I'm going to do a little bit of the same. the following. Last time, we explained to you about physical, mathematical principles behind the outer and the imaging. In this lecture, we will be more specific and how we can form different kinds of outer and images. But I still. So I feel quite good today. So we are doing second part of outer and the imaging. And after this lecture, we have two more lectures left. One is optical, the other is some really fancy, hard, very hard stuff. We are still learning as applied to medical imaging. So I will explain these fancy things in the future. At least you got some exposure to this emerging area. And this is paradigm-safety. And a lot of new ideas in the machine learning area. And as related to medical imaging and tremendous research opportunities. And different from the last two lectures. And in this lecture, we pretty much follow the green text book. So by the way, you read the chapter out, or found the imaging about 23 pages. So read the rule, you pretty much know what's going on. So I just taking this opportunity, I'm explaining the key things. The way I think help you summarize. You still need to read the text book. So not I just back it. You listen to my talk. Then no need to read the text book. Oh, I read the text book. Two-year-in-class room is not the case. So again, this is summary out, which are the imaging methods. And how specifically we follow images. And the two part, first one is imaging modes. We talk about different kinds of imaging modes. Basically, A modes, B modes, C modes, and I modes. What do you mean by all these things? So there are multiple ideas behind. And very importantly, the text book didn't cover. But I think you need to know this principle. And at the check internet, it pronounced as HURHENS principle. There's some very important physical idea. And we need to know this principle, so that you have better understanding about phase-re-based beam scanning and beam forming. You can do focusing. And at different times, a lot of flexibility. And in particular, in the second part, we talk about Doppler imaging. This involves dynamic image formation. And you can measure speed and direction of vessel or blood flow motion, cardiovascular chamber motion. So you have a lot of physical information. You can do so in multiple ways. You can easily use continuous ultrasound wave. You'll send sequence of pulses. So this is the very important ultrasound imaging mode. We talk about the echo correlation, color Doppler. All these things are clearly explained in the text book. You need to read very carefully. And last two part, image artifacts and some new things. This is the full fun. And we will not touch you about new ideas, new things. The first three part, in the text book, will be text data. So what's the A mode? A means amplitude. And we have few movies to show you. And wait for a while, because when I show movies, I need to quit this mode and change a little bit. It's not so easy. But let me just give you rough ideas about different ultrasound imaging mode. A for amplitude. So you send a pulse, send a pulse into biological tissue. The pulse will propagate into the tissue after machine layer I accidentally into you last time. So the chance is that the energy, this is ultrasound pulse, comes into body. And the heated certain sky turns or boundaries. And the partial energy will be reflected by, so keep guiding back. So you have the internal structures. A cool state can intrude in, in homogeneity. So keep reflect energy back. As the main energy goes into the biological tissue, the ultrasound energy intensity of flux, the weak, and the weak, partial energy, guide back when you go way back. The energy also subject to skytering, the absorption. So this is complicated process. But basically, you have energy, keep going and keep sending back. This will be graphically shown in this video tape. I will show you in moment. So this is not like X3 or gamma imaging. It goes through them. But ultrasound imaging, most likely, it goes wrong the trip. You send energy in, come back at different times. Anyway, so this is one thing, and I all you want to move it, video tape, and this is a moment. Second one, say B mode, B for brightness. So this is the powerful, powerful, key word associated with the name of the mode. B mode is kind of duplicated, not duplicated. This is the skyning, multiple A wave sky. You can see the two A wave A mode, so you guide the echoes from one line. Then move to next position, you do second line. You keep doing this, you form two dimensional amplitude or intensity display, so you got a picture. And you are not necessarily doing this power line beam skyning. For the general reason, X3 CT, you can do this fan beam thing. Now one beam directly into one direction. Then you keep doing this sweeping motion. So you guide a fan beam out or something. Again, this is another, another movie trip. I will display a moment. So the image will show here. And so let me just show you the two movies. So you have a visual impression. So what's going on? Just see how I can show this. OK, you see this. This is talking about A mode, very cursor. OK, here. Here, here, here. So the right pause is the ultrasound pause. You are sending into biological tissue. This is biological tissue. The blue scenes are back scattering or ICOs. So you will send the ICO here. You receive ICOs the same place. As I mentioned, the transducer can be used as an emitter and the receiver both ways. OK, so let me just play it again. So you see little better. Blue scenes are ICOs. See? The tail is very, very thin. We will be receiving the last part. You see? This is the A mode scan. A mode scan gives you one dimensional signal profile. So this is one A mode scan gives you one dimensional signal. You do multiple A mode scan. Then you guide two dimensional image. Let me show you. This is B mode scan. So this is A mode. This is B mode scan. Let me show you. So each line, you guide a dimensional. From each line, you guide a dimensional profile. So each line is operated in A mode. So many A mode put together. You have two dimensional display. This is a phantom scan. Just see, this is B mode. Outdoor scan image is not crystal clear as CT, no MRI, a lot of sparkles, noise, skyters. But you still see the major structure. The outdoor scan, the transducer, is caused effectively, very small, very compact. So you have other advantages. And the straight forward, high speed, is B mode scan. OK. Oh, Yes. Live aunque sensor is prominent at the end of your wake. The core Okay. So, how we return to normal. So, we talk about the A, B, A, I'm going to be brightness. I'm mode. I'm a for motion. So, I'm mode is pretty much the A mode. So, what you keep doing for same location. In B mode, you do scanning. So, one A mode profile relative to another A mode profile. The difference is in spatial location. These are angular or spatial different. You do scanning. But I'm mode scanning. This is the same location. Same angular. But you keep repeatedly collect out or sound signal. And water will be changed as the organ of visual wall. So, those anatomical structures will be changed as a function of time. So, like situation here, you can sync the reason of interest. You can see here. I think it's part of the heart like the chamber, life of the heart chamber. Keep expanding and contracting. So, although the spatial location is the same, each time you do A mode measurement, you will have something different. Maybe at this moment, you do one dimensional profile. Every other boundary, the scatters remain the same. But the moving structure will have the wall, the cardiac wall, move towards the transducer. Another time the wall is moving away from transducer. If you keep collecting signal, you will have this motion profile. So, you can still display as a two dimensional image. So, along this direction, that is just a typical A mode profile. And this is time orientation. So, you still have two dimensional display, but you can see how cardiac A is in motion. So, this is motion mode. So, last one, and I would say, is C mode, C for coronal image. So, you know three dimensionally, if you are part of a patient with a virtual plane, this way usually you call this transverse plane. So, every other patient, this way, you call it sagitou. But every other patient, this way, so you just think, I am facing you, just cut this way, it is called coronal image. So, you have three views. So, I will show some image. So, you do A mode imaging, along this direction. So, you have all the information, so the spatial dimension, along this direction, is your coronal system, just one axis. But you can do some echo gate-tay imaging. So, you send the pulse into that direction, so you wait a certain amount of time, then you see, waiting the small time window, if the echo will be back. And then, given the delayed time, so really you target a specific dive. So, this way you just get information from one line, see from this line, you just roughly calculate. The author sounds like, goes wrong the trip from transducer to the play, not comeback. So, suppose this is wrong type, this is for example, 100 milliseconds. So, you only see, water is amplitude after 100 milliseconds. 100 milliseconds is wrong trip, echo time, so echo goes here, hit the plane, comeback. So, 100 milliseconds. So, this 100 milliseconds, you report the amplitude as your pixel value. Then, these two dimensional coronal planes, you can keep the skyline, line by line, pixel by pixel. So, you make sure the time, wrong trip time is targeted at data position. So, you put all these amplitude values together, you form two dimensional images. So, that is the so-called coronal images. So, this is example, you have hands here, and you put the auto-sounds into the hand, and you recorded the echo. So, all timing coordinated right. So, you form internal image, just cut through your hand. So, you can see certain pieces of bones. So, there's some terminology I just learned, because metacopels, these light blue bones, you can see these light blue bones. So, the transducer is operated in C mode here. There are some good ideas, details are in this article. So, you have this image, the image really formed here. Then, the image in a pixel here is reflected by a self-sale word mirror, and viewed by a reader or doctor. So, this way, through this half-sale word mirror, and you see a paste in the body. And any image you see really superimposed onto paste in the internal structure. So, give your illusion, see you see into paste in the directly, you see the beating heart, and you can maybe use this as guidance to put the cancer there make a blood vessel open wider. So, this is a good idea. It kind of works with reality things, and it's a good idea. But, the C mode, nothing to do with this viewer. C mode can be understand only with this sub-figure. So, that's the idea. And the ultrasound imaging, so far, is straightforward. And what I have, I explain to you, A, B, C, I, so, you see later, a word you need to remember. Okay, so, this is the single crystal-based transducer can be used to do all these kinds of things. But, when you want to form two-dimensional image, you need a easy scan, or you need to do multiple times. So, you have a time dimension. With time dimension, with a single transducer, you can still form two-dimensional images. Certainly, this is quite a lot like pencil beam of x-ray imaging. First generation, you have a pencil beam of x-ray, you have a single detector, you can do scan. That's very inefficient. So, that's why we say, we have to use ultrasound transducer rays. This will allow you to do parallel data acquisition. Power-lile data acquisition is always desirable. And in the case of the chiral, chiral scenarios, faster imaging speed will reduce most artifacts and improves the report. So, a lot of good point to make. So, many types of ultrasound transducer, you have a linear ray, you can use it in different ways. You have this linear ray, and linear phase ray, and this is just one-half-d ray. So, this is one-dimensional ray, but you have several one-dimensional rays. The number is not too big. If the number is very big, so the x-y-direction are kind of symmetric, you have a truly 2-d ray. So, phase means, each individual ultrasound pixel needs not to be fired in the same way. And each pixel, you can sync as a source, as a vibrator. You can make single piezoelectric material vibrate in the way you want. You can control the vibration with electrical signal, through so-called piezoelectric effect, the reaction plane. And once we have two-dimensional ray or 1.5-dimensional, one-dimensional ray, and each individual pixel, each individual transducer can be visually controlled. Okay. So, with that individual control, we can do... Computer frozen. So, let me just see how to deal with it. Let me close the program. So, I will actually play a little bit about this. These are a reason. I think some computer problem. This is the tool. Okay. I think about linear ray. So, linear ray, and this is the put multiple cool-stake transducers along a line. So, you have multiple rays. And you can selectively make a sub-side of transducers on. So, this is the light. This is selected in this case. These rays are selected. This is the use of these three as your ultrasound sources. So, this beam will go down the road this way. Okay. So, you do scanning only as a if just this single transducer appear. Then, you can define next line. You just group differently. So, then you have a neighboring line, line 2, sending ultrasound wave. Downward. Okay. Next, the instant you generate lines 3. So, you have a line of piezoelectric element. The element is remaining. So, each time, say the first second you use this part. Second second, you use second group. You keep doing this. So, the physical effect is that you send one beam here. Next, you send another beam. So, you can keep doing A mode scanning. But, you do the beam scanning to form a beam mode image, not by manually changing location or angle. You just do so mechanically or electronically. So, this will be very convenient. You have a re-formed. So, you use the acoustic transducer array and you can perform scanning easily. And, not only scanning, you can also do some beam forming, a lot of flexibility. So, here, I would like to explain to you the very famous herringes principle. So, this is the try to guide this idea. Then, the different schemes for ultrasound scanning and beam forming with a re-autor ultrasound transducer will become very clear to you. So, called herringes principle, basically, say, if you have a source, just a simple example. If you have point source, it will generate a spherical wave. The wave will keep moving out. So, at certain time, you have a wave front here. So, the wave, just think ultrasound wave, you have a comprising, and you have a rare fraction. So, this is the wave frame. So, the principle suggests that, if you decompose the current wave front into small elements, you have a small element here, a small element here, multiple small elements. And because the wave will feel the keep vibrating, like ultrasound wave, you have a small element, the volume, getting smaller, getting bigger, keep oscillating around the nominal volume, or pressure, keep changing, following a single solid curl. And so on. So, this is by reason, if you view individually, you just isolate a small waxel, you see the waxel keep changing, vibrating, oscillating. So, you think, okay, this waxel is a single, small, solid, ultrasound solid, of electromagnetic wave, and you can think this is a small solid. So, you just treat that wave, and you say, how you predict or calculate next wave front. The next wave front, one wave, just solve the original wave equation. You can just go to the whole wave propagation process. The other way, you just forgot about this original solid. You think, at a given time, the current wave front, shown here, A, A prime, you decompose it into multiple segments. And the easy segment, you regard, easy individual segment, as a secondary small, the solstice, the solstice keep changing, okay, you just think, okay, this solstice keep changing, and the easy solstice will generate a small, spherical wave. So, next wave front, will be superposition of all the secondary spherical wave, I did together, forming the next or new wave front. So, this is so-called herring principle. So, the current wave front decompose into numerous, many small, solstice, and the next wave front will be computed from all these secondary solstice. So, in words, we say, A, A, current point, on a wave front, is a new solstice. This is what I just said, secondary solstice. It's a new solstice. Okay, and all such new secondary solstice collectively determined, the easy small, small, new solstice generate wave. So, all these subsequently generated wave, I did together, that will form a new wave front. That's the next wave front. So, this is the idea. So, looking at this picture, you think this is a current wave front? So, you have multiple, you see, okay, you have multiple small secondary solstice. Okay, here. You see, solstice form a small secondary spherical wave. So, these waves together, you see, the, the, the, the in-way loop, formed by all these secondary spherical waves. I did together, they form the next wave front. So, this, next wave front, is, is in the same shape, as the previous, or the current wave, wave front. This is the propagated in the spherical wave form. So, this looks right. So, if you have a planar wave, this is propagating, say, forward. And this planar wave front, you think, can be decomposed into solstice. So, ABCD, so on. So, you see, solstice, so you have secondary spherical wave. Then, again, the in-way loop of all these small spherical waves, and form a plane. This is a new wave front, in parallel to your current wave front, in parallel of the previous wave front. So, that's, that, it is straight, how plane wave will propagate along one direction, which is the direction of beam propagation. So, if you have a small aperture, planar wave goes down here, because you have multiple yellow solstice, and each yellow solstice is treated, as individual point of solstice, vibrating out or water wave or electromagnetic wave solstice. So, if you look at this diffraction, it's observed. So, the light or sound wave will no longer go straight direction, it will turn around. So, as if it goes this way, it's turn around. Okay. So, you have two slates. The wave will interfere due to face difference. And at certain point, the two spherical waves, one from here, the other from, from the other opening. So, they will interfere. At some places, two waves will constructively hide together. Other places, two waves will cancel out. So, you have, if you have a screen here, you will observe bright and dark strips. This is called interference. And the reflection, and the transformation, and the old optical or ultra-scientific phenomena can be explained similarly. So, you have a plane wave here. The wave is frowned. So, at the surface, and the wave will be treated as yellow-salt-sibot. And it depends on location. So, this place, it's hit earlier, then the secondary spherical wave will be generated in this way. And this yellow-sibot will be generated later. So, it will form a spherical wave, a little smaller extent. So, the A-way-low will be defined by the power-like planes, depending on the speed of the sound or light in the two, relative speed, in the two medium. And you will see the transmitted beam will change direction. The direction change really determined by relative speed of the wave in the first and second medium. So, this explains a lot of wave phenomena. So, very cool thing. So, ultra-scientific transducer already here. It blue box already. So, if you have some beam, focus towards certain direction. It's shining in certain mode. And you will have wave-front in this blue box. So, what is all over the way? It is. But, there is a two-d acoustic transducer, so you can replace that wave-front with this piece of two-dimensional acoustic transducer. Then you can light, you can electronically control the transducer. This is the operate in the same way as the original wave-front should be. So, this wave is the immuulate, the same effect of wave field. So, you can do same thing, like focusing, skyning. So, you have all the flexibility. As long as the easy individual, you will be able to visualize behavior, easy individual, visualize behavior in the correct way. So, let me just make it clearer to you, with this linear phase ray example. So, you see, if you have the pulse, all come at the same time. So, all the individual elements will be fired on, and the direct outer-shape beam will go this way. But, if you do timing little differently, that means you fired the element 1 and 5 little earlier. So, this is time axis. So, the time here, the time axis, you think this is time 0. So, then time 1, so you got this two fired. Okay, so you got the two spherical wave, I made it in spherical wave this way. Then, later on, you have two and four, I made it in spherical wave, little later. And the latest firing is done for the central element. So, all these small wave light, I did together, you are forming the outer-shape field downwards, and the base of focus about here. And how you determine the focus about distance, from here all the way back to the surface of the transducer, that's really depends on this relative time delay. Okay, relative time delay. Okay, if you do the delay, little bit more gently, so this focus about will be deeper. And also, you can linearly save the delay, like this. So, you really make focusing focus about on the life-hand side. Or you do the other way, you focus the beam towards the right-hand side. So, you can just have all the flexibility. The essential idea is a herring principle. So, you can just use individual, self-slide, individual, transducer, generate the wave form, relative phase, any wave, one, then you can form different optical, acoustic effect. So, this is phase-dry, and you can extend the idea to two-dimensional situation. So, you can use two-dimensional rays, make the phase change, alright, so you can purposely focus just along the principal axis. Or you just focus life-the-world, right-world, you can even make circular scanning. Or you make the outer sound re-circulately symmetric. And you can, basically, circular, symmetric arrangement, you cannot do this circular scanning. You can only focus along the principal direction, but you can determine the focal distance. You can make a focal distance small or large. That is something you can easily do. Okay. So, beam-forming idea you introduce the time delay. So, you have scatters at a different location. And E1, E2, and E3. So, you have different icons. And on the receiver side, and you receive the signal, and keep guiding the signal. But if you add the signal together, with individual delays shown here, this means time delay. And you have a tall bar, means you introduce a higher time delay. And this different modulation will determine with the equal signal you want to detect. So, at this location, so the phase difference between central element and the peripheral element will be large. So, the relative delay will be large. So, you guide signal from the central channel. You keep the signal. Okay. Then, you guide signal from here. And this takes a longer time for the icon to reach the peripheral element. So, this longer time is the time delay. So, you add the time delay together. If the time delay is distributed, in this way, you add five signals, with five individualized time delays. I did the together. You form strong icon for icon 1. But if you use all the uniform time delay, then you are focusing to infinity delay remote point. So, you can do all these things to guide the coherent icon at different diffs. So, this is the so-called beam forming idea. And the scanning and beam forming can be combined for desirable performance. So, let me just copy this figure to show you the idea. So, this is one dimensional auto sound array. If you just use this group of transducer, you can certainly do beam forming. You do focusing in this way, based on relative time delay. And you do focusing at this depth. So, from the surface to this focal plane, and you make focus about the size here. So, you guide signal basically from this reason of interest. You guide signal. Then, this group signal can be moved. So, from live to right, you do scanning. You guide this line. And you can sync to dimensional array. You just do line by line, then you have the signal imaging. And also, the idea I mentioned like here, you can sweep live right. And when you do auto sound imaging, you can use the data idea to do compound imaging. So, you have face array, all the auto sound beams, so towards live. So, you have multiple image, multiple lines, A mode. Together, you form an image over a reason of interest. Then you can type a change in this angle. And finally, you make all the auto sound beams towards the right direction. You have form the same reason of interest, multiple times. Then you add all these images together. You calculate our reason. What's the benefit? So, the same reason of interest, like here, is the reason of interest. You collect images in beam mode in different ways. So, one way you use all the beam lines, so you have all the beam lines towards live. And all the beam lines, just perpendicular, all beam lines towards the right direction. But all these complex reason, cover the same reason of interest. So, you have multiple acquisition, multiple beam mode images. You add together. Then you say, auto sound imaging. It's subject to strong artifacts and noise. If you do image acquisition, in different ways, the structure is the same. But the scattering sparkles, those things are randomly changing, frame-by-frame. So, if you add them together, you can achieve noise or artifacts, consolation effect. So, this is the image in your text book. You see the image is quite smooth, without the typical sparkling, so on. So, this is called compound imaging. It's something similar, as noise or the region. So, this is the different ways for you to perform auto sound imaging in different ways. A mode, B mode, C. A mode, Hercons principle. So, this is the five different auto sound elements in one or two dimensional way, in the way you want. So, you can scan the field, you can do focusing in different ways. So, all these flexibility. So, read the green text book, understand the imaging principle. So, this is pretty much the first part. The second part, is the focus on dynamic imaging. So, you want to compute velocity, the blood flow velocity, or heart beating patterns, so on. So, you rely on Doppler effect. So, water is Doppler effect, so this is a cartoon. And you have a personal experience, so, if you are in train station, when train comes towards you, or moving away from you, you hear the visual, it will be different. Also, the warning sound, when the police car moving towards you, or away from you, if the car moving away from you, the sound from the car will be perceived as lower frequency signal. If the car moving towards you, you feel the tone is quite sharp, because the frequency is high. So, that is to say, the perceived frequency depends on the relative velocity of the sound source. So, this is Doppler effect. And in your text book, you have a diagram shown here. You have to say, this is the testable reason. This is the bladder vessel. Right bladder shell, reflect ultrasound energy. You send the ultrasound energy towards the right bladder shell. Red bladder shell, just reflect, but the bladder shell is in motion. And the vertical components is V. This is the bladder stream velocity. This absolute velocity times cosine theta, you got this vertical component. Then you have several equations to say, if the bladder shell is in motion, the reflected frequency would not be the same as the incident frequency. So, there will be a small difference. This difference is called Doppler frequency safety. And for ultrasound sound, for optical waves, for electromagnetic waves, this is a universal effect, Doppler effect. Why we have this? So, here is the key paragraph. So, again, it is the reduced size of the duplicated diagram. So, you have this motion, incident frequency, and you have reflected frequency. Basically, the derivation goes as follows. It says, the frequency, reflected by right bladder shell, is given by equation 3.40. The C is the speed of the sound in the tissue. Then V is the bladder stream velocity. This is theta is cosine angle. And this is the whole thing divided by lambda. So, how you derive this? It is a signal ball. So, lambda moves to life-time side. Frequency times lambda. This is a parent frequency, right bladder shell.

Lambda times frequency. That gives you wave lines. It is pretty much the unit time. It is the distance traveled by the sound. And the C is the velocity. And the V times cosine theta is the velocity. So, these two together, we got a relative velocity between transducer and bladder shell. So, this is a little different from the original high-meta frequency. The outer sound frequency, originally from transducer, is IF-incedent. So, this frequency will be related. This frequency should be speed of the sound divided by lambda. Or lambda equal to C divided by IF-i. The difference is here. Okay, this is the difference. So, the difference between incedent and reflecte, is shown in the last equation. And that means given the frequency Doppler-safety, you can infer what is the velocity. The velocity is vertical components. You can measure the velocity, relative velocity. So, this may not be immediate clear to you. Let me give you a very easy cartoon. So, you understand why you have Doppler-safety. So, you think, look at this, the transducer, the outer sound wave at the speed of C towards a stationary object. So, in this case, speed of C equal to frequency times wave lines. So, wave lines is a bicycle, how far you move. And how many times you vibrate? So, frequency times wave lines. So, this is speed C. So, in a unit time, in this case, so you see four pulses. I should make a plural form. Four pulses are sand into the object. This is the reason. And this is the thing that gave you a simple, but I just drew more example. Now, you are thinking about moving situation. I say, moving object, you will see a parent frequency, will be changed. How that happens? I think about this. Now, let's say this stationary object, a static motion towards the transducer. This is for simplicity. In fact, the object motion also in velocity C. Also in velocity C. So, in unit time C, unit time, you will have the sound, move C. In unit time, you have four pulses into the object. But now, in the second case, the object is a static motion. So, also moving velocity C. So, within unit time, this moving object will cover distance C. Because it covers distance C, if it stays here, it will take four pulses. It moves towards the transducer. So, those four pulses in the middle, not reaching the stationary object yet, now, in the second case, it has been eaten by this object. So, the object will take a diagonal four pulses. So, all together, you have eight pulses into the object. So, these are supposed to object is perfect reflector. So, in the first case, you have four pulses into the object. It will reflect four pulses, within unit time. So, the reflected back, you get the reflected signal. Within unit time, you got four pulses. So, the frequency is same. You have four pulses. You just vibrate four times. But if you're moving back, earlier, I said, moving object will take eight pulses. If it is a perfect reflector, and it's moving object, it will reflect eight pulses now. Eight pulses moving that direction. And these eight pulses are reflected within unit time. So, the frequency reflected pulse is doubled. So, this is how moving object will change frequency. So, you reflect a signal back in higher frequency, and the frequency difference between stationary and dynamic cases is a topical effect. So, this is the idea. Think about this simple diagram, then you reveal these equations. Think about the connection between them. You will have better understanding about the formula, particularly this one. Let's say, the components of the components velocity, VE times cosine theta. So, only power out to this direction can be measured as the carrying frequency.

This is incident frequency. And frequency is safe, the Doppler is safe. This normalization factor is the speed of sound. So, you think about this. Half of the power is raised, then I come back. Doppler imaging. Doppler imaging is an important part of ultrasound chapter. So, to understand Doppler imaging, the key is to understand this formula. And if you follow the derivation, so things may not be totally clear with you. But if you understand this cartoon, then you see how the Doppler frequency is safe, it's generated. The same idea can be applied. So, you follow these formulas systematically. Then you know what's going on? Why you have this connection between Doppler frequency safe and the velocity components, you are measuring along the ultrasound beam direction. So, if the motion is parallel, it's perpendicular to the beam direction. You cannot measure it. You can only measure the Doppler frequency safe. So, this is simple. But give you an idea. So, now, we talk about how you do Doppler imaging. And you can use continuous wave. You keep sending waves all the time. All you just send a pulse. One pulse at a time. You send a train of pulses to measure Doppler information. Also, you can perform echocorylation. So, you send a signal, a guide bag, send another signal, guide bag, and see the relative phase change by correlation. A correlation helps you detect the signal. In the foundation part, we mentioned K-S Equality, Causing Shua Z Equality. And that shows if you do correlation, if the two wave form match, that means at a particular location, the signal indicates that the echo will be. So, you can find a relative shift. And if you have stationary reflector, you have certain standard distance. If the reflector moves, the relative shift will be different. And you can combine Doppler imaging with beam mode imaging. beam mode imaging gives you an atomic background. This is a image, beam mode imaging. If you have multiple two dimensional beam mode imaging, you have 3D outer triangle. So, that's always nice. But on top of an anatomical structure, we call it as a reflective signal strands. And you can superimpose velocity distribution. The velocity is a vector. You have velocity amplitude, you have direction. So, you can adjust the color code of velocity. So, you make sure certain direction. This direction is right, this direction is green. The other z direction is blue. So, depends on the direction. You have different colors. And the intensity will be proportional to the amplitude. With the color coding, you know the velocity field. So, you have this combined effect. Now, we now explain each of them. So, you know in practice how you measure Doppler or motion information. And these things are all, I think, straight forward. You just know, needed to know as your general knowledge. So, continue with the wave. Basically, you have a transducer divided into two parts. One part is for transmission. You keep sending out some wave towards the region interested. The signal will be reflected. So, the reflected signal will be received by the other part of the transducer. So, you have one transducer, two parts. When sine signal, the other just recall the signal. So, when you send the signal, the signal will be at certain frequency. So, frequency is a standard. And reflect the signal as I explained, may subject to certain change due to Doppler-sift, Doppler effect. So, what I send is some frequency here. What I guide is frequency different. And the frequency difference related to the motion. Certainly, the motion is along the beam direction. So, this is the reason of interest. You send the beam, collect the signal. You must have the common reason. And the wave invades. The signal can be received. And can also be seen by the receiving element. And if you have some element here, it will not work. If you have the element here, you receive the signal. But the signal will not be reflected back to the receiving element. So, this is just the simple set-up. Continuous wave, you do things continuously. So, you cannot use single element for both emission and detection. You have to have two parts for separate functionalities, emission and detection. So, continuous wave will need two parts. Then, water is signal. So, the signal in and signal out, so it will be a little different. So, you have the signal in at a certain frequency. And then you detect the signal. So, you receive the signal. You will subject to this delta-if, Doppler frequency safety. So, this is the two signals of the signal. One is the emission frequency, i5i, the other is the i5i plus delta-if Doppler frequency safety. Delta-if could be positive or negative. Then, with the digital signal processing technologies, and you can multiply your standard signal without Doppler safety, with this signal potentially containing Doppler safety. You do multiplication. The circuitry can do the multiplication. You make the signal together with some 90-year circuit components. This multiplication and the mathematically can be expressed as summation. This is a high frequency and a really double frequency. The i5 is incident very high ultrasound frequency. Plus, delta-if, delta-if is small. But interesting thing is that you have second term, which is the low frequency. Because this signal is a wave, multiplication, the two factors, both, are at a high frequency. You can multiply together, you can decompose into a high frequency and a low frequency. Then, with water, you learn low-pass filter. The delta-if in range relatively low and the two i5i plus delta-if, these are in high frequency range, high frequency region. So, you make a low-pass filter, just to surprise the high frequency components. I saw the low frequency components, which is this part. You multiply half a, this half a, onto the low frequency components. You get this precise signal. This will show you what is delta-if. Once you know delta-if, you can estimate V. The last line, you remember you have that formula. So, this is the idea for Doppler signal detection for continuous wave. And this continuous wave imaging, you do not have precise information. You know the velocity. So, from the delta-if, you know velocity. But the whole sensing region, why is the velocity, you do not know precisely. Because this is continuous wave. You can get velocity information. But you do not know exactly location. Second mode is pulse wave. Second mode. So, you do not use continuous wave. You separate each pulse, like delta-function. It is not exactly delta-function. You can see the data-function. At time 1, you sign the int to the T-axis. The delta-signal back. Then time 2, you sign the second wave. So, the second pulse. You sign the 1 by 1. This is C, the I-O, the I-Code comes back. And I copy the two pictures from another text book. So, this is a very graphical. So, you sign the pulse. This is the pulse lines. So, int to the T-axis. And another time you sign the another one. So, you get multiple pulses. Sign the int to biological T-axis. And between these and the pulse, you have certain delay. The time repetition is 1 over frequency. So, this is the, this is the -tile parameter. You sign these wave int to the place in the body. And the R-C-U-X-Bagotate, you can receive I-Code. So, the scatter the back, I-C-1, I-C-2, I-C-3, you get signal back. So, A-F-N-O-Motion. So, the scatter signal from certain surface. So, the frequency, the interval between adjacent scatter the I-Code will be the same. But if there are relative motion, still remember the last cartoon I showed you. Because it is a motion, so this distance, this distance will be different from this distance. So, from that you can, h-day-meter, what's going on. And this mode can be targeted to certain dipes. Okay? So, you can focus the beam to certain dipes, try to sign the motion in this reason. You can focus little bit, in little bit higher resolution, or lower resolution, little deeper or smaller. So, this is signed information by analyzing the relative change of all these I-Codes. And how you just signs the relative I-Code. So, you assume, assume you sign one I-Code back, and I target to say that student. I sign the I-Code to him. Suppose he is stationary. I know, because I know, I have targeted dipes, I know that. So, the sound go wrong to the trifer. This is for example, 100 milliseconds. So, I just make this central line, 100 milliseconds. Okay? So, I sign the signal to him, the relative back. So, this is look exactly like this. I sign the second signal, the same way. And I wait, not the certain amount of time, so I sign the first signal. I wait for one second, not the signal. So, the rig I-Code will be delayed by one second, but will be back. If the student or the surface is stationary, the second I-Code after one second delay, will be exactly the same, like this one. But if the surface is more little bit, move towards me, the I-Code will be back, little sooner. So, this is slow. So, you see the relative peak. Could be a little bit like, could be in the winds. So, if the surface is in signal-solid motion, so I just keep recording this amplitude value at a gated dipes. Gated dipes, I mentioned 100 milliseconds. So, I'll just show you. So, I just make this point. I mentioned 100 milliseconds. The ultrasound will travel to the student. It will come back. So, if no motion, the amplitude always, always A or one, always the same. But the surface will keep moving, the amplitude will be oscillated around this line. So, the signal measured will, if the surface is in signal-solid motion, and this will be reflected as recorded signal. You can perform Fourier transformation. You can find the frequency. Usually, the motion is not purely in your soil, it's some periodic motion, certain things. You do one-dimensional Fourier transform, and you can see the Doppler frequency. So, this is the idea you use to pause the mode. This is a little trickier than continuous wave. So, I will use the fuselage, and I will show you some more again. So, pause the wave, Pw Doppler. That's not to make use of Doppler principle directly. You just really directly analyze the relative change. So, the I code waves, and each wave as I mentioned, you only take one point measurement. So, the first I code, I measure here, second I code, I measure here, third one. So, each profile, I just do one measurement. I take a data-difference. So, this is just the kind of, I'm more the acquisition. You see the first I code, second I code, the reflector, keep changing location. So, the relative phase of this placement will be changed. And this change, reflect the motion, the velocity. Okay. And I pause the wave, and I have two more ways to show you. So, let me just show you again. I hope the computer will not mess up. But I think good for you to see two more ways here. Just try. Okay. Okay. Try to pause the state, it means the reflector or surface does not have a motion. So, let me show you this one. Keep sending blue paths, one, two, three. Let me do again. See, this is the stationary thing. So, if I line up, sub-sequent blue paths, the field form at a gated time instant, will be in same phase. You see, always in this phase, keep guiding icons. So, for each icon, I only take one point. So, all the points will be same value. So, this is a one situation. And if we have, go here. See. Very crucial, not very good at base-less. Okay. Let me see this one. This is the situation. When this reflector keeps oscillating, so this is what will happen. See the icon signal, at a gated time instant, will change the amplitude value. So, you got signal here for the first icon. And the second icon, this is value. And the third one, you got all these. So, all these individually select points, will form a signal-solid curve. If the right reflector is oscillating in signal-solid mode last time. By the way, let me show you this, Putin, and you know, wave form. This is your transducer array. So, you can put any face you want, and you can see this as a different wave form. This gives you a visual adjacent. Okay. This is a whole, the computer on the cries. Okay. So, the essential idea, there are multiple formulas in your green text book. So, you read two pages on the pause the wave of Doppler imaging, two pages, and the multiple formulas. So, you read the first one, but the essential idea is that, when you send a train of pauses, and the easy pauses come back, you collect signal at given, given distance, given time instances. And you get one signal out, one data point, out of each echo. And if no relative motion, so these signal strands will be always the same, but if they are relative motion, like what I show you twice, if the reflector of the scatter is in sinusoidal oscillation, the data point you form from pause 1, 2, 3, 5 will form a sinusoidal. Certainly, if the reflector of the scatter is not in sinusoidal motion, if the object is in uniform motion, towards the one direction, and the in your detected signal, will not be sinusoidal, will be just something like a line. So, these, these pauses mold works to certain, extend. If you move too fast, the echo could be not, you may say the first part, maybe the second part comes in, and you have the same, so called ILA signal artifacts. So, there are several formulas in the text book, but I would emphasize what you need to understand is this is related mechanism. So, you have a relative motion, so this is a relative motion. This is a relative motion, really determined by relative motion in the reflector, or scatter. So, this can be related back to Doppler frequency. So, you can finally find the relative motion of the vessel or cardiovascular features. So, this is just the second mold. Then we have, so called correlation method. This part is quite easy, I would say. So, you have a transducer. So, you can sign the pulse, so this is signal back. Okay, the whole signal. It's not just recorded one point. You record a whole signal profile as a function of time. You got this one. You sign the second pulse, and the second pulse will reflect signal back as well. But in the second case, the right blood cell already moved a little bit towards the left hand side. Then, what's the relative distance between the position one and the position two of the right blood cell? You do correlation. You see this wave form after certain time delay, tau will be most similar. So, after this time delay, tau. So, this time delay, tau, will be more similar. So, after this time delay, tau. So, this time delay, tau, will be determined by the relative location in the case one and the case two. So, tau times the speed. Speed along this component. So, the equal to the other relative displacement. So, this is a correlation principle. And again, you can find relative motion, and you can find the velocity if you like, you can compute Doppler frequency. So, this is the third measure. Last one is not hard either. So, this is what I already mentioned. Just show you Doppler effect can be utilized to my frequency velocity. And you can superimpose the velocity field onto the B-model image. B-model image gives you an anatomical structure like a big blood vessel here. Then you want to know, you want to know the blood stream velocity. So, your color code is in RGB. So, towards a wave, this is, you put green, you have different ways to do color coding. So, this way, you have transducer. You code it right, blue, green, and you only can share about one dimensional motion. The right velocity, right color means the blood is moving towards the transducer. The green components shows the signal variance. So, for uniform blood stream motion and you will not see green is torn. So, that means there is no turbulence. That will be good. And the subactual Doppler, and you perform Fourier transformation. You can guide the velocity distribution. So, this is something that is not single frequency. You have multiple frequency. And this is your figure 3.2 2.3. So, you have a signal amplitude. So, in different cardiac cycle, so the heart may be in systolic state, or in diacyl state. So, the velocity will be different. So, you can use subactual Doppler imager to mod inter cardiovascular Doppler. So, all about Doppler imaging. So, four things. Continuous wave pulse, wave correlation. And you can do most informative things. The subactual color Doppler is superimposed B mode and velocity map. So, these are the key point for the second part. So, the third one is the ultra-high-autofax. And the like with any imaging modality, you have some image artifacts. And for ultra-high-autofax, we actually play the ultra-high-autofsignal will be tiny-autofax. So, if you do not do anything, just recall the signal amplitude or intensity. So, the deeper the features of the spectators are, the weaker the signal. So, really the the penetration and the wave flexing. So, these two wave are tiny-autofax. The signal will be very weak. So, on the surface, the wave flexing is strong. So, if you play the signal directly, you have a strong wave flexing. But, in the middle, you pretty much follow quick exponential decay. So, you know generally, this thing is how many years you have this exponential decay. So, you can see that the wave flexing is strong. So, you have a very strong wave flexing and the wave flexing is strong. But, in the middle, you have a very strong wave flexing and the wave flexing is strong. So, you can correct for the decay. You put the exponential increase the gain as a function of depth. You apply this curve to code amplification factor. You compensate for exponential decay. You apply this exponential amplification. That counter-react with exponential decay. You multiply the gain compensation. Then, you got this kind of uniform ultra-shound image. So, you see this is much better. Otherwise, you have this attenuation problem. So, you have the decay, the signal wave, and no longer quantitative. But, even you apply this correction. This correction is based on certain properties. This is a useful homogenous self-tatial. So, the quantitative accuracy is not perfect. Like in CT-A-Maging, you have beam hardening artifacts. You can correct. But, normally, it is still not perfect. Anyway, this is time gain compensation. So, different time means different echo time means different depth. So, the deeper effect, the more you apply stronger amplification effect. So, I can recover the signal. So, this is the idea. Then, talk about next artifacts is due to the slope. So, you know, we are dealing with ultra-shound wave. And, no matter how you modulate individual ultra-shound transducers on the two dimensional or one dimensional, even single transducers, no matter what you do, you never can form a perfect beam line. So, this single point will become a spherical wave. And, this you have an aperture. You can treat us in the visual wave. You have two dimensional different elements. You can set any phase amplitude as you want. But, no matter what you do, you really eat in the visual components. We will generate a spherical wave. So, you will not be able to form straight forward perfect pencil beam. That's a physical limitation. So, the best that you can do so far, you can form a main slope. The main slope is strong. And, towards the principal direction. And, the cause that you form is a main slope. It comes as a multiple side slope. Remember, when you do Fourier analysis, you have a main slope. You have some oscillation. And, when you try to try to approximate this gate function. And, near the edge, you have so-called gafers-ringing. Because, all you can use sine, cosine, different frequency amplitude and phase. And, after all, you use sine-usoidal. Try to approximate this idealized wave. Here, you use all the wave propagation wave kind of sine-usoidal. You try to put all these together. Try to form a pencil beam. Direct beam. That's not possible. So, you have this kind of ringging. You have side slope. But, as a result, when I probe things, just one target here. This is a primary beam. I do the beam of the scanning to this wave. So, the primary, the main slope is the main slope. Do the scanning. Report there. It's signal here. Okay, go back. No signal. So, you got one major echo. It's very bright due to main slope. But, when I do this scanning, I have side slope. So, I do scan. This is side slope. I mean, I mean, this is side slope. So, this is the main slope. This is side slope. So, when I do the scanning, this is the main slope. This is the main slope. This is the target. But, when I do scanning, the side slope always the main slope. Okay, the side slope will report a minor signal. You also have this one because you have second side slope here. So, this is artifacts. You look at this. Okay, I have three reasons. You have exactly the same shape. But, one is very bright. There are other symmetrical location. Very dark. We do report in your reading report. You know the ultrasound physics. Then, you move the do-show. It's say, okay, this is the only one. This is the artifacts. Okay, and also, you know, in human tissue, there are multiple layers. And, the network you have boundary layers. And, the two mediums, this is the above and the below the the interface. If the acoustic impedance are not included match, then the strong echo will be formed. So, we have so-called network brilliance. That means the signals, the icons will come back multiple times. You send one echo. You really get one pause. You get a multiple echo. You see here, there's one layer, and the second layer, third layer, it happens in many ways. For example, you have a long, here long, long top surface, bottom surface. You send the ultrasound to first the surface, you get an echo. Some energy penetrated into long, hit the bottom surface, you get an echo. This echo made this surface will be echo back. So, this is the multiple layer, echo back, and the fourth, generate a multiple echo. Pretty much like the other day I mentioned, when you say, hello, in some mounting area, you may hear multiple, hello, hello, but really only set side so once. So, all kinds of artifacts will understood. So, you need to be able to, another thing, so, you have this sideowing artifacts, is because this is, oh, this is something like kidney stone, it's a cow stone. The stone is very dense, ultrasound energy couldn't penetrate. So, no signal behind. So, any significant features behind the stone wouldn't be probed. So, this is a sideowing artifacts. So, it's just really your text book, understand typical ultrasound artifacts, how they formed, so, just conceptually understand these things. Okay, so, last part, I just say a few interesting new things, new ideas, and we will not text, just let me know. We have a new faculty member, Prof. Ping-Kun Yan, he did excellent work, he is an actually collaborators, and the Philip is a medical imaging company. So, what they are trying to do, they try to combine ultrasound imaging and MRI imaging, and for prostate cancer surgery, and they say you can do pre-operative ultra-operative MRI imaging. So, MRI imaging give you very good spatial resolution and sensitivity, biological, spatial sensitivity, then you see, okay, this is a problem, so, prostate cancer, you want to take it out, you got this image, as a prior information. It's good in terms of spatial resolution and sensitivity, sensitivity, but the MRI scanner is very expensive, it's not cost effective, and the MRI scanner has high resolution, and it goes very slow, CTA is quick, but the MRI is slow, so you have two advantages, and two drawbacks for this MRI imaging, you learned before, and in the exact measurements, we will cover ultrasound MRI, so you need a STO review MRI chapter, so these are related strands, and the weakness is, and on the other hand, the ultrasound imaging and the spatial resolution, not very good, you show some images, spatial resolution, not very good, sensitivity, sensitivity, not very good, but the edge is cheap, and the temporal resolution is very high, you just have to move around, you immediately get an image, so then you say you do preoperative MRI imaging, then the introoperative, when the patient brings into surgical suite, you use ultrasound, doing ultrasound imaging something like this, and then ask surgical guidance, okay, you want to do image registration, so over life days, on to MRI imaging, why you want to do image fusion, because on MRI images, you see why it is problem clearly, individual imaging, hybrid imaging, so you got some images like this, and the device system got very good clinical trial results, and graphically, you see if you do not do good image registry tracing between ultrasound image and MRI image, so the ultrasound results, and the MRI results are not very lined up, you cannot based on that to perform surgery, because you do ultrasound, you see certain things, and how you relate back to MRI images, so if you don't do very smart image registry, and the clinical utility will be very limited, but on the other hand they deviled some machine learning software to do ultrasound image and MRI image registry, then the result becomes much better, I think they might get quality in terms of what we learned structural similarity, so it becomes much better, so based on this you perform surgery, and the surgeon got higher confidence, and the better surgical outcome, so this is a combination between ultrasound and MRI, used for surgical guidance, very how to research topic a lot of results, okay, the next one, talk about ultrasound imaging, and the optical imaging, we will explain optical imaging in the next lecture, ultrasound imaging, and the optical imaging, put together, we have a new mode called photocoustic tomography, so the idea is something shown here, okay, you inject into some animal, some contrast of the material data is graphene based micro bubbles, so once you introduce micro bubbles, and the ultrasound will be stronger, okay, so you have a stronger signal, and also graphene can also light wave turn into heat, so you send near-infrared light pulses, so this light signal is active with these micro bubbles, so it will, the opposite of heat, so we will expand in volume, so because it comes in pulse, when pulse comes in, the volume is big, okay, you will absorb certain energy, the heat, so expand, expand it a little bit, then pulse goes away, it will cool down, okay, then the next signal, so if you send the ledger pulse in ultrasound frequency, this is the vibration, we will generate cool take wave, so this can be detected by ultrasound transducer, so this is optically introduce the contrast, will be detected by cool take transducer, so you go, so first near-infrared light is the graphene of the shock, heating and the thermal expansion, generating cool take wave, ultrasound detects it, then you can perform diagnosis, and last time you might see some drug can be detected by micro bubbles, so you do diagnosis, and you can also do therapy, and a lot of research going on in this area, so Li Hong is my friend, and he is sorry for the photo cool take tomography, so you can use it on multiple scales, so from cellular level to animal patient level, got good resolution, if you purely use optical imaging, the resolution isn't very good, but contrast is very good, you use ultrasound imaging, the contrast resolution, the pattern is very good, you use ultrasound imaging, the penetration depth is resolution better than optical imaging, but contrast is not as good as optical imaging, if you do the combination, you get benefit from both imaging modality, so this is another example, so in the benefit of multi-modality imaging, okay? then last example, this is this is something, I'm not source, I think this is my idea, I think it's a new idea, but I didn't check, this is always particularly in graduated level classes, I often mind some primal true idea, here we say ultrasound imaging, last lecture we say the I mind send the iPhone eventually can make, can be make like a transducer, so we put the iPhone in certain part, we can make velocity, and I think this velocity, Doppler measurement, I guess, I'm not sure, it can be used to measure blood pressure, so the blood pressure usually you put a cow or do measurement, I think I want if you have iPhone, anytime I want to measure blood pressure just put here, here, and immediately get blood pressure, that will be really cool, another idea like blood sugar, these are very important measurement, blood sugar could be measured, also maybe with the iPhone, they put the iPhone on my tongue, then optical signal, send the ink and then get blood sugar like, I don't need to do blood drawing, and I will mention little bit more next class, let me give more thought, but for ultra sound measurement of blood pressure, we can follow different principle, the previous principle, you need to make blood vessel collapse, then the pressure pulls through, so here the sound, that's a conventional way, principle to measure blood pressure, but here we say Doppler imaging, this is a gold ascetic, this is my logic, you may or may not agree, so you have velocity moving this way, the velocity could be changing, while changing your heart beating, the pressure pulls blood through the vessel, okay, when you pull blood through the vessel, the blood velocity will change, and the pressure on the blood vessel wall, the pressure is high, make the diameter of the vessel increase, then the area will be cross-irere, will be increased, and the other way it goes back, the velocity, velocity is high, the cross-sexonal area will be, velocity is high, cross-sexonal area will be small, if we total fluxes should be the same, so the area is small, then you feel stronger blood pressure, pressure will be increased, so this velocity change, and this geometrical dimensional change, can both be measured, velocity change can be measured in terms of Doppler effect, and the geometry, like the vessel wall, this top surface, bottom surface, will be demonstrated at a relative distance, if you have all these information together, then we train the whole work flow using machine learning network, the modeling is very hard, but if we use machine learning for work, the chance is not, the don't need to use, don't need to feel the tightness, just any transducer, you pull the pin here, you measure the vessel, and the screw analysis of the relative, saved, and the velocity, and the use of machine learning to H-t-made, your blood meter, do the calibration, after the calibration, you have individual light profile, just put here, I immediately get measurement, that will be quite easy, and the easyness make life hollow, and you have continuous monitoring, so on, so this is the, this is simple thing, even the current blood pressure measurement is not possible, but if you reduce, you use iPhone walls, constantly measure blood pressure, you don't feel the tightness, then you will have multiple reliable information, your whole day blood wave, and the blood sugar, so you can get more information, right? So this is some idea, maybe wrong, just put some idea, I show a recent carbon material, and those things I think make the transducer surface, iPhone surface, really flexible, and you can get a natural cool-stake machine, just the possibility, okay? Last slide, okay? Today I would not give you any regular homework, but good time for your start reviewing I'm on the outro chapter, so for my class room teaching, I want to let you know some considerate, traditional class room teaching, okay? That's about knowledge transfer, knowledge transfer, really just a bunch of knowledge you need, you're familiar with other people already and you can repeat, you know the step, you can repeat, you can guide the same result, and you remember the formulas, remember the rules, numbers, so this is nothing wrong, this is still good, but now they try to inspire you to have new ideas, so to that purpose you need to understand what's going on, like I said, that's simple example, just to let you see how you guide the Doppler system, not just remember the formula, you see the different, then we encourage you not only just copy what other doing, you see some building bridge, then you do same, you need a create, you need to innovate, generate new ideas, so this is more important, not this, so do the talking about review now, so we still do close book, so the close form study, you can, this book, and even you don't understand anything, I say you read the green chapter, you know the knowledge, the solutions, and the answers, and I wouldn't test for undergraduate, but for your long term learning and research, you really need to think most importantly, you identify problems, so when you do review, you may see how pioneers, earlier researchers, they identify the problem, they have the idea, and you know how to use tools, even the green types, that's not give you answer, you do Google search, you do some web of science search, you have certain tools to find what you need, then you solve the problem, you identify, and you need to have strong motivation, so traditional way, wouldn't test these new ideas, wouldn't motivate you, but the teaching really through the underlying things, so anyway, so that's all for today.