This article originally appeared in Trail Blazer magazine (Issue #8) 2005.

Hoof Adaptability

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The hoof should be viewed as an amazing engineering feat and is quite unique in its design. The horse is the only quadruped that has a limb finishing into a single digit: the horse runs on a single toe! This means that the tissues encapsulating the pedal bone are highly specialized since they not only provide nutrition and protection to the bone but also have to be able to withstand incredible amounts of force applied to them. These tissues have to be able to provide shock absorption and energy dissipation. This article focuses mainly on the hoof capsule itself.

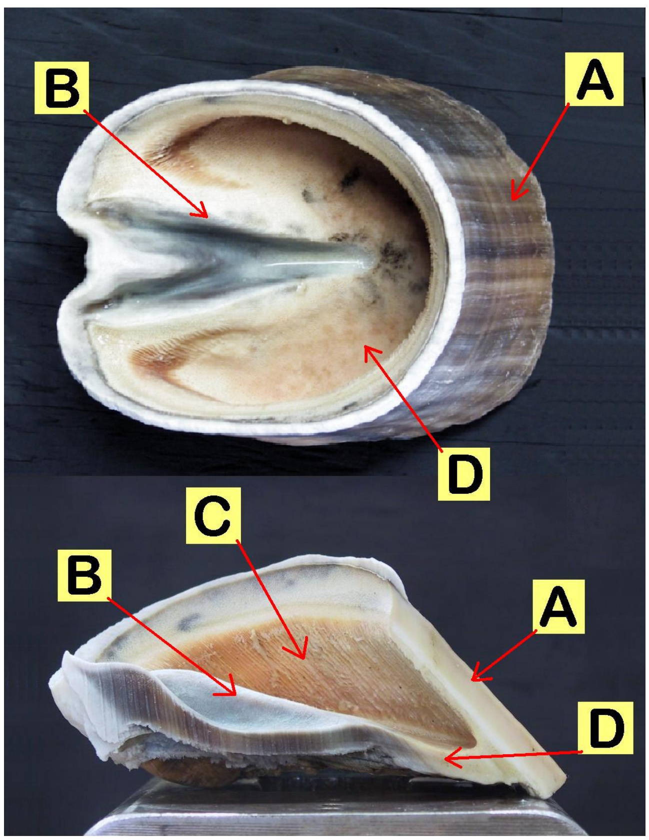

Figure 1. The hoof wall (A) protects the digit. The 'arch' (B) is a structure formed by the commissures of the frog (the 'valleys' on either side of the frog). The insensitive laminae (C) connect the hoof wall (A) to the inner sensitive structures. The sole (D) and the arch (B) support the pedal bone. Images courtesy Michael T. Savoldi.

The sensitive laminae (fig.2) attach to the bone and to the hoof capsule (fig.1.) There are approximately 600 primary sensitive laminae and about 100 secondary laminae per primary laminae. The sensitive laminae hook up with the insensitive laminae of the hoof capsule (fig.1.) This system of interlocking grooves ensures that the hoof capsule cannot detach from the rest of the foot.

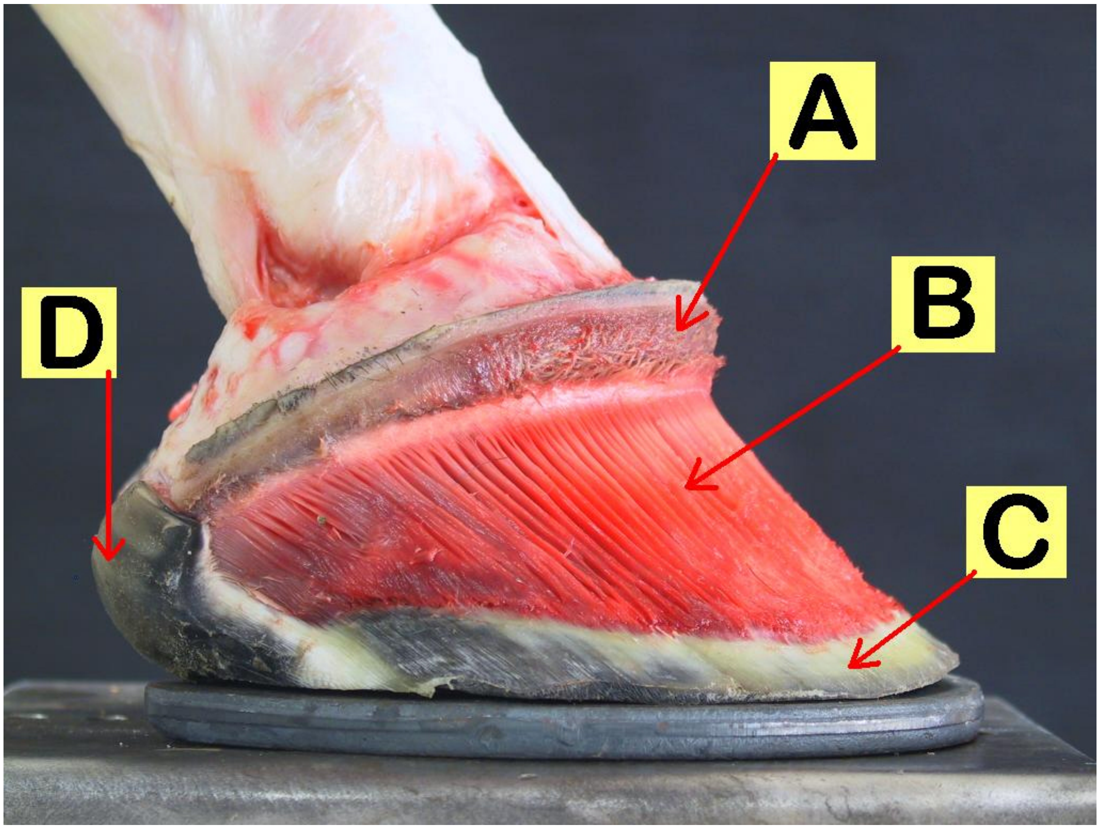

Figure 2. The coronary cushion (A) is just below the hairline. The sensitive laminae (B) interlock with the insensitive laminae of the hoof wall. The sole (C) supports the foot with the bulbs (D) in the rear portion of the foot. Image courtesy Michael T. Savoldi.

The hoof capsule can be thought of as 'intermediate' between soft tissues and hard bones. While mature bones do not adapt a great deal, the hoof capsule can better adapt to external changes than other living tissues. The hoof capsule can change shape quite radically over a period of time (fig.3.)

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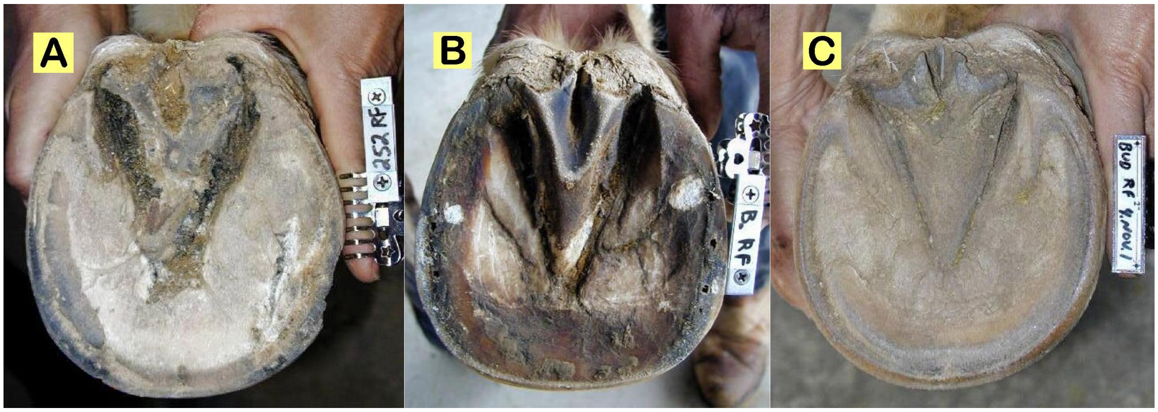

Figure 3. The hoof can change quite dramatically under the influence of different trimming and shoeing methodologies. These images are of the same hoof over the course of 14 months. Each image was taken at the end of the shoeing cycle – so in each case, it is time for a trim. Figure 3A taken on August 2000, figure 3B taken on January 2001, and figure 3C taken on November 2001.

The hoof capsule is made of alpha-keratin, a substance found in all mammals, including humans. For instance, the outer layer of your skin is made of keratin, so are your hair and nails. Obviously your hair or skin is quite different to the touch than the equine hoof. It is truly how the keratin is structured at a micro scale that allows for the difference in mechanical properties and ultimately function. From a material science point of view, the horn can be categorized as a composite material. Material science is the study of physical properties of materials, for example tensile strength of steel, compressibility of plastic or the lattice structure of diamonds. Composite materials come in different forms from things like plywood to various mesh re-enforced materials. The later resemble the structure of the equine horn. Composite materials exhibit great mechanical strength. The main difference between man made composite materials and living natural composite materials (such as bone and horn) lies in their capacity to restructure and mend themselves during their lifetime.

The equine horn can also be characterized as a viscoelastic material. We are all familiar with memory foam -- you press your finger into it, and as you remove your finger you can see the foam return to its original shape. This example is somewhat rudimentary, but essentially it is how a viscoelastic material behaves. This does not mean that a viscoelastic material has ability to always restore to its primary shape. There is a point of no return, where the physical stress placed on a viscoelastic material will cause failure.

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Figure 4. The hoof wall keratin can undergo changes in mechanical properties as the health of the hoof improves or deteriorates. These figures show the same hoof recorded about 6 months apart.

Although the equine horn is well adapted to withstand forces applied to it, it has also limits. Improper trimming and/or shoeing, poor hoof conformation/quality, hoof diseases (i.e. laminitis) and age are contributing factors to weakening the equine horn (fig.4.)

Moisture content also affects the mechanical properties of keratin. Wet hoof capsules lose some their shock absorption ability. You may have noticed that often during the wet season, hooves tend to look more splayed than during the dry season. This causes the arch of the hoof capsule to lose some of its definition (fig 1.) This loss of arch definition will change bone alignment within the hoof capsule. Soil mechanics also will affect the hoof.

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A dry abrasive ground will shape the hoof differently than a wet soft soil (fig. 5A and 5B.) The wear at the hoof is also a function of how each individual horse moves.

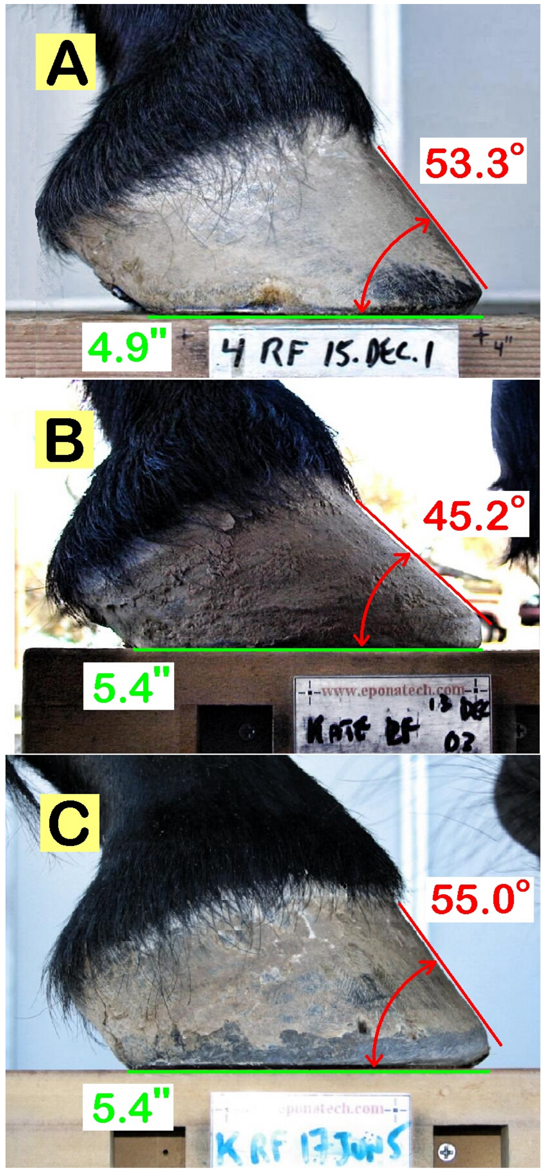

Figure 5. These images are of the same hoof over 3.5 years. In red font, the hoof angle is displayed, and in green font, the "support length" of the foot.

In an ideal situation, a horse with healthy strong hooves and good conformation will have no problem to adjust its shape from dry to wet and vice versa. Ideally, a horse would live permanently outside with plenty of space to move, consistent soil and with minimal moisture fluctuation.

The hoof in figure 5 belongs to one of my horses. I have owned this horse for six years, and up until December 2003, this horse was left barefoot since birth. This horse was trimmed by me. As an aside, I am not pushing any particular agenda concerning whether horses should be shod or left barefoot -- this depends on the horse and use. I live in the central coast region of California and our total rainfall averages about 11 inches. The picture in figure 5A was taken in December 2001. That December was relatively dry. This horse was also on a mostly limestone non-irrigated pasture. I decided to change from the limestone pasture to a softer dirt pasture because my horse started to self-trim (wear itself) too much at the toe. The photo of figure 5B was taken in December 2003; that month was a wet month and the softer ground did not drain as well as the limestone pasture. In Spring 2004, I decided to put plastic shoes on my horse. Note that the hoof in figure 5 is the ‘flatter’ of the two hooves, meaning the horse has a natural tendency to load harder onto this leg. Figure 5C shows the same hoof in the summer after removing the plastic shoes and after trimming. What prompted me to put shoes on my horse by my concern about my horse’s loss of arch definition. In Spring 2004, my horse’s hoof did not seem to return to its usual shape. It is not just the rainy season that is to blame for this but also perhaps the age of my horse. As horses and humans age, gravity seems to win over weight bearing structures.

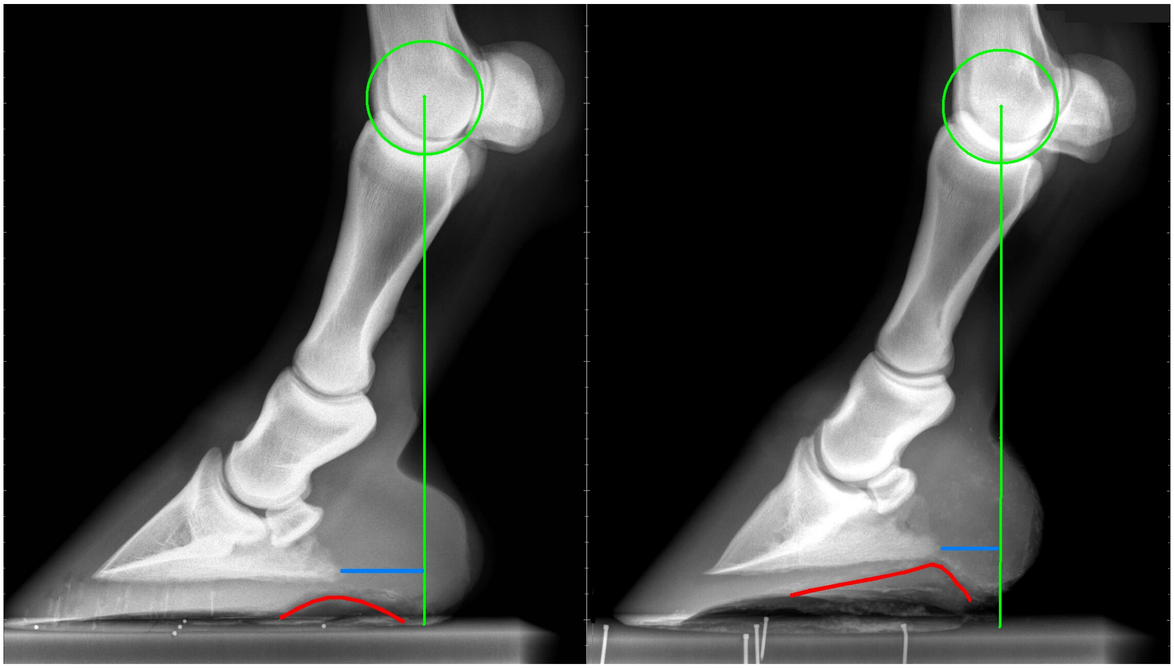

Figure 6. The hoof in image A has a low arch. The hoof in figure B has a high arch.

Why am I so concerned about a loss of arch definition? The arch provides support to the back part of the pedal bone (fig 6B.) The pedal bone angle relative to the ground (sometimes called the "palmar angle") is largely dictated by the shape of the arch. This in turn will define the bone alignment within the hoof capsule. In figure 6B, the arch has a good definition and the pedal bone angle is about 5.0 degrees and the pedal bone is providing support to the bony column. In figure 6A, the arch shape is very poor and the pedal bone angle is negative 1.1 degrees. Note that not all hooves with poor arch definition have a pedal bone with a negative angle. I don't believe in any 'ideal' value for the angle of the pedal bone: in my experience a range from perhaps 1.5 degrees to 6.0 degrees may be fine depending on the horse. Outside of this range I begin to worry. Having the pedal bone 'under' the bony column may be more important than it having some specific pedal bone angle.

I believe when the arch area starts to fail, the pedal bone will shift inside the hoof capsule (fig. 6A.) The pedal bone starts to sink towards the sole and to 'migrate' towards the toe part of the hoof capsule. In figure 6A, the pedal bone is no longer providing adequate support to the bony column (see the distance marked in blue in figure 6A is longer than that in 6B.) This change in bone alignment will affect the weight distribution through the hoof. Although these adverse changes do not necessarily happen overnight, they will eventually affect the horse's soundness. If the pedal bone is loading incorrectly, it will start to prematurely reshape itself. It too can lose its shape and become flatter. Some of these changes can be seen radiographically: a flattening of the pedal bone, a small "ski jump" forming at the tip of the bone, changes to the outer periphery of the bone, etc.

I am a believer in taking preventative radiographs and also photographs to record the changing shape of the hoof both inside and out. Noting these changes can help you catch situations before they develop into long term problems. The image sequence in figure 5 tells one of these stories: I was able to bring my horse's hoof back to a better conformation before any permanent problems set in. Remember – **the hoof changes** and it is good to stay on top of it!