Bioelectricity

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Lecture – 26

Welcome back to the lecture series on Bioelectricity. So, we are into the 26th lecture. The twenty-fifth lecture, we talked about I introduced you to the cardiac system, we talked about the anatomy of the heart, and the different cell types of the heart, their electrical properties, the kind of action potential they shoot, and we figure out that the conduction system has different action potential pattern as compared to the contracting system. And how from the conductional system action potential are transmitted to the contraction system, and how this is all coordinated.

So, this class is just like when we are studying about the brain, you people remember, we talked about the activity of the individual neurons, and then a small population, and then at the end we talked about the electro electroencephalogram, the overall activity of the brain. Exactly the same way, the heart has overall activity. As if you now we have talked about the individual activity of the individual circuits within of the heart, the conduction system, contracting system, and there are two distinct electrical phenomena, which are regulating one of them is regulating, the other one is happening. But if you put electrodes on top of the heart, there you get a global phenomena of what is happening, and that all falls under EKG cardiogram, when the German are ECG - Electrocardiogram, C or K which over you, kind of you know highlighted.

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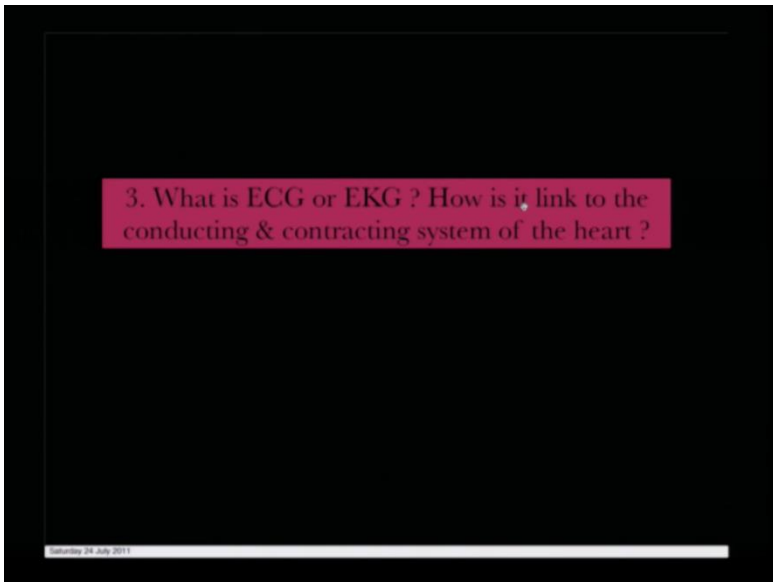

So, the question what we are going to ask now is where we stop the last lecture is, what is ECG or EKG, and how it is linked to the conduction, and contracting system of the heart. Coming back to the our slides. So, this is the question with which we are starting this class.

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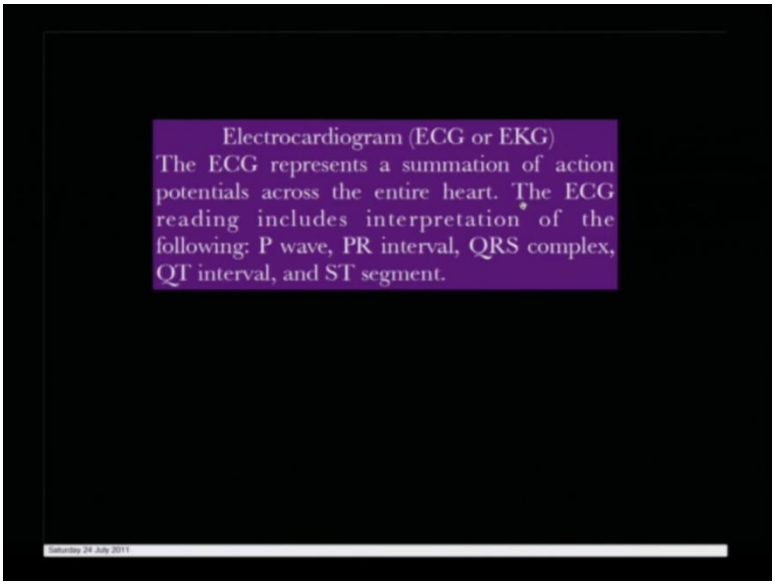

So now electrocardiogram or EKG by definition, it represent a summation of action potential across the entire heart. Just remember what we did in EEG - the electroencephalogram I told you that you put electrodes on top of your head like this you

know, and they do all the recordings. Where you get the electroencephalogram picture or electroencephalogram recordings

So, same way in e k g what you do e c g represent the summation it is o addition of algebraic addition of all the electrical phenomenon, and e c g reading includes interpretation of the following p waves. So, there are different waves, what you see if you go to the doctors here p wave p r interval q r s complex q t interval, and s t segment do not get worried. These words are at this point will sounds you to has some greek in latin, but very soon it will be very clear it is very straight forward, and I am not going into the vectorial analyses of it.

I am just keeping it very simple for your understanding, and I will give the reference very simple reference where you can understand how these different waves are been generated. So, simple vectors calculation. So, it is not a big deal, but I am not just not touching at this stage, but I will give you the idea of it the physic bind this whole process.

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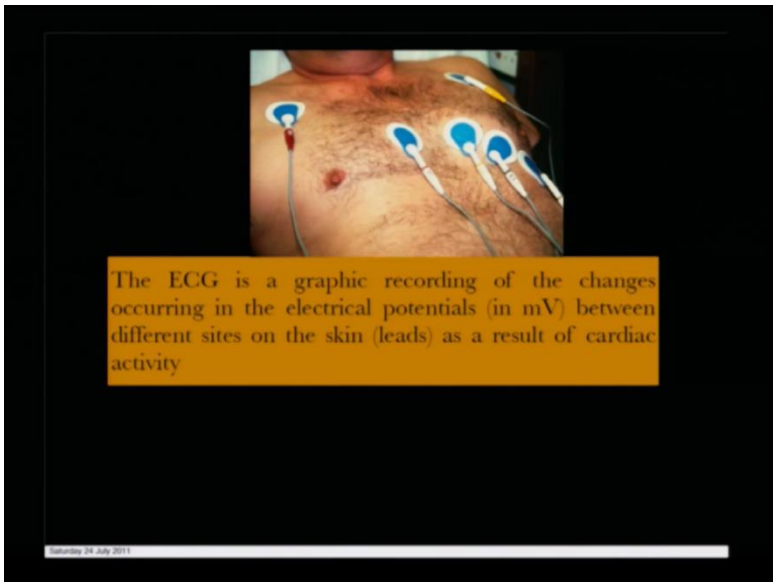

So, coming back to the slides. So, this is how the e c g is a graphic recording of the changes occurring in the electrical potentials in milli volts between different sites on the skin the. So, these are your leads you are putting the leads in the surface as a result of cardiac activity this is how it is being majored. So, this is essentially how you are majoring you are keeping different leads the surface electrodes these are all your all your

surface electrodes which are on your body, and which are actually picking up the global electrical signal of the heart.

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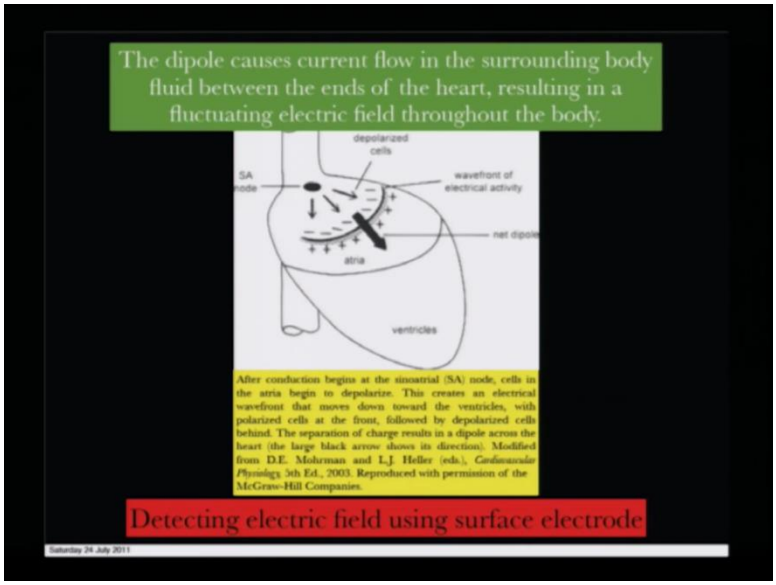

So, now moving on to why exactly, so I told you that I am not going to deal with vectorial analyses, but what essentially happen is this. So, the way the wave the when the heart is beating I told you there is patter by which it beats first the upper chambers. This sends the blood to the lower chamber from the lower chamber blood is either come to the rest of the body or to the heart to the lungs for purification through the either through the pulmonary artery or it will be sent through the aorta, and pump.

So, there is pattern of event. So, if you look at this picture you see from the s n o out here the pattern moving like this. So, polarization de polarization polarization de polarization polarization de polarization as if there is c of dipole or or it just like a dipole like you know as if there is moving dipole, and if you follow this. So, as if this wave is moving positive negative positive negative positive negative positive negative likewise. So, this is there is wave of dipole.

So, if see the dipole causes the current flow in the surrounding body fluid between ends of the heart resulting in a fluctuating field throughout the body, and I have given you reference you can you people can go through it after conduction begins that they say note cells in the atria begin to depolarize. This creates an electrical wave front that moves down toward the ventricles this essentially what is happening, because initially your

upper two chambers are getting filled followed by the blood moves to the lower two chambers. From there it is either distributed to rest of our body or sent for purification to the ha to the lungs. So, this is exactly what the slide is telling you followed by depolarized cells behind separation of charges. So, this is very important to read

The separation of charge result in a dipole across the heart the large black arrow shows its direction you see follow this black arrow. So, this is how the direction is moving. So, detection of this change in electric field using surface electrode is essentially what you do in the e c g recording, and the vectorial component of these different dipoles using simple mathematical transformation. You get the e c g waves where we are talking about p waves, and q t travel q r s complex, and all those things what do de dealing now.

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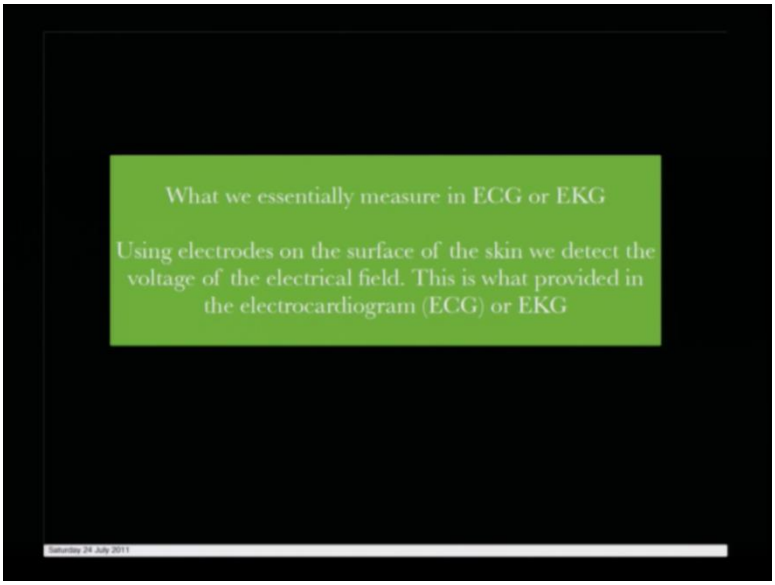

So, now as you know the geometrically what is happening. So, at different stages of this, we are getting a different vectorial summation, and which will becoming next is, what we are essentially major in e c g or e k g is is a electrode on the surface of the skin. We detect the voltage of the electrical field remember this this is what provided the electrocardiogram e c g or e k g now moving on how this wave is generated now they are coming to the those all those Greek in Latin words what scared you people.

So, this is in milli volt, because if go back. So, what you are majoring you are majoring the voltage of the electric field, and electrical field is generated out here. So, if you follow these diagram these is an electric field which is moving electric field as if the

diploes are moving polarization de polarization polarization de polarization polarization, and following this arrow and… So, you will be majoring the voltage.

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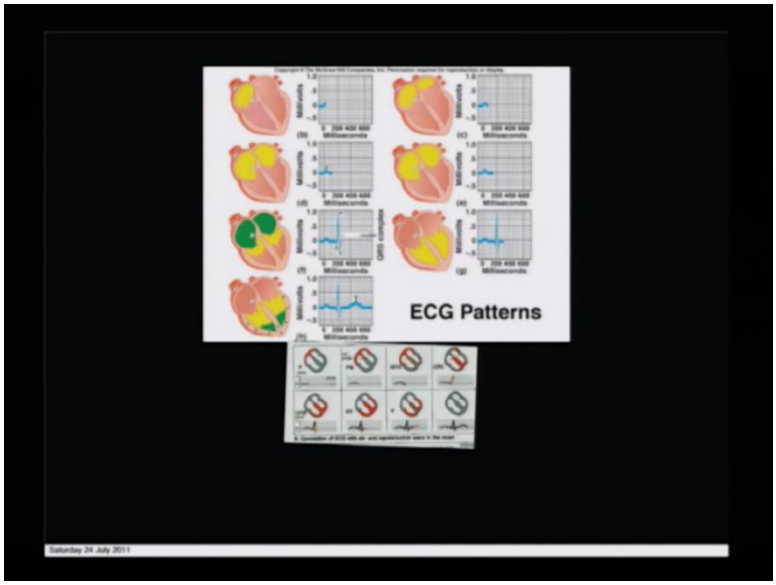

So, here on your y axis you have the milli volts, and these yellow are showing which part of the heart is exacted, and which part is not exacted and. So, the first when the upper chamber out here is exacted when you see this is the trace in the blue you see the trace the electrical trace the overall electrical on the electrode followed by this one when both the upper chambers are partially activated. So, the it forms small ha hump out here you see the sum this is the p wave when, and this p wave becomes complete when both the upper chambers are completely exacted.

So, yellow is indicating the complete exaction followed by this exaction moves on to the lower chambers out here, and this green showing it is no more exacted it is it has already sent the it is in the process of you know sending the liquid or the blood to the two chambers out here. So, it is spreading in the lower two chambers, and in the mean time you see this p, and there is a q r s you see this over all electrical impulse showing like this you could follow this. So, this is what is called q r s complex, and this is all the recording this surface electrodes.

So, what is happening followed by the q r s complex this is again the repetition the q r s complex where the whole lower two chambers are completely exacted are completely you know active followed by from the lower two chamber blood is now pump to the it is

in the process of getting pump to the either to the aorta or to the pulmonary artery this is where your t is coming you see this t out here, and if you follow this diagram you see this is the e c g case. So, first of all this red area is showing which part of the heart is exacted, and the contrast you have that ash color.

So, its starts here p, then you have the p q, then you have the q r s complex, then again the q r s is further going through q r s is a long complex. So, see how this whole thing is building up this what you see this was kind of it when slightly more in advance. So, here you can build up the whole story how this whole graph of p q r s complex is forming

So, the p complete formation of the complete p no w the q is started now r s is going up, and further coming down, and then it is ending the s t, and then the t wave coming through, and this is the complete p q r s complex.

So, this is what essentially is the change in the electric field what you see which is being measured. So, the definition wise now see that re what is the definition of it using electrodes on the surface of the skin we detect the voltage of the electrical field this is what we called has the electrocardiogram or the e k g, and this is the whole process how what. So, whenever a doctor sees now what are the practical significant of this whole process say for example, you see two p waves.

So, one p wave followed by another p wave, and then the q r s complex is coming what does that mean think of it essentially; that means, you need more power to pump the heart pump to pump the blood from the two upper chamber to the lower chamber it means something very significant that it means in your pace maker circuit or in your conduction circuit there are blockages or there are damages because, then only you need more energy to pump this or say for example, you I was telling you that what are the things you look forward to here suppose your two p waves p r interval is longer or your q r s complex of some you know some kind of a normally. So, this is the situation which doctors looks. So, whenever the doctors if you see the doctors whenever they taken e c g trace the kind of look for all those things whether, but let me tell you there are certain things which e c g can tell, and there are certain things e c g will never will will come to that.

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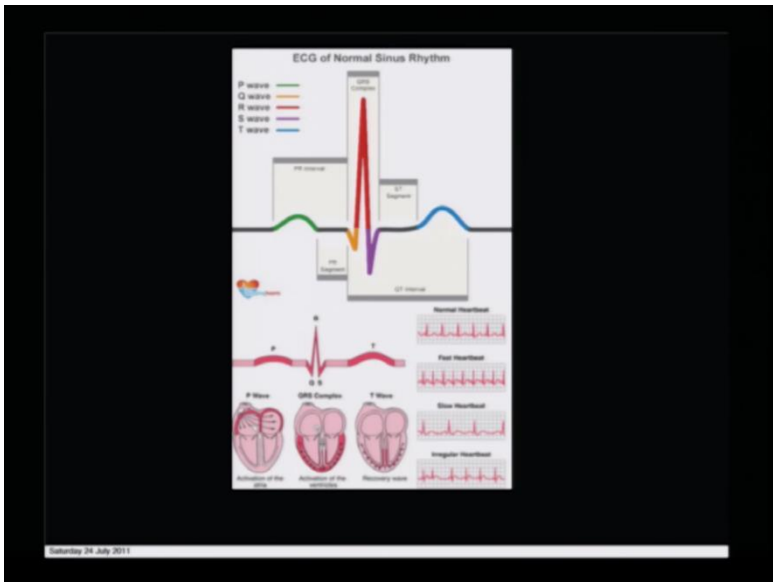

What the e c g pattern can tell, and what it cannot tell now looking at the e c g pattern of sinus rhythm. So, this is how it looks it is much more graphically much more well represented you have the p waves out here in green you see that followed by the p r interval out here p r pr interval out here sorry segment out here, and the p r interval out here I am sorry, and then you have the q waves you see this orange color, then you have the r which is the complete red, then you have the magenta which is showing the s s component, and then you have the s t segment, and then you have the t waves

So, this is how the p waves q r s, and t waves this is, and when this normal heart beat that is what what s doctor see is when there is fast heart beat. So, basically the you see the frequency has increased, and in there is slow heart beat the frequency as decreased, and when there is a irregularity this is what the doctor looks forward to…

So, this one whole figure can give you a complete idea about the whole p q r s complex, and what the what the doctor really looks into whenever they see your you know e c g trace this is what they are looking for to a normal heart beat a fast heart beat a slow heart beat or a irregular heartbeat, and what they essentially look for there is a p wave there could be I told you there is a there could be a situation where there could be two p waves or you could have p r segments slightly more.

There is at it means there is a delay in in sending the message to the q r s to the lower chambers or you have a s t segment, which is slightly moving it means recovery time is taking is more or you have larger q t interval or the t wave has some issues.

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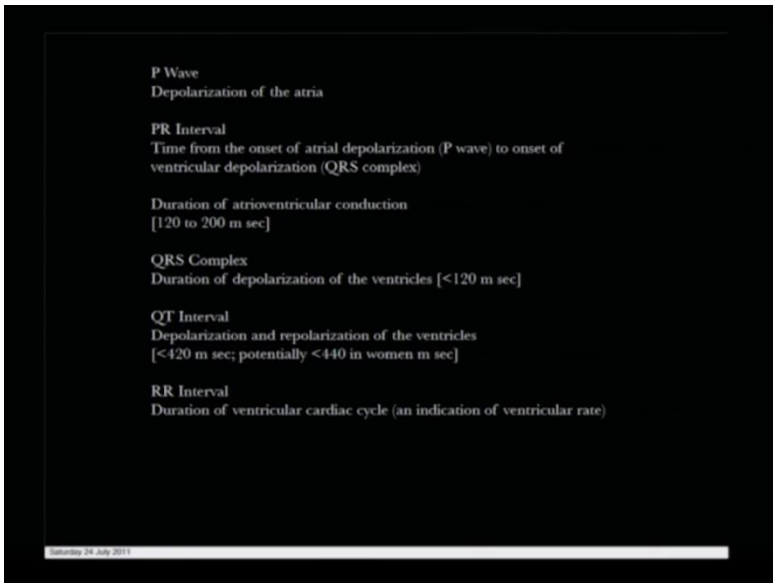

So, this is what in sinus rhythm a doctor looks forward to now p waves what these individual waves stand for the p wave stand for the depolarization of the atria p r interval time from the onset of atrial depolarization of or within that the p waves to the onset of ventricular depolarization.

Because I told you that atrial said this is the process of depolarization depolarization depolarization depolarization depolarization depolarization. So, the first part is the atrial depolarization the upper chambers they are getting depolarized where the p waves getting generated if you correlate this with this picture see yellow this is the depolarization process which is going on.

So, now coming back. So, this is where atrial depolarization to the onset of ventricle depolarization duration of the a v conduction is hundred twenty to two hundred milli seconds. So, if anything changes here it means this is the range when there is problem now comes the q r s complex duration of depolarization ventricle of the ventricles of the lower chamber is less than hundred twenty milli seconds this is where q r s complex we will go back see this is q r s complex out here ventricle depolarization taking place look at this very carefully.

Coming back to the ventricle depolarization this is where the ventricle depolarization take a place, then comes the q t interval here is the q t interval which is essentially is the depolarization, and repolarization of the ventricles. So, the wave has move from the lower chambers all the way the blood has been now pumped either to the lungs or to the atrial depending on from which side it is going through to the aorta sorry ok

So, the depolarization, and repolarization of the ventricle, which is less than four twenty milli seconds, and then the p r. So, this is your p r interval duration of the ventricular cardiac cycle an indication of the ventricular rate. So, this is what this individual waves stands for coming back to the atrial fiber, and ventricular action potentials.

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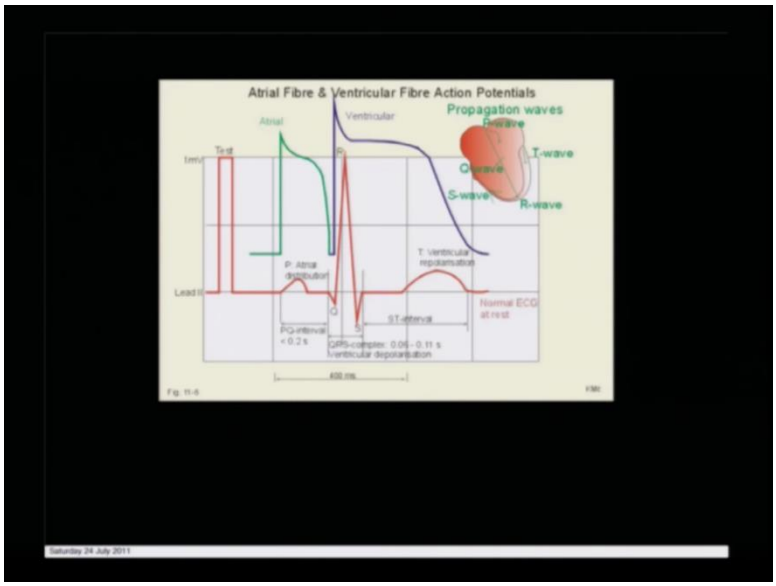

So, as if you now we are talked about the these are the action potential of the individual cells this is the global picture, and you can in this you can put the you know the action potentials of the conduction system. So, here is a comparison between, but let me tell you this is just the global picture, and this is the individual cellular picture atrial, and the ventricle action potentials.

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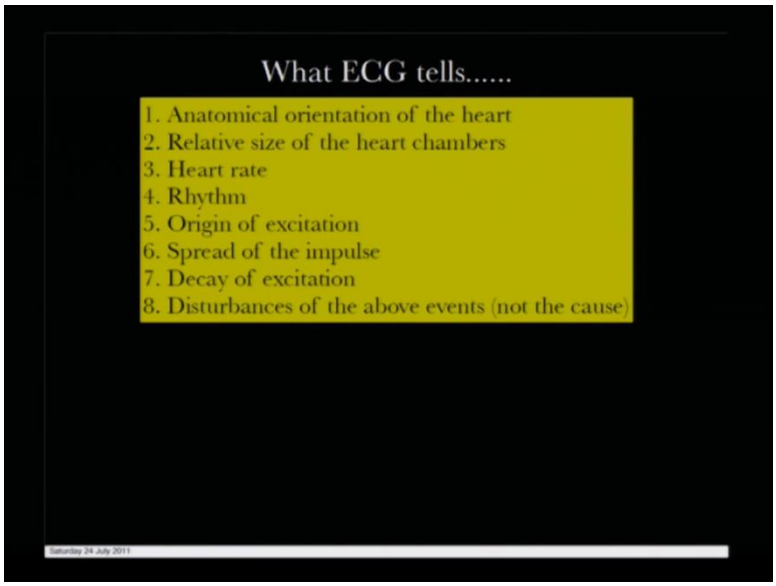

What e c g tells now this is very important to go through very very carefully e c g can tell you about the anatomical orientation of the heart is the heart anatomically in right ache is the way moving from atrial to the ventricles relative size of the heart chambers can tell, because depending on the time if you look at the time window it can tell you relative size.

Heart rate that you have already seen it could tell you the heart rate is it normal heart or fast heart beat or a slow heart beat or irregular heart beat it can talk you about the rhythm you have seen the rhythm it can talk about the origin of a excitation this is exactly what I was trying to tell you that if you have two p waves what will happen it is a defect it is a there is a problem there is pathological situation spread of the impulse how the impulse is spreading, because you can you have seen that it is all a time bond game

So, there is a time factor involved out here. So, based on the time factor you should be able to say the is the impulse moving in right time or not, then the decay of excitation, and any disturbances of the above event not the cause it cannot tell cause it can only tell that there is a disturbances it cannot tell you the reason for the disturbances.

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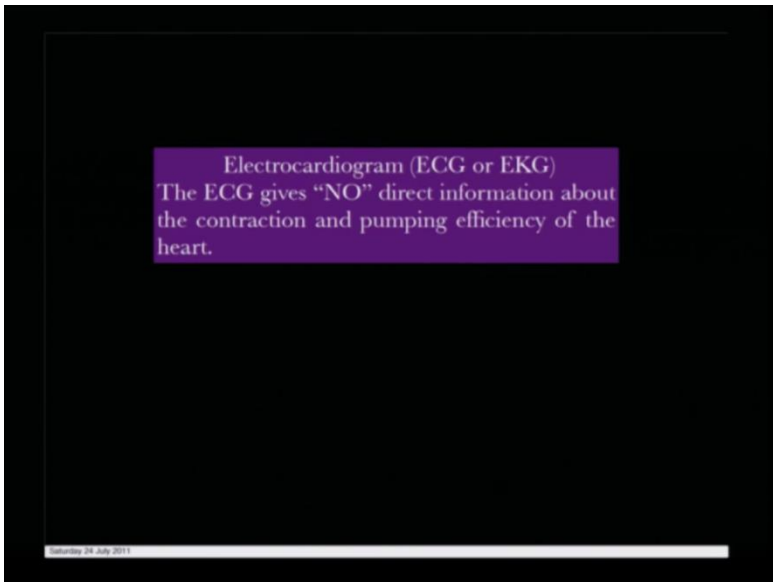

So, e c g gives no direct information about contraction, and pumping efficiency of the heart please do remember this e c g has absolutely no clue from e c g, that what are the mechanic or what are the mechanistic damage or problems with the pumping efficiency of the contraction.

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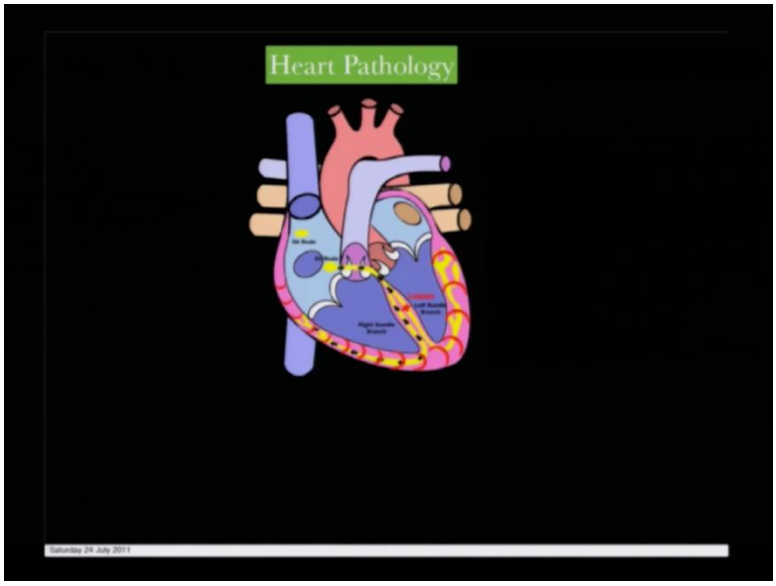

Coming to the heart pathology, where all the pathology can take place there are different places where pathology can take place the s a note there could be a blockage there could be ligands you could see all these red lines what you showing there could be ligands out

there these ligands could or there could be a blockage out here, so all the red lines. So, this circuit could have discontinuity at any point between p, and a v note we did not sorry s a, and a v note there could be a distant unity s a note may not be you know meeting at the right frequency there could be blockage there could be ligands there could be you know something very unusual you know expression of the ion channels.

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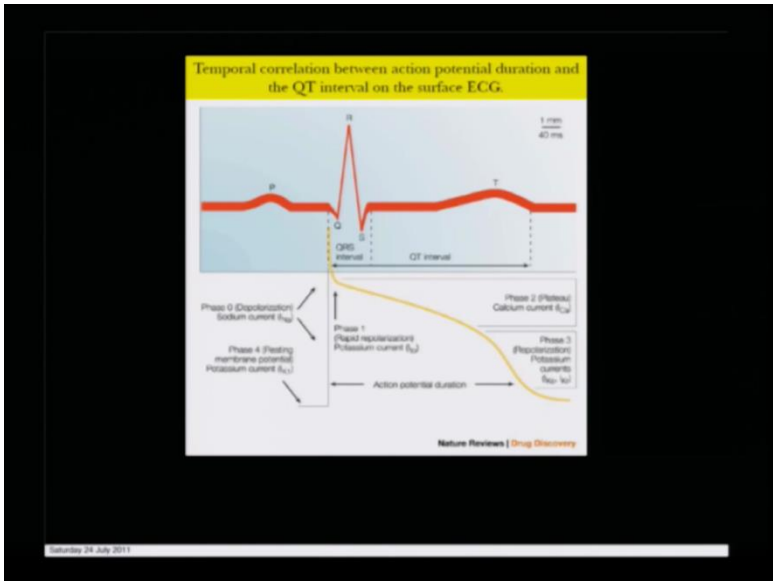

So, now coming to the temporal correlation between action potential duration, and q t interval on the surface e c g. So, this is what you are seeing the e c g traces, and if you look at the time this is just a comparison of the time window what is a time window we are talking about, and this is an action potential this is the ventricular action potential where you see the rise of the just this is the recap of what we have already done the movement of the sodium ions, and but mind it there is no functional as such you cannot really see this, and make any predication about it

Or see this, and make any predication about this this is just to give you a temporal correlation just to give you the time window of an action potential, and e c g trace how much closer how much far away they are from each other in terms of the time that said this is nothing to do with the functionality, because this is the purely purely this action potential is purely a cellular phenomenon, and this a holistic phenomenon of the whole heart.

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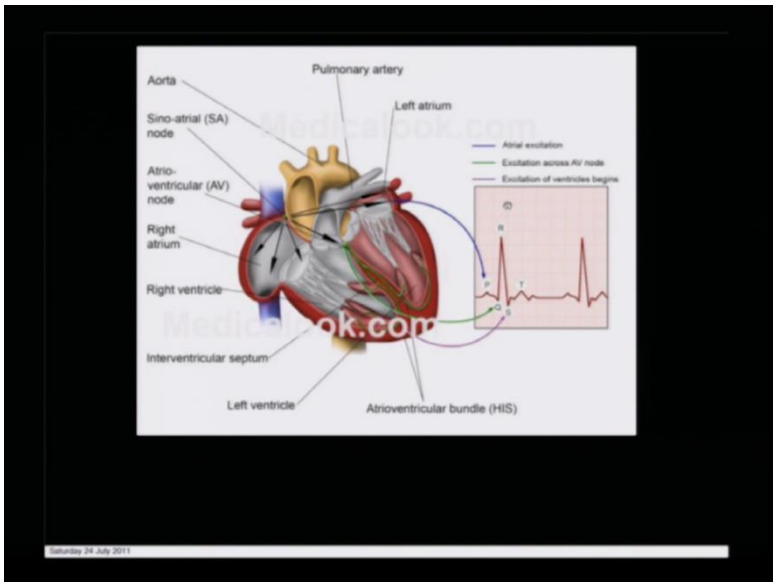

So, coming to the different part of it it real excitation which is taking place which are the location excitation across the a v note, and excitation of the ventricle begins this just there are different ways I am giving you.

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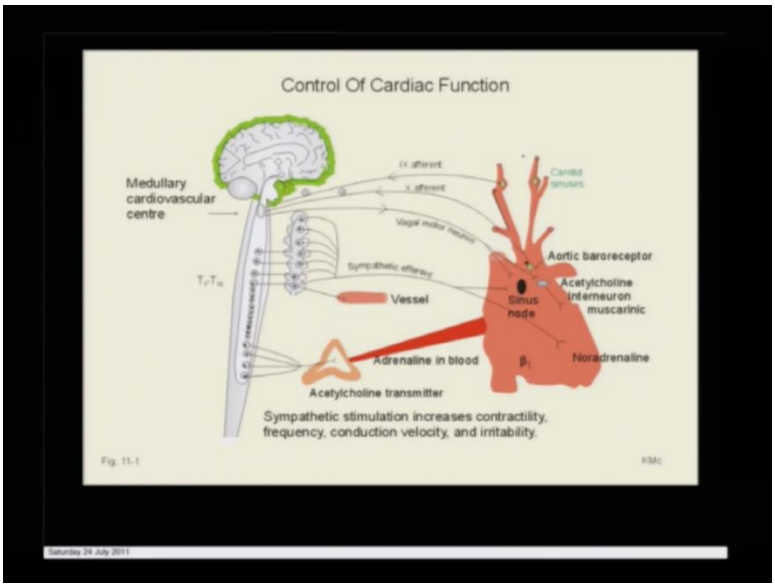

So, that it helps you know kind of appreciate it far better. Now coming to the control of the cardiac functions. So, the cardiac function is controlled by mostly the sympathetic, and parasympathetic conditions.

So, if you see that there is sympathetic stimulation increases contractility frequency conduction velocity, and irritability. So, this is the whole circuit. So, here you get an idea about sympathetic systems where this sympathetic efferent are you see the viagol nerves motor neurons you see ten efferent which are coming here you see the ninth efferent which are coming here its cartio sinus, and here you see the sympathetic efferent which are coming, and influencing, and they all do through beta one receptors as well as there is an acetyl choline trans transmission which is taking place.

So, mostly is a sympathetic efferent nor adrenaline adrenaline which is essentially responsible for you know regulating, and this is this picture is very important, because this is the these are the on list parts where the nerves system is controlling the heart, and these are very hot pharmacological targets the electro which controls the frequency of this conduction note, and this is all of these are mostly regulating the contractile the sorry the conduction circuit or the pace maker circuit of of this whole thing.

So, coming back what are the problems if the heart is not functioning the one of the option is that we have stem cells which will help you to you know there are two possible lets enumerate the problems first either there could be problem in the pace maker cells if there is a challenge in the pace maker cells your option lies you implant artificial pace maker which will generate signals, and will ensure that the conductions circuit functions properly this is one route.

Say for example there is a problem in the contractile element. If this problem is in the contractile element, then option is that you have to replace that patch of the heart or that part of the heart by a contractile cell.

So, you have to grow the stem cells to form contractile element you have to incorporate them at that part of the heart like I know kind of a patch, and that patch will eventually will get integrated into into the myocardium, if you remember that myocardium picture what I showed you.

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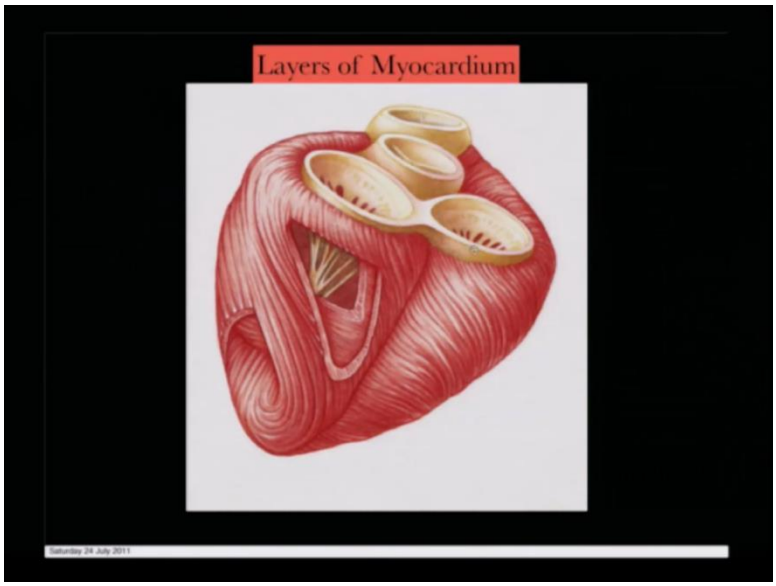

So, if you if I go back now to that picture which will make more sense now in the light of this what we have now discussed let me go now think of it. So, any of this parts myocardium is not functional. So, that is where you have to put those stem cells.

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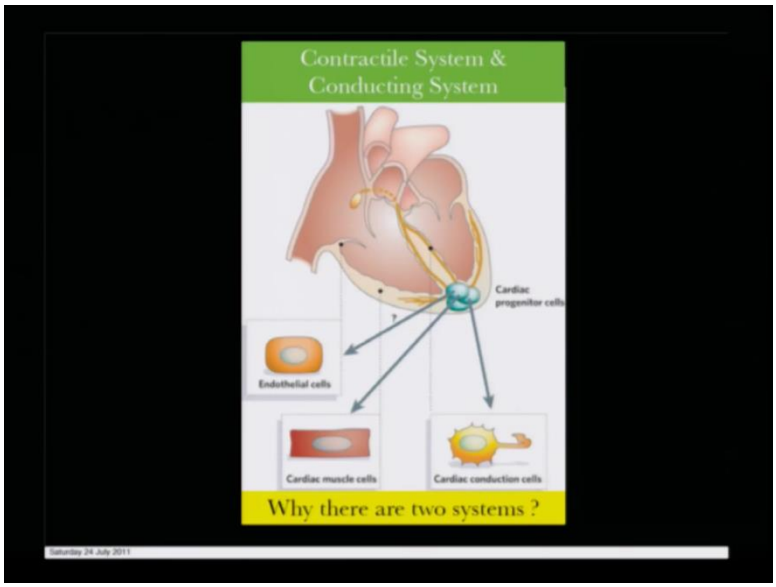

Now in the light of this this picture will also make more sense this cardiac pro generated cells these cardiac pro generated cells could be implanted at a specific sites, which will eventually will you know incorporate or form the contractile element, which will

essentially will lead to you know the reappear of that particular part of the tissue which is kind of getting damaged this is one route.

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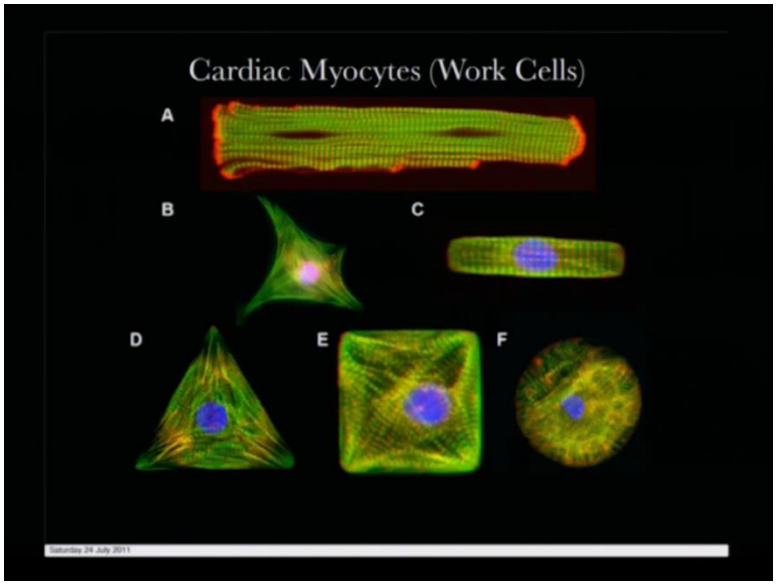

Apart from it there is lot of work which has been done by a companied called bio code they have worked on. So, so these are the contractile element which are another hot seat of research for the stem cell biologists for trying to make these kind of tissues, and use them as patch to put in that part of the heart where there is a damage.

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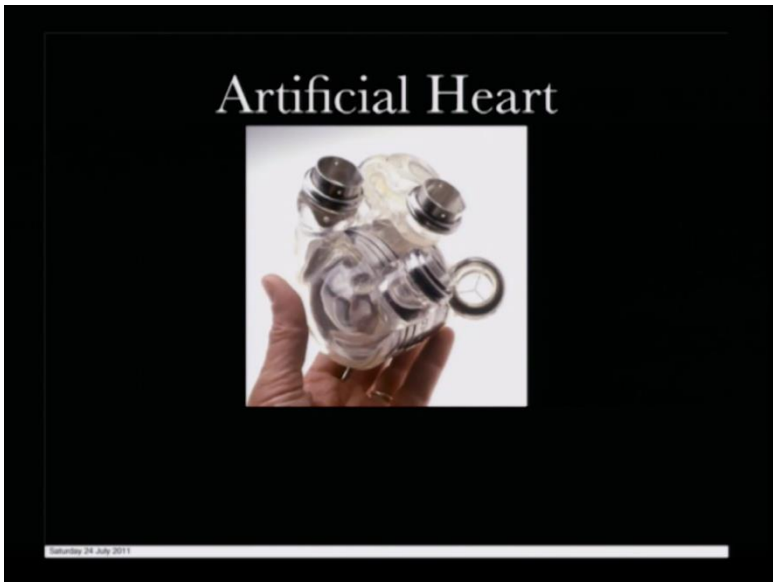

Now, one second let me just scroll down other option is if one goes for the artificial heart develop these kind of devices.

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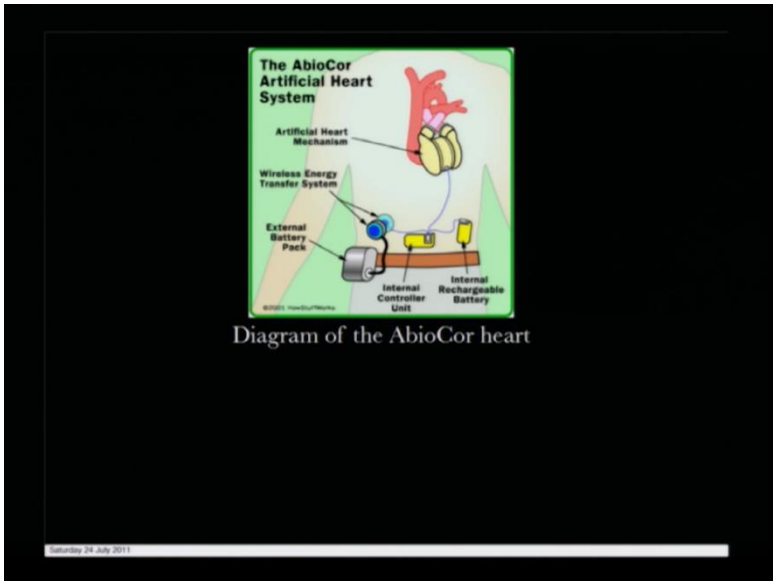

And they pretty much work like this is a abiocor the artificial heart systems they they pouches as you could see this is one example the picture is showing one such a device with different chambers in the walls, and there they regulated wall there is a external battery pack outside your body this is under the extreme situation your heart is not function. It has internal rechargeable batteries it has a internal control unit, and it has wireless energy transfer systems.

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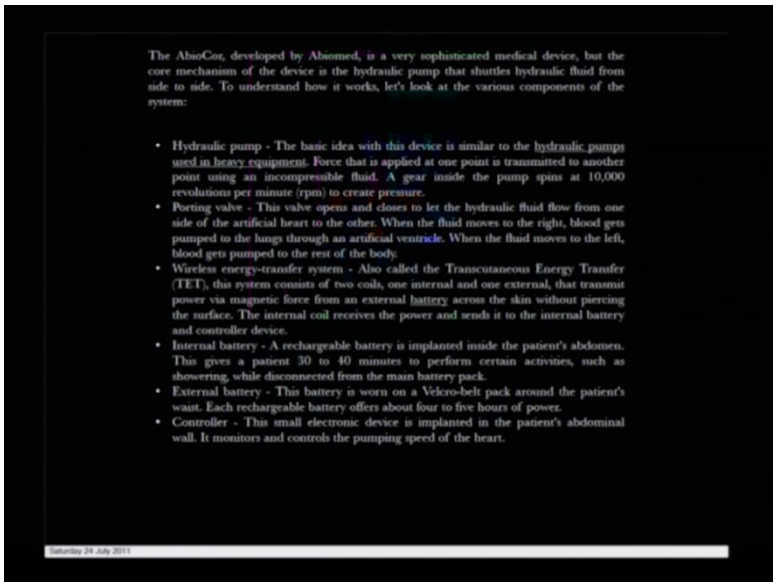

We going to see an artificial heart mechanism this is where this is functioning just like those four chambers are functioning you have exactly the same module out here in the artificial heart, and I have I have given you fairly good amount of you know information's which is available on the internet or in different books which will give you an idea how these kind of artificial heart could be incorporated into the system.

So, that you know in case of extreme emergency where there is no room left you know you can put these kind of you know organs which will get in incorporated into it, and could help the person to survive I mean those success rate is very low as if now, but you know that is pattern parcel of the whole research itself it will take time before we are in a position to replace damaged heart or develop something which is using regenerated medicine tools which is something very close to the machine which is functioning for you remember

The first lecture of this fragment I told you hundred thousand times per day that something that is a feat which is just unimaginable feat what the our heart kind of you know under goes every day. So, coming back. So, this is basically where have the closing in. So, let us summarize what we have discussed. So, in these last two lectures we talked about the atomy of the heart the four chambers we talked about the the valves which are present there in the, if you remember all the different part try cesspit valve by cesspit valve mitral valves we talked about the circulation local circulation in terms of

systemic (( )), sorry in terms of the pulmonary circulation as well as the systemic circulation pulmonary where it involves the circulation between heart, and the lungs, then we talked about the circulation from the heart to the rest of the body.

Then we talked about the different cellular component the pace maker cells the contractile cells the endothelial cells, and at the end we talked about all the sympathetic nerves or regulation of the heart, then we talked about the individual electrical signature of these conduction system, and the contraction system, and we did comparative action potential analyses of contractile system conduction system, and within the contractile system we made comparison between skeletal muscle, and the cardiac muscle after this we talked about the global electrical activity of the heart in terms of the how the electrical field is changing just as if there is a moving dipole polarization depolarization depolarization polarization likewise, and from there we talked about how the e k g traces are being generated electrocardiogram traces, and then we talked about what all the e k g traces can tell you, what the e k g traces cannot tell you what are the in formations gathered by the physician looking at the e k g traces, and how the e k g traces frequencies changes deper depending on the physiological status of your body there we talked about the different pathological situations, and we talked about the end we talked about what is the different strategy in terms of using a pace maker to compensate for the compensate for the irregularity of the conduction system, and in case of damage in the contraction system putting cardiac patches using stem cell therapy or re genitive medicine therapy, and in an extreme situation you may need to resort to artificial heart that bio co module of artificial heart.

So, over all the takeover message from this two fragment is end of the day it is those individual ion channels which dictates the electrical activity of these different cell types of the heart, and I will be providing the specific ion channels which are responsible I will be providing you those specific ion channels which are responsible for the electrical activity of the conduction system in one of the notes. And another critical thing the spontaneity or the entrancing ability is attain, because of the inherent ability of the conduction system to stay at resting membrane potential of between minus forty to minus fifty milli volts.

So, this is the overall summary what we kind of you know developed after going through this lecture section kindly go through the notes and. So, will close on this before we

move on to in one of the lectures will be talking about the man machine interfacing where nerves system will be interfaced with the how it has been interfaced with a with computers, and will talk little bit more about the syballs, and the robert's, and everything.

Thanks a lot.