

which probably remain submerged for ever; I have not yet ascertained whether these submerged flowers are fertile; if they are so, they can hardly fail to be cleistogamic. FRITZ MÜLLER

A STUDY IN LOCOMOTION¹

II.

III. *The Paces of the Horse.*—Every one can recognise whether a horse is walking, trotting, or galloping, and yet few would be able to point out the rhythm and order of succession of the movements of the limbs in different paces. These movements, in fact, succeed each other

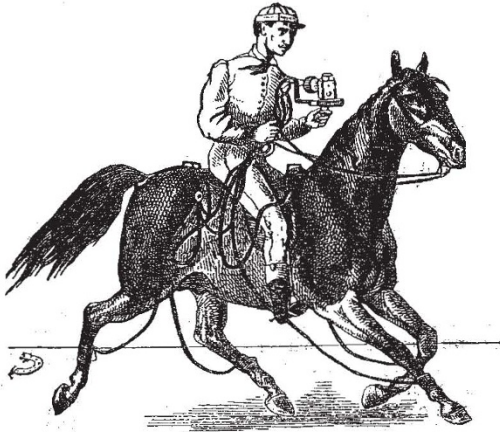


FIG. 8.—Registering apparatus for horse's paces

too rapidly for the eye to follow them, and their rhythmic succession is more readily perceived by the ear than by the eye. It is indeed ordinarily by the ear that we become aware of a horse's pace. When at each return of the step (*revolution du pas*) we hear two distinct strokes of the hoofs, we call it an amble, or a trot; three

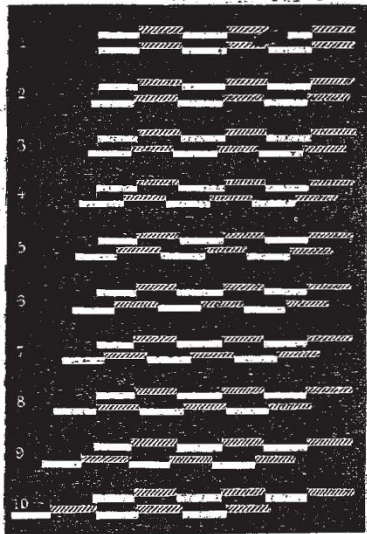


FIG. 9.—Synoptic table of the different paces of the horse, after the classic authors: 1, amble; 5, foot-pace; 8, trot, &c.

strokes unequally separated denote a gallop; lastly, four strokes indicate a foot pace. But these paces may be

¹ "Moteurs animés; Expériences de Physiologie graphique." Lecture by Prof. Marey at the Paris meeting of the French Association, August 23, 1878.

more or less irregular, variable, or crippled; besides that, when an animal passes in a very short space of time from one pace to another, how shall we decide upon the manner in which the transition is effected? To clear up these points great efforts have been made by horse-

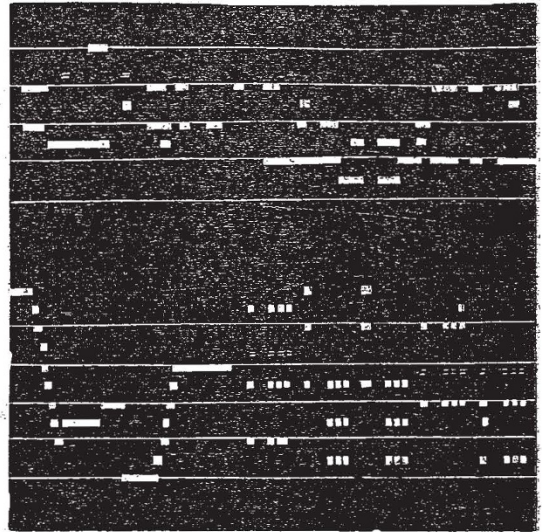


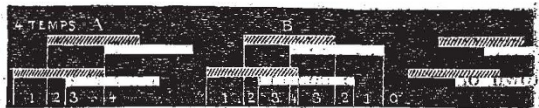
FIG. 10.—Notations of two airs, A and B, executed upon the keyboard of a harmonium.

trainers and veterinary surgeons, to whom the questions involved are of considerable importance.

Now, as I have just said, the ear judges better than the eye as to the rhythm of successive movements, but in order to demonstrate the production of these rhythmic strokes in twos, and threes, and fours, it is essential to know to which foot each separate sound is to be attributed. Ingenious experimenters have attached to the four feet of the horse bells of different tones, but in perfect harmony with each other. Varied melodies or harmonies are thus produced, according to the succession or synchronism of the strokes. But such an arrangement would certainly not give the length of time each foot remained upon the ground, therefore the question of the paces of the horse has not been entirely resolved even by this method. Turn to any special treatise on the subject, and you will see that beyond the amble, the downright



Gallop of 3 steps. A, indications of the three steps; B, indications of the number of feet which form the support of the body at each instant of the gallop of 3 steps.



Gallop of 4 steps.
FIG. 11.—Notations of the gallop of 3 and 4 steps.

trot, and the three-step gallop, there is, perhaps, not a single pace respecting which contradictory theories are not held. In face of the difficulties of this problem, you will doubtless foresee what will be my conclusion; it will be necessary to have recourse to the graphic method which will solve the question in the simplest manner possible.

Let us take up the question at the point to which it has been brought by the experimenters to whom I have just alluded. The succession of the movements of the horse's legs, since it is rhythmical, and since also we produce



Transition from the trot to the foot-pace.



Transition from the trot to the gallop of 3 steps.



Transition from the gallop of 3 steps to the trot.

FIG. 12.—Transitions between different paces.

from each foot a different tone, forms a sort of music. Now this music is very simple, because it is only composed of four tones. The following arrangement will

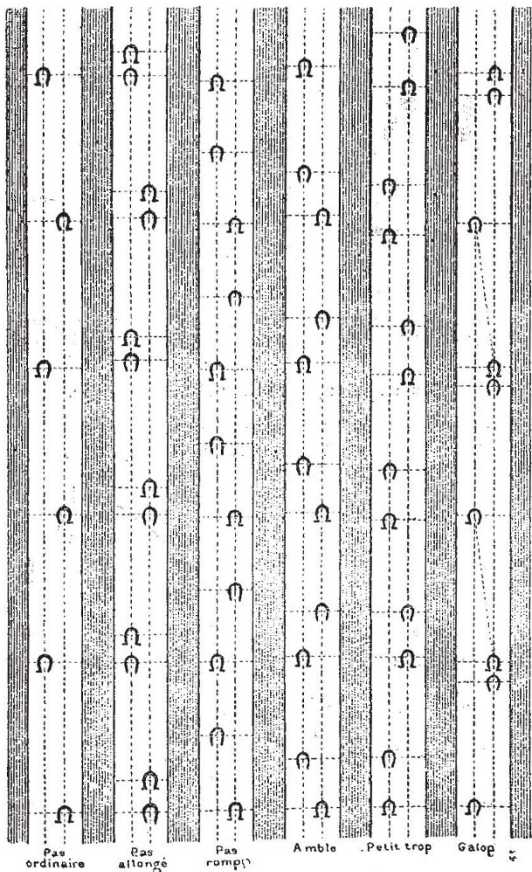


FIG. 13.—Diagram of the tracks of horses in different paces.

permit us to obtain the notation of this music, written by the horse himself. Under each of the horse's shoes we place a bag (*ampouille*) full of air, which, by means of a tube is connected with another similar small bag, which, by

its changes in bulk, acts upon a pencil. When the horse plants its foot upon the ground, it raises a pencil, which remains raised as long as the foot is kept down. Four pencils are placed in position, connected with the four under the horse's feet, and these pencils placed in a right line parallel with the axis of the cylinder, spontaneously trace the succession and duration of each setting down of a foot.

Fig. 8 shows the arrangement of the apparatus. The four limbs of the horse bear four india-rubber tubes, which converge to the hand of the jockey, and so to the inscribing apparatus on the cylinder which he holds.

The results thus obtained by the different paces are shown side by side to the number of ten in Fig. 9. Each foot, as in musical notation, has its characteristic sign, by the height of which the symbol of its stay on the ground is traced. We will agree that the fore feet shall mark upon the lines above, the rear feet upon the lines below. Now the horse can, with his four feet, execute the most rapid movements, and yet nothing will be wanting from the inscription. And in the first place, in order to give you confidence in the employment of this method, let us show you how it solves a problem still more difficult. When a clever pianist passes his fingers over the keyboard, who could describe the movements that he executes, say what note has been touched first, and for how long, then what notes followed, together or separately, with their rhythms and tones? But let us write down these movements, and when they are fixed upon paper we can analyse them with ease.

In the apparatus which I use, the keys act by pressure upon the bags of air connected by tubes with other bags, which cause pencils to move. See with what ease these little pencils reproduce all the movements of the fingers passing over the mute keyboard; you will presently see the instrument in operation. I present to you, first of all, what it has just written (Fig. 10). Observe these notes drawn up in gamuts and arpeggios, these varied accords, these changes of tone where sharps and flats reveal themselves by strokes drawn longitudinally. This instrument, which is now in action for the first time, has been constructed by our colleague, M. Tatin, whose skill has already excited the admiration of all who know him.

And now that you no longer doubt, I trust, the faithfulness of the method, let us analyse the tracings on the diagram I have just now shown you (Fig. 9). In order to understand it fully, let us borrow the ingenious idea of Dugès, and compare the horse or any other quadruped to two bipeds walking one behind the other. If the two walkers execute the same actions at the same time, that is to say, if they both simultaneously raise and set down the right foot and then the left, it is the *amble* (No. 1) which is produced. The ear only detects two sounds at each combined step, because two feet touch the ground together. This is an example of *lateral bipedal* movement. If the rearmost walker has half finished the resting of one of his feet when the foremost walker plants the same foot on the ground, it represents the *foot-pace*. Here the four footsteps are separate, and the ear distinguishes four equidistant sounds; the order of succession would be (commencing to count by the right foot), *foremost right, rearmost left, foremost left, rearmost right*. Let us imagine that the rearmost walker makes movements absolutely the reverse of those of the walker in front, that is to say, that one of the right feet strikes the ground when the other right foot rises from it, we shall then have the trot. Two feet will be always associated and will give but one sound, and these feet will exemplify *diagonal bipedal* motion.

Such, then, is our knowledge of the rhythm of paces, or at least the points upon which all are agreed. But if we desire to gather from divers authors the definition of more complicated paces, intermediary to those we have

just described, we shall only find, as I have before stated, a number of contradictions between writers holding different views. In the most rapid pace, the gallop, that of three steps,

The gallop of three steps may be distinguished in two forms; the right-hand gallop, in which the right-hand

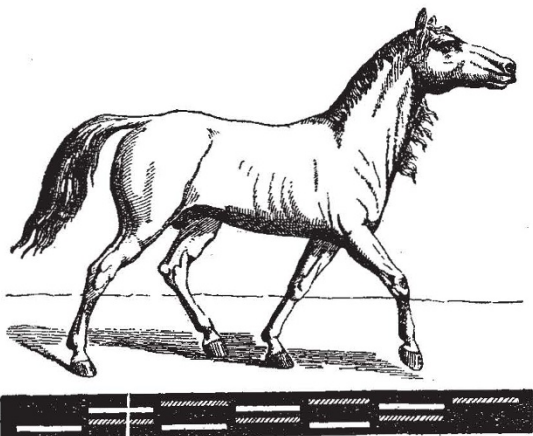


FIG. 14.—Trotting horse represented at the moment of diagonal support.

for example (Fig. 11), the first step is with the hind-foot, upon which the horse falls back after it has raised itself

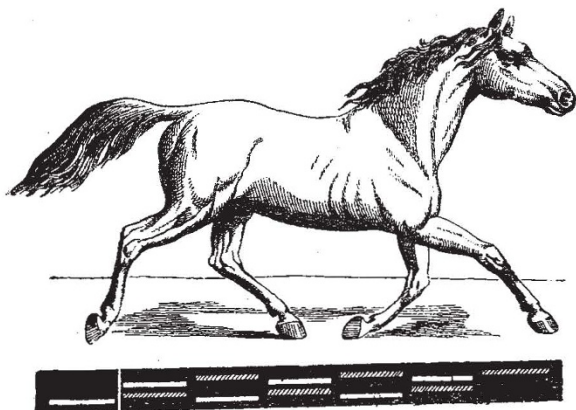


FIG. 15.—Trotting horse at the moment of suspension.

from the ground; then the other hind-foot and fore-foot which is associated with it diagonally fall together, and

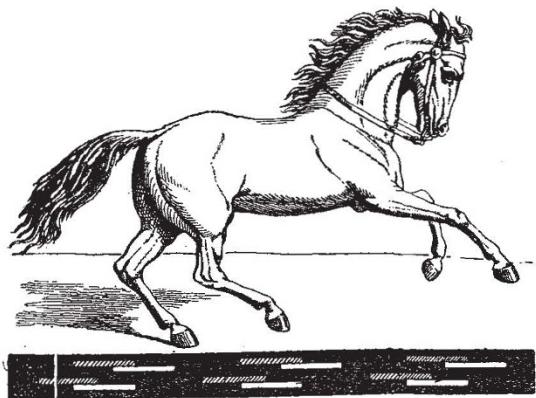


FIG. 16.—Horse at a gallop of three steps. Moment of the first step.

form the second step. Lastly, one hears the other fore-foot fall, and this is the third step.

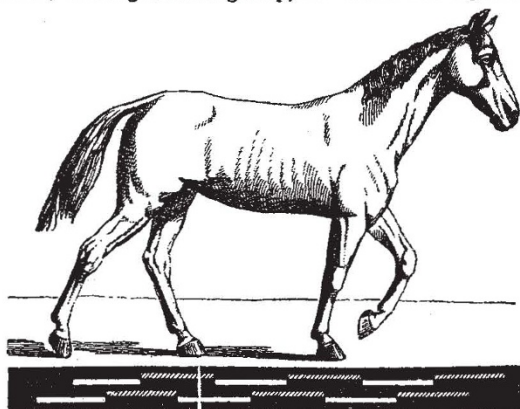


FIG. 17.—Foot pace with effort of traction.

hind foot reaches the ground last; the left-hand gallop, in which the left fore-foot is the last to reach the ground.

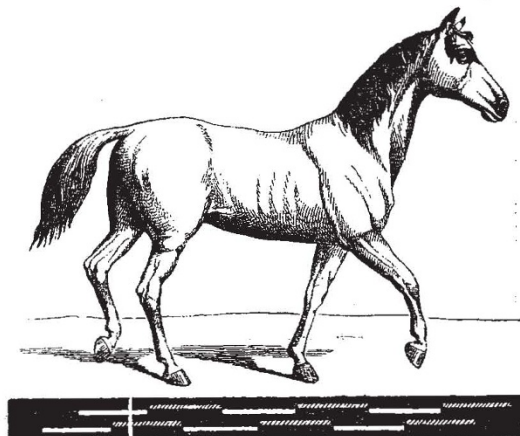


FIG. 18.—Foot pace, moment of diagonal support.

Do we desire to know upon how many feet a horse is supported at different moments of the gallop? Fig. 11

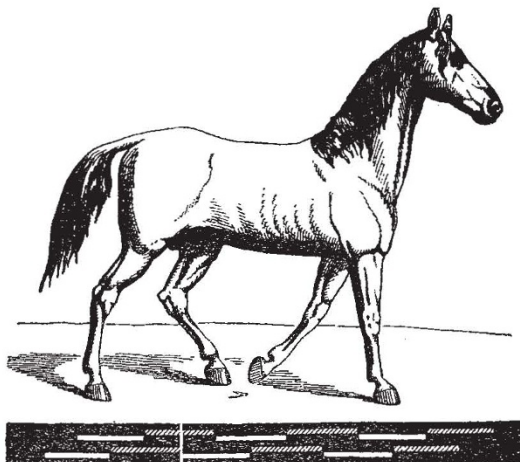


FIG. 19.—Foot pace, moment of lateral support.

responds to this question also. Just as the notation of a piece of music shows how many fingers rest at once upon

the notes on the keyboard, in the same way Fig. 11 shows that the horse, at the moment when he falls back upon the earth, is supported only by one foot; then, when the two diagonal feet strike the ground together in their turn, the horse has at this moment a triple support. Without the notation of paces we had certainly failed to distinguish this series of supports.

The gallop of the racecourse used generally to be considered as a pace of two steps, in which the horse struck the ground alternately with the two fore-feet and the two hind-feet. This gallop shows itself in the notation as a pace of four steps; the tracing dissociates the two fore-feet and the two hind-feet, although they follow each other at a very short interval.

The transition from one pace to another, impossible to determine by direct observation, is clearly inscribed in Fig. 12.

IV. *Artistic Representation of the Horse and other Animals.*—The artistic representation of animals requires a special and varied acquaintance with their peculiarities. Nothing can replace the patient study by which the painter or the sculptor acquires an anatomical knowledge of the limbs of animals and the aspects which they assume in different positions. But if the painter or the sculptor wishes to animate his work, if he wishes to show the horse putting forth its efforts in powerful traction, or to represent it urged rapidly forward in the race, it is necessary to have an exact acquaintance with different paces.

That which is true of the horse is equally so of other animals; but all present among themselves such great analogies in this respect, that if we are acquainted with the paces of the horse, we can represent those of any other animal.

The summary analysis we have just now made of the rhythms of steps in each pace is not yet sufficient to express the attitudes which represent them; we have as yet only examined in connection with these movements one of the two essential ideas. We are acquainted with the relations of time; it is necessary also to become acquainted with the relations of space, that is to say, to know at each moment in what place to find each of the members raised or planted upon the ground. Obligated to abridge this already long discourse, I will not tell you how one determines graphically the phases of the movement of a foot that is raised, but I will show you summarily how we determine the place where each foot is brought down. This indication is furnished by the imprint which the horse leaves upon the ground. M. de Curnieu, Capt. Raabe, and M. Lenoble du Teil have studied with particular care these imprints or tracks of the horse at different paces. The smooth sand of the sea-shore presents a surface admirably adapted for this study. Persons who have acquired the habit, easily decipher such imprints. But in order to render them easily read by every one, we have conceived the idea of giving a different form to the shoes of the fore-feet from those of the hind-feet by furnishing the latter with clamps. The principal paces represented by their tracks have been thrown together in Fig. 13, which I have borrowed from M. Lenoble du Teil. In combining with the idea of the rhythms, that of the place where each foot would be planted, the errors of attitude which disfigure so many *chefs d'œuvres*, would be avoided. You will, perhaps, say that few persons are capable of recognising faults of this kind. On this point one might repeat what Baron Dupin said with respect to perspective in its relation to the art of painting. "In proportion as exact knowledge becomes more widely diffused, many faults which to-day only shock a small number, will shock the general public, and artists will no longer be able to perpetrate them with impunity."

Those artists who at the present time make such praiseworthy efforts for the correct representation of the horse, would find great assistance from making use of the

notation of paces. Let us see in what way. Take, for example, the notation of *the trots*. We all grant, in the first place, the possibility of dividing each step into a series of successive instants, ten or twenty, for example. At each of these instants the horse will have a different attitude, but throughout the time the limbs diagonal to each other will be executing the same motions at the same time.

Let us take one of these instants at random and mark it by a vertical line (Fig. 14). The notation shows us that at this instant the right hind-foot and the left fore-foot are planted upon the ground, but that the right fore-foot and the left hind-foot are still raised, and are about to be set down. That is exactly as represented in the figure.

Upon another notation (Fig. 15) we have chosen another instant, that in which the horse is suspended in the air, and when the hind-feet have already quitted the ground, whilst the fore-feet do not yet touch it.

Let us pass on to the pace of the gallop (Fig. 16). The moment chosen is that in which the horse falling back upon the hind-foot has just made his first step. Two limbs in diagonal relationship are about to strike the ground at the same time, namely, the right hind-foot and the left fore-foot, represented as already being lowered towards the earth. As to the right fore-foot, that will strike the ground last, accordingly it is shown as still the furthest removed from the earth.

With regard to the foot pace, which is the most difficult to explain, three instants have been selected on the notation: 1. That where the hind-foot is about to be raised, and where the fore-foot is in the middle of its elevation (Fig. 17). At this moment there are three feet at rest, which only takes place with horses when making an effort of traction. 2. The moment in which the two diagonal feet are raised, the one having just quitted the ground and the other being about to be placed upon it (Fig. 18). 3. The moment when the animal, supported by two feet on the same side, is raising one of its fore-feet and is about to set down one of the hind-feet on the same side (Fig. 19).

These pictures have no other pretensions than to be correct as regards the position of the members; it would be the artist's duty to add elegance of form. But is it not something to have a simple and sure means of representing a horse in any pace and in any phase of the steps in that pace? The employment of the graphic notation would give to the artist the double advantage of representing the paces with truthfulness and of varying them to an extent almost illimitable. Now, imperfection in art is not displayed solely by errors that may be committed, for too often an artist who is thoroughly acquainted with a correct attitude repeats it with regrettable monotony.

(To be continued.)

GEOLOGY OF NATAL AND ZULULAND

SOME years have now passed since Mr. Griesbach gave to the Geological Society his paper and map illustrating the geology of Natal and the borders of Zululand. Passing events now give to his investigations the greatest interest, not simply due to the possible light that may be thrown on unsolved, or partly known, problems by the sojourn in that area of the contingent that has lately left our shores, but from the fact that the safety and success of our forces in great measure depends on the surface contour and physical character of the country to be traversed, which are necessarily directly dependent on its geological structure.

Few can have studied a geological map, without noticing the close connection between long lines of escarpment and belts of level plains with particular rocks, or noticing the marked uniformity in direction of strike of geological formations over large portions of the earth's surface; rock series after rock series plunging beneath its neigh-