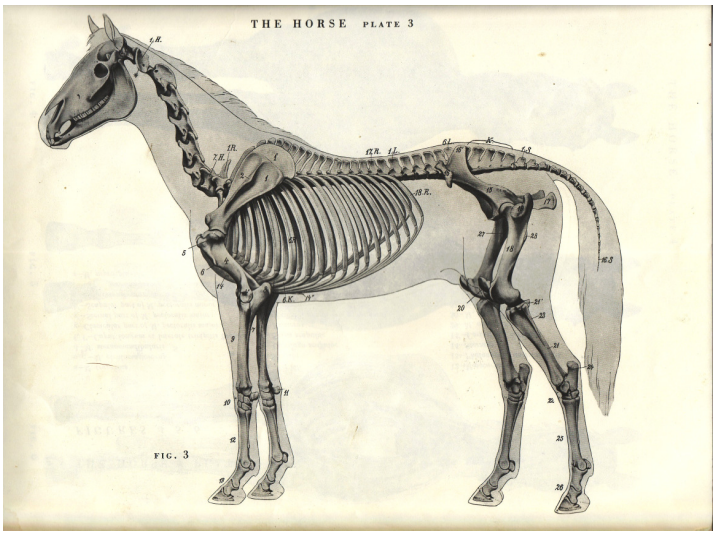
Anatomy and Function of the Hoof

A Brief Overview

Hooves have to support the horse's weight, aid in traction, absorb impact shock and protect the vulnerable inner structures. They also need to aid in circulation as there are no muscles below the knee, and blood needs to be returned up the leg via a mechanism similar to hydraulics. There is a saying that a horse has 5 hearts.

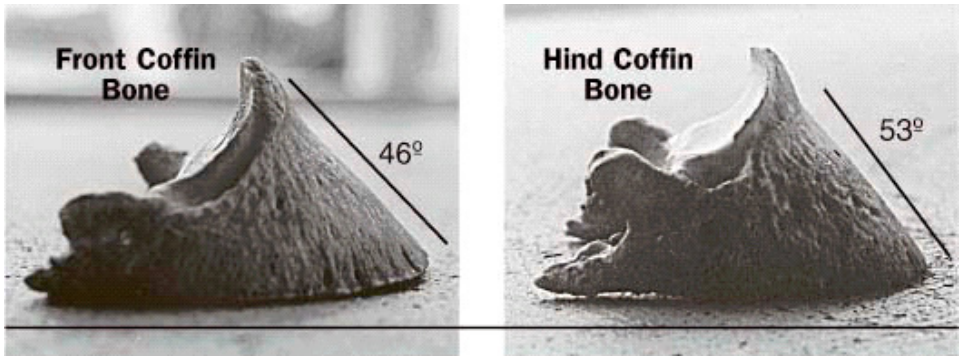
In order to be comfortable and move to his best abilities, the horse's hooves have to be in perfect balance and health.
As they are at the very base of the horse's skeleton they have tremendous impact on the entire structure above.
If they are not balanced correctly toward the ground, all the rest of the horse will be affected.

Hooves As Support Of The Whole Body



It begins with the fact that nature designed the horse with a steeper angled coffin bone in the rear vs. the front, usually by about 5 degrees.

Front And Hind Coffin Bone



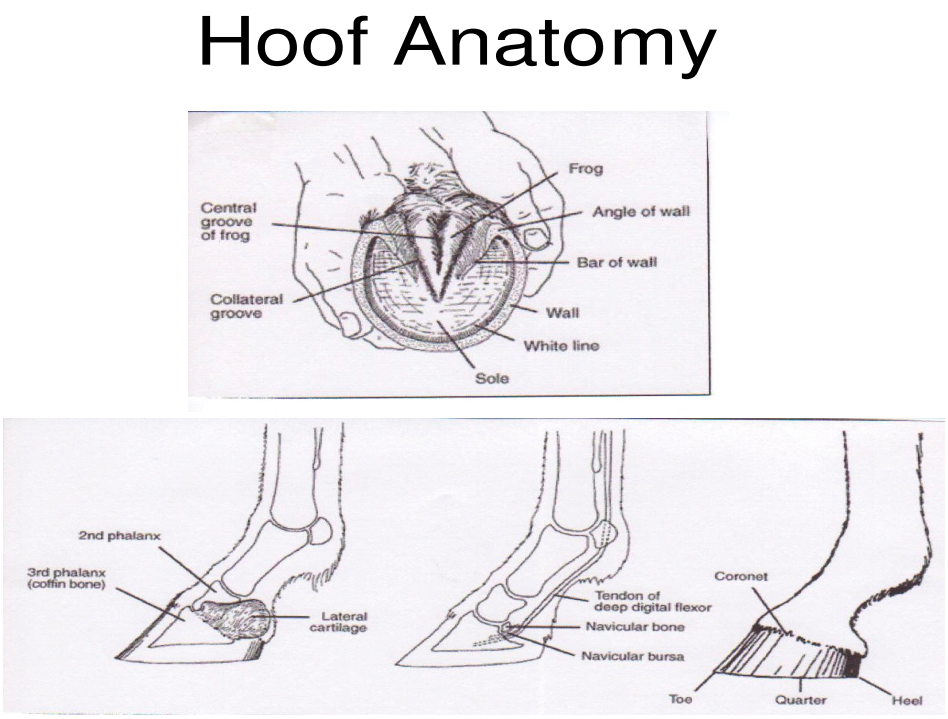
This is due to the fact that front and hind legs have very different function for the horse: the front legs are mostly for weight support during forward motion while the hinds are the engine. The hind feet are also more triangular for this reason, with an almost pointy toe, so they can dig in better, while the front feet are more round, to accept the weight better.

Front Hooves Hind Hooves

When artificially raising hoof angles in front by either allowing heels to grow too tall or applying wedge pads, this balance gets disturbed and has far reaching consequences, esp. on the shoulders and pelvis of the horse. I am not sure what mechanism causes this, but whenever front angles get too steep, hind angles in response get shallower. The whole base of the horse is thus changed.

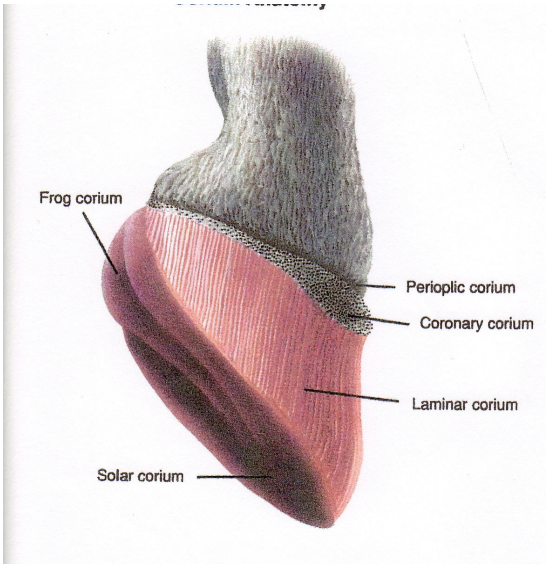
Basic Anatomy

To really appreciate the complexity of all this, one needs to understand a few basics about the anatomy of the hoof capsule.



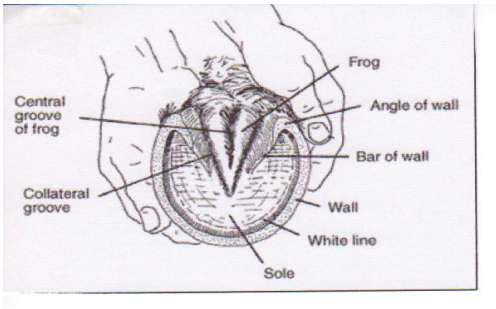
The visible part of the hoof, the hoof wall and the sole and frog, are a protective covering for the complex structures inside. There, in this relatively small space, one finds the coffin bone, navicular bone and part of the short pastern bone. And as an extension to the coffin bone the lateral cartilages on each side of the foot.
Additionally, the large extensor and flexor tendon insertions, and numerous ligaments which keep the joint capsule together. One also will find a huge amount of blood vessels, a “blood sponge” called the corium which surrounds the entire outer surface of the coffin bone and lateral cartilages, and from which the inner part of the wall grows, and on the bottom of the foot the sole and frog. The outer part of the wall grows down from the coronary band. There are of course lots of nerves, and last but not least a structure called the digital cushion which fills a large part of the hoof capsule below the frog.

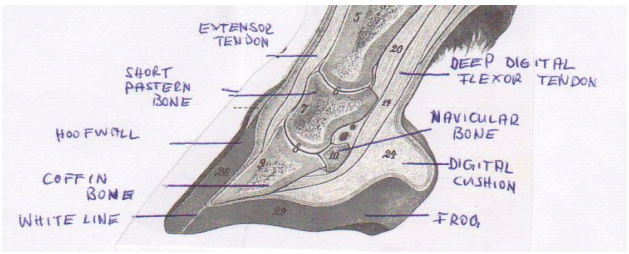
The Corium

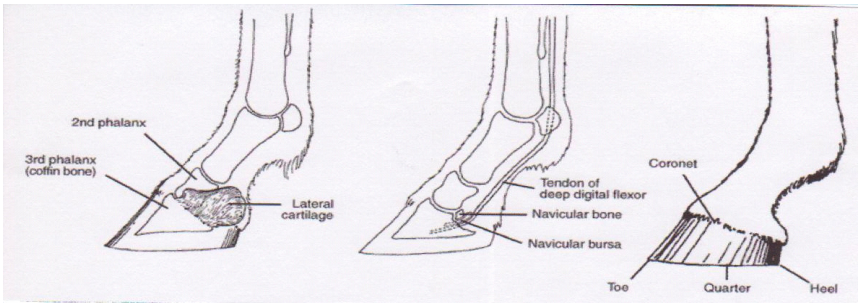


The Corium

Hoof Anatomy







Basically, the front half to two thirds of the hoof are relatively static, while the remainder is relatively deformable. I say relatively because there is no part in the hoof except the bones themselves that is not deformable to a certain degree, or which is not also responsible for support or protection.
The reason why the front part is more static is that the hoof capsule is tightly connected with the coffin bone. In the rear part, it is connected to the lateral cartilages which are quite deformable, and in the heel area the hoof capsule is open, the ends returning toward the center of the sole and thus forming the bars. The rest of the heel area is filled out with the heel bulbs and the frog. Both these structures are highly deformable. The only hard horn and truly firm and supportive part in the heel area are the corners that the hoof wall creates.

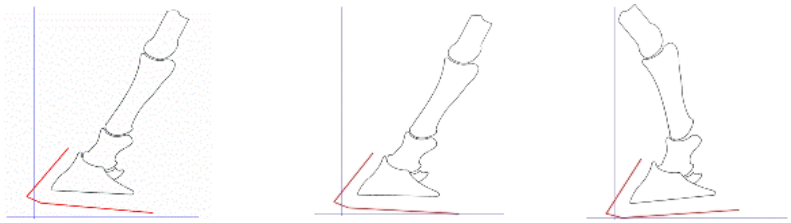
So it makes sense that the rear part of the hoof is designed to absorb impact shock while the rest of the foot is there to support the weight in general.

Heel First Landing

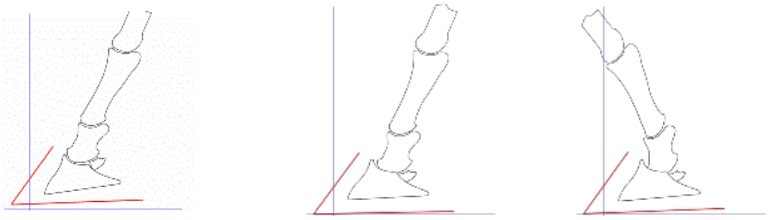
This means that the horse must land heel first on all 4 feet if impact absorption is to be optimal. The entire movement sequence of the limb is set up this way. If the horse lands toe first, a totally different loading sequence needs to happen, overstressing ligaments of the joint capsule and the deep flexor tendon.
On the other hand, a horse will always land toe first going uphill and heel first going downhill,

he has no other choice for as soon as the knee straightens and locks into the extended position, the hoof has to hit the ground where it falls. It is really only on a level surface that one can make an accurate observation.
The better balanced the hoof the more correctly the horse can load it. In other words, the longer it is possible for the horse to land heel first, even going uphill, and the sooner the toe area can leave the ground again, the less stress on the structures. This is especially important for a driving horse as the load of a carriage increases dramatically the steeper the hill, putting that much more weight onto the hooves.

Heel First Landing (with optimum bre ak over)



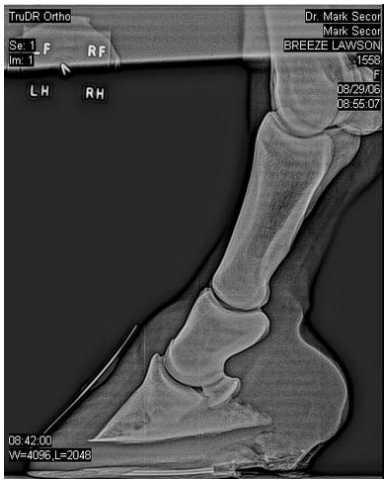
Toe First Landing (with delayed break over)



Break over

Break over should occur when the extended line of the front surface of the coffin bone would hit the ground. Often this is not the case as too much toe has been allowed to grow, thus delaying this moment. Often one can tell only with a good x-ray where the exact location is, as hooves can become very deformed and contorted by wrong trimming or shoeing.

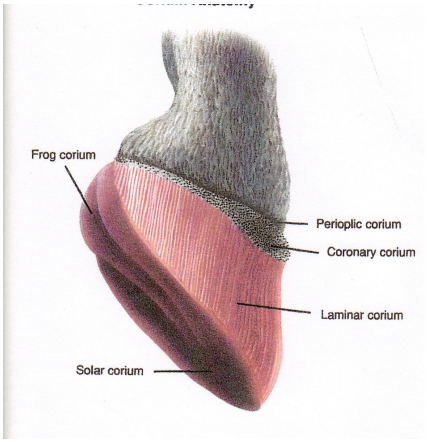
Break Over

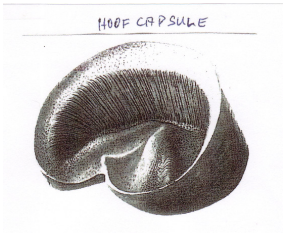


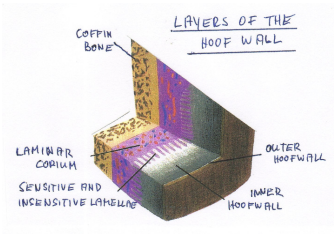
The Suspension System

The coffin bone itself only weighs a few ounces, is pretty much triangular from every view point, and has a very sharp bottom edge. It would be impossible for this small bone to withstand the enormous weight from above if it was not for the ingenious suspension system that holds it literally in space.
Before I mentioned the corium, the blood rich soft tissue that surrounds and is tightly attached to the bone and cartilages. Where the hoof wall is produced it looks like lamellae on the underside of a mushroom. These lamellae keep producing horn around themselves, thus creating a mirror like horn structure and connecting it to the wall that pushes down from the coronary band. It is sort of like a velcro connection, and through this immensely strong but also somewhat flexible connection the coffin bone suspends itself within the hoof capsule.
When viewing the hoof at sole level, one can see this juncture as it grew down to ground level. It is called the white line and is quite narrow all the way around, about 1/8 inch or less, in a healthy foot.
So the bone itself is never truly loaded or stressed on impact. It is all soft tissues that disperse impact energy. The bone really is only the base where all the soft tissues can attach to.
This can change dramatically when wrong stresses affect the hoof capsule. As strong as this “velcro” connection is to shearing forces, it is also very vulnerable to wrong lever forces acting upon it, like too long walls, too long toe walls or too high heels. Like velcro, it can quite easily be pulled apart sideways, thus weakening the suspension of the coffin bone and not seldom allowing it to actually drop to ground level.
Needless to say that this will make the horse very sore, one reason why many horses “need” to wear shoes.

The Suspension System

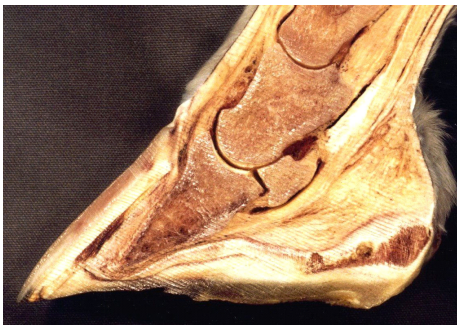






Failing Of The Suspension

Coffin bone detached from hoof wall



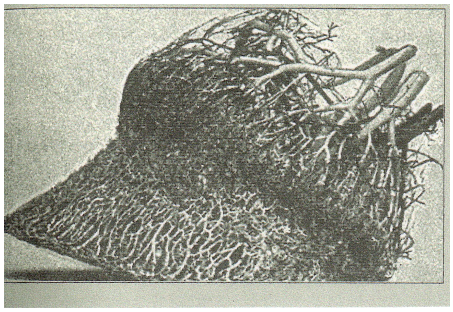
Tightly suspended coffin bone

The Hydraulic System

Equally ingenious is the way the initial impact is absorbed in a heel first landing. When the foot is in the air, blood rushes down into the hoof capsule.

On impact, this blood is forced through tiny micro vessels in the heel area of the foot, acting like a hydraulic system. There are no valves in these vessels so the blood can move where ever it is pushed to. Then, on complete landing, soft structures within the hoof capsule become compressed, empty out the arterial blood, the venous complexes collect the blood and through the enormous interior pressure that has been created blood will be pushed back up the leg.

The Hydraulic System

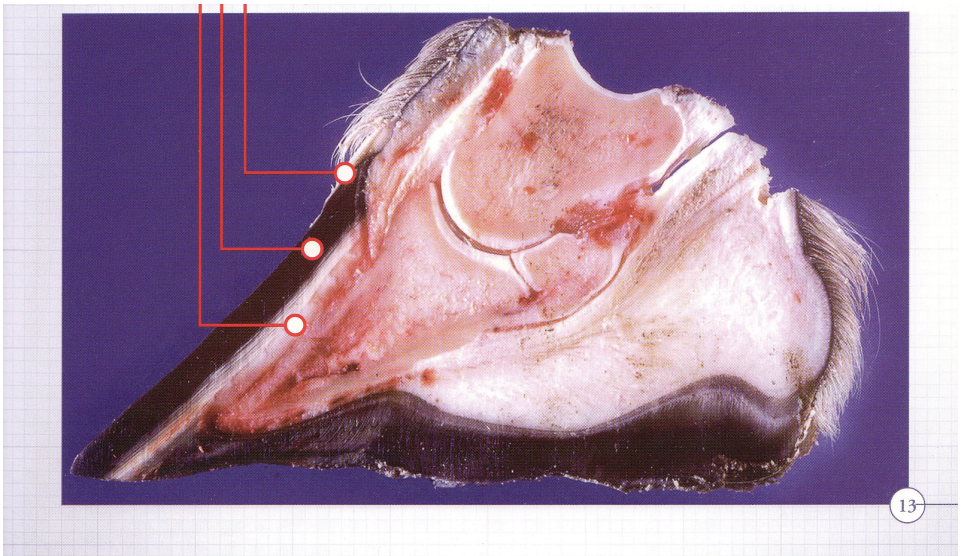


Function of the Frog

Another important factor to understand is the role of the frog.
Aside from aiding in the flexibility of the hoof capsule and better traction, its main purpose is support of the coffin bone joint.
When the horse loads the foot, the fetlock joint gets pushed down, which in turn pushes down onto the joint connection of the short pastern bone and coffin bone. While the deep flexor tendon limits how far this joint can be stretched, it relies on support from the frog from underneath. As mentioned earlier, below the entire frog area and back part of the hoof, the digital cushion fills the hoof capsule. As the coffin joint descends, it can sink into the forgiving structure of the digital cushion without any harm. But if the frog is not touching the ground, and act as a counterforce and thus limiting this descent, the digital cushion itself cannot totally absorb the descending weight, the sole and inadequate frog get pushed toward the ground and the deep digital flexor tendon gets overstretched. This puts too much strain onto the tendon, the navicular bursa and the navicular bone itself, and also stresses all the ligaments of the joint capsule.
The cross section below demonstrates a frog that is fully touching the ground and thus supporting the digital cushion. One can see how the digital cushion, (the white mass filling the

hoof capsule below the joint,) takes up a huge part of the hoof capsule.

Cross Section Of Hoof Capsule



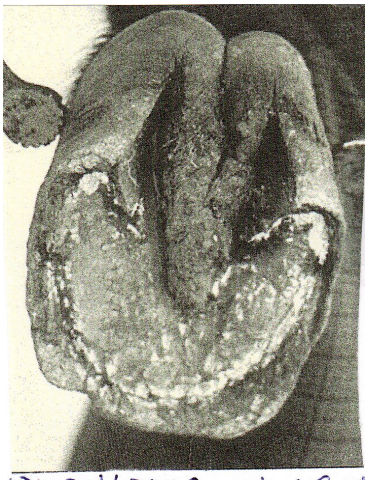
Deformation of the Hoof Capsule

Since the hoof capsule is so flexible, it can also easily be deformed by wrong pressures. One of the most common deformities is contraction. This is a state where the rear part of the hoof capsule becomes compressed, often to a point where the frog is only a thin and weak structure that no longer can fulfill its job. It often also goes hand in hand with underrun heels. Contraction is mostly caused by too long toes. As the hoof capsule is a cone shaped structure, the too long toe gets too much pressure, esp. also from toe first landing, and the entire structure becomes narrower and longer.
It is also very commonly caused by shoes, for the same reason as just mentioned, but also when shoes are applied too tightly, are left on for too long or the horse is shod at a young age.
Coffin bones do not mature until the age of 5, and when horses are shod earlier the coffin bones cannot grow to their full potential.
In many cases, the bone gets deformed so the hoof will never be able again to reach its full potential.

Below is an illustration of underrun heels. The heels are really much too long, but they are bent forward and cannot support the back part of the foot like they are supposed to. Many farriers assume that the horse has no heel and leave those long heels in place, exacerbating

the problem. In addition, they shoe the long toe, which in turn will only get longer. Meanwhile the pressure from the forward lying heels is being transmitted to all the wrong places within in the hoof capsule, mostly the area of the navicular bone and the descending P3 joint.
Both, the long toe and the pain created from the wrong pressure transmission cause the horse to land toe first, and often barely loading his heels.
Often, these horses are also put in wedge pads in order to raise the much too low appearing angle of the coffin bone, exacerbating wrong pressures.
Note the puny frog, the severely contracted heels and the huge distance from tip of frog to the toe wall. This condition causes this horse great discomfort.

Underslung Heels



The picture below illustrates various front hooves with contraction.
The picture on the top left shows a very badly forward stretched toe in addition to the contraction.
The next 3 photos show hooves which are quite functional in spite of the contraction. They will never be able to expand any further as the coffin bone has been deformed and will not allow a different shape. Breeds from very arid terrains sometimes have hooves like that as the norm.
The healthy hoof is from a warmblood type horse living in normal terrain, somewhat on the

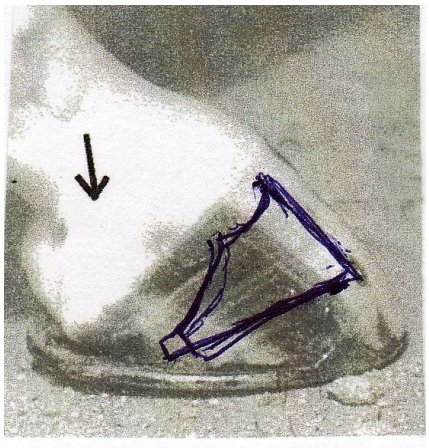
wet side.
The last photo shows a dried up cadaver hoof capsule. I put it there to illustrate how far the wall can contract when the soft structure of the frog is either diseased or underdeveloped. It demonstrates the importance of a strong and healthy frog for keeping the heels expanded.

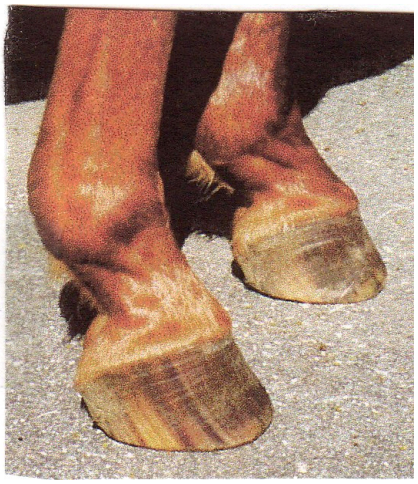
Contraction

Good front foot

Below is a bull nosed foot with tilted back coffin bone, called also negative plane of P3. This is very detrimental for the horse, as too much weight is put onto the soft structures of the back part of the foot and thus crushes them, disabling shock absorption. Meanwhile, the toes are much too long, delaying breakover. A condition like that can severely cripple a horse.
The other picture shows the other extreme, too high a heel. The toes become overloaded, one can see how the hoof wall is compressed in this area. The toe gets too much abrasion, the soles wear too thin, and often the coffin bone loses its tight suspension, creating a visible toe flare. These feet don't show much of it, but it is there. This causes the tip of the coffin bone to rest more on the sole, making the horse sore in this area. This wrong balance also causes an overloading of the suspensory ligaments. One can clearly see the forced pastern angle toward the horizontal and the protruding ligaments. The fetlock is also swollen and very hard. Once the heels were gradually lowered on this horse, his suspensories healed, the fetlocks returned to normal and the horse was painfree.

Low Heel High Heel





This following picture shows a cross section of a cadaver hoof.
This horse must have foundered a long time ago and never got trimmed.
It is very interesting to see how this foot healed itself within that grossly disfigured hoof capsule. With a correct trim, this horse could have been returned to soundness.

High Heel And Neglected

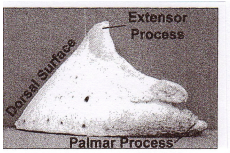
The illustration below depicts long toes. The hoof on the left is run under with the toe

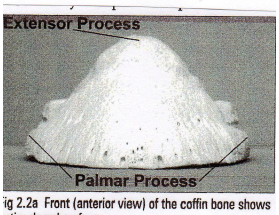
stretched way forward. At the very top of the hoof, one can see the angle the hoof would like to grow down in, but bad shoeing totally prevented that. Good trimming can restore this foot to health and soundness.
The picture on the right shows hind hooves of the same horse, one just shoed a few days ago, the other deshoed and trimmed to proper length. It is just amazing what damage poor farriery can inflict on a horse.

Long Toe

Below are some coffin bones.
On the left, a quite healthy coffin bone from side, front and back. Note the triangular looking shape.
In the middle another fairly healthy bone from a different angle.
On the right a bone deformed by contraction. Instead of being triangular, it is actually oval, with the palmar processes closing in instead of staying wide open.
A disfigurement like this is permanent, and hooves with such a coffin bone will always remain contracted, most likely causing lameness and early demise of the horse.

Coffin Bone





ig 2.2a Front (anterior view) of the coffin bone shows ntire dorsal surface.