Classical Horse Training

Combining art with science to achieve balance and harmony

Basic Biomechanics

"Because bodies never lie"

MANUAL 2020

"LIVE AS IF YOU WERE TO DIE TOMORROW. LEARN AS IF YOU WERE TO LIVE FOREVER." — MAHATMA GANDHI

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Foreword

Welcome to this manual in which I will explain basic biomechanics of the horse. This manual is complementary to the video series so please make sure to study both materials.

This document is the result of many years of research and personal experience world-wide. I sincerely hope that it will be useful to your personal learning experience and contribute to your personal training and development.

To bring about this document, I have chosen to include comparative literature research of some of the most influential scientific works. However, I need to state a caution to interpret this research. There has been a fair amount of research done on spinal biomechanics. However, it is important to realize there are differences in methodology, number of horses used, outcomes and interpretation of results. Therefore, ‘*‘the more I learn, the more I realize how much I don’t know’’. Biomechanics is not knowledge. It is a dynamic study so always keep that in mind.*

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DEFINITION

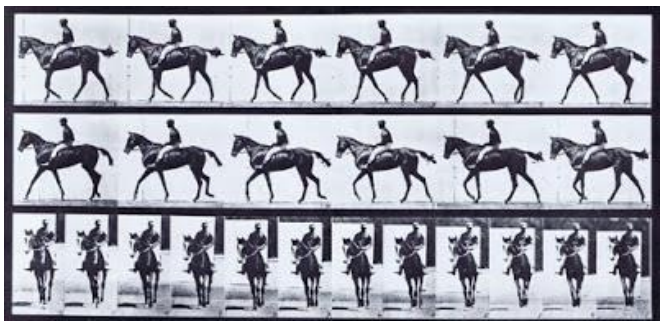
Biomechanics is a popular term in the equine world. But what does it actually mean?

Looking at its definition, *'' the word "biomechanics" (1899) and the related "biomechanical" (1856) come from the Ancient Greek βίος bios "life" and μηχανική, mēchanikē "mechanics", to refer to the study of the mechanical principles of living organisms, particularly their movement and structure.'' - Wikipedia*

So in short, biomechanics is the study of the mechanics of a living body – in our case the horse, and includes kinematics – motion, and kinetics - forces (Fung 1993).

I'd like to specifically point out that biomechanics is an ongoing study and not knowledge. There is no single biomechanical truth that applies for all horses. I always get a bit nervous when people state biomechanics as if it is a fact or static knowledge that applies the same to every horse. Biomechanics is an exploring adventure. Furthermore, biomechanics is not the same as pathology – although the two are intimately connected. Understanding biomechanics will help you to differentiate between what is normal – including variation, or abnormal movement.

One of the earliest and most famous photographers trying to analyze equine gait cycles was Eadweard Muybridge (1830-1904).

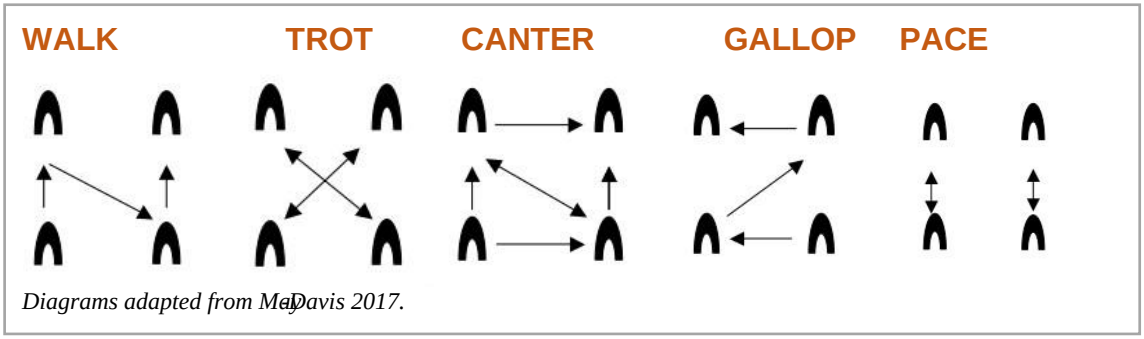


And right there, we get to the difficult question: what is normal? Today, so many horses seem to have abnormal movement that it is hard to determine what actually normal movement is and how it looks like. It is through this manual that I aim to answer this complex question by providing my knowledge acquired through both science and experience.

As always, studying biomechanics is not necessarily easy as we're dealing with nature. Hence, I'll try to make it as *''simple as the complexity allows, but not simpler.''* - Einstein

As a final remark I'd like to point out that, because of its importance and complexity, the biomechanics of the vertebral column will be treated extensively in a separate manual. Furthermore, this manual will not include palpation as there are also separate manuals and complementing videos covering this part of assessment.

NATURAL GAITS



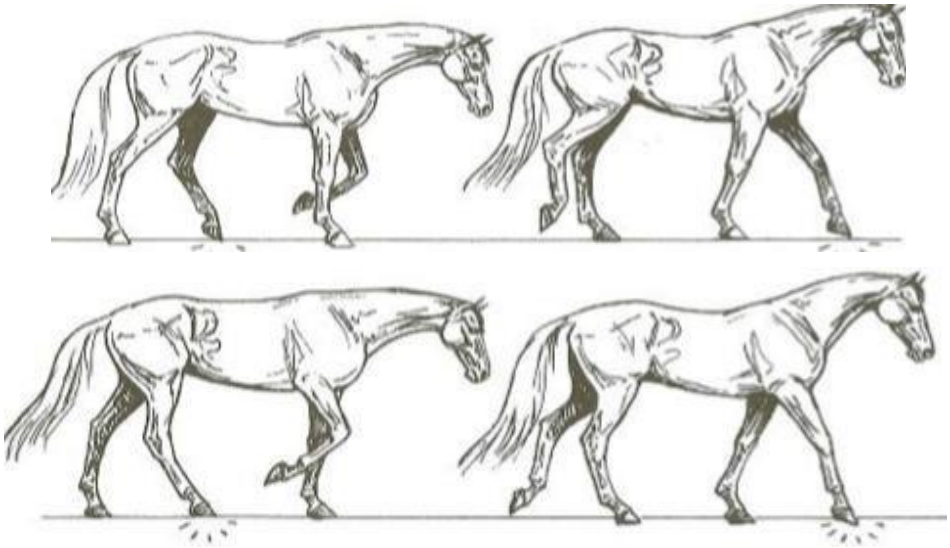
Diagrams adapted from May-Davis 2017.

Each horse has four natural gaits, namely: walk, trot, canter and gallop. However, gaited horse breeds[1] also have the natural ability that includes an extra gait such as 'pace' and 'tölt'. Although an ambling gait is a hereditary trait for such horse breeds, some of these horses may not always gait. The diagrams above outlines the footfall patterns for those gaits encountered on a regular basis.

Now let's dive a bit deeper into each of these gaits.

WALK

The walk is an asymmetrical four-beat gait with a lateral footfall and no aerial phase. It has both a bipedal and tripedal support phase. As speed increases, tripedal support decreases while bipedal support increases.



The walk should have a rhythmical action that is evenly spaced in length and time. As this is the gait where most back movement occurs, the horse should move with a mobile back and barrel, a figure of eight motion in the pelvis and a loose 'swinging' tail. The head should display a small – J shaped, lateral movement at a working pace, but will become more vertical in action when the walk is sped up or lengthened.

[1] *A few examples: Tennessee walking horse, Pasafino, Icelandic horse, American Saddlebred.*

Some horses display a lateral walk in which the natural sequence of four footfalls is disrupted and turned into two diagonal footfalls, which looks pace like. A lateral walk is often training related. Horses with a very scopey natural walk combined with a tight top line and back may run the risk of developing a lateral tendency, especially when starting to ask for collection.

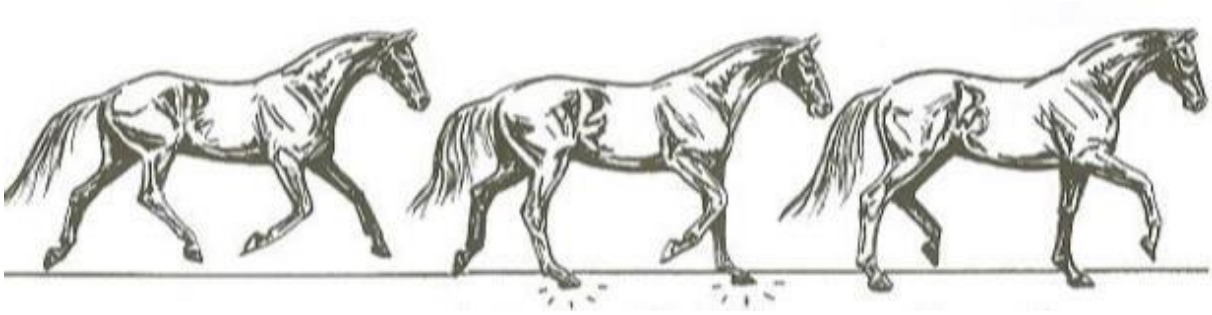
Lateral walk. Picture adapted from: DressageHub Youtube 2015

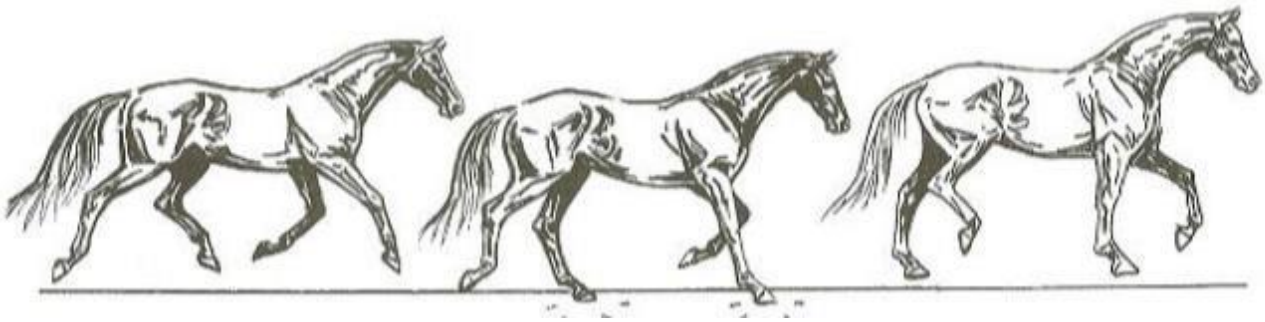
At the walk, a common sign of front limb lameness is head-bobbing when the painful limb becomes load bearing. A sign of hind limb lameness is a hip 'hike' and gentle 'J' shape head movement when the lame limb becomes load bearing.

Where the Old Masters adopted the trot as the basic gait of dressage, it was Baucher who introduced the walk as the basic gait. François de Lubersac even stated the walk at the *''queen of gaits''* as its movement requires great precision and coordination since all limbs travel separately. Remarkedly, de Lubersac trained his horses only in the walk, and when he decided they were ready, so he claims, they could do everything at all gaits. I too believe that the walk is a very important gait as it *''is at the pace of walk that imperfections of dressage are most* evident'' (FEI). It is one of the hardest gaits to improve. However, it must be said that in case of biomechanical deficits such as proprioception issues or the tendency of the neck to be too flexible that it is exactly the properties of the walk that makes this gait not always suitable as the basic gait to improve those deficits. Hence, I would like to argue that the basic gait for training differs within the individual horse as well as its current state of being. At some stage in its life, walk might be adopted as the basic gait whereas in a different momentum the trot might be considered more benefical as the basic gait of training.

TROT

The trot is a symmetrical two-beat gait with a diagonal footfall separated by an aerial/ suspension phase. The back & barrel is kept most rigid in this gait.





A clear moment of suspension is often considered a key element of an ‘expressive’ trot. However, suspension has nothing to do with driving the horse faster or with unnatural leg movement such as seen in some versions of extended trot nowadays. Horses that are taught to trot with its knees up its eyeballs do not have suspension. The joints and muscles of the hind limbs and shoulders act like a spring, propelling the horse up and forward. The ‘upwards’ push or ‘bouncing up in the air’ is not desirable in most kinds of riding, except dressage. However, not all ‘bouncing up’ is suspension either as it can also come from stiffness and tension. Only when the joints and muscles operate freely with an engaged back and hind legs it is true suspension. The amount of suspension a horse has varies within individuals.

Nowadays, certain variations in diagonal footfalls have been noted, which is referred to as Diagonal Advanced Placement (DAP) or Diagonal Dissociation which is often not considered as lameness, but either a training or breeding condition. When the hind leg of the diagonal pair touches down before the diagonal front leg, it is known as positive DAP. When the front leg of the diagonal pair touches down before the diagonal hind leg, it is known as negative DAP (Clayton 2005).

Whether or not DAP in general should be considered gait impurity remains an open question which is complicated by the fact that certain modern bred horses display DAP already as a foal or without ever being ridden[2].

In my personal opinion, negative DAP should always be considered undesirable as these horses are carrying more weight on the forehand than necessary which results in inefficient movement. From experience, I has been demonstrated that negative DAP can always improve and even disappear with correct [rehabilitation] training. In Barbara Schulte's

[2] *In 2016, Barbara Schulte released a video titled 'The Million Euro Coup – Spectacular Gaits vs. Health in which she refers to DAP as 'one-legged' trot being a result of modern breeding.*

words: *''Let's stop breeding horses for thrust and hypermobility, and for the benefit of horses, concentrate on carrying capacity and stability instead.''*

From a training perspective, the trot is widely considered as the most improvable gait of the horse due to its diagonal support, which naturally provides the horse with more support to keep its balance. As mentioned earlier, the Old Masters adapted the trot as the basic gait of dressage. La Guérinière wrote:

> *''De La Broue [another master] could not give a more exact description of a well-dressed horse than by saying that he is one who shows suppleness, obedience, and accuracy (…) The first of these qualities [suppleness] may only be achieved through the trot. This is the general consensus of all the knowledgeable masters, past as much as present, and if there are certain of the latter who would prefer, without any ground-work, to dispense with the trot and seek to develop this initial suppleness and freedom by use of the collected walk, they are wrong, because one can only develop these qualities by making the horse vigorously work all the parts of his body. It is through the trot, the most natural of all gaits, that the horse is made light to the hand, without having his mouth spoiled, and stretches his limbs without risk of injury. This is because during this type of action, which is the most elevated of all the natural gaits, the horse's body is equally supported on two legs, one front and the other behind; this ensures that the other two legs, which are off the ground, may be easily elevated, sustained, and extended forward, thereby resulting in an initial degree of suppleness throughout the entire body.''*

Of course these words don't mean the walk should be forgotten or the work in trot to be abused to an exhausting enterprise. But La Guérinière was right in that good trot work is essential to acquire suppleness, but also strength. In the trot, the forces acting on the trunk are higher. Hence, this gait requires more muscular contraction to provide an incline against gravity and to remain in balance. Contrary to the walk, the back is thus kept most rigid in this gait – but of course it should still move.

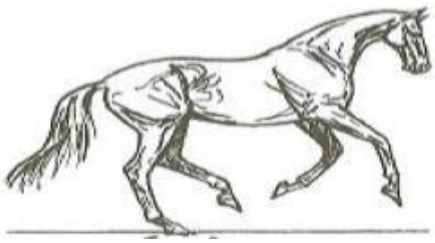
From experience, a sound trot, has proven to be an excellent and necessary means to strengthen supportive musclues around the hindquarter joints. For example: to strengthen the quadriceps to support and protect the stifle joints. Furthermore, the trot is an excellent means to stabilize necks that tend to be too flexible – a common problem nowadays.

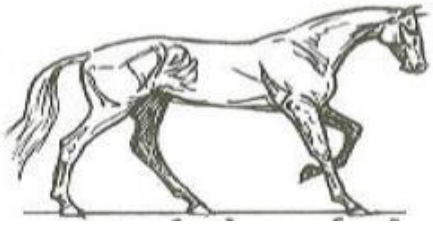
Finally, we must also note some limitations. Since the back is held most rigid in this gait, I generally do not recommend narrow trot-pirouettes as this might put the Biceps Femoris muscle under unnecessary strain.

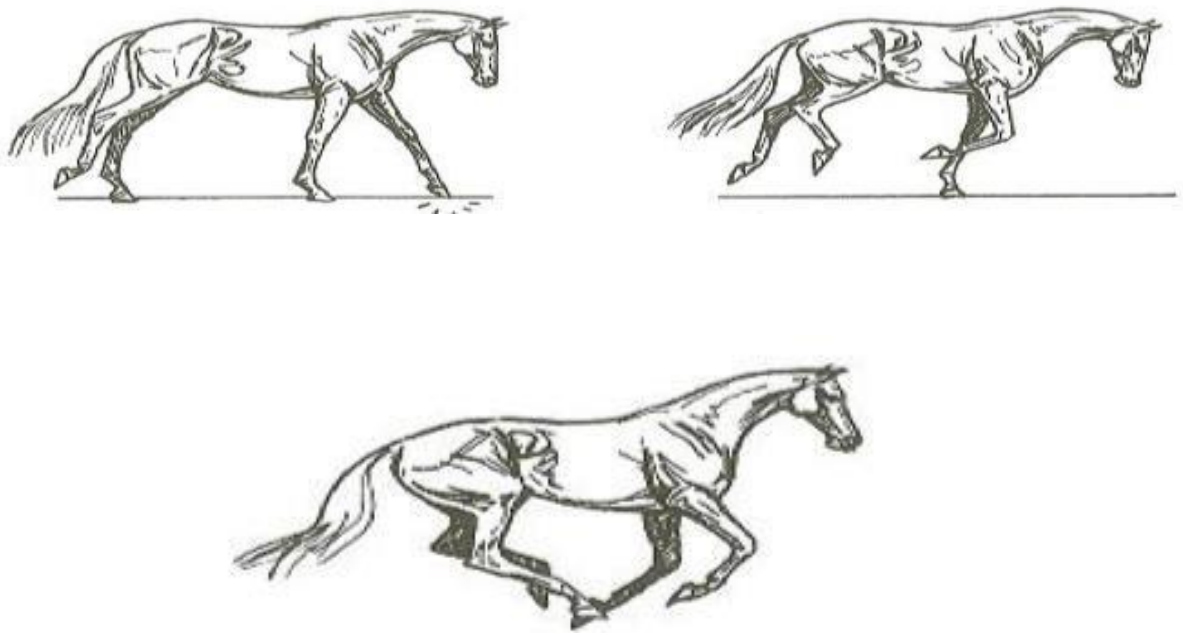
CANTER

The canter is an asymmetrical three-beat leaping gait with transverse limb placements separated by an aerial/suspension phase. The canter displays a leading leg which can be explained as either the first leading hind limb or the final footfall of the last front limb. Because of the diagonal foot falls, the back must be arched and engaged in order to maintain rhythm and engagement.

Science has found a linear connection between canter velocities and LS movement (Johnson et al 2012). Hence, this gait requires the most loin coiling and thus a healthy lower back and hindquarters to do so. Any canter that lacks this engagement will look downhill with the hindlegs somewhat trailing behind instead of under the body.







DAP has also been observed in this gait, most notably referred to as a four beat canter in which horses show a 'broken' diagonal pair landing on the ground at different times. Extreme collection such as canter pirouettes often induces a four-beat canter, but some horses display this pattern throughout.

A four-beat canter seen in a youngster. This is often wrongly considered as being 'uphill'.

A four-beat pattern comes normal to the gallop in which the diagonal pair becomes naturally dissociated with the hind leg landing before the front leg. So is a four beat collected canter technically a gallop? Is the extreme movement and elevation bred in today's competition horses actually damaging the clarity of their basic gaits? Or is it about time we changed the definition of what those gaits truly are in light of advances in biomechanical studies? It is an interesting discussion for sure. From personal experience, I always strive for the purity of a three-beat to allow the horse the greatest efficiency and protect the lumbar spine.

Apart from a four-beat canter, another common variation is a canter lacking the suspension. In this case, the gait shows a three-beat purity, but the outside hind limb already takes off for the next stride before the inside leading front limb takes off into the air.

Very often it is seen in hypermobile horses as well as certain genetic conditions such as ECVM – to be explained later. A canter lacking suspension can feel very comfortable, and thus easily fool the rider, but poses immense challenges. Think for example about lead changes. For these horses, it is key to not want to collect the horse too quickly and increase speed and trust. Short, explosive transition usually provide to be key, but the questions remains: Is it fair or even possible to train 'in' suspension when it doesn't come natural to

the horse? I think the answer lies in trying to manage the horses we have, but ultimately the change has to start at the level of breeding.

Finally, general lameness is hard to detect in canter. Often, the horse changes leading legs to compensate and uses the diagonal pairing to support the compromised limb. It must also be considered that Sacroiliac, Lumbo-Sacral and Hip issues become more clear in canter (compared to walk-trot) as this gait requires most engagement of the LS joint. Hence, in doubt where a [vague] lameness might come from, it might be a good idea to ask for a canter.

Concluding this section considering the from a training point of view I'd like to quote Steinbrecht who said:

''Although the trot must always be practiced with priority, the canter should by no means be excluded since it is a quit natural gait which requires the greatest thrust and impulsion from the haunches, like a jump (…) It not advisable, however, to force young horses to canter, at least not in the arena where they are required to perform regular turns (…) Consequently, we must first exclude the canter during the first training phase for horses that do not carry themselves sufficiently in natural balance, that is, all clumsy, inflexible horses, and use it only after we have given them, through trot work, the necessary self-carriage and thus the ability to carry the load primarily on the hind legs. Second, we must avoid tight turns in the first canter exercises and therefore use either continuous straight lines or a large circle whose track is curved only slightly (…)

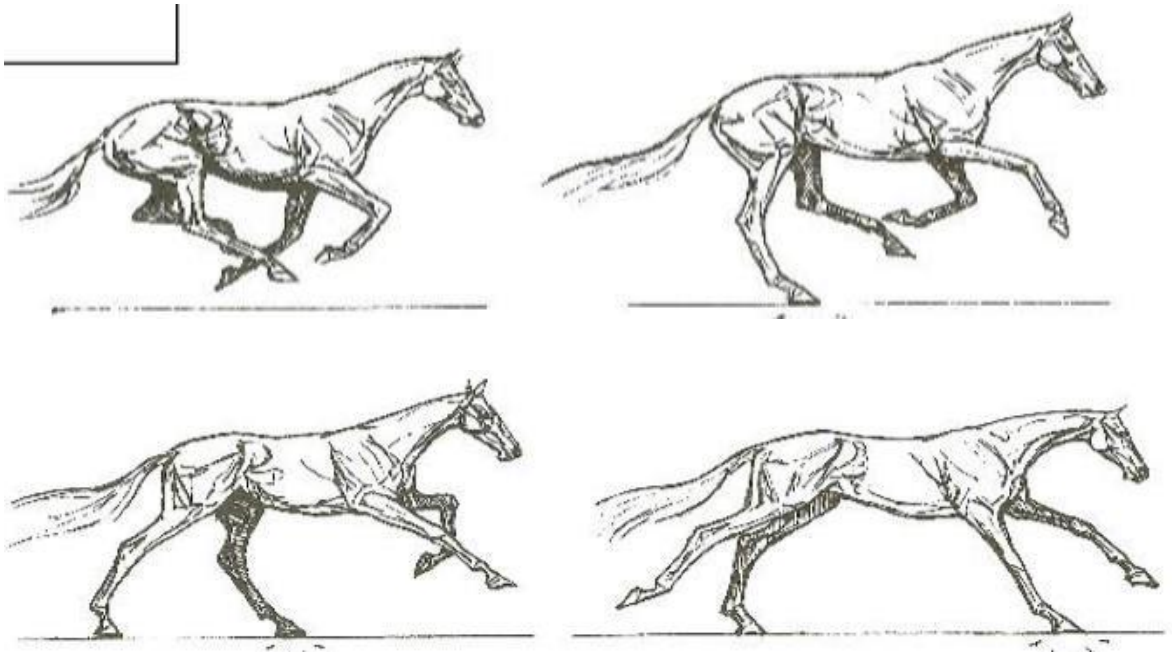
If these facts and recommendations are considered the canter may also be very useful in the early stages of training since it is the fastest way to cause the young horses to willingly yield its back muscles, takes away its barn freshness, and best prevents it from being foolish.''

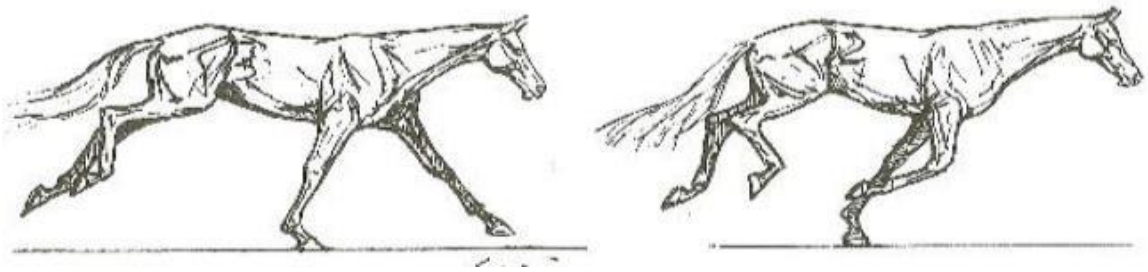
In these words, Steinbrecht urges the rider to always use the canter intelligently in a way that it is actually beneficial for the horse. How true are these words still today.

A bad canter can be improved with time. Pictures of Acaliena with 3 years in between.

GALLOP

The gallop is an extended gait with long strides and great engagement, exhibiting extreme flexion of the Lumbosacral junction and SI joint. Simultaneously, abdominal muscles are utilized to aid hind limb engagement per stride and this assists breathing mechanisms. The head and neck oscillate back and forward in large balancing gestures carrying the momentum forward.





A racing gallop can reach between 60-70 km/h and 260 heart beats per minute. Just as in the canter, the gallop has a leading limb, but as explained earlier, the gallop becomes rotational and very stressing on the stifle and suprascapular nerve.

The gallop is best served for outdoor horsemanship as well as racing. Hence, it has no purpose for Academic Dressage, apart that if the horse offers it on a trail ride it might serve as a refreshing means for body and mind.

STRIDE PHASES

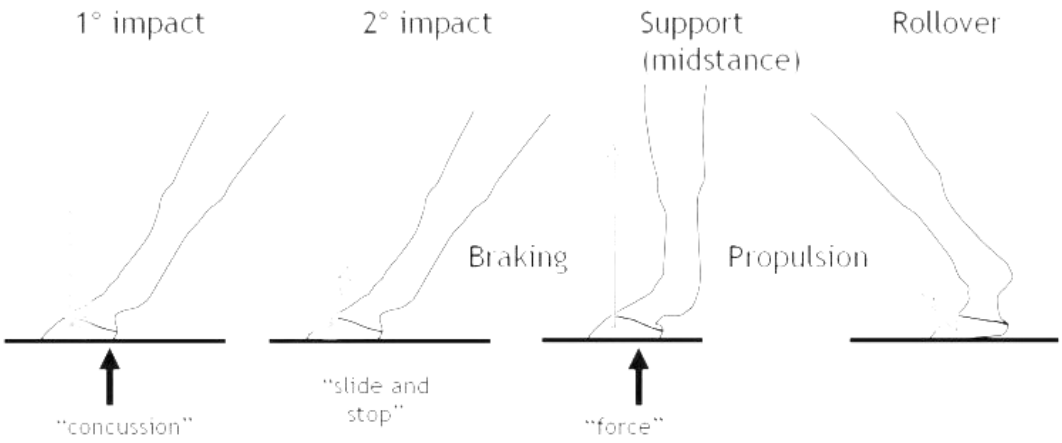
In most gaits, each stride consists of several phases:

- **Stance phase** → when a foot is in contact with the ground.
- **Swing phase** → when a lifted hoof is brought forward in a pendulum action.
- **Suspension phase** → when no hooves are in contract with the ground. There is no suspension in the walk.

The stance phase itself can be further divided into four different stages:

- First impact (load absorption)
- Second impact (load absorption)
- Midstance (full weight bearing & support)
- Breakover (pushing the horse's body forward)

The diagram below shows the differences of each phase in acceleration (red) and ground reaction force (blue). *''When the blue arrow is tilted, it indicates that both vertical and horizontal components of the ground reaction force are present. The arrow shows the direction in which the ground is pushing the horse.''* - Peterson et al., 2012



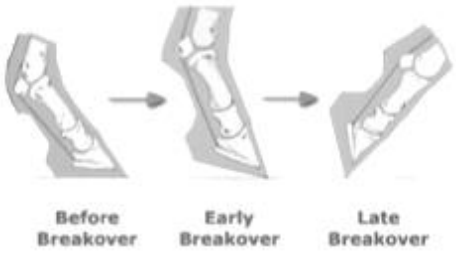
Loading of the limbs during the stance phase occurs in two stages. Immediately after the hoof contacts the ground – the impact phase - it is rapidly decelerated giving rise to a shock wave that travels proximally through the bones and joints. From the initial contact moment and the remainder of the stance phase – the loading phase, the limb is loaded more gradually as it accepts the body weight and then pushes off against the ground coming into the swing phase.

In general, hard tissues – bones and joints – are more prone to injury during the impact whereas the soft issues are more likely to sustain injury during the loading phase.

When lameness is present, the horse usually head bobs upon the support phase when the limb becomes fully loadbearing.

The next phase in a stride is the transition into the next phase. **The break over** is the moment in time when the hoof starts to tip forward and rotate over the toe to loose contact with the ground, the transition between the stance phase and swing phase. During this phase there is tension in the Deep Digital Flexor tendon and Deep Accessory Ligament as well as the navicular ligaments. Hoof balance will influence the place of break over, especially the hoof angle and length of toe. A Low heel and long toe will create a longer breakover but doesn't change other biomechanics of the stride. Abnormalities in the swing phase of the stride will lead to an off center break over, this is often associated with upper limb biomechanical abnormalities. i.e. lateral break over of the hind foot with stifle issues. The hoof should land heel first, a toe first landing will decrease shock absorption and circulation in the hoof as well as lead to a weak caudal heel.

On a firm surface the hoof will stay on the ground until the heel comes off. On a softer surface there will be toe rotation in the surface before the heel comes off, this reduces tension on the soft tissues within the foot such as the Deep Digital Flexor Tendon and navicular ligament (Butler 2017).



The swing phase consists of the forward and upward movement of the limb and is influenced by the confirmation and movement of the horse's shoulder and its muscles:

> *''With regard to conformation, a sloping shoulder facilitates forward and upward movement of the limb during the swing phase, so conformation of the shoulder may play a role in gait quality.'' - Holmström et al., 1990*

The swing phase involves joint flexion and extension. During retraction there is maximum flexion mid swing and then there is maximal joint extension in the protraction phase to prepare for landing.

When assessing the quality of a horse's movement, some professionals tend to focus on the swing phase, since this is when the expressiveness of the horse's movement is apparent. But one must keep in mind that expressiveness does not equal correctness.

Furthermore, in the search of the cause of lameness, the swing phase is relatively unimportant because the forces associated with this phase of the stride are small. It is during the stance phase that large forces are applied to the musculoskeletal system, so evaluation of the stance phase is usually more informative in relation to performance-limiting factors or lameness (Clayton).

A common technique to improve the swing phase is trot over poles. A 2014 study aimed to compare limb kinematics in horses trotting over level ground, over low poles and high poles to determine changes in joint angulations and hoof flight arcs. Their results showed that height of the fore and hind hooves increased significantly and progressively through increased swing phase joint flexion:

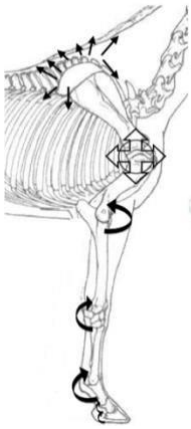
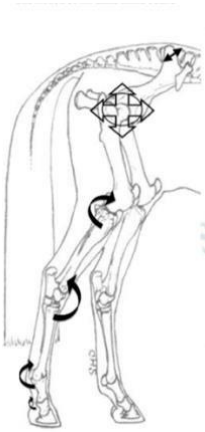
> *''The increases in swing phase joint flexions indicate that trotting over poles is effective for activating and strengthening the flexor musculature. Unlike the use of proprioceptive stimulation devices in which the effects decrease over time due to habituation, the horse is required to elevate the hooves to ensure clearance whenever poles are present. The need to raise the limbs sufficiently*

to clear the poles and place the hooves accurately requires visuomotor coordination which may be useful in the rehabilitation of neurological cases.'' - Brown et al. 2014

The suspension phase has already been mentioned in the previous chapter about the basic gaits and will thus does not require further elaboration.

JOINT ACTIONS

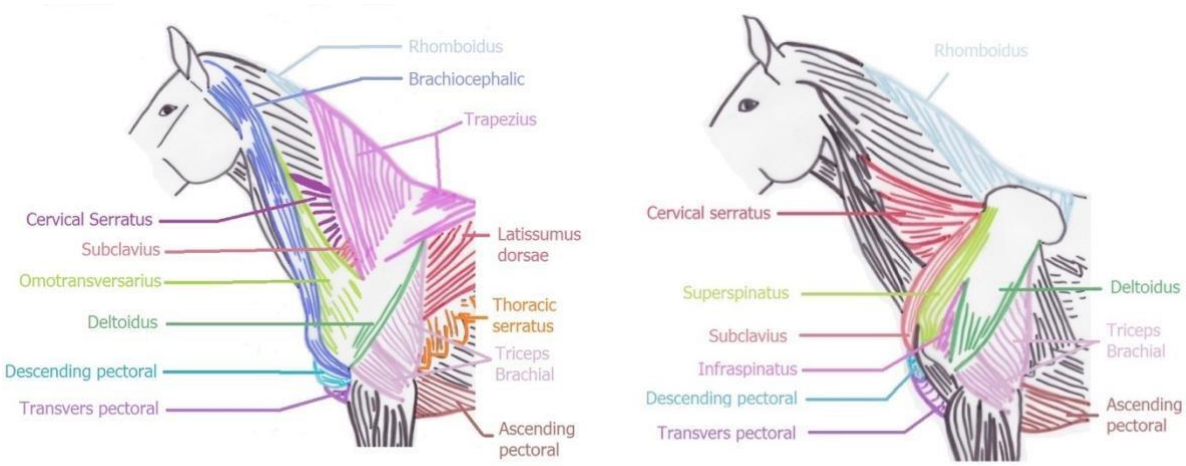
To properly analyze movement, it is important to look at the action of both front- and hind limb joints. See the table below for a schematic oversight of all relevant articulations.

FRONT LIMB	HIND LIMB
	
Shoulder [Scapula]	Lumbo-Sacral [LS]
Knee [Carpus]	Sacroiliac [SI]
Fetlock – also in hind	Hip [Coxofemoral]
Pastern – also in hind	Stifle
Coffin – also in hind	Hock
	Fetlock, Pastern & Coffin

FRONT LIMB JOINT ACTIONS

SHOULDER [SCAPULA]

The shoulder joint is the articulation between something called the *glenoid cavity* of the scapula – or shoulder blade – with the head of the *Humerus*. Unlike humans, horses don't have a collarbone linking the shoulder joint with the ribcage. Furthermore, unlike any other joints in the horse's body, the shoulder has no defined collateral ligaments governing its range of motion. It thus depends on a great deal of muscles. By now you should now I am getting super excited as I get to mention the importance of the *Thoracic Sling* apparatus again as well as the importance of direct muscles such as the *Brachiocephalic, Deltoid, Supraspinatus, Infraspinatus, Teres Major & Minor, Biceps and Triceps* – if you are ever going to participate in a dissection with Sharon May-Davis she'll have a great story about the relationship of these muscles.



Pictures adapted from Louise-Mauferon Vernet 2018 www.animal-osteo.com

Since the shoulder joint is a ball and socket joint, it can allow for F/E, but also circumflex and allow for rotation. The joint mainly moves in flexion/extension, where it is going to slide against the ribcage either forwards or backwards. The

flexion happens in stance phase, the extension during swing phase.. In lateral movements you can clearly see the abduction/adduction taking place.

The common used term *'sweeney'* describes a condition that affects the suprascapular nerve of the shoulder, which in turn influences the locomotive inactivity of the *Supraspinatus and Infraspinatus* muscles. The shoulder muscles atrophy and thus display an abnormal prominence of the shoulder joint and spine of scapula. As a result, the affected shoulder and front limb display an outward rolling – or rotational – action as the horse moves. Treatment via electro stimulation has proven to assist in rebuilding muscle tone and function.

ELBOW

The elbow is a hinge joint located between the knee and the shoulder. It consists of three bones: Humerus, Radius and Ulna.

In a normal standing position the elbow lies between 140-150 degrees at the dorsal angle and is braced in this position by collateral ligaments and muscular co-operation.

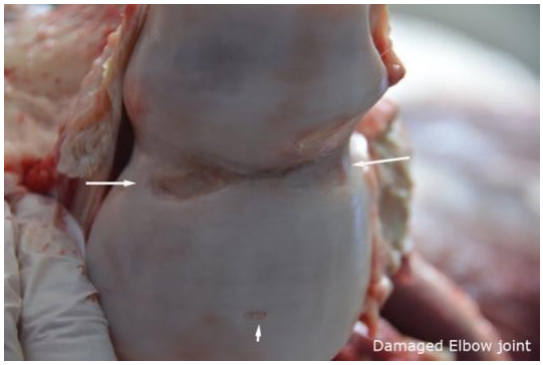
The elbow mainly moves in one plane – flexion/extension, but also slight rotation is possible:

> *''In flexion, the collateral ligaments loosen allowing the radius and ulna to slightly rotate outwards due to the structural nature of the trochlear groove in the distal Humerus and the action of the anconeal process into the olecranon fossa.''* – Butler 2017

Some important muscles surrounding the elbow joint includes the *Triceps, Tensor Fasciae Antebrachii, Anconeus, Biceps and Ulnaris Lateralis.*

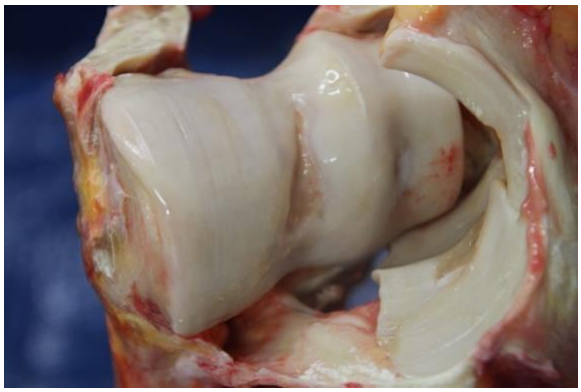
Sharon May-Davis needs to be accredited for discovering lesions in the elbow that show as substantial degradation of the Humerus, Radius and Ulna. Under dissection, 100% of ridden and driven horses exhibit this condition to a varying degree within three months of riding. Horses in harness exhibit the condition to a lesser extent.

> The lesions *''appear worse on the same side as an upright foot or compromised inferior check ligament…the action looks like a slip and/or double 'clunk'…The actual changes in the action begins when the front leg is in the stance phase during the stride as the limb goes into the posterior phase of the stride. It is more obvious going down a hill…As such, the muscles around the elbow joint brace under load and in particular, the Lateral Triceps muscle, which can become quite painful under palpation.''* -
> *- May-Davis 2016*



Picture on the left: clean elbow of a non-ridden 5 year old. Picture adapted from Sharon May-Davis 2016.
Picture on the left: damaged elbow of a ridden 7 year old. Pictures copyrighted by Classical Horse Training.

Most horses appear to handle this condition and continue with a normal life if not pushed to the extremes. However, it should be something kept in mind and some horses may require additional joint support to help sustain the elbow and other joints that may compensate for a change of action. Furthermore, jumping horses are more inclined to land with straighter front limbs. Be mindful that jumping, downhill work (so also a horse on the forehand!) and extended movements could possibly make the condition worse due to damage of the Biceps Brachii muscle – this was alreadyed explain in Module 1. on Anatomy.



Left: A picture of Shafai. His elbows were really bad and showing up with a clear 'double' clunk. Right: how the elbow looked upon dissection. For more pictures and videos please access the dissection case study file of Shafai.

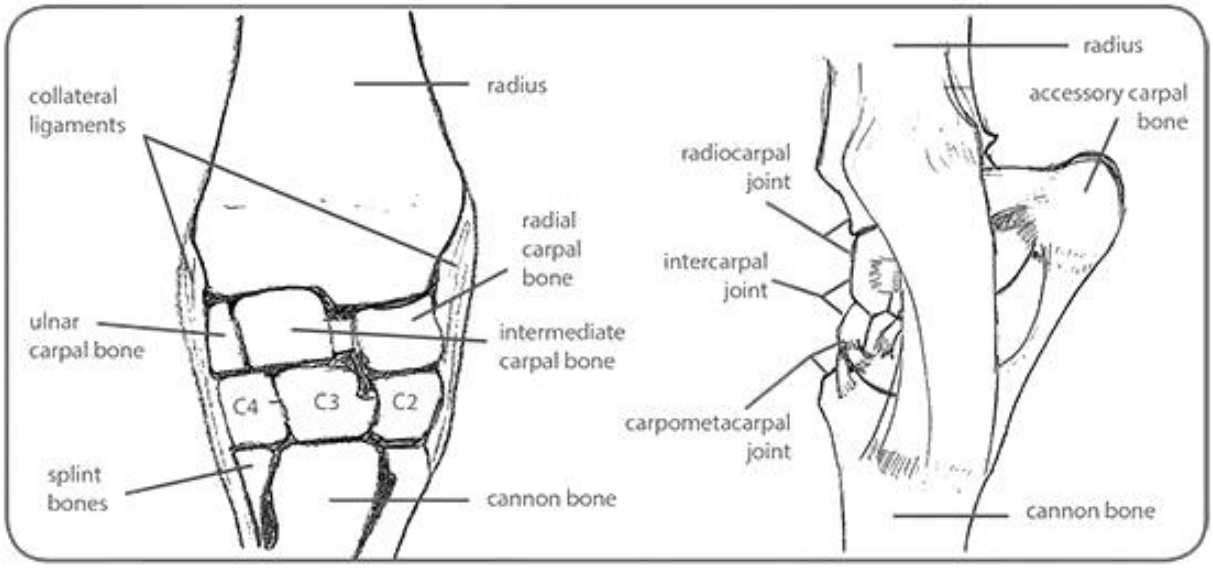
On the other hand, I personally believe it makes a great case for groundwork and work in hand. I have personally witnessed the degree of lesions to be less on those horses that were on the ground as well compared to those ridden only.

A final remark for bodyworkers that massaging the triceps – especially the lateral triceps – actually seems to exacerbate the condition *''as the massage releases the cast-like formation that this muscle provides the joint in an attempt to stabilize the condition.''* - May-Davis 2016

KNEE [CARPUS]

The knee – or carpus, is considered a hinge joint between the radius, two rows of carpal bones and the 2nd - 4th metacarpals. It is one of the most complex regions in the front limb because there are several small bones and ligaments all combining to form the three main joints: the *antebrachiocarpal joint, the middle carpal joint and the carpometacarpal joint.*

It moves exclusively in one plane – flexion or extension -, although the carpals glide within the joint to allow this range of motion. Overextension is prevented by occlusion of dorsally located stop facets on the rows of carpal bones, and by the support of a stay apparatus (Deane & Davies 1994).

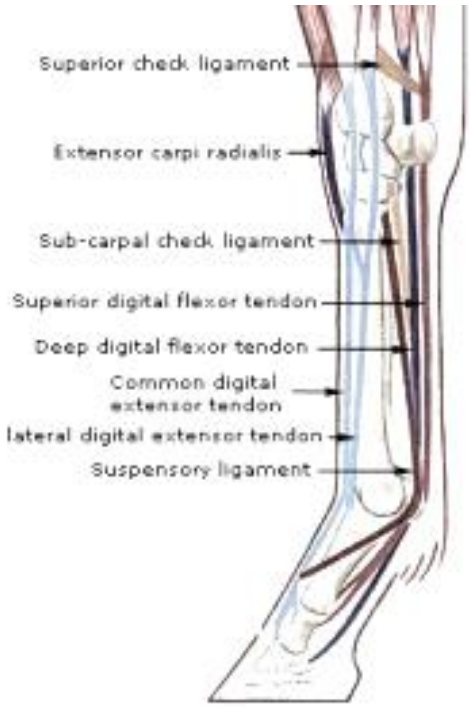


The carpus rapidly snaps into the close-packed position after initial ground contact, and this allows the fore limb to act as a propulsive strut throughout most of the stance phase (Clayton 2015).

There are no muscles from the knee below, only tendons and ligaments. Some the most important structures surrounding the carpus include: *superior check ligament, extensor carpi radialis, digital flexor and extensor tendons, and the suspensory ligament* – see image below.

FETLOCK

The fetlock is another typical hinge joint located between the 3rd metacarpal and 1st phalanx in both front- and hind limbs of the horse. It allows for flexion and extension as its ROM. The sesamoidial apparatus along with strong collateral ligament prevents overextension of the joint.



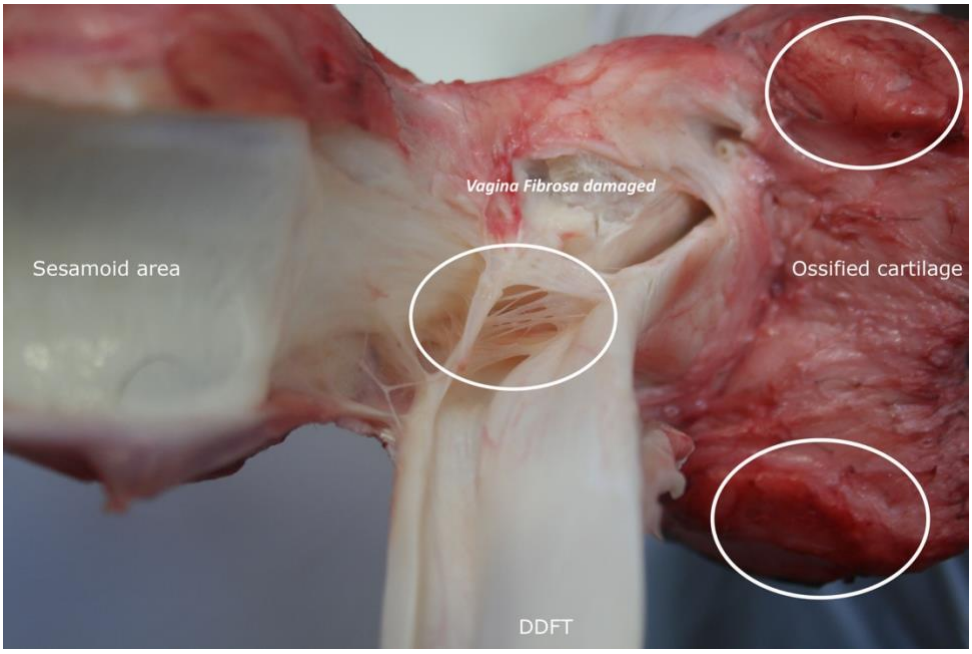
The fetlock joints and the palmar soft tissues behave like an elastic spring to conserve energy. In the early part of the stance phase the fetlock joint extends as it sinks toward the ground, reaching maximal extension

at midstance, which corresponds with the time when the cannon bone is vertical. As the fetlock joint extends, the palmar soft tissues are stretched. After midstance the fetlock rises allowing the elastic structures to recoil, thereby releasing elastic energy that was stored during the stretching process. This energy helps to flex the distal joints during the swing phase – see chapter 2 for a visual (Clayton).

Because of its function, racehorses are statistically most vulnerable to fetlock injuries. Unfortunately, fetlock issues are getting more common within other disciplines too.
A common visual sign is hyperextension – or dropping – of the fetlock during movement.

In a perfect world the elastic support structures stretch like a spring, store energy and then recoil with additional energy to give the horse's movement more spring. In a not to so ideal world, these support structures overstretch which lead to damage and lameness.

A common cause for this to happen is hypermobility through modern breeding programs for spectacular movements. Excessive freedom of movement – hypermobility – creates large spectacular movement and an unprecedented athletic capacity in lateral movements. However, the horses pay the price as it is a painful condition which causes them to struggle for general balance and stability.



Another cause of hypermobility is damage of the Vagina Fibrosa ligament. This is very important 'check' ligament that isn't mentioned in any anatomy books. The Vagina Fibrosa keeps the range of motion of the Deep Digital Flexor Tendon in check. When inflamed, damaged or ruptured, the DDFT is no longer protected and movement becomes hypermobile. It often shows in a 'wobble' of the foot. Unfortunately, this type of damage is very common upon dissection – see picture above.

When one fetlock drops more than the fetlock on the other side it is also possible you're seeing signs of weight-bearing lameness – often in the opposite limb. Alternatively, a fetlock may show excessive drop if there has been damage to the structures in the leg. Finally a common condition causing this movement is often reffered to as ESPA – known as DSLD or degenerative *Suspensory Ligament Desmites.*

In all cases, it is a reason to worry and requires change in your management and training schedule.

Dropped fetlocks can be improved through correct training. However, it is very difficult since there are no muscles from the knee below. It takes a lot of time and patience. When looking at this pictures, the fetlocks were first priority in training. Now that the fetlocks function better, the back – especially lower part – needs improvement.

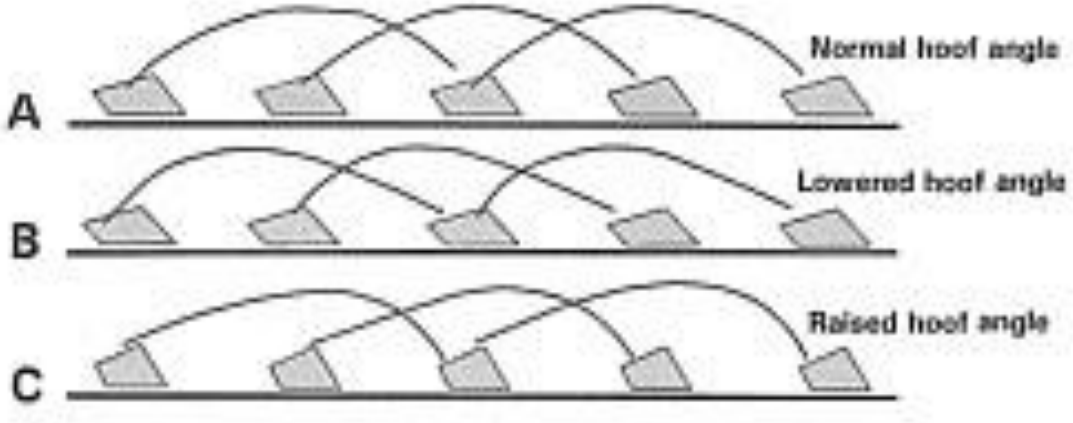
PASTERN

The pastern is located between the 1st - 2nd phalanx. It incorporates the short and long pastern bones which are held together by two sets of paired ligaments to form the pastern joint (*proximal interphalangeal joint*). It has very limited ROM due to multiple ligamentous attachments including collaterals that are supported further by extensor and flexor tendons.

Although the joint has limited movement, it does help to disperse the concussive forces of the horse's stride and also has some influence on the flexion or extension of the entire leg.

The pastern is vital in shock absorption. When the horse's front leg is grounded, the elbow and knee are locked. Therefore, the fetlock and pastern – apart from the hoof, are the joints responsible for all the absorption of concussive forces of a footfall. Together, they effectively distribute it among both the bones of the leg and its respective tendons and ligaments.

The slope of the shoulder ideally matches the slope of the pastern. The angle of the pastern should also match the angle of the hoof after the latter has been trimmed. The angle will change as the hoof grows and may be off in a few weeks. However, in general we could say that shoulder angle = pastern angle = hoof angle. Ensuring an appropriate angle keeps the bones of the pastern and coffin joints in correct alignment, with a straight line running through their core. An angle broken forward or back increases the stress on these bones, joints, tendons, and ligaments and alters the movement pattern.

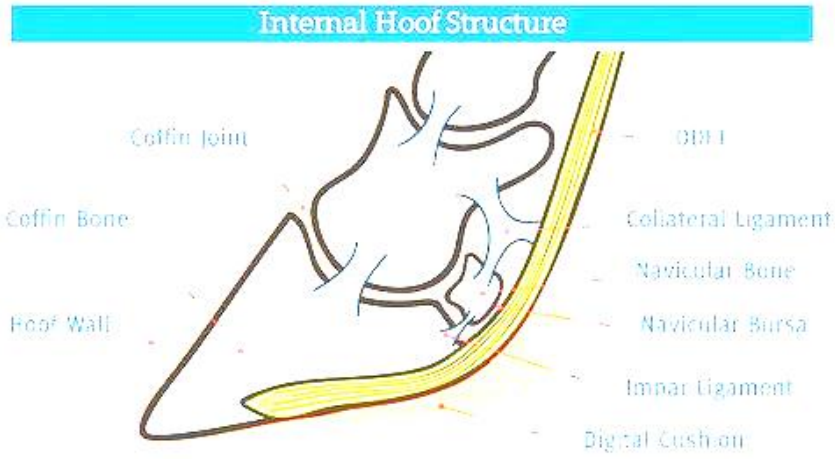


Long sloping pasterns are often seen in thoroughbreds and warmbloods. Short, upright pasterns are more commonly associated with cold bloods, quarter horses and some warmbloods.

COFFIN

The coffin joint is located between the 2nd - 3rd phalanx and exhibits a ROM similar to the fetlock with the distal sesamoid -navicular, behaving as a suspensory apparatus.

Navicular syndrome is a common cause for lameness in horses. Veterinarians often treat this syndrome with a coffin joint injection. However, in general I would personally consider those injections as a last resort and always first consider a general Osphos injection first.



HIND LIMB JOINT ACTIONS

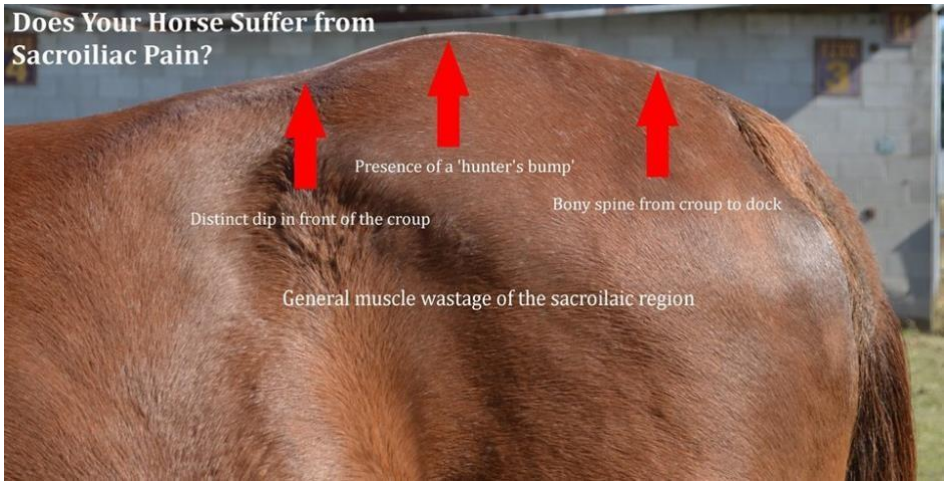
SACROILIAC [SI]

The pelvis forms the link between the vertebral column and the hind legs through the sacroiliac (SI) and hip joint. The SI joint is a small flat, and synovial joint that attaches the sacrum – sacral wing, to the pelvis – ilium at approximately a 30 degree angle. It is primarily ligamentous in its attachment and has mostly a stabilizing function. The SI has a limited range of motion that only allows for minimal flexion/extension dependent on the relative position of the pelvis. There is more movement when the pelvis tucked under compared to a rigid neutral position.

The sacroiliac is particularly inaccessible due to its depth within the pelvis and surrounding musculature, making it impossible to palpate the joint externally (Goff 2018).

In recent years, there seems to be a lot of attention towards SI dysfunction. The most important concept relative to SI injury is lack of stability. Since it has such miniscule range of motion, damage appears due to excessive movement. Since the lack of stability is the main issue, all therapies attempting to release muscles, tendons and fascia involved in the stability of the sacroiliac joint are likely to create sacroiliac dysfunction instead of treating the problem.

SI injuries are notoriously hard to pin down, with subtle and confusing signs, easily mistaken for other physical or even behavioral problems. The first hints of trouble may be a change in the horse's performance and attitude. The horse might be not working at his usual level or seems unwilling to work. He lacks impulsion behind, and the quality of movement isn't what it was. Some horses are difficult to trim on their hind feet. SI problems usually because more visible in the canter. Asymmetrical muscling in the hindquarters is another red flag along with difficulty in performing lateral work, resistance against the bit, bucking, canter problems – flying change or swapping leading legs – and the horse might be reluctant to jump.



However, most signs of SI pain can be produced by other conditions. In fact, SI pain often appears along with other musculoskeletal problems. In Dr. Dyson's study, 25 percent of the horses also had lameness in a front or hind limb, and another 25 percent had arthritis or other problems somewhere in the vertebral column.

A very common misconception is the belief that one tuber sacrale being higher than the other is an indication of SIJ misalignment. The tuber sacrales are the two small protuberances which are visible on the top of the croup. Sometimes the tuber sacrale appear asymmetrical, and this can also be seen in clinically normal horses. Historically, it was attributed to misalignment of the sacroiliac joint, but there is very little evidence to suggest that this can happen. So what can cause this apparent asymmetry? The most likely reason is difference in thickness of the overlying soft tissues, possibly the result of previous injury – in which case it may signal a subluxation- , or simply that sometimes there are normal asymmetries in the growth and development of the bones. Another case leading to the same visual impression is inverted rotation of the thoracolumbar spine which places the sacrum and the pelvis in a slight twist to the left or right - making it look like one side is higher than the other. This means it's important that the practitioner that is treating your horse is able to differentiate between primary and secondary dysfunction. When only treating the secondary, symptomatic issues, the underlying problems are very likely to return.

HIP [COXOFEMORAL]

A little further down the SI the hip attaches the femur to the pelvis. In contrast to the rigid SI joint, the hip is a highly mobile joint that allows for a ROM in every direction.

In order to prevent hypermobility and to perform its function optimally, the hip joint is protected, stabilized and assisted by a layer of fat, [accessory] ligaments and big hind end muscle groupings such as the quadriceps and the hamstrings. These muscles often perform multiple functions, creating close interconnection with the hock and stifle.

For example: *Rectus Femoris* [quadriceps] flexes the hip while extending the stifle. *Semitendinosus* [hamstrings] extends the hip and hock joints while flexing the stifle. *Biceps Femoris* [hamstrings] extends the hip, stifle and hock, and FLEXES the stifle. *Tensor Fasciae Latea* flexes the hip joint and extends the stifle while tensing the Fascia Latea. The *Illiopsoas* [Psoas major & Illiacus muscles] flexes the hip joint and rotates the femur.

Proper functioning of the hip joint essential for any desired performances while ensuring the horse's health. Any dysfunction will hugely impact the horse's ability to properly carry our weight. Despite the hip being so important, issues are quite common, but unfortunately, often get underestimated or simply not recognized. This might be due to some diagnostic challenges.

The hip is located deep within. As mentioned before, its well protected by a layer of muscles, ligaments and fat. This makes it impossible directly palpate the hip joint. However , it is possible to directly palpate most of the hind end muscles - apart from the *Illiopsoas* which you can only indirectly palpate - connected to the hip joint. X-rays are not able to go through to the joint. Furthermore, any procedures around the hip joint, such as arthrocentesis is tricky and always needs to be done with utmost care due the proximity of the sciatic nerve.

However, a lack of proper diagnostic tools to analyze the joint does not mean issues are not present. In fact, I personally observe a lot of problems in this area. Think about it, because the hip joint is so mobile, horses often choose to use it as a compensating mechanism.

A most common sign is rotation of the joint in movement. Since the hip joint is connected to so many of the hind quarter musculature, any hip joint dysfunction naturally affects the entire hind end and the horse's ability to properly coil the loins.

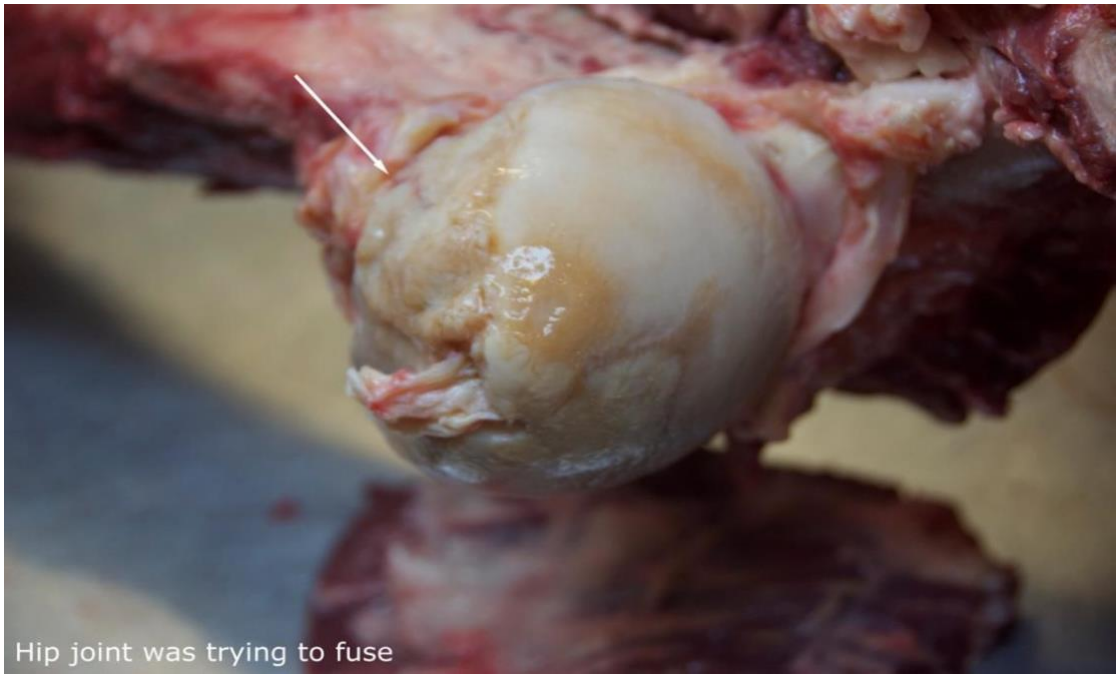
See picture on the right for an extreme example of an extreme hip joint rotation. Rotation of the hip can be recognized when the horse lands the hoof and then when it is on the ground 'twists' with the entire limb to the outside.

Assessments for lameness are usually only performed in walk and trot on both hard and soft surface. While lameness indeed is most (obviously) visible in these gaits, hip problems usually also affects the canter. Although rotations of the hip joint can be spotted in the mostly the walk for the trained eye, the quality of the canter usually shows the problems clearly. Coxofemoral problems might give a lot of vague or subtle signals which not necessarily show in obvious lameness or are not recognized as such. When increasing the forces acting on the hip joint, by asking for a canter, the signals usually become a bit more clear and might be worthy to include in the assessment.

Upon dissection, the most common injury that I have observed is damage and even ruptures of the round- and accessory ligaments in the joint itself as well as arthritis and [past] fractures.

Since there is not a lot that can be done for the joint itself – apart from general pain medication or joint injections such as Pentosan, it is possible to alleviate any possible discomfort through proper training. Correct training can help the surrounding musculature to better stabilize the joint and thus alleviate discomfort. I have witnessed

many horses in which hip joint rotations were straightened after a period of sound lateral work [especially transitions in between] in hand and/or ridden.



A very badly damaged hip join. Often, dissection proves to be the only means to learnabout hip joint issues. This horse was displaying rotations in hip, hock and stifle. Picture copyrighted by Thirza Hendriks.

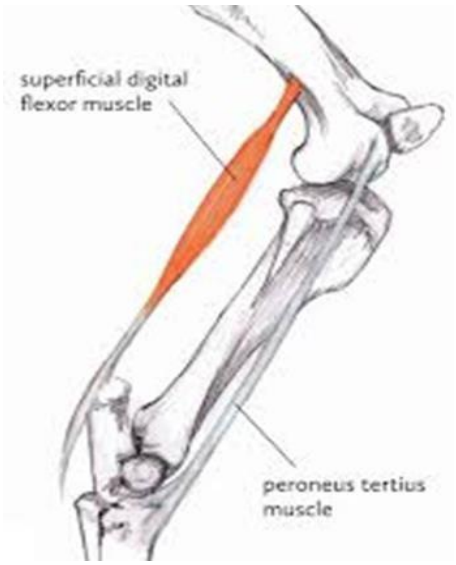
STIFLE

The stifle is often referred to as the most complex joint in the horse's body. Where the hip joint has most directions of movement, the stifle is the most mobile joint of the hind limb.

The stifle is located between the femur and tibia - medial and lateral compartments. It consists of two joints: the femoropatellar joint and the femorotibial joint – lateral and medial compartments. ''*There is a complex arrangement of soft tissue in the stifle – 12 ligaments, 2 menisci and numerous musculo-tendinous support structures – that provide functional stability, force transduction and locomotion.*'' - Fowlie et al. 2012

The stifle is designed to clear the horse's barrel when in motion. Although it is primarily a hinge joint with principally flexion and extension as its ROM,

''the femur is designed to allow outward rotation whilst supported by the two menisci of the tibia. The patellar glides between two trochlear ridges and aids rotation with this action whilst providing stifle extension.'' - May-Davis 2015



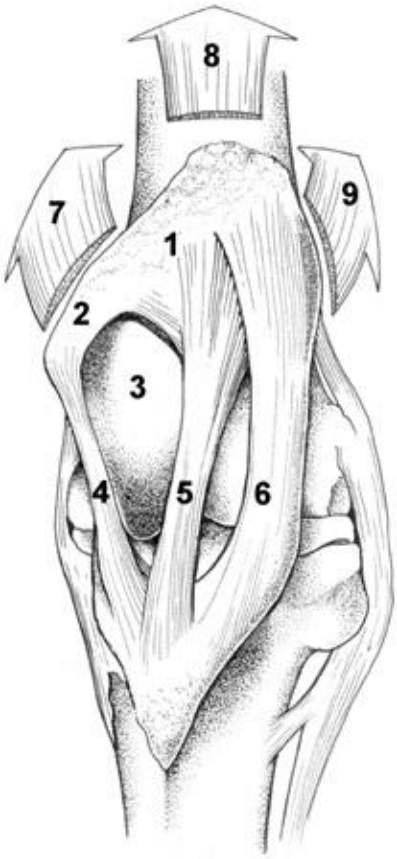
The stifle and the hock the hock have a reciprocal arrangement and are synchronized in their movements through the *superficial digital flexor* muscle and the *peroneus tertius* muscle. When the stifle flexes, the hock flexes, when the stifle extends the hock extends.

Picture adapted from R. Butler (2018).

Just as with the hip, the stifle is also closely related to the lumbar spine due to muscle connections which are innervated from L3-S2. A common sign of stifle issues is a 'roached' back in the lumbar area. Due to stiffness in the stifle, the horse cannot engage the hind limb which results in a brace in the lower back. The Psoas Major – a major hip flexor, then usually gets overworked and tight pushing up against the lumbar spine resulting in a so-called 'roached back'.

Again, this example shows that many muscles involved in the movement of the stifles are also involved in the movement of the hips. Hence, this clear shows that a problem in any of those joints always affects the others. It is therefore that we usually can observe 'hip, hock and stifle' all together. The difficulty is then trying to localize the primary cause of the problem.

Finally, the section wouldn't be complete without looking at the stifle's locking mechanism. A locked stifle joint occurs when the patella (1) with the parapatellar fibrocartilage (2) is hooked over a ridge on the head the of the femur bone – the medial ridge of the femoral trochlea (3), by means of the patellar ligaments (4-6).



The *quadriceps femoris muscle,* inserting to the patella, serves to extend and the stifle joint. It may assist in keeping the patella in locked position. The patella is released by *Quadriceps Femoris contraction and Tensor Fasciae Latae and Biceps Femoris* lateral pull.

In order to stabilize, the stifle joints are actually meant to lock under certain circumstances. For example, to enable a horse to sleep while standing or simply to rest and take weight off another leg, the patella locks in order to support the horse to keep standing upright.

Normally, the horse can flex the joint with little effort to unlock it through a contraction of the muscles listed earlier. Things start going wrong when the patella fails to unlock when the horse want to flex the leg. This condition is called 'upwards fixation of the patella'.

This condition is quite common and, as should be clear by now, affects all the other joints in the hind limbs as well as those of the lower back. Clinical signs of an upward fixation of the patella include:

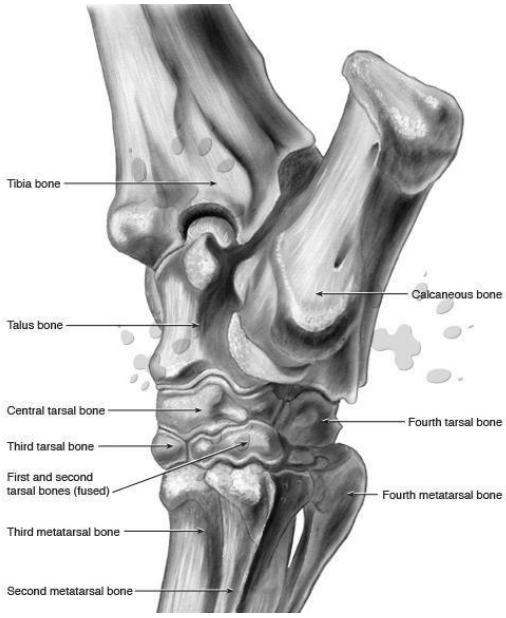
Hind limb locked in extension	**Dragging of the toes**
Feet to the outside	**Shortened / stiff stride of the hind limb**
Clunking of clicking noise of the stifle	**Hindquarter muscle wastage**
Cramping ❼ can look like stringhalt	**Swelling, pain & inflammation**
Problems going downhill	**Roach back**

The condition can be improved through mobilization techniques, taping and rehabilitation training[3] with a focus on strengthening supporting muscles - Quadriceps group & core, and function of the lumbar spine.

HOCK [TARSUS]

The hock or tarsus is a hinge joint located between the tibia and cannon bone of the horse's hind limb. Although the hock is often referred at as if it were a single entity, it actually is a complex apparatus and often considered as one of the hardest working joints in the horse's body.

The hock consists of four joints – supported by various ligaments. The top and largest is the *Tibio-tarsal joint* which is a 'high motion but low concussion' joint responsible for 80-90% of the total flexion/extension movement within the hock. The three smaller hock joints in descending order are the *proximal Inter-tarsal, distal Inter-tarsal and Tarso-metatarsal joints*. These 'low motion high concussion' joints make up for 10-20% of total movement.



The hock primary allows flexion and extension as its range of motion, but it also has but has accessory medial, lateral and rotational motion. The 3 degrees of translation are more pronounced at the trot.

The hock apparatus has a very important function in shock absorption. Because of the horse's anatomy the hock joints are always under a certain degree of flexion in the early stance phase, enabling it to absorb concussion from the shock waves that directly travel up the limb and the rotational force [torque] produced by the break over phase of the stride. In the later part of the stance phase, the hock extends as it generates propulsion to drive the horse forwards.

Since the hock plays such a major part in the generate of power to jump and gallop, as well as to 'sit' in dressage, it is prone to both degeneration as well as injury. The lower joints are the most common sources of lameness in horses because they are under significant stress in a working horse. The most common problems around the hock include thoroughpin, bog & bone spavin, osteochondritis dissecans (OCD) and osteoarthritis.

As already mentioned before, the hock acts in unison with the stifle and lower back joints. I cannot state enough that because of this interconnection, any problem within the hock will also affect the other joints.

ASSESSMENT SKILLS

Now that you've studied the basics of anatomy & biomechanics, it is time to put it all together in learning how to analyze movement through performing an assessment.
To set you up for success, you will need to employ your senses:

- Sight – in order to observe the entire body
- Hearing – in order to hear the footfalls and internal noises
- Touch – to gather bodily information through your hands
- Smell – in order to detect possible infections
- 6th sense – To employ your gut-feeling

A basic assessment usually consists of observation and palpation. Always remember to assess only and never undertake a diagnostic approach as this contravenes the veterinary act. An assessment does not replace veterinary diagnosis and no definite medical conclusions can be drawn from its results.

Put simply, there are two possible outcomes of every assessment: biomechanics is either normal or abnormal. When biomechanics appears to be not normal there can be various reasons to consider:

- Dysfunctional anatomy
  - Congenital
  - Genetics
  - Living life
  - Treatment
- Pathology
  - Management
  - Acceptable or not

Examples of a congenital dysfunctional anatomy are heart problems or an uneven ribcage. Horses can have 17 ribs to one side and 18 to the other. In this case, sometimes a rib thinks it is a vertebrae, or sometimes a vertebrae thinks it is a rib, resulting in what is known as transitional ribs/vertebrae. Naturally, this provides a problem for sounds biomechanics.

Examples of dysfunctional anatomy caused by genetics is Equine Vertebral Complex Malformation [EVCM] and Equine Polysaccharide Storage Myopathy [PSSM] which is genetical muscle default disease. A final example would be Development Orthopedic Disease [DOD].

When you have a dysfunctional anatomy, you end up with pathology such as lameness and/or [chronic] inflammation. The first logical step is to treat the horse. When you treat a horse for about 3-4 times the horse should be healthy again restoring normal biomechanics. If that is not the case, the pathology adapts a more chronic nature, which requires you to do something about your management. For example, you might need to change the way you are training, asking your therapist to treat more on a regular basis or change your horse's living area. Sadly, sometimes, all of this is not enough and the horse seems to be suffering in which case you need to make a decision.

In case of the latter, I get a lot of people reaching out to me if they can donate their horse for dissection. It provides closure for the owner and at the same time offers an opportunity

for many people to learn. The main goal of doing dissections and research is to learn about possible prevention or enhanced treatment of various pathologies so that less and less horses have to end up with the same fate in the first place. Although nature is complex and cannot be controlled, it is possible to save many horses from an unfortunate fate through early detection of any abnormalities and adequate adaptation in management. It is therefore important to always look at your horse through fresh eyes.

In the coming chapters, I will elaborate in-depth on all factors contributing to analyzing biomechanics so that you are enabled to react adequately where needed.

GENERAL INFORMATION

To assess each individual horse, it is vital to always list the following general information:

- Age
- Breed
- Discipline/Training
- Medical History
- Management

Age can play a factor in assessing for lameness. In general, foals are more likely to have infection causes of lameness. A young horse just coming into training may be lame due to a developmental orthopedic disease such as OCD. Older horses more into training are likely to experience arthritis.

Certain issues, especially genetic disorders, are more prevalent in certain **breeds**.
Below, you find a general overview of genetic conditions by breeds system.

Arabians	Cerebellar abiotrophy, Juvenile epilepsy syndrome, lavender foal syndrome, Occipital Atlanto-Axial Malformation (OAAM)
Quarters	Glycogen branching enzyme deficiency, Hyperkalemic period paralysis [HYPP], Malignant hyperthermia [all musculoskeletal]; Heritable Equine Regional Dermal Asthenia [HERDA] [Dermatologic]
Drafts	[Musculoskeletal]; Junctional Epidermolysis Bullosa [JEB] [Dermatologic]; Recurrent Laryngeal Neuropathy [RLN] [Respiratory]; Chronic Progressive Lymphadenopathy [Miscellaneous]
Warmbloods	Osteochondrosis/ osteochondritis dissecans [OC/OCD] [Musculoskeletal]; Equine Recurrent Uveitis [ERU] [Ocular – especially German Warmbloods]; Guttural Pouch Tympany [Respiratory – especially German Warmbloods]; Equine Complex Vertebral Malformation (ECVM] [Musculoskeletal & Neurologic]
Thoroughbreds	Recurrent exertional rhabdomyolysis; Recurrent Laryngeal Neuropathy [RLN] [Respiratory]; Congenital Stationary Blindness [Ocular]; (ECVM] [Musculoskeletal &

	Neurologic]
Miniature horses	Dwarfism [Miscellaneous]
New Forest Ponies	Myotonia [Musculoskeletal]
Appaloosa	Equine Recurrent Uveitis [ERU], Congenital Stationary Blindness [Ocular – also common in Paso Finos]
Connemara	Hoof wall separation disease [Miscellaneous]
French trotters	Osteochondrosis/ osteochondritis dissecans [OC/OCD] [Musculoskeletal];
Friesians	Corneal Dystrophy [Ocular]; Chronic Dermatitis [Dermatologic]; Dwarfism, Chronic Immune Deficiency [Misceanoullous]; Megaoesophagus [Respiratory]; Aortic Rupture [Cardiovascular]
Various	Neuroaxonal Dystrophy/ Equine Degenerative Myeloencephalopathy [NAD/EDM], Cervical Vertebral Compressive Myelopathy [Wobblers], Equine Complex Vertebral Malformation [ECVM] [Neurological]; Polysaccharide storage myopathy type 1 & 2 [PSSM 1 & 2]; Grey horse melanoma [Dermatologic]; Equine Multiple Congenital Ocular Anomalies [MCOA] [Ocular]; Recurrent Airway Obstruction [heaves], Exercise induced pulmonary haemorrhage [Respiratory]; Equine Metabolic Syndrome [Misceanoullous]

Another factor to take into account is **discipline**. Certain lameness's and bodily issues are associated with certain uses. See diagram below for a general outline.

DISPLINE	CONDITIONS
Dressage	Vertebral column & pelvic issues, hip/hock/stifle; fetlock changes; bone and bog spavin; neck & lumbar arthritis
Reining	Hamstring tears; Fibrotic myopathy; SI strain; early hock arthritis; bone & bog spavin; curb and fracture of the 2nd phalanx in the hind
Endurance	Bowed tendons; pedal osteitis; hoof and leg injuries; bruised soles; back pain and fatigue/stress fractures
Racing	Bucked shins; fatigue/ stress fractures; bowed tendons; carpitis; carpal chips and slab fractures; fetlock arthritis and chip fractures; sesamoid changes and fractures; subluxation of SI joint; stifle strain; vertebral changes
Jumping	Navicular syndrome; bowed tendons; ligament sprains; SI strain; back pain; vertebral changes muscle fatigue

Diagram adapted from Sharon-May Davis 2015.

The **medical history** of a horse should also be considered. An old injury may be re-injured. On the other hand, the horse might also show bodily issues due to long time compensation for a past injury. In the case of a progressive disease, such as osteoarthritis, a horse will often experience recurrent lameness that must be managed. Shifting lameness may suggest a bilateral injury or infectious cause of lameness.

Finally, the **management routine** of the horse should be considered. Recent changes in training, turnout, exercise, diet and/or trimming/shoeing are known factors that play an important role.

KEY FACTORS TO TAKE INTO ACCOUNT

After noting the general information of the horse, you can continue the assessment with observation to gain more information about the possible course of the horse's limbs. The course of the limb is primarily determined by:

- Hoof balance
- Alignment of the leg
- The ability of the leg to articulate smoothly
- Tendons, ligaments, fascia and muscle groups involved in locomotion

General asymmetries can be best spotted when the horse stands square with its head and neck straight in front of the sternum. When observing a horse, stand back a few meters and observe from the front, back and then both sides. In addition, it can also be useful to stand on a heightened surface such as a mounting block.

From this standpoint, you can observe several aspects of the horse that will assist you in noting which limbs are loading correctly and which are not and make an informal judgement as to what area requires addressing:

- Confirmation, posture and type
- Muscular hyper- and atrophy
- Abnormal swellings or blemishes
- General Health issues
- (A)symmetry
- Limb deviations

OBSERVATION SCAN: CONFIRMATION OR POSTURE?

First, you need to start with a big observation 'scan' to consider the whole horse. What is the first impression the horse gives you? Look at its emotion and energy and then mainly consider the horse's confirmation and posture. It is important to be able to differentiate between these two concepts and as such I will elaborate on this more below.

Just as humans, horses come in many different, shapes, sizes and colors with a variety of individual variations. Some of the differences and variations can be categorized by breed. Horse breeds vary according to where they originated and characteristics have been altered by humans deliberately breeding dominant genes to enhance or achieve a desired trait (Rogers 2010). Over time, each breed has been developed according to a standard of excellence for 'type' that includes correct conformation representing the requirement of the breed to perform specific tasks. These standards are of course ideal and in reality there can be broad individual variations, even among horses of the same breeds. Confirmation is usually the most important factor of interest to breeders or judges at tests. Certain traits such as 'long back', 'roach back or 'sway back' are considered conformational 'faults'. But are they necessarily to do with confirmation, or can there be underlying influences – such as postural issues - causing these appearances?

To clarify the terms, confirmation describes characteristics derived from breeding such as hair color, length and size of skeletal structure. Posture on the other hand is how the horse organizes itself in the way it stands and moves. Being able to identify the difference between confirmation and posture can be crucial as posture can be improved whereas confirmation cannot.

To judge confirmation it is most important to judge for function, that is, in relation to performance expectations. A horse with non-ideal confirmation for jumping could have excellent confirmation for dressage. That being said, there are many horses that excel in any chosen discipline without having perfect conformation.

Many traits assigned to ‘poor confirmation’ are in fact due to ‘poor posture’. This opens up a whole lot of new possibilities as with a little knowledge and experience, you can take the action needed to bring your horse’s body and mind back into balance. *‘‘This may not only improve the appearance of its confirmation, but also make a significant difference to its performance ability, comfort and long-term healthy.’’* - Rogers 2010

The way we look at horses is hugely influenced by history. Visual documentations of horses through time have been referred and relied to as the reference of what is ‘normal’. A significant point that needs to be realized is that a majority of horses in art show imbalanced postures. *‘‘While aspects of the horse, such as head size, varied in paintings from era to era, the posture stays true and has very minimally been influenced by the way they were painted’’.*

Especially through bombastic eras such as the renaissance period there are many depictions of horses that would now be considered to have typical conformational flaws. Not only in paintings, but also in visual arts there are many examples of horses depicted in unbalanced postures. If you walk around in a random city, chances are you will find a statue of horse and rider somewhere.

Very often, these statues show incorrect movement, open mouths, tension and hollow backs. This type of imaging hugely influences the way we perceive the 'normal'. Most of what is now perceived as conformational issues – my horse is just poorly bred – are actually postural. We have become so accustomated to seeing imbalances in horses – ewe necks, cow hocks, swayback etc. – that these are often accepted are natural conformation and thus not subject to change. However, the possibility that many of those characteristics might in fact be postural will open a door way for change and improvement.

In the words of Dr. Ian Bidstrup *''poor posture is killing your horse''*. Closely observing and palpating your horse on a regular basis will reveal information that you need to determine the difference between confirmation and posture with the general rule that if something appears to be present from birth, it is conformational, as to whether it occurred during life, it should be considered postural, which can often be improved with proper management adaptions to ensure the best life possible for the horse.

Pictures of Femme Fatale taken 3 months apart. She had many 'deemed' conformational flaws such as an ewe neck, dropped spine, poor shoulder angle, hoof/pastern axis and cow hocks. After three months in exact the same feet stance you can see the improvement which shows that most of the issues were in fact postural.

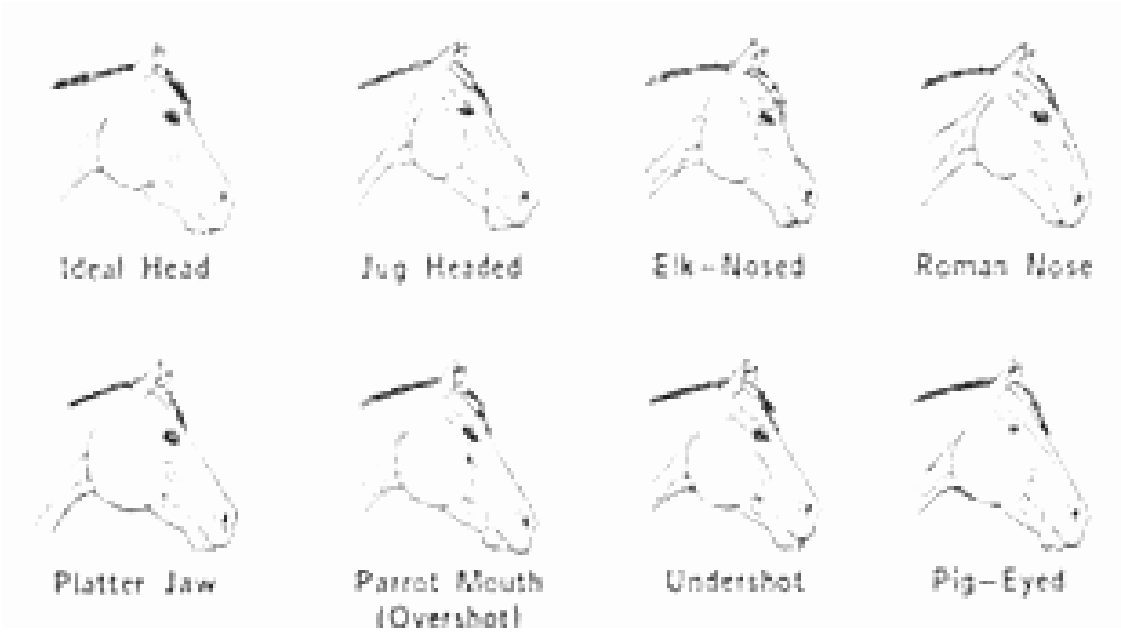
SEGMENTAL OBSERVATION

So now that I've discussed the different between conformation and posture, let's continue by all relevant observation points in a segmental way: from front to back and from left to right.

FACE

Start to observe the horse's face. Look at the muzzle shape. Concave muzzles are often associated with the Arabian breed and its adaptation to airflow resistance and increasing aerobic endurance. On the opposite, more convex profiles – a so-called Roman nose, are often associated with cold bloods and more baroque type of horses.

Observe the balance between the eyes and nostrils. No face is 100% symmetrical, but the nostrils and eye-height are important indicators for straightness. Furthermore, possible health issues might be observed. Are the eyes and nostrils dry or is there fluid present?

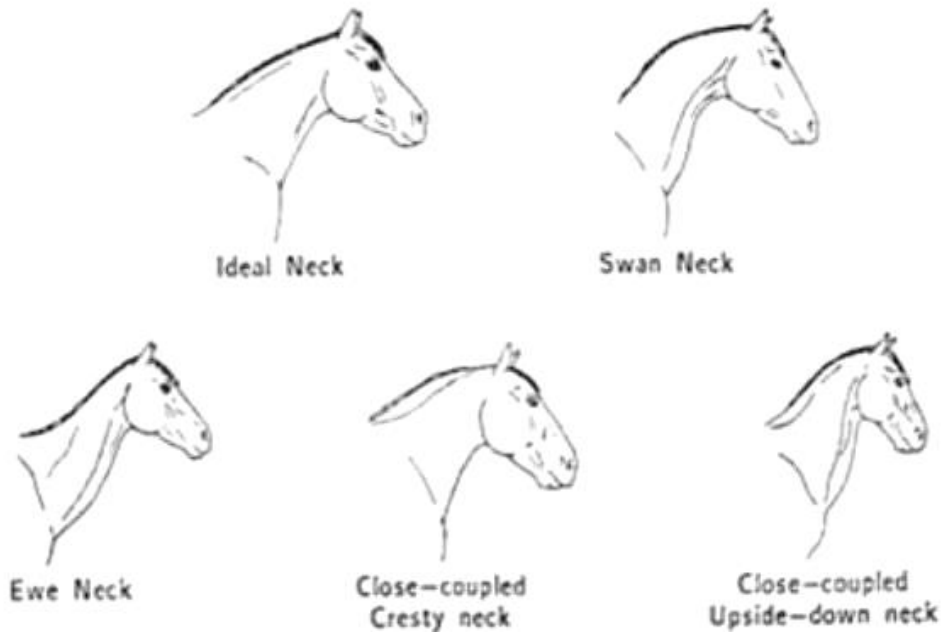


Furthermore, look at the size and shape of the jaw. Defaults are often linked to dentistry issues which affects the horse's ability to chew properly. The upper and lower teeth must meet evenly – hence the incisors must be aligned, otherwise the horse will have problems eating. Furthermore, gait abnormalities can sometimes be directly linked to teeth and abnormal head carriage. A parrot mouth is quite common and displays an overbite in which the upper jaw – the maxilla – extends further out than the lower jaw – the mandibula. The opposite and less common is a so-called monkey mouth.

NECK

The neck should be size proportionally to the rest of the body. Ideally, the neck should be about 1/3 of the horse's total length. A short neck is one less than 1/3 the length of the horse whereas a long neck is more. Both variations are quite common and in general it can be said that a long neck hinders the balancing ability of the horse the most.

Looking at the shape of the neck it is important that the musculature looks smooth without any major muscle linings visible in a relaxed stance. A well trained horse displays a slightly concave shape when looking from above. Horse's trained beyond the vertical often display a convex shape with a strong developed underline and a weakened topline of the neck.



The topline/underline ratio of the neck is very important. The topline of the neck is measured from poll to wither and the underline is measured from the throatlatch to the shoulder junction. The ideal ration would be 2:1 – topline / underline. A common default is a so-called 'ewe' neck. An ewe neck limits the horse's performance and is often and acquired postural issue due to poor training practices.

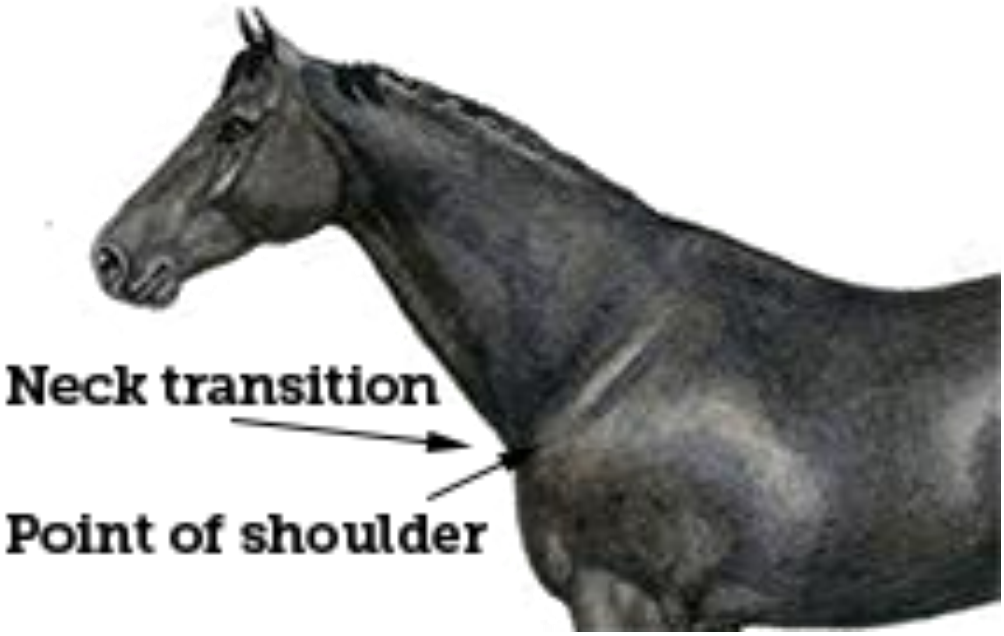
Another default often caused by incorrect training and false collection is a so-called swan neck which is set at a high upward angle, with the upper curve arched, yet a dip remains in front of the withers and the muscles bulge on the underline of the neck.

Certain horses display large crests at the topline of the neck. It is most often see in stallions, ponies and draft breeds. A large crest is usually caused by excessive fat deposits about the nuchal ligament and can be due to obesity or insulin resistance. Changes in the horse's diet might prove to minimize the crest back to more normal proportions.

Finally, it is important to take into account that the outline of a horse's neck is greatly influenced by the slope of the shoulder. Hence, always look at the bigger picture of the body as a whole.

SHOULDER

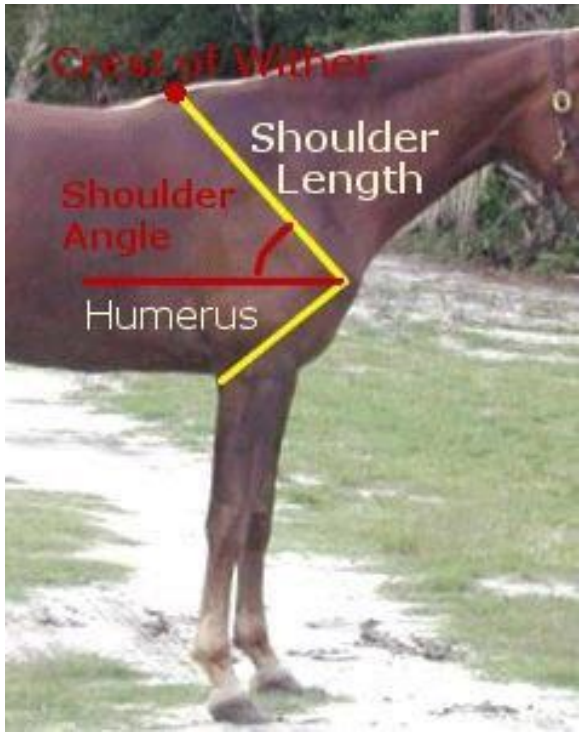
The slope of the shoulder directly influences the horse's stride length and is one of the most crucial aspects to consider as it ties in closely with other body parts and proportions such as the length of the back, neck and hoof angle.



The slope of the shoulder measures the angle of the horse's scapula and is commonly measured from the top of the scapula near the withers to the point of the shoulder. If a line is drawn from the top of the scapula near the to the point of the shoulder and another line is drawn through the top of the scapula near the perpendicular to the ground, the ideal shoulder angle is approximately 45 degrees – reffered to as a sloping shoulder. It often is accompanied with a high wither and deep chest. This provides the horse with elasticity and a free swing of its shoulders and front limb stride.

A straight shoulder on the other hand is often accompanied with low whithers. The horse has shorter muscular attachments and thus less ability to contract and lengthen. This shortens the stride lengths and has a greater risk of injury to structures in the front limbs and hastened muscular fatigue.

Another important aspect to consider is the shoulder angle. Ideally, the angle between the Humerus and point of shoulder should be around 90 degrees. The Humerus should be about 50-60% of the length of the shoulder.



The Humerus is considered too long when it is more than 60% the length of scapula. This often happens when the shoulder muscles become overstretched. It restricts proper movement and lead to the horse standing under itself with front limbs too far under the body and chest sticking out.

The Humerus is considered too short when it is less than 50% the length of the shoulder. The Humerus is usually in a horizontal position which closes the shoulder angle to less than 90 degrees. A short Humerus increases the impact of stress on the front limbs, especially the feet and thus contribute to a short, choppy stride with an increase chance to front-end lameness. The horse will also struggle more to perform lateral movement.

In general, when selecting horses for function, a show-jumping horse is best served with a short Humerus as this makes it easier to pull up the front limbs under the body and clear a fence. A dressage horse on the other hand is best served with a longer Humerus as this provides more athletic capability to perform lateral work.

CHEST

The overall shape of a horse's chest plays a key role in the front leg movement. The horse's chest should be well defined and *not* blend into the neck. Width of the chest is measured from shoulder to shoulder, at the point of shoulder. The most important thing to remember is that the chest width allows for lung expansion and determines agility!

When viewing the chest from the front, the chest should be wider at the bottom than at the top. The shoulder blades should be much closer together at their tops, toward their withers, than at the points of shoulders where the front legs attach.

Well-sprung ribs have a greater degree of curvature. Horses with slab-sided ribs tend to have less developed core strength and stamina as well as a longer, weaker loin.

With the horse standing square, the width between the front legs is relatively narrow. However, this can be skewed by how far apart feet are placed at rest. A narrow breast often represents general thickness and development of shoulder. Narrowness in the chest may be from immaturity, poor body condition, inadequate nutrition, or under-developed breast muscles from a long time in pasture and lack of consistent work. The horse usually has undeveloped shoulder and neck muscles. The horse may tend to plait, and is more likely to interfere, especially at the trot.

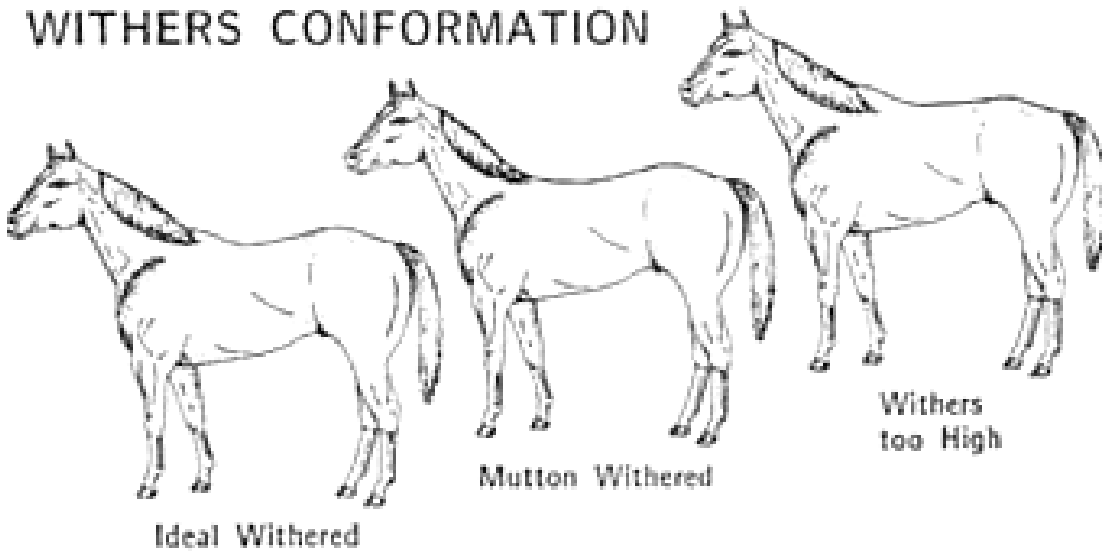
A pigeon breast [see left picture] refers to a stance in which the front limbs standing back too far under the body. The issue is often postural in nature. The sternum becomes protruding and this common flaw is commonly associated with a longer shoulder blade that drops.

The point of shoulder – a too long Humerus as described earlier, is somewhat low with the arm bone relatively horizontal, setting the elbow more to the rear. This position infers with the efficiency of the horse front limbs to produce vertical impulses and thus balance control.

WITHERS

The withers are an important attachment for ligaments and muscles that extend the head, neck, shoulder, and spinal vertebrae as well as those that assist in expanding the ribcage.

High whithers are often seen in Thoroughbreds, Saddlebreds and Warmbloods. High whithers provide a lever for the muscles of the vertebral column to work together efficiently. The backward angle of the whithers is usually associated with a sloping shoulder. However a note must be made that if the whithers appear to be too high and/or narrow there is a chance that a [poorly fit] saddle will impinge on withers and slip back too far, creating pain especially with the rider's weight. Performance and willingness will suffer.



A hollow appearance – muscle atrophy of the *Spinalis & Trapezius Thoracis* – behind the whither is usually found in wither high horses of any breeds. It hinders the horse for riding performances as it does not have sufficient muscles to protect the spine. Also, it might be uncomfortable for the horse to roll all the way over when it wants to. The muscular atrophy can be due to poor saddle fitting or training practices and is therefore an area prone to improvement.

Mutton whithers refers to flat and wide whithers and can be seen in any breed. It makes it difficult to hold on a saddle as the horse is quite round.

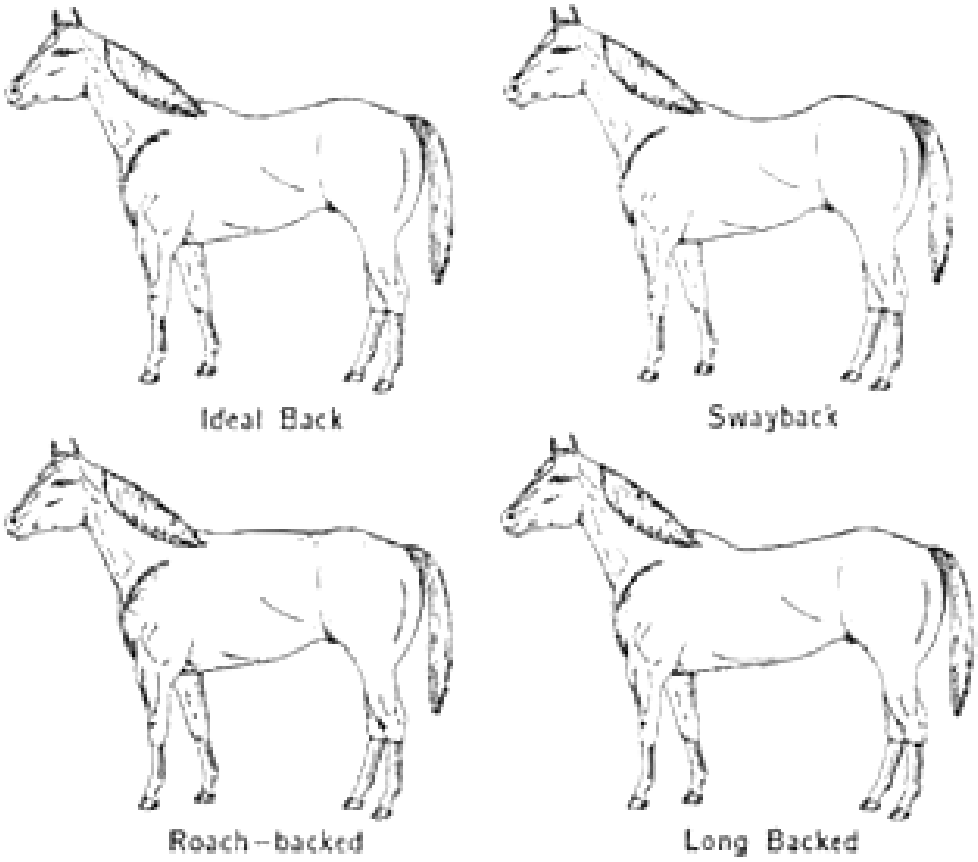
BACK [THOROCOLUMBAR SPINE]

Just as the neck, the back should be proportionally sized and consist about 1/3 of the horse's overall body length. An important ratio to consider is the topline/underline. The topline is measured from the withers to the point of coupling. The underline is measured from a point under the belly – just behind the elbow, between the horse's front limbs to a point roughly even with the stifle. In a balanced horse, the topline is always shorter than the underline. A longer topline indicates a long, weak back.

This horse shows a weak back as the underline and topline are even lengths.

A long back exceeds the ideal proportions and is usually associated with weak loins. It can be seen in any breed, but is most common in gaited horses, saddlebreds, thoroughbreds and warmbloods. A long back is more flexible, but much harder for the horse to coordinate and straighten to develop true collection. It is difficult to develop proper strength of the back muscles, so the horse is more likely to fatigue under the rider and sway over time. The abdominal muscle will have more difficulty in compensating, so they are also less likely to develop.

A short back measures less than the ideal proportions and enhance agility and better ability to carry rider weight – compared to a long back. However, there is risk of having more difficulty bending.



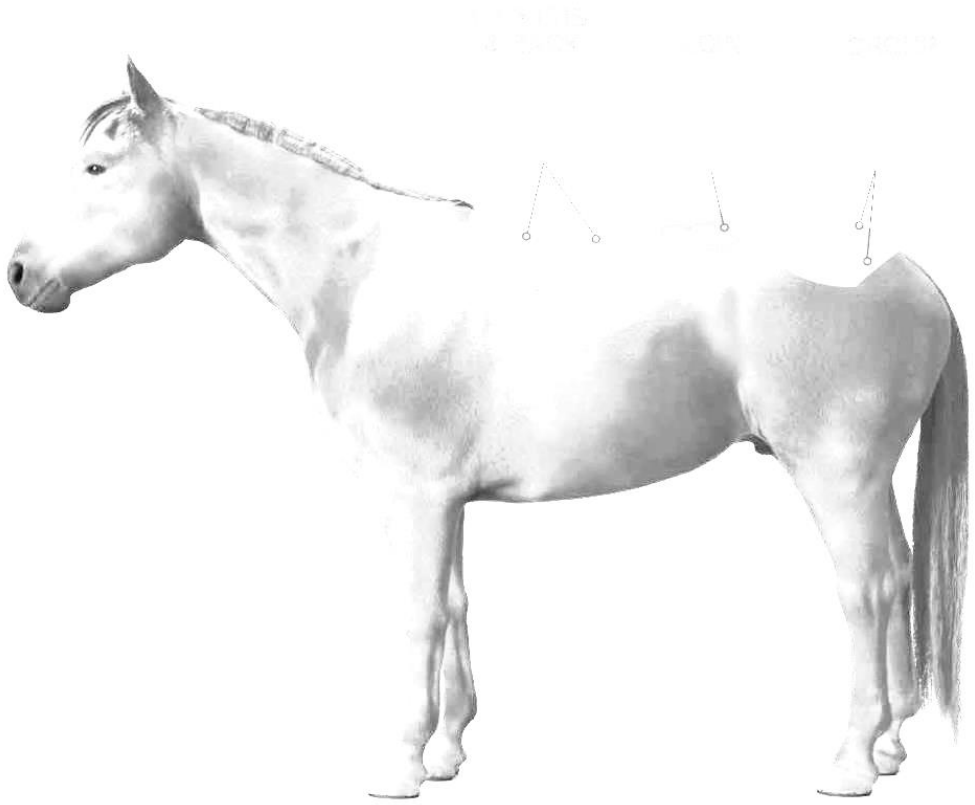
A hollow sway back is – as mentioned before – often associated to a long back. A congenital form of swayback is mostly present in certain lines of American Saddlebred Horses. More often, it is an acquired problem as well due to poor training practices or the process of birthing in brood mares. Naturally, it also appear more in the process of aging. No matter the cause, a sway back will always be problematic and hinder true collection. The back also gets more sore from lack of support and the rider's weight.

A roached back is an upward convex curvature of the spine and is often the result of a short back, injury, poor training practices or misalignment of the lumbar vertebrae, The roach appears in the so-called coupling area where the back and loins joint the croup.

This causes the horse to stiffen the back and it may experience pain. As explained earlier, a common causes for a roach back is weak or problematic stifles.

LOIN

The loin is the area from the last rib to the point of hip. Ideally, the lumbosacral joint should be directly over the point of hip [Tubercoxae]. Weak coupling is when the lumbosacral joint is further to the hindquarter.



A long loin is often associated with a long back and is often displayed with a flat croup. A short loin on the other hand is associated with a short back and said to be better for collection. However, I'd like to argue that in the ideal world, I'd neither prefer a short or long back, but just a normal one relative to the horse's total body and movement.

A rough coupling or widow's peak refers to a confirmation in which the horse has a hollow area in the loin that is considerably lower than foremost part of the croup.

Horses with weak or slack loins might have good lateral bend, but collection suffers as this depends on coiling the loins to bend the hind legs. Horses unable to coil the loins move with stiff backs and a flattened LS joint, throwing the hind limbs out behind. This limits the ability of dressage.

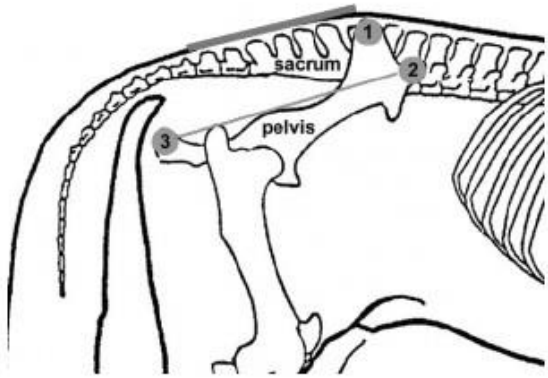
The LS-joint comes under a lot of strain in long-and-low as well as the Rollkur position due to the pull of the Supraspinous ligaments as well as the Longissimus Dorsi muscles. When the horse is asked to lower its head, it provides a pull forward on the structures over the entire length of the back. Remember the curvature of the spine[4]? This way, the first thoracic vertebrae will be pulled up a bit straighter – what is often referred to as a whither lift. However, since the spinous processes of the lumbar spine lean a bit forward, these also get a forward pull and thus result in extension in this area. As a result, the LS-joint has to counter-lever this effect by limiting the extension. Repetition of this action often causes strain. I have seen various gradation of LS arthritis and it isn't pretty and can be painful[5].

CROUP, HIP & HINDQUARTER

The croup runs from the LS joint to the tail. It is often explained as the line from the point of hip to the point of buttock. To make it even more complicated, the point of hip isn't actually the hip but referring to the Tubercoxae of the pelvis. The point of buttock is at the ischium – toward the *Tuber Ischii.* The area below the croup is called the hindquarter.

Length and width of the croup are important since the length of muscles provide speed and the width is associated with power. While the angle of the croup and 'hip' are linked, they do not necessarily correlate. A horse can have a relatively flat croup but well angled 'hip'. In general, the croup should be slightly rounded, neither too flat nor too sloped and in balance with the whithers. The croup and whither height should be approximately the same.

[4] *See manual: Mechanisms explained: The Thoracolumbar Spine*



Picture of the line of croup. No 1 being the point of croup. No 2. The point of 'hip' and No. 3 the point of buttock.

A croup high conformation means that a horse stands taller over the croup than the withers. A horse that is croup high naturally puts more weight on the forehand and thus results in a downhill motion. For such horses, it is harder to collect compared to a horse with a balanced croup-wither conformation / posture.

On the other opposite some horses are higher at the whithers than croup. As already mentioned, this is often considered with more uphill movement but could also pose some other challenges such as saddle fitting and rolling.

When assessing croup-whither ratio you should always keep in mind though that the croup of a young horse will grow faster than its whithers. Therefore, a 2 year old might look croup high as its growing but may catch up as it reaches maturity.

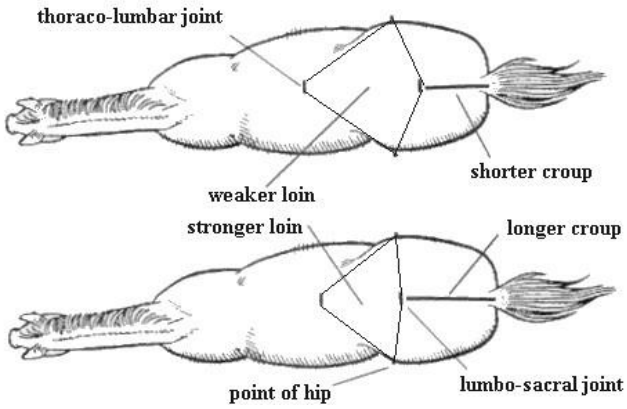
A steep croup or 'goose rump' is when the top of the tail sits below the point of hip when the horse is standing square. It is often linked to shortened stride. However, it is preferred in some breeds such as Quarter horses. A steep croup should not be confused with a hunter's bump as the latter is the prominence of the tuber sacrale. A hunter's bump is often considered as a sign of SI trauma, however I have seen foals already having it from birth. It is then not ideal, but in those cases could not lead to significant problems. As a general rule, I usually start to worry when a horse didn't had it before but started to develop it in a later stage of life.

Opposite to a steep croup is a flat or 'horizontal' croup when the topline continues in a relatively flat manner to the base of the tail rather than rounding off at the point of hip. It is often linked to more pushing power. It enables the horse to go faster, especially when a flat croup is sufficiently long to allow a greater range of muscle contraction to move the boney levers of the skeleton. It is therefore mostly seen in Arabians and Gaited horses, but undesirable for a dressage horse.

A short croup means that the length from the LS-joint to the base of the tale is insufficient for proper muscular attachment and thus reduces the power of the hindquarters. The LS joint is backwards which shortens the croup but lengthens the lumbar span – the weakest area of the horse's back. This conformation increases the stress placed on this area and is usually seen in combination with other hind quarter flaws.

Top picture: LS joint behind the point of hip and thus shortening the croup.

Bottom picture: LS joint is forward, lengthening the croup and thus shortening the lumbar span. The stress in this area is then minimized.



Talking about overall hindquarter conformation it, should ideally be at least 30% of length - with an ideal length of roughly 33% with racehorses going up to 35% - of the overall horse. Anything less is considered as short which results in a weaker loin coupling and provides insufficient length of the muscles needed for rapid muscular contraction. It may also cause the horse to have a goose rump or to be sickle hocked with the hind limb being too far under the body. So for those horses is it much more difficult to collect and engage the hindquarters properly.

Also, hindquarter conformation can be measured by means of the hip-stifle ratio. An ideal hip frons a triangle in which all three sides are equal – also called equilateral triangle, between the point of buttocks, point of hip and the stifle. A short hip is created by a short femur which raises the level of stifle above the sheath line. A long hip is created by a long femur which drops the level of stifle to or below the sheath line.

Another aspect to look at is the width of the point of hip. However, always keep in mind that the overall shape is partially dictated by the development of the hindquarter muscles. A narrow pelvis is seen quite common and does seem to contribute to speed, but alters with the carrying power of the horse as a narrow pelvis is crowded and limits the size of muscular attachments and thus puts more strain and stress on the back and hind limbs. It is seen quite common, mostly in Thoroughbreds, Warmbloods, Saddlebreds, Arabians and Gaited horses.

A ‘wide’ pelvis is most commonly seen in more heavy breeds such as Quarter horses and drafts but sometimes also appear in other breeds. Wide hips places the horse’s upper hind limbs too far apart and often shows in a base narrow stance – not straight from behind. This places more stress on the joints. Wide hips are often amplified by poor muscling and thus could be improved through proper training.

Finally, when looking from behind, some horses display one Tubercoxae – point of hip, higher than the other. Some horses might have a conformational crooked pelvis, but it can also occur after the occurrence of a traumatic event. In either case, a horse will always be more prone to develop muscular and ligament strain and/or injury.

ASSESSING LIMBS

Just as with everything discussed so far, the assembly of limbs has certain principles that need to be in place in order for them to function correctly. In an ideal situation, the horse's bodyweight – and potentially that of a rider – must be carried down to center of each of the limbs, front to back and side to side. This means that the bones and joints have to be aligned and all 'face' the same direction. However, sometimes this is not the case. There are three common divergences:

- Offset
- Deviation
- Rotation

As the name suggests, the term **offset** is used when the alignment of a bone is offset from a joint. Both bones on either side of the joint may be straight vertically speaking, but they don't match on the same plane. So for example, when the forearm bone 'enters' the carpus at one point and the cannon bone 'exits' the knee from a different vertical plane.

The term **deviation** is used when the bones are not vertical. So there is no offset – the bones connect to the joint at the right spot - , but one of the bones points at an angle.

Finally, **rotation** describes a deviation of direction in which the bones are assembled. Without rotation, the bones should all point forward in the same direction. With rotation,

the assembly of bones looks twisted. So there may be no offset or deviation, but the limb looks more like a spiral staircase than a ladder.

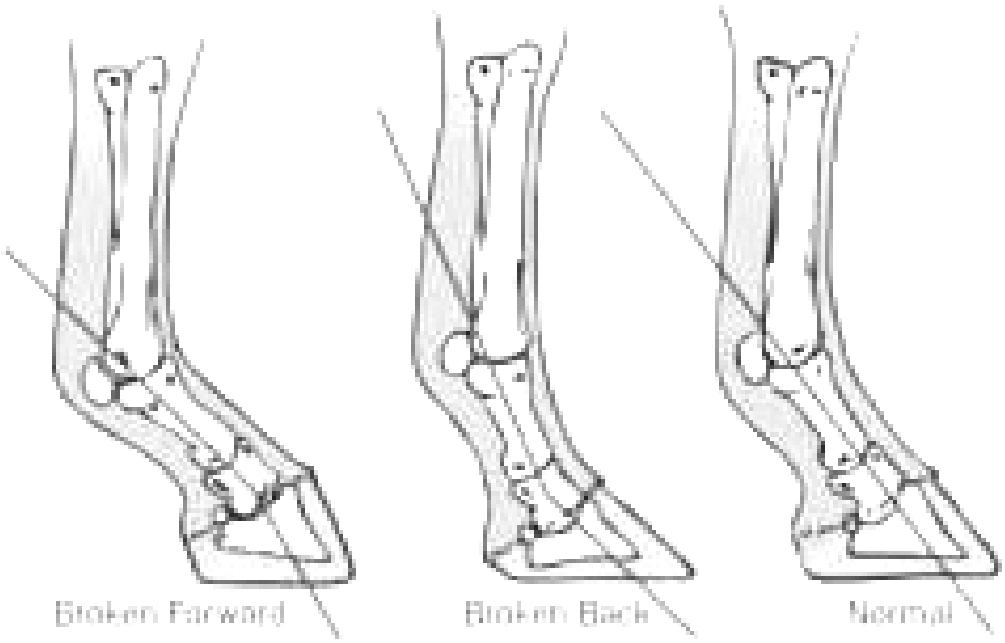
So now that we've tackled terminology it's time to look at some practical aspects for assessing the horse's limbs. These include:

- Cannon bone length
- Hoof/pastern axis

To start off with **cannon bone length**, there is no specific measurement for it. It is thus fairly subjective. In general, the cannon is considered long when the knees appear high relative to the overall balance of the horse. A horse with a long cannon bone is more prone to tendon and/or ligament strain. Uneven terrain or imbalanced feet will magnify the stress on the knees since longer tendons are not as stabilizing to the lower leg as the shorter ones.

On the opposite a cannon bone is considered relatively short if the knees are relatively low in relation to the ground. This way the length from fetlock to knee is also shorter compared to knee to elbow. In general, a shorter cannon bone is preferred as it enables an efficient pull of the tendons across the back of the knee or point of hock to move the limb forward and back. It also reduces the weight of the lower limb so less muscular effort is needed to move the limb and is thus preferable in most discipline. Longer cannon bones would more suited for gaited horses or flat racing short distances.

Another very important aspect is to assess the **hoof-pastern axis -** or in short HPA.
You should be able to draw an imaginary line through the center of the three phalanges. From the front – dorsal – or back – palmar/plantar- aspect, the line should equally bisect the hoof and pastern and be perpendicular to the ground. When looking from the side, the angle from the pastern should match the angle of the hoof. The imaginary line should be straight and parallel to the hoof wall.



A straight hoof pastern angle means that the movement within the joints will be as efficient as possible and the soft tissue will not be placed under additional strain. If the angle does not match, it could be an indication of poor trimming, but some horses may also have an underlying (conformational) defect. The appropriate angles for a straight hoof pastern axis differ slightly between front- and hind limb:

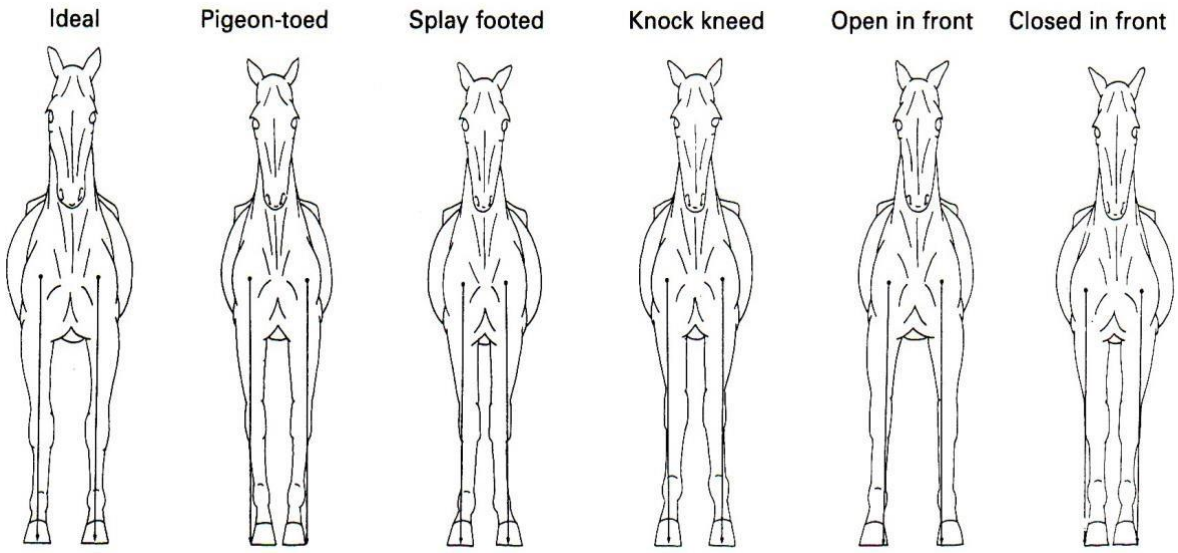
> *''When assessing conformation in the forelimb it is accept that the HPA should correspond with the angle of the shoulder 48- 55 degrees and that it will be more upright in the hinds by 1-5 degrees.''* - Logie 2017

When the hoof-pastern angle is not straight, it is either broken forward or broken back (negative). If the HPA is broken forward, more strain is placed to the extensor region. If the HPA is broken back, more force is placed on the flexor tendons, which is transmitted as pressure into the navicular area.

FRONT LIMBS

Apart from the general observations discussed in the previous section, I will dive deeper into the specifics of the front limbs in this chapter.

When looking from the front, start with straightness. If you draw an imaginary line from the point of shoulder, the leg should fall nicely straight. The ideal is where the line should go right through the middle of the front knee – carpus – and continue right down through the middle of the pastern and hoof. The average horses will probably deviate a bit from this ideal. Any of these deviations could be either conformational or postural. Hence, it is very important to discover whether the deviation was apparent at birth or acquired later on.



A **pigeon-toed** appearance means that the toes of the hooves face in toward each other. It is quite commonly seen. When the feet are turned in or out it puts abnormal strain on various tendons and ligaments. It predisposes the horse to ringbone, sidebone and bruising of the sole. The appearance could be a trimming problem but also the result of misalignment of joints and/or a postural issues in how the horse loads the limbs. Very often, the horse moves with a paddling motion in front.

On the opposite, in a **splay footed** horse the feet are turned outward from each other. It is also quite commonly seen and the horses often wings inwards. Again, it can have multiple causes. For example, when a horse is tied in behind elbow it has restricted movement of the upper arm because the Humerus angles too much into the body. The reduced clearance of the limbs causes the horse to toe-out to compensate.

A horse has **knock knees** – sometimes also referred as Carpus Valgus or Medial Carpal Deviation - when one or both knees deviate inward toward each other, with the lower limb angles out, resulting in a toed-out stance. The lower part of the forearm also seems to incline inwards.

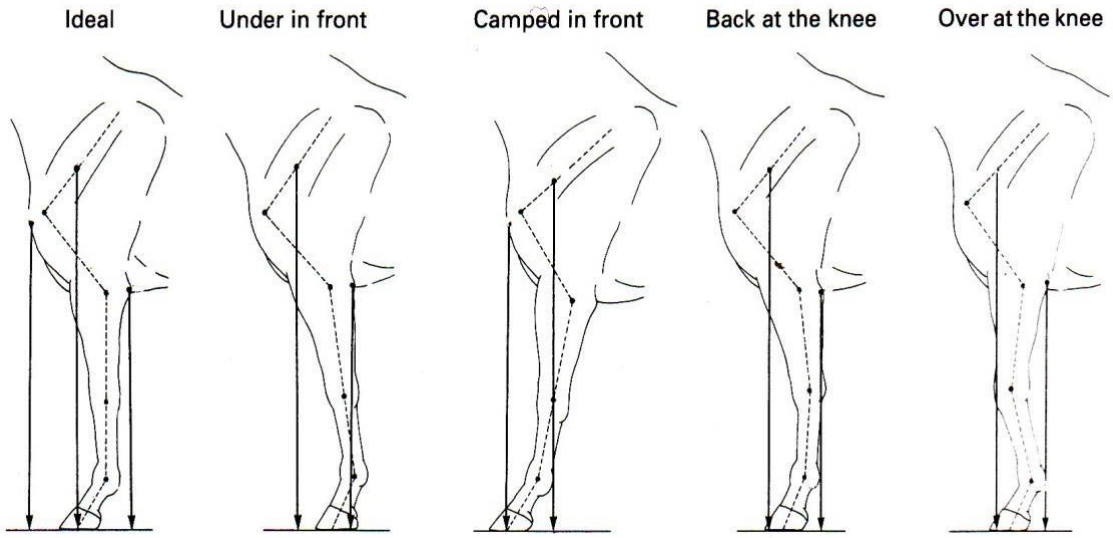
A **rotated cannon bone** means that the cannon rotates to the outside so it appears twisted in its axis relative to the carpus. May still be correct and straight in alignment of the joint, but more often associated with appearance of carpus valgus – which will be explained later. A rotated cannon bone places excess strain on the inside of the carpus and lower joints of the limb. Any horse can inherit this. It commonly occurs as a result of unequal development of the growth plates, but it could also be acquired as the result of a traumatic injury or development orthopedic diseases (DOD).

When a horse is open in front or **base wide** it stands with its feet places wider at the shoulders. It is often associated with a narrow chest. When a horse is base wide and toed out it lands hard on the outside of the hoof wall and places excessive strain on the medial structures of the fetlock and pastern. It often causes the horse to wing-in with the front limbs predisposing the horse to injuries of the joints, tendons, ligaments and the splint bone. On the other hand, when a horse is base wide and toed in the horse lands hard on the inside of the hoof wall, placing excessive stress on the medial structures of the limb. It often causes a paddling movement of the front limb.

Opposite to open in front**, base narrow** or closed in front describes a condition in which the feet are closer together and more under the body than the shoulders often combined with either toe-in or toe-out. When a horse is base narrow and toed out it stress the outside

structures of the limb most. It causes a winging motion and predisposed the horse to plaiting. When fatigued, the horse often tends to hit himself. On the other hand, when a horse is base narrow and toed in most strain is placed on the lateral structures of the fetlock, pastern and outside of the hoof wall. It often causes the horse to paddle.

When looking from the side, you should be able to draw a straight vertical line from the center of scapula. This ideal position allows for most efficient movement.



A common deviation that may be observed are **camped under** or camped out in front.
A horse that is camped under will place the front limbs too far underneath the shoulders, causing increased strain on the entire limb. Since the horse carries too much weight in front, it can cause lameness and predisposes the horse to stumbling. However, it is very important, again, to assess whether it is a structural or a postural deviation. Most horses are trained too much on the forehand resulting to a stance that looks under in front but in fact is postural – and thus prone to improvement – and not conformational.

On the opposite, a horse that is **camped out** in front will place the limbs too far in front of the scapula. The joints are almost always in extended position as if the horse were bracing. Again, although it could be a conformational defects, horses can also adopt this stance as a result of (hoof)pain such as navicular diseases or laminitis.

When a horse is **over at the knee** – sometimes also reffered to as Bucked, Sprung or Goat Knees – the knee is inclined forward of the imaginary line. It is often associated with poor muscle development on the front of the forearm and more stress is applied to the tendons and fetlocks as the angle of attachment of the Deep Digital Flexor and check ligament is increased , predisposing the horse to tendon and/or ligament strain. It the pasterns are also more upright there is even further stress. It can be congenital, but very often is the result of an injury to the check ligament of structures at the back of the knee.

Right: a picture of a statue of famous race-horse sea biscuit who clearly was over at the knee.

When a horse is **back at the knee** – sometimes also reffered as Calf Knees – the knee is inclined backwards to the imaginary line. It places excess stress on the knee joint as it overextends – especially at high speeds and when loaded with weight. Naturally, it weakens the mechanical efficiency of the forearm muscles as. They pull across the back of the knee. Again, the horse is more prone to tendon and/or ligament injury and should be very carefully trimmed to avoid long-toe low-heel stance.

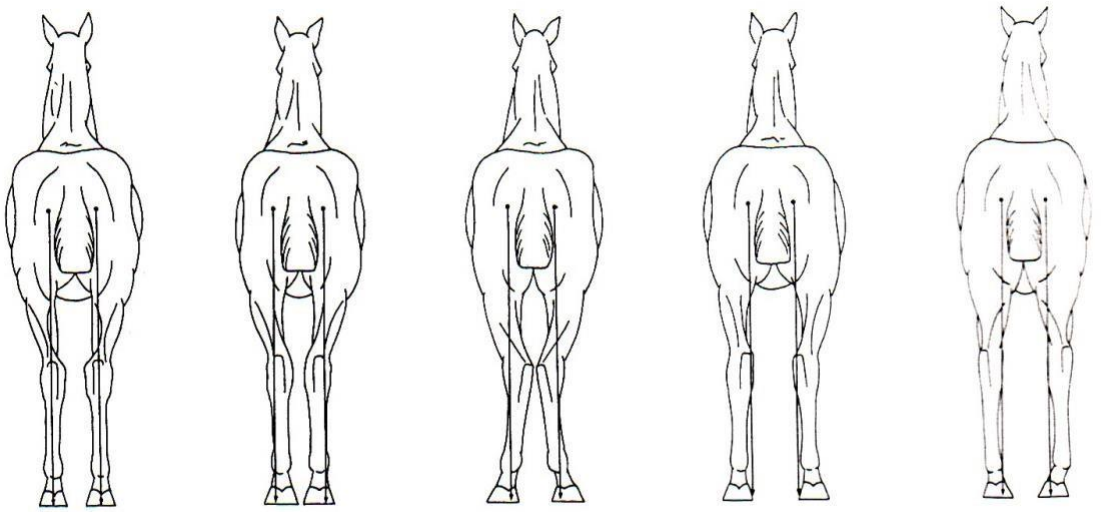
A horse is said to have **Offset Knees** when the cannon bones are set to the outside of the carpus so an imaginary line doesn't fall straight through the middle. It causes excessive strain on the lateral surfaces of the joints from the knee down and on the outside portions of the hoof. It also loads the medial splint bone excessively, which could cause splints.

A horse is **tied-in below the knee** when the cannon bone, just below the carpus, appears 'cut out' with a decreased tendon diameter. The condition is often associated with a

reduced size in the accessory carpal bone over which tendons pass. Rather than being parallel with the cannon bone, the tendons are narrower than the circumference measured above the fetlock. This limits the strength of the flexor tendons, making the horse more prone to tendon and ligament injuries, especially at the midpoint of the cannon or just above. It negatively affects power and speed as the leverage of muscle pull is decreased as the tendons pull against the back of the knee rather than a straight line down the back of the limb.

HIND LIMBS

When looking from behind facing the hindquarters, you should be able to draw a straight vertical line from horse's buttock through the center of the hock, cannon bone, pastern and foot. This way, concussion travels straight through the joints and the feet get loaded evenly.

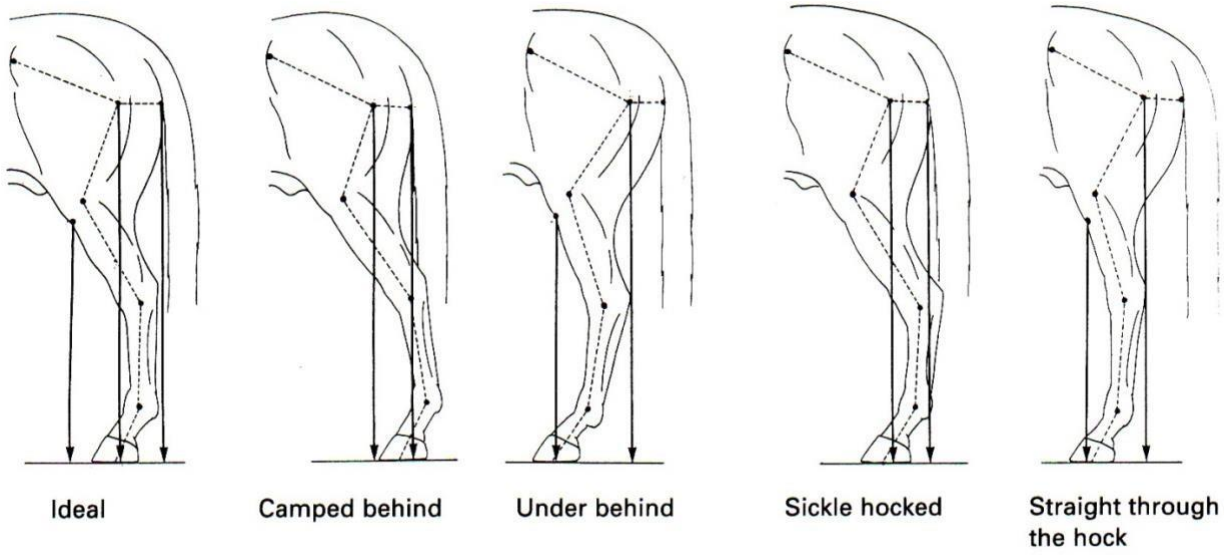


When a horse is **closed behind**, the hocks are slightly inwards and usually wear the outside of the hoof. It can cause the horse to move narrow behind in the sense that the hind limbs might travel almost with the same path. A closed behind stance could be anatomical – confirmation – but it could also be due to postural issues in which weakness in the hind end (musculature) is compensated by a closed stance.

Opposite to being closed behind, an **open behind** confirmation or stance suggests the hind limbs are too wide from each other which loads the medial aspect of the hoof.

In a **cow-hocked** horse, the hocks deviate medially toward each other and loads the medial part of the hoof. When viewed from the side – lateral view, the cannon and fetlocks are out of alignment to the outside of the hocks. It gives the appearance of a half-moon contour from stifle to hoof. The deviation causes strain on the inside of the hock, predisposing it to bog and bone spavin. The twisting of the cannon and pastern predisposes the fetlocks to injury as well. Cow hocks often goes together with sickle hocks. A horse with a wide barrel will be forced to turn the stifles more out and thus will always give the appearance of being cow-hocked.

Horses that are **bow-legged** have the opposite condition of cow-hocked horses. The hocks deviate to the outside and this is sometimes also referred to as a 'bulldog' stance. When moving, the hoof swings in when the horse picks it up and then rotates out, causing excess stress on lateral hock structures and thus again predisposing it to injuries.



When examining a horse's hind limbs from the side – lateral view – you should be able to draw a line perpendicular to the ground that touches the last point of buttock, the back of the hock and the back of the fetlock. The hock angle ranges from 155-165 degrees. This ideal

confirmation allows the horse to carry weight well over its hindquarters and reach under itself as it moves to allow for maximum power.

A horse that is **under behind** places the hindlimb too far forward under its body which subjects strain in the hocks. The cannon bone is unable to maintain a vertical position and the horse looks like it is in a squatting position. Very often it is in combination with cow hocks or sickle hocks.

On the opposite a horse that is **camped behind** stands out farther with the hind limbs than they should be. The cannon bone and fetlock are behind the imaginary line dropped from the last point of buttock. The hind limbs move with greater swing before the hoof contacts the ground which reduces stride efficiency and places greater stress on the joint, tendons, ligaments and hoofs. Furthermore, the horse will have greater difficulty to bring the hocks and cannons under to engage the back or the haunches unless it makes a sickle hocked configuration.

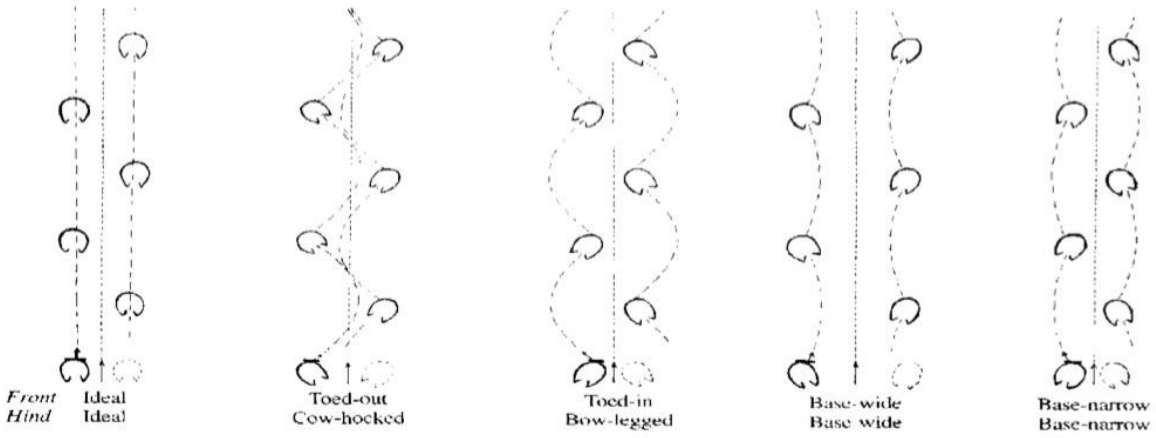
A horse has **'sickle' hocks** when the point of hock lines up under the buttock, but the cannon bone angles forward in front of the imaginary line. This way, the horse is standing under from the hock down as the cannon bone is unable to maintain a vertical position.

It can result from imbalances between the gaskin-hock ratio. When a horse has a short gaskin – tibia bone – combined with a long cannon it raises the hocks noticeably higher than in an ideal conformation – it may even be combined with a croup high appearance. This often leads to an inefficient gait and/or overreaching and then results in a sickle hock conformation. On the opposite, when a horse has a long tibia with short cannon bones it creates an appearance of squatting – or under behind. A long tibia causes the hocks and lower limbs to go behind the body in a camped behind position. The leg must then sickle to get it under the body to develop thrust, resulting in all consequences thereof.

A sickle hocked horse will always be predisposed to injuries in the joints, tendons, ligaments and hoofs.

Finally, when a horse is **straight behind** the angles of the hock and stifle are open. The hock angle is usually greater than 165-170 degrees – opposed to the normal range of 155-165. The tibia is fairly vertical, rather than having a more normal 60 degrees slope. It predisposes the horse to problems such as bog and bone spavin, locking stifle and tendon/ligament injuries.

Finally I'd like to refer to the diagram below to show the impact of front- and hind limb abnormalities and how it affects the general flight arc and thus biomechanics.



FEET

It is very important to closely observe the hoofs. After all ''*no hoofs, no horse''.* The hoofs must be balanced. Correct hoof balance allows for even distribution of forces through the leg and hoof. Poor hoof balance, due to conformational flaws or poor trimming, can cause lameness from musculoskeletal injury.

Any deviation from the norm could be characterized by a gait that shows either paddling or wining and plating. The arc of the hoof indicates either normality or other anomalies that can happen elsewhere in the body. When looking at an abnormal arc, always check feet first for balance, then the alignment of the legs and finally for any muscle atrophy or skeletal asymmetry up higher as sometimes, muscular or skeletal problems higher are indicators of

issues lower. For example: Hypertrophy of the Trapezius often indicates problems in the front limb below the knee. Just always keep in mind that any deviation away from the ideal, places load bearing strain elsewhere on the body.

When assessing, the most important aspects are an appropriate hoof-pastern angle – which has already been discussed - and **mediolateral balance.** The latter refers to the relative symmetry of the hoof and should be assessed by viewing the foot in front and behind, as well as from above with the foot lifted up. Medio-lateral imbalance leads to uneven loading of internal structures of the foot, which can cause inflammation, injury and lameness.

Picture adapted from Wayne Wells, americanfarriers.com. This hoof is much wider on the medial half than the lateral half. Note the distance from the medial wall to the center of the frog is exactly 2 1/2 inches, but the lateral half is just over 2 inches wide. In balance, this hoof would measure 5 inches across.

Apart from the medio-lateral imbalance it is also important that both feet are symmetrical to each other. A common deviation from the normal is the so-called **high heel, low heel** syndrome – also affecting the HPA. This asymmetry also affects the structures higher up:

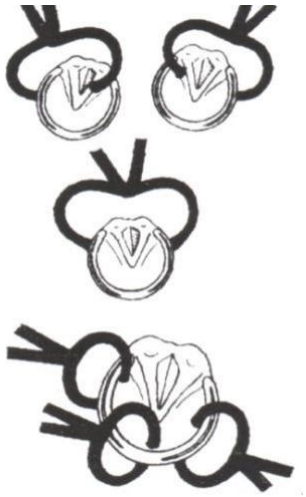
- Up foot → elbow → concussion
- Low foot → shoulder → soft tissue trauma

Causes can be found in dysfunctional anatomy, for example in case of ECVM, but also poor posture. It is very important to react adequately when this issue is present and reduce trimming intervals to every 3-4 weeks.

Apart from abnormalities in its balance, the foot can also become infected. Examples are thrush, hoof abscess, bacteria, white line disease [metabolic], laminitis [metabolic] and navicular disease.

Away to assist proper examination of the foot is to do a hoof test. This requires the use of a hoof tester, *''with the benefits being that a specific area can be pinpointed as the problem and thus a course of action can be outlined. When one point only is found on the sole, this may indicate a stone bruise, while those incorporating the frog and bulbs of heel may indicate navicular syndrome.''* - May-Davis 2016

The diagram on the right shows basic hoof testing; 1. Around the full circumference of the wall (bottom) 2. Each side of the frog (top) 3. Finish with an examination of the navicular area (centre).



ASSESSING LAMENESS

''The most common cause of lameness is lameness.''- Rooney, 1979

Looking at the definition of lameness, it can be qualified as an abnormal gait that is the result of dysfunction of the locomotor system that affects the horse's health and quality of life. Lameness itself is a clinical sign and not a diagnosis. There can be multiple lameness's presenting in different circumstances and some lameness's are only obvious under specific conditions.

Generally speaking, lameness is most commonly caused by pain, but may also be the result of a neurological dysfunction or mechanical restriction. There are mainly three types of lameness's:

- Loading lameness → more in bone. For example: inside hind limb on the circle
- Movement / Mechanical lameness → more in soft tissue. For example: outside hind limb lame on the circle
- Combination → Some horses are lame on ALL legs → as soon as one limb deviates, the others have to come around it. Hard to detect.

No grading scale can take into account a bilateral symmetrical lameness, the horse may show subtle shortening of stride – nerve block in one limb may show up the lameness in the other limb.

General sign of lameness include:

- **Lameness in front:**

  Head bobbing → head up on load bearing sore leg

  head low when falling in on healthy limb

- **Lameness in hind:**

  Hip hike (uneven pick up hind feet)

  Acute lameness → hip higher on sore side

  Chronic → hip often higher on healthy side

  Also: head bobbing: head low in stand phase sore leg

  (so opposite to front end lameness)

- **Upper limb lameness** → tends to be swinging, movement restricted

- **Lower limb lameness** → tends to be a weight bearing lameness

- **Neurological complications** → horse often just goes EVERYWHERE as if it is drunk → so not always lameness but a coordination issue for example ataxia:

  Low grade hindlimb ataxia – can mimic hindlimb lameness and both can be present.

Mild ataxia can create a bouncy, croup high, stiff legged hindlimb gait on a downward trot to walk transition with irregular height of steps. The hind feet may be placed more deliberately on the ground with sideways movement of the foot. There may be toe dragging and a lack of hind limb impulsion. The horse might have a croup high canter on the lunge.

As far as pain goes, we simply don't always really know. Mechanical lameness is often qualified as being caused by a physical abnormality that prevents normal movement of a limb, but does not necessarily cause [chronic] pain. In humans, it is know that reported pain feeling varies along the same condition. For example, there are cases of huge spinal malformations that report almost no pain, whereas there are also case of very small malformations of which people reported a very strong intermittent pain.

Hence, also in horses, it is possible that a scar – as this tissue is 1000 times more sensitive than regular tissue and the skin is strongly innervated – can cause intermittent nerve pain in one horse, whereas in others it might not be the case.

The difficulty is that humans can speak in verbal language, whereas horses show pain more in their body language. Hence, it is up to us to recognize. The diagram below assists in showing which possible signs to take into account to determine pain in horses.

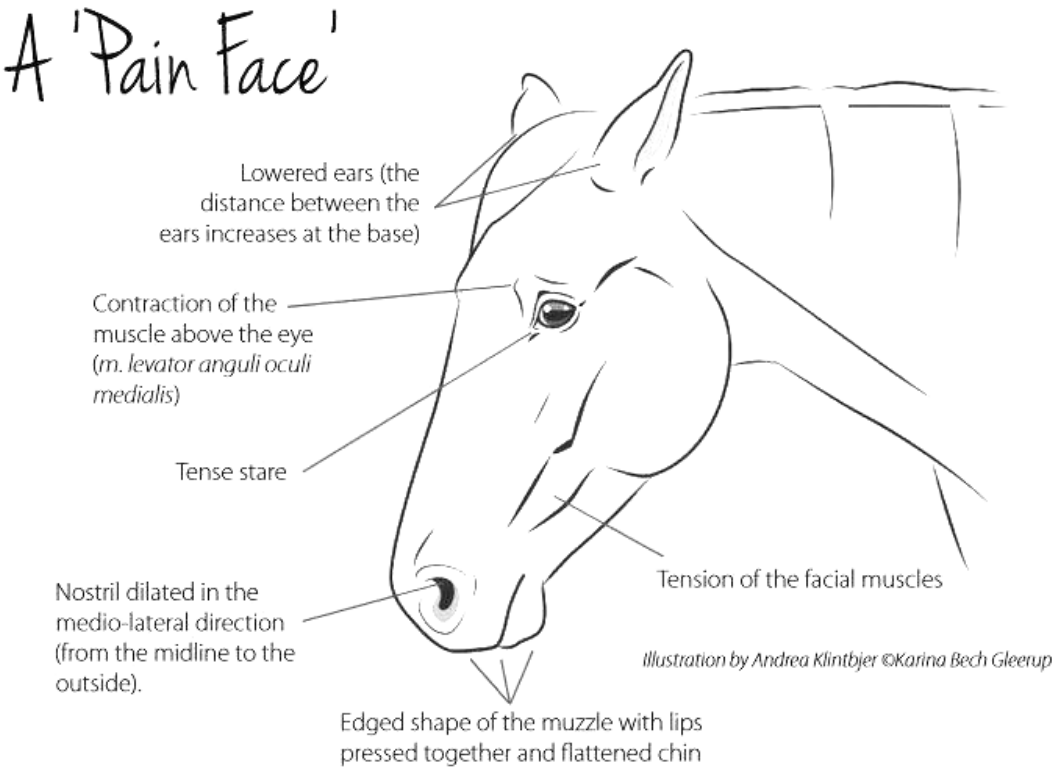


Diagram adapted from Gleerup et. al (2015) who performed a clinical study inducing pain in 6 adult horses.

When assessing movement on the straight line and circle, there are some common gait adaptations to lameness that can be spotted. To assess for stride abnormalities check:

- **Hoof placement** → placement of the hoof in relation to each hoof print, observing for deviation away from the ideal that is placing load bearing strain elsewhere on the body. Straightness and symmetry.

- **Sole presentation** → how much of the sole can be seen

- **Toe height** → how far is the toe coming off the ground in all phases of the stride arc of the stride – through the swing phase of the stride

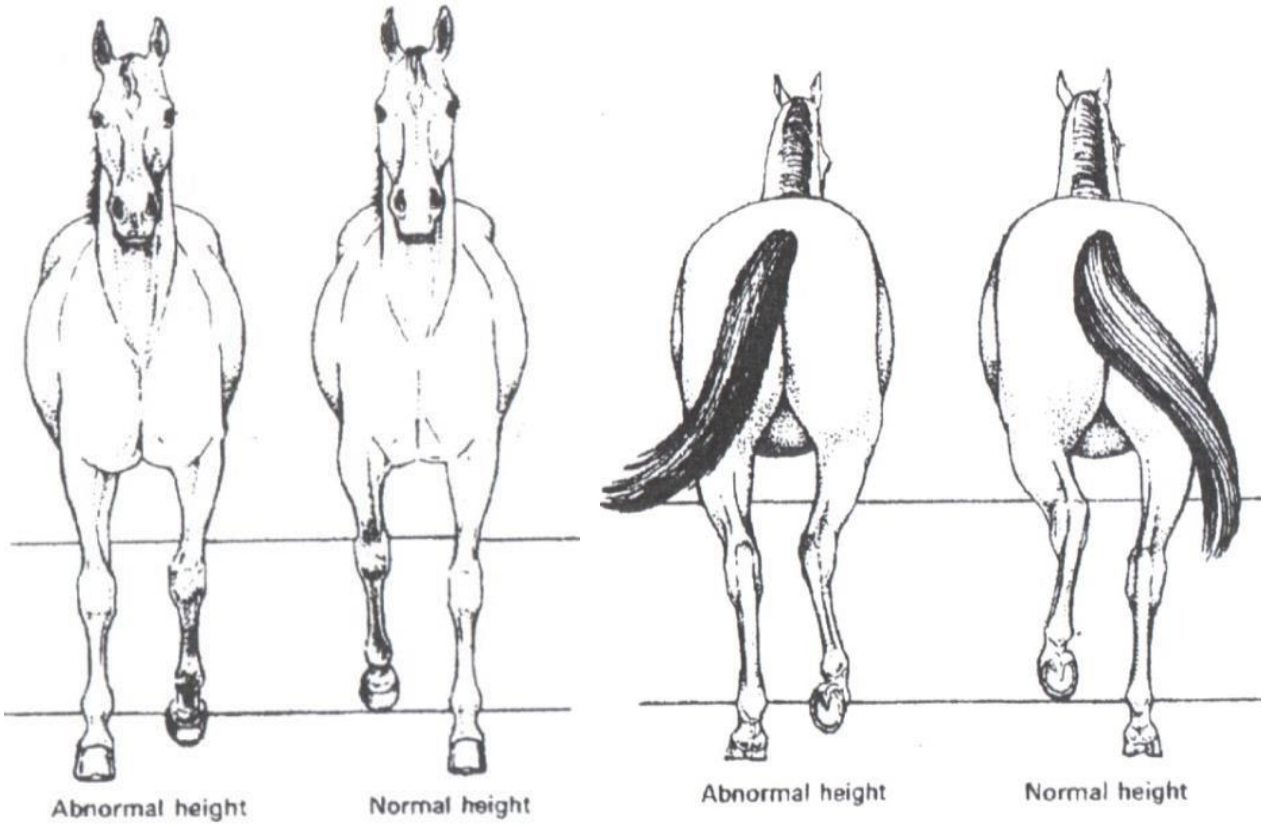
- **The upside down V** → observe the symmetry and size of the upside down V in between the front legs and hind legs. This will indicate length of stride.

- **Movement of each joint** → even energy distribution through the joints,

  symmetry Bony landmarks → position, movement, and symmetry

Please see the diagram below for common lameness patterns listed per gait.

WALK	• When a front limb is lame, and depending upon the intensity of the lameness, the head will either "bob" gently or more violently when the lame limb becomes load bearing (May-Davis 2016). • The hind limb will display a hip "hike" and gentle 'J' shape head movement when the limb becomes load bearing. The bottom of the 'J' is when the lame limb lands (May-Davis 2016). • *''Abnormal stride length may also be recognized by the failure to extend, or lift a limb to normal height.''* - Smith & Goody 1993
TROT	• When a limb is lame in trot, it performs identical body movements to that lameness's found in walk. However, in many cases the diagonal limb will land first to take a compensatory load off the diagonal pairing, but beware of "Advance in Trot" when assessing for lameness.
CANTER	• Lameness is hard to detect in canter. Very often, the horse changes leading legs to compensate and use the diagonal pairing to support the compromised limb.



Diagrams adapted from Smith & Goody (1993). Left: Abnormal stride length might be recognized by the inability to extend, or lift a limb to normal height. Right: Flight of the hind limbs at trot. The foot and hock should rise equally both sides, but a lame horse might not lift its hock or foot to a normal height.

Left: the head will bob on a lame front limb. Right: the hip will hike on a lame hind leg.

General theory learns that lameness is often diagonal, but keep in mind that in practice lameness might also appear laterally. Also, when it seems hard to detect a lameness, but Movement just doesn't seem 'right', keep in mind that some horses are lame on all four legs, making it hard to notice.

When lameness is present, please always consult a professional to further investigate. Regarding management and training, always strive to restore soundness as much as possible and keep looking at the horse with daily fresh eyes.

From my personal experience, chronic pain is my absolute boundary. But with that single absolute boundary, there is quite a big grey area. I have worked with horses who could never become 100% sound again, but were happy and content living life and doing adjusted work to keep fit.

On the opposite, I have met horses who were clinically much more talented and close to perfectly sound, but mentally completely shut down and clearly not enjoying life or training in general. Hence, you should always take both body and mind into account to make a well-balanced decision for the horse.

SUMMARY

Biomechanics is the continuous study of the movement of the horse. Of each particular horse. Biomechanics is a fluid concept. In order to differentiate between what is normal, what is a variation and what is abnormal you need knowledge of anatomy as well as using your senses of sight, hearing, touch and smell to proper assess each horse.

Today, it is hard to find 'normal' biomechanics. Hence, I hope, that through spreading this knowledge that a change will occur in how we breeds horses. In the meantime, I hope that you

now have some tools on how to better read your horse 'inside-out'. When biomechanics appears to be not normal, the Online Support Program provides a platform with information on how to optimize treatment and management of your horse as much as possible.

Let's make sure each horse's voice is heard. Let's evolve ourselves!

APPENDIX: BONUS CHAPTER

EQUILIBRIUM, STABILITY OR BALANCE?

In the equine world, the terms equilibrium, stability and balance are generally considered key concepts when it comes to confirmation, posture and training goals. Usually both words are used interchangeably. Also in the dictionary, both words are described as the same and given as each other's synonym. Although the concepts are highly related, there are differences from the point of biomechanics – especially in the field of dynamics or kinematics.

It is not worth to get lost in a semantic discussion, but understanding the basic difference and the application of these concepts will allow you to better train you eye and feel – and ultimately become a better trainer to your horse.

To achieve balance skills, athletes – so both horse and rider - must have adequate strength to support the body and they must be able to shift the weight quickly into the correct position at the right time. Furthermore, balance is related to the functioning of the nervous systems and therefore both athletes need to have proper proprioception as well as possess coordination, agility and flexibility. Now let's have a closer look at the meaning of these concepts.

Balance	The ability to control equilibrium – either static or dynamic – in relation to gravity only. Think about holding a handstand – or the equine variant of a levade.
Equilibrium  **Static equilibrium** **Dynamic equilibrium**	A state of zero acceleration where there no change in the speed or direction of the body. When the body is at rest or completely motionless. Think about posture. When all the applied and inertial forces acting on the moving body are in balance resulting in movement with unchanging speed and direction.
Stability	The resistance to a change in the body's acceleration, or the resistance to a disturbance of the body's equilibrium. Think about a soccer defender trying to push the ball or resisting a push or a horse in the float widens its hind limbs for better stability throughout the ride.

So in summary, equilibrium is a state of no acceleration and can be both static or dynamic. Therefore, balance can also be both static or dynamic, but it must not have acceleration

occurring. If acceleration is occurring, we are talking stability as the body needs to respond to the acceleration – whether the force is internal or external.

To practice the Academic Equitation requires you to first optimize your own stability – think core stability – in order to control equilibrium and achieve balance. Only then it is possible to achieve harmonious balance with your horse in which you melt together as 'one'. It is important to realize that achieving balance works slightly different in the horse than in the human. A major contributing factor is the fact that the horse has four legs instead of two. So let's look at the basic ingredient that are needed to achieve balance. In short, balance relies upon three elements:

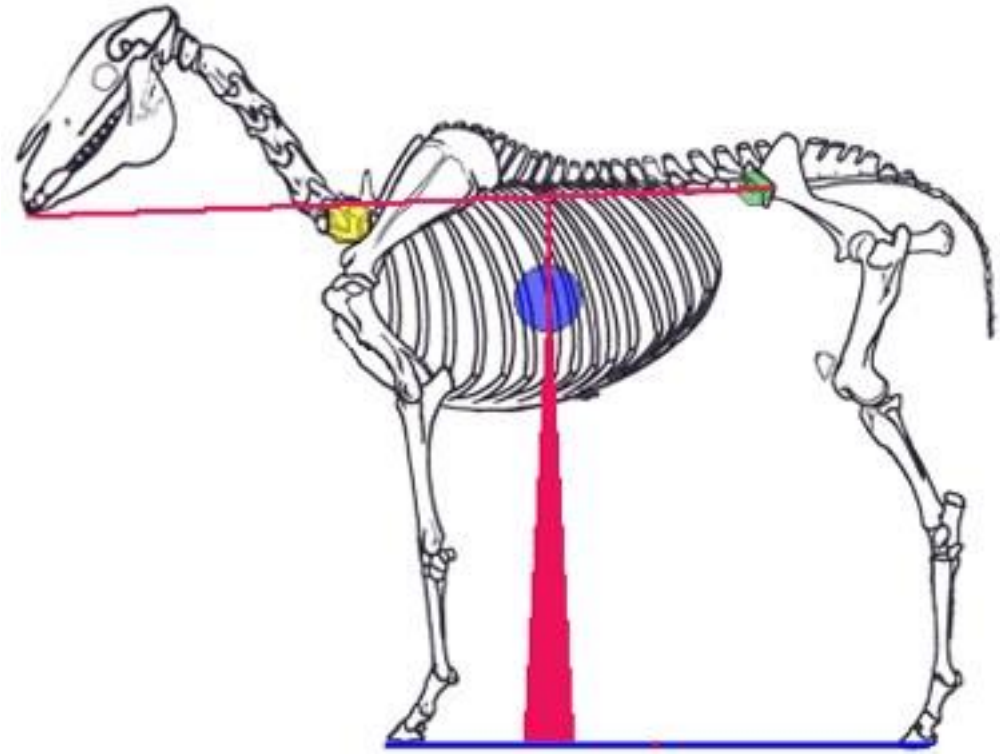
- **Base of support (BOS)** ❼ refers to the surface with which the mass – the horse - makes contact with the ground and the distance between these points. In the horse, equilibrium is maintained by controlling the body's center of mass over its base of support.

- **Line of gravity (LOG)** ❼ refers to the direction of gravity acting upon the horse. It can be thought of as an imaginary line downward from the center of gravity. The force is also proportional to the length of the line. If the line of gravity is within or close to the base of support, the body is more stable and balanced. If the line moves outside the base of support, the horse must move in order to avoid falling to the ground.

- **A center of mass (COM)** ❼ Sometimes also called as the center of gravity. Refers to the point at which the mass of the body is centralized. The center of gravity moves according to the body's position. Think for example about a horse taking of for a jump where the center of mass moves forward or a horse moving 'downhill'.

So in order to achieve balance, a mass – let's say horse and rider - must be evenly distributed with respect to the center line. This doesn't mean that the mass is evenly

distributed above the support surface. Think about a rope dancer who constantly distributes its weight differently – balancing - relative to the support surface without it falling.



Picture adapted from Dausend (2005) illustrating the base of support (blue line between feet), the line of gravity (vertical red line from the center of mass) and the center of mass (blue round dot) in a balanced standstill position.

Training a horse properly requires constant balancing between the relative distribution of the weight of horse and rider between the front and hind legs – horizontal balance – and the left and right limbs – vertical balance – with the ultimate goal of achieving true collection in which the horse can carry a rider with maximal efficiency and coordination and minimum effort. However, by doing so we are shortening the base of support and thus decreasing the horse's stability and making it more susceptible for influences from the outside – such as the rider. Therefore, we are creating to what we can call an unstable balance.

To elaborate on this point, let's also take a closer look at to what elements contribute to stability. In general, stability can be optimized by:

- Widening base of support
- Lowering the center of mass
- If the line of gravity is within – or near – the base of support

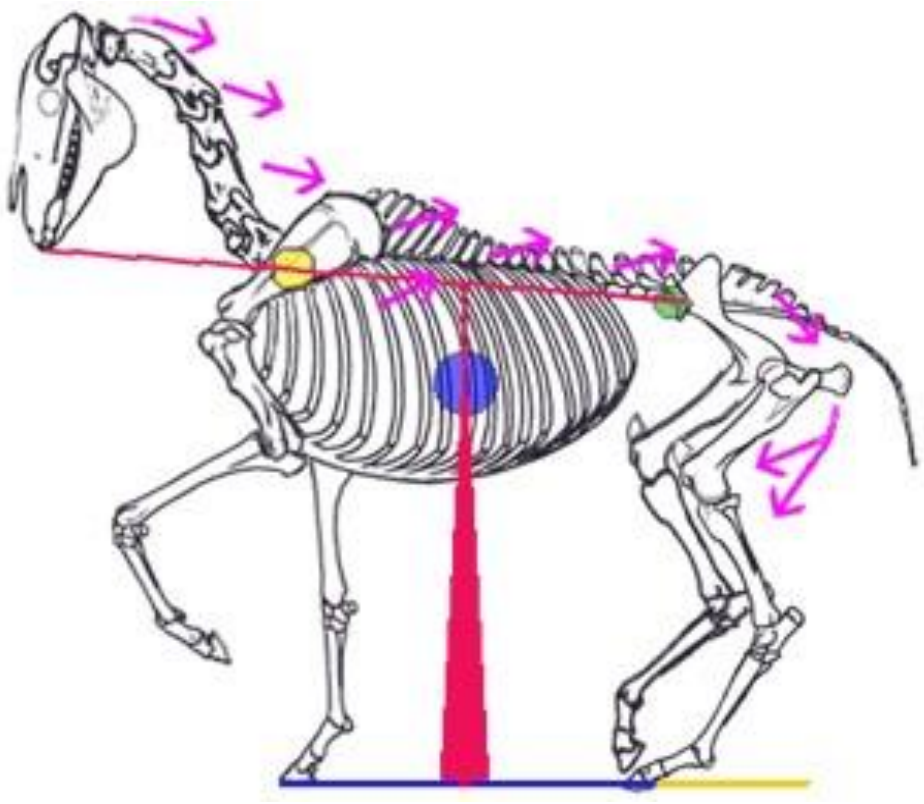
When travelling with horses, it is quite common to find your horse standing 'wide' when you open the tailgate of the horsebox. They do so in order to cover more ground and being able to stabilize themselves better during the journey. Another example might be when a horse gets sedated. The horse will often stand very wide in order to stabilize and not fall over. Now compare the pictures below.

On the left you can see a male Sumo wrestler in a stable balance. First of all, the greater the mass, the more balance. The weight of this wrestler therefore is the first factor that enhances its stability. Then, the base of support - white horizontal line - is widened. The center of mass is displayed by the blue circle and the line of gravity is exactly within the base

of support. From this stable position, it will be hard to throw this wrestler out of balance. However, the increased stability leads to decreased mobility! It is therefore that a widening of the base of support is not desired within horse who are required to move with high mobility.

On the right you can see a woman doing yoga. The base of support is small - horizontal line at the feet. The center of the mass is around the blue circle and the line of gravity is just at the front as the base of support. So she is balanced, however, it wouldn't take much to become unstable by a force or someone trying to push her over. We could refer to this as an 'unstable' balance.

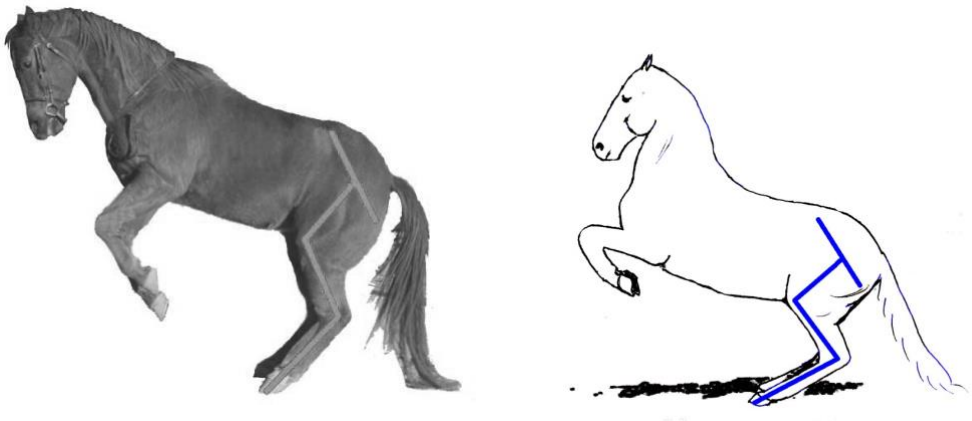
In dressage, a horse is thus asked to work in an unstable balance – making it mobile and susceptible to small external influences of the rider. Unstable balance can be optimized when the base of support is both narrowed laterally and shortened longitudinally.



For example, in the piaffe the combined center of gravity of the horse and rider is directly over the center of the horse's base of support. The sensitivity of the balance is so precise that its balance can easily disturbed by the mere weight of a hair.

In modern dressage, piaffe and passage are considered the highest achievement of balance. However, within a classical tradition the airs of the ground are considered the highest achievement of balance, especially the levade. But why? Because it is the ultimate move from which the horse transitions from an unstable balance – piaffe – into a stable balance – levade! In the levade, the horse is optimizing stability through widening its base of support slightly on the hind limbs, lowering the center of mass and the line of gravity is always within or near the base of support. The levade is thus an optimal exercise to play with both balance and stability! From this, it is also clear that the levade is not a trick and should always be preceded and followed by movement.

Compare the pictures below to train your eye. The horse's stability on the left is not optimal as it is pushed high of the ground and therefore the horse will tire quickly and easily be pushed out of balance. The horse on the right however displays optimizes stability by lowering the center of mass correctly.



Pictures adapted from Dausend (2005).

So in conclusion, when working with horses, we are always playing with equilibrium and stability to achieve balance which requires a lot of finesse and riders 'tact'. I will conclude with the famous quote from Alois Podhasjsky:

''To master a living creature one must first and foremast master oneself.''

LIST OF TERMS & ABBREVIATIONS

Abduction	Movement of a body part away from the midline of the body (mid-sagittal plane)
Adduction	Movement of a body part towards the midline of the body (mid-sagittal plane)
Agonist	The active one. Refers to muscle action
Anatomy	Branch of science concerned with the bodily structure of a living organism
Antagonist	The opposing one. Refers to muscle action
Appendicular	Part of the skeleton that consists of the thoracic (front) and pelvic (hind) limbs, including the pelvis
Aponeurosis	A tendinous sheet that attaches muscle to other tissue
Articulate	Divided into or united by two joints and moveable
Atlas	The first cervical vertebrae (C1)
Atrophy	Wastage of tissue. Muscles display a loss of mass and tone
Axis	The second cervical vertebrae (C2); A straight line about which rotation occurs

Axial Part of the skeleton that includes the skull, vertebrae, ribs, sternum

Ballistic contraction Ability to contract with momentum allowing fast movements to produce a larger range of motion.

Balance The ability to control equilibrium – either static or dynamic – in relation to gravity only.

Bursa A capsule like structure filled with synovial fluid

Biomechanics The study of the mechanical principles of a living body. It includes and both kinematics – motion - and kinetics - forces

Bipedal A portion of the stride in which two limbs support the body

Concentric contraction Muscle shortens generating tension

Conformation describes body characteristics derived from breeding such as hair color, length and size of skeletal structure.

Costal Relating to the ribs

Coxofemoral Relating to the hip

Centre of mass The point about which the total mass of a body is evenly balanced

Cervical The anatomical name for the neck

Circumduction A circular movement that consists in part of all the previous actions except for rotation. E.g. a horse that plaits or paddles

Diagonal Advanced Placement DAP	When the hooves of a diagonal pair of limbs- in trot or canter do not contact the ground at the same moment.
Dorsiflexion	Upward flexion of the foot at the pastern
Dynamics	The branch of dynamics that deals with motion and the way in which forces produce motion.
Eccentric contraction	Muscle lengthens as it generates tension
ECVM	Equine Complex Vertebral Malformation. Previously known as C6/C7 malformation.
Equilibrium	A state of zero acceleration where there no change in the speed or direction of the body.
Extension	To extend or open the angle of a joint
Extrinsic	Operates outside e.g. forelimb muscles with insertions on the trunk
Fascia	A fibrous collagen tissue that wraps around everything in the body.
Force	The mechanical action or effects of one body on another, which causes the body to accelerate relative to the inertial reference frame.
Flexion	Closing the angle of the joint. E.g. carpus, elbow, intervertebral joints
Foramen	Perforation or hole in the bone to allow vessels to pass through

Holistic Characterized by the belief that the parts of something are intimately interconnected and explicable only by reference to the whole

Hypermobility Congenital disease with too much stretch in supportive soft tissue

Frontal plane Any plane passing longitudinally through the body from side to side, at right angles to the median plane and dividing the body into dorsal and ventral parts. Also referred to as dorsal or coronal plane

Ground Reaction Force: The force exerted by the ground against a limb that is in contact with the ground. Acts in opposition to the force exerted by the limb against the ground

Hypertrophy Increase of tissue. Muscles display show an enlarged mass and tone

Insertion The point of muscle attachment that is more moveable

Isometric contraction No change in muscle length as it generates tension

Kinematics The branch of mechanics that is concerned with the description of movements

Kinetics The study of internal and external forces, energy, power and efficiency involved in the movement of a body

Manubrium The upper part of the sternum

Median Divides the body into left and right sides via a centerline demarcation.

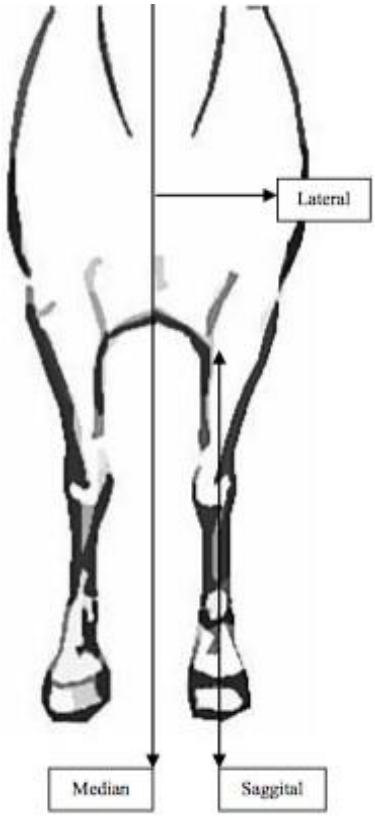
Medial	Refers to structures closer to the median line or towards the inside of an anatomical structure.
Negative DAP	When the foreleg of the diagonal pair touches down before the diagonal hind leg
Origin	The part of muscle attachment that is least moveable
Ossification	The process of bone formation
Overtracking	Distance between the hind limb and front limb hoof strike; it is positive if the hind limb lands in front of the front limb.
Paddling	A type of gait abnormality usually associated with a toe-in confirmation of the front limbs. The foot breaks overs the lateral toe wall and deviates outwards during flight.
Plaiting	Extreme form of paddling where the horse places one hoof – either front- or hind limb – in front of the other in a straight line.
Positive DAP	When the hind leg of the diagonal pair touches down before the diagonal foreleg
Posture	Describes how the horse organizes itself in the way it stands and moves.
Proprioception	The subconscious awareness of the relative position of the body and its limbs in space, their relationship to each other and the surrounding environment

Protraction	Movement of a body part forwards
Retraction	Movement of a body part backwards
Range of motion ROM	The full movement potential of a joint
Rotation	Twisting movement around a longitudinal axis. E.g. shaking the head; twisting the vertebrae
Sagittal plane	An anatomical boundary that exists between the left and right sides of the body. The sagittal plane runs parallel to the longitudinal axis
Stance phase	When a foot is in contact with the ground
Stability	The resistance to a change in the body's acceleration, or the resistance to a disturbance of the body's equilibrium
Swing phase	When the hoof is lifted and brought forward in a pendulum action
Suspension phase	When no hooves are in contract with the ground
Sweeney	A condition that affects the suprascapular nerve of the shoulder. The shoulder muscles atrophy and flatten with abnormal prominence of the shoulder joint and spine of scapula. The shoulder and limb have an outward rolling action as the horse moves
Synergy	The working together of systems. i.e. nerves and muscles
Synovial fluid	Lubricating fluid found in most joints with hydraulic properties

Tensor	To stretch out. E.g. Tensor Fascia Latae
Thorax	Region found within the chest cavity cranial to the diaphragm
Transverse plane	An imaginary plane that divides the body into superior and inferior parts. It is perpendicular to the coronal plane and sagittal plane. Also reffered to as axial plane

DIRECTIONAL TERMS

Caudal	Towards the tail
Cranial	Towards the skull
Distal	Away from the point of attachment
Dorsal	Towards the top line
Lateral	Towards the side of the body
Medial	Towards the midline of the body
Proximal	Towards the point of attachment
Rostral	Structures located towards the nose
Ventral	Towards the underside



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