BioEd℠

THE SCIENCE OF THE HEART AND CIRCULATION

A System of Transport

by

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RESOURCES

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

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http://www.fda.gov/hearthealth

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 http://www.nsbri.org.

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

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.

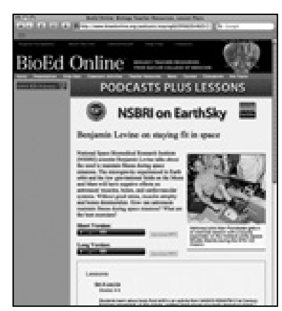
SCIENCE, HEALTH & MATH SKILLS
- Measuring
- Creating a model
- Comparing
- Questioning
- Calculating
- Drawing conclusions

* 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

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

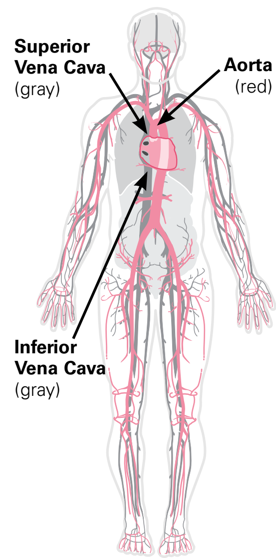


Fig. 1. The Circulatory System is the "transportation system" for the body, and blood serves as the transport vehicle.

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

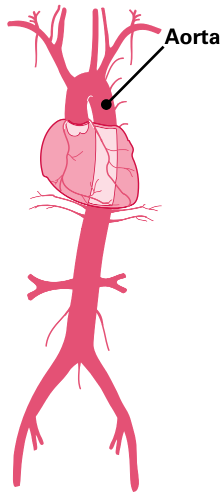


Fig. 2. There is no larger artery in the body than the aorta. It carries blood and nutrients away from the heart (see Fig. 1, p. 2).

The Vena Cavas

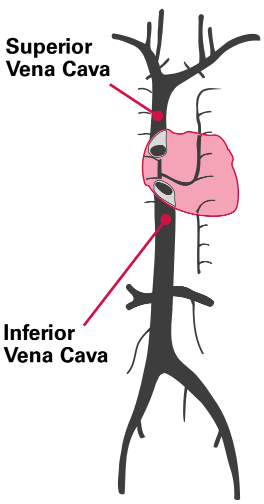


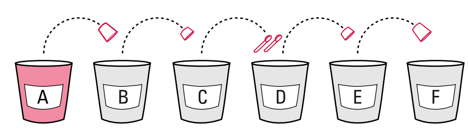
Fig. 3. The vena cavas are the two largest veins in the body. The superior vena cava brings blood from the arms and head to an opening at the top of the heart. The inferior vena cava brings blood from the legs and trunk to an opening in the bottom of the heart (see Fig. 1, p. 2).

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

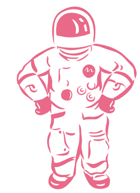
Continued

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. 2, 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 this activity can be found on page 6.

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

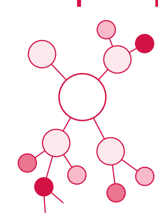
Is designed to carry

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
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).

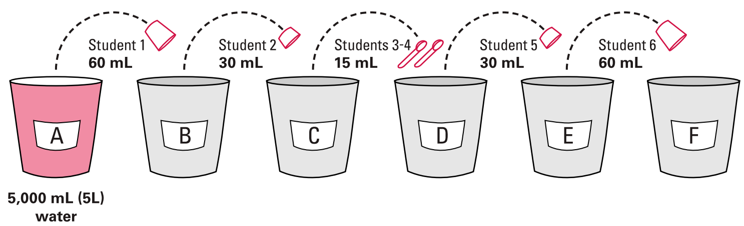
2. Gather six tubs or buckets, labeled A–F, a graduated cylinder, four plastic cups, two tablespoons, paper towels, a roll of masking tape and a pair of scissors.

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.

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

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.

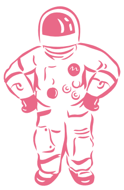
	Water mL
Starting Amount in Tub A	**5,000 mL**
Amount in Tub F at End of Relay	**mL**

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

An Astronaut's Point of View

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.



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…