would obviously be fallacious if we were to form an estimate of the general state of aggregation from that of the few masses we can judge of in our immediate vicinity; but we should require to know the condition of a region of an extent that we have no chance of overlooking, and under the principles of the kinetic theory, the local variations of the states of aggregation (themselves depending on local variations in the velocities of the masses) would fluctuate within wide limits. In order to have an idea of the actual (mean) state of aggregation, a being would be required that could (on comparative scale) sweep over the universe with the same facility as we sweep through or examine regions in a gas representing a multiple countless millions of times that of the mean distance of the detached portions of matter composing the gas.[1]

We are led to apply the principles of the kinetic theory to the case of the universe not so much as a speculation, but rather as a necessary deduction following from the known principle that detached masses moving freely in space (as the stellar masses are observed to do) and at such distances apart that gravity between the several masses is incompetent to deflect the path of the masses appreciably, must move in straight lines, and have their motions regulated under the mutual encounters in accordance with the principles of the kinetic theory. Only in the relatively near approach of the masses to one another does gravity come sensibly into play and deflect the path, causing under certain conditions rotation about a common centre (double stars), or, perhaps, by almost direct impact, nebulæ with but feeble rotation, &c.[2] To carry the analogy again to the smaller scale-case of a gas, it is there known that the molecules are in some cases feebly impelled towards each other at a near approach, the path of the molecule being thus deflected at its termination, whereby the conditions are given for causing a temporary rotation of the pair of molecules about a common centre, in an analogous way. The relatively vast distances of the stellar masses, compared with their dimensions, would involve, as a rule, an extremely long mean path before the encounters, corresponding to a proportionally long epoch of time adapted to the conditions of life. The apparent extreme simplicity of the means to the end by the application of the kinetic theory to the case would at least seem not to be out of harmony with its truth.

Thus the final conclusion to which these considerations lead would be that the universe has attained its final state of temperature equilibrium (if we set no fixed limit to its past existence), in the sense that if we were able to measure the temperature (or contained energy), of a sufficient number of masses through a sufficiently extensive region, we should find that in every such *equal* region throughout the universe the temperature (or contained energy) would be the same; just as (on a smaller scale) in the case of a gas, if we could measure the temperature of some thousands of millions of molecules in a given region, we should find that though the temperature differed to a practically unlimited extent from molecule to molecule, yet the temperature of every such equal region was the same.

[1] Just as in the case of a compound gas, the *uniformity* of temperature, of states of aggregation, &c., does not apply to the individual unit lumps of matter (molecules) forming the gas [which may be in vastly different states from one to the other]—but to unit *volumes* containing vast numbers of such units; so in the case of the universe, the uniformity of temperature, state of aggregation, &c., would not apply to the unit lumps of matter (stellar masses) but to unit volumes. In fact the universe may be regarded as a larger scale gas, with the difference that the central force producing the aggregated lumps of matter that move as wholes is not chemical action but gravific action. If we imagine (merely for illustration) a being on relative scale situated on a single compound molecule of a gas in a state of normal temperature equilibrium; this minute being would observe vast differences of temperature and of states of aggregation around him (some molecules in scattered parts glowing in a state of dissociation, &c.), and he would form a perfectly wrong judgment of the state of the gas from such a narrow point of view. So the observer connected with one unit lump of matter of the universe (stellar mass) can form no idea of the state of the rest from his narrow point of view.

[2] The occasional flashing out of stars, as if due to some sudden convulsion that might be referred to collision as a suitable cause, is a notorious fact in astronomy; though, from the extremely limited view of the universe that we possess, it would be unreasonable to expect such phenomena to be of frequent occurrence.

So in an analogous way as regards the *state of aggregation* of the matter of the universe, since this depends on the temperature, it would follow, assuming an indefinite past time, that the mean state of aggregation of the matter, like the mean temperature (mean energy), is the same throughout, *i.e.*, the average size of the separate masses, or the number in unit of volume (taking sufficiently large units of volume for comparison) would be equal throughout, though indefinite fluctuations of dimensions would occur from one mass to another, in analogy with the fluctuations of velocity from one mass to another.

It would further follow from the known principle that molecules of different densities (molecular weights) tend forcibly to become uniformly diffused, that by an indefinite past duration of the universe all the matter must be uniformly diffused if (as in the case of uniform velocity and uniform state of aggregation) regions of sufficient extent could be taken for relative comparison. This again resembles in principle the smaller scale case of a gaseous mixture, where it is known that the small detached portions of matter (molecules) are uniformly mixed, only when appreciable regions containing vast multitudes of molecules are examined, but that there is room for considerable local fluctuations of mixture (such as if only a few hundred thousand molecules were examined).

Thus it appears that the kinetic theory, applied to the universe, would have the peculiar characteristics of allowing almost indefinite local fluctuations of temperature, of states of aggregation, and of composition, of the matter forming the universe within regions very extensive, absolutely speaking, but infinitesimal, relatively speaking (*i.e.*, in comparison with the boundless universe), these regions being amply extensive enough to allow an amount of activity and variability of energy adapted to the conditions of life; while at the same time the principles of the theory, from their very nature, involve perpetually recurring and yet indefinitely variable changes within certain localised limits, the constitution of the vast whole (looked at broadly) remaining uniform throughout.

S. TOLVER PRESTON

FRITZ MÜLLER ON A FROG HAVING EGGS ON ITS BACK—ON THE ABORTION OF THE HAIRS ON THE LEGS OF CERTAIN CADDIS-FLIES, &c.

SEVERAL of the facts given in the following letter from Fritz Müller, especially those in the third paragraph, appear to me very interesting. Many persons have felt much perplexed about the steps or means by which structures rendered useless under changed conditions of life, at first become reduced, and finally quite disappear. A more striking case of such disappearance has never been published than that here given by Fritz Müller. Several years ago some valuable letters on this subject by Mr. Romanes (together with one by me) were inserted in the columns of NATURE. Since then various facts have often led me to speculate on the existence of some inherent tendency in every part of every organism to be gradually reduced and to disappear, unless in some manner prevented. But beyond this vague speculation I could never clearly see my way. As far, therefore, as I can judge, the explanation suggested by Fritz Müller well deserves the careful consideration of all those who are interested on such points, and may prove of widely extended application. Hardly anyone who has considered such cases as those of the stripes which occasionally appear on the legs and even bodies of horses and apes—or of the development of certain muscles in man which are not proper to him, but are common in the Quadrumana—or again, of some peloric flowers—will doubt that characters lost for an almost endless number of generations, may suddenly reappear. In the case of natural species we are so much accustomed to apply the term reversion or atavism to the reappearance of a lost part that we are liable to forget that its disappearance may be equally due to this same cause.

As every modification, whether or not due to reversion, may be considered as a case of variation, the important law or conclusion arrived at by the mathematician Delbœuf, may be here applied; and I will quote Mr. Murphy's condensed statement ("Habit and Intelligence," 1879, p. 241) with respect to it: "If in any species a number of individuals, bearing a ratio not infinitely small to the entire number of births, are in every generation born with any particular variation which is neither beneficial nor injurious to its possessors, and if the effect of the variation is not counteracted by reversion, the proportion of the new variety to the original form will constantly increase until it approaches indefinitely near to equality." Now in the case advanced by Fritz Müller the cause of the variation is supposed to be atavism to a very remote progenitor, and this may have wholly prevailed over any tendency to atavism to more recent progenitors; and of such prevalence analogous instances could be given. CHARLES DARWIN

Blumenau, St. Catharina, Brazil,
January 21, 1879

MY DEAR SIR,

If I remember well, I have already told you of the curious fauna which is to be met with between the leaves of our Bromeliæ. Lately I found, in a large Bromelia, a little frog (*Hylodes ?*), bearing its eggs on the back. The eggs were very large, so that nine of them covered the whole back from the shoulders to the hind end, as you will see on the photograph accompanying this letter, Fig. 1 (the little animal was so restless that only after many fruitless trials a tolerable photograph could be obtained). The tadpoles, on emerging from the eggs, were already provided with hind-legs; and one of them lived with me about a fortnight, when the fore-legs also had made their appearance. During this time I saw no external branchiæ, nor did I find any opening which might lead to internal branchiæ.

FIG. 1.

There is here another locality in which a peculiar fauna lives, viz., the rocks of waterfalls, which are of very frequent occurrence in almost all our mountain rivulets. On these rocks, along which the water is slowly trickling down, or which are continually wetted by the spray of the waterfall, there live various beetles not to be met with anywhere else, larvæ of diptera and caddis-flies, and a tadpole remarkable for its unusually long tail.

The pupæ of caddis-flies living on the rocks of waterfalls (I examined three species belonging to the *Hydropsychidæ*, *Hydroptilidæ*, and *Sericostomatidæ* [*Helicopsyche*]), as well as those living in the Bromeliæ (a species belonging to the *Leptoceridæ*), are distinguished by a very interesting feature. In other caddis-flies the feet of the second pair of legs (and in some species those of the first pair also) are fringed in the pupæ with long hairs, which serve the pupa, after leaving its case, to swim to the surface of the water for its final transformation. Now neither on the surface of bare or moss-covered rocks, nor in the narrow space between the leaves of Bromeliæ, the pupæ have any necessity, nor would even be able, to swim, and in the four species living on such localities which I examined, and which belong to as many different families, the feet of the pupæ are quite hairless, or nearly so, while in allied species of the same families or even genera (*Helicopsyche*) the fringes of the legs, used for swimming, are well developed.

This abortion of the useless fringes in the caddis-flies inhabiting the Bromeliæ and waterfalls appears to me to be of considerable interest, because it cannot be considered, as in many other cases, as a direct consequence of disuse; for at the time when the pupæ leave their cases and when the fringes of their feet are proving either useful or useless, these fringes as well as the whole skin of the pupa, ready to be shed, have no connection whatever with the body of the insect; it is therefore impossible that the circumstance of the fringes being used or not for swimming, should have any influence on their being developed or not developed in the descendants of these insects. As far as I can see, the fringes, though useless, would do no harm to the species, in which they have disappeared, and the material saved by their not being developed appears to be quite insignificant, so that natural selection can hardly have come into play in this case. The fringes might disappear casually in some individuals; but, without selection, this casual variation would have no chance to prevail. There must be some constant cause leading to this rapid abortion of the fringes on the feet of the pupæ in all those species in which they have become useless, and I think this may be atavism. For caddis-flies, no doubt, are descended from ancestors which did not live in the water, and the pupæ of which had no fringes on their feet. Thus there may even now exist in all caddis-flies an ancestral tendency to the production of hairless feet in the pupæ, which tendency in the common species is victoriously counteracted by natural selection, for any pupa, unable to swim, would be mercilessly drowned. But as soon as swimming is not required and the fringes consequently become useless, this ancestral tendency, not counterbalanced by natural selection, will prevail, and lead to the abortion of the fringes.

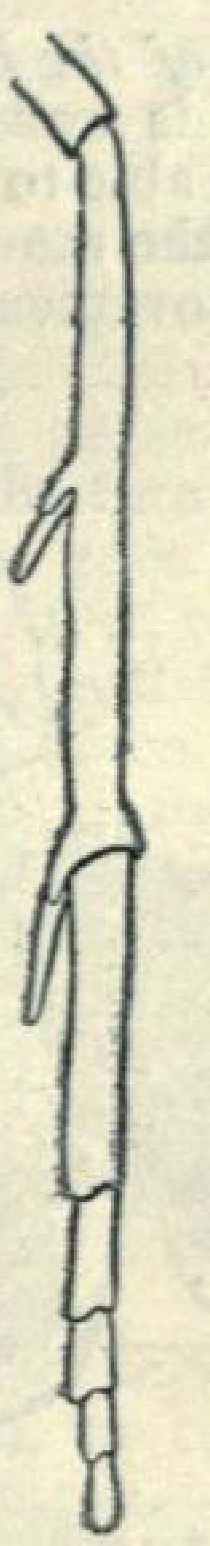


FIG. 2.

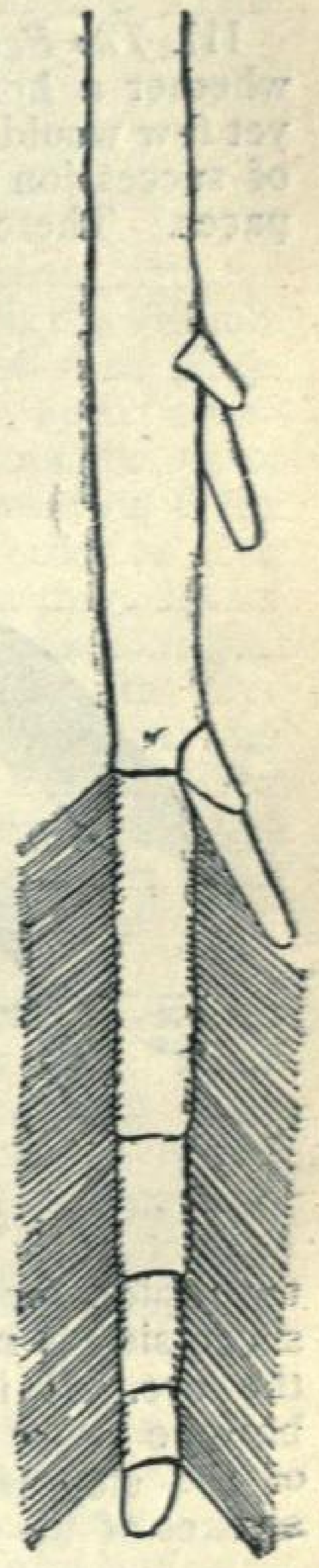


FIG. 3.

FIG. 2.—Tibia and tarsus of the two pairs of legs of the pupa of a species of Leptoceridæ, inhabiting Bromeliæ. FIG. 3.—The same of a nearly allied species inhabiting rivulets.

I do not remember having seen, in any list of cleistogamic plants, the Podostemaceæ. These curious little aquatic plants, which Lindley placed near the Piperaceæ, Kunth between the Juncagineæ and Alismaceæ, and which Sachs considers as being of quite dubious affinity, cover densely the stones in the rapids of our rivers; on the branches which come above the surface of the water, there are pedunculated, open, fertile flowers; but there are numerous sessile flower-buds also on the branches, 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 LOCOMOTION[1]

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

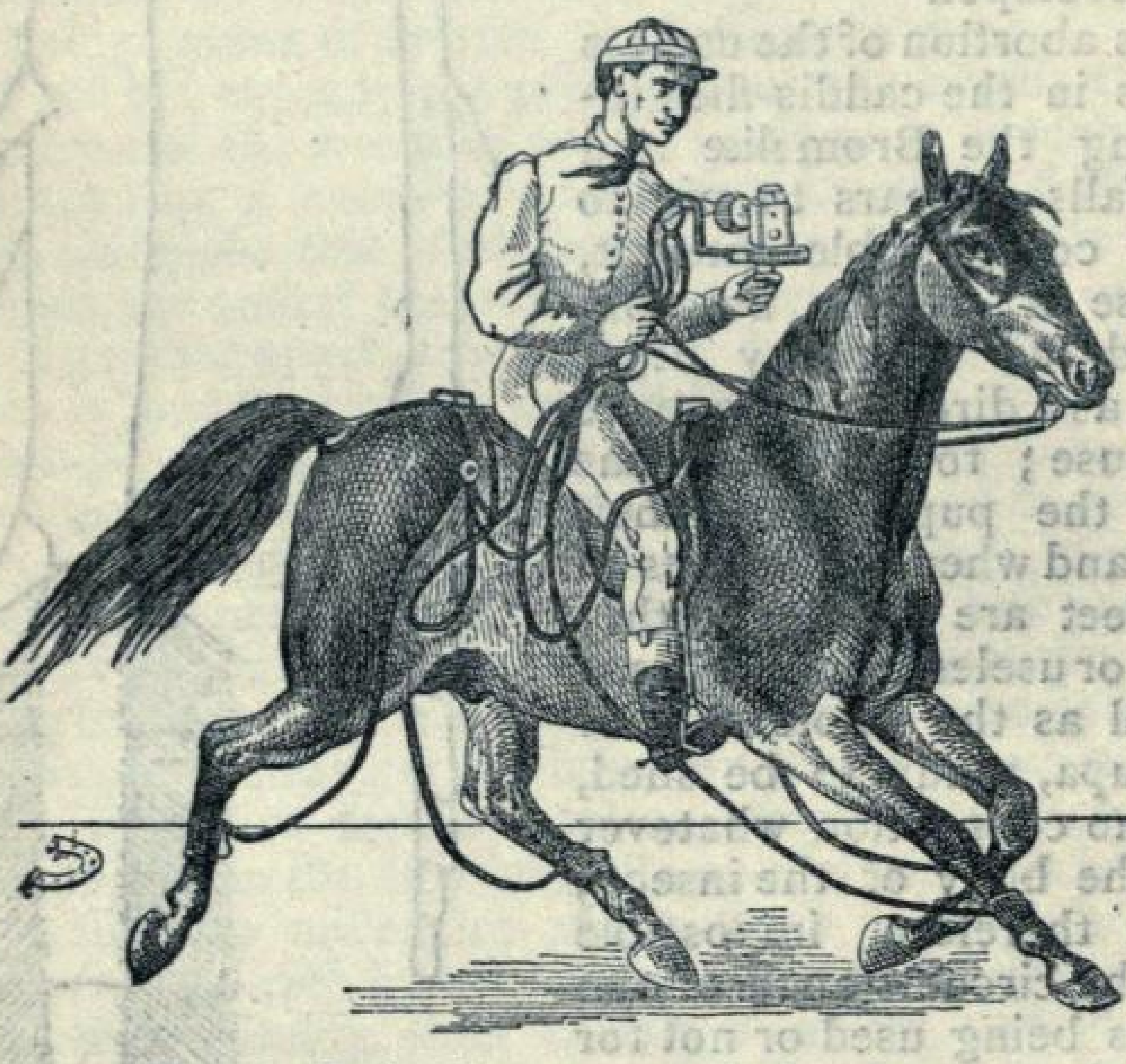


FIG. 8.—Registering apparatus for horse's paces.

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

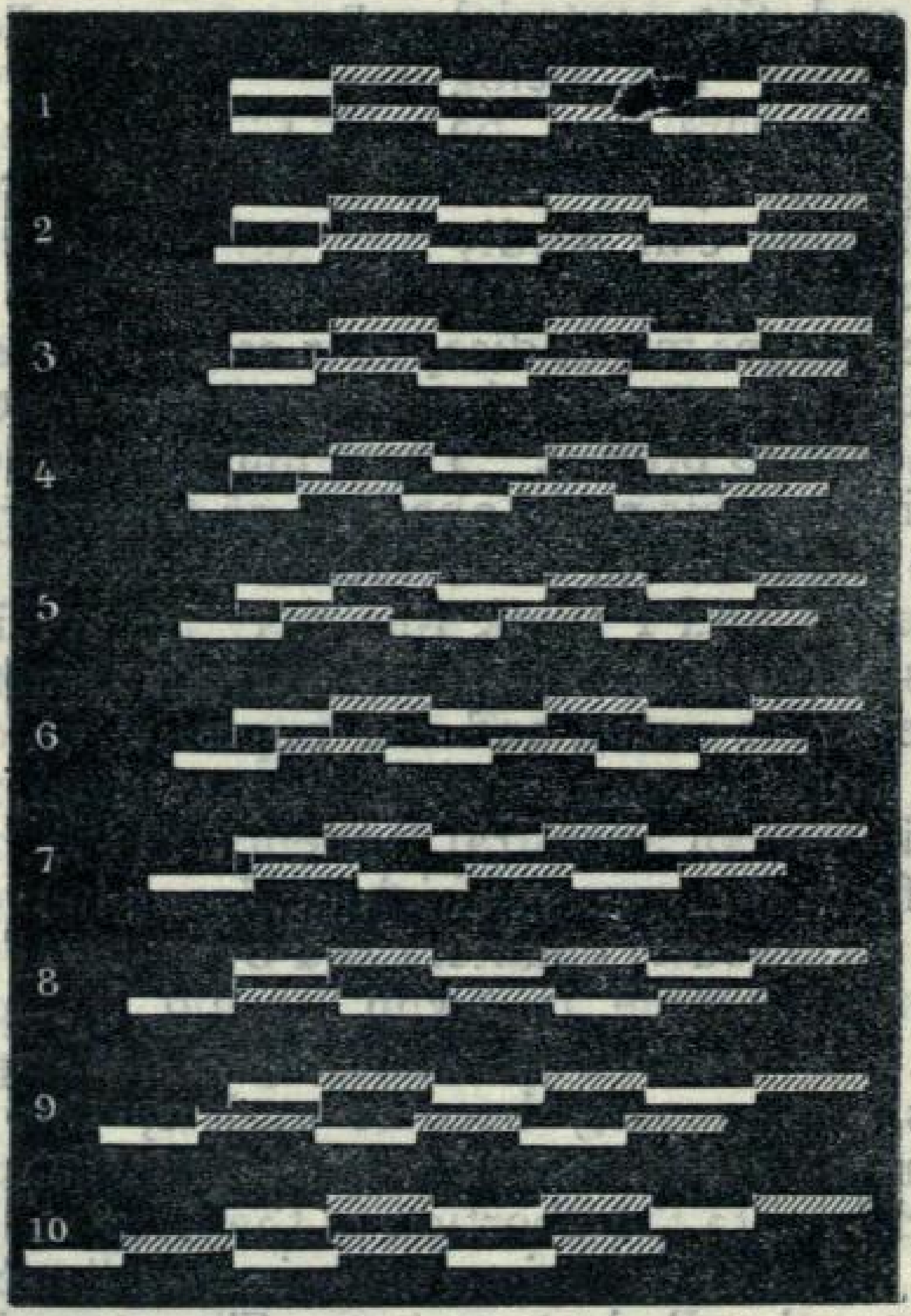


FIG. 9.—Synoptic table of the different paces of the horse, after the classic authors: 1, amble; 5, foot-pace; 8, trot, &c.

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

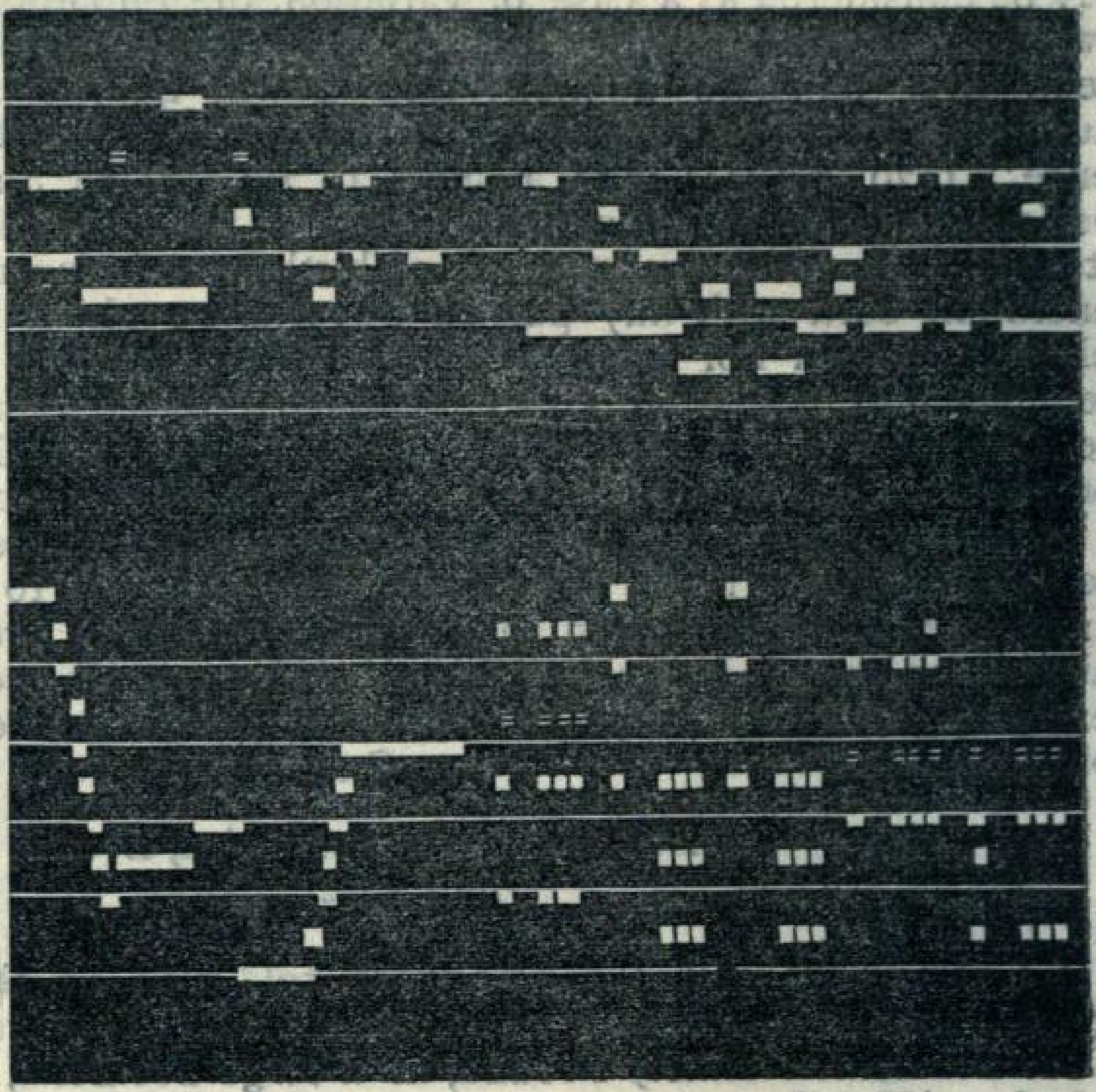
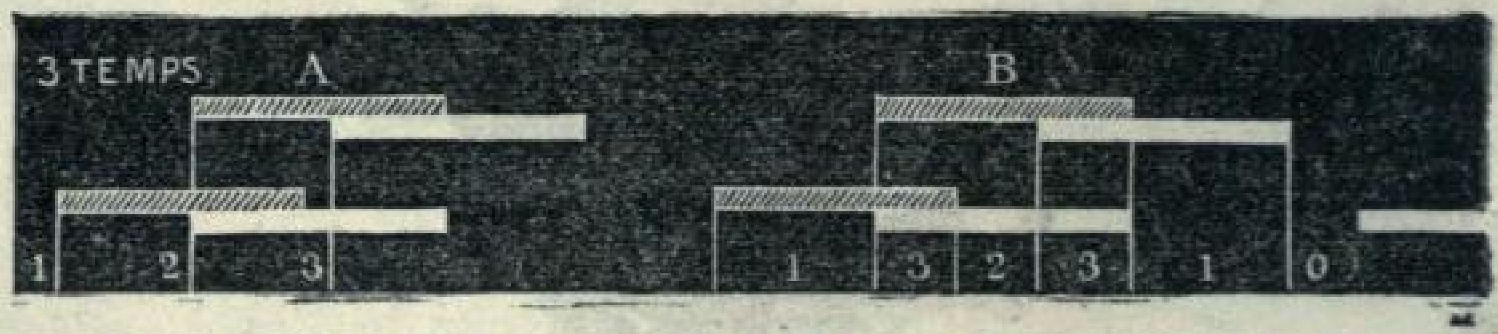


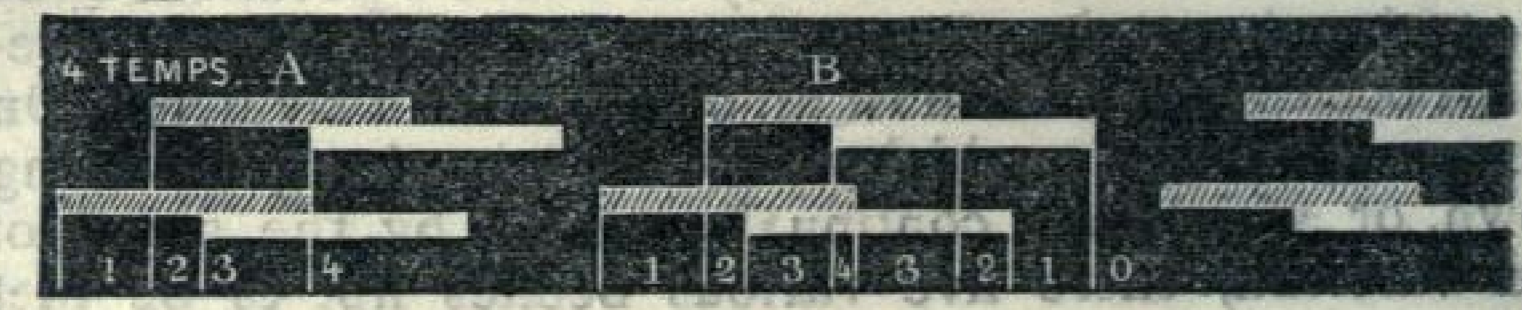
FIG. 10.—Notations of two airs, A and B, executed upon the keyboard of a harmonium.

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 treatises 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.

[1] "Moteurs animés; Expériences de Physiologie graphique." Lecture by Prof. Marey at the Paris meeting of the French Association, August 29, 1878.