Autonomic Nervous System Regulation

Lessons and Activities

GRADES 5–12

Section IV
Autonomic Nervous System Regulation

TOPIC

How did the bodies of Neurolab astronauts function in space?

The autonomic nervous system is the control center of automatic body functions.

INTRODUCTION

In the course of daily living, we seldom think about the many processes that are occurring automatically within our bodies. Fortunately, we don’t have to remember to direct our process of digestion; to maintain our body temperature at 37°Celsius; or to control blood pressure and the flow of blood within our circulatory system. All of these processes (and many more) are governed by a component of the nervous system known as the autonomic nervous system—the body’s automatic control center.

One of the many questions that the Neurolab team asked concerns what happens to blood pressure regulation in a weightless environment. The circulatory system functions to distribute blood throughout the body under conditions created by Earth’s gravity. For example, when you stand, the pull of gravity draws blood away from your head and toward your feet. However, you do not faint from lack of oxygen-carrying blood to the brain. Why not? The answer lies in the body’s ability to regulate blood pressure. In spite of standing rapidly, the pressure is adjusted in order to maintain a constant flow of blood to the brain. The level of blood pressure—the pressure within your arteries—is determined by the pumping of blood into the vessels by the heart and the resistance to blood flow by those blood vessels. Your blood flow to the brain does not change because your autonomic nervous system responds to the challenge of gravity on blood flow by modulating the blood pressure.

This section contains three activities that will help you and your students explore the autonomic nervous system’s regulation of blood pressure.

Things to Know

THE HEART AND BLOOD FLOW

The heart and blood vessels called arteries are responsible for carrying oxygen, nutrients, and other substances to all parts of the body. Metabolic waste products are removed from the tissues by the blood and carried to specific organs designed to remove them from the body by capillaries and veins. Blood moves through the heart and body because of a very simple principle: blood (or for that matter, any fluid) flows according to pressure difference—from where pressure is higher to where pressure is lower. The
heart, which acts as a pump, is responsible for creating pressure within the closed confines of the circulatory system.

Blood pressure within a blood vessel is defined as the force exerted by the blood against the walls of the vessels. Blood pressure within the arteries rises and falls with the cycles of the heart, or stages by which blood is pumped through the four chambers of the heart and out to the circulation. Blood passes through the heart in a fixed sequence. The heart has four valves—the tricuspid, pulmonary, mitral, and aortic—which regulate blood flow between chambers and between the heart, the pulmonary vessels, and the systemic vessels (Figure 72). First, blood enters the right atrium from very large veins (the superior and inferior vena cavae). The right atrium squeezes, the tricuspid valve opens, and blood flows to the right ventricle. Next, the right ventricle squeezes, the tricuspid valve closes, the pulmonary valve opens, and blood is injected into the pulmonary artery. Blood then travels through the lungs, where it takes on oxygen and discharges carbon dioxide, and enters the left atrium through the pulmonary veins. The left atrium squeezes, the mitral valve opens, and blood flows into the left ventricle. Finally, the very muscular left ventricle squeezes, the mitral valve closes, the aortic valve opens, and blood is ejected into the aorta, the largest artery of the body. From there, the oxygen-rich blood is carried to other parts of the body by a branching system of vessels.

The walls of the blood vessels contain concentric layers of smooth muscle. These muscles and the muscles of the heart are controlled by autonomic nervous system nerves that regulate blood vessel size. A decrease in the diameters of the blood vessels makes it more difficult for blood to flow through the vessels. When this decrease in size occurs, greater pressure is required to force the blood through the vessels. This increased pressure is exerted by the heart as it forces blood into the aorta. In contrast, when the smooth muscles of the blood vessels relax, increasing the diameters of the vessels, resistance to blood flow is reduced and less blood pressure is required to maintain a given flow rate. Not only does the autonomic nervous system control the diameter of blood vessels, it also modulates the rate at which the heart pumps—either by speeding it up, or slowing it down. Through these functions, the autonomic nervous system regulates blood pressure.
REGULATION OF BLOOD PRESSURE BY THE NERVOUS SYSTEM

The challenge of maintaining constant blood flow to the brain and other tissues while subjected to the effects of Earth’s gravity is met by the regulation of blood pressure by the autonomic nervous system. The brain receives continuous information regarding the pressure exerted by the blood on the wall of the larger arteries. This is accomplished by pressure sensors (baroreceptors) strategically located in the wall of these vessels, especially one of the major arteries to the brain (internal carotid artery). These sensors transmit pressure information through nerves to the brainstem where the autonomic nervous system (Figure 73) monitors this information and reflexively makes the appropriate adjustment of the blood pressure. For example, if the blood pressure momentarily falls below a given set point, the autonomic nervous system increases the resistance to blood flow by reducing the diameter of various arteries within the body and increases the rate and force of contraction of the heart, which together result in an appropriate increase in blood pressure.

![Figure 73 Diagram of the Autonomic Nervous System.](image-url)
The Neurolab Autonomic Team investigated the adaptive changes in the regulation of blood pressure in the microgravity environment of space. They were particularly interested in understanding more about why some astronauts faint from low blood pressure when they try to stand upon their return to Earth from space missions. Focus has been directed on possible changes in the sensitivity of the pressure sensors and possible changes in the autonomic nervous system in its ability to effectively coordinate changes in arterial resistance and heart rate in the appropriate modulation of blood pressure, after exposure to microgravity for extended periods.

LEARNING ACTIVITY I:
Measuring Blood Pressure in Space

OVERVIEW
Students will learn how to measure heart rate and blood pressure accurately and to obtain consistent measurements during repeated tests.

SCIENCE & MATHEMATICS SKILLS
Observing, communicating, collecting quantitative data, creating charts and graphs, drawing conclusions

PREPARATION TIME
10 minutes

CLASS TIME
25 minutes

MATERIALS
Each group of students will need:
- Watch or access to clock with a second hand
- Stethoscope*
- Sphygmomanometer*
- Alcohol wipes to clean stethoscope ear plugs after each use
- Copy of student activity sheets: “Determining Pulse Rate Manually,” “Determining Heart Rate with a Stethoscope,” and “Measuring Blood Pressure with a Sphygmomanometer.”

MAJOR CONCEPTS
- The heart supplies the energy to move blood through the system.
- Blood moves from where pressure is higher to where pressure is lower.
- Blood pressure is recorded as systolic (highest pressure in the pulse) and diastolic (lowest pressure in the pulse).

*These may be obtained from the school nurse.
BACKGROUND

This lesson introduces students to two tools—the sphygmomanometer and the stethoscope—that are used to measure blood pressure and heart rate and engages them in measuring blood pressure and heart rate changes that occur when the body assumes different postures—lying, sitting, and standing. The Neurolab Autonomic Team was interested in obtaining information on the astronauts’ blood pressures in the microgravity environment. They used more sophisticated instruments to continuously measure blood pressure and heart rate. Blood pressure is generally obtained by using a sphygmomanometer and a stethoscope. Heart rate can be obtained by using the stethoscope (Figure 74) to listen to the rate at which the heart beats or by palpating arteries that are close to the surface of the body, and counting the pulse beats.

During this activity, students will hear the sounds of the blood as it is pumped into the aorta to identify sounds caused by blood turbulence as a result of two sets of valves within the heart that close at slightly different times. The first and second heart sounds, which occur in close sequence, represent the closing of different valves. When using a stethoscope, the doctor will hear these valves’ closure as “lup dup, lup dup, lup dup.” Heart rate is determined by counting either the “lups” or “dups.” Usually it is easier to count the latter during the relatively long pause. (This is the diastole or resting period that occurs between the second and first heart sounds.)

Students also will learn to find their pulse points and to take (or count) their pulse beats. Palpating pulse occurs as a result of the expansion of an artery from the blood pushed out by the contraction of the left ventricle. Expansion of an artery, or pulse, can be felt in the neck, at the front of the elbow, behind the knee, and in the foot. Most physicians and nurses palpate the radial artery pulse. It can be felt in the forearm, on the thumb side, where the forearm meets the palm.

Heart rate, or the speed at which the heart is beating, can be measured in several ways. The simplest method is to record the electrical activity of the heart with an electrocardiogram. However, counting heartbeats heard through a stethoscope or pulse beats felt in the wrist or neck for a period of time are other ways to determine heart rate.
Determining Pulse Rate Manually

PROCEDURE

**Note to Teacher:** You may want to invite a nurse to assist younger students in identifying heart rate by counting the number of pulse beats. Divide the class into teams of three. One student will be the subject, one will count the pulse beats, and one will record the results.

1. Have the student counting the pulse beats place the tip of his/her index and middle fingers on the radius (the bone on the thumb side of the human forearm), and then gradually move the fingertips toward the center of the subject’s wrist (Figure 75).

2. Tell the student not to begin counting the pulse beats until the subject is stationary. The student can begin counting the subject’s pulse beats when the second hand of the watch is on 12. (Have the student do this for 30 seconds and he/she should record his/her answers.)

3. Have the student count the number of pulse beats felt during 30 seconds and record on chart (Figure 76).

4. Each pair of students should take at least three measurements of each other’s pulse rate. Have students record the results. You also may want each student to calculate his/her average pulse rate. Record the average pulse rate of all the students on a class chart on the board.

5. Have the student repeat procedures three and four with the same subject and record the number of pulse beats in 30 seconds.

6. Ask the students whether, based on the results shown on their individual charts, the subjects of each of the tests were in a steady state. Why or why not?

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**Pulse Rate Data**

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<tr>
<th>Student Name</th>
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**Figure 76** Chart for recording pulse rate.

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**Figure 75** Photograph of a manual pulse rate count.
STUDENT ACTIVITY SHEET
Determining Pulse Rate Manually

Name ________________________________________________ Date __________________

OBJECTIVE To learn how to measure heart rate accurately by counting pulses and to obtain consistent measurements during repeated tests.

MATERIALS • Watch or access to clock with second hand.
• Note pad
• Pen or pencil

DIRECTIONS This activity requires a team of three. One student will be the subject. One student will count pulses and one will record the results.

PROCEDURE

1. The student being measured should sit comfortably in a chair with feet flat on the floor.

2. The student selected to take the pulse should place the tip of your index and middle fingers on the radius (the bone on the thumb side of the subject’s forearm) and then gradually move the fingertips toward the center of the subject’s wrist (Figure 77).

3. Do not begin counting the pulse beats until the subject is stationary. You can begin counting the subject’s pulse beats when the second hand of the watch is on 12. (Do this for 30 seconds.)

4. Count the number of pulses felt during the 30 seconds and multiply the result by two to express the pulse rate as heart beats/minute. Record your answers (Figure 78).

5. Take at least three measurements of each other’s pulses. Record the results.

6. Repeat procedures three and four with the same subject and record the number of beats.

Pulse Rate Data

<table>
<thead>
<tr>
<th>Student Name</th>
<th>Pulse Rate</th>
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Figure 77 Photograph of a manual pulse rate count.

Figure 78 Chart for recording pulse rate.
Listening to Heart Sounds  
with a Stethoscope

**PROCEDURE**

*Note to Teacher:* This experiment should be done in pairs of students of the same gender.

1. The first task is for students to learn how to use a stethoscope. They should take care to make accurate measurements. Students may work in pairs or groups of four, depending on materials available.

2. Have one student within each group place the stethoscope’s earplugs in his/her ears. (As the stethoscope hangs down from the student’s ears, the metal tubes should be held slightly in front of the student.)

3. Direct each student with a stethoscope to apply the bell (stethoscopes usually have two heads—a bell and a diaphragm (Figure 79) very lightly to the chest of another student (preferably male, so that the heart sounds will be louder). The diaphragm, applied firmly, is better for high-pitched sounds. The stethoscope should be placed to the left of the sternum (or breastbone) of the student who is being tested (Figure 74).

4. As the student listens, he/she should move the stethoscope around on the subject’s chest, to the left of the sternum. Have students notice the loudness of the sounds. In general, sounds will be louder when the stethoscope is close to the structure generating the sounds (the heart, in this case) than when it is far away. Make sure that students are able to identify the two sounds (“lup dup”) typically made by the heart.

5. Have the students take turns with the stethoscope, so that all have a chance to hear and identify heart sounds.
Determining Heart Rate with a Stethoscope

PROCEDURE

*Note to Teacher:* This experiment requires at least three students. The experiment should be done by two students of the same gender. Another student should be the recorder.

1. Have the student being measured sit comfortably in a chair with feet flat on the floor.

2. Have one student place the stethoscope's earplugs in his/her ears. (As the stethoscope hangs down, the metal tube parts should be directed slightly ahead).

3. Instruct the student to apply the bell of the stethoscope very lightly to the subject’s chest on the left side of the breastbone.

4. Tell the student to listen to the subject’s heart rates by moving the stethoscope around the subject’s chest. Inform the student that sounds will be louder as you get closer to the heart valves. Have one student record the number of beats in 30 seconds on the chart on the Student Activity Sheet (Figure 80).

5. The student should take at least three measurements.

6. Have the students select another subject of the same gender and repeat procedures two and three.

7. To convert heart rate to beats/minute, students should multiply values in Figure 78 by two.

Individual Heart Rate Data

<table>
<thead>
<tr>
<th>Student Name</th>
<th>Heart Rate Beats Per 30 Secs.</th>
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</thead>
<tbody>
<tr>
<td>Student 1.</td>
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<td></td>
<td></td>
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<tr>
<td>Student 2.</td>
<td></td>
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</tbody>
</table>

Figure 80 Chart for recording heart rate.
STUDENT ACTIVITY SHEET
Determining Heart Rate with a Stethoscope

Name ______________________________ Date __________________

OBJECTIVE
To learn how to measure heart rate with a stethoscope.

MATERIALS
• Watch or access to a clock with a second hand
• Stethoscope
• Pen or pencil
• Note pad

DIRECTIONS
Do the following procedures and record your data on the chart.

PROCEDURE
1. One person from your group should place the stethoscope's (Figure 81) earplugs in his/her ears. (As the stethoscope hangs down, the metal tube parts should be directed slightly ahead.)

2. This person should then apply the bell very lightly to the chest on the left side of the breastbone of a classmate who is the subject. (Students of the same gender should perform this activity on one another.)

3. The person applying the bell should listen to the classmate’s heart rates by moving the stethoscope around the chest. Sounds will be louder when he/she gets closer to the heart’s valves.

4. Listen to the number of beats while watching the clock.

5. Record the number of beats heard per 30 seconds on the chart (Figure 82).

6. Take at least three measurements.

7. Select another student (of the same gender) in the group and repeat procedures two and three.

Individual Heart Rate Data

<table>
<thead>
<tr>
<th>Student Name</th>
<th>Heart Rate Beats Per 30 Sec.</th>
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<tbody>
<tr>
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<td>Student 2.</td>
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Figure 81 Diagram of stethoscope.

Figure 82 Chart for recording heart rate.
Measuring Blood Pressure with a Sphygmomanometer

PROCEDURE

1. Introduce the students to the sphygmomanometer. Most of them will have had their blood pressure taken at some time at a doctor’s office. Ask for a show of hands of students who have had their blood pressure measured.

2. With a student, demonstrate how to use the stethoscope and sphygmomanometer together to measure blood pressure.

3. Have the person being measured sit comfortably in a chair with feet flat on the floor.

4. Be sure that the person has not over-exerted himself/herself during the last thirty minutes, e.g., exercising.

5. Attach blood pressure cuff over the **brachial artery**. This artery is located inside the arm approximately one inch above the bend of the arm (Figure 83).

6. Place the earplugs of the stethoscope in the operator’s ears.

7. Pump the blood pressure cuff up to approximately 200 millimeters of mercury.

8. Place the diaphragm of the stethoscope just above bend of arm. Slowly release cuff at two millimeters of mercury per second.

9. Listen carefully for the first two consecutive beats. This is your ***systolic*** blood pressure reading.

10. Continue to listen carefully until you hear the last of the two consecutive beats. This is your ***diastolic*** blood pressure reading.

11. Release the pressure from the cuff.

12. Record your readings (Figure 85).

13. Remove the cuff.
STUDENT ACTIVITY SHEET
Measuring Blood Pressure with a Sphygmomanometer

Name __________________________ Date __________________

OBJECTIVE
To learn how to measure blood pressure with a sphygmomanometer (an instrument for measuring arterial blood pressure consisting of an inflatable blood pressure cuff, inflating bulb, a gauge showing the blood pressure, and a stethoscope).

MATERIALS
• Watch or access to clock with a second hand
• Stethoscope
• Sphygmomanometer
• Alcohol wipes to clean stethoscope ear plugs after each use
• Pen or pencil
• Note pad

DIRECTIONS
Do the following procedures and record your data in the table.

PROCEDURE
1. Have the person being measured sit comfortably in a chair with feet flat on the floor.

2. Be sure that the person has not over-exerted himself/herself during the last thirty minutes, such as by exercising.

3. Attach blood pressure cuff over the brachial artery. This artery is located inside the arm (Figure 84).

4. The operator should place the earplugs of the stethoscope in his/her ears; place diaphragm of stethoscope just above bend of subject’s elbow.

5. Use the inflating bulb to pump the blood pressure cuff up to approximately 200 millimeters of mercury.

6. Slowly release cuff at two millimeters of mercury per second.
7. Listen carefully for the first two consecutive beats. This is your **systolic** blood pressure reading.

8. Continue to listen carefully until you hear the last of the two consecutive beats. This is your **diastolic** blood pressure reading.

9. Release the pressure from the cuff.

10. Remove the cuff.

11. Record your readings (Figure 85).

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**Blood Pressure Data**

<table>
<thead>
<tr>
<th>Student Name</th>
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<tbody>
<tr>
<td></td>
<td>Diastolic</td>
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<tr>
<td></td>
<td>Systolic</td>
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Figure 85 Chart for recording blood pressure.
SIGNIFICANCE OF THE TWO MEASURES TAKEN

- Blood pressure measures utilizing the stethoscope and sphygmomanometer cuff will yield the systolic and diastolic pressures.

- Heart rate can be monitored with a stethoscope placed near the valves of the heart.

- Taking pulse palpitations by placing the tip of the index and middle fingers on the radius will also yield heart rate.

\[
\text{Pulse} = \text{heart rate} \\
\text{Sphygmomanometer and stethoscope} = \text{diastolic and systolic pressures}
\]

Evaluation

At this point, your students should understand two basic tools necessary for studying the heart and circulatory system, the stethoscope and sphygmomanometer. They should also know how to measure and record individual heart rates.

REVIEW QUESTIONS

1. What different methods can you use to measure heart rate?
   The simplest way to measure heart rate is to count the pulse beats. Pulses can be found wherever an artery is accessible. Most people use the radial pulse, located at the wrist. Heart rate can also be measured from beat-by-beat blood pressure recordings or from the electrocardiogram.

2. What is responsible for the movement we call pulse?
   The pulse occurs when a sudden rush of blood stretches the artery. Arteries stretch as the left ventricle ejects part (over 55%) of its volume into the aorta—the largest artery.

3. Why do we take measurements of both systolic and diastolic to determine blood pressure?
   To determine the maximum and minimum pressures in the circulatory system.

THINKING CRITICALLY

1. Using the class data, have students determine if the heart rate and blood pressure averages they observed from their classmates are high, low or average for their age group. Ask students to identify and find resources necessary to make this determination.

SKILL BUILDING

1. Have students use resources at the library or on the Internet to investigate lifestyle habits that may cause high blood pressure (hypertension).

2. Based on their research, have students design a lifestyle for someone who may suffer from hypertension.
CONCLUSION

Explain that the astronauts on the Neurolab mission used different methods to study blood pressure. They used a small cuff device on the finger (photoplethysmograph) that actually measures the amount of light passing through the tissues of the fingers at different times (Figure 86). As the heart beats, light transmission through the finger varies with the amount of blood in the finger. The pressure in the cuff is regulated continuously to maintain light transmission in the finger at a constant level. Pressure in the cuff is measured by an electronic pressure gauge, and this measurement is used as an accurate index of actual blood pressure. You may want to make an overhead transparency of the photograph below to show to students.

When you believe your students are comfortable with, and have mastered measuring blood pressure, the next activity can be assigned as an extension to the previous one. It will allow students to see how the body adapts to changes of posture and the regulation of blood pressure.

![Diagram of a Photoplethysmograph around a finger.](image-url)
# LEARNING ACTIVITY II:
Changing Body Positions:
How Does the Circulatory System Adjust?

## OVERVIEW
Students will make and compare measurements of heart rate and blood pressure from three body positions: sitting, standing, and lying.

## SCIENCE & MATHEMATICS SKILLS
Observing, communicating, collecting quantitative data, recording data in tables and graphs, interpreting data, drawing conclusions.

## PREPARATION TIME
None

## CLASS
30 minutes

## MATERIALS
Each group of students will need:
- Watch or clock with a second hand
- Stethoscope*
- Sphygmomanometer* (an instrument for measuring arterial blood pressure consisting of an inflatable blood pressure cuff, inflating bulb and a gauge showing the blood pressure)
- Alcohol wipes to clean stethoscope ear plugs after each use
- Copies of Activity Sheet: “Changing Body Positions”
- Table or bench long enough for a student to lie down

*These may be obtained from the school nurse.

## BACKGROUND
This activity goes to the “heart” of one of the body’s fundamental mechanisms: regulation of blood pressure. When you stand, blood tends to collect in the lowest parts of the body. Such translocation of blood could present problems if the body did not have a method to counteract it. For example, if you do not have adequate blood flow (and thus, oxygen) to

## MAJOR CONCEPTS
- When a person is standing on Earth, his/her brain is above the heart and gravity is pulling fluids toward the Earth.
- The brain must have adequate blood flow.
- On Earth, blood flows to the brain because the pressure within the system is high enough to force blood upward against the pull of gravity.
the brain, you will faint. Fortunately, blood within the circulatory system flows under pressure that is high enough to counteract the force of gravity and allows blood to reach your brain even when you are standing.

This activity will demonstrate one way in which the body responds to changes in posture.

While conducting the activity, students will measure heart rate and blood pressure in three different body positions—(1) sitting, (2) standing, and (3) lying (Figure 87). Since students will be spending a short period of time in each position, they probably will find that heart rate and blood pressure have not reached a steady state when they make their measurements. Students should document these changes during the time spent in each of the positions. Measurements made every two minutes will allow students to observe some of the effects of changes of body positions.

As discussed in the previous lessons and activities, scientists on the Autonomic Team used tools that allow for much more precise measurements of blood pressure and heart rate. After this activity, students should have a very good idea about how the body adapts to changes of posture, based on their own experimental data.

PROCEDURE

1. Have students conduct this activity in groups of four. One student in each group should serve as the subject, one should measure heart rate (measured as number of pulse beats felt in one minute), one should measure the blood pressure from the other arm, and the other should record measurements as they are called out (Figure 88).

2. Explain to the groups that they will be investigating changes in heart rate and blood pressure that occur when the body moves from sitting to standing to lying. Ask the students to think about and predict changes that might happen. Explain that measurements for each position will take seven minutes with a maximum of 30 seconds allowed for subject to change positions.
3. Pulse beats should be counted for 30 seconds and blood pressure should be measured within one minute. Both of these should be measured simultaneously within one minute. For each position, three sets of measurements are made at two-minute intervals. Students making measurements should call out their results to the group recorder, who should write the values on the data sheet.

4. Have the groups conduct their experiments as follows:
   - Subject sits quietly for three minutes.
   - Students should take measurements of heart rate and blood pressure simultaneously for seven minutes.
   - After seven minutes, the subject should stand. New measurements should begin as they did in the previous trial.
   - After seven minutes, the subject should lie on table. Once again, measurements should begin as they did in the previous trials.

5. After all the data have been collected, the students should convert the 30 second counts of heartbeats into heartbeats per minute by multiplying each of the values by two. Have students create two charts: one of heart rate vs. time and another of blood pressure vs. time.

6. Ask the class to compare the two charts of heart rate and blood pressure. How are the two charts similar? How are they different? What do the results tell us about how the circulatory system adapts to posture changes? Have students think about what might happen to this activity were it conducted under conditions of microgravity.

**Evaluation**

**REVIEW QUESTIONS**

1. How does blood flow to the brain?
   Blood flows to the brain (and everywhere else in the body) on the basis of pressure. For blood to flow to the brain, the pressure must be lower in the brain than in the arteries that carry blood to the brain.

2. Where does the blood go when the body is in a standing position?
   In a sitting position?
Blood goes to the lowest part of the body, according to the degree of gravitational pull. Tall people, who have much higher columns of blood than short people, are more prone to experience reductions of blood pressure when they stand. Less blood is pooled in the sitting position because the height of the column of blood is less than in the standing position.

3. What happens to blood flow, blood pressure, and heart rate when the body moves from lying to sitting?
The heart rate begins to speed; this occurs very rapidly, often within one second. Speeding of the heart helps to prevent a major fall in blood pressure. Also, the vessels constrict to increase resistance to flow and keep blood pressure up.

THINKинг CRITICALLY

1. Challenge your students to think about how the circulatory system might respond to changes in a microgravity environment. Which aspects of the system might stay the same? Which might be different?
Absence of gravity causes major changes in the circulation. The most important of these is that there is no gravitational pull of blood toward the feet when a person stands. Pressure in the feet is the same in lying and standing positions. Therefore, blood redistributes from the lower body to the upper body. The autonomic nervous system does not have to adjust to body positions as on Earth. This is not to say that there is no autonomic nervous system control of the circulation in space.

2. Ask students to think about why people feel faint or dizzy (Figure 89A) when they stand up very rapidly. Or conversely, why are people instructed to put their head between their knees (Figure 89B) when they feel faint?
Rapid standing causes a rapid fall of blood pressure. The fall of pressure reduces blood flow to the brain momentarily, until the regulatory mechanisms in the brain and circulation can kick in and restore pressure to normal levels. By putting one’s head between the knees, the head becomes dependent, pressure in the arteries of the brain increases, and blood flow to the brain increases.
SKILL BUILDING

1. After each group has graphed the sets of measurements they obtained from the experiment, have them produce a written interpretation of the data. Let each group share its write-ups with the class.

APPLICATION

Your students should now have a better understanding of how heart rate and blood pressure change in response to body movement. The Autonomic Team studied similar questions under conditions of microgravity. They used different methods, however, to gauge the postural responses in space. One of the main issues is that, although astronauts can stand in space, they (and their circulatory systems) do not experience the pull of gravity as they do on Earth. To simulate the gravity environment, the astronauts had the lower halves of their bodies enclosed in a chamber that was sealed around their waists. Suction was applied to the chamber so that a reduced pressure drew blood to the lower body. The actual chamber that was used is shown in Figure 90.

Figure 90 Photo of a pressure chamber.
STUDENT ACTIVITY SHEET
Changing Body Positions

Name ________________________________________________ Date __________________

OBJECTIVE
To measure the changes of heart rate and blood pressure with changing body positions.

MATERIALS
• A watch or clock with a second hand
• Stethoscope
• Alcohol wipes
• Pen or pencil
• Note pad
• Sphygmomanometer

DIRECTIONS
Follow the procedures and record data on the charts (Figures 91 and 92).

PROCEDURE
1. Four students are required to do this activity. (One is the subject, one counts pulses, one measures blood pressure, and one records results. Select the role each person in your group will perform.

2. Have one student from your group sit quietly in a chair with feet flat on the floor.

3. One student should count the number of pulse beats for 30 seconds, then multiply that number by two and call out the number to the recorder. (Heart rate is expressed as pulse beats per minute.)

4. Simultaneously, another student should measure blood pressure within one minute and call out the number to the recorder.

5. Take three separate measurements at two minute intervals.

6. The recorder should write the numbers called out on the chart.

7. Repeat procedures “2” – “6” with the student subject standing.

8. Repeat procedures “2” – “6” with student subject lying.

9. In order to calculate the heart rate, multiply the number of pulse beats per 30 seconds by two.

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<table>
<thead>
<tr>
<th>Minutes</th>
<th>Sitting</th>
<th>Standing</th>
<th>Lying</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diastolic</td>
<td>Systolic</td>
<td>Diastolic</td>
</tr>
<tr>
<td>Minute 1</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minute 2</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minute 3</td>
<td>30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 91 Chart for recording heart rate.

<table>
<thead>
<tr>
<th>Minutes</th>
<th>Sitting</th>
<th>Standing</th>
<th>Lying</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diastolic</td>
<td>Systolic</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 92 Chart for recording blood pressure.
LEARNING ACTIVITY III:
Baroreceptor Reflex Role Play

OVERVIEW
In this activity, the students will learn the importance of maintaining adequate arterial blood pressure through a role playing exercise which demonstrates the baroreceptor reflex (BR) arc—a human model of the BR loop. The BR arc will demonstrate how the brain processes information and sends out signals to the heart and arteries.

SCIENCE & MATHEMATICS SKILLS
Prediction, observing, collecting quantitative data and interpreting data

PREPARATION TIME
10 minutes

CLASS TIME
45 minutes

MATERIALS
• Index cards to be used as cue cards indicating students’ roles (nine students per group)

BACKGROUND
Baroreceptors are specialized neural receptors that sense changes in blood pressure. The baroreceptor reflex relies on sensing pressure changes in the aorta and carotid artery. If stimulation of the baroreceptors is altered, such as in a microgravity environment, a change would occur in the firing frequency of the nerves connected to the baroreceptors that send signals to the brain.

The baroreceptor reflex circuit includes both sympathetic and parasympathetic nerves to the arteries and heart in order to maintain proper arterial blood pressure. The baroreceptor reflex can either increase or decrease arterial blood pressure in order to return it to normal levels. If the arterial blood pressure increases, the firing rate of the baroreceptors increases, sending a greater frequency of impulses through the afferent (inflowing, i.e., towards the brain) baroreceptor nerves. The reflex in this instance will cause activation of the vagus nerve, decreasing the rate of heart contraction to reduce arterial pressure. If the pressure falls, decreased

MAJOR CONCEPTS
• If development in microgravity alters the development of the baroreceptor afferent neurons, the circuit may not function normally on Earth.
• The functions of each part of the baroreceptor reflex are required to properly maintain arterial blood pressure.
firing and frequency of impulse result. In turn, the sympathetic nerves are activated, thereby causing the heart to contract more rapidly and of blood vessels to constrict, which will increase arterial blood pressure.

Through this reflex circuit, arterial blood pressure is maintained. It is crucial to maintain blood pressure within this specified range because the organ functions of the body depend upon an adequate supply of blood at a relatively constant pressure.

**PROCEDURE**

This activity requires nine students per group.

1. Students should be arranged in groups of nine to represent the parts of the baroreceptor reflex loop according to the diagram in Figure 94.

2. Explain the role of each student so that the students will have a clear understanding of their roles before the activity begins (Figure 93).

3. Tell the student playing the arterial pressure (student #1) to squeeze the arm of the baroreceptor (student #2) firmly to represent increased pressure. In turn, instruct the baroreceptor (student #2) to use a number system to signal increased or decreased pressure to the baroreceptor afferent (student #3). The number system could be one to signal low pressure, two to signal normal pressure and three to signal increased or high pressure.

<table>
<thead>
<tr>
<th>Position</th>
<th>Role</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Arterial pressure</td>
<td>Squeeze the arm of student #2</td>
</tr>
<tr>
<td>2</td>
<td>Baroreceptor</td>
<td>Assign the numeric value according to pressure to student #3</td>
</tr>
<tr>
<td>3</td>
<td>Baroreceptor afferent</td>
<td>Relay the numeric value to student #4 or #5</td>
</tr>
<tr>
<td>4</td>
<td>Vasomotor center</td>
<td>If the number is low (low pressure), student #4 becomes activated</td>
</tr>
<tr>
<td>5</td>
<td>Vagal center</td>
<td>If the number is high (high pressure), student #5 becomes activated</td>
</tr>
<tr>
<td>6</td>
<td>Vagus nerve</td>
<td>Receive information from student #5 and tell student #8 (heart) to decrease rate of pumping</td>
</tr>
<tr>
<td>7</td>
<td>Sympathetic nerves</td>
<td>Receive information from student #4 and tell student #8 (heart) to increase rate of pumping and tell student #9 (arteries) to constrict to increase pressure</td>
</tr>
<tr>
<td>8</td>
<td>Heart</td>
<td>Tell student #1 what to do</td>
</tr>
<tr>
<td>9</td>
<td>Arteries</td>
<td>Tell student #1 what to do, then student #1 tell student #2 what to do</td>
</tr>
</tbody>
</table>

Figure 93 Chart of students’ positions, roles and tasks representing the baroreceptor reflex loop.
4. Direct the baroreceptor (student #2) to report these numbers to the two areas of the medulla—the vasomotor center (student #4) and vagal center (student #5).

EXPLANATION

Note to the teacher: At this point, use procedures 5 through 8 to help the students understand how the baroreceptor reflex loop works.

5. Once the baroreceptor signals high pressure, the **vagal** center will tell the vagus nerve to go into action.

6. The vagus nerve goes to the heart and tells it to stop pumping quite so hard and fast. The heart will tell arterial pressure to relax the grip on the baroreceptor’s arm to reduce the number reported by the baroreceptor to two, normal pressure.

7. If the baroreceptor signals number one (low pressure), the vasomotor center tells the sympathetic nerves to go into action.

8. The sympathetic nerves tell the heart to increase its pumping rate and the arteries to constrict. The arteries and the heart tell the arterial pressure to increase the grip to two, normal pressure. In this case, the baroreceptor would signal normal pressure.

Once pressure is back to normal, you can introduce certain things that would change the pressure. For instance, you could say that a lion was just spotted and the heart should automatically tell pressure that it increased its pumping, the vessels should tell pressure that they constricted and the pressure should go to number three (high pressure).
Evaluation

REVIEW QUESTIONS

1. What two things are primarily responsible for making arterial blood pressure increase or decrease?
   The rate at which the blood is pumped into the arteries by the heart and the resistance to blood flow within the arteries are primarily responsible for changes in arterial blood pressure.

2. What areas of the brain are involved with the baroreceptor reflex?
   The areas of the brain that are involved in the baroreceptor reflex is the vasomotor center and vagal center.

3. What part of the loop might microgravity influence through its presence during human development?
   Any part of the baroreceptor reflex loop could be influenced by lack of gravity during human development. The baroreceptor nerves were studied on Neurolab.

4. Why is blood pressure so important?
   An appropriate blood pressure is important to maintain blood flow through the blood vessels to the brain and other vital organs.

THINKING CRITICALLY

Have your students write a brief paragraph and explain why they do not faint when they stand up. You also can have them explain why they feel light-headed for a few moments when they stand up quickly.