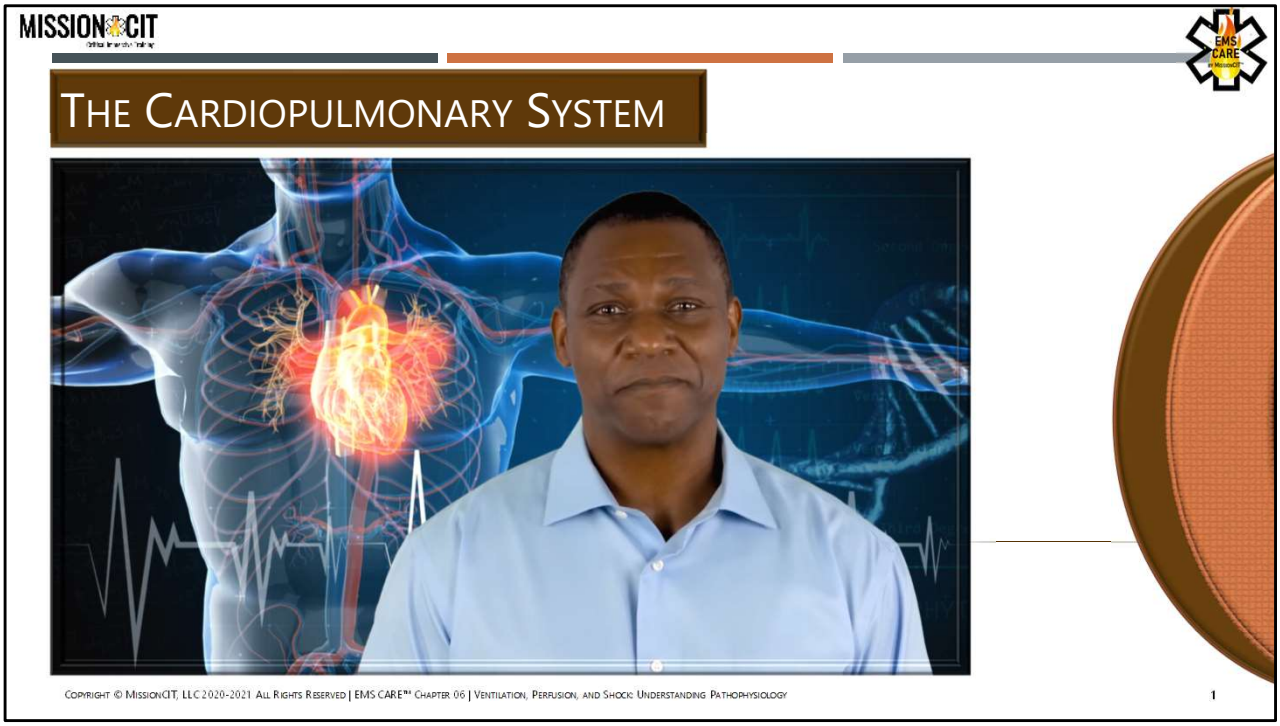
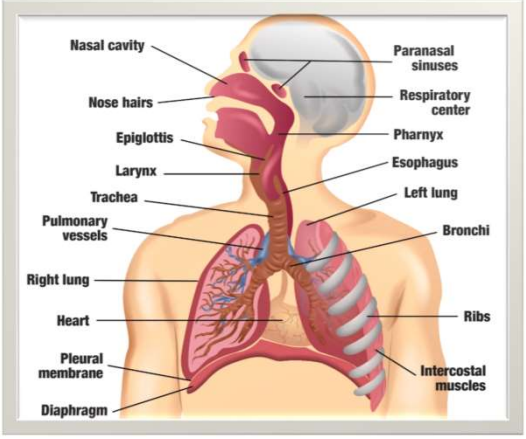


In this lesson, we will talk about the Cardiopulmonary System. This includes the heart, blood vessels and blood, blowhole, trachea, bronchi, and lungs. These interdependent systems are responsible for picking up and carrying oxygen to the cells of the body and transporting and discarding carbon dioxide. Let's talk more in detail.

MISSION CIT

Functions of the Cardiopulmonary System

- Primary purpose – deliver oxygen and remove carbon dioxide
- Respiratory and cardiovascular systems work together
  - ✓ Bring oxygen into body
  - ✓ Distribute to cells
  - ✓ Remove waste products
- Any breakdown can result in system failure



Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

The primary purposes of the cardiopulmonary system are to deliver oxygen to metabolically active tissues and to remove carbon dioxide and metabolites. External respiration, or gas exchange between the lungs and atmosphere, is linked to internal cellular respiration by the cardiovascular system.
The Cardiopulmonary System is where the respiratory and cardiovascular systems work together to do three vital functions:

- First, bringing oxygen into the body.
- Next, distributing oxygen to the cells.
- And then, removing waste products from the cells.

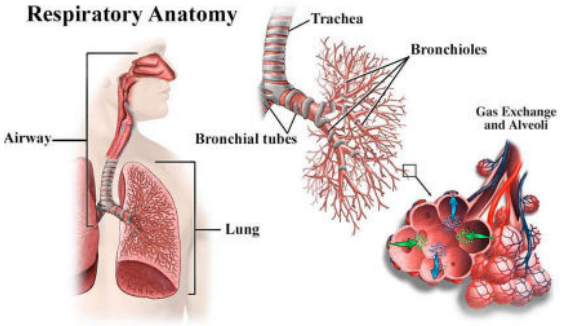
Note that any breakdown can result in system failure.

Let's discuss more about the respiratory and cardiovascular systems in detail.

MISSION CIT

Respiratory System

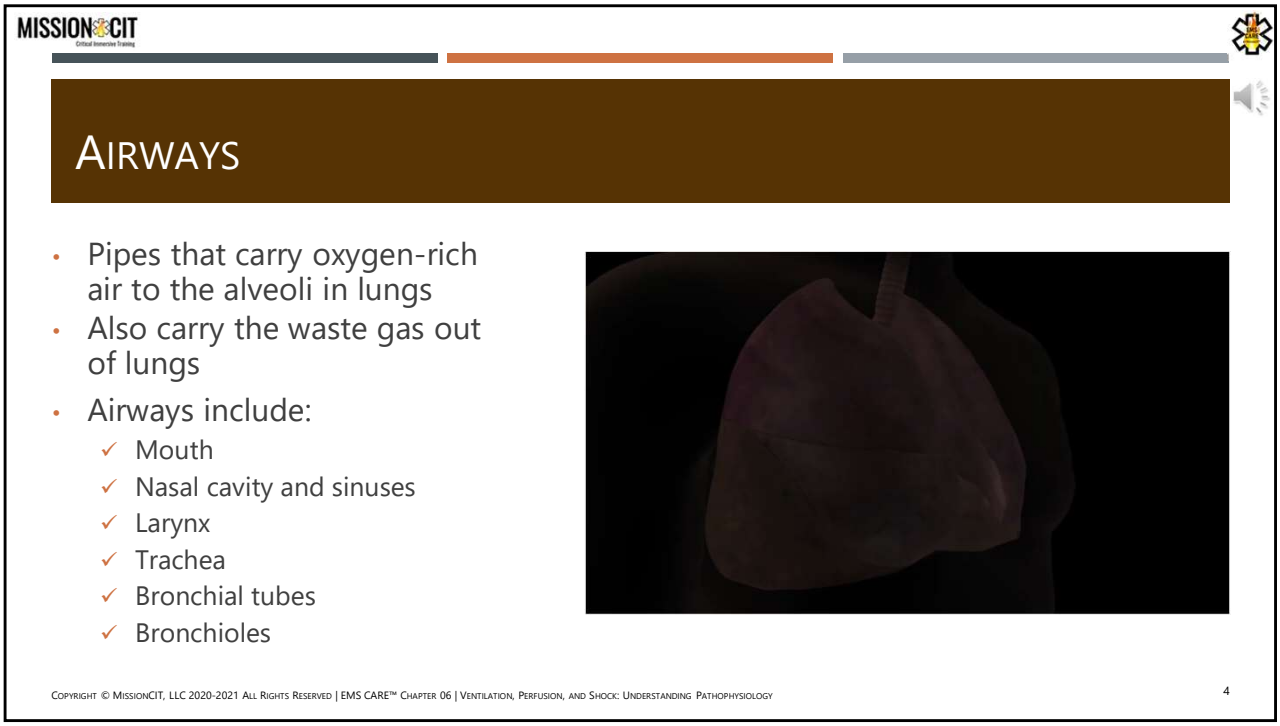
- Body cells need a continuous supply of oxygen
- Sequence of events that results in the exchange of oxygen and carbon dioxide between the atmosphere and the body cells
- Works with circulatory system to provide oxygen and to remove waste products of metabolism
- Helps regulate pH of blood



Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

When the respiratory system is mentioned, people generally think of breathing, but breathing is only one of the activities of the respiratory system. The body cells need a continuous supply of oxygen for the metabolic processes that are necessary to maintain life. The respiratory system works with the circulatory system to provide this oxygen and to remove the waste products of metabolism. It also helps to regulate the pH of the blood.

Respiration is the sequence of events that results in the exchange of oxygen and carbon dioxide between the atmosphere and the body cells. Every 3 to 5 seconds, nerve impulses stimulate the breathing process, or ventilation, which moves air through a series of passages into and out of the lungs. After this, there is an exchange of gases between the lungs and the blood. This is called external respiration. The blood transports the gases to and from the tissue cells. The exchange of gases between the blood and tissue cells is internal respiration. Finally, the cells utilize the oxygen for their specific activities: this is called cellular metabolism, or cellular respiration. Together, these activities constitute respiration.



The airways are pipes that carry oxygen-rich air to the alveoli in your lungs. They also carry the waste gas carbon dioxide out of your lungs. The airways include these parts of your body:

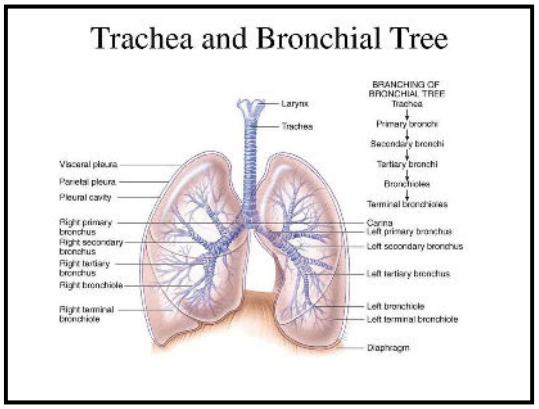
- Mouth
- Nose and linked air passages called the nasal cavity and sinuses
- Larynx or the voice box
- Trachea or the windpipe
- Tubes called bronchial tubes, or bronchi, and their branches
- Small tubes called bronchioles that branch off of the bronchial tubes

When you breathe in, air comes in your nose or mouth and travels down your windpipe and into your lungs. The oxygen you inhale goes into your bloodstream, and carbon dioxide from your body comes out when you exhale. Watch this video to learn more about what happens when you breathe.

MISSION CIT

TRACHEOBRONCHIAL TREE

- The branching tree of airways beginning at larynx and extending into the lungs as bronchioles
- Constitutes:
  - ✓ The trachea
  - ✓ Left and right main bronchi
  - ✓ Intermediate branches
  - ✓ Smaller subdivisions



COPYRIGHT © MISSIONCIT, LLC 2020-2021 ALL RIGHTS RESERVED | EMS CARE™ CHAPTER 06 | VENTILATION, PERFUSION, AND SHOCK: UNDERSTANDING PATHOPHYSIOLOGY

The tracheobronchial tree is the branching tree of airways beginning at the larynx and extending inferiorly and peripherally into the lungs as bronchioles. The luminal diameter decreases as the branching increases more peripherally into the lungs. The walls of the airway down to the level of the bronchioles contain C-shaped rings composed of hyaline cartilage to maintain luminal patency.

When described as an inverted tree, the tracheobronchial tree constitutes:

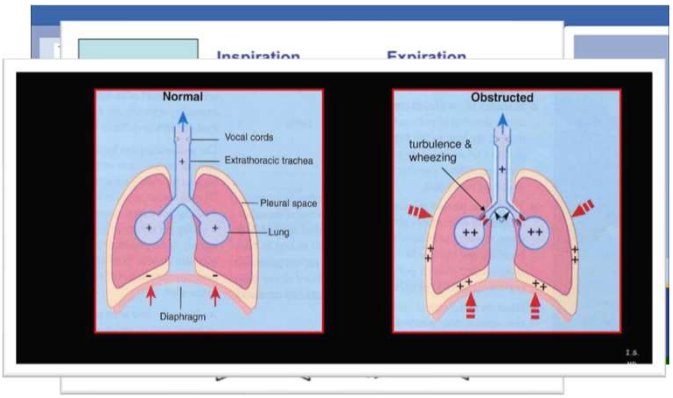
- The trunk: The trachea
- Two major branches: The left and right main (primary) bronchi which bifurcate at the carina located in the transthoracic plane of Ludwig
- Several intermediate branches: The lobar (secondary) and segmental (tertiary) bronchi within the lungs
- Many further consistent smaller and smaller subdivisions, terminating in the alveoli in the

peripheral of the lungs

MISSION CIT

AIRWAY OBSTRUCTION

- Upper airway obstruction:
  - ✓ Caused by a foreign body, tumor, inflammation, infection, injury or a congenital condition
  - ✓ Croup, wheezing, laryngitis or difficulty breathing
- Lower airways obstruction:
  - ✓ Occur when vocal cords close or become narrow
  - ✓ Prevents adequate amount of air inhalation



COPYRIGHT © MISSIONCIT, LLC 2020-2021 ALL RIGHTS RESERVED | EMS CARE™ CHAPTER 06 | VENTILATION, PERFUSION, AND SHOCK: UNDERSTANDING PATHOPHYSIOLOGY

Airway obstruction is a blockage of respiration in the airway. It can be broadly classified into being either in the upper airway or lower airway. Airway obstruction can be congenital (present at birth), or it can be acquired later in life.

Upper airway obstructions can be caused by a foreign body, tumor, inflammation, infection, injury, or a congenital condition. Croup, wheezing, laryngitis, or difficulty breathing because of a swallowed or inhaled foreign object can cause upper airway obstruction.

Lower airway obstructions are sometimes referred to as obstructive lung diseases. Lower airway obstruction

condition occurs when the vocal cords close or become narrow. This prevents the right amount of air inhaled in each breath, and it also prevents the pulmonary arteries from receiving the right amount of oxygen. Chronic Obstructive Pulmonary Disease (COPD) is a common type of lower airway obstruction.
This video by Learn More Breathe Better, a national health education program sponsored by the National Heart, Lung, and Blood Institute (N-H-L-B-I), part of the National Institutes of Health (NIH), aims to raise awareness about lung health.

The Lungs

- Part of lower airway
- A pair of organs in the chest
- Have spongy texture and pinkish-gray in color
- Inhale (Breathe in):
  - ✓ Air enters lungs and oxygen from the air moves from lungs to blood
- Exhale (Breathe out):
  - ✓ Waste gas moves from blood to lungs is exhaled



Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

The Lungs are part of the lower airway. Your lungs are a pair of organs in your chest. They have a spongy texture and are pinkish-gray in color.

When you inhale, air enters your lungs and oxygen from the air moves from your lungs to your blood. At the same time, carbon dioxide, a waste gas, moves from your blood to the lungs and is exhaled. This process is called gas exchange and is essential to life.

Lung Anatomy

- Lungs lie on each side of the heart inside the chest cavity
- Right lung divided into three lobes (sections)
- Left lung divided into two lobes
- When you breathe in, air enters airways and travels down into the alveoli (air sacs) in the lungs

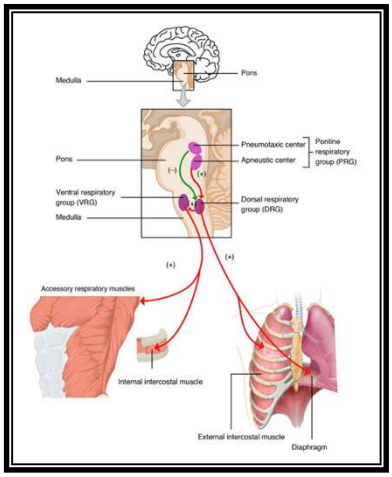


Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

Your lungs lie on each side of your heart inside your chest cavity. The right lung is divided into three lobes, and the left lung is divided into two lobes. Your left lung is slightly smaller than your right lung, since your heart takes up some space on the left side. When you breathe in, air enters your airways and travels down into the alveoli in your lungs. This is where gas exchange takes place.

Respiratory Dysfunction

- Disruption of respiratory control
  - ✓ Respirations controlled in brain by the medulla oblongata
  - ✓ Any event impacting function of the medulla oblongata can affect minute volume
  - ✓ Infection, drugs, toxins, trauma



Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

9

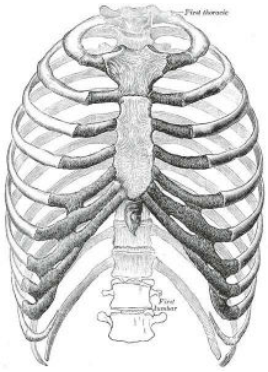
Breathing is usually automatic, controlled subconsciously by the respiratory center at the base of the brain. Breathing continues during sleep and usually even when a person is unconscious. Sensory organs in the brain, the aorta, and carotid arteries monitor the blood and sense oxygen, and carbon dioxide levels. Normally, an increased concentration of carbon dioxide is the strongest stimulus to breathe more deeply and more frequently.

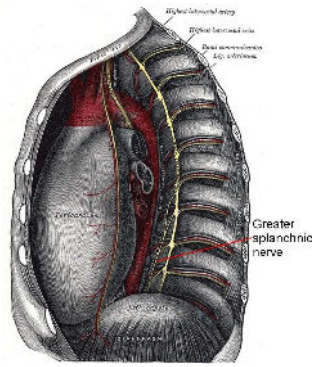
Conversely, when the blood's carbon dioxide concentration is low, the brain decreases the frequency

and depth of breaths. Several important conditions may disrupt respiratory control. Respiration is controlled by the respiratory center in the brain stem in response to CO2 levels. Medulla Oblongata sets the basic rhythm of breathing. Pons smooths out respiratory rate and influence depth and length of respiration. As such, any event impacting the function of the medulla oblongata can affect minute volume. This includes infection, drugs, toxins, or trauma.

Respiratory Dysfunction (Cont.)

- Disruption of pressure
  - ✓ If wall of thorax is compromised (punctures, rib fractures), ability to inhale and exhale is impacted and minute volume is reduced
  - ✓ Air or blood accumulating in chest (pleural space) also compromises respiration



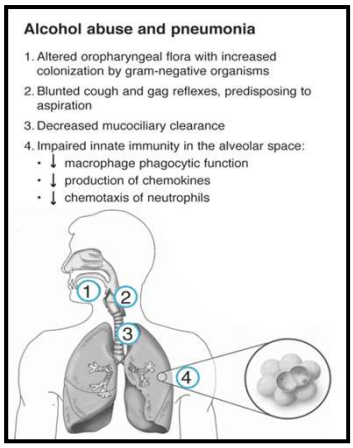


Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

So, if the wall of the thorax is compromised, for example by punctures or rib fractures, then the ability to inhale and exhale is impacted, and minute volume is reduced.
In addition, air or blood accumulating in the chest called the pleural space also compromises respiration.

Respiratory Dysfunction (Cont.)

- Disruption of lung tissue
- Trauma or medical problems can compromise the ability of alveoli to exchange gases
- Less oxygen gets in; less carbon dioxide gets out.
- Can result in low oxygen levels (hypoxia) and high carbon dioxide levels (hypercapnia)

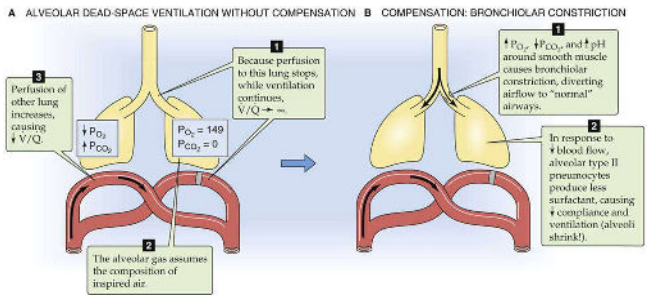


Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

There are several important conditions that may cause disruption of lung tissue. First, trauma or medical problems can compromise the ability of alveoli to exchange gases. So, when less oxygen gets in; less carbon dioxide gets out. Together, this can result in low oxygen levels or hypoxia, and high carbon dioxide levels or hypercapnia.

Respiratory Compensation

- Body attempts to compensate for gas exchange deficits
- Chemoreceptors detect changing oxygen and carbon dioxide levels
- Brain stimulates respiratory system to increase rate and/or tidal volume

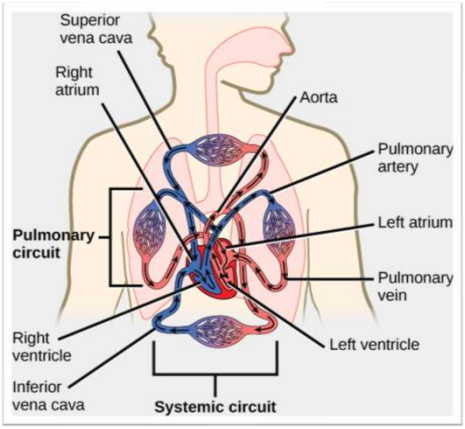


Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

Respiratory Compensation occurs when the body attempts to compensate for gas exchange deficits.
First, Chemoreceptors detect changing oxygen and carbon dioxide levels.
Then, the Brain stimulates the respiratory system to increase the rate and/or tidal volume.

Circulatory System

- Any change in tidal volume or respiratory rate reduces minute volume
- Respiratory dysfunction occurs any time something interferes with minute volume



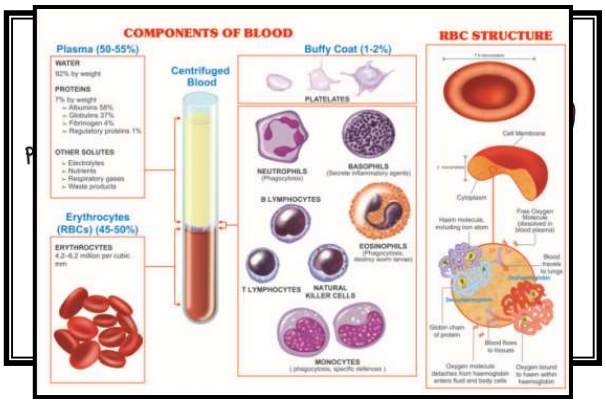
Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

Next, we discuss about the circulatory system, which is made up of the heart and blood vessels, supports the respiratory system by bringing blood to and from the lungs. The circulatory system helps to deliver nutrients and oxygen from the lungs to tissues and organs throughout the body and removes carbon dioxide and waste products. Other body systems that work with the respiratory system include the nervous system, lymphatic system, and immune system.

MISSION CIT

Blood and Its Components

- Red blood cells
  - ✓ Carry oxygen to the body
- White blood cells
  - ✓ Part of the body's immune system
- Platelets
  - ✓ Help with clotting
- Plasma
  - ✓ Carries different types of blood cells to all parts



Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

Blood carries oxygen and nutrients to living cells and takes away their waste products. It also delivers immune cells to fight infections and contains platelets that can form a plug in a damaged blood vessel to prevent blood loss.

Through the circulatory system, blood adapts to the body's needs. It has four main components: plasma, red blood cells, white blood cells, and platelets. Blood has many different functions, including: transporting oxygen and nutrients to the lungs and tissues.

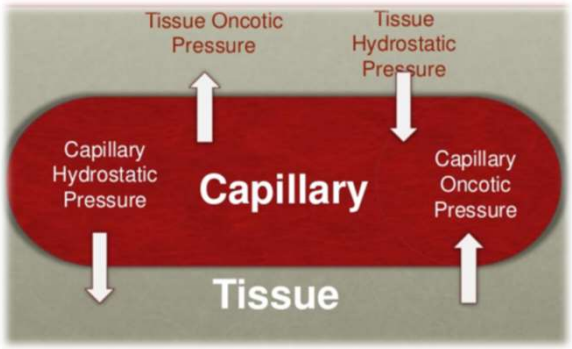
- Red blood cells (RBCs) carry oxygen to the body. Each RBC lives for about 4 months. RBCs contain a protein called hemoglobin. Hemoglobin allows RBCs to pick up oxygen from the lungs. Iron is needed to make hemoglobin.
- White blood cells (WBCs) are part of the body's immune system. WBCs, help fight infections and diseases. There are different types of WBCs. These include neutrophils, lymphocytes, monocytes, eosinophils, and basophils. WBCs live for hours, days, months, or years depending on the specific type.
- Platelets are cells that help with clotting. When you have a cut or bruise, platelets come together to form a clot or "plug." This helps to control bleeding, so your body doesn't lose too much blood. Platelets live in the body for about 7 to 10 days.
- Plasma is the liquid portion of blood. It carries the different types of blood cells to all the parts of the body. Plasma also carries proteins including clotting factors.

Clotting factors help platelets with the clotting process.

MISSION CIT

THE BLOOD

- Plasma oncotic pressure
  - ✓ Proteins in plasma attract water away from the area around cells and pulls it into bloodstream
- Hydrostatic pressure
  - ✓ Water is pushed back out of the blood vessels towards the cells
- Problems with these proteins can cause an imbalance



COPYRIGHT © MISSIONCIT, LLC 2020-2021 ALL RIGHTS RESERVED | EMS CARE™ CHAPTER 06 | VENTILATION, PERFUSION, AND SHOCK: UNDERSTANDING PATHOPHYSIOLOGY

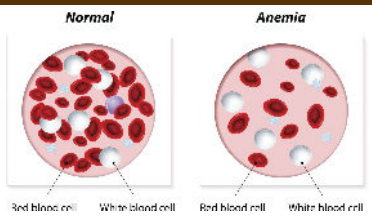
Two important concepts about Blood and pressure.

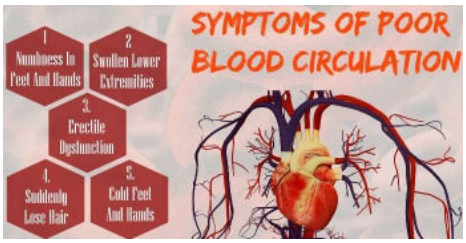
First, Oncotic pressure, or colloid osmotic pressure, is a form of osmotic pressure induced by proteins in the plasma. This attracts water away from the area around cells and then pulls it back into the bloodstream.

Second, Hydrostatic pressure is where Water is pushed back out of the blood vessels towards the cells.
Problems with these proteins can cause an imbalance in overall pressure.

Blood Dysfunction

- Without enough blood, oxygen and carbon dioxide cannot be properly moved around
  - ✓ Bleeding
  - ✓ Dehydration
  - ✓ Anemia
  - ✓ Liver failure





Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

The heart, blood vessels, and blood combine to provide oxygen to the cells. Disruption at this level interrupts perfusion.

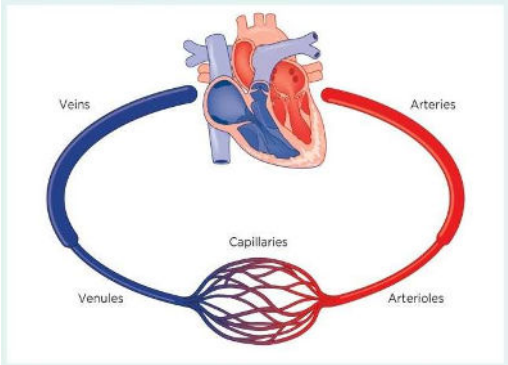
So, without enough blood, oxygen and carbon dioxide cannot be properly moved around. Four significant conditions that can contribute to insufficient blood are:

- Bleeding
- Dehydration
- Anemia, and
- Liver failure

MISSION CIT

The Blood Vessels

- Transport blood throughout the body
- Transport blood cells, nutrients, oxygen to the tissues
- Five types:
  - ✓ Arteries
  - ✓ Arterioles
  - ✓ Capillaries
  - ✓ Venules
  - ✓ Veins



Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

The blood vessels are the components of the circulatory system that transport blood throughout the human body. These vessels transport blood cells, nutrients, and oxygen to the tissues of the body. They also take waste and carbon dioxide away from the tissues.

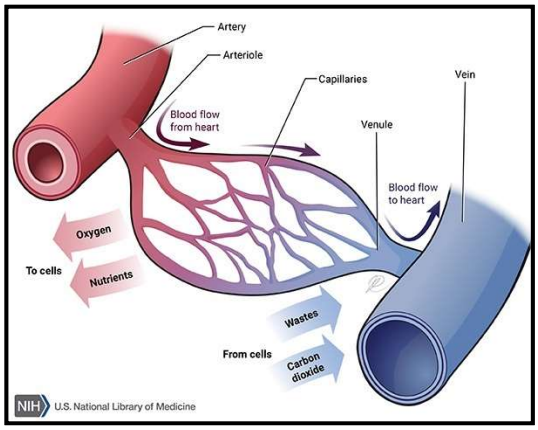
There are five types of blood vessels: the arteries, which carry the blood away from the heart; the arterioles; the capillaries, where the exchange of water and chemicals between the blood and the tissues occurs; the venules; and the veins, which carry blood from the capillaries back towards the heart.

Here is a diagram of the blood vessels showing the network of arteries, veins, and capillaries.

MISSION CIT

THE BLOOD VESSELS (CONT.)

- Take oxygenated blood from lungs via heart to capillaries
- Where gas exchange takes place
- Between cells and capillaries
- Return blood to lungs via heart for gas exchange
- Between capillaries and alveoli



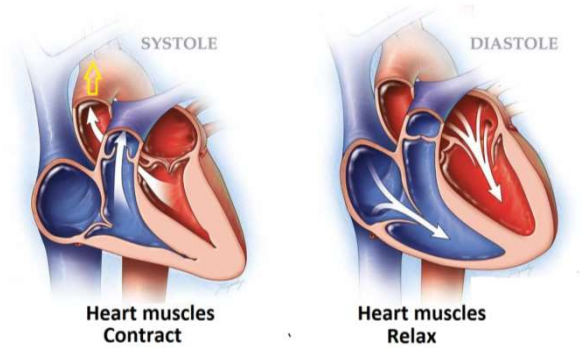
COPYRIGHT © MISSIONCIT, LLC 2020-2021 ALL RIGHTS RESERVED | EMS CARE™ CHAPTER 06 | VENTILATION, PERFUSION, AND SHOCK: UNDERSTANDING PATHOPHYSIOLOGY

Blood vessels function to transport blood. In general, arteries and arterioles transport oxygenated blood from the lungs to the body and its organs, and veins and venules transport deoxygenated blood from the body to the lungs.

First, blood vessels take oxygenated blood from the lungs via the heart to capillaries. Gas exchange takes place between the cells and the capillaries. The blood is then returned to the lungs via the heart for gas exchange between capillaries and alveoli.

THE BLOOD VESSELS (CONT.)

- Need adequate pressure to make cycle work
- Pressure controlled by changing diameter of blood vessels
- Stretch receptors monitor pressure
- Pressure can be increased or decreased depending on situation

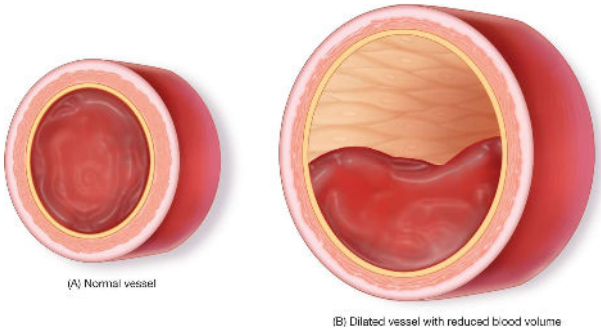


COPYRIGHT © MISSIONCIT, LLC 2020-2021 ALL RIGHTS RESERVED | EMS CARE™ CHAPTER 06 | VENTILATION, PERFUSION, AND SHOCK: UNDERSTANDING PATHOPHYSIOLOGY

So, blood vessels need adequate pressure to make the overall cycle work properly. The changing diameter of the blood vessels controls this function, while the stretch receptors monitor the pressure.
Hence, pressure can be increased or decreased depending on the situation.

Blood Vessel Dysfunction

- Loss of Tone
  - ✓ Vessels lose ability to constrict and dilate
  - ✓ Pressure drops
- Causes Include
  - ✓ Trauma
  - ✓ Infection
  - ✓ Allergic reaction

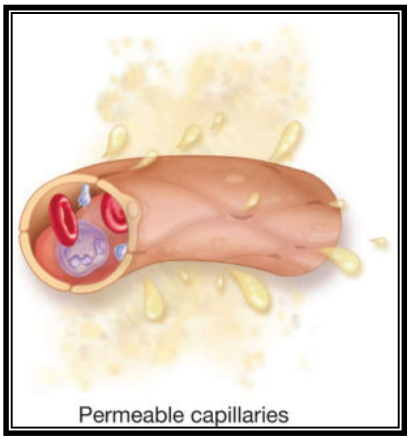


Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

Blood Vessel Dysfunction may be caused by the Loss of Tone. Loss of Tone is where Vessels lose the ability to constrict and dilate. The main symptom is that Pressure drops. Causes include: Trauma, Infection, and Allergic reaction. This image showing Blood Vessel Dysfunction presents a normal vessel and a dilated blood vessel. The dilated blood vessel shows reduced blood volume as a result of the condition.

Blood Vessel Dysfunction | Excessive Permeability

- Capillaries leak fluid out of their walls
- Caused by severe infection (sepsis), high altitude, and certain diseases

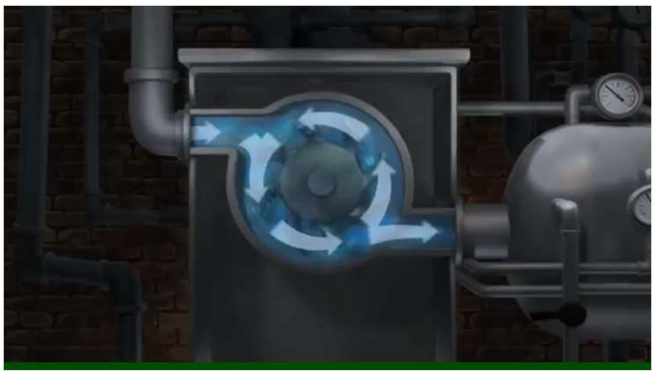


Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

Another cause of Blood Vessel Dysfunction is excessive permeability. Excessive permeability is where the capillaries leak fluid out of their walls. It may be caused by severe infection or sepsis, high altitude, and certain diseases. This image shows permeable capillaries. Note how the increased permeability allows too much fluid to escape through the capillary walls.

Blood Vessel Dysfunction | Hypertension

- Hypertension – When the force of blood pushing against the walls of blood vessels is too high
- Causes significant long-term effects
  - ✓ Leading cause of
  - ✓ Heart disease
  - ✓ Stroke
  - ✓ Kidney disease
  - ✓ Death

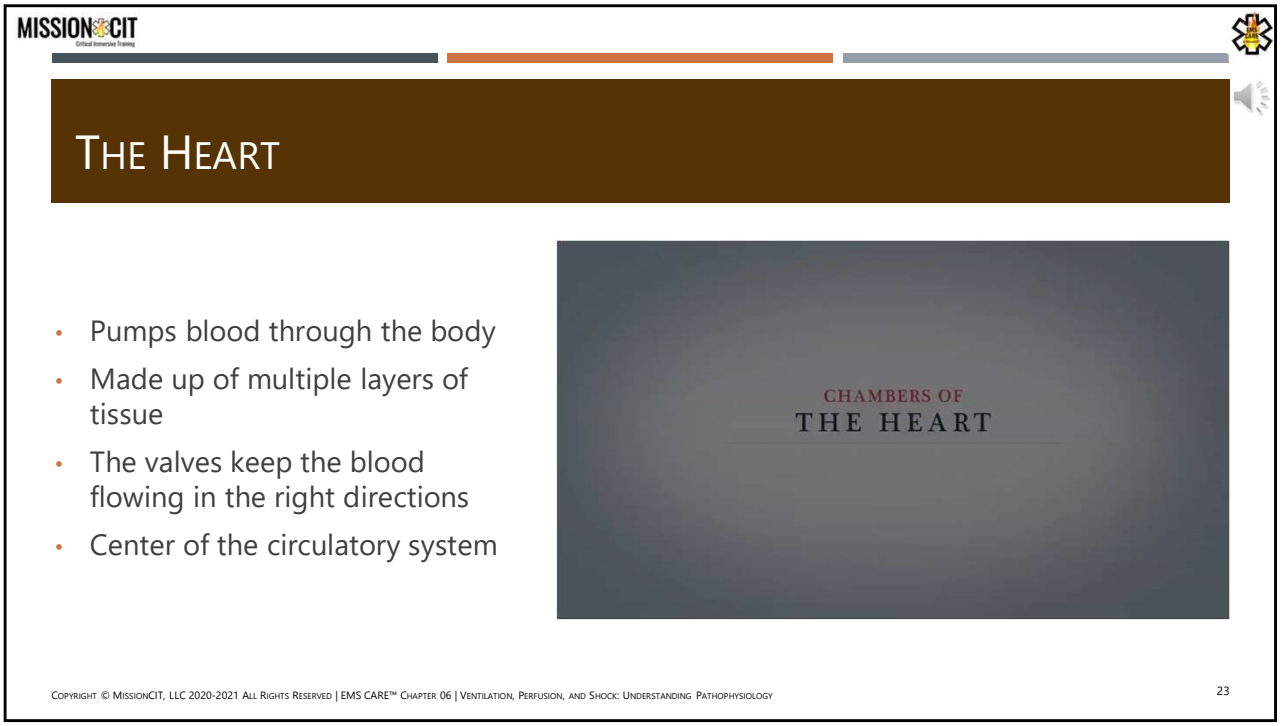


Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

One of the common causes of Blood Vessel Dysfunction is Hypertension or High Blood Pressure. Hypertension is when your blood pressure, the force of your blood pushing against the walls of your blood vessels, is consistently too high. There may be significant long-term effects of high blood pressure. These include major risk factors for coronary artery disease, stroke, heart failure, atrial fibrillation, peripheral arterial disease, vision loss, chronic kidney disease, and dementia.

Systemic vascular resistance (SVR) refers to the resistance to blood flow which contributes to the blood pressure level.

Find out what's really happening in the body when the heart is working overtime due to high blood pressure, a leading cause of death in the United States. Watch this video to learn how.



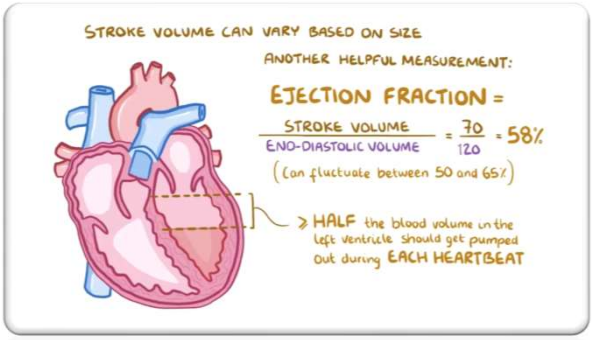
The heart is an organ about the size of your fist that pumps blood through your body. It is made up of multiple layers of tissue.

Your heart is at the center of your circulatory system. This system is a network of blood vessels, such as arteries, veins, and capillaries, that carries blood to and from all areas of your body. Your blood carries the oxygen and nutrients that your organs need to work properly. Blood also carries carbon dioxide to your lungs so you can breathe it out. Inside your heart, valves keep blood flowing in the right direction. Your heart's electrical system controls the rate and rhythm of your heartbeat. A healthy heart supplies your body with the right amount of blood at the rate needed to work well.

Watch this video to learn more about the different parts of the heart and how they work together.

Stroke Volume

- Stroke volume is based on:
  - ✓ Preload
    - Amount of blood returning to heart
  - ✓ Contractility
    - How hard heart squeezes
  - ✓ Afterload
    - Pressure the heart has to pump against to force blood out into the system



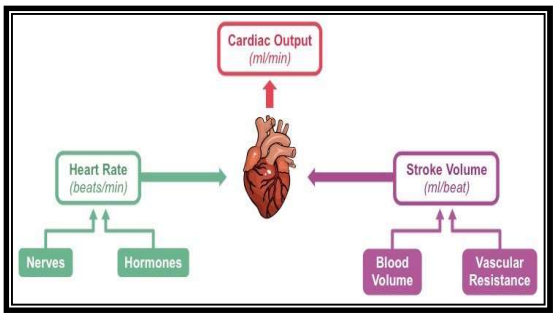
Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

24

Stroke volume is the volume of blood pumped out of the left ventricle of the heart during each systolic cardiac contraction. The heart's stroke volume is based on three factors. The first is the Preload. Preload is the amount of blood returning to the heart. The second is Contractility which is how hard the heart squeezes. The third is Afterload. Afterload is the Pressure the heart has to pump against to force blood out into the system.

Cardiac Output

- Stroke volume x beats per minute = cardiac output
- Slowing heart rate or decreasing stroke volume reduces cardiac output
- Very fast heart rates reduce cardiac output
  - ✓ Inadequate time for heart to refill between contractions

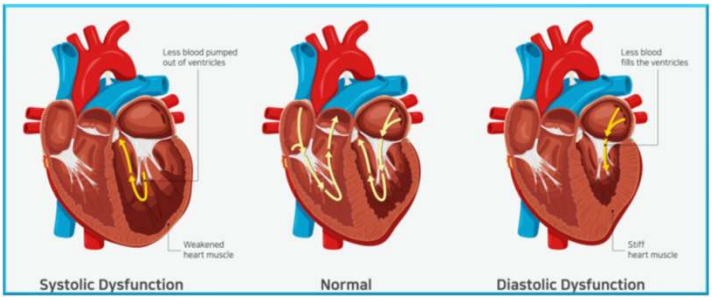


Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

Cardiac output (CO) is the amount of blood pumped by the heart per minute, and is the mechanism whereby blood flows around the body, especially providing blood flow to the brain and other vital organs.
The heart rate and the stroke volume determine the cardiac output. Note that a slowing heart rate or decreasing stroke volume reduces cardiac output. But also, very fast heart rates reduce cardiac output, too as there is inadequate time for the heart to refill between contractions.

Heart Dysfunction

- Mechanical problems
  - ✓ Physical trauma
  - ✓ Squeezing forces
  - ✓ Cell death (heart attack)
- Electrical problems
  - ✓ Damage to heart's ability to regulate rate



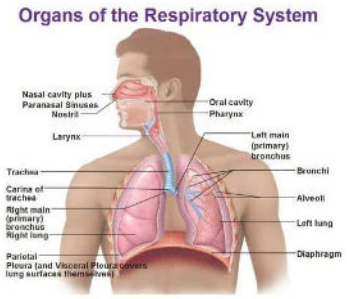
Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

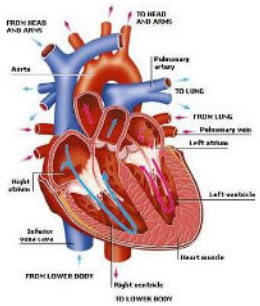
If disease or injury weakens your heart, your body's organs will not receive enough blood to work normally.

Reasons for Heart Dysfunction include Mechanical and Electrical problems. Mechanical issues may be a result of physical trauma, squeezing forces, and cell death, or heart attack. A problem with the electrical system or the nervous or endocrine systems, which control your heart rate and blood pressure can also make it harder for the heart to pump blood.

The Cardiopulmonary System

- Respiratory and circulatory systems work together to maintain homeostasis
- Must be a balance between ventilation (V) and perfusion (Q) for system to work properly
  - ✓ V/Q match
- Any breakdown in system impacts ratio causing possible life-threatening situation





Copyright © MissionCIT, LLC 2020-2021 All Rights Reserved | EMS CARE™ Chapter 06 | Ventilation, Perfusion, and Shock: Understanding Pathophysiology

So, the respiratory and circulatory systems work together to maintain homeostasis. The respiratory system moves gases into and out of the blood. The circulatory system moves blood to all parts of the body. There must be a balance between ventilation (V) and perfusion (Q) for the system to work properly. And, any breakdown in the system impacts a ratio causing possible life-threatening situations.

Also, remember that perfusion is the passage of blood, a blood substitute, or other fluid through the blood vessels or other natural channels in an organ or tissue. On this note, we complete this lesson and in the next, we discuss Shock.