

THE SCIENCE OF THE

# HEART AND

# CIRCULATION



## The Heart is a Pump

*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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# BioEd<sup>SM</sup>

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<http://www.k8science.org>

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<http://www.sph.uth.tmc.edu/headsup>

UT SOUTHWESTERN MEDICAL CENTER  
AT DALLAS

<http://www.utsouthwestern.edu>

### UNIVERSITY OF MARYLAND MEDICAL CENTER

[www.umm.edu/news/releases/laughter2.htm](http://www.umm.edu/news/releases/laughter2.htm)

### U.S. FOOD AND DRUG ADMINISTRATION

<http://www.fda.gov/hearthealth>

# TEAMING WITH BENEFITS

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

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.



Dr. Jeffrey P. Sutton

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

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

# 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

### 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!

*Continued*



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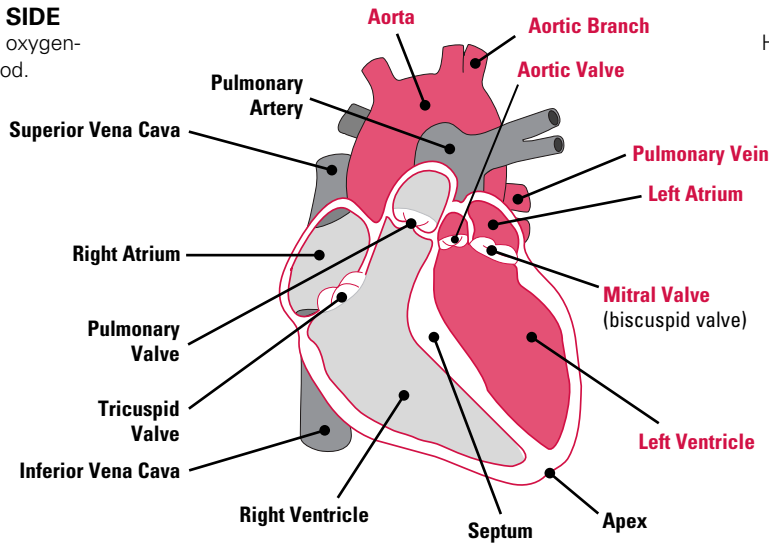
**INTERNAL STRUCTURE OF THE HEART - ANTERIOR VIEW**

**RIGHT SIDE**

Handles oxygen-poor blood.

**LEFT SIDE**

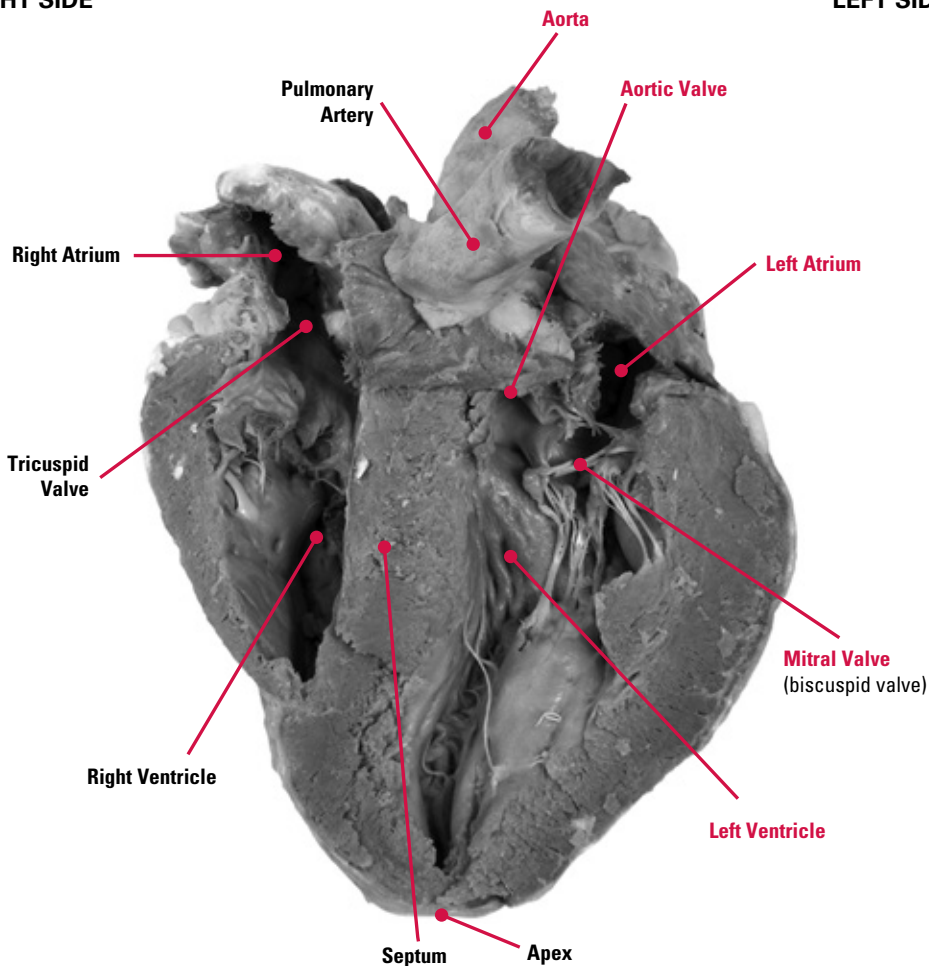
Handles oxygen-rich blood.



**INTERNAL STRUCTURE OF THE HEART - ANTERIOR VIEW**

**RIGHT SIDE**

**LEFT SIDE**



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

M.S. Young from LifeART © 2012 Williams & Wilkins. All Rights Reserved. Sheep heart photo by JP Denk © 2012 Baylor College of Medicine.

**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](http://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](http://www.BioEdOnline.org) or [www.k8science.org](http://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



 **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.

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.

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

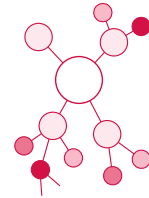
## SETUP & MANAGEMENT

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](http://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



# ACTIVITY 4

# INSIDE THE HEART

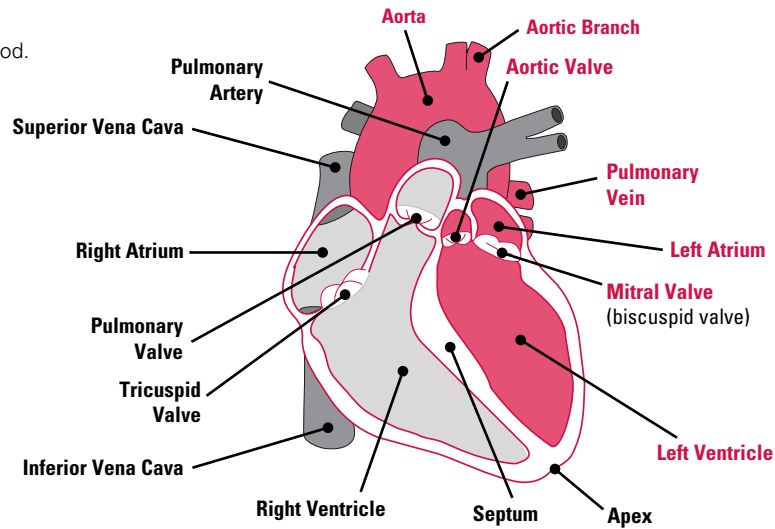
## INTERNAL STRUCTURE OF THE HEART - ANTERIOR VIEW

### RIGHT SIDE

Handles oxygen-poor blood.

### LEFT SIDE

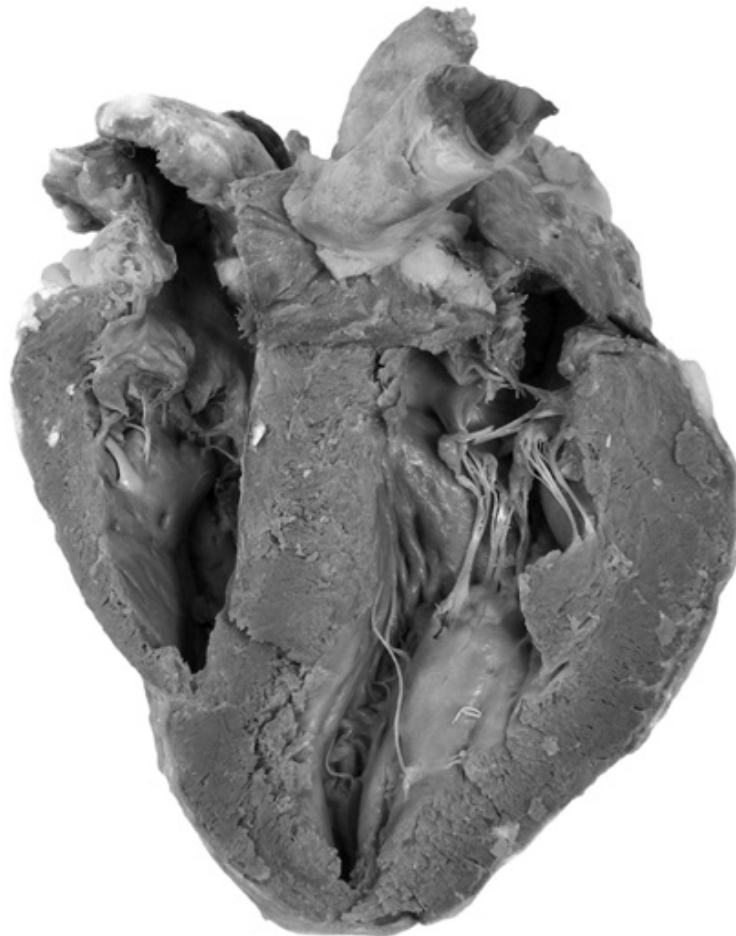
Handles oxygen-rich blood.



## INTERNAL STRUCTURE OF THE HEART - ANTERIOR VIEW

### RIGHT SIDE

### LEFT SIDE



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

M.S. Young from *LifeART* © 2012 Williams & Wilkins. All Rights Reserved. Sheep heart photo by JP Denk © 2012 Baylor College of Medicine.