PHOTOGRAPHIC ANALYSIS OF THE MOVEMENTS OF ATHLETES.[1]

M. MAREY has again applied his chronophotographic methods in making an analysis of the movements of athletes while exercising their strength in different ways. His delightful experiments, which have been but little repeated by others, are described in detail in "Le Mouvement" (par E. Marey. Paris: 1894. Translated into English by E. Pritchard. London: Heinemann, 1895). The methods are, for the most part, so simple, and the results so valuable, that they should prove themselves attractive to the student of those subjects in which movement of any kind is to be measured. In 1900, during the exhibition in Paris, there was a large gymnastic meeting and athletic sports. The administration of the exhibition nominated a commission of physiology and hygiene, for the purpose of following the meetings and gathering from that unique assembly of the best athletes in the world the information which it afforded. Its object was to determine, from a physiological point of view, the action of the various forms of exertion on the organic functions, viz. the respiration, the circulation of the blood, the digestion and, finally, the general health. The commission also studied different kinds of sports with a view to understand their mechanical details and discover the secret of the superiority of certain athletes.

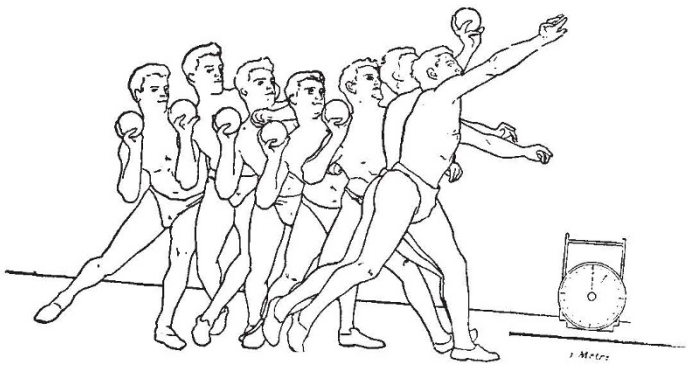

FIG. 1.—Composite picture of putting the weight by Sheldon.

The chronophotographic method gives a series of instantaneous photographs, on a long ribbon which is unwound; the number of pictures varies from fifteen to twenty or more per second. By this means the phases of a movement are perfectly represented. Figures so produced on a band being somewhat difficult to compare with one another, it was found to be more convenient to arrange them, as in Fig. 3, in three columns, the succession of pictures in each column reading from top to bottom, commencing on the left. The subject is that of "putting the weight" by the American athlete, Sheldon. The weight used by all competitors was 7·25 kilogrammes, = 15·95 lb., or the 16 lb. shot used in English athletic sports, and the distance covered was 14·02m. = 45·98 feet. Fig. 3 shows the athlete at the moment of his take-off from the right leg. At the end of his jump, and at the moment when the left foot touches the ground, he brings his right arm into action, which moves the shot upwards and forwards, giving it the greatest velocity possible.

The competitor is allowed a run of 2m., and he stands in a square traced on the ground, the boundary of which he must not pass. In order that the velocity of the different movements of the athlete may be estimated, it is necessary to introduce into the pictures the representation of both time and space. The time is measured by means of a chronograph (visible only in the five last pictures); it consists of a black dial furnished with divisions, over which a white pointer moves; the pointer makes one revolution in one second. The angular space swept out by the needle between two successive pictures indicates the time which has elapsed. An easy way of measuring these intervals is to determine the number of images contained in one, a half or quarter revolution of the needle. In Fig. 3, the last five pictures were made in one quarter of a revolution of the pointer, or at the rate of twenty pictures per second, so that between two successive images the displacement (which is estimated for any point on the body) is made in 1/20th second, and it is the same for the displacement of the weight. The true extent of displacement is finally determined by placing a divided metric scale on the ground; this rule is photographed at the same instant as each new position of the athlete, and it serves as a scale whereby the path traced out by each point under consideration may be computed—M. Marey gives the following *method of comparing images by superposition.*

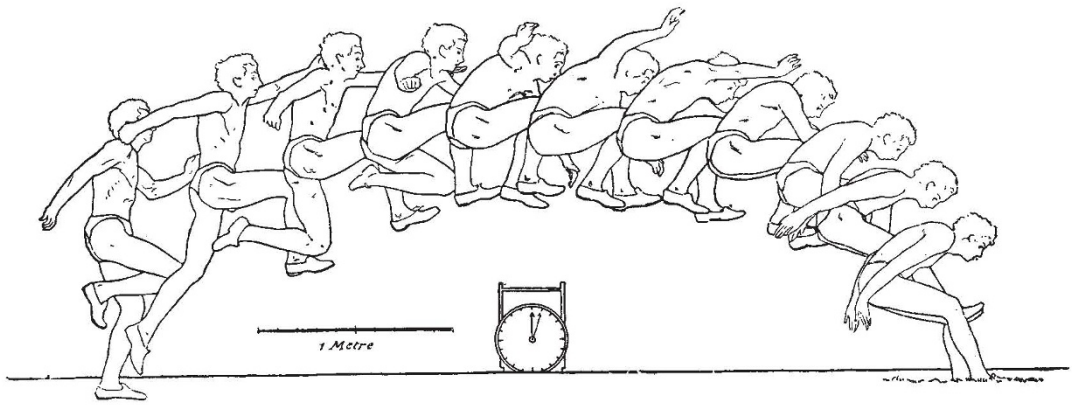

FIG. 2.—Composite picture of long jump by Sweeney.

[1] The accompanying illustrations are from *La Nature.*

Project the first image of a series (Fig. 1) on to a piece of paper, mark the ground line and a fixed point on it, *r*—a small stick planted in the ground—then trace

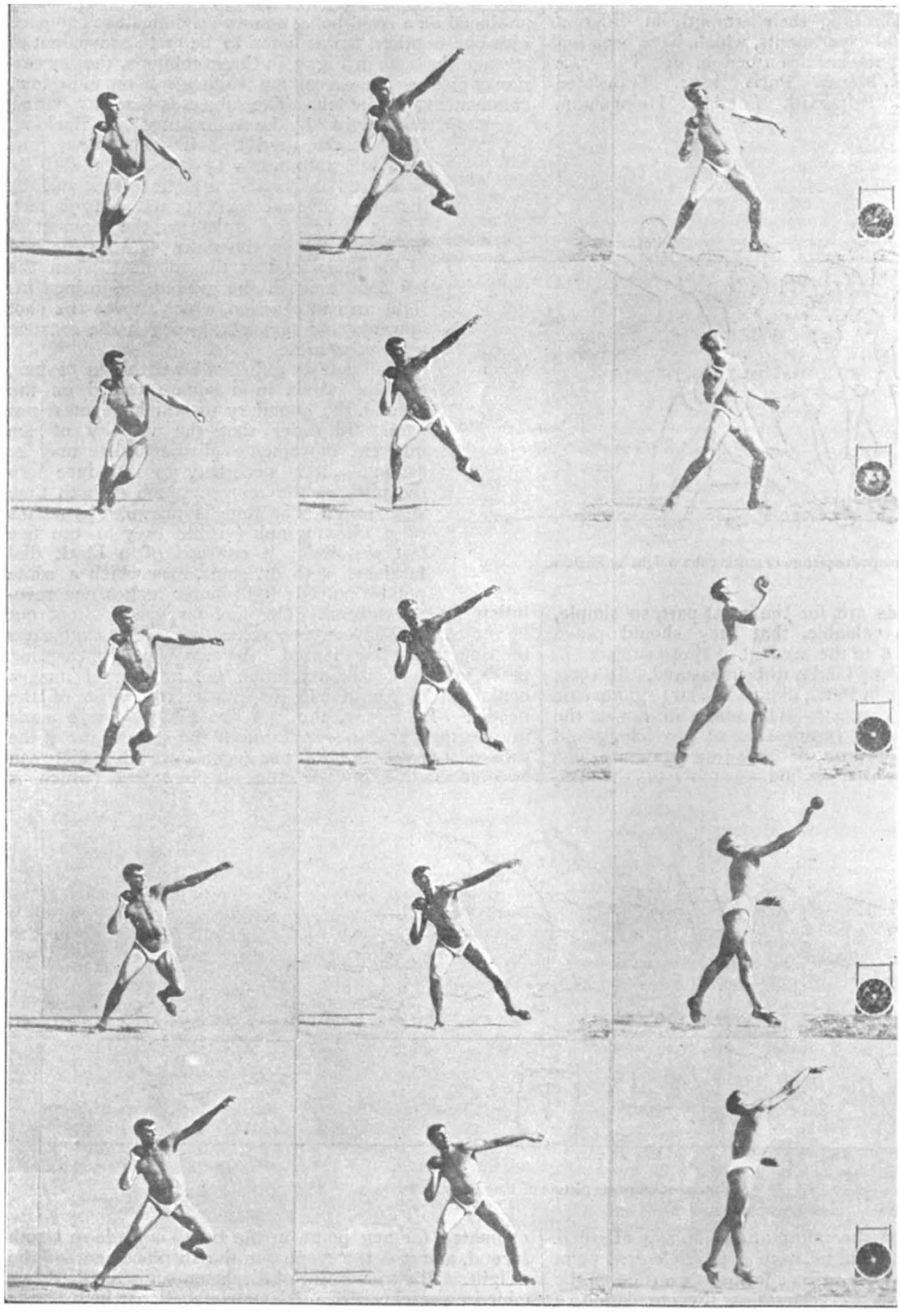

FIG. 3.—Putting the weight by Sheldon.

with care the contour of the body and limbs of the gymnast. This done, project the second figure of the series. In order to bring this image into its correct position, relative to the first, shift the paper until the ground line and the point of reference correspond with those points already marked on the paper. We shall see that the second image does not coincide with the first; since each part of the body has moved, trace the outline of the second image and repeat the operation for each image in the series. The result is a composite diagram, and by reference to the original pictures it is easily interpreted. In the composite diagram only every third image in the original has been used, otherwise the result would have been confusing. In Figs. 1 and 3 the movements of the athlete are put before us in series. He begins with a jump, which imparts a certain acceleration to the shot; during this period the arm is inactive, since the shot rests on the shoulder. Next is added a new acceleration, due to the arm. In order to discover, for example, the force acting on the shot at any instant, all the images of the shot must be represented (the figure of the man being left out, as it would complicate the diagram). After the successive positions of the shot have been traced on the paper, the accelerations can be determined and their curve traced; by means of this the work done by the

athlete at any instant may be found. M. Marey's excellent work in chronophotography is again illustrated by the analysis of the long jump (Fig. 4). The columns are to be read from right to left and from top to bottom. As in the former diagram, a composite picture has been made from several consecutive images. In this instance, owing to the rapid movements of the jumper, the figures have less tendency to be confused by superimposition. By eliminating every other image, a clear and comprehensive representation of all the actions has been obtained — actions which no language could describe with sufficient accuracy. The means of determining the extent and the duration of these movements is as perfect as possible. The chronograph shows that the interval between the images is 1/14th second, whilst the metric scale gives the length of the jump as 4·69 m. The same method of measurement shows that the space traversed by the jumper in 1/14th second was 52 cm., giving him a velocity of 7·28 m. per second. If the detail of Fig. 2 is closely studied, it will be seen that different points of the jumper's body do not cover the same space in the same time. For example, the head is displaced with unequal velocities, because the arms and legs are at each successive moment in different positions. Several other analyses of the movements of celebrated athletes, French and American, were obtained, and in all cases much light has been thrown on the rapid movements of the limbs in the case of clearing hurdles in a race.

The evidence collected in each section of the inquiry instituted by the commission of physiology and hygiene should prove itself to be most interesting and valuable matter, since it should lead to a complete modification of the system of athletic training and establish it on the study of nature itself, instead of on theories devoid of experimental foundation and often contradictory. M. Marey's methods of time measurement are very excellent, simple and effective, and a study of his work, "Le Mouvement," ought to stimulate English experimentalists to work in the same direction, which should prove itself to be a fruitful field for research in a country in which athletic exercises of every kind are so vigorously practised by all classes.

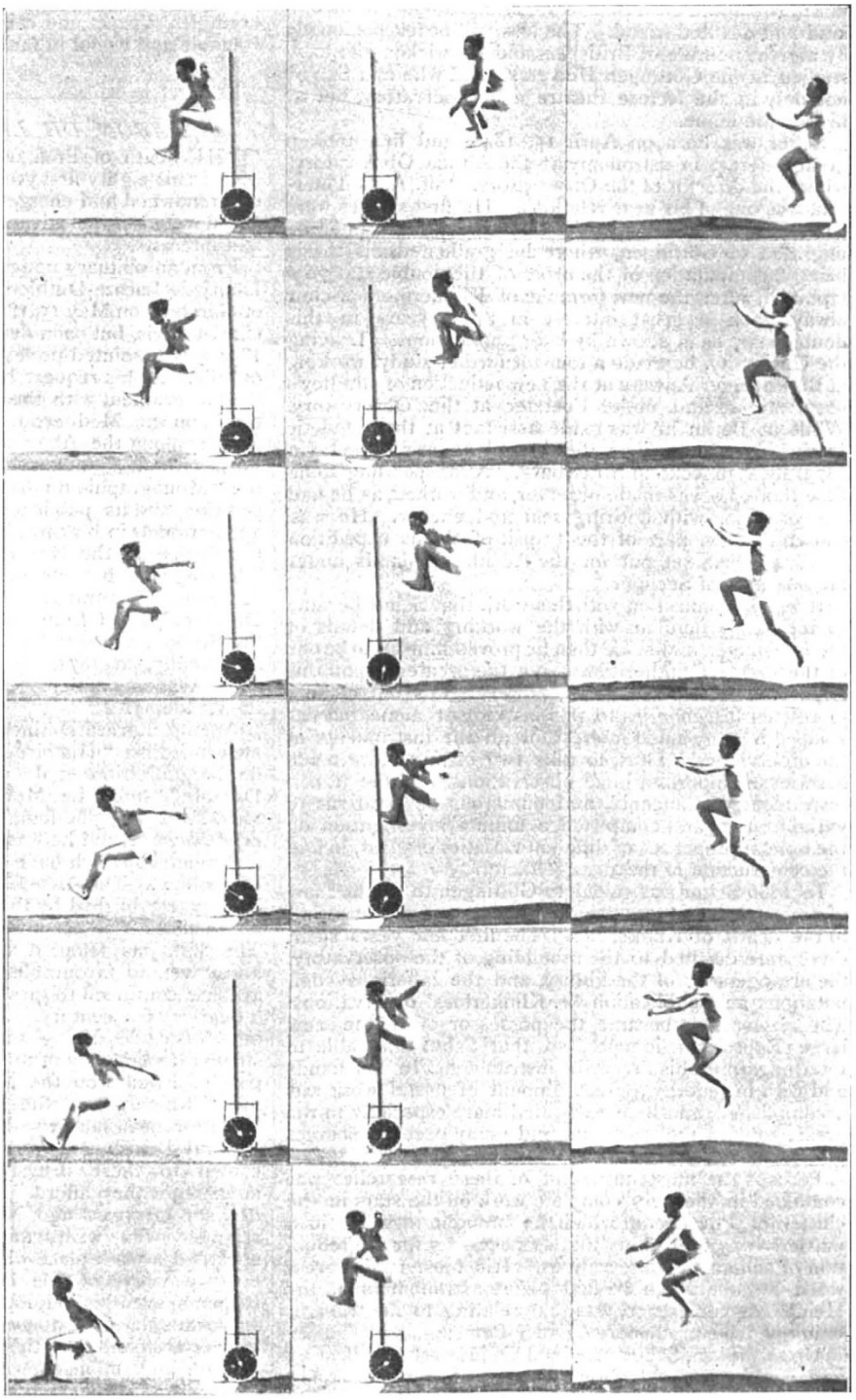

FIG. 4.—Long jump by Sweeney.