Educator's Guide and Script For *Human Body: The Muscular System*

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INTRODUCTION

The goal of this program is to present an upper level high school or introductory pre-med or pre-nursing school overview of the anatomy and physiology of the muscular system. Using the latest in 3-D graphics, medical imaging and for the first time detailed cadaver dissection, this program is designed to maximize student learning. This program begins with an introduction to the muscular system and how it interacts with the skeletal system, using the principle of the lever to move the skeletal system around. Muscle and bone anatomy are described in the next chapter. Next, muscle chemistry and how muscles work are examined in depth. In muscle anatomy and physiology, the different muscles of the body from the head to the feet are described. Then, the important glue tying the muscles and bones together - the tendons, ligaments and fascia - is looked into. A cadaver dissection of the knee follows with a look at muscles diseases and exercise. The program ends with a discussion of the involuntary muscles that pump blood through the arteries and veins and move food through the digestive tract.

ADVANCED VOCABULARY DEFINITIONS

- **Achilles tendon**: Thickest and strongest tendon in the human body, extending from mid-calf to the heel
- **Anterior cruciate ligament**: A primary stabilizing ligament within the center of the knee joint that prevents hyperextension and excessive rotation of the joint.
- **Biceps**: A group of muscles present in the upper arm, which are flexors of the elbow joint
- **Cardiac muscle**: The muscle tissue of the heart
- **Collagen fibers**: found in cartilage, tendons, skin, and bones and the fine fiber structure gives them great strength

- **Collagen protein**: A natural protein found in humans that forms connective tissue and provides strength, resilience, and support to the skin, ligaments, tendons, bones, and other parts of the body
- **Deep fascia**: A layer of fascia which can surround individual muscles, and divide groups of muscles into compartments
- **Fascia**: A sheet or band of fibrous connective tissue separating or binding together muscles and organs
- **Femur**: The longest and thickest bone of the human skeleton; extends from the pelvis to the knee
- **First class lever**: In a first class lever the fulcrum is located between the applied force and the load as with a crow bar or teetertotter
- **Fulcrum**: The pivot about which a lever turns
- **Gastrocnemius muscle**: The muscle in the back part of the leg that forms the greater part of the calf;
- **Hamstring muscle**: One of the three muscles in the back of the thigh
- **Heart attack**: Myocardial infarction (MI) or acute myocardial infarction (AMI), commonly known as a heart attack, is the interruption of blood supply to part of the heart, causing some heart cells to die
- **Humerus bone**: long bone in the arm or forelimb that runs from the shoulder to the elbow
- **Involuntary muscles**: The smooth muscles that are not directly controllable at will
- **Lever**: A rigid object that is used with an appropriate fulcrum or pivot point to multiply the mechanical force (effort) that can be applied to another object (load).
- **Ligaments**: A band of strong, fibrous connective tissue that connects one bone to another
- **Patella**: A small flat triangular bone in front of the knee that protects the knee joint
- **Posterior cruciate ligament**: The ligament, located in the center of the knee, that controls backward movement of the tibia
- **Quadriceps muscles**: The strongest and leanest muscle in the human body, it is a large muscle group that includes the four prevailing muscles on the front of the thigh
- **Radius**: The outer and slightly shorter of the two bones of the human forearm
- **Second class lever**: In a second class lever the the load is situated between the fulcrum and the force as in a wheelbarrow
- **Smooth muscles**: An involuntary non-striated muscle
- **Stroke**: The sudden loss of consciousness resulting when the rupture or occlusion of a blood vessel leads to oxygen lack in the brain
- **Tendon**: A tough band of fibrous connective tissue that usually connects muscle to bone
- **Tenocytes**: Cells located in tendons, they are elongated fibroblast type cells
- **Third class lever**: In a third class lever, the force is applied between the fulcrum and the load as in the human elbow joint when flexing
- **Ulna**: The inner and longer of the two bones of the human forearm

SCRIPT

HUMAN BODY: MUSCULAR SYSTEM

The miracle of all miracles on this planet is the human body. Now see it in a way never revealed before.

The muscular system is perhaps the most fascinating of all the body's structures. Hello, I am Dr. Mark Reisman. Of all the body systems, the muscular is the one we have the most control over. Yet there is a part which is just the opposite. It is the part that keeps us alive. And in a unique way, the muscular system even helps us communicate with each other, communicate our emotions in a way no other species in the animal kingdom can do.

Introduction

These muscles, the ones that produce a smile and a frown, are attached to the skull bones. There are around 30 facial muscles in all. The ones surrounding your eyes are the most active and you probably blink over 14,000 times a day. As we can see and feel, they do not move the bones of the skull.

However, most muscles do move the bones of the skeleton. They animate the body. Remarkably, muscles, together with our bones, make all our daily movements possible. Sean and Paula are skillful tennis players. Through practice and training they have developed control over their muscles so they can move about the court with speed and a high degree of accuracy, speed and accuracy that allow them to hit the ball with just the right amount of power. One of the miracles of the human body is just how brilliantly the skeletal and muscular systems work together, work together creating such a wide range of movements.

Let's look at a model of the human skeleton. Now let's add the muscles. Incredibly the skeleton is covered and surrounded by muscles.

So what makes it possible for the full range of movement available to the human body to be produced by these two systems? Ingeniously, the muscular and skeletal system work together as a simple machine.

A simple machine like a playground teeter-totter. A teeter-totter allows a person using a fulcrum to easily lift a heavier person on the other end. It's called the principle of leverage.

Lever Principle

There are four aspects to any lever: the lever itself, in this case, the teeter-totter plank; the load or the object to be moved, the heavier person; the force – the lighter person; and the fulcrum, the point on which the board rests.

Now a mechanical advantage is gained when the distance from the fulcrum to the lighter person is greater than the distance from the fulcrum to the heavier person.

So in your body the bones are the rods or planks. Joints are the pivot points or fulcrums. The muscles supply the force. And what's moved? … a leg or an arm.

The teeter-totter represents a first-class lever. There are two other types of levers, and the human muscular system employs all three. A tennis player, as he prepares to serve, illustrates all three types of levers.

In tilting his head back, Sean is employing a first-class lever like the teeter-totter.

Now looking at his feet, we can see that Sean has moved the weight of his body onto his toes and in doing so is using a second class lever.

However, third class levers are the most common in the body. In bending his knees and pulling his racket back, Sean is now employing a third class lever, as illustrated here. Now in real-time: head tilting back, the swing of the racket, and the lifting of the foot. All fluidly executed in one motion.

Remember the teeter-totter, Marcus here can lift the load on the other end by either pushing or pulling. Muscles of the body only pull. They do this work by contracting, and they do this in a most ingenious way. They work in pairs. Muscles that move the skeletal bones always work in pairs. A little over 300 pairs in all.

Lifting and straightening the leg while walking is typical of how a paired group of muscles work together.

As Sean is walking back from the net to serve, he is constantly lifting one of his lower legs off the ground, pulling it up and then straightening it back down. Then he does the same thing with the other leg. This is basic walking.

Muscle and Bone Anatomy

Let's look at how the muscles and bones work together to produce movement. Here is the bone of the upper leg, and the lower leg bone. And here they are connected at the knee joint, and as you can see, the patella.

Running along the back of the upper leg bone are the powerful hamstring muscles. To the front are the quadriceps muscles. See how they attach to the lower leg bone. For the lever principle to work, a muscle must cross over a joint. In this case, the bones, muscles and joints form a classic third class lever. Remember it's the most common kind of lever in the body.

So, when Sean needs to lift his foot, the hamstring muscles contract. At the same time the quadriceps muscles relax and lengthen.

Then, when Sean needs to straighten his leg, the quadriceps contract and the hamstrings relax.

Moving onto the arm, here is how the muscles and bones relate to each other.

Now going inside, see how the humerus bone is connected, by the bicep, to the radius bone, and the ulna and humerus bone by the tricep muscles.

Muscle Chemistry

Together they produce this movement. Muscles need a ready supply of energy, chemical energy stored as glycogen in the muscles and brought to the muscles by the blood of the circulatory system. Chemical energy that is in the form of sugars, which are converted in the muscle cells to ATP - adenosine triphosphate, which in turn is then converted to mechanical energy. Do this a number of times and eventually Ray is going to need to rest. He will run out of energy. While resting, Ray is letting the ATP get replenished as sugars are brought to the muscles from the blood stream.

Now Ray can resume his workout.

How Muscles Work

Pairs of muscles working together beautifully. But how do muscles contract in the first place? What is the mechanism? Deep inside the muscle tissue itself lies the answer.

The first thing to notice is that muscles are striated, that is, the muscle fibers, or filaments, lineup parallel to each other.

As we go a little deeper, we find that there are two kinds of muscle fibers: actin filaments and myosin filaments, myosin filaments that are characterized by a club-like protrusion at their head end. It is this club-like protrusion - powered by ATP - that flexes. As it flexes, it pulls a nearby actin molecule. Together they act as sort of a ratchet system. The pulling is the contraction, the mechanical action at the molecular level, a mechanical action that when spread across the whole muscle produces the large contraction. That is the bodybuilder curling his bicep. And because muscles are sensitive to nerve impulses from the brain, the whole process is triggered, when Ray decides to lift the barbell.

So we have just learned how muscles do their work by contracting and then relaxing.

Muscles Anatomy and Physiology

There are over 600 muscles of the body. Interestingly, the average adult male's skeletal muscle make up 42% of his weight. The average female's skeletal muscle makes up 36%.

Some muscles are involuntary. That is, they are muscles we have no control over. For example, our heart beats without us ever having to think about it. But most muscles are voluntary.

We can control them, such as our tennis players are doing here. Let's look in detail at these first. Most voluntary muscles are skeletal muscles. They are the fleshy part of the body. They move bones around. Let's take a trip through the skeletal musculature of the human body.

Starting with the head we find there are many muscles for many functions.

This one raises eyebrows.

Moving down the skull here is the muscle that closes the eyelid.

This one raises the upper lip, and this one pulls down the lower lip, which comes in handy when puckering or kissing.

Next, when talking about putting force on an external object, nothing beats the masseter or jaw muscle, a muscle used in chewing and closing the mouth. Indeed, the human bite can deliver a force equal to 150 pounds per square inch. Interestingly, the reason this muscle is the strongest is not because there’s anything special about the muscle itself, but its strength derives from the fact that it maximizes the leverage principle more than any other muscle.

Moving down to the chest area, we find a number of well-known muscles.

The trapezius, which rotates the shoulder blade.

The pecs or pectoral muscles, the muscles that give definition to many bodybuilders. Curiously they have a remarkably limited function, rotating the arm toward the body.

Raising the arm or moving it away from the body is the job of the deltoids.

And then there are the intercostals, muscles that move the ribs.

Rotating to the back of the body, we come across a muscle that covers the largest surface area in the body – the latissimus dorsi.

Underneath the latissimus dorsi and below the intercostals are the internal abdominal obliques. They support the abdominal wall; help in breathing; facilitate moving from the center, and help form the infamous body builder’s six pack.

Staying on the back side of the body, here are the muscles that stabilize and rotate the hips.

Below them is the bulkiest muscle in the body: the gluteus maximus. Its function is to pull the body back into an upright position when walking, running, or after jumping. By another definition of strength, this muscle is the strongest, that is, its strength refers to the force exerted by a muscle. And because the tension exerted by an individual muscle fiber varies little across all the skeletal muscles, the one with the largest cross sectional area becomes the strongest.

We have already looked at the role of the hamstrings, and so we come to the gastrocnemius and soleus, the calf muscles.

Now, if we rotate back to the front, we see the quads, which we illustrated earlier. And, of course, we have already looked at some of the main arm muscles.

Tendons, Ligaments and Fascia

We know that we can isolate both bones and muscles in the lab, but somehow in the body they must get connected. What is the glue that ties the skeletal and muscular systems together into a movable functioning unit? There are three different kinds.

Tendons, or sinews, connect muscle to bone. Tendons anchor all muscles that cross the body's major joints. Strong but not very elastic, tendons are made up of specialized cells, called tenocytes, water, and fibrous collagen proteins. Millions of these collagen proteins weave together to form a strong strand of flexible tissue like this, tissue that grows into the bone and forms a tough mineralized connection. This connection creates a permanent bond between the muscle and bone that is extremely tough to break.

Ligaments are the fibrous, slightly stretchy connective tissues that hold bones together in the body, bones that form the bodies many joints. What ligaments do is stabilize and control the range of motion of a joint. For example, they prevent your elbow from bending backwards. Ligaments are composed of strands of collagen fibers that are arranged in crossing patterns giving them their strength.

Fascia is a brilliant piece of biochemical engineering. It is thin, fibrous and strong. One of its functions is to connect the skin to the muscles that lie just below it. On your head it holds your scalp on by connecting your skin to your skull. Deep fascia covers the muscles and organs helping to keep them divided and protected.

There you have it, the 3 kinds of connective tissue that let the skeletal muscles do their job, moving you about powerfully and freely. So let's now look at them for real.

Knee Anatomy

Recalling what we learned about the muscles, now let's use this beautiful anatomical specimen of the leg to demonstrate some of those aspects. Here you see the top part of the leg, or the thigh, and this is the muscles or the quadriceps of the thigh. Quadriceps represent the four muscles that ultimately insert into a tendon. A tendon, as you recall, is a connection between muscle and bone. In this particular aspect of the leg, the tendon is basically inserting into the patella. And as you can see, this very smooth and glistening patella ultimately articulates with the bone below, which is the leg bone, or femur. Below, you see some very important aspects as well. In particular, you see here, what I'm grabbing, is the anterior cruciate ligament. This is the ligament very often injured when football or basketball players hurt their knees. As you can see, it's a very, very large and very, very strong ligament. Again, the anterior cruciate ligament. Behind it, you will find what's called the posterior cruciate ligament.

Muscle Disease

This is one of my patients, who's chief complaint was soreness in his elbow. The patient is an avid tennis player, and predominately he complains of a lot of discomfort in the lateral aspect of his elbow. This is a very typical overuse syndrome, especially in tennis players. It's really involving the muscles and the tendons, and it really is about having an inflammation of the particular joint. But it's always important just to get an x-ray just to be absolutely sure there are no bony abnormalities. As you can see here, this looks like a very nice and normal x-ray. So the diagnosis for this particular patient would be what we commonly call tennis elbow.

One of the most devastating sports injuries is rupture of the Achilles tendon. Here, I've localized the Achilles tendon, and it's attachment between the ankle and the very large calf muscles, or gastrocnemius muscles. This particular tendon takes a tremendous amount of wear and tear as we walk and jump and do other sports activities. Clearly it has to be very, very strong, and rupturing it has significant consequences, because as you can see, this tendon is integral to both flexion and extension of the foot. I'd like to just demonstrate how thick it is by attempting to cut it. As you can see, I have isolated it with these two hemastats, and even with these very sharp scissors, I'm having quite a bit of difficulty in cutting this thick tendon. And here you can see the thickness of that tendon, and why it plays such an important role.

Muscles and Exercise

As everyone knows, through exercise, we can increase the size of our muscles and become more powerful. A bodybuilder like this can increase his lean muscle mass by an astounding 10% in extreme cases.

What's amazing about increasing muscle size and strength is how quickly the body responds to exercise. In literally a few days, a positive change can be experienced. Indeed, working out for only a few minutes every other day will increase muscle mass. Muscle mass grows in part because the number of muscle cells have increased. But most of the growth of muscle mass occurs because the muscle cells themselves have gotten bigger.

Increasing muscle mass increases BMR – Basal Metabolic Rate – and more muscle mass is very important if you want to lose weight. On their own, muscles burn 3 times more calories than fat.

Unfortunately, as fast as muscle mass can build up, it can go away even faster, as fast as two weeks if you stop exercising.

Because muscle building is a high impact exercise, Ray can only lift these weights a few times before fatigue sets in.

Low impact exercise, such as long-distance running, increases endurance. A long-distance runner can run for many miles before muscle fatigue sets in for him**.**

Muscles also contribute to the miracle of the human body in three surprising ways. One, they are electrochemical sensors that can respond to the environment and send messages to the brain. For example, muscles send messages about whether they are contracting or relaxing to the brain.

Two, muscles give us our sense of where our body and limbs are in three-dimensional space. Proprioceptors in the muscles are specialized sensory receptors that provide internal information about joint angle, muscle length and tension.

Finally, they are little chemical factories that turn chemical energy into mechanical energy and heat, heat that is used to keep our body temperature at a constant 98.6°F.

Involuntary Muscles

Ever wonder how food gets sent along a digestive tract once it's swallowed? ... or wondered how the blood is moved through the veins to the heart? It's because of the second type of muscle tissue in the body, called smooth muscles. And unlike skeletal muscles, they are non-striated and don't work in pairs. They are involuntary muscles.

They just do their job all by themselves throughout the lifetime of an individual. And what they all have in common is that they contract and relax slowly.

And then there is the most miraculous muscle tissue in the body, found in only one place. The cardiac muscle is located in the heart. It is different than both striated and smooth muscles. The heart can be viewed as one big muscle.

It works constantly, on average 70 beats per minute, every day, every year, sometimes for over 100 years.

Conclusion

Tennis, weightlifting and running are important exercises to maintain health not only for your muscles, but for the most important muscle, and that being your heart. Exercise is very critical to reduce the risk of stroke, heart attack, and helps manage your blood pressure. So make exercise a critical part of your normal daily routine.

Looking once again at the beauty, power and fluidity of our tennis players, we now know that the muscular system is the very essence of life, animating everything we do, pumping blood through the cardiovascular system, moving food down the digestive tract and out the excretory system. Using the principles of leverage, it turns the skeletal system into a motion machine. Lastly the muscular system lets us be human, communicating and sharing our feelings and emotions.

So, isn’t it just incredible, the human body? Through the simplest of motions, a tiny contraction performed at the cellular level deep inside each muscle - tiny contractions performed millions of times each day - has turned us into the most dynamic animal species on the planet. That’s the beauty of the muscular system. Thanks for watching, I’m Dr. Mark Reisman.

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Executive Producer
William V. Ambrose

Hosted by Dr. Mark Reisman
Medical Consultants: Ray W. Howe, M.D. and Jennifer Hronkin, M.D

Educator’s Guide and Script by
Ron Meyer and Mark Reeder

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