flavoring become dispersed in the water, even if you don't stir the mixture.

Single-celled living organisms rely on diffusion to obtain some of the resources necessary for life and to eliminate wastes. It is not a coincidence that almost all unicellular organisms live in water-based environments, where dissolved nutrients are readily available just outside the cell membrane. Single-celled organisms also can move wastes outside the cell membrane into the surrounding water.

What happens in large organisms, such as humans, that consist of many millions of cells? These organisms' cells are bathed in water, but the cells often are far away from the external environment. Diffusion is not sufficient to provide needed nutrients or to remove waste from distant cells. In addition, most larger, complex organisms carry out important tasks—obtaining nutrients, exchanging gases, removing wastes, etc.—in specialized regions of their bodies (such as the lungs or kidneys in humans). Consequently, most multicellular organisms have specialized systems (such as the circulatory system) to transport nutrients, waste and other materials from one region of the body to another. This activity allows students to investigate the process of diffusion and to consider why many organisms have internal transport systems.

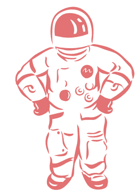
SCIENCE EDUCATION CONTENT STANDARDS*
GRADES 5–8

LIFE SCIENCE
- Living systems at all levels of organization demonstrate the complementary nature of structure and function.
- All organisms are composed of cells—the fundamental unit of life.
- Cells carry on many of the functions needed to sustain life. They take in nutrients, which they use to provide energy for the work that cells do and to make the materials that a cell or an organisms needs.
- The human organism has systems for digestion, respiration, reproduction, circulation, excretion, movement, control and coordination, and for protection from disease.

PHYSICAL SCIENCE
- The motion of an object can be described by its position, direction of motion and speed.

SCIENCE, HEALTH & MATH SKILLS
- Observing
- Graphing
- Interpreting data
- Applying knowledge

* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.



AstroBlogs!

Continue the "blog-wall" with an AstroBlog entry written for Activity 3. It's located on page 42.

Solutions in Water

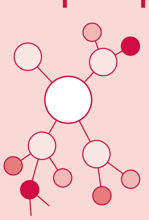
A solution is a uniform (homogeneous) mixture of two or more substances at the molecular level. Many substances dissolve in water because water molecules have a slight positive charge at one end and a slight negative charge at the other. Similarly charged particles of other substances are attracted to and mix with the water molecules, forming a solution.

Brownian Motion

In 1828, the English botanist, Robert Brown, observed that pollen grains suspended in still water jiggle around in a more or less random, zig-zag fashion. Then, in 1905, Albert Einstein published a paper in which he used mathematics to predict that particles much smaller than pollen grains would move in similar, zig-zag patterns. Einstein later would build upon this finding to make his case for the existence of molecules.

According to what is now referred to as Brownian motion, a larger particle in liquid constantly is bumped and jostled on all sides by other, smaller particles. These unequal, random collisions cause suspended particles, even molecules, to move in a non-predictable way.

Update Concept Maps



TIME

10 minutes for setup; 45–60 minutes to conduct activity

MATERIALS

Each group of four students will need:

- 2 sheets of graph paper (0.5-cm grid)
- Graduated cylinder (100-mL or 250-mL)
- Lid or bottom of a Petri dish
- Pencil
- Small dropper bottle of food coloring (red, blue or green; do not use yellow)
- Tape
- Timer, watch or clock
- **Optional:** Digital camera for recording observations

Each student will need:

- Copy of the student sheet (p. 12)

SAFETY

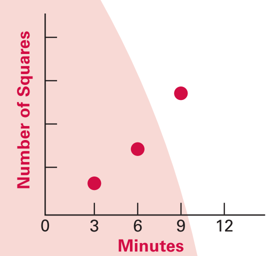
It is a good idea for students to wash their hands with soap and water before and after any science activity. Food coloring may stain hands, clothing and some surfaces. Make sure any spilled water is cleaned up promptly. Follow all district and school safety guidelines.

SETUP & MANAGEMENT

Place all materials in a central location for each group's Materials Manager to collect. Students will work in groups of four.

PROCEDURE

1. Ask students, *Have you ever added sugar to lemonade?* Follow with questions such as, *What did you do after you added the sugar? Was it necessary to stir the mixture? What would happen if you didn't stir the mixture?* Tell students that they will be investigating the movements of a substance when it is dissolved in water.
2. Have Materials Managers pick up the materials listed above for their groups.
3. Students will follow the instructions on their student sheets to observe and record the rate at which a drop of food coloring disperses through the water in a Petri dish. A simple way to measure the area reached by the food coloring is to place the dish over a sheet of graph paper before beginning the investigation. Students will make observations every three minutes (or, you may prefer to have students decide upon the frequency of observations). For each observation, students will count the number of squares in which tint from the food coloring is visible. Students should count only every other partial square, or divide the total number of partial squares by two.
4. Have students graph their results and answer the questions on the student sheet, or record the same information in their lab notebooks. Make certain that students choose an appropriate type of graph for the information being represented (line graphs are generally used for measurements made repeatedly over a continuous period, as in the sample graph (right).



5. Discuss diffusion (the process by which molecules or particles are dispersed randomly through another substance, such as a liquid) with the class. Ask, *Based on your observations, do you think diffusion helps to distribute nutrients from one place to another in the body of a living organism, such as an animal?* [yes] *What are the limitations of diffusion for transporting nutrients and other materials through the body?* [very slow, and only moves from regions of higher to lower concentrations] *How might organisms transport nutrients more quickly?* [with a dedicated transport system, such as the circulatory system in animals]
6. Have students revisit their concept maps and add any new ideas.

Activity 3

Water Transport

How quickly will a concentrated substance spread through water? Think about it. When you add sweetener to a drink, you stir to help the sweetener dissolve evenly. What happens if you don't stir the mixture? This activity will help you find out.

Materials

Lid or bottom of a Petri dish; graduated cylinder (100- or 250-mL); water; two sheets of graph paper (0.5-cm grid); tape; small dropper bottle with food coloring; timer; watch or clock

1. Tape one sheet of graph paper (at the corners) onto a table or countertop. Place the Petri dish on the paper. Using a pencil, trace around the Petri dish to make a circle. Remove the Petri dish and mark the center point of the circle. (Hint: Count the number of squares across the widest part of the circle and mark the center of the middle square.)
2. Measure 35 mL of water into the Petri dish.
3. Carefully place the dish back on the circle you drew on the graph paper.

Investigate

How quickly do you think a drop of food coloring will spread (diffuse) through the water in the Petri dish?

1. Carefully add one drop of food coloring to the center point of the dish.
2. Every three minutes, count the number of squares that have become tinted with food coloring (not all squares will have the same intensity of color). Count only every other partial square, or divide the total number of partial squares by two. Record your numbers in the appropriate box to the right.
3. Record your observations for up to 18 minutes, or until the color is completely diffused through the water in the dish.

Time Interval (minutes)	Number of Squares Tinted
0	
3	
6	
9	
12	
15	
18	

4. Using your second sheet of graph paper, make a graph of your observations. Mark the time (minutes) along the X axis and number of squares tinted by the food coloring along the Y axis.
5. Based on your investigation, answer the following questions. If needed, use the back of this sheet or a separate sheet of paper to record your answers.
   a. Did the food coloring spread completely during your observations?
   b. How could you use your graph to predict how long it would take for the color to spread over the area of the entire dish? What is your estimate?
   c. Is the process you observed (diffusion) an efficient way to spread a substance through water? Explain.
   d. Could an animal rely on the process of diffusion to distribute nutrients from one part of the body to all other parts? Why or why not?

OVERVIEW

The circulatory system consists of the heart, blood, and blood vessels. The heart, which is slightly larger than the fist, provides the initial force for blood flow.

Students are introduced to the heart, its role in circulation, and its external appearance.

ACTIVITY 4

It Begins with the Heart

The heart is a relatively small organ—only slightly larger than a person's fist. Yet it initiates all movement of blood around the body. Why is the movement of blood important? Because blood picks up and carries oxygen and nutrients to all parts of the body. Blood also carries wastes to appropriate places in the body for disposal. This activity, and the two that follow it, will focus on the structure of the heart, its function as a pump, and the circulatory system's critical role in distributing oxygen and removing carbon dioxide.

The circulatory system consists of the heart, blood and blood vessels. All vertebrates (animals with backbones) have closed circulatory systems, meaning their blood is contained within vessels, separate from the fluid surrounding cells in the body.

At first glance, the heart's outer surface seems to offer few clues about its important function. However, careful external examination reveals many key structures. For instance, one will notice that the human heart consists of four chambers. Two chambers receive blood from outside the heart, and the other two pump it out of the heart. The receiving chambers are known as atria (the singular form is atrium). The right atrium receives oxygen-depleted blood from the body's major veins (vessels that bring blood to the heart), and the left atrium receives oxygen-rich blood from the lungs. The two pumping chambers (the ventricles) receive blood from the atria and pump it away from the heart. The right ventricle pumps oxygen-depleted blood via a short loop of blood vessels through the lungs, where it is replenished with oxygen, while the ventricle pumps the oxygenated blood back out into the body through large

Continued

SCIENCE EDUCATION CONTENT STANDARDS*
GRADES 5–8

LIFE SCIENCE

Structure and function of living systems

- Living systems at all levels of organization demonstrate the complementary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms and ecosystems.
- Specialized cells perform specialized functions in multi-cellular organisms. Groups of specialized cells cooperate to form a tissue, such as a muscle.
- Different tissues are, in turn, grouped together to form larger functional units, called organs. Each type of cell, tissue and organ has a distinct structure and set of functions that serve the organism as a whole.
- The human organism has systems for digestion, respiration, reproduction, circulation, excretion, movement, control and coordination, and for protection from diseases. These systems interact with one another.

SCIENCE, HEALTH & MATH SKILLS

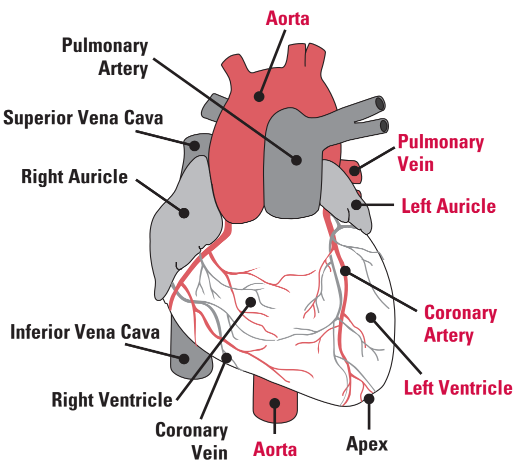
- Communicating
- Using information
- Interpreting information
- Applying knowledge

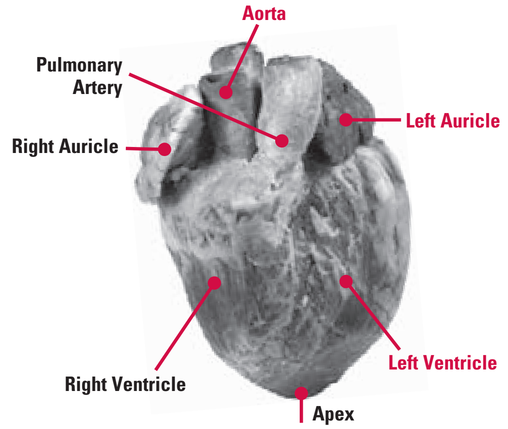
* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

The Heart Needs Exercise, Too!

Like any muscle, the heart can be strengthened with exercise; and it will weaken with a lack of exercise. The heart also will weaken during periods when it doesn't have to work against the pull of gravity. Because gravity's effect on the circulatory system decreases when a person is lying down, extended bed rest, such as that sometimes required during a long illness, can weaken a person's heart. Similarly, an astronaut's heart works less in the reduced gravity of space than on Earth. As a result, it becomes weaker, and even a little smaller, during spaceflight.

ANTERIOR VIEW OF THE HEART





Not shown on photo: vena cavas, pulmonary vein

Aorta - large artery that carries oxygen-rich blood away from the heart to other arteries leading to different regions of the body.

Inferior Vena Cava - large vein that returns blood from the body's trunk and legs to the heart.

Left Auricle - muscular flap visible on the *outside* of the heart's left atrium (receiving chamber). It slightly increases the capacity of the atrium.

Pulmonary Arteries - arteries that carry oxygen-poor blood away from the heart to each lung.

Pulmonary Veins - large veins that return oxygen-rich blood from the lungs back to the heart.

Right Auricle - muscular flap visible on the *outside* of the heart's right atrium (receiving chamber). It slightly increases the capacity of the atrium.

Superior Vena Cava - large vein that returns blood from the head, neck and arms to the heart.

arteries (vessels that carry blood away from the heart). In short, the left side of the heart works with oxygen-rich blood, and the right side of the heart works with oxygen-depleted blood.

Visible on the exterior of the heart are the coronary arteries, usually surrounded by a layer of fat. These arteries supply blood to the heart muscle itself. It may sound odd, but the heart cannot use the blood contained in its chambers. Instead, it has its own network of blood vessels, called the coronary arteries and coronary veins. Also visible on the exterior of the heart are the let and right auricles (sometimes referred to as "dog ears"), which increase the capacity of the atrium to which they are attached.

TIME

45 minutes to conduct activity

MATERIALS

Each student will need:

- Copy of the student sheet (p. 16)

SETUP & MANAGEMENT

Conduct as a class discussion, followed by student work in groups. For the last part of the activity (see Procedure, Item 7), access and view the video, "A Look at the Heart, Part 1," at www.BioEdOnline.org. Look under the Resources tab and click on Videos to access the file.

PROCEDURE

1. Ask students, *What are the parts of the circulatory system?* Encourage student responses by referring to previous lessons, using follow-up questions, and clarifying information until students have provided the following answers: pump (heart), fluid (blood), and tubing (vessels). Explain that in this activity, students will focus primarily on one component of the circulatory system: the heart.
2. Discuss students' ideas about the human heart by asking questions such as the following.
   - *How big is the heart?* Tell students to

Coronary Artery Disease

Sometimes cholesterol and fatty deposits build up on the inner lining of the arteries, beginning as early as childhood. This buildup is called arteriosclerosis. It causes the inner lining to become less elastic, a condition sometimes referred to as "hardening of the arteries." If these deposits occur in the coronary arteries and cause them to become narrowed or blocked, the supply of oxygen to the heart becomes limited, which may result in a heart attack. During a heart attack, cardiac muscle cells become injured and die due to lack of oxygen.

Some risk factors for coronary artery disease, such as a family history of heart disease, cannot be controlled. However, other factors—exposure to cigarette smoke, diabetes, high levels of blood cholesterol, being overweight or physically inactive, and high blood pressure—can be addressed, and can affect young people as well as older adults.

AstroBlogs!

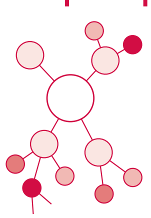
Continue the "blog-wall" with an AstroBlog entry written for Activity 4. It's located on page 42.

Anterior and Posterior

Most heart diagrams illustrate the heart as viewed from the chest. This perspective usually is called anterior, from the Latin *ante*, which means "before." The back view is referred to as posterior, from the Latin *post*, which means "coming after."

The anterior perspective also is referred to as "ventral," and the posterior perspective as "dorsal."

Update Concept Maps



POSTERIOR VIEW OF THE HEART

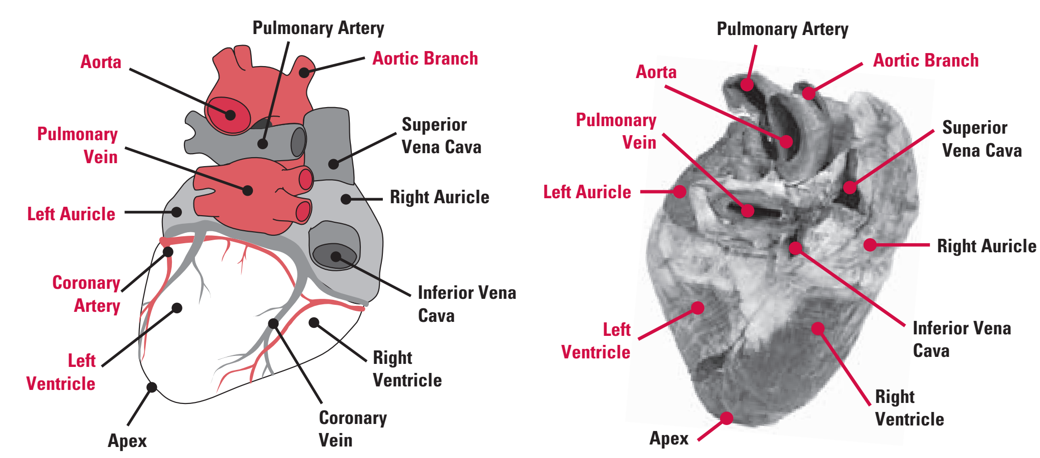


Illustration from *LifeART* © 2009 Williams & Wilkins. All Rights Reserved. Sheep heart photo by JP Denk © 2009 Baylor College of Medicine.

make a ball of one fist. The heart is slightly larger than a fist, and it weighs between 200–425 gm (7–15 oz).

- *Where is the heart located?* Explain that the heart is not located on the left side of the chest, as most people think. Instead, it is found in the center of the chest, between the lungs, tilted slightly to the left. Instruct students to sit quietly and try to locate their hearts by feeling for a heartbeat, just to the left of center of the chest.
- *What does the heart look like?* Mention that a real heart, which is somewhat conical in shape, looks only somewhat like a valentine.

3. Explain that students will be working in groups to learn more about the circulatory system, especially the heart. Give each student a copy of the student sheet, with labeled diagrams and unlabeled photographs of a heart.
4. Begin by explaining that when looking at the diagram, students should imagine they are facing another person's heart. This means that the side of the heart to be labeled "right" is on the left side as you face it. You can illustrate this point by having students face each other and raise their right hands.
5. Tell students to locate the right side of the heart on the heart diagram. Next, have them find and label the corresponding area on the photograph. Working in groups, students should continue to find and label on the photograph each part that is identified on the diagram. Explain that this initial focus on appearance of the heart is for orientation only, and not for memorization or testing.
6. Circulate through the class to provide direction, as needed. When students have finished labeling their heart diagrams, let them share their work within their groups to check answers and discuss any discrepancies or questions. Ask students to share any additional observations about the heart. For example, they may notice the fat deposits that surround the blood vessels on the surface of the heart.
7. Show the BioEd Online video, "A Look at the Heart, Part 1." Lead a class discussion of the similarities and differences between the sheep heart shown in the video and the photo of the heart that students used for this activity. Or, use a model of the human heart to demonstrate the external parts that students identified in the photograph. If you will be conducting Activity 6, tell students they will have an opportunity to observe these structures on a real, preserved specimen.

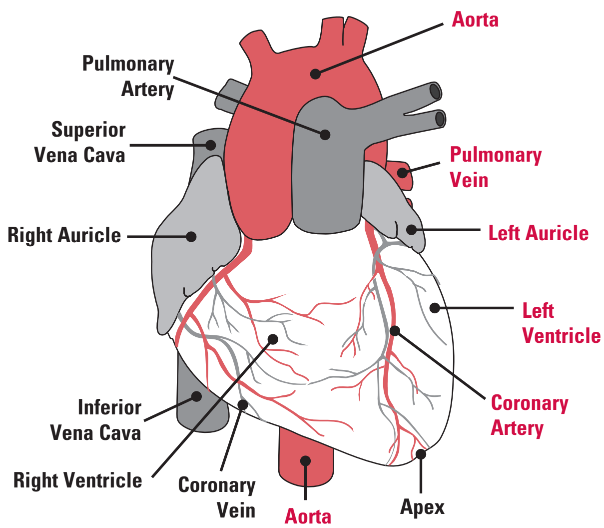
ACTIVITY 4

THE HEART: EXTERNAL

ANTERIOR VIEW OF THE HEART

RIGHT SIDE
Handles oxygen-poor blood.

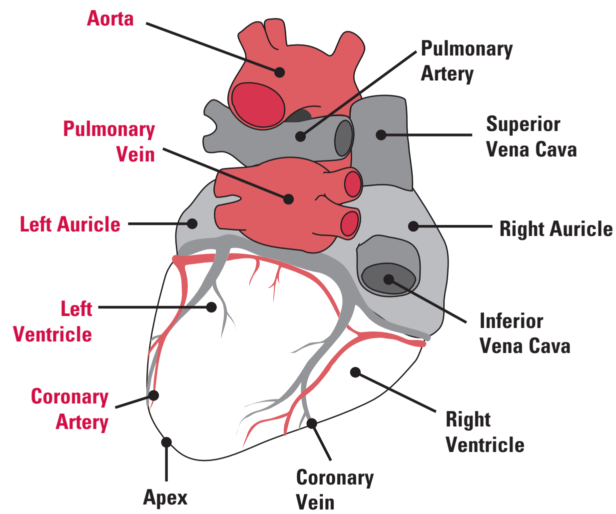
LEFT SIDE
Handles oxygen-rich blood.



POSTERIOR VIEW OF THE HEART

LEFT SIDE
Handles oxygen-rich blood.

RIGHT SIDE
Handles oxygen-poor blood.

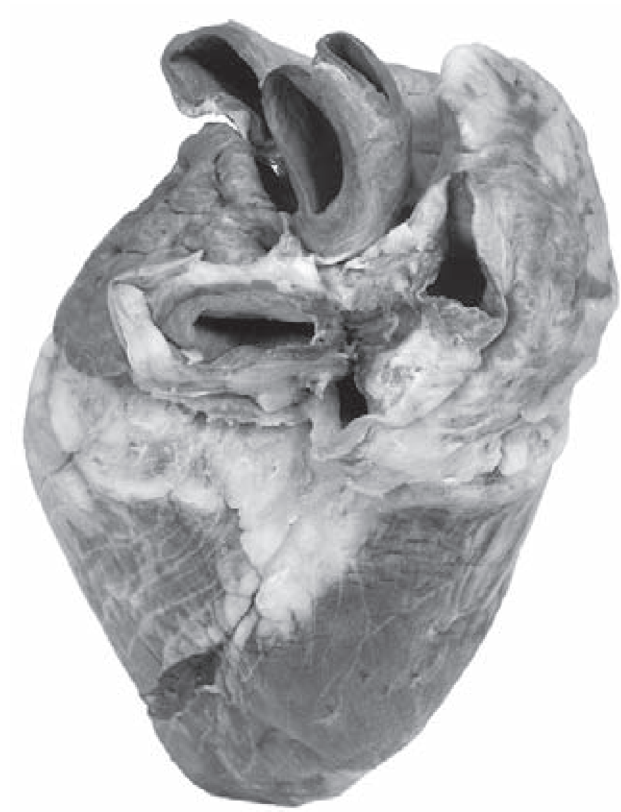


ANTERIOR VIEW OF THE HEART

RIGHT SIDE **LEFT SIDE**

POSTERIOR VIEW OF THE HEART

LEFT SIDE **RIGHT SIDE**



Not shown on photographs of sheep heart: vena cavas, pulmonary vein

OVERVIEW

Circulation begins with the heart, a complex pump that provides the initial force for blood flow through the body. One-way valves in the heart promote one-way circulation. Blood flows through two separate loops, one through the lungs and another through the rest of the body.

Students will learn about the internal structures of the heart, and the roles these structures play in circulating blood to the lungs and the rest of the body.

ACTIVITY 5

THE HEART IS A PUMP

The heart is a sophisticated mechanical pump made of strong muscle. Thus, to understand how the heart works, it is helpful to know a little about pumps

A pump is a mechanical device that moves fluid or gas by pressure or suction.

> **SCIENCE EDUCATION CONTENT STANDARDS***
> GRADES 5–8
>
> **LIFE SCIENCE**
> Structure and function of living systems
> - Living systems at all levels of organization demonstrate the complementary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms and ecosystems.
> - Specialized cells perform specialized functions in multi-cellular organisms. Groups of specialized cells cooperate to form a tissue, such as a muscle.
> - Different tissues are, in turn, grouped together to form larger functional units, called organs. Each type of cell, tissue and organ has a distinct structure and set of functions that serve the organism as a whole.
> - The human organism has systems for digestion, respiration, reproduction, circulation, excretion, movement, control and coordination, and for protection from diseases. These systems interact with one another.
>
> **SCIENCE, HEALTH & MATH SKILLS**
> - Communicating
> - Using information
> - Interpreting information
> - Applying knowledge
>
> * National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

Consider, for example, a simple bicycle pump. When you pull the handle up, you create a vacuum inside the metal tube, which fills with air through a hole in the side. When you push the handle down, a one-way valve in the hole closes and air moves through the rubber tube, into the bike tire. What keeps the air from coming out of the tire and back into the pump? Another one-way valve at the end of the rubber tube prevents the air from moving backward.

A lotion dispenser illustrates the same principle. A plastic tube goes down from the top of the dispenser into the lotion. When you push down on the dispenser, the lotion already in the top of the tube (above the pump) squirts out into your hand. It does not flow back down into the pump mechanism because a one-way valve closes behind it when you push down. When you let go of the dispenser, a spring-driven pump pushes the top back up, sucking more lotion up into the top of the tube and pulling more lotion from the bottle to fill the tube below the pump.

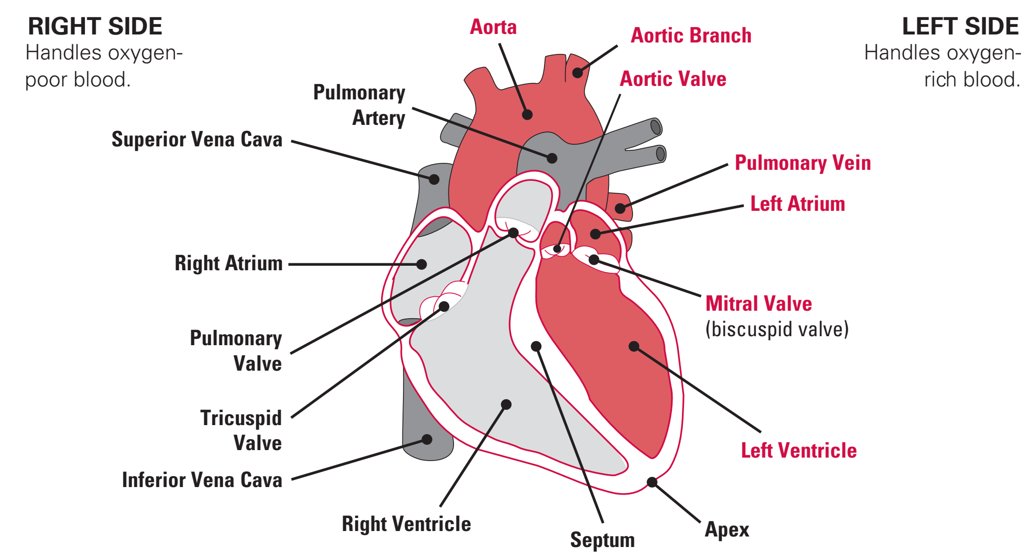
Note that both a pumping mechanism and a one-way valve are required to make a pump work. The lotion bottle has two chambers (in the tube below the pump and in the dispenser above the pump). The lower chamber of the dispenser holds

Continued

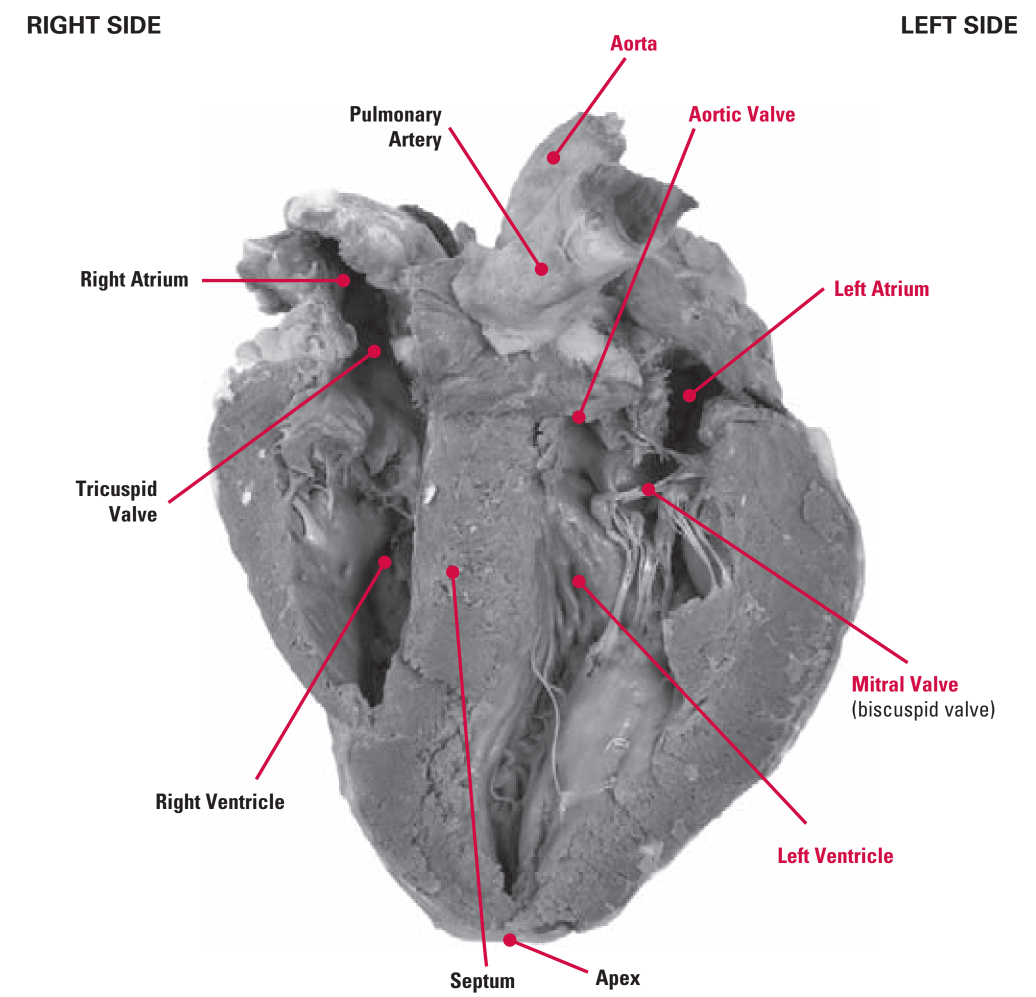
That's Moving It!

Each time your heart beats, it pumps about 60–130 mL of blood from the left ventricle out to the body. If you consider that the average heart beats about 70 times per minute at rest, your heart is moving about 4.5–5 liters of blood per minute . . . more than two 2-liter soft drink bottles!

INTERNAL STRUCTURE OF THE HEART - ANTERIOR VIEW



INTERNAL STRUCTURE OF THE HEART - ANTERIOR VIEW



Not shown on photo: vena cavas, pulmonary valve, pulmonary vein

Heart Sounds

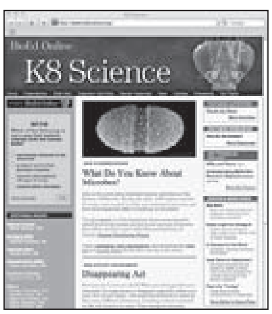
The "lub-dub" sound of a normal heartbeat comes from the sounds of blood being pushed against closed valves in the heart. The "lub" sound happens when the ventricles contract. The "dub" sound occurs when blood exits the heart.

Heart murmurs are abnormal sounds that result from turbulent blood flow within the heart. Murmurs most commonly result from narrowed or leaking heart valves, or the presence of abnormal passages in the heart.

Health in Space

Astronauts often collect data on the responses of their own bodies to microgravity. They also help evaluate new technology, such as performing blood tests using a tiny "lab on a chip." To find out more about what astronauts actually do while in space, explore the NASA Astronaut Journals page at www.nasa.gov/centers/johnson/astronauts/journals_astronauts.html.

Teacher Resources



Online presentations of each activity, downloadable activities in PDF format, and annotated slide sets for classroom use are available free at www.BioEdOnline.org or www.k8science.org.

a portion of lotion, ready to move up into the pump.

Like the lotion pump, some animals, such as fish, have a two-chambered heart. The first chamber (atrium) fills with blood returning from the body and then passes it to the second, more muscular chamber (ventricle). The ventricle contracts, pushing the blood out into the vessels that carry it through the gills for oxygenation and on to the body. A one-way valve prevents the blood from flowing backward into the atrium. Other animals, such as reptiles and amphibians, have three-chambered hearts.

Birds and mammals, including humans, have four-chambered hearts. Two chambers receive blood and the other two pump it out. The receiving chambers are known as atria (the singular form is atrium). The right atrium receives oxygen-depleted blood from the body's major veins (vessels that bring blood to the heart), and the left atrium receives oxygen-rich blood from the lungs. The atria transfer their blood, through one-way valves, into the two different pumping chambers, called ventricles. The right ventricle pumps oxygen-depleted blood via smaller blood vessels through the lungs, where it is replenished with oxygen, and cleansed of carbon dioxide. The left ventricle squeezes (contracts) to pump oxygenated blood out into the rest of the body through large arteries (vessels that carry blood away from the heart).

So ultimately, animals with four-chambered hearts have two circulation loops. The first loop travels to and from the lungs (pulmonary circulation). Blood filled with carbon dioxide enters the lungs, where carbon dioxide is replaced with oxygen, and then carried from the lungs back to the heart for pumping to the rest of the body. The second loop carries blood to all parts of the body, delivering oxygen and nutrients and gathering wastes for proper disposal (systemic circulation). This very efficient system keeps blood moving in the right direction, and to the right parts of the body, 24 hours a day.

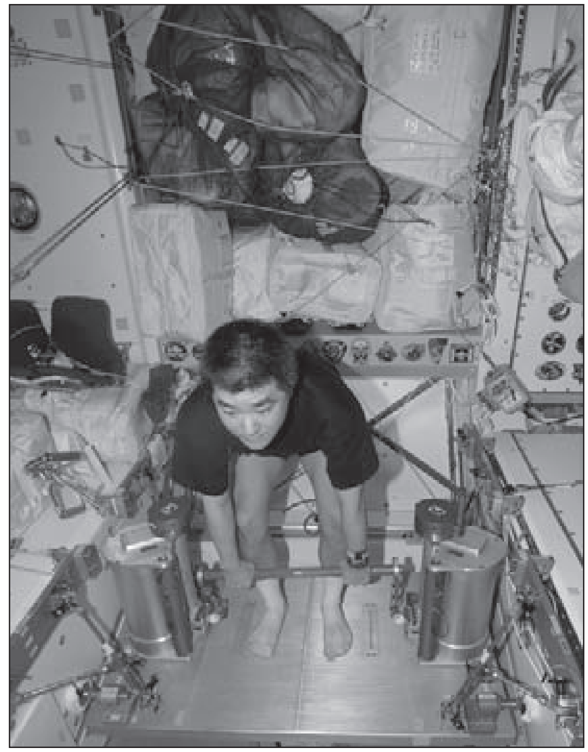


Photo courtesy of NASA.

Astronaut Daniel Tani, Flight Engineer, NASA ISS Expedition 16, uses the short bar of the Interim Resistive Exercise Device (IRED) to perform upper body strengthening pull-ups. This helps his heart muscles and bones stay strong while he works and lives in space.

Why doesn't the blood get pushed back into the atria when the ventricles contract? Valves! Remember the one-way valves in the mechanical pumps? Similar one-way valves between each chamber in our hearts ensure that blood moves in only one direction. The heart also has valves at the exits to the ventricles, so blood can't get sucked back in. Thanks to valves, the blood in our bodies always moves forward, never backward.

Continued

TIME

45 minutes to conduct activity

MATERIALS

Teacher (see Setup)

- Pump dispenser of lotion or soap

Each student will need:

- Copy of the student sheet (p. 21)

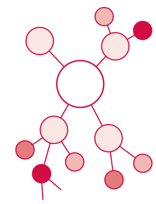
SETUP & MANAGEMENT

Begin with a class demonstration and discussion. Follow with students working in groups. At the end of the activity (see Procedure, Item 7), the class will view a BioEd Online video, "A Look at the Heart, Part 2." To access the file, go to www.BioEdOnline.org, look under the Resources tab, and click on the Videos link.

PROCEDURE

1. Show students the pump dispenser and demonstrate its use. Ask, *What does this dispenser do?* Allow students to provide a variety of answers. When someone mentions, "pump," ask, *What is the job of a pump?* Help students understand that many kinds of pumps use compression and suction to move a fluid or gas. Humans use suction, for example, when drinking from a straw. The lotion pump uses suction to draw lotion up into a tube. It then releases the lotion when pressure is applied to the top of the dispenser. Mention that a one-way valve keeps the liquid from running out of the bottom of the tube when the top is pressed.
2. Ask, *How is the lotion dispenser like a heart?* [both are pumps] Explain that like a lotion pump, the heart relies on suction, pressure and compression, which allow it to initiate the movement of blood through the lungs and the rest of the body.
3. Give each student a copy of the student sheet, which provides a labeled diagram and an unlabeled photograph showing the inside of the heart. Direct students to identify on the diagram the receiving areas (atria) and pumping areas (ventricles) of the heart. Help students find the same structures on the photograph. Ask, *Which chambers receive blood from the body or lungs?* [atria] *Which chambers pump blood away from the heart?* [ventricles]
4. Point out the valves in the heart diagram. Ask, *What might the valves do?* [prevent blood from flowing backward] Have students find and circle all of the valves in the heart diagram.
5. Now, have students locate and label on the photograph each part that is identified on the diagram. When students are finished labeling their heart photographs, let them share their work within their groups to check answers and discuss any discrepancies or questions.
6. Conduct a class discussion about the internal structures of the heart. Ask, *Which chambers have thicker walls?* [ventricles] *Why might the ventricle walls be thicker?* [they work harder to squeeze blood out through the arteries] *Are the muscular walls of the two ventricles equally thick? Why or why not?* [No. One ventricle pumps blood to more distant parts of the body.] *What would happen if a valve stopped working?* [blood might leak back into the atrium and pumping might be less efficient]
7. As a class, view "A Look at the Heart, Part 2" (see Setup & Management). Lead a discussion about the similarities and differences between the sheep's heart shown in the video and the diagram of the heart that students used for this activity. Or, use a model of the human heart to demonstrate the internal parts that students identified in the photograph. If you will be conducting Activity 6, tell students they will have an opportunity to observe these structures on a animal specimen.
8. Have students add any new information to their concept maps.

Update Concept Maps

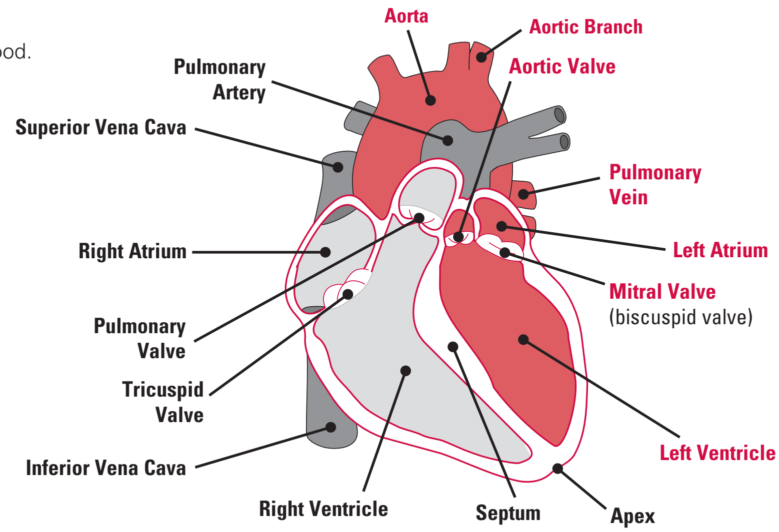


INSIDE THE HEART

INTERNAL STRUCTURE OF THE HEART - ANTERIOR VIEW

RIGHT SIDE
Handles oxygen-poor blood.

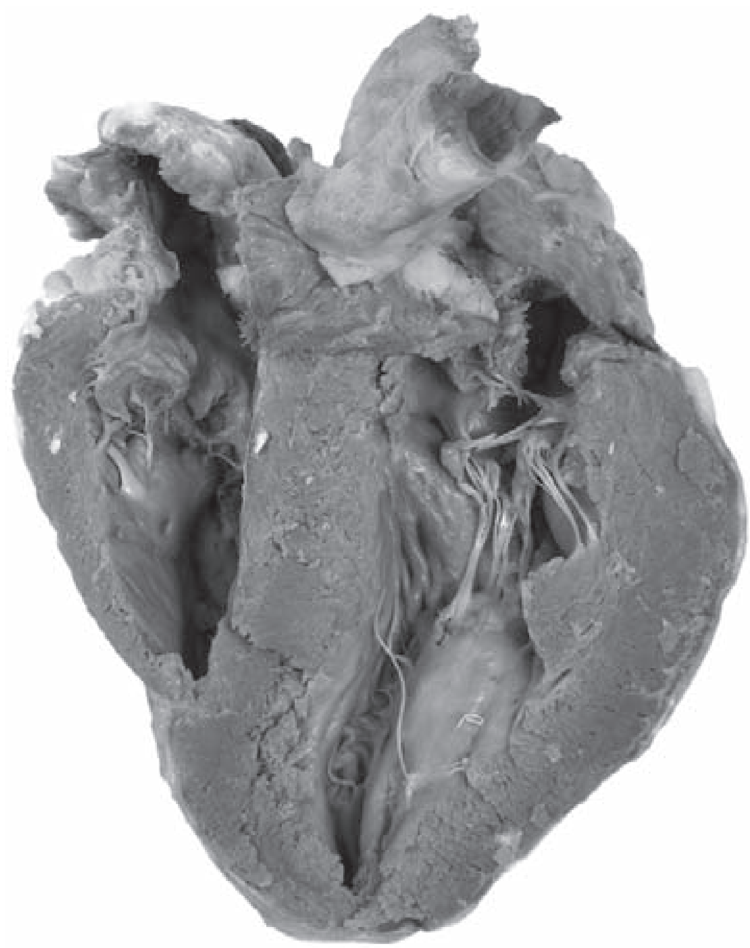
LEFT SIDE
Handles oxygen-rich blood.



INTERNAL STRUCTURE OF THE HEART - ANTERIOR VIEW

RIGHT SIDE

LEFT SIDE



Not shown on photograph of sheep heart: vena cavas, pulmonary valve, pulmonary vein

OVERVIEW

Mammals and birds, including humans, sheep and chickens, have four-chambered hearts. This design completely segregates oxygen-rich from oxygen-poor blood.

Students will examine sheep or chicken hearts to learn about the heart's structure and the flow of blood through the heart.

ACTIVITY 6

EXAMINING THE HEART

The heart is made mostly of a special kind of muscle, known as cardiac muscle, which is very resistant to fatigue. Cardiac muscle cells are able to contract on their own, without receiving stimulation from the nervous system. Due to this important characteristic, the heart does not require a signal from the brain or spinal cord every time it needs to contract. A small bundle of nervous tissue, called the sinoatrial node (SA node), in the wall of the right atrium initiates each contraction and serves as a "pacemaker," setting the rate and timing of heartbeats.

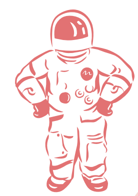
> **SCIENCE EDUCATION CONTENT STANDARDS***
> GRADES 5–8
>
> **LIFE SCIENCE**
> Structure and function of living systems
> - Living systems at all levels of organization demonstrate the complementary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms and ecosystems.
> - Specialized cells perform specialized functions in multi-cellular organisms. Groups of specialized cells cooperate to form a tissue, such as a muscle.
> - The human organism has systems for digestion, respiration, reproduction, circulation, excretion, movement, control and coordination, and for protection form disease.
>
> **SCIENCE, HEALTH & MATH SKILLS**
> - Observing
> - Comparing and contrasting
> - Relating knowledge
>
> * National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

The signal from the sinoatrial node spreads to another small bundle of nervous tissue, the atrioventricular node (AV node), located in the heart wall between the two chambers on the right side of the heart. Together, the SA and AV nodes regulate contractions of the ventricles and atria, and allow the heart to work as an efficient double pump. Additional signals about pace can come from the brain (nervous system) and hormones (endocrine system). Fever also raises heart rate.

The heart is a double pump with four chambers. The two upper chambers, the atria, receive blood returning from the body (right atrium) and the lungs (left atrium), and pass it into the lower chambers, the ventricles, so that they can pump it to all other areas of the body. As students examine and dissect a heart, be sure they note the thick, muscular, elastic walls that allow the ventricles to pump blood effectively throughout the body. The walls of the atria are not as thick as those of the ventricles. Students also should note that there are several one-way valves in the heart that prevent blood from moving backward from the atria into the veins, from the ventricles back into the atria, and from the arteries back into the ventricles.

TIME

20 minutes for setup; 45 to conduct activity



AstroBlogs!

Continue the "blog-wall" with an AstroBlog entry written for Activity 6. It's located on page 43.

Muscle Tissue

There are three main categories of muscle in the body.

- Skeletal muscles are responsible for voluntary movement (such as raising your arm).
- Cardiac muscle makes up most of the heart.
- Smooth muscle makes up the supporting tissue of blood vessels and hollow internal organs, such as the stomach, intestines and bladder.

A Broken Heart?

The term, "heart disease," is very common, but what does it mean? In fact, it does not refer to one specific ailment, but to any of a number of conditions that can impair the heart's normal function.

One example of heart disease is arteriosclerosis, which causes the walls of the arteries—normally strong and elastic—to thicken and harden. Sometimes, plaques of fatty material form inside arteries, leading to a condition called atherosclerosis. Heart attacks can occur when plaques break off and clog the arteries that supply oxygen and nutrients to the heart itself. A buildup of plaque can restrict the flow of oxygen, cause damage to the heart, and lead to a heart attack. The severity of the heart attack depends on how much tissue is damaged.

Sometimes, malfunctions of the sinoatrial node (the heart's pacemaker) cause the heartbeat to become irregular. Without regular, coordinated electrical signals telling the ventricles to contract, blood is not pumped to cells of the body as needed. In such cases, an artificial pacemaker may be used to send electrical impulses to the heart and help it pump properly.

MATERIALS

Teacher (see Safety; Setup)

- Masking tape and long pins
- PowerPoint® slides or transparencies of all student sheets

Each group of four students will need:

- 13 long pins with masking tape flags
- 2 pipe cleaners
- Chicken heart (fresh) or sheep heart (preserved)
- Lab notebook or sheets of paper
- Paper plate
- Pair of dissecting scissors, plastic knife or scalpel
- Dissection kit
- Dissection tray

Each student will need:

- Highlighting marker
- Magnifier
- Pair of disposable gloves
- Pair of safety goggles
- Copy of student sheets (pp. 25–26; from previous activities: pp. 16 and 21)

SAFETY

Before the activity begins, instruct students on the proper way to handle sharp instruments. All students should wear gloves and goggles. After the activity, surfaces exposed to raw chicken must be sanitized. For proper disposal of sheep hearts, refer to the Material Safety Data Sheet shipped with the hearts. Seal chicken hearts in a plastic bag and dispose of normally. Students should wash their hands with soap and water before and after any science activity, even if they will be wearing gloves. Always follow all district and school laboratory safety procedures.

SETUP & MANAGEMENT

Purchase chicken hearts from a grocery store or order sheep hearts from a biological supply company (these hearts are preserved and can be used for several weeks). Keep the sheep hearts in tightly sealed plastic bags.

Place all necessary dissecting materials on paper plates or trays, with one set of materials for each student group. Make pins with masking tape flags for each group, or have students make their own. Have students perform the dissections in groups of four.

This activity may be conducted as a class demonstration. Or visit the Virtual Heart Web site (http://thevirtualheart.org) to provide a three-dimensional class demonstration of the heart's structures.

Download PowerPoint® slides from www.BioEdOnline.org or make copies of student sheets for this activity, along with the sheets from Activities 4 and 5.

PROCEDURE

Part One: Exterior of the Heart

1. Discuss students' previous explorations of the exterior and interior of the heart (Activities 4 and 5). Ask students to share any questions they still have about the heart's structure or function. Record their questions to refer to at the end of this activity.
2. Tell students that they will be examining chicken or sheep hearts similar to the ones they viewed in the videos previously.

   Safety Note: Be sure all students wear gloves and safety goggles, even if they only will touch the heart. Inform students that there will be no blood involved in the dissection (it is clotted). Monitor students, as some people may begin to feel a little uncomfortable during the procedure.
3. Distribute copies of the "Heart Dissection" page and have students read it within their groups.
4. Have each Materials Manager pick up a tray of materials for his or her group.
5. Have students examine the heart specimens. Ask, *How does the heart feel when you touch it?* [smooth, tough, rubbery] If using sheep hearts, explain to

Continued

students that the heart's texture has been altered by the preservation chemicals. Have students locate, and then gently press on, the upper and lower chambers of their heart specimens. Ask, *Does one part feel thicker or more muscular than another?* [There is more muscle around the lower chambers.]

6. Because most diagrams show the anterior (front) view, the right side of the heart appears on the left side of the diagram. To demonstrate this to your class, ask each student to face another student and raise his or her right hand. Explain that they are looking at an anterior (front) view of their partner student's body. Therefore, each student's right hand will appear on the left for his/her partner. The same will be true when they study a ventral view of the heart.
7. Have students continue to observe the heart by following the dissection instruction sheet.
8. After students have completed "Part One: Exterior of the Heart," review what they have learned so far. You may wish to display a copy of the worksheet while students check the location of the pins on their specimen hearts. Ask each group to check another group's work and discuss any differences. Or, have students create their own labeled drawings.
9. Have students remove all pins from their specimens before proceeding to Part Two.

Part Two: Interior of the Heart

1. Before they begin, instruct students on the proper way to handle sharp instruments. You may demonstrate how to make the first cut into the heart, or simply complete this step for students.

   First, insert the point of a pair of dissection scissors, plastic knife or scalpel into the superior vena cava (large vein that enters the right atrium—sometimes present only as a large hole). Cut down the superior vena cava into the wall of the right atrium and continue down to the apex of the heart. Students should be able to see the right atrium and ventricle.
2. Students will use Part Two of the student sheet to complete the heart dissection.

   Note: You may want to assist students when they open the left atrium and ventricle. Insert scissors or knife into one of the pulmonary veins (may appear as a large hole) on the left side of the heart, and cut through the wall of the left atrium. Once again, continue forward toward the apex (or tip) of the heart.
3. Distribute copies of the "Blood Pathways" sheet to each student. Have students read the descriptions of how blood flows through the heart.
4. If using sheep hearts, have students discuss and demonstrate the flow of blood through the heart specimen, beginning with the point of entry at the superior vena cava. Have students push pipe cleaners through the large vessels to discover where they lead.
5. Once students understand the flow of blood via heart-lung-heart-body circulation, explain that the right and left atria contract at the same time, followed by contractions of right and left ventricles. In a properly functioning heart, the synchronized work of the four chambers will cause the atria to expand and fill with blood as the ventricles are contracting.
6. When finished, students should clean and return all dissection equipment. Have students clean their desktops and wash their hands thoroughly with soap and water. Dispose of hearts properly (see Safety, p. 23).
7. Revisit and discuss students' questions about the heart. Have students add new information and observations to their concept maps.

Update Concept Maps

Activity 6

Heart Dissection

The instructions below will guide the dissection and help you to locate and identify various parts of the heart. Read carefully and make observations as you go.

Part One: Outside of the Heart

A. Find and observe the "front" (or **anterior**) side of the heart. This is the how the heart would appear if we were to open up the chest. From this angle, the heart usually appears rounded. Note that the back side of the heart is flat, with several large openings for blood vessels.

B. The white material is a layer of fat. A little fat is normal. It protects and covers some of the blood vessels around the outside of the heart. With scissors, carefully cut away as much fat as possible. (This will take some time.)

C. The heart has four chambers: two at the top and two at the bottom. The two chambers at the top of the heart are the **right and left atria**. (Atria is plural for atrium.) The two chambers at the bottom are the **right and left ventricles**.

D. Observe the flaps on the heart, called **auricles**. The auricles expand to help the atria hold more blood. You will notice that there is one auricle on either side of the heart.

E. When you are certain the front of the heart is facing you, find the two large blood vessels at the top. The first vessel, in the center at the top of the heart, is the **pulmonary artery**. Blood in the pulmonary artery leaves the right ventricle and goes to the lungs. The large vessel just behind pulmonary artery is the **aorta**. The aorta is the largest blood vessel in the entire body. It takes blood from the lower chamber of the heart—the left ventricle—and sends it to all parts of the body, from head-to-toe.

F. Turn the heart over and look at its back (or posterior) side. The severed vessel nearest the right auricle is the **superior vena cava**. Just below and a little toward the center of the heart is the other severed vessel that enters the right auricle. It is the **inferior vena cava**.

G. To the left of the inferior vena cava is the severed **pulmonary vein**, which enters the left auricle.

H. Stick numbered pins into the parts of the heart that you can observe.

1. Right auricle
2. Right atrium (general area)
3. Right ventricle (general area)
4. Left auricle
5. Left atrium (general area)
6. Left ventricle (general area)
7. Pulmonary artery
9. Aorta
10. Superior vena cava (opening)
11. Inferior vena cava (opening)
12. Pulmonary vein (opening)

Part Two: Inside of the Heart

A. You or your teacher already have made the first cut through the heart, exposing the chambers on the right side. Pull the two sides of the heart apart and look for three flaps, or membranes, on the right side. These flaps make up a **valve**, or one-way door. When the right ventricle contracts, the valve closes to prevent blood from traveling backward.

B. The upper chamber is the **right atrium** and the lower chamber is the **right ventricle**. You will notice that the walls of the ventricle are thicker than the walls of the atrium.

C. The large opening in the center of the top of the heart is the attachment point for the artery that takes blood to the lungs (called the **pulmonary artery**). If you are working with a sheep heart, thread a pipe cleaner through this opening into the right ventricle.

D. Make a lengthwise cut through the **pulmonary vein** (you will only see an opening). Continue through the wall of the atrium and ventricle, and down toward the **apex** (tip) of the heart. Pull the two sides apart. Here, you will find another **valve** with two flaps, separating the **left atrium** and the **left ventricle**.

The left side of the heart is noticeably thicker than the right side because it pumps blood throughout the entire body. The right side of the heart pumps blood to the lungs, which are very close to the heart.

ACTIVITY 6
BLOOD PATHWAYS

Now that you know more about how the heart is put together, it will be easier to understand the flow of blood through the heart and circulatory system. Remember that blood flows in only ONE direction, thanks to one-way valves. Let's start with drops of blood in the tiny capillaries of your fingertips and follow the path of that blood through the circulatory system. The journey begins at the bottom left corner of the page, with Item 1.

5 Out of the Heart / Into the Lungs

The arteries that carry blood from the heart to the lungs are called **pulmonary arteries**.

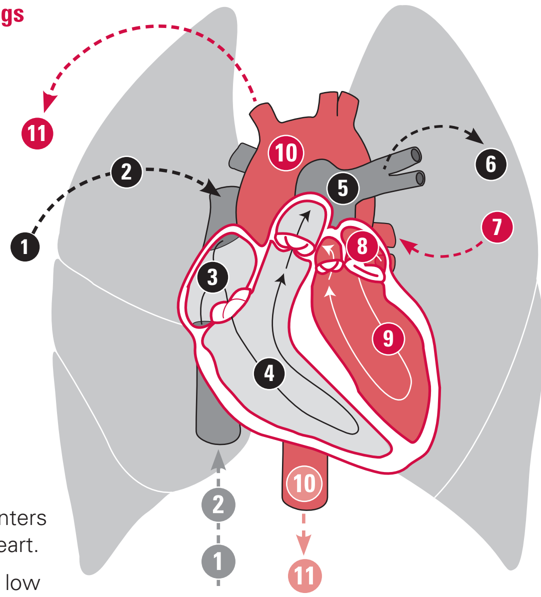
4 Into the Right Ventricle

When the right atrium is filled with blood, it contracts, pushing the blood through the one-way **tricuspid valve** into the **right ventricle**. When the right ventricle is filled, it contracts, pushing blood through the **pulmonary valve** into arteries leading to each lung.

3 Into the Right Atrium

Blood from both vena cavas enters into the **right atrium** of the heart.

Blood returning to the heart is low in oxygen. It must be replenished with oxygen from the lungs before it can make another trip around the body.



The complex flow patterns between the heart and lungs are shown in the illustration above.

6 Inside the Lungs

Once in the **lungs**, blood moves into smaller and smaller arteries, and finally, into capillaries that surround the tiny air sacs in the lungs. Here, the blood drops off carbon dioxide (breathed out of the body), and picks up oxygen (breathed into the body), which it will carry to cells of the body.

7 Out of the Lungs / Into the Heart

The oxygen-rich blood moves from the lung's capillaries, to veins, and back to the heart through the **pulmonary veins**. Notice that the oxygen-rich blood on the left side of the heart is kept separate from the oxygen-poor blood on the right side.

8 Into the Left Atrium

Blood in the pulmonary veins moves into the heart's **left atrium**. When the left atrium is full of blood, it contracts and forces blood out through the **mitral valve** (also called the bicuspid valve) into the left ventricular chamber of the heart.

9 Into the Left Ventricle

Blood is pumped from the left atrium into the **left ventricle**. When full of blood, the left ventricle contracts, pushing blood though the **aortic valve** and into the largest artery in the body (the aorta).

2 Out of the Veins / Into the Vena Cava

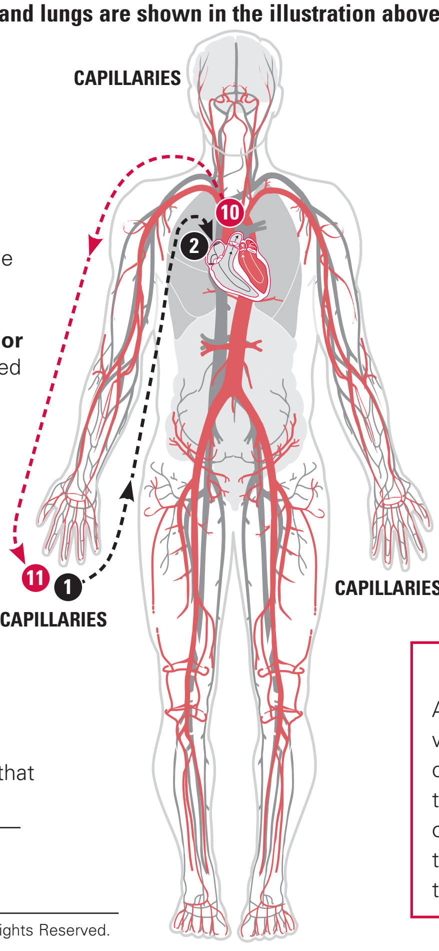
(See both illustrations.)

Smaller veins carry blood to two large collecting veins that connect to the heart. Blood from the hand (and upper parts of the body) flows into the **superior vena cava**, above the heart. Blood from veins in the lower part of the body flows into the **inferior vena cava**, below the heart (see "2" located beneath the heart in the upper illustration).

1 Out of the Capillaries / Into the Veins

Capillaries are very fine, branching blood vessels that form a network between arteries and veins. Because capillaries are very narrow, it is easy for nutrients, water and oxygen to move from the blood to body cells, and for wastes and carbon dioxide to be transferred from the cells into the blood.

As blood travels from the capillaries in the hand toward the heart, it enters tiny veins that connect to larger veins. One-way valves in the veins keep blood from moving upward—especially in your legs.



10 Out of the Aorta / Into the Arteries

(See both illustrations.)

This large artery is called the **aorta**. From the aorta, blood travels out to the rest of the body through smaller and smaller branching arteries.

11 Out of the Arteries / Into the Capillaries

Now, blood has made a full circuit and returned to the capillaries in your fingertip, rich with oxygen and ready to pick up waste and carbon dioxide to start the circle again.

FULL CIRCUIT

A drop of blood releases oxygen and picks up waste and carbon dioxide at the body cells. It circulates through the right side of the heart, and to the lungs to release carbon dioxide and pick up oxygen. It then circulates through the left side of the heart and returns to the body cells to start this path of continual circulation again.

ACTIVITY 7

OVERVIEW

When a person exercises, his or her body must adjust to supply muscle cells with more oxygen. To meet the demand for oxygen during physical activity, a person's heart rate and therefore, the amount of blood pumped per minute, increases. Heart rate slows with rest.

Students will measure their heart rates after a variety of physical activities and compare the results with their resting heart rates, and with the heart rates of other students in their groups.

Heart Rate and Exercise

Almost every day, we see, hear or read in the media about the importance of exercise for heart health. Why? What is the relationship between the heart, circulation, and exercise? This activity will help students learn how their hearts respond to physical activity.

Even when you are sleeping, reading, or watching TV, your muscles, brain, and other tissues use oxygen and nutrients, and produce carbon dioxide and wastes. If you get up and start moving, your body's demand for oxygen and the removal of carbon dioxide increases. If you start running, your body demands even more oxygen and the elimination of more carbon dioxide. The circulatory system responds by raising the **heart rate** (how often the pump contracts) and **stroke volume** (how much blood the heart pumps with each contraction), to increase the **cardiac output** (the amount of blood pumped from the left ventricle per minute). During exercise, heart rate can rise dramatically, from a resting rate of 60–80 beats per minute to a maximum rate of about 200 for a young adult.

While you are running, blood flow is diverted toward tissues that need it most.

Continued

This activity is adapted with permission from the HEADS UP unit on Diabetes/Cardiovascular Disease (2003). The HEADS UP unit was produced by the Health Education and Discovering Science While Unlocking Potential project of The University of Texas School of Public Health (www.sph.uth.tmc.edu/headsup) and was funded by a Science Education Partnership Award from the National Center for Research Resources of the National Institutes of Health.

SCIENCE EDUCATION CONTENT STANDARDS*
GRADES 5–8

LIFE SCIENCE

Structure and function of living systems

- Different tissues are, in turn, grouped together to form larger functional units, called organs. Each type of cell, tissue and organ has a distinct structure and set of functions that serve the organism as a whole.
- Specialized cells perform specialized functions in multi-cellular organisms. Groups of specialized cells cooperate to form a tissue, such as a muscle.
- The human organism has systems for digestion, respiration, reproduction, circulation, excretion, movement, control and coordination, and for protection from diseases. These systems interact with one another.

SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES

Personal health

- Regular exercise is important to the maintenance and improvement of health. Personal exercise, especially developing cardiovascular endurance, is the foundation of physical fitness.

SCIENCE, HEALTH & MATH SKILLS

- Measuring
- Observing
- Interpreting data
- Applying knowledge

* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

Aerobic

You've probably heard this term many times, but do you now what it means? Aerobic comes from the Greek word *aeros* (air) and *bios* (life). Aerobic exercise refers to activities that involve or improve oxygen consumption by the body.

The American Heart Association recommends at least 30 minutes of moderate-to-vigorous aerobic activity per day for most healthy people. Examples of beneficial activities include: brisk walking, stair-climbing, jogging, bicycling, swimming, or activities such as soccer or basketball that involve continuous running.

Even moderate-intensity activities such as walking for pleasure, gardening or dancing may provide health benefits.*

*American Heart Association www.aha.org

For example, muscles in the arteries in your legs relax to allow more blood flow. Meanwhile, muscles in the walls of the arteries that take blood to your stomach and intestines tighten, or constrict, so these organs receive less blood. Breathing rate increases to match greater output by the heart. The whole system works together to give your hard-working muscles what they need at just the right time.

Have you noticed that after you finish a run, your heart rate and breathing rate don't return to normal immediately? Why? It's because the circulatory and respiratory systems have to "catch up." You may not have realized it, but while you were running, the muscles of your body produced so much carbon dioxide and other wastes that the body's systems couldn't keep up with the increased demand for elimination. So even after your run ends, your heart rate and breathing rate remain elevated until the excess wastes are eliminated.

If the heart and circulatory system have to do so much extra work when you exercise, why is exercise good for you? One simple answer is, "Use it or lose it." The heart is a pump made of muscle. It needs regular exercise to remain strong, healthy and efficient. The same is true of the circulatory system. Exercise helps keep the arteries strong and open. The contraction of leg muscles during exercise helps to move the blood along. Without exercise, body chemistry actually changes. These changes can lead to a whole range of unhealthy conditions and diseases. Bottom line: to maintain a healthy heart pump and circulatory system, "use it."

The pumping heart makes the sound we refer to as the "heartbeat." The "lub-dub" of a heartbeat comes from the sounds of blood being pushed against closed, one-way valves of the heart. One set of valves (tricuspid and bicuspid) closes as the ventricles contract. This generates the "lub" of our heartbeat. The other set of valves (pulmonary and aortic) close when the pressure in the ventricles is lower than the pressure in the pulmonary artery and aorta. This leads to the "dub" of our heartbeat.

As the heart beats, it presses the blood against the muscular, elastic walls of the arteries. Each artery expands as blood is forced from the ventricles of the heart. The artery wall then contracts to "push" the blood onward, further through the body. We can feel those "pulses" of blood as they move through the arteries in the same rhythm as the heart beats. The number of pulses per minute is usually referred to as pulse rate. The average pulse rate for a child ranges from 60 and 120 beats per minute.

Photo courtesy of NASA.

Astronaut Sunita Williams gives a "thumbs up" as she trains for the Boston Marathon while onboard the ISS. Not only did Suni run the marathon 216 miles above Earth, she ran with her sister, Dina Pandya, who completed the race in Boston. They finished the 26.2-mile race about nine minutes apart, with Dina crossing the finish line at 4:14:30 and Suni finishing on the ISS at 4:23:10.

Invention of the Stethoscope

This is the 1819 model of R.T.H. Laennec's first stethoscope, which he made himself and gave to a number of colleagues. The pieces are made of wood and brass, and fit together to form a one-piece stethoscope that is about 12 3/4-inches long.

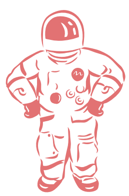
The first stethoscope was a simple rolled paper tube used by Rene Theophile Hyacinthe Laennec to listen to the heartbeat of an obese female patient. "I rolled a quire of paper into a kind of cylinder and applied one end of it to the region of the heart and the other to my ear, and was not a little surprised and pleased to find that I could thereby perceive the action of the heart in a manner much more clear and distinct than I had ever been able to do by the immediate application of my ear."*

*Laennec R.T.H. De l'Auscultation Médiate ou Trait du Diagnostic des Maladies des Poumon et du Coeur. 1st ed. Paris: Brosson & Chaudé; 1819.

Photograph © TESSERACT-Early Scientific Instruments, www.etesseract.com.

It's the Number

During exercise, red blood cells move more quickly to deliver oxygen through the system. But even when a person exercises, red blood cells do not carry MORE oxygen than they do at any other time. The hemoglobin in the blood fully loads up with oxygen each time it passes through the lungs, regardless of whether a person is resting or exercising. Only by moving more quickly through the circulatory system do r ed blood cells carry more oxygen to the tissues.



AstroBlogs!

Continue the "blog-wall" with an AstroBlog entry written for Activity 7. It's located on page 43.

Did You Know?

Air is only about 21% oxygen (O_2) and 0.4% carbon dioxide (CO_2). When we breath, all of the gases in air enter our lungs. A tiny percentage of O_2 is removed. Similarly, the air we exhale contains a tiny bit more CO_2, which represents waste from our bodies.

Have students find out about other gases in air and how they affect us.

THE HEART IN SPACE AND ON EARTH

The heart does not have to work as hard in space as it does on Earth, because in space, the heart does not have to pump blood against the pull of gravity. In addition, astronauts are less active physically in space than they are on Earth. Measurements taken after space flights have shown that heart muscle mass can decrease by up to 10% during a mission. Astronauts try to counteract this reduction in heart muscle (and other muscles) by exercising on treadmills or stationary bicycles while in space. Of course, they have to strap themselves to the exercise equipment. Otherwise, they would float away!

Similar reductions in heart and other muscle mass can occur on Earth during extended illnesses or injuries that require bed rest. As late as the 1960s, heart attack patients were kept in bed for a long recovery to allow their hearts to "heal." Actually, this treatment had the opposite effect. The remaining active heart muscle became smaller and weaker due to lack of use, thus making the patient even more susceptible to future heart attacks. The approach today is to involve heart attack patients as soon as possible in rehabilitation programs that include exercise.

Photo courtesy of NASA.

Astronaut Michael E. Lopez-Alegria, Commander and Science Officer, NASA ISS Expedition 14, exercises on the Cycle Ergometer with Vibration Isolation System (CEVIS) as part of his endurance training program onboard the ISS.

TIME

Two class periods of 45–60 minutes, one to collect data and one to process, present and interpret measurements

MATERIALS

Teacher (see Setup)

- Stopwatch or watch with a second hand
- CD player or other player for music
- Two music selections without words (one song with a strong, up-tempo beat, and a second song that is slow and relaxing)

Each student will need:

- Access to a clock or watch with a second hand (or one stopwatch per team of students)
- Copy of student sheet (p. 32)
- Optional: Lab notebook

SAFETY

Do not have students find their pulse in the neck. Too much pressure on the carotid artery can stimulate a reflex mechanism that slows down the heart. Have students use their wrists (see Procedure, Item 2). Be aware of risks to students with respiratory illnesses, such as asthma. Make sure students understand that all activities are to be carried out in an orderly fashion. Always follow all district and school laboratory safety procedures.

SETUP & MANAGEMENT

Read all instructions before beginning. Select appropriate music. Data collection can be done individually by students or in teams of two, but data analysis should be done by students in groups of four.

Continued

PROCEDURE

1. Ask students if they think heart rate can vary, or if it always is the same. Ask, *What kinds of situations might cause heart rate to change?* [exercise, nervousness, lying down, standing up, walking up stairs, etc.]
2. Show students how to measure heart rate (beats per minute) by feeling blood surge through an artery. Have each student find his or her pulse by placing slight pressure on the wrist with the middle and ring fingers (see illustration, right sidebar). Tell students not to use the thumb, as it has a pulse of its own.

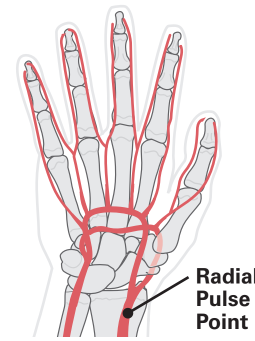
   Allow students to practice counting their pulse rates several times while you count off 15-second intervals. Instruct students to multiply their pulse count by four to determine how many times their hearts beat in one minute.
3. Distribute the student sheet to each student.
4. Review the activity sheet with students, stopping periodically to ask questions and make sure they understand the content.
5. Ask students to complete the prediction section for the first activity. Explain that predictions should be made in order, and for only one activity at a time. (The outcome of each activity may influence their predictions for the next.)
6. Have students sit quietly for minute. Then, instruct them to count their pulses while you time them for 15 seconds. To establish their resting, or beginning, pulse rates, students should multiply by four the number of pulses they counted in 15 seconds. Have them record this number on their activity sheets.
7. Instruct the class to sit quietly and listen to soft music for one minute. Then, have all students measure/record their pulse rates once again. Continue to lead students, as a class, for the first three activities on the sheet. During the deep breathing exercise, make a point of telling students when to inhale and exhale, to be sure they maintain a very slow rate. Instruct students to continue this pattern of slow breathing as they take their pulses.
8. Explain that students should complete the remaining activities listed on the sheet, in order. Each student may work with a partner, if desired. Remind students to record their pulse rate predictions at each step. Students should apply previous experiences when making each new prediction. Be sure students have sufficient time to regain their resting pulse rates before beginning each activity. You may wish to have students record the time it takes for them to return to their resting heart rates. (Pulse rates will recover more quickly if students are seated.) Some students may notice that their heart rates fall below their resting heart rates before returning to normal.

   Be sensitive to students who may feel uncomfortable doing jumping jacks or sit-ups in front of the class.
9. Instruct students to complete the data collection, analysis and conclusion portion of the activity sheet.
10. Have students form groups of four. Each group should share its data, create a presentation of its collective results (graph, table, picture, etc.), and give its presentation to the class.
11. Ask, *What have you learned about heart rate?* Students should have been able to observe that heart rate increases with increased levels of activity. Ask students, *What happened to your breathing during activities that increased your heart rate?* Students should have noticed that with physical activity, breathing rate and volume of air taken in increased. Help students to understand the connection between the body's need for more oxygen during exercise and the

Safety Note

Do not have students use the carotid artery in the neck to find their pulse. Applying too much pressure there could stimulate a reflex mechanism that can slow down the heart.

Radial Pulse Point



The safest and most common site to check pulse is on the thumb-side of the wrist (radial pulse).* Use the middle finger and ring finger together to apply slight pressure at the location shown above.

* Pulse site recommended for the general public by the National Heart, Lung, and Blood Institute, National Institutes of Health.

Taking the Pulse of Infants

One of the easiest pulse sites to locate on small children and infants is the inside of the upper arm, between the elbow and shoulder (brachial pulse).

How Much Is Too Much?

You may have heard about athletes undergoing "blood doping" (taking medicines to stimulate overproduction of blood cells), or even having transfusions of red blood cells. These practices, intended to provide an athletic advantage, are prohibited in competitive sport. Their effects are very short-term, and they can harm the athlete's health.

Some athletes train at high altitudes (usually above 2,500 meters) to obtain a similar advantage in a fair way. At high altitudes, the body naturally adjusts to the reduced availability of oxygen by increasing the numbers of circulating red blood cells.

EXERCISE

- Walking and running are excellent exercises to keep the circulatory system healthy and burning off extra calories. However, running presents a higher risk of injury than some other aerobic activities, such as brisk walking.[1]
- Walking, cycling, jogging and simulated stair climbing let you work out at a productive level, but don't require a lot of practice or equipment. They simply require you to get moving! Activities such as aerobic dancing, bench stepping, hiking, swimming and water aerobics also provide a great workout, but they take practice before one will get a consistent workout. The degree to which sports such as basketball, racquetball or volleyball benefit your circulatory system depends on how intensely you play.
- Even your immune system responds to exercise. Each year, more than 425 million cases of colds and flu occur in the U.S. But people who exercise regularly catch significantly fewer colds, and their infections last fewer days![2]

[1] www.acsm.org/AM/Template.cfm?Section=Current_Comments1&Template=/CM/ContentDisplay.cfm&ContentID=7994 (American College of Sports Medicine)
[2] www.acsm.org/AM/Template.cfm?Section=Current_Comments1&Template=/CM/ContentDisplay.cfm&ContentID=7997

heart's effort to deliver oxygen (by pumping blood more quickly).

12. To conclude the activity, have students write a journal entry describing connections between the intensity of activity and heart rate. Students should complete the following statements, and may want to draw pictures to accompany their words.
    - I discovered...
    - I learned...
    - I never knew...
    - I was surprised...
    - I enjoyed...
13. Have students add any new knowledge or ideas to their group concept maps.

EXTENSIONS

- Ask students, *Why would an athlete have a slower resting heart rate than a non-athlete?* Remember that the average resting heart rate for an adult is 72.

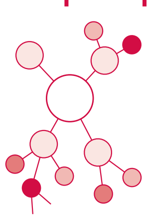
Consider the following average resting heart rates in beats per minute (bpm).

- Weightlifter 65 bpm
- Football Player 55 bpm
- Swimmer 40 bpm
- Marathon Runner 40 bpm

Ask, *Why would a slower heartbeat during rest indicate a healthier heart?* Explain that regular exercise strengthens the heart, and that a well-conditioned heart can pump the same amount of blood with fewer beats. In addition, cardiovascular exercise increases the size of cardiac muscle cells and the size of the heart chambers, so the heart actually increases in size. Therefore, even though the amount of beats per minute is lower, a healthy, fit heart pumps more blood per minute than a heart that is not accustomed to exercise. For the best health, exercise must be a lifestyle, not a temporary fitness "kick." Studies have found that non-activity for as little as three weeks can reduce heart muscle size and stroke volume (amount of blood pumped from the left ventricle in one contraction).

- Have students read and discuss "The Science of Cardiac Research" on page 33.

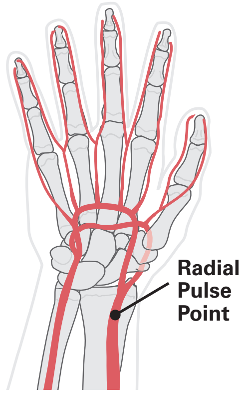
Update Concept Maps



ACTIVITY 7

HEART RATE

Heart Rate



You can measure your heart rate by taking your pulse. Each pulse that you feel in your wrist represents one heartbeat. What do you think happens to your heart rate after different kinds of physical activity? You're about to find out, as you observe the response of your pulse rate to a variety of activities.

Sit quietly for one minute. Then, measure your resting heart rate by counting your pulse for 15 seconds. Multiply the total by 4 to obtain the number of beats per minute. To feel your pulse, *lightly* press your ring and middle fingers against the inside of your wrist (see illustration, left). *Do not use your thumb.*

____________ **beats in 15 seconds x 4 =** ____________ **beats/minute**

Make a prediction before you begin each activity below. Carry out each activity for one minute. Then, stop and immediately take your pulse for 15 seconds (multiply by 4 to obtain the number of beats per minute).

Before starting each new activity, sit quietly until your heart rate is close to your resting heart rate. Calculate the difference between your pulse rate after each activity and your resting pulse rate. Record the difference in the appropriate column (Increase, Decrease or Same).

TYPE OF ACTIVITY	PREDICTION ABOUT PULSE RATE (CHECK ONE BOX)			PULSE RATE IMMEDIATELY AFTER ACTIVITY	DIFFERENCE BETWEEN RESTING PULSE RATE AND RATE AFTER ACTIVITY (BEATS PER MINUTE)		
(Conducted for 1 Minute)	Increase	Decrease	Same	(Beats Per Minute)	Increase	Decrease	Same
1. Listen to soft, slow music							
2. Listen to fast music							
3. Breath deeply							
4. Walk briskly around the room							
5. Do jumping jacks							
6. Do sit-ups							
7.*							

*Record Activity of Your Choice.

1. What effects do the different activities have on your heart rate?

2. Compare your data to your predictions. Then, compare your personal data with the data collected by your fellow group members. What did you discover? Were there any surprises? How will you present your findings to the class?

CARDIAC RESEARCH

NSBRI Web site: www.nsbri.org

If one part of a car isn't properly maintained, it can affect the performance of the entire vehicle—especially if it's driven on a long trip. The same can be said for the human body. That's why, when it comes to fitness in space, it's important to create a program for the whole body.

To keep astronauts healthy on long missions, researchers with the National Space Biomedical Research Institute (NSBRI) are developing an exercise program that addresses many of the physical changes caused by microgravity. In one experiment conducted on Earth, participants stayed in a bed tilted at a six-degree angle, with their feet positioned at the higher end of the bed. In this position, the heart works about 15–20% less than it does under normal living conditions. In addition, blood pressure changes and work capacity is lessened. All of these things also happen to astronauts during long-term spaceflights.

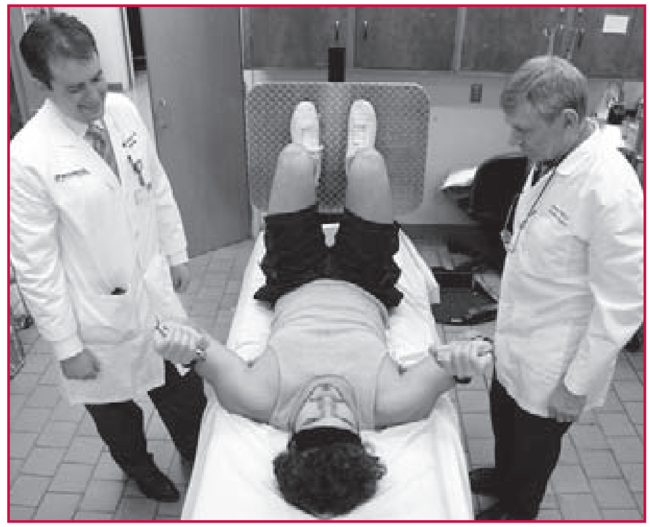


Photo courtesy of UT Southwestern Medical Center at Dallas.

To preserve astronaut health on long missions, scientists are researching the benefits of an exercise program to counteract space-related heart, lung, muscle and bone problems.

The study involved 24 subjects divided into three groups. One group (the control group) stayed in bed and did no exercise. The remaining two groups performed exercise training while in bed. Half of the training subjects received a dietary supplement.

Strength training (rowing, lifting weights) forces muscles to contract enough to briefly interfere with blood flow into muscles. Endurance training exercise (swimming, running and cycling) forces large-muscle groups to contract regularly.

The test subjects exercised using a rowing machine (strength and endurance training in one) with their knees level to their hearts. Subjects also trained with the same regimen athletes use to achieve maximal physical benefit: a program consisting of base training, followed by threshold, interval and recovery training.

The base-training session consisted of moderate rowing exercise performed at a level where subjects could still carry on a conversation, but with slight shortness of breath. With threshold training (one to two days per week), subjects worked at their maximum sustainable effort. For example, at this level, professional marathon runners run hard, but do not sprint.

The interval-training segment was a high-intensity exercise effort in which subjects pushed their hardest for one to three minutes, building power and explosive energy. Each interval training session was followed by a recovery session, during which subjects exercised at low intensity. The regimen included one long, slow distance effort. Scientists found that this kind of exercise routine preserved heart size and function, muscle size and bone strength.

Researchers now are developing a single exercise routine for astronauts that will prevent damage to their cardiovascular systems, bones and muscles. On Earth, doctors already are using this type of exercise regimen with patients, and are seeing very satisfying results.

The NSBRI, funded by NASA, is a consortium of institutions studying the health risks related to long-duration spaceflight. The Institute's science, technology and education projects take place at more than 60 institutions across the U.S.

OVERVIEW

Blood pressure, the force of blood against the walls of blood vessels, is responsible for the movement of blood through the arteries. When blood pressure is measured, two numbers are recorded. The first number represents the pressure while the heart is contracting to pump blood through the arteries. The second number represents the pressure while the heart is relaxing and refilling.

Students will measure their own blood pressure and learn about the health effects of high blood pressure.

ACTIVITY 8

WHAT IS BLOOD PRESSURE?

Students now have learned about the heart, the blood vessels, and blood. But what about blood pressure? Blood behaves like any other liquid and exerts pressure against the vessels in which it is contained. Blood pressure is the force of blood against the walls of blood vessels, specifically the arteries, and is responsible for the movement of blood through the arteries. Blood pressure is much higher in arteries than in veins and capillaries.

Most students have had their blood pressure measured with a blood pressure meter consisting of a cuff attached to a mercury or mechanical measuring

Most students have had their blood pressure "taken" with a blood pressure cuff attached to a measuring device (sphygmomanometer). In this common practice, a cuff is secured just above the bend in a person's elbow and inflated to increase pressure against the artery of the upper arm (brachial artery). A stethoscope is placed on the inside of the elbow to listen for the whooshing or pounding sound of blood flowing through the brachial artery. The cuff is inflated until no pulse or sound can be detected with the stethoscope. At this point, blood flow has stopped. Then, air is slowly released from the cuff, and the stethoscope is used to listen for the first sounds of blood flowing again through the brachial artery.

The force of blood flowing through the artery at this point, known as systolic pressure, is slightly greater than the pressure being exerted against the artery by the cuff. The systolic pressure indicates

SCIENCE EDUCATION CONTENT STANDARDS*
GRADES 5–8

PHYSICAL SCIENCE
Motion and forces
- The motion of an object can be described by its position, direction of motion and speed. Motion can be measured and represented on a graph.

LIFE SCIENCE
Structure and function of living systems
- Living systems at all levels of organization demonstrate the complementary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms and ecosystems.
- The human organism has systems for digestion, respiration, reproduction, circulation, excretion, movement, control and coordination, and for protection from disease. These systems interact with one another to protect us from diseases.

SCIENCE, HEALTH & MATH SKILLS
- Measuring
- Collecting data

* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

Blood Pressure and Gravity

On Earth, the heart must pump against two factors: 1) the normal resistance of the arteries to blood flow and 2) gravity. Additional pressure is required to push blood to the brain and other parts of the body above the heart. The pull of gravity actually aids blood flow down to the lower limbs. But then, leg muscles must help to squeeze blood back up through the veins, to the heart, against the force of gravity. In space, gravity does not affect blood movement in any direction.

AstroBlogs!

Continue the "blog-wall" with an AstroBlog entry written for Activity 8. It's located on page 44.

A Laughing Matter

Laughter has been linked to the healthy function of blood vessels. Researchers at the University of Maryland Medical Center found that watching funny movies caused volunteers' blood vessels to relax, thereby promoting increased blood flow.

www.umm.edu/news/releases/laughter2.htm

the amount of pressure in the artery while the heart's ventricles are contracting. Systolic pressure is the larger (and first) of the two numbers in a blood pressure reading. For instance, it is the "120" in a blood pressure reading of "120 over 80."

Once systolic blood pressure is measured, air is slowly released from the cuff until the beating or whooshing sounds no longer can be heard through the stethoscope. Then, another reading is taken to measure diastolic pressure, which is the pressure in the artery while the heart is relaxing and refilling. Diastolic pressure is the smaller (and second) number reported in a blood pressure reading (it is the "80" in a reading of "120 over 80").

One of the first accurate tools for measuring blood pressure was a mercury manometer (measures pressure with a column of mercury, similar to a thermometer). That's why today, blood pressure always is reported as millimeters of mercury, even when it is measured by an aneroid device (calibrated dial with a needle) or a digital monitor.

A blood pressure measurement of 100 mm Hg indicates a force of blood pushing against the arteries sufficient to hold up a column of mercury that is 100 millimeters high. And a blood pressure reading of 120/80 (or 120/80 mm Hg), means the systolic and diastolic pressures are 120 and 80 millimeters of mercury, respectively. Knowing what these two values mean is important to health and well-being. Normal blood pressures vary by age (see table, above right).

When a person has pressure in the arteries that is considerably higher than normal during inactivity, we say he or she has high blood pressure (also called hypertension). A doctor must make this diagnosis, but readings higher than 140/90 usually signal high blood pressure. A rise in heart rate, increased blood volume, or a narrowing of the blood vessels all can cause high blood pressure by increasing the force of blood against the artery walls. Uncontrolled high blood pressure is sometimes called the "silent killer," because the individual who has it feels normal. High blood pressure can damage the arteries, heart, brain, kidneys or eyes in a number of ways.

Many factors contribute to hypertension. Some, such as genetics or age, cannot be changed. A person is more likely to develop high blood pressure if his or her parents have the condition. And the chances for developing hypertension increase with age. High blood pressure also can be caused by medical conditions, such as kidney disease and diabetes. Fortunately, we can control some of the risk factors for high blood pressure. For instance, we can get regular exercise, limit the consumption of alcohol, salt and saturated fats (fats that are solid at room temperature), maintain a healthy body weight, and reduce stress.*

Since there are so many negative health effects of high blood pressure, it may seem desirable to have low blood pressure (called hypotension). And it is true that people who exercise regularly tend to have lower blood pressure than those who are not as fit. However, blood pressure that is too low may signal the presence of

Age-Appropriate Blood Pressure Ranges in mm Hg

Age	Systolic	Diastolic
Birth	50–70	25–45
Neonate (0–1 month)	60–90	20–60
Infant (1–8 months)	87–105	53–66
Toddler/pre-school (9 months–5 years)	95–105	53–66
School age (6 years)	97–112	57–71
Adolescent (15 years)	112–128	66–80
Adult (18+ years)	120	80

Source: *Pediatric Advanced Life Support Provider Manual*, American Heart Association.

* www.americanheart.org/presenter.jhtml?identifier=4650

Continued

underlying problems, such as a heart condition, low blood sugar, or even dehydration. Some experts say that readings below 90 systolic or 60 diastolic indicate low blood pressure, but since there are so many factors involved, these numbers can be misleading. What is normal for one person might be considered low for someone else.

TIME

10 minutes for setup; two 45–60 minute sessions

MATERIALS

Teacher (see Setup)

- Electronic blood pressure monitor with a self-inflating cuff (sold in drugstores)

Each student will need:

- Lab notebook

SAFETY

Make sure all students are seated while taking blood pressure. Over-inflation or excessive duration of inflation of the blood pressure cuff may cause discomfort or injury. Always follow all district and school laboratory safety procedures. It is a good idea for students to wash their hands with soap and water before and after any science activity.

SETUP & MANAGEMENT

Obtain an electronic blood pressure monitor with a self-inflating cuff. Do not use a manual blood pressure monitor because students easily could over-inflate the cuff and cause injury. Read and follow the manufacturer's instructions, which can vary between models.

Place the monitor in a central location, where students can take turns measuring their blood pressure. While students are waiting their turn at the blood pressure center, teams may begin to research and discuss the provided questions (see Procedure, Item 6).

If a blood pressure monitor is not available, ask students to measure their blood pressure, under the supervision of their parents/guardians, at a public blood pressure kiosk, usually found in drug or grocery stores.

Have students work in teams of two.

PROCEDURE

1. Ask, *Have you ever had your blood pressure taken? If so, what do you think was being measured?* Explain that when a health care provider takes a patient's blood pressure, he or she briefly restricts the flow of blood through one of the patient's arteries by applying pressure to the artery. The health care provider then slowly reduces the pressure until he or she hears (using a stethoscope) the sound of blood forcing its way through the vessel. The measurement taken at this point is called the systolic pressure. The health care professional continues to reduce the pressure until he or she no longer hears any sounds. The measurement taken at this point is called the diastolic pressure.

   Explain that the top number in a blood pressure reading (systolic) represents the pressure when blood is forced from the ventricles, and the bottom number (diastolic) represents the pressure when the ventricles are at rest, or between beats (filling with blood). Remind students that even when blood is not being forced from the heart, it continues to flow. There always is a certain amount of pressure maintained in the blood vessels.
2. With a student volunteer, demonstrate how to take a blood pressure reading. Have the student sit in a chair with feet flat on the floor and with shirt sleeves rolled up. Place the monitor cuff just above the bend of the student's upper arm. Ask the student to raise his or her arm to the level of the heart. Place your arm underneath the student's arm to support it. Ask the student to relax his or her arm. Take a reading according to the manufacturer's instructions for the monitor.

Can High Blood Pressure be Cured?

High blood pressure is the most common disease of the circulatory system. For most people, it cannot be "cured." But it can be controlled by changes in lifestyle (exercise and diet) and/or by medications. Some medicines relieve pressure by causing the arteries to relax and open up. Others lower blood pressure by reducing the heart's output, or by causing the body to lose salt and water. Of course, each medicine has side effects, and a healthy diet and exercise always are important factors in the treatment of high blood pressure.

www.americanheart.org/downloadable/heart/119626772541850%20WhatisHBPMedication%209_07.pdf

A Silent Killer

According to the American Heart Association, almost one-third of adult Americans have high blood pressure. And about a third of those people don't even know they have it! They may have high blood pressure for years, unaware that it is damaging their heart, blood vessels and other tissues.

www.americanheart.org/presenter.jhtml?identifier=2114

Reliable Sources

Reliable information about heart health and related topics is available online at the following Web sites.

American Heart Association
www.americanheart.org

Centers for Disease Control and Prevention
www.cdc.gov

MedLine Plus*
http://medlineplus.gov

National Heart, Lung, and Blood Institute
www.nhlbi.nih.gov

U.S. Food and Drug Administration
www.fda.gov/hearthealth

*Health information is available in more than 40 languages.

Photo courtesy of NASA.

Astronaut Jeffrey N. Williams, Science Officer and Flight Engineer, NASA ISS Expedition 13, holds up two finger cuffs on a Continuous Blood Pressure Device. Small, portable medical devices created for use by astronauts also can be used here on Earth.

3. Mention that several factors might lead to an inaccurate blood pressure reading. These include physical activity (standing up quickly, walking fast, etc.), posture, medications, emotions, temperature and diet. Ask, *Why would blood pressure be an important measure of a person's overall health? Do you think it is more dangerous to have high or low blood pressure? Why?* Remind students of earlier lessons about the heart and valves. Just as too much air pressure can damage an over-inflated tire, high blood pressure, over time, places additional stress on the heart, valves, arteries and other organs of the body.
4. Have teams of two students visit the blood pressure center, one team at a time. Students should take turns using the blood pressure monitor and recording their pressure readings in their lab notebooks. Be sure students record their results by writing the higher number on top and the lower number below (for example, 115/75). You may want teams to begin working on their research questions (see Item 6, below) while they wait to use the blood pressure monitor.
5. Discuss healthy ranges for blood pressure (see table, p. 35). Remind students that if their readings do not fall within the healthy range, they may want to have their blood pressures checked by a health care professional. You may wish to construct a class graph of students' blood pressure measurements.
6. Have each student team investigate one of the following questions related to blood pressure. Each team should conduct its research on the Internet and/or in the library, and then present its findings to the class during the next class period. Teams may want to develop their own topics for investigation. Students should include lists of the sources they consulted.
   - What is the relationship between eating high-fat foods and blood pressure?
   - How does family history (for example, whether one of your parents has high blood pressure) affect your chances of developing high blood pressure at some time?
   - How does diabetes affect a person's chances of having high blood pressure?
   - What effect does walking or running three times per week have on blood pressure?
   - Do stress levels influence blood pressure? If so, what is the effect?
   - How does heavy alcohol consumption affect blood pressure?
   - How does eating a lot of salty food affect blood pressure?
   - What types of foods, if any, help to maintain blood pressure in a healthy range?

OVERVIEW

The circulatory system is able to adjust to different external conditions. On Earth, gravity causes blood to pool in our lower legs. But in space, beyond the pull of Earth's gravity, blood distributes itself evenly throughout the body. The body adjusts to this condition by decreasing the total volume of blood, which can cause problems, such as low blood pressure and fainting, when a person returns to Earth.

Students will use water balloons to simulate the effects of gravity and microgravity on fluid distribution in the body.

ACTIVITY 9

CHALLENGE: MICROGRAVITY

If students have been reading the Astroblogs (pp. 42–44), they already know quite a lot about the challenges faced by the circulatory system when humans travel into a microgravity environment. Living in microgravity changes both the heart and the blood.

On Earth, blood is pulled downward by gravity and tends to pool in the lower half of the body. In microgravity, blood is no longer pulled toward the feet, or in any particular direction. Without the effects of gravity, the distribution of blood in the body changes, with less blood than normal in the legs and more blood than normal in the upper body. Therefore, astronauts in space get skinny "chicken legs" and puffy faces, and often feel stuffiness in their ears and noses. Suddenly, the heart is not moving five liters of blood (the amount in most adults) against the strong pull of gravity. Because it does not have to work as hard, the heart becomes slightly smaller and weaker while in space.

In microgravity, the body senses the extra blood in the upper body and interprets it as too much fluid (over-hydration). This signals the kidneys to remove water from the blood and dispose of it as urine. Astronauts lose as much as 20% of their blood volume during a space mission. Other sensors in the body then discern that there are too many red blood cells for the amount of blood circulating, so the body reduces the amount of red blood cells to match the plasma. This reduction in red blood cells is called "space anemia." After only one day in space or in orbit, astronauts have a lower blood volume. However, their ratio of red blood cells to plasma is similar to that experienced on Earth.

SCIENCE EDUCATION CONTENT STANDARDS*
GRADES 5–8

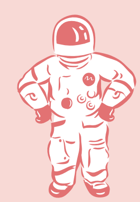
LIFE SCIENCE
Structure and function of living systems
- Living systems at all levels of organization demonstrate the complementary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms and ecosystems.
- Regulation of an organism's internal environment involves sensing the internal environment and changing physiological activities to keep conditions within the range required to survive.

SCIENCE, HEALTH & MATH SKILLS
- Creating a model
- Comparing and contrasting
- Questioning

* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

Post-Assessment Reminder

To conclude this unit, have students complete the post-assessment and present their final concept maps, as described on page 3.



Final AstroBlog!

It is time to complete the "blog-wall" with an AstroBlog entry written for Activity 9. It's located on page 44.

What is Blood?

Blood is a mixture of cells and a pale yellow liquid, called plasma, in which red blood cells (carrying oxygen), white blood cells (infection fighters) and platelets (clotting agents) float. In addition, plasma transports vitamins and nutrients, proteins, enzymes, hormones, cholesterol, and carbon dioxide, among other things like sugar and electrolytes (sodium, potassium and calcium). Even with all of these components, plasma still is made up of almost 90% water!

The cardiovascular system adapts well to microgravity, but what happens when an astronaut returns to Earth and "normal" gravity? By the time a spacecraft or orbiter begins reentry into the Earth's atmosphere, astronauts have fewer red blood cells, their hearts have not been working as hard as they do in normal gravity, and their blood volume is lower than normal. These changes occurred over several days (or even longer), but reentry into normal Earth gravity happens quickly. This abrupt change creates important challenges for the circulatory system. And it can be dangerous for astronauts, because they must function effectively during reentry and landing.

In the previous activity, students learned about high and low blood pressure (hypertension and hypotension, respectively). One consequence of low blood pressure is reduced blood flow to the brain. Upon returning to Earth's gravity, astronauts sometimes experience a specific type of low blood pressure, called orthostatic hypotension, which you also may have experienced if you've ever stood up quickly after being seated on a chair. You get a little dizzy because gravity pulls the blood in your body down toward your feet. For a moment, your blood pressure falls slightly, and you feel dizzy. The dizziness goes away as your heart speeds up and stroke volume increases.

This same experience of orthostatic hypotension can happen to astronauts returning from space. Upon reentry, the pull of the gravity increases and blood is pulled back toward the lower body, as it is on Earth. However, since an astronaut's total blood volume has decreased while in space, the effect is quite a bit stronger than when a person stands up from a chair. Astronauts can become very dizzy, or even lose consciousness during reentry. This condition can last for several days after returning to Earth, until the changes in the astronaut's circulatory system reverse themselves and the body's overall blood volume returns to a normal level. Scientists are working to develop short-acting medications to help prevent the effects of orthostatic hypotension and allow astronauts to function normally during landings.

Many biomedical researchers and astronauts also are conducting experiments to determine the impacts of longer-term spaceflight on astronauts' circulatory systems. For example, would an exercise routine be sufficient to prevent long-term changes in heart strength and size, blood volume, and the number of circulating red blood cells? Researchers are working to answer these questions. Their work also may produce better treatments for people on Earth who are bedridden for long periods of time, or who have diseases of the heart or circulatory system.

TIME

60 minutes

MATERIALS

Each group will need:

- Highlighters
- Oblong-shaped balloon
- Paper towels
- Tub half-filled with water (large enough to float a filled balloon)
- Group concept map (ongoing)

Each student will need:

- Copy of student sheet (p. 41)

SAFETY

It is a good idea for students to wash their hands with soap and water before and after any science activity. Make sure any spilled water is cleaned up promptly.

SETUP & MANAGEMENT

Depending on time and the ages of your students, you may want to fill water balloons in advance, instead of having students fill the balloons during class.

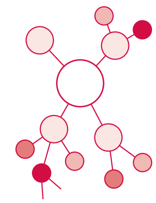
Have students work in teams of four.

Continued

PROCEDURE

1. Give each group of students a long balloon. Instruct students to fill the balloon with water at a faucet and tie a knot at the top. This task is best accomplished by two students working together.
2. Ask, *Do you think the shape of the water balloon will remain constant?* Tell students that they will investigate the shape of the balloon under different conditions: lying horizontally on a flat surface, held vertically, and suspended in water. Student groups should discuss and predict the shape of the balloon under each condition.
3. Have students place their water balloons on a flat surface. Each student should observe and draw the balloon's shape as it lies on the table.
4. Next, have one student from each group hold the balloon up by the knot. Instruct students to observe and draw the balloon again.
5. Finally, have students place their balloons in the tubs of water, and then observe and draw the balloon's shape again. Under each of their three drawings, have students write a brief description comparing and contrasting each shape, and explaining why the shapes are different.
6. Ask, *Why does the balloon change shape?* [Walls of the balloon stretch in response to pressure exerted by the water inside the balloon. The force of gravity pulls the water toward the lowest part of the balloon when it is lying on a table or held by the knot. This does not appear to happen when the balloon is in water.] Discuss the ways in which a water environment might mimic conditions in space, where gravity does not have an effect (microgravity). [The water balloon suspended in water is similar to an astronaut suspended in air within the space shuttle. The density of the water balloon is the same as the density of the water surrounding it, so gravity does not pull on the water balloon any more than it does on the rest of the water in the tub. In a sense, the water surrounding the balloon counteracts the pull of gravity on the balloon itself.]
7. Ask, *In what way could you compare the human body to the balloon? Is there liquid water inside the human body? What percent of a human's body weight is water?* [55–65%]
8. Hold the balloon vertically. Ask, *If this were a human body, where would the blood pool? Does blood flow down in the body like water does in the balloon?* Explain that the fluid (blood) in a human body does travel downward through the blood vessels. Under normal conditions, blood is forced back to the heart by: a) continuous flow of blood through the body, b) constriction of the muscles in the walls of the blood vessels, c) contraction of muscles surrounding the veins, and d) "one-way" valves inside many veins that allow blood to move in only one direction—back to the heart.
9. Ask, *How might the body function differently in space? What would happen if the water were not pulled downward by gravity?* Remind students of the appearance of the balloon when it floated in the water.
10. Distribute the student sheet. Have students read and highlight important facts from the article.
11. Have students individually complete the "3-2-1" activity (see sidebar, right). When they have finished, let individual students share responses within their groups.
12. As a class, have students discuss possible answers to the questions generated by the activity. Assign groups of students to research questions that are not resolved, and have them present their findings to the class in any format they choose.
13. Ask students if they have anything to add to the concept maps they have compiled over the course of the unit.

Finalize Concept Maps



3-2-1 Activity

Have students respond individually to the following prompts in their lab notebooks or on a sheet of paper.

3 Things you learned

______

______

______

2 Things that surprised you

______

______

1 Question you have

______

Go To Page 3

Conduct a final unit assessment with students.

WHEN SPACE . . .
MAKES YOU DIZZY

It's terrible to feel dizzy when you're trying to land a spaceship, yet that's what happens to some astronauts. Their legs become heavy and their heads feel light, even as the planet below expands to fill the windshield. It's an unwelcome side effect of returning home from orbit . . .

Researchers have learned that dizziness experienced by returning astronauts is caused, in part, by orthostatic hypotension—"in other words, a temporary drop in blood pressure," explains NASA Chief Medical Officer, Rich Williams. On Earth, you can feel orthostatic hypotension by standing or sitting up too fast. Gravity has much the same effect on astronauts returning from a long spell in space: blood rushes down toward their feet and the space travelers become, literally, lightheaded.

Each person responds differently. Some astronauts are hardly affected, while others feel very dizzy. About 20% of short-duration and 83% of long-duration space travelers experience some symptoms during reentry or after they land.

"Cosmonauts who spent a long time onboard Mir commonly had to be carried away in stretchers when they came home," recalls Williams. Fortunately, their Soyuz return capsules did not require a pilot to land, so it didn't matter much. Shuttle pilots, on the other hand, must perform complex reentry procedures. To them, it matters a great deal.

Orthostatic hypotension can strike Earth-dwellers for many reasons. Weak hearts might not pump enough blood, for example. Certain medications, or even a hot shower, can dilate blood vessels and cause blood pressure to drop. Women—especially pregnant women—are more likely to suffer from it than men. "Some patients with this condition are afraid to leave home or even get out of bed," writes neurologist Phillip Low of the Mayo Clinic.

What Is G-force?

G-force refers to the force that an accelerating object "feels." The term refers to the backward push you feel when you are going uphill on roller coaster, or when you are in plane that is taking off. An object at rest on Earth's surface experiences a g-force of 1, which corresponds to the effect of Earth's gravity. When astronauts return to Earth, they experience strong g-forces as they accelerate back toward the surface of the planet.

Astronauts experience orthostatic hypotension because of the way human bodies respond to gravity. On Earth, gravity pulls blood toward the lower body. But in space—either in free-fall or far from a source of gravity—blood that normally pools in the legs collects in the upper body instead. That's why astronauts have puffy-looking faces and spindly "chicken legs."

Astronauts don't feel orthostatic hypotension while they're traveling through space. But they do begin to feel it during reentry (when g-forces mimic gravity) and after landing. Blood returns to the lower body and blood pressure to the head is suddenly reduced. Hence the dizziness, which can continue for a while after landing.

It's a classic case of "use it or lose it." Veins in human legs contain tiny muscles that contract when the veins fill with blood. Their function is to send blood "uphill" toward the heart and thereby maintain blood pressure. But in space, there is no "uphill," so those tiny muscles in the veins are used less—a normal adaptation to weightlessness.

During reentry, those muscles are needed again, but they have temporarily "forgotten" how to contract. They fail to push blood back toward the heart and brain. "This effect is more severe after prolonged spaceflights," notes heart researcher Richard Cohen.

For many years, astronauts have tried to counteract orthostatic hypotension by drinking lots of salt water, which increases the volume of bodily fluids. (There is a general loss of body fluids during space missions.) Astronauts also wear "G-suits"—rubberized full-body suits that can be inflated with air, which squeezes the extremities and raises blood pressure. These suits are similar to what fighter pilots wear, and for the same purpose of counteracting "g" force.

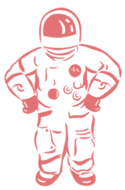
Such countermeasures are only partially effective. "Almost all returning astronauts experience changes in gait and balance," continues Williams. (Gait is the way someone moves on foot.) Nevertheless, "most are able to walk around just fine. A small number experience orthostatic changes that render them quite dizzy." Scientists are looking for other ways to reduce dizziness problems for astronauts. Their research is likely to help people on Earth as well.

Adapted from "When Space Makes You Dizzy," Science@NASA. An audio file of the original article is available at http://science.nasa.gov/headlines/y2002/25mar_dizzy.htm.

AstroBlogs

Create a “blog-wall” in your classroom to stimulate students’ thinking and encourage students to express their ideas in writing. Periodically, post a copy of one of the AstroBlog entries below to spark students’ interest. Suggested use with specific activities is noted with each entry.

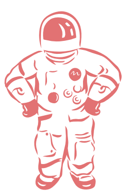
Activity 2



AstroBlogs

The human circulatory system is very well adapted to work under normal Earth gravity. In fact, some parts of the circulatory system count on gravity to help move blood through the body. When I’m floating in space, where humans hardly feel the effects of gravity, my circulatory system faces some real challenges. But even in low gravity, my circulatory system still has to accomplish its transportation function. If it doesn’t, I (and my fellow humans!) would not be able to survive space travel. In this unit, you’ll learn how the circulatory system functions on Earth, and discover some of the challenges we space travelers face when we’re in orbit and when we return home. More on that later…

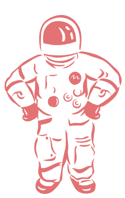
Activity 3



AstroBlogs

The floating food coloring in this activity shows how things float when we are orbiting the Earth. In orbit, we don’t feel the effects of gravity. This condition is called microgravity. You may have experienced microgravity conditions momentarily on Earth. For example, if you ever felt like you’ve floated out of your seat as you reached the top of a roller coaster, you experienced a moment of what some people call “weightlessness.” Do you think we actually become weightless in a situation like this one, on the roller coaster?

Activity 4



AstroBlogs

We use lots of pumps in our spacecraft—pumps for water and fluids that drive different mechanical devices. These pumps have to work in microgravity just as they do on Earth. Can a pump really work in microgravity? As long as it doesn’t need gravity to operate, yes.

For example, a sump pump, like those used in basements, would have a hard time working in space. It depends on water flowing “downhill” to refill the pump each time. In space, that water would float right where it was! So in microgravity, it is better to have a pump with elastic walls.

Think of a sponge underwater. If you squeeze the sponge and let it go, it will refill with water, due to the negative pressure left when the elastic sponge walls return to their original shape. The water is drawn into these spaces because the water pressure outside the sponge is greater than the pressure in the empty spaces inside.

Our hearts work in a similar way. The strong, elastic walls of our hearts are like the sponge. After they contract and push blood into the next chamber or arteries, they spring back to their original shape so the chamber can refill with blood. Therefore, my human heart pump works just fine while I’m floating in space. Whew! That’s a relief!

AstroBlogs

Activity 6

AstroBlogs

As you can see, the heart is a powerful pump. But like any pump, it can malfunction, sometimes because of our choices for exercise and diet. What about when we are floating in space? Does microgravity affect the heart muscle? Yes!

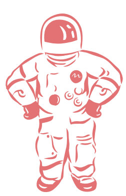
If you think about it, a lot of the work done by the cardiovascular system involves moving blood upward against gravity. For example, your heart has to push blood more than a foot upward to your brain. If you've ever sucked soda up a super-long straw, you know it takes some work to move liquid against gravity through a narrow tube.

Due to the downward pull of gravity, our blood tends to pool in the lower half of our bodies. While I float in the space shuttle as it orbits the Earth, the blood in my body is not being pulled by gravity toward my feet. Because, of course, there is very little gravity in space! Therefore, more blood than usual will stay in the upper half of my body, and less will stay in the lower half. After just one day in space, my legs start to look skinny and my face starts to look puffy. My nose and ears feel stuffy, too… not fun! It's no surprise that while I'm floating in space, my body doesn't have to use its muscles to hold me upright against the Earth's gravity. This makes my heart rather lazy. It slows down and doesn't have to work as hard to pump blood to the different parts of my body. And we all know what happens to muscles when we don't work them, right? They get weaker and smaller.

*This can happen to an astronaut's heart, too. How do we avoid this? The same way we do on Earth: exercise, and lots of it! We have treadmills and stationary bikes in space to keep our skinny chicken legs and our hearts strong. When I get back to Earth, I'll feel a little dizzy and weak-kneed for a while. But my body will readjust to Earth's gravity pretty quickly and my heart will get strong again. The recovery time happens even faster if I keep exercising. Gotta go… Time to ride the bike!**

* www.esa.int/esaHS/ESAGO90VMOC_astronauts_0.html

Activity 7



AstroBlogs

It's another beautiful day in space! I just finished my lunch. Did you know that we eat tortillas instead of sliced bread up here? Why? Well, if you drop a few crumbs on Earth, they just fall to the floor. If I drop a few crumbs in space, they float around the spacecraft and get in everyone's noses or eyes, or worse, into the machinery. Not cool. But tortillas don't crumble. And besides, I like them with my fajitas, with lots of hot sauce to get my blood moving.

Speaking of blood, did you know that even my blood will change while I'm floating in microgravity? Yep! I get a little dehydrated up here. In fact, my blood plasma volume will drop as much as 20% during a space mission. Then my body reduces my red blood cells so my blood isn't too "thick." We have to work hard to keep hydrated. Luckily, our bodies will return to normal after we're back on Earth for a while. I can eat crumbly potato chips then, too!*

* www.esa.int/esaHS/ESAGO90VMOC_astronauts_0.html. Note: Another resource is Donald E. Watenpaugh. Fluid Volume Control During Short-term Spaceflight and Implications for Human Performance. *J. Exp. Biol.* 2001 204: 3209-32.

An Astronaut's Point of View

AstroBlogs

Activity 8

AstroBlogs

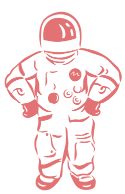
Exercise! You can't imagine how important it is to those of us who travel through space. We don't just exercise for a half hour or an hour. Sometimes we exercise several hours a day! Why so much?

Well, first, we need to keep strong. Floating around inside the shuttle is easy, but working outside, in a pressurized suit with tools, is really hard. You have to be fit to do this kind of work. More important, exercise helps to slow down, or even reverse, some of the changes that microgravity causes in my circulatory system. Exercise even helps to relieve the stuffy head I get when extra blood collects in the upper part of my body.*

When astronauts exercise, we often collect information about our heart and breathing rates, our muscle mass and our strength. That data is really important for planning long-term spaceflights. Speaking of which, did you know we are working towards launching the first human mission to Mars? That trip will last more than two years. We need to know how to exercise in space, so that we don't end up being Martian couch potatoes when we get there!

* www.esa.int/esaHS/ESAGO90VMOC_astronauts_0.html

Activity 9



AstroBlogs

Blood pressure is an important issue for astronauts, especially during take off and landing. When we blast off from Earth, our hearts have to push the blood against Earth's gravity. Then, as we move into orbit and the microgravity of space, our bodies' control systems tell the circulatory system to adjust. This causes our blood pressure to drop.

When we return home, we have a bigger problem. As we approach Earth, the pull of gravity increases. This makes the heart work harder to move the blood to all parts of the body, including the brain. If the heart doesn't respond quickly enough, we can get light headed, and even faint. Not cool, especially when you're flying a spacecraft at several thousand miles per hour!

Not all astronauts get light headed during reentry, and it's hard to predict who will react this way. I hope that when we land from this mission, I will be clear-headed all the way down. I'm not flying the shuttle, but I want to see the whole landing process. Besides, if I pass out, I might drool inside my helmet. That would be embarrassing!