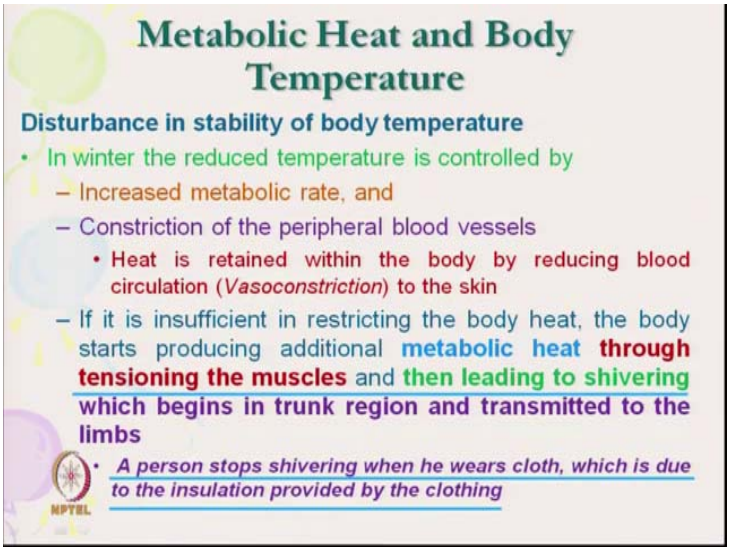
Science of Clothing Comfort
Prof. Apurba Das
Department of Textile Engineering
Indian Institute of Technology, Delhi

Lecture – 14
Neurophysiological Processes in Clothing Comfort (contd…)

Hello everyone. So, we will continue with the topic that metabolic heat and body temperature how to control?

(Refer Slide Time: 00:26)



How the body temperature is controlled, by human physiology and then by using the cloth to keep our self safe and comfortable. So, disturbance in stability of body temperature as we have discussed in winter, it is a totally different physiology and in summer the physiologies are totally different. So, in winter, we have mentioned that the reduced temperature is controlled, that in winter, our body tries to release heat at very high rate. Because of the temperature gradient that body temperature or skin temperature is around 34-35 degree Celsius.

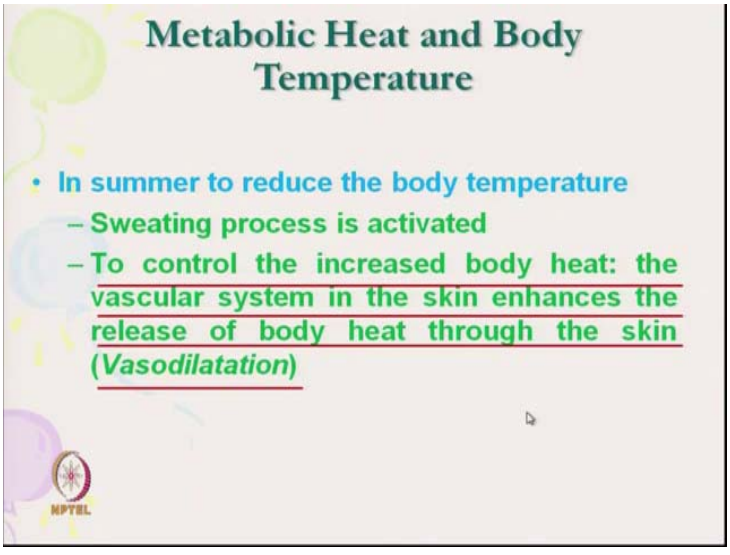
And, the outer temperature, the environmental temperature is much lower than the body temperature. So, our heat is released at very high rate as we have discussed by conduction, convection & radiation. And, it is the net outward heat is much more than the heat which our body generates by metabolic heat. So, the there are 2 ways of stopping that, by body physiology and if physiology fails then by using the extra layer of

clothing. So, the body physiology works at lower temperature, when our body starts releasing the heat out to the environment at that temperature our metabolic rate increases automatically in winter that is why it in winter our metabolic rate is more.

Then our blood vessel gets constricted as we have mentioned. So, it releases less quantity of blood flow it allows less blood flow. So, tries to retain the body heat, because blood flows out to the up to the skin means it takes away the body heat and from there it comes out. So, heat is retained within the body by reducing the blood circulation. So, vasoconstriction is the is there it release the reduces the body blood circulation up to the skin, then as we have mentioned if it is insufficient, then our body starts, another physiological phenomena which is called which is known as shivering by tensioning the muscles.

And a person can be comfortable if we are stop releasing the heat, the heat goes it if we actually retain the heat by wrapping the clothing. So, after if one layer of clothing is not enough then we keep on increasing the layer till, the body starts shivering is the extreme condition where the body physiology is not able to retain the body heat. So, person stops shivering when he wears cloth which is due to the insulation provided by the clothing.

(Refer Slide Time: 04:21)

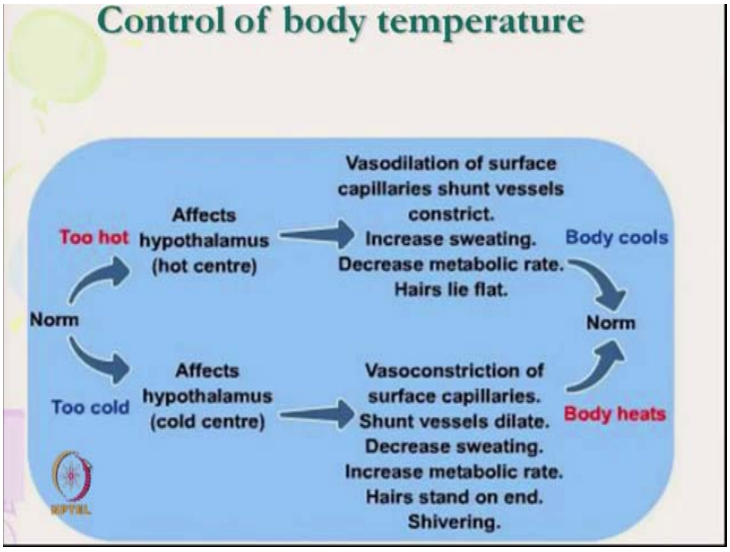


Now, in summer what happens? Just almost opposite phenomena takes place. In addition to that in summer, the sweating process is activated.

In sweating through sweat directly releases the heat. So, if sweat comes out, it releases. So, that is why in summer our sweating activities start. So, it starts from say when temperature say around from 10 degree Celsius to say it goes on increasing 30 degree Celsius, then sweating activity starts ok.

So, to control the increased body heat so, to release the increased body heat so, just opposite thing happens, but in case of in winter, the vasoconstriction was there is here, we need the extra blood flow to the skin. So, vasodilatation is there. So, vascular system to enhance the heat flow from the skin so, vasodilatation started.

(Refer Slide Time: 05:40)



So, this picture shows very nice detail about what are the things happening here? So, our body always tries to keep the temperature in normal zone. So, if it is too hot. So, it affects the hypothalamus. Hypothalamus has got 2 types of sensation, it is cold centre and hot centre. So, if it is too hot. So, hypothalamus send signal to our body and what happened? The vasodilation starts.

And, the capillary vasodilation of the surface capillary shunts the constrict vessels. So, it stops the constriction it starts the dilation; that means, extra blood flow takes place then sweating increases, decrease in metabolic rate. So, as soon as along with the increasing sweating, vasodilatation so, metabolic rate at summer at hot temperature it reduces. So, that our body does not generate extra heat, although already it has received heat. So, to reduce and to maintain that in reduced level. So, it metabolic rate has reduced and hairs

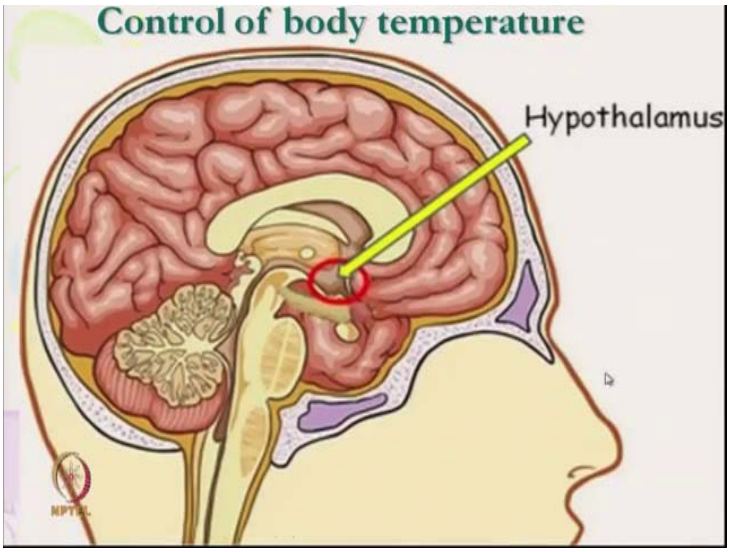
lie flat. So, that is one phenomena, because here tensioning of hairs is not there. So, hair lies flat and all this phenomena helps in cooling of body.

So, that is to bring it to normal temperature. In case of cold temperature so, that in cold centre of hypothalamus, it is send signal where vasoconstriction is activated; that means, blood flow is not there not there means blood flow is reduced the sweating has decreased almost you we can see that in cold we do not sweat, because we do not need to release the heat we have we have to actually we need to retain the heat. So, sweating is a not activated increasing metabolic rate. So, to have to increase the heat so, metabolic rate has to increase. So, hair stands on the end. So, be due to the muscle toning. It is a tensioning that hair gets straighten and then shivering starts, shivering by shivering as we have mentioned that a body tries to get extra heat by mechanical vibration.

So, this body heat increases it to maintain the body heat. Now, if it is not enough to cool in hot, if it is not enough to cool, what happen then the cooling takes place by external process of evaporation. So, these are the all this phenomena it is activity by physiological activity, but if it fails then the extra body heat in summer is taken away by the in form of latent heat of evaporation that we have discussed earlier.

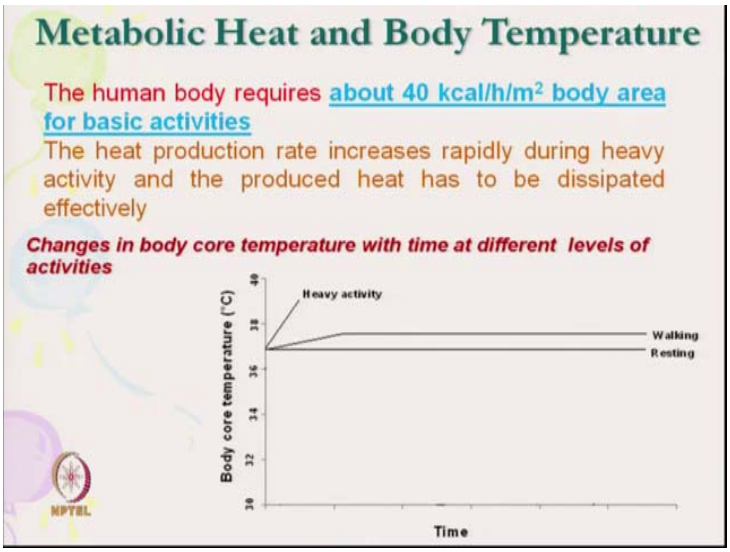
Similarly, if it this all these activities physiological activity fails to retain the body heat in cold, then what we have to do? We have to actually use extra layer of cloth to retain to release to actually restrict the release of body heat. So, all these activities are actually done along with the clothing to maintain our body core temperature.

(Refer Slide Time: 10:01)



So, this is the Hypothalamus in the brain, which actually sense the cold and warm sensation.

(Refer Slide Time: 10:11)



Now, the human body requires about 40 calorie per hour per square meter. Body area for the basic activities that is the energy which is required for our basic activity, but the heat production rate increases that metabolic heat, this is the basic metabolic heat is required. But this metabolic rate increases rapidly with the activity if we keep changing the activity the metabolic rate increases. And, that sometime creates problem of overheating.

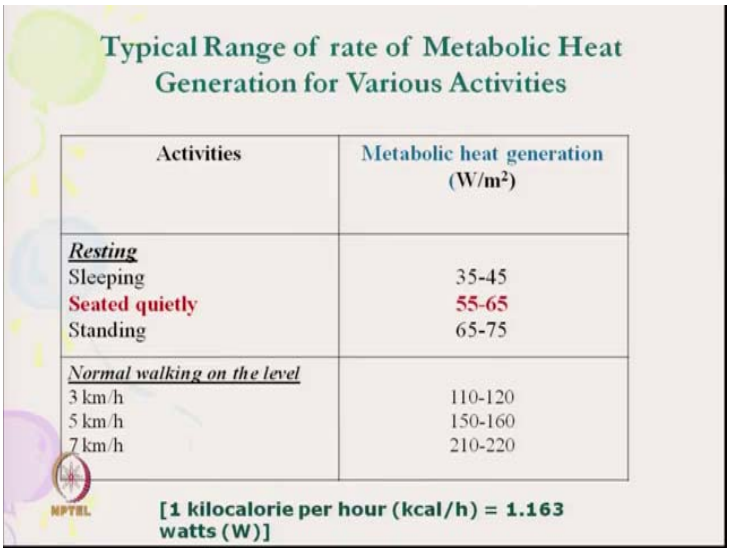
So, this things, I will just discuss and produced heat has to be dissipated effectively. So, our then our clothing has to act so, not to retain the heat, but how to release the heat? So, at different activity we have different level of metabolic heat, and also with the activity as we our metabolic heat increases our body core temperature also changes due to the activity.

So, changes in body core temperature with time at different level of activities are shown in this graph. So, just at rest, our body core temperature remains same. So, we are resting we are actually not doing anything or basic activity we are generating this much heat 40 calorie per hour per square meter of body blood, typically it is around 80 to 90 calorie because our human body area is around say 2 square meter. So, that type of body heat we generate and we release that heat.

So, our body temperature remains constant, but when we start walking, this metabolic heat increases and the rate of heat generation is more than the rate of heat release. So, our body core temperature increases little bit. Initially then after that it gets stabilized so, with the time, but when a person do heavy activity. So, at that heavy activity, so, it generates more and more heat huge quantity of heat and our body core temperature increases.

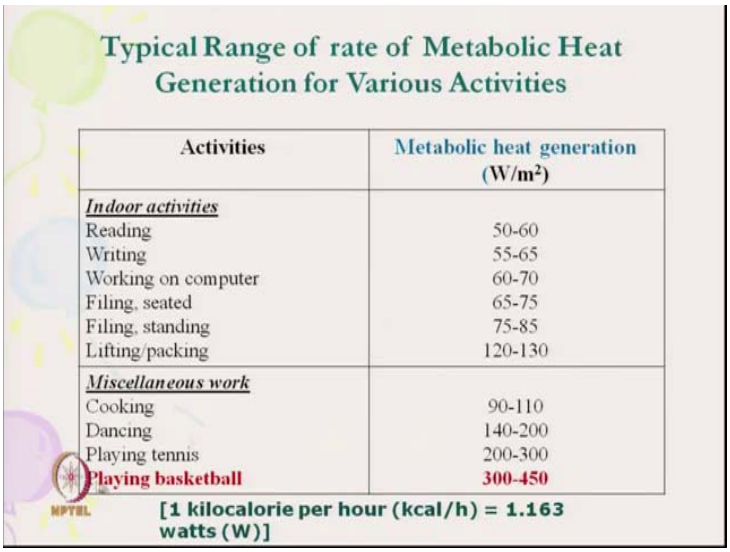
So, it goes beyond the sometime it goes around say 39-40 degree Celsius. So, that temperature it is the one has to actually maintain, cool down that body heat, that core temperature by proper physiological activities.

(Refer Slide Time: 13:32)



Now, try to see that for different activities, what are the different level of heat generation, metabolic heat generation? So, at steady quite condition quite seated condition so, it is around say 55 to 65 watt per square meter. So, if this is coming around say 85 to 90. So, that this is the seated quietly, basic metabolic heat that is when it sleeps so, as the activity increases. So, our body heat actually increases so, our metabolic heat. So, if you walk at 3 kilometer per hour speed we will generate almost double. So, that 110 to 120 watt per square meter. And, similarly for at higher speed, we generate higher heat.

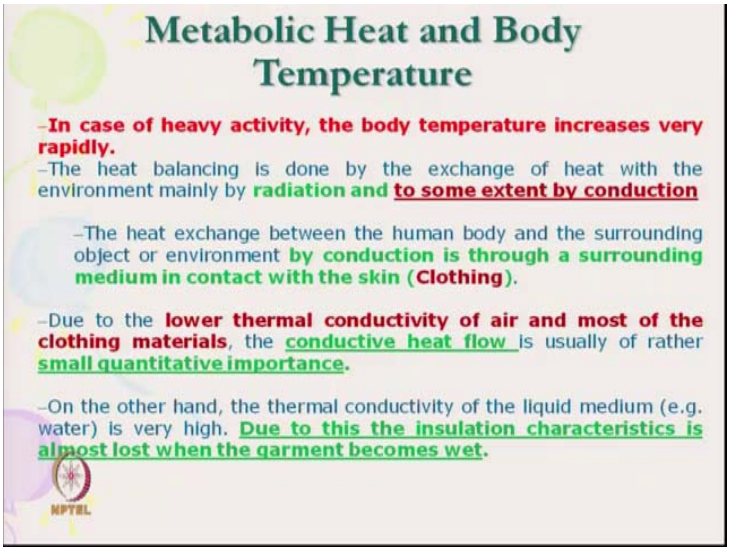
(Refer Slide Time: 14:32)



So, and so, a person suppose he is playing basketball at high active. So, the metabolic heat generation will be very high. So, that at different activity level so, our body heat generation is more and is changing. So, depending on that our body core temperature also changes.

So, our function of our clothing is to maintain the body core temperature, to keep one self-comfortable and safe. So, that, we can only do by proper release of or evaporation of sweat.

(Refer Slide Time: 15:13)

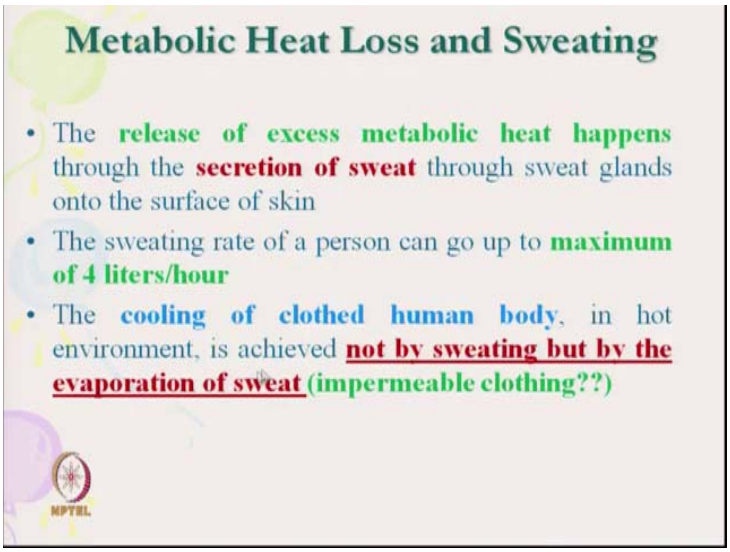


So, in case of heavy activity the body temperature increases very rapidly. And, the heat balancing is done by exchange of heat with the environment mainly by radiation. And, to some extent by conduction, conduction is very less. Mainly by radiation, why conduction is less? Because, the clothing or surrounding layer, thermal conductivity is very low.

So, by and that is why this surrounding object like or environment by conduction is through contact. So, this is actually least amount that we have seen earlier also. So, radiation is the process by which we can maintain our body core temperature. Due to lower thermal conductivity of air and most of the clothing material, the conductive heat flow is usually very low, less importance, but when the fabric gets wet, the wet fabric has got very high thermal conductivity.

So, in that condition, our clothing releases a heat at very high rate. So, on the other hand the thermal conductivity of the liquid medium like water is very high. Due to this the insulation characteristics is almost lost when the garment is wet. So, then at wet condition, we feel in even when the body temperature is very high.If we wear a wet cloth then we will have feel cooler feeling. Because garment lost it is thermal insulation and it releases body heat quickly.

(Refer Slide Time: 17:17)

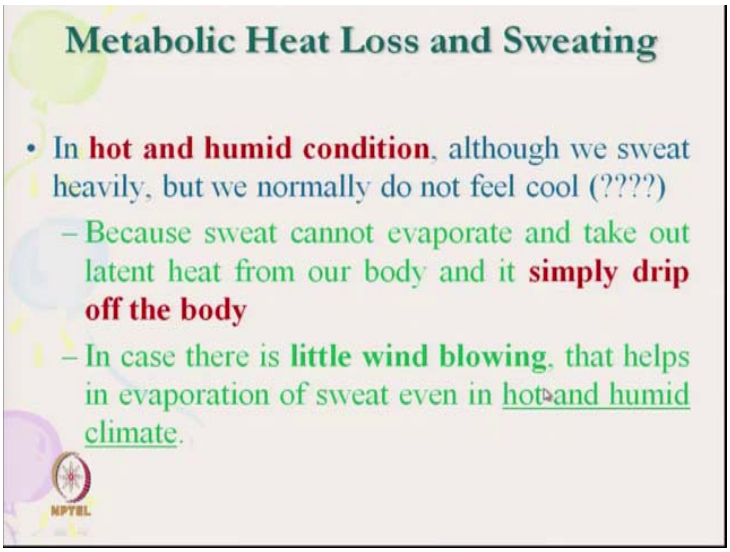


The release of excess metabolic heat happens through the secretion of sweat through the sweat gland and it comes out of the skin. The sweating rate, sometime can be very high; it is a maximum 4 liters per hour that at that rate one can actually release the sweat. The cooling of cloth human body in hot and humid environment in hot environment, is achieved not by sweating because the body heat it is it releases the sweat to release the body heat, but the cooling is not completed. Until and unless this sweat gets evaporated our body physiology as we have discussed, it starts releasing the sweat.

But, that may or may not be sufficient to keep our body cool. If, it is not sufficient then our, that sweat has to whatever sweat has been released, that sweat has to be evaporated. So, that it gets the excess latent heat. Now, we can get feeling, when we wear one impermeable clothing. In hot environment, what happens? The body physiology releases the heat in with the help of sweating, but the sweating the impermeable or non-absorbent cloth. It is not absorbing the sweat and it is not also transmitting the sweat from inside

microclimate to environment, what happens the sweat simply start dripping. So, it is not able to take away the excess heat by evaporation. So, the person may not feel cooler, may not feel comfortable.

(Refer Slide Time: 19:35)

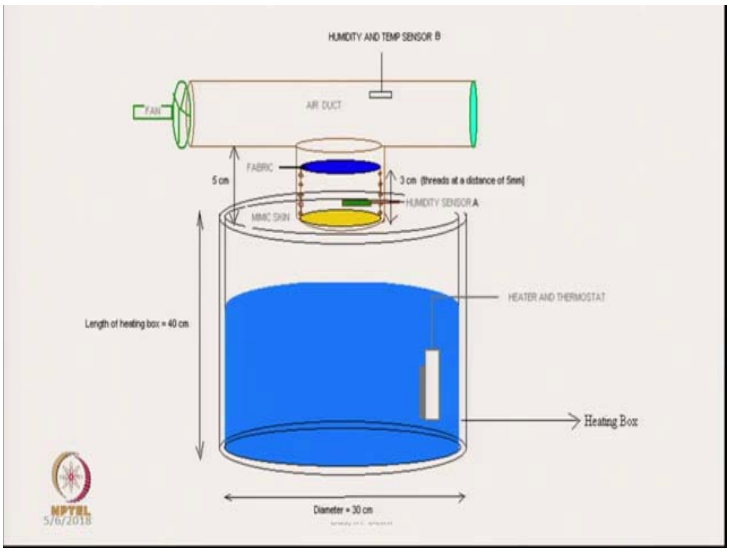


So, in similar thing happens in hot and humid environment. In hot and humid environment our body physiology releases the sweat.

But, as the humid environment is already saturated with water. So, that it does not take excess sweat and that is why the person may not feel comfortable. So, we normally do not feel comfortable or cool, because the sweat cannot evaporate, it cannot get in and takes away the latent heat from our body and the sweat simply drips. If it drips; that means, it takes the heat from only by physiologically; physiologically it through the sweat it takes out heat, but it may not be sufficient. In the case there is in case there is a little wind blowing. So, if in that case in hot and humid weather, it is little wind blows; that means, it takes away the humid air and then it enhances the evaporation.

And, we feel comfortable even in the hot and humid climate we feel cool due to that why due to the release of latent heat (Refer Time: 21:11). So, in extremely hot and dry climate so, we will discuss this one before that the wind blowing, if we the blow the wind; that means, that it takes away the heat in terms of the latent heat of evaporation.

(Refer Slide Time: 21:36)

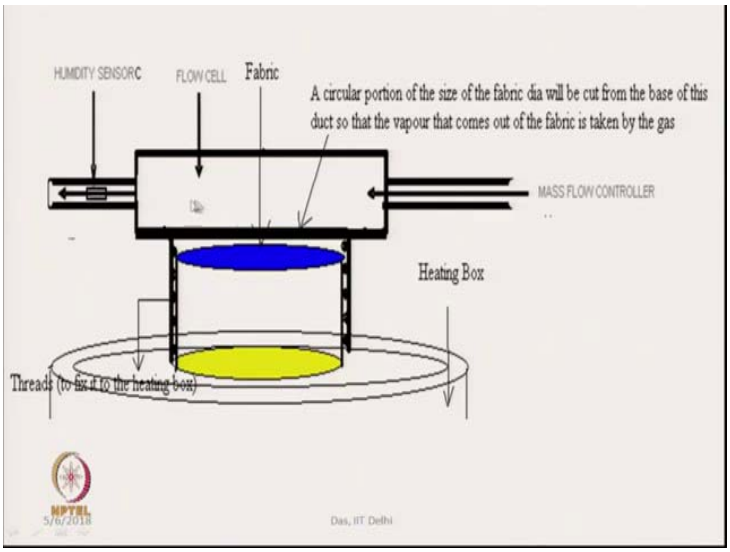


So, we can see there is an instrument, it was developed here to see the microclimate temperature and humidity at different level of air velocity. So, here this is the chamber which actually it is partially filled with water and heater is there to maintain the heat temperature, this is thermostat control; that means, the heater will generate actually that humidity.

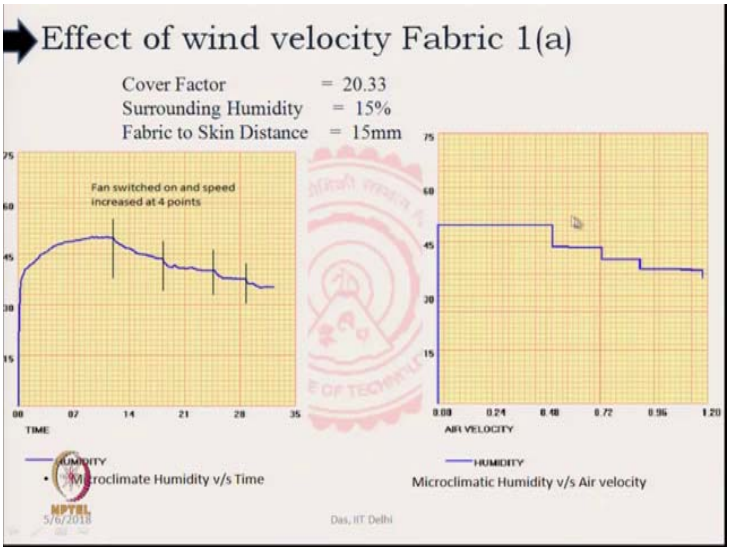
So, it actually that it gets evaporated this the yellow color, this is the mimic skin it is actually simulates our human skin with micro pores. And, there are there is a gap and this one, it is a blue color it is a fabric sample. So, in between the skin and the fabric we can control the gap. So, this place is known this is actually simulating the micro climate. Micro climate means, it is a place between our between our skin and the fabric. This is the place where we actually feel comfortable or not.

Now, this microclimate and above the micro this fabric there is a air duct which simulates the flow of air. So, we can change the flow of air by changing the fan speed. So, as the air blows, it will take away the excess humidity from here and that or microclimate, we wanted to study the effect of microclimate on the at different flow velocity. And, this is the picture.

(Refer Slide Time: 23:47)



(Refer Slide Time: 23:51)

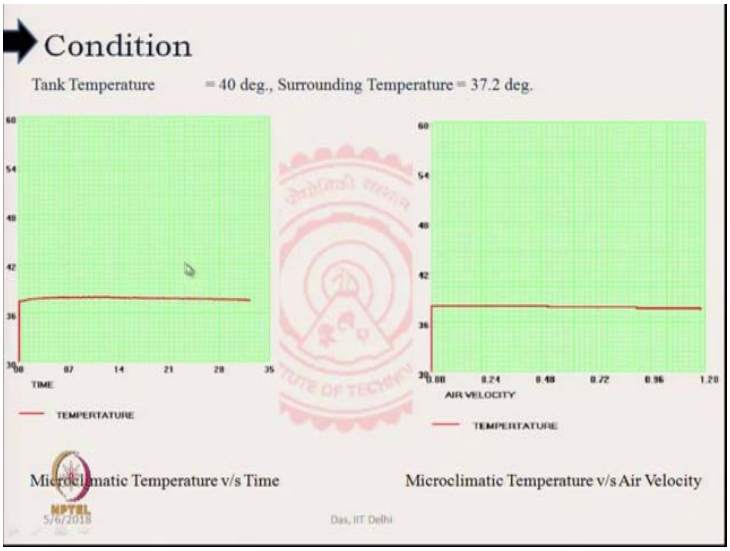


Now, here we can see as with the time. So, at different time. So, this is initially at the microclimate the humidity increases. This is increase in humidity because the gradually humidity is accumulated from the skin to the microclimate. So, humidity increases here. And, at this point say here we switch on the fan. And, speed increases at 4 different points 1 this at 2, 3, 4 at different point we actually change the fan speed so, air blow rate.

So, we try to study it is effect on microclimate. So, immediately after starting the fan, the humidity of the microclimate reduces. That means, due to the forced convection it takes away the moisture.

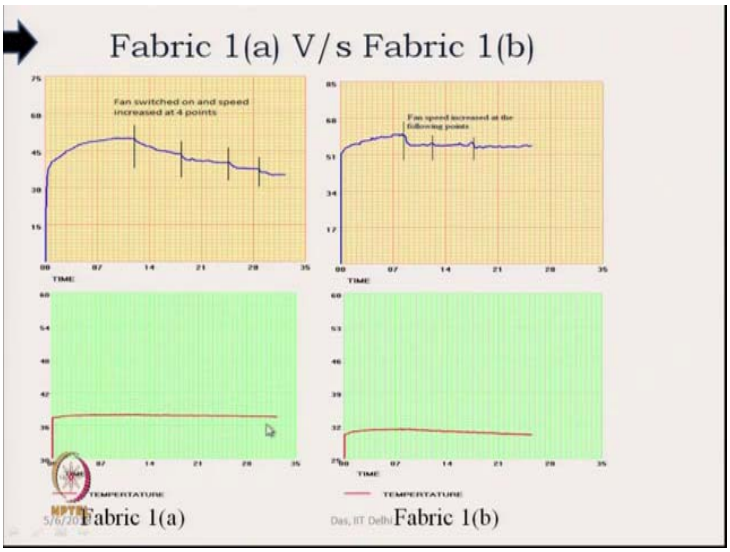
So; that means, in micro climate zone the humidity reduces due to forced convection, the water molecule or water particles is coming out from the fabric. So, our body gets little bit dry. So, that is why as we keep on increasing, the rate of reduction of humidity is more and more.

(Refer Slide Time: 25:31)



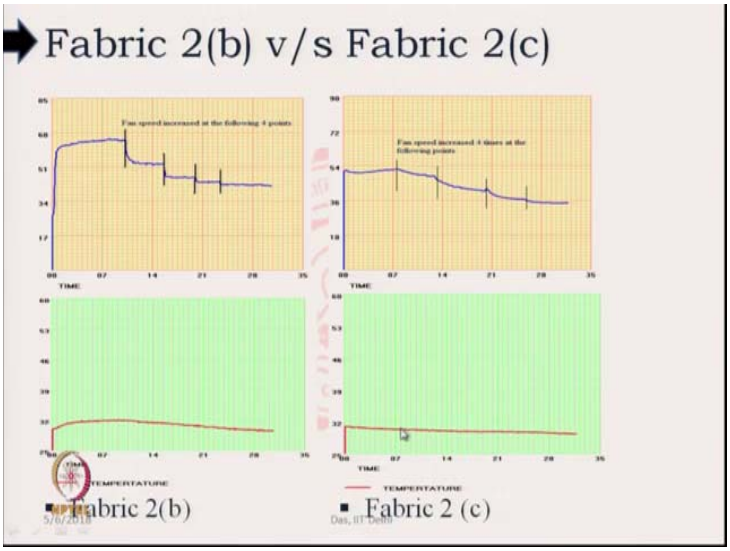
So, similarly, if you see at certain temperature, here the temperature of the microclimate is constant, when we do not change the fan speed.

(Refer Slide Time: 25:47)



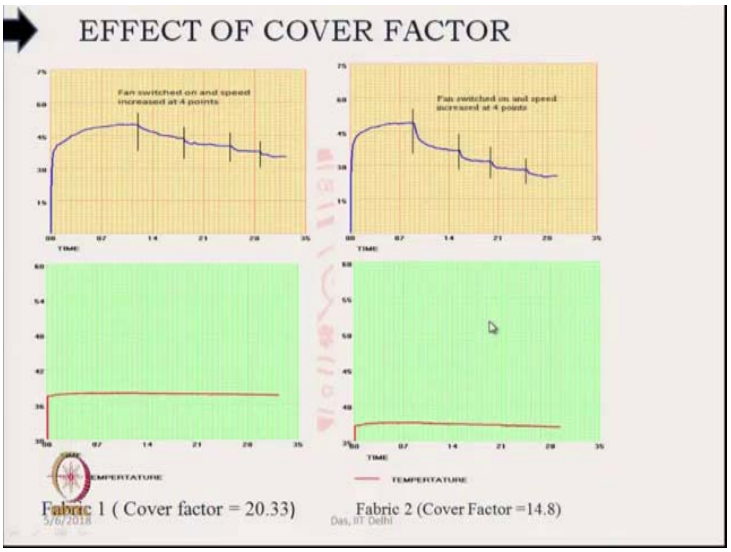
But, if we change the fan speed it gradually starts dropping, by climate temperature drops along with the drop in the humidity. So, this drop in temperature is due to that evaporation. So, that we have seen that there is a drop in temperature. So, initially increases then, it is again it is drops. So, for different types of fabric it has been studied.

(Refer Slide Time: 26:18)



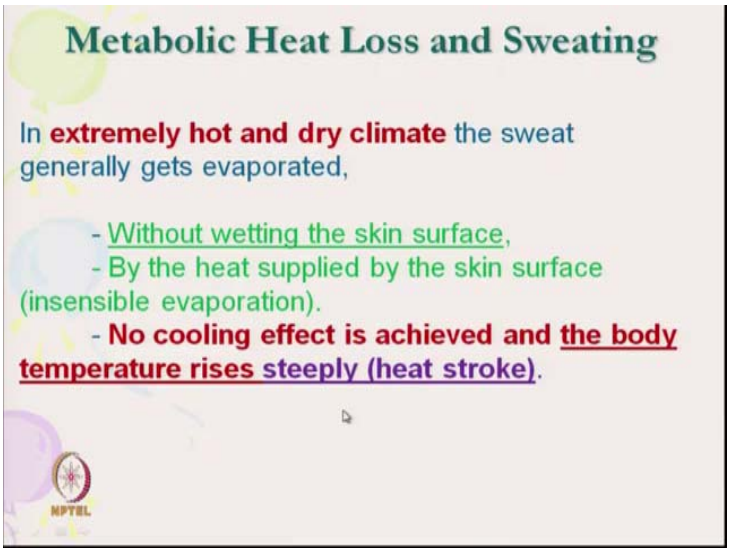
So, different fabric they actually respond differently. So, these are the different activity.

(Refer Slide Time: 26:23)



So, that which shows that the wind blowing also has got direct impact on that the temperature of our skin and the humidity of the skin. So, we will come back again here. So, in hot and humid condition in case there is little windblown, that helps in evaporation of sweat even in hot and humid climate. So, that it evaporates and our body gets cooled down so, it helps in our physiological activities.

(Refer Slide Time: 27:03)



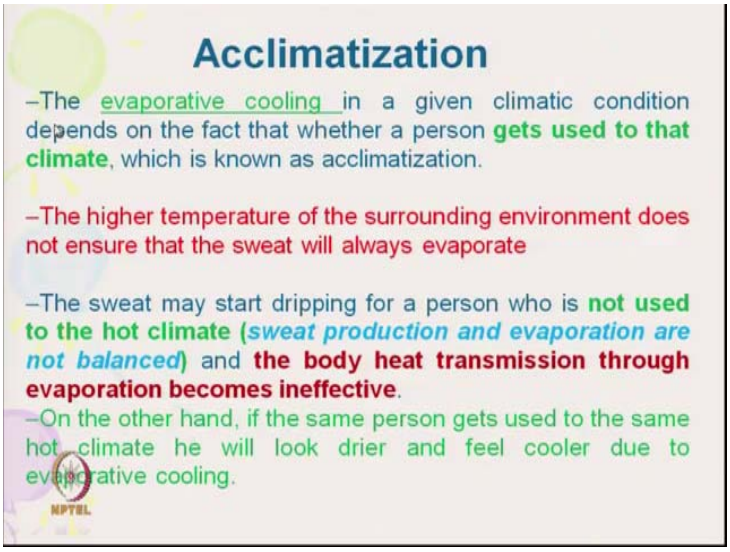
So, what happens then in extreme hot and dry climate? So, in extreme hot and dry climate, we sometime feel that we do not sweat.

Because, sweat actually gets evaporated as soon as sweat generates and in extreme dry condition sweat as soon as it generates, it gets evaporated from the skin, sweat is does not come out in the form of liquid. Without wetting our skin, does not wet our skin, if it does not wet; that means, we will we do not get the evaporative cooling. So, we have seen that in extreme summer, in dry summer so, we do not sweat that actually if we do not sweat then it is a threat basically, because evaporative cooling helps in extra, it takes away extra heat from our body. So, body temperature remains it is maintained.

So, by the heat supplied by the skin surface so, it the insensible evaporation takes place automatically it gets evaporated. So, no cooling effect is achieved and the body temperature rises steeply. So, that we do not get the evaporative cooling so, cooling extra cooling effect we do not get. So, steeply our body; that means, sometime what happen at very high and dry temperature our sweat gland actually fail. So, sweating we stop sweating in that case the heat stroke take place. So, if the body temperature, the sweating is actually activated around 30-32 degree Celsius. So, that, but if it is say 45-46 degree Celsius at high temperature sometimes sweat gland may fail. So, we stop sweating.

So, this sweat gland and as then as we sweat gland stops it fails then so, evaporating cooling does not takes place, now coming to the phenomena of acclimatization.

(Refer Slide Time: 29:37)



So, acclimatization is the evaporative cooling, where one a person is acclimatized in a particular situation, particular environment, what does it mean?

It means that the type of at certain that temperature at that condition the level of sweating what he is generating? And level of heat that sweating evaporation is actually balanced. If it is not balanced, then the person will feel uncomfortable. Like the evaporative cooling in a given climatic condition depends on the fact that whether the person gets used to that climate, which is known as acclimatization. So, he has to be used to that environment.

If a person comes from other place a cold place to suddenly in the warm place. So, you will not be actually he is not used to that place. So, at higher temperature of the surrounding environment does not ensure that the sweat will always get evaporated. So, always it may not get evaporated. The sweat may start dripping for a person who is not used to that hot climate; that means, at that temperature, he will start releasing more and more sweat.

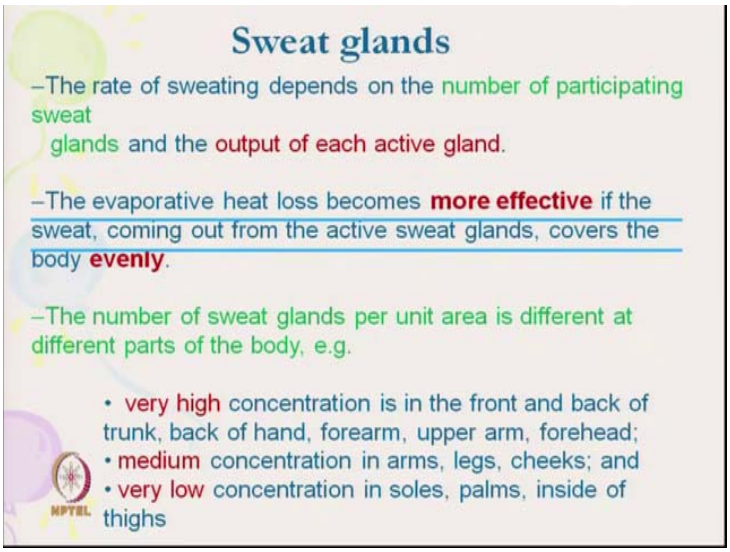
So, that release of heat, release of sweat an evaporation of a sweat is not balanced, he is not used to that particular environment. So, the sweat produced and evaporation rate at not balanced. So, that person is not acclimatized in that particular environment; that means the body heat transmission through evaporation becomes ineffective. So, it is actually a person who is in say acclimatized in cold zone.

He suddenly he comes into a some warm and humid place he will for few days he will start feeling uncomfortable, he will start sweating, because the sweating production and sweating evaporation is not balanced. So, on the other hand, if the same person get used to that same hot climate; that means, body physiology will control the release of sweat, rate of release of sweat.

And the person whatever sweat he is releasing he will start evaporating that sweat and he will feel cooler. So, this is the phenomena and if during that time the clothing has to take active role in making that person comfortable.

So, sweat production and sweat evaporation is not balanced. After some time, he will start because he is acclimatized at that condition.

(Refer Slide Time: 33:04)



And, now the rate of sweating depends on the number of sweat glands. So, number of sweat glands are actually different at part of the body, the number of sweat glands are different. The rate of sweating depends on the number of participating sweating glands and output of each glands; that is this output is important, this output depends on the temperature.

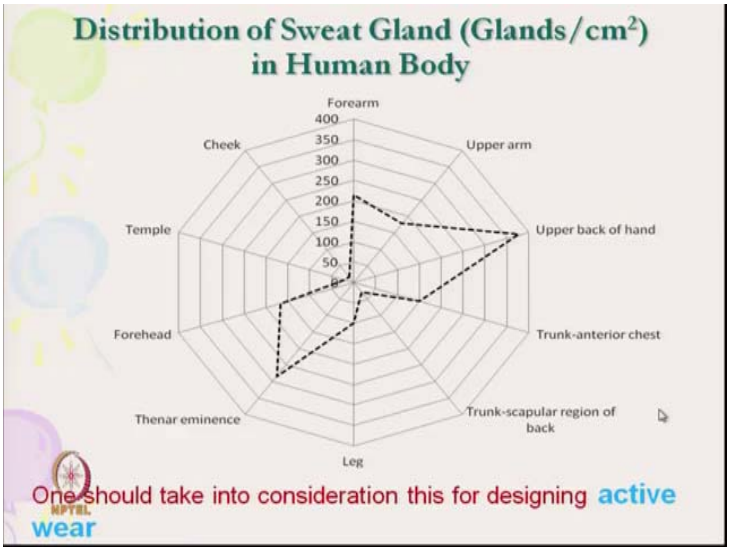
The evaporative heat loss is more effective, if the sweat coming out from the active sweat gland covers uniformly, covers actually evenly in our body, but it is not that because our body different parts of the body the concentration of sweat glands are different. If it is actually uniform then it will be perfect evaporative, in some places we will find, that we are sweating too much.

So, we are sweating too much; that means, at that point the sweating rate is more than the evaporated rate. So, sweating sweat will start dripping, but on other places we do not sweat that much. So that how it is not actually distributed uniform evenly. So, number of sweat glands per unit area is different at different parts of the body. Very high concentration is in the front and back of the truck here so, at the trunk and back of hand, forearm, upper arm, and forehead. So, forehead and there we will see that we start sweating because number of sweat glands are very high there.

And, the active this number of sweat glands are a different at different parts of the body. And, medium concentrations are there in arms, legs, and cheeks. There we normally do

not gets sweat and it is very low, it is of sole and palm. Here we normally sweat do not sweat. So, depending this different concentration, we sweat at different way.

(Refer Slide Time: 35:35)



So, these are the different concentration of the sweat glands per square centimeter. These are the number of sweat glands here, if you will see upper back of hand it is around say close to 375 per square centimeter. It is a number of sweat glands are (Refer Time: 35:54). So, these are the different types of and a minimum as at the cheek and temple. And depending on this type of number of sweat glands we have to design our active clothing. So, active clothing if we know the number of sweat gland at different portion of our body, we should be able to design our active clothing which is actually supposed to absorb the sweats.

This sweat absorption so, where the; that means, at these zone upper back of the trunk. Here, if we design our active sports clothing. So, we know, for active wear, we know that this zone our sweating will be high. So, our type of fabric should be such that it enhance the evaporative cooling from that. And, where it is low we can actually eliminate that we can we need not take that much precaution.

So, this is at the different zone is we can design our clothing accordingly. And, this sweat gland is activated at different temperature as we have discussed, as the temperature increases from say 10 to say 30 degree Celsius. So, at during this increase the sweating the sensation, which physiological sensation, which we receive we get it gets a enhanced.

So, sweating is peak at say 35-36 degree Celsius and as we as the temperature goes on increasing the sweating rate drops and at very high temperature, the sweat glands fail.

So, these are the various physiological activities we have neurophysiological activities we have discussed. So, in this segments, we have discussed the different types of sensors available in our sensors, are receptors available in our skin to sense the different stimuli. The sensors are mechanical sensors and thermal sensors, mechanical sensors are of different types, tactile sensors, the pain sensors, pressure sensors, vibration sensors, that we have discussed, also the thermal sensors we have discussed, that thermal sensors are basically 2 types; one is warm sensor, another is cold sensor. Warm sensor can be divided into 2 types it is a normal warm and warm pain, hot pain sensor. Cold sensor are of 2 types; the normal cold and cold pain sensor. And, knowledge of all this things are required to design our clothing for comfortable human being.

So, we can design if we have detailed knowledge of all these sensations on neurophysiological activity. We can design our clothing for comfort of our human being. So, we will end this neurophysiological sensor phenomena of clothing comfort here.

And in next segment we will start with our tactile sensation of clothing. Where, we will discuss a different clothing structure; that means fabric structure and how different measurement technique and different handle technique, handle measurement technique, this we will discuss.

Thank you.