

JR. HIGH STUDENT



VOL. 2

# INTRODUCTION TO ANATOMY & PHYSIOLOGY

*Cardiovascular and Respiratory Systems*

wonders of the  
**HUMAN**  
**BODY**

Dr. Tommy Mitchell

First printing: June 2016

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Master Books,  
P.O. Box 726, Green Forest, AR 72638

Master Books® is a division of the  
New Leaf Publishing Group, Inc.

ISBN: 978-0-89051-928-8  
Library of Congress Number: 2016935317

Cover by Diana Bogardus  
Interior by Jennifer Bauer

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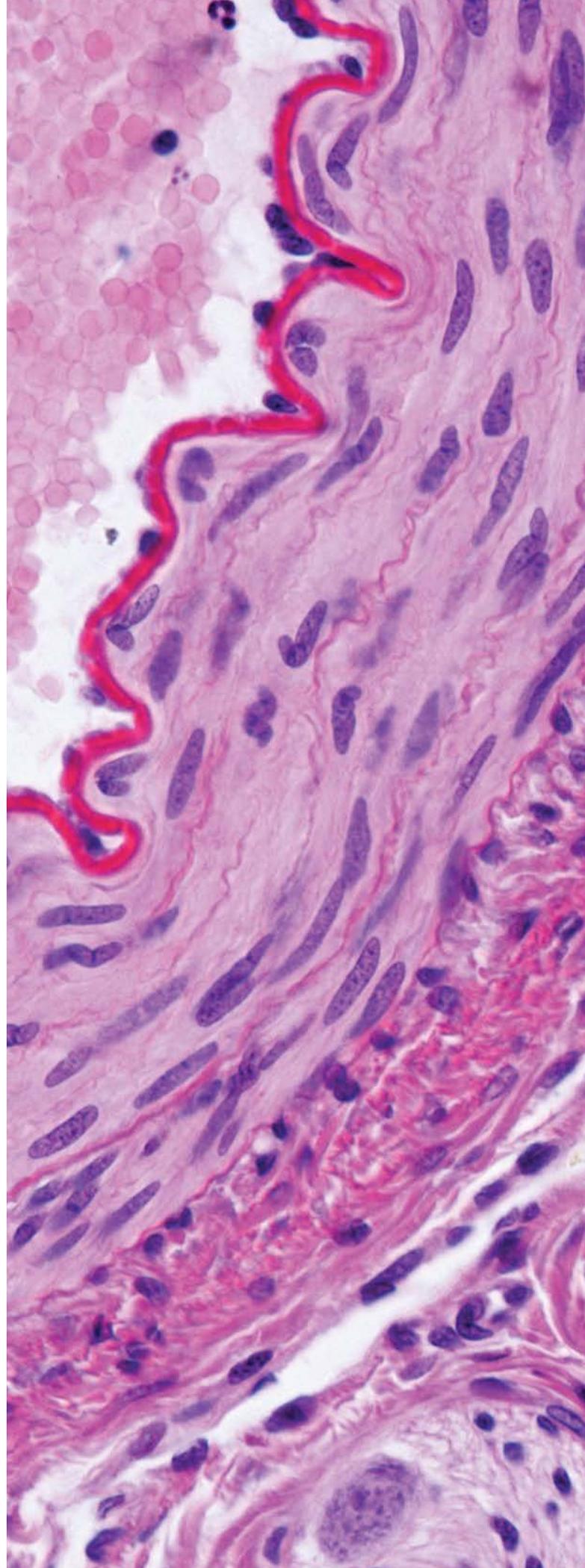
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#### **Dedication**

*For my three beautiful daughters,  
Mary, Ashley, and Sarah*

*Light micrograph of a cross-sectioned muscular artery, showing  
a thick and wavy internal elastic lamina, a middle layer with  
smooth muscle fibers, and an outer connective tissue adventitia.*





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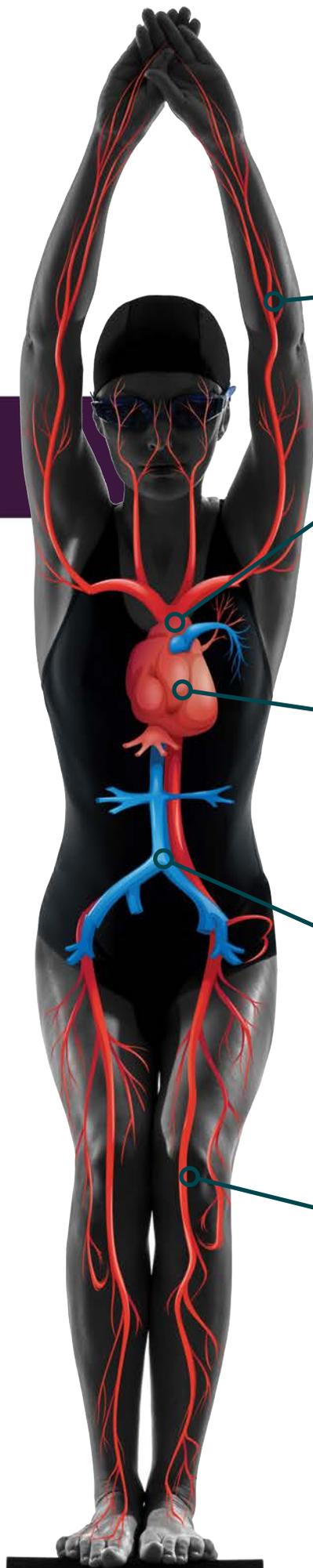
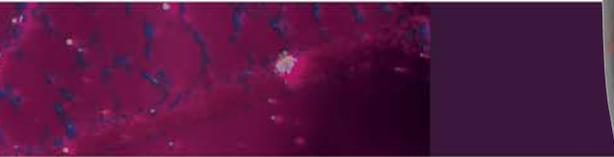
## SECTION 1

# THE CARDIOVASCULAR SYSTEM

The heart must ceaselessly move blood around your body to keep you alive. It pushes that blood through a system of blood vessels. Those vessels branch out to carry blood all over your body, making oxygen, nutrients, water, and dissolved electrolytes available to every cell in your body. They also carry away waste materials for disposal or recycling. The heart, with all its associated vessels, is called the cardiovascular system. This name — cardiovascular — is one of those anatomy word puzzles: cardio- means “heart” and vascular means “vessels.”

For You formed my inward parts;  
You covered me in my mother’s womb.  
I will praise You, for I am fearfully and wonderfully made;  
Marvelous are Your works,  
And that my soul knows very well.  
My frame was not hidden from You,  
When I was made in secret,  
And skillfully wrought in the lowest parts of the earth.  
Your eyes saw my substance, being yet unformed.  
And in Your book they all were written,  
The days fashioned for me,  
When as yet there were none of them.

(Psalm 139:13-16)



In one year your heart pumps enough blood to fill an Olympic sized swimming pool!

The first human to human heart transplant was performed by Dr. Christiaan Barnard on December 3, 1967.

The heart generates its own electrical signals. It can beat even if taken out of the body!

Your heart began beating 22 days after you were conceived. It beat about 54 million times before you were born!

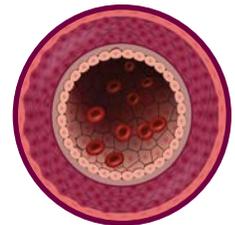
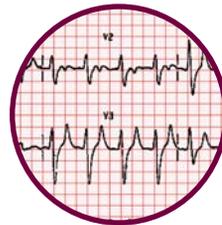
Bone marrow helps to create red and white blood cells, and these help us in many ways, including fighting bacterial. You have around 60,000 miles of blood vessels in your body. That's enough to circle the Earth twice with 10,000 miles to spare!

# INTRODUCTION

Have you heard your heart beat or felt your pulse? Have you ever blown up a balloon or had your milk “go down the wrong way”? Do you have any idea why people sneeze or cough?

Do you have a friend with asthma? Do you know what a heart attack is? Has someone in your family had heart surgery? Have you wondered how CPR works? Wouldn't it be great to know these things?

The purpose of this book is to explain how God's amazing designs enable your heart and lungs to move blood and oxygen around in your body for a lifetime. Once you understand how these systems work, you'll be able to understand many of the things that go wrong with them and the things you can do to keep yourself as healthy as possible.



The human body is a collection of organ systems which all work together to keep you going. Your heart, lungs, kidneys, stomach, and liver are examples of organs. An organ system is a group of organs working together to do an important job. Your circulatory system consists of all the parts of your body that move blood around. The heart and many blood vessels, large and small, make up your circulatory system.

Another system, the respiratory system, gets oxygen from the air; you need oxygen to live. The respiratory system also gets rid of the carbon dioxide your body makes. The respiratory system consists of the lungs and all the tubes (called airways) that air must travel through.

The circulatory (or cardiovascular) system and the respiratory system work together. The oxygen your lungs obtain from the air must be carried to all parts of your body, even into the tiniest places far from your lungs. How these systems work together so precisely is a testimony to our marvelous Creator, the One who designed our bodies with great care.

## How We'll Proceed

The body has many organ systems that will be the subjects of other books in this series. But since all parts of the body work together, we'll mention other organ systems a lot. For example, your brain and nervous system help control your respiratory system. We'll talk a little about those systems whenever we need to right here in this book, and then you can learn more about the other systems later in the other books in the Wonders of the Human Body series.

When we learn about an organ system, we first will show you its parts and learn their correct names. Learning the names for things in science is like a puzzle: a lot of the names are built of little words and syllables which help you guess and remember the names of other things in science. We'll use lots of

pictures and illustrations to show you anatomy — the way your parts are put together.

Organs are made of tissues, and tissues are made of cells. Sometimes we will show you pictures of what those tissues and cells look like under a microscope, amazing details too small to see with the naked eye. Those “photomicrographs” not only show you the anatomy but also help us to understand how the organs work.

Once you see the anatomy of an organ system and know its parts, you'll be able to understand how the system works. How the systems work is called physiology. When you finish this book, you'll know where the organs are (anatomy), how they work (physiology), and what you can do to keep them healthy.

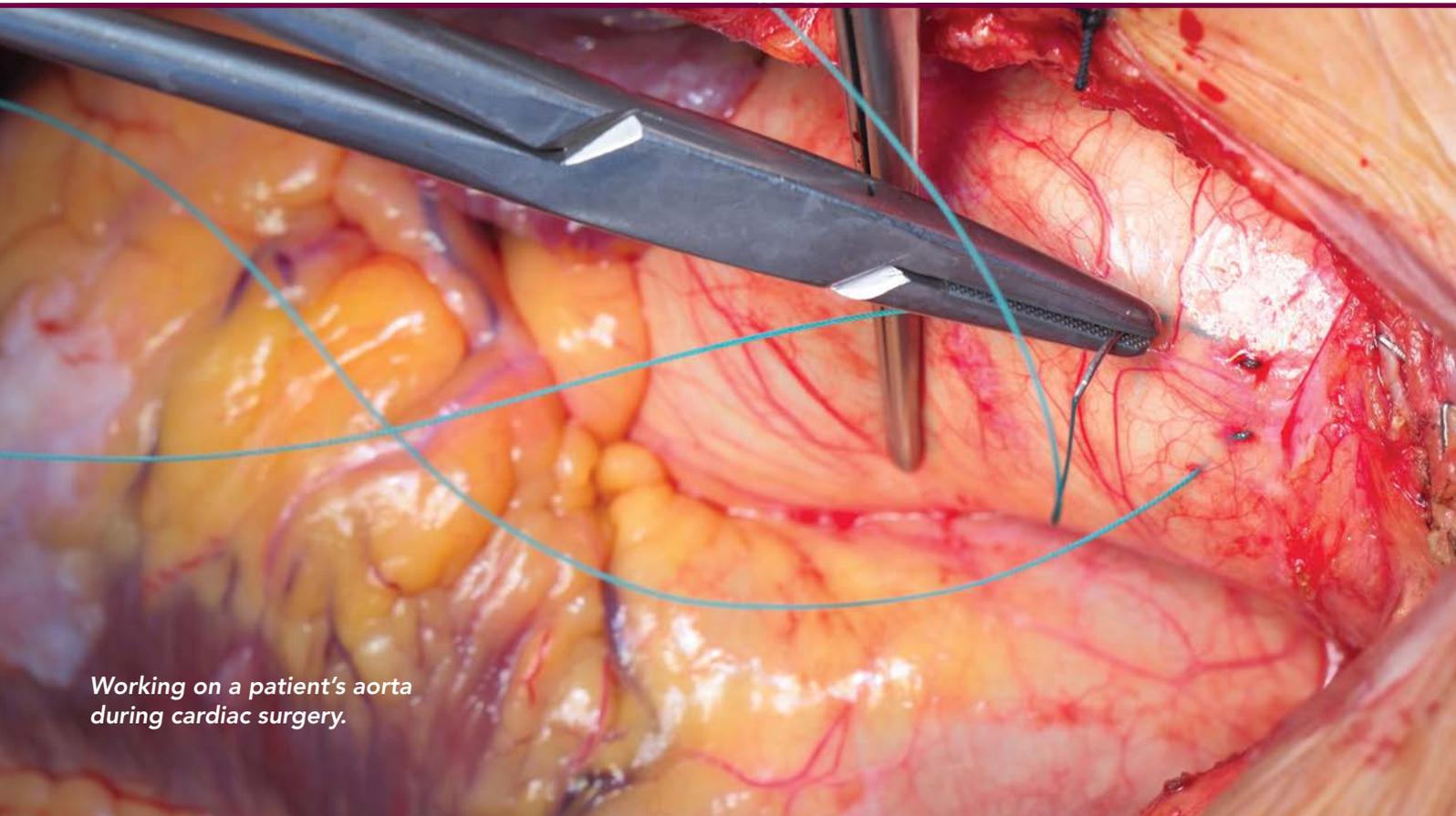
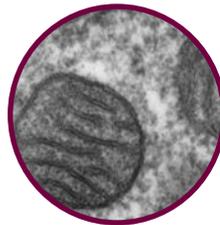
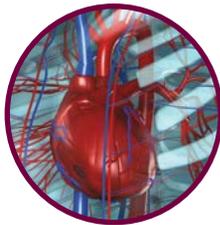
Often, learning about what happens when things don't work right helps us understand how organ systems work in the first place, so we'll discuss some diseases and how they affect the heart and lungs.

## In the Beginning . . .

You may have heard that the incredible systems in your body evolved little by little over millions of years, but in fact, God created them perfect and complete in the first man and woman, Adam and Eve, about 6,000 years ago. Their hearts and lungs would have worked perfectly forever if they had not sinned, but disobeying God caused disease and death to enter a perfect world. When we learn about diseases, we are learning about the many things that have gone wrong in the world since Adam and Eve first sinned. In this book we'll talk a lot about the heart that moves your blood around, but in the Bible you can learn about another kind of heart — not the physical heart that beats in your chest, but the invisible heart that can believe in Jesus Christ. Look in the Book of Romans, chapter 10, verse 9. God wants you to pay attention to both kinds of heart.

# THE HEART

A normal heart is about the size of a person's fist. It is mostly made of **cardiac muscle**. There are two other kinds of muscle — skeletal muscle and smooth muscle. Muscles that enable you to walk or use your hands are examples of skeletal muscles. So is your diaphragm. Muscles that move your food through your digestive tract and the muscles that surround your arteries in order to allow them to influence your blood pressure are examples of smooth muscles. Cardiac muscle cells are designed to communicate efficiently with each other to pass along the electrical impulses that cause the heart to contract. Cardiac muscle cells are packed with **mitochondria**, tiny power-generators that keep the heart muscle continually supplied with energy. Incredibly, the heart only rests for about a fourth of a second during each "heartbeat." After all, the heart cannot afford to take a break!



*Working on a patient's aorta during cardiac surgery.*

The heart in an average adult pumps around 5 liters of blood every minute when resting. In a trained athlete, the heart can pump up to 33 liters per minute during vigorous exercise. On average, the heart moves 7,200 liters of blood per day. You've only got about 5 liters of blood altogether, so you can imagine that the blood circulates throughout the entire cardiovascular system many, many times in a day.

The heart “beats” on average around 72 times a minute when at rest. A young, healthy person’s heart may beat up to 200 times a minute while exercising vigorously.

To keep up this steady pace, the many mitochondria in the muscle cells constantly use oxygen to convert glucose (a form of sugar) to energy. Therefore, those cells must be constantly supplied with oxygen. Without oxygen they cannot contract or even survive. If cardiac muscle cells are damaged by lack of oxygen, they have very little capacity to regenerate or replace themselves. Dead cardiac cells are replaced with scar tissue, but scar tissue cannot help pump. When people eat “heart healthy” foods and do “aerobic exercise,” they are trying to keep their heart tissues in good shape to work well for a lifetime.

## The Heart, a Workhorse

To really understand how much work the heart does, let's do some calculations.

We will base our calculations on a person with an average heart rate of 72 beats per minute. At rest, the heart pumps roughly 70 mL (2.4 ounces) per beat. So . . . if the heart beats 72 times a minute, that means it beats 4,320 times in an hour, 103,700 times in a day, 37,843,000 times in a year. So, in a person who is 70 years old, for instance, the heart has already beat roughly 2,649,000,000 times. That is almost 3 billion heartbeats (yeah, that's billion, not million)!



*The average heart pumps 5 liters of blood a minute.*

Looking further, if the heart pumps 70 mL per beat, that means it pumps 5 liters a minute, 302 liters per hour, 7,257 liters (1917 gallons) per day, 2,649,000 liters (699,798 gallons) per year. So the heart of our 70-year-old would have pumped 185,431,680 liters (48,985,000 gallons)!

And your heart does all this without taking any time off. It works 24 hours a day, seven days a week. So you would think it wise to keep your heart healthy, right?

## Location of the Heart

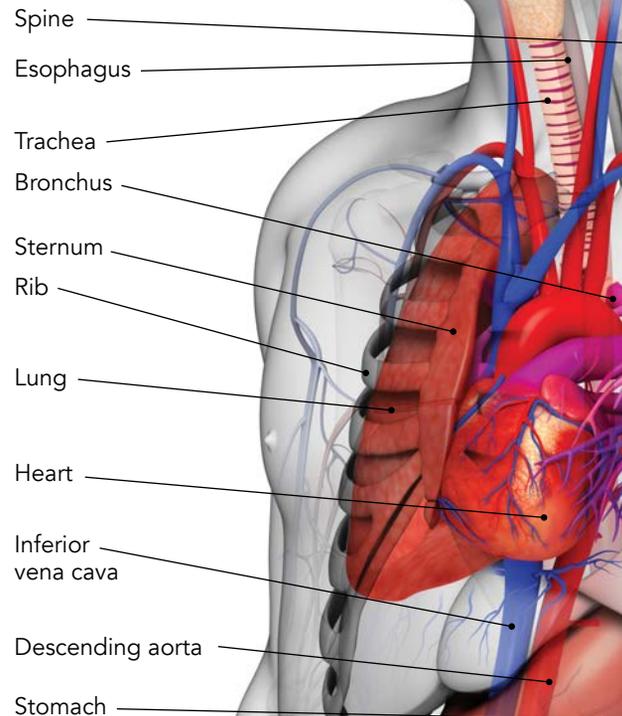
Your heart is in the center of your chest, under your *sternum*, or breastbone. The heart is shaped sort of like an upside-down pyramid. It is pointed so that its apex is below the middle of your left collarbone. That is why when you put your hand over your heart to say a pledge, you place your hand a little to the left of the sternum, because this is where the “beats” of the heart can be easily felt.

Your thoracic cavity, or chest cavity, has three main compartments. The left and right are occupied by your lungs. Your heart is in the middle one — the *mediastinum*. (The word comes from the Latin word

for “middle.”) The heart isn’t alone in this space. Also in the mediastinum are some important nerves, the large blood vessels (and lymphatic vessels) that enter and leave the heart, and the esophagus and trachea. The esophagus carries the food you swallow to your stomach. The trachea carries the air you breathe to your lungs. There is a lot of traffic in the mediastinum, and with the ever-beating heart the mediastinum is a busy place!

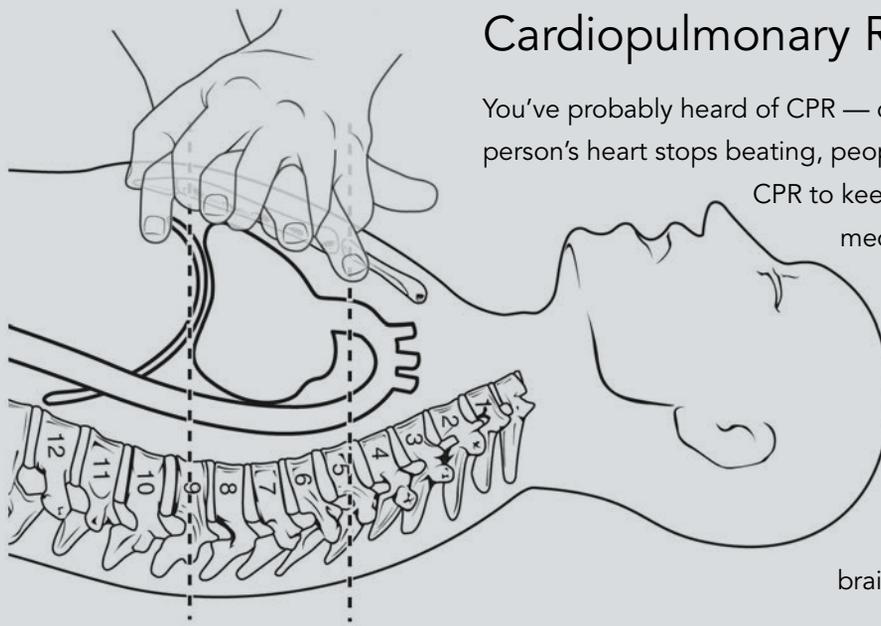
If we look at the mediastinum from front to back at the level of the heart, we’d see the sternum in front, then the heart. Behind the heart is the esophagus, but not the trachea. The trachea splits into the right and left bronchi before it reaches as low as the heart. Behind the esophagus is the descending aorta, and then the spine.

### TAKING A CLOSER LOOK Thoracic Cavity



Then, below the mediastinum is the diaphragm. The diaphragm is a large sheet of skeletal muscle that separates the chest cavity from the abdominal cavity.

## Cardiopulmonary Resuscitation (CPR)



You’ve probably heard of CPR — cardiopulmonary resuscitation. When a person’s heart stops beating, people trained in this form of first aid can start CPR to keep the blood circulating until emergency medical help can arrive. Now that you see the heart is really between the sternum and the spine — and not way off to the left — you can see how CPR works. With proper training, a person can press on the chest to squeeze the heart between the sternum and the spine, forcing enough blood out of the heart to keep the brain and body supplied with some oxygen.

## The Pericardium

As the heart pumps, it constantly rubs against the other structures in the mediastinum. You might think that would create a lot of friction. Friction would generate heat and lots of wear and tear on the outer surface of the heart. To prevent this, God designed the heart with its own lubrication system. (After all, blisters from friction like you get on your feet wouldn't do your heart any good!)

Like many other organs that we'll learn about, the heart grows inside a pushed in, double-layered, balloon-like sac during embryonic development. Imagine a slightly inflated balloon containing a tiny bit of lubricating fluid. Now imagine pushing your fist into the balloon so that two layers of rubber are against your fist. Try it yourself with a few drops of

cooking oil inside a slightly inflated balloon. Is your hand inside the balloon? Not exactly. But when you wiggle your fist, the oiled rubber surfaces should slide smoothly against each other. The oil prevents friction.

Your heart is inside just such a sac, the *pericardium*. *Peri* means "around." This sac goes around the heart. The *pericardial sac* has an outer layer called the *fibrous pericardium* and an inner layer called the *serous pericardium*.

The fibrous pericardium is composed of tough, inelastic connective tissue. It serves to protect the heart, and to hold the heart in position in the chest.

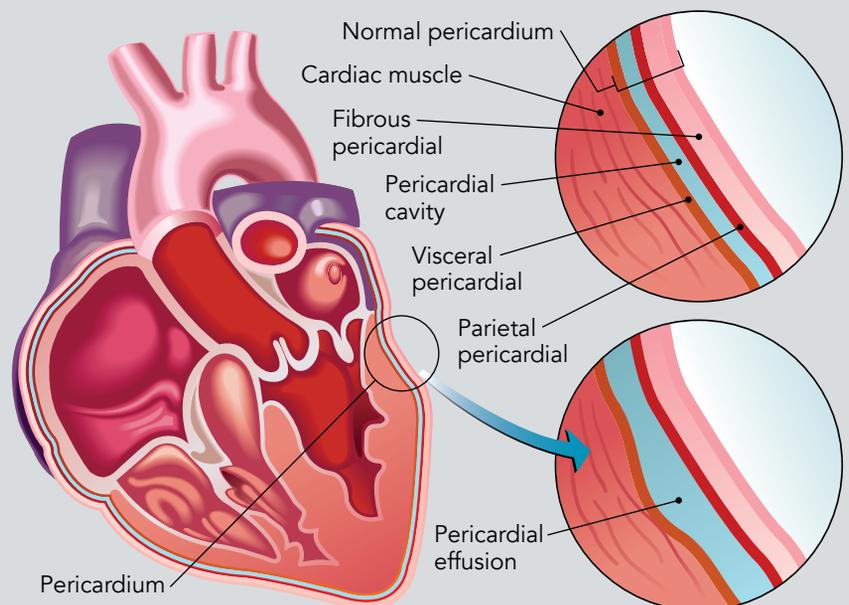
The serous pericardium itself is made of two layers. The inner layer of the serous pericardium is called

## Pericarditis

Occasionally, the pericardium can become inflamed. This condition is known as pericarditis.

It can occur suddenly, and it causes chest pain that is quite often severe. This pain sometimes radiates to the left shoulder and can be mistaken for a heart attack. The inflammation can be the result of a viral, bacterial, or fungal infection. Other causes include malignancy (cancer), heart attack, and trauma.

Some cases of pericarditis are quite mild and are treated with medication that controls inflammation. Other cases can be more aggressive and cause thickening of the pericardial sac, which can limit the movement of the heart. At times, the inflammation is severe enough that fluid begins to collect inside the pericardial sac. (This is called a **pericardial effusion**). Small amounts of fluid are easily tolerated and often resolve with treatment. However, in certain cases the amount of fluid that accumulates in the pericardial sac is enough to compress the heart and alter its ability to pump blood. This dangerous condition is a medical emergency known as **cardiac tamponade**. It is most often treated by inserting a needle into the pericardial sac and draining the fluid.



the visceral pericardium. The *visceral pericardium* is a thin layer stuck to the outer surface of the heart, just like the inner layer of balloon rubber was against your fist. The outer layer of the serous pericardium is called the *parietal pericardium*. The parietal pericardium is fused to the fibrous pericardium.

The visceral pericardium secretes a small amount of fluid, known as *pericardial fluid*, that provides lubrication between the visceral pericardium and the parietal pericardium. This fluid minimizes friction as the heart beats. You see, our Master Designer thought of everything!

If we peeled back the pericardium, we'd see the great vessels emerging from the upper part of the heart. The upper end of the heart is called the *base*, even though it is on the top, because it forms the broader part of the pyramid-like heart's shape. (The *apex* is the pointy bottom end.) Peeling back the pericar-

dium would also reveal the coronary arteries and the cardiac veins running across the surface of the heart and sending their smaller branches down into the muscle of the heart.

## The Layers of the Heart

The wall of the heart consists of three layers: the *epicardium*, the *myocardium*, and the *endocardium*. Now you can see how thinking of anatomical names as word puzzles can help you! *Peri*, as in “pericardium,” means “around,” and the pericardium surrounds the heart. *Epi* means “outer,” *myo* means “muscle,” and *endo* means “inner.” And of course *cardium* means “heart”! Therefore, these words are names for the layers of the heart itself.

Remember, we said that the pericardium consists of the outer parietal pericardium and the inner visceral pericardium, which is plastered to the surface of the

heart. The outermost layer of the heart is actually the visceral layer of the pericardium. Where this membrane contacts the heart it is called the *epicardium*. It is made mostly of connective tissue and provides a protective covering for the surface of the heart.

The middle layer forms the bulk of the heart and is called the *myocardium*. As you might expect, knowing that *myo* means “muscle,” this layer

### TAKING A CLOSER LOOK

#### Pericardium and Layers of the Heart

