Marey, Etienne-Jules. - Comparative locomotion of differents animals [translated from La Nature, September 2, 1893, p. 215-218]

In : Annual report of the Board of Regents of the Smithsonian Institution (...) to July, 1893, 1894, p. 501-504

COMPARATIVE LOCOMOTION OF DIFFERENT ANIMALS.*

By E. J. MAREY,
Member of Institute of France.

In the study of organized beings, it is a matter of special interest to seek for the tie which exists between the special structure of each species and its characteristic functions. The more and more intimate union of anatomy and comparative physiology will, without doubt, lead to the discovery of the fundamental laws of morphogeny, laws which will permit us from the form of an organ, to foresee its peculiar uses. These relations are already partially within our grasp, so far as the locomotor apparatus of vertebrates is concerned. The volume and length of muscles, the relative dimensions of the bony rays of the limbs, the form and extent of the articular surfaces, permit us to predict the gait of a mammal. And, on the other hand, the correctness of these predictions may be tested by means of chrono-photography, which fixes the character of these movements in a series of instantaneous images.

The readers of this journal already know how the gait of man, of the horse, and of the principal mammals may be represented by true geometrical diagrams on which one can readily trace the angular motions of the different segments of the limbs, and the speed of each part of the body, at every instant and for each gait.

The different types of flight among birds and insects have also been studied by means of chrono-photography. This method can be extended to the analysis of the locomotion of all living beings, even to those moving in the field of the microscope. This done, it will then be possible to unite and classify in a pictorial atlas a series of types of animal locomotion. These types, compared with the anatomical descriptions of the various species will furnish the necessary elements for the comparison which we wish to make.

It will be a work of time to gather and compare all these anatomical and physiological data. The principal difficulty in the way of studying

* Translated from *La Nature*, September 2, 1893; vol. XXI, pp. 215–218.

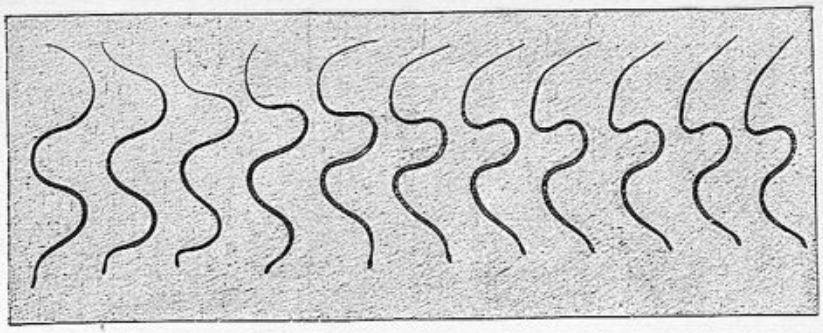
different types of locomotion is encountered not so much in obtaining great numbers of species of animals alive, but in finding suitable methods for photographing each of them in its normal gait.

The greater part of domestic animals lend themselves very well to these studies; they are readily led to a track prepared and will travel over it regularly. With wild birds the difficulty is greater; we have however succeeded in obtaining a number of types.

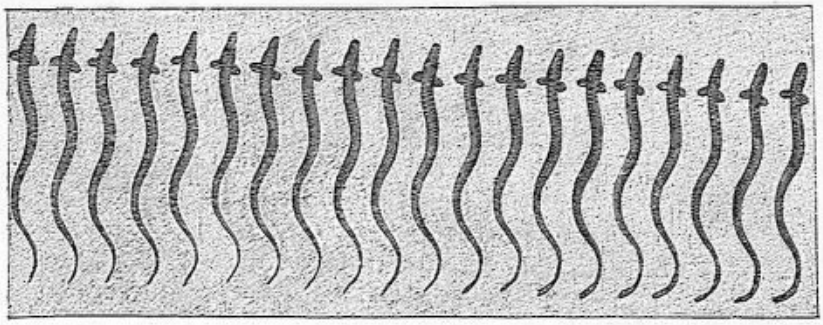
Fishes, reptiles, mollusks, and insects are more difficult to manage; it is necessary to devise for each species some method which will compel it to travel regularly before the camera. Moreover, we must, according to circumstances, so vary the conditions of illumination that the animal will sometimes show dark on a light ground, and sometimes appear light upon a dark background. I have succeeded, nevertheless, in obtaining good pictures of a considerable number of different species, as may be judged from the illustrations (Pl. XXIII–XXV). This series of figures shows certain analogies in the mode of progress of species which approach each other in their anatomical characters. Thus the adder and the eel both progress by means of horizontal undulations which move over the entire length of the body from the head to the tail (Pl. XXIII). The analogy would be still greater if the eel and the serpent both swam in the water, or crawled upon the earth, for it is the resistance of the medium, or in other words the nature of the point of support, which governs the motions of crawling. In water the undulations of the body are more regular and more efficacious than on the ground, while at the same time they are less extended, and the retrograde speed of what we may call the wave of motion is but little less than the animal's rate of progress. That is, by the time an undulation has run from head to tail the animal has advanced by nearly the length of its body. On level ground, and still more on a slippery surface, the undulations of the serpent and eel are very much extended and progress is slow.

Among coleopterous and orthopterous insects progress is much as it has been described by naturalists. Carlet and M. de Moore have shown that insects rest on three legs while the other three move. The supporting legs constitute a triangular base, formed by the first and third leg of one side, and the middle leg of the opposite side. (Pl. XXIII, XXIV.)

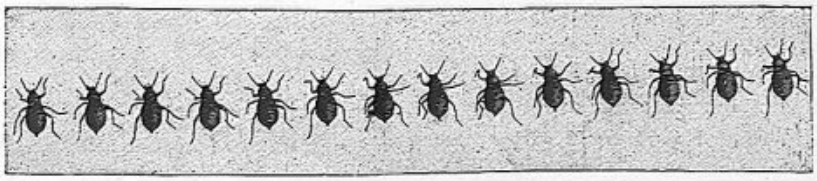
Among arachnids there are on either side two supporting legs, and two legs raised at the same time. But in the spider and scorpion which we have taken as types, the walk is so rapid that it is not easy to follow the successive motions in their proper order although they were photographed at the rate of 60 a second. In such cases it is necessary to increase the number of figures, and above all, to resort to such methods of illumination as we have adopted in studying the spider. This consists in so illuminating the animal above and below, that while it is clearly shown in outline, its shadow is projected upon the track over



1. SNAKE CREEPING. (Succession of figures from left to right.)



2. EEL SWIMMING. (Succession of figures from right to left.)



3. COLEOPTERUS INSECT WALKING. (Succession of figures from left to right.)
(Reproduced from "La Nature.")

which it runs. This shadow gives much information in regard to the position of the legs for when the feet are resting on the ground the leg and its shadow touch at their extremities. (Pl. XXIV.)

One of the most interesting points in these physiological comparisons is to see how the anatomical resemblances of different animals correspond with their functional resemblances.

Among fishes, for example, we meet in varying degree, with the reptilian undulation which forms the eel's sole mode of progress, but find that it has lost much of its importance. Still very apparent in the dogfish (Pl. XXV) it is found only in the caudal region of those fishes whose thick set bodies have lost the greater part of their flexibility, but in these cases the widened tail acts more efficiently for it meets with great resistance in the water.

Batrachians in different phases of their development have modes of locomotion corresponding to the state of their organs. The tadpole of a toad, in which the feet are still imperfectly developed (Pl. XXV, fig. 2, upper line) swims with its tail after the fashion of a fish. Later on (lower line) the legs begin to be used for locomotion, but the tail still keeps up its energetic action and vibrates continually, while the legs move in alternate jerks. Still later (middle line) the tail has disappeared and the hind legs are alone used in progression. This role of the hind limbs which presents so striking an analogy to the swimming of man is effected in the following manner.*

The animal flexes its legs, bringing them well under the body, then spreads them wide apart in such manner that the two legs, directed laterally, form a right angle with the axis of the body. Propulsion is effected by bringing the outstretched feet quickly together, after which they are gradually flexed and brought towards the body, and the series of movements recommences.

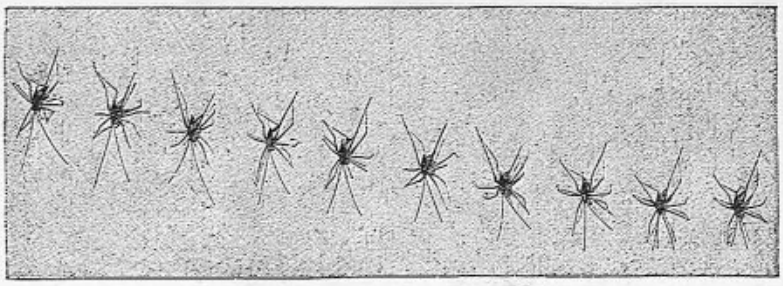
The lizards, which anatomically approach the serpents, also preserve in their progression something of the undulatory movement which we have represented above, but this undulation is complicated by the action of the limbs, which play the leading part in the crawling of these reptiles (Pl. XXV). In the gecko (Pl. XXV) the undulation of the body is plainly to be seen; it is scarcely apparent in the gray lizard. In both species it is impossible for the eye to follow the incessive movements of the feet, and to compare them with those of other quadrupeds, but from their chrono-photographic images it is easy to see that, taking the order of the movements of the limbs as a standard, the lizards are trotting animals. The limbs, in short, move diagonally—that is, the right fore leg and left hind leg, move simultaneously.

The undulations of the body are so combined with the movements of the legs that the feet are brought close together on the concave side

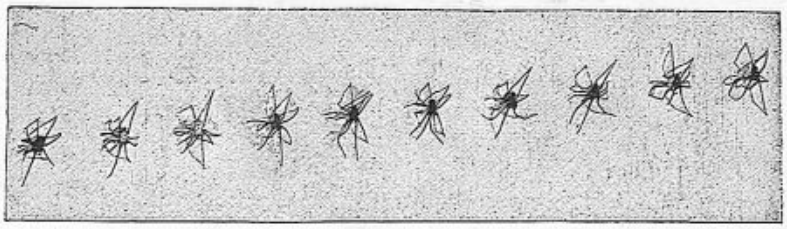
*Several of the views shown in the illustrations have been reversed.

of the wave, and widely separated on its convex side. This implies an absolute agreement between the number of undulations of the body and the steps of the animal.

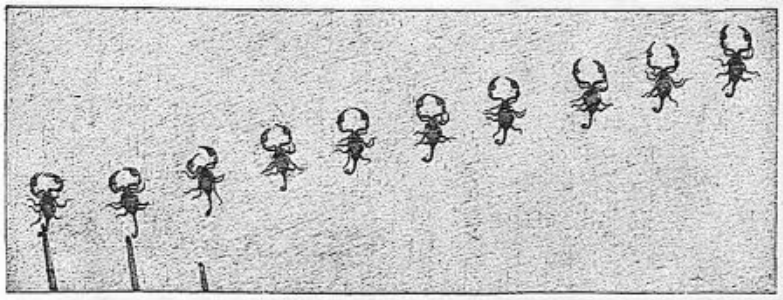
It is easy to see from the examples just cited that chrono-photography gives us vastly more information on the subject of animal locomotion than we can gain by the closest observation, and that, thanks to this method, we can, as previously said, compare the anatomical structure and the functional characters among the different species of animals.



1. ORTHOPERUS INSECT WALKING. (Succession of figures from right to left.)



2 SPIDER WALKING. (Succession of figures from left to right.)



3. LOCOMOTION OF A SCORPION. (Succession of figures from left to right.)
(Reproduced from "La Nature.")