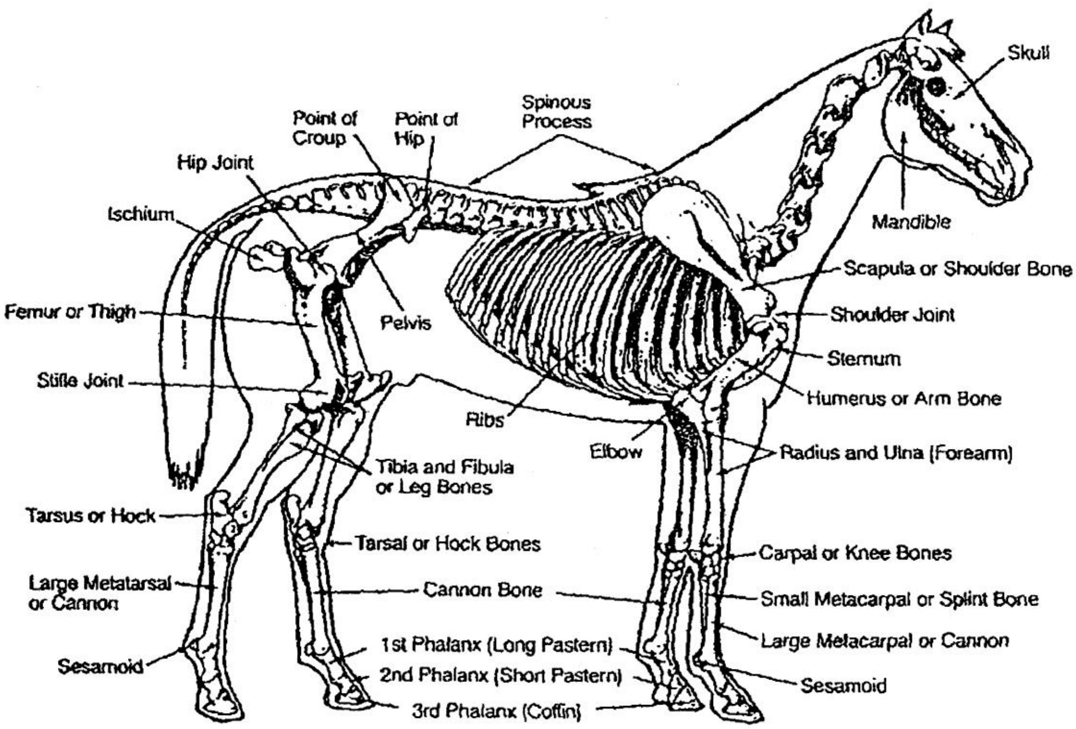


Systems

Information compiled by Lezah Williamson

Edited by David Dedrick

Contents

Systems

Recommended videos on Youtube for all systems:

- *Anatomical teaching model of a horse - (Victoria Gallery and Museum)*
- *Inside Nature's Giants - Racehorse (approximately 45 minutes; WARNING - some graphic content - autopsy scenes)*
- *3D Horse Anatomy Software (some information is available for viewing online, or can be purchased) www.biosphere.com br*

The systems of the body are separate entities, each based around specialized organs

The systems include:

- musculoskeletal system
    - skeleton
    - soft tissues:
        - muscles
        - tendons
        - ligaments
        - cartilage
- cardiovascular system
- respiratory system
- digestive system
- lymphatic system
- nervous system
- urinary system
- integumentary system
    - skin
    - hair
    - hooves
- endocrine system
- excretory system
- reproductive system
- immune system

Many inter-relate, working in close harmony with and being supportive of each other, or in some circumstances, against each other

For example:

- The horse is one of the most impressive natural athletes in the world, due largely to its cardiovascular system which works in concert with the respiratory system to accommodate the enormous oxygen demands put forth by the muscles
- However, the enormous potential of the cardiovascular system coupled with that of the musculoskeletal system makes the horse very susceptible to exercise-induced injuries
    - the horse's cardiovascular system is so strong it allows the horse to outperform itself
        - this results frequently in damage to the musculoskeletal system
    - studies on thoroughbreds have shown that the proportion of skeletal mass exceeds 50% of the horse's body weight
        - this means the energetic capacity of the muscular system far exceeds the capabilities of the cardiovascular system to deliver oxygen

Directional Terms and Body Planes

Check out *Horse Anatomy Diagrams at www.lovehorsebackriding.com/horse-anatomy-diagrams.htm*

In order to discuss the horse, it is best to have a basic understanding of directional terms and body planes

Important common directional terms include:

- near side - the horse's left side
- off side - the horse's right side
- dorsal - toward the back (top of the horse)
- ventral - toward the belly (underside of the horse)
- anterior - front of horse
- posterior - back of horse

Axes:

- an axis is a straight line that an object rotates around. The three axes of rotation are:
    - sagittal axis: passes horizontally from posterior to anterior
    - frontal axis: passes horizontally from left to right
    - vertical axis: passes vertically from inferior (lower) to superior (upper)

When discussing the horse from the knee and hock up:

- caudal - a structure located closer to the tail, in comparison to another

- cranial - a structure located closer to the head, in comparison to another

When discussing the head:

- caudal - as above (closer to the tail)
- rostral - a structure located closer to the nostrils, in comparison to another

On the limbs:

- proximal - a location closer to the body/attached end of the limb
- distal - a location further from the body

Below the knee and hock:

- dorsal - replaces cranial (closer to the head)
- palmar - replaces caudal for the forelimb (closer to the tail)
- plantar - replaces caudal for the hind limb (closer to the tail)

When viewing the front of a horse's leg:

- axis - a line down the middle
- axial - located toward/nearer the axis
- abaxial - located further away from the axis

When viewing the horse's body from the front, imagining that a line (the axis) splits his left and right sides apart:

- medial - closer to the centre of the horse, near to the axis
- lateral - further away from the middle

Important **body planes** include:

When viewed from the front:

- median plane - the horse is split down the middle (axis) into left and right halves
- sagittal plane - any slice taken of the horse parallel to the median plane

When viewed from the side:

- transverse plane - splits the horse in half, separating the front and back halves of the horse

Other:

- dorsal plane - a line at mid-body that runs parallel to the ground and separates the upper part of the horse from the lower part (approximately where a trace clip line would run across the torso)

Musculoskeletal system

The musculoskeletal system is the horse's largest body component

- comprises over 60% of the horse

The musculoskeletal system is comprised of:

- skeleton
- muscles
- tendons
- ligaments
- cartilage

The musculoskeletal system has been implicated in 15-20% of cases of poor performance

- the musculo-skeletal system is the most common cause of poor performance and wastage (lost training days on either a permanent or temporary basis) in the equine industry

Skeleton

Recommended Youtube videos of the skeleton:

- *The Horse's Skeleton: Overview (The Horse) - approximately 5 minutes*
- *Equine Anatomy on a Live Painted Horse (equisportmedicine) - approximately 5 minutes*

Evolution has adapted the horse's skeletal frame to complement its needs as a flight animal

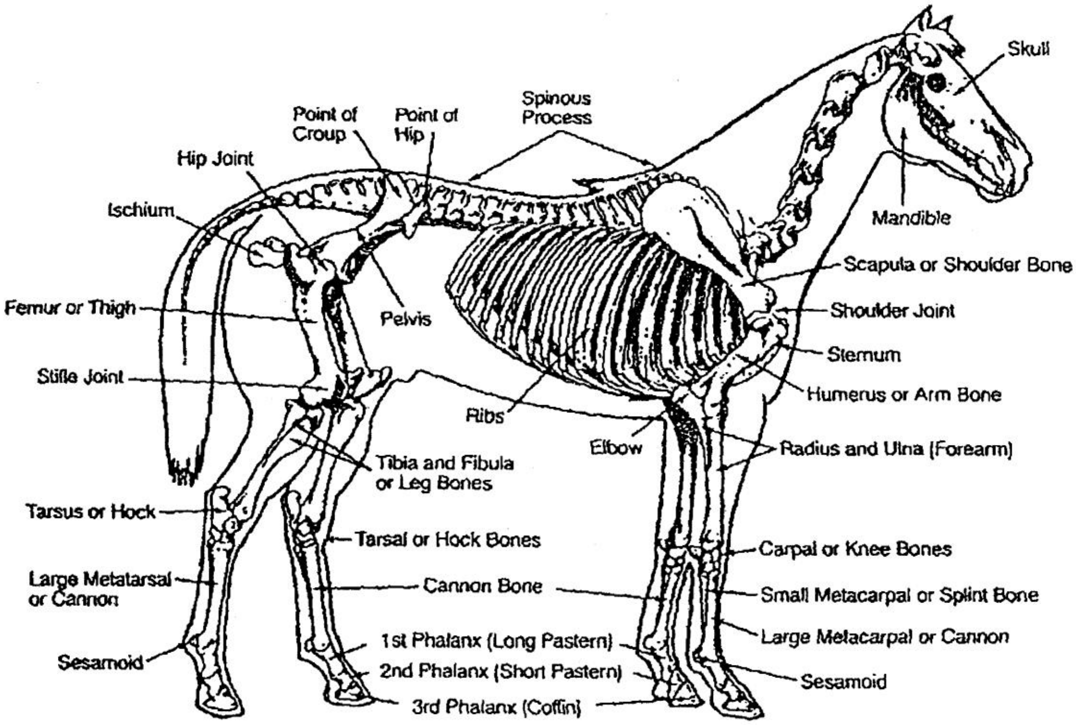
- the horse has an elongated, perpendicular skeleton ideal for impulsion and acceleration
- the bone mass of the lower limbs is reduced to help make the horse quicker

There are 205 bones in the horse's body

- the bones are articulated together at joints

Purpose of the skeleton:

- provides a rigid structure and framework for the body
- shields internal organs from damage
- supports the soft parts of the horse's body



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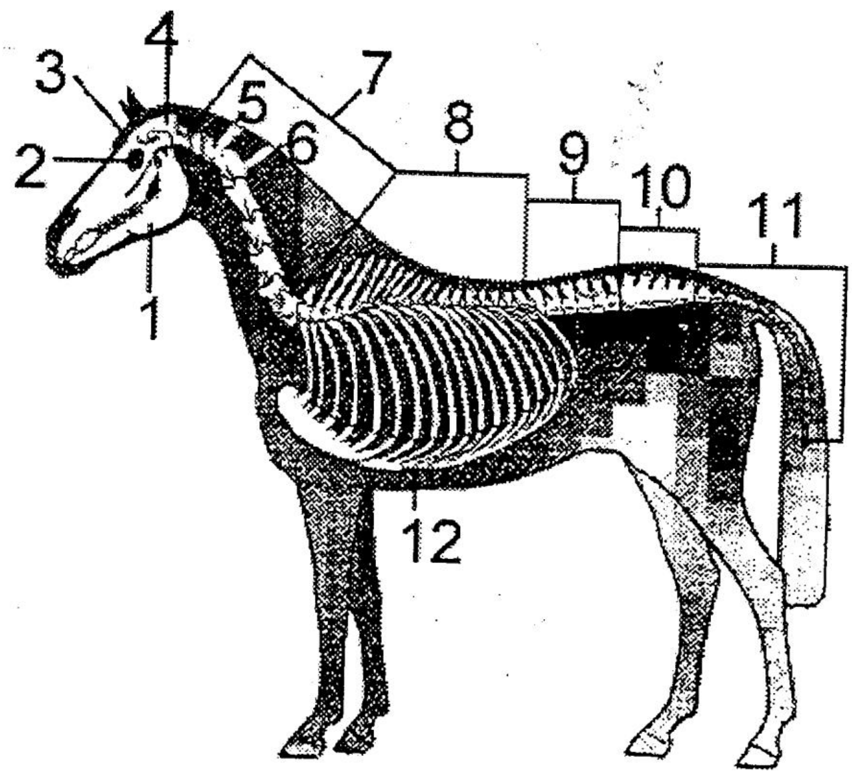
Axial Skeleton

The axial skeleton is comprised of the :

skull

- **Purpose** of the skull:
- defense
- protects the brain

- supports facial muscles
- entry and exit places for the vascular and nervous systems



skull (continued)

- architecturally, the head is bulkier than necessary
- practically, the horse uses this weight in a pendulum-like way to help balance
- raising and lowering the head allows the horse to instantly change its centre of gravity

    - the skull consists of two main portions, the cranium and the face
    - there are 34 bones in the skull, 14 of them major bones
    - these bones are mostly flat and fused together in early life by cartilage that is later (by 8 years of age) replaced by calcium
    - the major bones of the skull include:

incisive (premaxillary or os incisivium) -
part of the upper jaw where the teeth attach
nasal (os nasale)
covers the nasal cavity
#1 *mandible* (manibula)
largest bone in the skull, the lower portion of the jaw

#2 *lacrimal* (os lacrimale)
contains the nasolacrimal duct
#3 *frontal* (os frontale)
the forehead
parietal (os parietale)
from the forehead to the back of the skull
occipital (os occipitale)
joint between the skull and first vertebrae
temporal (os temporale)
transmits sound
zygomatic (os zygomaticum)
attaches temporal bone to cheek bone
palantine (os palatinum)
forms back of hard palate
#4 *sphenoid* (os sphenoidale)
at base of skull;
can fracture if the horse goes over backwards
vomer -
inside of nasal cavity
pterygoid -
small bone attached to sphenoid that extends down

- vertebral column
  54 bones

- *7 cervical vertebrae* including - atlas = C1 and axis = C2 (#5, 6, 7)
- atlas, the first cervical bone, lacks a body that is present in the other, a ring or tube carrying a wing
- axis, the second cervical bone, has a tooth-like projection, the odontoid process
- the upper surface of the axis is roughened for the attachment of a ligament
- has a very strong, large spinous process that allows the nuchal ligament to attach
- the cervical spine is highly flexible
- *18-19 thoracic vertebrae* (#8)
- there is very little movement in this part of the spine
- *5-6 lumbar vertebrae* (#9)
- the lumbar bones of the horse are different from all other species in that the last three carry articular facets that prohibit movement
- it is not uncommon to find that, as the horse ages, these vertebrae will fuse
- *5 sacral vertebrae* (fuse to form the sacrum) (#10)
- *15-25 caudal* (average number is 18) (#11)

The vertebral formula is $C_7T_{18}L_6S_5Ca_{15\text{-}21}$

ribs

- 8 true pairs of ribs
- 18 total
- the rib is a highly elastic bone that is elongated by cartilage that extends on to form the sternum
- the first rib is the smallest but also carries a collection of nerve trunks that supply sensory and locomotor impulses to the foreleg

sternum aka breastbone

- the lower part is formed of cartilage (#12)
- it's held in position by the first eight pair of ribs
- comprised of 7 sternebrae that never become completely bony

Appendicular skeleton

Contains fore and hind limbs

These bones are responsible for:

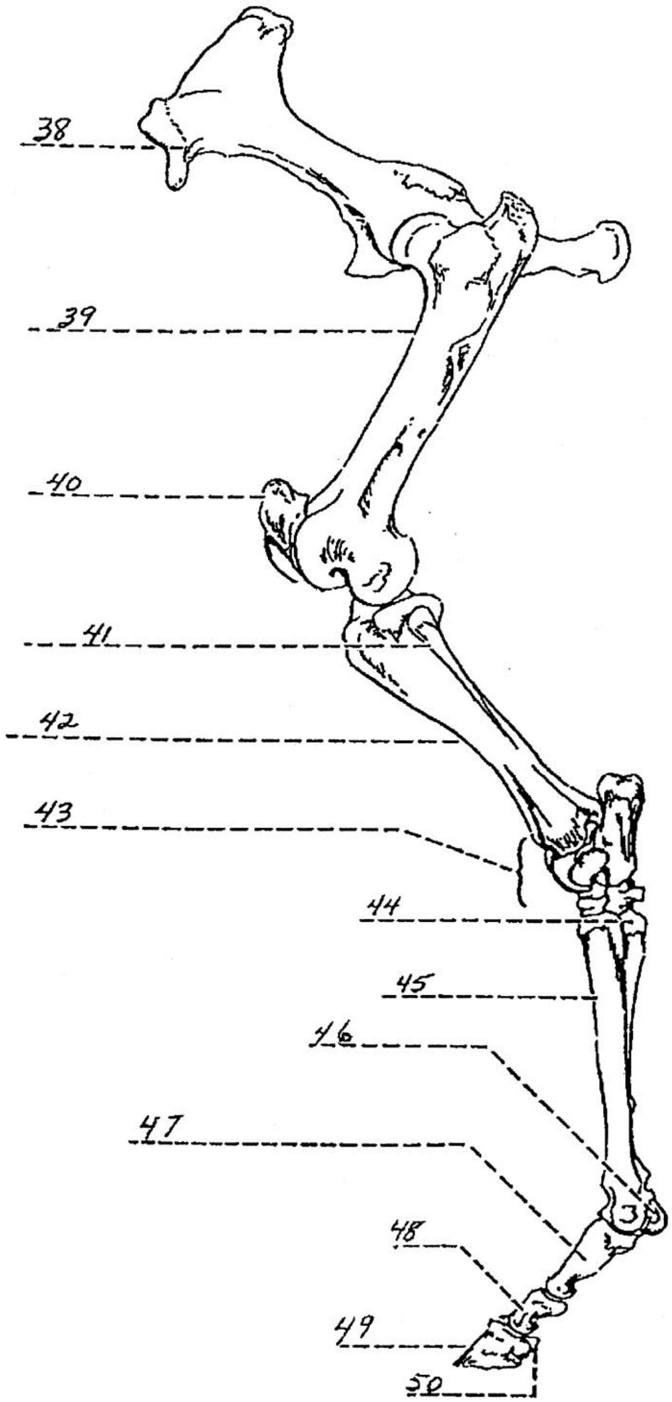
- weight bearing
- movement
- speed
- power
- these bones accommodate the attachment of the large muscles
- they protect and house smaller muscles

Hind limbs

- attach to vertebral column via pelvis
- support 40% of the horse's weight
- create most of the forward movement

Pelvis is made up of os coxae

- the diameter of the pelvis determines the size of the horse's hindquarters
- it is the largest flat bone in the horse
- contains the : ilium
- ischium
- pubis
- cavity = acetabulum, acts as socket of hip joint
- larger in a mare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femur

- largest long bone in the horse
- one of the heaviest and strongest bones in the horse's body
- the length and angle of the bone is important to the horse's strength, athletic scope and function
- is the medium between the hip and the stifle
- serves as attachment point for the deep and middle gluteal muscles and the accessory and round ligaments
- at hip joint, forms ball and socket joints with pelvis
- at stifle joint, meets tibia and patella

Patella

- aka stifle
- equivalent to the human kneecap

Tibia

- runs from stifle to hock
- proximal end - attachment for patellar ligament, meniscal ligament, cruciate ligament, collateral ligament
- distal end - attachment for collateral ligament of hock
- fibula - completely fused to tibia in most horses

hip joint

- ball and socket joint is made up of acetabulum of pelvis and femur
- very stable

stifle joint (femoro patellar joint)

- largest, most complex joint in the horse's body
- responsible for lifting the limb up and forward
- the #2 site for hind limb lameness
- stifle lameness is often hard to evaluate
- bones in the joint are:
- femur
- tibia
- patella
- composed of three joint compartments:
- femoro patella joint
- media femorotibial joint
- lateral femorotibial joint

- all stabilized by network of ligaments
- the stifle has an articulation angle of 150 degrees

tarsus

- 6 bones (1st and 2nd tarsal) aligned in 3 rows
- largest bone is the calcaneus which corresponds to the human heel
- that is at the point of hock (tuber calcis)
- attachment of tendon of gastronemius attachment for portions of biceps femoris
- attachment for portions of superficial digital flexor tendon

Forelimb

- the forelimb does not directly attach to the spine
- the horse has no collarbone
- the body is suspended by muscle and tendon
- this allows:
- great mobility
- a great deal of concussion to be absorbed
- the horse to fold his forelegs when jumping
- the forelimbs support 60% of the horse's weight
- the forelimbs are the site of 90% of lamenesses

Scapula

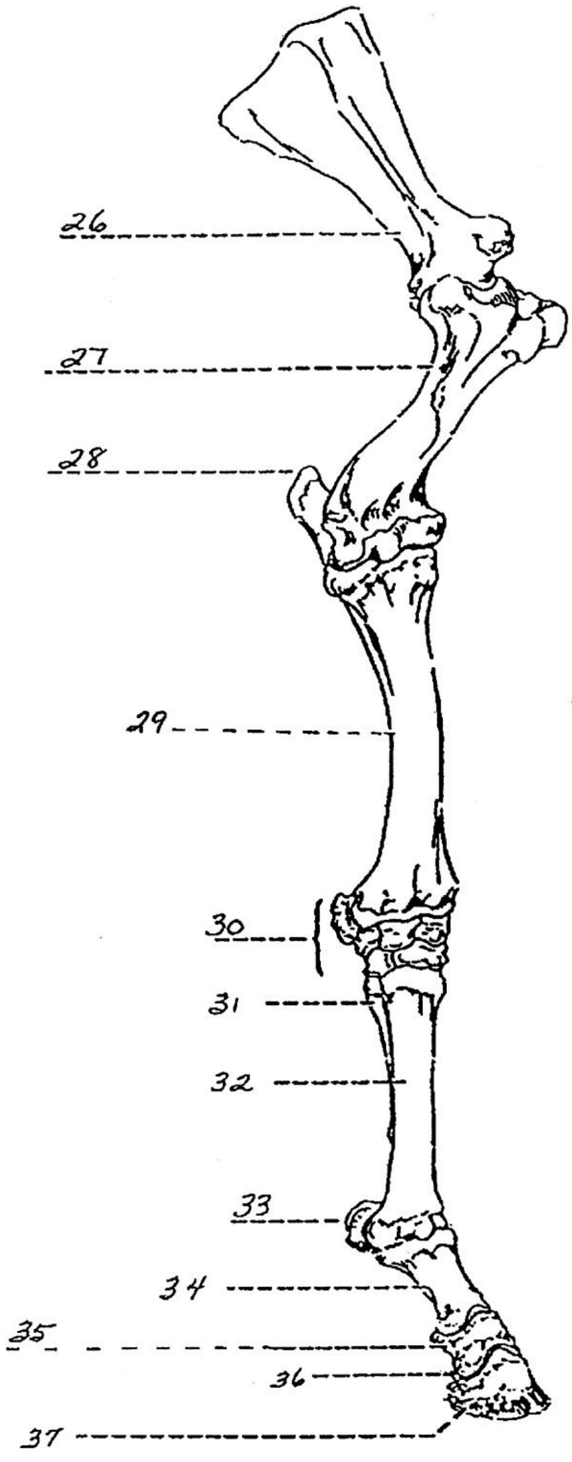
- partially forms withers
- the thorax and ribcage are suspended between the two scapula
- the scapula are able to glide freely over the ribs
- this allows the horse to move at great speed while cornering or travelling over uneven ground
- the longer the scapula, the more forward the inclination, which therefore produces a longer stride

humerus

- situated between the scapula and radius
- usually inclined at an angle of 50-55 degrees with the ground
- one of the strongest bones in the body

radius

- from elbow to carpus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ulna

- caudal to radius
- it is small and short (in man and most other animals, the ulna is the larger of the two bones)
- has no central marrow cavity
- it is partly fused to the radius by adulthood

shoulder joint (scapulo-humeral joint)

- the angle is 120-130 degrees
- can extend to 145 degrees
- can flex to 80 degrees

Elbow joint (humeroracial joint)

- hinge joint
- can flex 55-60 degrees

carpus/knee joint

- 7 bones in 2 rows with 3 joints
- a ginglymoid joint, which only moves in one direction
- 1st carpal bone present only 50% of the time

bones of the lower leg

cannon (3rd metacarpal/metatarsal; large metacarpal/metatarsal; 3Mc/Mt) aka shannon in hind leg

- a major bone in the support structure of the leg
- eventually fuses with the 2 splint bones and becomes known as the *metacarpal tuberosity*
- the cannon is where the measurement of '*bone*' is taken, a measurement of the circumference of the leg immediately below the knee, used informally to determine substance and strength of bone

splint (2nd and 4th metacarpal; 2 Mc/medial small metacarpal; 4 Mc/lateral small metacarpal)

- there are two splint bones in each leg, one on either side of the cannon bone
- 8 in total in the horse
- vestigial bones
- a remnant from when the horse was 5 toed
- does provide some support to the knee bones

- a horse can, in cases of severe injury to this bone (e.g., fracture), have the bone removed and still return to work as it is not a primary weight-bearing bone
- eventually fuse to cannon in adulthood

proximal sesamoid (medial - PSm; lateral PSl)

- two bones located at the back of the fetlock joint
- shaped like a three-sided pyramid
- help to support the fetlock joint
- they act as a buttress for the joint
- act as a pulley block so the deep digital flexor tendon, can glide with increased leverage
- subject to a great deal of strain
- strongly supported in the joint by ligaments

long pastern (proximal /1st phalanx/P1/PP)

- has a medullary cavity
- is sandwiched between the extensor and flexor tendons

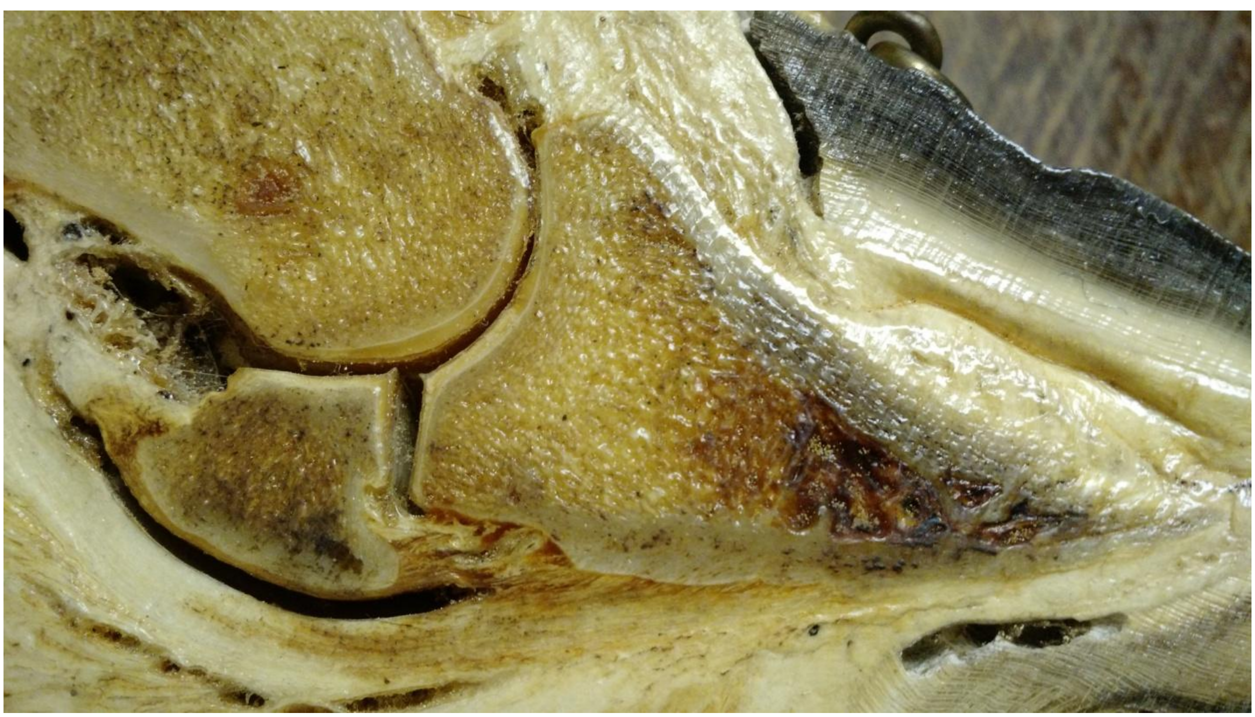
short pastern (os coronae/middle/2nd phalanx/P2/MP)

- this bone is solid throughout and has no medullary cavity
- it is the first free limb bone to sustain concussion when the foot hits the ground, making it susceptible to ringbone
- the superficial flexor tendon attaches to the short pastern bone

- the bone is angled and supported underneath by the deep digital flexor tendon; this may help to lessen the degree of concussion

coffin (distal/3rd phalanx/pedal/os pedis/P3/DP)

- major hoof bone
- supports the majority of the horse's weight
- is the same shape as the foot
- occupies the front third of the hoof cavity
- the front (toe) of the bone is inclined downward rather than being parallel with the ground
- it is the second densest bone in the horse's body
- the surface of the coffin bone is filled with holes called *foramina* that blood vessels pass through
- the plantar arteries enter on either side of the bone and join together in the middle
- it is the point of attachment of the extensor tendon and the deep digital flexor tendon
- the solar surface is united to the insensitive sole via papillae, that secrete the insensitive sole
- when undue weight falls on the pedal bone, like when the horse is jumping, the pedal bone is pressed down into the sole of the foot



navicular (distal sesamoid/DS)

- small shuttle shaped bone
- acts as fulcrum to the deep digital flexor tendon
- controls the angle of attachment of the deep digital flexor tendon to the solar surface of the sole
- arguably the weakest spot in the machinery of the horse is the relationship between the navicular bone, the pedal bone and the deep digital flexor tendon

differences between front and hind limbs

- the 3rd metatarsal is 1/3 longer than the 3rd metacarpal
- the hind 2nd and 4th metatarsals are longer than the 2nd and 4th metacarpals
- the 1st phalanx is shorter in the hind leg than in the front
- the 2nd phalanx is longer in the hind leg than in the front
- the hind 2nd and 3rd phalanx are narrower than the front
- the angle is steeper in the hind pasterns by 5 degrees
- a higher percentage of concussion-related injuries occur in the front limbs due to the horse carrying more weight there

Purpose of bones

- act as levers
- store minerals
- site of red blood cell (RBC) formation

Classification of bones

- long bones:
- typically in the limbs and are
- for locomotion
- to store minerals
- to act as levers
- for RBC formation in a process called *hematoiesis*
- short bones:
- typically found in joints
- to absorb concussion
- flat bones:
- typically the ribs
- enclose the body cavity

- irregular bones:
    - typically the vertebrae
        - to protect the central nervous system
- sesamoid bones:
    - embedded in tendons

Bones need proper nutrition for growth

- essential proteins and amino acids:
    - bioactive whey, hydrolyzed collagen proteins, lysine, proline, isoleucine, alanine, glycine
    - for optimal skeletal density, all work synergistically to:
        - support protein synthesis
        - improve collagen formation
        - supply structural proteins
- minerals:
    - silica, strontium, zinc, copper, calcium manganese and boron
    - support :
        - calcium incorporation into bone
        - optimal bone protein formation
        - antioxidant mechanisms
        - these reduce internal pro-oxidative stresses that reduce bone density and health
- enzyme SOD (super oxide dismutase) reduces pro-oxidative stresses
    - is made in the body in part from zinc, copper and manganese
- vitamin D3 and vitamin C support bone protein synthesis and incorporation of calcium to bone
- connective tissue support ingredients also contribute to healthy bone formation by supporting joints

Bones all have the same basic structure

- bone is made up of three types of cells and extracellular matrix
    - *osteoblasts*
        - a bone-forming engine
    - *osteoclasts*
        - cells that break down and resorb bone
    - *osteocytes*
        - cells that control the levels of osteoblasts and osteoclasts
    - extracellular matrix

- made up of:
    - several types of protein including collagen
    - growth factors
    - mineral component calcium hydroxyapatite
        - 70% of the skeleton is made up of this mineral
- the long bones have a shaft consisting of a tubular bone
    - there is an *epiphysis* or growth plate at each end
        - articular cartilage covers the ends of the bone where it meets another bone
    - it has a thinly layered wall of dense *cortical* or compact bone
        - formed by densely packed cylindrical *osteons* of cells and bones with channels for blood vessels
    - this surrounds a *marrow* (medullary cavity)
    - the outer layer of bone is *cancellous*
        - this is softer bone mixed with marrow
        - *cancellous* (spongy) bone is arranged in *trabeculae* (little beams) to give support against stress
        - these are oriented in a regular pattern along stress lines
    - the *endosteum* lines the marrow cavity and is where bone is laid down
        - the nutrient artery carries blood to the endosteum

The bone matrix consists of a collagen base

- bone matrix is the intracellular substance of bone
- the matrix has many *osteocytes*
- has many cells capable of becoming active *osteoblasts* (bone forming cells)
- it is perforated by canals containing blood vessels and nerves
- the main blood supply enters through the nutrient foramen
    - then it passes into the medullary cavity
    - then it radiates into the cortical bone
- bone salts (mainly calcium phosphate) are deposited in the collagen
- *Sharpey's fibres* are specialized fibres in tendons that penetrate into bone to make a secure attachment
- outside of the bone, it is covered by a fibrous tissue called the *periosteum*

Bones are covered with periosteum

- periosteum protects and envelops the bone
- periosteum has a similar collagen make-up to that of the tendon
- it is bone-producing

- there is no periosteum in areas where there are cartilage
- periosteum has no pain receptive nerve endings
    - this can allow bones to become twisted out of shape without causing excessive pain
- tendons insert into the periosteum of bones and cartilage via specialized cells called *Sharpey's fibres*

Bone is a working organism in partnership with blood

- bone is a storehouse for:
    - magnesium
    - phosphorous
    - calcium
- bone helps to maintain correct levels of these minerals in the blood

Joint: the place where bones intersect

Purpose:

- allow limbs to bend
- enable movement
- transfers load

Joints are made up out of a fibrous capsule made up of articular cartilage

- this improves the structural integrity
    - the inner lining = synovial membrane
        - secretes synovial fluid
        - provides lubrication

There are **three kinds of joints**, structurally

- *fibrous joints*
    - immovable
    - ossify with age
        - e.g., the skull
- *cartilaginous*
    - limited movement
        - e.g., pelvis
- *synovial*
    - moveable

- parts of a synovial joint include:
    - articular cartilage
        - a smooth, glassy, hyaline cartilage
    - synovial membrane
        - the inner layer contains cells which secrete synovial fluid to lubricate the joints
    - fibrous joint capsule
        - a membrane called the joint capsule covers the joint
        - the outer layer is thick and acts as a support for the joint
    - collateral ligaments

The **type of synovial joint** formed determines the degree and direction of motion

- ball and socket joint
    - rotates
        - e.g., hip joint
- hinge joint aka ginglymus
    - only allows bending and straightening
    - flexion decreases the angle while extension increases the angle
        - e.g., elbow joint
- sliding joint aka plane joint
        - e.g., intercarpal joints
- pivot joint aka trochoid joint
        - e.g., atlantoaxial joint
- ellipsoid joint aka biaxial movement
        - e.g., antebrachiocarpal joint

Try these quizzes:

- *Horse - UK College of Agriculture; www2.ca.uky.edu/agripedia/agmania...horseskel.html*
- *Purpose Games - http://www.purposegames.com/game/horse-skeleton-system-quiz*

Work and the skeletal system

bone is strong

- up to three times the horse's weight is placed on bone when the horse gallops

bone is constantly remodelling in response to the stresses placed upon it

- bone is dynamic
    - bone can change shape
        - bone is constantly changing in order to maximize strength due to the changing demands of work
    - bone is constantly depositing and absorbing minerals
- remodelling occurs in
    - fracture repair
    - 5% of the skeleton is turned over yearly in the normal remodelling process
- as the horse exercises, bone responds to the compression and displacement of training affecting bone growth and maintenance
- bone responds to training by either:
    - strengthening
    - breaking down
- gradual adaptation strengthens bone, while over-work breaks it down
    - gradual, strategically applied work of varied intensity improves bone
        - long slow distances do ***not*** signal new bone formation (but are a useful way to condition the CV system)
    - bone cells via *osteoclasts* (cells that destroy bone) are removed
    - bone cells are replaced by *osteoblasts* (cells that make a cartilage matrix that then mineralizes)
    - bones that are not used become thinner and demineralize

Proper nutrition is required in order for the bone to remodel successfully

- the horse needs calcium, phosphorous, magnesium, copper, since, manganese and vitamins A and D

Bone modelling and remodelling

- skeletal modeling occurs as a result of breeding (the horse's genetic make-up) and exercise
    - this is the blueprint of the horse, what you start with
- for bone remodelling to be successful, it must be work/discipline specific
- *adaptive training* is what leads to successful bone remodelling
- bone trains to the *level* of work, not to the *amount* of work
    - the cardiovascular system is not the same as it responds to *amount* of work
    - in order to successfully train bone, shorter, harder work is better than longer, easier work
    - another aspect to successfully training bone is to vary the work

Wolff's Law: "Bone is laid down where strength is needed and removed where strength is unnecessary"

- the greater the load, the larger the bone mass
- horses carry this to an extreme
- this means that in horses, the joints are highly vulnerable
- joint surfaces like the distal cannon cannot change size because they are within a joint
- instead, if stressed, they will change their structure (shape), resulting in unsoundnesses

How bones train

Biological systems remain plastic, never gain elastic status

- overloads result in micro-fractures
- over-repairs result in *hypertrophy* (increase in volume due to the increase of a tisssue's component cells)
- bones fail when there is inadequate time to repair

The horse has such a strong cardiovascular system that this allows the horse to outperform itself

- this can result in damage to the musculoskeletal system
- the musculoskeletal system requires the most training
- the musculoskeletal system sustains the most wear and tear

How bones change

In a study done of racehorses, it was noted that

- the dorsal cannon hypertrophies to twice its yearling diameter
- the caudal tibia almost doubles in thickness
- surrounding sites then need to adapt as well by increasing in density and changing shape
- enlargement of the front of the cannon bone occurs in thoroughbreds in response to intense exercise
- other racehorse studies have shown strengthening of the front of the carpal bones and of the sesamoids occurs after 5 months of hard work

In a study done in the Netherlands and at Michigan State University, it was noted that

- horses kept in stalls had significantly less bone density compared to horses that experience regular exercise or turn out

In a treadmill study, it was noted that

- short periods of galloping at +43 km/hr (27 mph) resulted in an increase in bone density of 4-5%
- intense exercise is necessary to see positive changes in bone

In a Kentucky Equine Research study, it was noted that

- the horse's bone mineral content was reduced *the moment* a horse was confined to a stall
    - a 5% change was noted over a period of 12 weeks
- plasma calcium and plasma osteocalcin levels drop when horses are confined to a stall, and increase with intense exercise, increasing bone formation

How bones best maintain

- allow time for repair
- encourage normal bone remodelling
    - this can only come from a combination of adequate nutrition, turn out, short duration intense exercise and lay-off to provide time for repair
- normal distal limb circulation is most effective at its evolutionary optimum
    - the horse was designed to be moving long, slow distances on a daily bases (ranging up to 60 km/day)
        - there are no venus valves in the limbs
        - the horse is dependent on motion for the return of circulation to the heart
- restricted exercise creates:
    - stagnation of circulation
        - this results in stocking up
        - this causes an increased incidence of bone remodelling diseases

Contributing factors to lameness developing

- anatomy
    - the result of what we breed
        - conformation
    - the result of how we select
        - we are selecting for the wrong thing, which is typically what can get us the best, most extreme result (best mover, highest jumper) fastest
        - rather, *we need to select for **longevity***
- age
    - the training of skeletally immature horses has a negative impact on soundness
    - the older the horse is, the higher the chances are it will have wear and tear on bones and joints
- shoeing
    - schedules
    - angles

- surfaces
    - overly soft or deep, and overly hard surfaces are both bad
    - moisture levels of surfaces also directly affect soundness
- training methods
    - irregular or inconsistent work
    - ineffective training regimes
        - asking a horse to do work beyond its training and fitness level
        - too much work
        - working too hard, too soon
        - over-conditioning
        - trying to maintain peak fitness for too long
        - not allowing horse to have lay-offs; constant training
    - poor warm up
    - inadequate cool out
- type of work
    - racing and jumping are both very hard on horses
        - racing over fences has a 1.4% fatality rate due to bone breakdown
        - design of fences can influence soundness
    - sports that require quick turns can also influence soundness negatively
- intrinsic individual biomechanics
- management practices
    - feeding practices
    - housing
    - bedding
    - turnout practices
    - footing
- medication abuse
    - working sore horses
- accident/trauma
    - post anesthetic lameness appears spontaneously in 6% of horses undergoing surgery
        - this has been attributed primarily to hypotension and length of anesthetic period

Skeletal system disorders

- Arthritis - DJD, bone spavin, ringbone
- inflammatory joint disease
- bucked shins
- curb

- degenerative suspensory ligament desmitis (DSLD) and suspensory sprans
- fractures
- locked kneecap
- navicular
- osteochondrosis
- sesamoiditis
- splints

Muscles

Some muscles are:

- complex
- simple

There are three types of muscles:

- cardiac
- smooth
- skeletal

Purpose of muscles:

- *skeletal muscles*
    - 700 different skeletal muscles are present in the horse
    - skeletal muscles
        - support and protect the skeleton
        - create posture and movement
        - maintain joint stability
        - control range of motion
        - protect internal organs from trauma
        - contribute to thermoregulation through shivering
- *smooth*
    - found in all internal organs and tissues
    - facilitate processes in the body like blood flow and digestion
    - function automatically due to voluntary or autonomic activity in the brain or nervous system

- *cardiac*
    - make up the heart, which beats about 100 000 times a day
    - fatigue resistant
    - highly specialized
    - striated
    - thick
    - strong
    - coordinate the propulsion of blood into, out of and around the heart
    - function automatically due to voluntary or autonomic activity in the brain or nervous system

Function of muscles:

- *strength*
    - the greatest amount of force a muscle can produce in a single maximal effort
- *power*
    - the rate of force generation
- *endurance*
    - the ability to perform repeated, sub-maximal contractions prior to local fatigue occurring, preventing further contractions

Structure of skeletal muscles

- muscles are made of:
    - 75% water
    - 22% protein
    - 7% lipids and inorganic salts
- these muscles are highly elastic
- they have strong contractile powers
- muscles have three parts:
    - point of origin (anchor)
    - muscle belly
    - point of insertion
- skeletal muscle are made up of several muscle bundles
    - the bundles make up the belly
- bundles are made up of muscle fibres
    - muscle fibres are made up of long slender muscle cells
        - these are made up of two types of protein filament called *myofibrils*

- myofibrils are tiny threadlike filaments found by the thousands in a muscle fibre
- they are parallel to one another
- are able to contract due to actin and myosin
- *myosin* filaments are thicker protein filaments
- *actin* filaments are smaller protein filaments
- a motor nerve impulse triggers a chemical reaction between actin and myosin filaments
- glycogen and triglycerides are stored in the muscles fibres
- these are sources of energy for muscle contractions
- motor nerves control muscular movement
- sensory nerves monitor the amount of stretch and tension in a muscle
- muscles are covered by fascia

  other muscles can attach to fascia
- muscles are supplied with blood vessels
- muscles are enclosed in a sheath called the *epimysium*
- types of muscle fibres:
- every horse has both types, but some breeds have more than others:
- ***slow twitch*** muscles are best suited for aerobic metabolism
- a horse with a lot of these muscle fibres are best suited for aerobic activities like endurance riding
- ***fast twitch***
- the number of these muscle fibres will not change with conditioning
- use anaerobic metabolism to produce contractions of great strength but short-lived energy
- horses with a lot of these muscle fibres are best suited for sports requiring brief, strenuous muscular effort such as jumping and dressage
- an all-round athlete should have a mix of both types of muscle fibres
- all muscles have nerves coming from the brain or spinal cord
- impulses are transmitted to the muscle via the nerves to produce contraction leading to movement

location of muscles

- muscles run from bone to bone across joints
- when the muscles contract, the joints move the bones and movement arises from the joint

Muscles are under voluntary or conscious control

Muscles are divided into two groups:

- *flexor* muscles bend the joints
- *extensor* muscles pull the joint back into position

Other movements of the limbs:

- *adduction*
    - movement toward the median place
- *abduction*
    - muscles only pull, they do not push
    - movement away from the median plane
- *rotation*
    - limited amount around the limb's axis
- many flexor and extensor muscles work in pairs
    - the reciprocating apparatus involves both groups of muscles operating simultaneously
    - this allows the horse to sleep while standing

Muscles only pull, they do not push

- many flexor and extensor muscles work in pairs
- reciprocating apparatus involves both groups of muscles operating simultaneously
- this allows the horse to sleep while standing

Classification:

Skeletal muscles can be classified as either deep muscles or superficial muscles

- *deep muscle*
    - primary function is posture and stability
        - they attach directly to bone
        - they are located close to joints
        - they often have a number of point of origin and insertion
        - they are often responsible for supporting individual joints
        - they have a high number of nerve endings
        - they are more sensitive to postural alignment
- *superficial muscles*
    - primary function is movement
        - they are located between deep muscles and skin
        - they vary in size and shape

- they can be bulky
- they can appear sheet-like
- they are located further away from bones and joints
- they have points of origin and insertion into bone, fascia and other muscles
- the surface of these muscles is palpable through the skin

Skeletal muscles are usually arranged in pairs

- they oppose each other (are antagonists)
- one flexes the joint
- the other extends the joint
- one must be released for the other to contract
- a muscle and its tendon(s) that operate together to cause flexion or extension of a joint are referred to as a flexor unit and an extensor unit

Muscle Contraction

- a muscle may only contract a few or may contract all fibres
- a fibre can only contract fully, not partially
- muscle contractions require energy that is produced from:
- *aerobic metabolism*
- *anaerobic alactic metabolism*
- *anaerobic lactic metabolism*
- each leg muscle has two parts:
- upper part - belly consisting of red muscles with great contracting powers
- lower part - tendon, which is fibrous connective tissues that transmit the action of the
- muscle to the bone
- muscles contract and release
- contraction is a generated process
- release happens when the muscles is not contracting
- when a muscles gets tight or does not release, strain is put on other areas e.g., tendons
- *contraction:* this leads to the muscle pulling a tendon which in turn pulls a bone
- moving the bone results in either flexing or extending a joint
- this happens when the CNS send a signal to the muscles via the nerves, which converts chemical energy into movement

Aerobic metabolism

- aerobic metabolism (energy production) uses:
- oxygen

- glycogen - fuel created primarily from carbohydrates (CHO) and fats (lipids)
- it creates energy to move muscles
- it produces energy at a fairly low rate
- it can be sustained for long periods of time
- examples include endurance riding, hunting, phase B in long format eventing

Anaerobic alactic metabolism

- anaerobic means without oxygen
- alactic means without lactate
- produces energy using:
- creatinine phosphokinase a substance present in limited amounts in muscle cells
- glycogen
- produces a short but intense burst of energy lasting 10-20 seconds
- ends when the muscle's stores of creatinine phosphokinase are exhausted
- energy is used for short bursts of energy in brief, intensive efforts including jumping or a racehorse accelerating out of a starting gate

Anaerobic lactic metabolism

- produces energy without oxygen
- uses glycogen (CHO) as a fuel
- produces lactate (lactic acid), a toxic waste product
- lactate is carried away by the circulatory system
- more builds up than can be carried away so this results in fatigue and a burning sensation
- most strenuous activities that last more than 20 minutes involve anaerobic lactic metabolism

Conditioning:

The effects of conditioning on muscles are:

- conditioning changes:
- the structure of muscle fibres
- the chemical composition of muscle fibres
- muscle growth, or *hypertrophy*, will increase in size and weight
- a fit horse will have 50% of his weight in muscle
- an unfit horse will have 42% of his weight in muscle
- enzyme levels will change as the horse gets fit
- the amount of energy substrates stored in the muscle with change
- *type* of conditioning will affect the muscles:

- endurance work
    - enhances aerobic capacity
    - compromises power and speed of muscle contraction
- sprinting
    - stimulates glycolytic machinery to enhance horse's power and speed

Connective tissues

Connective tissues are most the most widespread and abundant tissues in the body

Together, connective tissues are the:

- tendons
- ligaments
- cartilage

The **function** of connective tissues is to:

- support
- anchor
- connect

Proper nutrition is needed for the connective tissues, including:

- HCL (hydrochloride)
- Chondroitin sulfate
- hyaluronic acid

All contribute both to a healthy bone protein matrix, and also to help support joints, tendons, ligaments, and joint buffer tissues like cartilage

Tendons

Tendons are tough bands of connective tissue made up of a protein called collagen

Purpose:

- attach muscle to bone

Stretch very little

- less elastic than muscle
- more generous than ligaments

Have high levels of strength

At selected points tendons are located within sheaths that allow them to move easily

- tendons are protected by tendon sheath which contains synovial fluid

Classified as:

- *extensor*
  - straightens the leg in flight phase to prepare the leg for the next phase of the stride
    - in the foreleg, the **common digital extensor tendon** (CDET) (also known as deep digital extensor tendon or DDET) runs from its attachments with the muscles above the knee:
      - radial carpal extensor muscle
      - common digital extensor muscle
      - lateral digital extensor muscle
      - lateral ulnar extensor muscle
      - oblique carpal extensor muscle
    - the fibrous *extensor retinaculum* forms the *carpal canal*, and holds the carpal and extensor tendons, vessels and nerves in place over the carpal joint
    - the CDET that runs down the front of the cannon bone and attaches to the front of the coffin bone
- *flexor*
  - flexes or bends the leg causing it to leave the ground
    - in the foreleg, the flexor tendons arise from these muscles above the knee:
      - lateral ulnar muscle
      - descending pectoral muscle
      - transverse pectoral muscle
      - radial carpal flexor muscle
      - ulnar carpal flexor muscle
    - the fibrous *flexor retinaculum* forms the *carpal canal*, and holds the carpal and digital tendons, vessels and nerves in place over the carpal joint
    - the **superficial digit flexor tendon** arises from this
      - it runs along the back of the cannon bone, around the fetlock joint and attaches to the back of the short pastern bone
      - it functions to resist downward motion

- the **deep digital flexor tendon** (DDFT) also arises from this muscle bundle
- it runs down the back of the leg, around the fetlock joint and coffin joint, and attaches to the solar surface of the coffin bone
- some tendons flex multiple joints and extend others
- flexor tendons of the hind limb flex the fetlock, pastern, coffin and extend the hock

Tendon attachment:

- *origin* attaches muscle to bone that are least pliable, flexible and moveable
- *insertion* attaches muscle to bone that are most pliable, flexible and moveable
- these experience the greatest force of their muscle's contractive powers
- this is where stress points form when muscles are worked past recognized acceptable levels of exertion
- tendons attach to bone and cartilage via specialized cells called *Sharpey's fibres*

Ligaments

Tough cords formed of strong, white and yellow fibrous connective tissues

- white fibres are inelastic
- yellow fibres are elastic
- ligament fibres are similar in make-up to the periosteum
- have a poor blood supply so if injured, take a long time to heal
- can stretch to some extent
- rich in nerve endings, making injuries to ligaments painful

Purpose of ligaments:

- surround joints
- support structures
- stabilization of joints, preventing excessive or abnormal range of motion to prevent injury
- connect bone to bone

Four different types of ligament:

- *supporting* or suspending
- e.g., suspensory
- *annular*
- a broad band of ligament that directly pulls on a tendon

- *inter-osseus*
    - ligament between bones like that between the splint and cannon bones
- *funicular*
    - cord-like ligaments that hold bones together like on the spinal column

Ligaments of the upper body:

Nuchal and supraspinous:

- helps support the vertebral column

Intercapital:

- 1-11 ribs
- prevents thoracic disk herniation

Ligaments of the legs:

suspensory

- from back of cannon between splint bones, split into two to attach to sesamoid, continue down to attach to extensors
- purpose:
    - supports fetlock joints
    - braces fetlock joints
- prevents overextension
- the suspensory is a modified muscle
    - contains tendon fibres and residual muscle fibres
        - this allows it to have more give

interosseus

- connects cannon bone to each splint bone
    - in the case of the horse developing a *splint*, this is the ligament that becomes *ossified*
    - *ossified* = takes on calcium or turns to bone

check ligament

- inferior check ligament
- superior check ligament
    - check ligaments 'check' or prevent the tendons from becoming overstretched

proximal and distal sesamoid

- proximal from the radius, attaches to the superficial flexor tendon
- distal from palmar carpal ligament, attaches to the deep digital flexor tendon

plantar

- in the hind leg only, down the lateral side of the tarsus
- attaches to fibula, 4th tarsal and 3rd metatarsal

intersesamoidean

- runs between two sesamoid bones
- a supporting ligament

distal sesamoidean

- runs from seasmoids to two pastern bones
- attaches these bones together
- important in the *stay apparatus*

impar

- between navicular and 3rd phalanx

annular

- around back of fetlock
- attaches to sesamoid
- supports and protects the fetlock

sacrosciatic

- from sacrum and coccygeal vertebrae to the pelvis

Cartilage

Cartilage is

- smooth
- firm
- flexible
- resilient
- capable of withstanding considerable stress and repeated loading

Purpose:

- cushions joints
- covers the articular surface of bones to allow them to move freely
- allows frictionless movement
- helps absorb shock
- provides a matrix in immature bone that absorbs calcium, turning to bone as the horse matures

Cartilage is made up of:

- a glass-like structure containing cells
- the glass-like structure is on the outside of the matrix
- the matrix is made of :
- collagen
- molecules of proteoglycans
- water

Cartilage is typically found

- on the articular surface of bones
- in other places like between the bones of the skull that will eventually fuse

Cartilage has:

- no blood vessels
- limited capacity for repair
- no nerve elements
- no lymphatic system

Cartilage turnover is very rare once the horse reaches maturity

Tendons attach to bone and cartilage via specialized cells called *Sharpey's fibres*

The lateral (collateral) cartilages on either side of the pedal bone help to expand and contract the foot

Respiratory System

Recommended Youtube videos:

- *Respiratory system of the horse -video learning - WizScience.com (5 min.)*
- *Respiratory system: Physical examination of the horse (Beef Elite) - 14 minutes*
- *Advanced Equine Studies - the Horse's Respiratory System DVD (MouseHole Farm)*
- *Equine Respiratory System (Matt Walsh)*

The respiratory system works in concert with the cardiovascular system

The respiratory system is a system composed of two major parts:

- ***lungs***
    - used for oxygen and carbon dioxide exchange
- ***tubes***
    - ancillary
    - serve as a conduit for air to move between the outer environment and the lungs

Respiratory dysfunction is the second leading cause of exercise intolerance and poor performance

The respiratory system is the horse's weak link due to the difficulty (and in some cases, impossibility) of repairing any damage that may occur

Purpose of the Respiratory System

- the function is to exchange oxygen with carbon dioxide
    - oxygen is *inspired* for use by the tissues
    - carbon dioxide is *exhaled* as a waste product
- the cardiovascular system delivers oxygen and nutrients to tissues
- respiration provides oxygen to facilitate metabolism
- it carries off waste
- it has a role in thermoregulation
- it is involved in maintaining the acid-base balance

Divisions of the respiratory tract:

- These divisions are both anatomical and functional
- *Upper respiratory tract*
    - highly complex
    - adapted for exercise
    - airflow is very high
    - the horse is an obligatory nasal breather
        - they cannot breath through their mouth
        - the upper airway system of the horse can become overwhelmed in situations of high temperature and humidity
            - a dog would pant or a human would switch to mouth breathing in this situation but this is not an option for the horse
    - small abnormalities result in a marked decrease in performance
        - 47-49% of cases of poor performance have been attributed to upper respiratory tract issues

- *Lower respiratory tract*
    - where O_2 and CO_2 exchange occurs

Upper Respiratory Tract is made up of:

nose, nasal turbinates, larynx and pharynx

- purpose:
    - regulates temperature and humidity of inspired air
    - phonation
    - protects airways against foreign bodies
- the respiratory tract is lined with a delicate membrane
    - mucus lines the surface of this membrane
    - mucus is moved by cilia toward the front of the nose
        - this is called the *mucociliary blanket*
            - it traps bacteria and foreign irritants
            - it acts as the first line of defence against infections

nares (nostrils)

- can expand greatly during exercise
- has an outer ring of cartilage (*alar cartilage*)
- holds them open when inhaling

nasal passages

- the horse's nasal cavities are longer than those of most other species
- assists in the cold weather warming of air before it reaches the lungs
- 2 conchae on either side = increases the surface area the air is exposed to
- small pocket inside (nasal diverticulum) filters debris with help of hair
- nasal cavity also has a lacrimal duct which drains tears from eyes and out of nose
- nasal passage joins to larynx via pharynx

pharynx

- is 15 cm long in adult
- includes nasopharynx
- protects the entrance to the auditory tubes (oropharynx)
- contains tonsillar tissue (laryngopharynx)

paranasal sinuses

- parallel to nasal pharynx

- air-filled sacs in head
- communicate with the respiratory tract
- reduces the weight of the head

soft palate

- soft palate blocks off the pharynx from the mouth
    - except when swallowing
- prevents the horse from inhaling food into lungs
- does not allow the horse to use the mouth to breath
    - this means the horse cannot pant like a dog in order to thermo-regulate
- soft palate is a dynamic structure
    - can readily displace dorsally
        - for some, only displaces when subject to high airway pressure
        - soft palate displacement can occur only intermittently

gutteral pouch

- unique part of the respiratory system
- equalizes air pressure on the tympanic membrane
- has a capacity of 300-500 ml
- fills with air when the horse swallows or breaths

larynx

- between the pharynx and the trachea
- allows horse to vocalize
- prevents aspiration of food
- controls the volume of air inhaled

trachea

- a tube that carries air into lungs
- 75-80 cm long
- held permanently open by 50-60 'C' shaped cartilaginous rings 5-6 cm in diameter
- at the bifurcation of the trachea are two bronchi, which start the respiratory tract

Lower Respiratory Tract is made up of:

bronchi, bronchioles, lungs, alveoli

purpose:

- site of oxygen and carbon dioxide exchange bronchi

- the right one is slightly larger
- they divide and become smaller in diameter to form the bronchial tree

bronchiole

- arise from segmental bronchi
- are smaller in diameter
- have no cartilaginous support
- ultimately branch out to become even smaller alveoli

lungs

- made up of the stretchy, spongy material made up of bronchi, bronchioles and alveoli
- left and right lobes lie in a pleural sac
- only attached by roots to *mediastinum*
- are fairly free within the thoracic cavity
- left lobe (apical lobe):
- has cranial and caudal lobes
- cranial lobes not subdivided
- right lobe (caudal lobe):
- has cranial, caudal and accessory lobes
- middle lobe is absent
- larger

alveoli

- oxygen in the inhaled air is delivered to the alveoli
- there are very thin walls between oxygen-laden air in lungs and blood vessels containing red blood cells (RBC) that will carry oxygen to tissues
- oxygen is now in close proximity to blood in the capillaries
- oxygen diffuses across alveolar and capillary walls into the blood, then attaches to RBC
- CO_2 diffuses out similarly

Blood is carried to the lungs via the pulmonary artery

- blood is oxygenated at the alveoli
- it is returned to the heart by the pulmonary artery

The respiratory system is also influenced by the expansion and contraction of the ribcage

- repetitive ribcage action can be positively or negatively influenced by axions of muscle around the ribcage and diaphragm

Diaphragm

- a muscular sheet of tissue that divides the lungs from the abdominal cavity
- the principle muscle of inspiration
- contracts away from the thoracic cavity
- aids in lung expansion
- decreases pressure
- pulls air into lungs
- when fully expanded can reach back to the 16th rib
- responsible for locomotor respiratory coupling:
    - this is the adaptation that helps the horse to conserve energy and breath more efficiently when at hard work
        - while cantering and galloping, the horses breaths in rhythm with the stride
        - in the *first phase of the stride*, the head rises, while the gut contents slide back
        - in the *second phase of the stride*, the head lowers and the gut contents slide forward, helping to expel air by pushing against the diaphragm which in turn pushes against the lungs
    - the diaphragm act as a bellows
    - it helps to conserve energy and push air out of and pull air into the lungs

Capacities

From a study at Cornell:

- tracheal pressures in the horse range from -4905 Pa to 274.68 Pa
    - (Pa = pascals, a measurement of force per unit area; one pa = one Newton per sq/m)
- airflow velocities are recorded at up to 80 L per second (64-79 average)
    - (comparatively, a hairdryer is 40 L/s)
- maximal oxygen uptake is 160 ml/kg/min
- a horse's working uptake is 40X greater than their oxygen uptake at rest
    - (a human's is 6-8X greater than at rest)
- the limit to *minute volume* is achieved during maximal exercise at 200+ bpm (beats per minute)
    - at 200+ bpm, blood leaving the lungs might not carry enough oxygen to service tissues, resulting in arterial hypoxia
- the respiratory system can deliver at up to 180 bpm
    - past this, it will eventually start to falter

Respiratory Response to Exercise

At the onset of exercise

- respiratory rate rises rapidly
- tidal volume rises rapidly

At canter and gallop, respiratory rate couples with the stride rate

- this is referred to as locomotor respiratory coupling
    - the horse uses his head and neck like a piston
        - this acts to cause the ribs to expand on the upward phase and relax on the down phase of the stride
    - on the upward phase of the stride, all the internal organs shift back
    - inspiration starts when the leading foreleg leaves the ground
    - on the downhill phase of the stride, the internal organs shift forward against the diaphragm
    - the diaphragm acts as a bellows
- when work stops, respiratory rate decreases as it is no longer driven by the locomotor forces

Problems with the respiratory system:

- respiratory tract infections (EHV and strangles)
- Laryngeal lymphoid hyperplasia (aka pimples)
- Dorsal displacement of the soft palate
    - creates expiratory obstruction
        - in the top two most important causes of poor performance associated with the respiratory tract
    - present in 10-20% of all horses
    - can appear intermittently
    - results in:
        - reduced *minute volume* = amount of gas exhaled per minute
        - reduced *tidal volume =* amount of gas inhaled and exhaled in one respiratory cycle
        - reduced *oxygen consumption*
- Nasopharyngeal collapse
- Laryngeal hemiplegia
    - 5-8% of Thoroughbred racehorses suffer from this
    - when it affects the left side, it is referred to as *roaring*

- in the top two most important causes of poor performance associated with the respiratory tract
- Epiglottic entrapment
- 1-2% of all horses are affected
- Exercise Induced Pulmonary Hemorhaging (aka EIPH, Bleeder)
- 60% of all working horses, 87% of Standardbreds and 97% of Thoroughbreds suffer from this
- Pneumonia
- Pleuritis
- Inflammatory Airway Disease (IAD)
- 50% of thoroughbreds and Standardbreds are affected
- In a treadmill study done on horses with no abnormalities at rest but poor performance and/or abnormal respiratory noises that were used in competition where exercise was submaximal:
- 77% were diagnosed with dynamic airway obstruction
- 54% with soft palate dysfunction
- 38% with laryngeal collapse
- 24% axial deviation of aryepiglottic folds
- 18% pharyngeal wall collapse
- enforced poll flexion was found to be a contributing factor in 24% of cases
- in some cases, psychological stress was thought to have worsened the situation

Cardiovascular System

Recommended Youtube videos:

- *Circulatory System of the horse -video learning-WizScience.com*
- *Cardiovascular System (Beef Elite)*

The ***key element to the cardiovascular system is the*** **heart**, a muscular pump which is about 1% of the horse's body mass (0.6% in drafts; 1.4% in thoroughbreds)

- the horse has a Type B heart
- comparatively, humans have a Type A heart
- this is based on electrical conduction systems of flight animals versus predators
- the horse has an enormous ability for athletic first response to go from resting state to a heart rate of 200+ bpm in an extremely short time
- the spleen is another adaptation that allows for this extreme response

In cases of poor performance, 22% have been attributed to cardiac issues

In addition to the heart, the cardiovascular system also involves the:

- blood
- blood vessels
- arteries
- veins
- capillaries
- spleen

Purpose

- pumps blood through the whole system
- the circulatory system also helps to dissipate heat by diverting blood to the skin surface during exercise
- circulates out into the horse's body:
    - oxygen
    - nutrients
        - energy substrates:
            - glucose
            - fatty acids
    - lymph
    - hormones
    - antibodies
- this constant flow and supply of blood through organs, tissues and cells ensures
    - good health
    - tissue repair
    - cell production
    - cell renewal
- provides a burst of energy via oxygen delivery to muscles during times of stress and great exertion
- helps with the removal of waste products
    - lactate
    - carbon dioxide (CO_2)
    - water (H_2O)

Two main types of circulation:

systemic circulation

- the flow of oxygenated blood from the heart to the rest of the horse's body
- the return of deoxygenated blood to the heart that is ready for the removal of carbon dioxide

pulmonary circulation

- the flow of deoxygenated blood from the heart to the lungs for the removal of carbon dioxide
- where the blood re-oxygenates itself prior to the return out to the body

Parts of the Circulatory System:

Heart

- average horse's heart weighs 3.6 kg (7.9 lb.)
    - can be twice that size (or more - see pp. 54-55)
- grows until the age of 4
    - can also increase slightly in response to conditioning
- heart size does not necessary correlate to the size of the horse
- oxygenated blood arrives via Pulmonary Vein directly from the lungs
- the heart is split into 4 chambers
    - blood first enters the *left atrium*
    - passes through the one way *bicuspid valve*
    - next goes into the *left ventrical*
    - exits the heart and travels to the major organs and tissues delivering oxygenated blood
        - waste products are then collected for the return trip
    - blood is re-oxygenated and enters the heart via the *aorta*
    - from there goes to the *right atrium*
    - then through *tricuspid valve* to the *right ventricle*
    - from the right ventricle deoxygenated blood goes to the *lungs* and becomes oxygenated

blood vessels

- consist of veins, arteries and capillaries
- used to transport blood around the body to and from heart

veins

- transport blood and tissues from body *to heart*
- most veins are satellites or companions of the arteries
- veins are different than arteries
    - contain a larger volume of blood
    - have thinner walls
    - usually have valves to prevent blood flowing backward

- smaller veins are known as venules
  - capillaries unite to form larger vessels called venules that joint to form veins
  - venules branch out and link with capillaries
- veins flow slowly with no pulse
- veins have low blood pressure
- blood is squeezed along by contractions of the skeletal muscles alongside them
- blood from the intestines are carried by the hepatic portal vein
  - this vessel is unlike others as it transports organ to organ, not organ to heart and vice versa

arteries

- transport oxygenated blood *from heart* to body
  - the Pulmonary Artery is the exception as it carries blood from the heart to the lungs
- are under high pressure
- have a pulse
- oxygenated blood from arteries is a bright red

capillaries

- join veins and arteries together
- within thin walls of capilllaries the exchange of oxygen and carbon dioxide takes place
- capillaries can become larger and greater in number with conditioning

frog

- the frog plays an important role in circulation in the body by returning blood back to the heart
- it helps force blood from the foot back to the heart via concussive pressure

spleen

- a reservoir for extra red blood cells
- releases red blood cells into the body during times of stress or exercise to provide more oxygen
- found on the left side of the body

Purpose of the spleen

- removes damaged/diseased white blood cells
- removes damaged RBC
- holds extra blood cells, releasing them during exertion, increasing blood volume and amount of oxygen to tissues

The spleen's participation in the cardiovascular system is what helps horses become such tremendous athletes

- when the horse is relaxed, the spleen is relaxed and expanded to its largest size
    - it covers the area from the 9th rib to the point of the hip
        - this covers the majority of the left side of the abdomen
- can hold 30 L of blood
- under excitement and stress, the spleen contracts
    - this releases 25 L of blood into vessels
- RBC are then available to muscles
    - this doubles the oxygen carrying capacity
    - this improves aerobic capabilities and athletic efficiency within seconds

Heart rate

The horse's average resting heart rate (HR) is 36-40

- foals have a higher resting heart rate than adult horses
- the HR range for an adult horse is 20-250+ bpm (at maximal exercise)

As exercise increases, the respiratory rate and heart rate increases

- this delivers more oxygen and nutrients to the brain
- average HR at walk - 80 bpm
- average HR at trot - 130 bpm
- average HR at canter - 180 bpm
- average HR at gallop - 240 bpm

HR drops significantly 15-30 seconds after exercise stops

HR can also increase with:

- anxiety
- pain
- dehydration
- anemia
- fever

Blood pressure

Horse's blood pressure is typically 120/70

- horses rarely become hypertensive (*they do not get high blood pressure*)
- they also do not develop:
    - arthrosclerosis
    - plaque in the vessels
    - *cardiac infarction* (heart attack)
        - most horses that are said to die of heart attacks actually die of aortic rupture
- horses can get *hypotension* (low blood pressure) due to:
    - dehydration
    - colic
    - blood loss
    - *sepsis* (infection)

Capillary refill

- capillary refill time (CRT) is the time taken for normal colour to return to an external capillary bed after pressure (as from a finger) is applied
- CRT should take *no more than 2 seconds*
- this is usually checked on the horse's gums
- prolonged refill time is an indicator of shock, dehydration, or decreased peripheral perfusion

Blood

- the average 450 kg horse has 34 L (9 gallons) of blood in it (can have up to 40 L)
- this is about 8% of the horse's weight

Blood is composed of:

red blood cells (RBC) aka erythrocytes

- made in bone marrow
- have a lifespan of 100-120 days
- contain hemoglobin
- purpose of RBC:
    - iron containing proteins called hemoglobin bind oxygen for transport to vital organs and tissues
    - transportation of oxygen is the primary function of the RBC
    - remove carbon dioxide from tissues and take it to lungs
    - transport hormones and antibodies
    - transport lymph fluid from issues

- remove waste products such as lactic acid, urea, and dead blood cells
- transport nutrients
- regulate temperatures
- 30-40% of RBCs = *packed cell volume (PCV)*
- PCV = the measurement of the cellular portion of the blood as a percentage of the blood volume
- PCV decreases if the horse loses blood or has anemia
- when PCV increases, water in the bloodstream is less, leading to dehydration

white blood cells (WBC) aka leukocytes

- the infantry cells of the immune system
- manufactured in the spleen
- renewed every 10 days
- two main groups:
- *granulocytes*, that include:
- *basophils* that fight allergic reactions
- *neutrophils* that fight bacterial and fungal infections
- *eosinophils* that fight parasitic infections
- *agranulocytes*
- *lymphocytes* that produce anitbodies, monocytes and macrophage cells that help to remove foreign bodies and fight infection
- transportation to site of infections
- typically the composition is 55% neutrophils, 35% lymphocytes, 5% monocytes, 4% eosinophils, and 1% basophils

platelets

- are specialized cells formed in bone marrow
- the purpose is :
- blood clotting
- helping to control blood flow
- how it works:
- contact with air (after a cut occurs) triggers a reaction where platelets quickly divide and act with the protein Fibrinogen to form Fibrin
- this covers the cut and forms a blood clot to halt blood flow
- Fibrin dries with air contact and becomes a scab

plasma

- a pale yellow fluid that platelets, RBC and WBCs are suspended in
- contributes to greatest volume of blood

- contains:
    - water
    - proteins
    - antibodies
    - dissolved minerals (electrolytes)
    - vitamins
    - clotting factors
    - hormones
    - salts
    - sugar

Cardiovascular capacity

- The heart and blood vessels together contain on average 34 L (9 US gallons) of blood in a 450 kg (990 lb. horse = 76 ml/kg (1.2 oz/lb), or 3 500 cc
- It takes about 40 seconds for the blood to make a complete circuit through the horse's system
- A measurement of the cellular portion of the blood as a percentage of the blood volume is called the packed cell volume (PCV) which is usually 30-40% in the resting horse
- plasma protein can also be measured to determine if the horse is dehydrated
    - if PCV is higher than 50% and plasma protein is higher than 8.5 g/dl for longer than 30 minutes after exercise, the horse is in danger
- maximal heart rate is 220-280

Maximal oxygen consumption and heart size are more important predictors of performance for distance horse because energy consumption is mainly aerobic

- *stroke volume* = amount of blood pumped with each beat
    - can increase 33% with exercise
- multiply the heart rate X stroke volume = *cardiac output*
    - cardiac output = total amount of blood pumped by the heart at any given time

Cardiovascular Response to Exercise

- at rest
    - 15% of the horse's blood is being circulated to the body
- during strenuous exercise
    - 85% of the horse's blood is being circulated to the muscles

metabolic activity determines blood flow

- higher activity = higher blood flow

heart rate while working

- horses will have an anticipatory rise in their heart rate during saddling prior to exercise
    - 40-50 bpm in older saddle horses
    - 70-90 bpm in young thoroughbreds
- with the onset of exercise, horses experience a rapid rise in HR
    - with a slow warm up, the HR will first overshoot and then stabilize within 2-3 minutes
    - the size of the overshoot and the HR at stabilization depends on:
        - horse's fitness
        - level of intensity of work
            - with a rapid introduction into sustained hard work (*skipping the warm up*), the HR does not overshoot and *does not stabilize*
- heavy demands are made on limb muscles during locomotion
    - there is a linear relationship between speed and heart rate when horses gallop at a steady speed on flat ground at speeds of 350-700 m/m (13-26 mph)
- red blood cells are stored in the spleen and released on demand due to:
    - stress
    - hard work
        - because of this, horses suffer less from altitude changes as they can just release blood from the spleen
- during very hard work , where a horse is exercising maximally for a long time:
    - more blood is sent to the skin during the cooling process
    - dehydration becomes a factor
    - plasma is lost in the process
        - catch 22: blood cools the horse, but loss of plasma through dehydration results in a loss of oxygen-carrying capacity to fuel tissues
- at heart rates below 140 m/m, psychogenic factors affect heart rate:
    - if the horse spooks, the heart rate rises
- the horse adapts to cardiovascular conditioning demands rapidly
    - conversely, adaptation to musculo-skeletal demands occur much more slowly
- as fitness improves:
    - HR and cardiac output rates decrease during work
    - maximal HR stays the same
    - ability to consume oxygen improves
        - the CV system becomes more efficient in the delivery of oxygen to muscles
        - the ability of muscles to extract oxygen from blood is better
        - the capillarization of muscles increases
            - this takes 3-4 months
- it is important to use sport specific conditioning as this will best prepare your horse for the demands of his discipline

- When high intensity work ceases
    - there is a rapid deceleration of the horse's heart rate immediately
        - the fitter the horse, the faster the horse's heart rate returns to normal
    - there is a rapid deceleration of the horse's respiratory rate immediately
    - the horse's internal temperature will continue to rise for 10 min.
        - *this is why, during cool out, you will check heart rate and respiratory recovery, but your final check will always be a hand on the chest to feel that the horse's core temperature has returned to normal*

Factors Affecting Heart Efficiency

The respiratory system requires a strong circulatory system and vice versa

- The two have a special relationship

The Pearson product-moment correlation coefficient (a measure of strength and direction in the linear relationship between two variables) shows a link between oxygen uptake and echocardigraphic measures

Measurements of heart size that do have a correlation with dynamic function are:

- internal diameter of the ventricles
    - limits how much blood is stored and pumped each beat
- thickness of the ventricular muscles
    - determines the strength of the contractions

Heart score

- this is a measure of ventricular width
- previously, this was taken by measuring the ventricular width of an EKG by averaging three separate EKG leads
- today, this measure is taken more commonly as a direct measure by ultrasound

Trivia

(should not be used for testing as this has not yet been definitively proven - but it's still interesting!):

X Factor - this is a long-standing theory (that has yet to be scientifically proven or peer reviewed) in which a single mutation in a gene on the X chromosome results in a larger than average heart

The X factor is believed to be found in some lines of the thoroughbred breed

- heart for the average horse is 3.2 kg (7 lbs)
- however, some exceptional racehorses have been noted to have much larger hearts:

- Eclipse's and Pharlap's heart sizes - 6.4 kg (14 lb)
- Sham - 8.2 kg (18 lb)
- Secretariat - 10 kg (22 lb)
- this is equivalent to a car having a larger engine
- larger engine = more horsepower
- Pocohontas was the original mare who is believed to be homozygous for the X factor
- with this theory, this helps to explain why Secretariat was not a great sire of winners, but was a great mare sire (grandfather of winners, as this trait is passed on by the mother)
- the X factor is believed to be found in 4 major thoroughbred lines:
- Princequillo
- War Admiral
- Blue Larkspur
- Mahmoud

Digestive System

Recommended Youtube videos:

- *3D Horse Digestion Guide (Purina Mills TV)*
- *The Horse's Digestive System (Dengie Horse Feeds)*
- *The Equine Digestive System (Hy Gain Feeds)*
- *Balanced Horse Feeds Equine Digestive System Dissection HD (GRAPHIC CONTENT-autopsy)*

The horses' digestive system falls between that of ruminant and non-ruminant

- the horse is a non-ruminant herbivore

The horse's digestive systems is designed for continuous grazing of grass forages

It is divided up into the:

- foregut
- mouth (including lips)
- teeth (incisors and molars)
- tongue
- oesophagus
- stomach
- small intestine

- hindgut
    - cecum
    - large colon
    - small colon
    - rectum
    - anus

Accessory organs include:

- salivary glands
- liver
- pancreas

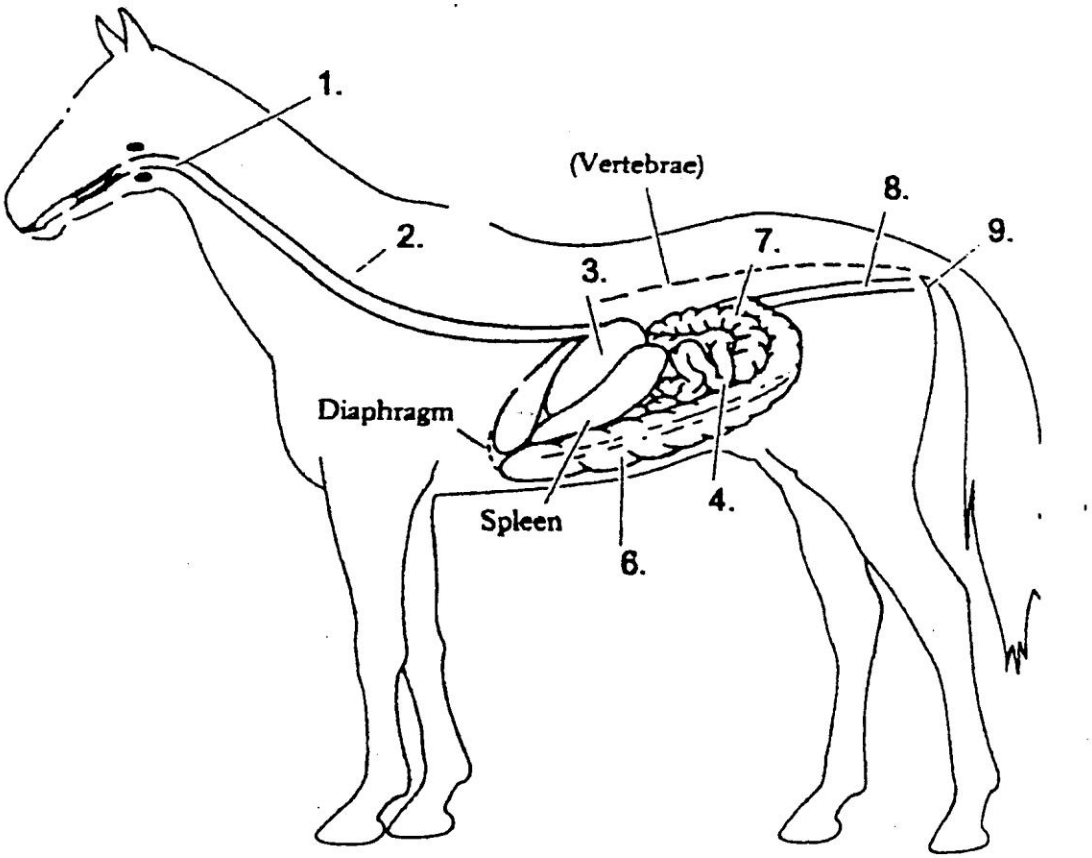
The Foregut

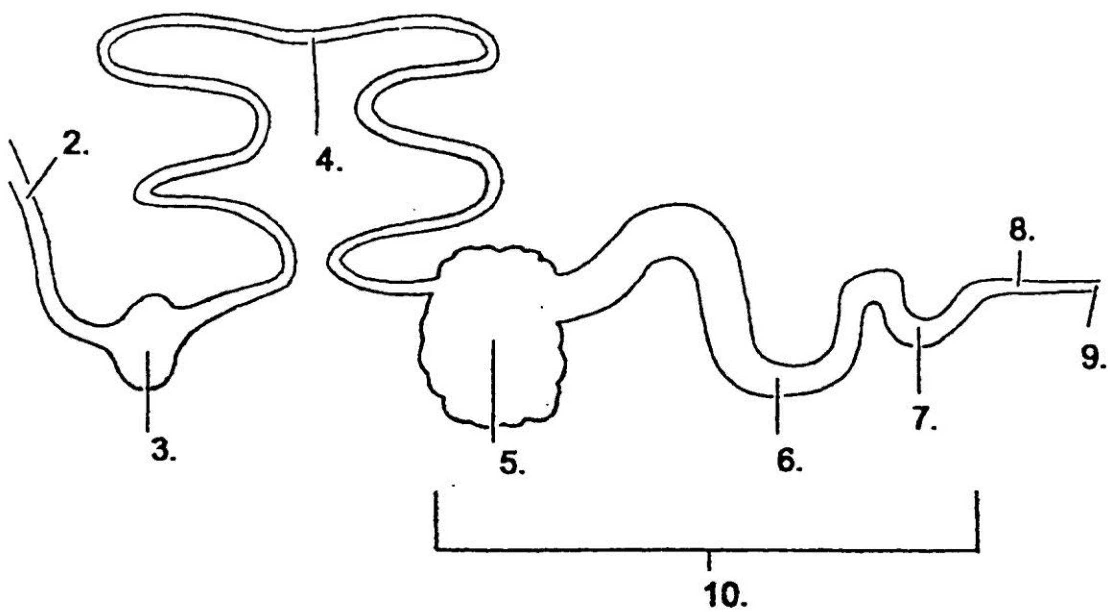
- the foregut from the mouth to the small intestine is similar to that of humans
- all true digestion is by enzymatic digestion
    - this takes place in the foregut
        - the foregut is the site of 52-58% of the crude protein digestion

close to 100% of all soluble carbohydrate digestion (not including fibre)

The foregut is comprised of:

- The Mouth
    - *lips*
        - bring food into mouth
        - select to avoid foreign matter (rocks, wire, etc.)
    - *incisor teeth*
        - bite or cut grasses
    - *tongue*
        - acts as a conveyor belt to move food toward the back of the mouth
    - *molar teeth*
        - chew and grind food
        - the average horse will take 60 000 jaw sweeps a day when grazing, but far less if confined to a stall
- oesophagus
    - aka gullet
    - 1.5 m long in a mature horse
    - uses one-way *peristalsis* (muscular contractions) and gravity to move food to stomach





- stomach
- the capacity of the stomach is 8-15 L
- the horse has the second smallest stomach of any farm animal

- that is about 8% of the gastrointestinal (GI) system
- emptying time of the stomach is about 12-20 minutes
- the stomach is U shaped
- it has three main sections
  - caecus region
  - fundic region
  - pyloric region
- the bottom 2/3 of the stomach is coated with a protective mucous layer
  - the top 1/3 is not coated and therefore subject to ulcer development
  - the division between these two sections is demarcated by the *margo plicatus*
- muscular contractions of the stomach and the addition of digestive juices help with the digestive process
- the stomach and small intestine can handle an almost continuous flow of food
- small intestine
  - made up of the:
    - duodenum
    - jejunum
    - ileum
  - the capacity of the small intestine is about 68 L
    - it is 21 m long
- this makes up about 30% of the GI tract
  - the rate of passage along the small intestine is about 30 cm (1 ft)/min.
- protein absorption takes place here
  - proteins are broken down into amino acids
- carbohydrate digestion begins
  - starches and sugars are broken down

Large intestine

- bacterial or microbial digestion of fibre occurs in the:
  - cecum
  - colon
- large quantities of volatile fatty acids (VFA) are produced through fermentation
  - these are then absorbed and passed onto the liver
    - they are then converted to glucose
- food can go from the mouth to the cecum in about 1.5 hours

Large Intestine is comprised of:

- Cecum
- Large Colon

- Small Colon

The Cecum

- is adapted to extract nutrition from the fibre of forage
- the cecum has a capacity of 28-36 L
- comprises 62% of the entire gut
- 7 m long
- 140-150 L volume
- it is about 15% of the GI tract
- 1.2 m long
- is a blind sac

large colon

- 86 L
- 38% of the GI tract
- 3-3.6 m long
- consists of left and right ventral colons and dorsal colon

small colon

- 16 L
- 9% of the GI tract
- 3-3.6 m long
- diameter of 10 cm

rectum

- is a holding tank for the formation of manure boluses

anus

- where manure is expelled

Lymphatic System

The lymphatic system is a circulatory system that is the primary defense against disease and the negative effect of injuries

The horse has twice as many lymph vessels as blood vessels

The lymph system

- transports lymphatic fluid
- collects excess fluid
- collects waste products

The lymph system originates in the peripheral body tissues and organs furthest from the heart

- plasma constituents exude through the walls of the capillaries then are transported into blood vessels
- lymph nodes and glands act as filters
- larger lymph vessels have valves to prevent lymph from flowing backward
- they trap harmful toxins, preventing them from reaching the heart

Toxins include:

- waste products
- lactic acids
- salts
- proteins from fluids in the body tissues

Lymph flow:

- at the heart, the lymph fluid is drained through two ducts
    - one on the left side of the heart
    - one on the right side of the heart
- there is a continuous flow of lymph
    - lymph flow is slow
    - since there is no organ like the heart to drive lymph, it is dependent on the body to keep flowing
- lymph works three ways:
    - Muscle, tendon, ligament, respiratory, digestive, and cardiovascular activity all contribute
        - involuntary contractions of skeletal muscles on lymph vessels causes fluid to be pushed through
        - with every inhalation, the thoracic cavity contracts, which pulls lymph fluid through vessels to the heart
        - tissue fluid leaving arterioles creates pressure on lymph vessels, pushing fluid through

Nervous System

The Central Nervous System (CNS) originates in the brain

- it runs through the neck and back vertebrae

Composed of

- cerebrum
- cerebellum
- midbrain (includes cranial nerves and brain stem)
- spinal cord
    - specialized tissues called meninges cover the brain and spinal cord

The Peripheral Nervous System (PNS)

- radiates from neck and back vertebrae housing sensory and motor nerves

Also houses the Autonomic Nervous System (ANS)

- this system operates involuntarily
- it ensures all life preserving automatic responses are performed (i.e., breathing)

The brain

- it is a common misconception that the equine brain is the size of a walnut
    - in fact, the equine brain is closer to the size of a grapefruit or two human fists
        - it weighs approximately 400-700 g
        - it is 0.1% of the horse's body weight
    - the horse has a smaller brain to body size ratio than man
        - the brain is 2% of body weight in humans
- there are many similarities in structure between the human and equine brain
    - differences include:
        - the equine brain is designed for analyzing information from the environment
        - the human brain is designed more for fine motor skills and language development
        - the cerebellum of the horse is larger comparatively than that found in humans, allowing the horse to specialize in:
            - sensory perception
            - coordination
            - motor control
- horses have the ability to
    - learn faster than humans

- retain the information for the rest of their lives
- score extremely high on spatial discrimination tests

There are two main types of nerves

- motor nerves
    - regulate movement
- sensory nerves
    - register sensation

When a horse is tired, stimulation from nerve impulses will be

- weak
- nearly absent
    - these can cause the horse to *'break out'* (into a sweat)after being cooled out after a hard work

Urinary System

Is comprised of the:

- kidneys
- ureters
- bladder
- urethra

Purpose:

- aids the respiratory and digestive systems in eliminating metabolic waste
    - contains the products of nitrogen and sulfur metabolism, inorganic salts and pigments
- maintain electrolyte and acid-base balance
- maintains water balance

All under the active influence of the endocrine system

Volume:

- the average horse will produce 1.4-8 L (1.5-8.5 quarts) of urine daily
- amount produced depends on:
    - quantity of water consumed
    - type of feed
    - amount of work being done

- physiological condition of the horse
- environmental temperature

Integumentary system

The integumentary system involves the skin, hooves and hair

- the skin is the largest organ in the body
- it comprised 12-24% of the horse's body weight
- the condition of the skin and hair coat is a general indicator of health

Purpose:

- skin, hair and hooves serve as a barrier to external agents
- skin and hooves protect against trauma
- skin and hair provides sensory information
- skin provides flexible support of internal structures
- skin and hooves control water loss
- skin, hooves and hair protect against excessive radiation
- skin aids in synthesizing vitamin D
- skin provides immunologic responses
- skin aids in regulation of blood pressure
- skin and hair are important in the control of body temperature
- the hair coat can help cool the horse in the summer, and the winter coat helps to keep the horse warm
- heat is generated by muscles immediately underneath the skin
- heat is dissipated through the skin and by the evaporation of sweat
- skin excretes waste products
- sweating
- changes in blood flow
- erection of hairs
- skin helps to rid the body of flies and other external flying insects
- hooves aid in weight bearing and movement

Parts of skin

- **dermis**
- the middle layer
- dense fibrous (collagenous) tissue
- supports and nourishes epidermis and skin appendages

- blood vessels supplying the epidermis are located in the dermis
- contains fat deposits
- contains the sensory nerves
- secretes collagen and elastin
- **epidermis**
    - the outer layer
    - the epidermis is the thickest in large animals like the horse
    - it is a stratified squamous eptithelium
    - composed of several layers of cells:
        - highly cellular tissue that has flat, horny surface cells
        - there are multiple layers of cells, each with specific functions
            - **keratinocytes**:
            - provides a protective layer that is constantly being replaced in a process called *keratinization*
            - these are the cells that make up the **hooves** and **hair**
            - new skin cells are created near the base of the epidermis and migrate up, producing a compact layer of dead skin cells
            - these keep fluids, electrolytes and nutrients in, while keeping infectious and noxious agents out
            - factors affecting rate of cell replacement include:
                - nutrition
                - hormones
                - tissue factors
                - immune cells in skin
                - genetics
                - disease
                - inflammation
            - **melanocytes**:
            - produces hair and skin pigment
            - production is controlled by hormones and genetics
            - protects cells from the damaging rays of the sun
            - **Langerhans cells**:
            - part of the immune system
            - damaged by UV lights and (glucocorticoids) anti-inflammatory drugs
            - **Merkel cells**:
            - associated with sensory organs, providing animals with sensory information
    - this tissue contains the hair follicle and hair bulb matrix
- **subcutaneous**
    - the innermost layer

- epidermis blends into *subcutis* to attach skin to underlying structures
- subcutis is loose connective tissue containing fat

Basement membrane:

- this is a layer of skin at the base of the epidermis
- it connects the dermis to the epidermis
- it serves as a protective barrier between the dermis and the epidermis

Skin contains:

- apocrine (sweat) glands
- helps regulate body temperature
- sweating takes place constantly but is usually imperceptible
- increased activity stimulates the blood vessels to generate more sweat
- sweating results in response to certain chemicals in the blood
- sebaceous (oil) glands
- secrete sebum (skin oil)
- keep skin:
- soft
- moist
- pliable
- gives hair its sheen
- has some antimicrobial properties
- blood vessels
- sensory nerves
- detect pressure
- pain
- temperature
- panniculus muscle
- allows the horse to twitch its skin to remove flies and shiver to create heat
- hair and hooves grow from skin
- hair:
- protects skin from damage and from UV rays
- helps regulate body temperature by cooling skin when it is hot
- in cold weather, aids in heat conservation
- hair grows from hair follicles, which includes the papilla (root), hair shaft, and erector pili muscles that stand hair up
- hooves:
- an important part of the structural support of the body
- help to protect the inner parts of the foot

These structures are horny outgrowths of epidermal tissue:

- ergot
- chestnuts

Immune System

- defends the body against disease-causing agents
- designed to protect a horse from invading pathogens
- very complex
- if the immune system is compromised, it increases the risk of developing a disease
    - stressed
    - lack of proper nutrients
    - old
    - very young
- antigen
    - any foreign substance that stimulates an antibody response
- antibodies (Ab) aka immunoglobulin (lg)
    - large Y shaped proteins produced by plasma cells to identify, engage in combat against and neutralize specific pathogens (antigens)

Excretory System

- eliminates waste from the body
- refer to the urinary system and the latter part of the digestive system for more information

Reproductive System

- the reproductive system involves the sex organs required for the production of offspring
- the estrous cycle in most mares typically normalizes between late April and August
    - this is referred to as the *breeding season*
- the mare's estrous cycle is 21 days long (+/- 3 days)
    - estrus usually lasts for 6 days but can be between 4-10 days long
- the pituitary gland is stimulated by longer daylight in the spring to release Follicle-stimulating Hormone (FSH)
    - also involved is:
        - estrogen

- lutenizing hormone
- progesterone
- prostaglandin
- a pregnant mare will foal 340 days after breeding (+/- 20 days)
- puberty is reached at 12-18 months
- at this point it is advisable to keep colts separate from mares and fillies
- feeding a mare well will have a positive impact on her reproductive abilities

Endocrine System

- provides chemical connections within the body using hormones
- the endocrine system is a collection of small organs
- purpose:
- produce hormones that travel through the bloodstream to distant sites in the body
- regulates:
- metabolism
- growth
- reproduction
- seating
- stress response
- directed by:
- signals in the brain
- response to outside stimulus
- hormone production is tempered by:
- positive and negative feedback loops
- this increases and decreases production respectively
- pituitary
- located on the floor of the calvaria (skull)
- connected to hypothalamus
- metabolism, reproduction, etc.
- adrenocorticosteroid (ACTH)
- acts on adrenal glanda to stimulate production of steroids especially cortisol in response to flesh
- Thyroid Stimulatin Hormone (TSH)
- metabolism
- growth
- Growth Hormone (GH)
- growth

- Anti-diuretic hormone (ADH aka vasopressin)
    - signals kidneys to retain sodium
- adrenal glands
    - metabolism
    - behaviour
    - stress
    - regulates protein, fat and mineral metabolism
    - anti-inflammatory effect on the immune system
    - produce catecholemines, responsible for fight or flight response
- kidney partially acts as endocrine gland
- thyroid glands
    - thyroxine (T_4)
        - young horse growth
        - oxygen metabolism
        - regulated metabolism
        - protein synthesis and breakdown
        - increases body heat production
        - sets basal metabolic rate
    - calcitonin
        - involved with calcium homeostasis
- parathyroid glands
    - parathyroid hormones
        - regulate calcium levels in the body
- pancreas
    - produces insulin and glucogon
    - modifies blood glucose levels

References

"Anatomy & Kinesiology: Body Position & Joint Movement" www.philipmelillo.com/anatomy_bodyposition.htm

"Anatomy, Physiology & Reproduction in the Mare" www.omafra.gov.on/ca/english/livestock/horses/facts/10-099.htm

Bailey, C. J., et al "Flat, hurdle and steeple racing risk factors for musculoskeletal injury" 23 Apr., 2010, Equine Veterinary Journal, Volume 30, Issue 6, pp. 498-503, Nov. 1998

"Behind the Bit: the Stifle: the mother of all joints" www.behindthebitblog.com/2008/10/stfle-mother-of-all-joints.html

Bentz, Bradford "Digestion in the Horse" http://www.thehorse.com/articles/33228/digestion-in-the-horse

Berro, Leslie " The Equine Musculoskeletal System" (2002) www.equisite.com

"Blood Circulation" www.eqinekingdom.com/data/.../horse.../circulation_system.html

"The Brain of the Horse" www.straightnesstraining.com/The Horse/Mind

Brama, P. A. J., et al "Functional Adaptation of equine articular cartilage: the formation of regional biomechanical characteristics up to age of year" Equine Veterinary Journal onlinelibrary.wiley.com/dov10.2746/042516400776563626.pdf

Bramlage, Larry " Training and Musculoskeletal System" Rood and Riddle Equine Hospital, https: www.grayson-jockeyclub.org/resources/bramlage.pdf

Byars, Doug "Comparing Horses and Humans" www.thehorse.com Oct. 8, 2008

"Cardinal Planes and Axes of Movement" www.physio-pedia.com/Cardinal_Planes_and_Axes_of_Movement

"Circulatory system of the horse" Wikipedia

Clarkson, Neil "Understanding Horse Intelligence" horsetalk.co.nz-features

Clayton, Hilary M. Conditioning Sport Horses Sport Horse Publications, Saskatoon, 1991

Cubitt, Tanya "The Horse's Digestive System" http://www.hygain.com.au/horses-digestive-system

Deffenbaugh, Claudia "Tendons, Ligaments, Joints & the Skeletal System," Middle California Region USPC Upper Level Horse Management Education pdf

Desjardins, Marc R. and Hurtig, Mark B., "Cartilage healing: a review with emphasis on the equine model" www.ncbi.nlm.gov/pmc/articles/PMC1480835

"Digestive Function of Horses" http://arbl.cvvmbs.colostate.edu/hbooks/pathphys/digestion/herbivores/horses.html

"Equine Circulatory System Vet Horse First Aid" Equestrian and Horse, https://www.equestrianandhorse.com/care/veterinary/circulatory-system.html

"Equine Digestive Tract Structure and Function" https://omafra.gov.on.ca/english/livestock/horses/facts/info_dgest.htm

www.equineholistictraining.co.uk

Franklin, S. H., et al "Videoendoscope evaluation of the upper respiratory tract in 93 sport horses during exercise testing on a high-speed treadmill" Equine Veterinary Journal, 2006 Wiley Online Library

Garreau, Jennifer "Equine Skeletal System" (Sept. 1, 2010) Examiner.com/article/equine-skeletal-system

Geor, Ray "Are Your Horse's Bones Tough Enough?" www.thehorse.com

Gore, Thomas, et al <u>Horse Owner's Veterinary Handbook Third Edition</u> Howell Book House, New Jersey, 2008

Hanson, Russell R. et al "Components of the musculoskeletal system of the horse," Merck Vet Manual (2011) www.merckvetmanual.com/components_of_the_musculoskeletal_system_of_the_horse.html

Harris, Susan E. <u>The United States Pony Club Manual of Horsemanship B, HA, A Levels</u> Howell Book House, USA, 1996

Higgins, Gillian "Horses Inside Out - The Anatomy of Muscles Part 1"

"The Horse's Brain" Equine Behavioural Resources Centre ebhrc.com/article2.html

"Joint Structure and Function" www.thehorse.com/articles/synovial_joints_and_how_they_work

Jones, Steven M. "Digestive System of the Horse and Feeding Management" University of Arkansas, United States Department of Agriculture, and County Governments Cooperating http://www.uaex.edu

"List of Systems of the Human Body" Wikipedia

Marcella, Kenneth "Inside the Equine Stifle" (June 1, 2006) DVM 360 magazine www.veterinarynews.dvm360.com/inside-equine-stifle?rel=canonical

Martin, Ben et al "Examination of the Upper Respiratory Tract" University of Pennsylvania Vet School 2001

Murray, R. C., et al "Identification of Risk Factors for lameness in dressage horses" The Veterinary Journal ,Vol. 184, Issue 1, Apr. 2010 pp.27-36 Science Direct Journals

"Muscular System of the horse" Wikipedia

McIllwraith, Wayne "Anatomy & physiology of equine joints" www.csu-cvmbs.colostateedu/academics/.../equine/equinejoints.aspx

Norton, Joan "The Equine Circulatory System" www.equimed.com/health-centres/general.../the-equine-circulatory-system

Norton, Joan, "Your Horse's Endocrine System" www.equimed.com/health-centres/general.../your-horse's-endocrine-system

Oke, Stacey "The Equine Respiratory System" Feb. 1, 2010, www.thehorse.com/articles/24958/the-equine-respiratory-system

"Parts of the Nervous System in Horses" http://merckvetmanual.com/pethealth/horse_disorders_and_diseasease/brain_spinal_cord...

Pratt-Phillips, Shannon "The Equine Digestive System" http://www.thehorse.com/articles/32922/the-equine-digestive-system

"Providing Nutritional Support for the Equine Skeletal System" (Feb. 14, 2011) www.bloodhorse.com/horse.../providing-nutritional-support-for-the-equine-skeletal-system

Richey, Meghan T. et al "Equine Post-anesthetic Lameness: a Retrospective Study" (29 Feb., 2008) Veterinary Surgery, Wiley Online Library

Rose, Mary The Horsemaster's Notebook Threshold Books, London, 1988

Ross, M. W. Diagnosis and Management of Lameness in the Horse books.google.com

Sellnow, Les "Anatomy and Physiology Part 11: of Blood and Breath" www.thehorse.com/.../anatomy-and-physiology-part-11-of-blood-and-breath

"Skeletal system of the horse" Wikipedia

Smythe, R. H. The Horse - Structure and Movement J. A. Allen and Co., London, 1967

"Structure of the Skin in Horses" www.merckvetmanual.com/.../horse.../skin...horses/structure_of_the_skin_n_horses.html

"Respiratory System" Wikivet https://www.thehorse.com/topics/horse..../respiratory-system