Bioelectricity
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Module No. #01
Lecture No. #25

Welcome back to the lecture series on bioelectricity. So, this is the twenty fifth lecture we are starting. So, as of now. So, we're in the animal electricity module, as of now, we have talked the electrical phenomenon in the nervous system special senses starting from eyes ears nose tongue touch stretch reflexes to the spinal cord up to the brain memory sleep learning neurological disorders like, Alzhiemers Parkinson amyotrophic lateral silicosis spinal cord injuries inhibitory excitatory signals different measurement technique including Cephalogram, then path clamp micro electro diaries field effect transistors, and different level of electrical competition what is involved.

So, now, from here, we will move on to the next aspect of bioelectricity that is in the case of heart which is a completely autonomous system which is functioning in order to you know ensure that we are alive. This is one organ which has a very very interesting ahm I should say very interesting electrical phenomenon, because it is governed by a set of cells which whose electrical phenomenon are entirely different from another set of cells they have a totally different kind of ion channels, and you'll come to that. So, before we start this cardiac bioelectricity, let us get some idea about the system itself.

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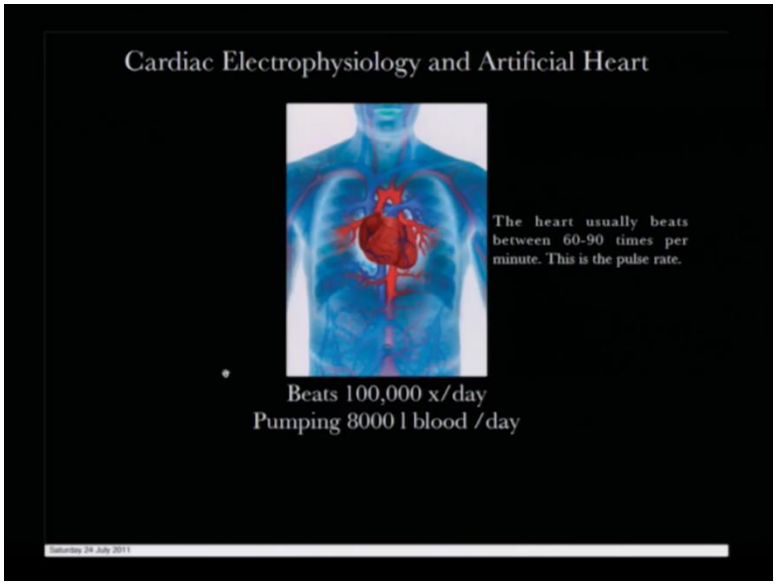

So, referring to the slides now. So, if you look at the cardiac electrophysiology, and artificial heart that is what we will be discussing your heart usually beats between 60 to 90 times per minute, which is essentially is the pulse rate. So, if you back calculated. So, what essentially; that means, 10000 times per day heart is beating, and it is pumping around 8000 litres of blood a day now, you can imagine for a system to function this for the whole life what should be the efficiency of this machine.

This is not an easy task. So, you're beating like you know 10000 times. So, nature the way the heart is evolved that is electrical processes is different from the nervous system, and that you'll be evident as you'll be seeing action potential generated by the big chunk of those contractile muscle system, which constitute your heart. So, this is just to give you a feel that you know, your heart is doing some amazing task if your average life span is seventy to eighty years, then this is just the mesmerizing this is probably one of the most efficient machine. You can think of, because this machine cannot afford to take rest, because if it takes rest, then you are in rest for ever.

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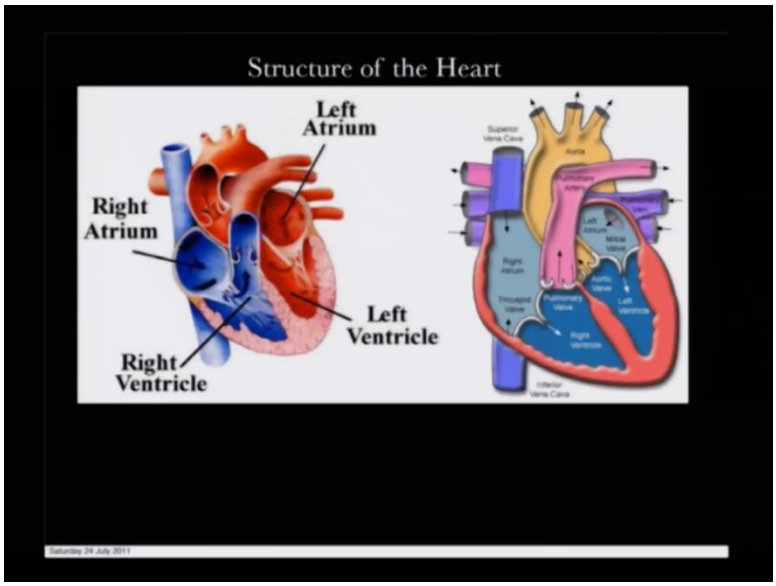

So, coming to the basic structure of it if you look, at that it has a four chambered structure if you look at it something on the left atrium out here it has a right atrium it is right ventricle it is a left ventricle, and essentially what happens is this the right atrium receives. If you could see the diagram from superior vena cava the right atrium is receiving the all the impure blood which is coming to the right, atrium through the

tricuspid valves it moves to the right ventricle the lower chamber from there this is pumped through the pulmonary artery is the only artery, which carries impure blood by the way. It goes to the lungs for the purification it comes back after getting purified in the lungs through pulmonary vein the only vein which carries oxygen rich blood otherwise an only artery the pulmonary artery carries oxygen deficient blood.

So, through the pulmonary veins it comes to the left atrium form the left atrium through the mitral valves you could see the mitral valves here, it moves to the left ventricle from the left ventricle through the aortic valve the blood is run through the aorta to rest of the body. And this whole process, and by the way the right, atrium is receiving blood from both inferior vena cava, and superior superior is coming from the upper part of the body inferior from the lower part of the body, and this whole process has to be synchronized in a very very well regulated fashion if there is any error in this, and we are in a big trouble.

So, this whole coordination the way. the heart works is coordinated by two inter related electrical events two inter related electrical events one is the master, and the other one is the slave, and based on them they have the name pacemaker system, and a contractile system. So, we will be coming to that the contractile system how it is being regulated by the pacemaker system we will come in depth, but slowly one by one we will move into that.

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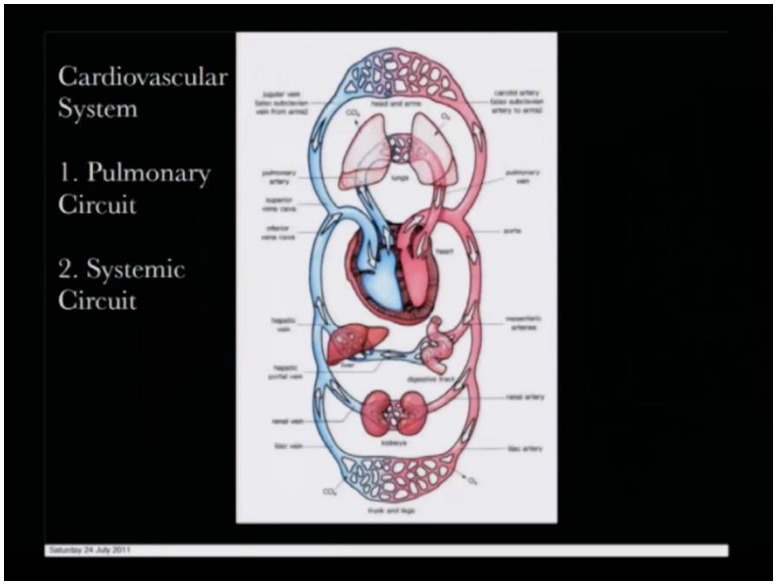

So, going back slightly into the next slide. So, this is what I was trying to tell you. So, this is the heart which is receiving sitting in the center out here, this is the heart, which is receiving from the inferior vena cava you could see the inferior vena cava of bringing the blood. This is the superior vena cava from upper part of the body bringing the impure blood from the aorta it moves to the from the upper chamber it moves to the ventricles from the ventricles, it moves all the way to lungs. So, the pulmonary artery, and from through the pulmonary vein it is coming back, and here this whole circuit is taking place.

So, there are two distinct circuit in the situation one is called the pulmonary circuit the other one is called the systemic circuit pulmonary, circuit is the circuit which is exclusively between the heart, and the lungs. So, the pulmonary artery taking the impure blood to the lungs, and the pulmonary vein bringing the oxygen rich blood back to the heart that small circuit. So, coming back to the slides this part of the circuit the disconnected circuit between the heart, and the lungs is called the plum pulmonary circuit and then you have the systemic circuit which is the rest rest of it is the systemic circuit.

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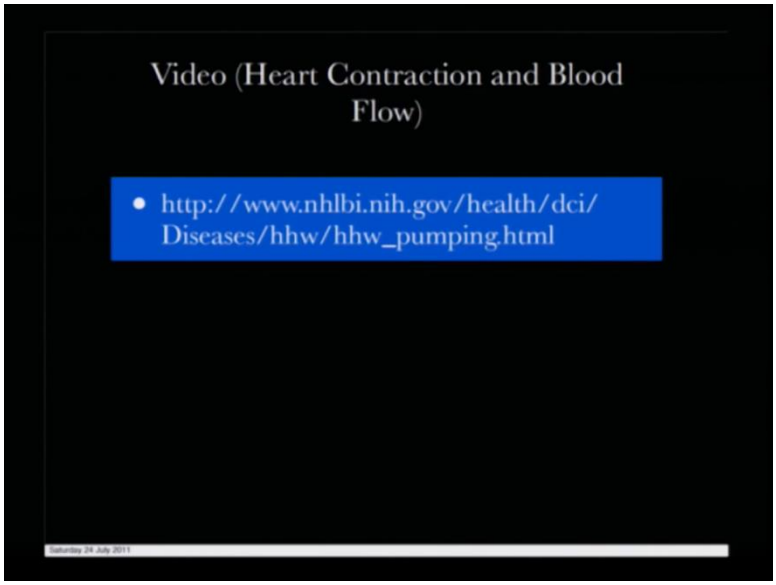

So, these are the two broad circuit, and much anatomy is essential for understanding coming to the next slide, I will recommend you please go through this link this link is still functioning you'll be able to see the heart contraction, and the blood flow there is a nice video out there, which I really cannot put, it here kindly go through which I have

provided the link for you to go through it it is a really very interesting video kindly go through this video.

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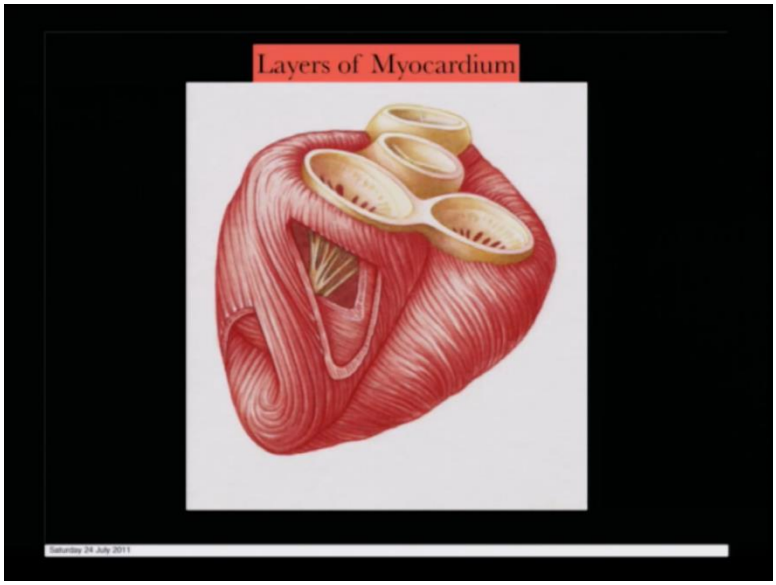

So, coming back to the next slide, this is how the heart architecture is is a kind of a myocardium limits it is a layer of tissue, because this has to be a really a strong organ, because this is hundred thousand times per day this is something. So, there is tissue is kind of you know, if you see in this picture your kind of you know as if I do not know how many of you have seen this like you know a have you seen this you know the ropes the ropes are tied. So, almost like if you look at this picture it will look like as though these ropes are tied, and these are the valves, you see these are the different kind of valves which are like you know kind of you know there is a portion.

And close like this, and likewise. So, this is to give you a feel about the anatomy of course, we're not going to deal with it at this point, but to just to give you an idea that, this is a very very well developed enormous amount of strength to ensure that the blood continuously flows, and continuously pumps in this whole process.

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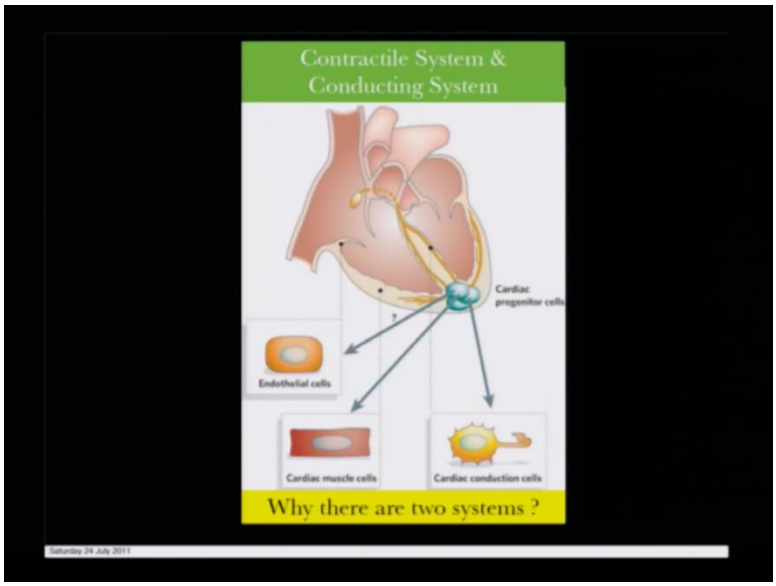

Moving on to the next slide now, this is what I was trying to tell you there are two circuits which are functioning here one is called conducting system or which is also in other words, called the pacemaker system the other one is called the contractile system. So, if you have to give what are the cellular players of the heart.

So, the cellular players of the heart include blood vessels, which constitute of the endoclear cells what you could see here all the endoclear cells which are making the blood vessels, then you have the cardiac muscles cells these muscles cells are the contractile system these muscle cells. What you see cardiac muscles are the contractile system. And, then you have the conducting system which constitute your pacemaker cells, and in this picture you see dotted dotted line the yellow line out here, this is your conduction system, and all these are originated from the cardiac progenitor cell which is mentioned in the picture.

Cardiac progenitor cells are the cells, which differentiates into contractile element conductile element of the pacemaker element as well as the endocrinal cell, and some of these cardiac progenitor cells are present in the adult heart too which could be differentiated into cardiac cells, people are attempting, the adult cardiac myocytes or adult cardiac progenitor cell to be differentiate into functional cardiac myocytes this is the overall structure of the heart we will be coming in depth.

But these are the key, cell the key cellular players of the game. So, if you look at the conducting system conductive system it looks like this. Now, if you compare this picture of this picture. So, this is what I was trying to tell you, and they have different names we will be coming to that.

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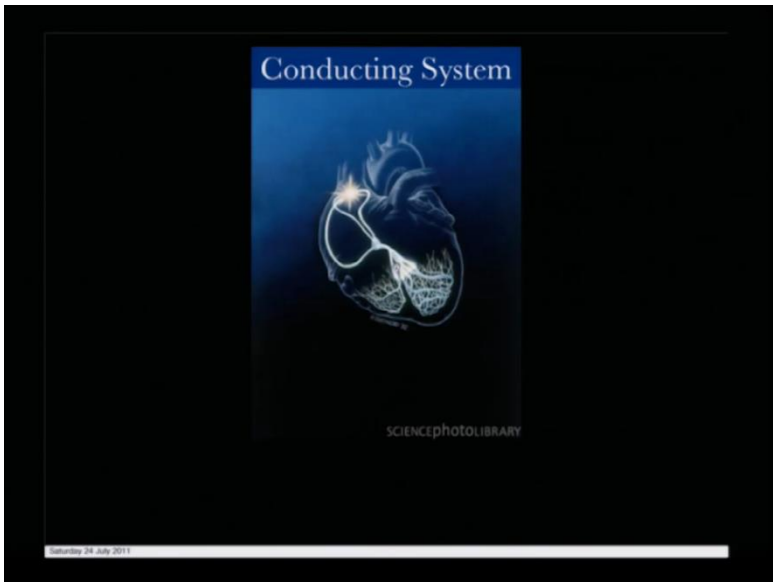

So, in better contrast if you see this picture. So, this is what you see this from here where you see the star kind of thing from here the electrical impulses originate to give you an idea what this contracting system, and conducting system does. So, before I get in depth you have to realize that heart is continuously beating without any electrical without any neural signals, it does not need it is automatic it is doing. So, in order to do. So, there is a circuit which just like a pacemaker just like, a oscillator it is it is oscillating like this taken like this oscillator circuit is absolutely automatic, it is this oscillator circuit exists, because it has a very unique combination of ion channels, which are totally different from the ion channels we have dealt with.

These oscillatory circuits which are present there, this oscillatory circuit ensures this what you see out here what I am outlining out here this is this oscillatory circuit which ensures rest of the heart functions. So, this oscillatory circuit number in terms of the number of cells is very very few with respect to you can see I mean how much area the rest of the heart is have up the cells are constituting this oscillatory circuit constitute the conducting, system or the pacemaker system, and whenever whenever you hear that

somebody is having have a implanted pacemaker that essentially means that this person's conducting system is in trouble.

It means within this circuit there are certain errors the signal the oscillatory circuit is unable to send this oscillatory message all across, that circuit always remember this this will help you to realize, and when I was telling you in the beginning of the lecture the master, and the slave. So, this conducting system is the master system which regulates the slave system which is the contracting system.

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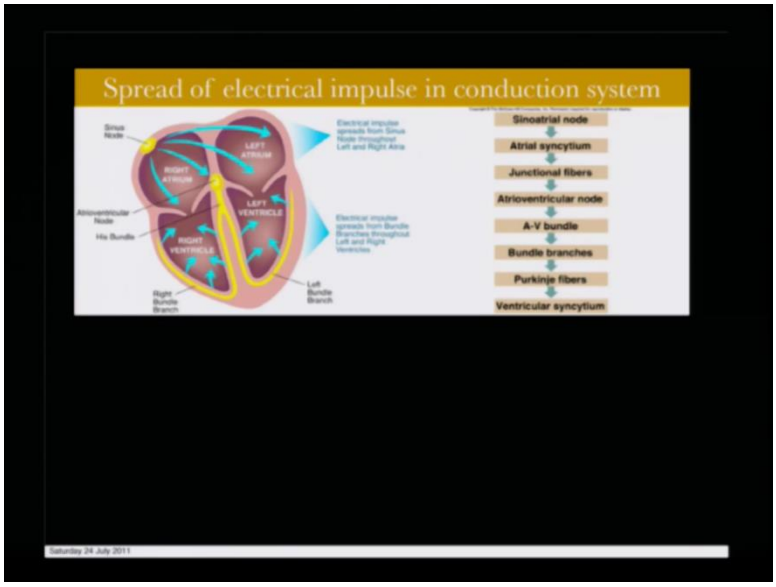

So, let us move on to the next slide. So, this is how this whole circuit works. So, this is where if you go back to the previous picture, this is what is called sinoartrial node this is star sign sino sinus this is sinoartial node, and from here the electrical impulse spread sinoartial node to arterial syncytium. So, this is the arterial syncytium where it is spreading, and there's a ray electrical impulse spread from the sinus node throughout the left, and the right artery. So, those blue lines what you see out here spreading. So, electrical signal is spreading like this automatically if the right atrium it will spread faster as compared to the left atrium, because it will take some time to reach to the left atrium, because of the shared distance.

Now, this node this is the again you have to refer to this. So, this is called a v node if this is called a node say node is this one where my curser is now, once again yeah. So, this is where you see this this is s a node sino arterial node, and this is a v node connected by

three connections. So, coming back in the from sino arterial node through the atrial syncytium through the junctional fibers. So, these junctional fibers are these one's through the junctional fibers it leads to atrioventricular node, which is this a v node atrioventricular node from the, and the electrical impulse spreads from sinus node throughout the left, and the right atria.

Now, next what happens from the atrioventricular node which is called a v node the signal gets split up into two could, you could see that the signal is kind of you know signal is like this, and this circuit is moving like this there's the splitting of the circuit. You could see in the picture that the circuit is splitting, and part of the impulse is reaching the left ventricle, and part of it is reaching right ventricle, and this further split up. So, to the left bundle Bundle branch which is called bundle of his his bundles these are called h I s you could see the arrow showing the his bundle from the his bundle to the left bundle branch, and the right. Bundle Bundle branch from the a v bundle to the bundle branch is to the purkinje fiber to the ventricular syncytium.

So, this is how the split up electrical impulse happens in the conducting system this is how it is being coordinated, and this happens at a specific frequency continuously this oscillator functions at a specific frequency though of course, that is a upper, and lower limit of it, but this is how the oscillatory circuit functions, and there are some sympathetic, and parasympathetic control which regulates some of these oscillatory frequencies, but when in this circuit. What this this circuit what I showed you out here whenever there's an error or there is a blockage in any of these part. So, what happens is that signal is not transmitted, and that is where you need the intervation intervention of prosthesis that is where pacemaker circuits have to be used pacemaker is nothing on the surface of the heart or on the body, you basically put another oscillatory circuit or a electronic oscillatory circuit which generates signals to ensure to compensate for the drawbacks of that existing conducting system.

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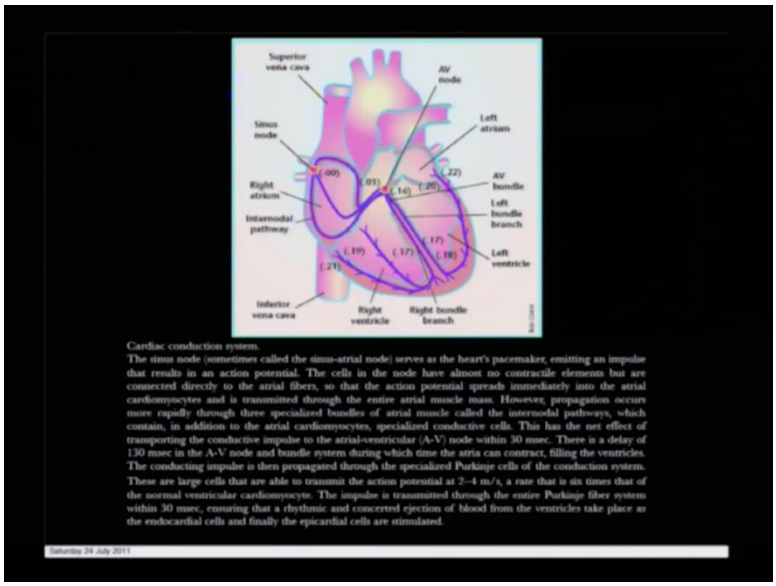

So, from here let us move on to the next slide, which is slightly more complex slide which will give you an idea about the time window. So, at the zero zero time point it is starting point zero three, and if you if you read through the sinus nodes sometimes called the sinus atrial nodes serves as the hearts pacemaker emitting an impulse that results in an action potential the cells in the node have almost no contractile elements, but are connected directly to the atrial fiber.

So, that the action potential spreads immediately into the atrial cardiomyocyte, and is transmitted to the entire atrial muscle mass. So, if you look at this propagation time from 00.003 to 0.0, 0.16, 0.17, 0.17, 0.1,8 likewise if you if you look, at it. So, here it reaches at point two one what is at point two two just, because it has to travel slightly bore on that site.

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So, this is how the signal is moving through, and based on those time points you could see how the signal is moving. So, again from sinus node to the a v node from a v node to the bundle of his to the left bundle of his to the right bundle of his once again another video if you people get see whether this video is functional please go through this one.

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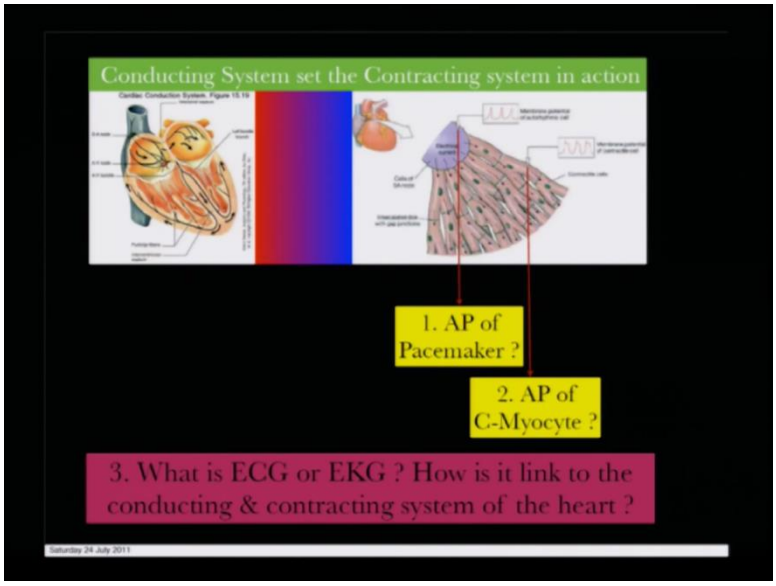

Now, coming to how these are linked with each other. So, when this conductor system is conducting this thing the electrical impulses moves from. So, you have to realize one thing if I go back to some of the very early slides let me go back here. So, there is a

sequence of event which is taking place here from the right atrium the blood is reaching both the right right, and the left atrium from it is pumped here from here it is pumped to the you know the pulmonary artery likewise.

So, this fashion has to be synchronized blood reaching right atrium moving to the right ventricle from right ventricle it is moving to the pulmonary artery similarly the blood coming from the left atrium coming to the left atrium to from the pulmonary veins moving to the left ventricle, and being pumped to the rest of the body this whole process has to be coordinated in a very systematic fashion there has to be a system by which you can coordinate that,

So, what essentially the conducting system does is the conducting system the electrical impulses which are generated by the conducting system here are transmitted to the contractile system these are the contractile system or the cardiac myocytes what you see here. So, these are the membrane potential of the or the action potentials of the s a nodes or the conductile system, and they spread to the heart muscles which are the these are the heart muscles. So, these are the action potentials of the pacemaker, and these are the action potentials of the cardiac myocytes a p stands for the action potential what is e c g, and e k g how it is linked to the conducting, and contractile system of the heart this is one of the fundamental question which you know.

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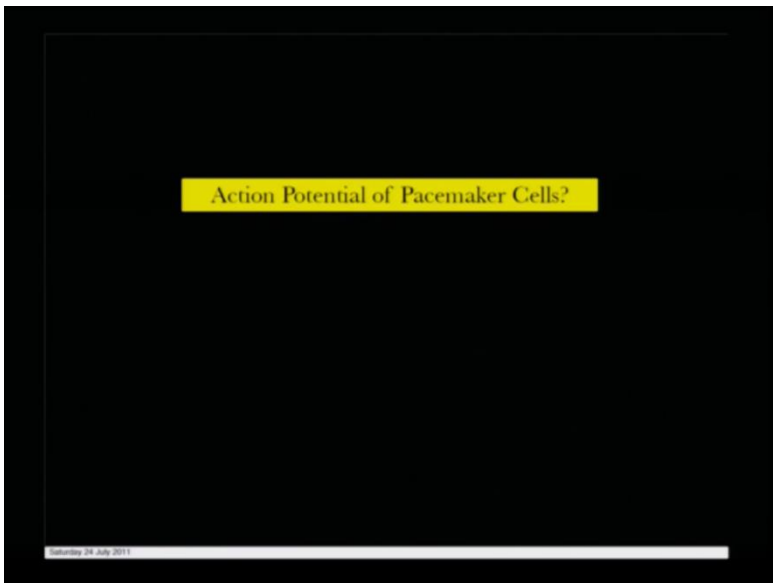

So, coming back to the action potential of pacemaker. So, first of all what we will be doing we will be talking about the action potential of the pacemaker cells, because there are two kinds of action potential you could see here, this is one set of action potentials which are generated by the conducting system, and there's another set of action potential generated by the contractile system. So, first of all we will talk about the membrane potential of the conducting system and then we will be talking about the action potential of the contractile system. So, coming back to the action potential of the pacemaker cells.

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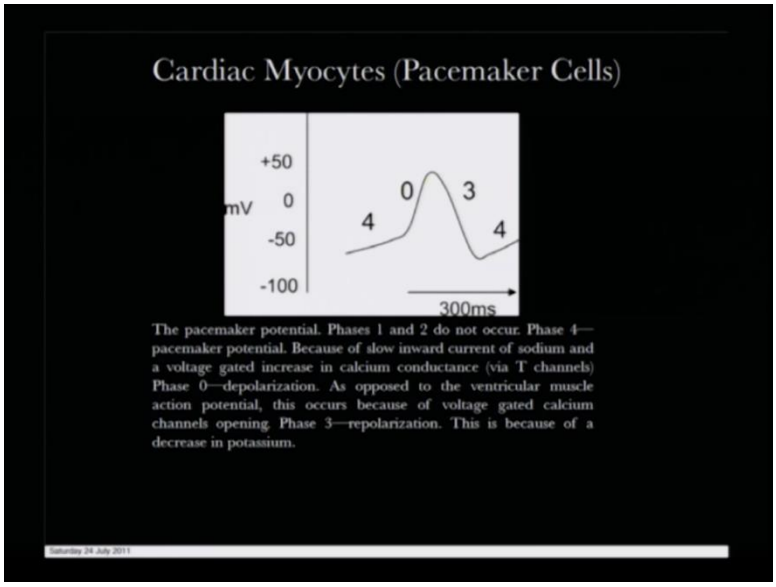

The pacemaker cell or the conducting system action potentials, it is very interesting. So, here to realize that these pacemaker cells, do not have sodium channels. So, as of now, in the nervous system whenever we have talked about action potentials. So, what essentially we have talked about is the action potential is started a cell sets at minus 70 or minus 60 or minus 70 or minus 80 milli volt from there some impulse comes some ligand comes, and binds or some light falls on that, and the membrane potential shifts to say minus 40 minus 50 from there it is all, and another action potential is united.

But in the case of cardiac myocytes pacemaker cells the story is totally different these cells do not do not mark my word very carefully do not set at minus eighty they set somewhere around minus you minus between minus forty between minus forty, and minus 50 they are spontaneously active they do not need any electrical impulse they do not need any kind of you know something to pull them. So, if you see the graph. Now,

you'll see they are sitting at around minus 40 around minus 40, and minus 50 they are spontaneous this activity is spontaneous.

So, essentially they do not have they have they, because they are slow invert current unlike unlike their counterpart in the neurons where there is a fast activating sodium current, they are slow sodium current, and they have a voltage gated calcium conductance's these are mostly regulated by the calcium conductance's, and they set out here, and from here they can overshoot they overshoot zero you see the action potentials.

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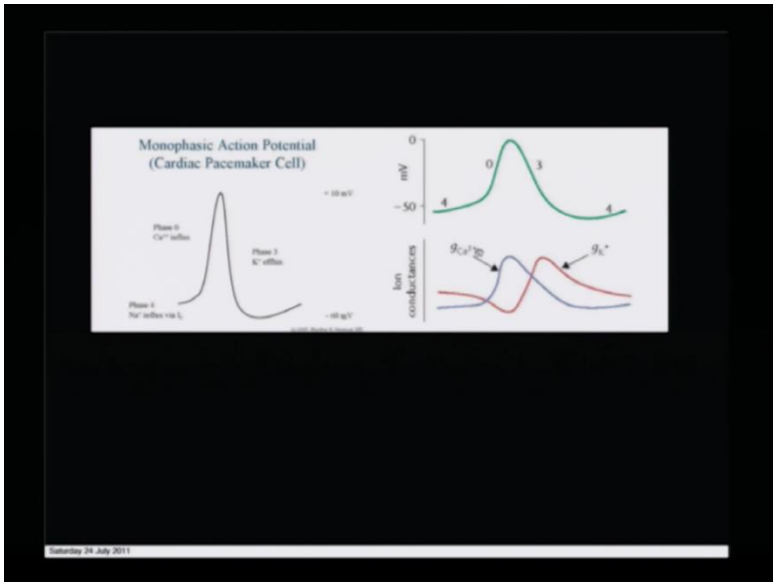

So, these are the zero is depolarization phase as opposed to the ventricular muscle action you see the difference between it, and phase three is the re polarization phase. So, if you look at the monophasic action potential of the cardiac myocyte. So, this is what is happening they are sitting at around minus 50 or minus 40 between minus 40, and minus 50 out here in the phase four slow sodium influx very slow sodium influx followed by a calcium influx followed by a potassium influx, and they come back, and again they goes back, because of the slow sodium influx. If you look at it as opposed to if you look at it, because of the slowing, invert current of sodium, and a voltage gated increase in calcium conductance by a t channels, there is a spontaneous depolarization which is taking place, and if you in this picture.

So, if they are if this is the whole thing the green, then green is showing the complete process. So, this these are the individual ionic conductance you see calcium, and there is

a slow invert sodium. So, it is the calcium which is the game changer. So, these cells do not sit at. So, one of the take home message from this is these cells do not sit at minus 80 milli volt they are sitting at minus between minus 40, and minus 50 milli volt, and they are spontaneously acted, because of the slow activating, because of the slow moving sodium channels, and coupled with a high percentage of calcium channels. So, they are spontaneously active throughout your life. So, this is all the conducting system is automatically spontaneously function like an oscillatory circuit they oscillate like this. So, this is the monophasic action potential of cardiac pacemaker cell.

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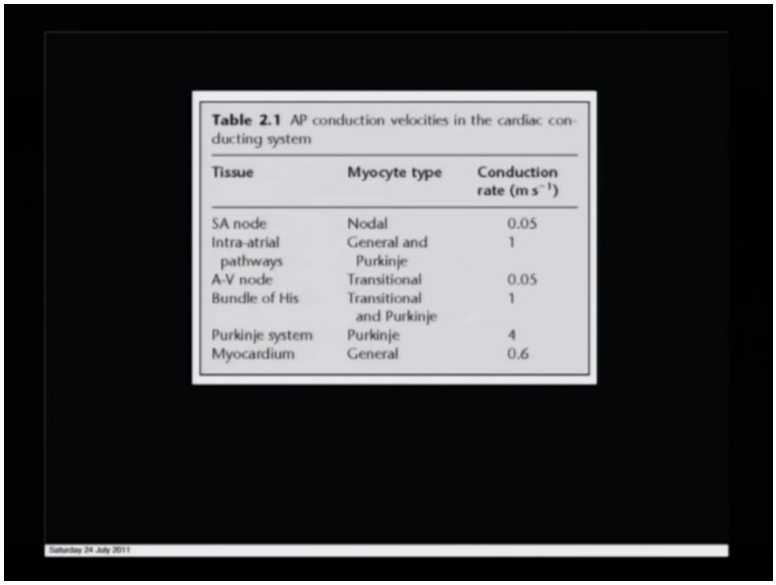

Now, moving on to the action potential velocities, if you if you look at it these are the different conduction rates. So, these cells now, in order to understand this what you have to to go back to this picture out here. So, at the different part of this circuit there are different kind of pacemaker cells, and they have different properties depending on, because since I covered the anatomy. Now, if you see this table that will give you an idea the at the s a node their conduction velocity is 0.05 meter per second, then at intra atrial pathway it is one this is from your higher into the purkinje cells it is even much more higher. So, these different velocities in actually ensures that they have different concentration, and different kind of ion channels, but they all sit at between minus 40, and minus 50 milli volt action membrane potential. So, that they are spontaneously active.

Now, what about the action potential of the cardiac myocytes we have talked about the conduction system we haven't talked about the contractile system let us look at the contractile system. Now, now we are moving onto the contractile system, and I have already shown the connection between the contractile, and the conduction system out here. So, these on the right hand side these violet color are the conduction system, and this whole process is the conduction system.

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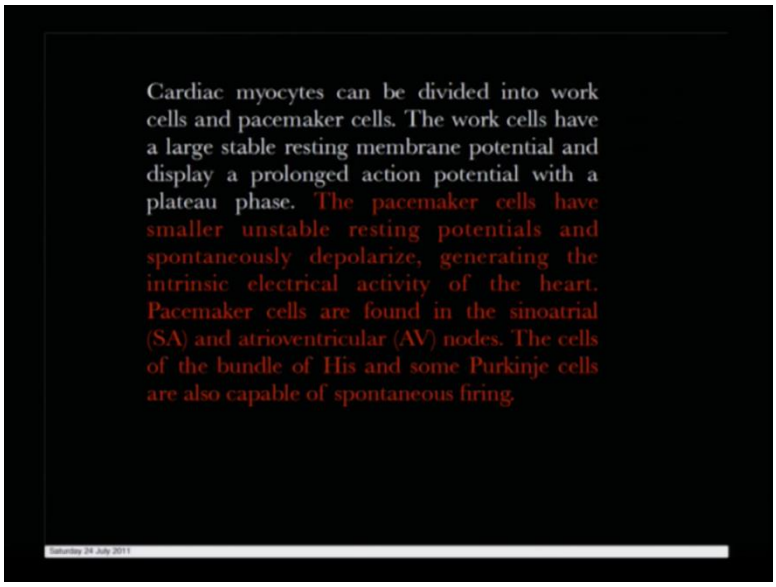

Now, coming back to the contractile system. So, cardiac myocytes can be divided into work cells, and pacemaker cells the work cells have a large stable resting membrane potential just like the neuronal counterpart the contractile system sits at minus 70 minus 80 milli volt, and displays a prolonged action potential with there is a difference of course, which we will come across, and where as if you compare in the red the pacemaker cells have smaller unstable resting potential, and spontaneously depolarize generating intrinsic this is very important to node intrinsic electrical activity of the heart pacemaker cells are found in the sinoatrial node, and they, and the atrioventricular a v nodes cells of the bundle of his, and some purkinje cell are also capable of spontaneous firing be very careful reading through these lines, because this is the most characteristic feature your contractile system follows the membrane potential of the neurons minus seventy minus eighty where as your pacemaker system do not sit there they are spontaneously intrinsically active.

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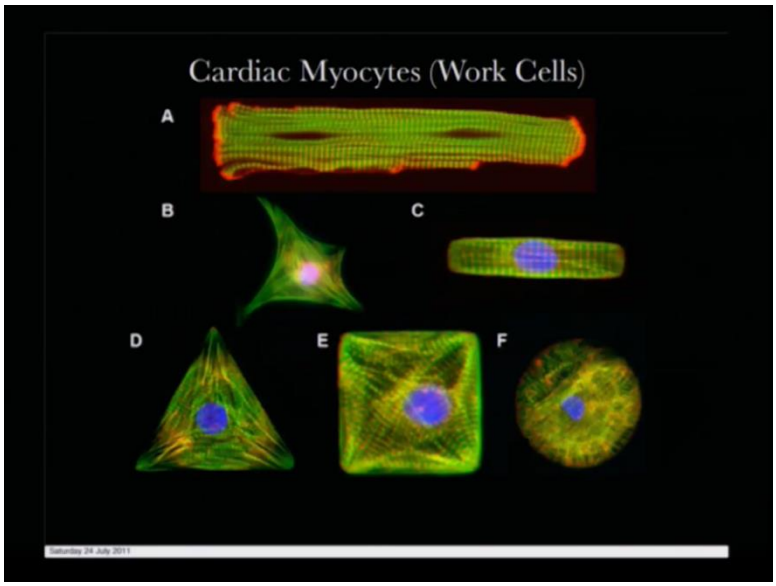

Coming moving on the next slide how the cardiac myocytes looks like these are the contractile element this is how they look like, if you take the cross section this is derived from several people who are packed on them, then you know they have grown you know specific pattern that is how they look like, and they are all you see these lines they are all connected with each other using gap junctions gap junctions are kind of you know between two sides they are connectivity. So, automatically this whole structure does not need to have the synaptic connection between individual cells they are all connected with each other using pipe like structures, and those pipes are called gap junctional gap junctions.

So, between two cells that is a physical physical pipe which is connecting one cell to another cell likewise. So, these cardiac myocyte or the work cell or the contractiles, then whichever you want to express it as long as you understand the whole concept they their morphology is something like this where you see, now, from here now.

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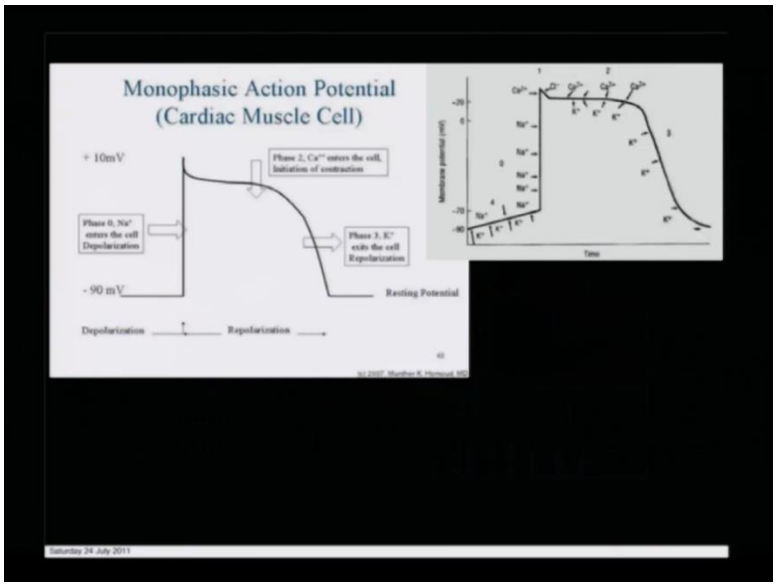

Let us see a monophasic action, potential of the cardiac myocyte. So, again see it is sitting in minus 90 milli volt there is fast activating sodium current which essentially overshoots zero plus 10 milli volt plus 10 milli volt, this is the difference between cardiac myocyte, and other neuron cell types. This is where you see there is a lot of calcium ions to which influx taking place out here, this is very interesting lot of calcium getting in, and it holds this cell at the positive potential for a prolonged period of time why is it. So, possibly, because these cells are to do their activity for all your life all your life. So, this is the zone where they are in a kind of you know they are not physically you know contracting they are just kind of you know slows down.

There is a kind of you know slows down, there is you know this is kind of you know they need some time to recover all the cha channels, and everything this is this ways this plato phase what you see lot of calcium, and potassium moving in along with potassium, because this is the this is the zone. Where there is in the neuron cell we observed that there is in three of all is potassium, but here you see that is huge entry of calcium along with it this is the zone, which ensures the cell come remains in a slightly rest situation and then it shoots the next action potential, because it has to continuously shoot action potential.

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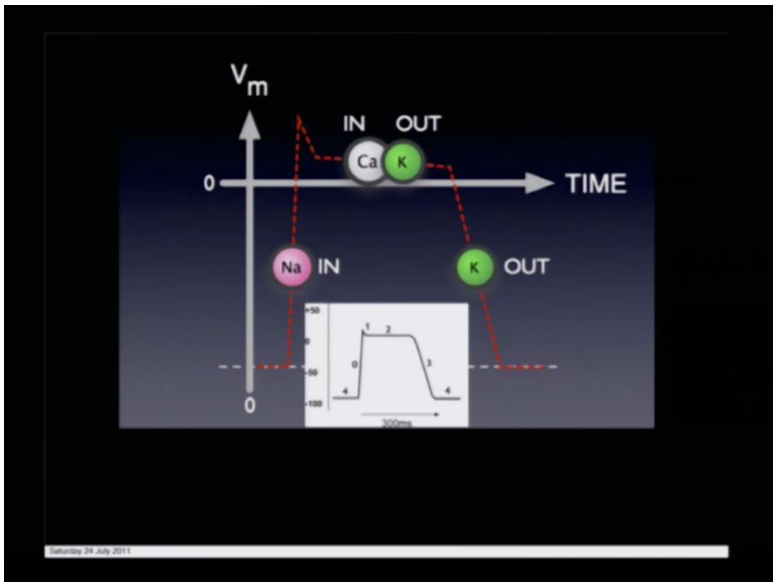

So, moving on to the next slide. So, this is what is happening entry of sodium entry of calcium, then potassium is going out, and this is further bringing in back, and this whole process is taking 300 milliseconds now, if you compare this three hundred milliseconds with other neuronal types in realize that this is far bigger as compare to other neuronal cell types.

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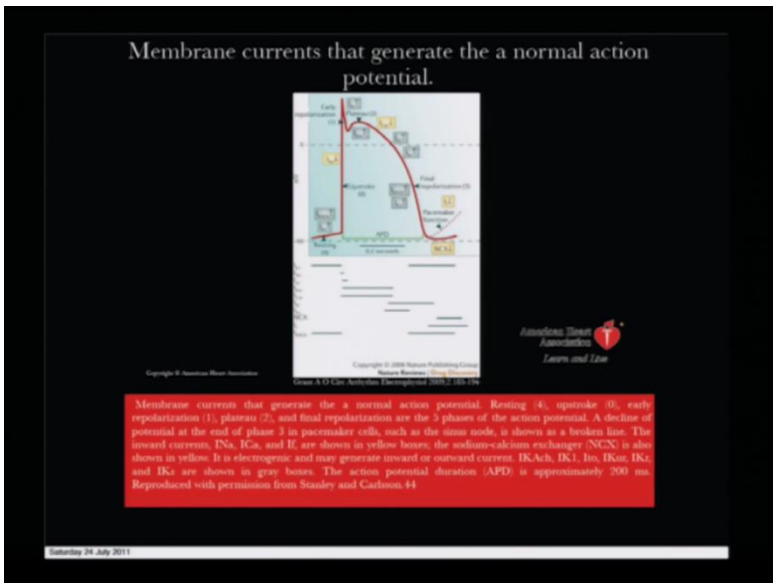

Now, moving on to the next. So, membrane current that generates the normal action potential. So, these are the different component. So, if you go through it this is this has

been taken from american heart association as I it has been acknowledged. So, you will see from the resting potential which is in minus 80, these are the different components potassium component sodium component in a calcium component, and several other, and the different piece maker how they are regulating this whole process.

So, membrane current that generate normal action potential. So, that general normal. So, there is resting there is an up stooge there is an auld de polarization there is a plateau phase, and there is final de polarization phase kindly go through this very carefully, because I mean this is going to you know enrich your understanding about how the hear is functioning from here.

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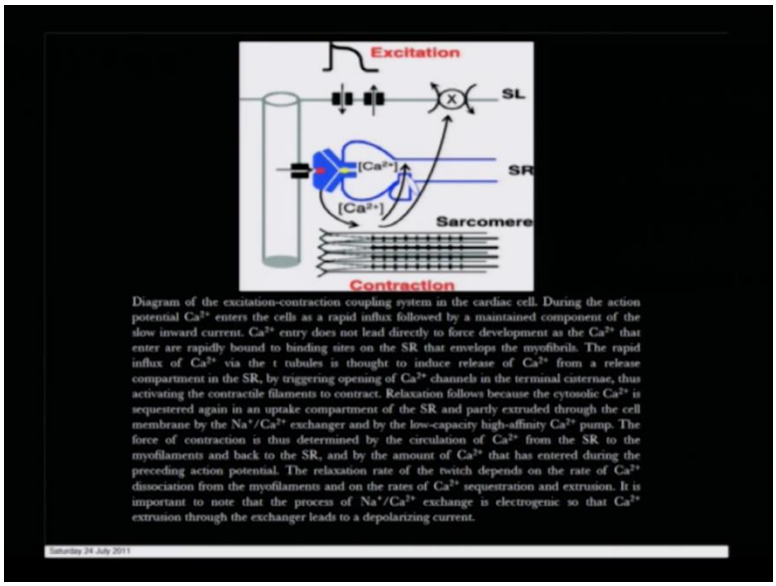

Back to if you remember while I was talking or I talk to you about the ry anodyne receptor, and dy hydro pyridine receptor. So, action potential leads to the motion or movement of the sliding sliding motion, which is regulated by the sarcomere. So, this is what you see the electrical impulses leading to the movement of the muscle through the excitation, contraction coupling a pirates in which mostly involved the ry anodyne receptor, and this helps a lot of this is of immense importance in the pharmacology there are lot of disorders, which are observed in that ry anodyne receptors this is what you see this is where it is happening this is where the action potential travel, and this is the zone where the ry anodyne dy hydro pyriditate.

So, electrical impulses coming an electrical impulses leading to the excitation of these muscle cells, and this is where dy hydro pyridine, and ry anodyne receptors are present, and they lead to the a flux of the calcium in this, these are both are calcium channels of course, this calcium leads to the contraction of the muscle in the sacromere which is this is this is a site of hot site of pharmacological interest.

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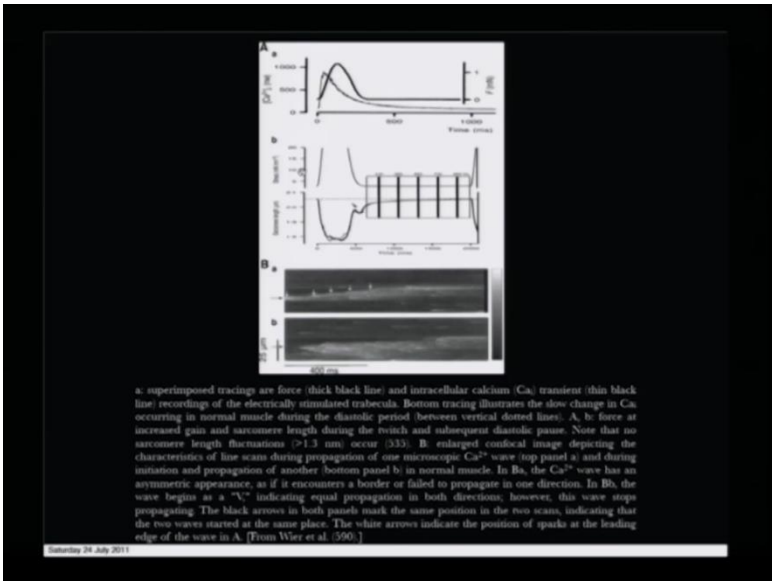

So, coming back again we are super imposing some of the tracing of the calcium transient calcium, and these are traces of the calcium recording. So, if you remember while I was covering the last lecture, of the nervous by electricity I talked to you about imaging calcium the waves of calcium which are moving through, and heart is very prominent organ, there where this kind of waves of calcium waves are being studied in greater in in greater details.

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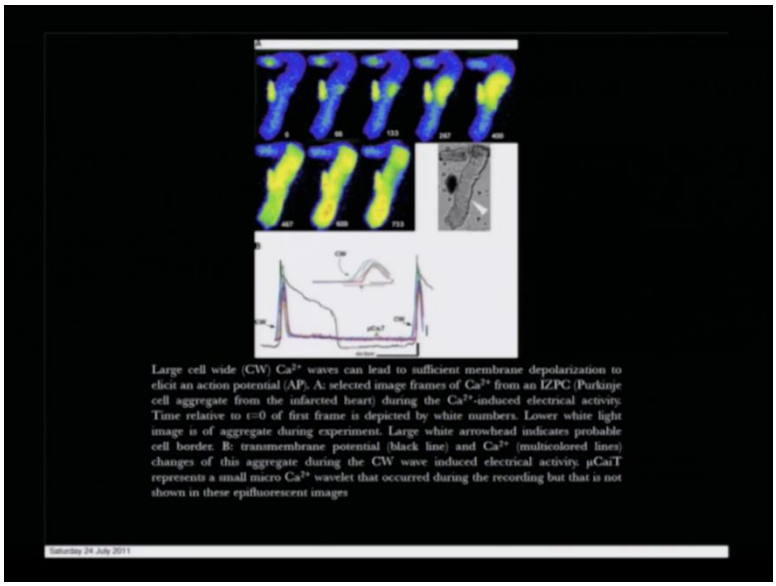

So, this is one such example where it has been shown I have given you the reference also you can go through the reference that will help you, and this is exactly the reason why I introduce this is what you see are the calcium in fluxes which are moving through your imaging calcium. So, if you see. So, what you see this yellow thing this is the way which is moving through a cardiac myrsite this was was a trying to highlight in the ne nervous di electricity that they were calcium imaging techniques which are being used.

So, near hue you can see how the calcium imaging is being done. So, you have dice which changes their color with the influx of calcium, and you what you are measuring is that change in color in the form of wave you see there is a, and this time0 8, 66, 133, 267, these are the seconds at different seconds how the calcium wave is generating. So, from here its change see the changes here, it become more intense more intense more intense, and it becomes really intense as it moves through, and it is now, dying out. So, this is moving through moving through the cell a wave moves through like this. So, this wave motion is the calcium, wave what I was trying to highlight.

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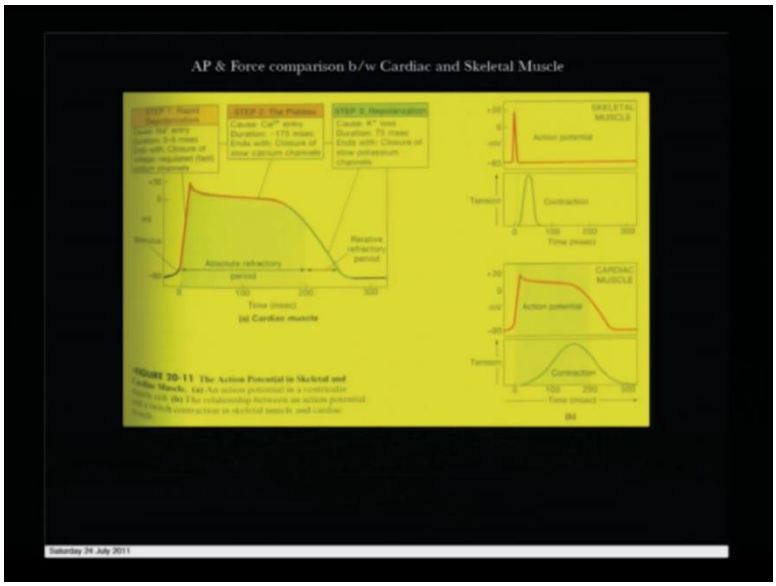

So, if do a comparison now, of the action potential this is what I have giving you an action potential comparison I told you this is almost three hundred milliseconds now, look at the contraction of a skeletal muscle which is far less it is nothing or a skeletal muscle contraction. So, there are two muscle type with a totally totally different action potential, and as matter of fact a smooth muscle, if I could have added here please go through or the refer reference takes a look you see the smooth muscle also have different kind of action potential pattern.

So, it is the time. So, if you compare it cause the sodium entry duration 3 to 5 seconds ensure the closure of voltage regulated fast sodium channels, then comes the plateau where the causes calcium entry duration almost of 175 milliseconds ensure the closure of the calcium channels re polarization where potassium lose starts and then of course, followed by that, you have this the sodium potassium a t ps pump calcium pump, and everything comes into play which ensures to pull back the calcium, and getting the getting the sodium out, and getting the potassium.

So, this is a comparative picture which I wish you people really go through very very carefully, because this is going to re help you to realize, how the heart functions for all your life, because all your this skeletal muscle does not have to function all the time when there is a impulse it function, that is said it has lot of time to take a rest, but your heart does not have any time to take rest it has to continuously function.

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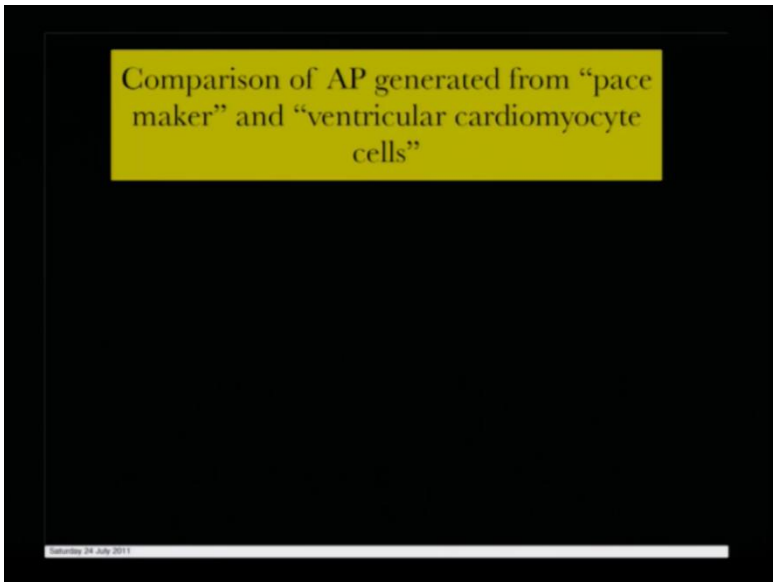

Kindly go through the this very very carefully now, a comparison of the action potential generated by the pace maker, and the ventricular cardio myocyte it could be this is it is ventricular cardio myocyte, it could be the the upper chamber cardio myocyte also.

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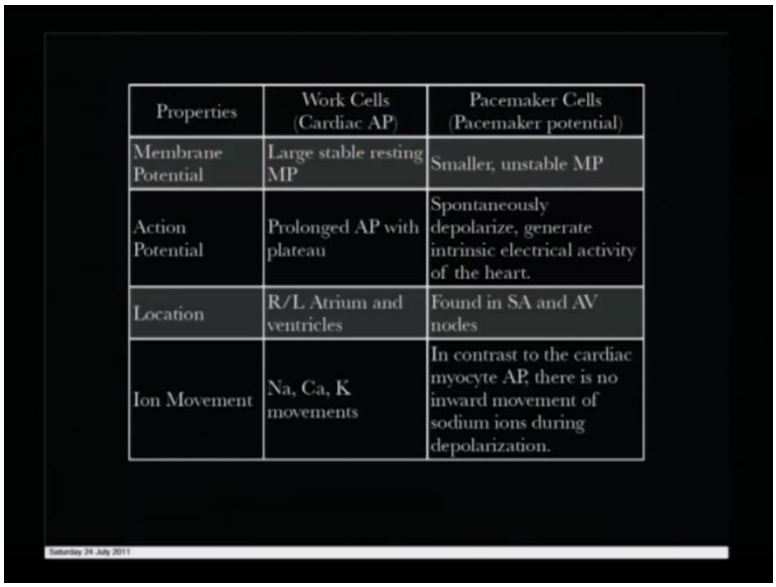

So, if you compare it the work cells or the cardiac or the cardiac myocytes, they have larger stable resting membrane potential m p stands for membrane potential where as pace maker cell has a smaller unstable membrane potential action, potential in terms of action potential they are prolonged a p stands for action potential with the plateau where

has a pace maker cells are spontaneously de polarized generate intrinsic electrical activity of the heart.

Location right or left atrium, and the ventricles where has pace maker cells are found in the s a node a v node bundle of his, and purkinje fibers ion movement sodium calcium, and potassium movement in contrast of the cardiac myocyte action potential there is no fast inward movement of sodium ions during, it could you should add this word fast movement of sodium ions during de polarization this is the overall comparison between the two.

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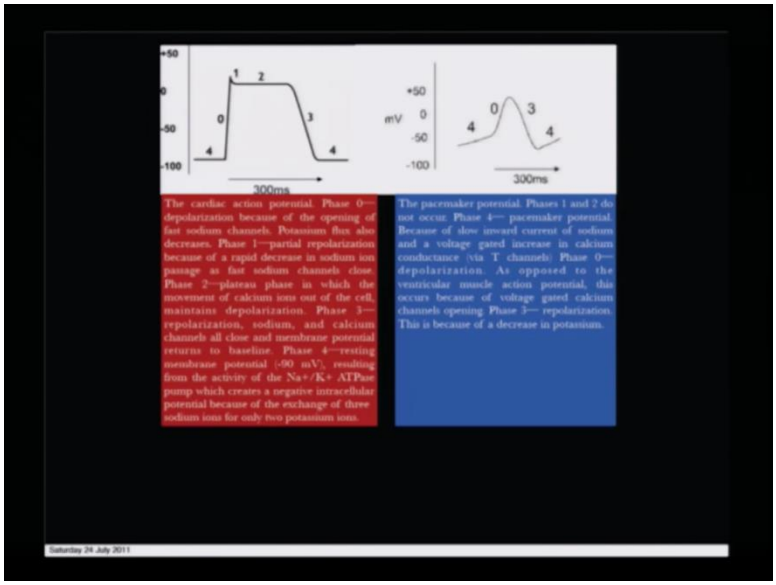

And in terms of the diagram. If you look at it look at, where they are resting this is resting at minus 80 this one is resting at between minus some are between minus 40, and minus 50, and these are the different paces what I have already highlighted if you go through those paces, its very fairly clear, and the impulses which are generated from this oscillator circuit is being used by sue to activate the cardiac myocytes which are present there. So, this compacted picture is very very essential for you people to you know kind of you know take in mind that, you know how beautifully this whole system is synchronized, because as if you now, we are talking cellular level, and afterwards will talk about the e k gs where these over all electrical activity, because of these two processes which are working an in an.

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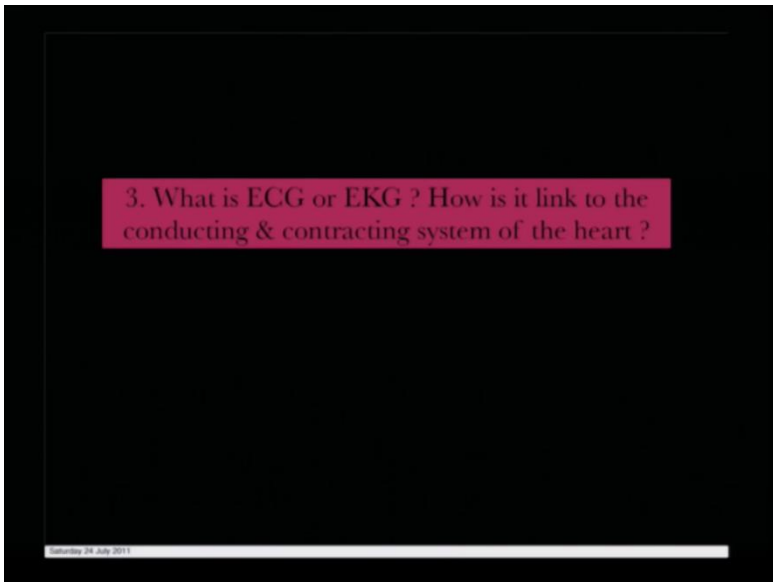

So, now, comes the question what is e c g or e k g, and how it is linked with conducting contracting system of the heart. So, I will closen here with this lecture the next lecture will start from here. So, to summarize what we have learnt as if you now. So, we have delta with an atomy of the heart we have talked about the different cell types of the heart, We have talked about two different contract conduct two different electrically electrical elements the contractile system conducted system, where conducting system is acting as the master, and contractile system is acting as slave, and the impulse generated by the oscillator of the contractor conducting system is transmitted to the conducting contracting system, and we have made comparison between the electrical properties of both of them. So, I will closing here in the next class we will talk about the e c g, and the e k g.

Thank you.