Ergonomics for Beginners Industrial Design Perspective

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Module No. # 02

Discipline Approach: Ergonomics/ Human Factors

Lecture No. # 07

Physiology, (Work physiology) and Stress

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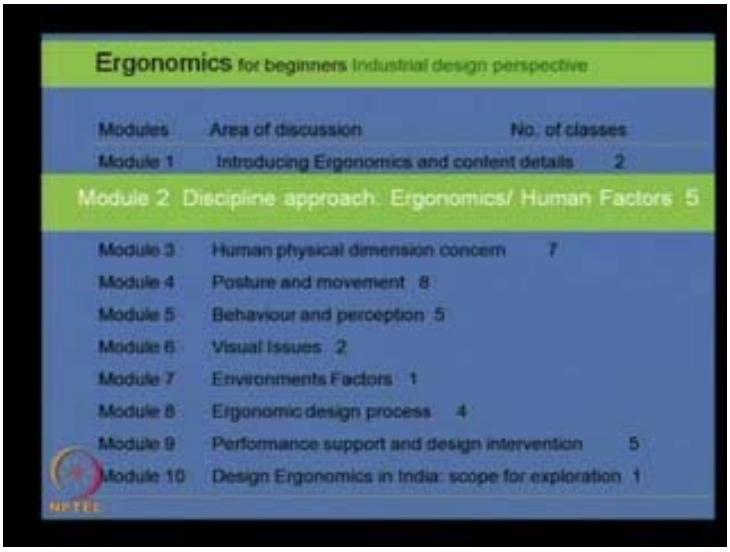

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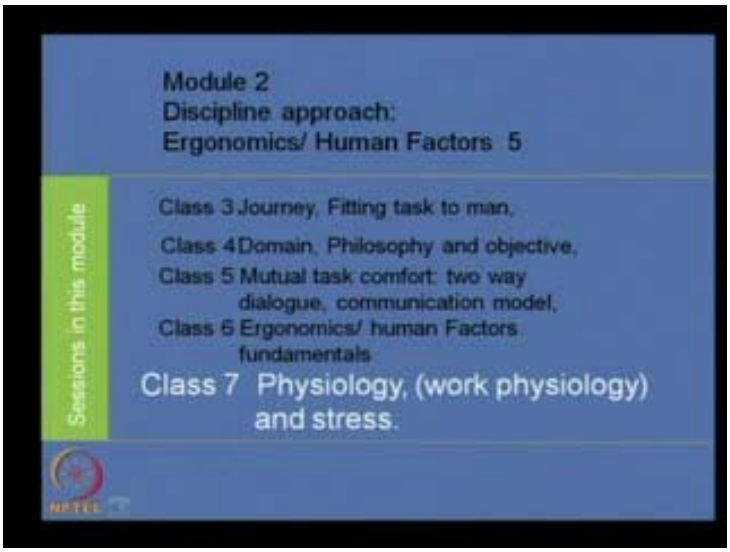

Today, is the seventh session of ergonomics for beginners industrial design perspective. Now, it is under module number 2, that is, discipline approach ergonomics and human factors. And there are total 5 sessions and this is the last session in this module is class 7 - physiology, work physiology and stress relevances.

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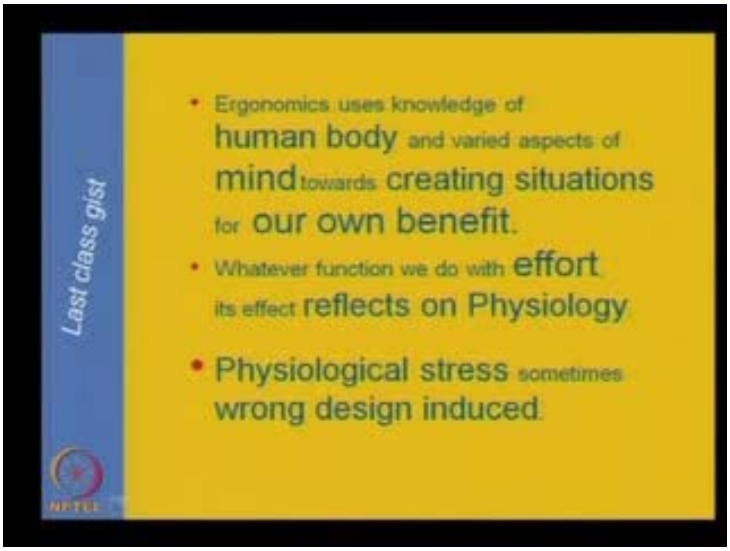

Now, whatever we discussed in earlier classes, let us have a summary of that. Ergonomics uses knowledge of human body and varied aspects of mind towards creating situations for our own benefit. Whatever function we do with effort, its effect reflects on

physiology. While using any product or any other utility item in a different manner, finally, the workload we are feeling or the stress we are feeling, it is visible through our body expressions and that is true, and also physiological parameters, if we measure, then we can find that what is the workload on that whether it is good or bad.

Now, physiological stress sometimes, wrong design is induced. If the design is not proper to use that, man has to take lot of troubles; then it creates stress and that reflects in physiology.

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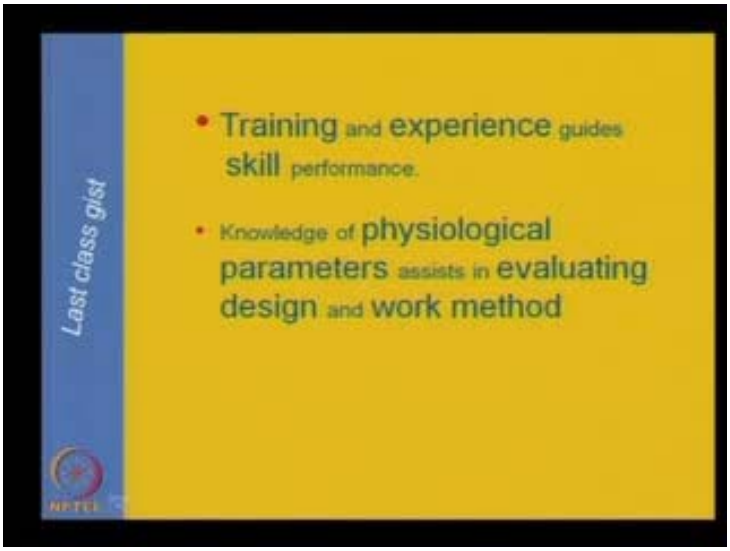

Training and experience, guides skill performance: the frequency we use or we do certain activities or skillful movement or skill increases. As for example, to do a certain job where men muscle force is required, the young person, he can use, he can do the same job using whole body muscles, but when a skilled person does the same job, then he uses specific muscles necessary to perform that job - that is the skill. So, we can say that a training and experience guides skill performance.

Now, why designers also need to know the physiological parameters? Because knowledge of physiological parameters assist in evaluating design and work method - whether it is really effective, it is good for our health.

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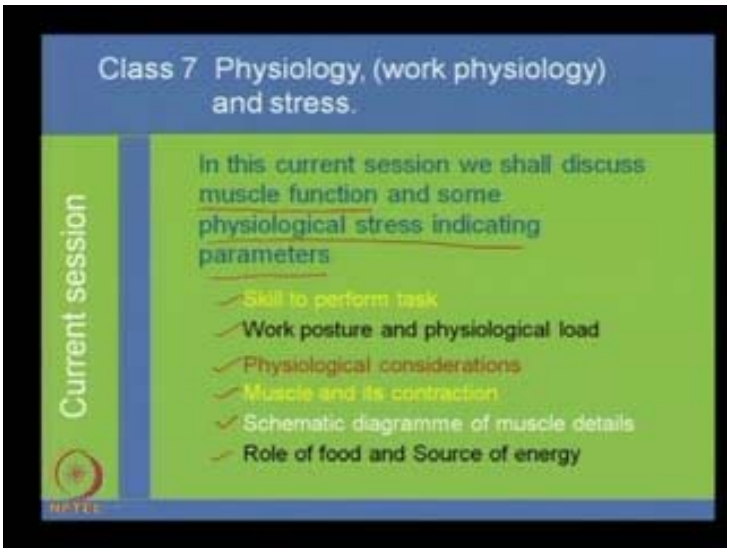

Now, current session, now today, we are going to discuss. In this current session, we shall discuss muscular function and some physiological stress indicating parameters through: skill to perform task, work posture and physiological load, physiological considerations, muscle and its contraction, schematic diagram of muscle details, and role of food and source of energy. These areas consists today's discussion.

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Now, if we see this figure, this is a hill. On this hill, after taking out some soil from this hill, the hill becomes barren. To cover this exposed surface, lump of grass is being fixed

with a small bamboo piece (that is a small bamboo stick here), the small bamboo sticks on a barren hill surface to cover it to save erosion and for beautification also. Now, work tool is a bamboo piece with a narrow holding area (to hold it) and a beating head (that is a thicker side). The task is nailing in nature. Now, in this, what can be said that, the person has to perform a balancing task while performing the door job. Now, he has to stand in a slanting surface. So, to maintain this body position, posture, a certain group of muscles are already involved, and over that, when he has to perform the skillful task of nailing the bamboo pieces with grass lumps, then it is also another skillful movement. So to do this job, he has to divert his total activities: one in maintaining balances of his whole body and to perform the task. Now, the whole outcome depends on how he can make balance between these two requirements.

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Now, if you see from the close point of close, he is just placing the lump of grass on this hilltop and bamboo pieces to be used to nail and the bamboo hammer are carried in hand. Here, both hands are used; so, this is a complex task. Now, while making this complex task, how we are manipulating our muscles, it makes a great impact - means the skill of using specific muscle groups.

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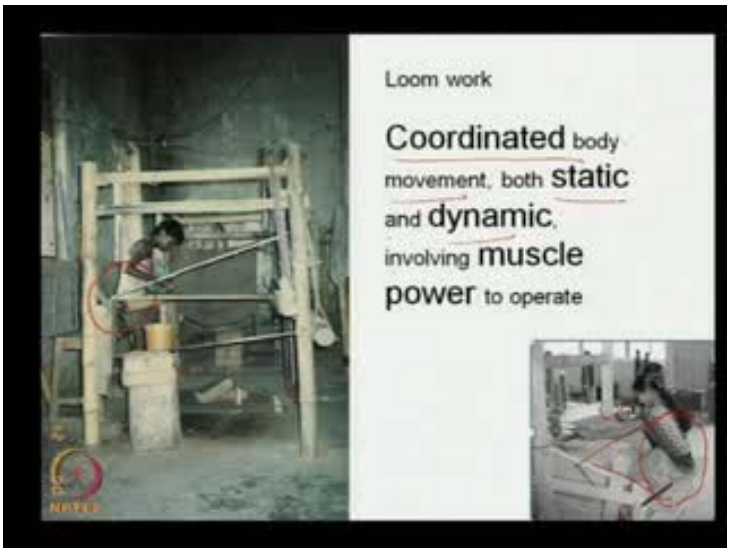

Now, if we see the loom work, in this loom work, this person is sitting on a bench and working. He is pedaling also here and also working; in this case, it can be said that this much portion remains static whereas his arm and leg portion are dynamic. In this case, here also it can be said that the same thing - the lady has to maintain a specific static posture at the buttock area, whereas the top portion and the leg, below leg portions - these two portions are dynamic. So, this task is a combination of static and dynamic - both. The coordinated body movement of both static and dynamic involving muscle power to operate, shows how skillfully we can use our muscles; the performance outcome is related with that.

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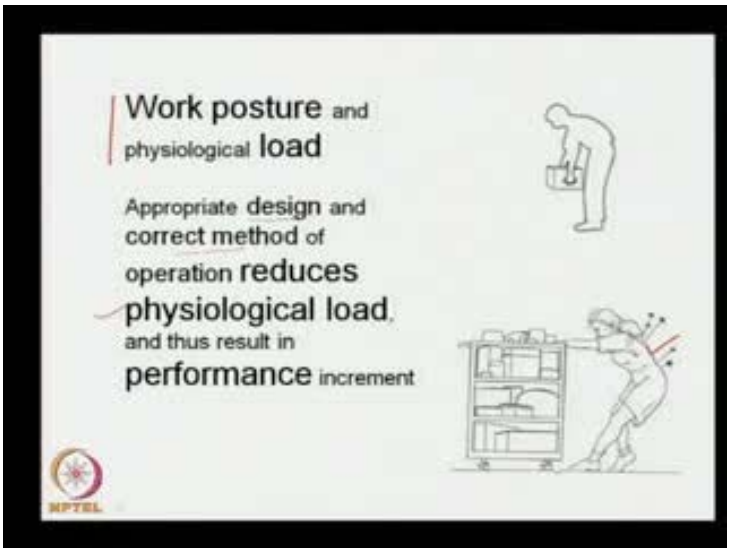

Work posture and physiological load - when we perform some task, the task demands specific postural adaptation. Now, for that, if we stand and bend forward, it is a normal practice, but if the task requires side bending and backward bending, it is not quite normal.

So, we have to maintain the control locations in such a way, that the person do not need to bend in sideways, back, or at the front, that is beyond his safe limit; and accordingly, the design has to be done. Like in this case, the lady is pulling a trolley, if the trolley design is not proper, then the total load, what is coming, it affects the back. So, it can be said that appropriate design and correct method of operation, reduces physiological load and thus result in performance increment. So, we must be aware of the posture.

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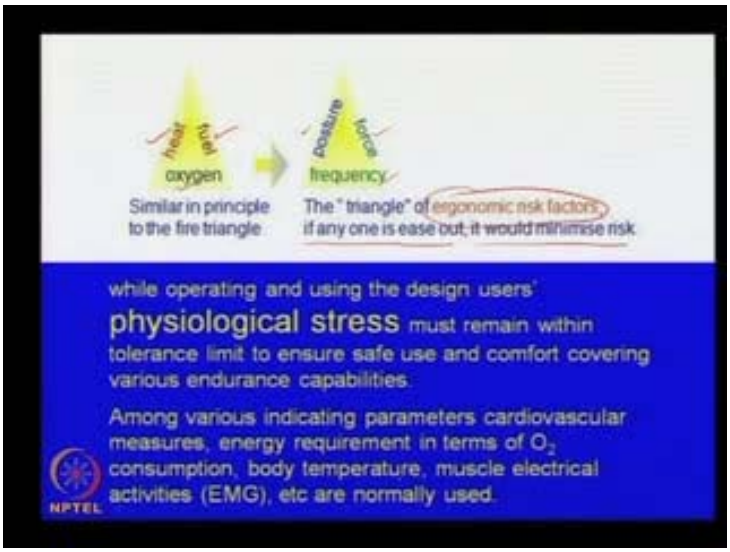

Now, if we see the ergonomic risk factors - if we explain from a fire triangle principle, that heat, fuel and oxygen that if any one or all three together, if we reduce its intensity, then the total fire intensity also decreases. In the same way, to do certain task, the posture of man, the force he is applying and the frequency of that force application and the posture adaptation, these three together, this triangle is called the triangle of ergonomic risk factors. If anyone is eased out, it would minimize the risk.

Now, how we can understand or measure this risk? Among many methods, the physiological stress measurement is mostly accepted. While operating and using the design, users' physiological stress must remain within tolerance limit to ensure safe use and comfort, covering various endurance capabilities.

What are the parameters? Among various indicating parameters - cardiovascular measures, energy requirement in terms of oxygen consumption (that is, the difference of oxygen in inhaled air and exhaled air), body temperature - when our body is in active or working, then our temperature increases. So, how much temperature is increasing, that gives that load feeling, muscle electrical activities (that is electromyogram), etcetera are normally used as parameters to understand the physiological stress while using a design and performing a task.

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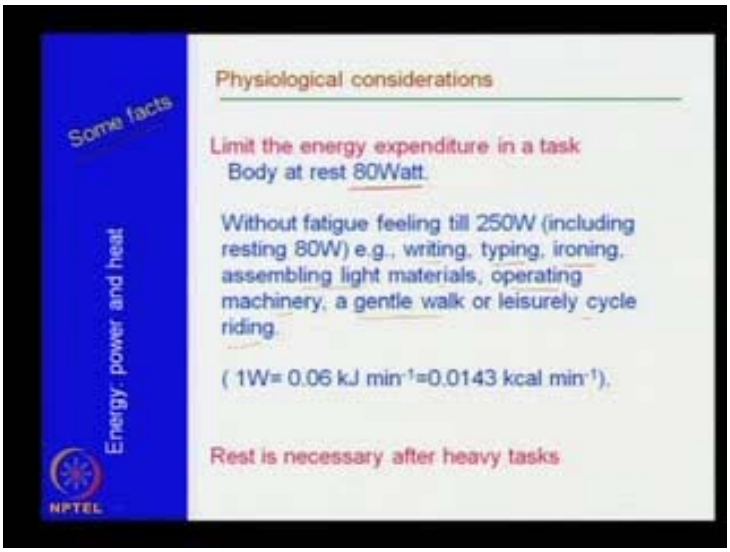

Now, some facts about the physiological considerations; energy, power and heat; limit the energy expenditure in a task. How we can limit this and what are the backgrounds? So, if we measure this energy to power and heat, then it can give us a judgment. As for example, it can be said that a normal body at resting condition, it spends around 80 watt, without fatigue feeling till 250 watt (including resting value of 80 watt); for example: writing, typing, ironing, assembling light materials, operating machinery, a gentle walk or leisurely cycle riding, it is there. This task requires around 250 watt; till that we do not feel much fatigue. So, now what is 1 watt? 1 watt is equivalent to 0.06 kilojoules per minute and that is 0.0143 kilo calorie per minute.

Rest is necessary after heavy tasks - why? Why this rest and pause system is there? Because, when we perform some heavy task, then our energy reserves are being utilized and to repay the debt, we need some time, so that during that time, an additional expenditure should not be there. So, it is said that rest is necessary after heavy tasks.

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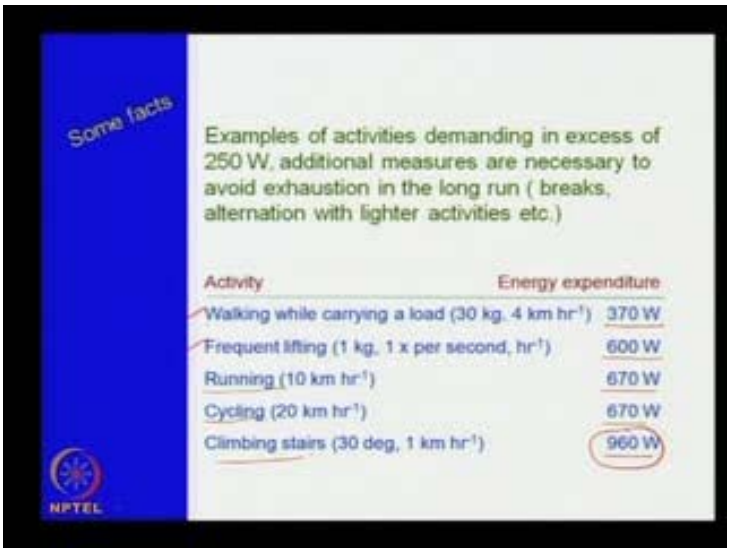

Examples of activities demanding in excess of 250 watt, that is, additional measures are necessary to avoid exhaustion in the long run (breaks, alternation of lighter activities etcetera, are necessary to be introduced). Now, just for some understanding, that activities (some activity) and energy expenditure are given below. Walking while carrying a normal load (around 30 kg for 4 kilometer per hour) if with that speed if he walks, then the energy expenditure reaches around 370 watt. Frequent lifting (that is, 1 kg of load for 1 time per second per 1 hour), that is around 600 watt. Running (in a speed of 10 kilometer per hour, but 10 kilometer in an hour) - 670 watt. Cycling (in 20 kilometer per hour) is 670 watt. Climbing stairs (in 30 degree stair angle for 1 kilometer per hour) is 960 watt. So, these are well measured.

So, if it requires more energy, suppose we have changed the angle of the staircase or the speed of climbing, then if we measure his energy requirement at that movement or energy expenditure at that movement, it will be more than this value? Then, we can say that whether or if we have less degree, or less or slow speed (slowly), then it may be considered around this, walking normally. So, there, this will be less. So, by that way, we can say that whether for a specific group of people or a specific person, the specific angle, what would be the ideal. So, along with this measurement, the subjective judgment is also necessary to understand whether he is feeling comfort.

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Now, people always say that if there is any problem, we anticipate and prevent. Now, how we can prevent and what are the mechanisms that can be used? Like it is normally said that warm up and stretch before activities that are repetitive, static or prolonged. Take frequent breaks from any sustained posture every 20 to 30 minutes. So, if you have to adopt a specific posture for more than 20 to 30 minutes, then it is better to break for some time, take rest, or change posture, and then come again.

Respect pain-positions or stop painful activity. Now, if we overlook, pain is an indicator of internal problems; if we do not give attention to this pain, then it may lead to a grievous problem. Recognize early signs of inflammatory process and treat early. Now, how to treat early? Here come the design activities - with proper design aid, we can treat this.

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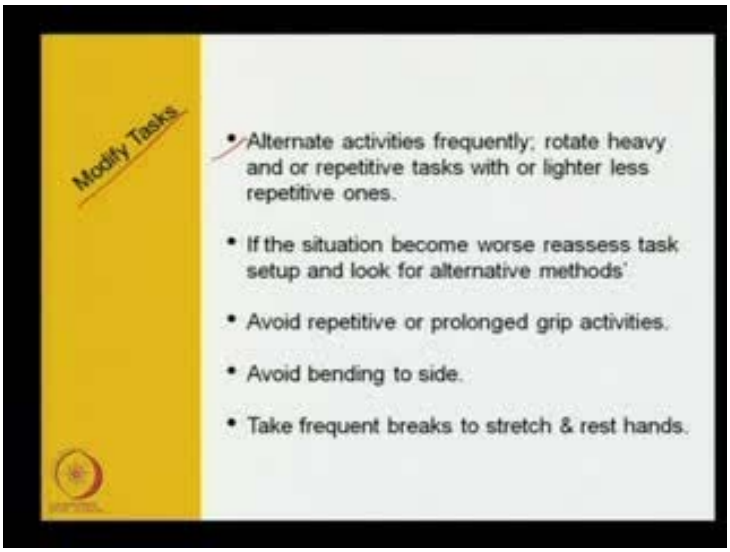

Now, people say that with addition to the design, try to modify tasks. How to modify task? If it is said that alternate activities frequently; rotate heavy and or repetitive tasks with or lighter less repetitive ones, you use it. If the situation becomes worse, reassess task setup and look for alternative models. Avoid repetitive or prolonged grip activities. Avoid bending to sides. Take frequent breaks to stretch and rest hands.

Normally, it is seen that while we are doing certain work, where our arms are not really involved, still, the stress on shoulder and arm is there. So, it is better to give whole body rest; at the same time, if it is not possible to give whole body rest, at least give arm support to have a rest.

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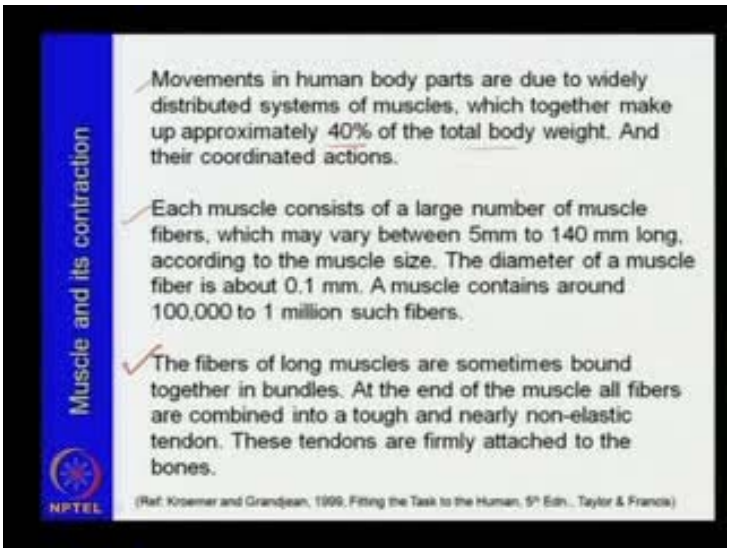

Now, if we see all the movements and etcetera are basically for muscles. If we see our body - on the bony structure, the muscles are there or muscles are distributed all over the body; different shapes and types of muscles are there. Mostly it is said that a muscle has two ends, that is, tendons; these tendons are joined with the bone pieces; that bone is joined with a hinge. Now, if both the places the tendons are joined, then what happens? With the muscle contraction through the tendon, the bone distant parts come closer - this is the flexion movement and at the same time, the opposite muscle - the extension muscle - it has to expand, otherwise the movement is not possible. At the same time, when extension is there, it means, when the extension muscle is contracted, the flexure muscle has to be relaxed. So, this is the basic matter.

Now, there are muscles and long muscles for normal movement as well as there are some oblique muscles to give the arm rotations, or any body-parts rotation. So, with combination of these muscles, the total skillful movement in our body is possible.

Now, we will see some facts about this muscle, muscle construction and some muscle activities. Muscle and its contraction: if we see the slide, this slide mentions that movement in human body parts are due to widely distributed systems of muscles, which together make up approximately 40 percent of the total body weight and their coordinated actions. Our skillful movement is due to the coordination or coordinated action of different muscles. Each muscle consists of a large number of muscle fibers - the

details in the figure, we will see now - which may vary between 5 millimeter to 140 millimeter long, according to the muscle size. The diameter of a muscle fiber is about 0.1 millimeter. A muscle contains around 100,000 to 1 million such fibers. The fibers of long muscles are sometimes bound together in bundles. At the end of the muscle, all fibers are combined into a tough and nearly non-elastic tendon. These tendons are firmly attached to the bones. With the muscle contraction, as the bony comparts are attached with tendons, it pulls the distant parts of bones so that a coordinated movement is possible.

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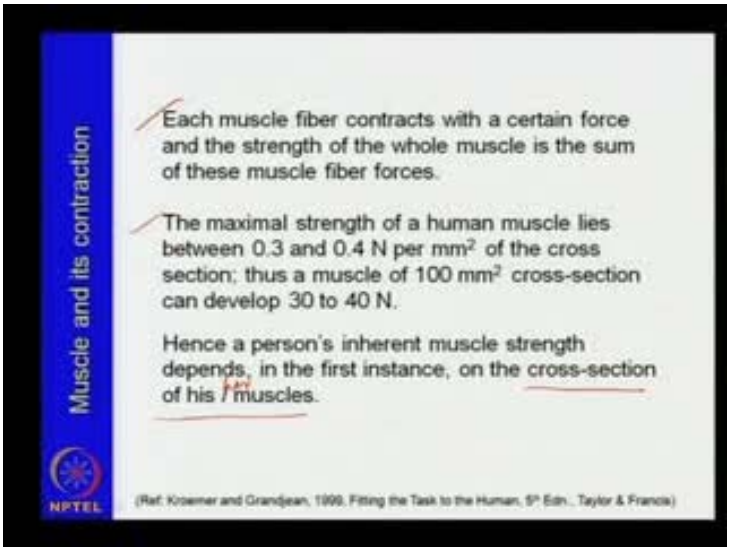

Each muscle fiber contracts with a certain force and the strength of the whole muscle is the sum of this muscle fiber force. The maximal strength of a human muscle lies between 0.3 to 0.4 Newton per millimeter square of the cross-section of a muscle; thus a muscle of 100 millimeter square cross-section can develop 30 to 40 Newton force. Hence, a person's inherent muscle strength depends, in the first instance, on the cross-section of his or her muscles.

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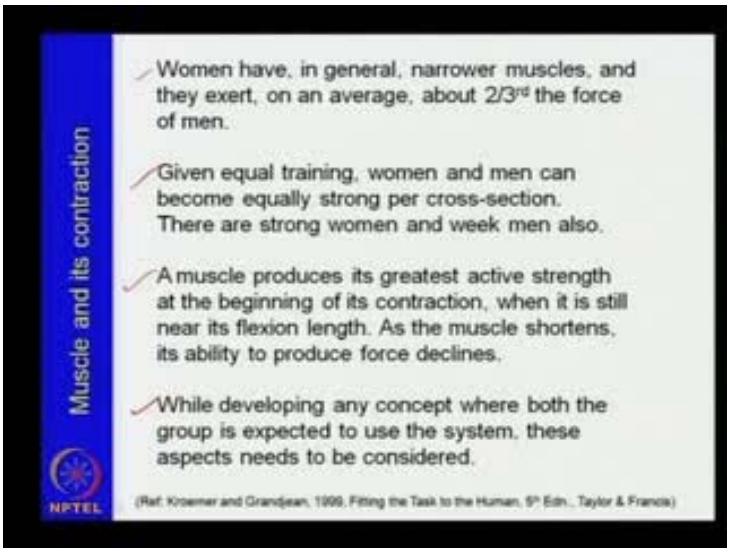

Male and female variations in muscle power: women have, in general, narrower muscles, and they exert, on an average, about two-thirds the force of men. Now, why we need to know this matter is, if we have to design a product where muscle force is necessary to operate, then whether it would be used by man or a woman, depending on that, force requirement mechanism has to be developed. If it has to be used by both, then obviously, the female force has to be considered, so that a big range of population can use that. So, for these types of decisions, this knowledge is necessary to understand by design communities. Given equal training, women and men can become equally strong per cross-section. There are strong women and week men also.

A muscle produces its greatest active strength at the beginning of its construction - when muscle starts contracting - at the beginning it exerts maximum force and then slowly it reduces or it maintains in that when it is still near the flexion length. As the muscle shortens, its ability to produce force declines. For that now, if we have to design a product where a gear or a lever, we have to pull, then, what is the distance of pulling where we can exert maximum force? That we need to understand. While developing any concept where both the groups are expected to use the system (male and female), these aspects needs to be considered.

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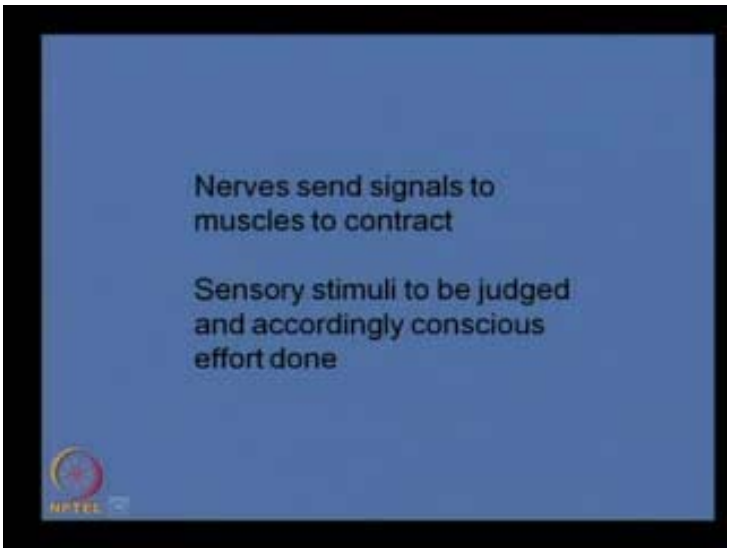

How do the nerves moves? Who asks not to contract or relax? The nerves send signals to muscle to contract and sensory stimuli to be judged, and accordingly conscious effort would be done.

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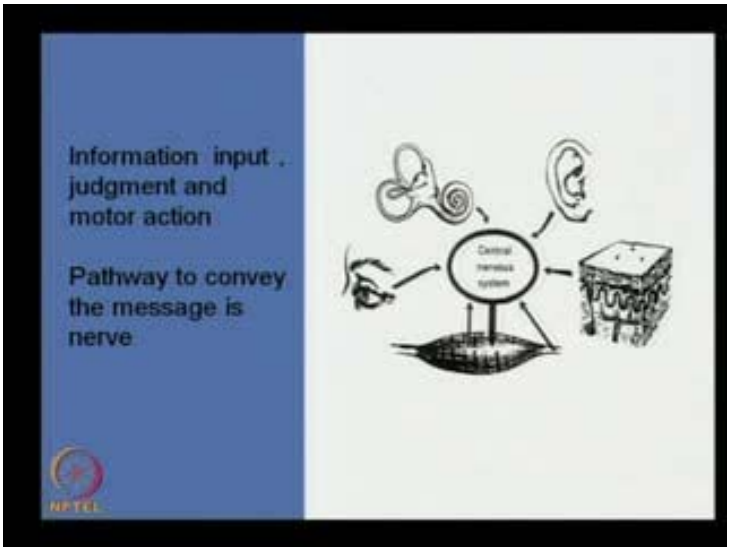

Means by how the input comes to us? Through all the senses - internal ear, external ear, eye, then skin, skin for tactile senses and taste, smell, etcetera. All the input, transfers to electrical signal, it goes to brain, it gets judgment and then the flow comes to

(information comes to) the muscles, and then accordingly muscle get contracted means or motor activity starts.

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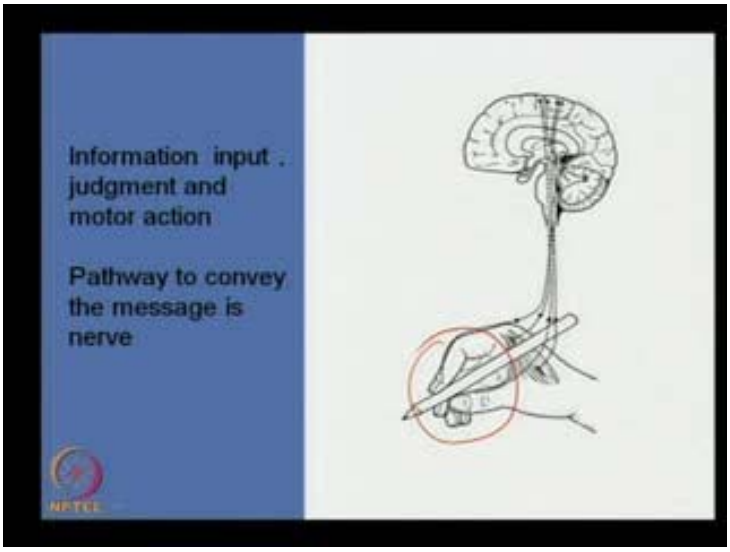

So, the pathway from this input entry and judgment done and it comes to the muscles for motor activity; the pathway to convey the message is nerve. Now, in this case, we can say that while operating, how much pressure and force is required here, it depends on the force, pressure we are applying on it and that gives an input to the brain - judges when judges, and whatever it is being written here, that another input goes through eyes and in the combined judgment, the input comes to the specific muscles - how much pressure to be exerted for a skillful movement?

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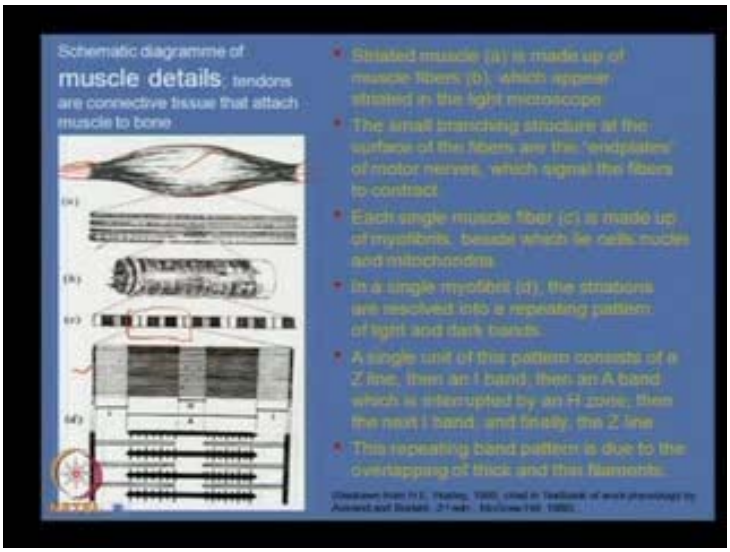

Now, we will see the muscle structure. Most of the body muscles are called striated muscles. Why it is called so? That we will discuss now.

With this in This is a schematic diagram of muscle; this is the total muscle; this end portion - a non-elastic filament (that is tendon) - and this is the muscle group, and muscle has many fibers. Now, the striated muscle (a) is made up of muscle fibers (b) (is with many muscle fibers - a combination of this, is the main muscle), which appear striated in a light microscope (this appears as striated - these marks). The small branching structures at the surface of the fiber are the endplates of a motor nerve. Now, on this, the motor nerve-ends come, which signal the fiber to contract.

Each single muscle fiber (c) is made up with myofibrils (small fiber), beside which lie cells, nuclei and mitochondria.

In a single myofibril (d), the striations are seen - it is specific pattern-wise. Now, what are the patterns? Here we can see that this is a small area - if we see here, then this mark is called Z line. So, between these two Z lines, there are some strands, it is that a single unit of this pattern consist of a Z line - this one; then an I band, a specific band position is there, is called I band; then A band, and again I band and Z band. So, this is a unit; within this event, there is some thick color - black color - and some are the white - little less thickness color.

So, then an A band which is interacted by a Z zone - this is the Z zone area. Then next I band comes and then Z band. Now, what are these things? In this, these bands are formed with two types of protein fibers - actin and myosin. This joinery of this muscle fiber forms Z band.

Now, actin and myosin, if we see from in between these two Z bands - in this Z band, these muscle fibers are attached like this way - and within this, some fibers are placed this way. So, with this actin and myosin fibers from this band, there are some small protrusions are there and this protrusions here in this fiber, some groups are there. So when this muscle is activated, then this muscle protruded tip, pulls this through these groups, inner side. So, what happens? This muscle becomes squeezed, because what happens, if it is like this - if it pull down like this, pulled inside – so, then total muscle fiber that check this band, it decreases. So, as a resultant force, the total muscle gets contracted.

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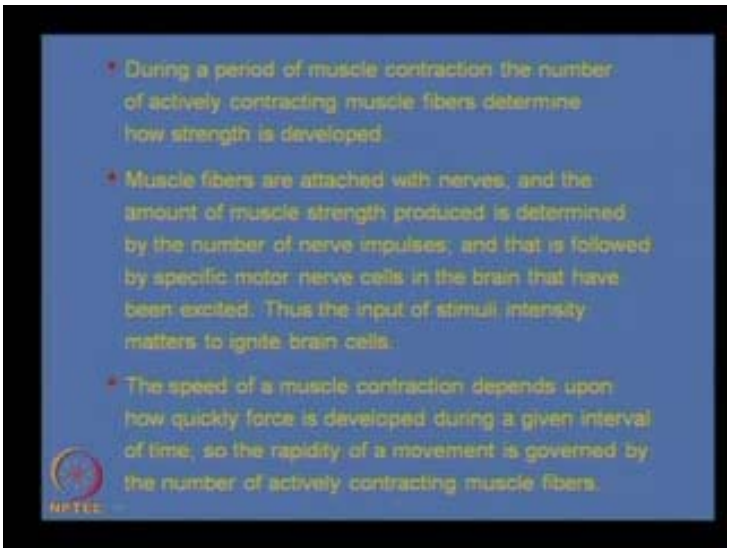

So, this muscle fiber - this repeating band pattern - is due to the overlapping of thick and thin filaments in this, and these filaments act like this. During a period of muscle contraction, a number of activities, actively contracting muscle fibers determine how strength is developed. Muscle fibers are attached with nerves, and the amount of muscle strength produced is determined by the number of nerve impulses, and that is followed

by specific motor nerve cells in the brain that have been excited. Thus, the input of stimuli intensity matters to ignite brain cells.

The speed of a muscle contraction depends upon how quickly force is developed during a given interval of time. So, the rapidity of a movement is governed by the number of actively contracting muscle fibers.

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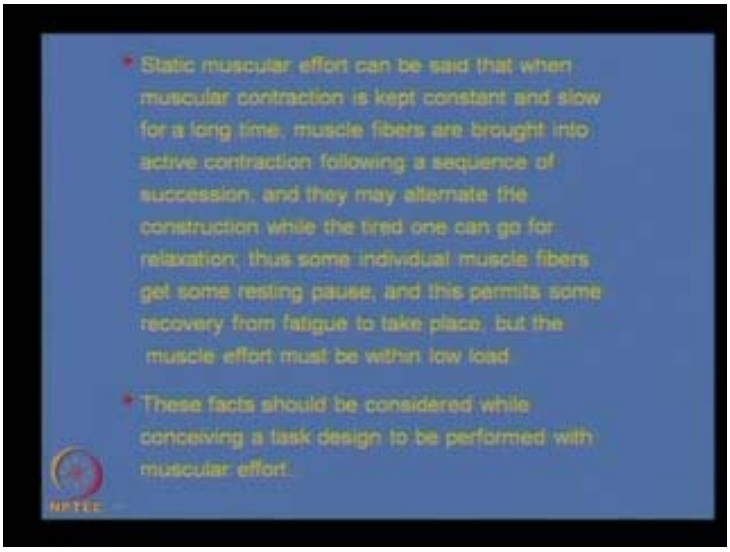

Now, some more facts can be discussed here: the static muscular effort can be said that when muscular contraction is kept constant and slow for a long time, muscle fibers are brought into active contraction following a sequence of succession, and they may alternate the construction while the tired one can go for relaxation; thus some individual muscle fibers gets some resting pause, and this permits some recovery from fatigue to take place, but the muscle effort must be within low load.

Perhaps we have seen, when we sit for a long time, we cannot maintain the same posture; there is a sway movement like this, or we try to change our body position. So, why it happens? This is the matter. It means, to maintain this position, a specific muscle group is involved, when those muscles extend are tired, then neighboring muscles, they take over the load and then earlier one gets rest. So, for that, what is happen, our body movement is there.

So, it is very difficult to sit for a longer time in a position without any movement. Now this knowledge - how we can use in a design? If the seating (the seat plate) is very hard, then the whole body load will be concentrated to some points and then a very specific selective group of muscle will be involved to maintain that posture, and quickly they will tire.

So, what happens? There will be some sway movement frequently, but if it is a soft padding is there, then what happens? The total load will be distributed to certain position where the (muscle-fiber) muscles responsible to maintain that posture, they will number will be more. So, their total load will be less; so, that position they can maintain for little longer time. These facts should be considered while conceiving a task design to be performed with muscular effort.

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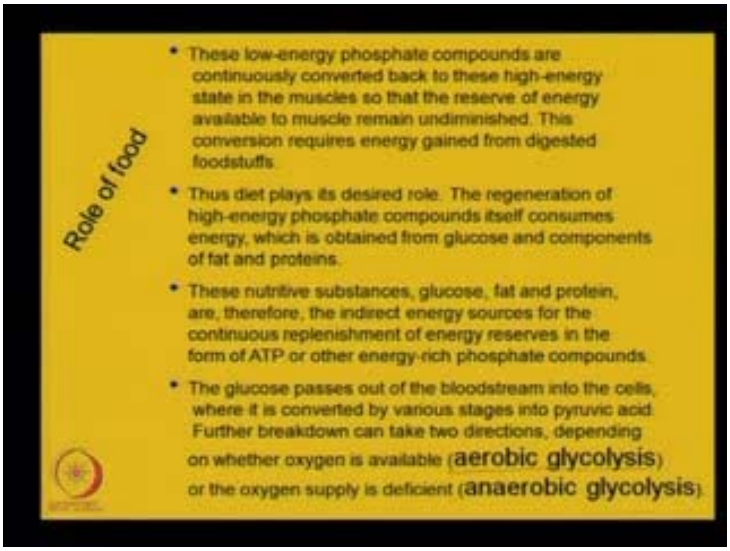

Role of food: how do we get the energy? Now, if we see the slide, here it is specifically mentioned that these low energy phosphate compounds are continuously converted back to these high energy state of the muscle, so that the reserve of energy available to muscle, remains undiminished. This conversion requires energy gained from digested foodstuffs means- in our body, whatever we eat, it gets digested then it goes to blood, and from blood it goes to the cells, inside the cell, and then inside the cell, it breaks down to pyruvic acid. Accordingly, in that process, in the presence of oxygen, it makes ATP (adenosine triphosphate) and these are the energy reserve.

So, when a muscle contraction takes place, this ATP triggers this actin-myosin movement and it breaks down to adenosine diphosphate. So, this total process is the aerobic glycolysis. Now, if the oxygen supply is deficient, then the process is anaerobic glycolysis.

Thus, diet plays its desired role; if the main diet is not proper, then this energy formation will also be less, then the total activity of the muscle will also be decreased. The regeneration of high-energy phosphate compounds (ATP), itself consumes energy (means - after consuming energy, it stores and then it), which is obtained from glucose and components of fat and protein.

These nutritive substances, glucose, fat and protein are therefore, the indirect energy sources for the continuous replenishment of energy reserves in the form of adenosine triphosphate (or ATP) or other energy-rich phosphate compounds.

The glucose passes out of the bloodstream into the cells, where it is converted by various stages into pyruvic acid. Further breakdown can take two directions, depending on whether oxygen is available (aerobic glycolysis) or the oxygen supply is deficient (then it is anaerobic glycolysis). So, what happens? When we do some heavy load work, our energy reserve goes down, so that we require more oxygen supply; so we start panting, and this also becomes an indicating factor to recognize the work load.

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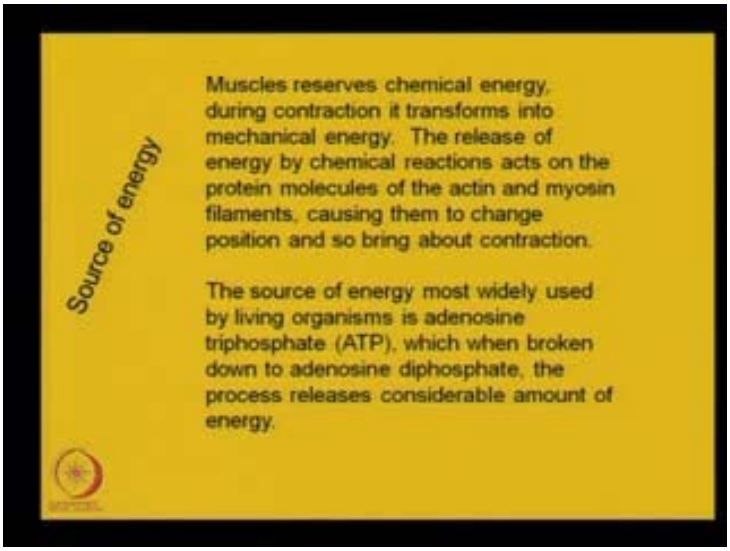

Source of energy: now muscle reserves chemical energy (that is adenosine triphosphate and that matter); during contraction, it transforms into mechanical energy. Stored chemical energy while doing some activity, this energy is transformed to mechanical energy. The release of energy by chemical reactions acts on the protein molecules of the actin and myosin filaments of the muscle, causing them to change position, and so bring about the contraction. So, each that from Z band to Z band, that unit it squeezes, another squeezes, another squeezes, like that. So, the total muscle gets contracted.

So, the source of energy most widely used by living organism is adenosine triphosphate, which when broken down into adenosine diphosphate, the process releases considerable amount of energy. This energy creates mechanical movement.

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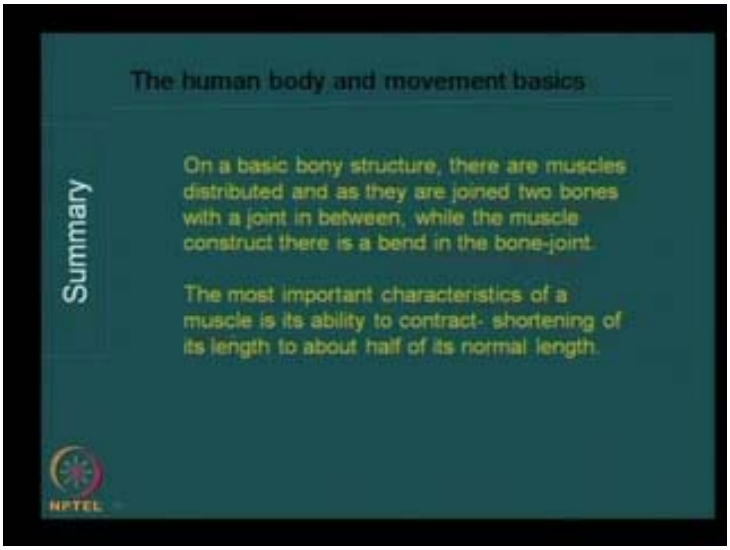

Now, the today's summary - if we summarize the total matter what we have discussed and we are going to point out specifically that the human body and movement basics - we are discussing; its application and biomechanics and etcetera, it will be the next classes, we will discuss. Now, on the basic bony structure, there are muscles distributed and as they are joined to bones with a joint in between, while the muscle contracts there is a bend in the bone-joint and this is the total movement.

If all the contractions are coordinated, then a skillful body movement is possible. The most important characteristics of a muscle is its ability to contract, that is shortening of

its length to about half of its normal length. This is the most important characteristic of a muscle, that is, it can contract till its half size - half of the length.

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When due to muscle contraction two bone ends come close is flexion (muscles are flexor muscles - we call them), and when it expands it is extension movement, (muscles are extensor muscles - like this). When a flex something, the flexor muscle that contracts and at the same time, the opposite muscle (the extensor muscle), it gets relaxed or extended. When we make the extension movement, then the extensor muscle - it contracts, flexor muscle - it relaxes.

For any bone joint movement, both the antagonistic muscle groups are active, if the flexion has to take place, flexion muscles contract and extensor muscle relaxes; for extension movement, the reverse action takes place, and with the coordinated movement, all these things takes place. Now, how much control we can exercise here that gives us skillful movement and all this is being judged by our brain power - our brain judges that.

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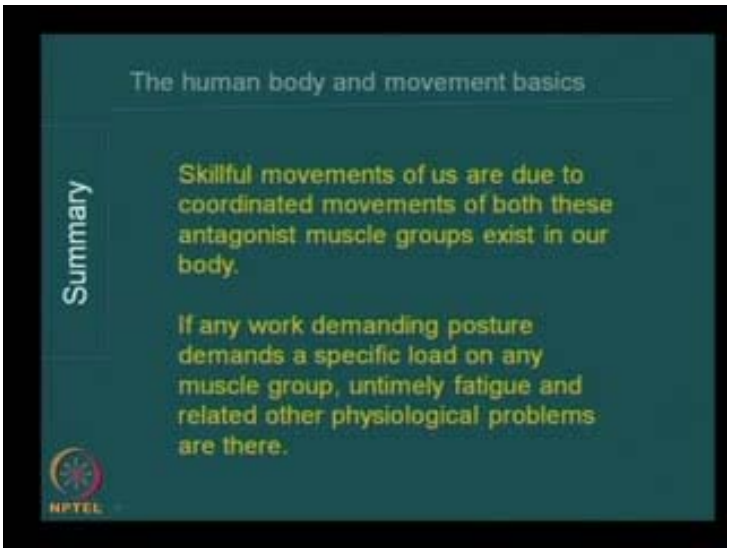

Now, skillful movements of us are due to coordinated movements of both these antagonistic muscle groups exist in our body. If any work demanding posture demands a specific load, on any muscle group, untimely fatigue and related other physiological problems are there.

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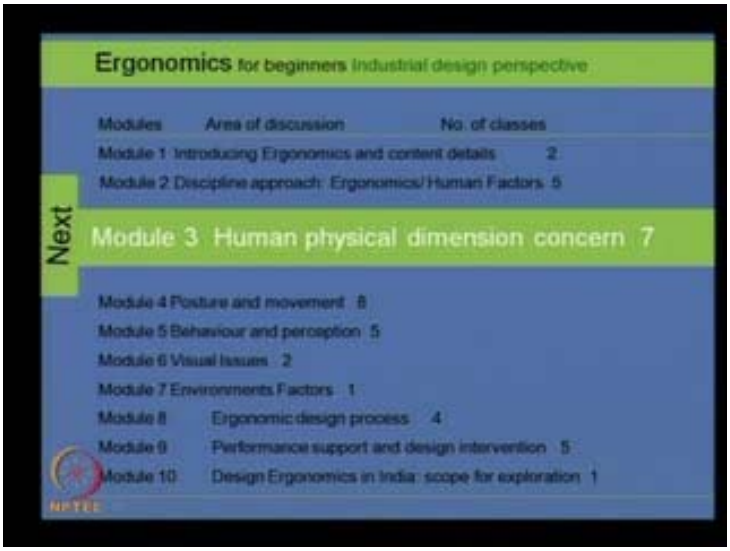

Now, whatever we discussed today, these are the general muscle matter - how we move, coordinated movement possible, what type of coordinated movement is not desired, if we

have to make a design or develop a work process, then what type of movement requirement we should consider, like this.

In next sessions, we will start the module 3. In this module 3, we will discuss the human physical body or human physical dimension concerns; mostly the human physical body, that is the length, the whole body structure, movement bionics etcetera and development of the body, and the structure and its growth relevances, and the male female variations and how to measure those things, human body dimension - that is anthropometry, etcetera, we will discuss in the next module. After these basics, we will see its design relevances.

So, till then, thank you very much. So today's session, it ends here.