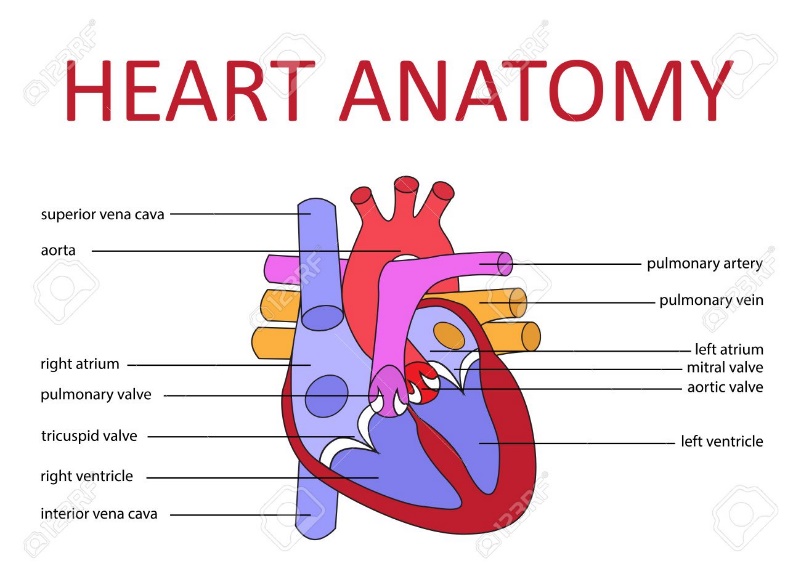
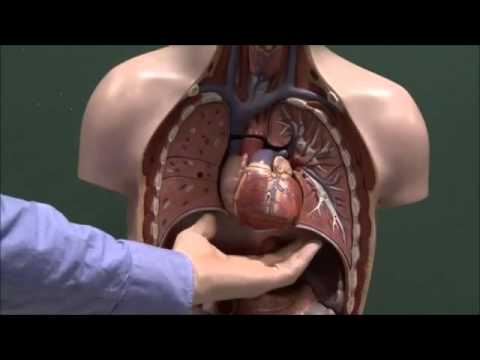
A brilliant way to start to look at the heart is to watch and remember:

<https://www.youtube.com/watch?v=JA0Wb3gc4mE>

<https://www.youtube.com/watch?v=7XaftdE_h60>

<https://www.youtube.com/watch?v=qmpd82mpVO4>

Notice how the heart seems to be lying on its backside and how the upper chambers, the atria, contract first and then the lower chambers contract next all in one single heartbeat. Notice the right lower chamber, the right ventricle is facing forward and the left lower chamber, the left ventricle, is more towards the back. So the heart inside your chest does not really look like the diagrams:

The diagram makes it look like the bottom pointed part is down when inside your chest that pointed lower tip is actually pointed forward. The heart is not straight up and down like all the diagrams show, but it is laying on it back. And notice now and later when you look at the heart in more detail that unlike all the diagrams, the heart in your chest is twisted so that most of the right side is facing toward you (facing forward) and most of the left side of the heart is facing toward the back, hidden from view when we look at the photograph on the right above. But I am way ahead of myself. Let’s read more and learn about these chambers. Notice the heart is twisted and laying on its back inside your chest. Let me also strongly recommend you go to the Acland Anatomy web site and view the REAL human heart and especially find the videos showing the opening and closing of the valves.

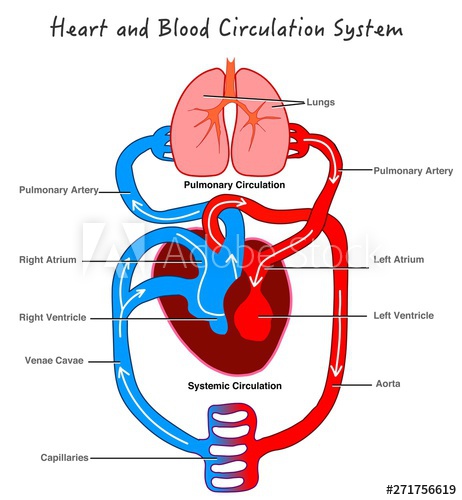
**Cardiovascular system:**

We will begin by focusing mostly on the heart. It is very, very important to actually understand the anatomy of the heart and not sort of, pretend to know the four chambers of the heart. The heart is so essential to life itself and so understanding how it actually works is vitally important. Also, if you are to ever really understand when things go wrong with the heart (hypertension, heart attack, and so on) you need a strong understanding of how it is put together and how each part works. Now having said all that, its anatomy is relatively easy. It is a muscle. All it will ever do is contract and relax. The cardiologists want to complicate things but there it sits in the center of your chest, your thorax, just a little bit pushed to the left and about the size of your own fist. It relaxes and fills with blood and then it contracts and ejects the blood inside of it. When it is relaxed and filling with blood, that is called ‘diastole’. When it is contracting and ejecting its blood, that is called ‘systole’. The blood it pumps out has oxygen in it, oxygenated blood, and that oxygenated blood is then sent out to provide oxygen to all the cells of the body. Well, along with transporting all the other important molecules to the cells of the body. Your body’s cells cannot move. They cannot get up and go to Trader Joe’s for groceries. Everything a cell needs to survive (oxygen, glucose, proteins, etc.) has to be brought to it via the blood stream. Also, all of your cells use the oxygen to convert the low energy ADP into the high energy ATP in their mitochondria. A byproduct of this conversion in the mitochondria is the gas carbon dioxide, CO2. That CO2 is a waste product of ATP production and constantly accumulates inside the cell. Too much CO2 inside a cell will kill that cell. Too much CO2 is toxic to your cells. So, all of your cells need to eliminate the CO2 and they do that by simply dumping the CO2 they make into the blood stream and it washes away from the cell. So, you are right now polluting your blood with all that waste CO2. The CO2 in the blood will eventually travel through blood vessels in the lungs and it is there that these CO2 molecules leave the blood and enter the tiny air sacs of the lungs to be expired from your next breath. You blow off CO2 when you breathe.

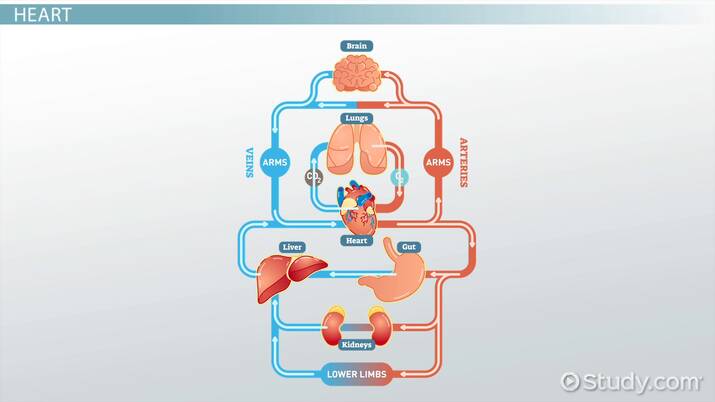
Gas Exchange. A big term that is used in anatomy and a lot in physiology. You breathe in oxygen, that oxygen enters the blood, is pumped by the heart to all the cells of the body. When the oxygen leaves the blood and enters the cells to be used for ATP production by the mitochondria, carbon dioxide is produced as a waste product. This CO2 is moved from the cell into the blood where it is carried to the lungs and blown off when you expire. So, there are two gasses: oxygen and carbon dioxide. Both moving in opposite directions at two places: (1) at the lungs – O2 into the blood and CO2 out of the blood; (2) at the cells – O2 entering the cell from the blood and CO2 exiting the cell and entering the blood. Get it now, Gas Exchange. So what is ‘Gas Exchange’? The movement of O2 and CO2 in opposite directions. Where does ‘Gas Exchange’ occur? At the lungs and at the cells. Everyone always talks about the heart and blood delivering oxygen to the cells and no one ever talks about the poor forgotten other gas, CO2. But we will. We care about CO2. Well, we care about getting rid of CO2 out of the body.

So, the heart pumps the blood. The heart is a hollow organ. A hollow muscle. It fills and empties. It relaxes and it contracts. Its job is centered on moving fluid under pressure. It contracts, it squeezes the blood that is inside of it, it pressurizes the blood that is inside of it and that glob of pressurized blood squirts out of the heart into the blood vessels.

But wait. The heart is not a hollow balloon. It does not have, as the biology textbooks would say, a single chamber. Some organisms do have a single chambered heart but we humans do not. Your human heart actually has four chambers. Why? Well, the heart pumps oxygenated blood to the body. The oxygenated blood leaves the heart and travels through all the blood vessels delivering O2 to all the cells. At some point the cells have removed the oxygen molecules from the blood and now the job is competed. This deoxygenated blood now must make its way back to the heart to go around again. So, this deoxygenated blood enters the heart. So how does it become oxygenated again before it is pumped back out again? Well, we all know the answer to that question. It has to travel through the lungs. So, this deoxygenated blood enters the heart and must be pumped through the lungs, return to the heart and then it can be pumped out to the body. So, from the heart, out to the body, back to the heart, to the lungs, back to the heart and then out to the body again. A sort of circle 8 pattern of blood flow.



Take you finger, or pencil, and trace the path of blood though the circle-8 pattern: out to the body, back into the heart, out to the lungs, back to the heart. Out to the body from the left ventricle. Out to the lungs from the right ventricle.



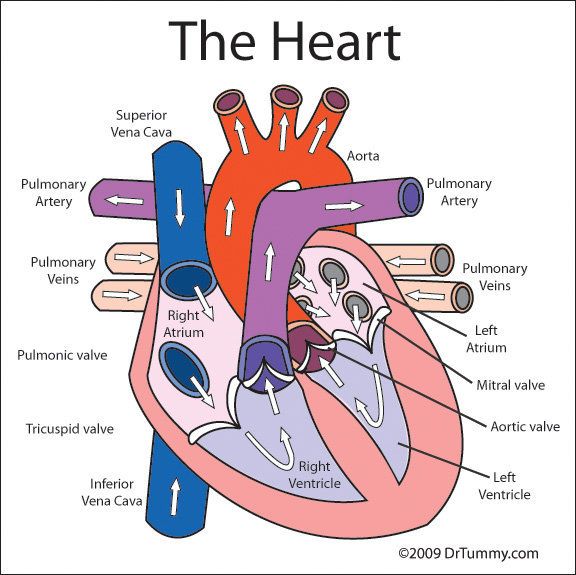
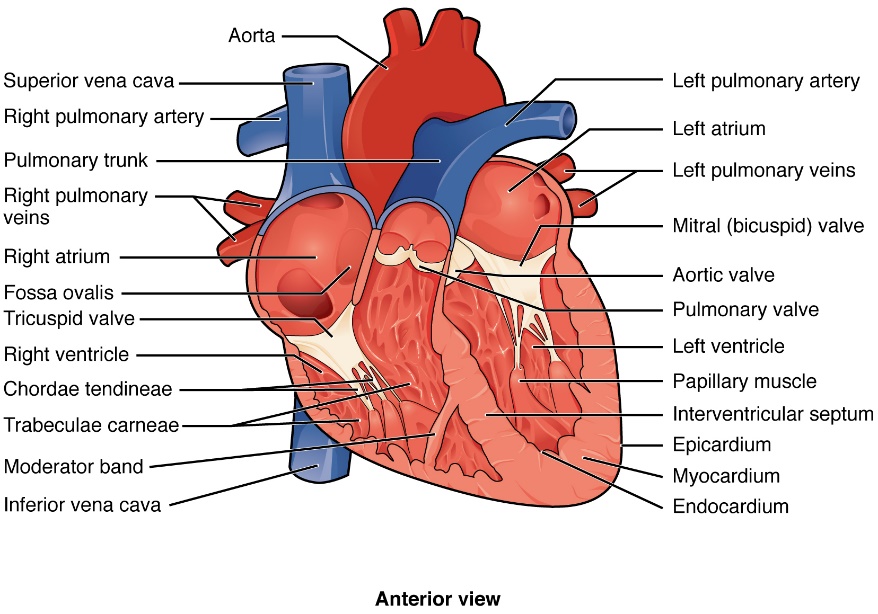
In order to have one heart pumping blood out to the body AND to the lungs at the same time, it is divided into a right sided pump and a left sided pump. There are two chambers on the right and two chambers on the left.

OK, this video is way too simple, but I liked it, nice and silly:

<https://www.youtube.com/watch?v=_oG14YQfl8g>

So, the right-sided pump, the right atrium and right ventricle, pump blood to the lungs. That’s it. Easy job because the lungs are right next to the heart. The muscle in the wall of the right ventricle (the muscle cells of the heart make up the myocardium) does not have to be very strong and so you will notice later on that when we cut the heart apart you’ll notice that the cut section of the right ventricle is relatively thin. The left-side pump, the left atrium and left ventricle, pumps blood to the entire body. It is a much stronger pump, much thicker myocardium on the left.

Any vessel that carries blood away from the heart is an artery. Any vessel that brings blood into the heart is a vein. So, leaving the right ventricle and the left ventricle are ‘arteries’. The artery leaving the right ventricle must be going to the lungs so it is called the ‘pulmonary artery’. The artery coming from the left ventricle is the ‘aorta’. What vessels bring blood back into the heart. Well it is the ‘vena cava’ bringing deoxygenated blood from the body back into the right side of the heart so it can be pumped to the lungs to be reoxygenated. This vein draining deoxygenated blood into the right atrium is the ‘vena cava’. After the blood has traveled through the lungs this freshly reoxygenated blood enters the left atrium through a vein called the ‘pulmonary vein’ since it is coming from the lungs (pulmonary/pulmonal = lungs).

So, we now have 4 chambers and 4 vessels. Each chamber has its own vessel attached. Let me now mention the 4 valves. Just like any plumbing system with fluid flow you have to include one-way valves so that the flow (blood in this case) always goes forward the way you want it to and never goes backwards (retrograde). Backwards flow of blood would not work so well. There are two valves at the junction of the atria and ventricles, one on the right and one on the left. These valves are called the ‘atrioventricular valves or AV-valves. And there are a pair of one-way valves between the ventricles and the arteries that they drain into. These are the semilunar valves because their flaps, called leaflets, look like partial moons.

<https://www.youtube.com/watch?v=CWFyxn0qDEU>

<https://www.youtube.com/watch?v=_qmNCJxpsr0>

<https://www.youtube.com/watch?v=UMTDmP81mG4>

So the basics are the: 4 chambers / 4 vessels / 4 valves (and the structures of the AV-valves).

<https://www.youtube.com/watch?v=2GMayj9O21o>

<https://www.youtube.com/watch?v=QSPfQTDcw34>

What about the heartbeat that you can hear? The Lubb Dupp sounds. What in the heart makes noise with every beat? The heart muscle makes no noise when it relaxes or contracts. Just put your biceps up next to your ear, contract your biceps and listen. No sound at all. Muscle contraction is quiet. So, what in the heart makes those loud noises? It is the closing of the valve leaflets. They pop open when blood travels through them and then those valve leaflets slam against each other when the valve closes. It is the slamming of the valve flaps (leaflets) together that makes the heart sounds, the audible heartbeat. The first heart sound, the Lupp, is produced by the first valves that close in a single heartbeat. That would be the AV-valves closing. The second heart sound is due to the closing of the semilunar valves, the aortic semilunar valve and the pulmonary semilunar valve, at the same time, the Dupp.

<https://www.youtube.com/watch?v=-4kGMI-qQ3I>

<https://www.youtube.com/watch?v=pMV3y8r6WOU>

Let me now mention another thing. You have a muscle that is constantly contracting. The heart muscle. It never rests. So, it requires an oxygenated blood supply. A good one. The heart muscle cells, the cardiac muscle fibers, the cardiac myocytes require an oxygenated blood supply from arteries. These arteries that bring oxygenated blood to the heart muscle cells themselves are called the ‘coronary arteries’. Two small arteries branch directly from the aorta. These are the ‘right coronary artery’ and the ‘left main coronary artery’. One will eventually travel to the right side of the heart and one will travel to the left side of the heart. Can you guess which one is which? Of course, the right coronary artery takes oxygenated blood to the right side of the heart. The left main coronary artery quickly branches and those two branches go to the left side of the heart. Those two branches from the left main coronary artery are the ‘left anterior descending coronary artery’ and the ‘left circumflex coronary artery’.

<https://www.youtube.com/watch?v=3wpT-4bSmoU>

Those coronary arteries continue to branch and bring oxygenated blood to every cell in the heart. But we are only responsible for the ones listed above.

<https://www.youtube.com/watch?v=dgAbpwp9gF8>

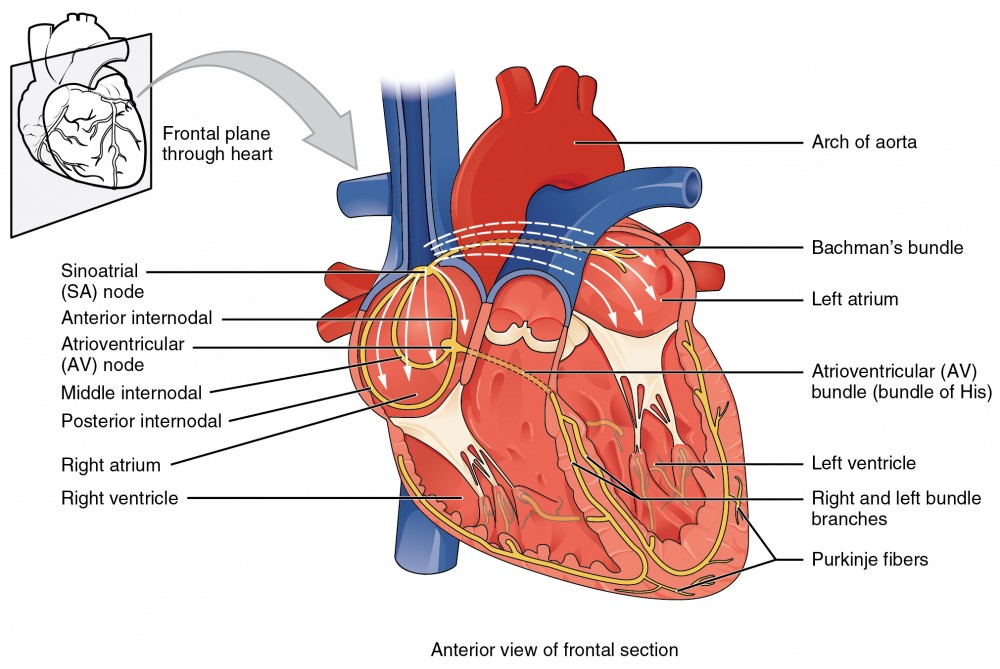
Let’s look at the position of the heart inside the chest, inside the thorax:

<https://www.youtube.com/watch?v=B_Q-vEnbwkA>

<https://www.youtube.com/watch?v=_yws2EeTJtk>

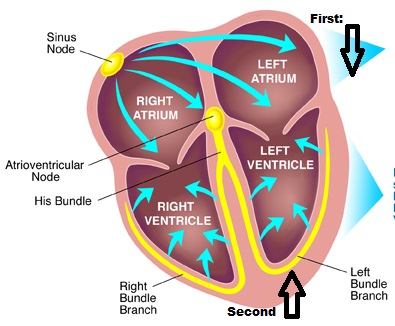
<https://www.youtube.com/watch?v=E1bkC2r5LxU>

Now for the heart to beat it needs a nerve signal from the brain. A nerve impulse. This nerve impulse from the brain arrives at a location in the wall of the right atrium called the Sino-Atrial Node or SA-Node. Two things happen here. Remember that cardiac muscle fibers (cells) have visible intercalated discs containing gap junctions. When that original nerve impulse from the brain arrives at the SA-Node, those cardiac muscle fibers are stimulated to contract. And also that same nerve impulse from the brain can travel to the neighboring cardiac muscle fibers through these gap junctions and so on and so on causing a wave of contraction to spread through all the atrial cardiac muscle fibers resulting in the contraction of the atria like a wave squirting their atrial blood into the already filled ventricles. Ignore the labeling, just notice the white arrows showing this wave of contraction spreading through the atrial from top down to squirt atrial blood into the ventricles (below diagram).



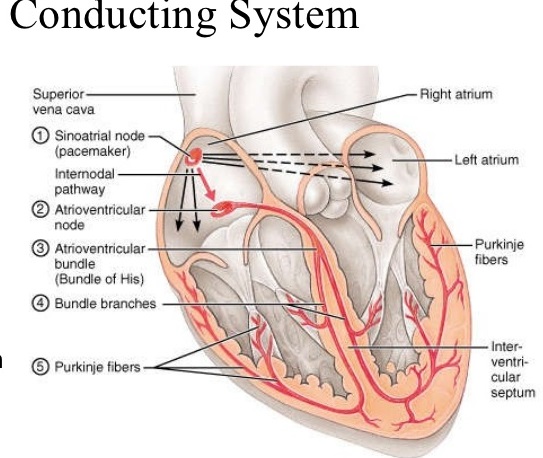
Now here is the problem. You cannot let the white arrows, this wave of contraction traveling through the gap junctions, to continue into the ventricles in this direction. If you let these white arrows move right into the ventricles, they will enter the ventricles at the top of the ventricles and move down to the bottoms of the ventricles. This will not work. The ventricles must have a wave of contraction move from the bottom of the ventricles up toward the tops of the ventricles. Why? Well, look at where the outflow arteries for each ventricle connect to the ventricles, at the very tops of the ventricles. The aorta and the pulmonary artery are located at the tops of these two ventricles. The ventricles must contract from the bottom up so that the right ventricle will squirt its blood into the pulmonary artery (at the top of the right ventricle) and that the left ventricle will squirt its blood up into the aorta which is found at the very top of the left ventricle.

How do we get the ventricles to send this wave of contraction, the white arrows, from the bottom up and how do we stop the wave of contraction moving down from the atria? Let me answer the second question right now. To stop the white arrows that are moving down from the atria into the ventricles, you must stop this electrical signal. That electrical signal that started at the SA-Node is stopped exactly at the junction between the bottoms of the atria and the tops of the ventricles by simply having at that junction a layer of connective tissue referred to as the fibrous skeleton of the heart. Connective tissue cannot conduct an electrical signal. It is connective tissue. No gap junctions here. And by having connective tissue at the junction between the atria and ventricles, this strong connective tissue layer helps to support the AV-valves which are found here and wiggle a lot do to their opening and closing of their valve leaflets.



In one heartbeat you have the atrial contracting squirting their atrial blood into the already filled ventricles and then still during this same heartbeat the ventricles have a wave of contraction spreading through them from the bottom up to squirt their ventricular blood out into their arteries found at the top of the heart. (Remind yourself about how the valves are also closing.) So, one nerve impulse from the brain has to trigger all of this.

So, getting back to the beginning of all of this. The nerve impulse arrives at the SA-Node located in the wall of the right atrium. Two things now happen. The white arrows begin, the wave of contraction spreads across both atria AND that same nerve impulse is directed down through a pathway located at the center of the heart. A pathway that looks and acts like a nerve pathway found inside the heart. This is the famous ‘conduction pathway’ of the heart. You see that as the red pathway in the below diagram. So looking at the below diagram, two signals are running through the heart simultaneously: (1) the black arrows, waves of contractions through the atria AND (2) the red line with this nerve impulse running right down through the center of the heart ending up at the bottoms of the ventricles. From here this signal spreads out into the Purkinje fibers to distribute this signal to all the ventricular muscle fibers and now the ventricles can contract from the bottom up. The ‘red’ conduction pathway travels through the connective tissue barrier between the atria and the ventricles.



The conduction pathways is named as you can see in the above diagram. Starting at the SA-Node, this pathway goes straight to the Atrioventricular Node or AV-Node, then moves into the Bundle of His (named after Wilhelm His, Jr.), then divides into the two right and left bundle branches to end up as I mentioned before branching out into the Purkinje fibers (named after Jan Purkinje).

Notice the ‘conduction pathway’ has nothing to do with blood flow, just the nerve impulse (an electrical signal) that moves through the heart signaling contraction.

<https://www.youtube.com/watch?v=qiIUrCe2Sxs>

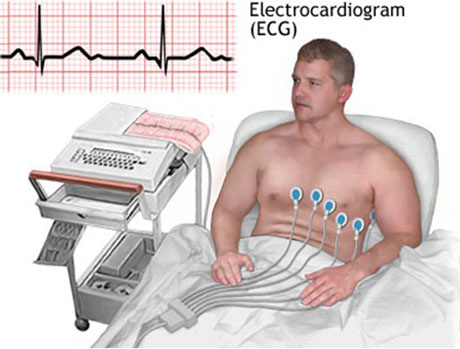
Now for the ECG.

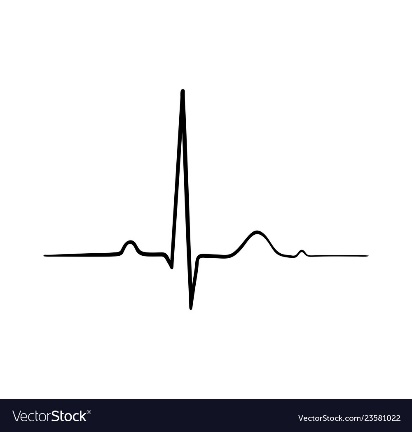
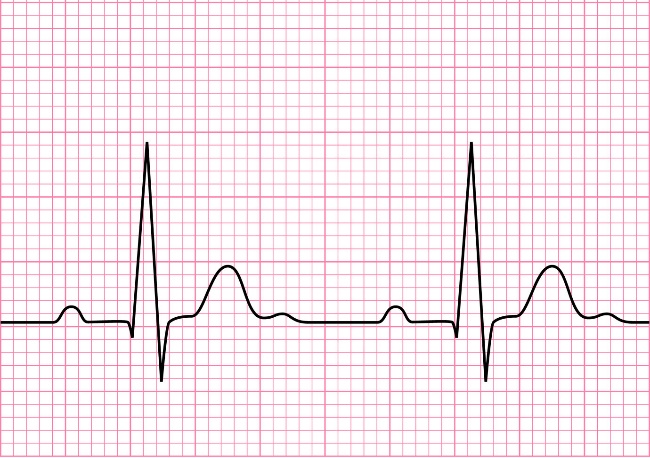
A single heartbeat looks like this. It begins with the atria contracting due to an electrical signal running across the atria through the gap junctions. Then the second part of a single heartbeat is the ventricles contracting due to this same electrical signal moving through the ventricular muscle fibers.

One heartbeat: Atria contract first, Ventricles contract next.

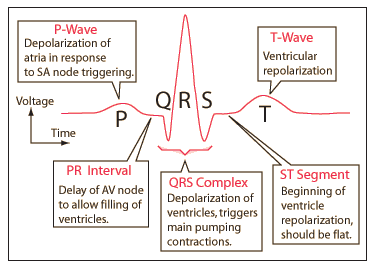
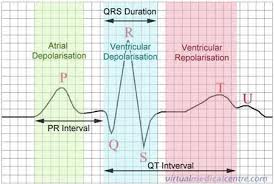
One heartbeat: Atria send electrical signal across them first, Ventricles send electrical signal across them second.

You can measure this electrical signal with a simple voltmeter. Now a more sensitive and reliable voltmeter to measure this electrical signal that moves through the chest would be called an Electrocardiogram machine and it would produce an ECG tracing on a strip of paper. The paper comes out of the machine and shows this below as the electrical signal moving across the chest with a single heartbeat.



The spikes of electrical signal are due to the large movement of electrical signals moving through the atria first and much larger ventricles second.



In the above diagram on the right, ignore the PR-Interval and the ST-Segment please.

<https://www.youtube.com/watch?v=RYZ4daFwMa8>

Watch only up to 6:45 (six minutes, 45 seconds) of this video: <https://www.youtube.com/watch?v=FThXJUFWUrw>

The end, for now.