Sensors and Actuators
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Lecture – 04
Sensors Part 4

Hi, welcome to this particular module. So, in the last two modules what we have seen? We have seen several sensors and its application and today's module we will be focusing on few more sensors and then we will move to actuators. So, another application of a sensor is in microfluidics. Now, a fluidic system is where the fluid can flow, when you make a channels of micron dimensions it becomes a microfluidic channel. Now, how can you use the microfluidic system for let us say drug screening? What do you mean by drug screening? If you are given 7 different drugs which drug will be effective for a particular patient, how would you know?

So, can we come with an engineering solution so, as to find a drug for that particular patient? So, out of 7 drugs this drug you give it to this particular patient, let us say drug number 3, while drug number 5 you give to the next patient. Because, that patients body is more; the drug number 5 is more has a more efficacy for that patient's body compared to the first patient where, drug number 3 was having more efficacy, efficacy is more effective. So, how we will screen the drug which drug to take screening of drugs, that is our idea and that is where our sensors will come into picture.

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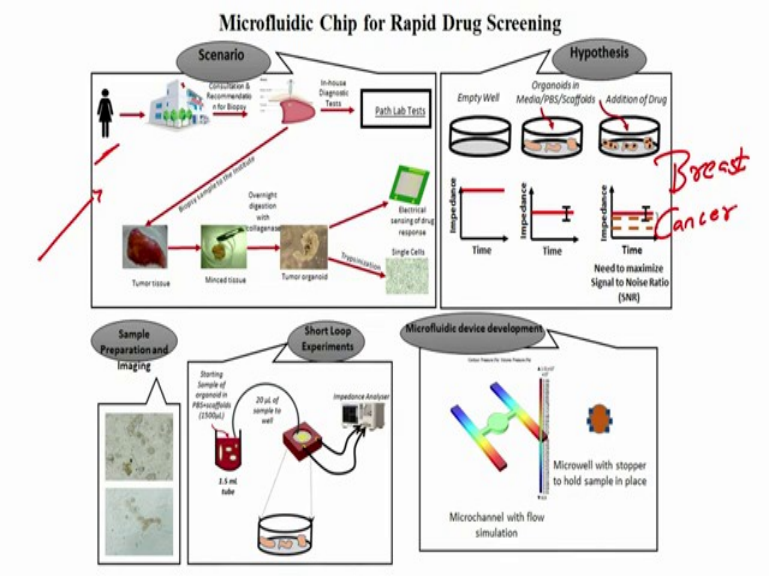

So, if you see the screen what you see here is a microfluidic chip for rapid drug screening and here you see is, let me first make you understand how the current scenario is; that from the time the patient goes to the hospital there is a consultation. So, we talk about here let us say we keep our focus on breast cancer because, like I said breast cancer is the 2nd largest cause of cancer related death in women. So, we focus on breast cancer.

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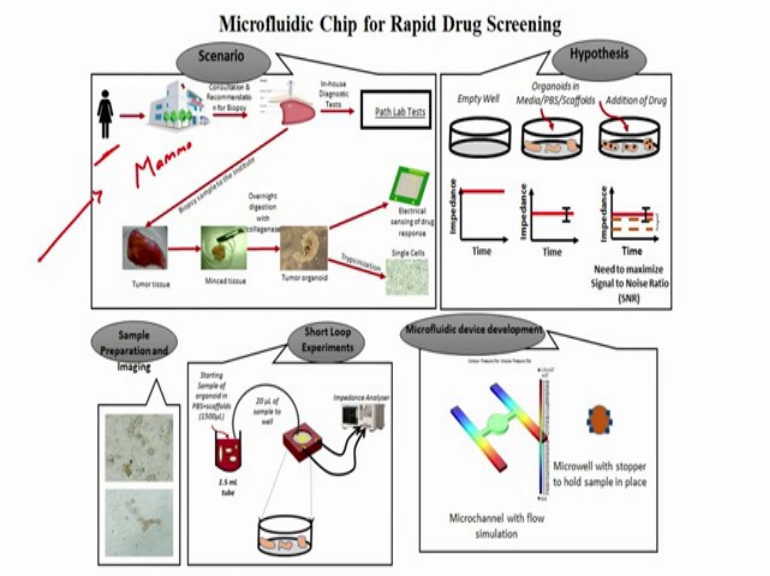

So, when a woman goes to hospital and there is a consultation in the screening which is called mammography. So, from the mammography it is found that there is a suspected region, then the person must go for a consultation and there is a recommendation of for biopsy.

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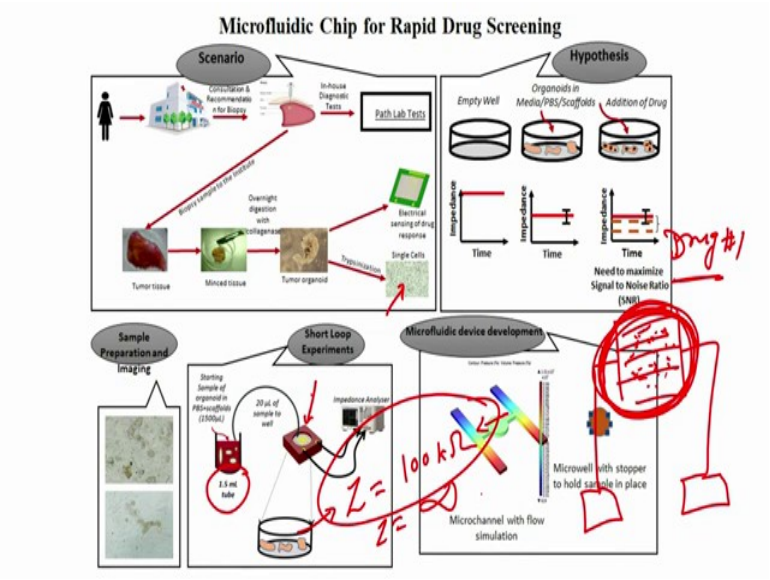

Biopsy is taking out the tissue from the body using a needle, using a biopsy needle alright. And, then after taking the biopsy tissue, there are some paths tab path lab tests are performed to understand whether that tissue is cancerous or not. Now, what we want to do? Now, for this particular tissue we want to take the tissue and we want to mince the tissue and then further we will overnight digestion with collagenase. And, this collagenase is used to digest the tissue and to form the tumor organoids and this tumor organoids we can do trypsinization and form single cells though.

So, do not worry about this whole procedure, I am just showing it to you nothing to worry about and once you have single cells you can also use a chip to understand the cell properties and the impedance of the cell. So, before we go to this particular test let us see this example so, we will understand it better. So, once you have this sample you see this sample, you load this sample in a 1.5 ml tube and then 20 microlitre of the sample you place on this particular chip, this chip is an impedance sensor. So, what I mean by impedance sensor is there are interdigitated electrodes like this and then there is a contact pad another contact pad.

So, if there is a well like this there is a well which you can see here, I will put cells on this particular chip with some Matrigel. What will happen initially when there were no cells my impedance is infinite, when there are some cells, I will have some impedance. Let us say I have 100 kilo ohm impedance value alright, Z equals to 100 kilo ohms, here Z equals to infinity when there are no cells; when I place the cells, my Z becomes 100 kilo ohm. Now, if I load a drug on this, if I load drug 1 what will happen? What is the role of a drug? Role of a drug is to kill the cells.

So, if the drug is effective and if the cells dies what will happen, there will be change in the impedance value. Why there will be change in impedance value? Because the conductivity will change, because the dying or lysing of cell will cause the constituents within the cell to come out and those constituents will increase the conductivity resulting in decrease in the impedance, got it? So, if I can have 8 of such wells with an interdigitated electrode and I place different drugs. And, I see which drug is effective based on how much is a impedance change I can say that the drug which is more effective would have the chip on which the drug we have loaded is more effective, would have more impedance change compared to the chip which the drug is not that effective.

So, that effectivity or the efficacy of the drug we can design, and we can determine with the help of a sensor. Where is our sensor here? Our sensor here is an interdigitated electrode within an SU 8 well or any well, you got it? We will see as a part of this course how to design and fabricate such sensor. Now, you see the screen.

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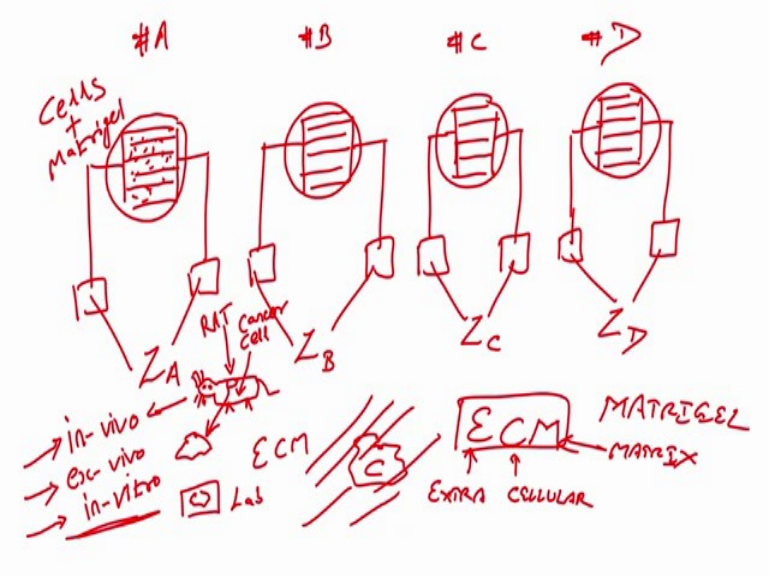

So, what I am saying is, let us take 4 different drugs just for an example, you can take 7 you can take 8, you can take 100 of course, there are no 100 drugs you have to try, but I am just saying. So, let us have this is A B C and D alright four different chips, interdigitated electrodes, four chips were interdigitated electrodes. Contact pads where you can measure impedance ZA ZB ZC ZD alright and you have a well. So, that the cells would not come out of the well you have well; so, cells would not come out of the well alright.

Now, what I said you load the cells so, understand when there is cancer; when there is cancer it is always surrounded by ECM. ECM stands for Extra Cellular Matrix, when there is cancer it is always surrounded by extra cellular matrix. So, from where we can get extra cellular matrix in our case? In our case our extra cellular matrix is Matrigel. So, we will load these cells plus Matrigel. So, the question would be what if this is a cancer this is ECM, your question should be what is the role of ECM?

The role of ECM in the case of cancer is to provide nutrition to the cancerous cells alright. So, the nutrition is formed or are given to the cells through the extra cellular matrix alright. Now, this is the in-vivo condition, you have to understand three different terms are in-vivo, ex-vivo and in-vitro. In-vivo is inside the body, it is funny drawing isn't it, but assume that this is a rat you have to assume.

Now, if I do experiments in the rat, if I load the cells in the rat's body cancer cells and I study what is going on within the body it is a in vivo study. If I take out the tissue, if there is a tumor here if I take out this tumor from the rat it is ex-vivo study. But if I replicate this same tumor on a platform in the lab it is a in-vitro study you got it. So, in-vivo, ex-vivo and in vitro three terms that you need to understand with my funny picture of a rat which you do not have to worry about.

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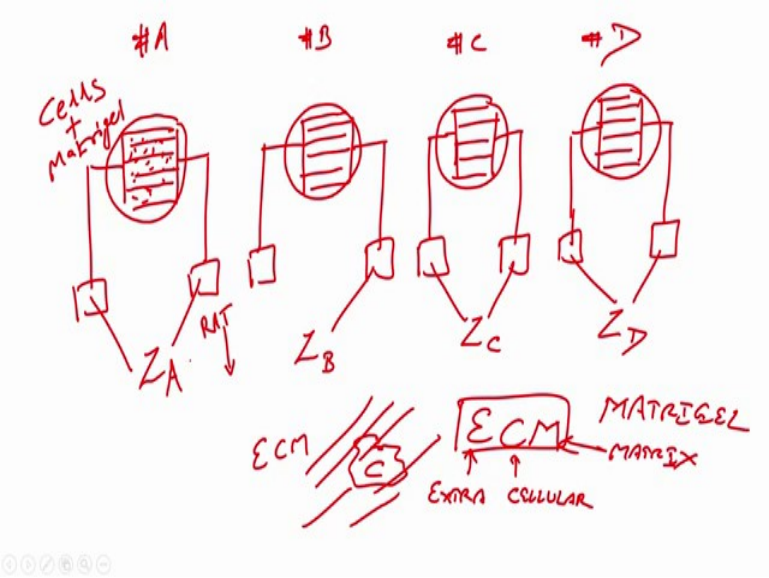

Z A, rat is deleted, Z B and Z C alright.

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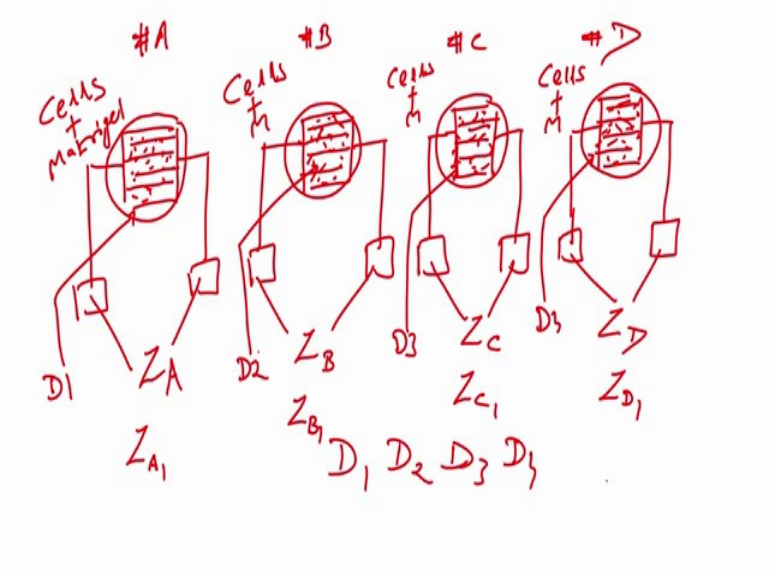

So, now if I load these cells with Matrigel and here also I will load cells plus Matrigel, here also I will load cells plus Matrigel and in the fourth chip also I will load cells plus Matrigel alright. So, let us say these are cells with Matrigel, cells with Matrigel and cells with Matrigel. Now, what did I say? Add different drugs so, there are 4 drugs D 1, D 2, D 3 and D 4.

These cells are from the same patient alright, cells are from the same patient and assuming that these cells are cancerous cells cancerous; cancerous cells alright, assuming these are all cancer cells. Now, if I load drug 1 here drug 1, I will load drug 2, I will load drug 3 and on drug 4, I will load in the chip number D. Now, I will see Z A 1, Z B 1, Z C 1 and Z D 1.

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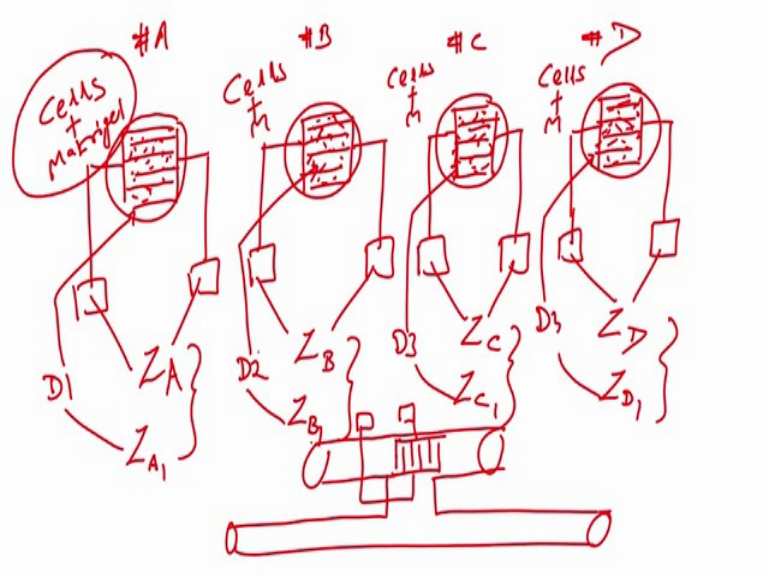

That is a change in the impedance value, when I have loaded the drug when I load the drug there will be change in the impedance value. The impedance change which is maximum from its base impedance; so, the change in impedance from its base impedance is maximum that drug I have to give to that particular patient, because that drug is more effective; you got it that is what I said. But there is a catch, what is the catch? That now the drug is in continuous contact with cells and Matrigel, drug is in continuous contact with cells and Matrigel. Then how can we use this drug? How we will relay on this data?

Because, now what you are talking about is that if I have some kind of problem in my body, let us say there is a cancerous tissue in the body. And, I have been given a drug then do you think that drug will go and stay in the same area? It will not, why? Because our body is not static, it is dynamic the blood flows the drug will flow in the blood and blood flows in the body and this is a dynamic system. But what we are talking about in the wells are all the static systems. Thus, the results that we obtained from the static system we may not relay completely on those results, you got it there is a difference.

We have to understand how a dynamic system would work alright and that is why we will design a microfluidic chip. So, if you come back to this particular design; now I have this same interdigitated electrodes, but I have a channel like this and connected like this . So, let me just remove these (Refer Time: 16:24) so, the you do not get confused. What I have drawn is there are two channels, you can see one small channel and one big channel; one small channel and one big channel. And, in the smaller channel there are interdigitated electrodes correct, there are interdigitated electrodes.

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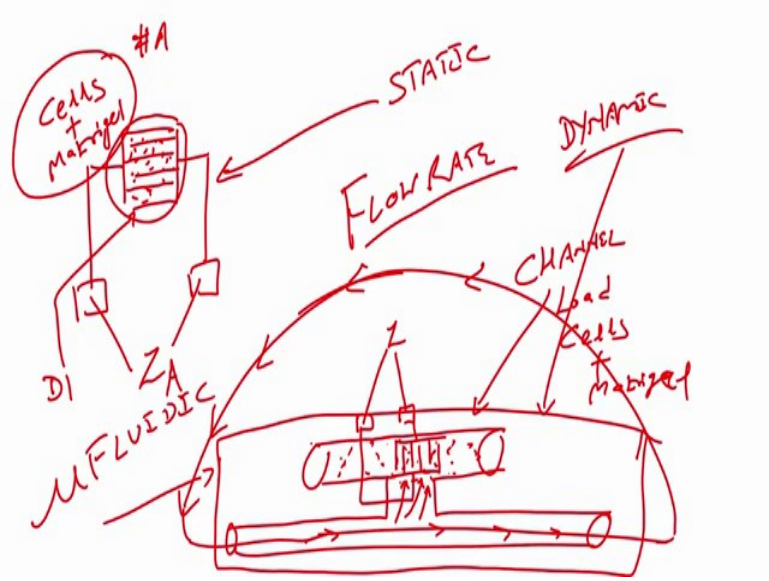

This is your impedance measurement Z, these are interdigitated electrodes, this is a smaller channel. This channel is used to load cells with Matrigel. So, everywhere there are cells like this cell are there, now I will pass the drug through so, everywhere there is Matrigel and cells. I will pass the drug through this channel continuously so drug will pass continuously through this channel. When the drug passes through this channel, the

drug will also infuse or diffuse into the smaller channel where, there is a Matrigel plus cells are there. This diffusion can be controlled with the help of a flow rate.

So, this flow rate can be designed such a way that to mimic the diffusion of the drug inside the body alright. So, this chip that we have designed, this is a microfluidic chip; the rectangle that I have shown is called micro fluidic microfluidic chip. Now, what will happen if my drug is effective, the cells in the smaller channel will start dying and the death would result in increase in the conductivity and decrease in the impedance, isn't it? I can develop four of these microfluidic channels and compare the results. This is my static platform; this is my dynamic platform you got it.

So, this is dynamic platform, this is static platform. Here I can see the change in impedance when there is a drug killing a cell, here also in the static platform also I can see the change in the impedance when the drug is effective. But the dynamic platform is which is close to the in-vivo situation, inside the body. Thus, we can mimic the in-vivo situation onto the in-vitro platform by designing a microfluidic chip with an electrical sensor which is our impedance sensor and that impedance sensor can be designed using interdigitated electrodes, got it guys easy. I will help you to understand how to design and fabricate this particular electrode now just focus on that.

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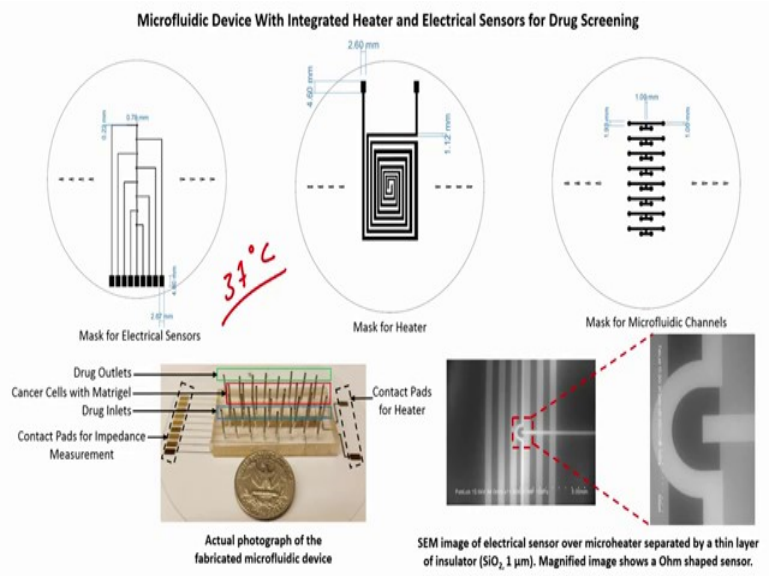

Now, another thing that I have discussed is that the cells should be alive at 37 degree centigrade. We require 37 degree centigrade temperature to keep the cells alive, that is why we require a heater.

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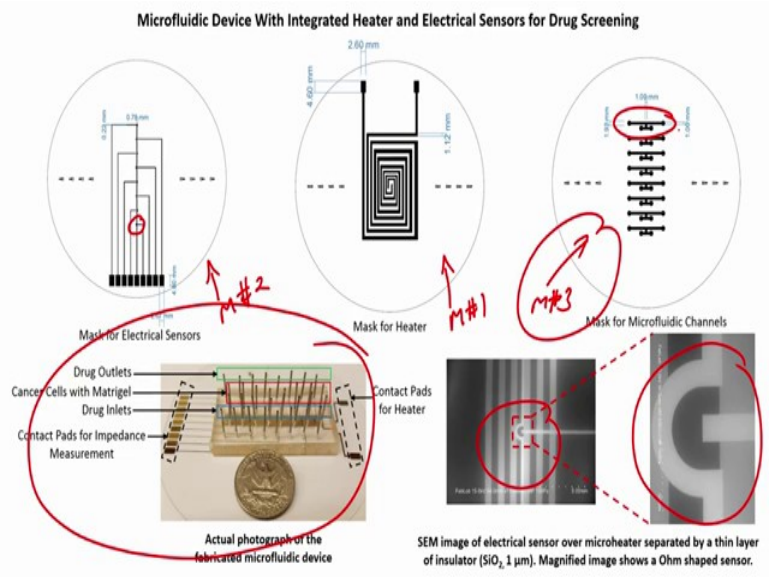

So now, we have this is called mask I will tell you what exactly mask means. This is mask number 1; this is mask number 2 and this is mask number 3. This is a separate mask for creating a moulds and you will see how you can design a micro fluidic chip, for understanding the which drug is effective. And, these are interdigitated electrodes, if I zoom this one it will look like this, I further zoom in looks like Ohm symbol, it looks like an Ohm symbol. And, these are microfluidic channels, you can see small channel and larger channel; we will see in detail when we talk about fabrication alright.

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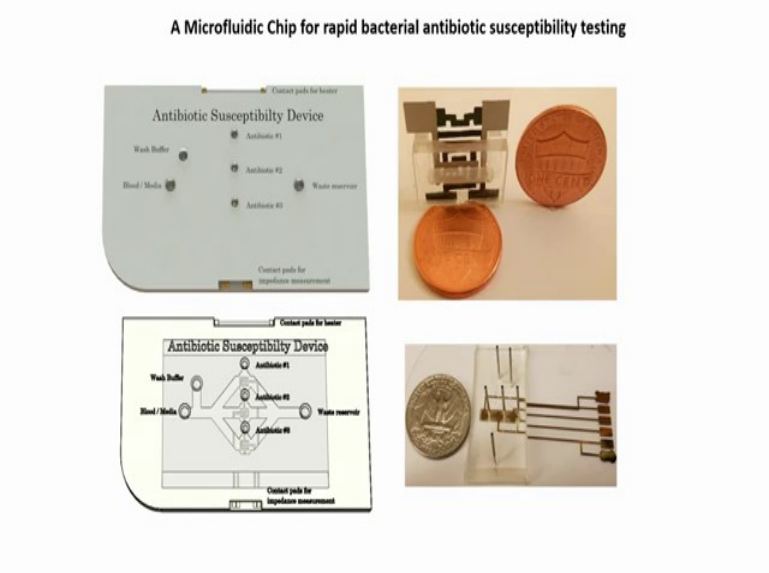

Now, I will come to a next sensor which is used to understand the rapid antibiotic susceptibility. Now, what exactly rapid antibiotic susceptibility is you understand this thing.

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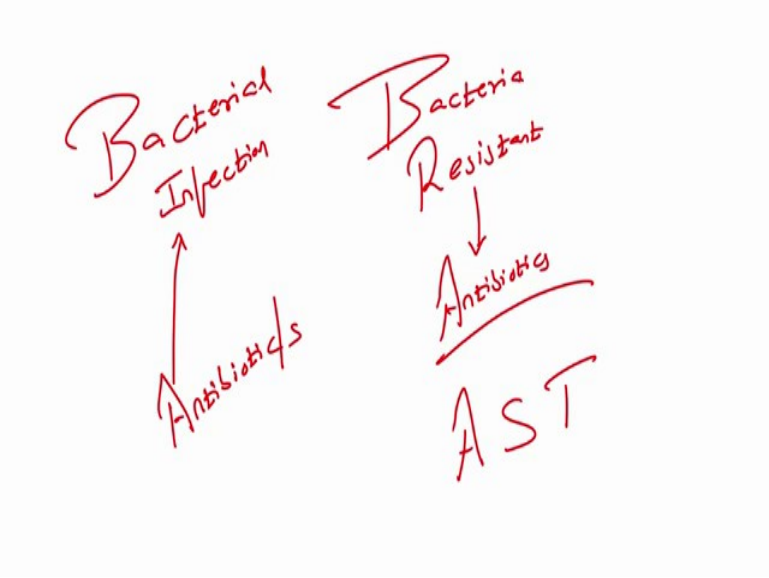

There is something called bacterial infection and we can kill the bacteria with the help of antibiotic or antibiotics. Antibiotics are nothing, but drugs alright. Now, recently these bacteria started showing resistant to the antibiotics; that means, if a person has the bacterial infection, if we give antibiotic which is a drug to kill the bacteria, the bacteria

are resistant to this antibiotic. So, how the person can be cured? Person cannot be cured. So, which antibiotic the bacteria are resistant, in which antibiotic the bacteria are susceptible we need to understand.

How can we understand? First of all, we to understand to capture the bacteria from a sample. Second, we need to understand whether the bacteria are resistant to antibiotic or not, for that we will see how to design a sensor for a rapid bacterial resistance measurement or antibiotic susceptibility measurement called AST; Antibiotic Susceptibility measurement or Testing alright. So, these are two different platforms, we will discuss this thing in detail in our class and this also on the sensor design alright.

So, let us finish the today's module on this particular note, I will discuss in detail the three more sensors which are one related to combination therapy, one related to flexible sensor, one related to electronic nose, one related to immunotherapy. And, then we move to and I will show you a very beautiful image of a fly, that we tried to measure the weight and followed by the actuators. And, then we will start understanding how to design the process flow for fabricating sensors alright.

So, till then you take care, I will see you in the next module. Bye.