Symmetrical Gaits of Dogs in Relation to Body Build

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ABSTRACT Symmetrical gaits of 37 breeds of dogs were analyzed. Usual walking and trotting gaits resemble those of other carnivores of similar size and conformation. Only certain long-legged dogs pace — usually at the fast walk or slow run. At the moderate walk, long-legged dogs tend to use lateral-couplets gaits, whereas short-legged breeds tend to use single-foot gaits. Many dogs must turn the axis of the body slightly from the line of travel at the trot to prevent interference between fore and hind feet. The relative duration with the ground made by fore and hind feet is discussed, usual support-sequences of the various gaits are presented, and the amount of variation is shown.

The principal objective of this study is to analyze the walking gaits of dogs of different body build in order to test a relationship between form and function that seems evident among many wild mammals. A second objective is to study the pace, a natural gait of some individual dogs and of few other animals. The trot is also of interest because at this gait many dogs turn their bodies slightly from the line of travel.

The various walks, running walk, trot, and pace have been designated symmetrical gaits because the two feet of a pair (fore or hind) strike the ground at even intervals of time. The gallops are asymmetrical because the feet of a pair strike the ground at uneven intervals of time. In previous papers (Hildebrand, '65, '66) I presented a numerical and graphical method for the analysis of symmetrical gaits. The basic concepts are not difficult and can be reasonably well inferred from figures of this paper. The symmetrical gaits of horses and primates have been described (Hildebrand, '65, '67, respectively), and in each of those papers comparative data were presented for many other tetrapods.

It is apparent from my published and unpublished records that during the walk, long-legged mammals tend to swing the legs on the same side of the body more nearly together when walking than do short-legged mammals. Restated in the more precise vocabulary developed for the analysis of gaits (refer to fig. 2), of the many mammals using lateral-sequence gaits (strike of hind foot followed by strike of forefoot on same side of body), genera with relatively long legs tend to use lateral-couplets gaits (footfalls of feet on same side of body related in time as a pair), whereas genera with relatively short legs tend to use the single-foot (all footfalls evenly spaced in time) or diagonal-couplets gaits (footfalls of diagonally opposite feet related in time as a pair).

It is desirable to test these general concepts by learning if corresponding differences in preference for the various lateral-sequence gaits pertain to animals having a wide range of body build yet belonging to a single species. The obvious choice of material is the domestic dog. Detailed study of locomotor function is prerequisite to analysis of structure.

MATERIALS AND METHODS

The raw material of this study is 1410 feet of 16 mm moving picture film. Four hundred and thirty feet were obtained from the Institute für den Wissenschaftlichen Film, Göttingen; this had been exposed at 72 frames per second (normal speed is 16, 18 or 24 frames per second). The remainder of the film was made for this study, mostly at dog shows in California, and was exposed at 64 frames per second.

The following 37 breeds of dogs were studied: Afghan Hound, Basenji, Basset Hound, Belgian Tervuren, Bloodhound, Boxer, Chihuahua, Chow Chow, Collie, Dachshund, Dalmatian, Doberman Pinscher, English Bulldog, English Springer Spaniel, Fox Terrier, French Bulldog, German Shepherd, Golden Retriever, Great Dane, Great Pyrenees, Irish Setter, Irish Wolfhound, Keeshond, Lakeland Terrier, Papillon, Pekingese, Poddle, Pug, Rhodesian Ridgeback, Russian Wolfhound, Saint Bernard, Saluki, Samoyed, Shetland Sheepdog, Weimaraner, Welsh Corgi, and Whippet.

The methods of recording and processing data were the same for this study as those described in the papers cited above. For each performance of one gait by a given animal, two percentage figures are calculated which together are called a gait-formula. The first figure of the formula varies with rate of travel. The second figure relates actions of the forefeet to those of the hind feet. The gait-formulas used in this study were derived by averaging the variables of two to seven (average 3.1) consecutive cycles of motion in order to smooth out the idiosyncrasies of single strides.

Gaits of dogs and other quadrupeds

To date, my data on tetrapod locomotion include 1143 gait-formulas for 158 genera. Of these, 240 are for the domestic dog. Thirty-three formulas for dogs were excluded from most of this study (explanation below) and the remainder are plotted on figure 1 as both dark and open circles.

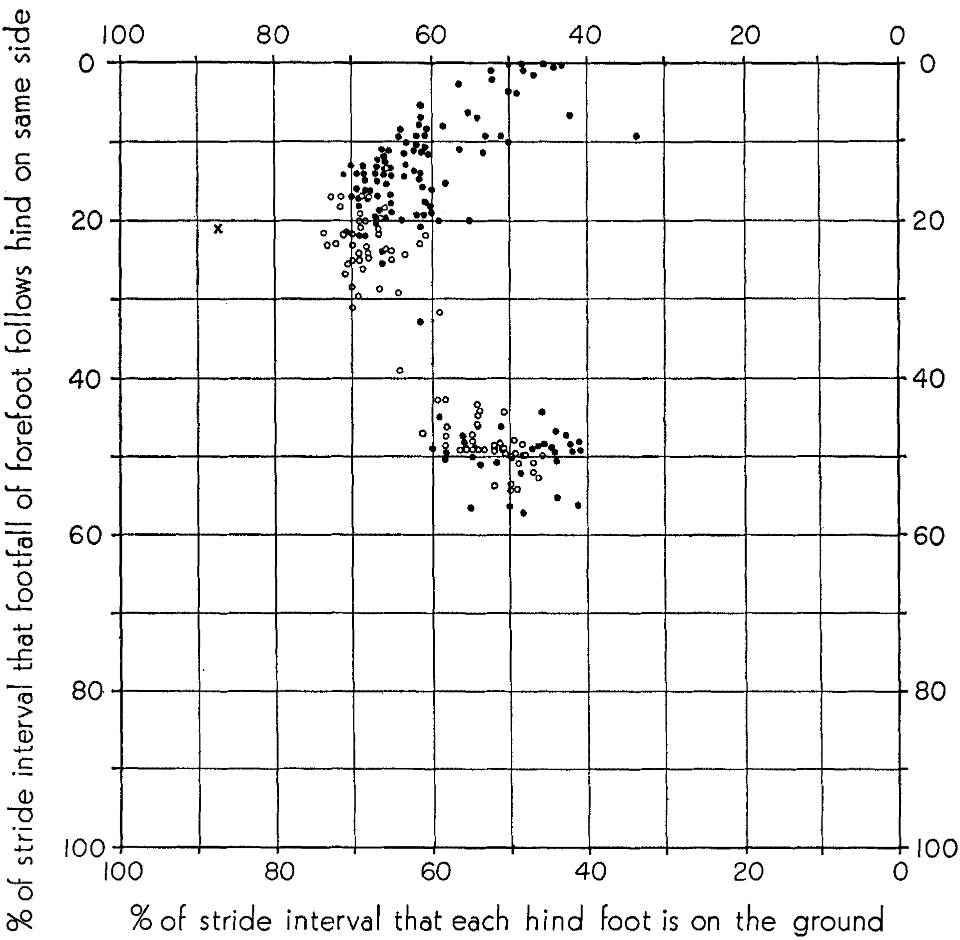

Fig. 1 Basic graph for the analysis of symmetrical gaits showing the distribution of 129 gait-formulas for 19 breeds of long-legged dogs (closed circle) and 78 formulas for nine breeds of short-legged dogs (open circles). One formula representing the early crawling gait of a pup is shown by an X.

Distribution, grouping, and variation within the species are shown. It is certain that very slow walks could be recorded that would extend plots to the left on the graph (see the single plot representing the crawling gait of a young puppy). However, dogs do not customarily walk slower than shown by the figure. Similarly, although dogs usually pace and trot no faster than the slow run (tending to break into the gallop at greater speeds), I am sure that many dogs pace and trot at the moderate run and believe large dogs could be trained to do these gaits at the fast run as Standardbred harness horses do.

Figure 2 relates the symmetrical gaits of dogs to those of all other tetrapods studied. Included (though not identified on the figure) are 21 gait-formulas for four other species of *Canis* (*C. aureus*, *C. dingo*, *C. latrans*, *C. macrotis*) and three other genera of Canidae (*Lycaon*, *Nyctereutes*, *Urocyon*). These formulas fall within the area ascribed to domestic dogs except one formula for a very slowly moving coyote and two for a semi-tame dingo straining at its leash and probably atypical. In general, the symmetrical gaits of canids resemble those of other carnivores of comparable size and conformation.

Figure 3 is provided to help the reader to visualize the differences among the symmetrical gaits of dogs. In the background is shown the area of the graph within which fall all gait formulas recorded for adult dogs. Thirteen specific formulas are identified by small circles, and tracings made from films show the particular performances from which the formulas were calculated. Each sketch was drawn from the first moving-picture frame of a cycle to show the left hind foot on the ground.

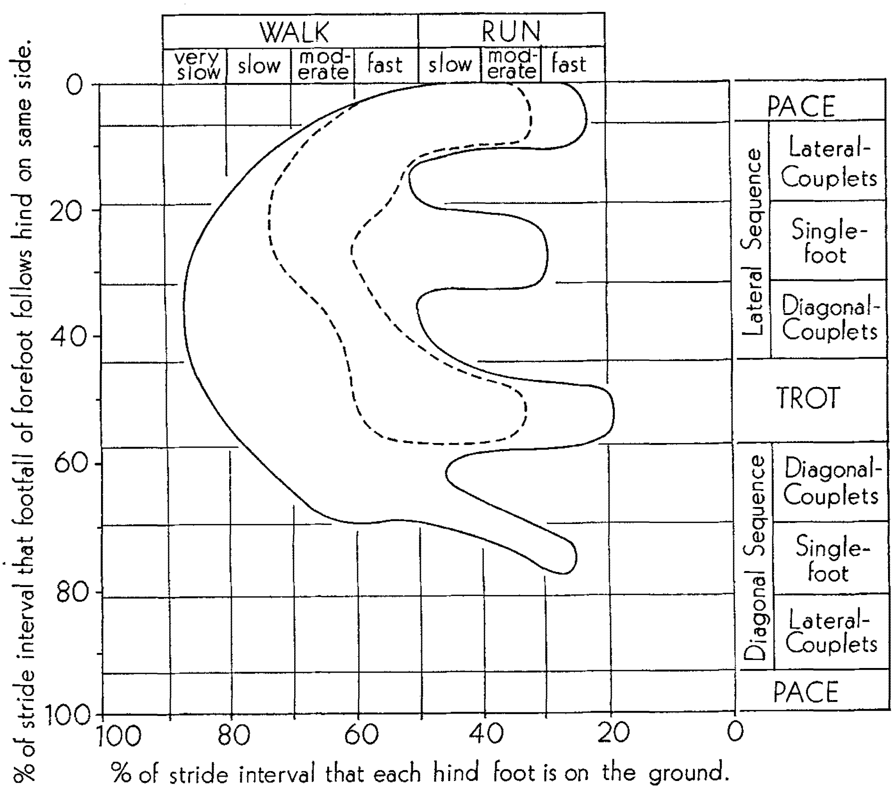

Fig. 2 Two hundred forty gait-formulas for 37 breeds of dogs fall within the area indicated by a dotted margin; formulas for other tetrapods of 158 genera fall within the area indicated by a solid margin (several scattered points excepted). Grid and marginal notations indicate scheme of naming symmetrical gaits.

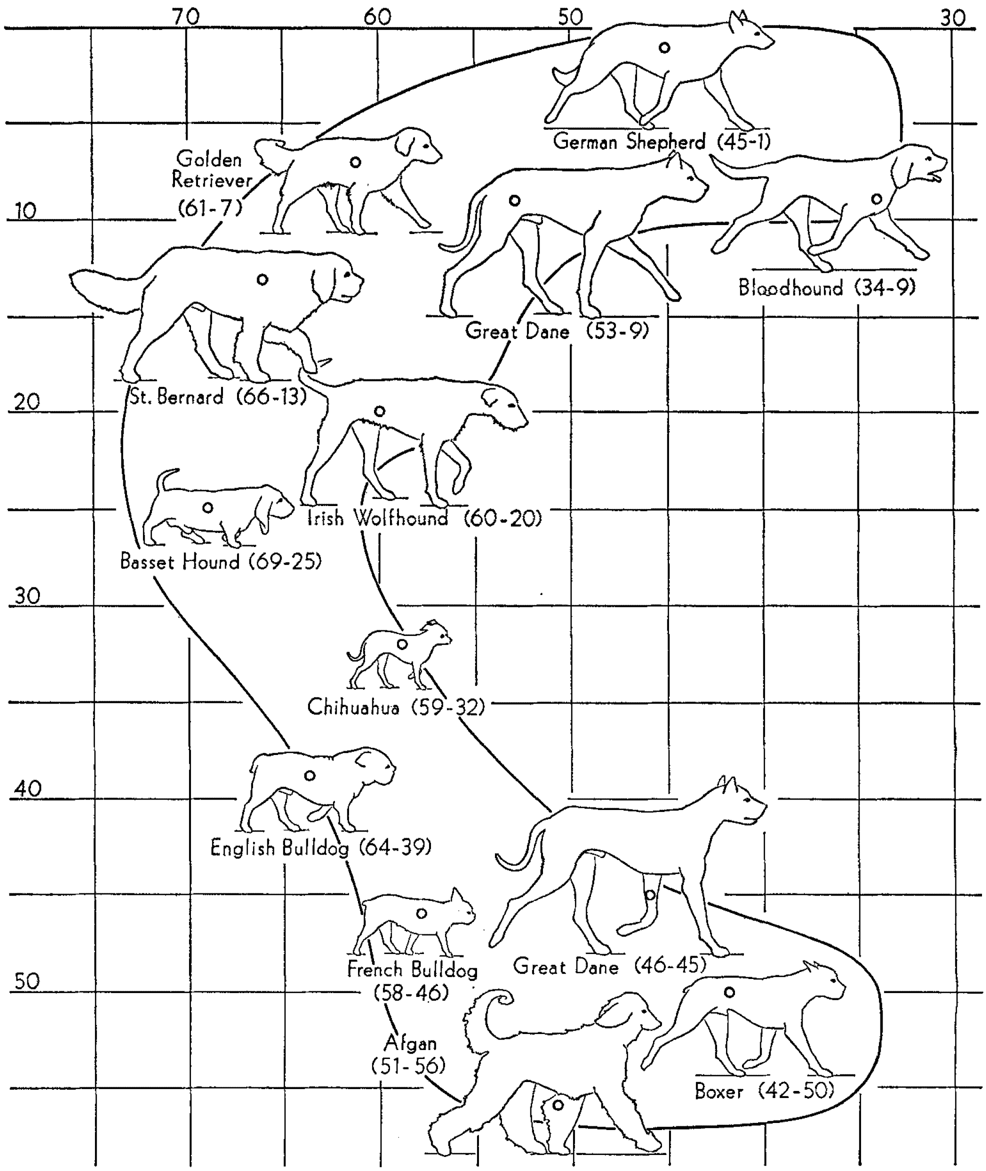

Fig. 3 In the background is shown the area of the basic graph within which fall all gait formulas for symmetrical gaits of dogs (compare figs. 1, 2). Thirteen specific formulas are located (small circles), and around each is drawn a silhouette of the dog moving as represented by the formula. In each sketch the left hind foot has just touched the ground.

I am, of course, aware that dog owners recognize differences among breeds in regard to carriage and movement of the legs. These may be worthy of study but are not considered in this paper.

The typical walks and the pace

The typical walks and less common walking pace and running pace are considered together because they form a single family of gaits.

It is these gaits that relate to body build. Objective data for length of legs relative to length of spine seem not to be available for the various breeds of dogs. The breeds studied were, therefore, arranged by visual impression into three groups according to relative length of legs and the middle group (33 gait-formulas for 9 breeds) was eliminated from the remainder of the study to obviate overlap resulting from error in estimation. (The eliminated formulas all fall within the area ascribed to dogs in figs. 2, 3.) Judged to have relatively long legs are the Afghan Hound, Belgian Tervuren, Bloodhound, Collie, Dalmatian, Doberman Pinscher, German Shepherd, Golden Retriever, Great Dane, Great Pyrenees, Irish Setter, Irish Wolfhound, Rhodesian Ridgeback, Saint Bernard, Saluki, and Weimaraner. The gait-formulas for long-legged breeds are plotted as dark circles on figure 1. Of these, 89 represent walking and pacing gaits.

Judged to have relatively short legs are the Basset Hound, Chihuahua, Dachshund, English Bulldog, Pug, and Welsh Corgi. The gait formulas for short-legged breeds are plotted as open circles on figure 1. Of these, 38 represent walking gaits. (Gait formulas for walking and pacing gaits are not available for the long-legged Whippet or short-legged Papillon, French Bulldog, and Pekingese.)

The highly significant difference between these two populations which is evident from visual inspection was verified by the Mann-Whitney U Test, a powerful non-parametric test for determing if two independent samples could have been drawn from the same population (see Siegel, '56). The value of p obtained is so small as to be off of the table provided in the reference cited. The prediction that short-legged dogs use walking gaits having a relatively long interval of time between the footfall of a given hind foot and the footfall of the forefoot on the same side of the body is, therefore, verified. The difference between the two groups is least marked at relatively slow rates of travel. It is probably that long-legged dogs that carry or pull loads tend to use the walking gaits otherwise characteristic of short-legged breeds. Such gaits are a little more stable.

No short-legged animal was observed to pace (compare figs. 2, 3) and only one even to use a lateral-sequence, lateral-couplets gait. Among long-legged breeds, the true pace (second digit of the gait-formula less than 7) was recorded for the Bloodhound, German Shepherd, and Golden Retriever. Gaits approaching the pace so closely that the lay observer would likely consider them such (second digit of gait-formula 7 to 10) were observed for the Bloodhound, Collie, Great Dane, Rhodesian Ridgeback, Saluki, and Weimaraner. Only certain individual animals of these breeds pace. Additional observation will certainly extend the list of long-legged breeds found to have individual dogs that use this gait.

Not all long-legged mammals pace, but many approach the pace at the fast walk, and animals that do pace (camelids, certain horses and dogs) are all long-legged. It seems that this body build enables a tetrapod to support itself by the two legs on the same side of the body without having the body tend to roll. Further, it is long-legged animals that are most subject to interference between fore and hind feet at the trot, the alternative middle-speed gait for mammals that do not pace (fig. 5).

The relative duration of the contacts made with the ground by the forefeet is expressed as per cent of the duration of contacts made by the hind feet. For dogs walking with the single-foot and lateral-couplets gaits, the range is 86% to 109% (90 records). The mean does not differ significantly from 100% (equal contacts by fore and hind feet), and records of long-legged breeds do not differ appreciably from those of short-legged breeds.

At the pace, the duration of contacts made by the forefeet ranges from 99% to 116% of contacts by hind feet and averages 106% (17 records). It appears that pacing dogs tend to have longer contacts by forefeet than by hind feet. Few individual dogs are represented, however, so the conclusion is tentative.

For each manner of moving, combinations of support by the several feet follow one another in what is called a support-sequence. In previous papers ('65, '66) I have related support-sequence to the position of the plot of the corresponding gait-formula on the basic graph, to individual variation, and to relative duration of contacts by fore and hind feet. Support-sequences are difficult to visualize and merit less emphasis today, I believe, than was once accorded to them. Briefly, walking gaits for which the second figure of the gait formula is greater than 30, usually use support-sequence 1 or 2 as shown in figure 4. Sequence 3 might be used momentarily. Dogs moving at the running pace would probably use sequences 4 or 5 but might use 6 and any of at least four others (and even more if the durations of contacts by fore and hind feet are not equal).

The second figure of the gait-formula (which relates actions of fore and hind feet) usually varies by 5 to 10 points for different performances of the same dog, but this range is exceeded by several of my records. This represents somewhat greater individual variation than I have reported for horses. In general, the smaller and more agile the animal, the greater the variation of gait.

The trot and related gaits

Eighty gait-formulas for the trot and related gaits are plotted on figure 1. These are evenly divided between long and short-legged breeds. It is evident by visual inspection that values for long-legged breeds (dark circles) are not significantly different than those for short-legged breeds (open circles). Most dogs swing diagonally opposite legs together or nearly so when trotting (second figure of gait-formula about 50) (Boxer on fig. 3). Some performances, however, are transitional between trotting and diagonal-sequence, diagonal-couplets gaits (hind foot strikes before opposite forefoot) (Afghan Hound on fig. 3), and some are lateral-sequence, diagonal-couplets gaits (hind foot strikes after opposite forefoot). Dogs seldom use gaits for which the second figure of the corresponding gait-formula is in the thir-

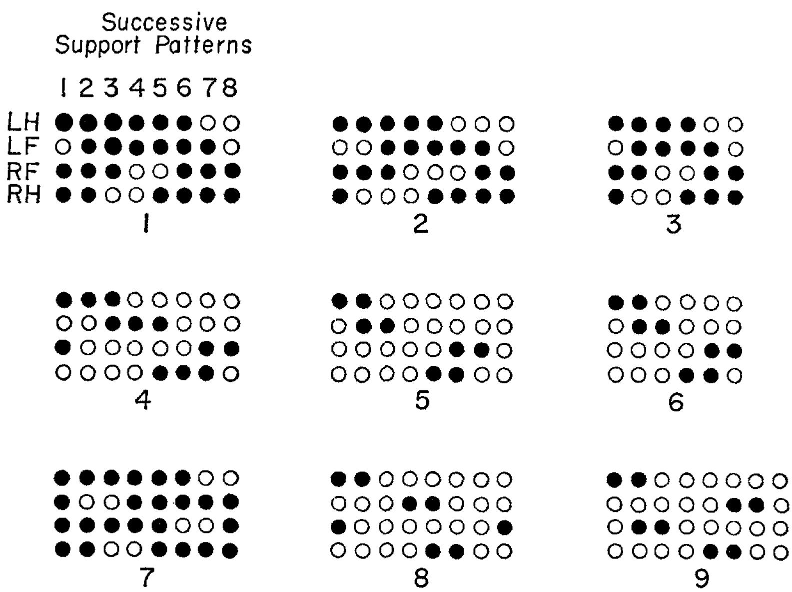

Fig. 4 Nine of the many support-sequences that might be used by dogs doing symmetrical gaits. The initials L, R, F, and H stand for left, right, fore, and hind feet. Dark circles indicate feet supporting weight; open circles, unweighted feet. Within each diagram, a vertical column of four circles shows a particular pattern of support. Each sequence starts with the football of the LH foot.

ties. Those recorded may represent transitional gaits of animals speeding up from a typical walk to a trot. However, all three formulas recorded for the raccoon-dog, *Nyctereutes*, fall in this area.

The duration of the contacts with the ground by the forefeet of trotting dogs varied from 77% to 114% of the duration of the contacts made by the hind feet (46 records)—a considerable range. Forefoot contacts of long-legged dogs averaged 93% of hind foot contacts, whereas the corresponding figure for short-legged dogs was 97%. I judge by the visual inspection of the plotted values (not illustrated) that the difference is mathematically significant. However, since individual dogs tend to be consistent in regard to relative fore and hind contracts, and since the two samples do not include equal numbers of performances recorded per dog, it is unlikely that the difference is biologically significant. It does seem probable, however, that trotting dogs tend to keep their hind feet on the ground slightly longer than their forefeet.

Support-sequences 7 and 2 (fig. 4) are frequent at the walking trot and sequences 8 and 9 at the running trot. A dozen other sequences are possible (though not very significant) when fore and hind contacts are equal and many more if they are not equal. (The explanation for this diversity is made apparent by examining the appropriate parts of figs. 5 and 6 in Hildebrand, '66.)

It is a common observation that many dogs turn their bodies slightly from the line of travel when trotting. Figure 5 shows such a trot and makes clear that the animal would strike its forefeet with its hind feet if it did not pass the hind feet around the forefeet. The presence and degree of potential interference depend on rate of travel and body build. Many smaller mammals (e.g., rabbit, squirrel, mouse, weasel) avoid similar difficulties at their respective gaits by passing each hind foot *outside* of the corresponding forefoot. Monkeys, when walking, and dogs, when trotting, instead pass each hind foot to the same side of the corresponding forefoot—both to right or both to left. I have shown that this behavior introduces slight asymmetry in the linear distance between footfalls and in the timing of the footfalls of some primates. I have not detected similar asymmetry in the trotting of dogs and would expect asymmetry, if present, to be slight because of the longer-coupled body and different shoulder action of the dog as compared to the primate.

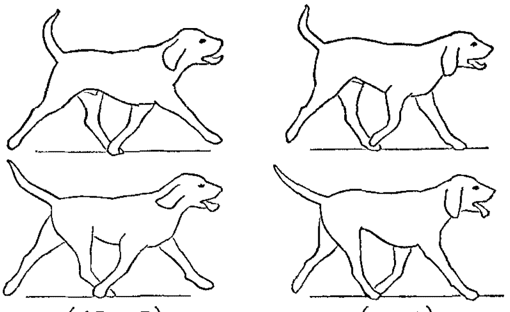

Fig. 5 A Bloodhound shown trotting (left drawings) and pacing (right drawings) as the left hind foot strikes the ground (above) and right hind foot strikes the ground (below). Note relation of gait to potential interference of fore and hind feet on same side of body.

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