Animal Locomotion for Animators

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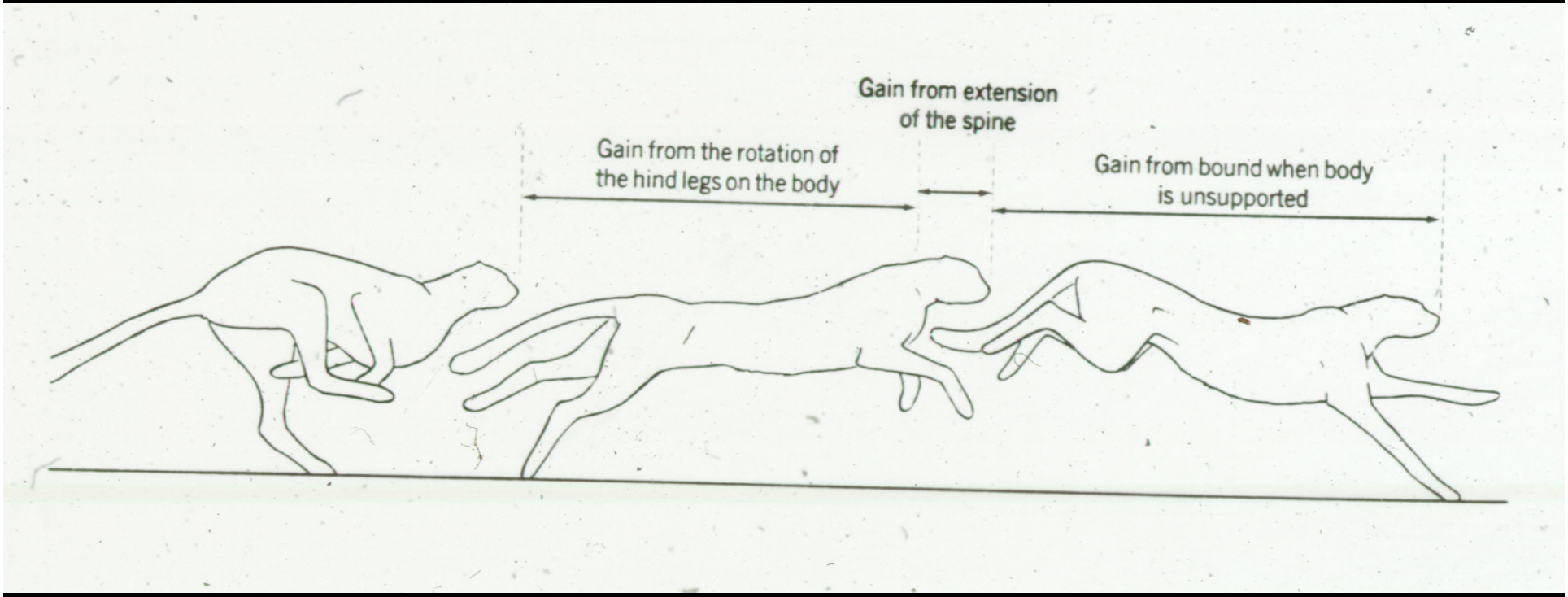
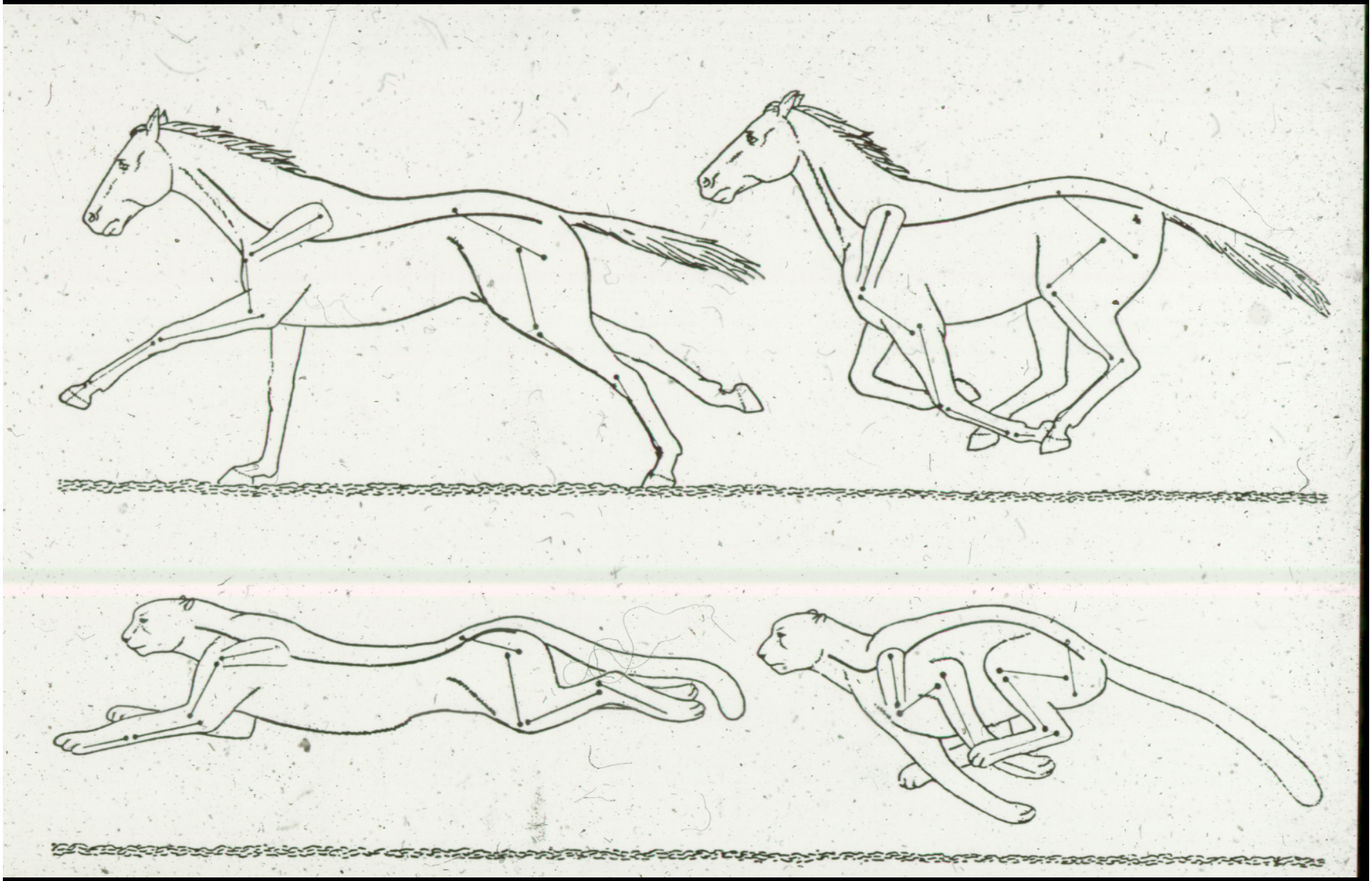
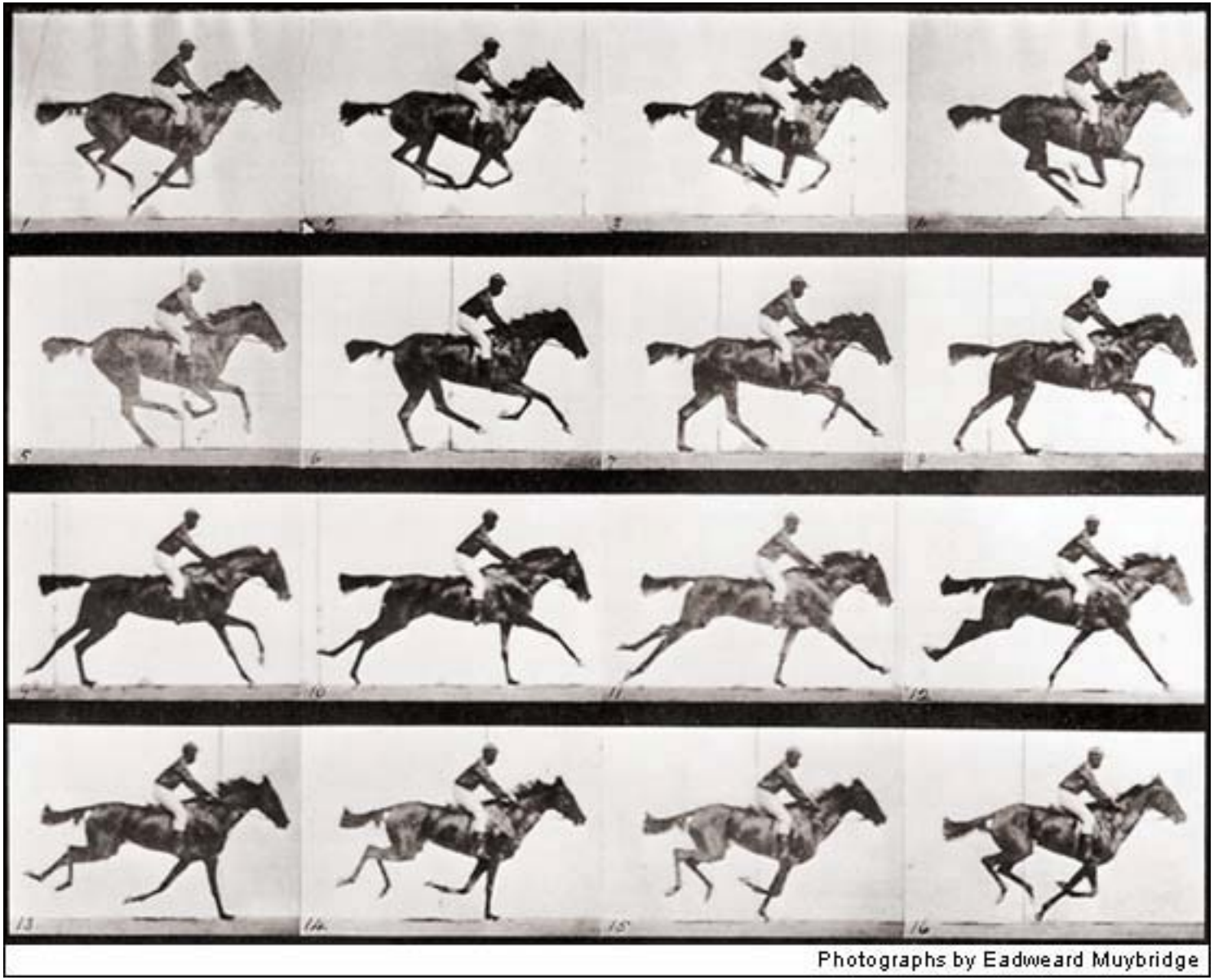
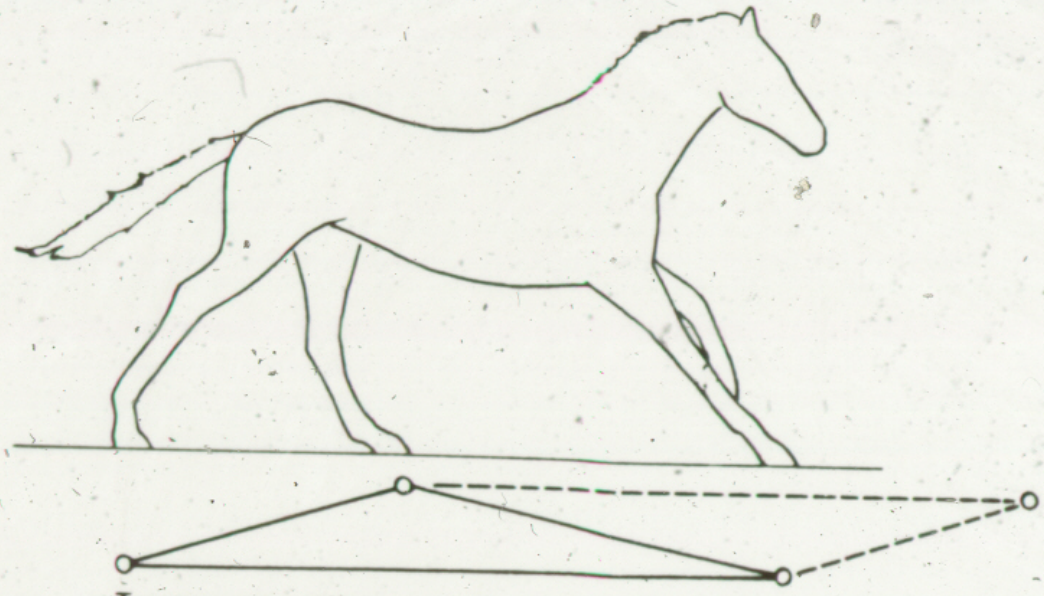

Gain from extension
of the spine
Gain from the rotation of
the hind legs on the body
Gain from bound when body
is unsupported

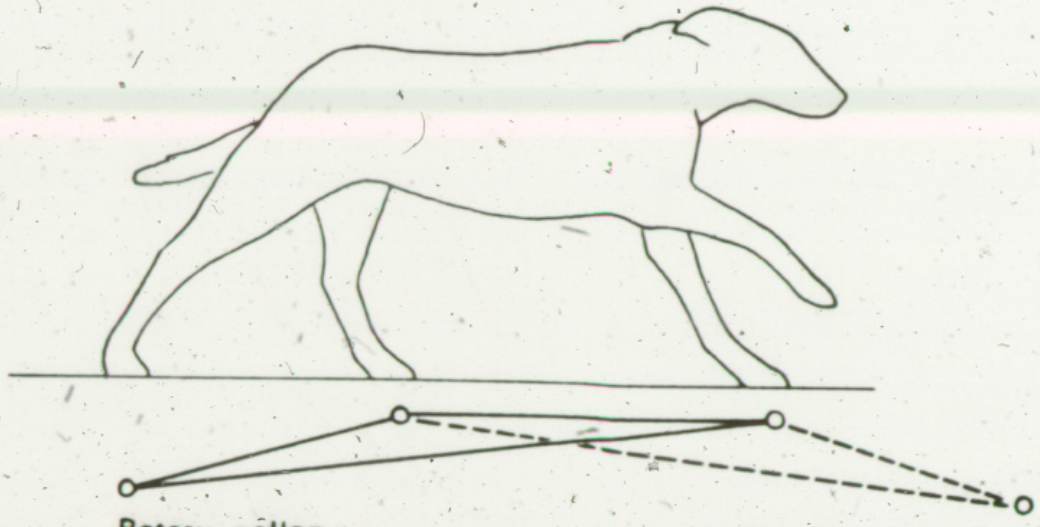




1878 – Eadweard Muybridge, hired by railroad baron Leland Stanford to understand horse locomotion and gait, simultaneously invents gait analysis and the technological basis of motion pictures.



Transverse gallop



Rotary gallop

Mammalian Locomotion

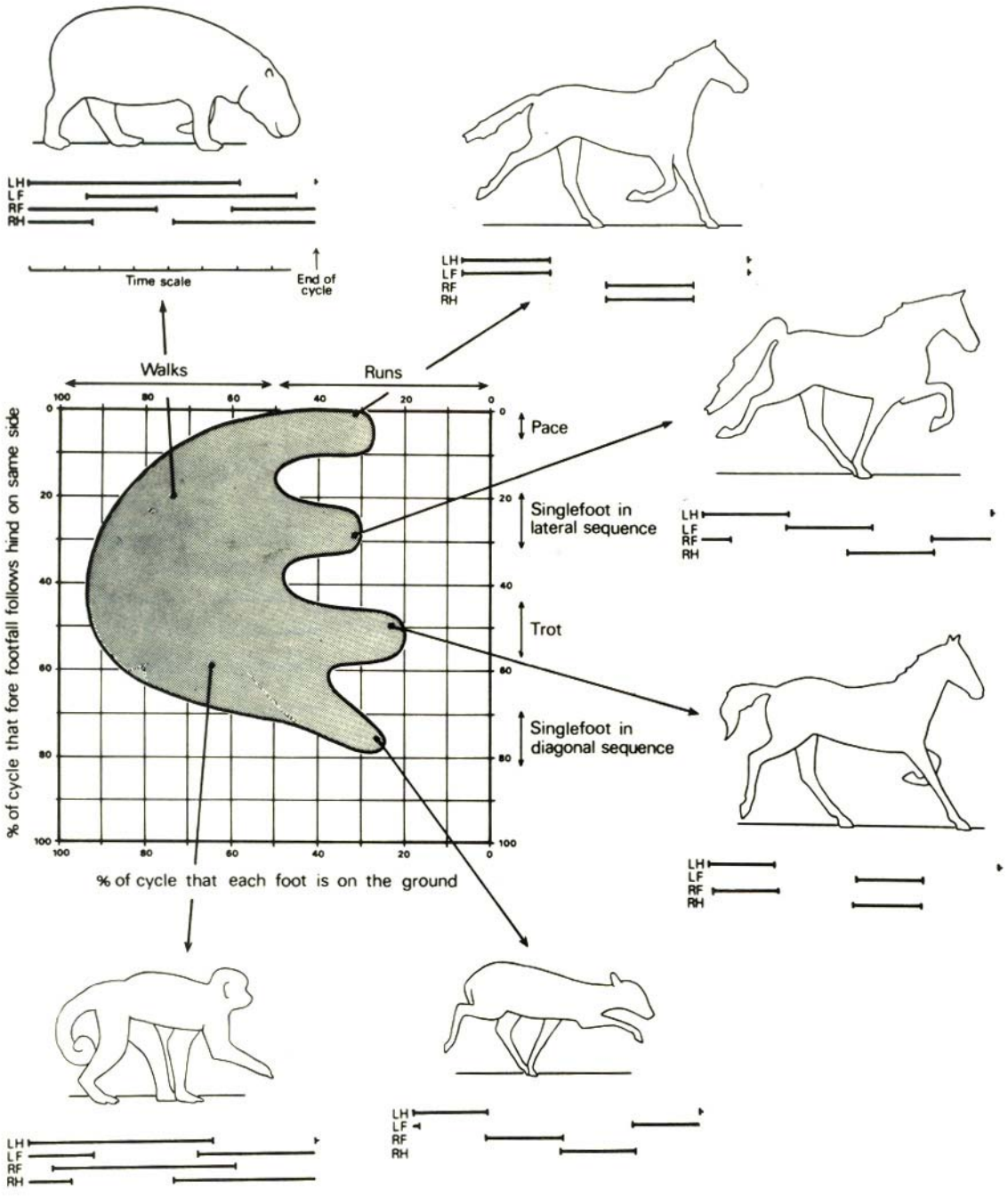
Walking
And
Unusual Walks

SYMMETRICAL GAITS:

Gaits are said to be SYMMETRICAL when the foot falls of two feet of any given pair are evenly spaced in time.

Generally, natural symmetrical gaits are associated with slower speeds and when at least one or more of the four feet are on the ground at any given moment.

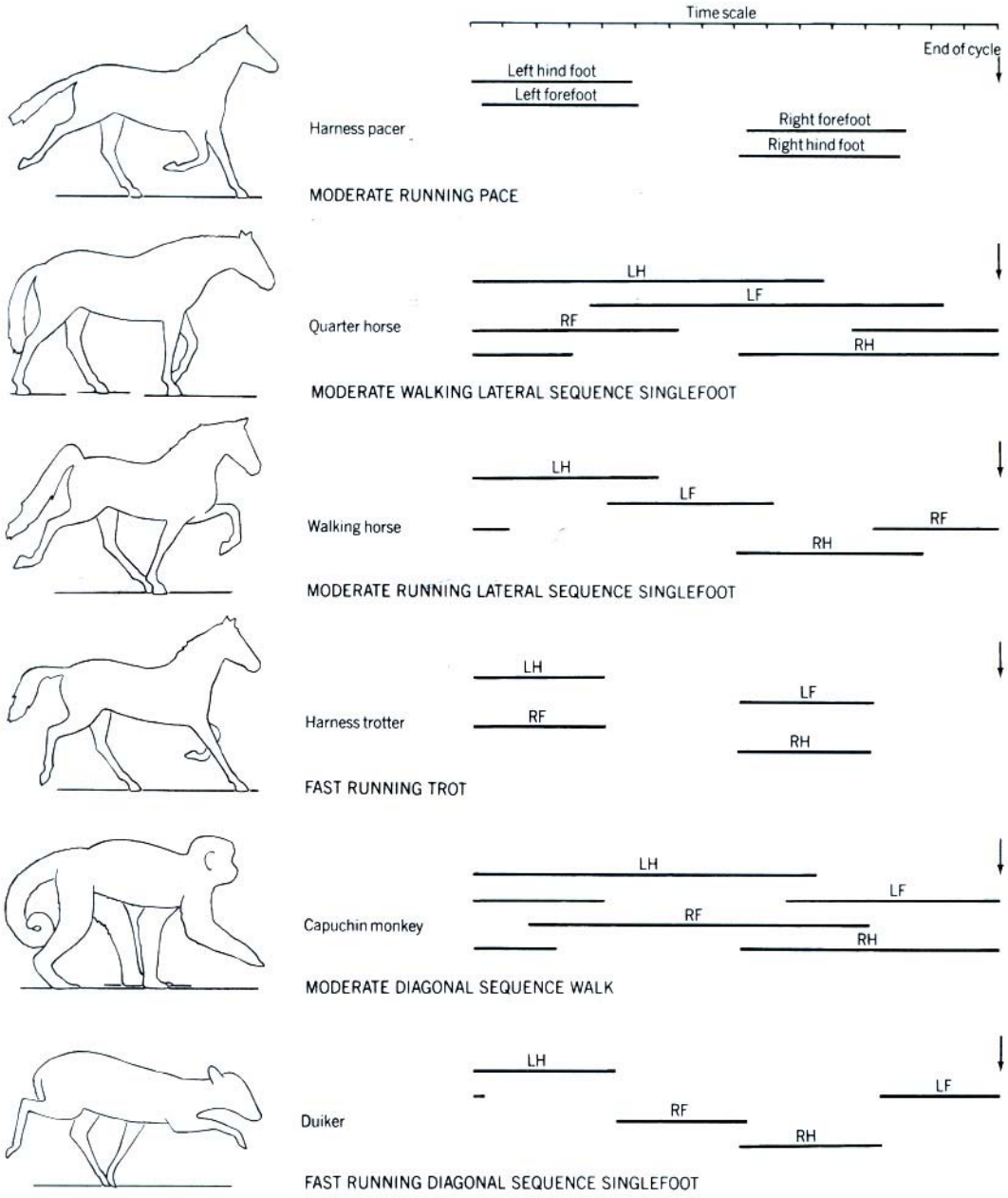
Walk



Pace

Lateral Trot

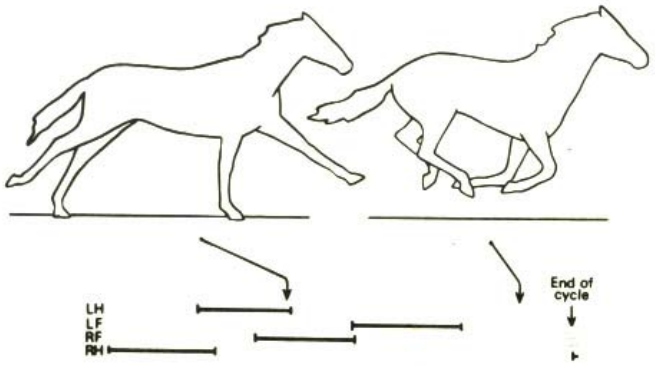
(Normal = “Diagonal” Trot


Time scale
End of cycle
Left hind foot
Left forefoot
Right forefoot
Right hind foot
Harness pacer
MODERATE RUNNING PACE
LH
LF
RF
RH
Quarter horse
MODERATE WALKING LATERAL SEQUENCE SINGLEFOOT
LH
LF
RF
RH
Walking horse
MODERATE RUNNING LATERAL SEQUENCE SINGLEFOOT
LH
LF
RF
RH
Harness trotter
FAST RUNNING TROT
LH
LF
RF
RH
Capuchin monkey
MODERATE DIAGONAL SEQUENCE WALK
LH
LF
RF
RH
Duiker
FAST RUNNING DIAGONAL SEQUENCE SINGLEFOOT

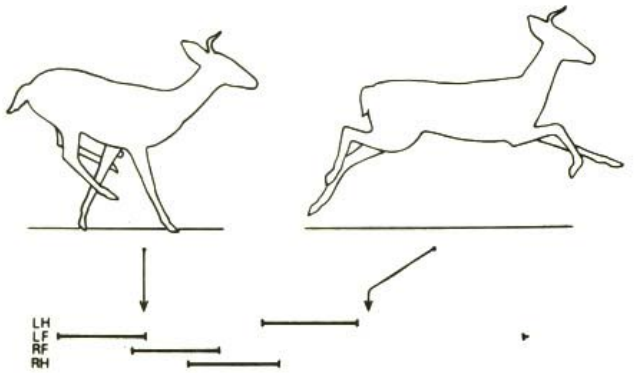
ASYMMETRICAL GAITS:

Gaits are said to be ASYMMETRICAL when the foot falls of two feet of any given pair are unevenly spaced in time.

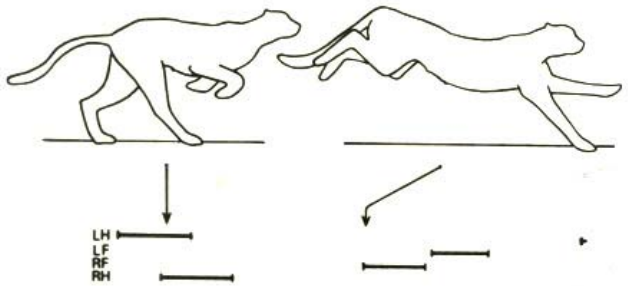
Generally, asymmetrical gaits increase the length of stride by introducing periods of suspension when all feet are off the ground.



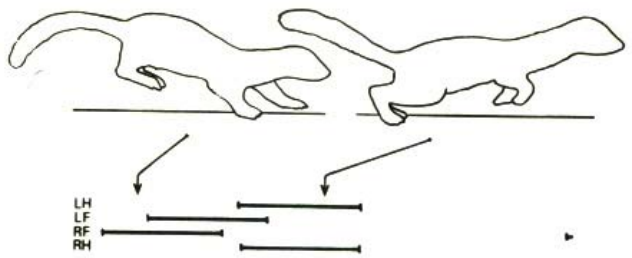
HORSE: Transverse gallop with gathered suspension



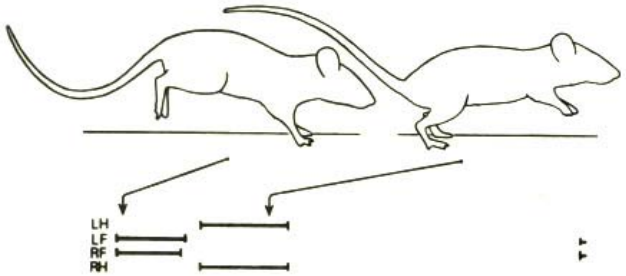
DEER: Rotary gallop with extended suspension



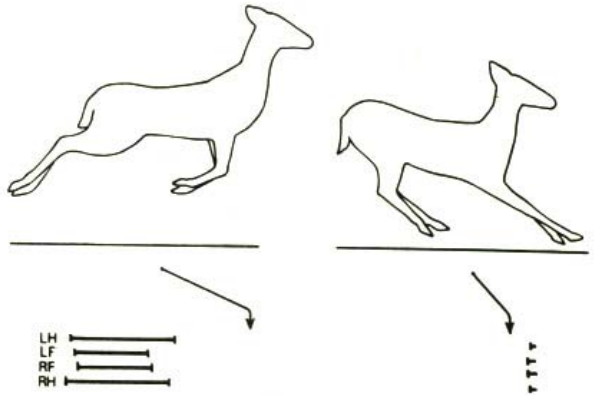
CHEETAH: Rotary gallop with both suspensions



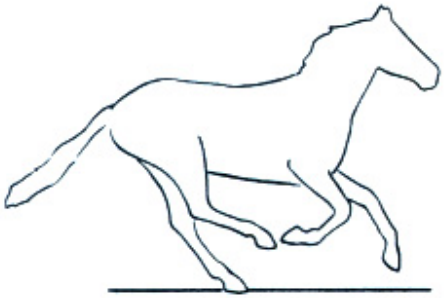
WEASEL: Half bound with extended suspension



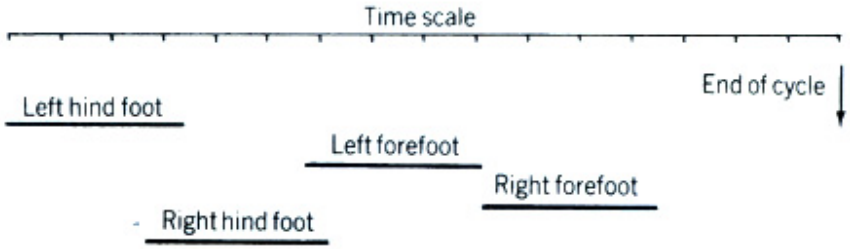
HOUSE MOUSE: Bound



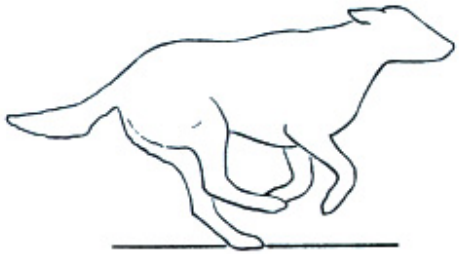
DEER: Pronk



Race horse

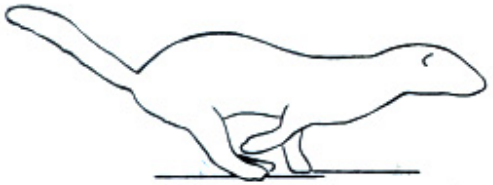


FAST GALLOP: SAME LEAD FORE AND HIND; SUSPENSION IN GATHERED POSITION



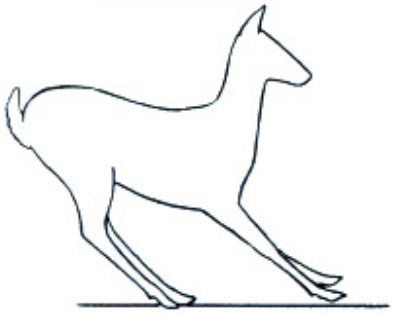
Shepherd dog

MODERATE GALLOP: DIFFERENT LEAD FORE AND HIND; SUSPENSION IN GATHERED POSITION



Weasel

HALFBOUND: ONLY FOREFEET HAVE LEAD; SUSPENSION IN EXTENDED POSITION



Mule deer

PRONK: ALL FEET MOVE IN UNISON

WALKING

•In four-legged mammals, a walk is usually characterized by having some stage of the step-cycle including a three-point under support – or triangular under support. In other words, at some point three feet are touching the ground. (Human walking is when right and left feet are both in contact at the same time during some part of the step-cycle.

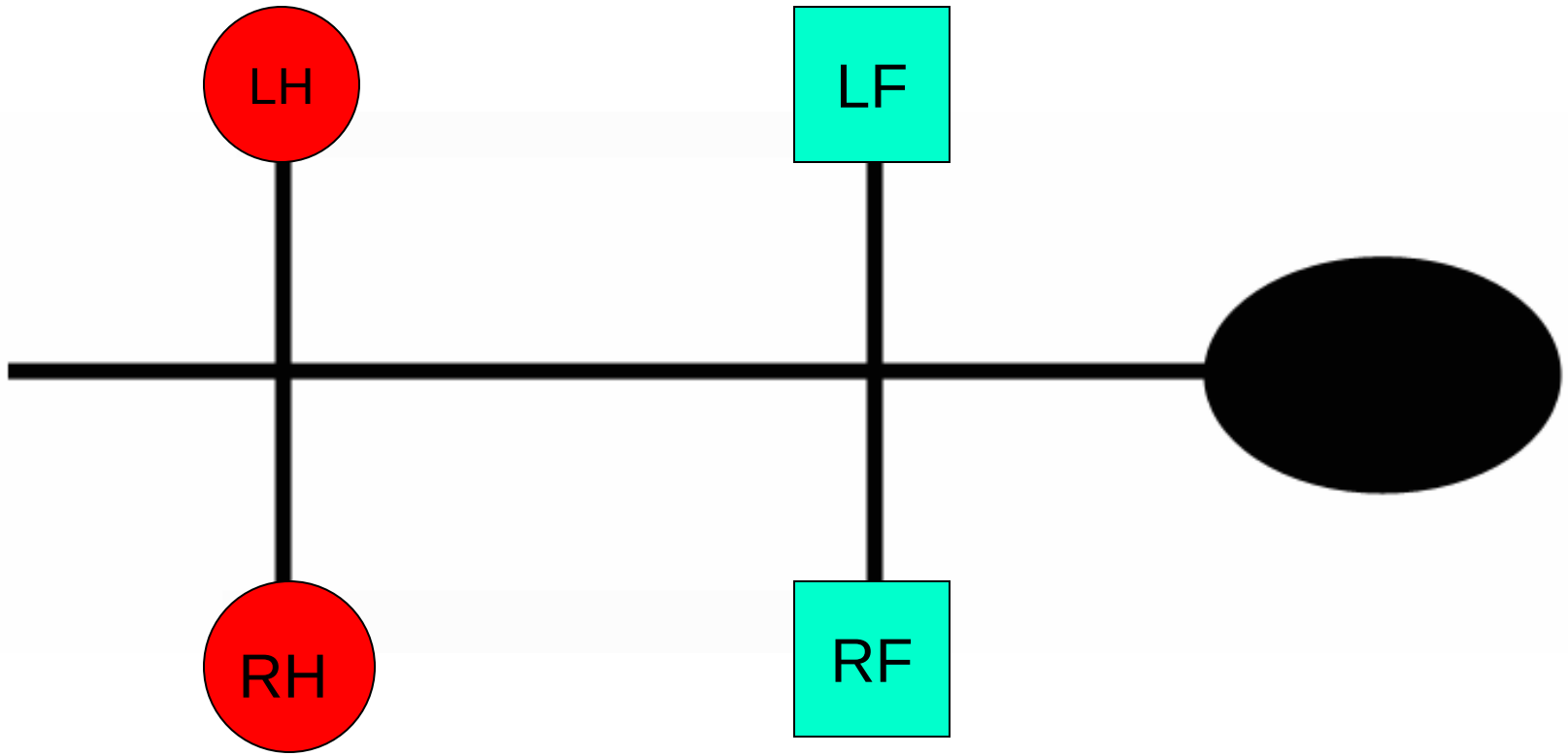
•Walking is considered the slowest of the quardupedal gaits.

•The standard mammalian walk is remarkably consistent from species to species – from mouse to mammoth: footfall sequence in order: Right Hind, Right Front, Left Hind, Left Front; Repeat.

CONVENTIONS

Left Hind

Left Front



Right Hind

Right Front

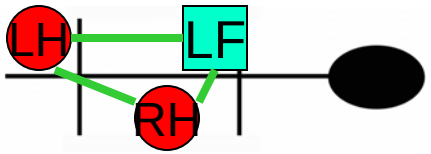
NORMAL/STANDARD WALK

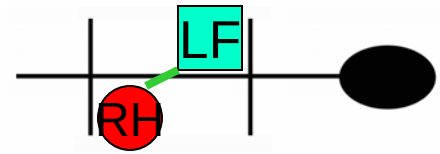
•The standard mammalian walk is remarkably consistent from species to species – footfall sequence in order: Right Hind, Right Front, Left Hind, Left Front; Repeat.

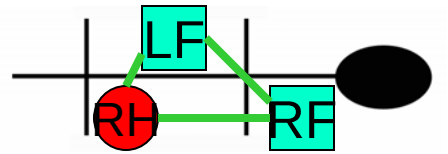
•In four-legged mammals, a walk is usually characterized by having some stage of the step-cycle including a three-point under support – or triangular under support. In other words, at some point three feet are touching the ground.

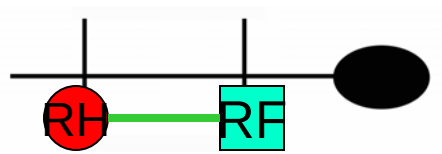
STANDARD MAMMALIAN QUADRUPEDAL WALK

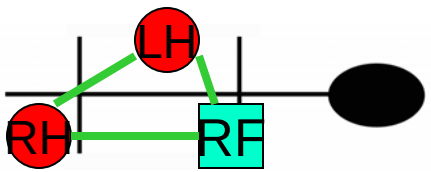


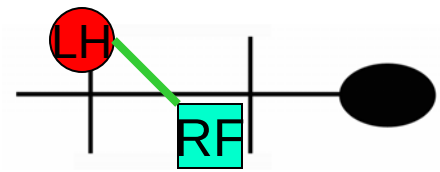


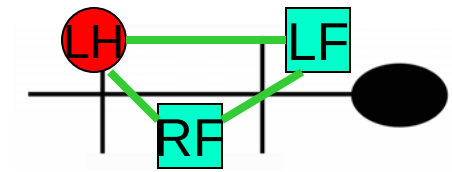


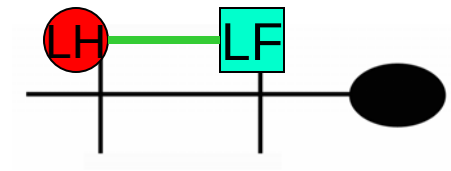












THE AMBLE

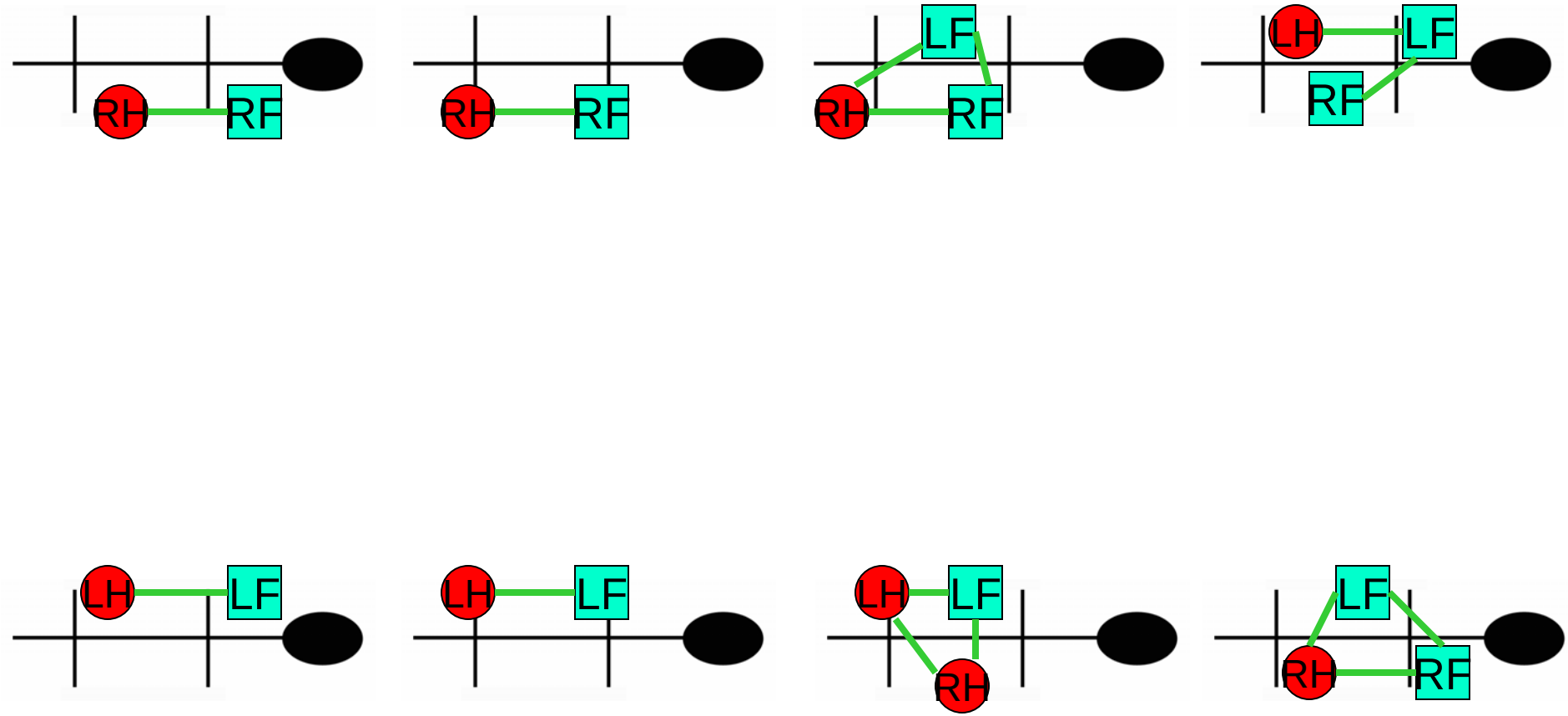
- The AMBLE is essentially a “sped-up” walk.

- It is a gait that is usually transitional between a normal walk and a trot.

- This sped up walk is what animals do when constrained to walking but when they want to move fast (think Stitch skittering along when he first gets to Lilo’s house).

- This sped up walk is what animals do when they are very large (e.g. elephants) and can’t truly trot.

THE AMBLE



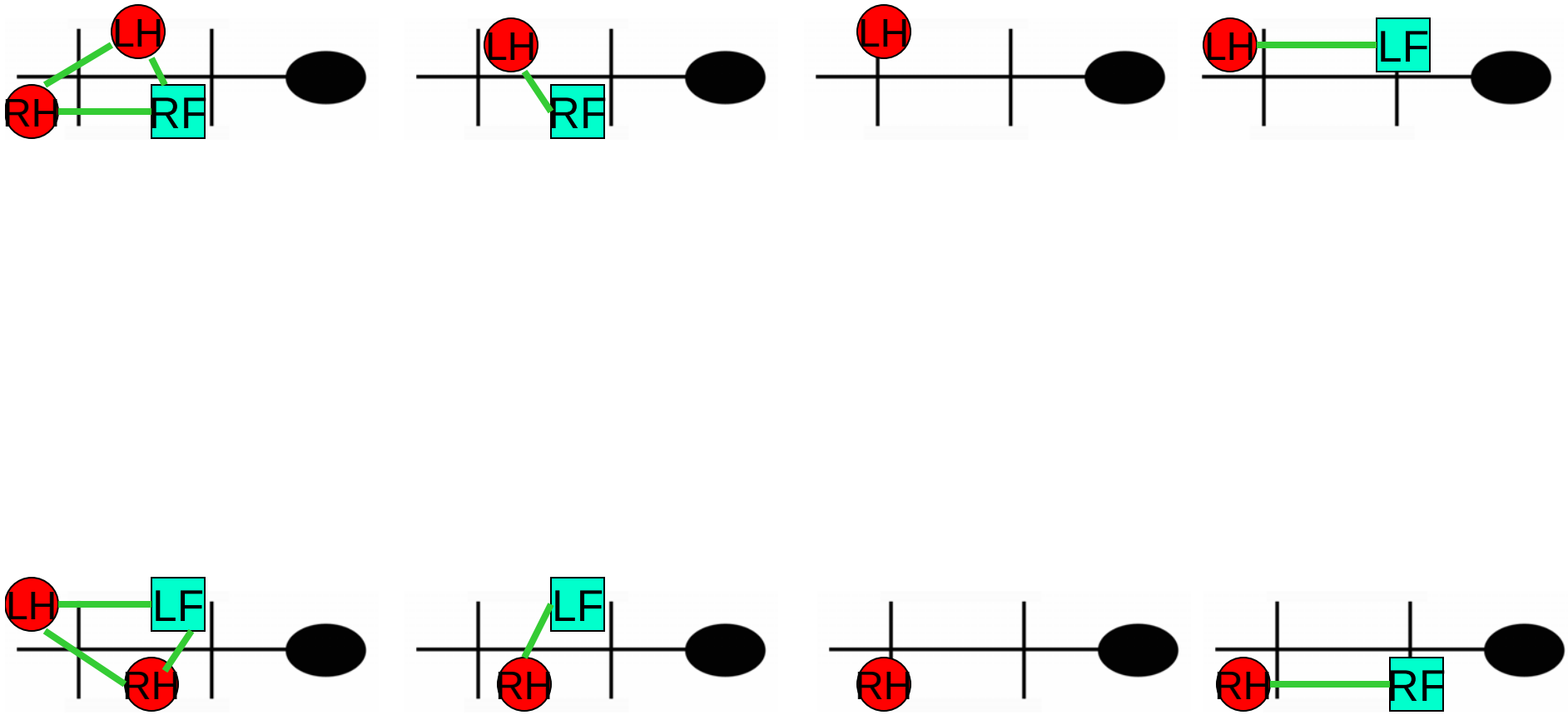
THE HIGH LEAD AMBLE

•The HIGH LEAD AMBLE is more common in large animals (e.g. horses, but is occasionally seen in medium to larger dogs)

•The walking gait is still a succession of hind-font couplets that alternate sides, but done at a higher speed – a high enough speed so that the animal doesnt' tip from one side to the other.

•This gait has only a very brief and smaller triangular under support.

THE HIGH LEAD AMBLE



Mammalian Locomotion

Pacing and Trotting
Transitions to Trotting

PACING

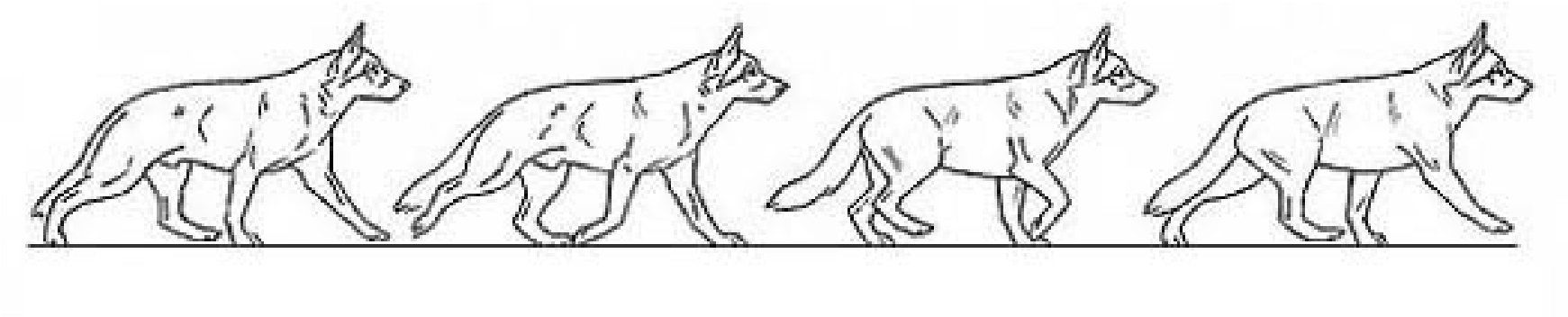
•In four-legged mammals, a pace is characterized by the step-cycle being dominated by alternating right and left couplets with the fore- and hind limbs on each side moving in register (almost parallel) with one another.

•Pacing is considered a slow to medium speed quadrupedal gait.

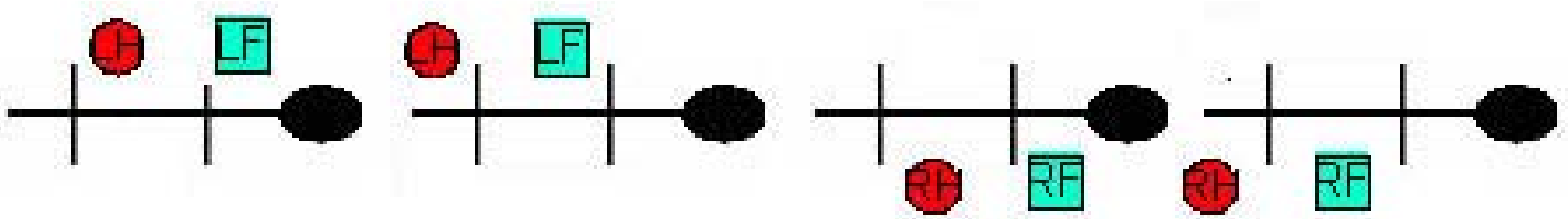
•Medium to larger sized dogs often pace to avoid banging and front limbs together on the same side.

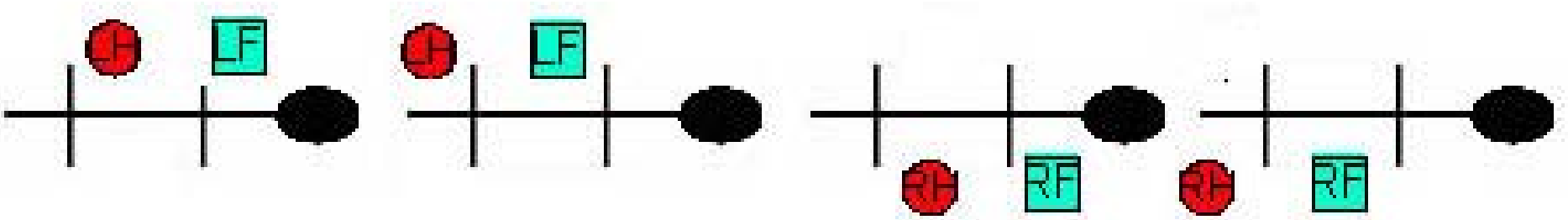
•The mammalian pace is often considered to be somewhat less stable than the diagonal support found in a typical trot..

PACING - In four-legged mammals, a pace is characterized by the step-cycle being dominated by alternating right and left couplets with the fore- and hind limbs on each side moving in register (almost parallel) with one another.



PACING - In four-legged mammals, a pace is characterized by the step-cycle being dominated by alternating right and left couplets with the fore- and hind limbs on each side moving in register (almost parallel) with one another.





TROTTING

•In four-legged mammals, a trot is usually characterized by most of the step-cycle dominated by alternating diagonal under support (also known as “diagonal couplets”).

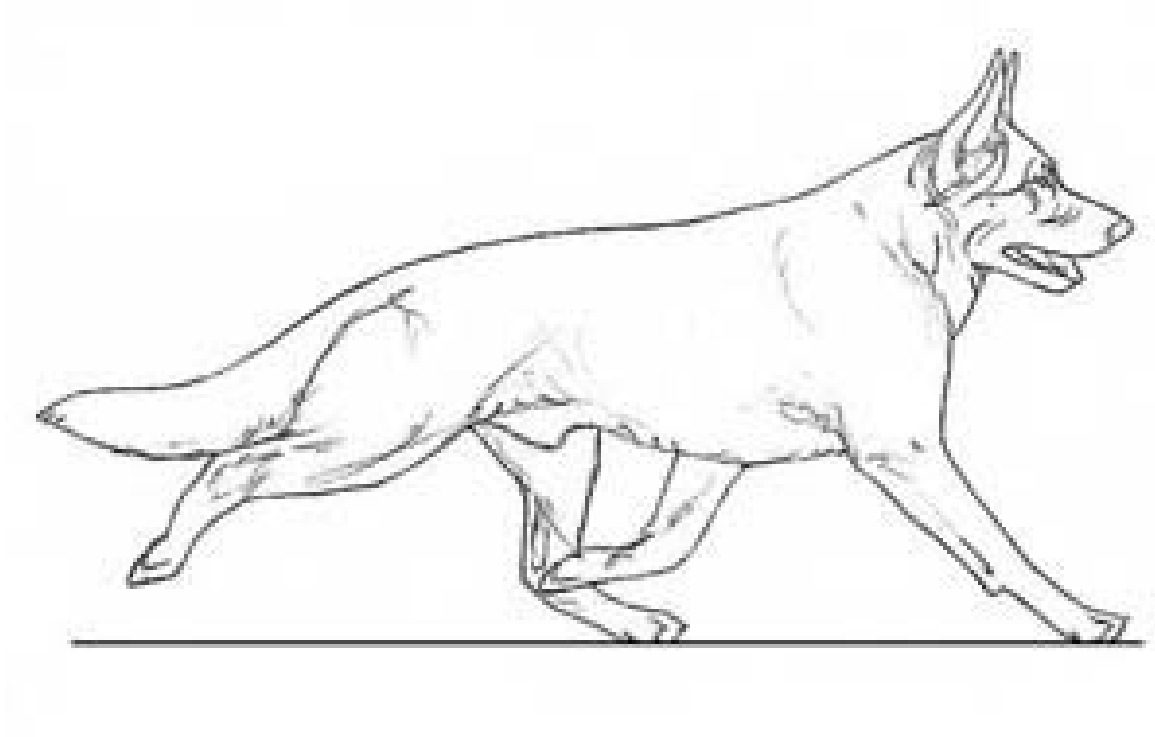
•Trotting is considered a slow to medium speed quadrupedal gait.

•Trotting is dominated by alternating contact with the ground of [right-hind+left-front] and [left-hind+right-front].

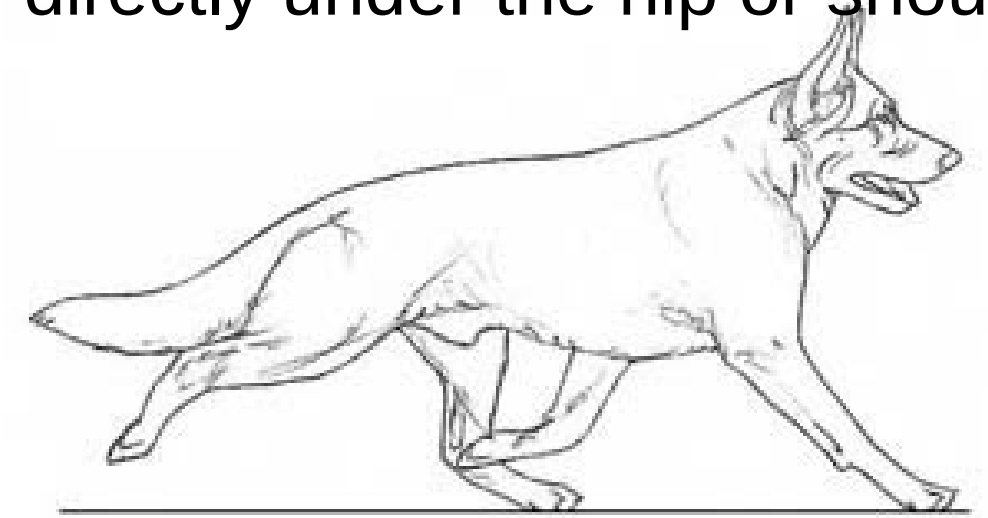
•The mammalian trot is often subdivided into a perfect “two-beat” trot (potential to be more cartooney) and a “four-beat” trot.

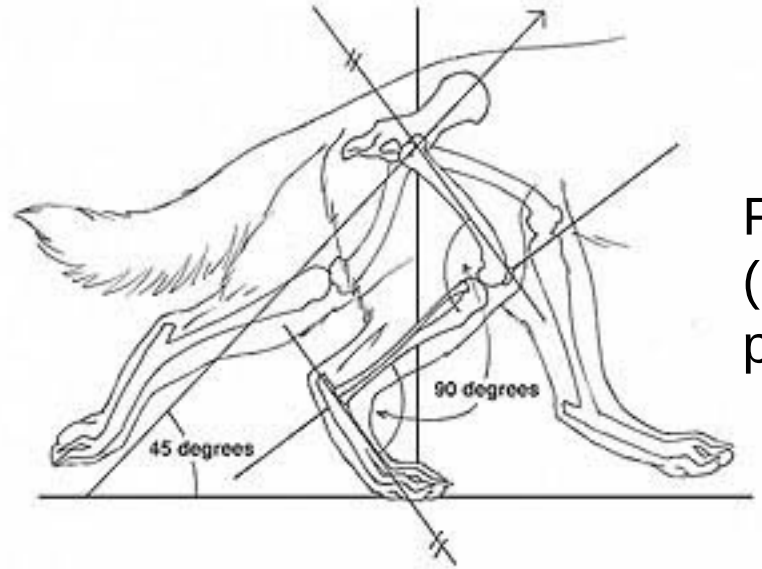
TROT

•Trotting is dominated by alternating contact with the ground of [right-hind+left-front] and [left-hind+right-front].



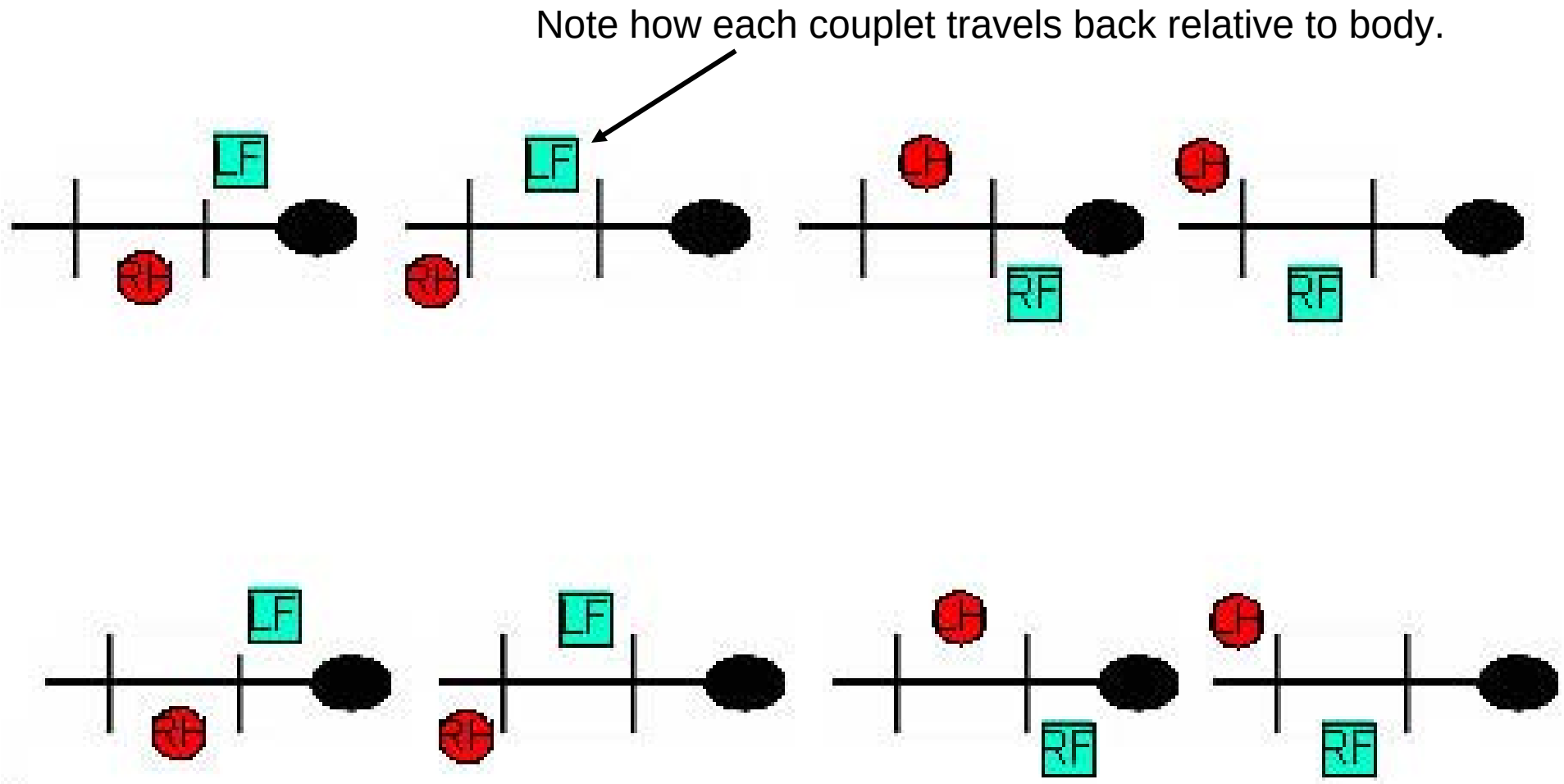
When moving at speed, each limb must overshoot the typical plane directly under the hip or shoulder joints.





Femur and foot almost (not quite, but almost parallel with one another.

A BASIC 2-BEAT TROT: Note that diagonal couplets are alternating in a very symmetrical manner.



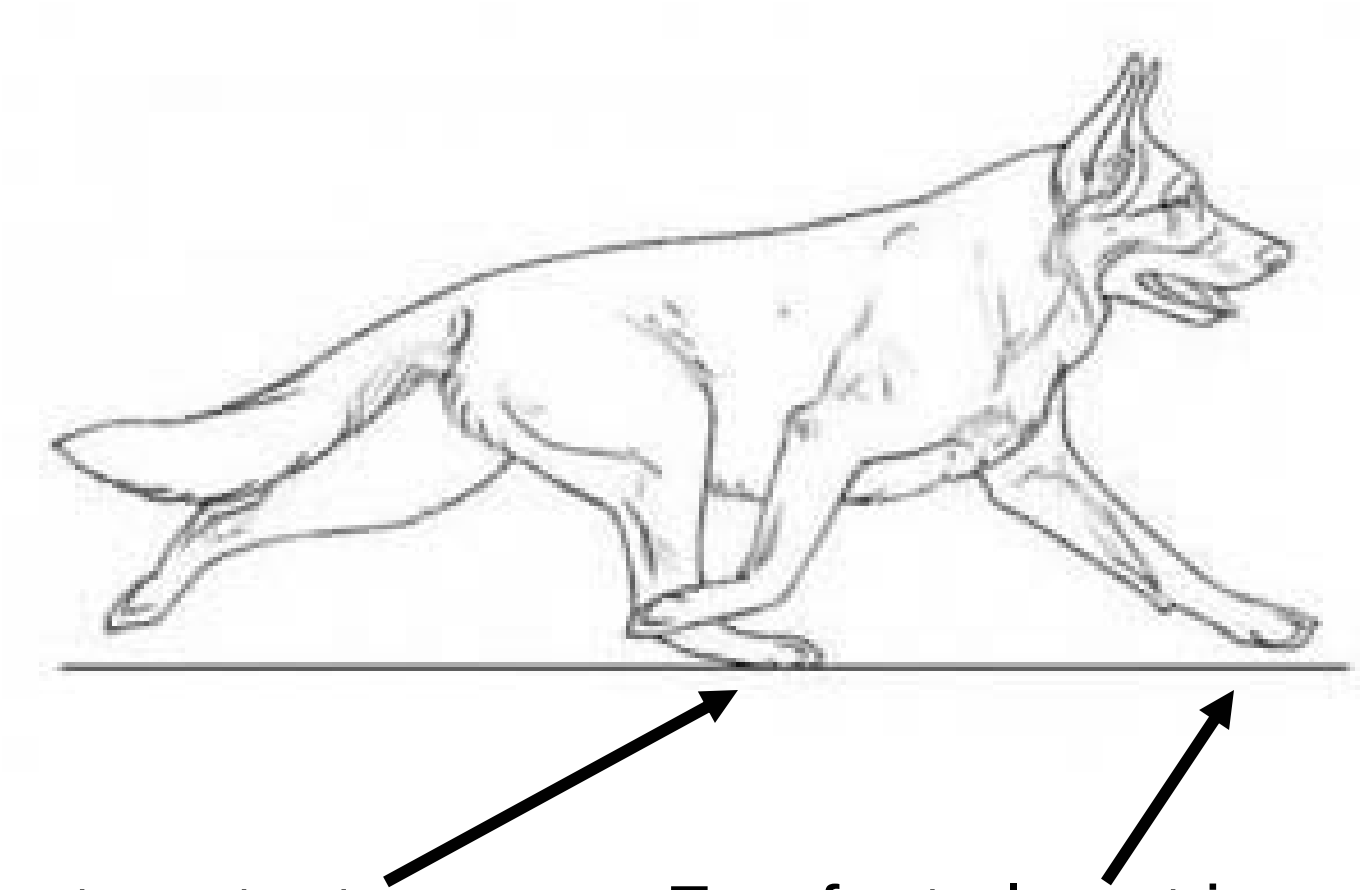
THE FOUR-BEAT TROT

•It is important to note that animals are rarely PERFECTLY symmetrical in nature.

•The four-beat trot is indeed dominated by diagonal couplets [right-hind+left-front] and [left-hind+right-front], but not that the hind member of each couplet lands a split second ***before*** the fore member of each.

•Additionally, the fore member of each couplet leaves the ground a split second ***after*** the hind member of each.

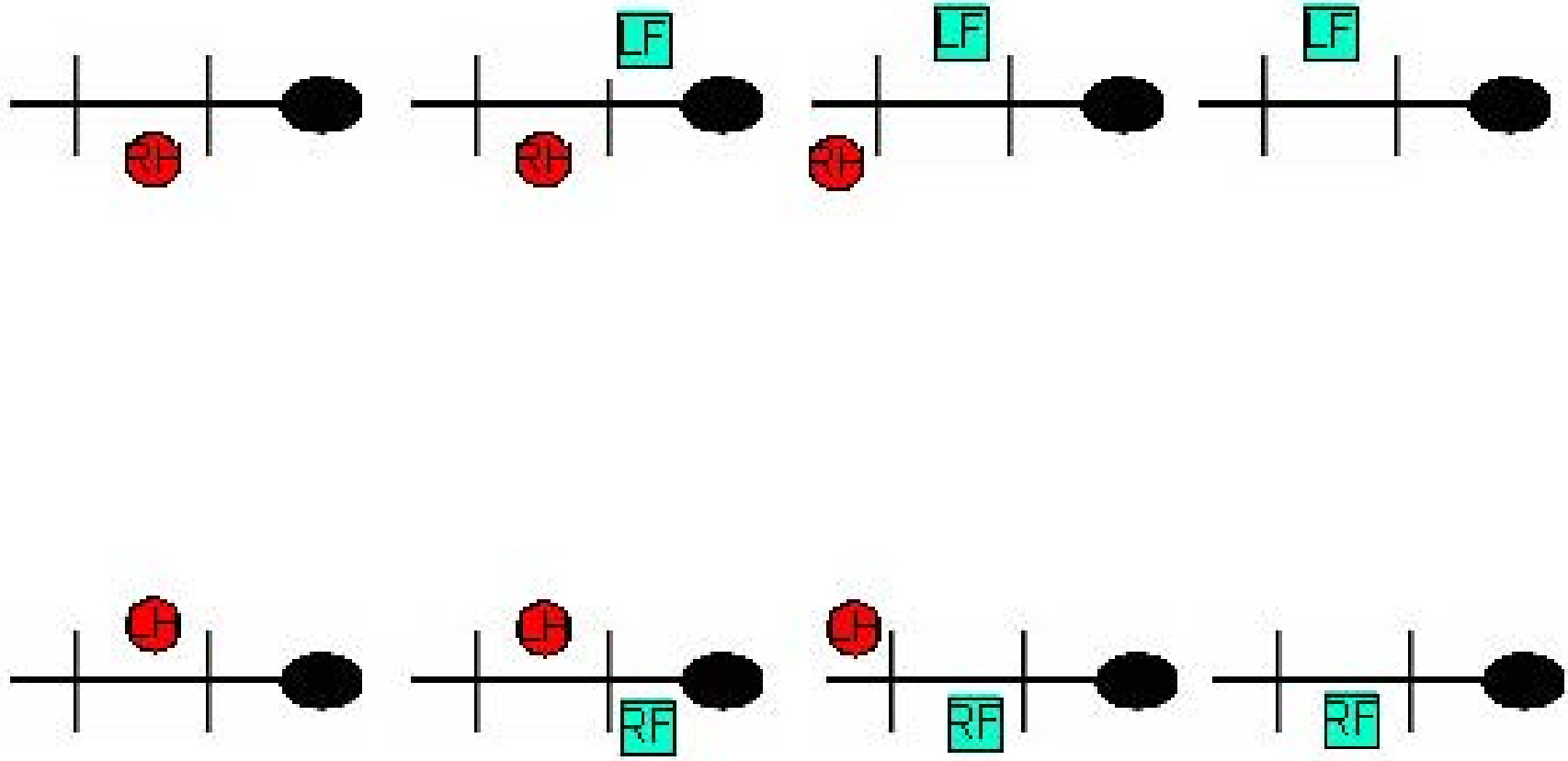
In the FOUR-BEAT TROT it is important to note that the hind member of each couplet lands a split second before the fore member of each.



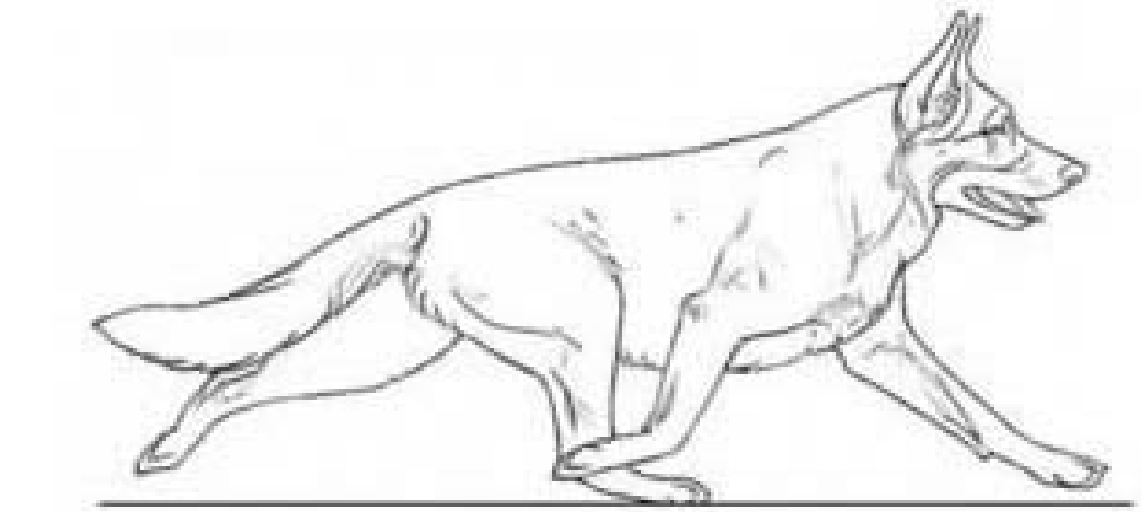
Hind foot contact.

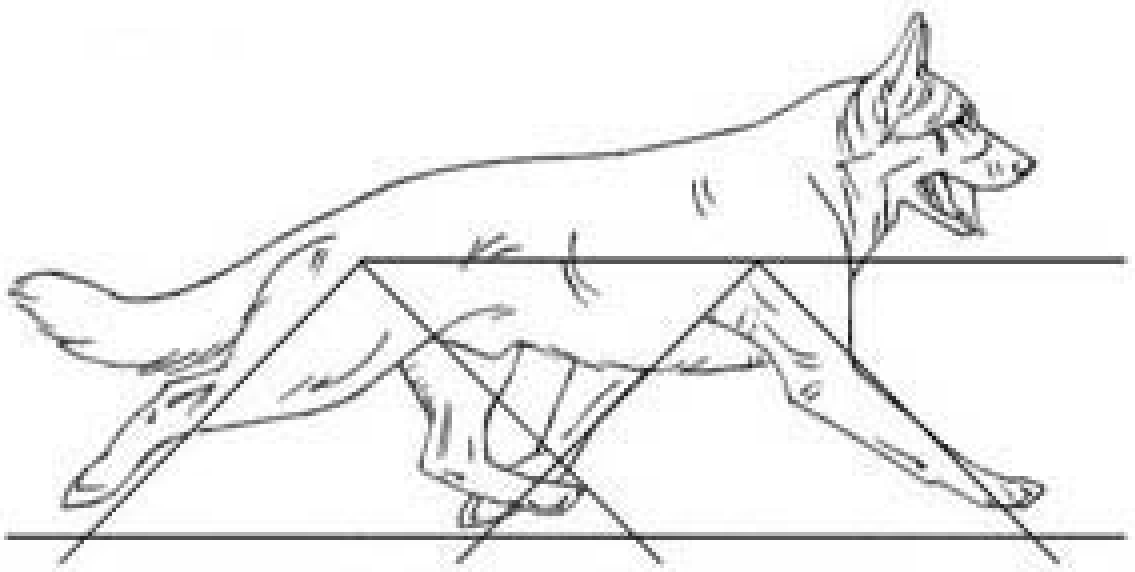
Forefoot almost in contact.

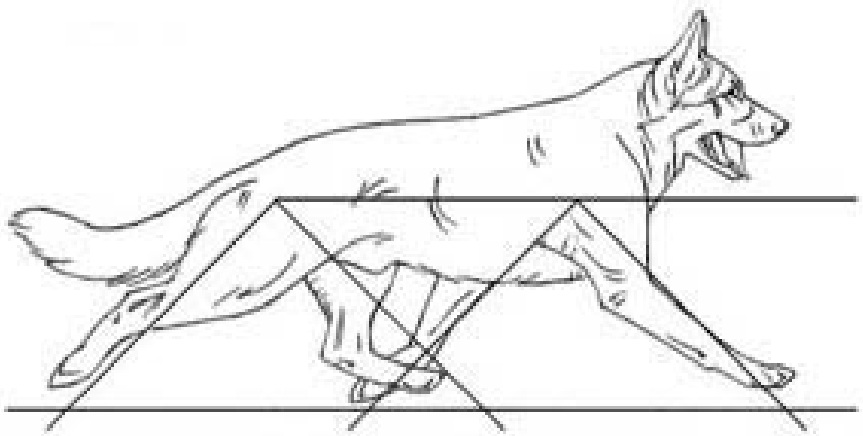
The four-beat trot is dominated by diagonal couplets [right-hind+left-front] and [left-hind+right-front], but not that the hind member of each couplet lands a split second ***before*** the fore member of each. Additionally, the fore member of each couplet leaves the ground a split second ***after*** the hind member of each.



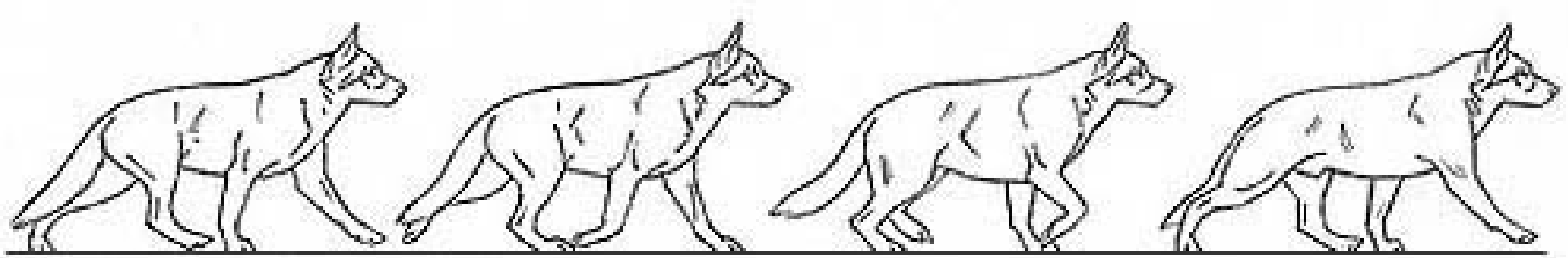
The trot is an extremely symmetrical gait.



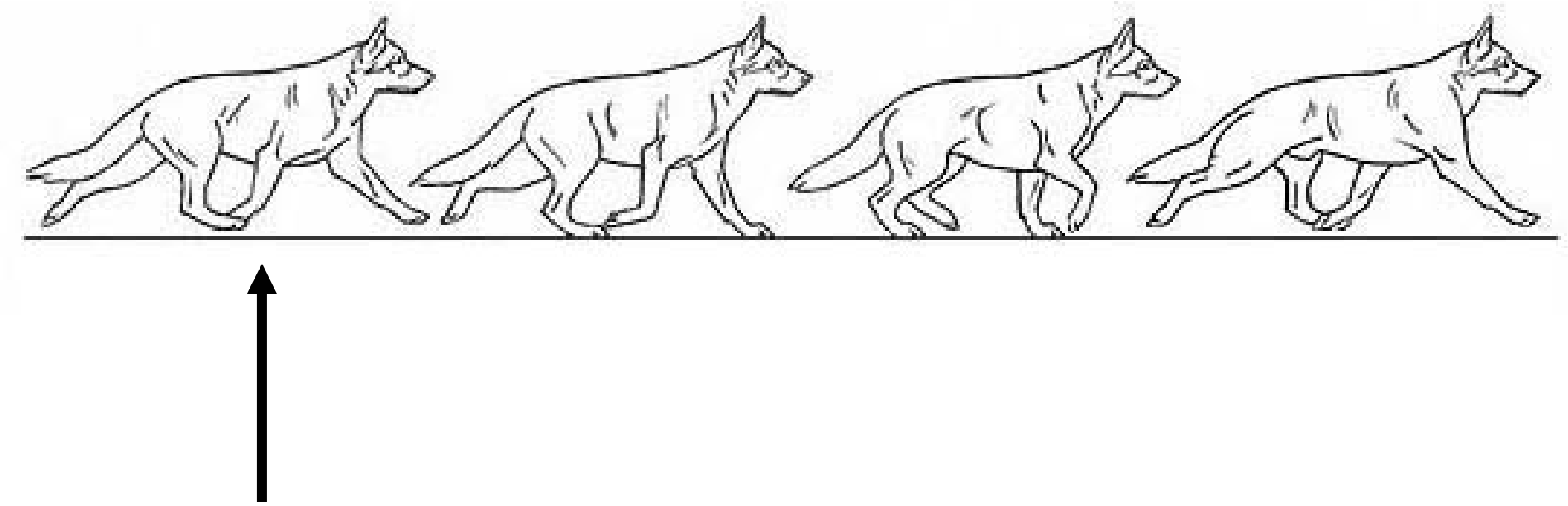




The very slowest of the “trots” is a fast walk at best, with the body never leaving the ground. If there is no period when all four feet are off the ground, it’s usually referred to as a “***supported trot***”.



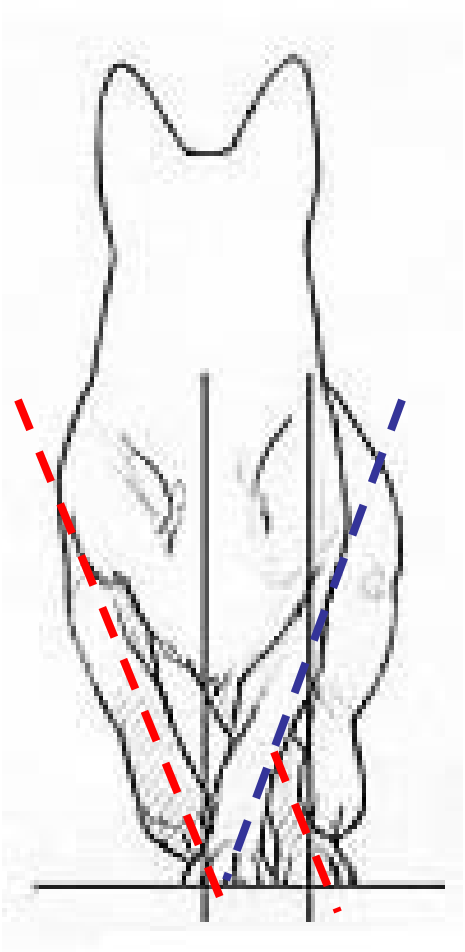
In faster “trots” the body/feet can leave the ground. This is usually referred to as a “***suspended trot***”. It is often a 4-beat trot.



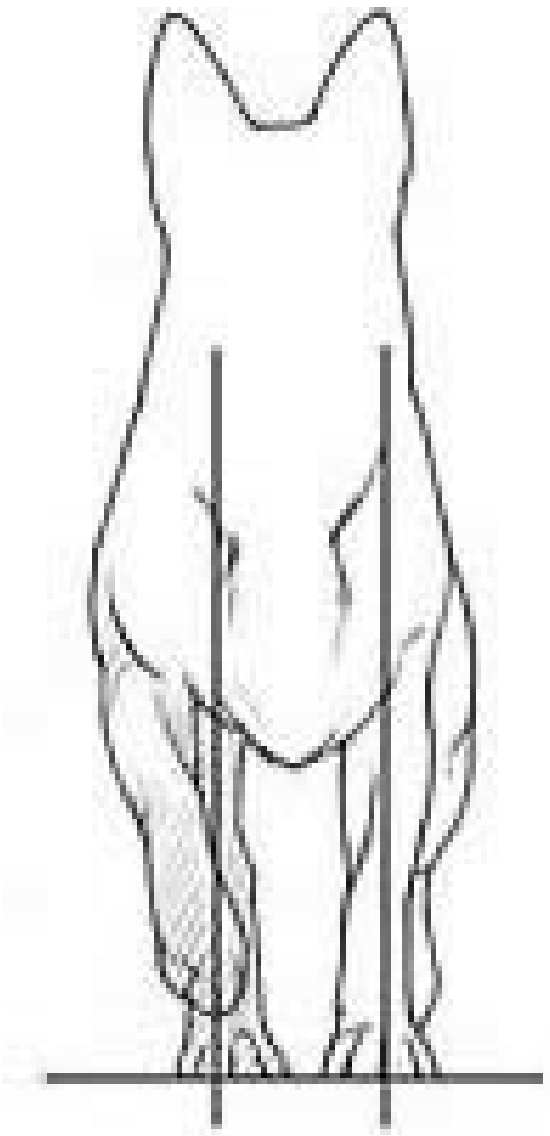
(Suspended)

TRACKING AT MODERATE SPEED

•Dogs are known to “single track”, “double track”, and “triple track”, depending on the situation.

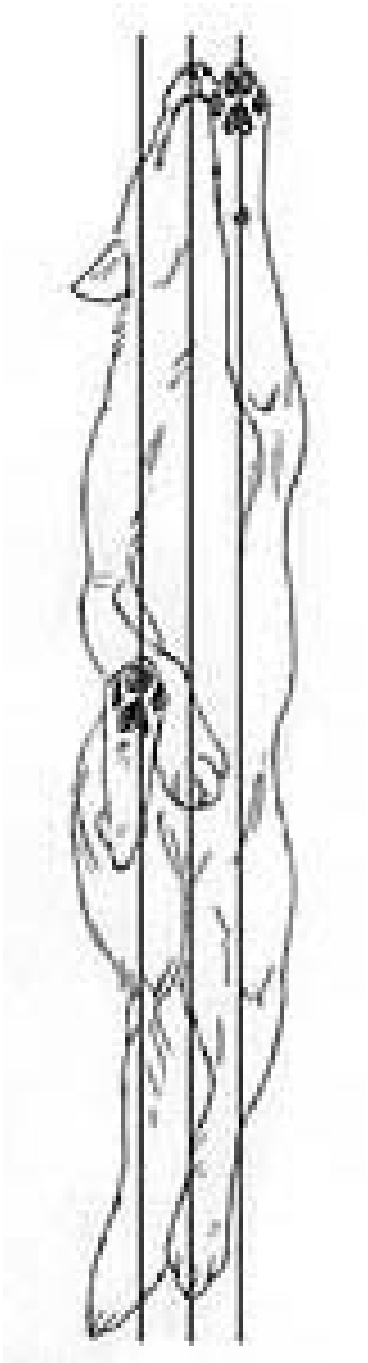


Single tracking requires moderate adduction of the limbs to the midline under the animal’s body.



Double tracking occurs in medium speed trots.

All four limbs project approximately straight down to the ground, perpendicular to ground.

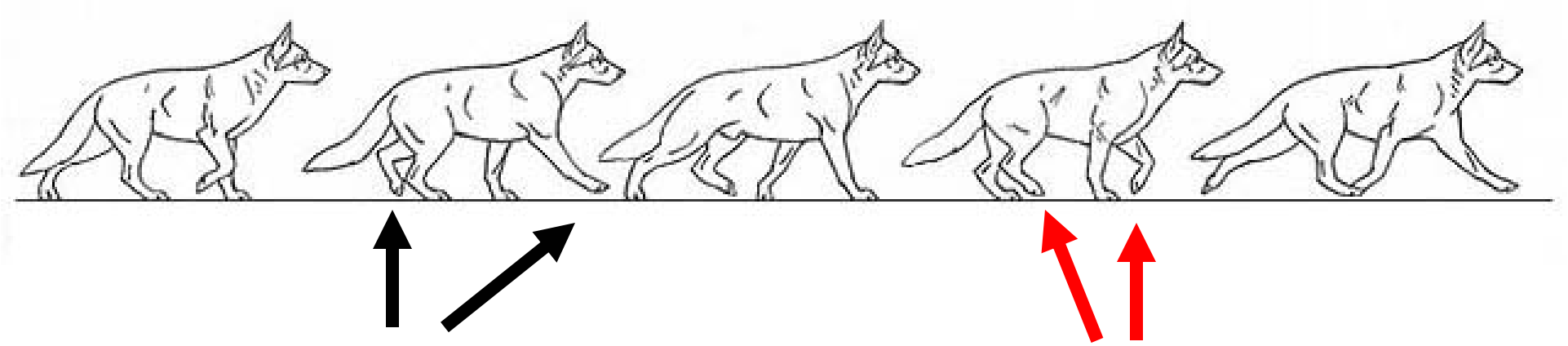


Triple tracking is done at the higher trotting speeds to that limbs don’t bump into one another.

Some animals keep one couplet central, others the other couplet.

Again, all four limbs project approximately straight down to the ground, perpendicular to ground.

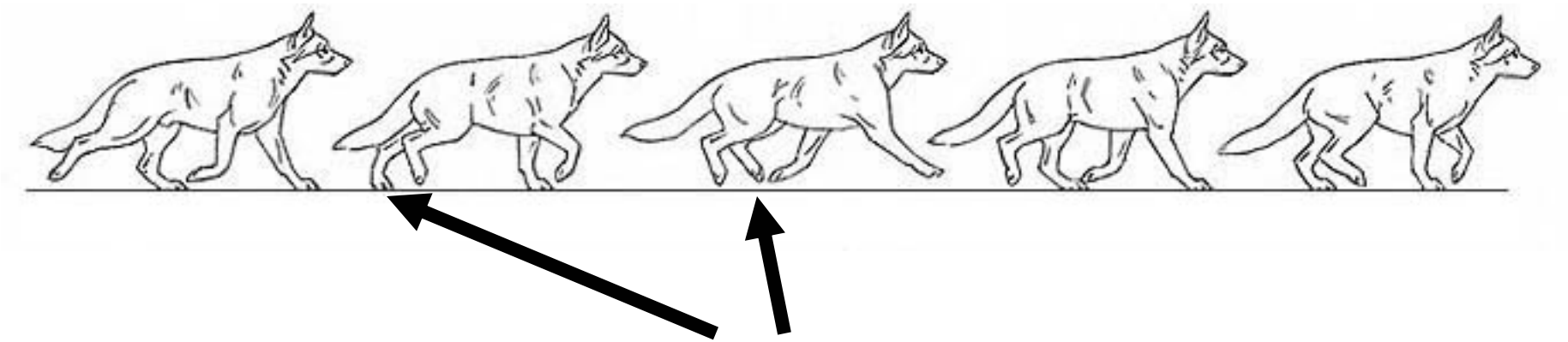
WALK TO TROT TRANSITION:



Hind limb picked up somewhat more quickly to bring into register with ipsilateral fore limb.

Fore limb on same side picked up somewhat more quickly to bring into register with its ipsilateral hind limb.

PACE TO TROT TRANSITION:



A skip of one of the hind limbs forward very quickly to pass other hind limb allows it to come into register with ipsilateral fore limb.

Mammalian Locomotion

High Speed Gaits
Galloping
Canter: Transitions from Gallop

RUNNING GAITS

•In four-legged mammals, a running gait is one where some part of the step cycle is spent in suspension – with all for limbs out of contact with the ground

•The most standard high-speed gait in dogs is the rotary gallop.

•The canter is an asymmetrical and infrequently used gait in dogs. When used it is often as a transition from the gallop as the animal is slowing down. It is also sometimes used when playing and the impression of speed is combined with interaction with other animals.

GALLOP

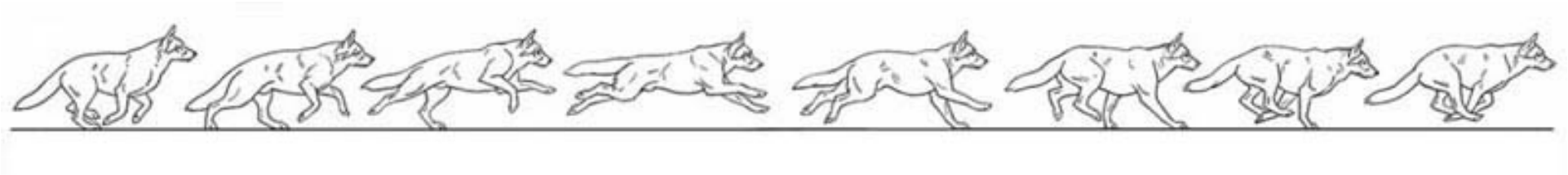
•In four-legged mammals, the highest speed gait is the gallop. It is a four-beat gait, with each limb contacting independant of the other three.

•In dogs, the gallop usually has a double suspension, or a floating phase with the limbs both gathered underneath as well as extended forward and back.

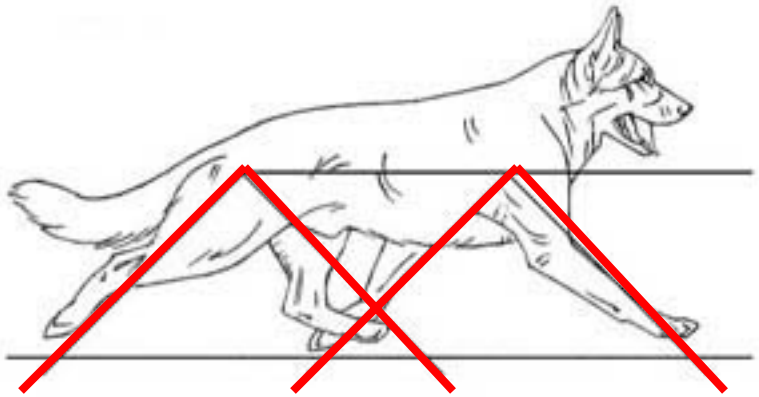
•The footfall sequence tends to be: right hind, left hind, left, front, right front. (Or left hind, right hind, right front, left front.)

GALLOP - In lightly built (usually carnivores) mammals such as dogs, the gallop is a four-beat gait.

In the example below: right hind, left hind, (extended suspension), left front, right front, (gathered suspension).



GALLOP compared to a TROT



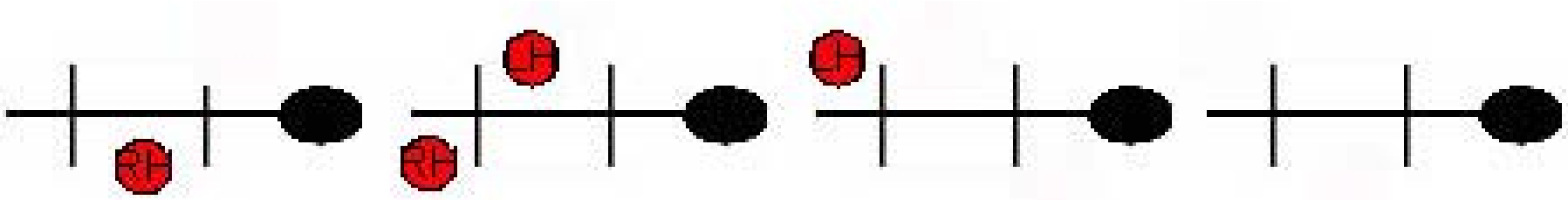
Note that in a trot, the fore- and hind limbs appear as complimentary angles.

Whereas in a gallop, the forelimbs are almost PARALLEL to the ground at some point.

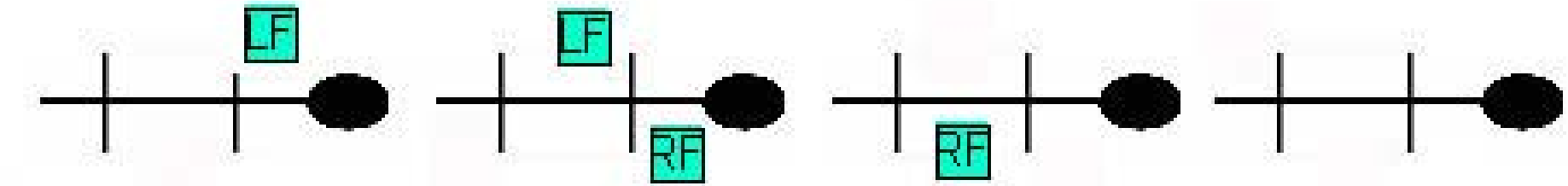
GALLOP

•In dogs, the gallop usually has a double suspension, or a floating phase with the limbs both gathered underneath as well as extended forward and back.

•The footfall sequence tends to be: right hind, left hind, left, front, right front. (Or left hind, right hind, right front, left front.)

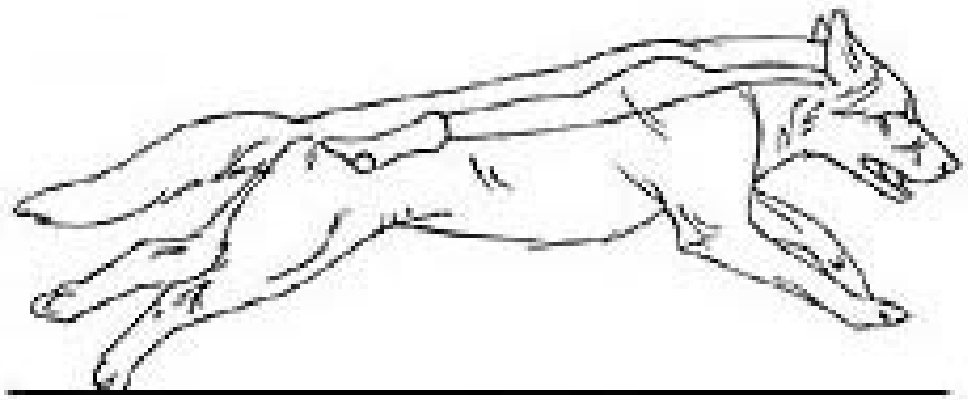


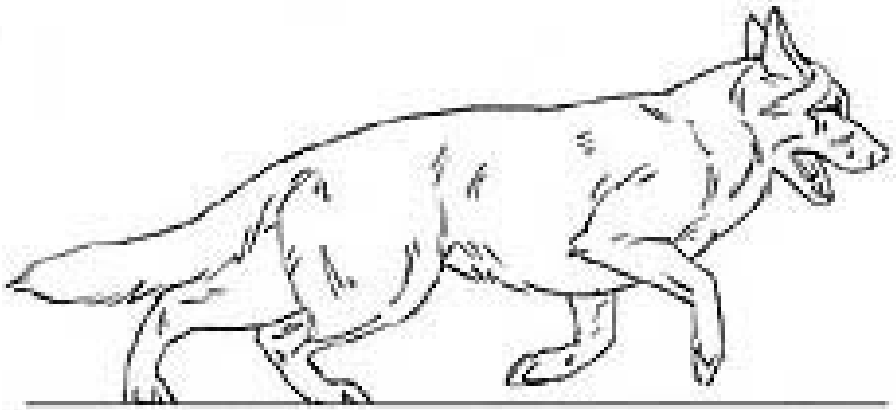
extended suspension

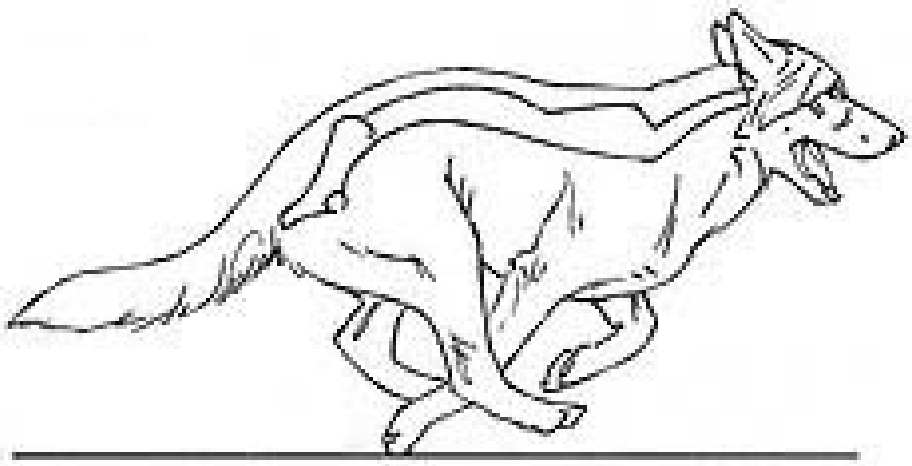


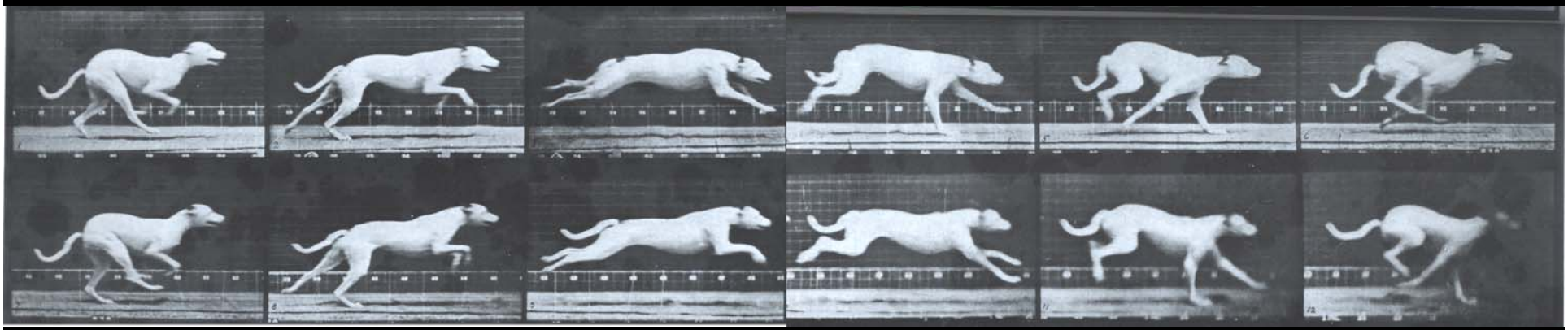
gathered suspension

Gallop

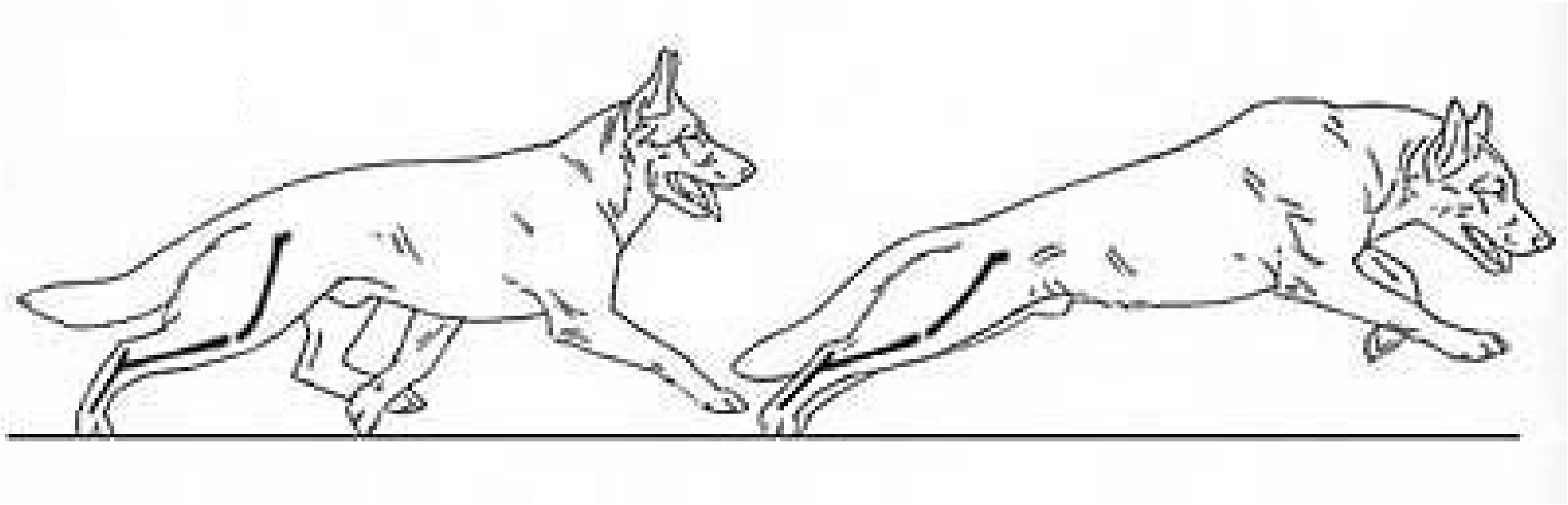






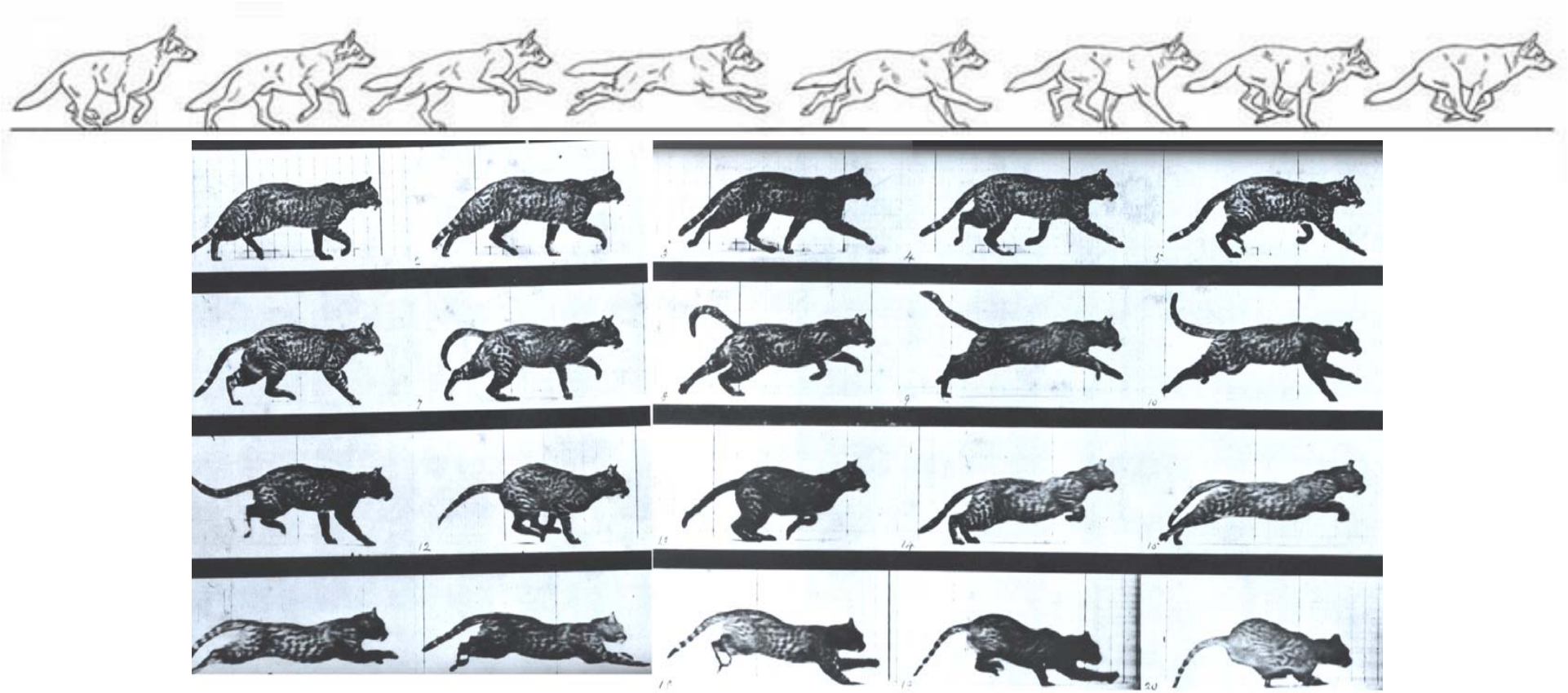


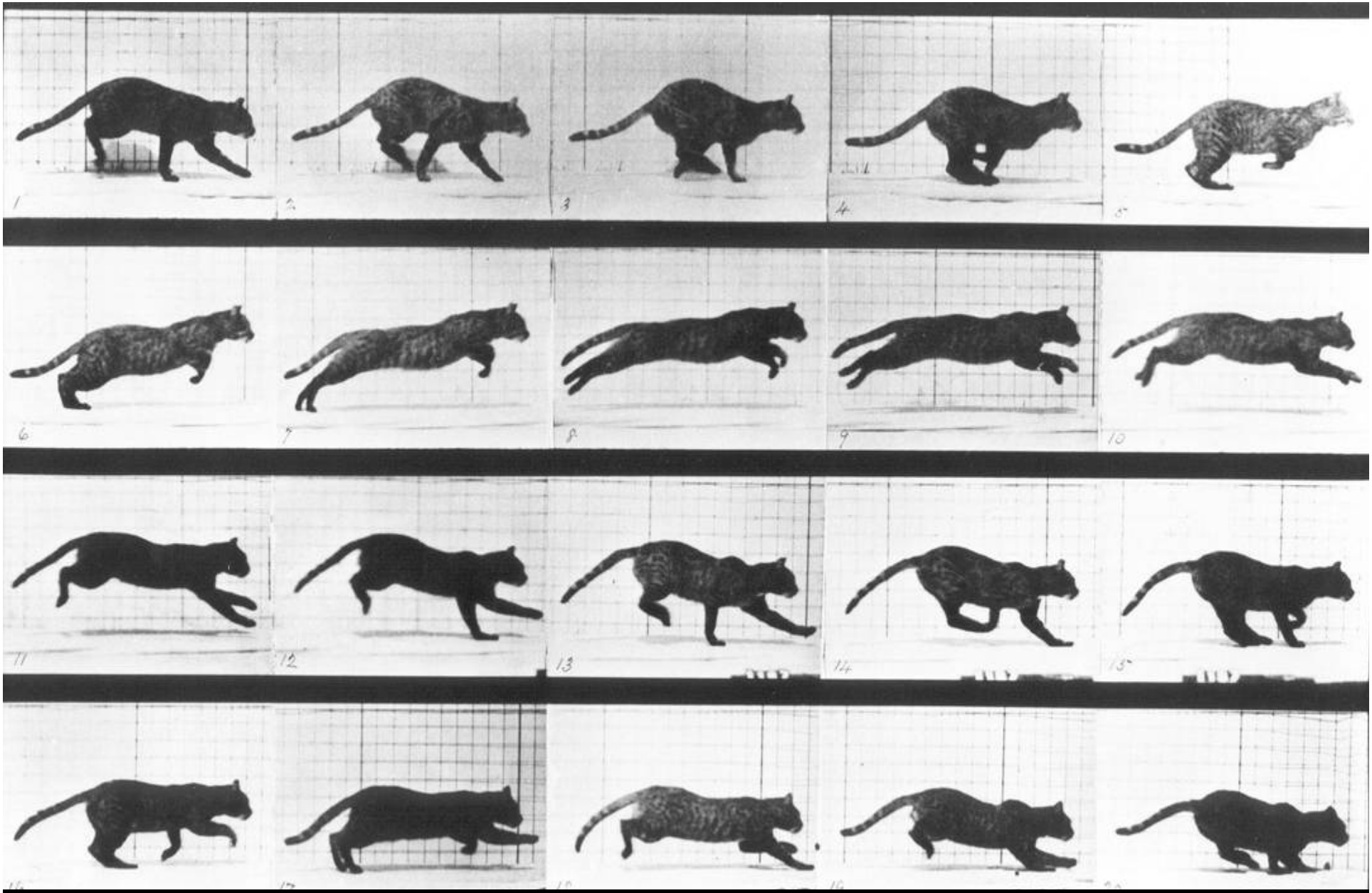
At pushoff, the hind limb is almost straight.



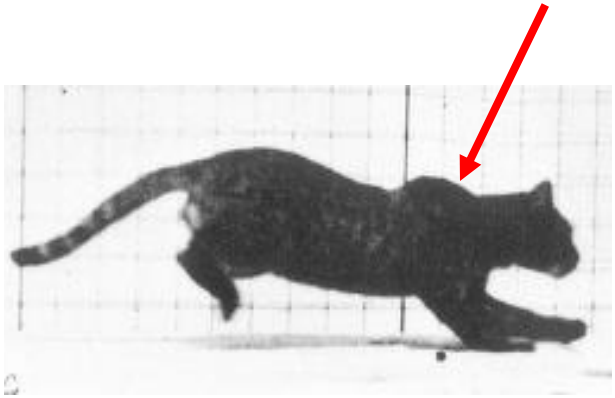
GALLOP - In lightly built (usually carnivores) mammals such as dogs, the gallop is a four-beat gait.

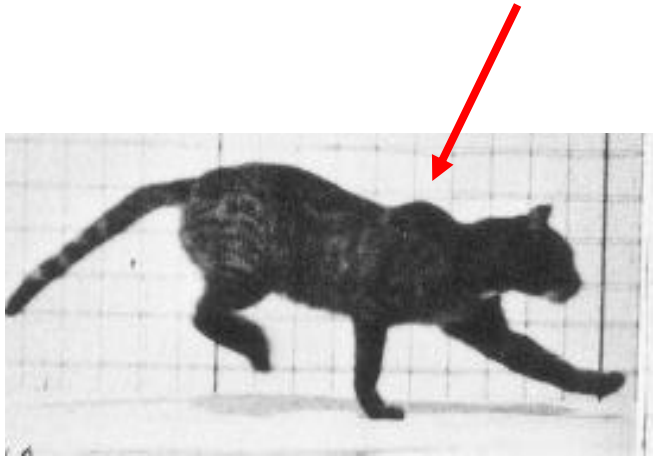
Although both of them show flexibility of backbone, flexibility is greater in cat.



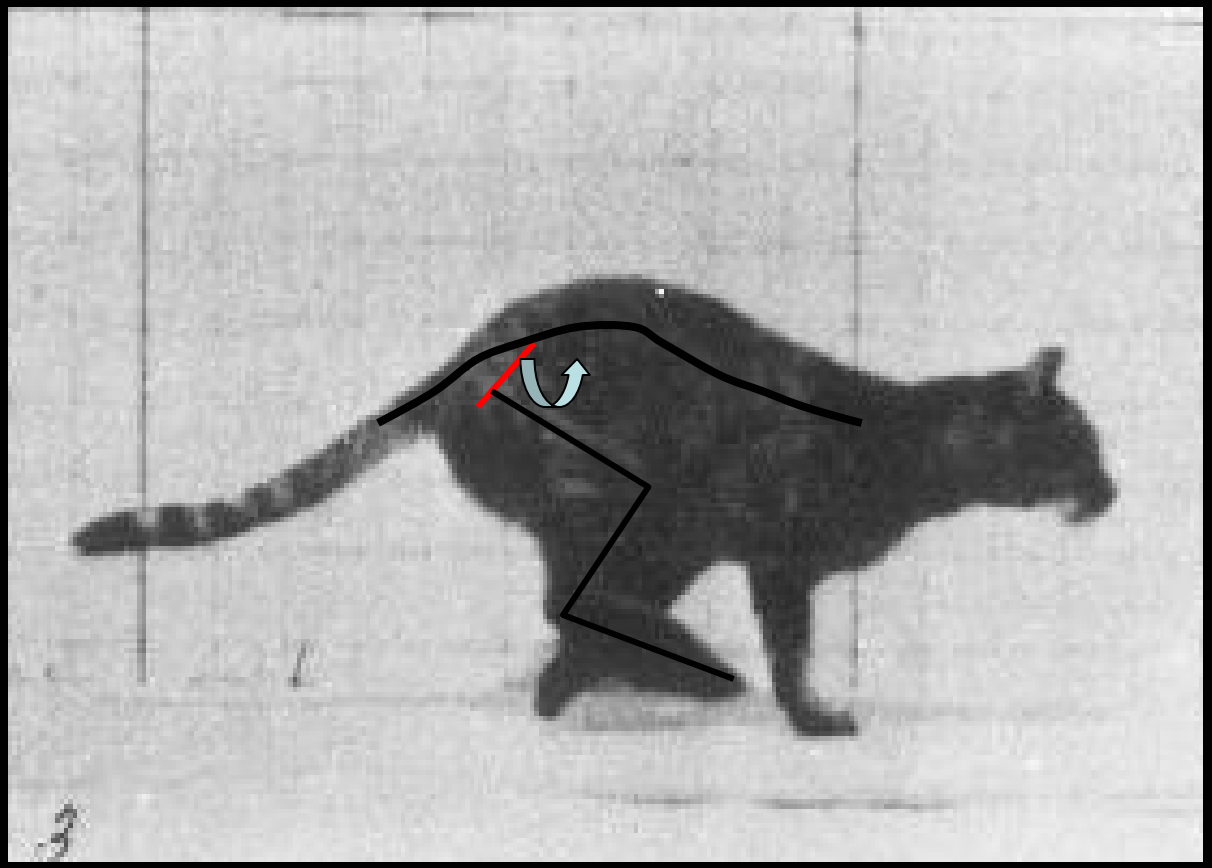


Cats often have greater duty-factor than dogs while running.





Cat scapula will show prominently, especially when weight is placed on the forelimb. This happens in all gaits, but is particularly prominent when galloping.



Cat hips will bend somewhat relative to the vertebral column, whereas those of a dog will not.


19
20

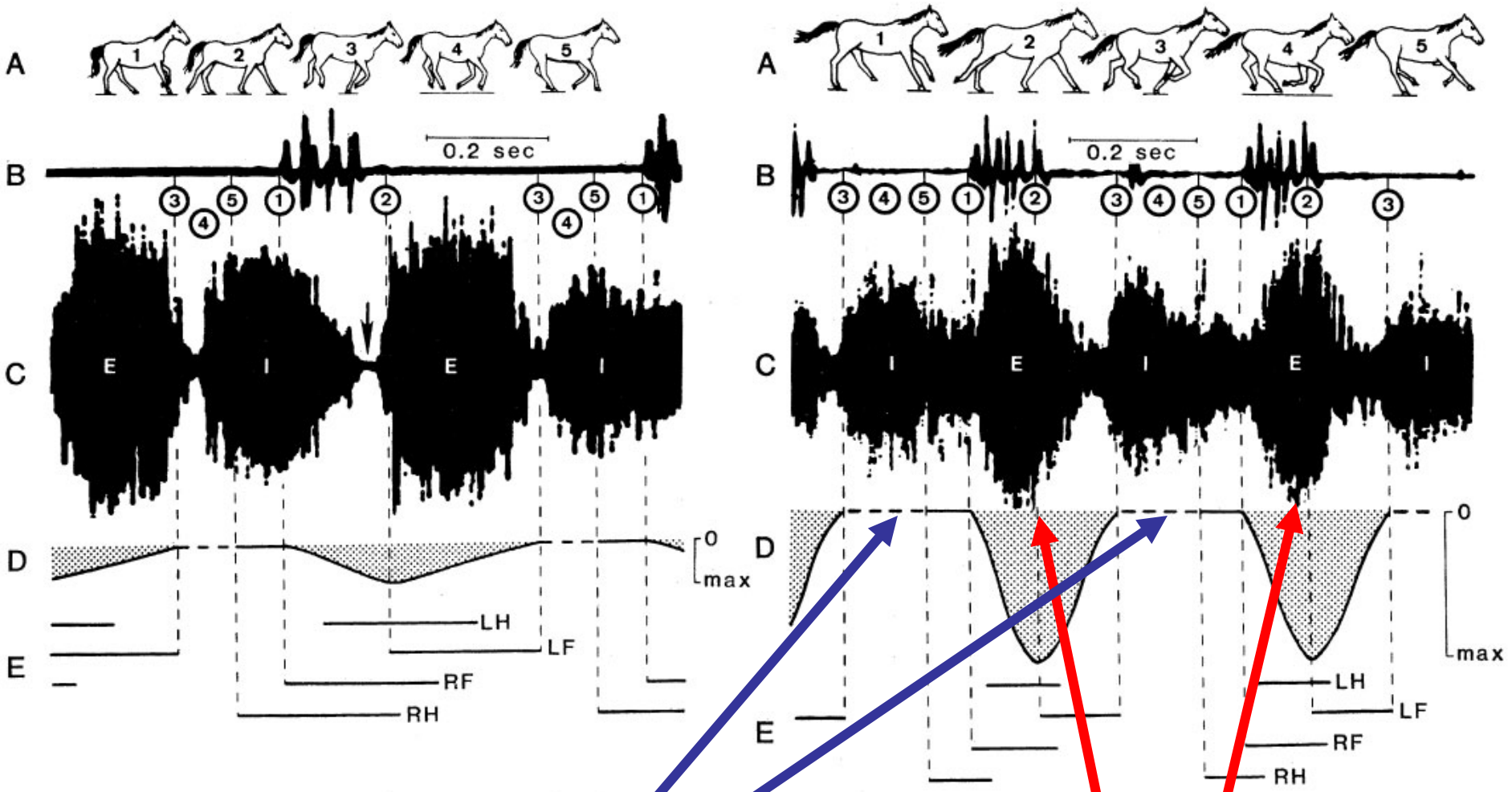


Fig. 3. Relationships of locomotor and respiratory cycle in the same horse at a canter (left) and gallop (right). (A) Tracings of body position at five selected points in locomotor cycle. (B) and (C) Oscilloscope tracings of footfall and breathing. (D) Hypothetical loading profile for thoracic complex (*28*). (E) Standard support diagram for the gait. Loading increases in the gallop as the animal spends a larger fraction of each stride off the ground. The arrow indicates the end-inspiratory pause. Abbreviations: *E*, exhalation; *I*, inhalation; *LF* and *RF*, left and right forelimbs; *LH* and *RH*, left and right hind limbs. See text for discussion.

Bramble, D. C., and D. R. Carrier. **Running and breathing in mammals**. Science 219: 251-256, 1983

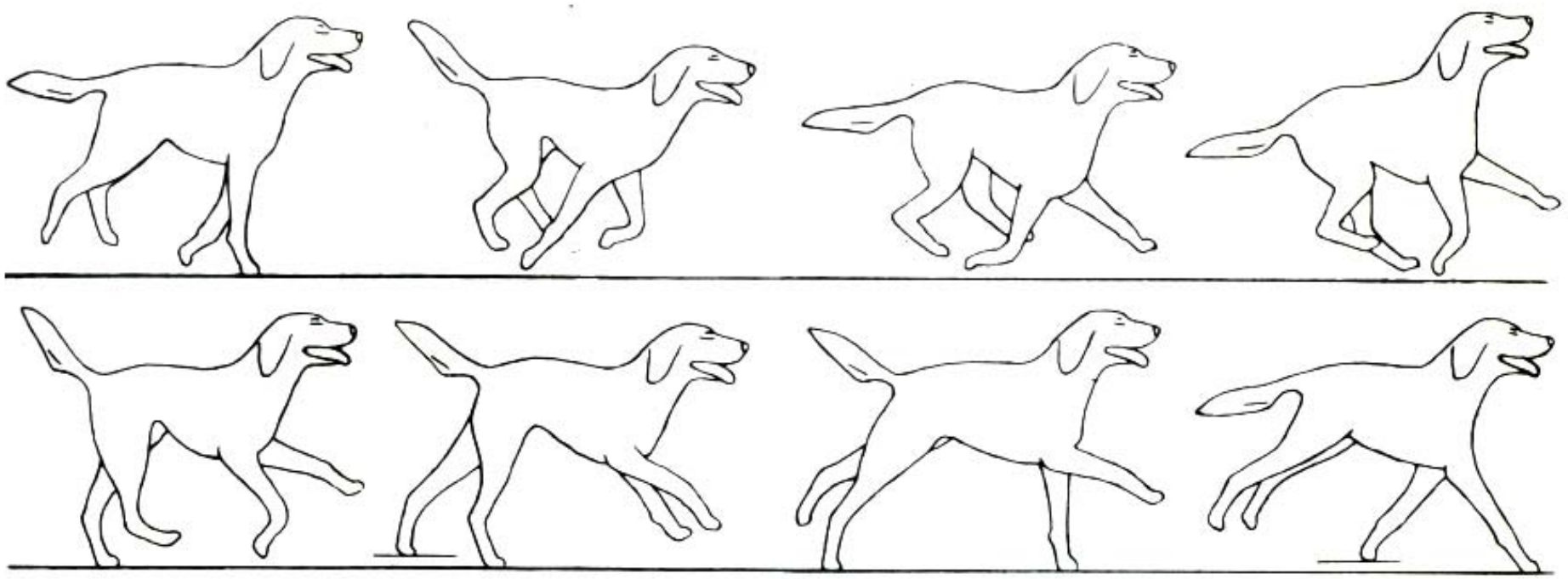
Breathing patterns when running: During the gallop, the animal exhales during suspensory phases. Inhaling tends to occur when forefoot lands (body brakes and viscera slam into diaphragm)

The SINGLE SUSPENSION GALLOP in Dogs

This is the slowest of the gallops (note there is still a suspended phase).

This is not quite a canter, as it remains a four-beat step cycle.

Note, this is technically a TRANSVERSE GALLOP



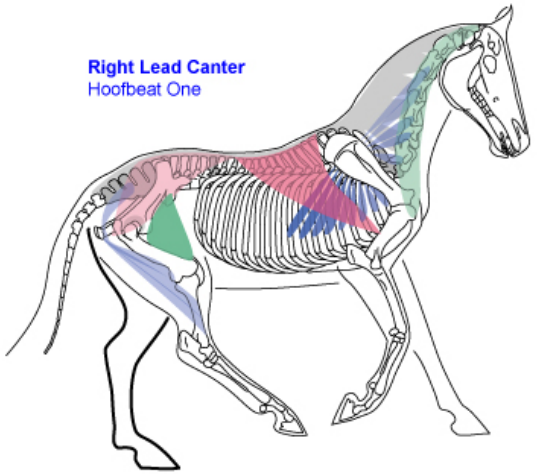
CANTER

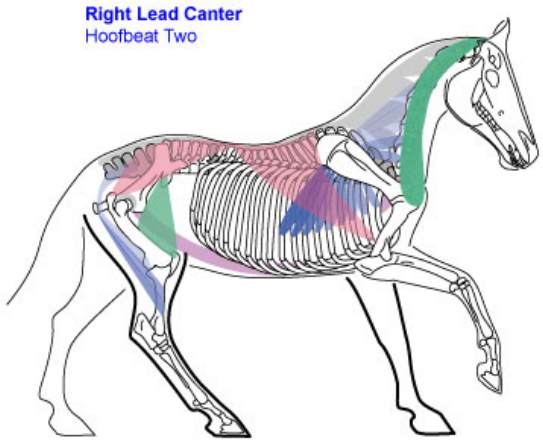
•The canter is a 3 beat gait. The beat sequence begins with a rear leg, moves to the paired diagonals and then finally the front leg diagonal to the hind leg in the first beat. The animal is then briefly suspended before the sequence is repeated.

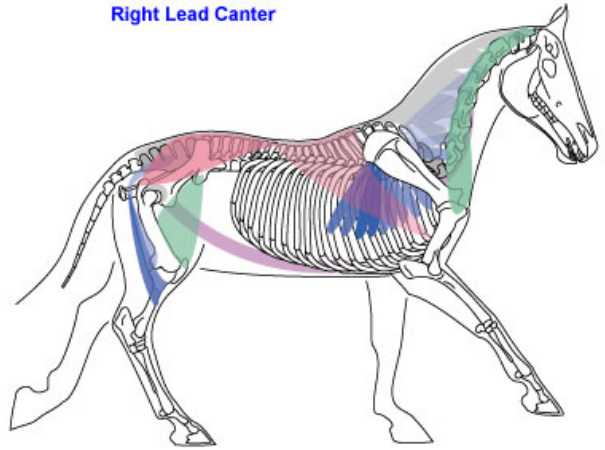
•If the right hind leg strikes the ground it is referred to as a left lead will if the left hind leg strikes the ground first it is a right lead.

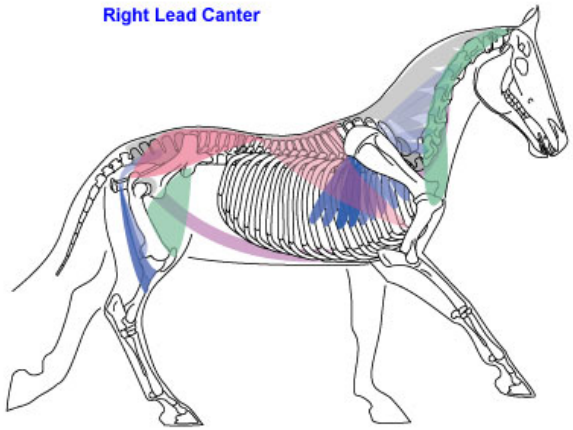
•The canter is an infrequently used gait in dogs. When used it is often as a transition from the gallop as the animal is slowing down. It is also sometimes used when playing and the impression of speed is combined with interaction with other animals.

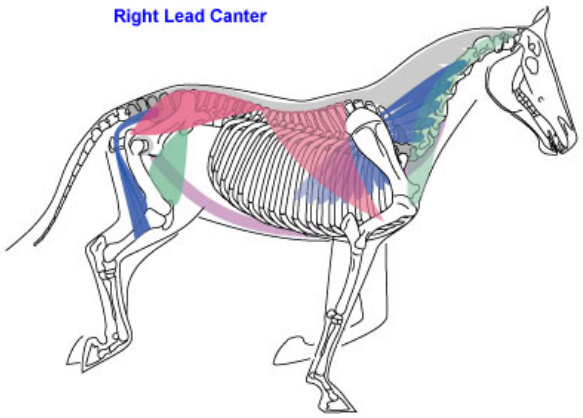
CANTER (in a horse)

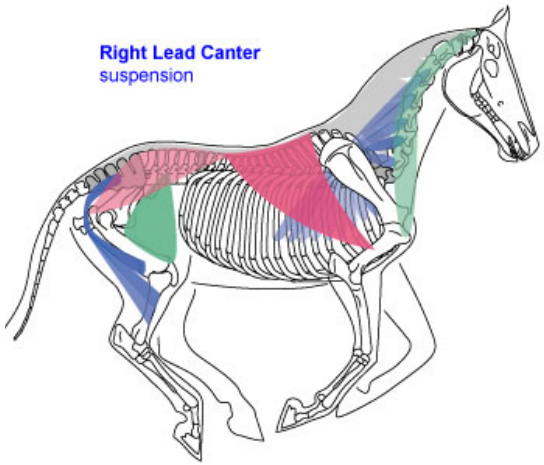












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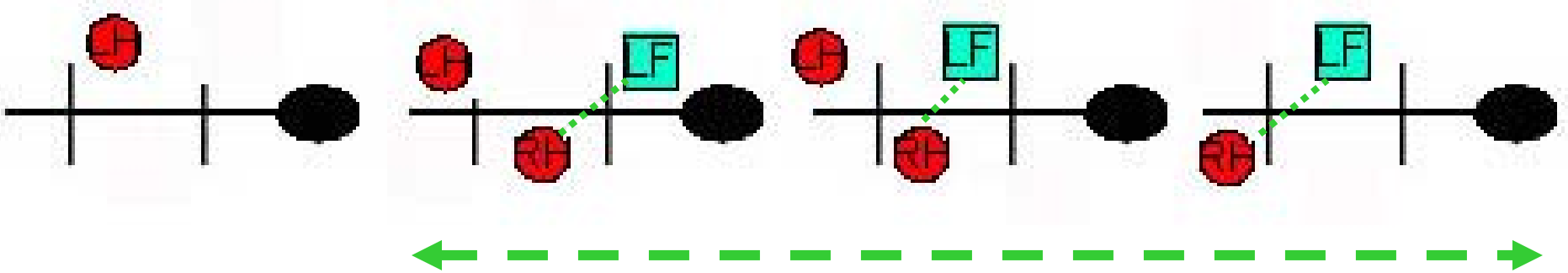
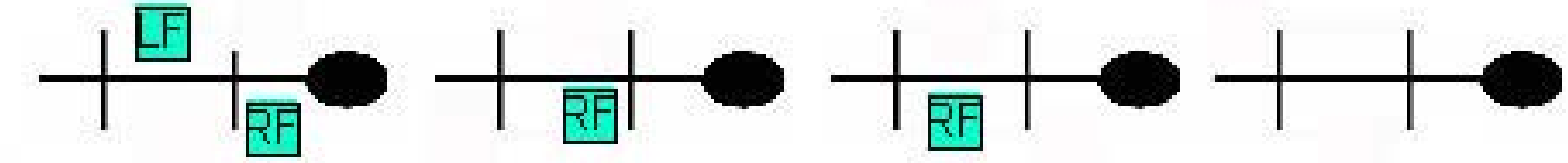
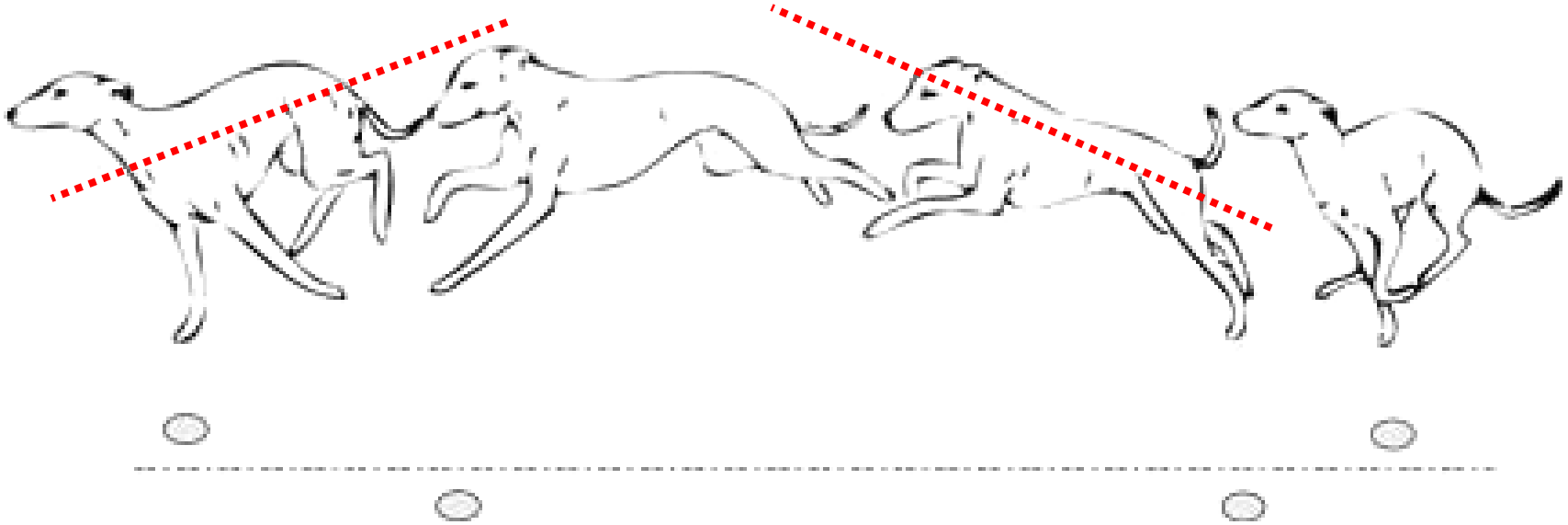


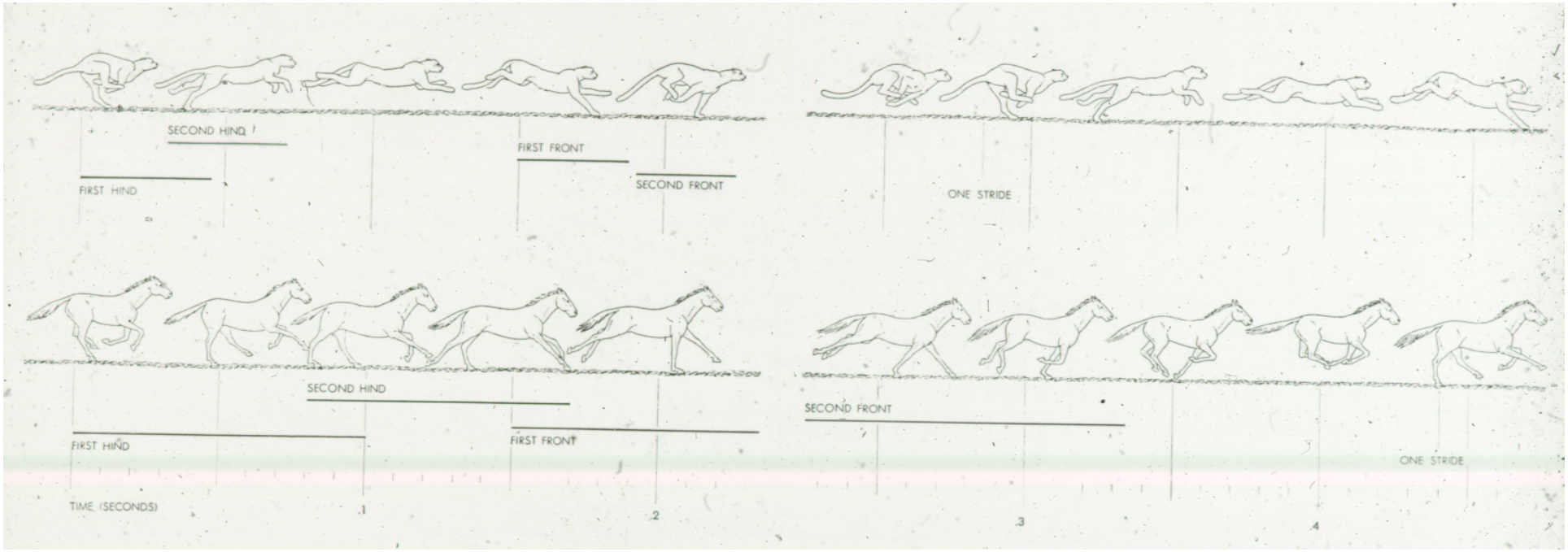
Only one diagonal couplet

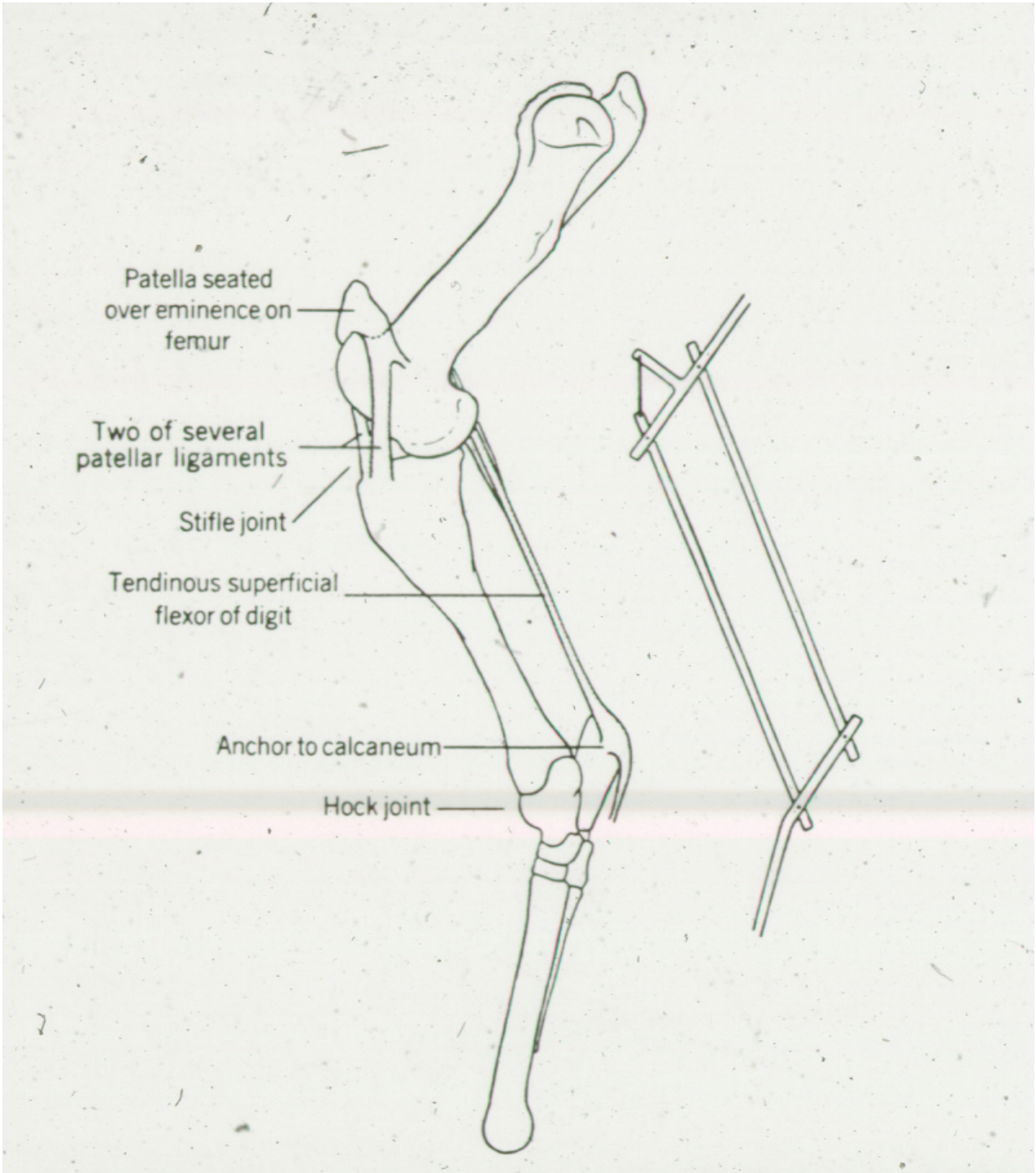


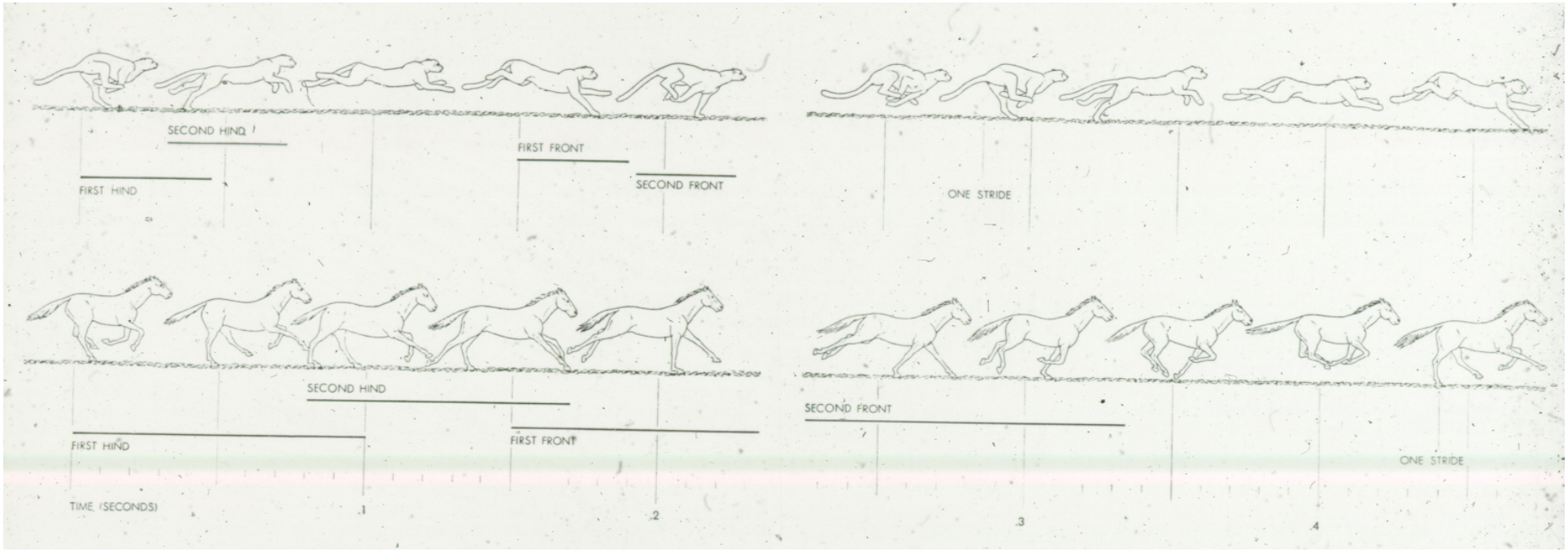
Body tilts forward

A partial canter in a dog. Note how the body rocks.




SECOND HIND
FIRST HIND
FIRST FRONT
SECOND FRONT
ONE STRIDE
SECOND HIND
FIRST HIND
FIRST FRONT
SECOND FRONT
ONE STRIDE
TIME (SECONDS)
.1
.2
.3
.4


Patella seated over eminence on femur
Two of several patellar ligaments
Stifle joint
Tendinous superficial flexor of digit
Anchor to calcaneum
Hock joint


SECOND HIND
FIRST HIND
FIRST FRONT
SECOND FRONT
ONE STRIDE
SECOND HIND
FIRST HIND
FIRST FRONT
SECOND FRONT
ONE STRIDE
TIME (SECONDS)
.1
.2
.3
.4

The Bigger You Are – the Harder You Fall
Locomotion of Unusual Sized Animals

Small: Medium to High Speed Locomotion:

- Half Bound
- Bound

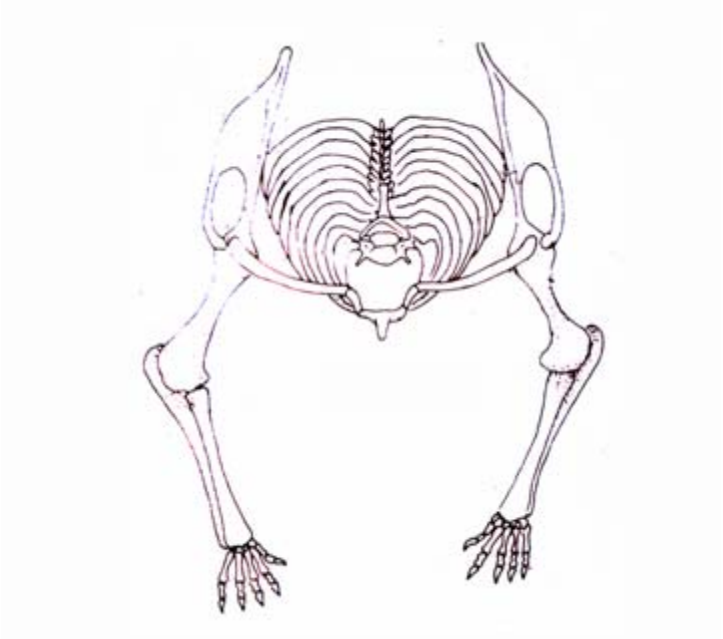
Small: High Speed Locomotion:

- Bounding

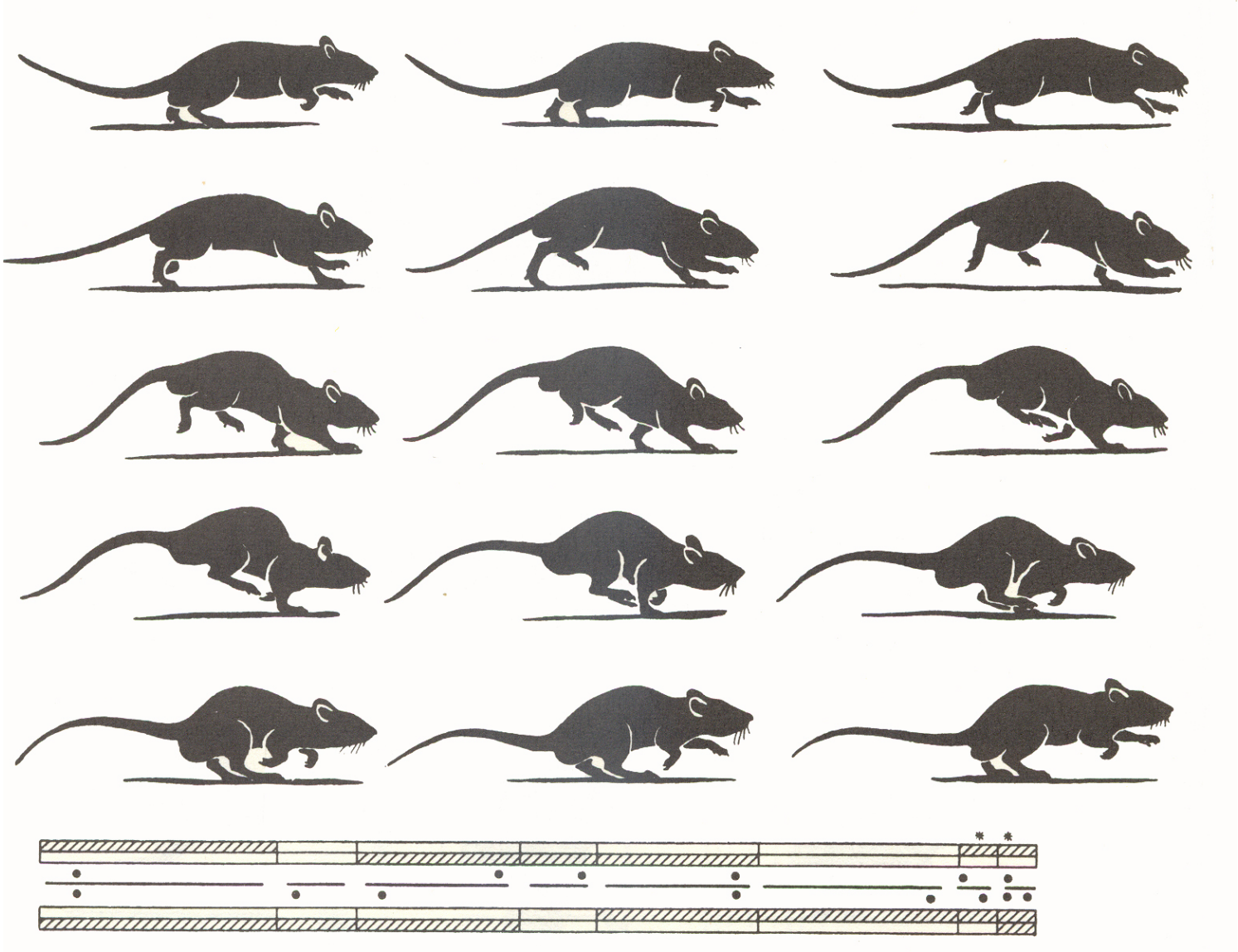
BIG

- Examples of a small rodent's locomotion.

- Small rodents are unusual in their mode of locomotion, yet very popular with animated projects!

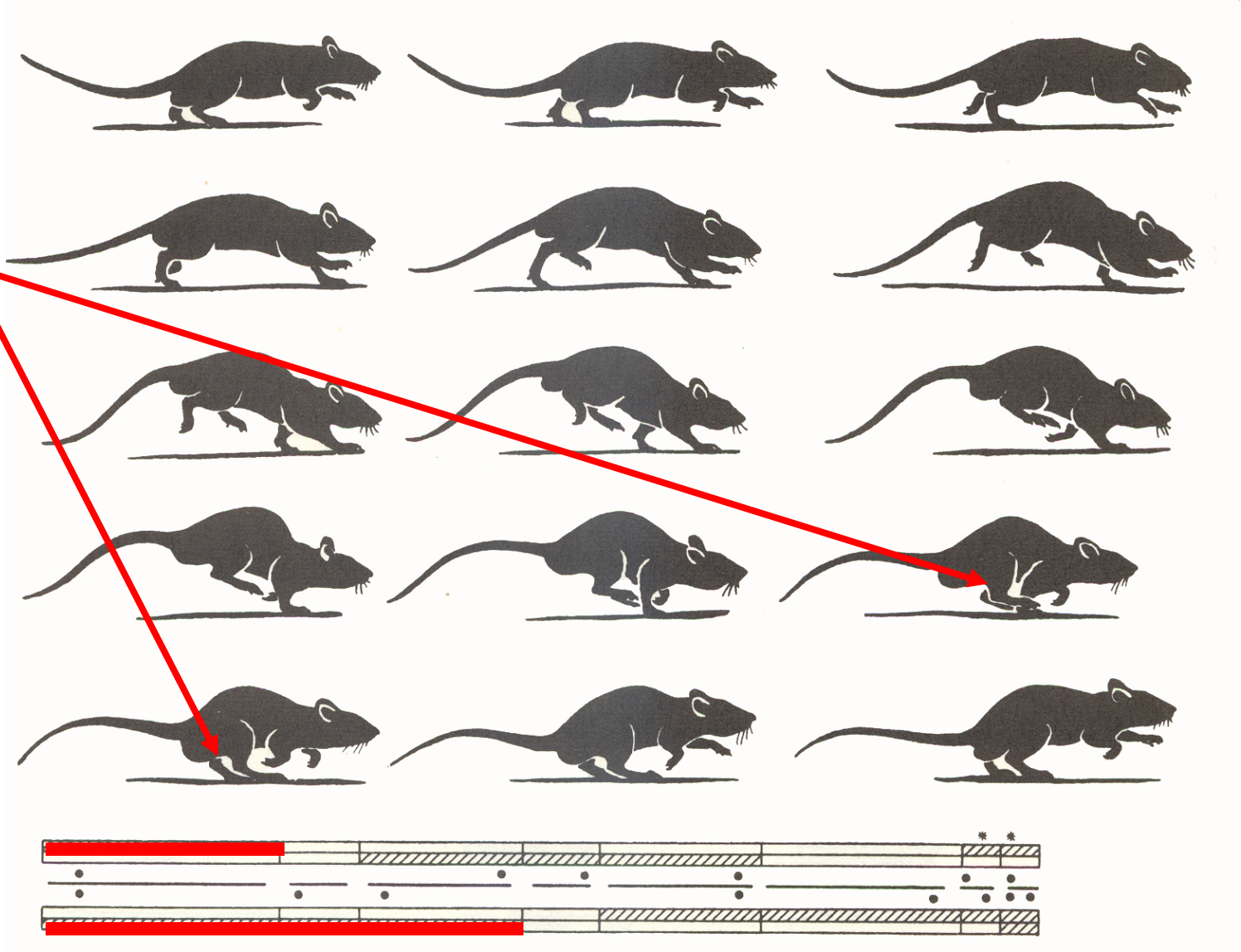


HALF BOUND is when hind limbs contact at same time, though they may not necessarily push off in symmetry – whereas forelimbs do not contact nor push off at exactly the same time.



Transition from slow to moderate speed locomotion – THE HALF BOUND

HALF BOUND is when hind limbs contact at approximately the same time, though they may not necessarily push off in symmetry – whereas forelimbs do not contact nor push off at exactly the same time.

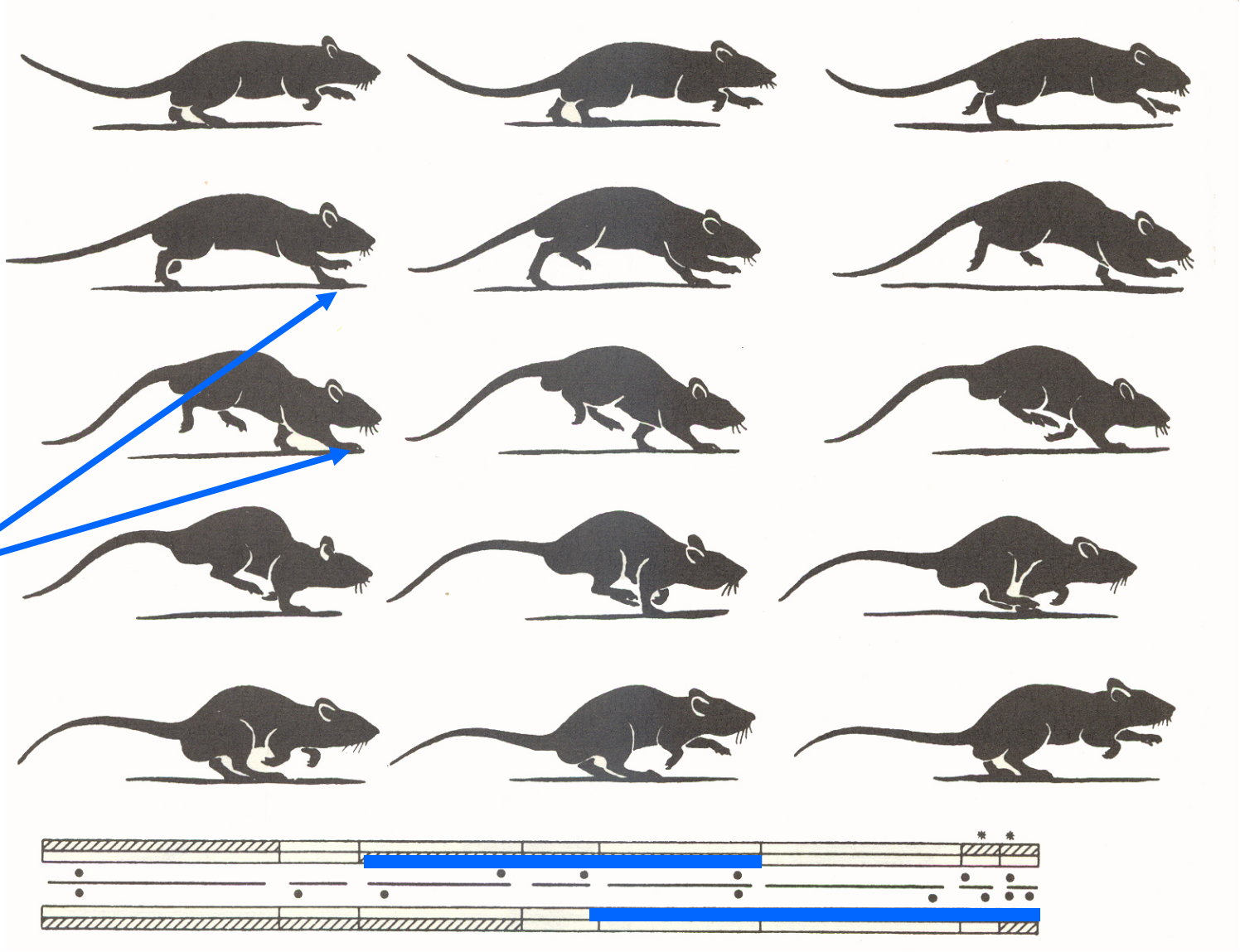


LEFT HIND

RIGHT HIND

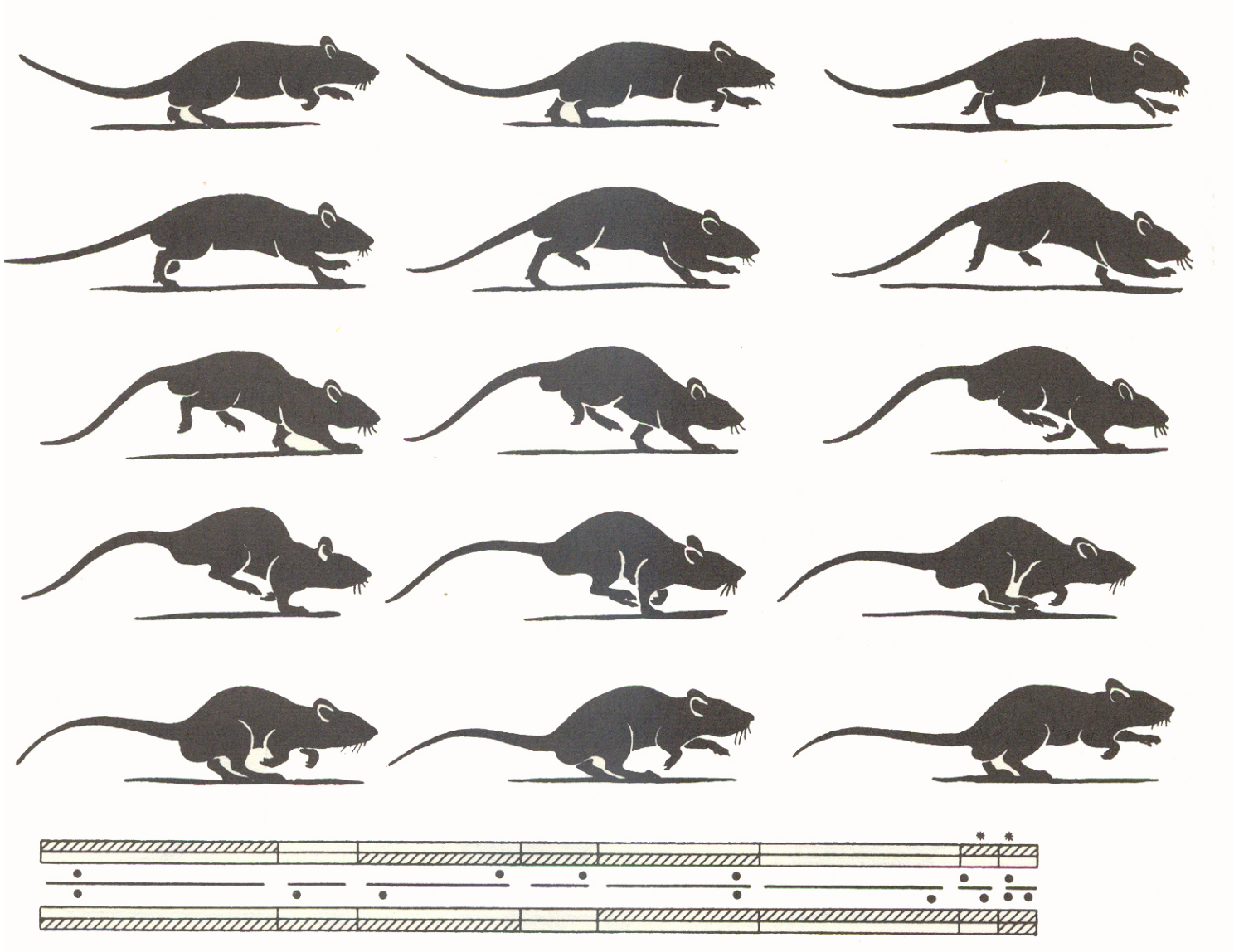
Transition from slow to moderate speed locomotion – THE HALF BOUND

HALF BOUND is when hind limbs contact at same time, though they may not necessarily push off in symmetry – whereas forelimbs do not contact nor push off at exactly the same time.



Transition from slow to moderate speed locomotion – THE HALF BOUND

FEATURES OF THE HALF BOUND:



The latter forefoot to contact leaves ground after first and even second hindfoot lands.

There can be a brief 3-point period of support (both hinds and last forefoot).

After 3-point stage of support, the remaining forefoot takes off, then a hindfoot.

The next hindfoot breaks contact, but only after a forefoot has resumed contact phase.

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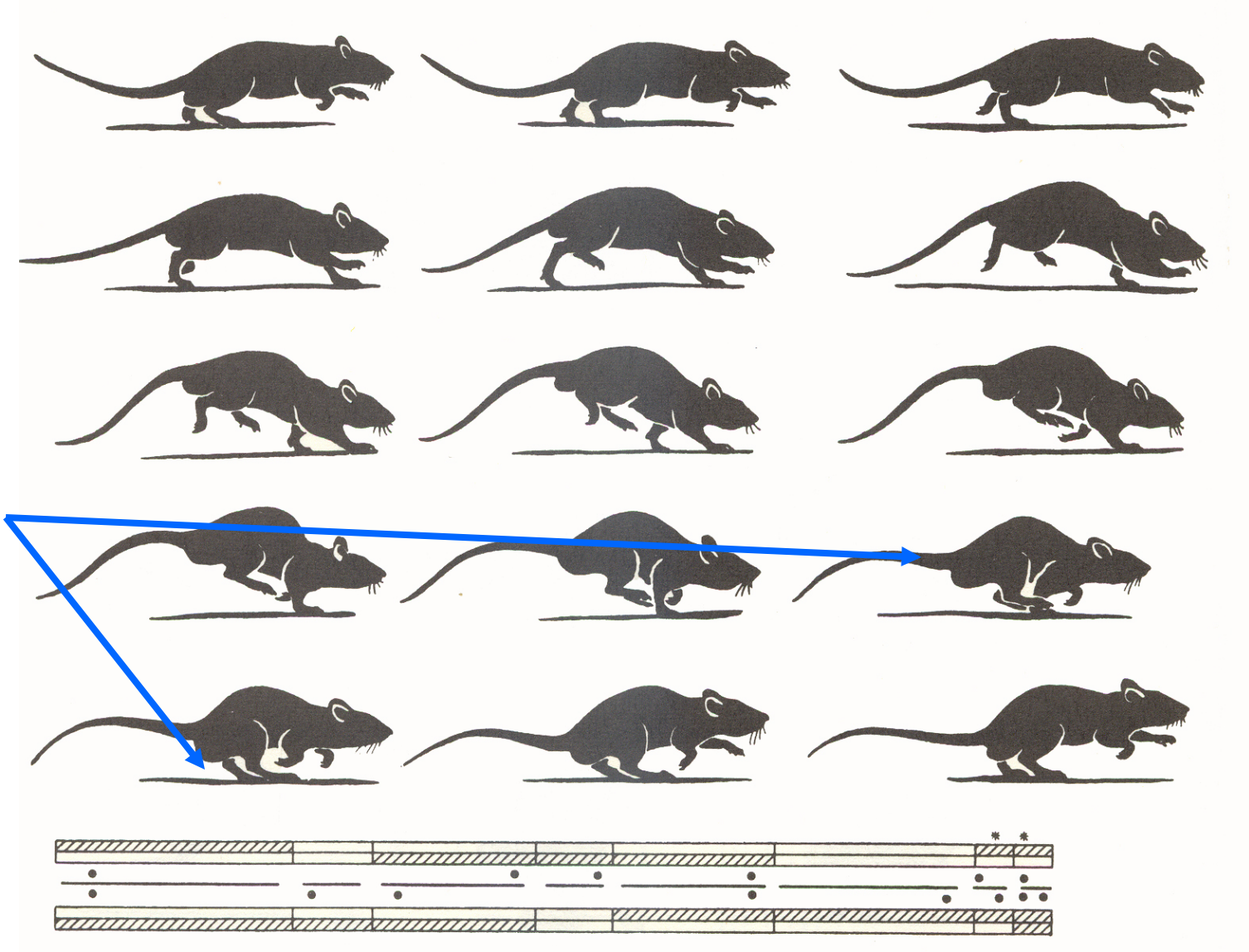

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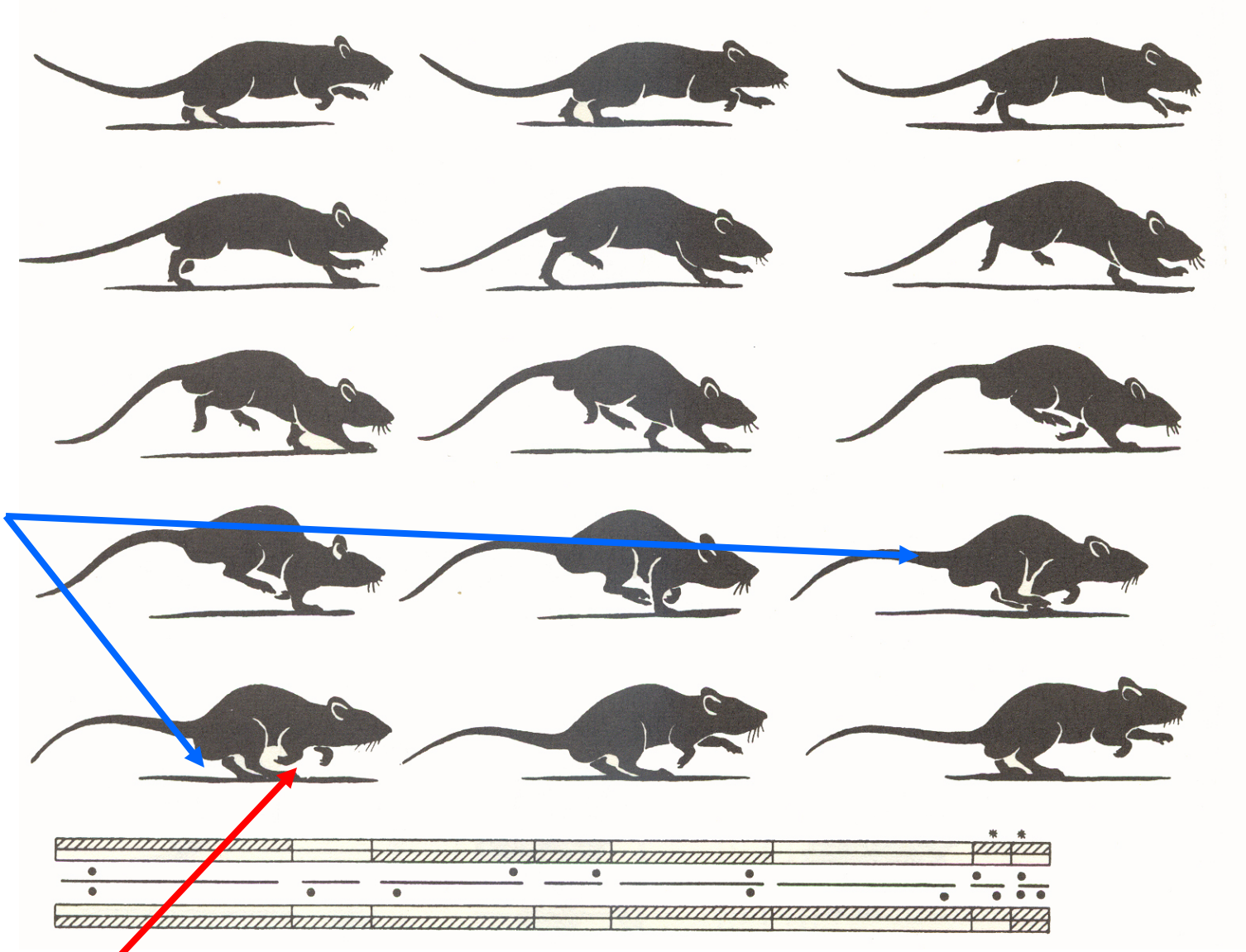

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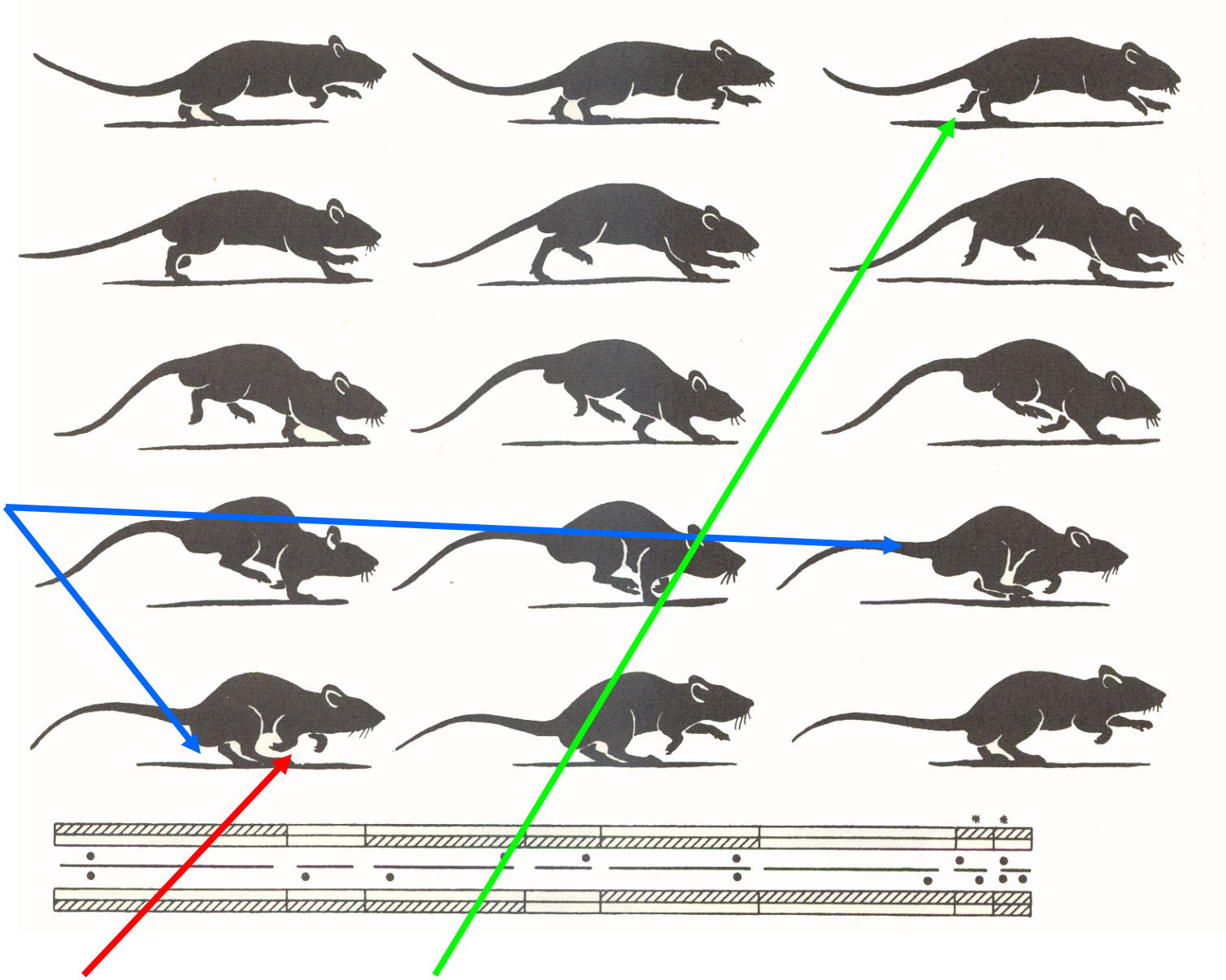

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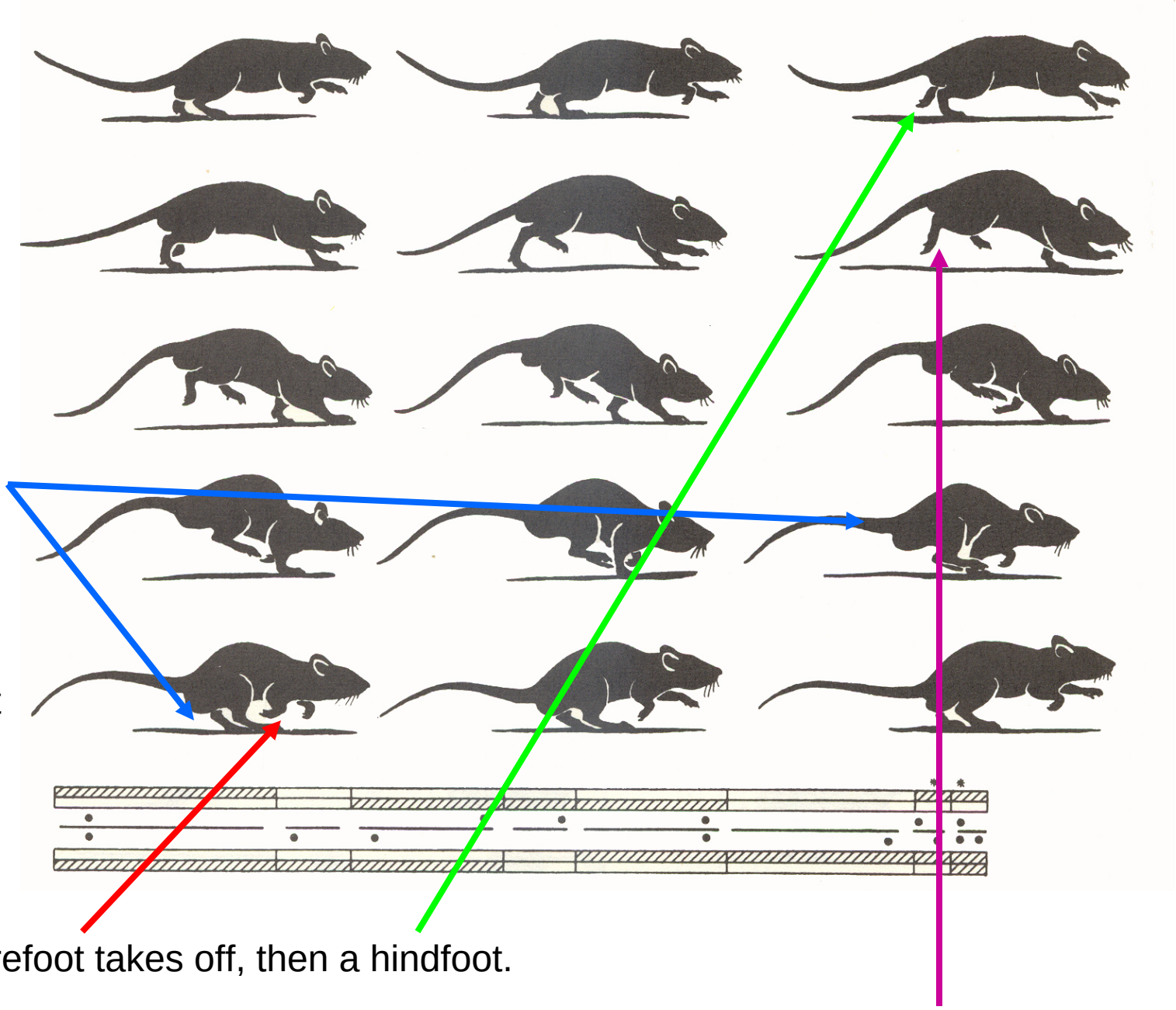

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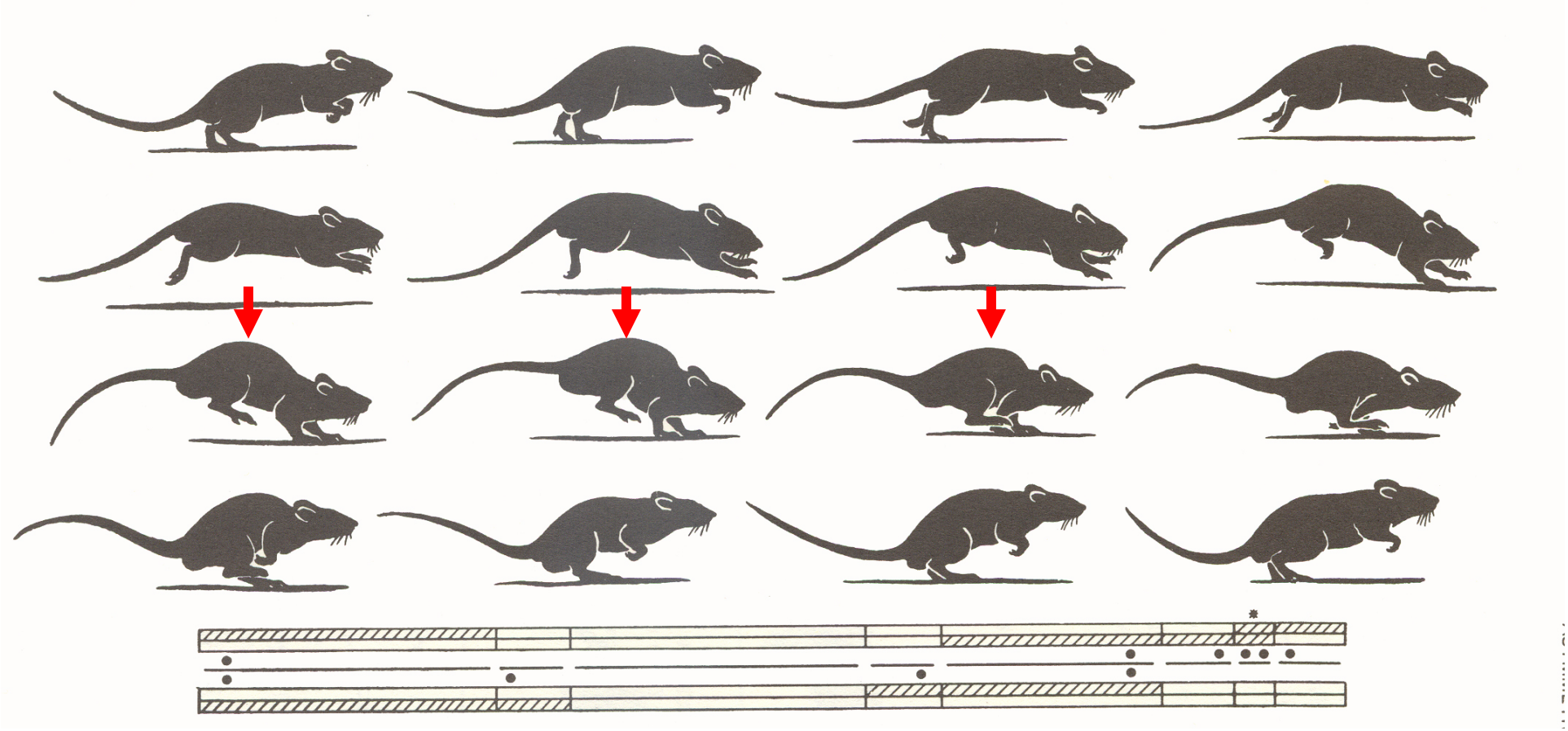
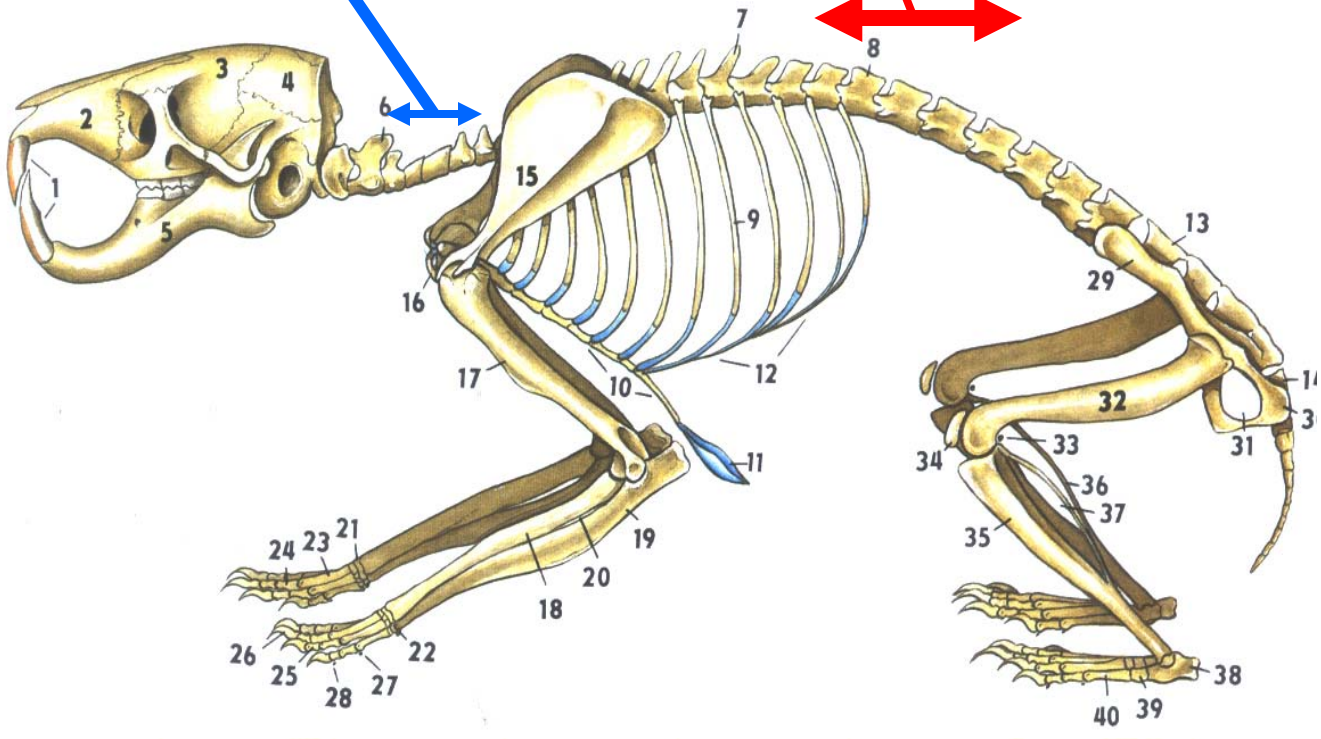
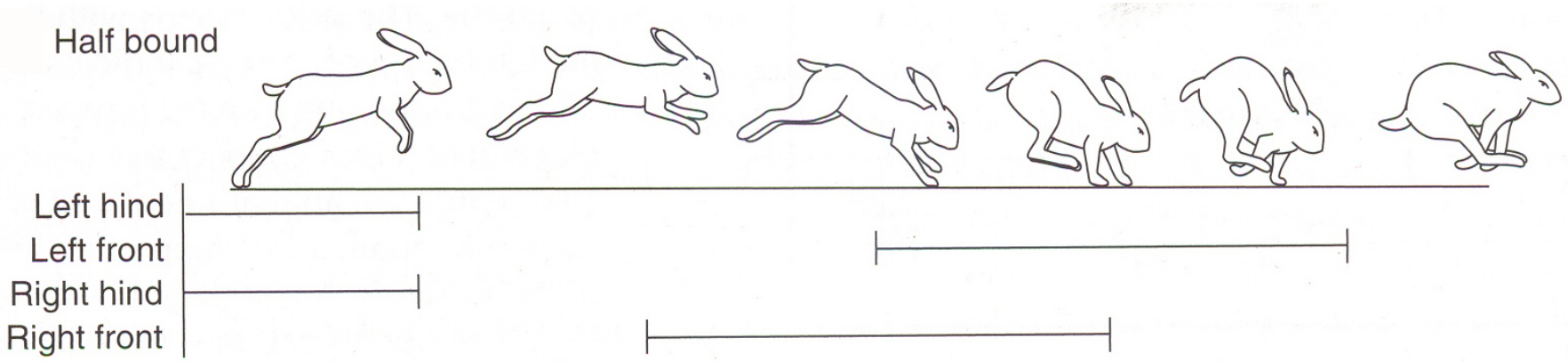


Apex of backbone curvature at approximately level of knee.

Most flexible region of backbone.

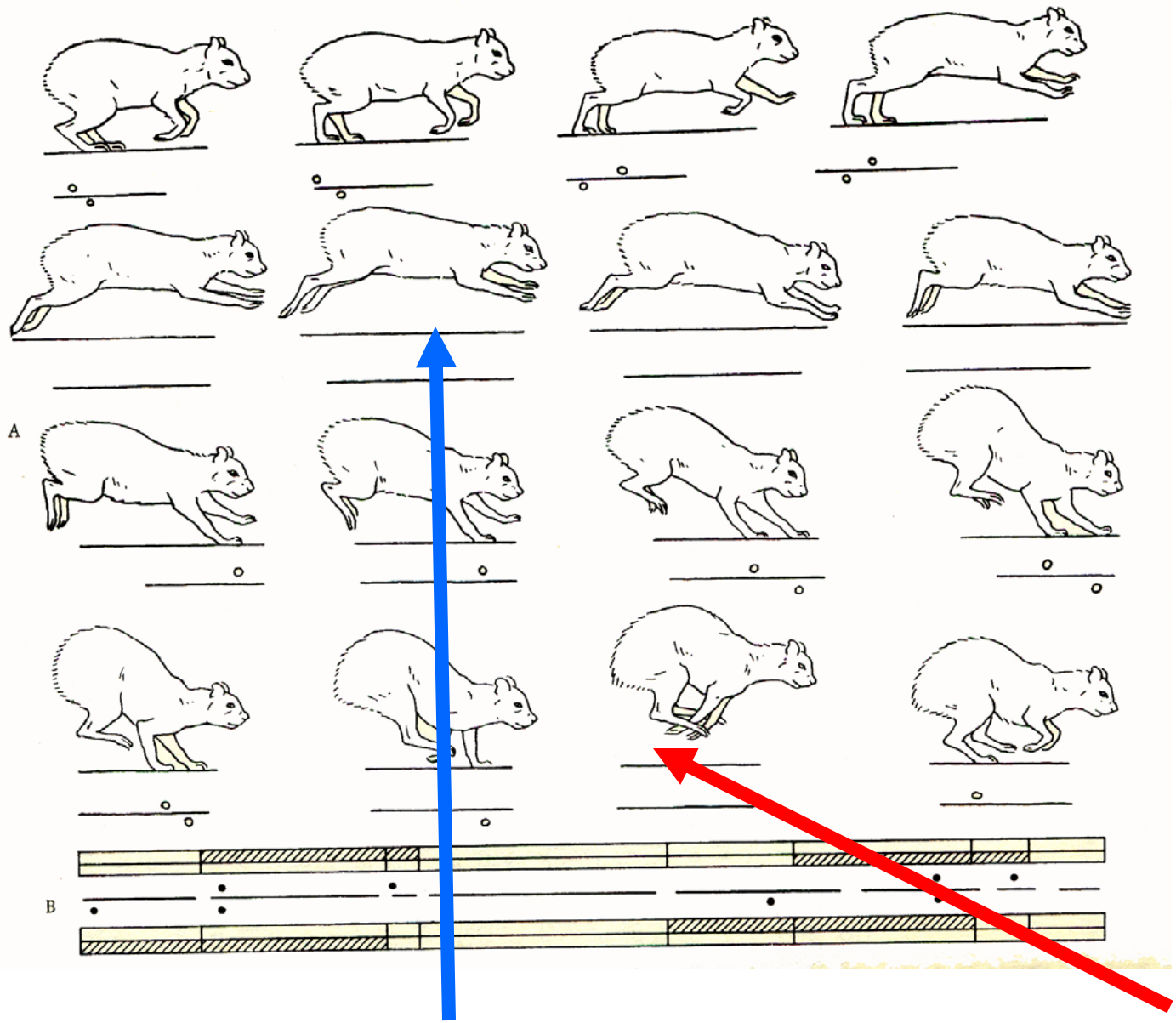
Stiff region (to maintain head stabillity)



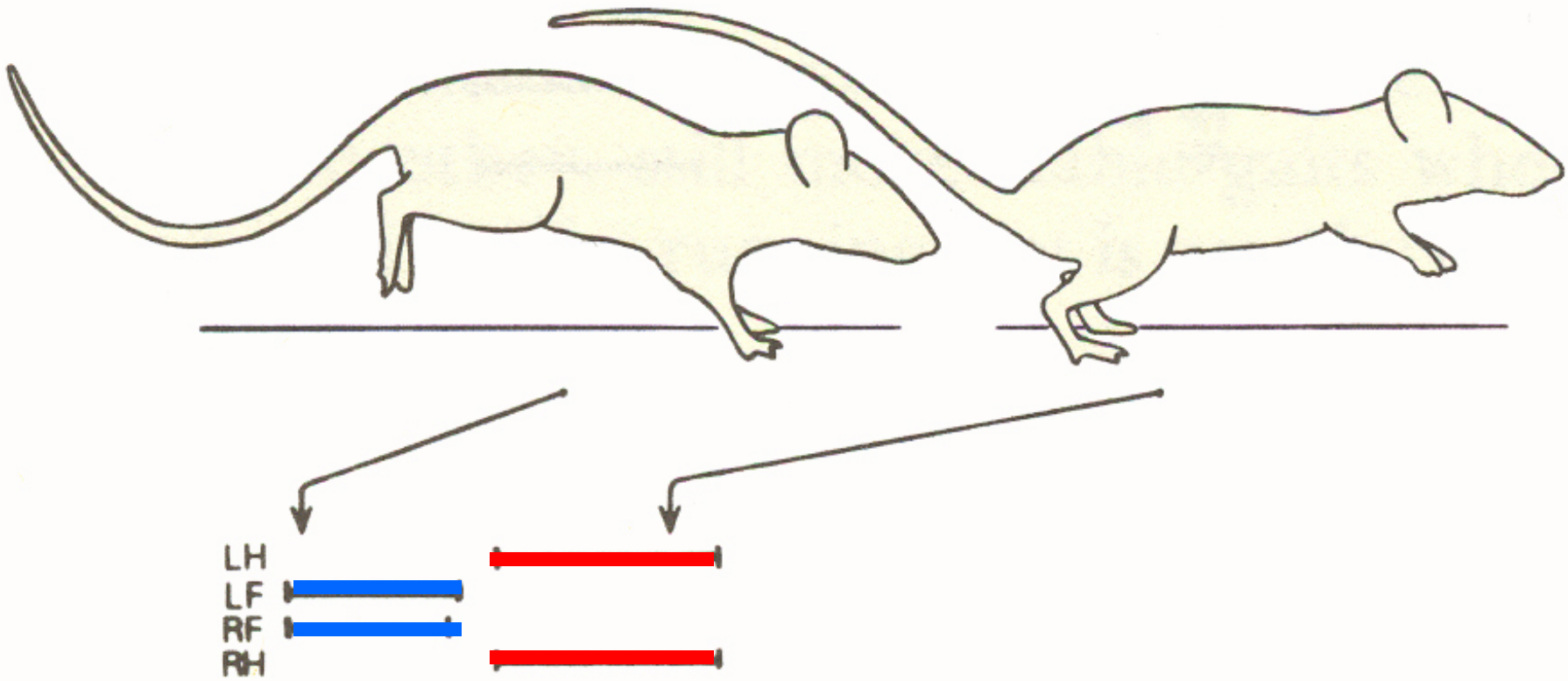


A classic type of half-bound. Note that in this example of a half-bound, forelimbs are not symmetrical in contact, but hind limbs are perfectly symmetrical in contact pattern.

In all half-bounds, hind limbs are lateral to (outside of) forelimbs.

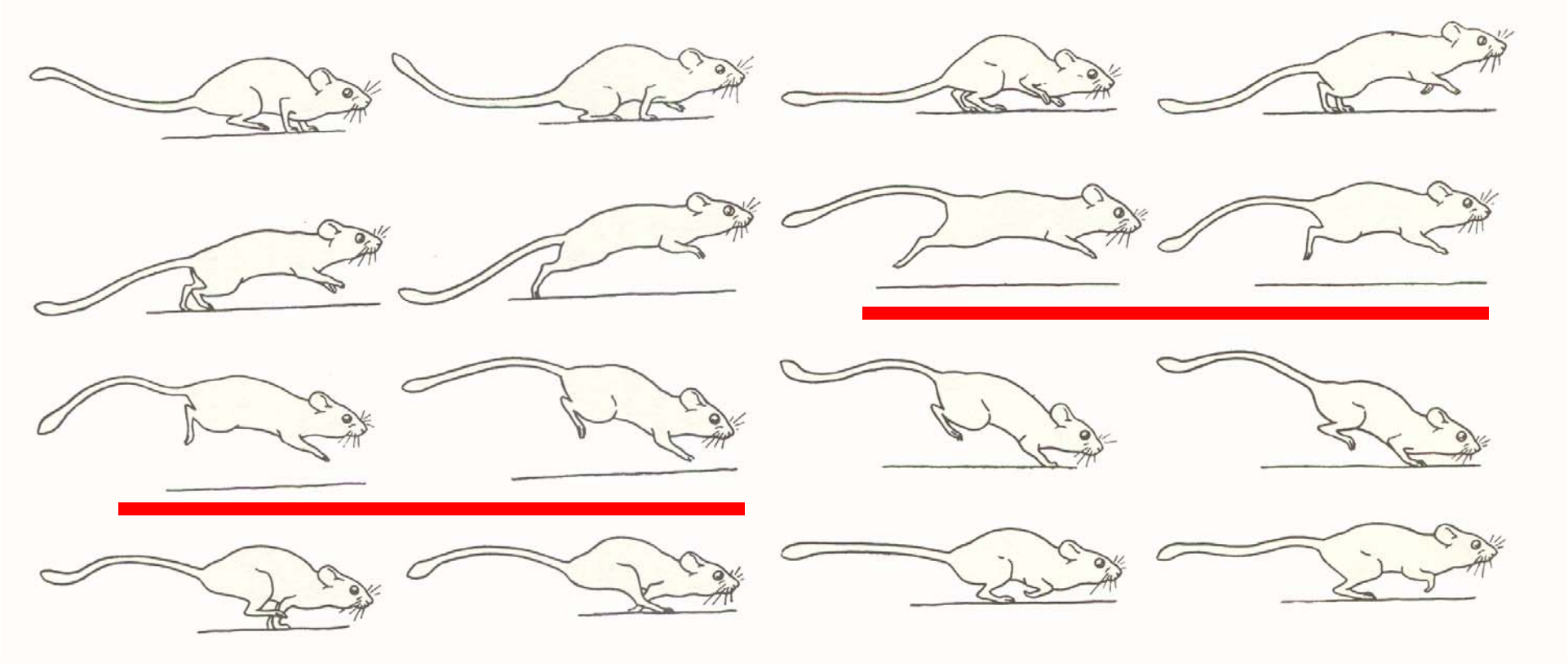


A half-bound with an EXTENDED FLOATING PHASE and a GATHERED FLOATING PHASE. This is not characteristic of hamsters (usually hamster half-bound has no true floating phases), but could be used to give impression of more light, bouncy character.

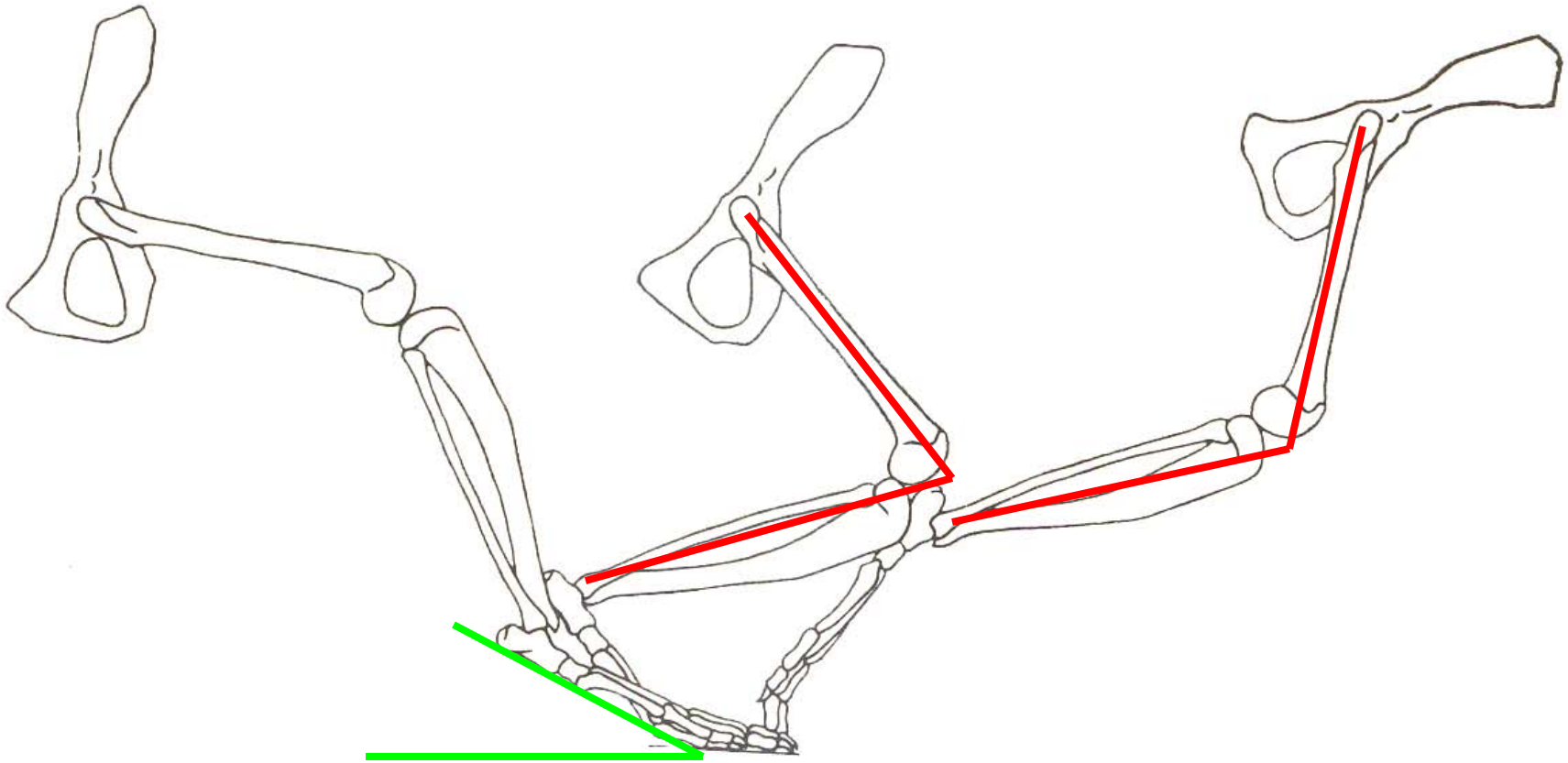


HOUSE MOUSE: Bound

Higher speed locomotion: transition to a true BOUND. In a true bound, each hindlimb has the same footfall pattern as other hindlimb and each forelimb has the same footfall pattern as other forelimb. Gives a “teeter-totter” look.



A typical true bound in rodents has an EXTENDED FLOATING PHASE, but no gathered floating phase. This is possible in hamsters.

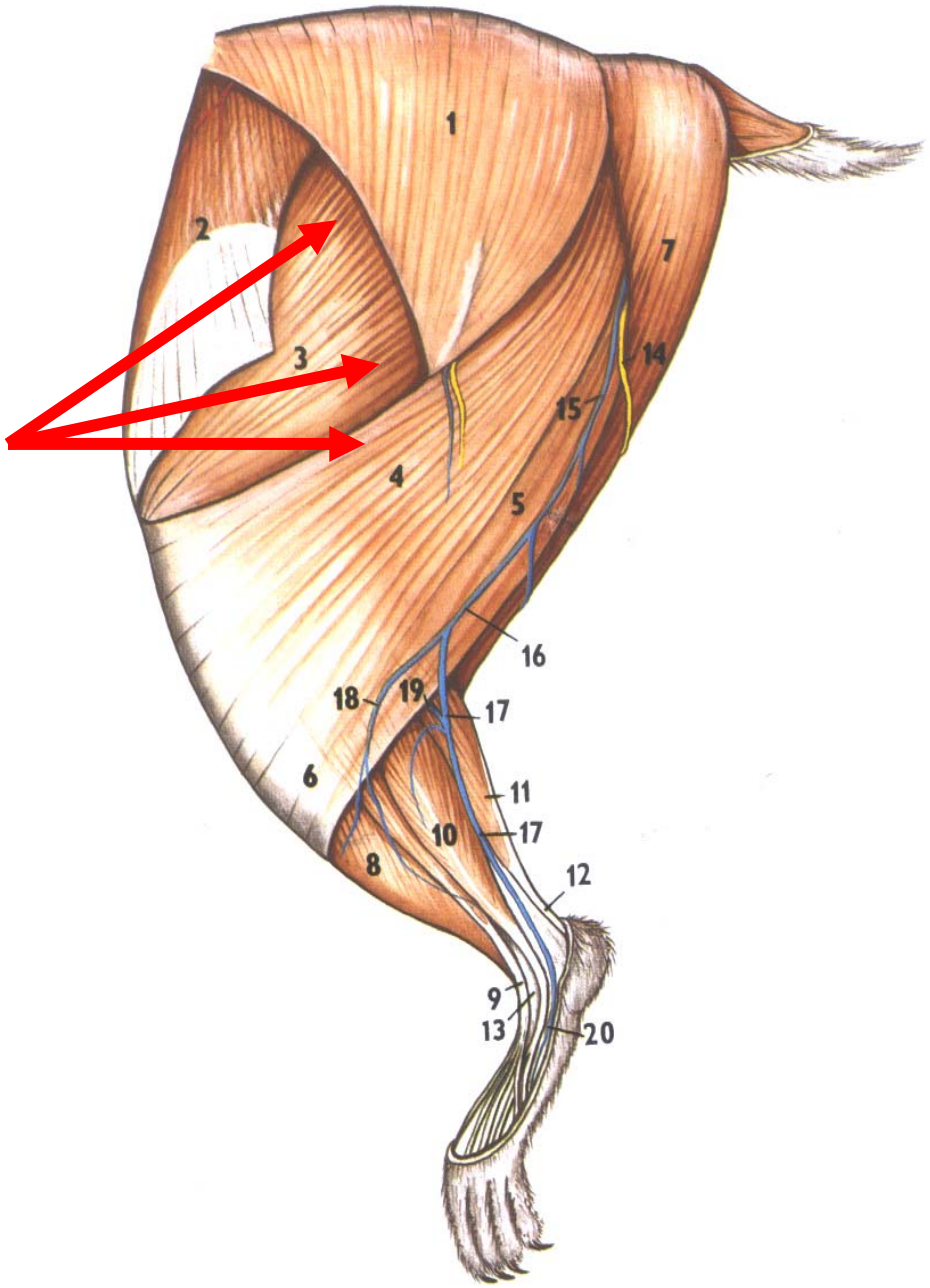


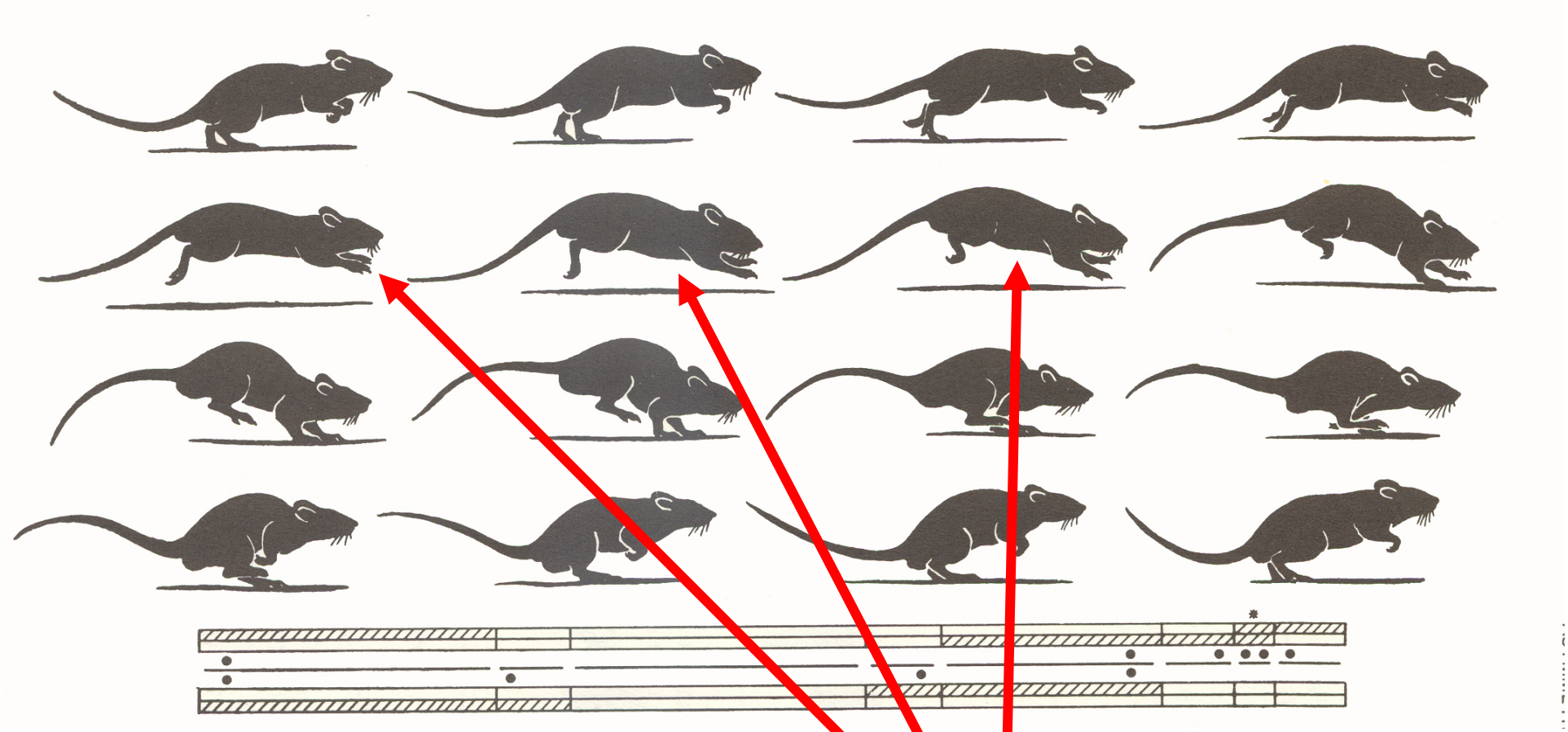
Most of the propulsive force come from extension AT THE KNEE. Much less from the hip or ankle.

Notice that foot lands almost parallel to ground.

Hamster…

Thigh Musculature is dominated by knee extensors.

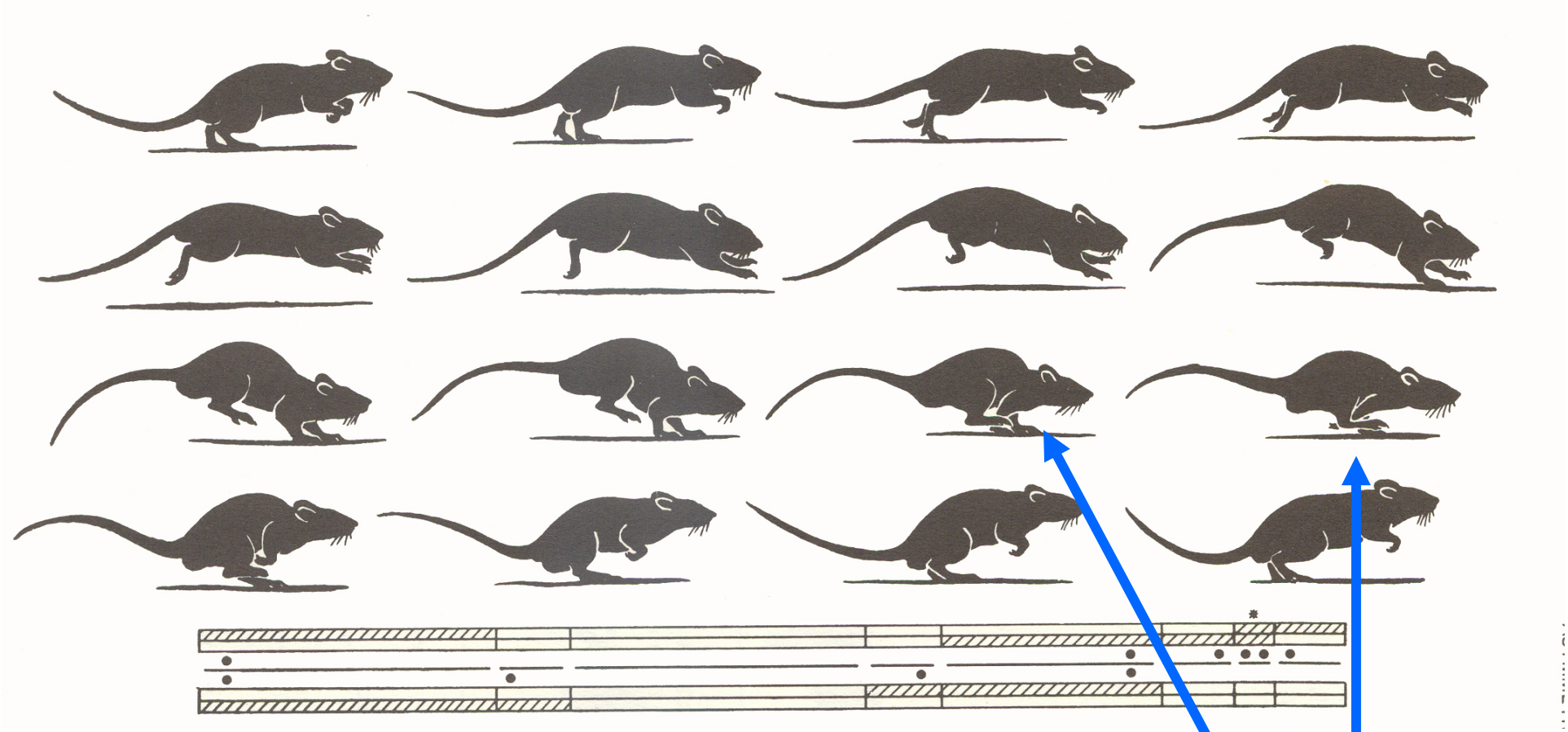




In asymmetrical true bound in rodents:

True floating phase (extended position only).

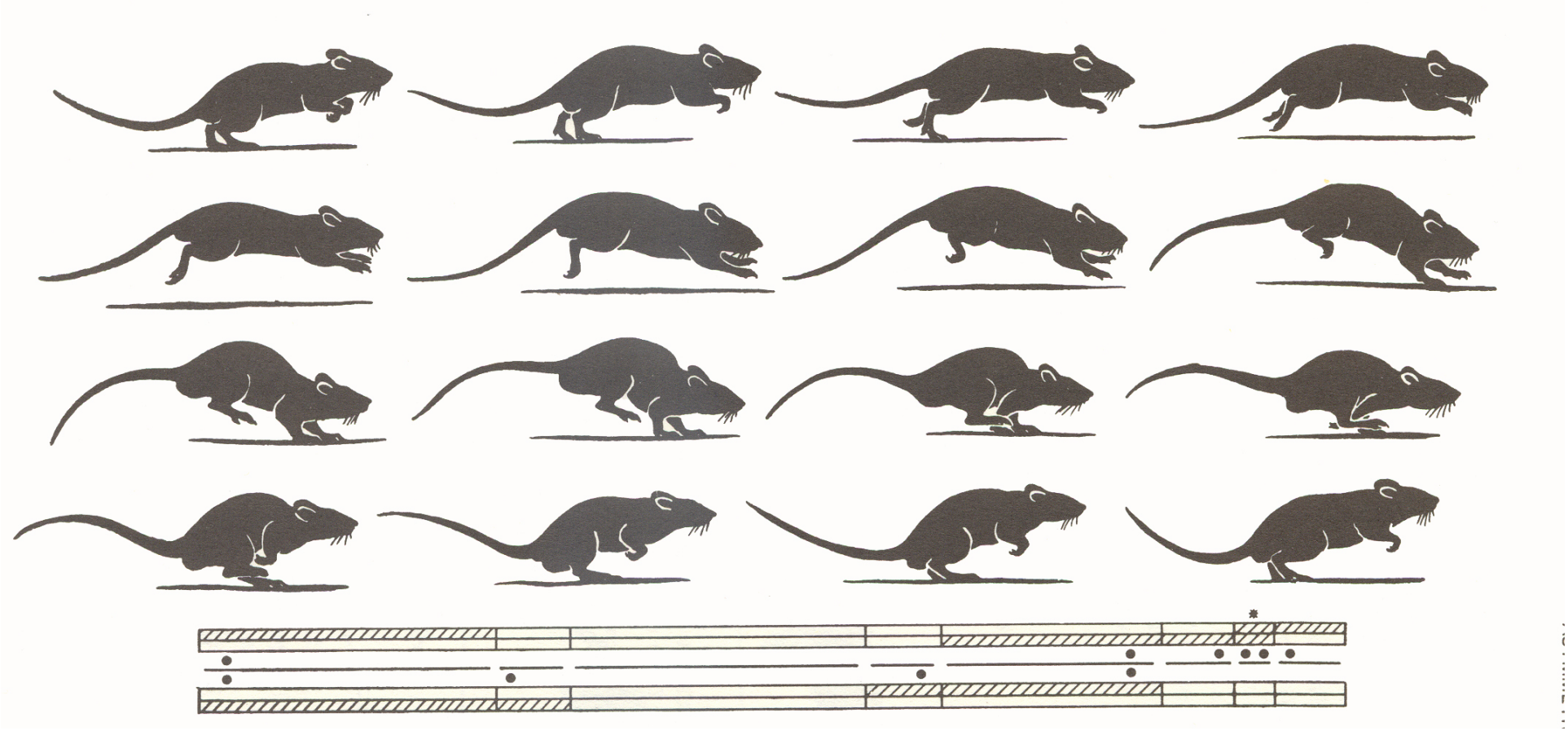
Hindfeet land before forefeet take off – this creates a brief period of 4-point support/contact.



In asymmetrical true bound in rats:

True floating phase (extended position only).

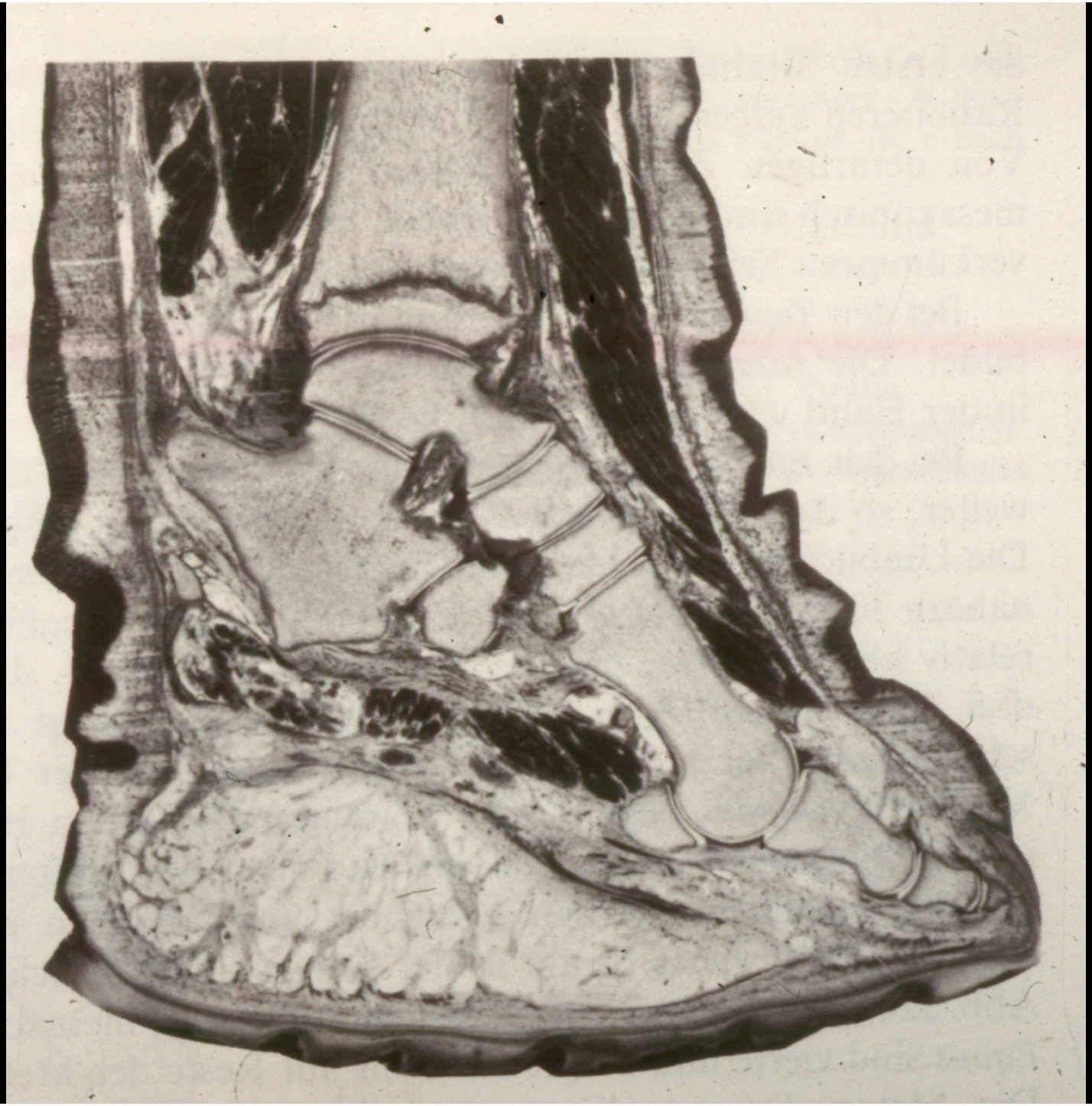
Hindfeet land before forefeet take off – this creates a brief period of 4-point support/contact.

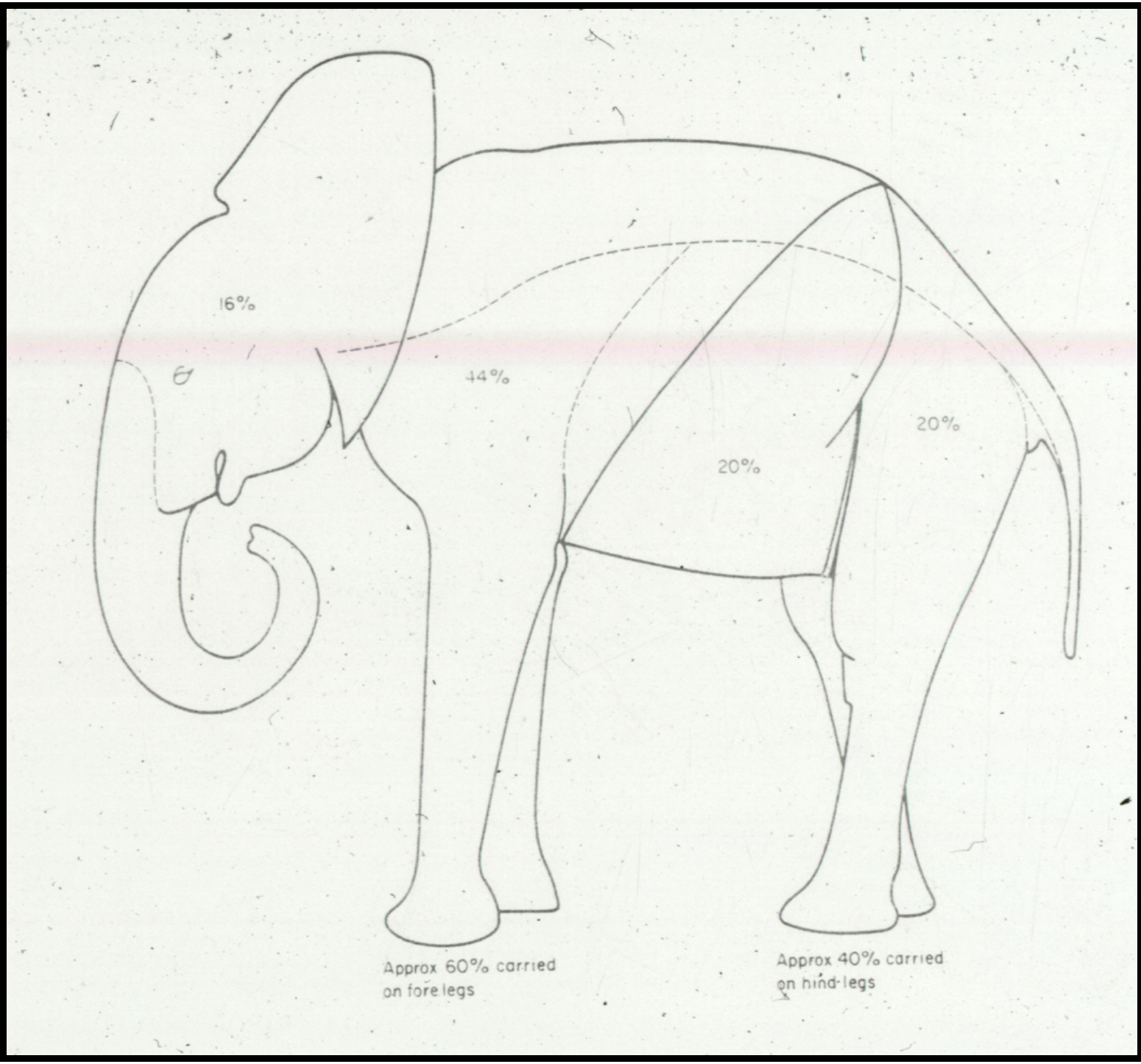


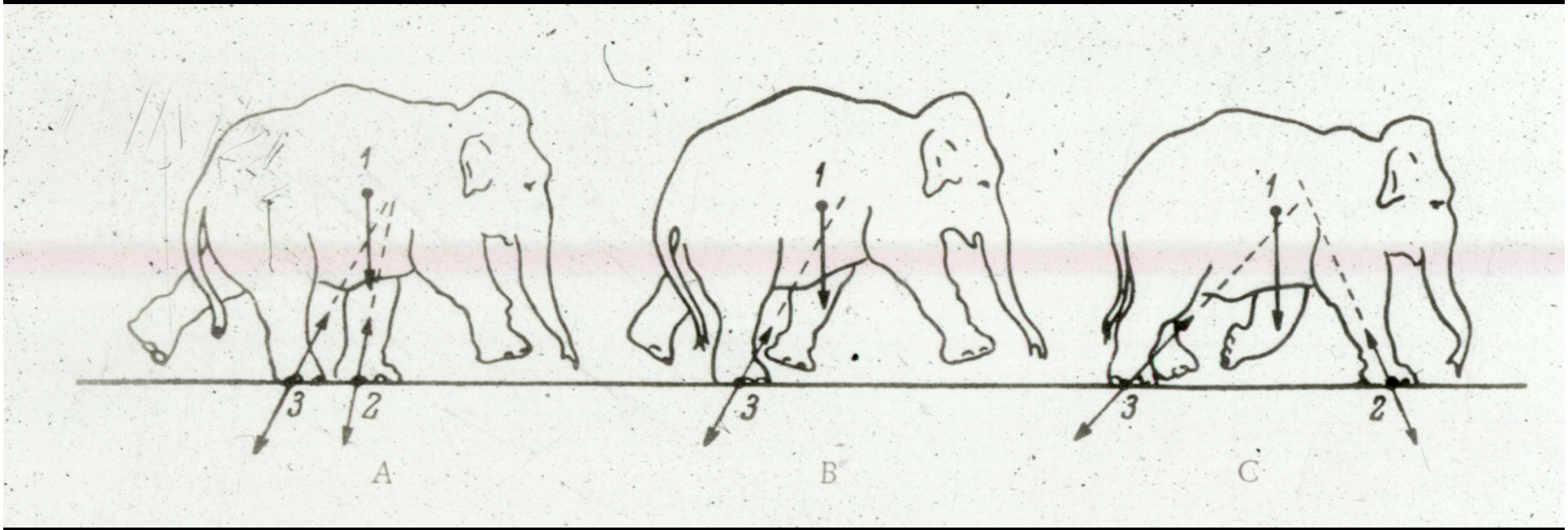
In asymmetrical true bound in rats:

Hindlimbs take up as much as 90% of propulsive force.

Forelimbs function more for shock absorption and steering.

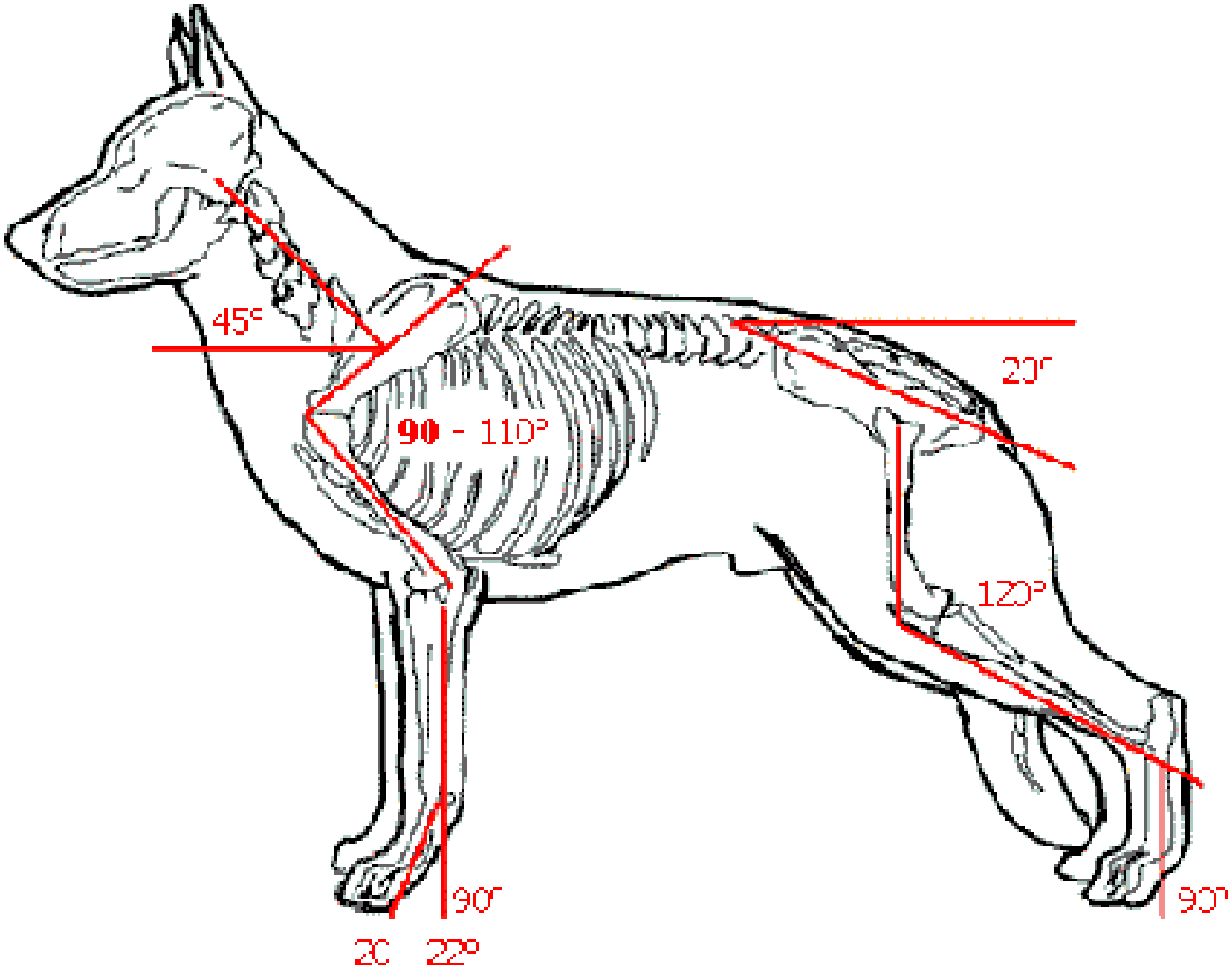



16%
44%
20%
20%
Approx 60% carried on fore legs
Approx 40% carried on hind legs


1
3
2
A
1
3
B
1
3
2
C

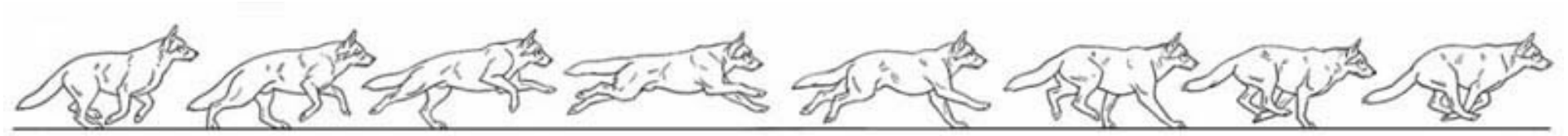
Mammalian Locomotion

Gait Related Behaviors
Jumping

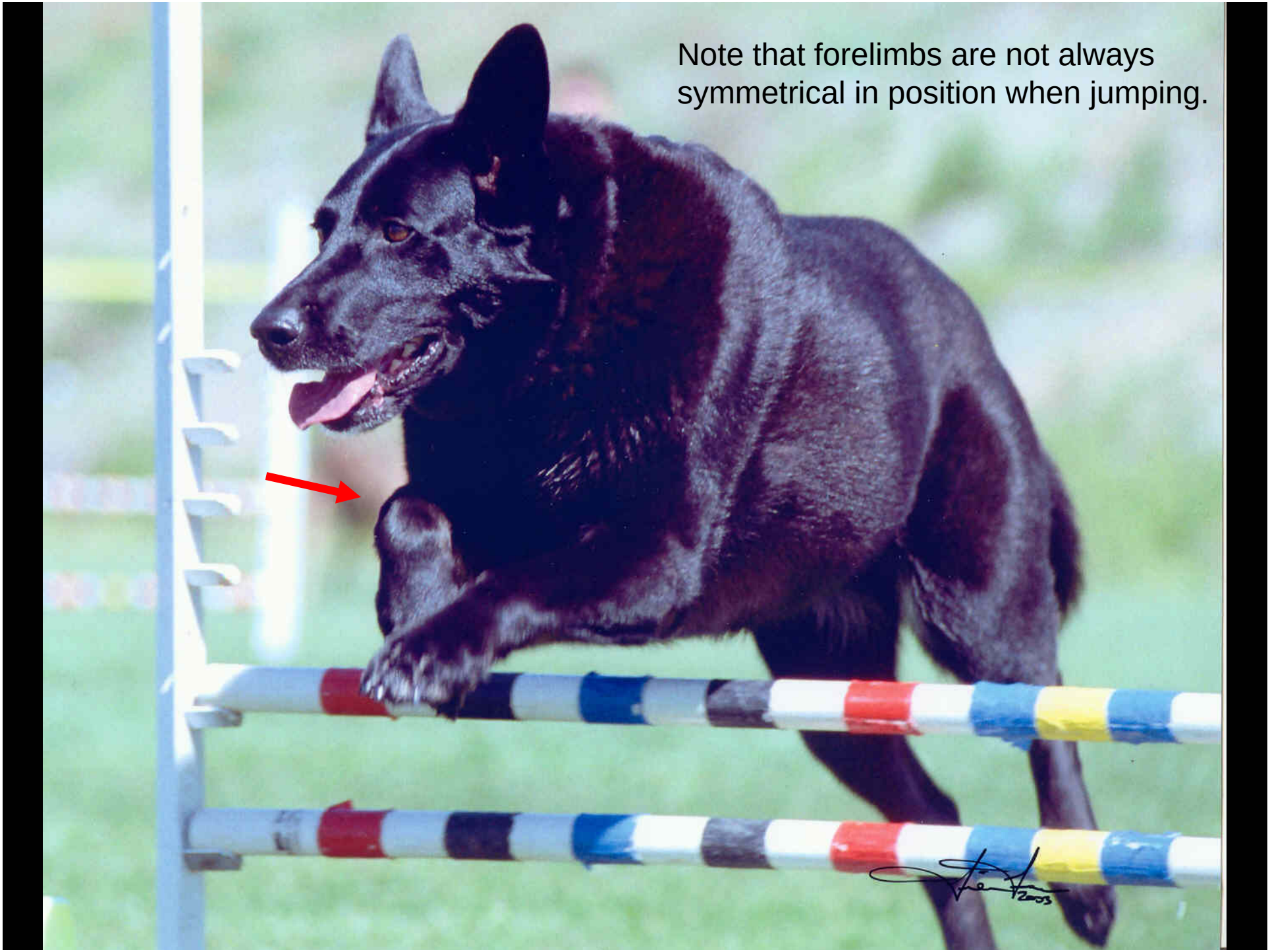


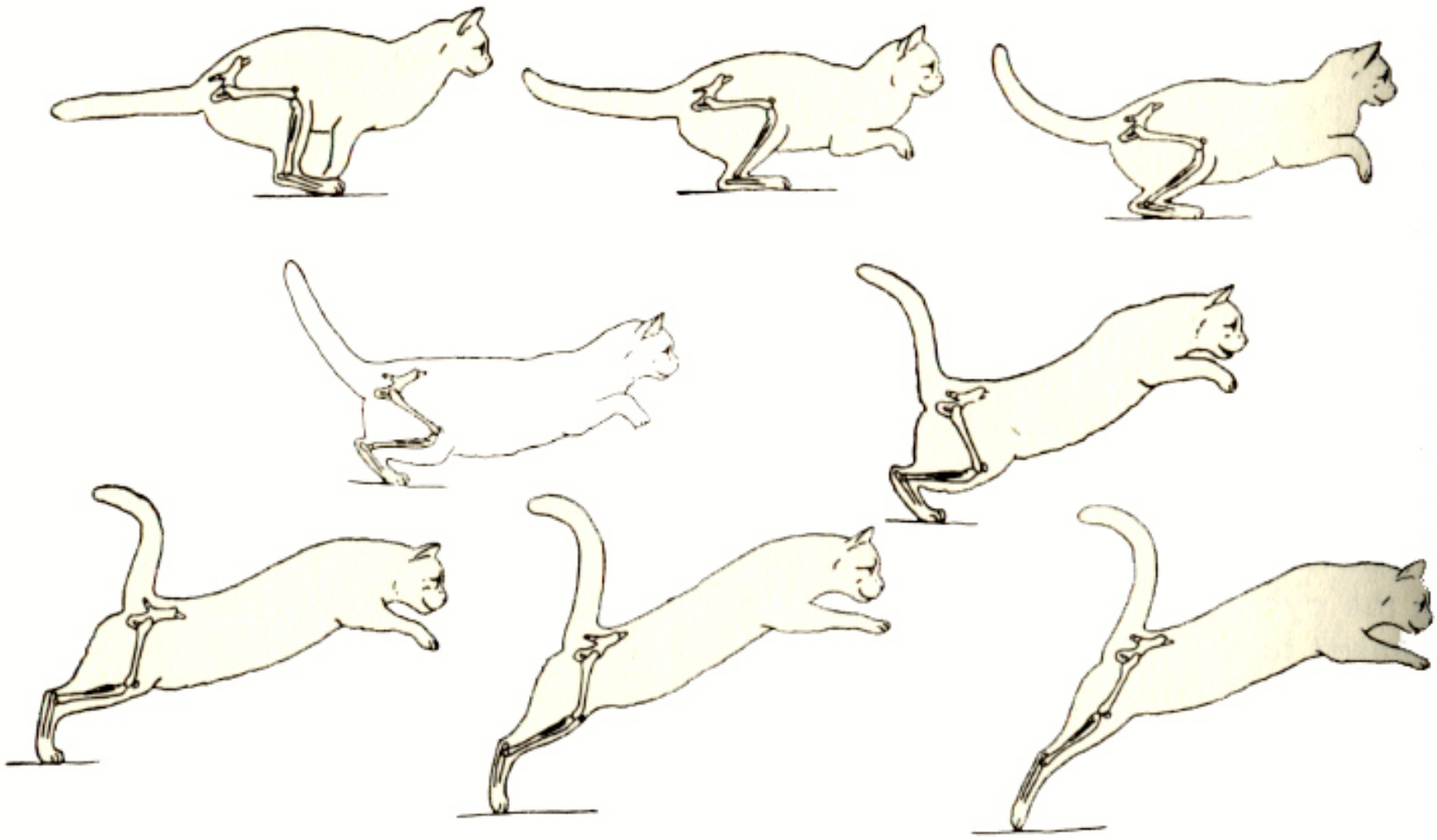
Dog skeleton with angles accepted as dog-show standards for correct German Sheppard confirmation.

In most dogs, a jump or leap is essentially a prolonged version of the extended suspension phase of a gallop. Thus, dogs jump from the hindlimb contact phase of high speed locomotion.

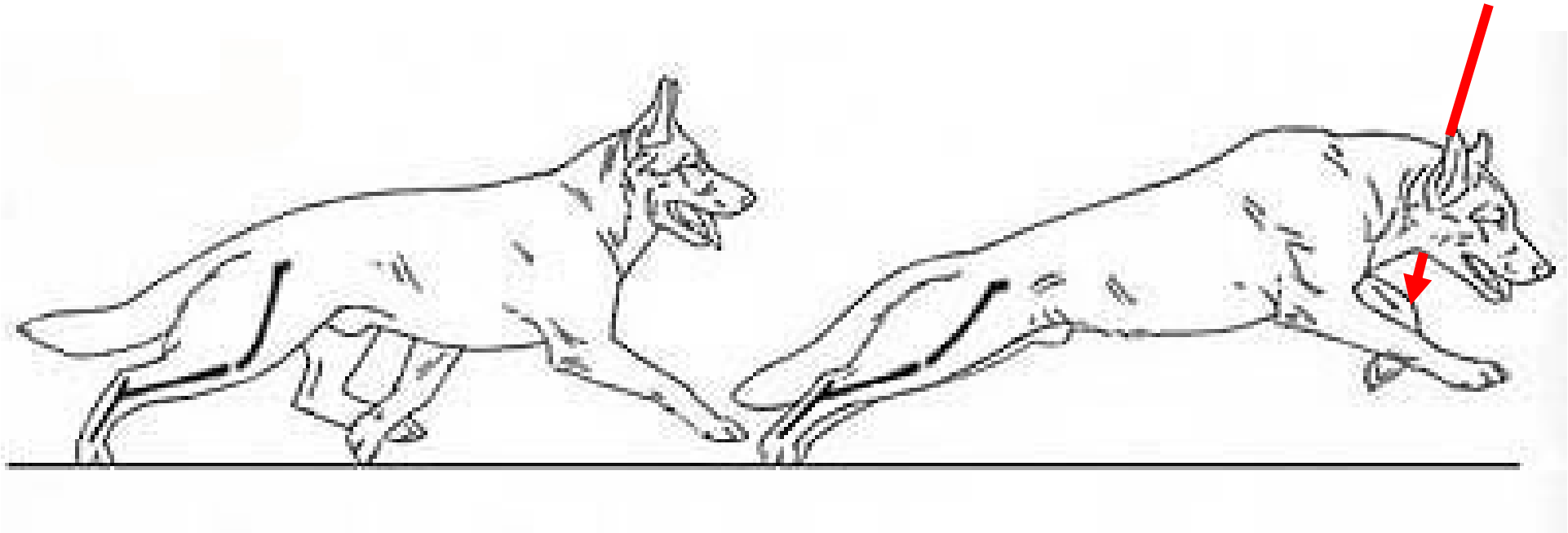


However, they usually pull hind limbs together to pushoff with both at the same time.


Note that forelimbs are not always symmetrical in position when jumping.

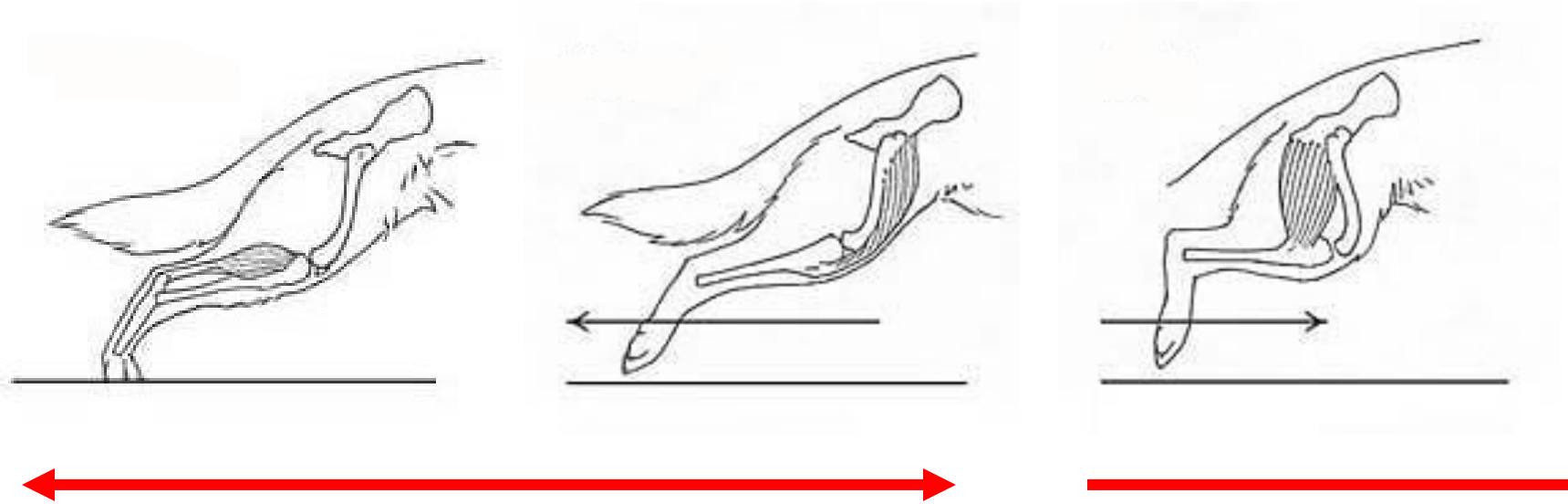


This is a view of a cat initiating a jump from hindlimb contact of a rotary gallop. Note that they usually pull hind limbs together to pushoff with both at the same time.



Note that they usually pull hind limbs together to pushoff with both at the same time.

At pushoff is as straight as the hind leg will get.



PUSHOFF

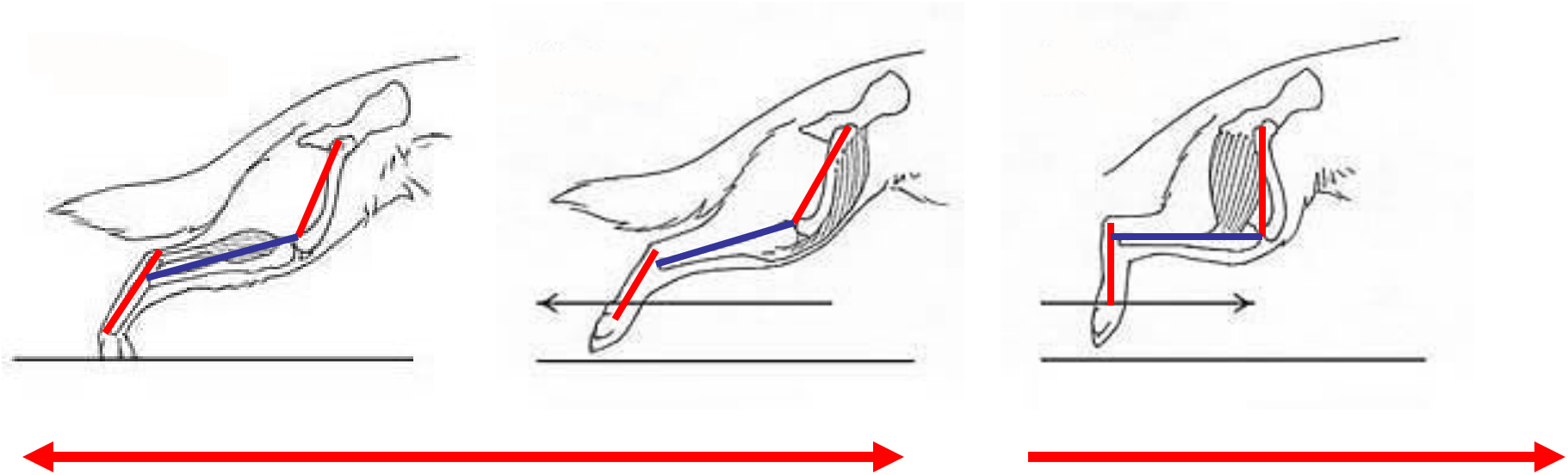
Engages calf (gastrocnemius) &

anterior thigh (quadriceps) muscles

RECOVERY

Engages hamstrings.

At pushoff is as straight as the hind leg will get.



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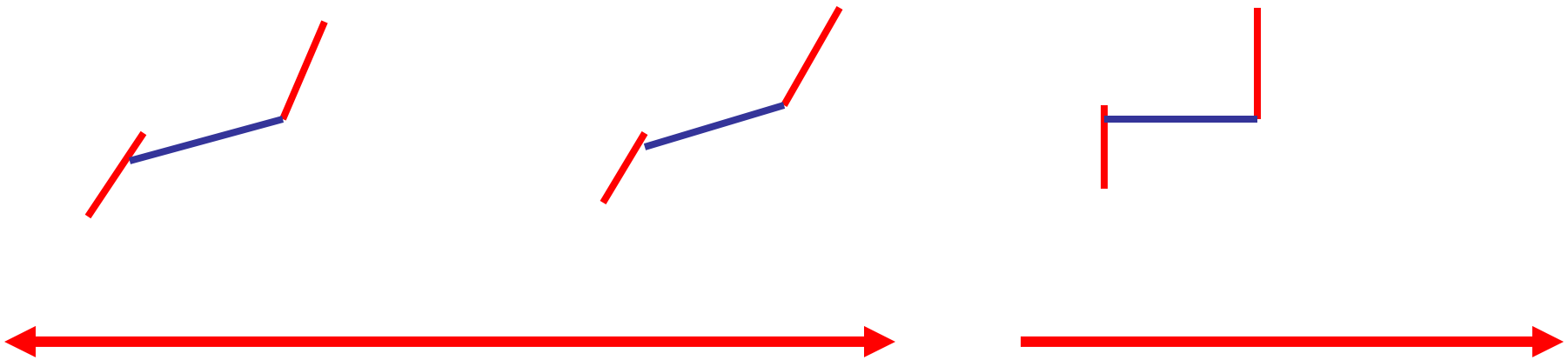

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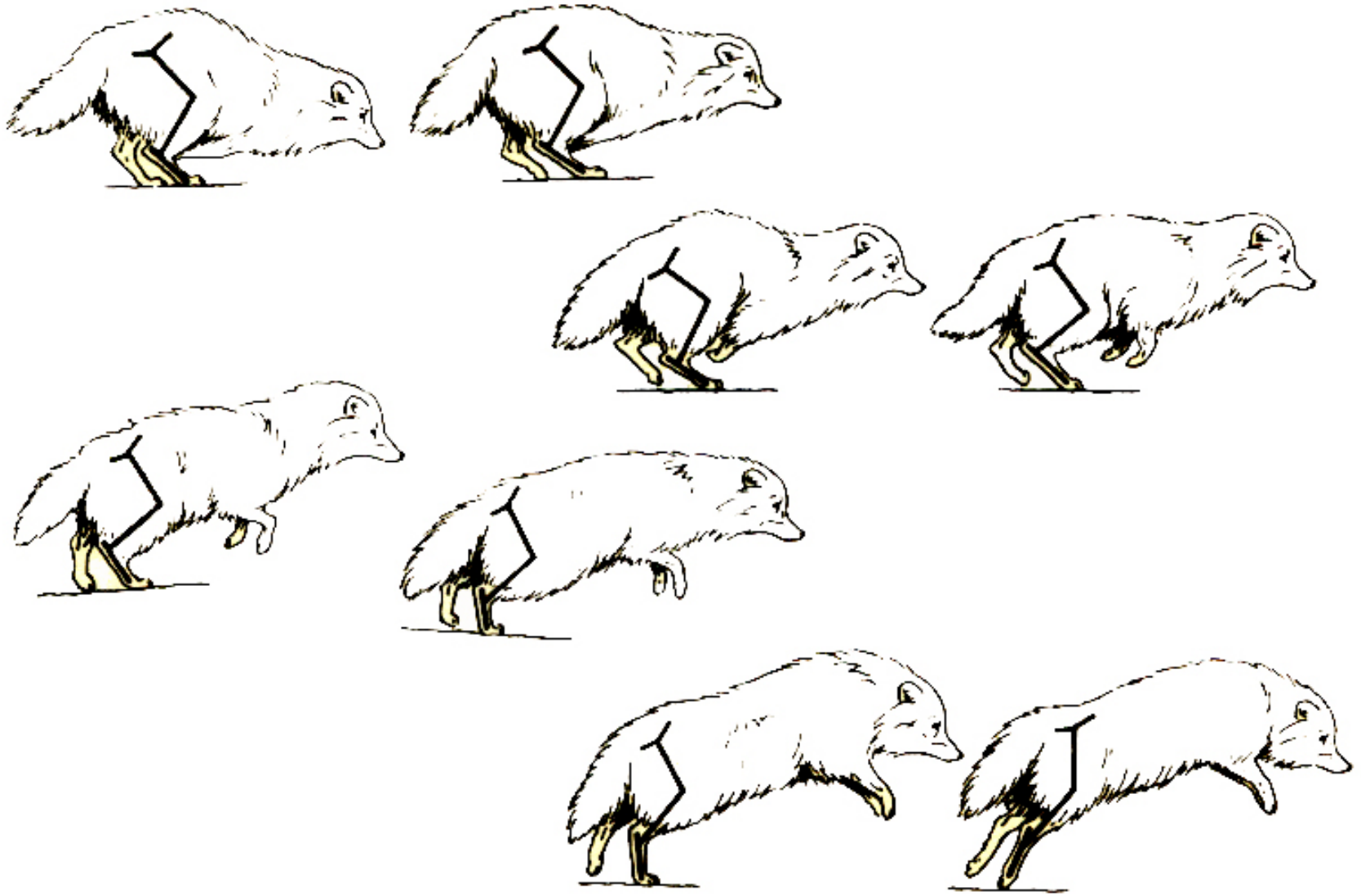
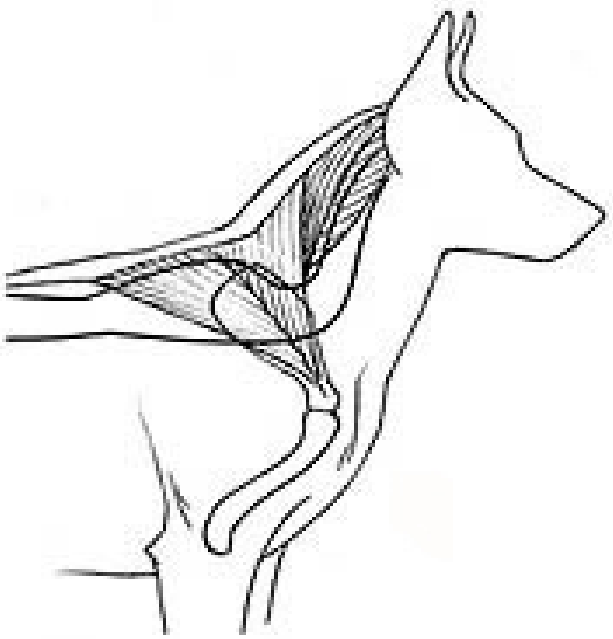
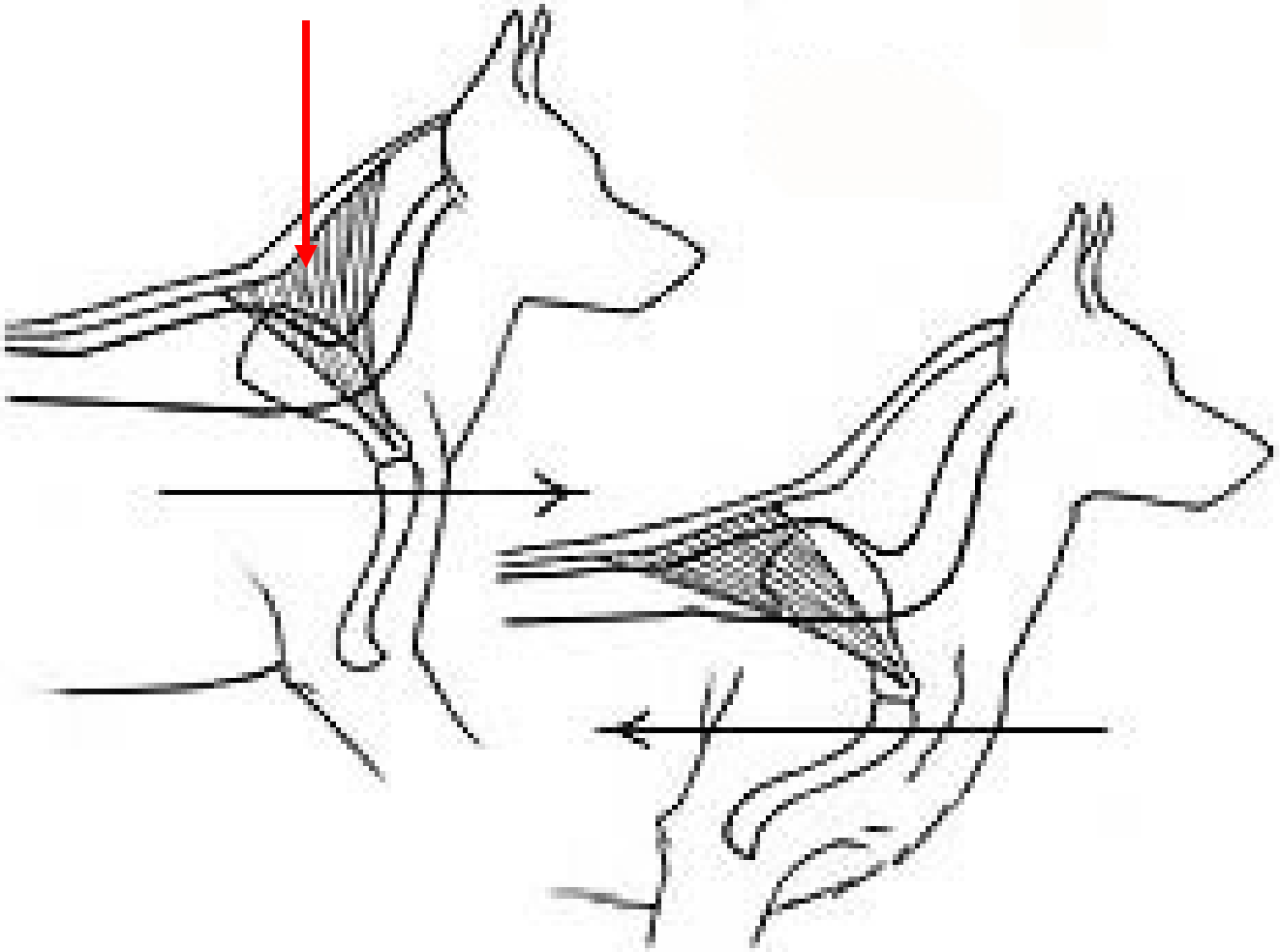


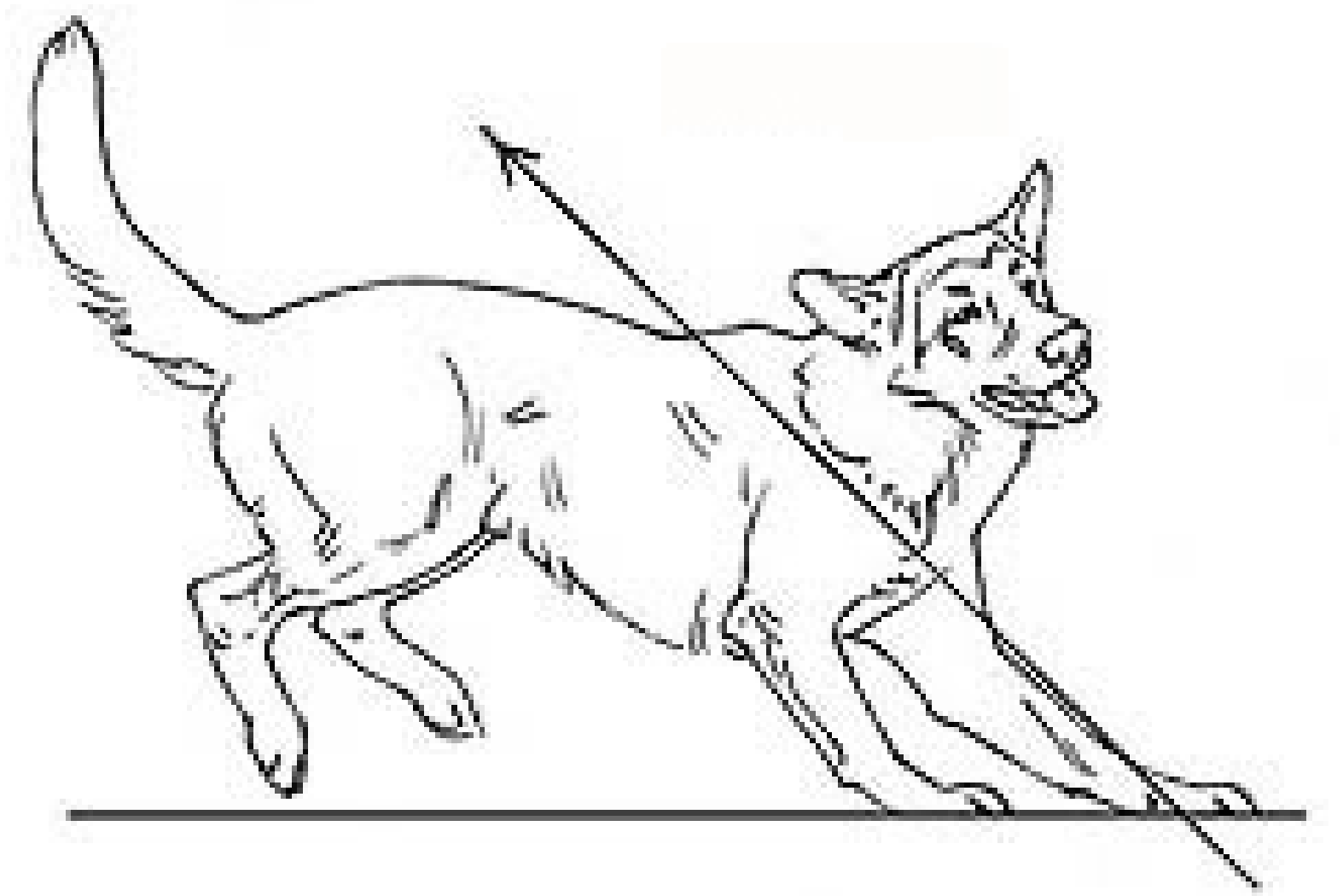
Short or playful jumps: If a dog is playing, or jumping up and down above a toy (or hole in the ground with something in it), she/he may jump more lightly off of one limb. This limb looks like a typical jumping limb, but the other is kept slightly more bent at each joint.

In LANDING, the forelimbs act as brakes and shock–absorbers. The body tends to thrust forward between the shoulders, so chest, back, and shoulder muscles stabilize this condition. Additionally, triceps muscles acting to keep the elbows straight contract powerfully



When dog lands and body weight is driven forward, the body tends to push forward between the shoulder blades (scapulae), so the cervical (neck) part of the trapezius muscle acts to resist this inertia when the limbs are angled forward. (Think of how your shoulders shrug if you were pushing against the ground.)





When landing or stopping from a powerful jump, the forelimb segment will be aligned with the shoulder blade in one or both limbs. Humeral segment is not perfectly straight, but close.