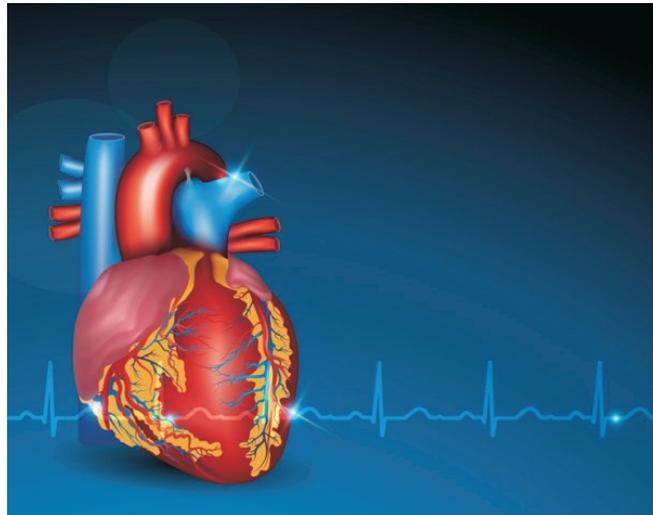


# Cardiovascular System: Anatomy and Physiology

**T**HE HEART, blood vessels, and blood make up the entirety of the cardiovascular system. Its purpose is to deliver oxygen to tissues and carry away waste through a complex network of blood vessels. If all the vessels of this network were laid end to end, they would extend for about 60,000 miles, which is far enough to circle the planet Earth more than twice!



## Objectives:



1. Identify and explain the primary organs and functions of the cardiovascular system.
2. Describe the blood flow through the heart identifying the deoxygenated portions (blue) and oxygenated portions (red) of the heart.
3. Relate the role of the cardiovascular system to other major body systems.

## Key Terms:



aorta	heart	pericardial sac
aortic valve	homeostasis	pulmonary valve
atria	homeostatic	semilunar valves
atrioventricular valve	hypertension	septum
atrium	hypotension	sinoatrial (SA) node
blood pressure	inferior vena cava	superior vena cava
bundle of His	left and right bundle branches	systolic
diastolic	mitral or bicuspid valve	tricuspid valve
endocardium	myocardium	ventricle
epicardium		

# Understanding the Cardiovascular System

The cardiovascular system has three main components: heart, blood vessels, and blood. The heart is a hollow, muscular organ that sits in the chest, slightly to the left of center. It beats approximately 100,000 times a day, pushing 2,000 gallons of blood through the body every 24 hours. All cells in the body need to have oxygen and nutrients, and they need their wastes removed. Most of the time, people are not aware of their heart. However, when they exercise or experience strong emotions, they might feel the heart beat powerfully and sense the blood pounding.

Most people associate the heart with pumping blood, but most do not realize that the cardiovascular system is also in charge of fighting disease and maintaining a stable internal environment, also called homeostasis, by regulating temperature and pH levels.

## FUNCTIONS OF THE CARDIOVASCULAR SYSTEM

The cardiovascular system has three major functions: transportation of materials, protection from pathogens, and regulation of the body's homeostasis.

**Transportation:** The cardiovascular system transports blood to almost all the body's tissues. The blood delivers essential nutrients and oxygen and removes wastes and carbon dioxide to be processed or removed from the body. Hormones are also transported throughout the body through this system.

**Protection:** The cardiovascular system protects the body through its white blood cells. White blood cells clean up cellular debris and fight pathogens that have entered the body. Platelets and red blood cells form scabs to seal wounds and prevent pathogens from entering the body. Blood also carries antibodies that provide specific immunity to pathogens that the body has previously been exposed to or has been vaccinated against.

**Regulation:** The cardiovascular system is instrumental in the body's ability to maintain **homeostatic** (tendency to maintain internal stability) control of several internal conditions. Blood vessels help maintain a stable body temperature by controlling the blood flow to the surface of the skin. Blood vessels near the skin's surface dilate during times of overheating to allow blood to cool down. In the case of hypothermia, these blood vessels constrict to keep blood flowing only to vital organs. Working with the lungs and kidneys the blood also helps balance the body's pH.

### The Heart

The **heart** is the complex pump of the circulatory system, pumping blood throughout the body for the purposes of tissue oxygenation and gas exchange. It is positioned between the lungs, behind and slightly to the left of the sternum. It is slightly larger than a closed fist which is approximately 5 inches long and 3.5 inches wide at its broadest point. By the end of a long life, a person's heart may have beat (expanded and contracted) more than 3 billion times. The average heart beats 100,000 times, pumping about 2,000 gallons of blood each day.

The heart is enclosed in a tough, protective sac called the **pericardial sac**. It is made of fibrous connective tissue and serves to protect the heart by providing lubrication allowing the heart to beat without friction. The wall of the heart consists of three layers:

The outmost layer of the heart is called the **epicardium**. It is a thin layer of connective tissue and fat that serves as an additional layer of protection for the heart.

The **myocardium** is the muscular, middle layer composed of specialized cardiac muscle cells.

The **endocardium** is the smooth, thin inner layer of the heart chambers that also covers heart valves.

## Upper Chambers

The inside of the heart consists of four chambers separated into two sides. Each side contains an **atrium** which receives blood into the heart and pumps it out to a **ventricle**, which pushes the blood out of the heart. The **atria** (plural for atrium) are the two upper chambers of the heart and receive the blood entering the heart. The right atrium receives deoxygenated

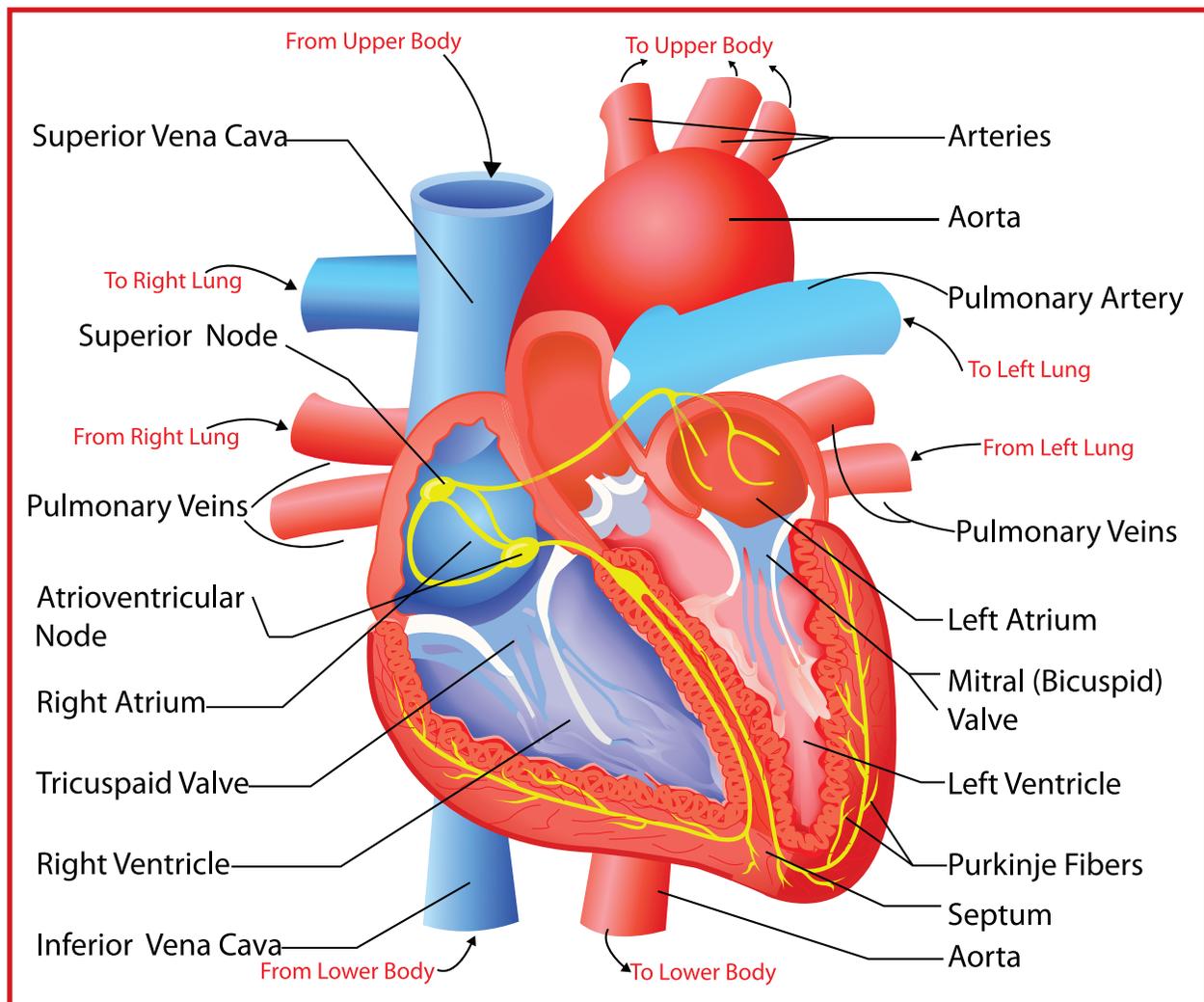


FIGURE 1. Anatomy of the heart and associated blood vessels.

blood from all parts of the body. The **inferior vena cava** brings blood from below and the **superior vena cava** brings blood from the upper parts of the body, the head, neck, and arms. The left atrium receives oxygenated blood returning from the lungs.

## Lower Chambers

The ventricles are the two lower chambers of the heart that pump blood out of each side of the heart. The right ventricle receives blood from the right atrium and pumps blood out to the lungs. The left ventricle receives blood from the left atrium and pushes blood out of the heart to the body

## Valves

As blood travels out of the heart chambers, it flows through valves that are designed to prevent blood from flowing backward. There is an **atrioventricular valve** that separate the atria and the ventricle on each side. The **tricuspid valve** consists of three flaps of fibrous connective tissue on the right side of the heart. The **mitral or bicuspid valve**, also made of fibrous connective tissue, is located on the left side.

**Semilunar valves** consist of three crescent-shaped cusps and prevent blood from flowing back into the ventricles. Blood passes through the **pulmonary valve** as it is ejected into the pulmonary arteries. Blood passes from the left ventricle through the **aortic valve** into the aorta. These valves allow blood to flow in only one direction through the heart, and the combination of the atrioventricular and semilunar heart valves determines the pathway of blood flow. Valves open or close based on pressure differences across the valve.

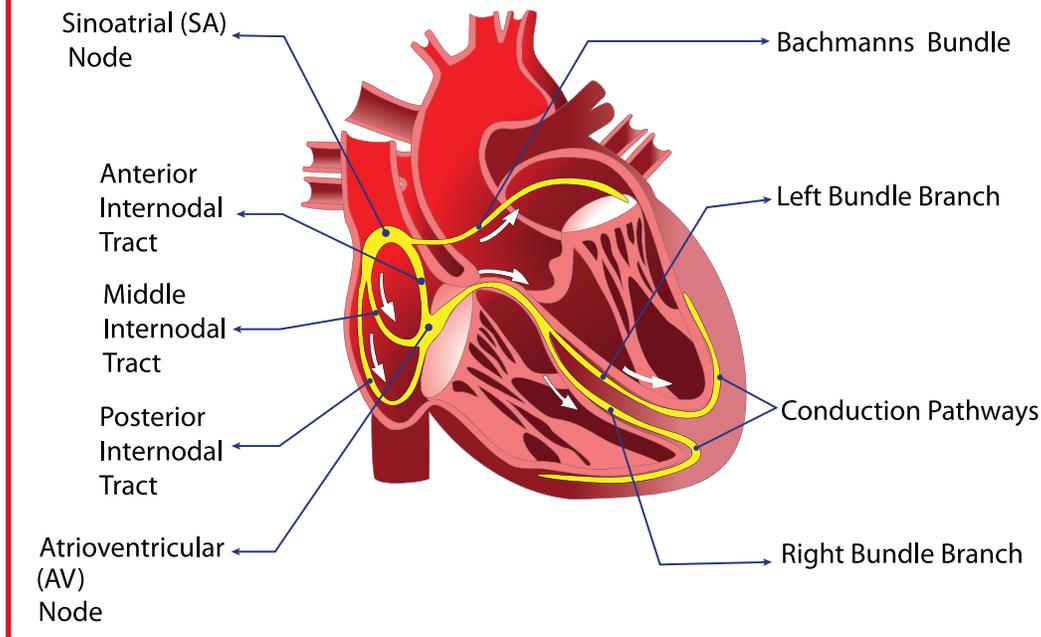
The sound of the heart valves shutting causes the heart sounds, often described as a “lub” and a “dub” that occur with each heart beat (lub-dub, lub-dub.) The closing of the mitral and tricuspid valves (atrioventricular valves) at the beginning of ventricular contraction cause the first part of the “lub-dub” sound made by the heart as it beats. The second part of the “lub-dub” is caused by the closure of the aortic and pulmonic valves at the end of ventricular contraction.

## Conduction System

A unique electrical conduction system in the heart causes it to beat in its regular rhythm. This electrical signal begins in the **sinoatrial (SA) node** and is sometimes called the heart’s “natural pacemaker.” It is a small area of tissue in the wall of the right atrium that sends out an electrical signal to start the contraction of the heart muscle. This signal causes the atria to contract first. The SA node fires to set a heart rate in a range of 60–100 beats per minute (bpm,) a normal range that varies from person to person. It is the sinoatrial node which determines the normal heart rate of an individual.

The **atrioventricular (AV) node** is responsible for slowing down the wave of contraction as the impulse enters the ventricles to allow the atria to completely contract and empty before the ventricles start to contract. The impulses then enter the base of the ventricle at the **bundle of His** (cardiac muscle fibers) which splits into two once in the ventricles, one going either

## Electrical System of the Heart



**FIGURE 2.** The sinoatrial (SA) node in the right atrium creates the electrical activity that acts as the heart's natural pacemaker.

side of the interventricular septum called the **left and right bundle branches** along the septum. These specialized fibers conduct the impulses at a very rapid velocity throughout the ventricles.

### Septum

The **septum** is the wall that separates the left and right side of the heart. This is an important function since the right side of the heart carries deoxygenated blood and the left side of the heart carries oxygenated blood. Without the septum, the blood would mix.

### Aorta

The **aorta** is the largest artery in the body. The aorta begins at the top of the left ventricle and receives blood through the aortic valve. Then the aorta extends down to the abdomen, where it splits into smaller arteries.

## NORMAL BLOOD FLOW THROUGH THE HEART

The heart's four chambers work as a double-sided pump. To move blood through the heart the cardiac muscle needs to contract in an organized way. The right and left sides of the heart work together. The atria first contract pushing blood into the ventricles. After the ventricles fill

with blood, they contract pushing blood either to the lungs or out to the body. The contractions are triggered by the electrical pulse that starts in the SA node and then travels through the ventricles.

The right atrium receives deoxygenated blood from the body and pumps it to the right ventricle through the tricuspid valve. The right ventricle pumps the deoxygenated blood to the lungs through the pulmonary valve. The left atrium receives oxygenated blood from the lungs and pumps it to the left ventricle through the mitral valve. The left ventricle pumps the oxygenated blood through the aortic valve out to the rest of the body. When the heart functions normally, all four chambers work together in a continuous and coordinated effort to keep oxygenated blood circulating throughout the body.

## Blood Pressure

**Blood pressure** (B/P) reflects the pressure exerted on blood vessels when blood is forced out of the heart during its contraction. Pressure in the ventricles increases during ventricular contraction and decreases during ventricular relaxation resulting in two measurements. **Systolic** pressure is the pressure that the heart produces when blood is forced out of the heart. Systolic blood pressure is always higher than diastolic blood pressure. **Diastolic** pressure is



## EXPLORING OUR WORLD...

### SCIENCE CONNECTION: Stress and High Blood Pressure

Hypertension is a silent killer because it has no early significant symptoms but creates an extra load on the heart and blood vessels. In stressful situations the body produces a surge of hormones. These hormones temporarily increase blood pressure by causing the heart to beat faster and blood vessels to narrow.

There's no proof that stress by itself causes long-term high blood pressure. But reacting to stress in unhealthy ways can increase the risk of high blood pressure, heart attacks and strokes. Certain behaviors are linked to higher blood pressure, such as:

- Smoking
- Drinking too much alcohol
- Eating unhealthy foods

Also, heart disease may be linked to certain health conditions related to stress, such as:

- Anxiety
- Depression
- Isolation from friends and family

Increases in blood pressure related to stress can be dramatic. But when stress goes away, blood pressure returns to normal. However, even temporary spikes in blood pressure can damage the blood vessels, heart and kidneys.

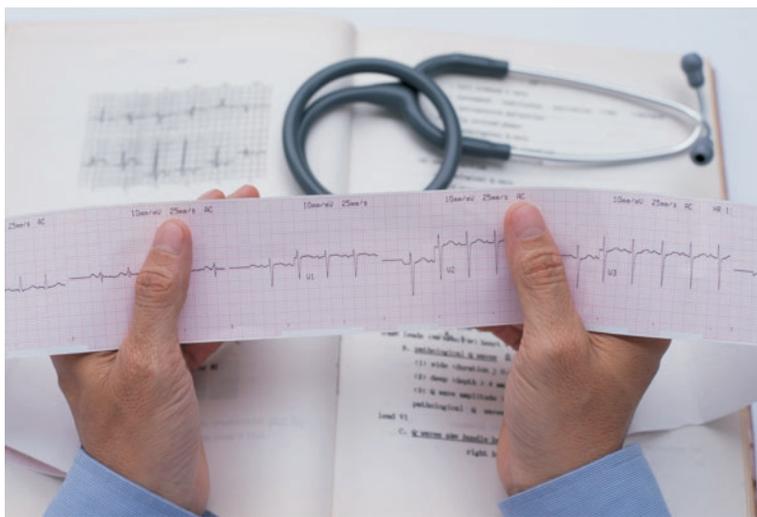
the pressure exerted when the ventricles are relaxed and filling. The normal range for blood pressure is between 90/60 mmHg and 120/80 mmHg.

**Hypertension** occurs when pressures are higher than 140/90 mmHg. **Hypotension** occurs with the systolic blood pressure of less than 90 mmHg or diastolic of less than 60 mmHg. Blood pressure is one of the principal vital signs.

## CARDIOVASCULAR SYSTEM AND HOMEOSTASIS

The cardiovascular system works closely with other systems in our bodies. It plays a vital role maintaining **homeostasis** (internal stability) through the continuous and controlled movement of blood to provide adequate blood to all tissues. Blood flow must be redirected continually to the tissues as they become more active. Circulation of blood supplies oxygen and nutrients to our bodies by working with the respiratory system. At the same time, the cardiovascular system helps carry waste and carbon dioxide out of the body.

In order to maintain homeostasis in the cardiovascular system and provide adequate blood to the tissues, blood flow must be redirected continually to the tissues as they become more active. For example, when an individual is exercising, more blood will be directed to skeletal muscles, the heart, and the lungs. Following a meal, more blood is directed to the digestive system. Only the brain receives a constant supply of blood whether a person is active, resting, thinking, or engaged in any other activity. Hormones produced by the endocrine system are also transported through the blood in the cardiovascular system.



**FIGURE 3.** Maintaining homeostasis requires that the body continuously monitor its internal conditions. From body temperature to blood pressure to levels of certain nutrients, the body's internal stability.

### Summary:



The cardiovascular system consists of the heart and the blood vessels. It provides oxygen and nutrients to tissues while removing wastes. The heart is divided into two atria and two ventricles working as a double-sided pump. The atria receive blood while the ventricles pump blood out of the heart.

The cardiac cycle consists of the atria contracting while the ventricles relax, and vice versa. The cardiac conduction system is a group of specialized cardiac muscle cells in the walls of the heart that send signals to the heart muscle causing it to contract. The main components of the cardiac conduction system are the SA node, AV node, bundle of His, and bundle branches. Electrical activity of the cardiac cycle can be recorded via an electrocardiogram.

Blood pressure is the force that blood exerts against the inside of the blood vessels. It is measured as systolic pressure over diastolic pressure.

The cardiovascular system runs as a complex system of checks and balances, maintaining homeostasis to regulate equilibrium of all body systems.

## Checking Your Knowledge:



1. Identify and explain the primary organs and functions of the cardiovascular system.
2. Describe the blood flow through the heart identifying the deoxygenated portions (blue) and oxygenated portions (red) of the heart.
3. Explain how the electrical impulse of the SA node travels through the heart.
4. Describe three body systems that the cardiovascular system works
5. Describe how homeostasis is maintained in the cardiovascular system.

## Expanding Your Knowledge:



For most of history, scientists weren't quite sure why our hearts were beating or even what purpose they served. Eventually, we realized that these thumping organs serve the vital task of pumping clean blood throughout the body. But how? Edmond Hui investigates how it all works by taking a closer look at the heart's highly efficient ventricle system. View his TedEd "How The Heart Actually Pumps Blood" at <https://www.youtube.com/watch?v=ruM4Xhx32U>.

You can feel your heartbeat by pressing your fingertips firmly against the inside of your wrist (radial pulse) or on your neck (carotid pulse.) Practice taking your pulse several times a day. Discover that your heartbeat varies with the activities you do (increasing during exercise and stress, and lowering during relaxation and sleep.)

## Web Links:



### **Anatomy of Your Heart**

<https://www.thoughtco.com/heart-anatomy-373485>.

### **Anatomy and Physiology**

<https://courses.lumenlearning.com/boundless-ap/chapter/the-heart/>.

### **Cardiology Games**

<http://www.anatomyarcade.com/games/gamesCirculatory.html>

### **Heart and Circulatory System**

<https://kidshealth.org/en/kids/heart.html>

### **Label the Heart**

[https://www.sciencelearn.org.nz/labelling\\_interactives/1-label-the-heart](https://www.sciencelearn.org.nz/labelling_interactives/1-label-the-heart)