Educator's Guide and Script For
Human Body: The Skeletal 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 skeletal 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. The program begins with a brief discussion of the human shape and how humans are part of the group of animals known as vertebrates. It then discusses the spine and the vertebrae, showing the spines several regions – the cervical, thoracic, lumbar, sacrum and the coccyx. Next, an in depth look at the bones shows how the different bones of the body provide unique functions from the dexterity weight bearing and the composition and protective function of the bones such as in the pelvis, skull and rib cage. The program ends with an examination of bone joints and how they work, how cartilage functions to allow joints to move smoothly and the how bone diseases impair the function of our bones.

ADVANCED VOCABULARY DEFINITIONS

- **Acetabulum**: The cup-shaped hollow in the hipbone into which the head of the femur fits to form a ball-and-socket joint
- **Anterior cruciate ligament**: A primary stabilizing ligament within the center of the knee joint that prevents hyperextension and excessive rotation of the joint
- **Ball and socket joint**: a freely moving joint in which a sphere on the head of one bone fits into a rounded cavity in the other bone; a joint that can rotate within a socket
- **Bone marrow**: The fatty network of flexible, connective tissue found in the hollow interior of bones
- **Carpals**: The eight small bones of the wrist
- **Cartilage**: A tough smooth elastic tissue that covers bone ends of a joint to cushion the bone and allow the joint to move easily without pain

- **Cervical spine**: The neck region of the spine containing the first seven vertebrae
- **Coccyx**: Commonly referred to as the tailbone, it is the final segment of the human vertebral column
- **Cortical bone**: The hard, strong outer shell of bone
- **Cortical layer**: The hard shell-like tissue of the bone, rich in minerals calcium and phosphate
- **Cranium**: The part of the skull that encloses the brain
- **Femur**: The longest and thickest bone of the human skeleton, it extends from the pelvis to the knee
- **Fibula**: The outer and thinner of the two bones of the human leg between the knee and ankle
- **Gliding joint**: A freely moving joint in which the articulations allow only gliding motions
- **Hinge joint**: A bone joint in which the articular surfaces are molded to each other in such a manner as to permit motion only in one plane - backward and forward
- **Lumbar spine**: The lower spine area consisting of five vertebrae,
- **Metacarpals**: Any bone of the hand between the wrist and fingers
- **Metatarsals**: The five long bones in the foot located between the ankle and the toes
- **Osteoarthritis**: The chronic breakdown of cartilage in the joints; the most common form of arthritis occurring usually after middle age
- **Patella**: A small flat triangular bone in front of the knee that protects the knee joint
- **Pelvis**: The large compound bone structure at the base of the spine that supports the legs. It consists of hip bone, sacrum and coccyx
- **Phalanges**: The bones that form the fingers and toes
- **Pivot joint**: A freely moving joint in which movement is limited to rotation
- **Posterior cruciate ligament**: One of the four major ligaments of the knee, it is located in the center of the knee and controls the backward movement of the tibia
- **Pubic symphysis**: The bony prominence in the pelvic bone found in the midline
- **Sacrum**: The wedge-shaped bone consisting of five fused vertebrae forming the posterior part of the pelvis; its base connects with the lowest lumbar vertebra and its tip with the coccyx
- **Spinal cord**: A long, thin, tubular bundle of nerve tissue that extends from the brain through the spinal column down to the space in between the first and second lumbar vertebrae
- **Spine**: The series of vertebrae forming the axis of the skeleton and protecting the spinal cord; also known as the vertebral column and the spinal column
- **Spongy bone**: The inner layer of bone; found at the ends of long bones and is less dense than compact bone
- **Sternum**: A long flat bone located in the center of the chest
- **Sutures**: Fibrous joints which only occur in the skull
- **Tarsals**: The seven bones of the ankle
- **Thoracic spine**: The 12 thoracic vertebrae compose the middle segment of the spine between the cervical vertebrae and the lumbar vertebrae

- **Tibia**: The inner and thicker of the two bones of the human leg between the knee and ankle
- **Vertebra**: An individual bone in the flexible spinal column that defines vertebrate animals
- **Vertebral joints**: The flexible joints of the spinal column

SCRIPT

HUMAN BODY: THE SKELETAL SYSTEM

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

Humans are part of that large group of animals we call vertebrates, animals with backbones, with a skeletal framework. But what separates humans from all the other vertebrates is that our framework of 206 bones allows us to walk upright effortlessly, hands free, for hour upon hour. Join me, Dr. Mark Reisman, as we explore this wonder of structural engineering.

Introduction

The human shape is quite distinct, distinct from a bird, from a deer, from an ancient dinosaur. Yet all these animals have in common the same basic set of bones. How they are laid out and molded gives each kind of vertebrate its unique shape and determines how it is able to move. While there are many body plans – bone layouts – in the vertebrate kingdom of animals, they all have two things in common: a skull and the backbone.

In humans, the back bone, or spine, is critical in shaping posture, posture that gives us humans good balance, helps us breathe comfortably, and provides flexibility to generate a wide range of movements.

Spine

When Ravi, a Yoga master, starts from an upright position and slowly moves to touch the floor, his backbone moves slightly backward. Not only can it bend backward, but it can twist a bit from side to side. This flexibility is possible, not because the backbone is elastic, but because it is made up of many parts.

Here is one of those parts, called the vertebrae. This is the body of the vertebrae. In between the bodies of the vertebrae are the discs. These discs are like shock absorbers for the person as they walk. If you look at the vertebrae, not only is it used for support, but it's also used for protection of the spinal cord and the various nerves – these yellow rubber tubes that you see here emanating from these vertebral bodies.

The human spine, or backbone, contains 33 of these vertebral bodies. And it's divided into five regions. Starting from the bottom with four fused vertebrae that form the coccyx, and ending at the base of the skull

The backbone, or vertebrae are separated into several regions. They all have common functions. They support the body, keep the body upright and afford us balance, and also for protection of the internal organs, like here in the chest – the heart and lungs – and also, of course, the blood vessels throughout the body. The vertebrae or backbone are separated into several regions. The top region, closest to the skull, is the cervical region. The skull has an attachment at C-1 called the atlas, and at C-2 called the axis. These two cervical vertebrae are very important and allow the skull to pivot back and forth and allow for a significant range of motion, as you can see what I am doing here.   The next segment, or region, is called the thoracic spine or thoracic vertebrae. There are twelve of these, and this is the part in which the ribs emanate from the backbone. The ribs encircle the thorax and allow for protection of those main organs in the chest. Just under the thoracic spine, lies the region known as the lumbar spine. This is really a critical location, and it's very important for weight bearing. Unfortunately, it's also the typical area where people develop lower back pain, specifically at the levels of L-4 and L-5. The origin of this pain is due to these discs that are placed between the bony vertebrae, and these discs can sometimes protrude and put pressure onto the nerves or spinal column. So this is the area, typically, where the pain emanates when a person would suffer with back pain. The next region is called the sacrum. And this is the area where most of the vertebrae are fused together. As you can see here, there are small holes in the sacral area. This is where blood vessels and nerves can emanate in the lower portion of the vertebrae. And finally the coccyx, the tailbone or last portion of the vertebral structure.

Bones

Human bones come is many sizes and shapes.

One simple way to look at the bones of the body is to divide them into three sections: the skull, the torso, and the extremities – arms and legs.

In humans, leg bones are the longest and the strongest. They need to support all the weight of the upper body, particularly as weight shifts from one foot to the next when you walk, or even more importantly, run. It all starts with the femur. Whose length makes up one fourth of your total height.

The femur, here, the thigh bone, is the largest bone in the human body. It directly bears the full weight of the upper torso. The head of the femur connects to the pelvis, or hip joint. The bottom of the femur helps form the knee. The knee is made up of the patella, which completes the connection with the tibia, and forms a hinge joint. The fibula, here, is another lower leg bone, but bears no weight. And lastly, here are the bones of the ankle and the foot.

The ankle and the foot bone are built for strength, strength to provide carrying capacity for the weight of the whole body. There are three main bone groups in the foot: the tarsals, the meta tarsals, that make up the sole of the foot, and the phalanges, your toes.

The foot's marvelous weight carrying strength has been achieved at the expense of mobility and precision. Just the opposite is true for the wrist and hand. Their fifty-four bones are also divided into carpals, meta carpals, and phalanges, or fingers. The entire hand/bone complex is controlled by more than fifty muscles. It is an engineering marvel, allowing for the most refined manipulation of objects in the animal world. Many will say this ease of manipulation is what has allowed humans to advance and develop all our technologies.

Bone Composition

Bone is a structural engineering wonder. It is incredibly light and strong, but not too rigid, not too brittle, and it does not break easily.

Bone is one of the strongest substances found in nature, but is it stronger than concrete? I had a bone sent over to an engineering lab to compare the strength of the two. First measurements had to be made of the bone. In the lab concrete used in construction is tested on a daily basis. Here Drayton will use the lab's compression machine to determine how much force is needed to break the concrete cylinder, over 4,000 pounds per square inch. Now it's time to test the bone. The strength of the bone is contained in the cortical layer of the bone shaft. This hard, shell-like tissue is rich in minerals: calcium and phosphate. At last the bone breaks. Drayton needs to do some calculations to compare the results.

Drayton Speaks

I'll take it over to the table, do some numbers and see about how it compared to that concrete sample we just took. Well, the results are in. After crunching some numbers and finding out what the PSI was, the concrete's PSI was 4332 and the bone's strength was 4738 PSI. So the bone wins in this comparison between the concrete and the bone.

Since the cortical layer makes up only a quarter of the calculated surface of the bone, bone is actually, four times stronger than concrete.

Protective Function of Bone

This strength of the bone is vital for the many productive functions it provides for the body.

As two boxers train for future fights, they frequently land blows to the rib cage. Inside the rib cage are vital organs: the heart and lungs, organs that must be protected at all costs. That's just what the rib cage does. It's a remarkable piece of body armor, protecting those vital organs from powerful blows to the body. It is body armor made up of 12 pairs of ribs that connect to the spine in the back and to the sternum, the breastbone, in the front. The whole encircling rib cage brilliantly performs the skeleton's twin functions: support and protection, as does the pelvis, often called the hip bone.

Pelvis Anatomy

The pelvis is a ring of bones that connects the spine to the femurs. The two femurs, or femural heads of your legs, would sit in these particular sockets on each side of the pelvis. It bears the weight of the upper body when sitting and standing, and it is pivotal in the transfer of weight from leg to leg when walking or running. Also, it protects the pelvic organs, such as the bladder and reproductive organs. They would sit here, in this cavity, and get protection laterally, from these large bones, as well as anteriorly, or in front, by virtue of the pubic symphysis, the bone that I'm demonstrating here. The two areas of the pelvis which can be felt, or palpated, is the hip, or point of your hip, which you would feel here, on the side of your leg. You can feel what we call the crest, or the pelvic crest, and also, in thinner people, you might feel a third part, which is this pubic symphysis in the front.

There are distinct differences between the male and female pelvis.

Here you see two radiographs, or x-rays, of the pelvis. On the left, you see the male pelvis, and on the right, you can obviously see, here, the wider female pelvis. In general, the female pelvis is larger and broader. The male pelvis is taller and narrower. Other differences in the female pelvis really relate to childbirth. The arch is wider, the outlet is wider and broader, and the sacrum is shorter and curved towards the back of the body.

Skull

If the rib cage protects the heart and lungs, the skull protects the brain. It protects it by not breaking or shattering when a blow is delivered to the head, and distributing the impact from the blow throughout the whole skull - in this case, by a boxer. Of course, the goal of the boxer is to knock his opponent out, producing what we doctors call a concussion - jiggling the brain so much, that the fighter briefly goes unconscious. Particularly effective in protecting the brain is the group of eight bones that make up the domelike top of the skull - the cranium.

When we analyze the cranium's design, it is both brilliant and extraordinarily functional. It has cavities, or holes, for the eyes, orbital bones; holes for the nasal passages, allowing us to breathe through our nose; and holes for the ears, letting sound waves in. And these cavities are situated to provide maximum protection for the exposed soft tissue, such as your eyes. Finally, the skull comes in two parts, parts that contain the teeth and together produce our chewing of food through the movement of the jawbone, or mandible.

This is the area where we're able to flex the bone to be able to speak and chew food. Now returning to the top of the skull, you can see here the various suture lines.

Bone Joints

Over the first year of life, the space between these bones slowly closes up and fuses, resulting in the sutures … Special bone joints that don't move. Not so with the body's other joints.

Rebecca is a tai chi master. In almost slow-motion, Master Rebecca allows us to see pretty much every type of movement the human body is capable of producing. Rotating the head, rotating the center, bending the elbow, circling the arm, curling the wrist, flexing the fingers, and bending at the knees - all movements made possible by the action of the body's muscles. But also movements that would not be possible without Master Rebecca's many joints, structures that connect the bones of the skeleton.

Remember the spine with its many vertebral joints? They produced very limited movement. However, the joints connecting the arms to the shoulders allow for a great deal of movement.

Again, where two bones meet is called a joint, as this elbow joint. Amazingly, the human body has over 300 joints. One important way we doctors classify joints is by the kind of movement a joint allows.

When the head rotates from side to side, one bone rotates inside a ring of another bone that is stationery. This is called a pivot joint.

There are four great ball and socket joints in the body. Two sit in the shoulders and the other two are where the legs meet the hips. Here the joint consists of a bone with a rounded end that fits into a cup like cavity of another bone. Clearly this kind of joint allows for the greatest possible movement and is why you can swing your arm and legs so freely.

A third type of joint in the body is the hinge joint, a joint that produces the kind of movement at the elbow, or when you bend your fingers back and forth. Like a hinge on a door, this kind of back-and-forth movement takes place in a single geometrical plane.

This specimen affords us a unique opportunity to look at one of the larger joints in the body, the knee joint. The knee joint is a hinge joint. And as you can see, I'm able to flex it in this one direction, up and down. The knee joint can also be demonstrated with the patella removed to the side. And with the patella moved off to the side, again, you can see the hinge nature of this joint, and the two very important ligaments, the anterior and posterior cruciate.

Gliding joints make up a fourth kind of joint. Found in the wrists and ankles, they allow the bones to move back and forth.

Cartilage

So, when all this movement takes place, remarkably there's no grinding of bone against bone. How is this possible? Ingeniously the body has come up with a solution. The solution is cartilage.

It's the padding on the ends of many of the body's bones such as the femur. Cartilage, if it were manufactured, would be called a miracle substance. It is flexible, light-weight, resistant to wear. And in the vertebral column, cartilage acts like a shock absorber between the vertebrae. However, cartilage can wear out or tear, and over time the joints, once protected by cartilage, is where arthritis occurs.

Bone Diseases

This is one of my patients who has arthritis. Arthritis is an inflammation of the joints. As you can see, his wrist joints have a little bit of inflammation and swelling on both sides, and even some of his fingers are slightly swollen around the joints of the knuckles, and around the fingers. Arthritis is typically something that happens in older populations, specifically osteo-arthritis, or inflammation of the bones, and very often it becomes worse with increasing activity and exercise.

Today, we're very fortunate to have ways to take care of patients who use their joints so much that they could either fracture, break, or they could get worn out. This x-ray demonstrates a patient, who on the right side, required a hip replacement. Here you can see the new hip replacement, and you see the ball of the new joint, which is sitting into what you call the acetabulum of the pelvis. This bone here is the thigh bone, or better known as the femur.

There is one other way the skeleton contributes to the human body's range of movement. The bones are the anchor for muscles. Without this anchoring, without this tying together of the skeleton and muscular systems, there would be no movement, or at least no movement that could sustain life for a human being. For example, when John is doing a squat exercise, one of the muscles at work is the powerful hamstring muscle on the back of his leg. The hamstring is anchored at the top to the pelvis, and connects to the two lower leg bones, the tibia, and the fibula, at the bottom.

The Living Bone

While bones may be as strong as steel, unlike steel, bone is alive. It is constantly replacing itself, replacing itself every two years. If it breaks or is damaged, then it will rebuild itself. And of course, as the body grows from infant to adult, each bone must adjust itself. It has to adjust its size and shape to match the gradual growth of the body over 20 years. So, let's look at the living bone, the anatomy of a bone, like this.

It starts with an outer surface, a layer of connective tissue, the place where the muscles attach. This connective tissue layer is rich in blood vessels. And this layer is where the cells are produced that repair damaged or broken bones. The pain of a broken bone is felt here. Not in the hard part of the bone, the mineral rich layer, also known as the cortical bone, the layer that gives a bone its strength.

Part of the reason that bones are light weight is that many are partially hollow. They have cavities. For example, the ends of this bone are made up of what's called spongy bone – which, by the way, is not squishy. It just looks that way. It is a lattice whose function is to protect the bone marrow. The bone marrow of the living bone is a blood factory.

And we're looking inside this cortical bone now. What you can appreciate is the bone marrow. And you could see here, I'm able to actually take out little portions of the bone marrow, this important part of the bone, which actually makes the blood cells of the body. As you can see, bone is truly a living part of the skeleton.

Conclusion

The human skeleton is a brilliantly functional system, a system that gives us our basic body plan, a body plan that lets us walk upright, freeing our hands for refined and precise manipulation of objects. It anchors the muscles, so we can move. As we clearly saw, the skeletal system protects our essential organs – the heart, lungs and brain. It is connected to the cardiovascular system by manufacturing red blood cells. So that's the human skeletal system, the foundation, the super-strong, lightweight frame on which the miracle of the human body is built. Thanks for watching, I'm Dr. Mark Reisman.

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