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Developing Learning Models to Teach Equine Anatomy and Biomechanics

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DEVELOPING LEARNING MODELS TO TEACH EQUINE ANATOMY AND BIOMECHANICS

By

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ABSTRACT

Animal owners and professionals benefit from an understanding of an animal's anatomy and biomechanics. This is especially true of the horse. A better understanding of the horse's anatomy and weight bearing capabilities will allow people to treat and prevent injuries in equine athletes and work horses. Currently, teaching anatomy is based on dissection of cadavers and study of figures in textbooks. Dissection is expensive and presents logistical difficulties associated with sourcing, storage, and disposal of cadavers. Also, *post mortem* tissue changes obscure how the muscles support the bones and make the specimens unsuitable for representing biomechanical principles. Cadavers may also be objectionable to hands-on learners that do not have the fortitude for dissections. Building a model from readily available materials, such as PVC pipe and rope, is one way to teach equine biomechanics and anatomy to equine professionals. We are currently close to completing a model of the horse, an effort that has taken nine years and multiple students each year. Currently, the head, spine, ribs, front legs, and back legs are complete, and the musculature for the spine, front legs, and back legs is finished. However, building an entire horse may be too time consuming to learn key biomechanical principles of the horse's feet and legs efficiently. However, the equine stay apparatus is a crucial system for enabling the legs to support the horse. Work is therefore now focused on making a model of the stay apparatus in the distal part of the foreleg that could be built in a laboratory teaching setting, and adapted to either a semester class, a half-day session, or a stand-alone kit for independent study. Development of such a model would greatly increase the availability of biomechanical instruction to equine community, especially veterinarians, horse trainers and farriers. It could also improve the welfare of horses through better management and prevention

of lameness. This thesis describes the development of such a model, and the development of a half-day learning activity in which a simplified version of the model is contructed.

ACKNOWLEDGEMENTS

I would like to thank Dr. Causey for all of his advice and inspiration on this project, as well as his help building the models of the complex and simple legs.

Many thanks to my committee members for their patience and support on my thesis.

I would like to thank all of the other students that worked on this project before me and have dedicated their time to the complete model PVC horse for their insight and experience that was passed on to me for these models of the distal leg. Since 2008 these students have worked on the full model, each focusing on different parts: Hind legs - Kasey Fitch; Fore legs - Rachel Keating; Saratis ventralis - Jaime Stukey; Muscular sling of the thorax - Helen Crawford; Spine - Heather Woodbury; Ribs - Arianna Goulatis; Skull and neck - Ericka Malley; Muscles of the neck - Kortney Cole; Nuchal ligament - Amanda Mayhew; Epaxial muscles - Libby Williams and Marie Barnes; Intercostal muscles - Zandalee Toothaker, Robert Paris; Other help along the way from - Scott Mitchell, Ashley Edwards, Susan Outman, and Jess Majors.

I would like to thank Robert Paris for his assistance with building the simple model of the leg.

And lastly, I would like to thank my family for their continued encouragement and motivation.

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INTRODUCTION

Impact of Equine Injuries

The Equine Injury Database of the Jockey Club shows that over the four years between 2009 and 2013, there were 3,582 fatal catastrophic racing injuries in Thoroughbred horses in the United States (jockeyclub.com). This represents not only a huge economic loss to owners, but also a major animal welfare concern, with racing fatalities occurring in almost two percent of all racing starts. A similar fatality rate in a human spectator sport would almost certainly be unacceptable to the general public.

Trainers, owners, and grooms can help prevent equine injuries through a greater understanding of biomechanics. In particular, the equine stay apparatus is a system of bones, ligaments, and tendons essential for weight bearing during the stride. Failure to engage this system, such as through tripping due to insufficient extension of the hoof to land on the heel, and instead landing on the toe, is an example of one way to cause such fatal leg fractures.

The interactions of the different parts of the distal leg also play a role of compounding injuries. Due to the inter-relationships of the bones distal to the fetlock (the digital flexor tendons, suspensory ligament, and collateral ligaments in the three phalangeal joints), an injury of one part may lead to a corresponding injury with other parts (Dyson, Murray, Schramme, & Blunden, 2011). Injuries, such as navicular disease, can be subtle and take a long time to show serious symptoms, therefore it is crucial to have a firm grasp of what to look for.

The size of the joints is also a point of concern. The greater surface area of larger joints reduces the stress caused by the weight of the horse. However, some horses are bred for a variety of deleterious anatomical conformations, such as small feet and joints, which may be soughtafter for visual effect. These practices run the risk of increasing predisposition to boney abnormalities, such as navicular disease, greatly impacting the welfare of afflicted horses (Mählmann, 2009).

Learning Prevents Injury – The Limits of Dissection

Learning more about the horse's anatomy and how the horse supports itself may help to prevent injuries through improved training and breeding practices or through superior racetrack design (Keating, 2012). It is important to learn the anatomy of the whole equine skeleton, because one area can affect other areas. For example, horses with a leg injury develop less flexibility in their back when trotting (Pourcelot, Audigié, Degueurce, Denoix, & Geiger, 1998).

While some professionals with careers relating to animals have a good understanding of equine anatomy, most of their information comes from textbooks and dissections. Unfortunately, there are limits to dissection. For example, the muscles and tendons in a dead horse's leg do not have the same properties as a live horse: joints do not flex in the same way, and therefore a person cannot fully appreciate the biomechanical functions. In addition, dissection can be unhygienic, and needs to be performed in a cleanable space. The body parts used are also not easily available and can be difficult to ship, store, and preserve. The body parts are sometimes treated with toxic chemicals for preservation. In addition, the effectiveness of dissection is limited because one may learn a limited amount from a leg before it is too damaged to be of further use. Furthermore, if one makes a mistake in cutting, separating, or removing tissue the fault often cannot be corrected.

The Benefits of Creation in Learning - Bloom's Taxonomy

Creating anatomy through "building" a leg, may be a more effective way of learning anatomy than destroying tissues. According to a recent organization of Bloom's' Taxonomy of learning. Researchers have revised Bloom's taxonomy of 2001 into two dimensions: knowledge and cognitive process. The four levels of the knowledge dimension - factual, conceptual, procedural, and metacognitive - apply to all levels in the cognitive process. In the cognitive process dimension, there are six levels (shown in Fig 1). The first level is remembering, where an individual must recall the necessary information from their long-term memory. The second is understanding, where an individual must comprehend and be able to explain a topic. The third is applying, where an individual must use what they learned. The forth is analyzing, where an individual must be able to differentiate and organize the parts of a topic. The fifth is evaluating, where an individual must be able to judge the value of a topic or its parts. The sixth and final part is creating, where an individual must be able to build or reorganize the parts of a topic into a new form. (Hunt, Carper, Ii, & Daniel, 2010). The purpose is that the further a person ascends the taxonomy, the more they must revisit the previous steps. To ascend you must learn more, understand better, and so on. If at any point they are unsure, they must, go back until theyare prepared to move forward again.

If a person is prepared to create, they must have great breadth of knowledge, and a understanding of the topic. Through creating, they can apply what they have learned and analyze the parts in an organized fashion. To create they must be able to evaluate what to focus on to finish the project. Building a model shows that a person can go further than before by making something new.

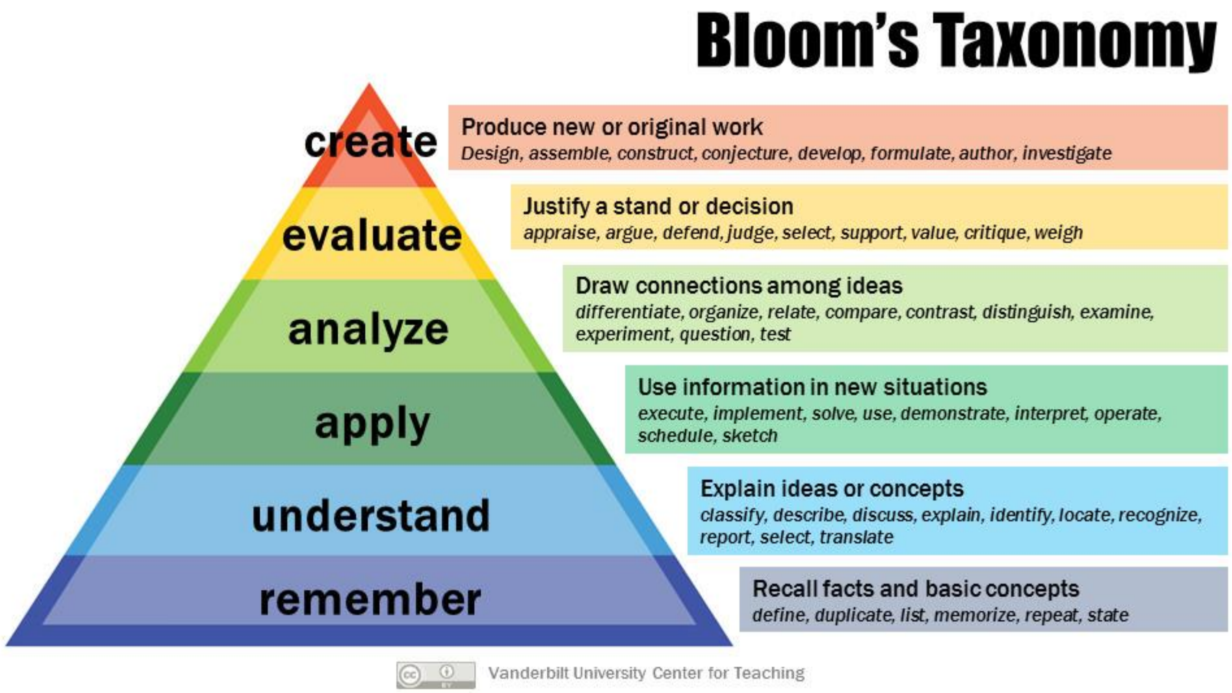


Figure 3: *The revised Bloom's Taxonomy includes six levels on the cognitive process dimension.*

Building the leg is a solution to the revised Bloom's taxonomy. A person can use the first five levels to reach the sixth: to create. By using everything a person knows and understands about the anatomy, one can apply, analyze, and justify why one would make certain cuts and structures on the model to better represent the horse leg anatomy and biomechanics. One can use biomechanics to repeatedly test the weight bearing ability of the structure, making adjustments to improve function, while using anatomy texts as references to ensure the model is valid.

By being able to improvise, analyse, and critique the materials and methods used for building the different structures of the model, students are able to fully realize Bloom's Taxonomy and the potential for building the model. In contrast, using a manual with step-by-step instructions, while good for learning the anatomy in a kinesthetic and tactile learning style, only utilizes the first step of the pyramid (knowledge). At this level learners are not necessarily capable of justifying why certain steps must be taken.

Because people learn in different ways (visual, audial, and kinesthetic), handling the model reinforces their knowledge, and allows for a deeper understanding. Utilizing senses in addition to seeing and hearing will help learners retain the knowledge more effectively (Lujan, Dicarlo, Lujan, & Dicarlo, 2006). Building a hands-on model in a laboratory setting is therefore a good way to supplement a lecture.

Building the model also has the benefit of improving hand eye coordination. This can be very helpful in orthopedic surgery, giving veterinary students the experience to work with bone-like shapes, involving cutting, drilling, manipulation and use of power tools. In addition, the model may require knot tying using a mono filament nylon (i.e. fishing line) with properties very similar to suture material. There may be ways to tie knots using techniques similar to suturing, such as using needle-nose pliers as needle drivers or forceps. In addition, the model may also require a person to thread fishing line blindly, greatly aiding the development of fine-motor skills.

Experience with Building a "PVC Horse"

Students in the past have worked to gradually complete a PVC horse skeleton to help deepen their understanding of the fundamentals of equine anatomy and biomechanics. This improved their knowledge and helped inform others with career goals of working with horses about the anatomy of the horse. Materials such as PVC pipe, tools, fishing line and rope are more readily available and more easy to store than dissected specimens. Using this model construction, students and the instructor (Dr. Robert Causey) learned much regarding anatomy and biomechanics. Because discarded PVC pipe could be used in different parts of the model, if a student made a mistake or needed to make a change, it was easy to acquire a replacement part.

Learning about the leg by building it, not destroying it, appeared to be a highly effective a way to learn the anatomy. This PVC model appeared that it could serve as a template for others to make additional model skeletons of horses, or other animals.

Work on the hind legs was completed in 2008 by Kasey Fitch and Dr. Causey. The forelegs were completed by Rachel Keating and Dr. Causey (Keating, 2012). The Serratus Ventralis, which connects the scapula to the ribs and to the cervical vertebrae, was initiated by Jamie Suckey, and is currently being completed by Helen Crawford, who will attach the legs to the thorax. A major breakthrough for this project was completion of the thoracic and lumbar spine by Heather Woodbury, following which the ribs were added by Arianna Goulatis. The nuchal ligament was made by Amanda Mayhew. The epaxial muscles were made by Libby Williams and Marie Barns. The skull and the neck were made by Ericka Malley. Most of the muscles of the neck were strung up by Kortney Cole. Figure 2 shows Helen Crawford displaying the PVC horse skeleton with the legs unattached at the Center for Undergraduate Research symposium in 2016.

The model helped us better understand how the horse bears weight. Students involved with the project also learned the anatomy, physiology, and mechanics of the horse by building this model. From this model, we developed a greater appreciation about the way injuries that a horse sustains during training and working affect the horse's skeleton. However, it would not have been possible to build an entire skeleton in a lab setting, even over an entire semester. Therefore, to be useful, the model building would probably need to be broken down into different learning modules of manageable proportions. It was felt that the most useful module of greatest relevance would be one in which learners create a model of the part of the equine stay apparatus which is most prone to injury, specifically the equine suspensory apparatus spanning the metacarpophalangeal joint (fetlock), proximal interphalangeal joint (pastern joint), and the distal interphalangeal joint (coffin joint). This is equivalent to the bones of the middle finger in the human beneath the wrist to the finger nail. This thesis will therefore focus on model building to develop an understanding of the equine suspensory apparatus.

Figure 2: *Helen Crawford with the almost complete model PVC horse, 2016.*

Comparative Anatomy

Figure 3 shows how anatomy of the equine suspensory apparatus is similar between animals. Therefore, even if one is not in an equine field, one can still learn anatomy that will be useful by studying the horse. Figure 4 shows how working on the large sesamoid bones of the horse draws paralleles with the structure and function of the sesamoid bones in the human hand, and how these critically important bones act as a fulcrum on the digit.

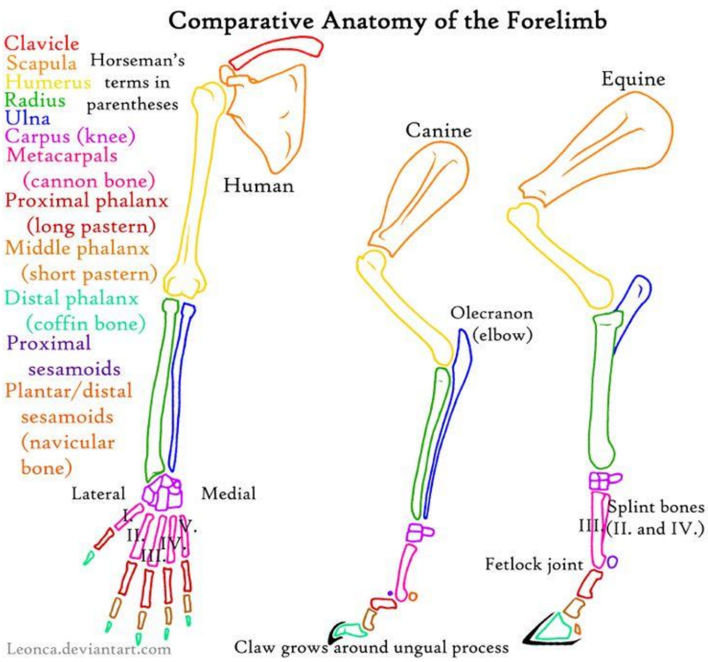


Figure 3: *Comparative anatomy of the forelimb of a human, dog, and horse shows that learning the anatomy of one will help you learn the anatomy of other animals.*

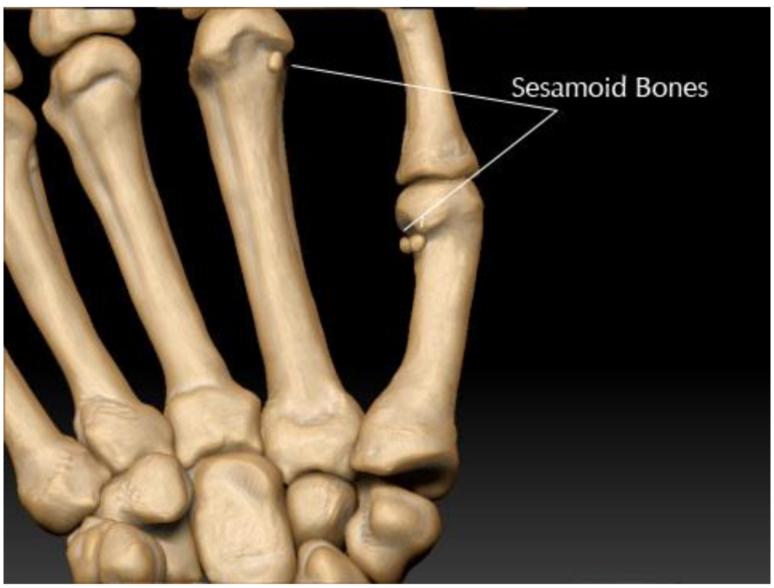


Figure 4: *Like the horse, the human hand has sesamoid bones that act as a fulcrum for moving the phalanges.*

Core-Concept – The Equine Suspensory Apparatus

The goal of this model is to explain the suspensory apparatus involving the suspensory ligament, the sesamoid ligaments distal to the fetlock joint, and collateral ligaments. The goal will be to show that we can assemble model bones fashioned from PVC, articulated using monofilament nylon to represent collateral ligaments such that the model can sustain a downward force similar to weight bearing.

As shown in Figure 5, the model will need to show how the interosseous muscle (suspensory ligament) plays a major role in stabilizing the fetlock joint, and keeps it off the ground. It is important to note that while the fetlock and coffin joints are capababe of flexion, the pastern joint is generally unable to do so, even when the pastern bones are parallel to the ground.

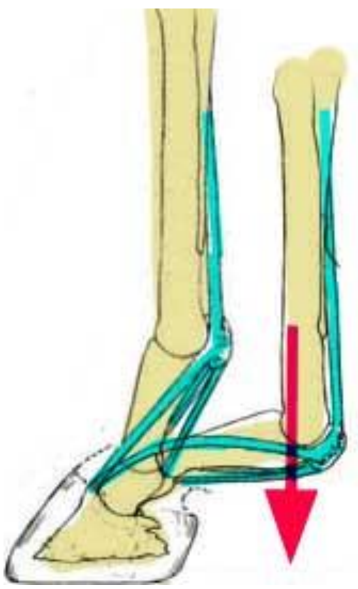


Figure 5: *Shows the suspensory ligament's role (green) in the stay apparatus when force is applied to the leg.*

Additional ligaments to be modelled can be seen in Figure 6.

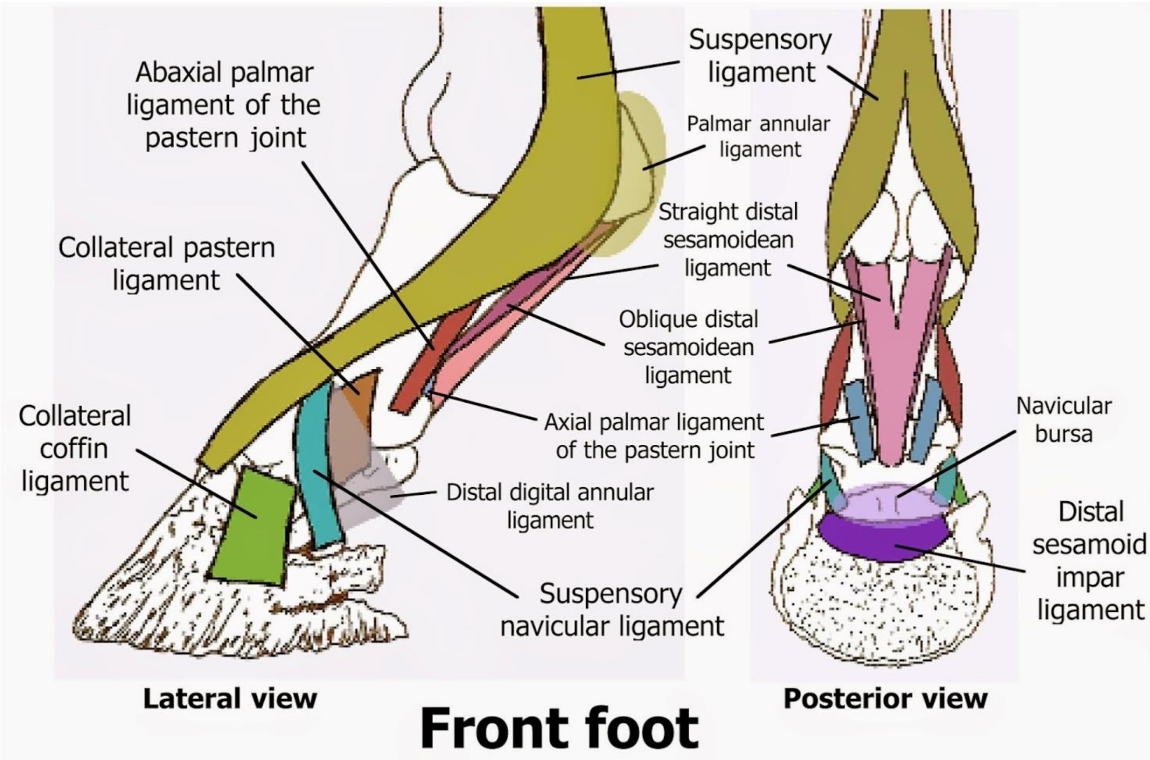


Figure 6: *Ligaments to be modelled to represent the equine suspensory apparatus*.

General Hypothesis

It will be possible to adapt a distal leg model in a class or workshop lab setting to model the suspensory apparatus of the horse.

Hypothesis 1

This model will achieve an acceptable representation of the fetlock joint, involving the sesamoid bones, suspensory ligament and distal sesamoidean ligaments as components of the stay apparatus.

Hypothesis 2

The model will achieve an acceptable representation of the pastern joint to show how its collateral ligaments make it stable and immobile, even under load bearing.

Hypothesis 3

The model will achieve an acceptable representation of the coffin joint and reveal the role of the navicular bone in stabilization of the coffin joint.

OBJECTIVES

Overall

The main focus of this project is to make an acceptable model of the distal leg that can be used to help teach anatomy, physiology, and biomechanics to a variety of learners, be they College students, children from 4H groups, professionals such as those at the Maine Farriers Association, or other interested parties.

Objective 1

Complete an anatomically correct model of the equine distal limb which could be constructed in 24 cumulative hours, including the stay apparatus, fetlock joint, pastern joint, and coffin joint.

Objective 2

Complete an anatomically correct model of the equine distal limb which could be constructed in 8 cumulative hours, but modelling only the fetlock joint, with the pastern and coffin joint modelled by immobile PVC components. Bones would be shaped by the learner.

Objective 3

Create an anatomically correct model of the equine distal limb which could be constructed in 4 cumulative hours merely by attaching the components, the bones having been previously shaped by the instructor.

MATERIALS AND METHODS

MATERIALS

Figure 7: *Materials for complex model leg.*

Complex Leg

Figure 7 shows most of the pipes and tools laid out that are necessary to build both model legs.

PVC Pipes

- 2” pipe – about 2’
- 1 ½” pipe – about 2’
- 1 ½” T junction – 2
- 1 ½” Cap
- 1 ½” Quick cap
- 1 ½” → 1 ¼” Male adaptor
- ¾” pipe – about 5’
- ¾” T junction – 2
- DWVP trap

Tools

- Tape measure
- Drill
- Drill bits (of various sizes)
- Driver
- Saw
- Pliers
- Scissors
- Screws (12 x ¾ self-tapping)
- Dremel
- Rasp

Other

- Eye protection
- PVC glue
- Fishing line (monofilament nylon)
- Fishing line (braided)

Simple Leg

The materials for the simple model leg is very similar to the complex model leg. However, because we are using only one piece to represent everything distal to the fetlock joint, there are fewer parts. Anything that represents the long and short pastern bones, and the navicular and coffin bones from the complex model is replaced with one piece of PVC pipe.

There is also the addition of the 1 ½” → 3” adaptor to represent the hoof and a 1 ½” 30˚ elbow to attach it at the right angle.

PVC Pipes

- 2” pipe – about 2’
- 1 ½” pipe – about 2’
- 1 ½” T junction – 2
- DWVP trap
- 1 ½” → 3” adaptor
- 1 ½” 30˚ elbow

Tools

- Tape measure
- Drill
- Drill bits (of various sizes)
- Driver
- Saw
- Pliers
- Scissors
- Screws (12 x ¾ self-tapping)
- Dremel

Other

- Eye protection
- PVC glue
- Fishing line (monofilament nylon)
- Fishing line (braided)

METHODS

Ever since the project was started in 2008, most of the methods were the same throughout the building process. Individual bones were constructed with PVC pipe, glue, and self-tapping screws. Supplies were bought at Park's Hardware (Orono, Maine), Aubuchon Hardware (Old Town, Maine) and local Lowes and Home Depot outlets. Bones were not screwed together to make the structure stand. Instead, they were attached by rope and cord to mimic the bone to bone attachments (ligaments), and muscle to bone attachments (tendons). To make the correct shape of the individual bones, different PVC pipe pieces needed to be cut with the saws, shaped with the dremels, and then were screwed and glued together to make the different processes and tubercles. Some of the PVC pipes, like the one representing the small navicular bones, were fragments cut from the sides of PVC pipe cylinders. A rubber cap was placed between the PVC pipes where the pastern joint needed cartilage. Holes were then drilled in the appropriate places for attaching the sinews that would hold the individual bones together. The bones were tied together with different colored rope, paracord, string, and monofilament fishing line. These were used to represent the ligaments, tendons, and muscles.

We were able to make the simple model in two sessions, one to build the bones and one to string them together. If the plan is to make it in one lab period, you either need to schedule 5+ hours for them complete the whole thing; or you can shape the bones beforehand and smooth the edges for the students, and then let them attach the bones together with the strings and fishing line during the lab time.

Threading the ligaments is also the most difficult part due to the overlapping threads and small holes to thread the strings through. Figure 8 shows a step-by-step process on how to use a loop or V of fishing line to catch the piece of fishing line threaded through the first hole, and pull it through the second hole.

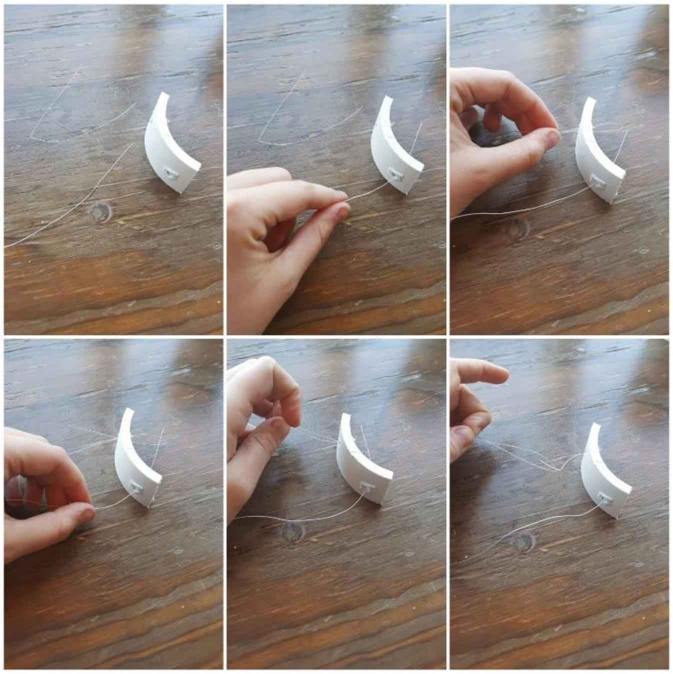


Figure 8: *How to get the thread from inside a tube of PVC pipe. 1) you will need a small V of fishing line, 2) feed the thread through the first hole, 3) feed the bottom of the V through the second hole, 4) feed the thread through the fishing line V, 5) pull on both ends of V, 6) Pull until the thread is through the second hole.*

RESULTS AND DISCUSSION

Building a model of the distal leg and stay apparatus in a lab setting was seen to be possible under the three objectives. In objective 1 a complex leg was made and assembled over a 24 – 30-hour period, roughly equivalent to a semester long class that meets once a week for about 2 hours. In objective 2 a simple leg was made in 2 sessions, each lasting 3 hours, the participants being familiar with hand tools. Scenario 3: A simple leg was assembled in one 3-hour session, the individual pieces having been shaped beforehand.

Details of model construction are as follows, and are intended to serve as a guide for construction by others.

COMPLEX MODEL MANUAL

The complex model is comprised of six parts that represent nine bones. The metacarpal III (cannon bone) and metacarpals II and IV (splint bones, figure 3) were not made into three individual parts on this model because they move as one and were modelled as a single cannon bone. The distal limb also contains both proximal sesamoid bones (the paired sesamoid bones) and a distal sesamoid bone (the navicular bone). On this model, both proximal sesamoid bones were constructed as one piece due to a strong cartilaginous attachment which holds them as a one unit. Therefore, in this paper, we will refer to these two bones as the sesamoid bone. The proximal phalanx (long pastern bone), middle phalanx (short pastern bone), and distal phalanx (coffin bone) are all represented individually in the complex model.

For convenience, this process has been split into four segments: cutting the bases for the bones, drilling holes in the bones, adding collars to the bones, and stringing the ligaments and tendons. However, some of these can be completed out of order, such as drilling some of the holes before you finish cutting all of the bones or adding the collars.

Segment 1: Cutting and Building the Bases for the Bones

At the end of this segment are different views of each bone before they were strung together and a few more cuts were made to them.

A good place to start was by making the coffin bone. A small piece of 2” PVC pipe needs to be cut out length wise so that the large piece can be glued around the 1 ½” pipe. Figure 9 shows how to set up the 2” PVC pipe around the 1 ½” pipe and secured it while the glue dries.

Figure 9: *Setting up the base of the coffin bone so the glue can dry*.

While the coffin bone dries, the rest of the pieces need to be cut. Figure 10 shows most of the different parts that need to be cut off the PVC pipe and accessories to make the bases of the bones that we built upon. On the left is metacarpal 3 also known as the cannon bone, represented by a two-foot piece of 1½” PVC pipe.

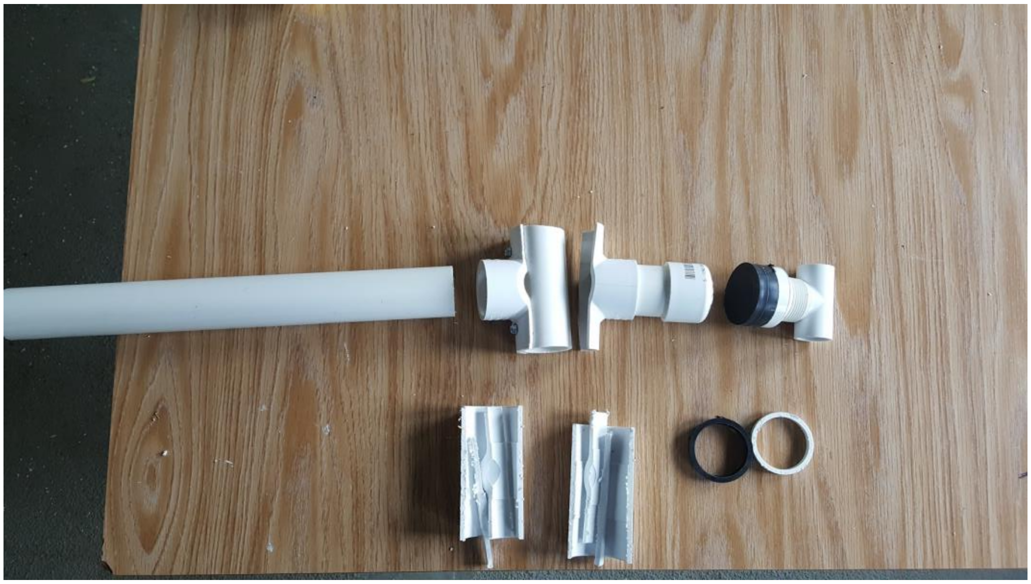


Figure 10: *Cutting pieces of bones. From left to right: cannon bone, head of cannon bone, long pastern bone, short pastern bone.*

The next part is the head of the cannon bone which was made by cutting a 1½” T junction (T) and filing the inside to remove the raised part meant to stop the pipe from too far into the T (shown in Figure 11). Note: the easiest way is to cut the T in half, then cutting the edges as needed to make the correct angle for the fetlock joint while you cut and compare it to the T for the long pastern bone (See Figure 12). Then the T needs to be screw to another piece of 1½” PVC pipe the length of the T (see Figure 10).

Figure 11: *Shows a cut T junction that has the stopping area filed down.*

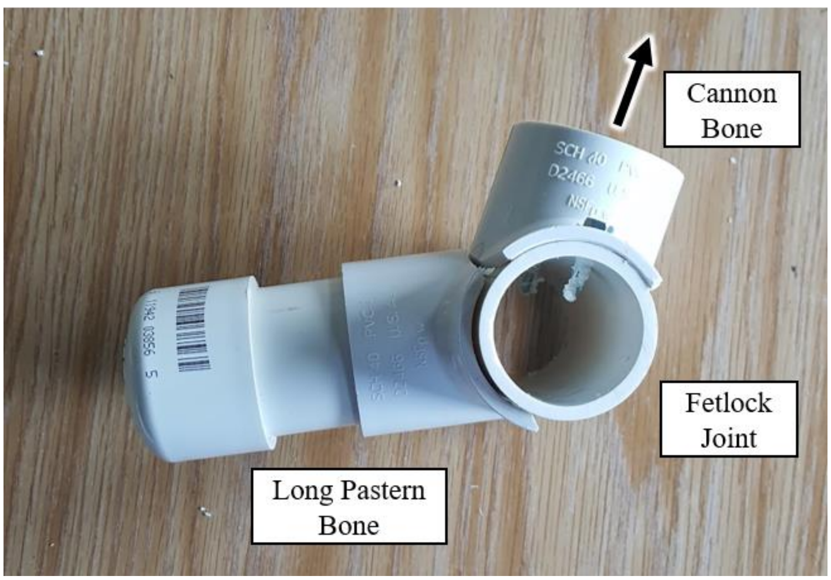


Figure 12: *Basic fetlock joint, comparing how much to cut off the T junctions for the head of the cannon bone and long pastern bone.*

Next is the long pastern bone also called the proximal phalanx. Cut and file another 1½" T, similar to the one for the head of the cannon bone. Then cut a piece of PVC to fit between the

T and the 1 ½” cap. Refer to Figure 12 to see the cap, PVC pipe, and cut T in place while it is compared to the T from the cannon bone to make the correct angle.

The small pastern bone has the most parts but is simple to put together (see Figure 13). First, the ¾” T needs to have the outside filed down, so that it can fit inside of the 1¼” end male adaptor. The tips of the 1½” ends of the male adaptor and quick cap need to be cut so that the fit completely around the small length of 1½” PVC pipe. Then you do the same thing as you did for the head of the cannon bone and cut the ¾” pipe the length of the T. Then assemble and screw the pieces together.

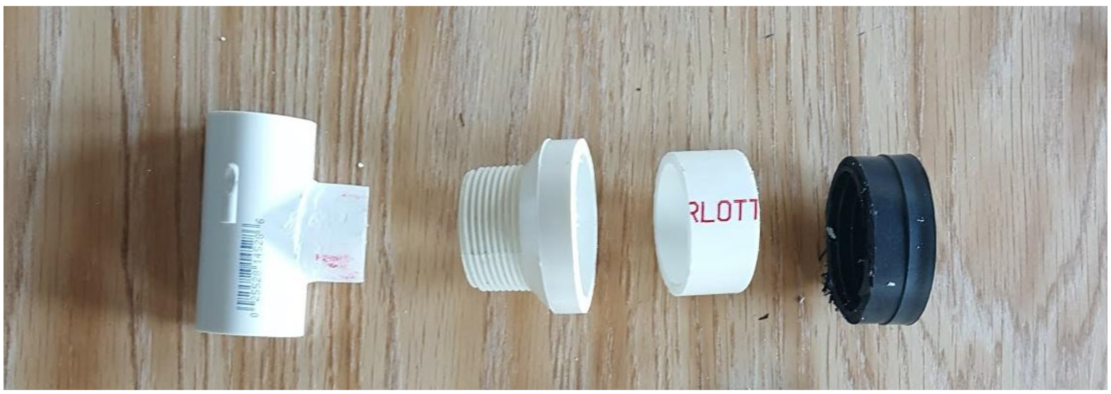


Figure 13: *Short pastern bone parts from left to right: ¾” T junction, 1½” →1 ¼” male adaptor, 1½” PVC pipe, 1½” quick cap* (missing the small length of PVC to go with the T).

Once the glue on the coffin bone base is dry, it can be cut diagonally to make the wedge shape. It must be cut along both of the outside dotted lines shown in Figure 14 or it will not have a flat surface on the bottom (see Figure 15). Two vertical slits must be cut, the middle section between the slits cut shorter, and the tops of the outside edges of the slits must be filed so the ¾” T can slot into place (see Figure 16 and 17). Cut the T like the other Ts so that it can fit with the ¾” T and pipe on the short pastern bone (See Figure 17).

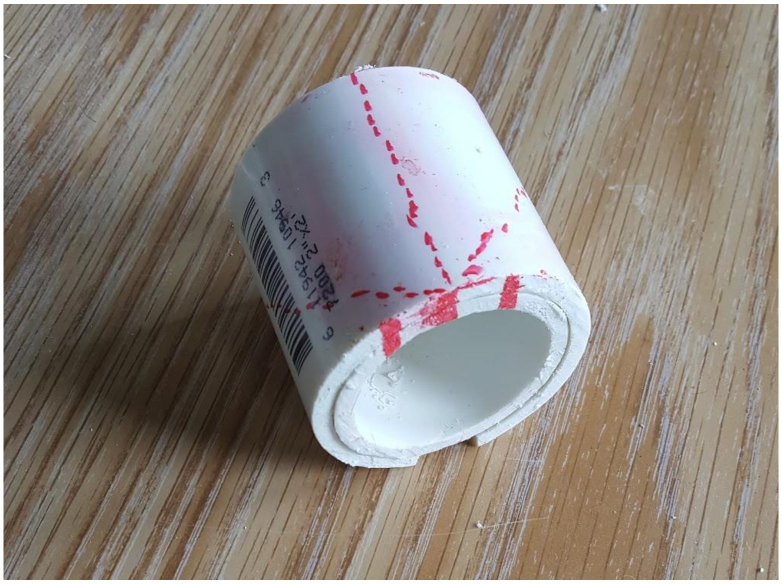


Figure 144: *Cut the coffin bone diagonally along both outside dotted lines to make the wedge shape with a flat bottom surface.*

Figure 15: *Cut two vertical sections that the T can fit in and file the bottom to be flat.*

Figure16: *Two vertical slits must be cut, the middle section between the slits cut shorter, and the tops of the outside edges of the slits must be filed so a T junction will fit.*

Figure17: *¾" T fit with the base of the coffin bone.*

The sesamoid bone needs the most cutting, filing, and filing. This one piece will represent the two sesamoid bones in the horse that are tightly held together. First the DWVP trap (The U-shaped piece in Figure 19) needs to be cut in half length wise, so that you cut both openings in half along the same plane. Then the ends need to be cut off down the openings so that only a quarter of a circle is left on each opening (See Figure 18). You can then cut the bottom trap corners off and file it into a smooth U shape with a small dip at the bottom to show where there should be a separation into two bones (See figure 19).

Figure 18: *Cut the trap in half length-wise, then each of the ends so that one quarter is left. Only one of the edges is cut off here.*

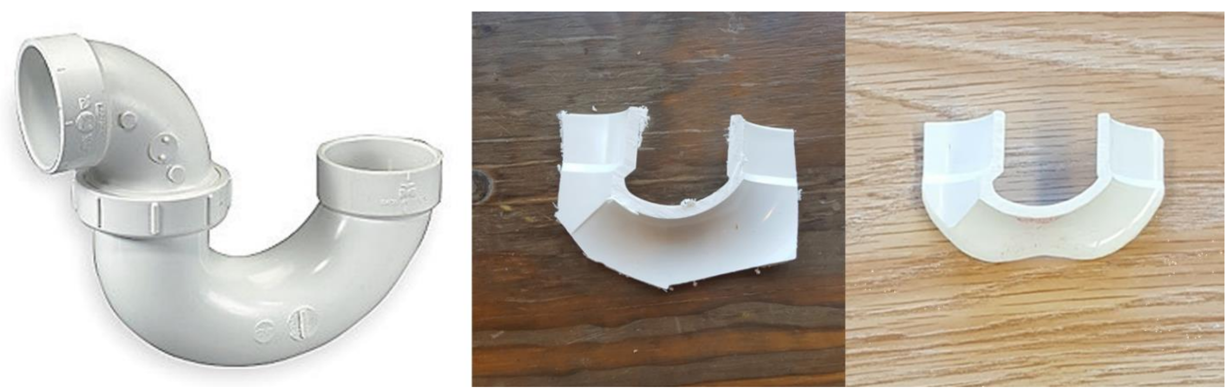


Figure 19: *Trap bend gets cut and then edges are filed smooth to make the proximal sesamoid bone.*

The navicular bone is the smallest bone in the leg of the horse. You only need to take a small piece of PVC pipe and cut it to be the length of the ¾" Ts in the coffin and short pastern bone. The navicular bone articulates with the short pastern bone and slides over the coffin joint, like the sesamoid moves with the bottom of the cannon bone and slides over the fetlock joint.

Figures 20 through 26 show what the base of each of the six parts should look like. Some of them include some of the holes that will need to be drilled in the next segment.

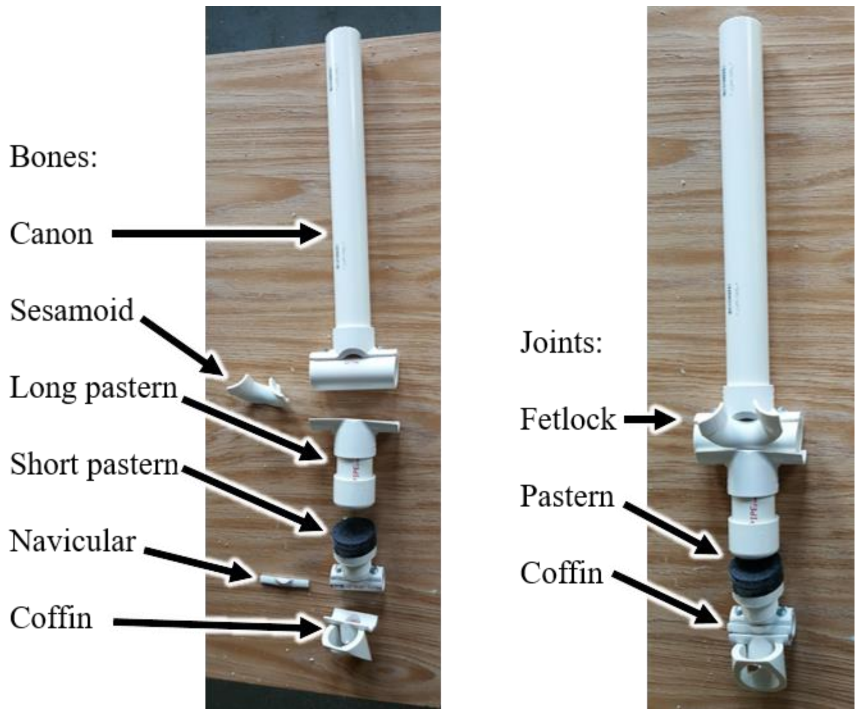


Figure 20: *Labeled bones and joints.*

Figure 21: *Cannon Bone (Metacarpal III)*

Figure 22: *Sesamoid bone (Proximal Sesamoid Bone)*

Figure 23: *Long Pastern (Proximal Phalanx)*

Figure 24: *Short Pastern (Middle Phalanx)*

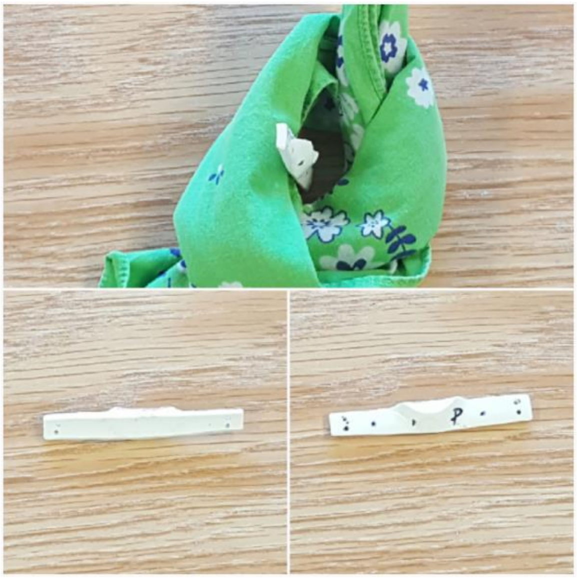


Figure 25: Navicular Bone (Distal Sesamoid Bone)

Figure 26: *Coffin Bone (Distal Phalanx)*

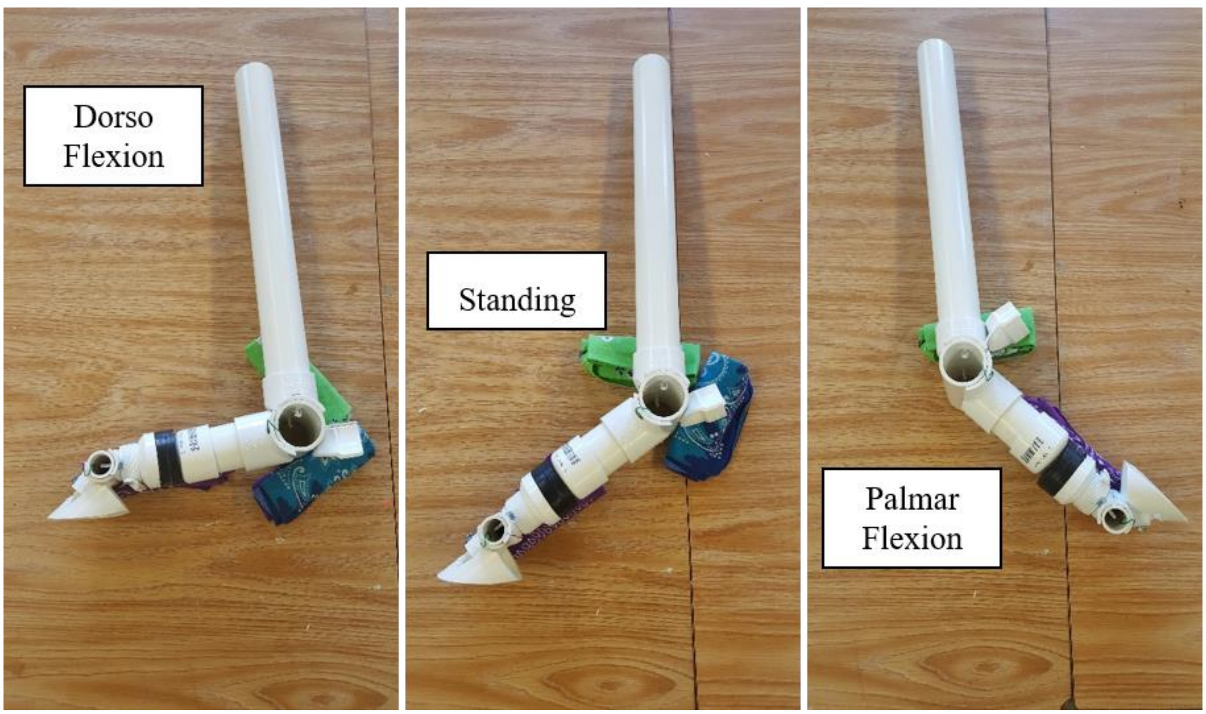


Figure 27: *Dorso flexion, standing, and palmar flexion positions, without ligaments holding bones together.*

Segment 2: Drilling Holes in the Bones

To attach the bones together with the fishing line, holes need to be drilled at strategic places on the bones. As seen in Figures 21 through 26 some of the holes have already been drilled. If working alone or in groups, the holes of one piece can be done before the rest of the bones have been finished. In some cases, it is best to wait to drill the holes until the collars have been added in segment 3, to make sure they don't get covered by the collars. However, where possible, it is best to drill all of the holes before stringing the ligaments to avoid damaging the strings with the drill.

The navicular bone is the most difficult to prepare, as some of the holes need to be drilled at an angle from the outside of the bone to the thin side, so that to holes do not exit the surface that will articulate with the coffin joint.

Segment 3: Adding Collars to the Bones

Looking at the difference between Figures 27 and 28 you can see difference in the size of the bones around the fetlock joint. This is because we added collars to bulk up the base of the bones. The bigger the joint, the better it is able to handle the forces put upon it. Figure 29 shows how to screw the two pieces of 2" PVC pipe together to make a collar before it is added to the model.

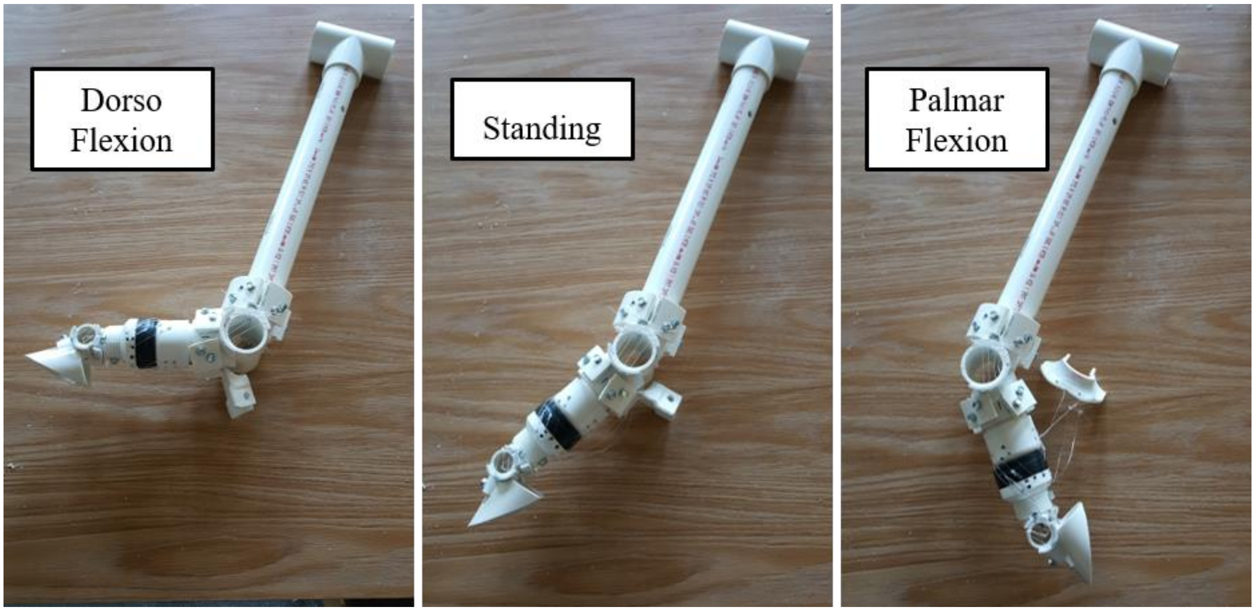


Figure 28: *Showing the positions with the addition of the collars and the ligaments holding the bones distal to the fetlock joint together*.


Figure 29: *Shows how to screw the collar together so it can be cut and fitted to the model.*

Segment 4: Stringing the Ligaments and Tendons

In Figure 28, you can see the dorso flexion, standing, and palmar flexion positions as you did in Figure 27, but this time with most of the ligaments holding the bones distal to the fetlock joint together.

Using the method shown in Figure 8, attach the bones together. It is best to attach the short and long pastern bones together first, and to do it while the quick cap is not attached to the short pastern bone (see Figure 30). The ligaments will be the axial (inside loop) and abaxial (outside loop) palmar proximal interphalangeal ligaments. Once those are done, you also need to connect the collateral ligament of the pastern joint.

If there are multiple people working on one leg, someone can be working on attaching the navicular bone to the coffin bone while the pastern joint is being secured. While most of the ligaments are secured in one loop of fishing line, the impar ligament that connects the navicular bone to the coffin bone needs to have many because the PVC pipe is weak at this point (see Figure 31). Therefore, we added many loops to give it more strength; this is also more accurate, because the ligament does stretch the length between the two bones.

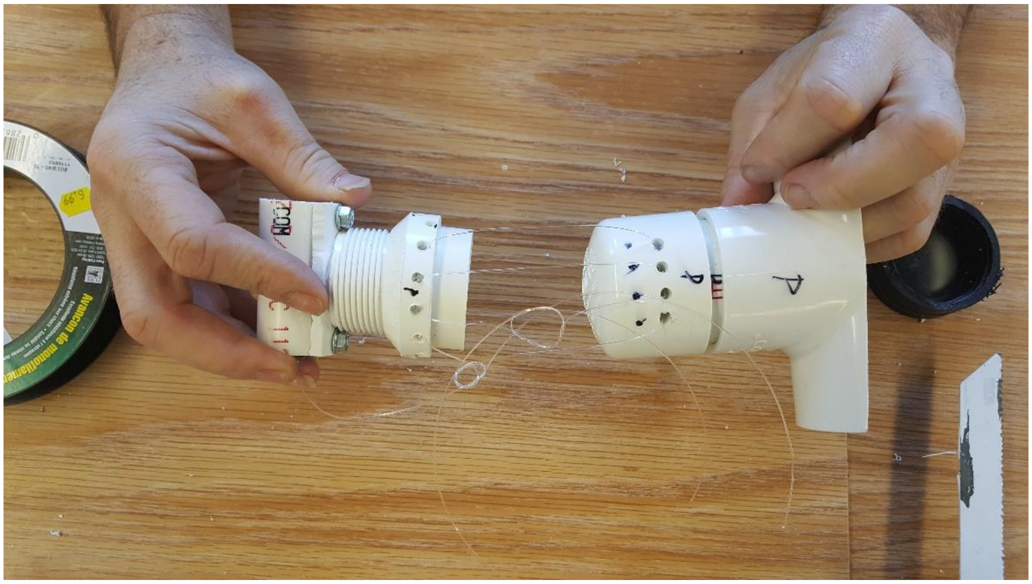


Figure 30: *Shows how to string the fishing line through the holes to attach the short (left) and long (right) pastern bones.*

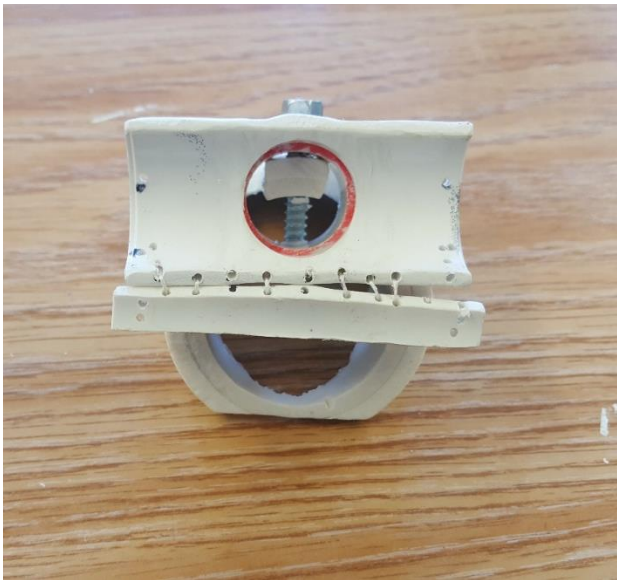


Figure 31: *Shows impar ligament of navicular bone.*

Once the ligaments of the pastern joint are strung, the pastern joint should not move or rotate. It is a stable joint that should not bend or flex even when under stress. See Figures 32 and 33 for a lateral and palmer view of the strung pastern and coffin joints.

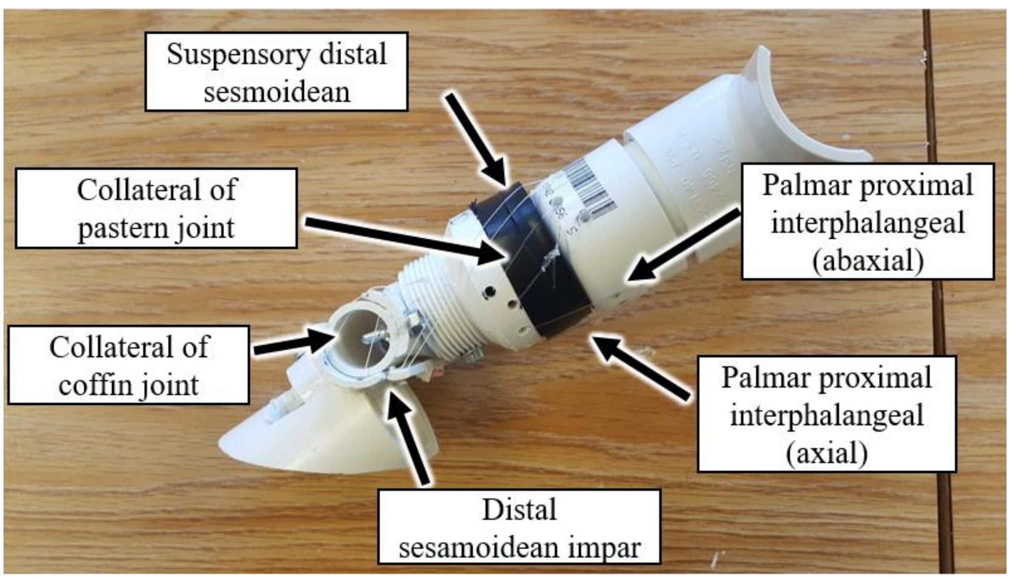


Figure 32: *Lateral view of the ligaments of the distal leg.*

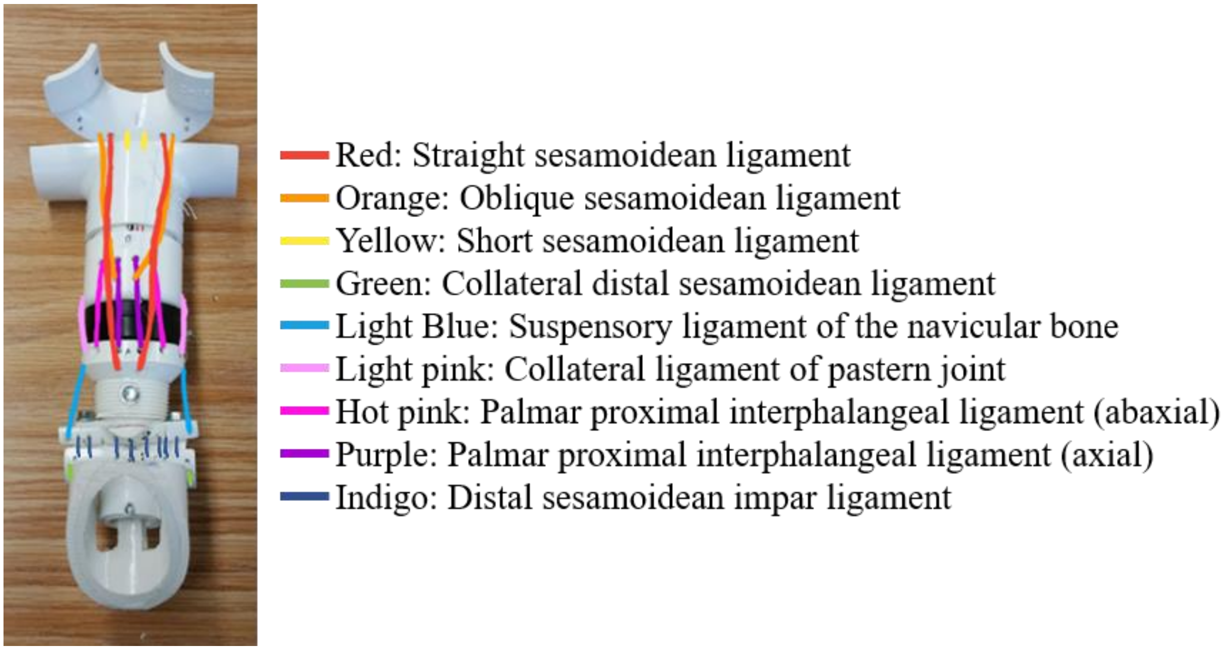
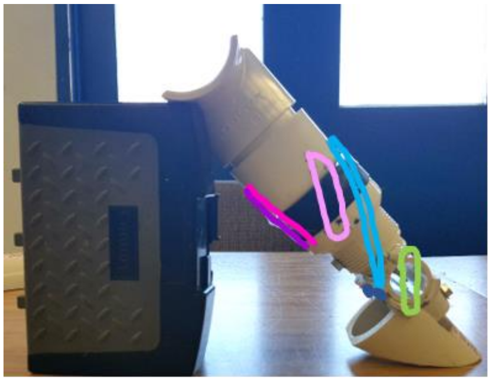
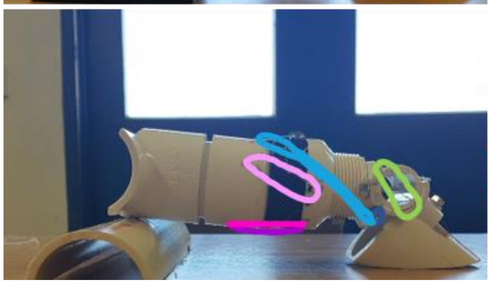


Figure 33: *Shows the ligaments that can be viewed on the palmar side of the leg distal to the fetlock with proximal sesamoid bone*.

Figure 34 shows how the model represents the proper tightening and loosening of the tendons of the coffin joint.



Green: Collateral distal sesamoidean
Light Blue: Suspensory distal sesamoidean
Light pink: Collateral pastern joint
Hot pink: Abaxial palmer proximal interphalangeal
Purple: Axial palmer proximal interphalangeal
Indigo: Impar



Green: Collateral distal sesamoidean
Light Blue: Suspensory distal sesamoidean
Light pink: Collateral pastern joint
Hot pink: Abaxial palmer proximal interphalangeal
Purple: Axial palmer proximal interphalangeal
Indigo: Impar

Figure 34: *Bolded items are tight in that position.*

The short sesamoidean ligaments, which will be seen to act in a similar fashion to the impar ligaments of the navicular bone, stabilize the sesamoid bone while the suspensory ligament exerts its force.

We placed the suspensory ligament so that it would show the branches of the suspensory ligament that fuse with the digital extensor tendon, serving to snap the hoof forward when the horse moves quickly. Figures 35 through 39 show how we improved our original design to show these aspects.

Those figures also show how to split the superficial digital flexor tendon and attach it to the two pastern bones around the deep digital flexor tendon.

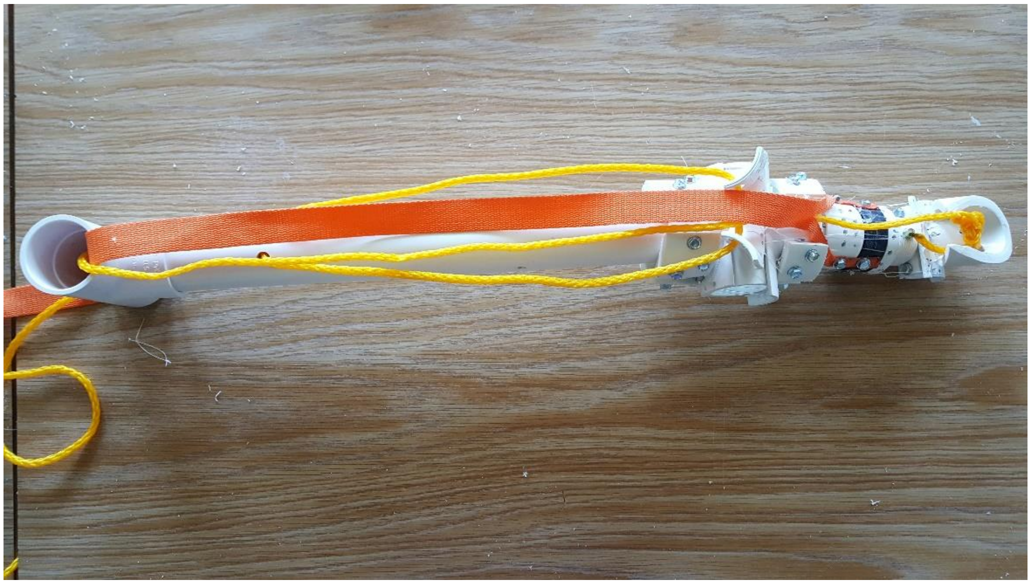


Figure 35: *First attempt to string the suspensory ligament (yellow and U shaped), deep digital flexor (yellow and strung down the middle), and superficial digital flexor tendon (orange).*

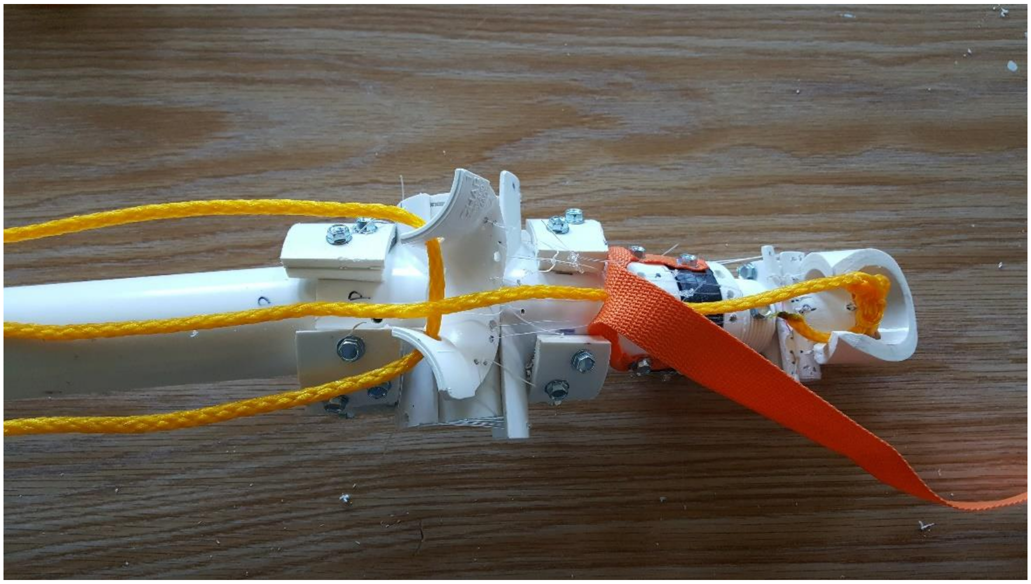


Figure 36: *First attempt to string the suspensory (yellow and U shaped), deep digital flexor (yellow and strung down the middle), and superficial digital flexor tendon (orange and pulled back).*

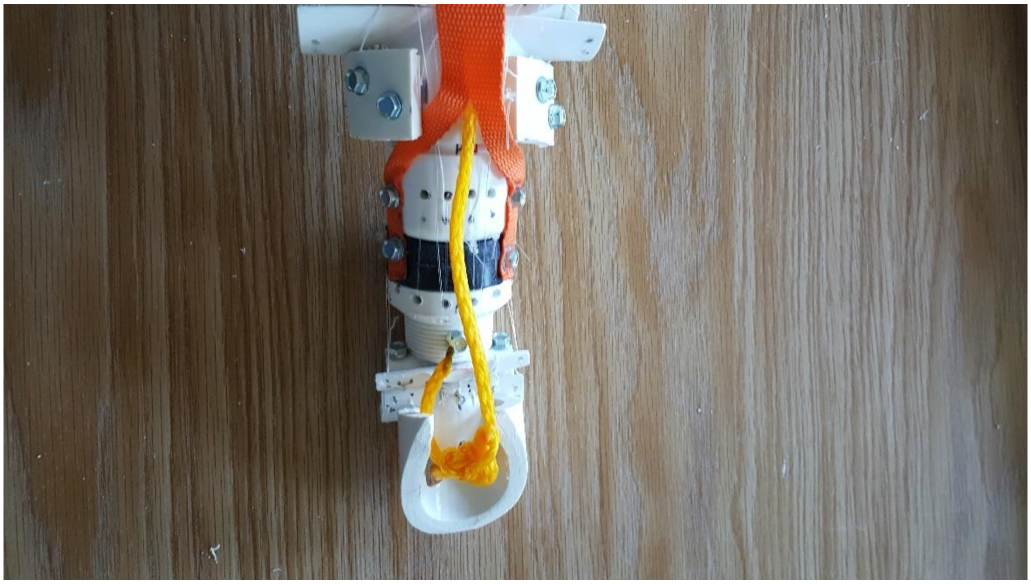


Figure 37: *Shows the bifurcation of the superficial digital flexor tendon (orange) around the deep digital flexor tendon (yellow) and the palmar ligaments of the pastern joint (clear).*

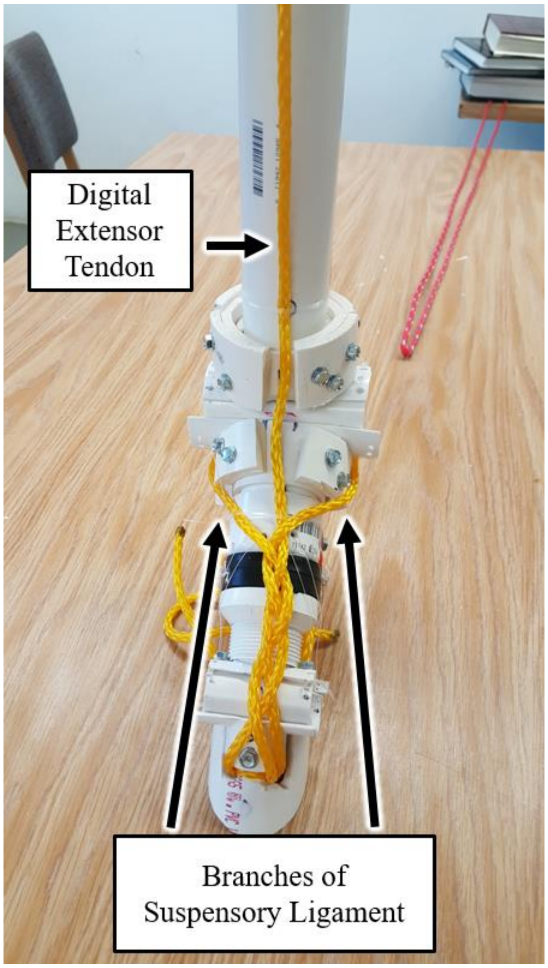


Figure 38: *Final way to string the stay apparatus. The end digital extensor tendon fuses with the branches of the suspensory ligament where they insert into the front of the leg.*

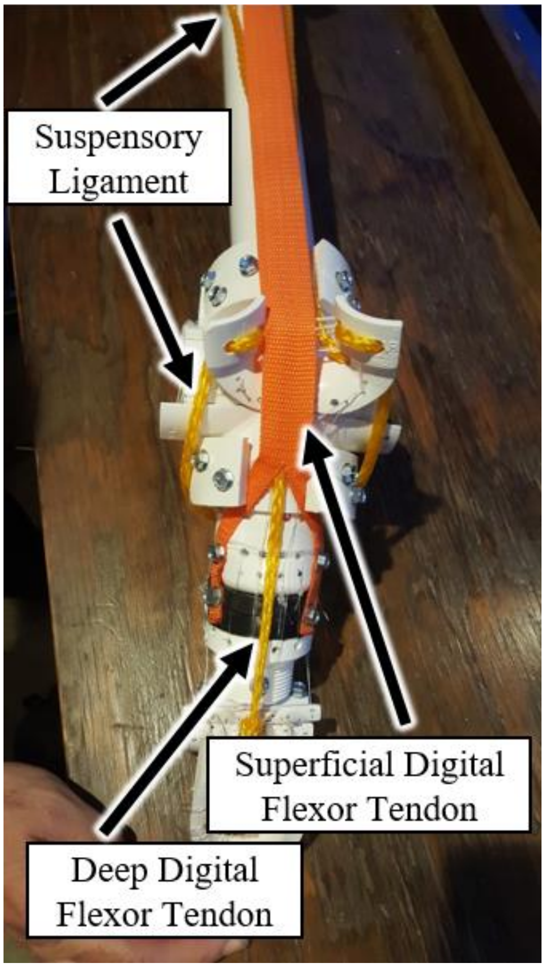


Figure 39: *Final way to string the stay apparatus. The suspensory ligament (partially covered by the superficial digital flexor tendon (orange)) connects from the proximal end of the cannon bone to the sesamoid bone. The branches of the suspensory ligament connect the outside of the sesamoid bone to the front of the leg. The superficial digital flexor tendon is covering the deep digital flexor tendon.*

SIMPLE MODEL

Because of the time-consuming nature of the complex model above, we developed a simpler model which combines the bones distal to the fetlock joint, representing the pastern joint as a single piece of PVC pipe. Attaching the coffin bone directly to the short pastern bone effectively models in a simple way the anatomy distal to the fetlock joint.

In addition, by fusing the bones distal to the fetlock, one reduces the number of pieces from six to three (see Figure 40).

Figure 40: *For the simple model, there are only three parts around the fetlock joint: proximal (left), sesamoid bone (top), and distal (right).*

Segment 1: Cutting the Bases for the Bones

Segment 1 of the complex model shows how to make the cannon bone and sesamoid bone. The T junction for the long pastern bone is constructed in a similar way. However, a single length of 1½” PVC pipe is used represents the long and short pastern bones and the coffin bone (see Figure 41).

Segment 2: Drilling Holes in the Bones

The same method is used as in the complex model, except there are no holes below the short pastern bone for the coffin joint, and no holes to hold for ligaments to hold the pastern joint together.

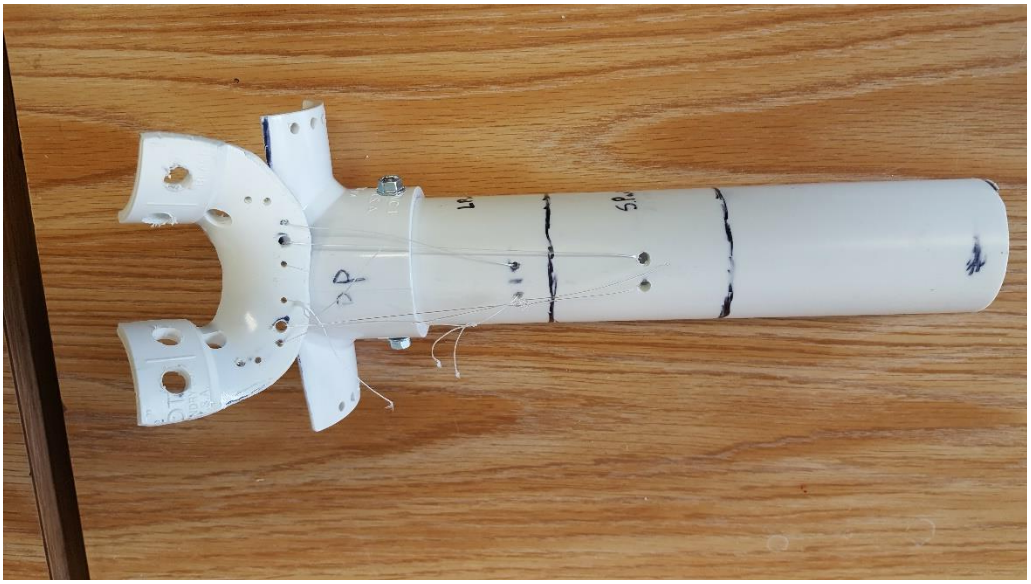


Figure 41: *To drill in the correct places, it is easier if you mark where the distal part of the simple model represents the long pastern bone, short pastern bone, and coffin bone (on the far left is the attached sesamoid bone).*

Segment 3: Stringing the Ligaments and Tendons

On the simple model, time was also saved by not adding collars to the bones. Therefore, after drilling the holes, one proceeded to attach the ligaments for the fetlock joint.

Figure 42 shows the progression of the simple model from the fishing line ligaments, to the addition of the suspensory ligament, and finaly to the addition of a 1½” → 3” adaptor and 1½” 30˚ elbow to simulate a hoof that can be a sturdy base to show the biomechanics of the fetlock joint.

Figure 42: *Stages of adding to the simple leg: clear ligaments, suspensory ligament, and hoof.*

RECOMMENDATIONS FOR FUTURE WORK

Building these models appears to be a valuable way to learn anatomy, physiology, and mechanics of the horse. We have seen that building a complete model skeleton is a lot of work, and requires many individuals. Future work could focus on refining a method for how a class of students could work together during the same year to build and teach each other the anatomy of the horse.

An additional goal remains as the completion of the full skeleton model of the horse. Construction of the sacroiliac joint at the junction of sacral vertebrae and the pelvis will be a major step forward toward that end. Another challenge will be attaching the front legs to the spine. It then only remains to make sure that the model can stand on its own.

There is also the goal to test how well students are able to replicate the process in a lab or class setting as described by objectives 1, 2, and 3. If there is enough time, students should be encouraged to complete the complex model. If time is a limiting factor, students can be tested by build the simple model.

More work could also focus on building models for different animal skeletons. There are many problems that arise from dairy cows that get lameness, and those problems might be managed better if people were able to understand the anatomy of the cow better.

Another method to look into for building the models to help streamline the process would be 3D printing the different bones. Students could learn the anatomy by having to put the structure into the program for the printer and then learn the physiology as they string the bones together.

CONCLUSION

In the process of building this model, people can increase their knowledge of anatomy and possible learn more anatomy than they would by from reference books alone. It is possible to build the models in a lab setting, however, the timeframe allowed dictates the complexity of the model. The complex model is better for a more in-depth analysis of the stay apparatus, the supporting ligaments around the long and short pastern bones, and the coffin and navicular bones. In contrast, the simple model shows the stay apparatus and can be completed in a few hours if the bones are shaped beforehand, or more than that if the students must also build the bones themselves. Overall, the creation of these models appeared to involve all the levels of Bloom's taxonomy. Building anatomical models may play a valuable role in increasing knowledge of the horse, which in turn may lead to improved equine welfare through reduced injuries.

Figure 43: *Comparison between complex (left) and simple (right) models.*

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APPENDIX A:

MANUAL FOR CONSTRUCTION OF A SIMPLE MODEL TO REPRESENT THE EQUINE SUSPENSORY APPARATUS

By: Zandalee Toothaker

This is an instructive manual of how to build a model of the suspensory apparatus of the horse mostly out of PVC pipe and fishing line. This involves the bones and ligaments of the fetlock joint in the distal leg of a horse.

There are three main sections:

I. cutting the bases for the bones,
II. drilling the holes in the bones, and
III. stringing the ligaments.

What you will need

PVC Pipes

- 1 ½" pipe – about 2'
- 1 ½" T junction – 2
- DWVP trap
- 1 ½" → 3" adaptor
- 1 ½" 30˚ elbow

Tools

- Tape measure
- Drill
- Drill bits (5/16, 9/64, 5/64)
- Driver
- Saw
- Pliers
- Scissors
- Screws (12 x ¾ self-tapping)
- Dremel

Other

- Eye protection
- PVC glue
- Fishing line (monofilament nylon)
- Fishing line (braided)
- Thin Cord or Rope
- Matches or lighter

Segment 1: Cutting and Shaping the Bases for the Bones

The distal leg is made of many bones, but this simple model will focus on the mobility of the fetlock joint, to represent the function of the suspensory apparatus. The structure of the pastern and coffin joints, with their associated ligaments, are included in a more complex model, but in this simple model, they are merely represented by rigid PVC pipe.

This model has six main parts: the cannon bone, the distal extremity of the cannon bone, the proximal extremity of the long pastern bone, the long pastern bone and short pastern bone, the sesamoid bone, and the coffin joint and hoof.

I. Cannon Bone (CB)

Cut 1½" PVC pipe to a length of 17"
Grind all edges smooth (using a Dremel is the fastest way)
Set aside until the Distal Extremity of the Cannon Bone is ready

II. Distal Extremity of Cannon Bone (DECB)

The distal extremity of the cannon bone is represented by a 1½" X 1½" X 1½" T – connector. It is necessary to remove a portion of the horizontal part of the T connector (HPT) to create a semicircular surface against which a piece of 1½" tubing will fit snugly, thereby forming the convex articular surface of the distal cannon bone. This is accomplished by making two cuts running the full extent of the horizontal T at approximately the 4 o'clock (front) and 7 o'clock (rear) positions (green line and orange line respectively in figure 1). To make a snug fit against the pipe it is then necessary to grind down the raised areas on the exposed interior surface of the HPT. This is best accomplished using a Dremel (figure 2). It is also necessary to remove ¼" at each end of the HPT, including the attached pipe, to allow for unrestricted movement of the collateral ligaments (red line figure 1). Detailed instructions are as follows:

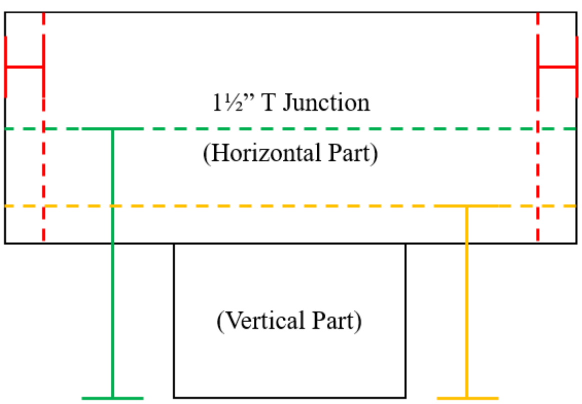

Figure 5 – Where to make cuts in the HPT.

Figure 6 – Grind the lip inside of the HPT flush with the rest of the HPT.

Figure 7 - Screw the piece of PVC pipe flush to the HPT, and then attach to the CB (also shown in this figure is the sesamoid bone and how it will articulate with the joint).

Figure 8 - Screw the DECB as close to the corner as possible, and make sure to screw into the PVC pipe inserted into the VPT and not the empty space below it (also shown in this figure are some of the holes drilled in the DECB, PELPB, and SB; and ligaments).

1. Cut ¼” off each edge of the HPT (shown by the Red dotted line in figure 1)
2. Cut along the front of the HPT 1¼” from the edge of the Vertical Part of the 1½” T junction (VPT)(Orange dotted line in figure 1)
3. Cut the back of the HPT 1¾” from the edge of the VPT (Green dotted line in figure 1)
4. Grind the narrower part on the inside of the T junction so that it is flush with the rest of the HPT (figure 2)
5. Cut a piece of 1½” PVC pipe to the same width as the HPT
6. Screw the piece from step 5 flush to the HPT to complete the DECB, and make sure to Screw the DECB as close to the VPT as possible to leave room for drilling holes for collateral ligaments (figures 3 and 4)
7. Insert the CB into the VPT and screw DECB to the CB, and make sure to screw into the PVC pipe inserted into the VPT and not the empty space below it (figures 3 and 4)
8. Grind all edges smooth
9. Label as the Cannon Bone, the front (cut in step 2) as Dorsal, and the back (cut in step 3) as Palmar

III. Proximal Extremity of Long Pastern Bone (PELB)

The Proximal Extremity of Long Pastern Bone (PELB) articulates with the distal extremity of the cannon bone. To model the PELB a second 1½” X 1½” X 1½” T – connector is used. This also needs to be cut and ground similar to the HPT above. The horizontal pipe at the end of the DECB will fit snugly against the PELB, but the two surfaces in contact will be free to move relative to each other, mimicking an articular surface.

Holes will also be drilled for attachment of the collateral ligaments. The terms HPT and VPT once more refer to the horizontal and vertical parts of the T piece, in this case the one representing the PELPB. Detailed instructions are as follows.

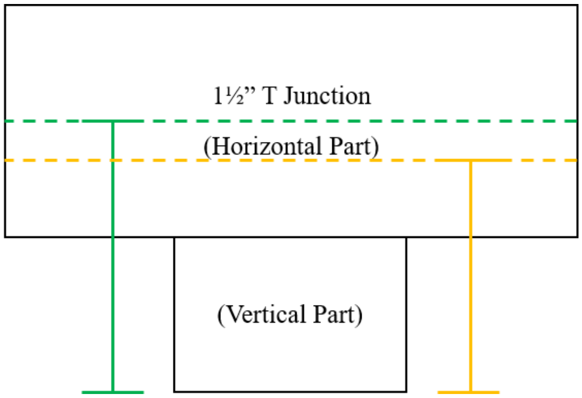

Figure 9 – Where to cut the T junction of the PELPB

1. Cut the front of the HPT 1½” from the edge of the VPT (Orange dotted line in figure 5)
2. Cut the Back of the HPT 1¾” from the edge of the VPT (Green dotted line in figure 5)
3. Grind the narrower part on the inside of the T junction so that it is flush with the rest of the HPT (figure 2)
4. Grind all edges smooth
5. Label the front (cut in step 1) as Dorsal and the back (cut in step 2) as Palmar
6. Set aside until the Long and Short Pastern Bone piece is ready

IV. Long Pastern Bone and Short Pastern Bone (LPB and SPB)

In this model, the long and short pastern bones (LPB and SPB) are modeled as a single length of 1½” PVC pipe. Therefore, all that needs to be done in this simple model is to attach the PELPB, prepared above, to a length of a 6’ length of PVC pipe representing the combined length of the long and short pastern bones.

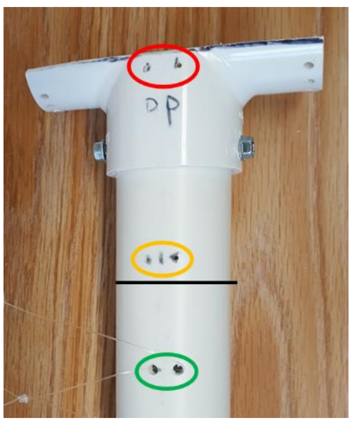

Figure 10 – Mark LPB and SPB to separate them, and attached PELPB (also shown in this figure are the holes drilled in the PELPB, LPB, and SPB).

1. Cut 1½” PVC pipe to a length of 6”
2. Mark 3” down all the way around to mark location of the pastern joint separating the LPB and SPB; label them as such (figure 6)
3. Insert the LPB end into the VPT of the PELPB and screw them together like the CB and DECB; make sure to screw into the PVC pipe inserted into the VPT and not the empty space below it (figure 6)
4. Grind all edges smooth
5. Label the front (the side that matches up with the dorsal side of the PELB) as Dorsal and the back as Palmar.

V. Sesamoid Bone (SB)

The paired sesamoid bones of the fetlock are modeled with a single piece of PVC, which in part represents the tight fibrocartilaginous attachment between the two bones. Because the sesamoid bones articulate with the distal extremity of the cannon bone they need to have an articular surface which also fits snugly around 1½” PVC pipe. The solution we have adopted is to use the U bend in a 1½” PVC trap as the basis for creating a shape which approximates the combined arrangement of the sesamoid bones. Other, perhaps better, solutions to this problem may exist. Detailed instructions for shaping the sesamoid bone as we have modelled it are as follows.

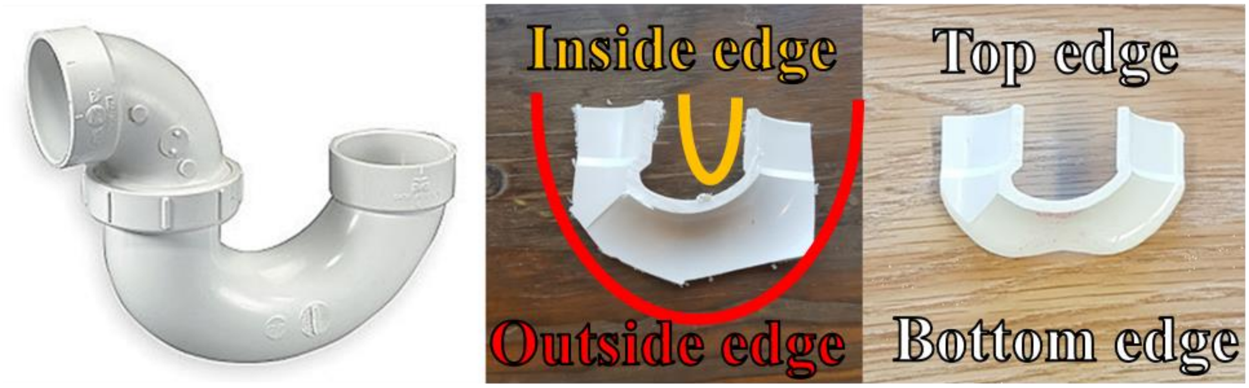

Figure 11 – Trap bend gets cut and then edges are filed smooth to make the proximal sesamoid bone (the middle and right image show the dorsal side).

Figure 12 – Cut the trap in half length-wise, then each of the ends so that one quarter is left. Shown here: trap is cut length-wise and only one of the ends is cut.

1. Remove the elbow fitting from the trap (elbow fitting attached to the trap shown on the left image in figure 7)
2. Cut the trap in half length-wise (figure 8)
3. Cut the ends off the trap (figure 8)
4. Cut the bottom edge off to make a rough U shape, there should be much that curves back out along the outside edge of the U (similar to the middle image in figure 7)
5. Grind the outside edge of the U smooth and grind an indent into the bottom edge
6. Grind the bottom edge so that it will fit flush against the PVC pipe of the DECB
7. Grind all edges smooth
8. Label the front as Dorsal (the face up side in the middle and right images in figure 7) and the back as Palmar (the side not seen in figure 7)

VI. Coffin Joint and Hoof

The coffin joint and hoof are represented as a single rigid structure in this simple model. Therefore, the action of the digital flexor tendons, coffin joint, navicular bone and associated ligaments are not represented. The primary goal is merely to create a realistic pastern angle with load-bearing ground contact to show the action of the suspensory apparatus at the fetlock. Detailed instructions are as follows:

Figure 13 – PVC 1 ½" 30˚ elbow joint acting as a coffin joint, and a 1 ½" to 3" adapter acting as a hoof.

1. Mark the 1½" 30˚ elbow joint (acting as a coffin joint) on the longer side of the curve as dorsal and the shorter curve as palmar
2. Attach elbow joint to the 1½" to 3" adapter (acting as the hoof) (figure 9)
3. Attach the other end of the elbow joint to the SPB, making sure to keep the dorsal and palmar sides in line (Shown in figure 9)

Segment 2: Drilling Holes in the Bones

The distal leg has many ligaments holding the bones together. This model focuses on those necessary for the proper function of the suspensory apparatus (i.e. suspensory and sesamoidean ligaments, and the collateral ligaments of the fetlock joint). It uses yellow rope to represent the suspensory ligament (including the extensor branch), monofilament nylon (fishing line) to represent the collateral ligaments and braided nylon to represent the several sesamoidean ligaments.

Special note 1: Drill bit sizes can be adjusted according to your needs, but we have found that the sizes shown are large enough to thread the different fishing lines and rope effectively, while still being small enough to fit at the necessary positions without compromising structural integrity.

Special note 2: For ease of threading nylon through two holes, when drilling each hole, slightly angle the drill to make a narrow funnel shape out of each hole, and to direct the channel of the holes towards each other. Also, be sure to remove any sharp PVC scraps that might still be connected to the holes, for these can wear down the nylon threads until they snap.

I. Cannon Bone (CB)

1. Drill two holes with the 5/16 bit, on the palmar side, 4” from the top, and 1” apart. This will represent the proximal point of attachment of the suspensory ligament to the palmar aspect of the cannon bone.

II. Distal Extremity of Cannon Bone (DECB)

1. Drill four holes with the 5/64 bit, on the dorsal side of the horizontal piece of PVC pipe, at 90˚ to the inserted CB, two holes ½” from the edges, and two holes ¾” from the edges and in line with the others (figure 4). This will represent the proximal point of attachment to the cannon bone of the medial and lateral collateral ligaments of the fetlock.
2. Drill eight holes with the 9/64 bit, four holes on each edge of the T, the first hole of each set ¼” from the dorsal side, and each hole ¼” apart from the others (figure 4) This will represent the point of attachment of the palmar annular ligament

III. Proximal Extremity of Long Pastern Bone (PELB)

1. Drill eight holes with the 9/64 bit, four holes on each edge of the T, the first hole of each set ½” from the dorsal side, and each hole ¼” apart from the others (figure 4). This represents the point of distal attachment to the long pastern bine of the collateral ligaments of the fetlock joint .
2. Drill two holes with the 5/64 bit, on the palmar side, ¼” from the top, and ½” apart (Circled in Red in figure 6) This will represent point of attachment of the short sesamoidean ligament

IV. Long Pastern Bone and Short Pastern Bone (LPB and SPB)

1. Drill two holes with the 5/64 bit, on the palmar side, 2½” from the top, and ½” apart (Circled in Orange in figure 6) This will represent point of attachment of the oblique sesamoidean ligament
2. Drill two holes with the 9/64 bit, on the palmar side, 4¼” from the top, and ½” apart (Circled in Green in figure 6) This will represent point of attachment of the straight sesamoidean ligament

V. Sesamoid Bone (SB)

A complicated system of ligaments attached to the sesamoid bones is critical for the effective functioning of the suspensory apparatus in the horse. This system includes the suspensory ligament proximal to the fetlock and its extensor branch distal to the fetlock; the palmar annular ligaments; the oblique, short, and straight sesamoidean ligaments. Only the collateral ligaments of the fetlock joint in this model do not involve attachment to the sesamoid bones.

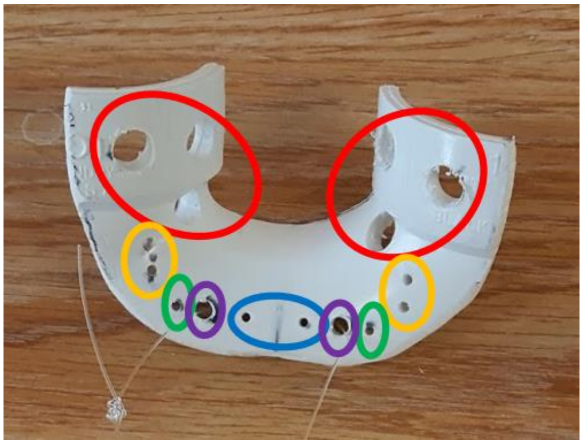

*Figure 14 – Mark where **all** of the many holes will be drilled into the sesamoid bone before drilling **any** holes. Depending on the grinding done to shape the bone, placement of holes may need to be adjusted to fit. Step 1 in Red, 2 in Orange, 3 in Green, 4 in Blue, and 5 in Purple.*

Special note 3: Depending on the size and shape of the SB left after the shaping process, the placement of the holes might need to be adjusted to make sure they all fit. Mark where all of the holes will need to be before you drill and adjust as necessary.

Special note 4: Drill holes for steps 3, 4, and 5 (six holes total) in a line about ¼" from the bottom and equal distance from each other and the outside edge of the SB.

1. For the suspensory ligament: drill six holes with the 5/16 bit, two ½" from the top and ½" from the outside edge, two ½" from the top and ½" from the inside edge, and two 1" from the top and ½" from the inside edge (Red in figure 10)
2. For the palmar annular ligaments: drill four holes with the 5/64 bit, two 1¼" from the top and ½" from the outside edge, and one ¼" beneath each of them (Orange in figure 10)
3. For the oblique sesamoidean ligaments: drill the two outermost holes of the line with the 5/64 bit (Green in figure 10)
4. For the short sesamoidean ligaments: drill the two innermost holes of the line with the 5/64 bit (Blue in figure 10)
5. For the straight sesamoidean ligaments: Drill the two remaining holes of the line with the 9/64 bit (Purple in figure 10)

VI. Coffin Joint and Hoof

1. Drill two holes with the 5/16 bit, on the dorsal side, 1½" from the top, and 1" apart. This will serve as the point of attachment of the extensor branch of the suspensory ligament.

Segment 3: Stringing the Ligaments and Tendons

This model has many ligaments holding bones together, and uses a nylon fishing line and braided fishing line to represent many of the ligaments.

Because threading these lines through holes in a closed pipe can be challenging, we have developed the following method for threading fishing line through a tube of PVC pipe:

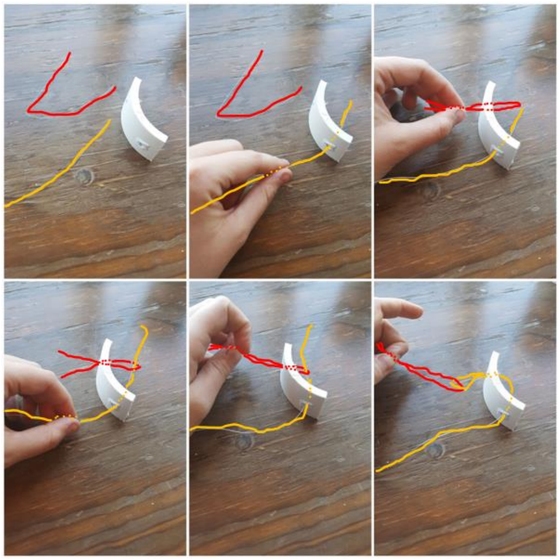

Figure 15 – Method for threading fishing line through a tube of PVC pipe (tube is cut for easier view).

1. You will need a small V of fishing line (outlined in red), the fishing line to be threaded (outlined in orange), and the PVC pipe
2. Feed the thread through the first hole
3. Feed the bottom of the V through the second hole
4. Feed the thread through the fishing line V
5. Pull on both ends of V
6. Pull until the thread is through the second hole

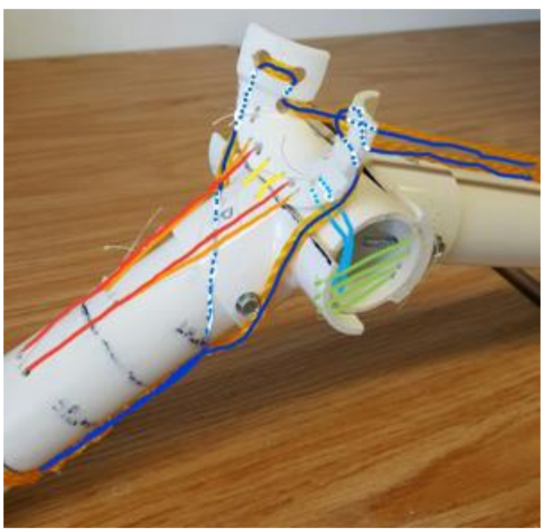

Figure 16 – Ligaments outlined in different colors.

For reference, the ligaments that will be strung are shown in Figure 12

I. Straight sesamoidean ligament (Red)
II. Oblique sesamoidean ligament (Orange)
III. Short sesamoidean ligament (Yellow)
IV. Collateral ligaments of fetlock joint (Green)
V. Palmar annular ligament (Light blue)
VI. Suspensory ligament (Dark blue)

I. Straight Sesamoidean Ligament (StSL)

1. Fit the SB and the PELPB together (make sure both palmar sides are facing you)
2. Feed the monofilament nylon fishing line down through the left hole of the SPB
3. Feed the fishing line up through the right hole of the SPB
4. Feed the fishing line down through the right hole of the SB drilled in step 5
5. Feed the fishing line up through the left hole of the SB drilled in step 5
6. Tighten the fishing line so that the SB sits at the edge of the PELPB

7. Tie the two ends together with three or more square knots (so that the knot doesn't slip) and cut the fishing line

II. Oblique Sesamoidean Ligament (OSL)

1. Continue with same bones as the previous step (make sure both palmar sides are facing you and that the fishing line from the previous step is not twisted)
2. Feed the braided fishing line down through the left hole of the LPB
3. Feed the fishing line up through the right hole of the LPB
4. Feed the fishing line down through the right hole of the SB drilled in step 3
5. Feed the fishing line up through the left hole of the SB drilled in step 3
6. Tighten the fishing line to the same tension as the StSL
7. Tie the two ends together with three or more square knots (so that the knot doesn't slip) and cut the fishing line

III. Short Sesamoidean Ligament (ShSL)

1. Continue with same bones as the previous step (make sure both palmar sides are facing you and that the fishing line from the previous steps is not twisted)
2. Feed the braided fishing line down through the left hole of the PELPB
3. Feed the fishing line up through the right hole of the PELPB
4. Feed the fishing line down through the right hole of the SB drilled in step 4
5. Feed the fishing line up through the left hole of the SB drilled in step 4
6. Tighten the fishing line to the same tension as the StSL and OSL
7. Tie the two ends together with three or more square knots (so that the knot doesn't slip) and cut the fishing line

IV. Collateral Ligaments of Fetlock Joint (CL)

1. Fit the DECB and the PELPB together (make sure both dorsal sides are facing you)
2. Feed the monofilament nylon fishing line down through the most dorsal hole of the DECB
3. Feed the fishing line down through the most dorsal hole of the PELPB
4. Feed the fishing line up through the second most dorsal hole of the PELPB
5. Feed the fishing line up through the second most dorsal hole of the DECB
6. Tighten the fishing line to make the two bones snug
7. Tie the two ends together with three or more square knots (so that the knot doesn't slip) and cut the fishing line

8. Feed a new piece of fishing line down through the third most dorsal hole of the DECB
9. Feed the fishing line down through the third most dorsal hole of the PELPB
10. Feed the fishing line up through the last hole of the PELPB
11. Feed the fishing line up through the last hole of the DECB
12. Tighten the fishing line to make the two bones snug
13. Tie the two ends together with three or more square knots (so that the knot doesn't slip) and cut the fishing line

14. Flip the model over and repeat steps 1-13 on the other side

V. Palmar Annular Ligament (PAL)

1. Fit the DECB and the SB together (make sure both palmar sides are facing you) (figure 4)
2. Feed the braided fishing line down through the top hole on left side of the SB drilled in step 2
3. Feed the fishing line beneath all of the collateral ligaments on the left side and into the horizontal piece of PVC pipe of the DECB
4. Feed the fishing line down through the hole father from the edge of the horizontal piece of PVC pipe on the left side of the DECB drilled in step 1
5. Feed the fishing line up through the hole closer to the edge of the horizontal piece of PVC pipe on the left side of the DECB drilled in step 1
6. Feed the fishing line up through the bottom hole on left side of the SB drilled in step 2
7. Tie the two ends together with three or more square knots (so that the knot doesn't slip) and cut the fishing line

8. Repeat steps 1-7 on the right side of the model

VI. Suspensory Ligament (SL)

Figure 17 – Palmar view of the fetlock joint and how to string the suspensory ligament.

Figure 18 – Side view of the fetlock joint and how to string the suspensory ligament.

1. Start with the dorsal side facing you and the hoof pointing toward you
2. Feed the rope down through the right hole of the coffin joint
3. Feed the rope up through the left hole of the coffin joint
4. Cross the rope to the right side of the model and hold it near the SB
5. Flip the model over so the palmar side is up and the rope is now on the left side of the model (figure 13)

6. Feed the rope from the dorsal side, through the upper left hole of trio of holes on the left side of the SB drilled in step 1 (figure 13)
7. Feed the rope from the palmar side, through the upper right hole of trio of holes on the left side of the SB drilled in step 1 (figure 13)
8. Feed the rope from the dorsal side, through the lower right hole of trio of holes on the left side of the SB drilled in step 1 (figure 13)

9. Feed the rope down through the left hole of the CB
10. Feed the rope up through the right hole of the CB

11. Feed the rope from the palmar side, through the lower left hole of trio of holes on the right side of the SB drilled in step 1 (figure 13)
12. Feed the rope from the dorsal side, through the upper left hole of trio of holes on the right side of the SB drilled in step 1 (figure 13)
13. Feed the rope from the palmar side, through the upper right hole of trio of holes on the right side of the SB drilled in step 1 (figure 13)

14. Flip the model over so the dorsal side is up and the rope is now on the left side of the model
15. Wrap the rope many times down the piece of rope that already crosses the dorsal side of the LPB and SPB
16. Feed the rope down through the left hole of the coffin joint (alongside the rope already there)
17. Feed the rope up through the right hole of the coffin joint (alongside the rope already there)
18. Tie the two ends together with three or more square knots (so that the knot doesn't slip) and cut the rope
19. Burn the rope ends so they don't fray and the knot a little so it doesn't slip

Now Test It

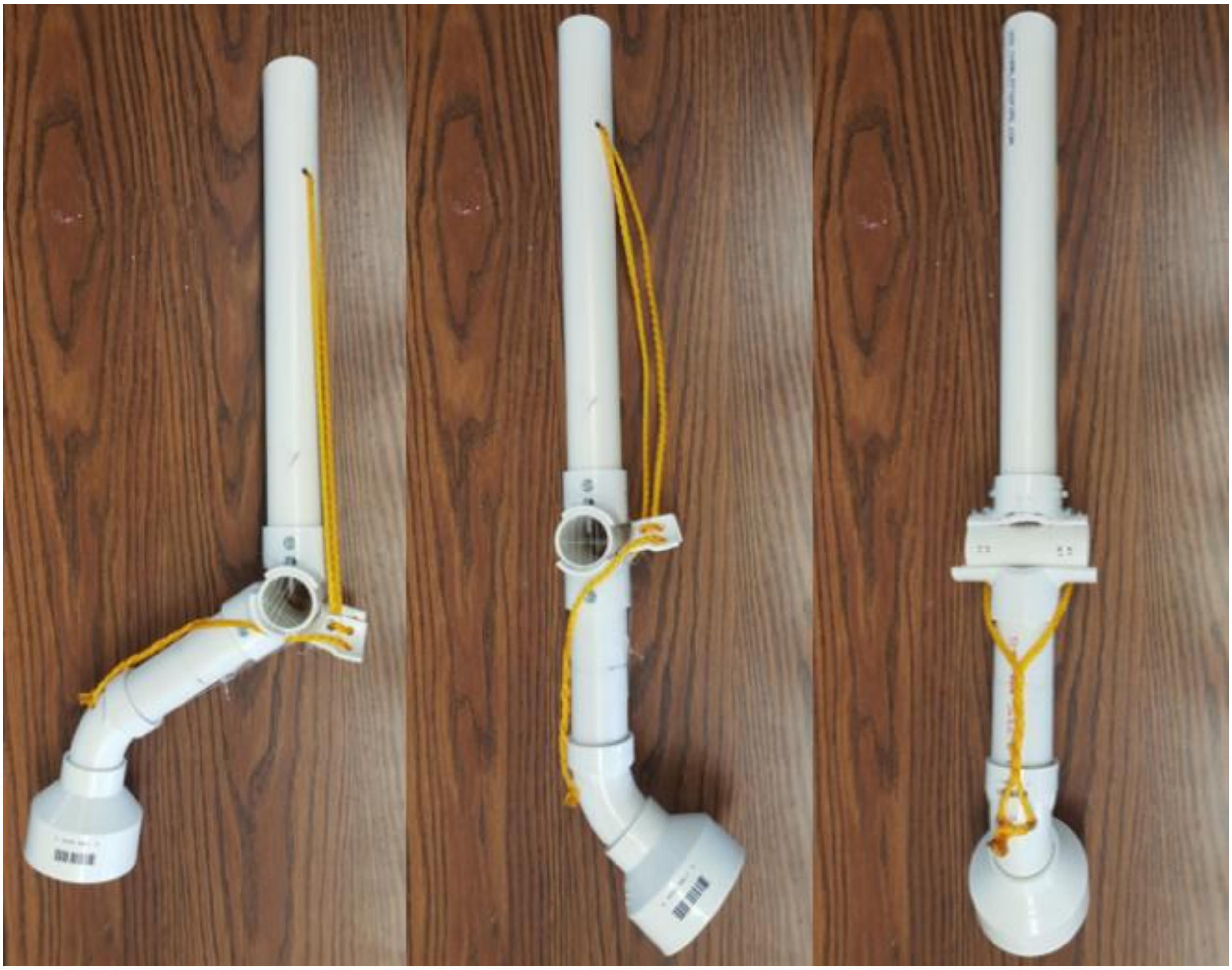

Figure 19 – Flex the model to see the ligaments' function.

1. Flex the model and watch which ligaments tighten when others loosen and vice versa (Shown in Fig).
2. Stand the model up, hold the hoof loosely in place, and gently press the cannon bone down to watch the ligaments of the suspensory apparatus tighten to keep the sesamoid bone articulating with the fetlock joint.

APPENDIX B: CATALOG OF EQUINE ANATOMY

This is an index of the bones, important parts of those bones (see Table 1), ligaments, and tendons (see Table 2) of the anatomy of the horse. The page numbers refer to the *ABC of the Horse Atlas* which has been our most used reference for this project. The bolded items are all represented in model distal legs.

Table 1: Bones

English	Page number	Latin
acetabulum	28, 48, 49, 50, 51	acetabulum
wing of atlas	17, 18	ala atlantis
wing of ilium	28, 48, 49, 50, 51	ala ossis ilii
wing of sacrum	24, 25, 26, 27	ala ossis sacri
angle of rib	22, 23	angulus costae
angle of mandible	10, 12, 14, 15	angulus mandibulae
anulus fibrosus	20, 21	anulus fibrosus
caudal thoracic aperture (thoracic outlet)	22, 23	apertuta thoracis caudalis
cranial thoracic aperture (thoracic inlet)	22, 23	apertuta thoracis cranialis
hyoid apparatus	14, 15	apparatus hyoideus
costal arch	8, 9, 22, 23	arcus costalis
dorsal arch of atlas	17, 18, 19	arcus dorsalis atlantis
ischial arch	48, 49	arcus ischiadicus
ventral arch of atlas	18, 19	arcus ventralis atlantis
arch of vertebra	20, 21, 24, 26	arcus vertebrae
zygomatic arch	10, 11	arcus zygomaticus
atllanto-occipital joint	8, 9	articulatio atlanto-occipitalis
calcaneoquartal joint	57	articulatio calcaneopquartalis
centrodistal joint	57	articulatio centrodistalis
hip joint	8, 9, 46, 47, 50, 51	articulatio coxae
elbow joint	8, 9, 29	articulatio cubiti
femoropatellar joint	54, 55	articulatio femoropatellaris
femorotibial joint	54, 55	articulatio femorotinialis
stifle joint	8, 9, 46, 47	articulatio genus

shoulder joint	8, 9, 29, 31, 32, 33	articulatio humeri
humeroradial joint	34, 35	articulatio humeroradialis
humeroulnar joint	34, 35	articulatio humeroulnaris
iliosacral joint	50, 51	articulatio iliosacralis sacroiliaca
coffin joint (distal interphalangeal joint)	**8, 9, 29, 44, 45, 46, 47**	**articulatio interphalangea distalis**
pastern joint (proximal interphalangeal joint)	**8, 9, 29, 44, 45, 46, 47**	**articulatio interphalangea proximalis**
lumbosacral joint	24, 25	articulatio lumbo sacralis
midcarpal joint	8, 9, 38, 39, 40, 41	articulatio mediocarpea
fetlock joint (metacarpophalangeal joint)	**8, 9, 29, 42, 43**	**articulatio metacarpophalangea**
fetlock joint (metatarsophalangeal joint)	8, 9, 46, 47	articulatio metatarsophalangea
joint of accessory carpal bone	38, 39, 40, 41	articulatio ossis carpi accessorii
radioulnar joint	34, 35	articulatio radioulnaris
sacroiliac joint	8, 9, 26, 27	articulatio sacroiliaca
sternocostal joint	22, 23	articulatio sternocostalis
talocalcaneal joint	57	articulatio talocalcanea
tarsal joint	8, 9, 46, 47	articulatio tarsi
tarsocrural joint	57	articulatio tarsocruralis
tarsometatarsal joint	57	articulatio tarsometatarsea
jaw joint (temporomandibular joint)	8, 9	articulatio temporomandibularis
tibiofibular joint	54, 55	articulatio tibiofibularis
carpal joints	8, 9, 29, 36, 37, 38, 39, 40, 41	articulationes carpi
intervertebral joint	8, 9	articulationes intervertebrales
joints of pelvic limb	46, 47	articulationes membri pelvini
joints of thoracic limb	29	articulationes membri thoracici
atlas (cervical vertebra 1)	8, 9, 16, 17, 18, 19	atlas (vertebra cerbicalis I)
axis (cervical vertebra 2)	8, 9, 16, 17, 18, 19	axis (vertebra cervicalis II)
basihyoid	14, 15	basihyoideum
base of third metacarpal bone	**42, 43**	**basis ossis metacarpalis III**
base of third metatarsal bone	58	basis ossis metatarsalis III
base of middle phalanx	**44, 45**	**basis phalangis mediae**
base of proximal phalanx	**44, 45**	**basis phalangis proximalis**
tympanic bulla	12, 13	bulla tympanica
calcaneus	57	calcaneus
interincisive canal	10, 11	canalis interincisivus
hypoglossal canal	12, 13	canalis nervi hypoglossi
solear canal	44, 45	canalis solearis
tarsal canal	57	canalis tarsi
head of rib	22, 23	caput costae

head of fibula	54, 55, 56	caput fibulae
head of humerus	31, 32, 33	caput humeri
mandibular head	14, 15	caput mandibulae
head of femur	52, 53	caput ossis femoris
head of third metacarpal bone	**42, 43**	**caput ossis metacarpalis III**
head of third metatarsal bone	58	caput ossis metatarsalis III
head of middle phalanx	**44, 45**	**caput phalangis mediae**
head of proximal phalanx	**44, 45**	**caput phalangis proximalis**
head of radius	34, 35, 36, 37	caput radii
costal cartilage	22, 23	cartilago costalis
scapular cartilage	30	cartilago scapulae
xiphiod cartilage	22, 23	cartilago xiphoidea
glenoid cavity = glenoid fossa od scapula	30	cavitas glenoidalis
ceratohyoid	30	ceratohyoideum
choana	10, 11	choana
cochlea of tibia	56	cochlea tibiae
neck of rib	22, 23	collum costae
neck of humerus	32, 33	collum humeri
neck of femur	52, 53	collum ossis femoris
neck of scapula	30	collum scapulae
condyle of humerus	32, 33, 34, 35	condylus humeri
lateral condyle of femur	50, 51, 54	condylus lateralis ossis femoris
lateral condyle of tibia	54, 55, 56	condylus lateralis tibiae
medial condyle of femur	52, 53, 54, 55, 56	condylus medialis ossis femoris
medial condyle of tibia	54	condylus medialis tibiae
occipital condyle	10, 11	condylus occipitalis
boody of rib	22, 23	corpus costae
body of fibula	56	corpus fibulae
body of humerus	32, 33	corpus humeri
body of mandible	12, 13	corpus mandibulae
body of femur	52, 53	corpus ossis femoris
body of ilium	26, 28, 48, 49	corpus ossis ilii
body of ischium	28, 48, 49	corpus ossis ischii
body of third metacarpal bone	**42, 43**	**corpus ossis metacarpalis III**
body of third metatarsal bone	58, 49	corpus ossis metatarsalis III
body of pubis	44, 45	corpus ossis pubis
body of middle phalanx	**44, 45**	**corpus phalangis mediae**
body of proximal phalanx	**44, 45**	**corpus phalangis proximalis**
body of radius	36, 37	corpus radii
body of sternum	22, 23	corpus sterni
body of tibia	56	corpus tibiae
body of vertebra	18, 19, 20, 21, 24	corpus vertebrae

rib	8, 9, 16, 22, 24	costa
false ribs (asternal ribs)	22, 23	costae spuriae (costae asternales)
true ribs (sternal ribs)	22, 23	costae verae (costae sternales)
cranium	8, 9	cranium
facial crest	10, 11	crista facialis
crest of humerus	32, 33	crista humeri
iliac crest	26, 48, 49, 50, 51	crista iliaca
nuchal crest	10, 11	crista nuchae
lateral sacral creat	24, 25	crista sacralis lateralis
medial sacral crest	26, 27	crista sacralis mediana
external sagittal crest	10, 11	crista sagittalis externa
sagittal crest of third metatarsal bone	42, 43, 58	crista sagittalis
lateral/medial supracondylar crest	32, 33	crista supracondylaris lateralis/medialis
transverse crest of radius	36, 37	crista transversa radii
ventral crest	17, 18, 19, 20, 24	crista ventralis
tooth of axis	17, 18, 19, 20, 21	dens axis
teeth	10, 12, 14	dentes
intervertebral disc	20	discus intervertebralis
iliopubic eminence	48, 49	eminentia iliopubica
intercondylar eminence	54, 55, 56	eminentia intercondylaris
lateral epicondyle of humerus	32, 33	epicondylus lateralis humeri
lateral epicondyle of femur	52, 53	epicondylus lateralis ossis femoris
medial epicondyle of humerus	32, 33	epicondylus medialis humeri
medial epicondyle of femur	52, 53	epicondylus medialis ossis femoris
epihyoid	14, 15	epihyoideum
caudal extremity	18, 19, 20, 21	extremitas caudalis
caudal extremity of sacrum	24, 25	extremitas caudalis ossis sacri
cranial extremity	18, 19, 20, 21, 24, 25	extremitas cranialis
cranial extremity of sacrum	24, 25, 26, 27	estremitas cranialis ossis sacri
articular surface for transverse process of sacrum	24, 26	facies articularis (inter-) transveraria ossis sacri
articular surface of head of rib	22, 23	facies articularis capitis costae
articular surface of head of fibula	54, 55, 56	facies articularis capitis fibulae
articular surface for carpus	36, 37, 38, 39, 40, 41	facies articularis carpea
articular surface of fibula	56	facies articularis fibularis
articular surface for second metacarpal bone	**38, 39, 40, 41**	**facies articularis ossis metacarpalis II**
articular surface for the third metacarpal bone	**38, 39, 40, 41, 42, 43**	**facies articularis ossis metacarpalis III**

articular surface for the third metatarsal bone	58	facies articularis ossis metatarsalis III
articular surface of distal sesamoid bone	**44, 45**	**facies articularis ossis sesamoidei distalis**
articular surface of patella	52, 53, 54, 55	facies articularis patellae
articular surface of distal phalanx	**44, 45**	**facies articularis phalangis distalis**
articular surface of transverse process of 6th lumbar vertebra	24, 25	facies articularis processus transversi vertebrae lumbalis VI
articular surface of transverse process of 5th and 6th lumbar vertebrae	24, 25	facies articularis processus transversi vertebrae lumbalis V-VI
proximal articular surface of tibia	54, 55, 56	facies articularis proximalis tibiae
articular surface for sesamoid bone	**44, 45**	**facies articularis sesamoidea**
articular facet of tubercle of rib	22, 23	facies articularis tuberculi costae
rough surface	52, 53	facies aspera
auricular surface of ilium	26, 27	facies auricularis ossis ilii
auricular surface of sacrum	24, 25, 26, 27	facies auricularis ossis sacri
medial costal surface	30	facies costalis
cranial surface of patella	52, 53	facies cranialis patellae
dorsal surface of third metacarpal bone	**42, 43**	**facies sorsalis ossis metacarpalis III**
dorsal surface of sacrum	24, 26	facies dorsalis ossis sacri
external surface of pubis	48, 49	facies externa ossis pubis
flexor surface of distal sesamoid bone	**44, 45**	**facies flexoria ossis sesamoidei distalis**
gluteal surface of ilium	28	facies glutea ossis ilii
lateral surface of scapula	30	facies lateralis sacpulae
palmar surface of third metacarpal bone	**42, 43**	**facies palmaris ossis metacarpalis III**
parietal surface of distal phalanx	**44, 45**	**facies parietalis phalangis distalis**
pelvic (ventral) surface of pubis	48, 49	facies pelvina ossis pubis
pelvic (ventral) surface of sacrum	24, 48, 49	facies pelvina ossis sacri
popliteal surface	52, 53	facies poplitea
sacropelvic surface	48, 49	facies sacropelvina
serrated surface of scapula	30	facies serrata scapulae
solear surface	44, 45	facies solearis
fibula	46, 47, 50, 51, 54, 55, 56	fibula
orbital fissure	8, 9	fissura orbitalis
palatine fissure	10, 11	fissura palatina
alar foramen	16, 17, 18, 19	foramen alare
infraorbital foramen	8, 9, 20, 21	foramen infraorbitale

interveterral foramen	15, 16, 17, 18, 19	foramen intervertebrale
foramen lacerum	12, 13	foramen lacerum
great foramen	10, 11	foramen magnum
mandibular foramen	14, 15	foramen mandibulae
mental foramen	14, 15	foramen mentale
obturator foramen	26, 48, 49, 50, 51	foramen obturatum
greater palantine foramen	10, 11	foramen palatinum majus
lateral solear foramen	44, 45	foramen soleare laterale
medial solear foramen	44, 45	foramen soleare mediale
supraorbital foramen	8, 9	foramen supraorbitale
transverse foramen of atlas	15, 16, 17, 18, 19	foramen transversarium atlantis
transverse foramen 2-6	15, 16, 17, 18, 19	foramen transversarium II-VI
vertebral foramen	16, 17, 18, 19, 20, 21, 24, 26	foramen vertebrale
lateral vertebral foramen	17, 18, 19	foramen vertebrale laterale
dorsal sacral foramina	24	foramina sacralia dorsalia
coronoid fossa	32, 33	fossa coronoidea
extensor fossa of femur	52, 53	fossa extensoria ossis femoris
fossa for articular surface of 6th lumbar vertebra	24	fossa faciei articularis vertebrae lumbalis VI
infraspinous fossa	30	fossa infraspinata
intercondylar fossa	52, 53, 54, 55	fossa intercondylaris
mandibular fossa fo temporal bone	10, 11	fossa mandibularis ossis temporalis
olecranon fossa	32, 33, 34, 35	fossa olecrani
fossa for lacrimal sac	8, 9	fossa sacci lacrimalis
subscapular fossa	30	fossa subscapularis
supraspinous fossa	30	fossa supraspinata
trochanteric fossa	52, 53	fossa trochanerica
caudal articular fovea	16, 17, 18, 19	fovea articularis caudalis
cranial articular fovea	16, 17	fovea articularis caranialis
articular fovea of middle phalanx	**44, 45**	**fovea articularis phalangis mediae**
articular fovea of proximal phalanx	**44, 45**	**fovea articularis phalangis proximalis**
fovea of head of femur	52, 53	fovea capitis ossis femoris
fovea of head of radius	34, 35, 36, 37	fovea capitis radii
caudal costal fovea	18, 19, 20, 21, 22, 23	fovea costalis caudalis
cranial costal fovea	18, 19, 20, 21, 22, 23	fovea cranialis
costal fovea of transverse process	18, 19, 20, 21	fovea costalis processus transversi
dental fovea	16, 17, 22, 23	fovea dentis
knee of rib	22, 23	genu costae
pterygoid hamulus	8, 9, 10, 11	hamulus pterygoideus

humerus	8, 29, 31, 32, 33, 34, 35	humerus
acetabular notch	26, 28, 50, 51	incisura acetabuli
glenoid notch	30	incisura glenoidalis
greater sciatic notch	26, 27, 28, 48, 49, 50, 51	incisura ischiadica major
lesser sciatic notch	26, 28, 48, 49, 50, 51	incisura ischiadica minor
popliteal notch	54, 55, 56	incisura poplitea
radial notch of ulna	36, 37	incisura radialis ulnea
scapular notch	30	incisura scapulae
trochlear notch of ulna	34, 35, 36, 37	incisura trochlearis ulnae
vascular groove for facial vessels	8, 9	incisura vasorum facialium
caudal vertebral notch	11, 19, 20, 21, 24, 25, 26, 27	incisura vertebralis caudalis
cranial vertebral notch	18, 19, 20, 21, 24, 25	incisura vertibralis cranialis
lamina of arch of vertebra	18, 19, 20, 21	lamina arcus vertebrae
ventral lamina	16, 17, 18, 19	lamina ventralis
temporal line	8, 9	linea temporalis
terminal line of pelvis	48, 49	linea terminialis pelvis
lateral malleolus of tibia	56	malleolus lateralis tibiae
medial malleolus of tibia	56	malleolus medialis tibiae
mandible	8, 9	mandibula
manubrium of sternum	22, 23	manubrium sterni
alveolar border of mandible	12, 13	margo alveolaris mandibulae
caudal border of scapula	30	margo caudalis scapulae
coronary border	44, 45	margo coronalis
cranial border of scapula	30	margo cranialis scapulae
cranial border of tibia	56	margo cranialis tibiae
dorsal border of scapula	30	margo dorsalis scapulae
lateral border of radius	36, 37	margo lateralis radii
medial border of radius	36, 37	margo medialis radii
soear border	44, 45	margo solearis
bentral border of mandible	12, 13	margo ventralis mandibulae
maxilla	8, 9, 10, 11	maxilla
external acoustic opening	10, 11, 12, 13	meatus acusticus externus
meniscus	54, 55	meniscus
nucleus pulposus	18, 19, 20, 21	nucleus pulposus
olecranon	34, 35, 36, 37	olecranon
orbit	8, 9	orbita
bony part of rib	22, 23	os costale
hip bone	8, 16, 46, 47	os coxae

femur	46, 47, 50, 51, 52, 53, 54, 55	os femoris
frontal bone	10, 11	os frontale
ilium	26, 27, 28, 48, 49, 50, 51	os ilium
incisive bone	8, 9, 10, 11	os incisivum
ischium	28, 48, 49, 50, 51	os ischii
lacrimal bone	10, 11	os lacrimale
second metacarpal bone (splint bone)	**8, 38, 39, 40, 41, 42, 43**	**os metacarpale II**
third metacarpal bone (cannon bone)	**8, 38, 39, 40, 41, 42, 43**	**os metacarpale III**
fourth metacarpal bone (splint bone)	**8, 38, 39, 40, 41, 42, 43**	**os metacarpale IV**
metacarpal bones	**29**	**os metacarpalia**
second metatarsal bone	57, 58	os metatarsale II
third metatarsal bone	8, 57, 58	os metatarsale III
fourth metatarsal bone	57, 58	os metatarsale IV
nasal bone	10, 11	os nasale
occipital bone	10, 11	os occipitale
palatine bone	12, 13	os palatinum
parietal bone	10, 11	os parietale
pterygoid bone	12, 13	os pterygoideum
pubis	28, 48, 49, 50, 51	os pubis
sacrum	8, 16, 24, 26, 28, 50, 51	os sacrum
distal sesamoid bone (navicular bone)	**44, 45**	**os sesamoideum distale**
lateral proximal sesamoid bone	**29**	**os sesamoidum proximale laterale**
sphenoidal bone	12, 13	os sphenoidale
temporal bone	10, 12	os temporale
zygomatic bone	10, 12	os zygomaticum
distal row of carpal bones	38, 39, 40, 41	ossa carpalia
distal row of carpal bones	8, 29, 38, 39, 40, 41	ossa carpi accessorium
skeleton of pelvic limb	46, 47	ossa membri pelvini
bones of the forelimb	**29**	**ossa membri thoracici**
metacarpal bones	**29, 38, 39, 40, 41, 42, 43**	**ossa metacarpalia**
second and third metacarpal bones (splint bones)	**8, 9**	**ossa metacarpalia II et IV**
metatarsal bones	46, 47, 57, 58	ossa metatarsalia
second and third metatarsal bones (splint bones)	8, 42	ossa metatarsalia II et IV

proximal sesamoid bones	**8, 28, 29, 42, 43, 46, 47**	**ossa sesmoidea proximalia laterale**
tarsal bones	46, 47, 57	ossa tarsi
caudal part of greater tubercle of humerus	31, 32, 33	pars caudalis tuberculi majoris
caudal part of lesser tubercle of humerus	31, 32, 33	pars caudalis tuberculi minoris
cranial part of greater tubercle of humerus	31, 32, 33	pars caudalis tubercu majoris
cranial part of lesser tubercle of humerus	31, 32, 33	pars carnialis tuberculi minoris
patella	46, 47, 50, 51, 52, 53, 54, 55	patella
pecten ossis pubis	48, 49	pecten ossis pubis
pedicle of arch of vertebra	20, 21	pediculus arcus vertebrae
distal phalanx	**8, 29, 44, 45, 46, 47**	**phalanx distalis**
middle phalanx	**8, 29, 44, 45, 46, 47**	**phalanx media**
proximal phalanx	**8, 29, 42, 43, 44, 45, 46, 47**	**phalanx proximalis**
anconeal process	34, 35, 36, 37	processus anconaeus
caudal articular process	17, 18, 19, 20, 21, 24	processus articularis caudalis
cranial articular process	17, 18, 19, 20, 21, 24, 26	processus articularis cranialis
cranial articular process of sacrum	24	processus articularis cranialis ossis sacri
condylar process of mandible	10	processus condylaris mandibulae
coracoid process of scapula	30	processus coracoideus
coronoid process of mandible	10, 14	processus coronoideus mandibulae
costal process (transverse process)	24	processus costalis (= processus transversus)
extensor process of distal phalanx	**44, 45**	**processus extensorius phalangis distalis**
extensor process of middle phalanx	**44, 45**	**processus extensorius phalangis mediae**
lingual process	14, 15	processus lingualis
mamillary process	20, 21, 24	processus mamillaris
mastoid process	10	processus mastoideus
nasal process of incisive bone	10	processus nasalis ossis incisivi
palatine process of incisice bone	12	processus palatinus ossis incisivi
lateral palmar process	**44, 45**	**processus palmaris lateralis (phalangis distalis)**

medial palmar process	**44, 45**	**processus palmaris medialis (phalangis distalis)**
paracondylar process of occipital bone	12	processus paracondylaris ossis occipitalis
retroarticular process	10	processus retroarticularis
spinous process	17, 18, 19, 20, 21, 24, 25, 26, 27	processus spinosus
lateral styloid process of radius	36, 37	processus styloideus lateralis radii
medial styloid process of radius	36, 37	processus styloideus medialis radii
styloid process of tempral bone	12	processus styloideus ossis temporalis
temporal process of zygomatic bone	12	processus temporalis ossis zygomatici
transverse process	17, 18, 19, 20, 21, 24, 26, 27	processus transversus
xiphoid process	22, 23	processus xiphoideus
zygomatic process of fronal bone	10, 12	processus zygomaticus ossis frontalis
zygomatic process of tempral bone	10	processus zygomaticus ossis temporalis
promontory of sacrum	24	promontorium ossis sacri
radius	8, 29, 34, 35, 36, 37, 38, 39, 40, 41	radius
caudal ramus of pubis	48, 49	ramus caudalis ossis pubis
cranial ramus of pubis	48, 49	ramus cranialis ossis pubis
ramus of mandible	14, 15	ramus mandibulae
ramus of ischium	48, 49	ramus ossis ischii
scapular notch	8, 29, 30, 31	scapula
	17	spatium atlanto-occipitale
	17	spatium atlantoaxiale
intercostal space	22, 23	spatium intercostale
interosseous space of antebrachium	34, 35, 36, 37	spatium interosseum antebrachii
crural interosseous space	56	spatium interosseum cruris
ischial spine	28, 48, 49, 50, 51	spina ischiadica
spine of scapula	30	spina scapulae
sternebrae	22, 23	sternevrae
sternum	8, 22, 23, 126, 127	sternum
stylohyoid	14, 15	stylohyoideum
extensor groove	54, 55, 56	sulcus extensorius
intertubercular groove	31, 32, 33	sulcus interubercularis
lateral parietal groove	**44, 45**	**sulcus parietalis lateralis (phalangis distalis)**
medial parietal groove	**44, 45**	**sulcus parietalis medialis (phalangis distalis)**
sustentaculum of talus	57	sustentaculum tali
pelvic symphysis	48, 49, 50, 51	symphysis pelvina

flat part (table) of ischium	48, 49	tabula ossis ischii
talus	57	talus
thorax	23	thorax
thyrohyoid	14, 15	thyrohyoideum
tibia	8, 46, 47, 50, 51, 54, 55, 56, 57	tibia
trangular rough area of proximal phalanx	**42, 43**	**trigonum phalangis proximalis**
greater trochanter	52, 53	trochanter major
lesser trochanter	52, 53	trochanter minor
third trochanter	50, 51, 52, 53	trochanter tertius
trochlea of humerus	34, 35	trochlea humeri
trochlea of femur	52, 53, 54, 55	trochlea ossis femoris
trochlea of radius	36, 37	trochlea radii
calcanean tuber	8, 57	tuber calcanei
tuber coxae	8, 28, 48, 49, 50, 51	tuber coxae
ischial tuberosity	8, 28, 48, 49, 50, 51	tuber ischiadicum
olecranon tuber	36, 37	tuber olecrani
tuber sacrale	8, 28, 48, 49, 50, 51	tuber sacrale
tuber of spine of scapula	30	tuber spinae scapulae
articular tubercle of temporal bone	10	tuberculum articulare ossis temporalis
tubercle of rib	22, 23	tuberculum costae
dorsal tubercle of C 3-6	18, 19	tuberculum dorsale C III - VI
infraglenoidal tubercle	30	tuberculum infraglenoidale
intermediate tubercle	31	tuberculum intermedium
greater tubercle of humerus	31, 32, 33	tuberculum majus
lesser tubercle of humerus	31, 32, 33	tuberculum minus
tubercle of smaller psoas muscle	28, 50, 51	tuberculum musculi psoas minoris
ventral pubic tubercle	48, 49, 50, 51	tuberculum pubicum ventrale
supraglenoid tubercle	30, 31	tuberculum supraglenoidale
tubercle of talus	57	tuberculum tali
tubercle of trochlea of femur	52, 53, 54, 55	tuberculum trochleae ossis femoris
ventral tubercle of atlas	18, 19	tuberculum ventrale atlantis
ventral tubercle of C 3-5	18, 19	tuberculum ventrale CIII - V
deltoid tuberosity of humerus	32, 33	tuberositas deltoidea humeri
flexor tuberosity	44, 45	tuberositas flexoria
tuberosity of third metatarsal bone	42, 43, 58	tuberositas ossis metatarsalis III
radial tuberosity	34, 35, 36, 37	tuberositas radii
lateral supracondylar tuberosity of femur	52, 53	tuberositas supracondylaris lateralis ossis femoris
teres major tuberosity	32, 33	tuberositas teres major

tuberosity of tibia	54, 55, 56	tuberositas tibiae
tympanohyoid	14, 15	tympanohyoideum
ulna	8, 29, 34, 35, 36, 37	ulna
caudal vertebrae	8, 16, 28	vertebrae caudales
cervical vertebrae	8, 16, 17	vertebrae cervicales
lumbar vertebrae	8, 16, 50, 51	vertebrae lumbales
sacral vertebrae	24	bertebrae sacrales
thoracic vertebrae	8, 16, 50, 51	vertebrae thoraciscae
vomer	12	vomer

Table 2: Ligaments and Tendons

English	Page number	Latin
accessoriocarpoulnar ligament	64, 65	ligamentum accessoriocarpoulnare
accessoriometacarpal ligament	64, 65	ligamentum accessoriometacarpeum
accessoriquartal ligament	64, 65	ligamentum acessorioquartale
accessorioulnar ligament	64, 65	ligamentum accessorioulnare
accessory carpal bone (pisiform bone)	64, 65	os carpi accessorium
accessory ligament	66, 67	ligamentum accessorium
acetabular lip	66, 67	labrum acetablare
acetabulum	66, 67	acetabulum
apex of frog	77	apex cunei
bar	77	pars inflexa parietis
base of frog	77	basis cunei
biceps brachii muscle	62	m. biceps brachii
border of sole	77	margo solearis
broad sacrotuberous ligament	66, 67	ligamentum sacrotuberale latum
calcaneus	70, 71	calcaneus
carpal ligaments	64, 65	ligamenta carpi
caudal costal fovea	60, 61	fovea costalis caudalis
caudal cruciate ligament	68, 69	ligamentum cruciatum caudale
caudal subigamentous nucal bursa	60, 61	bursa subligamentosa nuchalis caudalis
caudal vertebrae	66, 67	vertebrae caudales
central grouve of frog	77	sulcus cunealis centralis
central part of sole	77	corpus soleae
central tarsal bone	70, 71	os tarsi centrale
chondrocompedal ligament	72, 73, 74, 75	ligamentum chondrocompedale
chondrocoronal ligament	72, 73, 74, 75	ligamentum chondrocoronale
chondrosesamoidean ligament	**72, 73**	**ligamentum chondrosesamoideum**

collateral chondroungular ligament	**72, 73, 74, 75**	**ligamentum chondroungulare collaterale**
collateral distal sesamoidean ligament	**72, 73, 74, 75, 76**	**ligamentum sesamoideum distale collaterale**
collateral ligament of distal interphalangeal joint	**72, 73, 74, 75**	**ligamentum collaterale articulationis interphalangeae distalis**
collateral ligament of proximal interphalangeal joint	**72, 73, 74, 75**	**ligamentum collaterale articulationis interphalangeae proximalis**
collateral ligaments of metacarpophalangeal/metatarsophalangeal joint	**72, 73, 74, 75**	**ligamenta collateralia articulationis metacarpophalangeae/metatarsophalangeae**
collateral sesamoidean ligament	**72, 73**	**ligamentum sesamoideum collaterale**
coronary dermis	76	dermis coronae
coranary epidermis	76	epidermis coronae
costotransverse ligament	60, 61	ligamentum costotransversarium
cranial costal fovea	60, 61	fovea costalis cranialis
cranial cruciate ligament	68, 69	ligamentum cruciatum craniale
cranial subligamentous nuchal bursa	60, 61	bursa subligamentosa nuchalis cranialis
cranial tibial muscle	70, 71	m. tibialis cranialis
cruciate sesamoidean ligament	**72, 73**	**ligamentum sesamoideum cruciatum**
crural interosseous membran	68, 69	membrana interossea cruris
dermis of frog	76	dermis cunei
dermis of sole	76	dermis soleae
digital cushion	74, 75	tela subcutanea tori (pulvinus digitalis)
digital pad	77	torus ungulae
distal phalanx	**72, 73, 74, 75, 76**	**phalanx distalis**
distal sesamoid bone	**72, 73, 74, 75, 76, 78**	**os sesamoideum distale**
distal sesamoidean impar ligament	**72, 73**	**ligamentum sesamoideum distale impar**
dorsal carpometacarpal ligaments	64, 65	ligamenta carpometacarpea dorsalia
dorsal intercarpal ligaments	64, 65	Ligamenta intercarpea dorsalia
dorsal longitudinal ligament	60, 61	ligamentum longitudinale dorsale
dorsal plantar ligaments	70, 71	ligamenta tarsi dorsalia
epidermis of frog	76	epidermis cunei
extensor branch of interosseous muscle	**74, 75**	**ramus extensorius musculi interossei**
external layer	77	stratum externum
femur	66, 67, 68, 69	os femoris
fibula	68, 69	fibula
fourth carpal bone	64, 65	os carpale IV

fourth metacarpal bone (splint bone)	**64, 65, 74, 75**	**os metacarpal IV**
fourth metatarsal bone	70, 71	os metatarsale IV
fourth tarsal bone	70, 71	os tarsale IV
greater sciatic foramen	66, 67	foramen ischiadicum majus
greater sciatic notch	66, 67	incisura ischiadica major
head of femur	66, 67	caput ossis femoris
heel	77	angulus parietis
hip bone	66, 67	os coxae
hip joint	66, 67	articulatio coxae
hoof	77	ungula
hoof capsule	74, 75	capsula ungulea
horny frog	76, 77	cuneus corneus
horny sole	76, 77	solea cornea
horny wall	76, 77	paries corneus
humerus	62, 63	humerus
iliolumbal ligament	66, 67	ligamentum iliolumbale
infraspinous muscle	62	m. infraspinatus
intermedial carpal bone	64, 65	os carpi intermedium
intermediate patellar ligament	68, 69	ligamentum patellae intermedium
internal layer	77	stratum internum
interosseous membrane of antebrachium	63	membrana interossea antebrachii
interosseous muscle	**72, 73, 74, 75**	**m. interosseus**
interspinous ligaments	60, 61	ligamenta interspinalia
intertransverse ligaments	66, 67	ligamenta intertransversaria
intertubercular bursa	62	bursa intertubercularis
intervertebral disc	60, 61	discus intervertebralis
ischial tuberosity	66, 67	tuber ischiadicum
lateral collateral carpal ligament	64, 65	ligamnetum collaterale carpi laterale
lateral collateral ligament	**68, 69**	**ligamentum collaterale laterale**
lateral collateral ligament of elbow joint	63	ligamentum collaterale articulartionis cubiti laterale
lateral condyle of femur	68, 69	condylus lateralis ossis femoris
lateral condyle of tibia	68, 69	condylus lateralis tibiae
lateral crus of frog	77	crus cunei laterale
lateral crus of sole	77	crus soleae laterale
lateral femoropatellar ligament	68, 69	ligamentum femoropatellare laterale
lateral meniscus	68, 69	meniscus lateralis
lateral patellar ligament	68, 69	ligamentum patellae laterale
lateral sacral crest	66, 67	crista sacralis lateralis
lesser sciatic foramen	66, 67	foramen ischiadicum minus

palmar carpometacarpal ligament	**64, 65**	**ligamenta carpometacarpea palmaria**
palmar intercarpal ligament	64, 65	ligamenta intercarpea palmaria
palmar/plantar anular ligament	74, 75	ligamentum anulare palmare/plantare
palmar/plantar proximal interphalangeal ligaments	**72, 73**	**ligamenta palmaria/plantaria interphargea proximalia**
parietal dermis	76	dermis parietis
patella	68, 69	patella
peroneus tertius muscle	70, 71	m. peroneus tertius
podotrochlear bursa	74, 75	bursa podotrochlearis
proximal digital anular ligament	**74, 75**	**ligamentum anulare digitale proximale**
proximal phalanx	**72, 73, 74, 75**	**phalanx proximalis**
proximal sesamoid bones	**72, 73, 74, 75, 76, 77**	**ossa sesamoidea proximalia**
radial carpal bone	64, 65	os carpi radiale
radiate ligament of head of rib	60, 61	ligamentum capistis costae radiatum
radiocarpal ligaments	64, 65	ligamenta radiocarpea
radius	63, 64, 65	radius
rib	66, 67	costa
sacroiliac joint	66, 67	articulatio sacroiliaca
sacrum	66, 67	os sacrum
scapula	62	scapula
second carpal bone	64, 65	os carpale II
second metacarpal bone (splint bone)	**64, 65**	**os metacarpale II**
second metatarsal bone	70, 71	os metatarsale II
short lateral collateral cubital ligament	65	ligamentum collaterale cubiti laterale breve
short lateral tarsal collateral ligament	70, 71	ligamentum collaterale tarsi laterale breve
short medial collateral cubital ligament	63	ligamentum collaterale cubiti mediale breve
short medial tarsal collateral ligament	70, 71	ligamentum collaterale tarsi mediale breve
short sesamoidean ligaments	**72, 73**	**ligamenta sesamoidea brevia ligamenta tarsi**
shoulder joint	62	articulatio humeri
straight sesamoidean ligaments	**72, 73, 74, 75**	**ligamentum sesamoideum rectum**
subligamentous supraspinous bursa	60, 61	bursa subligamentosa supraspinalis
subscapular muscle	62	m. subscapularis
subtendinous bursa of common digital extensor muscle/	74, 75, 76	bursa subtendinea musculi extensoris digitorum communis/ bursa

subtendinous bursa of long digital extensor muscle		subtendinea musculi extensoris digitorum longi
subtendinous bursa of infraspinous muscle	62, 129	bursa subtendinea musculi infraspinati
subtendinous bursa of lateral digital extensor muscle	138	bursa subtendinea musculi extensoris digitorum lateralis
subtendinous bursa of subscapular muscle	62	bursa subtendinea musculi subscapularis
supraglenoidal tubercle	62	tuberculum supraglenoidale
supraspinous ligament	60, 61, 66, 67	ligamentum supraspnale
talus	70, 71	talus
tarsal bones 1-3	70, 71	ossa tarsalia I-III
tarsal interosseous ligaments	70, 71	ligamenta tarsi interossea
tendon of common/long digital extensor muscle	**74, 75, 76, 78**	**tendo musculi extensoris digitorum communis/longi**
tendon of deep digital flexor muscle	**74, 75, 76**	**tendo musculi flexoris digitorum profundi**
tendon of long digital extensor muscle	**68, 69**	**tendo musculi extensoris digitorum longi**
tendon of popliteal muscle	68, 69	tendo musculi poplitei
tendon of quadriceps muscle of thigh	68, 69	tendo musculi quadricipitis femoris
tendon of superficial digital flexor muscle	**74, 75**	**tendo musculi flexoris digitorum superficialis**
third carpal bone	64, 65	os carpale III
third metacarpal bone (cannon bone)	**64, 65, 74, 75**	**os metacarpale III**
third metacarpal/metatarsal bone	**72, 73, 74, 75**	**os metacarpale/metatarsale III**
third metatarsal bone	70, 71	os metatarsale III
tibia	68, 69, 70, 71	tibia
transverse acetabular ligament	66, 67	ligamentum transversum acetabuli
transverse costal fovea	60, 61	fovea costalis processus transversi
tuber coxae	66, 67	tuber coxae
tuber sacrale	66, 67	tuber sacrale
ulna	63	ulna
ulnar carpal bone	64, 65	os carpi ulnare
ungular cartilage	72, 73, 74, 75, 76	cartilago ungularis
ventral longitudinal ligament	60, 61	ligamentum longitudinale ventrale
ventral pubic ligament	66, 67	ligamentum pubicum ventrale
white zone	76, 77	zona alba

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Zandalee Toothaker was born on Camp Lejeune, North Carolina on 11 February 1994. She grew up all over the world as her family moved to Florida, Colorado, Maryland, California, England, and finally Okinawa where she graduated from Kubasaki High School in 2012. However, she would visit Maine often and it held a special place for her, even before she started college at the University of Maine.

Zandalee is majoring in Animal and Veterinary Sciences and has a minor in Equine Studies. She is a member of the UMaine Standardbred Drill team, and has been an officer in EWE-Maine Icelandics club, C.L.U.C.K.s, and Pre-Vet Club.

After graduation Zandalee will work for a year before applying for veterinary school, and would like to focus on small animal and exotic animal medicine.