

Introduction to the Heart

What do you think of when you see a heart: strong emotions of love and affection or the throbbing pulse in your neck?



Did you know? The heart is only a little bigger than your fist but can pump enough blood to fill the gas tanks of 100 minivans!

To a biologist the heart is a vital organ of the body needed for survival. The main function of the heart is to pump blood to all the organs and cells in your body. Blood contains the oxygen and nutrients that cells need to properly function.

Biology of the Heart

The heart is a powerful muscle that pushes blood through your blood vessels so that all the cells in your body get enough oxygen and nutrients to function. Every time the muscle in your heart contracts, blood is forced out of the heart. The **contraction** of the heart muscles, called the cardiac muscles, causes the heartbeat that you feel in your pulse.

The contraction of the cardiac muscles is **involuntary**. This means that there is no way for you to tell your heart when to beat. Other muscles in your body, like your arm and leg muscles, are voluntary, meaning you can tell it when to contract as you move.

The cardiac muscle is so powerful that it allows blood to be pushed to your brain and all the way to your feet!

Anatomy of the Heart

The heart has four cavities, or open spaces, which the blood flows in and out of. As shown in the diagram, the two cavities at the top of the heart are called **atria (singular; atrium)**. The two

atria form the curved top of the heart.

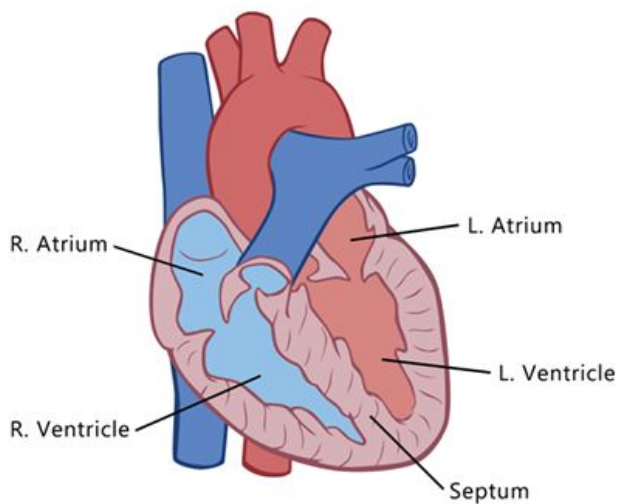
The two bottom cavities are called the

ventricles (singular; ventricle). The

ventricles meet at the bottom of the

heart to form a pointed base, which

points toward the left side of your chest.



The left side and the right side of the

heart is separated from each other by a

wall, called the **septum**. The atria on

each side are connected to the

ventricles of each side by heart valves. These valves allow blood to flow from the atria to the ventricles.

HOW DOES BLOOD CIRCULATE THROUGH THE HEART?

The blood does a lot of traveling throughout the body. Each trip begins in the heart.

Fresh blood, which is full of oxygen, is called **oxygenated blood**. Oxygenated blood is pumped into the aorta, which distributes the blood throughout the body.

Blood travels all over the body exchanging oxygen and nutrients while picking up wastes such as carbon dioxide from the cells. Blood that has given up all its oxygen is called de-oxygenated blood and must return to the heart.

The **de-oxygenated blood** enters the right atrium and then travels to the right ventricle. The right ventricle then pushes it out of the heart and into the **pulmonary artery**, which will carry it to the lungs. In the lungs, the de-oxygenated blood becomes exposed to the fresh oxygen that breathing brings in! The blood exchanges the carbon dioxide in it for the fresh oxygen. Thus, making the blood oxygenated again.

The oxygenated blood returns to the left atrium of the heart through the **pulmonary vein**. This blood moves from the left atrium to the left ventricle where it will be ready to circulate through the body again.

The oxygenated blood in the left ventricle must be pushed up to your brain and all the way to your foot. The muscle of the ventricle must contract very hard to give the blood enough force to do this. Thus, the left ventricle is a much bigger and stronger muscle compared to the right ventricle. When you feel your pulse in your neck, you are feeling the contraction of your left ventricle!

HOW DOES THE HEART BEAT?

A cardiac muscle is called an involuntary muscle because it can contract and relax on its own. So, the heart beats by itself without us having to think about it. Other muscles in our body, like leg or arm muscles, are voluntary muscles. This is because we have to consciously control its contraction and expansion to help us move.



Did you know? The average heart rate of a person of about 20 years old is between 100-170 beats a minute. Can you imagine if you had to instruct your heart to beat every time?

Cardiac muscle is special because it is extra strong and well supplied with oxygen. The cells called **cardiomyocytes** are self-stimulated as they can contract and relax on their own. All the cells contract and relax together at the same time making the heart beat!

Each cell in the cardiac muscle is connected to its neighbor by special joints through which an electrical signal can pass. When one cell stimulates itself to beat (contract and relax), it sends a signal to its neighbors telling them to do the same. This helps the cells to synchronize their beats.

This signal travels across the heart, allowing larger sections of tissue to react in a coordinated way. When all sections of heart tissue do this with the correct timing, it makes the heart beat!

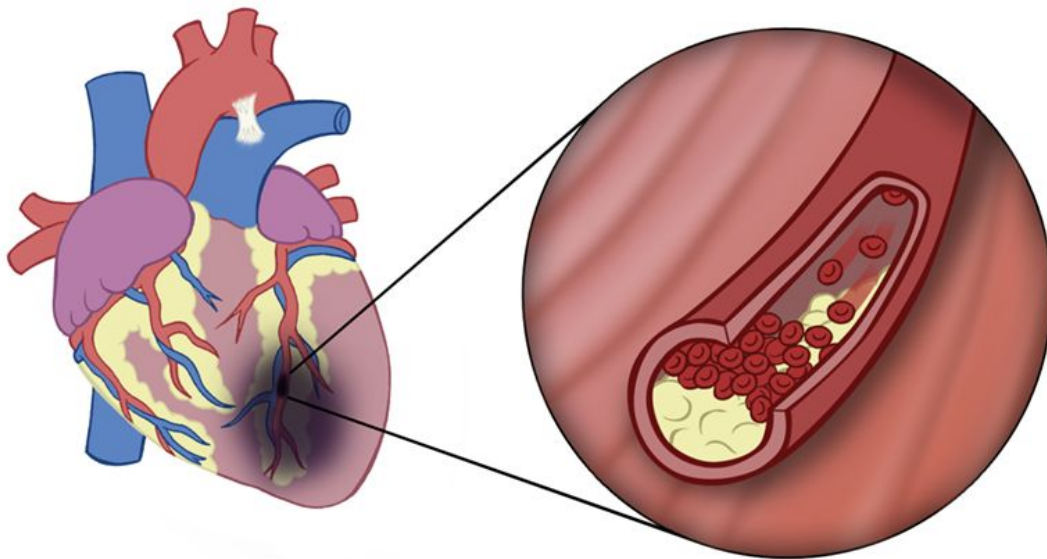
This type of communication is similar to what the nervous system uses to communicate!

Heart Injury

The main cause of damage to the heart tissue is **heart attacks**. A heart attack is an interruption of heart beats caused by damage to heart tissue cells (cardiomyocytes).

WHAT CAUSES A HEART ATTACK?

The main cause of heart attacks is a buildup of **plaque** in the blood vessels that supply the heart with blood. Plaque is made up of protein, calcium, and a fat called cholesterol. Poor diet is one of the main causes of plaque build-up, but many other things contribute to the problem. Smoking, obesity, and even some inherited traits can increase a person's risk of having detrimental plaque build-up. Plaque build-up also occurs in other blood vessels and causes other problems. For instance, plaque build up in the blood vessels that lead to the brain could cause a stroke.



As more and more plaque builds up in the blood vessels, the fibrous covering around it will rupture. This releases its contents into the blood vessels. The body responds to the rupture as if it were an injury and tries to make a blood clot around the plaque in hopes of healing it. As the blood cells clot they block the blood vessels preventing the blood from flowing through it.

If the clot forms in a blood vessel that supplies blood to the heart cells, then these cells will not receive enough oxygen to function. This will cause the cells to start dying.

Now, remember how all the sections of the heart muscle beat in a coordinated way? When one area of cells dies suddenly, it can affect the whole muscle and the heart can briefly stop beating!

The damage caused by a heart attack doesn't affect only the heart. If the heart stops even for a brief period of time, blood is not pumped to other tissues in the body. So, other cells around the body will not get enough oxygen and nutrients to function and will begin to die.

The heart renews its cells slowly and makes only a few new cells at any one time. So, after a heart attack, the body cannot replace the dead heart tissue with new heart tissue. Instead, it forms **scar tissue**. Scar tissue is a weaker and more disorganized version of the original tissue that is unable to function properly. Even though the heart recovers from a heart attack, the heart beat may be weaker or beat irregularly.



Modern Treatments for the Heart

HOW DO DOCTORS HELP SOMEONE WHO JUST HAD A HEART ATTACK?

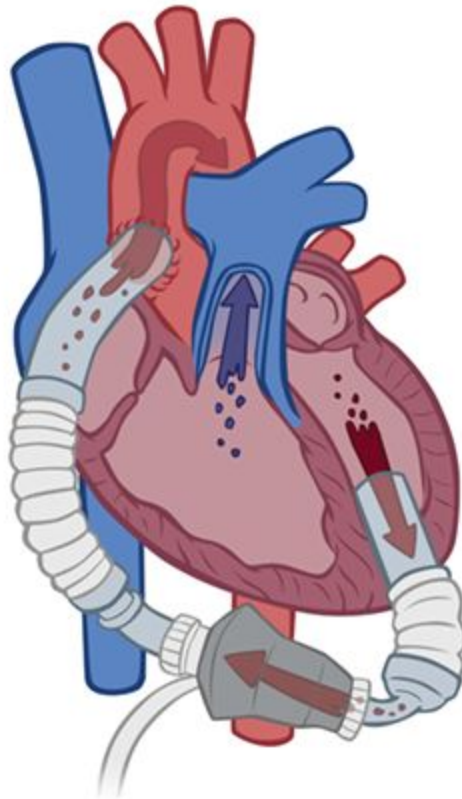
Those who do suffer a heart attack receive immediate care to get blood flowing back into the heart. A patient must have the blood clots removed so the blood flow to the heart resumes. The blood clot can be removed using two methods. If only a few hours have passed after a heart attack, an injection is used that dissolves clots. If it has been several hours after the heart attack, the clots need to be removed through surgery.

After a heart attack, there are two types of treatment a person needs. First, doctors will try to prevent another attack. Second, doctors will try to replace the weakened tissue.

Medication-based treatments can help reduce clots and prevent further plaque build up. If severe damage was caused to the tissue, doctors will have to use more invasive methods to treat the damage.

REPLACING INJURED TISSUE

Someone with a seriously damaged heart may need to have it replaced. This is called a **heart transplant**, and this technique was developed by Dr. Christiaan Barnard, a South African surgeon. There are about 2,000 of these transplants each year in the United States, but that is not nearly enough. Thousands more wait on long lists for donor hearts. Sadly, some of these people die.



There are other methods to help heal diseased hearts. If the heart is damaged enough that it cannot beat correctly, a heart surgeon may install a **ventricular assist device (VAD)**. The most common type of device is a left ventricular assist device. It is used most often because the left ventricle is responsible for pumping blood to the entire body and needs a lot of healthy muscle tissue to do so. The right ventricle only pumps blood to the lungs and back, which is comparatively a much shorter distance. A left ventricular assist device (LVAD) is a battery-powered pump that is attached to the left ventricle of the heart. In order to help a weakened left ventricle pump blood to the body, the LVAD takes blood from the left ventricle and pumps it to the aorta. By doing this, the LVAD provides the force to pump blood to the body and makes up for the weakened heart muscle. A patient could also have a right ventricular assist device or both. All VADs give the heart extra time to heal its damaged tissue and gives a patient more time to wait for an available transplant.

HOW CAN A DOCTOR HELP PREVENT A FUTURE HEART ATTACK?

Doctors can prescribe medication to reduce plaque buildup and blood clots. They will also suggest lifestyle changes to help prevent heart attacks in the future.

It is important to remember that everybody can reduce the risks of a heart attack by leading a healthy lifestyle. A healthy lifestyle includes: exercising regularly, eating healthy foods, avoiding smoking, and limiting alcoholic drinks.

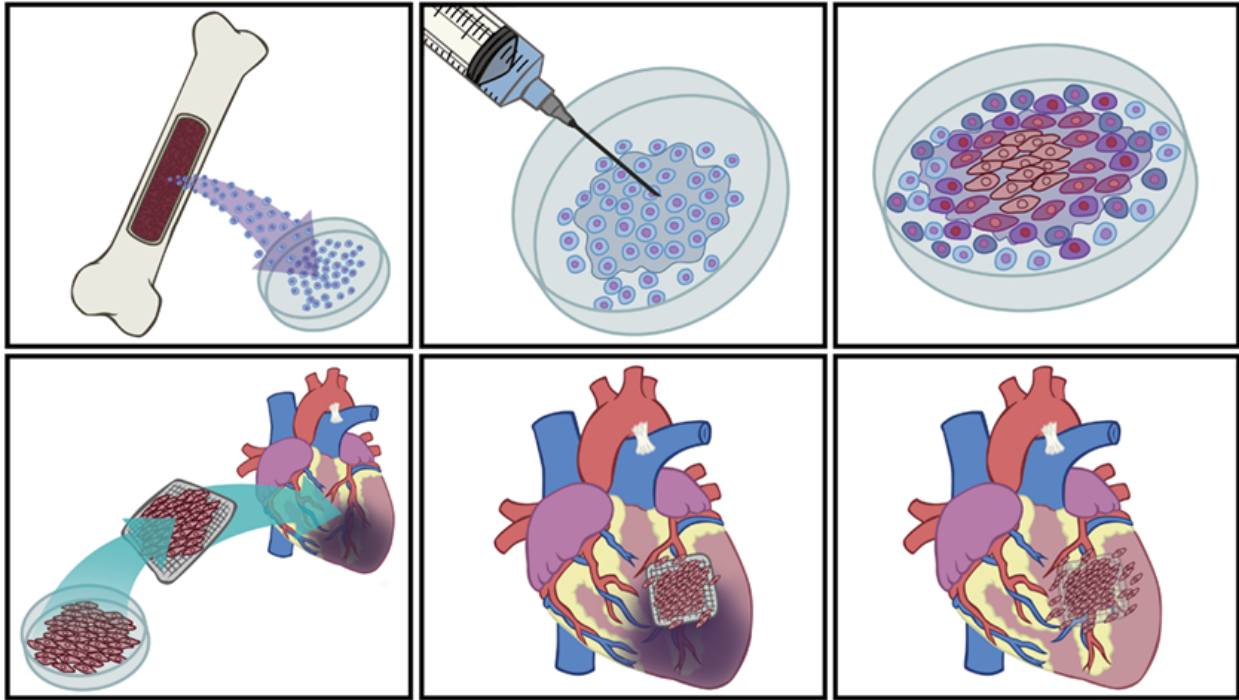
Regenerative Medicine in the Heart

WHAT IS REGENERATIVE MEDICINE?

Regenerative medicine can help people heal faster by enhancing the body's own natural healing process. Most treatments that are currently under investigation use stem cells found in the red bone marrow in the center of certain bones. These stem cells have the potential to become new blood, brain, bone, or heart cells. To find out more about the bone marrow, visit the Bone student reading page.

HOW CAN REGENERATIVE MEDICINE HELP PATIENTS RECOVER FROM A HEART ATTACK?

Stem cells taken from the bone marrow of the patient and exposed to **growth factors** in a lab cause the stem cells to multiply and turn into heart cells. These cells are then placed on a mesh patch, which is called a **scaffold**. This flexible patch is then placed in the heart, with a surgical procedure. Over time the cells on the patch grow into heart muscle cells and replace the damaged heart cells. This will allow the heart to continue its normal heartbeat rhythm. Eventually, the mesh patch is absorbed into the body.



Another treatment involves a simple injection. This injection stimulates the body to produce millions of stem cells in the bone marrow. These stem cells then circulate throughout the body in blood vessels and replace damaged heart muscle. The stem cells can find the damaged muscle and heal it on their own by picking up signals from the environment (called the extracellular matrix – see the Bone student reading page) that tell them to become heart cells.

See a movie on the formation of new heart tissue! Watch this [movie of a patch of heart muscle](#) that was created in a lab and is able to beat on its own! ***Please note, this movie might disturb some viewers.***

Remember! Regenerative medicine allows your body to re-grow damaged heart tissue where the body would normally produce scar tissue that weakens the heart.