Guided Tour: Horse Hoof Anatomy

Learn how your horse's feet work so you can understand how to keep them sound

BY CHRISTY WEST

Clip. Clop. The simple hoofbeats of your moving horse effectively hide the highly complex anatomy and physiology at work inside his hooves during each step.

As a horse owner/caretaker, knowing the basics of hoof anatomy and physiology can help you keep your horses sound and bring them back from lameness more quickly. Plus, it certainly helps to understand what the heck your veterinarian and/or farrier are talking about if your horse comes up lame.

Andrew Parks, MA, VetMB, MRCVS, Dipl. ACVS, professor of large animal surgery and head of the Department of Large Animal Medicine at the University of Georgia (UGA), puts it like this: "Understanding anatomy is a prerequisite to understanding physiology. Owners need to know what's in the foot for many day-to-day reasons; for example, if the horse steps on a nail, they need to know what structures might be damaged so they know how serious it could be." (Hint: A nail puncture in the middle third of the frog is particularly dangerous because the nail could damage several critical structures.)

In this article, we'll take a tour of equine foot/lower limb anatomy and physiology with Parks as our guide.

ARND BRONKHORST

The horse's foot is comprised of parts that fit and work together from the inside out to support his weight and act as levers to move his body.

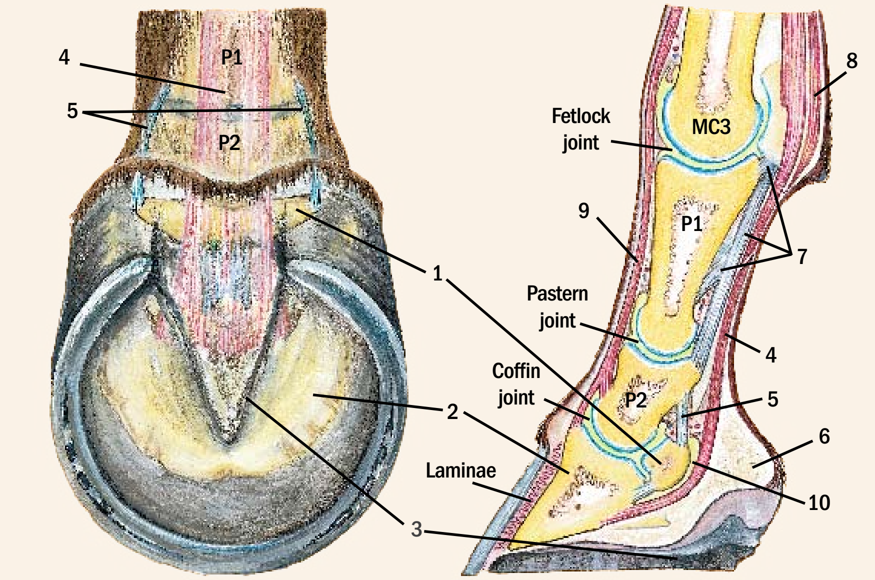
Basic Anatomy/Physiology Concepts

"I think of the horse's foot as a model, and try to envision the parts fitting together from the inside out (starting with the bones)," says Parks. "Bones support weight and act as levers (soft tissues move them to mobilize the limb and, thus, the entire horse). The animal and its hooves get their basic structure from the bones (bone shapes vary, leading to variable hoof shapes). Then the bones have to articulate (fit together), so you have joints. Joint shape depends on how the bones fit and move together. Ligaments hold bones together at joints and control their range of motion (direction/distance of movement).

"But so far we still don't have any way to move those joints, which is where muscles and tendons come in—they are the motors and pulleys of this mechanical system (tendons attach the muscles to bones)," he adds. "The muscles provide force to move joints and stabilize them.

"Then we have the nervous system within the foot, which controls its movement and also provides constant feedback to the animal regarding where the foot is, so he can correct its placement as needed," he says. "Lastly, there's the circulatory (blood) system, which delivers nutrients, oxygen, and everything else the tissues need."

THE BONES AND STRUCTURES OF THE FOOT



1 - Navicular bone
2 - Coffin bone (P3)
3 - Frog
4 - Deep digital flexor tendon
5 - Collateral ligament of navicular bone
6 - Digital cushion
7 - Sesmoidean ligaments
8 - Superficial digital flexor tendon
9 - Common digital extensor tendon
10 - Navicular bursa

DR. ROBIN PETERSON ILLUSTRATIONS

Bare Bones

The hoof contains two bones—the coffin bone (also called the distal phalanx, distal meaning situated further away from the central part of the body) and navicular bone—plus part of another, the short pastern bone (also called the second or middle phalanx). The latter is considered a long bone with a basically cylindrical shape that transmits force from one end to the other, with a joint at either end. The coffin bone, however, has a joint at only its upper (proximal) end where it meets the distal end of the second phalanx. The other end attaches to modified skin (the hoof capsule).

Stabilizing and Moving the Bones

The horse moves when muscles in the upper limbs pull on the bones of the limb and hoof, bending or straightening the joints of the leg and lifting or lowering the hoof. The joints of the lower limb include the proximal interphalangeal joint (also called the pastern joint, where the second and first phalanxes come together) and the distal interphalangeal joint (also called the coffin joint, where the distal phalanx and second phalanx articulate). There is also the navicular joint between the navicular bone and distal phalanx, but that doesn't contribute to limb movement.

Each joint has a joint capsule (light yellow in the diagram above), which is a large capsule containing fluid to lubricate the joint. You can see on the diagram that the capsules extend a good distance up the dorsal (front) and palmar (rear) surfaces of the bones, as those are the directions of joint travel. The lower limb joints don't have much side-to-side motion, so the joint capsules don't extend as far up the sides (not visible on this diagram).

Each joint is stabilized by ligaments—strong bands of connective tissue with limited elasticity that hold the bones in position (5 and 7 in the diagram). In conjunction with the shape of the bones' articular (joint) surfaces and the joint capsule, they control the directions in which the joint moves. If you've ever twisted an ankle, you know what happens when you damage these ligaments by flexing the joint hard in the wrong direction.

The tendons that move joints by transmitting the muscles' pull to lower limb bones (red bands in diagram) include the common digital extensor tendon and deep digital flexor tendon (DDFT). The first attaches to the upper, front aspect of the coffin bone and straightens the lower limb just before the foot lands, while the latter runs down the back of the leg and over the navicular bone to attach on the bottom of the distal phalanx. The extensor tendon isn't critical to helping the horse stand, only to straighten the foot while moving, while the DDFT maintains the foot's position on the ground. Thus, injury or disease of the DDFT apparatus tends to cause far more problems than extensor tendon injury.

When the deep digital flexor muscle contracts and pulls on the DDFT, it raises the heels as the animal "breaks over" its toe. The navicular bursa, a fluid-filled sac (light yellow, indicated on diagram), decreases friction as the tendon pulls around the navicular bone.

The DDFT, along with the superficial digital flexor tendon and fetlock suspensory apparatus that attaches higher on the limb, is quite elastic and stretches like a rubber band when the horse lands on it. When the horse unloads the foot, the "rubber band" rebounds to its original length, returning some of that energy for the next stride. The powerful pressure of the DDFT on the navicular bone and bursa can contribute to injury or disease in the bone, bursa, or tendon; hence the term "navicular syndrome" for pain in this region. This syndrome commonly affects horses with low-angled hooves and upright pasterns (called a broken-back foot-pastern axis) and, thus, a sharper "corner" for the tendon to go around.

Hoof Specifics

Bones, ligaments, and tendons exist throughout the horse's body, but within the hoof capsule are several structures unique to the hoof. We'll start with the collateral cartilages (seen in blue in the figures labeled "3D Learning" on page 48), which attach to the sides of the distal phalanx and act as flexible extensions of it, projecting upward and rearward. Their front halves attach to the distal phalanx, while the rear halves float free. They are thicker at the bottom, and their thinner upper edges can be felt above the coronary band. Presumably, they are part of the mechanism that allows the foot to expand slightly (1-2 mm) with weight-bearing. The term "sidebone" describes collateral cartilages that have hardened into bone, often from repeated concussion on hard surfaces.

Between the collateral cartilages and on top of the frog lies the digital cushion (6 in the diagram above, but also see the pink structure under "3D Learning" on page 48), which true to its name is a fibrous, fibrocartilaginous, and elastic structure that helps absorb the shock of landing.

Horses with sound, healthy feet have thick collateral cartilages and digital cushions, while those with low heels and flat soles often have thin collateral cartilages and a thin/crushed digital cushion that can't absorb as much energy as it should.

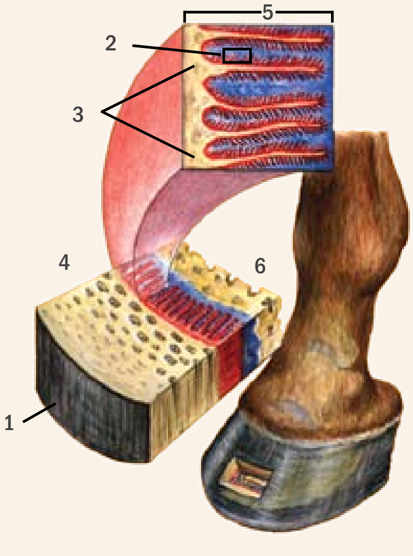
Moving outward, we come to the laminae—interlocking leaflike structures all the way around the coffin bone that attach it to the hoof wall (one set projecting outward from the coffin bone and one set projecting inward from the wall; see the structures labeled "3" in the diagram at right). The laminae include both primary laminae and secondary laminae; the latter are like additional leaves branching off of each primary lamina. Together, the roughly 550-600 primary laminae and 150-200 secondary laminae (per primary lamina) provide about 1.3 square meters of surface area attaching the hoof to the bone.

This attachment is unbelievably strong when healthy, suspending the coffin bone and thereby the horse's weight even with about 2,000 pounds of force landing on each forefoot during a running stride. One study of cadaver limbs found that the laminar junction absorbed 67% of the impact energy when the foot lands. However, the laminae can become weakened by repetitive injury or disease, leading to the inflammation, pain, and potential coffin bone instability with laminitis.

The last stop on our inside-out tour is the one visible part of the whole apparatus—the hoof wall. This specialized skin capsule wraps the internal structures in a tough, resilient shell that protects them and provides their interface with the ground. The wall is made up of tiny horn tubules that grow downward from the coronary band to the ground in a matrix of intertubular horn; together they provide great strength and resistance to fracturing. The hoof capsule constantly grows from the top and wears off on the bottom.

As with most biological structures, the hoof and many of its internal structures are viscoelastic, meaning that they respond (change shape) when you load them quickly (such as hoof expansion with each step), and they respond another way if you change the loading on them for long periods of time (such as hoof flares resulting from imbalanced shoeing/trimming). The latter, longer-term changes can be thought of as adaptations to changing stresses; the problem is that if the stresses on the hoof are bad for it (think shoes that are too small or imbalanced), the hoof can adapt its way right into a diseased condition such as crushed heels or sheared heels. And these adaptations might not be fully reversible.

THE LAMINAE



1 - Hoof wall
2 - Secondary lamellae
3 - Primary lamellae
4 - Lamellae
5 - Laminar corium
6 - Coffin bone (P3)

"Once you have secondary changes in the hoof, just reversing the insult won't get you back where you were," explains Parks. You can remove the causative force and some will correct fairly quickly, but some can take quite awhile. It makes the hoof very interesting."

Take-Home Message

"It's impressive that a running Thoroughbred racehorse can put more than twice his weight on a hoof that's only 5 inches in diameter," comments Parks. "It ought to capture people's imagination that the hoof can handle that."

Knowing how the hoof is built and what it is capable of can help you understand what it needs to stay healthy and recover if compromised. For further discussions of equine hoof anatomy, see the Anatomy & Physiology—Hoof category in TheHorse.com's online article library.

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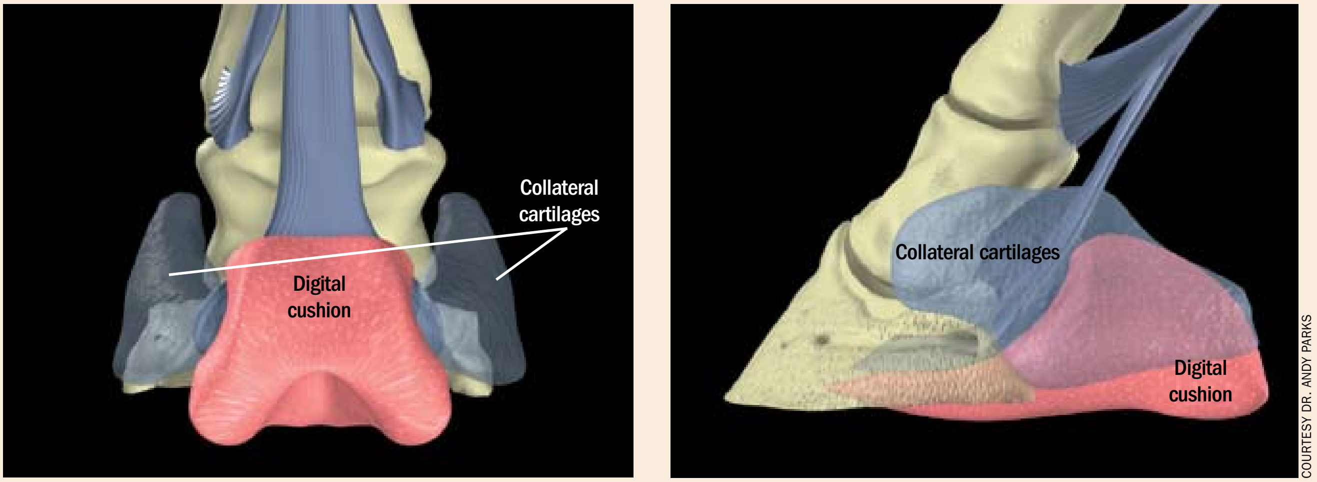
3D LEARNING



COURTESY DR. ANDY PARKS

Andrew Parks, MA, VetMB, MRCVS, Dipl. ACVS, of the University of Georgia, was the source for this article and provided the above images (labels ours) from The Glass Horse Project, "Elements of the Equine Distal Limb." He and colleagues collaborated on this project, which combines 3D interactive models with narrations and animations. Learn more at 3dglasshorse.com or purchase "Elements of the Equine Distal Limb" at TheHorse.com/Shop.