COLOR PHOTOGRAPHY.[a]

By Sir William J. Herschel.

The attempt to reproduce the natural colors of objects in a picture of them by means of photography may be regarded, according to a man's fancy, either as a confession of weakness—of lack of artistic power in oneself—or as a laudable ambition to invoke the powers of nature to do what, with all human skill, no artist can ever expect to do or ever claims to do. The artist, whether of the pencil or of the palette, has a liberty of expression which must forever make him master of the spirits of men when they seek the aid of painting or drawing to represent any scene to their senses. He alone understands the spirit that seeks his aid. He alone knows how to minister to it in the way that will most delight and instruct it. God has given him a great wealth of materials and the incomparable gift of genius in his use of them to interpret a scene to his fellow-man. If he fails, as he often does, in his task, that is no more than human frailty involves. When he succeeds he has given us a joy which we never dream of attaining in any other way short of once more beholding the object of our desires as we saw it in some happy moment of our lives. I am speaking, of course, only of realities and not of poetical or ideal art.

No one can be more conscious of the vast interval that lies between himself and the true artist than the humble follower of nature along the paths of color photography. To describe his position as a student fully and justly would occup[illegible]e time than you can spare me; but of this I am confident, that [illegible] can have his feelings more keenly cultivated, his appreciation o[illegible]licacies of hue and of shading more exalted, or his ambition to equal nature more excited by the first fruits of his labors than the patient, watchful handler of the camera and its adjuncts. The artist, indeed, stands at a strange disadvantage here. No joy can ever reach him which he has not, in the richness of his imagination, already tasted before he meets it face to face on his canvas. But who that has hung in eager expectation over the growing wonders of the sensitive plate would exchange his happiness when

[a] Presidential address by Sir William J. Herschel, Bart., to the sixteenth annual meeting of the photographic convention of the United Kingdom, Oxford, July 8, 1901. Reprinted from the British Journal of Photography, July 12, 1901, pp. 439–441.

success rewards him for that of the artist over his own handiwork; surprise, gratitude, exhilaration, these are the sudden moods of the photographer who throws himself into the arms of nature and trusts to her methods while incessantly pleading for more and more of her instruction. What shall I say of his many, many disappointments? Let them pass. We know their value, and the artist knows this, too. Our joys and his are not the same, but both are ripples of that ἀνηριθμον γελασμα, the countless laughter of the ocean on which God's great gift of light dances and entrances us.

So it is in the most perfect humility of spirit that we approach the subject of our discourse this evening—the practical methods now known to us of producing colored photographs.

These fall into two groups. In the first, as now in our common possession and practice, come those which employ colored glasses or films to feed the photographic plate, leaving the latter to take what it will, or refuse what it will, according to the high commands impressed upon it by the sun. Let no one be under the delusion that here is any room for the color artist, man, to tamper with the result, to distribute the colors according to his fancy. The very contrary is the case. No department of photography is so hopelessly bound to perfect honesty and freedom from trickery as color photography. A first-year apprentice in the studio of Mr. Herkomer would as soon think of improving the master's touches. It would mean ruin to the picture. Whatever color is supplied is fairly offered to the sun at every pin's head of the plate alike; but whether it is to be seen at all, and if seen whether it is to be seen in its full strength or weakened to any necessary extent, is not in our hands. That rests with the light itself to determine which falls there on the sensitive surface, and woe to the man who tries to interfere there. He may use some influence in regard to considerable areas at a time, just as the ordinary photographer can shade or modify the light to produce general effects, but as to details he dare not say a word. He might as well try to improve a miniature with a house painter's brush.

The first specimens of this kind which I introduce are those of Mr. Ives's process.

The three photographic positives here thrown on the screen together as one picture are plain black and white. They each act in the same way that the natural object did—they do not, indeed, absorb the color of the covering glass; but they do what comes to the same thing, they block it out either totally or in various degrees as each point of the object did by absorption. The positive was obtained by photographing the object through a glass of somewhat similar color. That it is not the very same color is due to the fact that the photographic power of colored light is not on all fours with its coloring power upon the retina.

A. HOEN & CO. LITHOCAUSTIC BALTIMORE

FROM A DIRECT PHOTOGRAPH IN COLORS

BY PROF. LIPPMAN

A. HOEN & CO. LITHOCAUSTIC BALTIMORE

FROM A COMPOSITE HELIO-CHROME

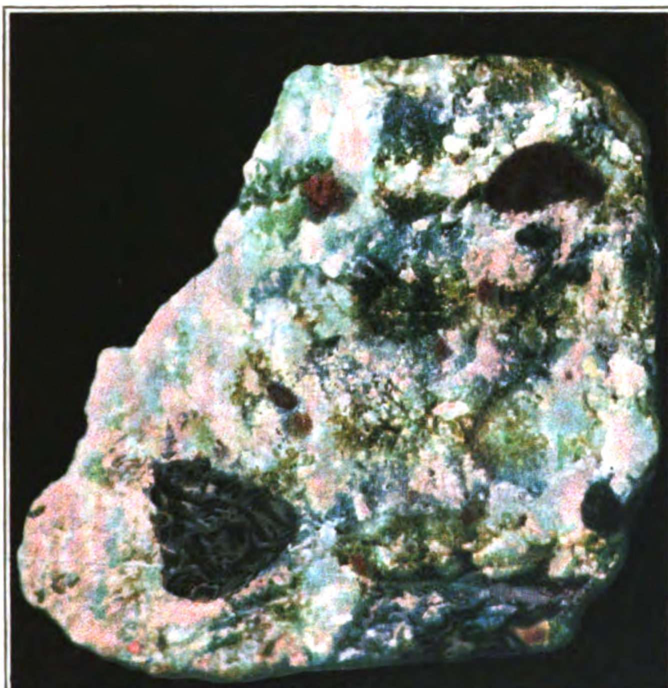
BY MR. IVES

To go into anything like detail on this complex and still debated part of the science of color photography would be quite impossible—and I am glad for your sakes that it is so, for only a strong expert like Mr. Ives or Mr. Sanger Shepherd could lead you aright there. Suffice it to say that at this point the judgment of the human eye is the final court of appeal, and no conclusions based upon anything less than large practical experience can be deemed final. We are still in the purely empirical stage of knowledge as to the physical connection between the color and the actinic power of any given light. We are not even sure that a given color of a given intensity has a constant actinic power on a given film. What we see here is the result of Mr. Ives's immense practical study.

His Kromskop introduces the three colors to the eye, not by superposition, which, as you will readily see, would put three extinguishers the top of each other, but still by true *com*-position. The mirrors cets of transparent glass) which do this are models of inventive wer. They are not clear glass, but tinted, and the reason for this is atter of refined delicacy. The already green image passes through a transparent green glass, placed on a slope which thus serves on its front face as a mirror for the blue image. The latter would be reflected from the back surface also if the glass were clear white; but being green, it absorbs the second reflection sufficiently (in the double passage of the blue light) to make it innocuous. The composite blue-green image passes on to the eye through another sloping transparent mirror placed to reflect the red image in the same line of sight. The same danger of a double red image is avoided here by tinting the m or blue-green, which lets the blue-green image pass, but kills the red light which endeavors to get twice through it. The perfection of the register is thus preserved.

Of a cognate character, but very different in its method, is Mr. Sanger Shepherd's process, in which three differently colored films are *super*posed one on the other in a single transparency. They are all positives without any opaque silver deposit to block out light. The only gradation is from clear white to the deepest color of the dye on each film—superposed they act as absorbents, and so effect the same fallibly, as far as I am aware; but, assuming it to be true, see what it means; nothing less than this, that we have, by the infinite delicacy of photography, obtained a definite ocular demonstration of the precise seat of power which ether waves have over chemical compounds. If I hesitate in committing my own belief to this explanation (and my belief is a matter of absolutely no importance to anyone else) it is because it is not inconceivable that the disruptive action which does take place may, after all, occur close round the spot where the stationary ether of the node, and therefore the matter which is affected, is under alternate tension and relaxation. However that may be in physics, the difference is not of immediate importance to us in photography that I see. The actinic planes were proved by Wiener to exist. Lippmann turned them to vital account for us, and gave us, in the way we all know, true color photography. He used thick films for the express purpose of securing what Wiener desired to avoid, reduplication of the actinic planes, and with them the strong creation of color. Here are some of the most exquisite results of his process. I owe them to Dr. Neuhauss, who kindly supplied me with a spectrum and a vivid picture from what I may call still life, and to Mr. Senior, who has placed his best specimens of a spectrum with the Frauenhofer lines at my disposal for your service. A more precious one than any of these is this given me by Dr. Lippmann himself, a tribute to my father's memory as a pioneer of photography, which I shall be happy to show afterwards. It is the simple naked film itself.

Before parting with Lippmann's process I feel sure that you will like to see the decisive evidence obtained by Dr. Neuhauss of the presence in the film of the supposed strata of silver spangles, as I may call what looks like a brown stain more than anything else, by transmitted light. He has actually made a microscopic section of the color cradle, and by means of the most refined conditions has been able to take once more by aid of photography a visible picture of the subtle work of light in the interior of a Lippmann film. Here is a copy of it on the screen which he has sent me himself, with his explanation of its import and its manufacture. All room for doubt (if science could cease from doubting its own creeds) would seem removed by this simple fibrous-looking strip of lines. It is a rare pleasure to be able to exhibit such brilliant colors, and such surprising demonstrations of their cause, here in Oxford, and to acknowledge at the same time that the whole series of investigation and invention which have furnished these magnificent results is the fruit of French and German industry and genius.



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FROM A COLOR PHOTOGRAPH BY THE McDONOUGH PROCESS

THE HISTORY OF CHRONOPHOTOGRAPHY.[a]

By Dr. J. Marey,

Member of the Institute of France.

By chronophotography [b] is meant a method which analyzes motions by means of a series of instantaneous photographs taken at very short and equal intervals of time. By thus representing, for example, the successive attitudes and positions of an animal, this art renders it possible to follow all the phases of the creature's gait, and even to construct exact drawings of it to scale. Of late years, chronophotography has taken another direction—that of the synthesis of motion. The analytic images are made to appear before the spectators' eyes in uniform sequence, so as to reproduce the appearance of the motion itself. Everybody is familiar with such animated views.

The International Exhibition of 1900 enabled us to bring together the documents relating to the invention and successive improvements of chronophotography.

PART I.

DESCRIPTION OF THE APPARATUS.

The principal instruments which, in the course of the development of chronophotography, have been devised by those who have pursued this art were collected in a large show case (fig. 1).[c] They were arranged according to the dates of their several inventions. In addition four large frames contained photographs resulting from the application of chronophotography to various branches of science.

No. 1 is Janssen's astronomical revolver, invented by that astronomer in 1873 in order to show successive positions of the planet Venus near the limb of the sun at her transits.

At the focus of a telescope pointed at the sun was a photographic camera, and the sensitive plate, which was circular, turned about its center by leaps, so as to bring into the field a different portion of its

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[a] Translation from "Exposition d'instruments et d'images relatifs à l'Histoire de la Chronophotographie, par le Docteur Marey, Membre de l'Institut," printed in pamphlet entitled Musée Centennal de la Classe 12 (Photographie) à l'Exposition Universelle Internationale de 1900 à Paris—Métrophotographie and Chronophotographie.

[b] Photochronography was the form of the word originally employed by the writer, but it has been modified in conformity to a decision of the Congress.

[c] The exhibits were arranged in chronological order and numbered, but the illustration (fig. 1) in Dr. Marey's article was on too small a scale to show details and is here omitted.

border at the end of every 70 seconds of time. In that way a series of images were obtained (fig. 2) which showed the successive positions of the planet on the sun. She was seen to penetrate the limb, to cross the disk, and finally to depart; and the interval between the images being known, the velocity of the movement could be measured. This experiment seems to have been the earliest achievement of a chronophotograph; for though others before Janssen conceived bolder

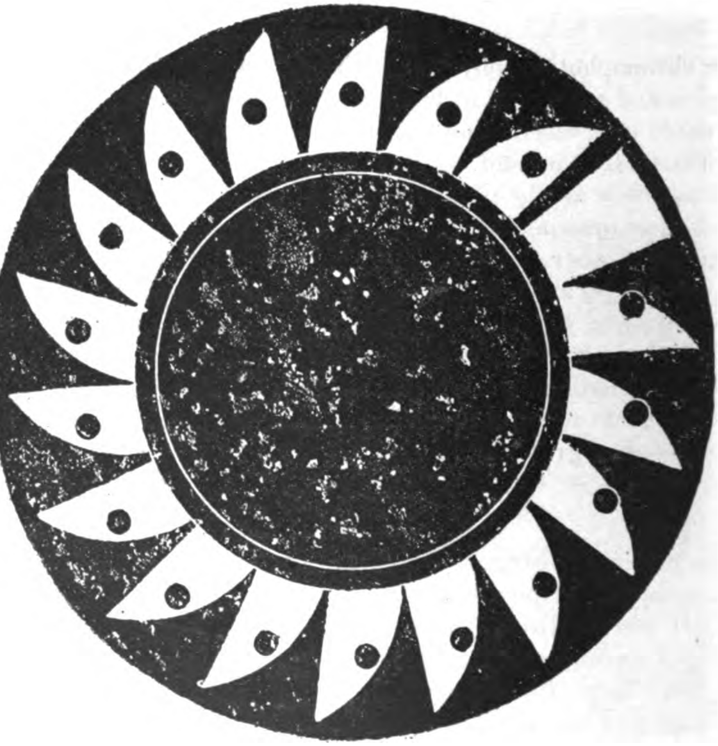


FIG. 2.

attempts, there was, in an exhibition of real things, no place to show plans or projects impracticable at the time of their invention.[a]

No. 2. Analysis of the motions of animals by the method of Muybridge, 1878.—This celebrated photographer of San Francisco suc-

[a] In an article on the "Beginnings of the Cinematograph" in Camera Obscura for February, 1901, Mr. Charles Niewenglowski refers to an ingenious idea of 1857 of Charles Adolphe Reville of bringing into a stereoscope a succession of double photographs of the phases of a phenomenon. But for that purpose it would have been necessary to take the photographs of the objects in motion, which at that date would have been impossible, except at the lowest velocities. The same article figures an apparatus devised in America about 1861 by Coleman Sellers. It was called a "stereophantascope," and was intended to obtain the same result as Reville. The most remarkable conception was, by all odds, that of M. Ducos du Hauron, who in March, 1864, took out a patent for *an apparatus for photographing any scene with all the transformations which it might go through in a given time.* 'How to take the photo-

ceeded in fixing in successive instantaneous photographs all the phases of the gaits of a horse, even at the swiftest gallop. He studied by the same method the motions of man, as well as the principal types of quadruped locomotion.

His arrangement was as follows: Multiple cameras, numbering from 12 to 24, according to circumstances, were arranged in series and pointed on a track where a horse was galloping. Each camera had a quick-acting shutter worked by an electro-magnet. In passing along the track the horse successively broke a series of wires, each of which in breaking set free the shutter of one of the cameras. Things were so arranged that, as he passed along, the animal caused the successive production of a series of instantaneous photographs (fig. 3).[a]

Muybridge's method was, shortly after, used by Anschütz, of Lissa, who seems to have made some improvements in it. In particular he

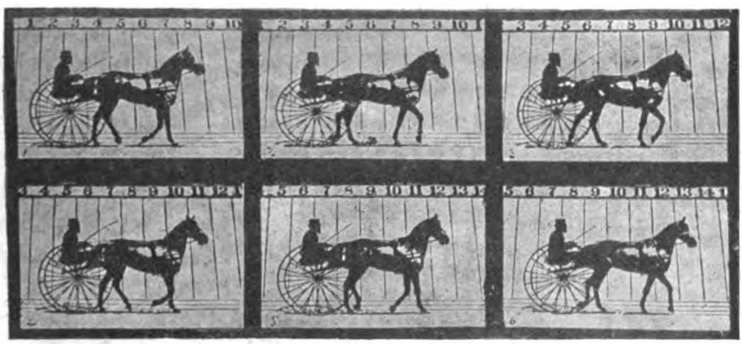


FIG. 3.

was favored by fortune in being able to use the newly discovered plates of gelatino-bromide of silver. Some fine series of photographs by Anschütz were shown in the glass case.

No. 3. Chronophotography on a plate fixed before a camera obscura, Marey, 1882.—The analysis of motion by chronophotography was already worthy of attention in 1882. The apparatus was, however, too costly, while the measures of distances and times were defective, when the writer endeavored at once to simplify the experiments, and

graphs and how to project them in animated form is thoroughly explained and figured in the patent of M. Ducos du Hauron; but the idea was entirely impracticable at the time.

It may be added, in all these apparatus the perception of movement is due to the persistence of retinal impressions, which was the principle of Plateau's phenakistiscope of 1833.

[a] We place the experiments of Muybridge along with those of chronophotography, although this ingenious experimenter did not succeed in taking his instantaneous photographs at equal intervals of time. For the velocity of the horse not being quite uniform, the equidistant wires were not reached at equal intervals of time. Besides, the wire was more or less stretched before rupture took place. From these causes there was a certain inequality in the rates of succession which Muybridge did not succeed in satisfactorily overcoming by letting off the shutters independently of the horse's motion.

at the same time to give them precision. The principle of the first method employed was as follows:

Suppose an ordinary camera to be pointed at a perfectly dark field, and that an opaque disk in front of the lens is pierced with narrow openings and turns about its center. Every time an opening passes before the objective the light would be admitted, if there were any light in the field. But there being no light, none penetrates the camera; and when the plate is developed it is seen not to have been affected. If a strongly lighted man or animal were to cross the dark field, each admission of light would produce an image of the animal, and as the latter moved, photographs of it would be taken on the plate at different places and in different attitudes. Such an arrangement, however, would not answer. Fig. 4 shows the apparatus in its real form. Within a cubical box is seen the camera with its lens. Behind it is the plate holder or back, C, which slides in grooves. Between the plate holder and the camera revolves the slitted disk grazing the sensitive plate—in short, what is called a plate-shutter. This disk, D, with its narrow openings, f, is worked by a clock movement furnished with a speed governor, and is set in motion by a handle. Fig. 5 (Pl. I) shows the flight of a white duck, which passes before the dead black background. The succession of images is from left to right. Eight different attitudes are shown during one complete stroke of the wings. They reveal the details of the mechanism of flight. In order to appreciate the dimensions of the animal and the extent of its flight, a divided rule is placed before the dark field. It is photographed and serves as a scale. Finally, in order to show the intervals of time between the successive images, at the lower right-hand corner of the dark field is placed a chronograph, consisting of a dial, which has a white hand completing an entire revolution in a second. Every time the shutter disk admits light and causes a photograph of the bird this hand is likewise photographed. Since it is seen to occupy eight successive equidistant positions on the dial, it is evident that the intervals have all been one-eighth of a second.

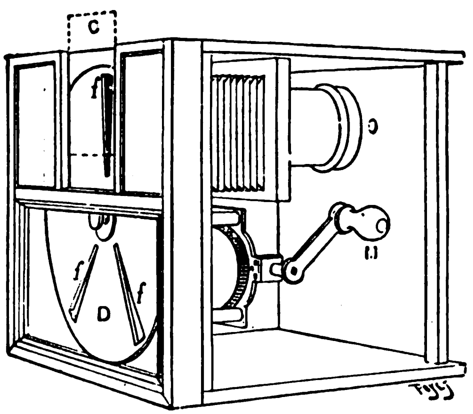


Fig. 4.

No. 4. Dark field for chronophotography on a fixed plate.—No body is quite black. Chevreul showed that absolute blackness can only be procured by means of a hole into a cavity with blackened walls, upon which no light is allowed to shine. [That is, there should be another

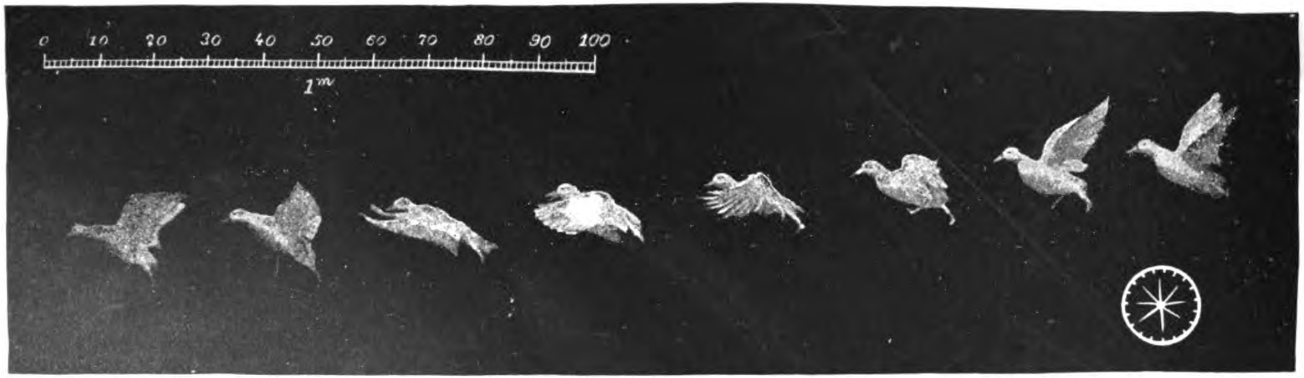


FIG. 5.—CHRONOPHOTOGRAPH OF A WHITE DUCK IN FLIGHT.

black hole facing the first.] In order to approximate to these ideal conditions, the writer constructed a deep shed tapestried with black velvet and facing so that no light penetrated it. In that way very sharp images are obtained upon an unclouded background.

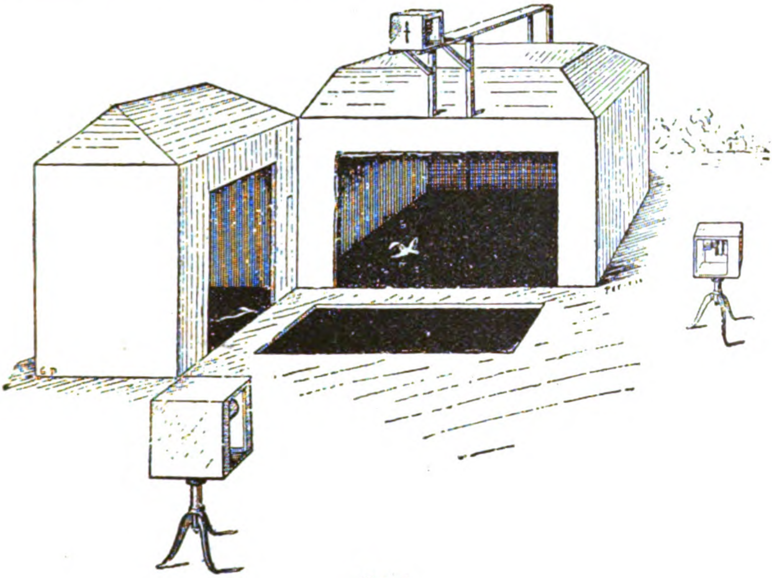


FIG. 6.

No. 5. Figures in relief obtained by the use of chronophotography.— A single apparatus only gives the projection of the motions on a plane perpendicular to the optical axis of the instrument. But if three chronophotograph cameras are focused on dark fields or dead-black

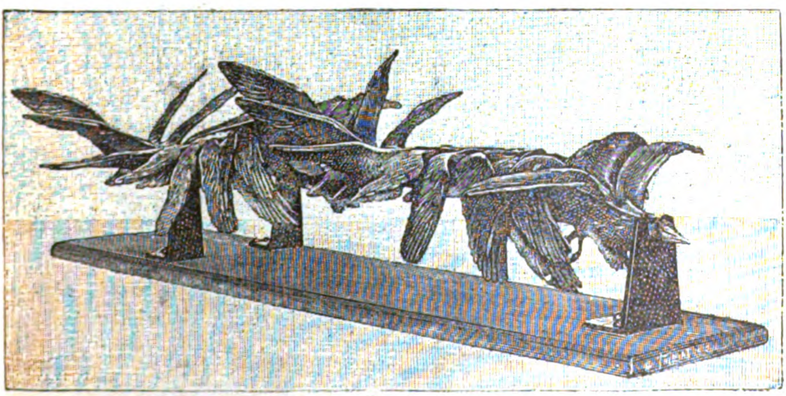


FIG. 7.

backgrounds perpendicularly to one another (fig. 6), the animal represented will be seen from three different points of view, which will enable us to understand its real attitudes by reference to the three dimensions of space. Fig. 7 shows a series of bronze figures, united each to the next, and representing the successive attitudes of a sea-gull in flight.

No. 6. Photographic gun, 1882.—In the study of the flight of birds the necessity of operating before a dark field or dead-black back-

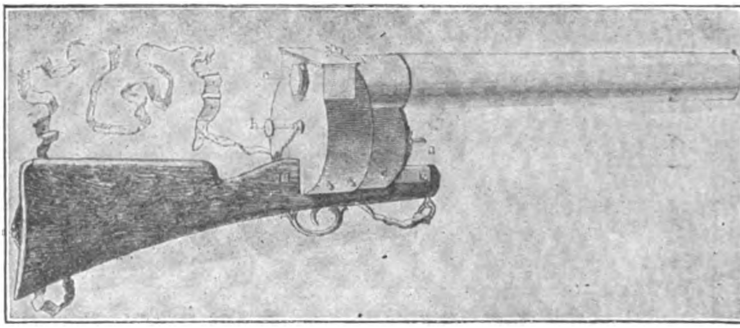


FIG. 8.

ground restricts extremely the number of possible experiments. In order to analyze free flight it was requisite to be able to operate in case of need on the bright sky and to arrange an apparatus capable of being

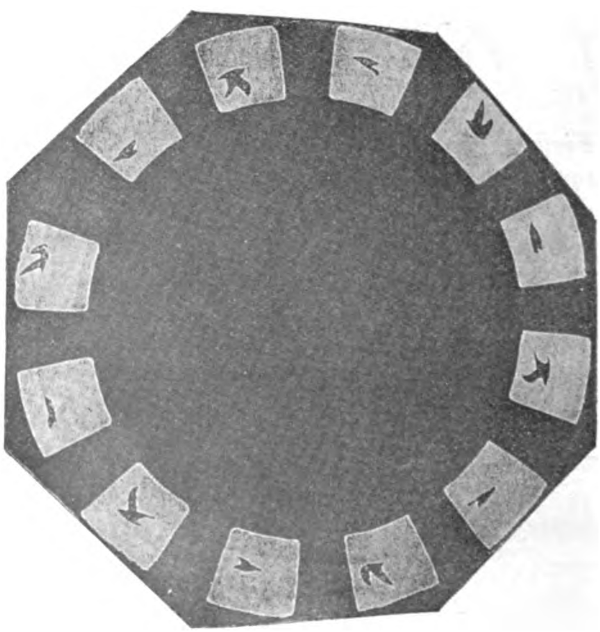


FIG. 9.

aimed at a moving bird like a gun. The photographic gun (fig. 8) contains in its barrel a long-focus objective. In its breech there turns a circular plate, which presents to the focus of the objective different points of its border. In short the apparatus is analogous to the astronomical revolver of Janssen, with this difference, that it produces pictures about 800 times more frequently, which calls for a pretty delicate mechanism. Fig. 9 shows the photograph of a gull in free flight.

No. 7. M. Londe's apparatus with multiple objectives, 1883.—Returning to the method of Muybridge, with a very important improvement, M. Londe, aided by M. Dessoudeix, constructed an apparatus in which a series of twelve objectives form their images upon different parts of a rectangular plate of large size. An ingenious arrangement causes the successive opening of these objectives at equal intervals as short as may be desired. The analysis of the motion is consequently very perfect. The order of the images can not be deranged, since they are all obtained on one plate. But the number of pictures is limited by the necessity of having a separate objective for each. General Sébert by a similar method analyzes the phases of the motion of torpedoes.

No. 8. Multiplication of the number of pictures: 1. Partial photographs. 2. Dissociation of the images before the dark field. 3. Photographs on a film ribbon in motion, 1887–88.—A perfect analysis of

Fig. 10.

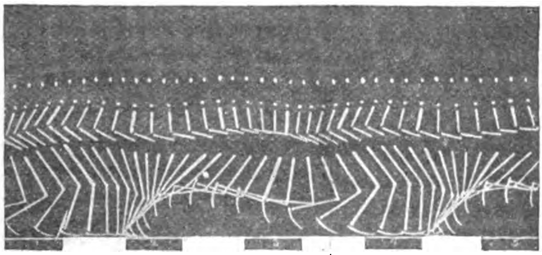


Fig. 11.

motion requires that the photographs be taken at as short intervals as may be, yet for as long a time as possible. If we merely make the rotation of the shutter-disk faster, the number of images will, it is true, be augmented, but the animal's locomotion not being thereby accelerated, the result will be that the photographs will be taken so close together that they interfere with one another and produce the confused effect seen in figure 7. A first way of avoiding this confusion is to photograph, not the entire body of the subject, but only certain points or lines whose position is significant of the facts we desire to know. A man dressed completely in black (fig. 10), and consequently invisible upon the dead-black background, wears certain bright points and lines, strips of silver lace attached to his clothes along the axes of his limbs. When this man, so rigged, passes in front of the apparatus, photographs will result that will be accurate diagrams to scale (fig. 11), showing without confusion the postures of upper and lower arms, thighs, lower legs, and feet at each instant, as well as the oscillations of the head and of the hips. The method also allows the play of the joints to be studied.

Still, it was desirable to multiply the images while showing the whole body. For that purpose the insufficiency of the advance of the subject has to be made up for by a displacement of the image on the plate. This can be brought about in several ways. In the first place, the camera, with its attachments, can be pivoted on its support and caused to turn about a vertical axis. The difficulty of moving the considerable mass uniformly caused, however, the abandonment of this method in favor of the rotation of a mirror by clockwork, causing the reflection to strike different points of the plate. In this way a series of complete photographs are obtained, following one another at extremely short intervals of time. Indeed, the frequency of the photographs may be made very great. Their total number is, however, restricted because the optical axis of the instrument, being dis-

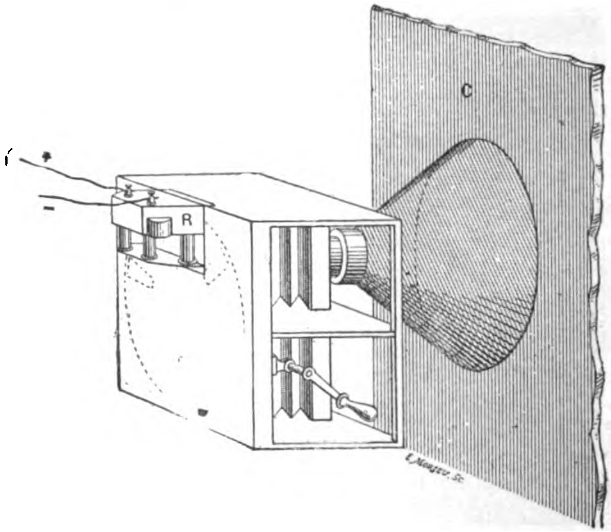


FIG. 12.

placed along the black background, soon reaches the end of it. A final solution was to take the photographs upon different points of a long fillet which moves along the focal plane of the camera and is stopped long enough for each exposure.

Chronophotography on a film ribbon, Marey, 1887: In consequence of the invention of the kodak, long paper fillets of gelatino-bromide of silver had become articles of commerce. A little later transparent films made their appearance; and these were still more appropriate for the chronophotography of long series of pictures. Three patterns of apparatus were exhibited in the case under No. 8. These showed the successive steps of invention.

Type a: The apparatus (fig. 12) worked in the red light of the dark room. The objective was pointed outward across a conical shade. In the place of the ordinary plate-holder was placed a shelf carrying a clockwork R, which led a long paper ribbon over rollers. The rotation of the disk made an electric contact at each passage of a slit, in consequence of which an electro-magnet squeezed the band and stopped it long enough for the exposure.

Type b: It was necessary to avoid the extreme inconvenience of only being able to photograph within the dark room. A small portable box, B, was therefore made for the fillet, which, having been filled in the dark room, could be carried out with the rest of the chronophotographic apparatus, as shown in fig. 13. The results were more satisfactory.

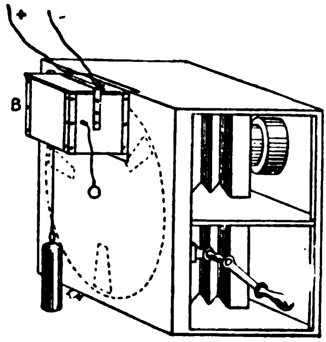


FIG. 13.

Type c: Ultimately the application of electricity was given up, and the motion and stoppages of the film, instead of being governed by an independent clockwork, were connected with the movements of the disk.

No. 9. Double-action chronophotography.—With a view of obtaining an apparatus which should, at pleasure, either work upon a fixed plate or upon a moving film, an instrument was constructed represented by No. 9 in the glass case. This apparatus (fig. 14) is composed of a fore part, which slides in grooves. This fore part carries the objective and is cut so as to allow the shutter-disk to pass. The movement of the latter is governed by a rod of variable

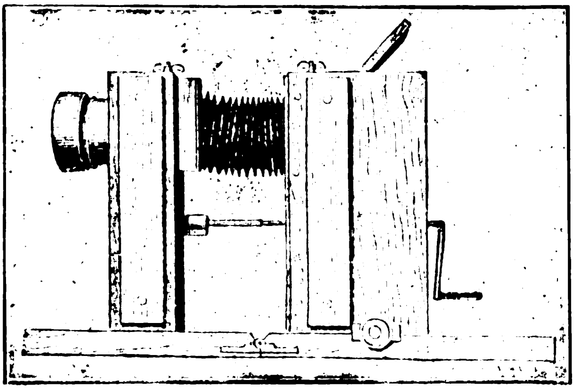


FIG. 14.

length (so as to permit focusing) connecting with clockwork within the after part of the apparatus. In this after part can be placed an ordinary plate holder for chronophotography on a fixed plate; or, if desired, the plate holder being removed, movable films may be introduced. These go into a back chamber, the open lid of which is shown in the figure. The film ribbons could be inserted in daylight in consequence of their being prolonged at both ends by ribbons of opaque paper (fig. 15). When the whole was wound up round its spool before being put in, the film was protected from light by outer layers of opaque paper; and when the work was done and the film was wound upon the other spool it was equally protected by the other terminal of opaque paper so that it could be removed from the apparatus in the light without becoming clouded.

This apparatus, which was easily used, sufficed for three years for the writer's researches into the motions of man and of animals. Like Muybridge, Anschütz, and Demeny, he aimed to obtain, by Plateau's method, the reproduction of the analyzed motions. At the exhibition of 1889, a zootrope moved by electricity showed animals in motion, as well as men, birds, horses at different gaits. But since the zootrope does not allow many figures to be shown, the writer was restricted to exhibiting short movements. He therefore cast about for methods of showing scenes of long duration.

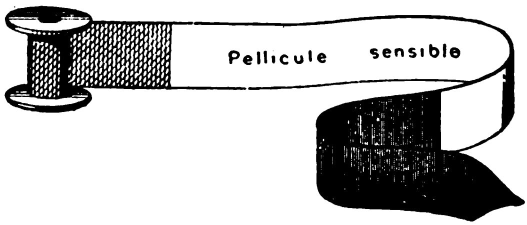


FIG. 15.

No. 10. Chronophotographic projector, 1893.—This apparatus carries an endless belt of photographs to the focus of an objective which projects them upon a screen. Fig. 16 shows the path of the rays in the projector. A pencil of parallel rays, reflected by a heliostat comes

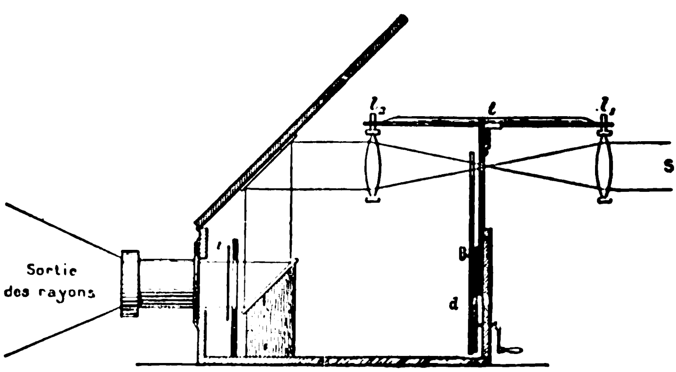


FIG. 16.

from S, and falls upon a convex lens l_1. This pencil brought to a focus, passes at t through a hole in a diaphragm, meets the shutter-disk d, which is turned by a crank, passes through every window that comes, then diverges and, meeting the lens l_2, similar to the first, regains its parallelism, is reflected at 45° from a mirror forming the lid of the box, falls vertically upon another mirror at the same inclination, and now passes to the objective. But in this last part of its course it traverses the film, *i*, which carries the positive photographs, and these photographs, magnified by the objective, are thrown upon the screen.

The motion of the film at its halts at each flash are brought about by an apparatus not shown in the figure. It is similar to that of the simple chronophotographic apparatus, with the difference that the positive film, having its ends fastened together to make an endless belt, passes over a series of rollers which stretch it taut. The principal imperfection of the chronophotographic projector was a jerkiness due to imperfect equality of the intervals.

No. 11. Edison's kinetoscope, 1894.—Mr. Edison found a means of equalizing the intervals. It was to perforate the sensitive film by a

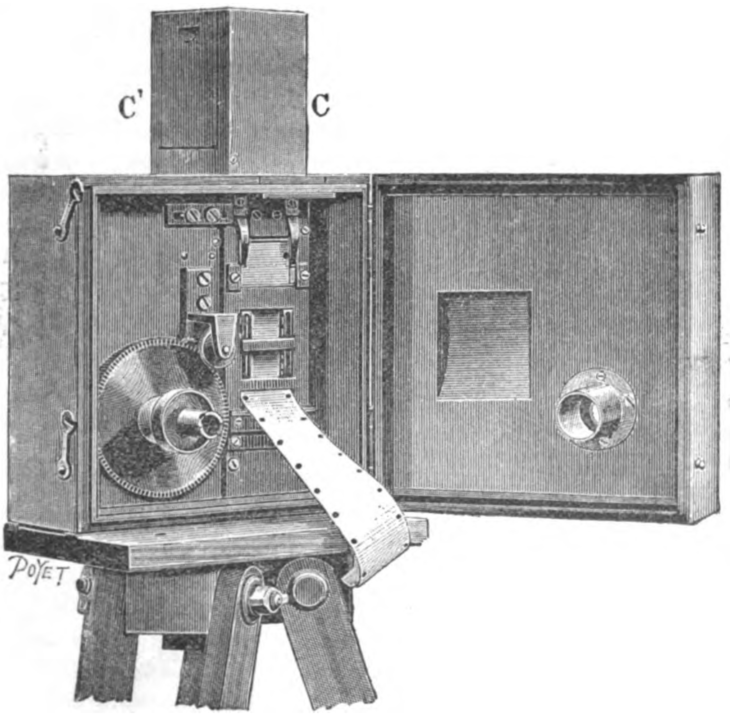


FIG. 17.

series of equidistant holes and gear it to a pin cylinder. It was impossible to procure a kinetoscope to exhibit in the glass case; but everybody, of late years, has seen this remarkable instrument in action. It shows living scenes acted out for more than a minute with absolute precision. In Edison's apparatus the film-ribbon never was arrested; but the images were rendered sharp by the extreme brevity of the illumination, which was only $\frac{1}{7000}$ of a second. A single spectator, looking through eyepieces, could see the living pictures of the kinetoscope.

No. 12. Lumière's cinematograph, 1895.—This instrument finally gave the desired result—that is to say, the projection on a screen of living scenes visible to an assembly and presenting a perfect illusion. The success of this invention was immense, and has not passed away. Fig. 17 shows the cinematograph open and arranged for taking photographs. A film, perforated like that of Edison, is rolled up in a closed box c^1c on the top of the apparatus. It passes, in an intermittent manner, to the focus of the objective, being drawn forward by a system of claws which catch in the holes of the film. The reciprocating motion of these claws gives intermittency to the motion of the ribbon. After exposure the film is received in another closed box, invisible in the figure. It was important to make the claws acquire and lose their velocity as gradually as possible, so as not to tear the film. The Messrs. Lumière succeeded in effecting this by means of a triangular cam, fig. 18, which is the essential part of the apparatus. During two-thirds of the whole time the film is at rest.

For the projection of the positives, the Messrs. Lumière make use of a special arrangement. A powerful electric lamp brilliantly illuminates the film. In this way very bright projections are obtained of 25 by 19 feet (7.75 m. by 5.80 m.), the figures on the film measuring only 1 by ⅞ inches (25 by 22 mm.). In the glass case by the side of the cinematograph several ribbons printed on paper showed the perfection and happy choice of the photographs obtained with this instrument.

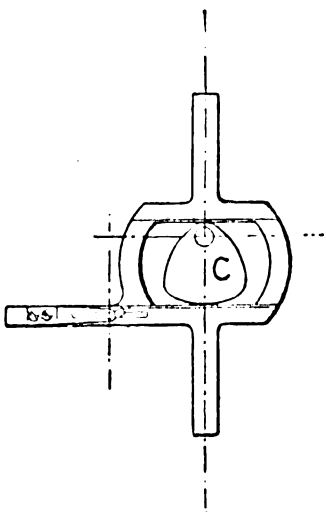


FIG. 18.

The success of the cinematograph gave birth to many forms of apparatus for the projection of living pictures. Most of them differ very little from the instrument of Messrs. Lumière, and were not shown. Two types, however, of marked originality merit special mention.

No. 14. Captain Gossart's apparatus with oscillating objective, 1897.—This instrument gives photographs of very large dimensions. Its author has applied it to the study of the gaits of the horse. Fine specimens of its work were exhibited. It is not adapted to projections.

No. 15. The Alethorama of Messrs. Chéri-Rousseau and Mortier, 1897.—This is a projecting apparatus in which the perforated film-ribbons, as they pass along, give reflections of their pictures from a series of prisms. The projections are exceedingly bright and steady, and altogether make a fine effect. The apparatus, however, seems to be hard to adjust, and does not appear to have been taken up practically.

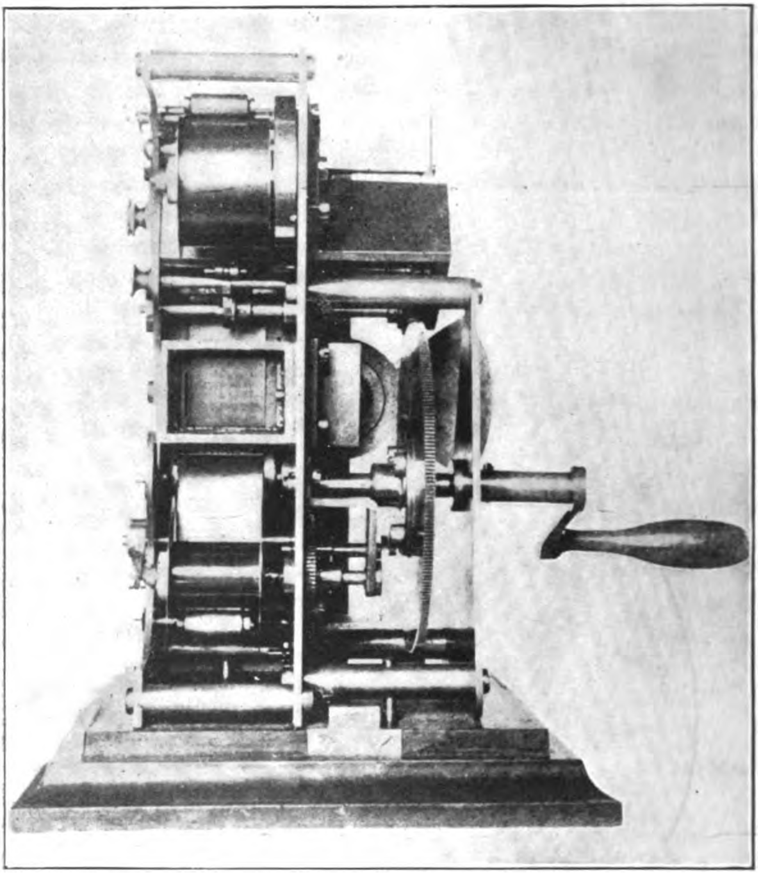


FIG. 19.—MAREY'S CHRONOPHOTOGRAPHIC APPARATUS.

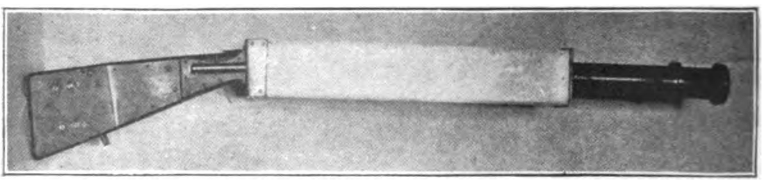


FIG. 20.—CHRONOPHOTOGRAPHIC GUN.

No. 16. Analyzing and projecting chronophotograph, Marey, 1898.—The writer has pushed the improvement of his chronophotographic apparatus, so as to obtain perfect equidistance of the views, and has succeeded in doing so while preserving the main principle of not perforating the films. For perforation, besides wearing, so as no longer to bring the pictures around regularly, also occupies a zone of $\frac{1}{10}$ of an inch (2.5 mm.) on each edge of the ribbon, a loss which is more important the narrower the film. The writer has succeeded in obtaining perfect regularity in exposures by modifying the first pair of rollers which takes the film. The apparatus is shown in fig. 19 (Pl. II).

In making projections, a further difficulty arose, namely, the positive film undergoes some shrinkage in the successive developments requisite to obtaining it, in consequence of which the pictures, being too near together, pass by too soon, and tend to leave the field of the screen. A simple drag or brake upon the magazine spool corrects this fault. Positive ribbons of different breadths were exhibited, showing the sharpness and equidistance of the photographs.

No. 17. Microscopic chronophotography, 1899.—The writer has adapted the chronophotograph to the study of motions which take place in the field of the microscope. In order to avoid exposing the animals studied to the heat of an intense illumination, an arrangement was adopted in which the shutter-disk only effects the lighting up of the preparation during the time of exposure, which is about one-five-hundredth part of a second. This done, the brightest light no longer produced any injurious effects. Numerous photographs were exhibited, together with the instrument.

No. 18. Chronophotographic gun with a film ribbon, 1899.—In its original form the photographic gun only gave twelve views. For a more extended series an instrument of a new type (fig. 20, Pl. II) was constructed, in which the successive photographs are taken on a band 66 feet (20 m.) long. The shutter is formed of a light-cock, which is far less cumbrous than a disk. In the stock of the gun is a clockwork moved by a dynamo. Whenever the trigger is pulled the circuit is closed and the film begins moving, and does not stop until the trigger is let go. Light accumulators, or a portable pile, furnish the necessary current.

PART II.

SCIENTIFIC APPLICATIONS OF CHRONOPHOTOGRAPHY.

Animated projections, interesting as they are, are of little advantage to science, for they only show what we see better with our own eyes. At best, they serve to slow a motion which is too quick for direct observation, or to accelerate it if its extreme slowness causes us to miss some of its features.

In the former case photographs are taken at the rate of 40 or 50 to the second and are projected in three or four times the original time. We can thus show a horse galloping or a bird flying so slowly that the eye can follow the motions of the limbs. In the other case the photographs are taken at very long intervals and are projected in rapid succession. For this purpose the writer's chronophotograph (fig. 19, Pl. II) is furnished with an arbor upon which, if the crank is fitted, the effect is that only one photograph is taken at each turn. The slowest, almost imperceptible motions of clouds, taken at long intervals and rapidly projected, are translated into a rapid and striking agitation.

What is generally important in the study of a motion is to obtain a geometrical drawing of it. Chronophotography upon a fixed plate gives such a drawing to scale exactly. Chronophotography on a movable film may do so by the aid of certain devices which will be described below. Chronophotography on a fixed plate has furnished the experimental solution of many problems of geometry, mechanics, physics, and physiology that no other method could so readily have solved.

GEOMETRY. *Formation in space of geometrical figures of three dimensions.*—Geometers define this sort of figures by saying that they are generated by straight lines or curves of different forms displaced in different ways. Chronophotography realizes this conception completely. Before the pitch-dark field a white rod, lighted up and subjected to a displacement in space, leaves on the photographic plate the vestiges of its successive positions. It generates on the plane of the plate the projection of the figure in three dimensions which it has formed. In that way has been obtained (fig. 21, Pl. III) the projection of a sphere on a plane. A band of paper, white on one side, black on the other, was curved into a semicircular form and rotated about its chord. The figure so formed would have altogether the appearance of a solid sphere if a greater frequency of the illuminations had prevented the discontinuity of the surface generated.

Fig. 22 (Pl. III), the projection of a [one-sheeted] hyperboloid of revolution, was generated by a string placed oblique to the vertical axis round which it turned.

If figures with their relief are sought, the photographs should be taken with a stereoscopic apparatus. Fig. 23 (Pl. III) shows in this way an hyperboloid with its asymptotic cone. These examples, taken from very simple cases of geometry, enable us to imagine what variety of forms would be obtained with complex curves subjected to varied motions. There would be very simple experimental solutions of problems of geometry sometimes most complicated.

MECHANICS.—Mechanics is founded on the laws of motion, laws of spaces described, of velocities, and of accelerations. The difficulties

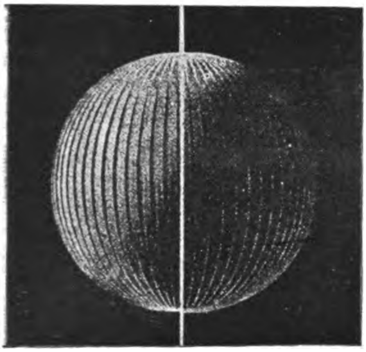


Fig. 21.

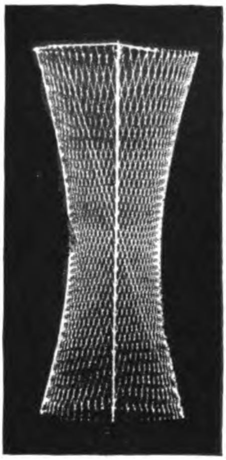


Fig. 22.

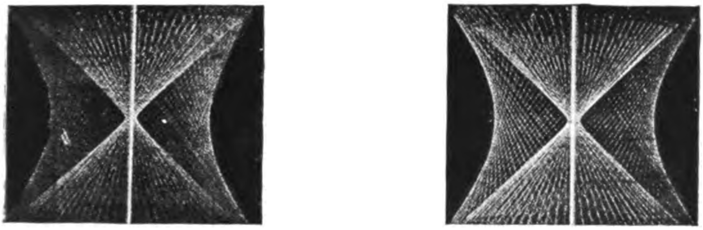


Fig. 23.

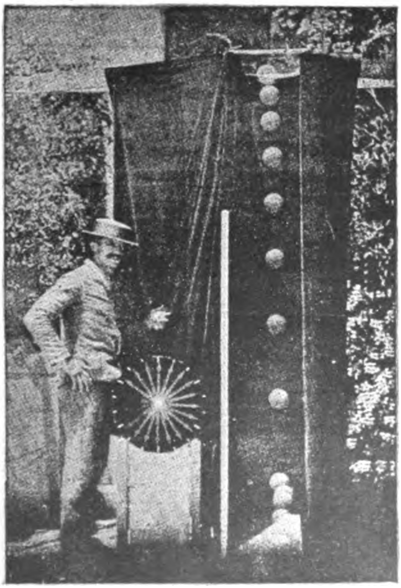


Fig. 24.

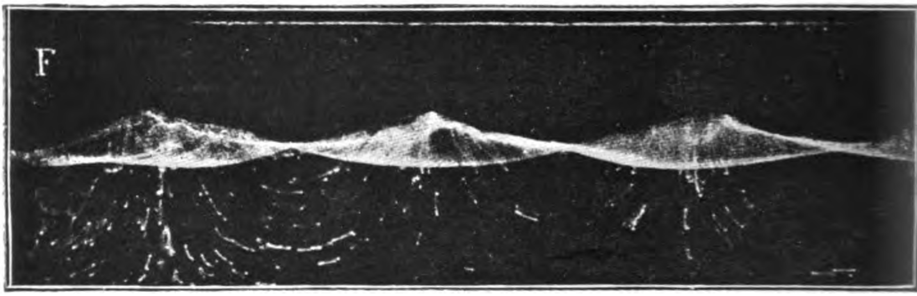


Fig. 25.

Fig. 26.

CHRONOPHOTOGRAPHS OF WATER IN MOTION.

which Galileo and Atwood surmounted to determine these laws will for the future be saved in all analogous cases for those who shall employ chronophotography for the purpose. We shall only have to allow the body whose motion (fig. 24, Pl. III) is to be studied to fall before the pitch-dark background, and its positions will be marked upon the sensitive plate; the chronograph will give the interval of time which elapses between the body's arrivals at the positions figured; the scale of millimeters will measure the distances described. The same arrangement enables us to make interesting studies of the resistance of the air.

Hydrodynamics is commonly taken to be one of the most complicated sciences. The nature of undulations, the nature of violent waves, the internal motions of molecules in a shaken liquid, the manner in which stream lines behave when they meet obstacles of different forms, all these questions are still discussed as if they were difficult. All these problems find their experimental solution in chronophotography.

All that is wanted is to render visible, and alone visible, before a dark background, those parts of the liquid of which we wish to know the motion. For that purpose into a canal formed of transparent plate glass is to be poured some very clear water. A mirror inclined at a convenient angle and placed under this canal reflects the light of the sun, which then traverses the liquid mass from below upward. The water is not illuminated; but at the surface of the water, at the point where the wall of the glass is moistened by the liquid, a meniscus is formed, and the under convex surface of this meniscus sends by total reflection a very bright thread of light, which oscillates like the surface of the liquid itself. The photographic objective will make upon the sensitive plate a photograph of this line with all its movements.

The interior of the liquid is not lighted up. In order to render certain points of this mass and to perceive the displacements which they undergo it is only necessary to put into suspension in the water small silvered pearls to which has been given the precise specific gravity of the liquid. These pearls by the agitation which they undergo will express the motion of the molecules of the water at different parts of the mass (fig. 25, Pl. IV).

Other phenomena of the same class can be studied by chronophotography. Thus, a thin inclined plane being presented to a liquid current, the bright pearls will express by the direction of their course the motion of liquid fillets. By the distances between their images they will express the rapidity of the current. A scale of millimeters immersed in the water will measure the extent of the motions, while the known interval of time which separates the flashes affords the means of evaluating the velocity. That having been explained, one glance at the scale diagram (fig. 26, Pl. IV) will suffice to show what movements will take place at the surfaces of liquids under conditions however varied, and also how the molecules themselves will move at the different points throughout the mass.

Motions of the air.—An analogous arrangement makes it possible to render visible by means of smoke certain fillets of air in the midst of a regular current. We ascertain in that case by chronophotography the changes of direction and of velocity of this current when it meets obstacles of different forms.

In a large canal having walls of plate glass and before a dark background a draft of air is created by means of a ventilator. In order to regulate the current it is filtered through a very fine silk gauze. At the top of the canal, we set free, by means of a series of little tubes, fillets of smoke which descend parallel to one another like the three cords of a lyre. Now, if we place in the interior of the canal obstacles of different forms, we immediately see the threads bend on these obstacles, slide over them, and form behind them eddies of varied forms. Figs. 27, 28, and 29 (Pl. V) show the same experiment under different conditions. In fig. 27 a magnesium flash light illuminates the phenomenon for a very short time. We see how the fillets of air lick the plane, slide on it, and form backwater behind it. Fig. 28 shows the same phenomenon with chronophotographic indications. The series of little tubes which bring the smoke are made to vibrate ten times a second, so that the smoke no longer appears in rectilinear fillets but as sinusoidal undulations, more or less elongated at each point according to the velocity of the current. The motion slows up upon approaching an obstacle and is accelerated at the sides of the obstacle. It will be remarked that the conceptions of time and space which are peculiar to chronophotography are brought together in this experiment. Finally, in fig. 29 the chronography is suppressed. The illumination is no longer instantaneous, but is produced by the combustion of magnesium ribbon, so that a sort of mean state of the current is recorded.

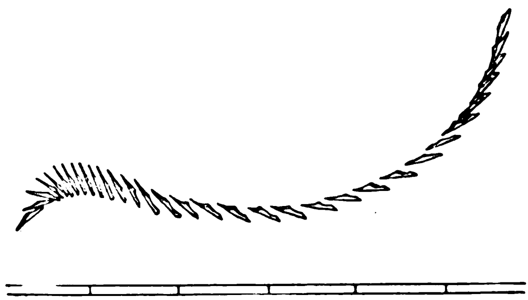


FIG. 30.

Resistance of the air to flying apparatus.—One of the applications of the previous experiments is to make comprehensible the action of the air on apparatus of different forms which move in this fluid. Fig. 30 shows more directly the effects of this resistance. It shows how a little paper soaring model left to fall vertically behaves and how it receives from the resistance of the air changes of direction and of velocity which are faithfully represented.

Vibrations of cords.—These motions are easily seen upon bright cords vibrating before a dark background. Our learned fellow-aca-

Fig. 27.

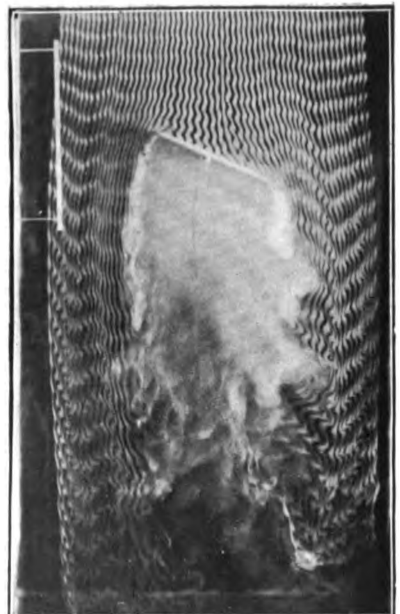


Fig. 28.

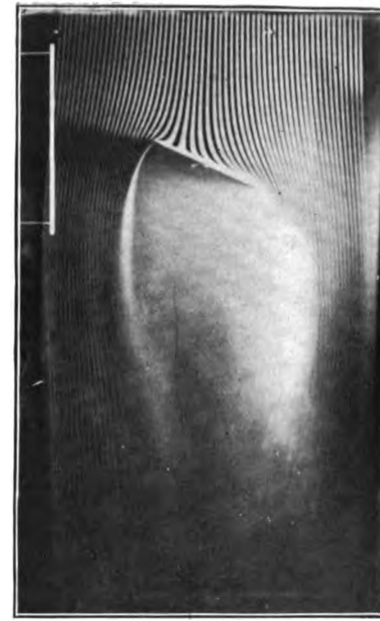


Fig. 29.

AIR CURRENTS PASSING OBSTRUCTIONS.

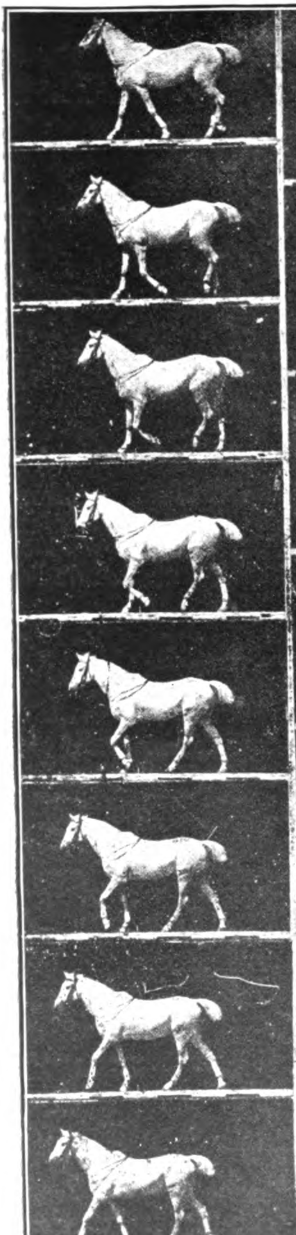


Fig. 32.

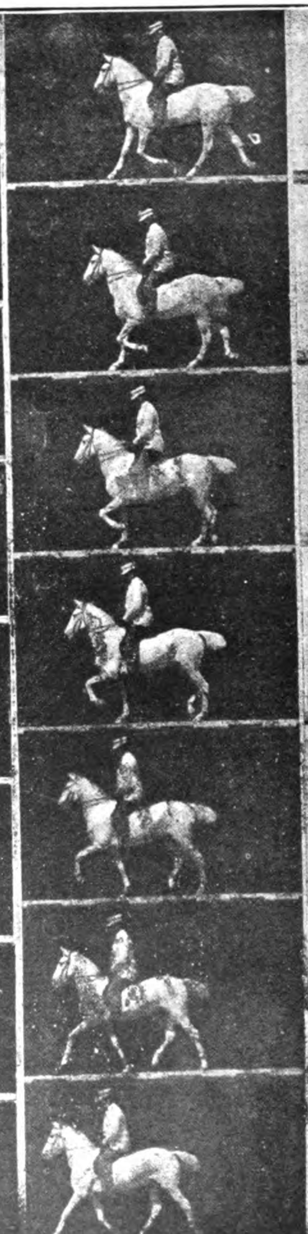


Fig. 33.

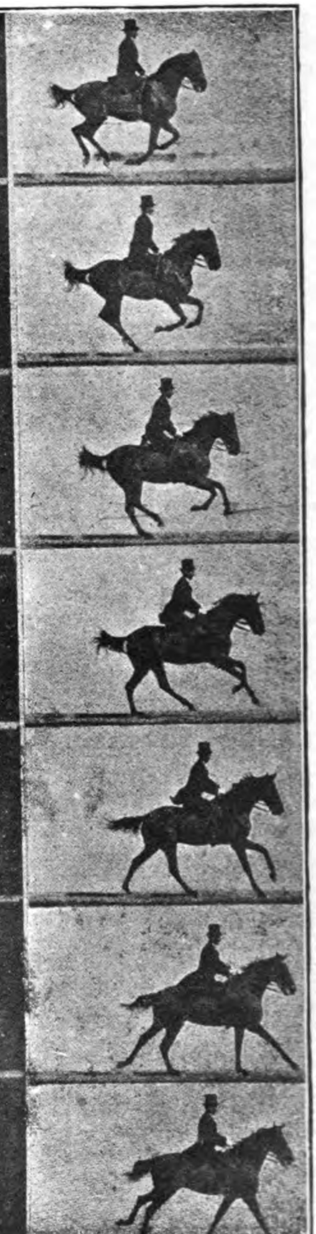


Fig. 34.

CHRONOPHOTOGRAPHS OF HORSES IN MOTION.

demician, A. Cornu, succeeded in this way in rendering perceptible in a cord vibrations of three kinds—the longitudinal, the transversal, and the torsional. A very light little mirror attached to the cord indicated these three kinds of motion on a plate having a uniform translation. Fig. 31 is the negative resulting from this experiment.

PHYSIOLOGY.—It is to the physiological study of the different gaits of animals and to the functional motions of their different organs that chronophotography has principally been applied. Some types of the experiments which it has rendered possible may here be illustrated.

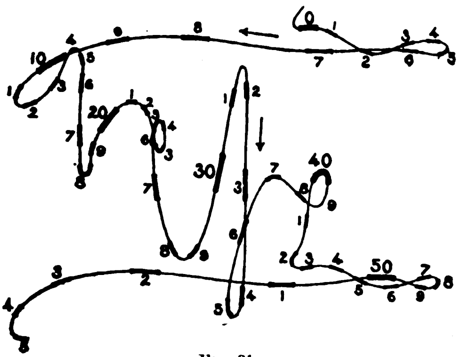


FIG. 31.

Terrestrial locomotion.—The series of photographs taken on moving films have represented all the phases of motion of man and of quadrupeds. Thus figs. 32, 33, and 34 (Pl. VI) represent the three normal gaits of the horse. One can easily follow the succession of attitudes during the advance of the animal. The sequence of time is from above downward. A disputed question of animal mechanics was whether a cat turns over in falling, and, if so, how she does it without any application of external force. Experiment has proved that, as a fact, she does so, thus enabling mechanicians to correct a current error of classical treatises.

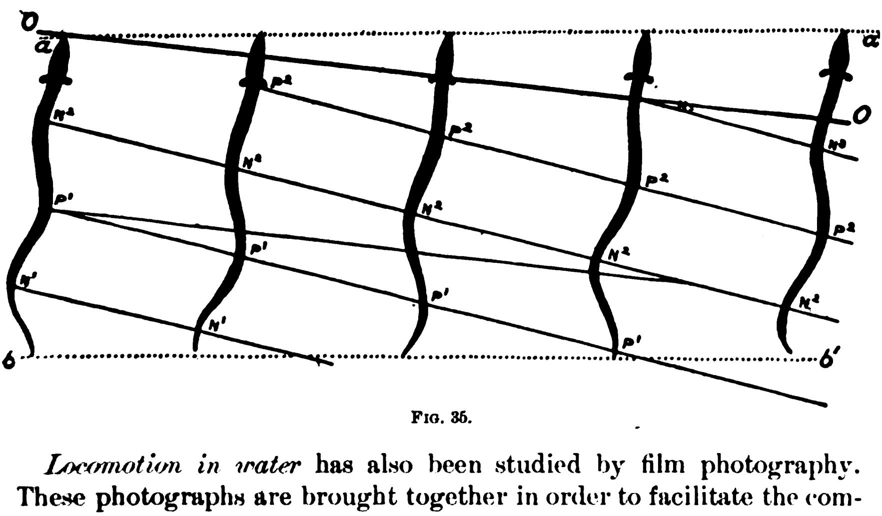


FIG. 35.

Locomotion in water has also been studied by film photography. These photographs are brought together in order to facilitate the comparison of them. The locomotion of the eel (fig. 35) shows the progression of undulations of the body of the animal from head to tail. Lines are drawn to show the direction of motion and the advance of the animal.

In certain fish the undulations take place in the lateral fins. The ray (fig. 36, Pl. VII) is shown in side view, swimming without advancing, its progress being impeded. The same fish seen from the front has motions which strongly recall those of a flying bird.

Locomotion in the air.—Not only the flight of birds, but that of insects, studied by chronophotography, shows the details of its mechanism. The extreme rapidity of these motions—several hundred per second—requires extremely short exposures. To avoid any defect of sharpness due to the velocity of the wing, the writer has reduced the duration of the flash to less than one twenty-thousandth of a second. Only isolated photographs have been obtained, but even these are highly instructive. Fig. 37 (Pl. VII) is a motionless crane-fly; fig. 38 (Pl. VII) shows it in flight. The torsion of the wing under the resistance of the air, a phenomenon which theory had predicted, and which explains the mechanism of insect flight, is shown in the picture.

Functional motions.—Independently of acts of locomotion, the different parts of the body execute various movements, the observation of which is in some cases excessively difficult. In speech and in mastication the lower jaw takes displacements that one would not have anticipated. The ribs, in respiration, rise and separate in a way that was of old unknown. In certain joints the bones move about a fixed center, while in others there is a rolling motion of the condyles over the surface in contact with them. Chronophotography on the dead-black background gives a drawing to scale of all these motions. Bright lines or points fixed to the organ under examination interpret the trajectory upon the photographic plate.

Thus the motions of the lower jaw in the act of opening the mouth are represented (fig. 39, Pl. VIII) by those of a rod bent at an angle and forced to move with the jaw. It will be seen that the motion is not a rotation round the joint, but takes place about instantaneous centers in the upright branch, while the condyle itself slides over the surface of the glenoid cavity, which is convex downward.

In respiration bright points fixed upon the ribs are displaced with the latter and interpret the motions of the rising ribs on a circular arc.

The heart of an animal, laid bare and brilliantly illuminated, gives on the moving film the succession of systole and diastole of its auricles and ventricles. The motions of the eyes themselves have been studied at the physiological station by M. Orchansky. He has chronophotographed the dotted trajectory of the eyes in reading, and in this motion has been able to distinguish the components, due respectively to the ocular muscles and to the displacements of the head.

Motions of the air in the utterance of the vowels.—The eminent physicist, R. Kœnig, conceived the idea of making the sonorous vibrations due to instruments or to the voice act upon capsules with membranous

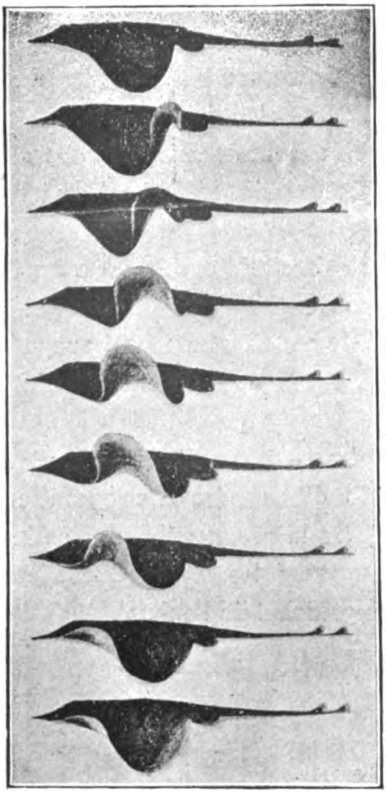


Fig. 36.

Fig. 37.

Fig. 38.

CHRONOPHOTOGRAPHS OF RAY AND CRANE-FLY.

Fig. 39.

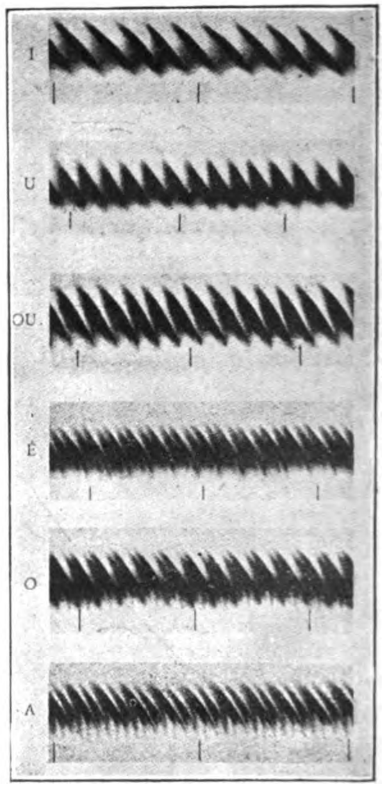


Fig. 40.

CHRONOPHOTOGRAPHS OF JAW MOVEMENT, AND OF AIR MOTION IN VOWEL SOUNDS.

walls placed on little gas-burners. These "manometric flames" vibrate in unison with the sonorous waves. Their images, dissociated in a revolving mirror, appear with indented mantling of various forms, according to the sound. But this fugitive phenomenon could not be fixed by photography until M. Marage, who has charge of the acoustic work at the Physiological Station, rendered the flames photogenic by substituting acetylene for ordinary illuminating gas. He has taken the photographs by chronophotography on a ribbon of sensitized paper having a translation of 2 meters per second (100 feet in 0.254 minute). Fig. 40 (Pl. VIII), shows the vibrations of the air for the French vowels *i*, *u*, *ou*, *é*, *o*, *a*. At the same time as the vibrations of the vowels, those of a special burner acted on by a tuning fork of 45 V. D. are photographed also, so as to determine the pitch.

Representations of motions in scale pictures conformed to separate photographs.—The impressions by chronophotographs on a moving film, complete as they are, are hard to utilize, on account of the difficulty of comparing the separate photographs. In some cases this comparison can be facilitated by bringing the photographs together. But it would be more satisfactory to be able to arrange them, each in its place, on a single picture to scale. The writer has accomplished this by means of successive projections and counter proofs on the same sheet of paper.

Let a gymnast throw a weight. (This is chronophotographed on a ribbon.) Let us project the first photograph and carefully counterprove the form of the body.[a]

After this first projection, let us project the second photograph upon the same sheet, and then a third, taking care to preserve the registry exact by fixed points which we have chosen. (That is, the horizontal line and object *r* will have been sharply drawn on the back of the drawing paper; and in making subsequent projections care is taken to have that line and object fall upon precisely the same places.) We shall thus have obtained a series of counter-proofs representing the successive attitudes of the gymnast. Fig. 41 has been constructed in this way. It affords complete information as to the extent and velocity of each of the motions represented.

In this case only every third photograph has been drawn, in order to avoid confusion in the picture to scale; but while reducing the num-

[a] I suppose he means that the perverted negative is projected, or in some way that the projection is perverted, and that the projection is made on a board. This projection must show the fixed object *r* (at the left of the horizontal line), which, with the horizontal line, is photographed from nature in all the photographs. He attaches, I suppose, to the board a sheet of carbon paper, and over it a sheet of drawing paper, face down. The projection appears on the back of the latter, and he marks with an agate stylus the outlines of the gymnast's body, the horizontal line, and the object *r*. These outlines are thus drawn correctly on the face of the drawing paper. That is how I understand his description.—TRANSLATOR.

ber of images of the athlete we might show all the successive positions of the weight, which would then have been very numerous. The series of these positions would have given the law of the motion impressed

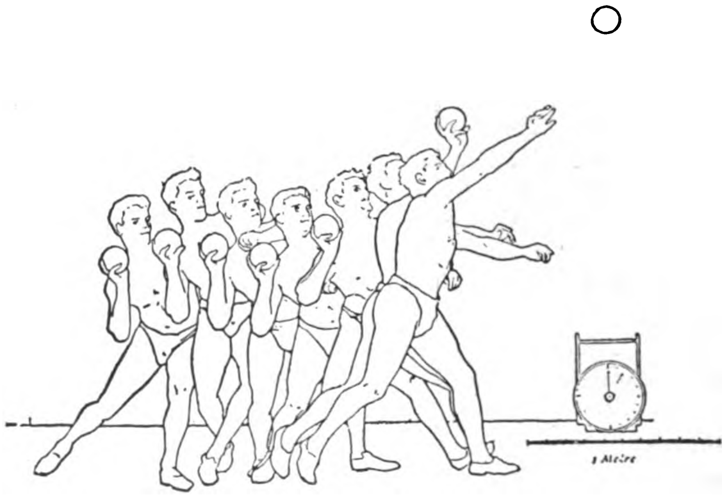


FIG. 41.

on the projectile, and the acceleration would have given in its turn the measure of the forces developed by the gymnast at each instant.

We can even push the analysis of muscular action so far as to give, in the successive pictures to scale, the positions of the skeleton within

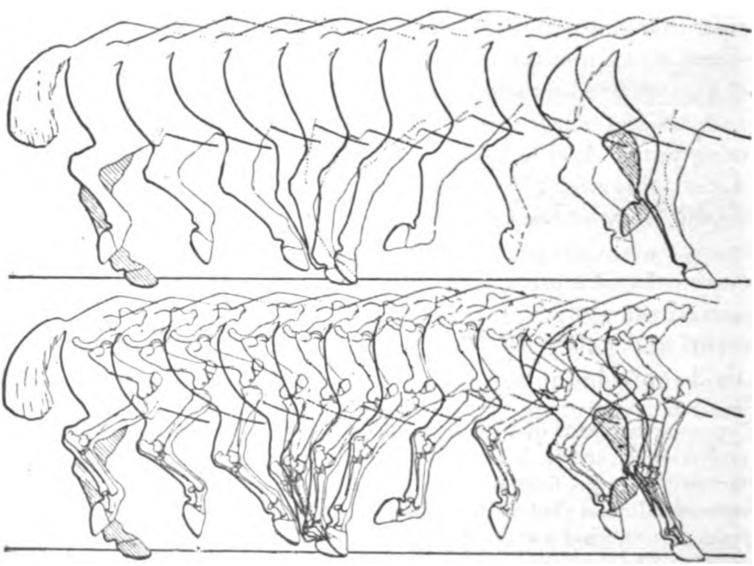


FIG. 42.

the subject, with the phases of extension and contraction of the principal muscles, whose insertions upon the skeleton are, of course, known. Fig. 42 contains such details.

This last application of chronophotography is sometimes somewhat laborious. It is only mentioned to show the extreme power of the method and the multiplicity of its applications.

In closing it may be added that since the exhibition new applications of chronophotography have been made at the physiological station, which promise the experimental solution of certain problems hitherto looked upon as insoluble.

[Subsequent notes by Dr. Marey, translated from the Comptes Rendus of the Academy of Sciences, Vol. CXXXII, p. 1291, meeting of June 3, 1901.]

Since the communication which I had the honor to make to the Academy on the 27th of May, 1900, I have seen that my apparatus needed to be entirely reconstructed in a better form, but the resources of my own laboratory did not permit it.

Our correspondent, Mr. Langley, who is interested in these studies, obtained from the Smithsonian Institution, whose Secretary he is, a subsidy which has permitted me to resume my experiments, and to present to the Academy these new results. I have also awaited the result of the remarkable experiments of Professor Hele-Shaw, and it has seemed to me desirable to bring together these two kinds of research, which have a common purpose, that of fixing by means of permanent images phenomena which escape direct observation.

Besides this, since my last communication I have learned of the labors of Mr. L. Mach, which are so closely related to my own that I notice them in giving the history of the new methods which seem destined to numerous applications.

It was on the 11th of March, 1893, that I had the honor of presenting to the Academy my first experiments, made by means of chronophotography, on liquid waves or movements of the internal molecules of these waves, and also of the changes of speed and direction in currents which meet bodies of diverse forms. After Mr. Mach's communication of his experiments on the behavior of a current of air under analogous circumstances, he developed this research in a later communication on the use of an inhaling turbine, passing a steady current of air into a quadrangular prismatic tube, whose section was 18 by 24 cm. The face of this tube, turned toward the observer, was formed of transparent glass; the opposite face was blackened to form a dark chamber, and an arc lamp projected its light into the interior of the tube.

Mr. Mach placed bodies of different forms and made of transparent substances in the air current, and took different ways to render the movements of the air in the vicinity of the bodies visible. Sometimes he projected light bits of paper or silk in the air current sometimes fine dust, sometimes smoke, and sometimes he hung flexible silk threads, which the current moved along; while sometimes he explored the direction of the air movements by means of little gas flames, which he applied at different points of the bodies that were in the tube. But the method which gave him the best results was that of Schlieren, which consists of rendering visible the movements of very small streams of air by changing the index of refraction, which is done by sending a current of hot air into a colder current. The small streams or threads, which are warmed, then show either clearer or darker than the surrounding air, and the magnesium flash light permits us to photograph the phenomenon.

Mr. Mach's experiments have given results quite conformable to those which I obtained in the movements of liquids under similar circumstances. So, for instance, on meeting the bodies the air current divides and re-forms behind them without producing many whirlpools, and when the plane is inclined under different angles and solids of different forms these disturb the air as if it were water. Mr. Mach measured the speed of his air currents by means of an anemometer, regulating the indications of the instrument by an acoustic method devised by his father, Prof. E. Mach. The vibration caused by a Koenig flame introduced into the air current gives the appearance of a cluster of little clouds, which move on while keeping their respective distance, and as the latter correspond to known intervals of time they enable one to measure the speed of the current.

Mr. Mach noticed a lack of fixity in the direction of air currents, which showed continual oscillations, and he attributes these movements to changes in the aerodynamic pressure.

These studies were not known to me when I presented to the Academy the result of experiments where I had studied the action of different bodies in an air current placed in conditions identical to those which I had studied with the liquid currents. To follow the movements of the air, I used smoke threads, which, drawn along with the air by the action of ventilators, entered with it and at the same speed into the glass tube. The air and smoke were filtrated through fine-meshed cloth and advanced parallel to each other in the interior of the tube as long as the current met no obstacle.

These experiments, like those of Mr. Mach, have shown that at the rates employed air and liquids behave in substantially the same way.

At this time Mr. Bertin, an engineer of the Navy, brought me into correspondence with Mr. Hele-Shaw, of Liverpool, who had been pursuing similar experiments in closed chambers for several years. The clear images given by photographing colored glycerin threads showed how the incompressibility of liquids affect eddies in an inextensible space, while the eddies always occur in different degrees behind bodies immersed in an air current, or even in a liquid current if it is moving in an open tube.

In the construction of my new apparatus the section of the air tube was increased from 20 to 50 cm. and the number of threads of smoke from 20 to 58. The filtering cloths were replaced by silk gauzes with a very small mesh, and I finally introduced into the experiment a chronographic system which allows us to measure the speed of each smoke thread in different parts of its course. For this purpose the system of little tubes which bring the smoke threads which are about to be aspired is subject to a lateral shake, repeated ten times every second. An electric vibrator regulates this movement with the above-named frequency, and under this influence the smoke threads do not form straight, parallel lines, but sinusoidal curves. These inflections are preserved during their whole path. In the interior of the tube a small scale 20 cm. long, in the same plane as the smoke threads, serves to measure the space traversed by the molecules of air in each tenth of a second.

Some examples of the results obtained will enable us to appreciate the progress which has been made in the new construction.

When there is no obstacle offered to the air current the smoke threads remain rectilinear and parallel. If we place an inclined plane in the current the smoke threads enlarge in meeting it, which indicates that they lose velocity before following opposite directions. Some mount toward the upper edge of the plane, others glide upon each other without mingling and escape by the lower edge. On each side of the obstacle the smoke threads continue their motion very close together, leaving behind the inclined plane a space where the air is motionless, and only gives a smoky cloud. This space where the eddies or whirlpools occur is larger in proportion as the obstacle to the air current is larger.

To note the speed of the air current in different parts of its course we repeat the experiment, subjecting the smoke threads to the above-mentioned vibrations, and then the threads instead of being rectilinear present a series of lateral inflections which are preserved during all their course. These inflections remain equi distant if the speed of the current is everywhere the same, but if the current speed diminishes the inflections are closer; if it is rapid, they are more distant from each other, and the space moved over in a given time is measured by means of the metric scale.

The figures which we have just seen are observed by a magnesium flash; that is to say, in so short a time, that each smoke thread seems immovable. If the light lasted longer the aspect of the figure would change and give the further condition of the air current as we see it in fig. 4[a], where the light produced by the prolonged combustion lasts about seven seconds.

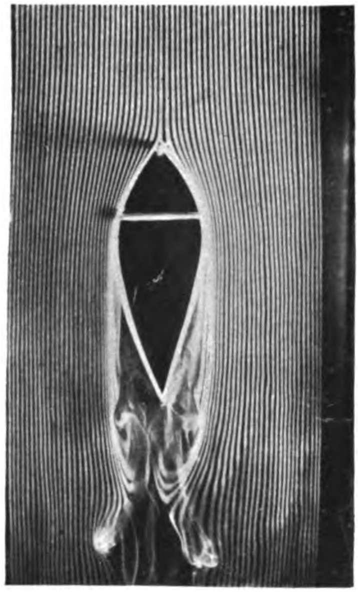
[a] This fig. 4 corresponds to fig. 29, Pl. v, of the foregoing paper on chronophotography, where are also shown other figures here referred to by Doctor Marey.

We can not enumerate all the numerous applications of this method, since the form and dimensions of the bodies in the air current and the velocity of this current itself can be varied without end.

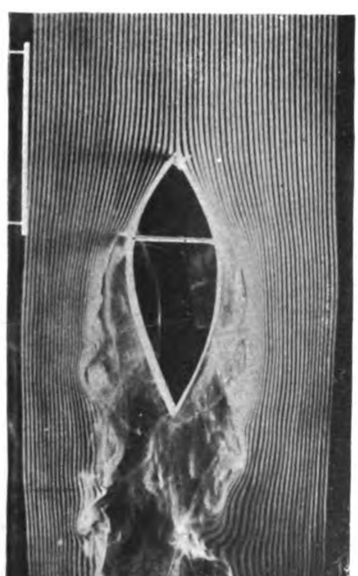
I have never observed the "jumps" noted by Mr. Mach, as making the current deviate from one side to another. These "jumps" might possibly be due to the unequal temperature of the moving air. It may be regarded, I think, as a proof of the precision of my method that if an experiment is repeated under the same conditions the observed images are identical and superposable on each other.

I believe I may add that this method will give the mechanical solution of many problems relating to propelling apparatus, fluids, and questions of ventilation, etc.

[To Mr. Marey's interesting article we add two other illustrations from his own experiments, since received from him by the Smithsonian Institution. These are numbered *a* and *b*, *a* being a form producing very little eddy, while *b* (a form not noticeably different) produces a very great one. These seem to be well calculated to show the importance and the delicacy of the method.]



A.



B.

AIR CURRENTS PASSING CURVED OBJECT.