BioEd℠

THE SCIENCE OF THE HEART AND CIRCULATION

It Begins with the Heart

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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U.S. FOOD AND DRUG ADMINISTRATION
http://www.fda.gov/hearthealth

A UNIQUE PARTNERSHIP: NASA AND THE NSBRI

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 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

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

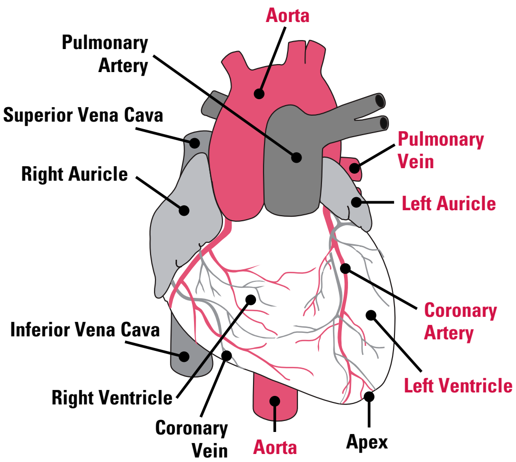
- Communicating
- Using information
- Interpreting information
- Applying knowledge

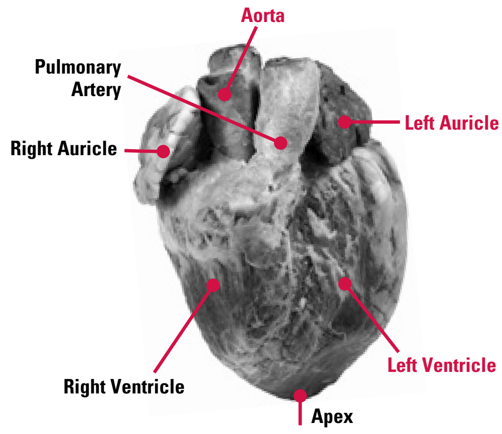
* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

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

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.

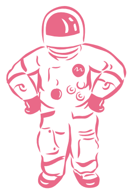
PROCEDURE

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!

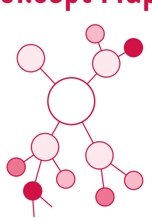
An AstroBlog entry for this activity can be found on page 5.

Anterior and Posterior

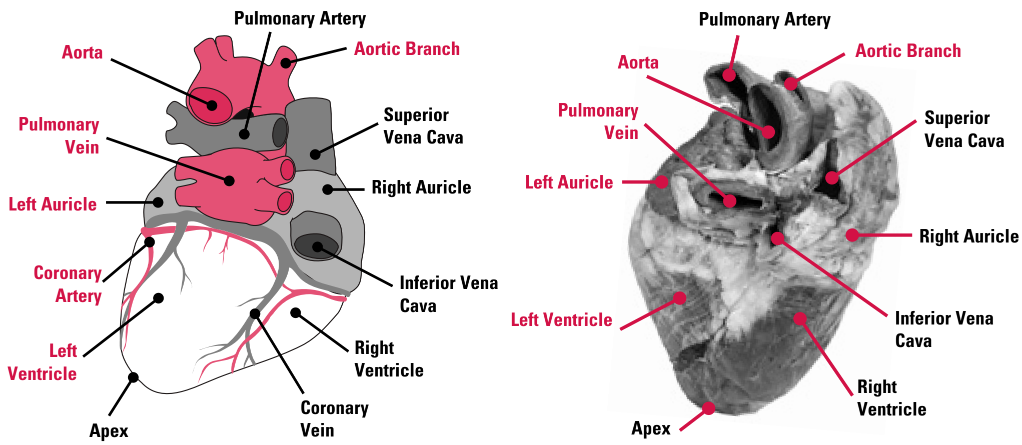
Most heart diagrams illustrate the heart as viewed from the chest. This perspective usually is called anterior, from the Latin *ante*, which means "before." The back view is referred to as posterior, from the Latin *post*, which means "coming after."

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

Update Concept Maps



POSTERIOR VIEW OF THE HEART



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 "Examining the Heart," tell students they will have an opportunity to observe these structures on a real, preserved specimen.

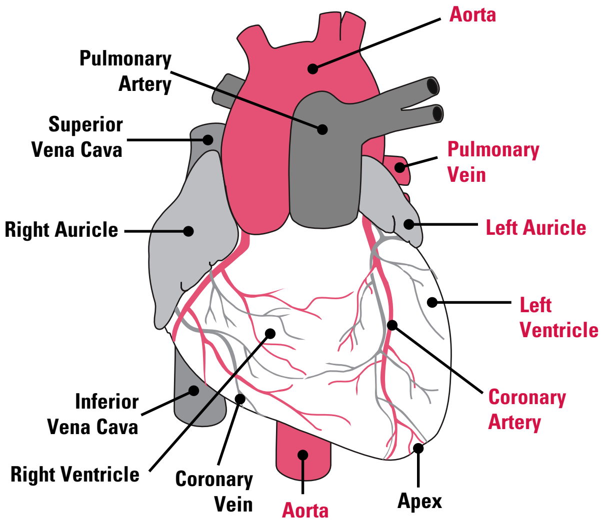
ACTIVITY

The Heart: External

ANTERIOR VIEW OF THE HEART

RIGHT SIDE
Handles oxygen-poor blood.

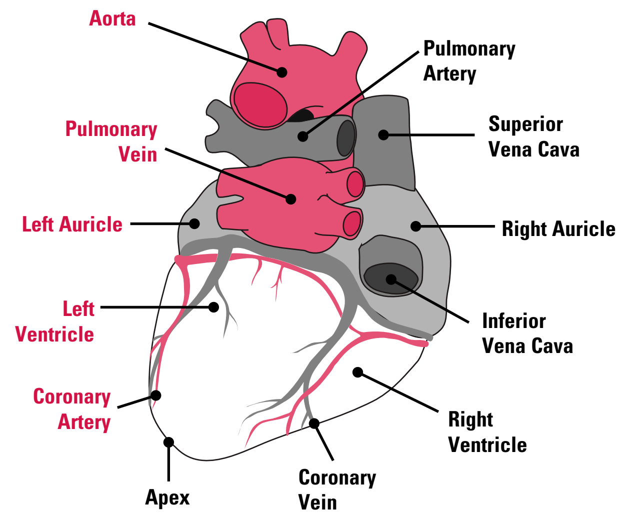
LEFT SIDE
Handles oxygen-rich blood.



POSTERIOR VIEW OF THE HEART

LEFT SIDE
Handles oxygen-rich blood.

RIGHT SIDE
Handles oxygen-poor blood.

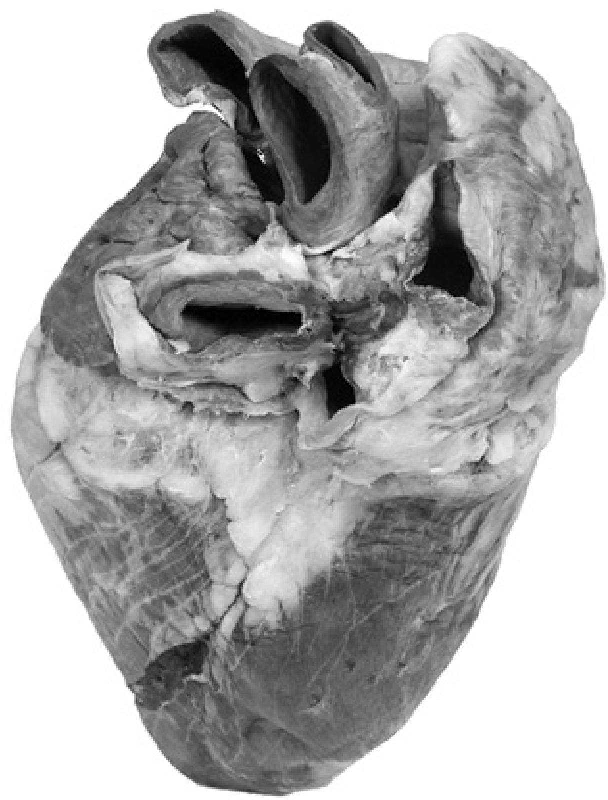


ANTERIOR VIEW OF THE HEART

RIGHT SIDE **LEFT SIDE**

POSTERIOR VIEW OF THE HEART

LEFT SIDE **RIGHT SIDE**

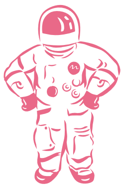


Not shown on photographs of sheep heart: vena cavas, pulmonary vein

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

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!