Science of Clothing Comfort
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Lecture – 22
Clothing Comfort Related to Thermal Transmission

Hello everyone. So, today we are going to start the Clothing Comfort Related to Thermal Transmission. In earlier segments, we have we have discussed the clothing comfort related to psychological comfort, psychological aspects you have discussed, then we have discussed a neurophysiological aspects, and in last segment we have discussed the textile aspects of clothing.

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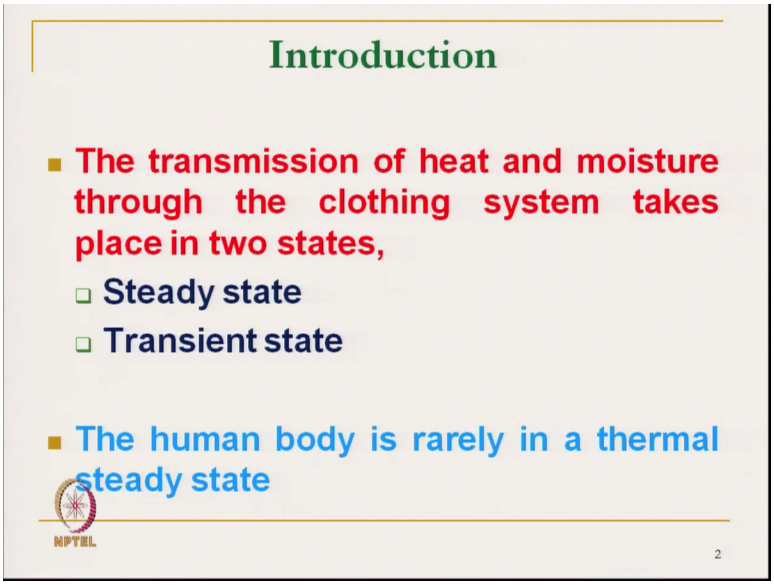

How the or clothing transmit signals related to touch pressure all those aspects we have discussed, and today topic is the thermal transmission.

So, and it is a dry heat transmission through clothing, and how this transmission affect the comfort sensation of human, ok. So, basically the transmission of heat and moisture, although moisture related part we will be discussed, we will be discussing in the next segment. But the transmission of heat and moisture through clothing system takes place in 2 states. One is the steady state condition; another is in a transient state condition.

Most of the situations the transmission takes place in transient state condition. So, it is the human body is rarely in thermal steady state condition.

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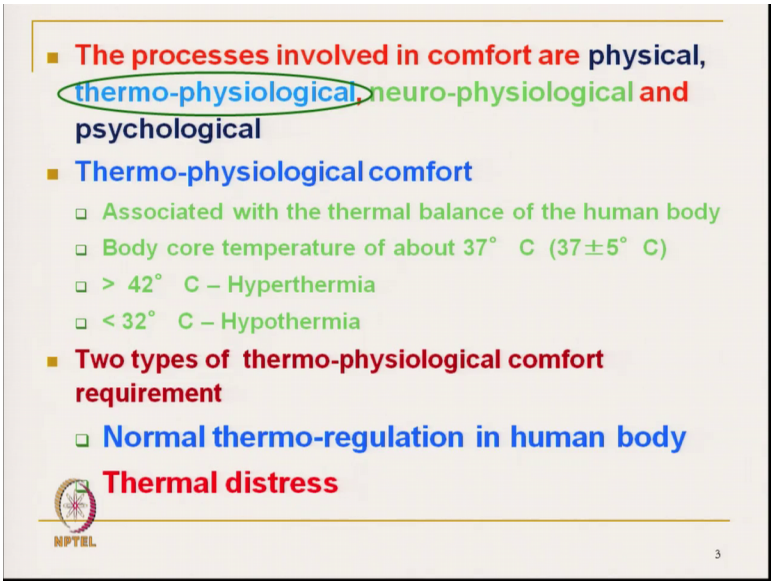

So, always it gets changed like the process involves in comfort are mainly physical thermo physiological, neurophysiological and psychological.

So, in this segment we will we discussing the thermo physiological aspects of clothing. So, that the thermo physiological aspect, it is basically associated with the thermal balance of human body. So, most of the cases we will see, this thermal balancing and all aspects are not in steady state condition, but for our discussion we will consider some steady state situations.

So, the first priority to be a thermally comfortable is that, it we have to maintain our heat balance. Basically our body core temperature we have to maintain our body core temperature, it is a 37 degree Celsius is the mean body core temperature for average adult. And it is a range is a maximum range is plus minus 5 degree Celsius, beyond that we cannot survive.

So, it is a if it is more than 42 degree Celsius, then we call it as the condition which is known as hyperthermia. And if it is below 32 degree Celsius, then it is called hypothermia. So, we have different situations and our clothing's main function is to maintain our body core temperature within the comfortable limit; although our

physiological phenomenon activities try to always maintain the body core temperature at 37 degree Celsius, but our clothing has to assist that.

So, 2 types of thermo physiological comfort requirements are there. One is the normal in normal condition normal thermo regulation in human body, which deals with the normal temperature which exists in the environment. And second is that it is a thermal distress, where the temperature is extreme either in extreme heat condition or it may be extreme cold condition.

In normal condition, normal thermal regulation system, which can be taken care of by our physiological processes most of the time. Our physiological process can take care of that of this normal condition, but the at thermal distressed condition our clothing has to come into picture to make ourselves comfortable.

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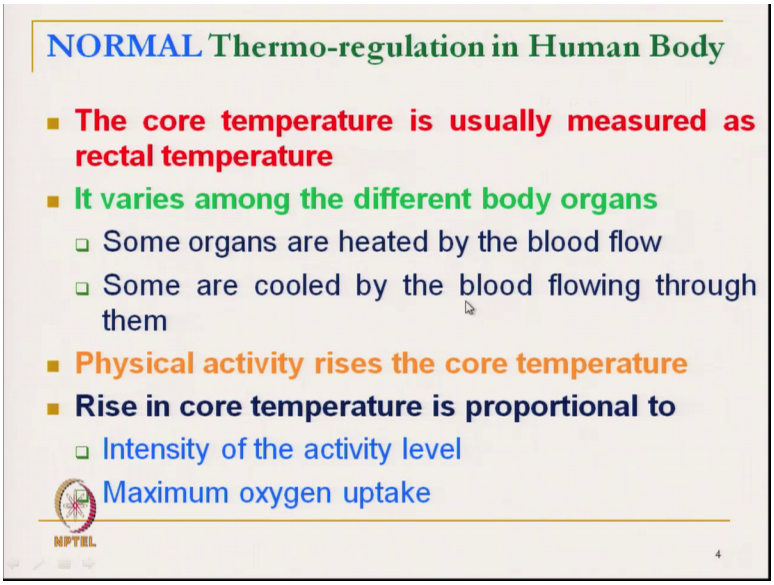

So, normal thermal regulator regulation in human body where it is a the core temperature is there we have to maintain it is a constant temperature. It is a measured as a rectal temperature, and the core temperature actually varies among different body organ. Normally, within a smaller range it varies, and some organs they are heated by the blood flow, and in some portion they are cooled by flowing blood through them.

So, that is how the temperature core temperature sometime vary, although it is very close to 37 degree Celsius. So, physical activity also rise our body core temperature that we

have seen in earlier segment also with the high activity. So, body core temperature increases rapidly.

So, the rise in core temperature is proportional to intensity of activity level, and also maximum oxygen intake, ok so, that we have seen although already.

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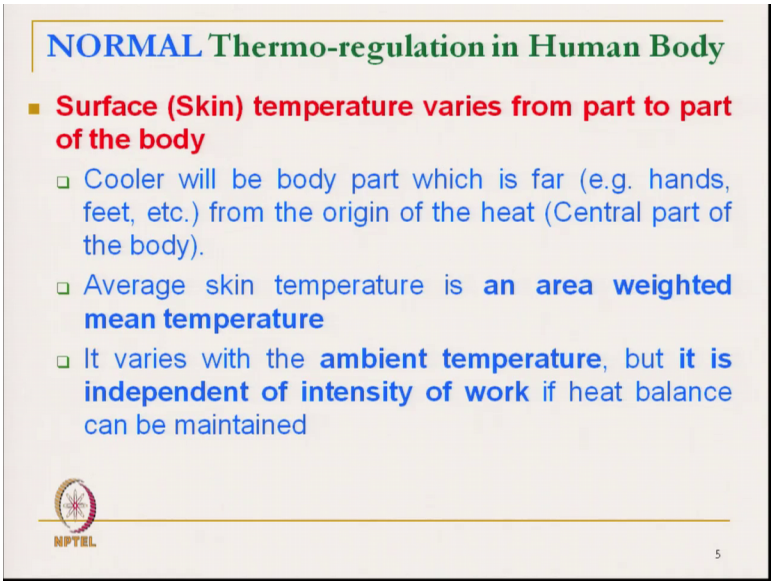

So, the skin now coming to the skin temperature so, skin that is surface temperature varies from part to part. So, our if we see our a different body parts the skin temperature is a different. So, it is a cooler if it is away from the origin of heat. That is central part of the body where our heat mainly generates, if we go further away from this central part, that like hand or feet it, temperature normally it is lower than that part ok.

So, average skin temperature how to get the average skin temperature? We can calculate the average skin temperature by weighted mean method; where the we if we know the temperature of a particular zone and mean area of that zone. So, if we get the weighted mean so, we will get the average temperature of skin. So, it varies from with the ambient temperature also. So, if the ambient temperature changes so, that the skin temperature and mean skin temperature will also change but it does not change with the level of activity.

So, intensity of work does not change the skin temperature, although it changes the body core temperature. So, it is just almost opposite way it works. The core temperature

normally does not get affected with the environmental temperature; whereas the skin temperature gets affected, and reverse is in case of the a level of work with the intensity of work core temperature changes.

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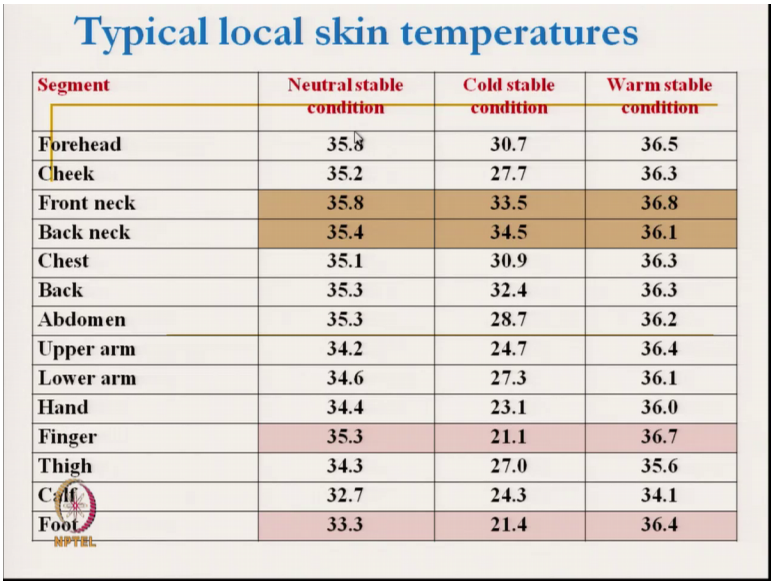

So, if we see the skin temperature at different zone of our body, at with the cold environment and the warm condition, they are actually they change. So, at different zone if you see the finger, it is a at the cold condition, it is as low as 21 degree Celsius, ok.

And foot also, it is the 21.4 degree Celsius. So, this is the these are the indicative value, and if we see in the warm state, warm condition, the skin temperature for most of the places is almost around 35, 36 degree Celsius. And that difference is less the variation in temperature is less at height warm condition. And whereas, in cold condition the difference is from say 21 degree Celsius to say 33 degree, 34 degree, 34.5 degree Celsius at the back of the neck.

So, this a different zone if we see it is the temperature is different. And this and that if we take the weighted mean of this different zone, we will get the mean skin temperature, and that for main all the calculations, we use this mean skin temperature as the reference.

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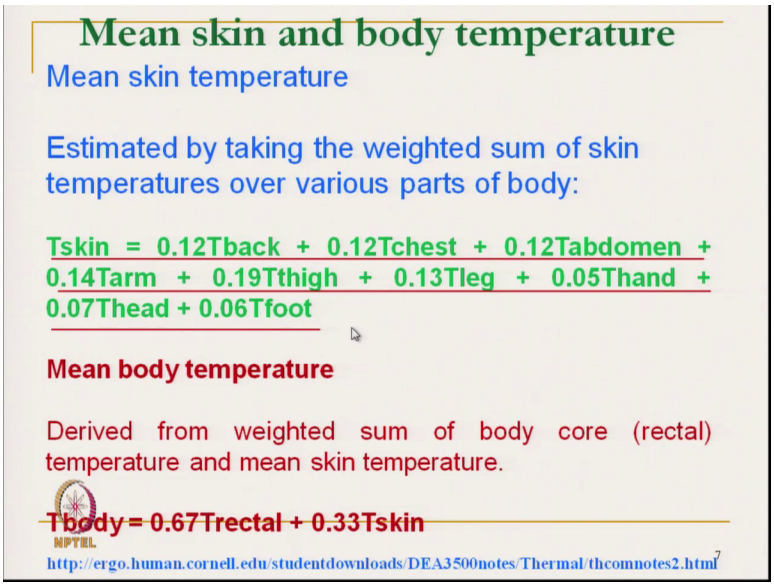

Because the heat flow from our body to environment or if we if we received the heat. So, it actually the reference point is the mean skin temperature. So, how is it being calculated? So, it is calculated like a Tskin. Tskin is the mean skin temperature by taking the weighted sum of the skin temperature over various parts of the body; like, it is a 0.12 of temperature at back.

So, if we take the temperature at back skin at back. So, if we multiply by 0.12, then 0.12 into chest then we take the temperature in abdomen, then we take the temperature of arm, thigh, leg, hand, head and foot. So, and this coefficients are approximately the a proportion of area covered by this particular zones and ultimately we get the mean skin temperature. And then the mean body core temperature we can calculate by again by deriving the weighted mean between the core temperature and the skin temperature.

So, core temperature is it is a basically 2 is to 3; 1 is to 2 ratio, it is a this is the core temperature, it is multiplied by 0.67 plus 0.33 into skin temperature. So, at the then we will get the mean body temperature. So, this is the way we calculate the mean body temperature and mean skin temperature.

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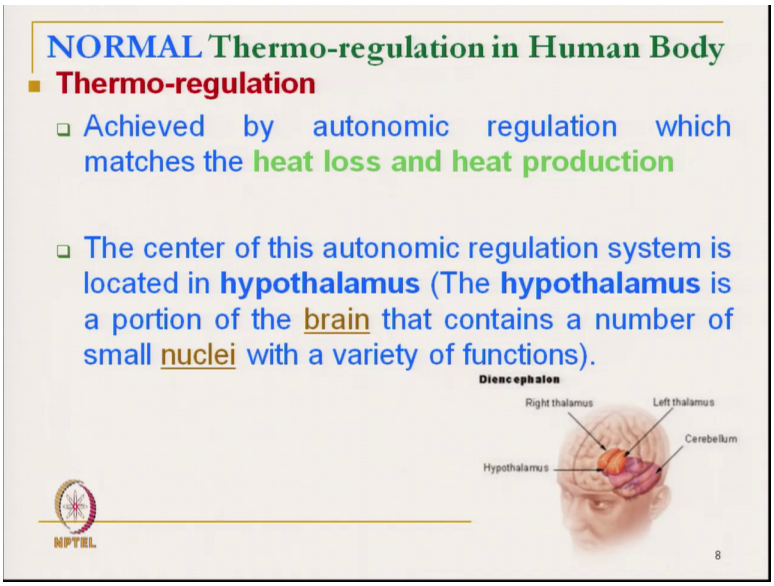

Now, that in normal condition, how do you get the thermo regulation? So, it is achieved by automatic regulation system, that is by our physiology and which matches the heat loss and heat production. So, physiologically it is automatically it gets matched to keep ourselves comfortable, whatever quantity of heat we produce. And the that heat has to be has to come out. So, if the rate is imbalance, then we will feel uncomfortable, and which is sensed by the brain. Basically, it is the system which is located in hypothalamus in the brain, and ultimately we get a sensation of cold and warms such that. But effectively the it has to be balanced.

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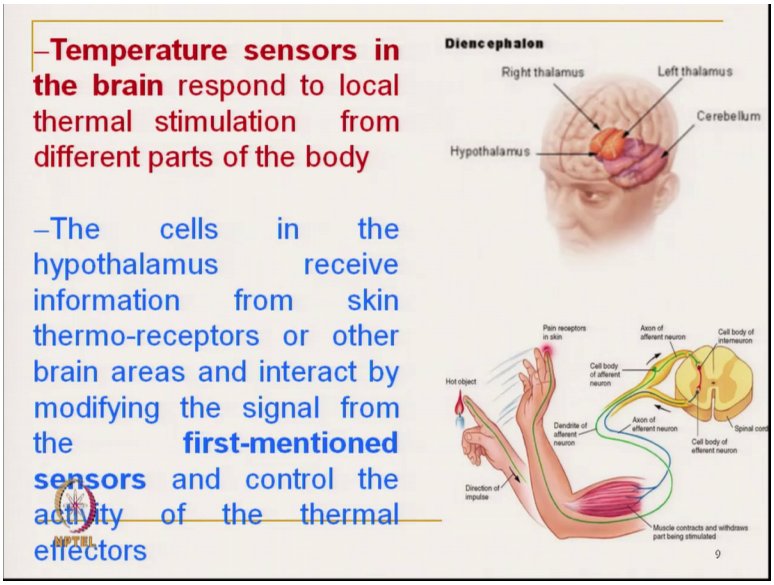

Now, the temperature sensor in the brain respond to the local thermal stimulation from different part of the body. So, at from different part of the body we get as we have discussed earlier, we get the textile sensation. Similarly, brain received the response from a different part of the body the temperature sensation, which is sensed by the thermo receptors. And then the cells in the hypothalamus receive the sensations, and ultimate it get gives the our sensation, ok and which was received by different sensors.

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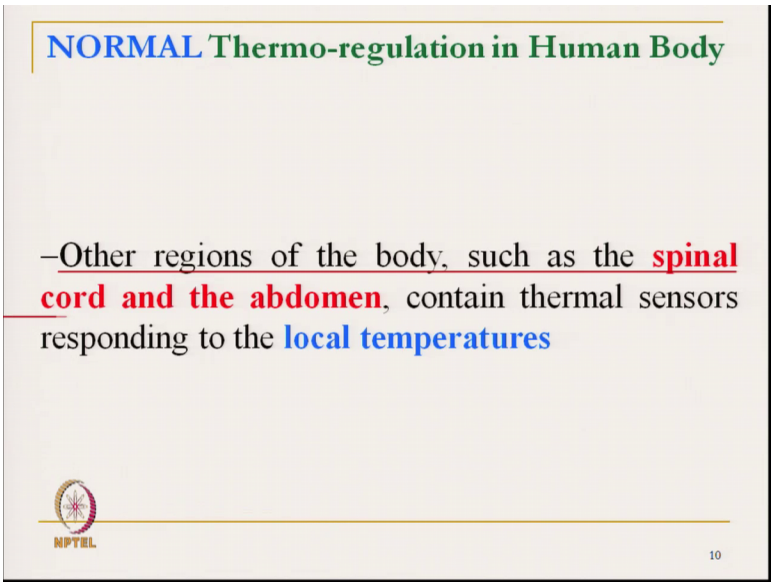

Now on the other hand, the other regions of the body, that brain gets the sensation the overall sensation from different parts of the body. But other regions like spinal cord and abdomen, though the they have some thermal sensors which actually respond to the local temperature. So, one is the overall temperature, the and another is the local temperature they also this local temperature response.

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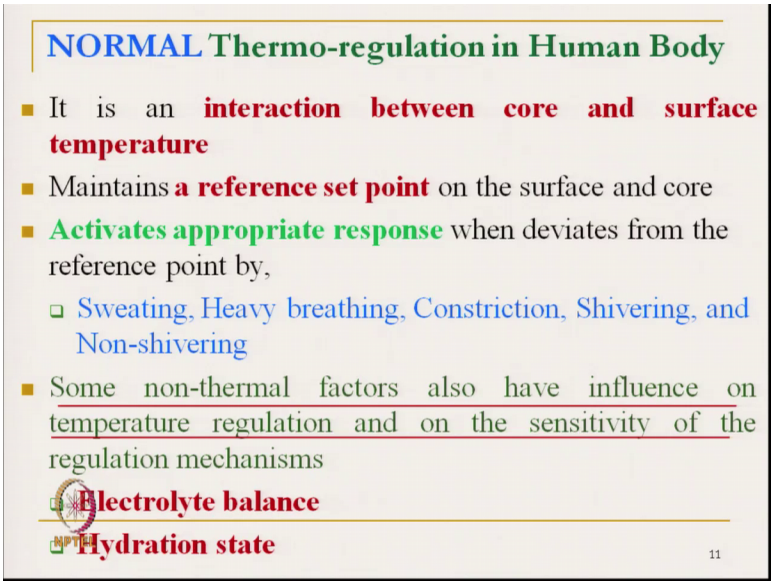

So, what is thermo regulation? Thermo regulation is a of a body, it is an interaction between core and surface temperature. So, that is the interaction within the body. And it is it maintains the reference point on the surface and the core. So, that way the it keeps balance. So, it activates appropriate response, when deviates from the reference point of.

So, when it always tries to maintain the balance; if it deviates, then it is activated by sweating by heavy breathing, by a constriction, by dilation shivering, or non-shivering whatever way so, our body physiology always tries to maintain the balance. So, in case of any deviation that particular one of this or maybe at a time many such physiological activities get activated.

So, and apart from this thermal activities so, there are some non-thermal factors also which affect the temperature regulation our body. These are all related to the shivering, constriction, all these things they are related to thermal directly thermal activities. So, some non-thermal factors like these are the non-thermal factors; like electrolyte balance and hydration state. Like, electrolyte with by electrolyte balance, we can our body can maintain the thermal regulation like a sweating it is a by electrolyte balance.

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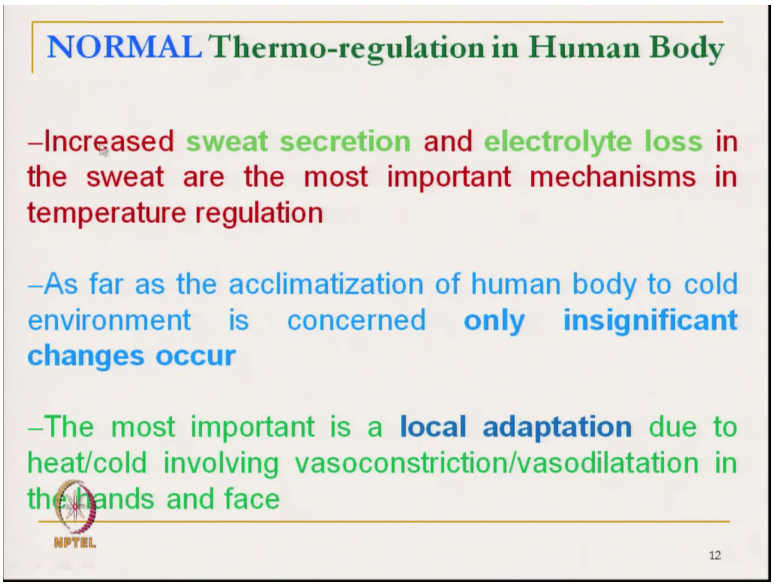

So, increased sweat secretion and electrolyte loss in sweat are the most important mechanism in temperature regulation. So, sweat loss and sweat loss by directly sweat loss we try to keep our body cool or by electrolyte loss, ok. So, and acclimatization that is in significant changes occur. So and most important is a local adaptation, due to heat and cold involve either by vasoconstriction or vasodilatation.

So, this actually this is most important for local adaptation, but a acclimatization is, it is a it does not work to it is effective in insignificant. So, this acclimatization we have discussed earlier also; so, how to maintain the body comfortable.

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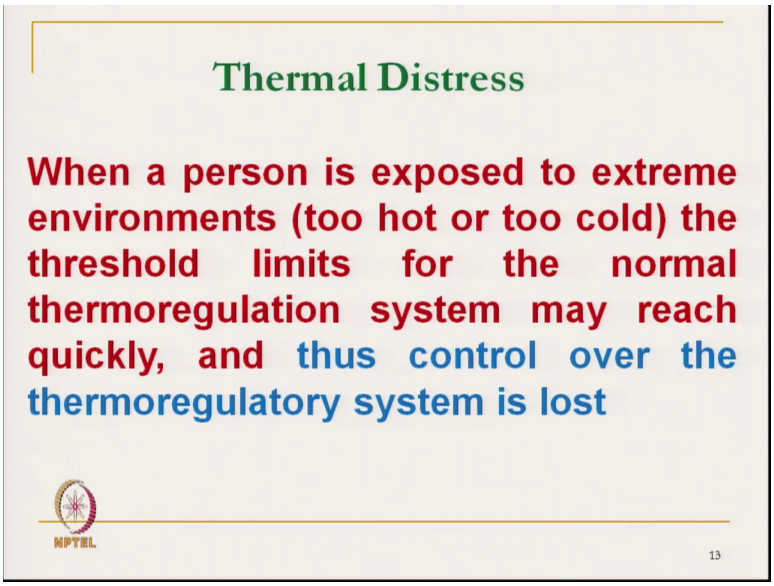

And after this normal thermal regulation, now we will discuss the thermal distress. So, thermal distress is that it is a condition when a person is exposed to extreme environment. It may be too cold or may be too hot ok.

And they actually the cross the threshold limit for the normal thermal regulation system. And thus the control over our thermo regulatory system is lost. So, this our thermo regulation that with the system works in particular temperature range. If it goes beyond that, then it will our thermo regulation will stop so; that means, we may stop shivering, we may stop sweating. So, all this if it actually it is actually beyond that if it is by either too cold or too hot. Then we will have problem, and our we have to bring down the temperature or if it is too hot or you have to warm up if it is too cold by using a proper clothing.

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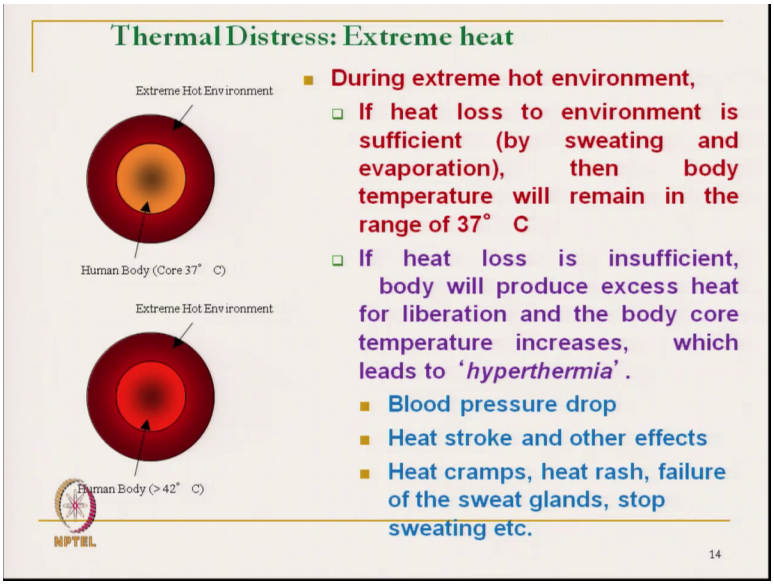

Now, let us see what is happening in thermal distressed condition. In case of extreme heat condition so, this is the extreme hot environment, and our body core temperature we were trying to keep constant it is a within 37 degree Celsius. So, at that extreme hot temperature if we want to keep during the extreme hot temperature, if heat loss to the environment is sufficient, by sweating and evaporation, that we have seen earlier, then body temperature will remain at 37 degree Celsius.

So, heat loss has to be sufficient at a high temperature. Because at high temperature we know that we most of the mechanism, it works that it we receive or body receive heat. So, only mechanism is that by sweating and evaporation. So, if we can sweat properly, and that sweat can be evaporated perfectly, then we can maintain our body temperature at 37 degree Celsius.

But if it does not, then the body temperature body core temperature may increase beyond our beyond that 42 degree Celsius; that means, condition of hyperthermia may take place in extremely hot condition, where that if we the heat losses in insufficient. So, we cannot lose heat by may be by sweating, body will produce excess heat for liberation. So, our body and the body core temperature increases. So, this condition is known as the hyperthermia.

And here what happens? Our blood pressure will drop. So, we will actually gradually go towards the heat stroke. So, may take place so, there may be other effects. So, heat cramp

may take place, heat rash failure of sweat glands that is the basically very severe condition; where a sweat gland will stop secretion of sweat so that will not be able to actually cool our body by a evaporation and sweating and we stop sweating.

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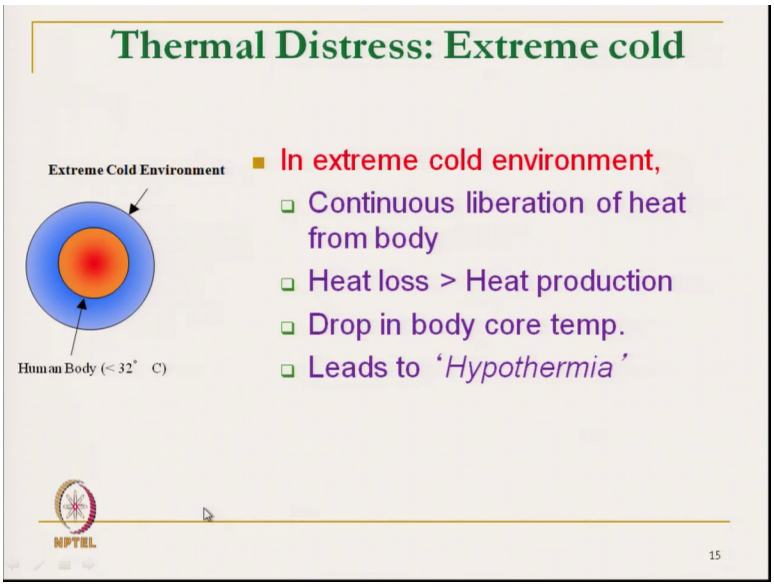

Similarly, for extreme cold environment. So, body core temperature if it is below 32 degree Celsius; if it is a extreme cold if we cannot protect. So, normally we can easily protect our body from extreme cold temperature by increasing the number of bloods, ok. But if we cannot do what will happen? So, in that case. So, our body will continuously release heat from the body. So, that means, heat loss is more than heat production. So, if we do not wear clothing properly. So, in that situation we will happen, and this we can control by proper insulation.

And then drop in body core temperature. So, body core temperature will gradually come down, and it may reach below 32 degree Celsius and this situation is known as hypothermia.

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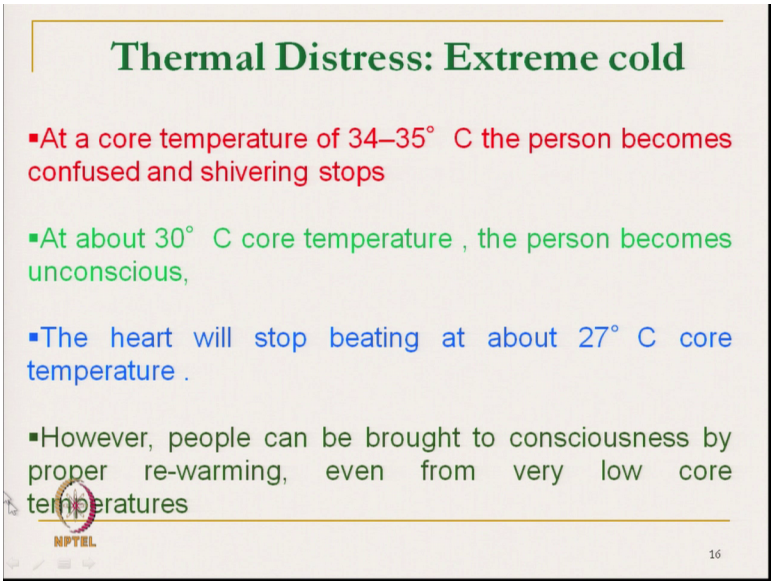

So, hypothermia condition at the at what happened here? So, at the core temperature so, core temperature should be around say 34, 37 degree Celsius. If it drops by 2 degree Celsius, what will happen? The person becomes confused and shivering stops. So, shivering starts around say one degree a lower couple of degree, but if it is around 2 to 3 degrees drop, then person will stop shivering, she will become confused.

Then if it drops further; so, at about 30-degree Celsius core temperature, the person become unconscious. So, that that is very severe condition and our heart beat may stop. So, at 27 degree Celsius because it is a very severe condition, and if one can take precaution proper precaution by a wrapping warm cloth so, that can be recovered.

So, basically that around say 30 or 32 degree below 32 degree Celsius, we should take this precaution. This we should actually we are protective clothing, but below 32 degree Celsius when hypothermia start, then there will be problem ok. So, we cannot survive around say 27, 28 degree Celsius of core temperature.

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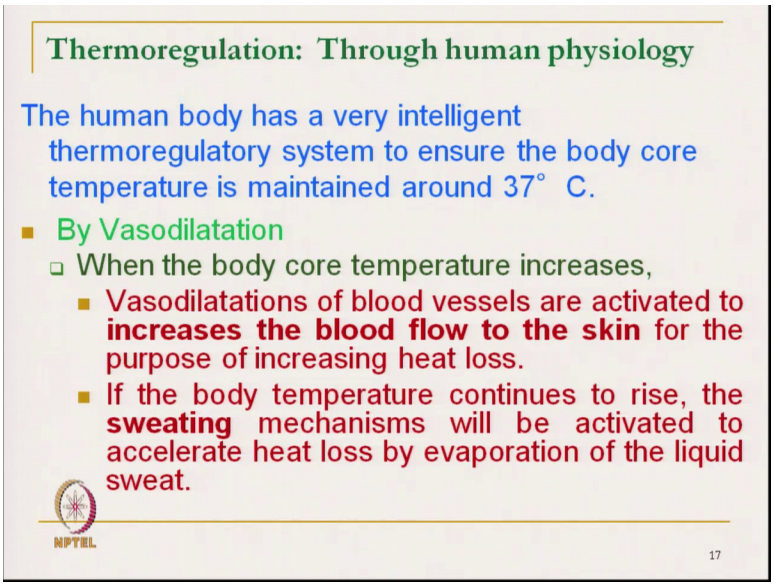

So, the human body has a very intelligent thermo regulatory system to ensure the body core temperature around say 37 degree Celsius. So, it is by vasodilatation, when body core temperature increases. So, do you and vasodilatation that is a increasing the blood flow. So, we can increase the body core temperature, and also when the blood flow from flow to the skin. So, the in that way our body if it is; so, body when body so, that we can actually release our body heat by excess rate of blood flow and also by sweating.

So, these are the mechanism which we can control our body core temperature, we can reduce our body core temperature by sweating and evaporation.

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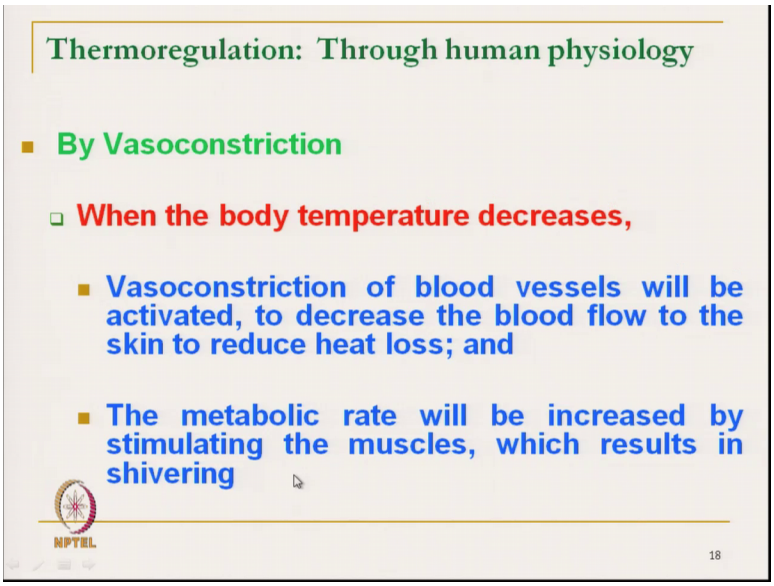

And the if it is at the cold temperature so, vasoconstriction comes into picture where when the body core temperature decreases. So, we are reduce the the by vasoconstriction, blood flow is automatically reduced. So, that it body temperature body heat remains inside the body and also to enhance the heat body the metabolic rate also increases by stimulating the muscles; which results in shivering. By shivering and higher metabolic rate automatically, we can increase our body core temperature.

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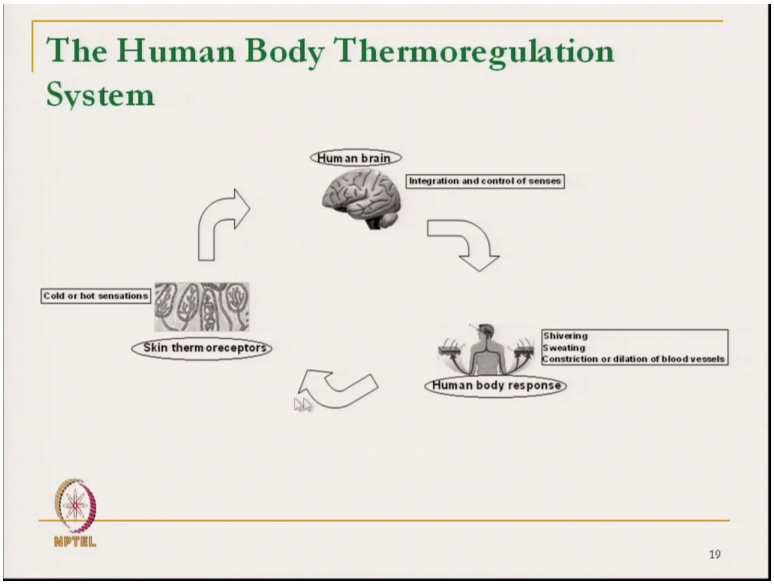

So, this is the system of thermo regulation in our body. So, this is the human body that our here we sense the temperature from environment by the receptor present in the skin, or brain sense and evaluate that sensation. And are the physiology, through physiology, shivering sweating we can maintain our core temperature. So, this is our physiology and to actually enhance to help this physiology in distressed condition we have to use our clothing.

So, now what is the importance of clothing in maintaining our body in thermally comfortable condition.

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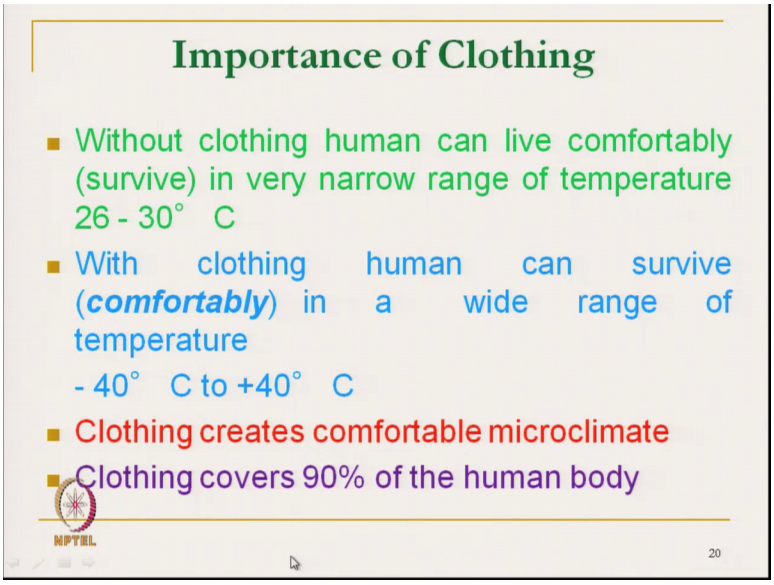

So, with the we can without cloth, we can be comfortable between a temperature of 26 to 30 degree Celsius. It is a we it is a comfortable temperature; that means, a if we normally we can survive comfortably without any clothing. So, maybe to 26 to 30 or maybe 32, 33 that range varies, this is the indicative range.

But if we use clothing, then we can survive comfortably within a wide range of temperature. Maybe minus 40 degree Celsius to plus 40 degree Celsius comfortably, ok. So, that is how that the wide range we can in that wide range we can be comfortable with by using proper clothing. So, clothing creates comfortable microclimate and that temperature a microclimate which is important. So, that it is a and clothing if you see it is it covers most of our body typically say 75 to 90 percent of our body is covered by clothing.

So, most of the body as it is covered. So, our proper designing of clothing proper, selection of clothing is important to maintain the our body thermally comfortable. So, to maintain the thermal exchange with the environment.

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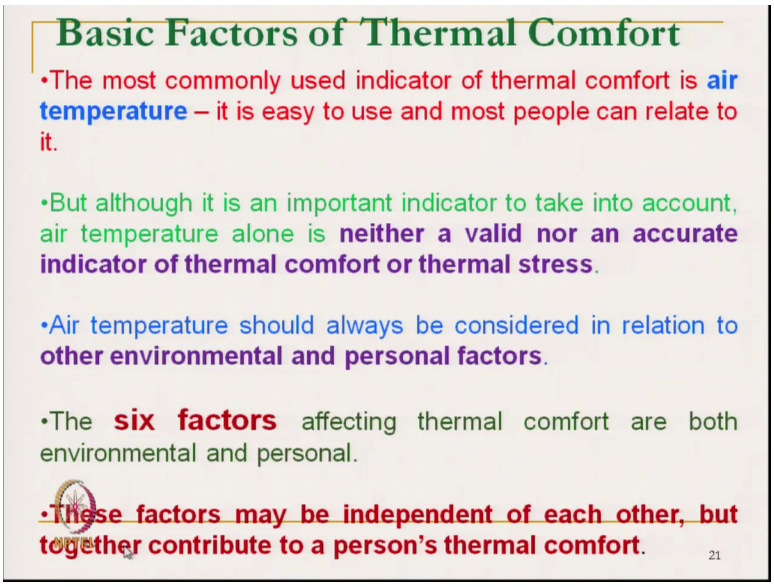

So now, let us see for comfortable thermal comfort, what are the basic factors in comfort? So, typically it is a most commonly we use we tell for thermal comfort it is a air temperature. Air temperature is the main factor of thermal comfort. If we know the air temperature, then we can tell whether we will be thermally comfort or not. But it is not true.

So, although its an important indicator thermal air temperature is an important indicator, but it is not the only. So, neither valid nor an accurate indicator of thermal comfort or thermal stress. So, apart from air temperature, there are many other factors. So, here it is a air temperature should always be considered in relation to other environmental and personal factor. There are 6 such factors for which on which the thermal comfort of a human body, it we actually it is depends. So, this factors are either environmental factor or personal factor or a environmental and personal factor plus clothing related factors.

So, these factors may be independent of each other, but together contribute to the persons thermal comfort. So, the 6 factors which we are going to discuss they may be independent but effectively all these factors together at give our sensation of thermal comfort. So, what are these factors?

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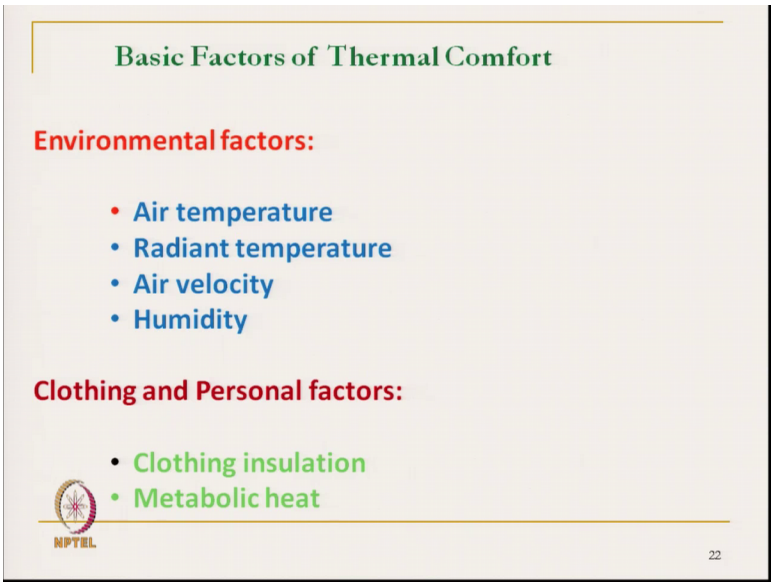

So, these factors we can divide into two parts. One is environment related factors. So, these are just we have discussed air temperature is one of the most important factor, then radiant temperature. Radiant temperature will discuss the any warm object which radiates heat. So, that is a radiant temperature, air velocity, humidity. So, these are the factors which directly affect our thermal comfort.

So, we will discuss detail air temperapture suppose if it is a warm air, air temperature is a hot air. But if the there is air velocity air blowing; so, we may feel different comfortable. So, basic comfort sensation will be different. So, at different at certain air temperature, if we change our air velocity or humidity, our totally comfort sensation will be different. So, we cannot say only air temperature factor thermal comfort. So, this all these factors at together gives a thermal sensation. Apart from this 4 environment related factors, to other factors one is clothing related factor so, it is a clothing insulation. And next is the personal factor.

So, what is the metabolic rate and on. Like a particular air temperature so, or radiant temperature or air velocity or air humidity, if we change the clothing insulation our comfort sensation will be totally different. So, we have to or if we change our metabolic heat. So, total thermal comfort sensation will be different.

So, all these 6 factors in combination gives us the sensation of thermal comfort. So, let us discuss one by one.

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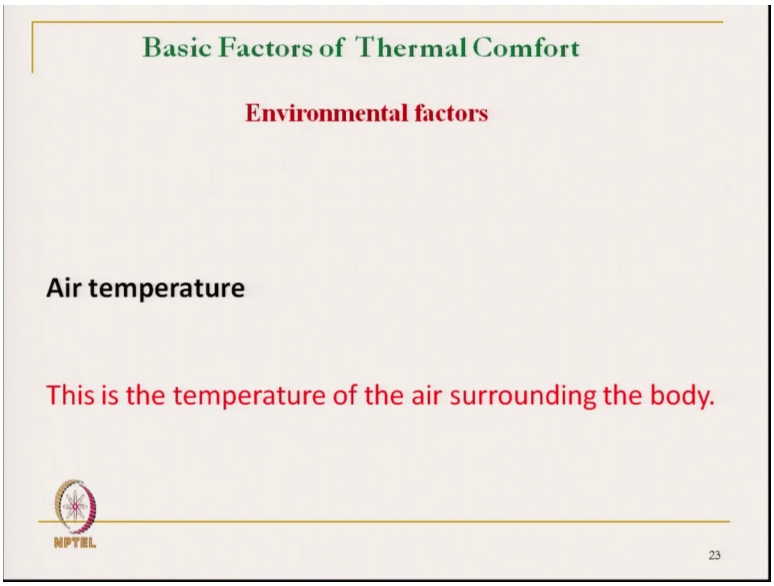

So, environmental factors, it is if air temperature is there. So, in air temperature, this is the temperature of surrounding air ok. So, this air is actually our bodies surrounded by this air. So, this temperature is very important, because our heat flow from body to environment depends on this surrounding air temperature. If it is low, then our body our an it is as compared to our skin temperature, our body will start releasing heat at a higher rate ok. And if it is high then we will receive keep receiving heat.

So, air temperature is very important. So, after that it is a radiant temperature.

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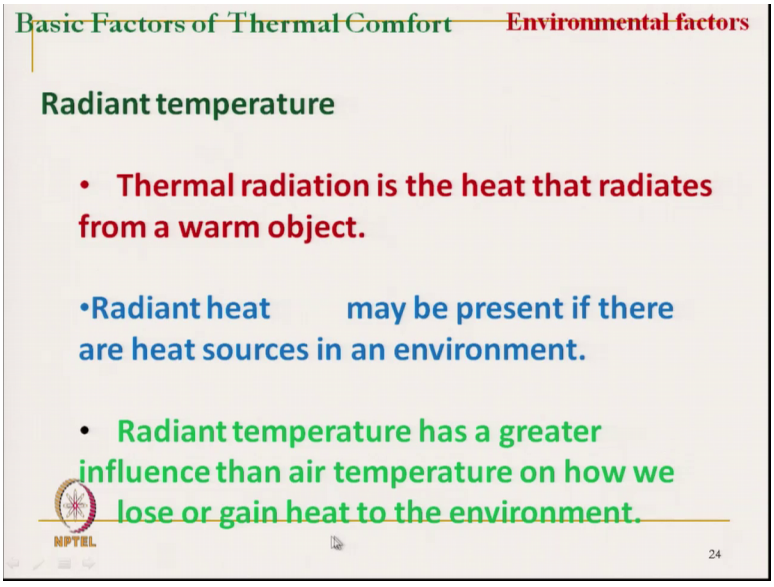

So, what is radiant temperature; the thermal radiation is the heat that radiates from a warm object. So, on any warm object the object may be woven may be fire. So, this that warm object may be anything anyone hot iron ok, this may be heater. So, that radiates heat so that depending on the temperature of that or fireplace. So, we our comfort sensation, thermal comfort sensation depends ok. So, radiant heat may be present if there are heat source in an environment.

So, if it is, if there is no heat source so, then radiant heat is not there. So, at the corner of the room if someone fireplace is there. So, then it will start it will change total heat equation because a radiant heat will start radiating heat, and our body will start receiving that it. So, radiant heat is very important. So, radiant temperature has a greater influence than the air temperature; on how we lose or gain heat to the environment. So, that is very important.

So, air temperature it is a basically, it creates the temperature gradient through which our body can release heat by say conduction ok, but the radiant heat it is import at you have seen earlier, the radiant heat it actually changes with the in it is with the power of a 4th order. 4th order of the temperature so that radiant heat is the major factor on our thermal comfort ok.

So, it is a greater influence how we lose or gain the heat ok.

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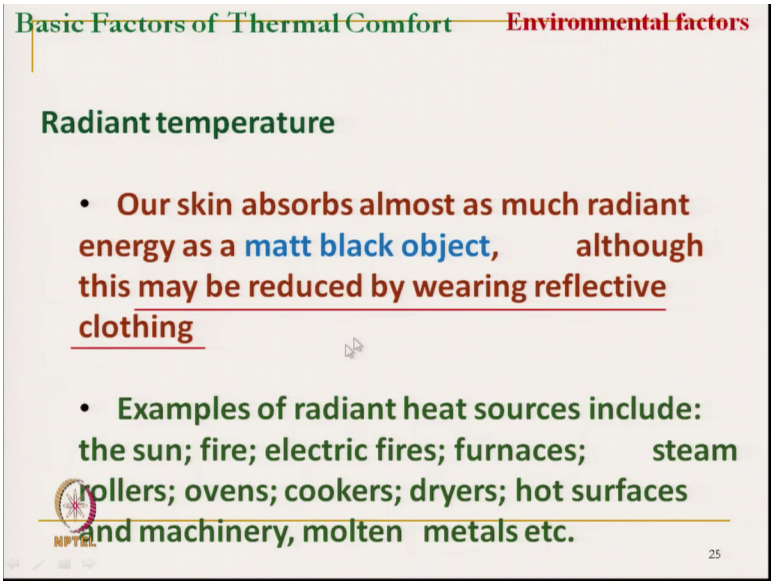

Now let us see our skin absorbs almost as much radiant heat as a matt black object. So, it is a our body whatever radiant heat we our body will receive absorb that heat, ok. So, we have to we our body cannot normally reflect back. So, whatever heat radiant heat is there so, if it our it is projected in our body, our body will start absorbing the heat and we will we will get our body core temperature we will get warm.

So, that means, if we are in front of fire, so that and if we are not closed properly. So, our body will start receiving that radiant heat, and will get heated up. So, and this may be reduced by wearing a reflective clothing. So, if we can wear proper clothing which reflects this radiant heat that radiation. So, that way we can keep our body cool.

So, the example of this very common examples of the radiant heat is a fire, electric fire like heat electric heater, furnace, steam roller, oven, cooker, dryer, any hot surface ok, any of machinery molten metal. So, these are these are the source common source of radiant heat, and for actually to prevent this radiant heat to heat up our body core to increase our body core temperature, we should wear a proper heat reflective clothing.

So, this is one some examples of.

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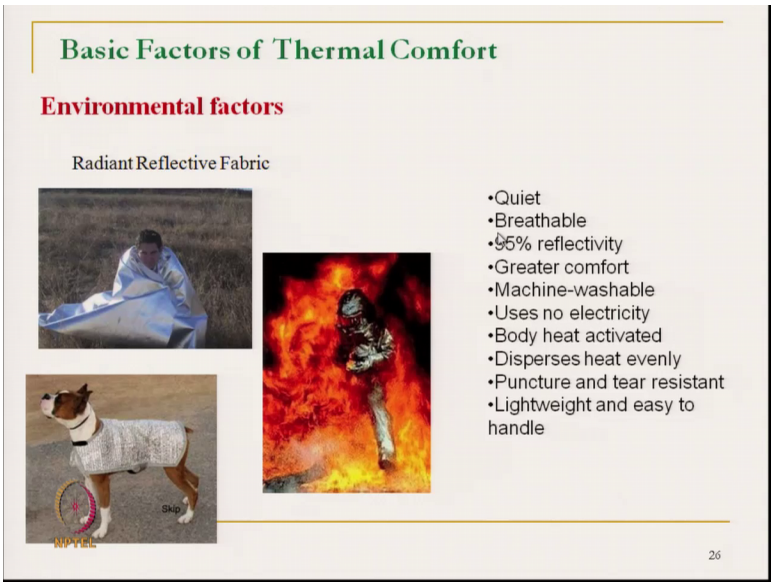

So, for say firefighter, firefighter for to actually to in addition to other layer to prevent him from radiant heat the some reflecting coated fabrics are used. So, there are different these are the typical characteristics of reflective coated cloth, it should be quite let me it

should not make sound, or it should be breathable. If it is not breathable, then our moisture will get accumulated we may get heated up. Very high reflectivity, it should create comfort, it should be washable ok. And disperse heat evenly ok, it should be lightweight. So, these are the characteristics of any reflective quoted clothing.

So, next factor is so, after air temperature, radiant temperature, next temperature factor is the air velocity.

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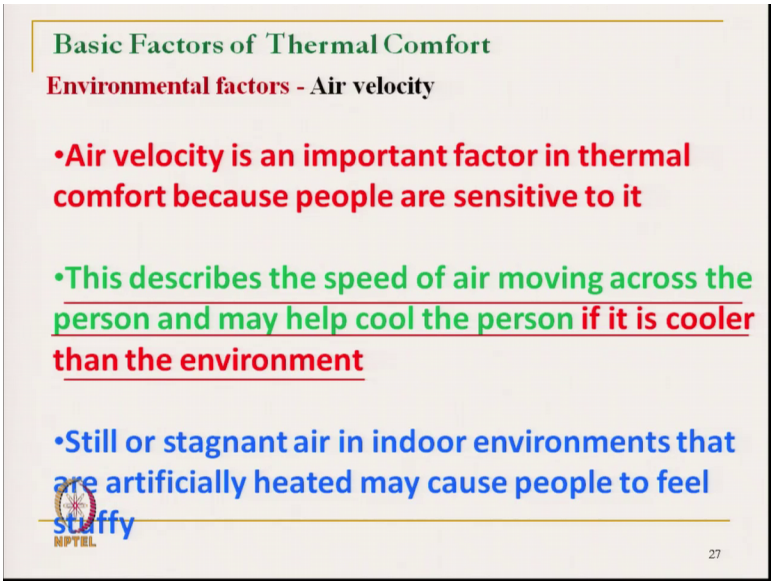

So, it is an important factors to control the thermal comfort ok. So, the because people are sensitive to it. So, it is a extremely important factor, this describes the speed of the air moving across the person, which may help cooling the person if it is cooler than the environment.

So, it one is the if directly if it is cooler than the environment, it directly it comes into contact with the body, and it cools the flowing air normally directly cools the human body. Just like if we turned in front of AC air condition and we immediately we the cold air will cool our body even if it is a warm. So, then also your body will get cool. So, because the movement of air brings the hot air from the body from around the body and our forced convection will come into picture.

So, for forced convection so, we need convective heat higher amount of convective heat loss will be there, if the air movement is high but in case on the other hand still and

stagnant air indoor ok. In indoor environments that are artificially heated ok, will cause the total environment stuffy, that if there is no air movement. So, it will become humid and the body heat will not be able to actually to come out from the body at a required rate. So, we will feel uncomfortable.

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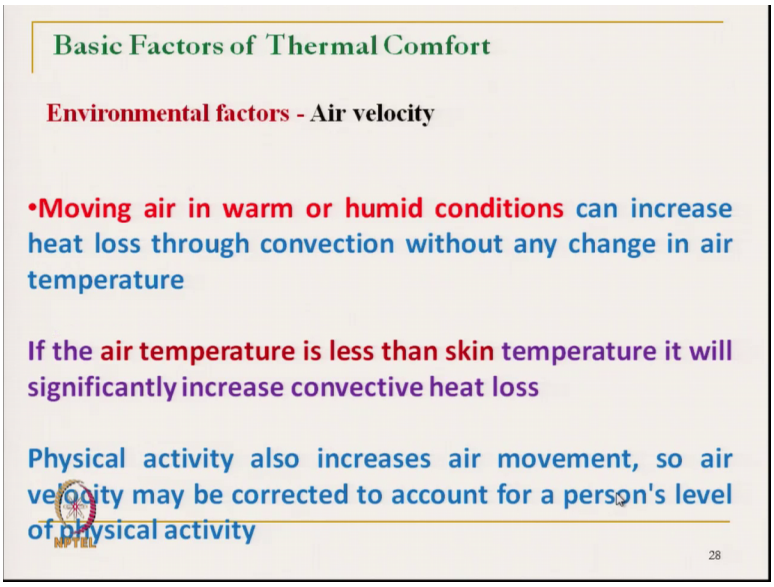

So, moving air in warm and humid condition can increase heat loss through convection without any change in air temperature. So, even if the air temperature is high, even if the humidity of the air is high if the air movement is there. So, if we increase the air movement, our body will be cooler we will have because the convective heat loss will be high. So, if the air temperature is less than the skin, temperature will be significantly increased; increase the actually that it will increase the convective heat loss properly.

So, if in case of high and humid condition, high temperature humid condition the there will be a loss of heat due to convection. And in case of lower temperature also, it will significantly increase the convective heat loss, we may feel cooler. So, physical activity also increase the air movement. So, if the in case of the stuff weather, in case of the still air, if we start moving, if we start walking, that movement will bring the forced convection. So, that air movement with reference to our body. So, air velocity may be corrected to account for persons level of physical activity.

So, that physical activity if we increase the relative air velocity will be there, and that way we will feel cooler.

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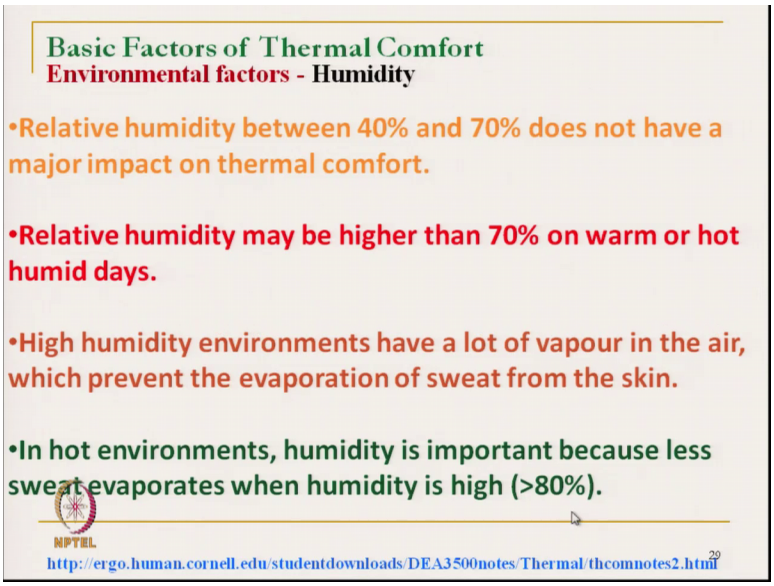

And next is that after the air velocity next is the humidity. So, relative humidity between say 40 to 70, it does not affect the comfort thermal comfort sensation, it is a we our required humidity is between 40 to 70 percent. But if it is more what happens? So, and then our relative humidity maybe higher than 70 percent on warm and hot environment.

So, if that be the case in a hot and warm environment, that at more than 70 percent relativity, then even if we sweat that our sweat will not get evaporated quickly. So, our body temperature will not be actually lowered will not be reduced. So, we will not feel comfortably. So, we need a proper humidity so, high humidity environment have a lot of vapour in the air which prevents the excess evaporation of sweat. So, that that is how the we will at high hot and humid condition, we normally feel very uncomfortable.

So, in hot environment humidity is important, because less sweat evaporation when humidity is high. So, basically humidity affect of humility is very closely related with the temperature of the environment. So, if it is at low temperature at a temperature is lower, than we can if humidity is little bit high, then we may not feel that much uncomfortable then if it is the temperature of air is the high ok. At higher temperature, if the humidity is high; that means, it actually it activates our sweat sweating system, and that will actually affect the evaporation.

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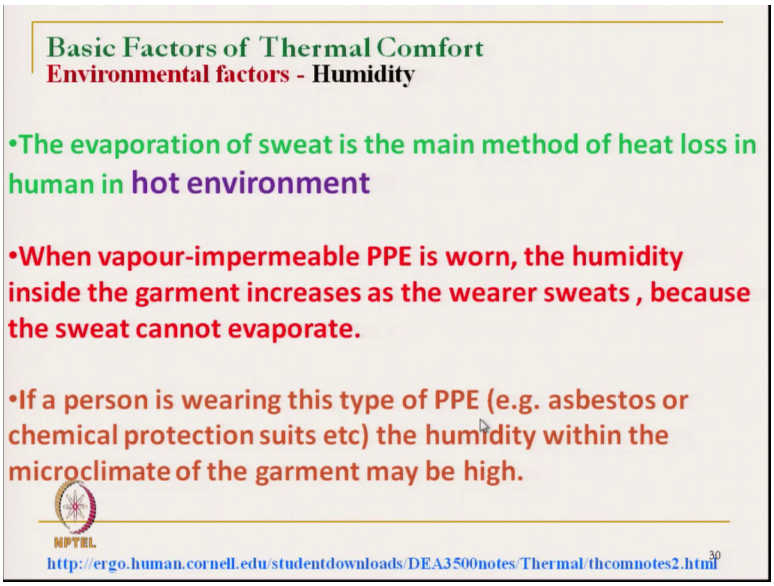

So, the evaporation of sweat is the main method of heat loss when the temperature of environment is high. So, that way at hot environment the humidity should be low. So, because otherwise we will feel uncomfortable. When the vapour impermeable PPE, Personal Protective Equipment we wear vapour impermeable at high and high humidity condition at hot condition, then we will feel very uncomfortable, because we start sweating and sweat does not get a evaporated. And this also happens if the this PPE does not have pour.

Actually the vapour permeability if a person wearing this type of PPE, asbestos or chemical protective suit, the humidity within the microclimate of the garment may be very high. And you feel very uncomfortable ok, and now we have discussed the 4 factors of environment related factors.

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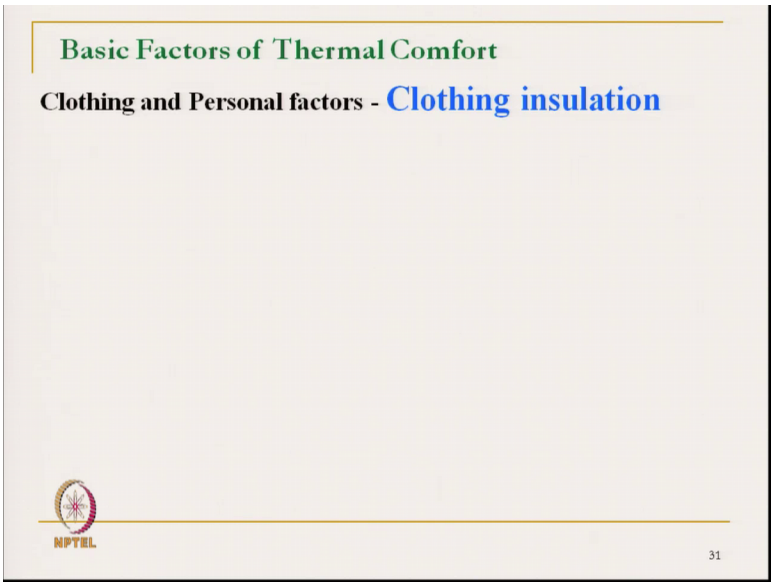

So, next we will class we will continue with these factors. So, some other aspects we will discuss.

Till then thank you.