

Anatomy and Physiology: Understanding the Importance of CPR

Overview This document gives you more information about the body's structure (anatomy) and function (physiology). This information will help you better understand and *remember* CPR after your class is over.

Three Body Systems All organs need oxygen to function. Three body systems work together to be sure that organs of the body have enough oxygen:

- respiratory system (brings oxygen in and takes waste out)
- cardiovascular system (moves blood and oxygen around)
- nervous system (tells organs what to do and when)

How These Systems Work Together The respiratory, cardiovascular, and nervous systems work together to maintain life. The lungs put oxygen in the blood, and the heart delivers oxygen-rich blood to the heart itself and to the brain and other organs.

What Happens When These Systems Fail When these systems fail, the process of dying begins. If oxygen delivery to the organs stops because an airway is blocked or normal breathing or circulation stops, the brain and other organs will begin to die within minutes.

How CPR Helps The miracle of CPR is that it can help save the life of a dying person with 2 simple actions:

- Delivering breaths to the victim's lungs
- Compressing the victim's chest

The Respiratory System: Airways, Lungs, and Muscles

Anatomy of the Respiratory System The respiratory system (Figure 1) has 4 parts:

- the airways that conduct air between the outside and the lungs
- the air sacs (alveoli) in the lungs where gas exchange happens

- the nerves that tell the muscles when to move and the muscles that let the air move in and out
- a set of blood vessels that move the blood to the organs and removes waste from the blood

Airway

The airway can be divided into the upper airway and the lower airways:

Upper Airway	Lower Airways
<ul style="list-style-type: none"> • Nose and mouth • Pharynx (behind the tongue) • Larynx (voice box) 	<ul style="list-style-type: none"> • Trachea (windpipe) • Bronchi (1 bronchus to the right lung and 1 to the left lung) • Bronchioles (branches of the bronchi that terminate in the alveoli)

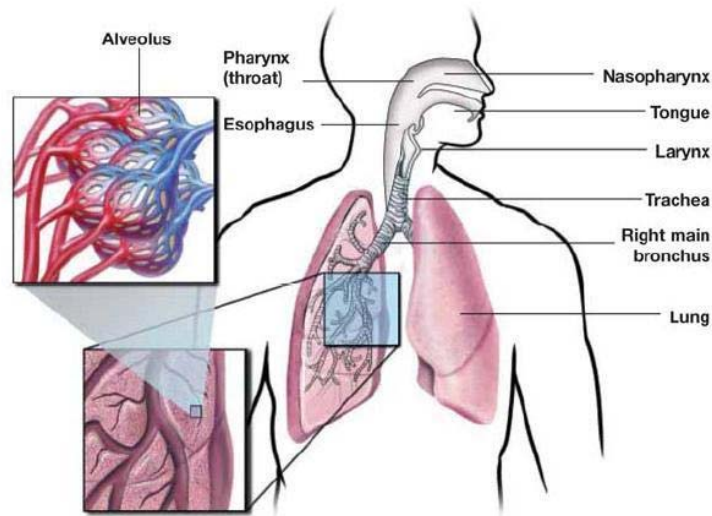


Figure 1. Anatomy of the respiratory system.

Alveoli

Alveoli are at the end of the airways. Oxygen can quickly move from the air sacs into the blood, and carbon dioxide moves from the blood into the air sacs. Blood that carries oxygen then flows back to the heart and is pumped to the body. Carbon dioxide from the air sacs moves out of the lungs into the air.

Neuromuscular Component

The neuromuscular component of the respiratory system includes

- the brain
- the nerves to and from the muscles for breathing
- the muscles of breathing

The major muscles of breathing are

- the large diaphragm
 - attaches to the margin of the lower ribs
 - separates the chest from the abdomen
- the muscles between the ribs
- some muscles of the neck and shoulder

Arteries, Capillaries, and Veins

The following table describes the functions of pulmonary arteries, capillaries, and veins:

Part	Function
Pulmonary Arteries	Carry blood with relatively low oxygen content from the right side of the heart into the capillaries surrounding the alveoli.
Pulmonary Capillaries	Create a web surrounding the alveoli. At the interface between the capillaries and the alveoli, oxygen moves from the alveoli into the capillaries and carbon dioxide moves from the capillaries into the alveoli.
Pulmonary Veins	Carry blood with high oxygen content from the lungs back to the left side of the heart.

Physiology of the Respiratory System

The respiratory system has two primary functions:

- bringing oxygen from the air to the alveoli where it can move into blood
- eliminating carbon dioxide that moves from the blood into the alveoli

All body cells need a continuous supply of oxygen to function. Metabolism (the work of the cells) produces carbon dioxide, which the body must eliminate.

Avoiding Too Many Breaths During CPR

During CPR, blood flow to the lungs is only about 20% to 33% of normal, so fewer breaths and smaller air volume is needed to provide oxygen and eliminate carbon dioxide during cardiac arrest than when the victim's heart is working normally.

When performing CPR, rescuers must pause compressions to give breaths. During these pauses there is no blood flow to the heart muscle and brain. To minimize effects on blood flow, the rescuer should try to deliver the 2 breaths as efficiently as possible to minimize the time the compressions are interrupted.

If a rescuer gives too many breaths or gives the breaths over several seconds, the rescuer will deliver fewer compressions than recommended. In that case, blood flow will be even less than the 20% to 33% of normal that is typically generated by CPR.

Cardiovascular System

The 2 primary functions of the cardiovascular system are:

- carrying oxygenated blood from the lungs to the cells of the body
 - carrying blood containing carbon dioxide from the cells of the body to the lungs
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In most healthy people the levels of oxygen and carbon dioxide in the blood remain relatively constant. The respiratory center of the brain tells the body to breathe.

When the level of carbon dioxide rises, the following process happens:

- The brain sends signals to the muscles of breathing.
 - Breathing rate and depth increase.
 - The signals sent by the breathing center in the brain decrease.
 - The breathing rate slows.
 - The blood level of carbon dioxide is maintained in a narrow range.
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Oxygen Content

The air around us usually contains about 21% oxygen and 79% nitrogen. Because only about a quarter of the oxygen in inhaled air is taken up by the blood in the lungs during respiration, exhaled air still contains a significant concentration (about 16%) of oxygen. When giving breaths during CPR, the air exhaled by the rescuer and delivered to the victim contains a sufficient amount of oxygen to give enough oxygen to the victim.

Mechanics of Breathing

Inspiration (breathing in) is an active process, while exhalation (breathing out) is generally a passive process. The diaphragm is the chief muscle of

inspiration.

The following list shows the process of breathing:

- Two sets of muscles contract at the same time—the diaphragm and the muscles between the ribs (the intercostal muscles).
 - The diaphragm contracts and moves down toward the abdomen, increasing the volume inside the chest.
 - The intercostal muscles contract and lift the rib cage, further increasing the volume inside the chest.
 - When the volume in the chest increases, the pressure in the chest and lungs falls.
 - The difference in pressure between the outside air and the lungs draws air into the lungs.
 - As the muscles relax, the ribs move down and the diaphragm rises, reducing the volume of the chest cavity.
 - The elastic lung passively becomes smaller, and the air inside the lung moves out (exhalation).
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Airway Blockage

Airway blockage, particularly choking, is presented in detail in the student workbook. The most common cause of airway blockage in the victim who does not respond is blockage by the tongue. Any condition that leads to the victim not responding can cause the tongue to fall toward the back of the throat and block the airway.

Death caused by airway blockage is relatively uncommon (1.9 deaths per 100 000) in the United States.¹ However, the need for proper emergency action in cases of choking is of key importance for safety at home, in restaurants, and in other public places.

Respiratory Arrest

The breathing center in the brain must function for breathing to happen and for breathing rate and depth to be enough to control carbon dioxide levels in the blood. The breathing center can be severely affected by inadequate blood flow to the brain resulting from

- stroke (disruption of the blood supply to an area of the brain)
- shock (not enough oxygenated blood moving to the body's organs)
- cardiac arrest (no response, not breathing, and heart not moving blood)
- head injury
- drugs that slow breaths (eg, sleeping pills)

Within a few seconds after cardiac arrest happens, breathing will stop. For the first minutes after a sudden cardiac arrest, the victim may gasp. Gasp is not breathing.

Additional causes of respiratory arrest can include diseases or injuries that

reduce brain function or interfere with normal contraction of the muscles of breathing.

The Cardiovascular System

Anatomy of the Cardiovascular System

The parts of the cardiovascular system are the

- heart
- arteries
- capillaries
- veins

Heart

The heart of an adult is not much larger than a fist. It lies in the center of the chest, behind the breastbone, in front of the backbone, and above the diaphragm. Except for the area against the backbone and a small strip down the center of the front of the heart, the heart is surrounded by lung (Figure 2).

The heart is a hollow organ divided into 4 sections or chambers. A sac called the pericardium surrounds the heart.

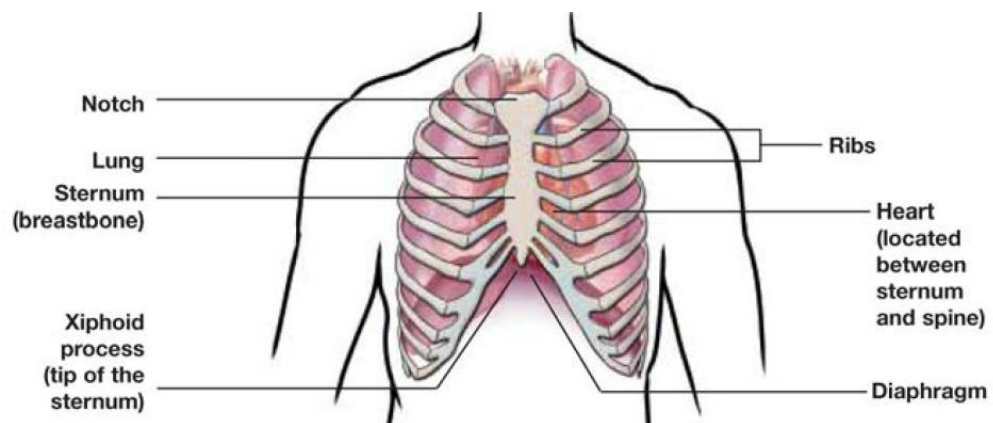


Figure 2. The heart in relation to other components of the chest.

The following table describes the function of several parts of the heart:

Part	Function
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Right upper chamber (right atrium)	Receives blood from the body
Right lower chamber (right ventricle)	Pumps this blood into the lungs
Left upper chamber (left atrium)	Receives oxygenated blood from the lungs
Left lower chamber (left ventricle)	Pumps this oxygenated blood into the main artery supplying the body with oxygenated blood
Valves	<ul style="list-style-type: none"> • Located between the upper and lower chambers and between the lower chambers and the 2 major arteries • Help maintain the forward flow of blood through the heart chambers and into the 2 major arteries

The heart has its own blood supply. The coronary arteries are the first branches of the aorta. They supply the heart muscle with oxygenated blood.

The Importance of Adequate Coronary Artery Blood Flow During CPR

Ventricular fibrillation (VF) is a condition that causes a victim's heart muscles to move in a fast, uncoordinated way that results in no blood movement. In victims of VF sudden cardiac arrest, chest compressions increase the chances that shock from an automated external defibrillator (AED) would be successful. Chest compressions are especially important if the first shock is delivered 4 or more minutes after collapse.

There are several important things to remember about chest compressions:

1. "Effective" chest compressions are essential for providing blood flow during CPR.
2. To give effective chest compressions, "push hard and push fast" with a compression depth of 1½ to 2 inches for the adult. Compress the chest at a rate of about 100 compressions per minute.
3. Allow the chest to return to its normal position after each compression, and allow approximately equal compression and relaxation times.
4. Minimize interruptions in chest compressions.

When chest compressions resume after an interruption for giving breaths or some other procedure, several compressions are required to return the pressure of blood flow to the level present before the interruption. Those first few compressions, therefore, are less effective than later ones. This is one reason why rescuers should minimize interruptions in chest compressions.

It is important to give both breaths and chest compressions, but rescuers should try to limit any interruptions in chest compressions to no more than 10 seconds except for specific interventions such as using an AED.

It is important for the rescuer to allow the chest to return to normal after each compression. If the rescuer does not allow the chest to return to normal after each compression, this will reduce the blood flow generated by later chest compressions.

Effective chest compressions—that is, chest compressions at the correct rate and depth with minimal interruptions and that allow the chest to return to normal after each compression—will be more likely to generate adequate blood flow during CPR. Effective CPR can improve survival from sudden cardiac arrest.

Physiology of the Heart

The function of the heart is to pump blood to the lungs and to the body (including the heart and brain). Arteries and veins carry the blood between the organs of the body and the heart. In the tissues, oxygen and carbon dioxide are exchanged between the blood and the cells. This exchange takes place at the organ's capillaries.

All body cells need a continuous supply of oxygen to carry out normal functions. Work of the cells (metabolism) produces carbon dioxide as a waste product.

The heart is actually a double pump.

Side of the Heart	Function
Right	<ul style="list-style-type: none">• Upper chamber receives blood that has returned from the body after delivering oxygen to body tissues• Lower chamber pumps this dark, bluish-red blood to the lungs, where the blood:<ul style="list-style-type: none">– Rids itself of carbon dioxide– Picks up a supply of oxygen, which gives the oxygen-rich blood a bright red color
Left	<ul style="list-style-type: none">• Upper chamber receives the oxygen-rich blood from the lungs• Lower chamber pumps blood into the aorta, which leads to smaller arteries that distribute it to all parts of the body

The adult heart at rest beats or pumps 60 to 100 times per minute. Each time the adult heart beats, it pumps about 2½ ounces of blood. At rest the heart

pumps about 5 quarts of blood per minute. During exercise the heart can pump up to 37 quarts per minute. The total blood volume of a person weighing 150 pounds is about 6 quarts.

Each contraction of the heart, or heartbeat, is begun by an electrical impulse. The heart has its own electrical stimulation center called a pacemaker. A special system sends this electrical impulse to the heart muscle and makes it contract. The contraction is followed by a period of relaxation. During relaxation the chambers of the heart fill with blood. This blood is ready to be pumped out by the ventricles with the next contraction.

Heart Disease and Symptoms

The heart muscle needs oxygen just like any other tissue in the body. The coronary arteries supply blood to the heart.

A coronary artery can be blocked by plaque buildup or a blood clot. If the artery is blocked, the blood cannot reach the heart muscle. When blood flow through a coronary artery is blocked, any one of several conditions may develop. These conditions are called acute coronary syndromes (ACS).

Heart Disease	Description
Angina	The pain that develops when the heart muscle does not receive oxygen.
Heart attack	<ul style="list-style-type: none"> • The heart muscle actually starts to die. • The size of a heart attack is determined by where the artery is blocked, how severe the block is, and how much heart muscle the artery supplies beyond the block.

The management of ACS has improved a lot over the last 2 decades. “Clotbuster” medications and certain procedures (including angioplasty and possible stent placement) can reopen blocked coronary vessels, saving lives and improving quality of life. Early diagnosis and treatment of heart attack significantly reduce mortality, decrease the size of the heart attack, improve heart muscle function, and decrease the incidence of heart failure. To be most effective, victims must receive these treatments within the first few hours of symptom onset.

Some victims of heart attack may develop an abnormal heart rhythm (arrhythmia) called VF. When VF is present, chaotic electrical impulses throughout the heart cause useless quivering of the heart. The heart stops pumping blood, and cardiac arrest is present.

VF is the most frequent initial heart rhythm in witnessed sudden cardiac arrest. It must be treated rapidly with CPR and electrical defibrillation. The probability of successfully changing VF to a normal heart rhythm with defibrillation decreases rapidly over time.

In addition, good CPR provides some continued blood flow and oxygen delivery to the brain during cardiac arrest, reducing the likelihood of serious brain injury.

If CPR is provided, VF will last longer. If VF lasts longer, defibrillation is possible for more minutes following cardiac arrest. CPR also increases the likelihood that shock delivery will eliminate the VF and that, following shock delivery and elimination of VF using defibrillation, the heart will resume a normal rhythm. This is why it is so important to do effective CPR quickly and get and use an AED as fast as possible.

The Cerebrovascular System

Anatomy of the Brain

The central nervous system is composed of the brain and spinal cord.

Part	Description
Cerebrum	<ul style="list-style-type: none">• The largest portion of the brain• Has nerve centers that control most sensory and motor activities of the body
Hemispheres	<ul style="list-style-type: none">• The cerebrum is divided into right and left halves, or <i>hemispheres</i>.• Each hemisphere contains a complete set of sensory and motor centers.• Generally the right hemisphere controls the left side of the body, and the left hemisphere controls the right side of the body.
Lobes	<ul style="list-style-type: none">• The cerebral hemispheres are further subdivided into <i>lobes</i>, or sections with specific, distinct functions. Lack of blood supply to brain tissue in a specific area can therefore result in distinct and limited loss of the specific function controlled by that area of the brain.

Brain stem	<ul style="list-style-type: none"> • The lower part of the brain. • Made up of bundles and tracts of nerves that travel down to the spinal cord from the cerebrum. • Includes distinct centers that monitor and control respiratory and circulatory function.
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Circulation of the Brain

The brain requires a constant flow of oxygenated blood to function. If blood flow to the brain is interrupted, brain damage or death can result.

Part	Description
Carotid arteries	<ul style="list-style-type: none"> • 2 large arteries in the front of the neck • Supply most (80%) of the blood to the brain
Vertebral arteries	<ul style="list-style-type: none"> • 2 arteries (right and left) in the back of the neck • Supply blood to the brain stem • Join the carotid arteries to form a network that supplies blood to the rest of the brain

Problems with Blood Vessels in the Brain and Symptoms

Injuries or insults to the brain that damage distinct areas can result in loss of specific functions while other parts of the nervous system continue to function normally. For example, the sudden disruption or blockage of blood supply in an artery that supplies a particular area of the brain is known as a stroke. This can result in loss of movement or sensation to one side of the body while the victim remains alert and is able to move the other side of the body normally.

Because each hemisphere of the brain controls motor function of and receives sensation from the opposite side of the body, stroke victims usually have weakness and loss of sensation in the arm and leg on the side of the body opposite the side of the brain affected by stroke. Additional symptoms such as slurred speech or visual disruptions may be present, depending on the location of the stroke within the brain.

Major injuries to the brain may cause more wide-spread brain injury. The victim may stop responding and have reduced functions of the brain. For example, severe head injury or severe stroke may lead to altered mental status.

Some changes in the body function affect all brain cells. A common example is lack of oxygen during a cardiac arrest. The victim:

- stops responding
- does not react to stimuli such as pain
- has no ability to move voluntarily
- loses control of vital functions such as breathing

When cardiac arrest develops, all cells in the body are affected, although the brain may sustain the most significant and immediate injury.

**Interaction of
Respiratory,
Cardiac, and
Brain
Functions**

The heart, lungs, and brain function interdependently. The lungs oxygenate the blood, and the heart delivers oxygenated blood to the brain.

Cardiac arrest keeps oxygen from the brain and other vital organs. Sudden blocks of blood flow or hemorrhage (bleeding) within the brain—the condition we call stroke—will keep oxygen from a portion of the brain. In either case this lack of oxygen will lead to a loss of brain function.

Brain function also affects cardiac and respiratory function, which special centers in the brain control. Because the brain is the controlling center for other vital organ systems, brain dysfunction, such as that which may develop after a stroke, may contribute to cardiopulmonary failure and death.
