>> Deb Feickert: Here we go. All right. So, we're tying out muscles and movement and muscles moving in our whole body and associating with things inside of our body. And we'll talk about all those things. But we also would say that it's not just movement, but other physiological processes that involve muscle tissue. And so, we are going to point some of those out along, of course, with dynamic interactions, meaning movement of our muscle tissue. And we've talked about this before in lab, where muscle tissue is composed of cells that are called fibers. So we have skeletal muscle fibers, cardiac muscle fibers, smooth muscle fibers, and that's just another word for the cells in muscle tissue. And those cells, those fibers are all contractile, contractile, meaning that they can shorten. So all muscle types, all muscle fibers, all fibers, which are cells can contract, shorten, and that creates a pulling force in some way. And so we're going to look at the three types of muscle. But today, we're going to stick with talking about skeletal muscle. So, skeletal muscle, when we talk about that pulling force, that contraction, that's moving the entire body by pulling on our bones, which we talked about a bit today with joints. Now we have our cardiac muscle. And the movement here is the movement of blood. So it pumps blood out of the heart, into and through the arteries and veins. And smooth muscle also creates movement. And this is more of a squeezing kind of a movement to move fluids and solids, for instance along the digestive tract. So again, we're going to talk about all three of these. We're going to encounter cardiac in much more detail when we talk about the cardiovascular system. We'll talk about smooth muscle in much more detail when we talk about the systems where we'll find smooth muscle. We'll finish our discussion on Thursday with a little bit of information about those. We're mostly going to spend our time on skeletal muscle because that's the group of muscles that relates to my bones and my joints, which is how we're grouping them. So, a skeletal muscle is an organ. And a skeletal muscle is either going to directly attach to the skeleton or indirectly attach to the skeleton. We'll look at some examples of what that would mean, indirectly attached to the skeleton. Here's some words we already know about skeletal muscle. Skeletal muscle is voluntary. That is, I have conscious control over the movement of my skeletal muscles. I control the contraction. The functions of skeletal muscle are certainly to bring about movement of my skeleton and my joints. So, we said today that muscle crosses a joint. And in crossing a joint, when that muscle contracts, it moves the bone and it moves the joint that it's crossing. But sometimes, I have contraction in skeletal muscle, but I'm not going anywhere. And so, if I'm sitting upright right now, or if I'm standing up, I don't fall over because my skeletal muscles are contracting even if I'm not moving to maintain my posture and body position. What did we talk about today? We also said that the skeletal muscles that surround a joint, that cross a joint are going to bring about structural support of that joint and also the soft tissues, nerves and blood vessels that would be next to or part of that joint or the bones in that area. And lastly, this is one of those physiological processes. Somebody mentioned a moment ago. Our skeletal muscles, more than any of our other muscles, although all three muscle types do this to some extent, help to regulate my metabolism, my metabolic

rate. And that's because skeletal muscle, as we're going to see at the end of this discussion, is– requires many mitochondria. It is a very fast contraction, it doesn't last long, but it requires a lot of energy. And in doing that and undergoing this movement and utilizing energy and mitochondria producing ATP to bring about this movement, the other thing that happens when my mitochondria are working, is that yes, I produce ATP to perform whatever task, in this case contraction of muscle, but the other thing that is formed is heat. And it is this constant movement, this constant ongoing production of ATP plus heat in my skeletal muscles that help to maintain my internal body temperature. And we'll come back to that in a bit, one of my favorite things to talk about with skeletal muscle. So we're going to start large scale, and as we move through these structures here today, talking again, about the skeletal muscle, we're going to start at the organ level, the organ called a skeletal muscle. And then we're going to get smaller and smaller and smaller. We're going to go from the organ level. And then we're going to go into the cellular level. And we're going to go into the organelle level, and keep getting all there as we move inward on a skeletal muscle. So we're going to start macroscopically large scale, this is what I can see as a muscle, the organ called a skeletal muscle. So here's some of the structures related. Tendons, we talked about in class today. Tendons are, right, there's my tissue, there's my histology, dense with an R, regular connective tissue. We mentioned that several times now, tendons and ligaments. The histology is dense regular connective tissue. And tendon attaches muscle to bone. There are a couple of specialized structures that we can talk about when we talk about tendons. One is called an aponeurosis. An aponeurosis is a wide flat, dense regular connective tissue sheet that now connects muscle to muscle. And so remember, at the beginning, we said that muscles either attach directly or indirectly to the skeleton, we have some muscles that attach in one place to the skeleton and another place to a muscle. And so, there's a large, why don't you just feel your abdominal cavity right now? There are some large muscles in my abdominal, along my superficial abdominal cavity, that there are no bones right in the midline of my body. And so those large muscles actually attach to each other by a wide, flat, dense regular connective tissue structure called an aponeurosis called the linea alba. And another structure that relates with the muscles are called retinacula. Retinaculum is singular, another dense regular connective tissue, but this is a band, and this band helps to hold tendons in place. So, one of the most famous retinacula bands is right over your carpals and you have a flexor retinaculum and an extensor retinaculum right at your carpals, right, and that is the carpal tunnel. So this– these are some related structures with the tendons. Another structure, and by the way, I want you all to know, I for whatever reason, I am unable to see our chat. So, if you have a question, please go ahead and just ask away because I cannot pull– I'm just glad we're recording at this point. So, I can't pull up our chat right now. OK. Epi means on top of mysi means muscle, epimysium is the– there's the word, superficial, outermost, the word is fascia. Now we're talking dense with an I, irregular connective tissue binding that surrounds the entire organ called the muscle. So it's called epimysium, superficial, outermost covering of the whole muscle.

Internally, within the muscle, is what's called perimysium. You know that peri means surrounding. And so now this is internal fascia, again, a dense with an I, irregular connective tissue grouping of bundled parallel skeletal muscle fibers. So we're going to look at a diagram in a second so we can see all of these. But inside of the muscle, we have groups of the skeletal muscle fibers that are bound together with some dense regular connective tissue. And that outside covering of that is called the perimysium. The bundles that are formed when they are surrounded by perimysium are called fasciculi or fascicles. And either one of those is fine. Those are both plural terms. So when I group skeletal muscle fibers together and I surround them with dense irregular connective tissue in a bundle, then that bundle is called a fascicle. And even, right, even more internal, what's called endo, within, mysium, endo means within. And now it's areolar connective tissue that surrounds each and every skeletal muscle fiber within a fascicle, endomysium. I'm also going to see blood vessels and nerves because this is living tissue. And I need to have blood vessels and nerves associated with all these fibers. So this is what it looks like. This is the humerus. And attached to the humerus is a tendon. A tendon attaches a bone to a muscle. And this is the entire muscle that we're seeing here. And in this position, this is the– would be the biceps brachii muscle. And so the entire muscle called the biceps brachii, OK, I want you to look right now, right, make a fist and flex your elbow. There it is. There's your biceps brachii right there on the anterior of your humerus. So, here's that biceps brachii muscle. And the whole muscle is surrounded by some dense with an I, irregular connective tissue called the epimysium, the whole muscle. But if I go inside the muscle, I'm seeing groups of fibers. These are each muscle fibers. So these are skeletal muscle fibers that have been grouped together. And the material that surrounds each of the groupings is called perimysium, also dense irregular connective tissue. And amongst the dense irregular connective tissue, perimysium are the blood vessels and nerves. You can see them scattered through here. That one group, that one group surrounded by a perimysium is called a fascicle. So I'm going to take one of those groups and pull it out of the muscle, that's a fascicle. So here's a fascicle, here's a fascicle, here's a fascicle. I've pulled one out. And with the fascicle pulled out, I can then also see in a more close-up version, this and this and this and this, these are individual skeletal muscle fibers, cells, skeletal muscle fibers. And then if I take just one of those, and by the way, each of those are now surrounded by an areolar connective tissue layer called endomysium. So when I pull out one fiber, one fiber, one cell, that's where we're going next. So, I'm going to look at now one of those cells I just pulled out, I just pulled it out. I just pulled out this one cell, one skeletal muscle fiber. And that's what we're going to look at next. So now I'm looking microscopically because it's a cell. And cells are microscopic. I'm going to look at a skeletal muscle fiber or a skeletal muscle cell. So, here's some terms I need you to know with just the cell. Every cell in your body is surrounded by a cell membrane. Skeletal muscle cells have their own name for their cell membrane. It's called sarcolemma. So this is the cell membrane of a skeletal muscle cell. The word sarco means flesh. So remembering what our skeletal muscle is, it's, right, it's meat. So, sarcolemma is the cell membrane of a skeletal muscle fiber or cell. And every single skeletal muscle fiber has a branch of a motor neuron. So let's just– we're going to just let that sit for a minute, we're going to look at this before we finish, and I will point this out to you again. We already know these words. We know that skeletal muscle cells, skeletal muscle fibers are multinucleated and striated, and that when they sit next to each other, they're arranged unidirectionally, they all face the same direction and they're parallel to each other, so some words that describe what skeletal muscle fibers look like under the microscope. You should be picturing that right now, what that looks like under the microscope. The other thing that skeletal muscle fibers have is cytoplasm, like all cells. And again, the cytoplasm in skeletal muscle fibers has its own name, sarcoplasm. And we know that within the cytoplasm, in this case, sarcoplasm of every cell are organelles. And so a skeletal muscle fiber would have all of the same organelles we would see in any cell. It's going to have, right, we know it's multinucleated, it's going to have smooth and rough endoplasmic reticulum. It's going to have the peroxisomes and the lysosomes and all of those things that we would see. But then it has its own specialized organelles unique to muscle cells, not just skeletal muscle, but we're trying a skeletal muscle today, called myofibrils. So myo means muscle, myofibrils are organelles within each skeletal muscle fiber that I'm only going to find in muscle cells. We've seen this before. This should look familiar. You see, it's like, yes, I know that, skeletal muscle, right, the striations and the multiple nuclei along the outside edge. They are long, they are parallel. They're all running in the same direction. Love it. So now, let's look at– here's my fascicle, like we just cut off a fascicle so we can see a fascicle. And remember a fascicle is multiple muscle fibers grouped together. And around the fibers is areolar connective tissue called endomysium. And then we take one, one, that's this one right here, sorry. I'm going to take one, one, one fiber, one cell and enlarge it here. And so I've got my endomysium, my areolar connective tissue that surrounds that fiber. And all of this is inside the cell. And so I have sarcoplasm and there's my sarcolemma. My sarcolemma is the cell membrane. So I'm seeing cell membrane right here. And I'm seeing these specialized organelles that I would only find in muscle called myofibrils. So now, we're going to take, yes we are, a myofibril and look at it. So we're still microscopic. And myofibrils are organelles. And so we're going to look at the structure of the organelle called the myofibril. Just like we looked at the structures of all the other organelles in our second day of lecture, we're going to now look at this particular organelle because we're talking about muscle now. So, here's what we know. A myofibril is an organelle. That's made up of protein. And the protein is grouped together, and filaments or rods that is long, slender, parallel structures. So these protein filaments are grouped together inside of the organelle called myofibril. And those protein filaments have the name. They're called myo for muscle filaments. So my myofibrils are my organelles that we just looked at a moment ago. And that organelle is made up of some protein filaments called myofilaments. And every skeletal muscle fiber has anywhere from a few hundred to over 1,000 of these organelles within the cell. And the number depends on the, where that muscle is, how active that muscle is, how trained that muscle is. And we'll talk about that in just a bit. So, those myofilaments, the protein rods that make up the organelle are arranged in very specific geometric pattern. And this very specific geometric pattern forms a structure that's called a sarcomere. And I'm going to show you diagrams of all of this. So a sarcomere is a repetitive subunit within the myofibril of these filaments. So the filaments are arranged in a particular pattern, and that forms a visible– under the microscope, a visible structure called the sarcomere. And please notice, please highlight it now, this– these repetitive subunits called sarcomeres, which are made up of these protein filaments are the basic units of contraction. This grouping of structures called sarcomeres is what brings about contraction in skeletal muscle. We'll look at it in just a second. Each sarcomere has a boundary. And the boundary that is an end to an end from one end to the other end of a sarcomere, the ends are called z-discs or z-lines. So what that means is the area between two z-discs is the sarcomere. So I see one z-disc, I see a second to z-disc. And in between those two z-discs is the structure called a sarcomere. So this is what it looks like. So I pulled out, right, pulled out a myofibril, an organelle, out of the cell. And I have a structure that I can see under the microscope called the z-disc. And I have another structure that I can see which is another z-disc. And I have another structure over here, which is another z-disc, and another. So, all of the space between one z-disc and the next, from this z-disc to this, from this z-disc to this, that is called a sarcomere. So here's one sarcomere. Here's another sarcomere. Here's another. They sit in a series that is one next to each other, these sarcomeres. And what we're seeing in the sarcomeres is we're starting to see this banding, this very visible, also under the microscope, these bands that we would see of protein filaments. And if I were to cut the end of a myofibril, and then look at it on the end. This is what we mean by a very specific geometric pattern of protein filaments. So I'm seeing these large protein filaments, and this very obvious pattern, and these smaller protein filaments, and this very obvious pattern. And this very specific placement of these protein filaments are what give this appearance of striations on the myofibril. So let's talk about the myofilaments and we'll look at some more diagrams. So the myo– remember, myofibril is the organelle. The organelle is made up of proteins called myofilaments. Proteins are molecules. So, I'm going to talk about the molecules called myofilaments. We're going to discuss two. We have one type of protein filament called myosin. And an example I just showed you, we'll look at it again in a second, in that very specific pattern we just looked at, the myosin were the thick protein filaments. They are going to be arranged in the center of a sarcomere, that is in the center between a z-disc and the next z-disc. And we're going to– I'm going to point all this out to you in just a sec. Every myosin myofilament on its ends, not in the middle but on the ends have little knobs that are called myosin heads or myosin crossbridges. So they have– they resemble– it's often described as resembling the head of a golfclub, these little myosin heads or myosin crossbridges. Again, we'll see them in just a sec. The myosin crossbridges overlap the ends of the second protein filaments called actin. And the actin are the thin protein filaments in the diagram we looked at just a moment ago. And we'll look at it again. And the actin are attached directly to the z-discs. So the z-discs, remember, are my boundaries for my sarcomere, the actin filaments attach to the z-disc, and the myosin filaments are in the middle. And those actin filaments are going to extend from the z-discs toward the center of the sarcomere, toward the center of the sarcomere. It looks like this. So, again, here's the z-disc to z-disc, that's a sarcomere. If I cut it at the end and look at it, what I'm seeing are the thick, these are the myosin now in green, and the thin surrounding them, actin, in red. And this is what it looks like. This diagram is what that would look like in a diagrammatic form. So this is what we just talked about. Here is a z-disc, here is a z-disc, there would be another z-disc over here, another one over here, but we're looking at one sarcomere. So between z-disc to z-disc is a sarcomere. And in the center is this thick, look how thick it is, a thick myosin filament, myofilament that on the ends have these little nobs, called crossbridges. And here they are on the other end. So I see the myosin crossbridges only on the ends of the thick myosin, not in the middle. And then attached to the z-disc are the thinner actin. And the actin are extending toward the center. This is what that means. They're attached here and they move toward the center of the sarcomere. They're attached here and extend toward the center of the sarcomere. And the actin overlaps the myosin crossbridges. Here are the myosin crossbridges. Here's actin, myosin crossbridges, actin. So that's what overlapping means. So what happens with muscle contraction? It's called the sliding filament theory. It is much more complicated than what we're about to mention. You'll talk about it in great detail in physiology. Here's what I want you to remember, just the mechanics of the sliding filament theory, not– none of the physiology. So, when a muscle contracts, the myosin crossbridges, the heads, the little parts that look like golfclub heads, pull the actin over the myosin. And when that happens, remember what the actin is attached to, the z-discs for the z-lines. We could say it either way, it's fine. And so, when the actin gets pulled over the myosin, the z-lines move closer together and the sarcomere shortens. And when the sarcomere shortens, that's contraction. Three steps, very basic, none of the physiology, just the mechanics, what is happening with our filaments. So, it looks like this. Here is– Here's my muscle. Here's my biceps brachii. This is a relaxed sarcomere that we just saw a moment ago. Myosin in the middle, actin attached to the z-discs here, here, here, here. It overlaps the crossbridges. When a muscle contracts, the crossbridges attach to the actin and pull from this end and pull from this end, moving the actin more toward the middle of the sarcomere. And if the actin is going to the middle, so are the z-discs. So that I start to see the actin overlapping even more of the myosin, and the z-discs are getting closer to each other, a little bit of contraction. Fully contracted, the actin fully overlap each other and the myosin and the z-discs are as close as possible to each other, full contraction on a sarcomere. And remember, this is just one sarcomere. There's another one here. There's another one here. There's another one here. There's another one here. And this is in just one, just one of the organelles called just one of the organelles– sorry, I can't say that enough, called the myofibril. So, skeletal muscles contract along their entire length, or they don't contract at all. The fiber, I should say, not the entire muscle, the skeletal muscle fiber, one cell. It's either going to contract, or it's not going to contract. It's called the all or none principle. So it either contracts or it doesn't. So what does that mean, though? We just looked at a couple of diagrams that showed the entire muscle, the biceps brachii, right? You can do this right now. You can partially contract that muscle, you can contract it a little more, you can contract it a little more. So what's happening? That difference in how much force you're exerting depends on the number of what we call motor units, how many motor units are in play, activated. And so what's the definition of a motor unit? We've mentioned this before and said we were going to come back to it. One motor neuron and all of the muscle fibers it innervates is called a motor unit, I'm going to show you a diagram. So, in order for a skeletal muscle fiber to contract, it needs to get a signal, it needs to be innervated, and get a signal from a motor neuron. And motor neurons have branches at their axon end that can interface many different skeletal muscle fibers, in this case, because we're talking about skeletal muscle. So I'm going to show you a diagram of that in a second. Skeletal muscle, I said this at the beginning, very high energy demand, and so there are going to be a lot of mitochondria. Remember our discussion of the cell. We said that different types of cells have different numbers of organelles. And when we talk about mitochondria, the number of mitochondria the cell has, has to do with how much energy that particular cell needs. Skeletal muscle needs a lot of energy. That movement of a skeletal muscle requires a great energy demand. What do mitochondria do? They produce ATP plus heat. So now we go back to that comment we made at the beginning, where we said that skeletal muscle helps us move, it helps support, gives us structural support of soft tissues, it crosses a joint for skeletal and muscular– skeletal and joint movement. But it also brings about metabolism. And so, I want you to think about this a minute. If you are wanting to increase your metabolism, that is, burn more calories all the time, the best thing you can do is build muscle because skeletal muscle is undergoing metabolism continuously. So someone that has a lot of skeletal muscle can eat a lot because they are burning calories all the time. So, continuing that thought, if I am on a weight loss program, weight control program, I don't necessarily– I shouldn't necessarily be worried about running 10 miles a day. That's good for my heart muscle. What I should be doing is building muscle and doing weight training to build skeletal muscle because it– there's a lot more fat than there is cardiac muscle and it is working continuously. Love the skeletal muscle. Internal body temperature connection, also helps regulate like internal body temperature, this ongoing release of heat. That's where my 98.6-degree temperature comes from, all of my cells undergoing metabolism continuously. The contraction in skeletal muscle is very fast. But it also fatigues quite easily, especially if not trained. So, I wish I could be in front of you. Some of you who have had other classes with me. One of my favorite things to demonstrate is the first day of freshman high school PE class, where your PE coach asks you or tells you– let me change that, tells you that today is the first day for the timed mile run. We're going to start with a baseline and we're going to go from there. And the coach says, on your mark, get set, go. And you start off and you're think you're looking pretty good, and you're jogging and you're jogging, and you're looking around at your friends, and you're laughing, and you're talking until you get about one half of the way around the first curve. That's about an eighth of a mile. And then you start. [Heavy Breathing]. And then you start kind of slowing down, and then oh, oh, oh, start getting that stitch in your side, and pretty soon, you're crawling because you have not trained your muscles. And you don't have enough mitochondria. And you're not utilizing the oxygen you're breathing into your body to produce ATP. And yeah, your body said, I don't think so today. Yeah, training, it fatigues easily without. So here's what a motor unit looks like, a single motor neuron will have multiple branches at its axon end. And that one motor neuron can innervate multiple, you can see here, multiple fibers, skeletal muscle fibers. So that one other neuron and all of the fibers it innervates is called a motor unit. So in order to get a higher force contraction, I need to engage more motor units. Muscle hypertrophy and atrophy, this will end our discussion. So, when I exercise, this is what I get an increase in the skeletal muscle fiber, the number of mitochondria. More demand, more organelles are produced, manufactured, I'm going to get more mitochondria. So with training, I don't feel so tired, I don't get the stitch in my side, I don't run out of energy. I get an increasing number of myofibrils, the other organelle, right? And so the net effect then is that I get hypertrophy, which means an enlargement of that muscle fiber. And so if I have all of my muscle fibers enlarging, then I am going to get a larger muscle at the organ level. If each of my individual fibers are getting bigger, when I put them all together, I'm going to get a larger muscle. Sadly, the opposite also occurs. If I'm not using my muscles, I'm going to get atrophy, which is a reduction in the number of mitochondria, the number of myofibrils, and the size of the muscle. This often happens. This may have happened to you before, right, if you have a limb in a cast, and you can't move the muscle. When you take that cast off, if it's been on for several weeks, you'll see a noticeable difference in the size of one muscle versus the other. And so, one last time, here today, this is my– this is our example today, the humerus, the muscle called– we're just going to say it, it's the biceps brachii. The tendon attaches the bone to the muscle. The outside covering is called the epimysium, dense irregular connective tissue. Internally, I have these groupings of muscle fibers. These are each muscle cells, muscle fibers. They're grouped together in a grouping called fascicle. And the outside covering grouping them is called peri, surrounding, mysium. I pull out one fascicle, these are muscle fibers, individual cells. They are surrounded by some areolar connective tissue called endomysium. And then if I pull out one of these, this is muscle fiber, muscle cell. And these are the specialized organelles that we call myofibrils. So, cool. I'm going to end the recording so that it sends to the cloud. And then I'll come back and see–