

THE SCIENCE OF THE
HEART AND
CIRCULATION



Examining the Heart

by

Barbara Z. Tharp, M.S.

Deanne B. Erdmann, M.S.

Marsha L. Matyas, Ph.D.

Ronald L. McNeel, Dr.P.H.

Nancy P. Moreno, Ph.D.

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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Printed in the United States of America

ISBN: 978-1-888997-55-2

BioEdSM

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Cover Illustrations: LifeART © Williams & Wilkins.

Cover Photos: Astronaut courtesy of NASA; boy and girl © Rubberball Production; electronic equipment © Fotosearch.

Authors: 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.

Senior Editor: James P. Denk, M.A.

Designer and Editor: Martha S. Young, B.F.A.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support of Bobby R. Alford, M.D., Jeffrey P. Sutton, M.D., Ph.D., William A. Thomson, Ph.D., Jeanne L. Becker, Ph.D., Marlene Y. MacLeish, Ed.D., Nancy Murray, Dr.Ph., and Kathryn S. Major, B.A. The authors also express their gratitude for the contributions of the following expert reviewers: Lloyd H. Michael, Ph.D., Robert G. Carroll, Ph.D., Michael T. Vu, M.S., and Gregory L. Vogt, Ed.D.

Special thanks also go to the American Physiological Society and to the HEADS UP project of The University of Texas School of Public Health (funded by the Science Education Partnership Award of the National Center for Research Resources, National Institutes of Health).

This work was supported by National Space Biomedical Research Institute through NASA NCC 9-58.

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NATIONAL SPACE BIOMEDICAL RESEARCH INSTITUTE

1 Baylor Plaza, NA-425, Houston, Texas 77030-3498

www.nsbri.org

CENTER FOR EDUCATIONAL OUTREACH

Baylor College of Medicine, 1 Baylor Plaza, BCM411, Houston, Texas 77030

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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)

Space is a challenging environment for the human body. With long-duration missions, the physical and psychological stresses and risks to astro-



Dr. Jeffrey P. Sutton

nauts 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

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

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.

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!

An AstroBlog entry for this activity can be found on page 6.

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.

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 from 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.



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 and sheets from activities “It Begins with the Heart” and “The Heart is a Pump”

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. 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

Continued



using sheep hearts, explain to 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

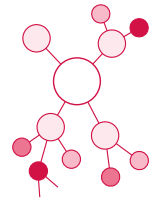
atrium—sometimes present only as a large hole). Cut down the superior vena cava into the wall of the right atrium and continue down to the apex of the heart. Students should be able to see the right atrium and ventricle.

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. 2).
7. Revisit and discuss students' questions about the heart. Have students add new information and observations to their concept maps.

Update Concept Maps



ACTIVITY

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**
 8. **Aorta**
 9. **Superior vena cava (opening)**
 10. **Inferior vena cava (opening)**
 11. **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 4

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 cava 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.

2 Out of the Veins / Into the Vena Cava

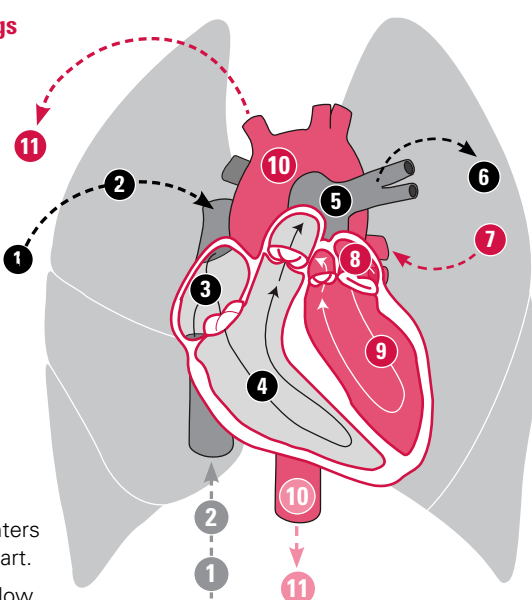
(See both illustrations.)

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.



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 through the **aortic valve** and into the largest artery in the body (the aorta).

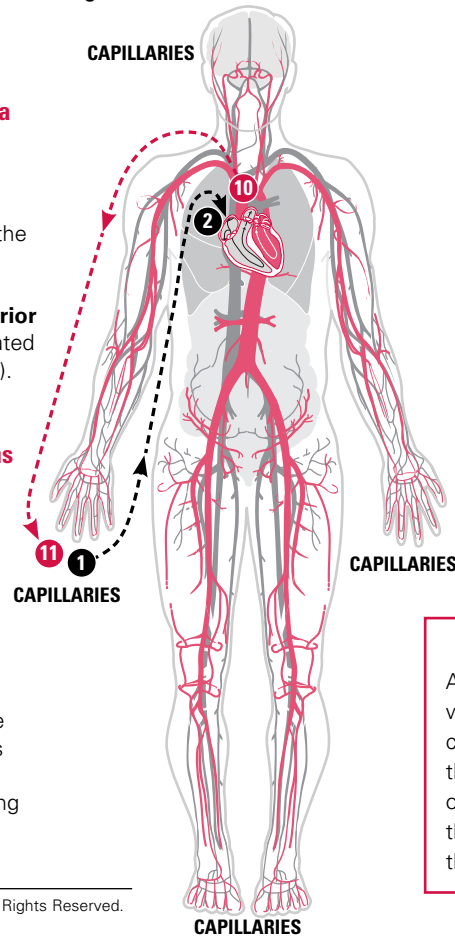
10 Out of the Aorta / Into the Arteries

(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.

AN ASTRONAUT'S POINT OF VIEW

ASTRO-BLOGS

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.



ASTRO-BLOGS

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

