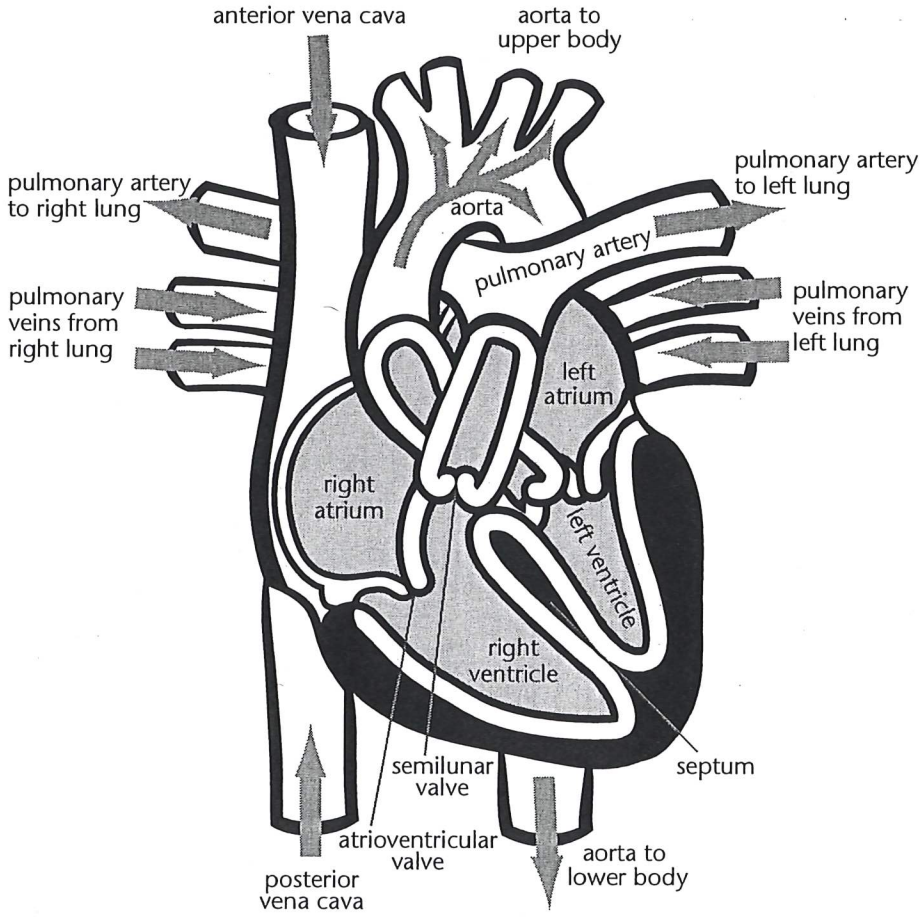
Section 3.3
The Heart

Section Overview

The heart is an amazing organ. The heart beats about 3 BILLION times during an average lifetime. It is a muscle about the size of your fist. The heart is located in the center of your chest slightly to the left. It's job is to pump your blood and keep the blood moving throughout your body.



Lesson 3.3A
Anatomy of the Heart

Overview

Your heart weighs less than half a kilogram. An elephant's heart weighs 20 kilograms. A blue whale has a heart the size of a Volkswagen beetle and an adult human could crawl into its aorta.It has been estimated that your heart beats over 100 000 times a day. If you live to be 70 years old, your heart will pump over 250 million litres of blood through your body. This lesson introduces the structures of the heart and the functions of its various parts.

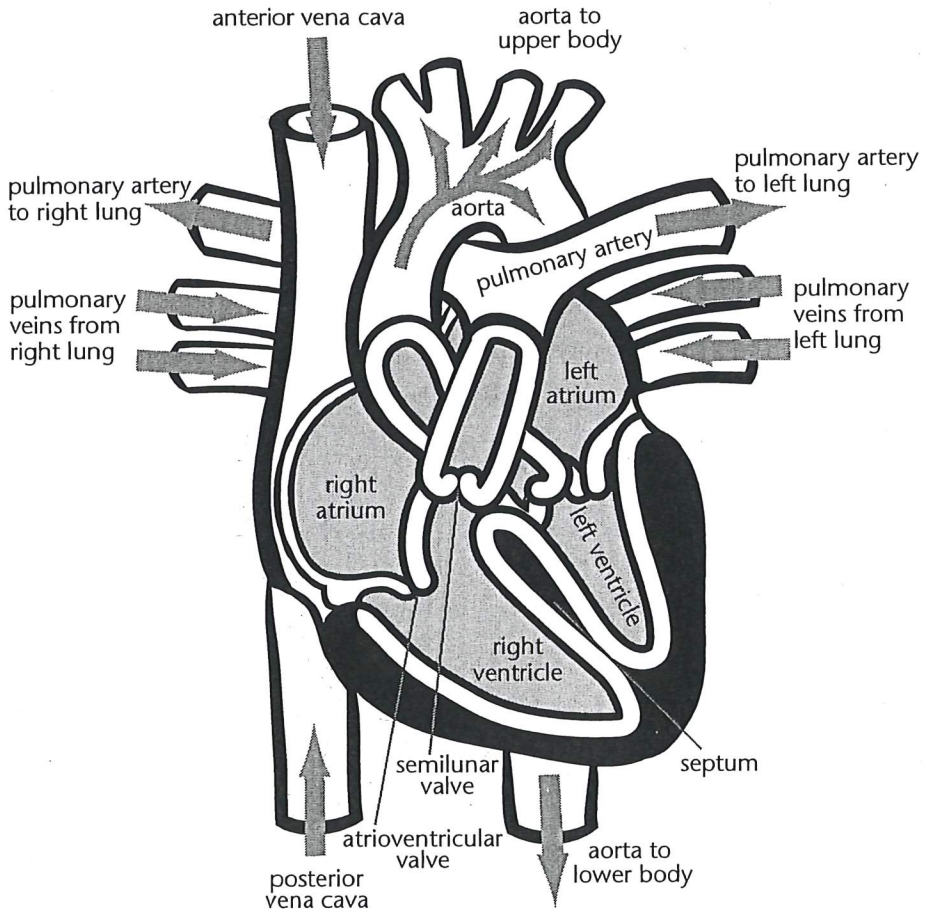
Resource List

- *Inquiry Into Life*
- *Biology 12 Provincial Exam Preparation package*
- *Biology 12 Web site*
  http://www.openschool.bc.ca/courses/biology/bi12/mod3.html
- *Biology 12 Media CD*

Heart Anatomy

The heart is a cone-shaped, fist-sized, muscular organ found within the thoracic cavity beneath the sternum and between the lungs. It is a double pump that pushes blood through the pulmonary and systemic circuits at the same time. The heart has four chambers—two atria and two ventricles. The right side of the heart pumps blood to the lungs via the pulmonary trunk, and the thicker walled left side of the heart pumps blood to the body via the aorta.

For an overview of the heart, see Figure 12.3 and 12.4 on pages 220–221 of your *Inquiry Into Life* textbook.



Contractions of the heart are synchronized so both atria contract to load the ventricles and then both ventricles contract to push blood into the pulmonary and systemic circuits. (Note: the septum dividing the two sides of the heart is muscle shared by both ventricles. During contraction, it provides force for both ventricles at the same time.)

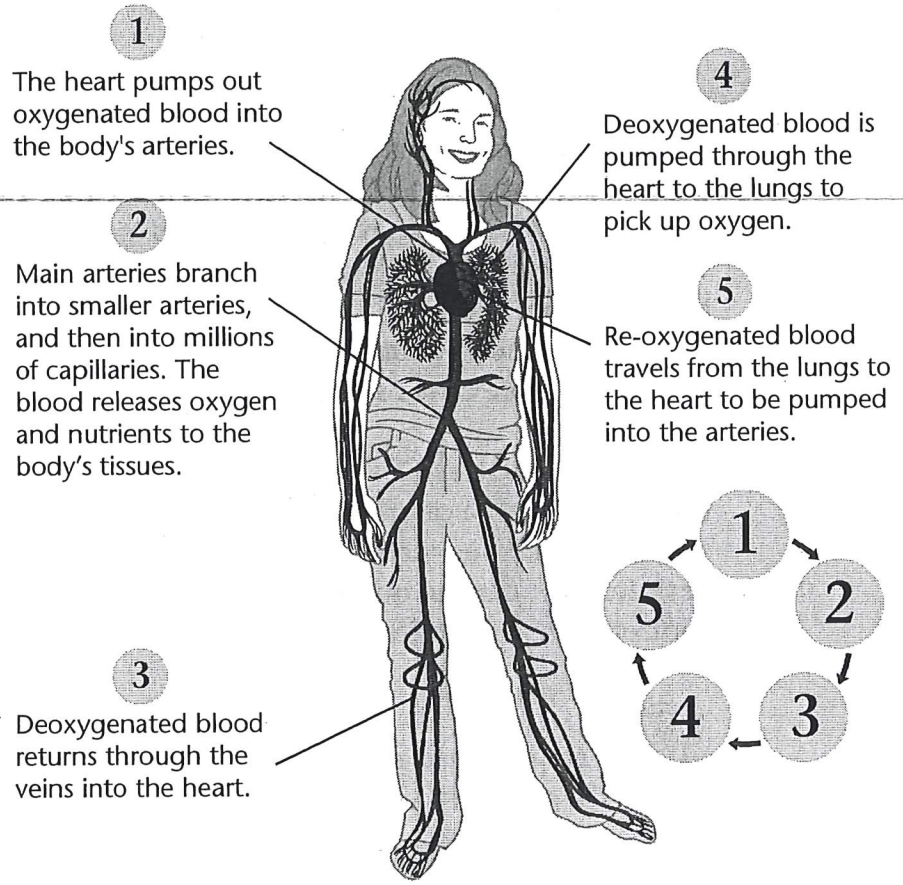
The valves inside the heart are crucial to its pumping action and ensure that blood moves in only one direction. As each chamber contracts, blood is forced backwards against the flaps of the valve, closing it and preventing backflow of blood.

The valves between each atrium and ventricle are called atrioventricular (AV) valves. Stringy fibres called chordae tendineae prevent the flaps of the AV valves from inverting. The AV valve on the right side of the heart has three flaps and is called the tricuspid valve. The AV valve on the left side of the heart has two flaps and is called the bicuspid or mitral valve. The valves that allow blood to pass from the ventricles to the pulmonary trunk (pulmonic valve) and the aorta (aortic valve) are called semilunar valves.

The cardiac muscle fibres that make up the heart are unique. The heartbeat (called a cardiac cycle) is initiated and synchronized by special nodal tissue that is part muscle and part nerve, and the heart beat does not depend on the nervous system. The heartbeat and its control is the topic of the next lesson.

If you have access to the Internet, go to the *Biology 12 Web site* Lesson 3.3A Anatomy of the Heart to do practice activities relating to heart anatomy.

The Pathway of Blood through the Heart



Blood flows through the heart structures in the following sequence:

- deoxygenated blood is returned to the right atrium from the body
- the right atrium pumps the blood through the atrioventricular valve into the right ventricle
- the right ventricle pumps blood through the semilunar (pulmonic) valve into the pulmonary truck and into the pulmonary arteries to both lungs
- oxygenated blood is returned to the left atrium
- the left atrium pumps the blood through the atrioventricular valve into the left ventricle
- the left ventricle pumps the blood under high pressure through the semilunar (aortic) valve to the body

Note that the contraction of both sides of the heart occurs together. Both atria contract and then both ventricles contract. The pathway of blood through the heart is something you will need to be able to describe.

If you have access to the Internet, go to the *Biology 12 Web site* Lesson 3.3A Anatomy of the Heart for practice activities relating to heart anatomy and to see a great site on virtual dissection.

If you have access to a computer and the *Biology 12 Media CD*, go to *Voyage of the Blood* now to see how blood flows through the heart.

Go to your:

Biology 12 Web site > Module 3 > Voyage of the Blood.

Summary of Heart Structure and Function

For this course you are responsible for knowing the following summary of the heart structures and functions.

Heart Structure	Description	Function
Right Atrium	Heart chamber	Receives blood from the vena cava and pumps it to the right ventricle to load it
Left Atrium	Heart chamber	Receives blood from the pulmonary vein and pumps it into left ventricle
Left Ventricle	Heart chamber	Pumps oxygenated blood into the aorta and to the body
Coronary Arteries	Blood Vessels	Carry oxygenated blood to the heart
Coronary Veins	Blood Vessels	Carry deoxygenated blood back to heart
Vena Cava	Largest Vein	Collects blood from upper and lower body and returns it to the right atrium
Pulmonary Vein	Blood Vessel	Carries oxygenated blood from the lung capillaries to the left atrium
Pulmonary Artery	Blood Vessel	Carries deoxygenated blood from the right ventricle to the lungs
Aorta	Largest Artery	Carries oxygenated blood from the left ventricle to the systemic circulation
AV Valves	Heart valves	Located between the atria and ventricles they prevent the backflow of blood
Chordae Tendineae	Connective Tissue	Prevent the AV valves from inverting during heart contraction (systole)
Semilunar Valves	Heart Valves	Prevent the backflow of blood in the pulmonary artery and aorta
Septum	Heart Muscle	Lies between the two sides the heart and is important in heartbeat conduction and contraction

If you have access to the Internet, go to the *Biology 12 Web site* Lesson 3.3A Anatomy of the Heart to check the resources for the heart and learn more.

Guided Practice 3.3A 1
Study Flash Cards

Using the information in your lessons, the *Inquiry Into Life* textbook, and the *Biology 12 PEP*, make a study flash card for each of the following vocabulary terms. Be sure the information is in your words, as that will be more meaningful to you.

Vocabulary terms to know for this lesson:

- anterior vena cava
- aorta, pulmonary
- arteries
- atrioventricular valves
- chordae tendineae
- coronary arteries
- coronary veins
- heart
- left atrium
- left ventricle
- posterior vena cava
- pulmonary trunk
- pulmonary veins
- right atrium
- right ventricle
- semilunar valves
- septum

Guided Practice 3.3A 2
Written Response

1. Use the *Inquiry Into Life* readings to complete the structure and function of the heart structures in the following table.

Heart Structure	Description	Function
Right Atrium		
Left Atrium		
Left Ventricle		
Coronary Arteries		
Coronary Veins		
Vena Cava		
Pulmonary Vein		
Pulmonary Artery		
Aorta		
AV Valves		
Chordae Tendineae		
Semilunar Valves		
Septum		

2. To which heart chamber does blood from the body (but not the lungs) return?

3. Veins usually carry blood that is low in which substance? Which veins defy this rule?

4. Name the valves through which blood leaves the ventricles.

5. Describe the pathway of blood through the heart.

Summary

Now do Section Assignment 3.3 Part A.

Completing this lesson has helped you to:

- identify the structures of the heart in a diagram
- name a function of each structure of the heart identified in the lesson
- describe the path of blood through the heart, including the valves it passes through

Lesson 3.3B
Regulating the Heartbeat

Overview

Your heart beats more than 100 000 times a day and if you live to be 70 years old, your heart will pump more than 250 million litres of blood through your body. The heartbeat is initiated by the SA node every 0.85 seconds. Artificial pacemakers can do the same. In general, heart rates are higher in small mammals and lower in large mammals. A blue whale has a heart the size of a small car that beats only five or six times per minute.

Resource List

- *Inquiry Into Life*
- *Biology 12 Provincial Exam Preparation package*
- *Biology 12 Web site*
  http://www.openschool.bc.ca/courses/biology/bi12/mod3.html

Heartbeat and Its Regulation

The heart is a double pump that pushes blood through the pulmonary and systemic circuits at the same time. The right side of the heart pumps blood to the lungs via the pulmonary artery, and the thicker-walled left side of the heart pumps blood to the body via the aorta. The contraction of the heart is synchronized so both atria contract to load the ventricles, and then both ventricles contract to push blood into the pulmonary and systemic circuits.

The active contraction of the ventricles is called systole, and the period in this **cardiac cycle** when the ventricles are relaxed is called diastole. (Note: the septum dividing the two sides of the heart is muscle shared by both ventricles. During contraction, it provides force for both ventricles at the same time.)

The cardiac muscle fibres that make up the heart are unique. The heartbeat or cardiac cycle is initiated and synchronized by special nodal tissue that is part muscle and part nerve. Because of these special nodal tissues, the heartbeat does not depend on the nervous system.

The focus of this lesson is the intrinsic control of the heartbeat by the sinoatrial (SA) node, the atrioventricular (AV) node, and Purkinje fibres.

For an image of the cardiac cycle, see Figure 12.5 on page 222 of your *Inquiry Into Life* textbook.

The SA Node

The specialized **sinoatrial node** (SA node) is located on the upper inside wall of the right atrium. The SA node is the **pacemaker** of the heart, and it initiates a heartbeat every 0.85 seconds. This signal travels across the atria, causing them to contract and load the ventricles with blood. The signal continues across the atria until it reaches the AV node.

The AV Node

The AV node, located on the bottom surface of the right atria, is responsible for initiating the contraction of the ventricles. When the signal from the SA node reaches the AV node, a slight delay allows the atria to finish loading the ventricles. Following this delay, the AV node relays the signal along two AV bundles found in the septum and on to the numerous **Purkinje fibres** found in the walls of both ventricles.

The AV node, the AV bundle, and the Purkinje fibres act together to create a smoothly coordinated and powerful contraction of the ventricles. This contraction of the ventricles pushes blood into the pulmonary circuit from the right side of the heart and into the systemic circuit from the left side of the heart. This active contraction of the ventricles is called systole. The relaxation phase of the ventricles is called diastole. These terms will be examined more closely in the blood pressure measurement lesson.

If you have access to the Internet, go to the *Biology 12 Web site* Lesson 3.3B Regulating the Heartbeat and try an animated quiz on the circulatory system.

Control of the Heartbeat

Although the heart initiates a signal every 0.85 seconds, the body has other mechanisms that will increase or decrease the rate and force of heart contractions. These mechanisms are needed in times of stress, illness, exercise, during sleep, or when you dive into cold water.

An individual's heartbeat, mainly the heart rate, constantly changes in response to the body's metabolic requirements and to changes in the environment that cause or alleviate stress. These changes in heart rate and force of contraction are not within an individual's conscious control. Changes in the heartbeat are controlled by the autonomic nervous system, specifically the **cardiac control center** in the medulla oblongata.

Divisions of the nervous system and the brain are covered in a different part of this course. The autonomic nervous system has two branches. The sympathetic nervous system responds to situations that involve increased activity or stress that elicits a fright response known as "flight or fight." The parasympathetic nervous system responds to reductions in stress and restful conditions.

The cardiac control centre in the medulla oblongata of the brain controls the heartbeat. In times of stress or exercise, the cardiac control centre sends sympathetic nerve signals to increase **cardiac output**. Stress hormones from the adrenal glands (epinephrine and norepinephrine) also increase rate and force of heart contractions.

In restful conditions such as sleep, the body needs less blood delivered to muscles, so the cardiac control centre sends signals via the parasympathetic nerves to decrease the heart rate.

If you have access to the Internet, go to the *Biology 12 Web site* Lesson 3.3B Regulating the Heartbeat and check the resources pertaining to the heartbeat, ECG, and conduction.

Guided Practice 3.3B 1
Study Flash Cards

Using the information in your lessons, the *Inquiry Into Life* textbook, and the *Biology 12 PEP*, make a study flash card for each of the following vocabulary terms. Be sure the information is in your words, as that will be more meaningful to you.

Vocabulary terms to know for this lesson:

- autonomic nervous system
- AV bundle
- AV node
- cardiac control center
- epinephrine
- heartbeat
- medulla oblongata
- pacemaker
- Purkinje fibres
- SA node

Guided Practice 3.3B 2
Written Response

1. Special tissues in the heart are responsible for coordinating the heartbeat. Describe the names, composition, location within the heart, and function of these tissues. Explain the steps involved in producing a heartbeat.

2. Name a hormone that increases the heart rate and the force of heart contractions. Which branch of the autonomic nervous system is responsible for increasing heart rate? Which branch decreases heart rate?

Summary

Now do Section Assignment 3.3 Part B.

Completing this lesson has helped you to:

- list the structures in the heart that coordinate the heartbeat.
- describe the steps that occur in the heartbeat.
- understand how the nervous system controls heart rate and force of contraction.

Lesson 3.3C
Blood Pressure—Hypertension and Hypotension

Overview

Normal blood pressures vary from species to species and from person to person. A giraffe has very high blood pressure to prevent it from getting light headed. For humans, average blood pressure changes as a person ages. Older people have an average blood pressure of 140/95. For young adults the average is 120/80 and for infants it is 80/45. About one in five North Americans has high blood pressure, which is a major risk factor for heart attack and stroke.

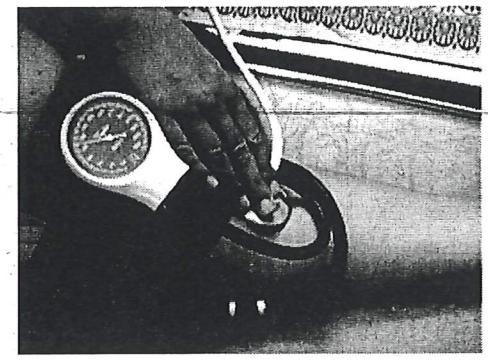
Resource List

- *Inquiry Into Life*
- *Biology 12 Provincial Exam Preparation package*
- *Biology 12 Web site*
  http://www.openschool.bc.ca/courses/biology/bi12/mod3.html
- *Biology 12 Media CD*

Measuring Blood Pressure

Blood pressure is the pressure exerted by blood on the walls of blood vessels. Blood pressure drops with increased distance from the heart due to the branching of blood vessels and the corresponding increase in cross-sectional area. The effect is much like a mighty river fanning out into a delta. Once the pressure in the capillary beds drops, it cannot be increased until the blood returns to the heart. The lower pressure in veins explains the importance of one-way valves and muscular movement to return blood to the heart.

Blood pressure measurement using a digital blood pressure monitor is demonstrated in this lesson. You may have taken your blood pressure at the pharmacy with a similar unit. The technical name for the instrument that measures blood pressure is a **sphygmomanometer**.



The basic principle behind blood pressure measurement is the same, whether done by a doctor with a cuff and stethoscope or by you with a cuff and digital monitor. In both cases, the cuff goes over the brachial artery on the inside of the upper arm. The cuff is then filled with air to a pressure of about 170 to 180 mmHg, which stops the flow of blood through the artery. Air is then released from the cuff. The larger or top number in the blood pressure matches the pressure at which the heart can force blood through the brachial artery past the cuff during ventricle contraction. The smaller or bottom number in the blood pressure matches the pressure at which blood begins to flow freely through the brachial artery and past the cuff in between ventricular contractions. A doctor using a stethoscope listens for the movement of blood through the artery below the cuff.

If you have access to a computer and the *Biology 12 Media CD*, go to the *Blood Pressure Measurement* media piece now. While you watch the video, take notes about the equipment used and list the steps involved in safely obtaining an accurate blood pressure measurement.

Go to your:

Biology 12 Media CD > Module 3 > Blood Pressure Measurement.

Now let's consider the two numbers in a blood pressure measurement. The first number recorded is called the systolic pressure, and it occurs during the contraction of the ventricles of the heart. This pressure matches the pressure at which the ventricles begin to force blood in the brachial artery past the arm cuff.

The second number is called the diastolic pressure, which occurs when the ventricles of the heart are relaxed. It matches the pressure at which the blood in the brachial artery can move past the arm cuff continuously.

If you have access to the Internet, go to the *Biology 12 Web site* Lesson 3.3 C Blood Pressure—Hypertension and Hypotension and do the Virtual Blood Pressure Lab.

What is Normal Blood Pressure?

Blood pressure is a measure of the force exerted by blood on the walls of the blood vessels. Blood pressure in arteries is highest when the ventricles are contracting (called **systole** or systolic pressure) and lower when the ventricles are relaxed (called **diastole** or diastolic pressure). For humans, the average values for systolic and diastolic pressures are approximately 120 mmHg and 80 mmHg, respectively. This blood pressure reading is often written as 120 over 80 or 120/80.

Blood pressure is greatest in the arteries at 120 mmHg during systole, and arteries have thick, elastic, muscular walls to accommodate this. Blood pressure is lowest in the vena cava (0 to 20 mmHg) because it is furthest from the heart. As blood moves away from the heart, the branching of arteries into arterioles and arterioles into capillaries reduces blood pressure and blood velocity. This reduction in pressure and velocity is due to the huge increase in cross-sectional area in the capillaries.

The lower velocity in the capillaries allows the time necessary for effective capillary tissue-fluid exchange. Blood leaving the capillaries converges into venules and then into veins. This results in a decrease in cross-sectional area and an increase in the velocity of blood flow, even though the pressure remains low.

Go to Figure 12.9 on page 226 of your *Inquiry Into Life* textbook to see a cross-sectional image as it relates to blood pressure and blood velocity.

Hypertension

Hypertension is a condition in which a person's blood pressure is above normal. High blood pressure exists when the systolic pressure exceeds 140 mmHg or the diastolic pressure exceeds 90 mmHg.

Causes of hypertension include sympathetic nerve activity that constricts blood vessels, too much salt in the diet or reabsorption of sodium ions from the kidneys, and artherosclerosis. Artherosclerosis is caused by fat deposits in the walls of arteries. These deposits reduce the size of the lumen and a greater resistance to blood flow, which increases the blood pressure.

Hypotension

Hypotension is a condition characterized by below normal blood pressure. Hypotension can be caused by problems with the autonomic nervous system or by blood loss following a severe trauma. Patients with low blood pressure are prone to fainting. Fainting can be a benefit because it gets the head into a lower position, making it easier for it to receive blood from the heart.

If you have access to the Internet, go to the *Biology 12 Web site* Lesson 3.3 C Blood Pressure—Hypertension and Hypotension and read the online resources about vessels and pressure.

Guided Practice 3.3C 1
Study Flash Cards

Using the information in your lessons, the *Inquiry Into Life* textbook, and the *Biology 12 PEP*, make a study flash card for each of the following vocabulary terms. Be sure the information is in your words, as that will be more meaningful to you.

Vocabulary terms to know for this lesson:

- blood pressure measurement
- diastole
- hypertension
- hypotension
- sphygmomanometer
- systole

Guided Practice 3.3C 2
Written Response

1. Explain systolic blood pressure and diastolic blood pressure.
2. What is a normal blood pressure reading for a young adult?
3. What is the name of the instrument used to measure blood pressure?
4. What are the names of the pulses located in your neck and wrist?
5. Describe how a sphygmomanometer and a stethoscope are used to determine a patient's blood pressure.

Summary

Now do Section Assignment 3.3 Part C.

Completing this lesson has helped you to:

- demonstrate how to measure blood pressure
- understand what blood pressure measurements mean
- explain the differences between systolic and diastolic pressures
- define hypertension and hypotension, and list their causes