

THE SCIENCE OF THE
HEART AND
CIRCULATION



Activity 1. Pre- And Post-Assessment

by

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RESOURCES

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

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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.

OVERVIEW

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



PRE- AND POST-ASSESSMENT

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

to cooler ones, and vice versa. Circulation in mammals relies on the following components.

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

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

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

PRE-ASSESSMENT TIME

10 minutes for setup; 45 minutes to conduct activity

MATERIALS

Each group will need:

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

Continued



AstroBlogs!

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

Image Citations

Source URLs are available at the front of this guide.

SCIENCE EDUCATION CONTENT STANDARDS* GRADES 5–8

INQUIRY

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

LIFE SCIENCE

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

SCIENCE, HEALTH & MATH SKILLS

- Graphing

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



USING COOPERATIVE GROUPS IN THE CLASSROOM



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

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

a specific role, or chaos may result.

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

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

Principal Investigator

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

Maintenance Director

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

Reporter

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

Materials Manager

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

Pre- and Post-Assessment Answer Key

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

Each student will need:

- Copy of assessment sheet (p. 4)

SETUP & MANAGEMENT

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

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

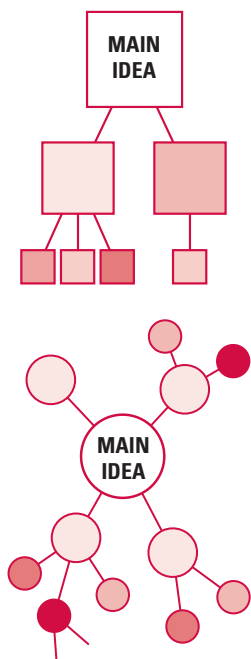
Unless noted, each activity in this guide is designed for students working in groups of four (see “Using Cooperative Groups in the Classroom,” above).

PROCEDURE

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

Concept Maps

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



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

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

or other form of graphic organizer that represents its collective knowledge and questions. Tell students that while they may not have much information now, they will be adding to their concept maps throughout the unit.

You may want to describe concept maps as a way for students to “picture” what they are learning, including relationships among concepts and other pertinent information. Then suggest some ways for groups to begin. Concept maps may be computer generated or built on large poster paper or poster board. Students may prefer to use sticky notes on their concept maps, so that ideas and concepts can be rearranged as students’ knowledge increases. Display the concept maps around the room.

POST-ASSESSMENT

To be conducted at the end of this unit.

TIME

Two 45-minute sessions (2 days)

MATERIALS

Each group will need:

- Group concept maps (ongoing)

Each student will need:

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

PROCEDURE

Session One

1. After completing this unit, have students work in their original groups to review their concept maps. Each group should discuss the additions made to its concept map and decide



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

which findings were most important.

2. Review each group’s concept map for accuracy and help students to correct any misconceptions. Discuss any remaining questions placed on the board (“parking lot”) over the course of the unit. Ask for volunteers or assign student teams to research unanswered questions. Provide time for student groups to change, add to or correct their concept maps.
3. Have each group, or a spokesperson from each group, present the group’s concept map. The presentation should explain the group’s approach to organizing material and concepts that it found particularly interesting or challenging. The presentations may be used as formative or summative assessments.

Session Two

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



ACTIVITY: ASSESSMENT

WHAT DO YOU KNOW?

Name _____

Circle the best response to questions 1 through 15.

- The heart is located
 - on the left side of the chest.
 - on the right side of the chest.
 - near the center of the chest.
 - in the abdomen.
- During exercise, heart rate increases to
 - supply muscles with more oxygen.
 - improve breathing.
 - aid digestion.
 - supply the lungs with more oxygen.
- What is the advantage of having a heart with four chambers?
 - There is extra capacity when needed.
 - Blood can be pumped separately to the lungs and to the rest of the body.
 - There is a chamber to supply blood to each of the four limbs (arms and legs).
 - It is twice as large as a heart with two chambers.
- Once it leaves the heart, blood flows from
 - arteries to capillaries to veins.
 - veins to arteries to capillaries.
 - capillaries to arteries to veins.
 - none of the above.
- Why do some blood vessels have thicker walls than others?
 - To handle blood at a higher pressure.
 - To carry thicker blood.
 - To force blood into the heart.
 - To handle blood at a lower pressure.
- Under normal standing conditions on Earth, blood is pulled toward the
 - arms.
 - heart.
 - legs.
 - head.
- Blood pressure is a measurement of the force of blood against the walls of the
 - heart.
 - arteries.
 - veins.
 - capillaries.
- In outerspace, where gravity is not felt, the heart must work
 - harder than on Earth.
 - not as hard as on Earth.
 - about the same as on Earth.
 - about the same as on the Moon.
- Blood pressure usually is reported as two measurements, such as "120 over 80." What does the second measurement describe?
 - Pressure that is calculated based on a person's age.
 - Pressure while the heart is contracting.
 - Pressure that is typical for a person with hypertension.
 - Pressure while the heart is relaxing.
- Animals without a circulatory system rely on this process to transport nutrients and waste.
 - Transfusion
 - Diffusion
 - Perfusion
 - Respiration
- When astronauts return from space, they often experience temporary changes in the circulatory system, which can cause
 - loss of hearing.
 - heart murmurs.
 - spikes in blood pressure.
 - dizziness.
- Pulse results from
 - a surge of pressure through an artery.
 - filling of a chamber of the heart.
 - valves found in veins.
 - the heart relaxing.
- The role of each atrium is to
 - pump blood out of the heart.
 - receive blood coming into the heart.
 - serve as a doorway between chambers.
 - connect the heart to the lungs.
- What might you do if you wanted to lower your resting heart rate?
 - Take frequent naps.
 - Eat carbohydrates.
 - Get more exercise.
 - Get at least eight hours of sleep every night.
- About how much blood circulates around the body of a typical adult each minute?
 - 100 mL
 - 500 mL
 - 1,000 mL
 - 5,000 mL

CARDIAC RESEARCH

NSBRI Web site: www.nsbri.org

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

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

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

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

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

The base-training session consisted of moderate rowing exercise performed at a level where subjects could still carry on a conversation, but with slight shortness of breath. With threshold training (one

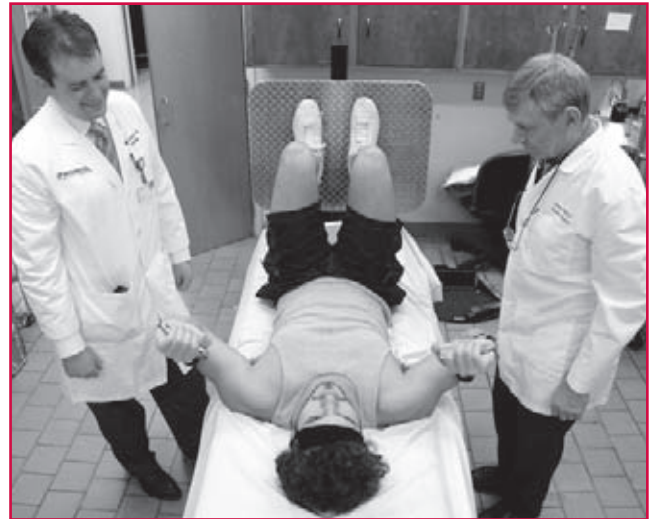


Photo courtesy of UT Southwestern Medical Center at Dallas.

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

to two days per week), subjects worked at their maximum sustainable effort. For example, at this level, professional marathon runners run hard, but do not sprint.

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

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



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

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.

Activity 2



ASTROBLOGS

The human circulatory system is very well adapted to work under normal Earth gravity. In fact, some parts of the circulatory system count on gravity to help move blood through the body. When I’m floating in space, where humans hardly feel the effects of gravity, my circulatory system faces some real challenges. But even in low gravity, my

circulatory system still has to accomplish its transportation function. If it doesn’t, I (and my fellow humans!) would not be able to survive space travel. In this unit, you’ll learn how the circulatory system functions on Earth, and discover some of the challenges we space travelers face when we’re in orbit and when we return home. More on that later...



Activity 3



ASTROBLOGS

The floating food coloring in this activity shows how things float when we are orbiting the Earth. In orbit, we don’t feel the effects of gravity. This condition is called microgravity. You may have experienced microgravity conditions

momentarily on Earth. For example, if you ever felt like you’ve floated out of your seat as you reached the top of a roller coaster, you experienced a moment of what some people call “weightlessness.” Do you think we actually become weightless in a situation like this one, on the roller coaster?



Activity 4



ASTROBLOGS

We use lots of pumps in our spacecraft—pumps for water and fluids that drive different mechanical devices. These pumps have to work in microgravity just as they do on Earth.

Can a pump really work in microgravity? As long as it doesn’t need gravity to operate, yes.

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

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

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



AN ASTRONAUT'S POINT OF VIEW

ASTROBLOGS

Activity 6



ASTROBLOGS

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

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

Due to the downward pull of gravity, our blood tends to pool in the lower half of our bodies. While I float in the space shuttle as it orbits the Earth, the blood in my body is not being pulled by gravity toward my feet. Because, of course, there is very little gravity in space! Therefore, more blood than usual will stay in the upper half of my body, and less will stay in the lower half. After just one

day in space, my legs start to look skinny and my face starts to look puffy. My nose and ears feel stuffy, too... not fun! It's no surprise that while I'm floating in space, my body doesn't have to use its muscles to hold me upright against the Earth's gravity. This makes my heart rather lazy. It slows down and doesn't have to work as hard to pump blood to the different parts of my body. And we all know what happens to muscles when we don't work them, right? They get weaker and smaller.

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

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



Activity 7



ASTROBLOGS

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

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

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



AN ASTRONAUT'S POINT OF VIEW

ASTROBLOGS

Activity 8



ASTROBLOGS

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

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

helps to relieve the stuffy head I get when extra blood collects in the upper part of my body.

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

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



Activity 9



ASTROBLOGS

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

When we return home, we have a bigger problem. As we approach Earth, the pull of gravity increases. This makes the heart work harder to move the blood to all parts of

the body, including the brain. If the heart doesn't respond quickly enough, we can get light headed, and even faint. Not cool, especially when you're flying a spacecraft at several thousand miles per hour!

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

