Things under Water

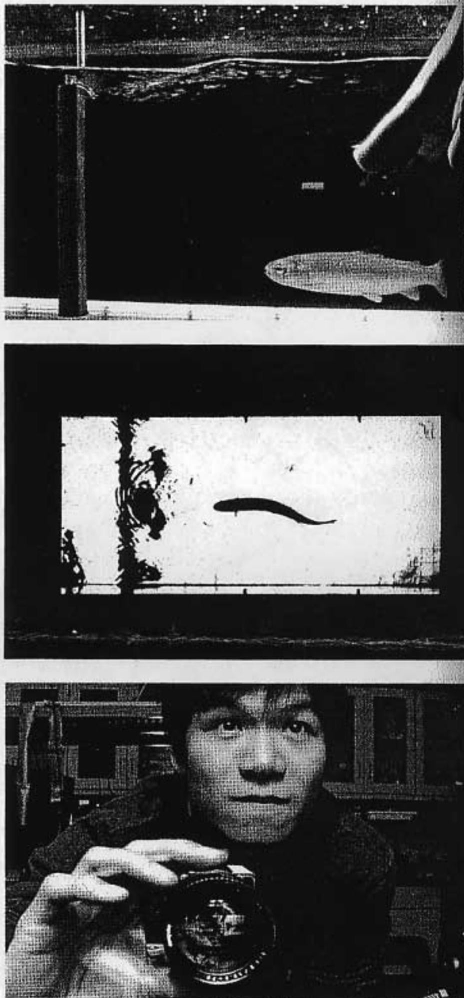
E. J. Marey's Aquarium Laboratory and Cinema's Assembly

Hanna Rose Shell

French physiologist Etienne-Jules Marey (1830-1904) developed famous graphical and photographic methods for the study of animal movement.[1] His photographic assemblies from the 1880s and 1890s of aerial and terrestrial locomotion – birds in flight, human limbs in motion – are well-known, as is his establishment of the Physiological Station in the Bois de Boulogne in Paris. The scientist's lifelong obsession with the Bay of Naples and the profound influences of the bright sunshine and Mediterranean waters on his innovations in representational practice are much less familiar, a story of the sea.[2] Photochronographic experiments with sea animals were the culmination of Marey's fascination with movement in water developed over his decades of meanderings along the Neapolitan shoreline (where he wintered from 1870 onwards). Exchanges with local fishermen, marine biologists and ladies of leisure turned his mind's eye to the ocean waves. His lens focused on creatures navigating the deep. Marey's photographic representations of locomotion in water portray organisms' passage through space and time as mediated by laboratory apparatus.

Although largely absent from the collective memory of Marey's oeuvre, his aquarium laboratory and results produced therein were provocative in their day. The Lumière Brothers, Auguste and Louis, impressed by his 1890 article in *La Nature*, were inspired to make their own film, *L'Aquarium,* a moving *nature-morte* of squirming fish, eels and frogs framed behind glass.[3]

Marey's laboratory practice and marine aesthetic continue to resonate with modern-day applications of high-speed video to marine navigation physiology.[4] Experiment and experience, past and present, are bound together by the photographic lens and the cinematic apparatus. Things under water appear visible as interwoven images of movement and time.



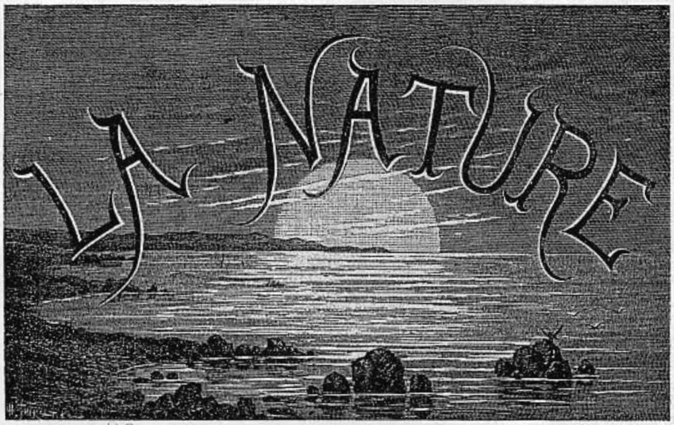
Hanna Rose Shell, *Locomotion in Water,* 2005, 4-channel video installation, c. 60 min, film stills, © the artist

1 Etienne-Jules Marey, *Du Mouvement dans les Fonctions de la Vie*, G. Baillière, Paris, 1868; *La Machine Animale*, G. Baillière, Paris, 1873; *La Photographie du Mouvement*, Georges Carré, Paris, 1892; *Le Mouvement*, Editions Masson, Paris, 1894.

2 Selected correspondence from Etienne-Jules Marey to Anton Dohrn at the Archives of the Stazione Zoologica Napoli (esp. 1886-1892). See also Virgilio Tossi, *Il Cinema Prima di Lumiere*, ERI, Turin, 1984, p. 221.

3 Georges Sadoul, *L'Invention du Cinéma, 1832-1897*, Editions Denoël, Paris, 1946, p. 41; also: *Le Cinéma et la Science*, CNRS Editions, Paris, 1994, p. 149.

4 See James C. Liao, David N. Beal, George V. Lauder, Michael S. Triantafyllou, "The Kàrmàn Gait: Novel Body Kinematics of Rainbow Trout Swimming in a Vortex Street," in: *The Journal of Experimental Biology*, 206, 2003, pp. 1059-1073; George V. Lauder, Eliot J. Drucker, "Experimental Hydrodynamics of Fish Locomotion: Functional Insights from Wake Visualization," in: *Integrative and Comparative Biology*, 42, 2002, pp. 243-257.



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LOCOMOTION IN WATER
As Studied through Photochronography
Written by
E. J. MAREY, 1890

Translated, Edited and Interpreted by HANNA ROSE SHELL, 2005*

Since its invention, photography has served as a means of comparing the present with the past, through authentic reproductions. Readers of my articles in *La Nature* over the past several years already know of my work on the photographic analysis of terrestrial and aerial movement.[5] They know that, by opening and closing the camera's shutter at regular intervals, I have been able to capture successive and instantaneous images of moving objects on a single glass plate. Indeed, by admitting light intermittently into a specially designed photographic apparatus, the "photochronographer,"[6] such as myself, is able to collect a series of exposures of animals and objects in successive phases of motion. Up until now, to avoid blurring the exposures, I have limited myself to luminous and fast moving subjects, always photographed against a black background.

Recently I have become interested in expanding the range of motions to which this photographic method can be applied. During my winters spent on the Bay of Naples, I often enjoy

* This interpretive translation is based on Marey's article "Locomotion in Water" (*La Nature*, no. 911, November 15, 1890, pp. 375-378) into which are woven fragments culled from correspondence with colleagues George Demenÿ and Anton Dohrn. Letters to the marine biologist Dohrn are housed at the Historical Archives of the Stazione Zoologica Napoli, overseen by Christiane Groeben. Letters to Parisian collaborator Georges Demenÿ have been collected in Thierry Lefebvre, Jacques Malthête and Laurent Mannoni's edited volume *Lettres d'Etienne-Jules Marey à Georges Demenÿ, 1880-1894*, Association française de recherche sur l'histoire du cinéma, Paris, 1999.

5 Marey's Note: For my first such article on this subject, see *La Nature*, no. 539, September 29, 1883, p. 275.

6 Throughout the 1880s and 1890s, Marey used the term *photochronography* to refer to his application of serial photography to motion analysis using methods that departed radically from the work of Eadweard Muybridge. In 1893, Marey began using the still-current term, *chronophotography*.

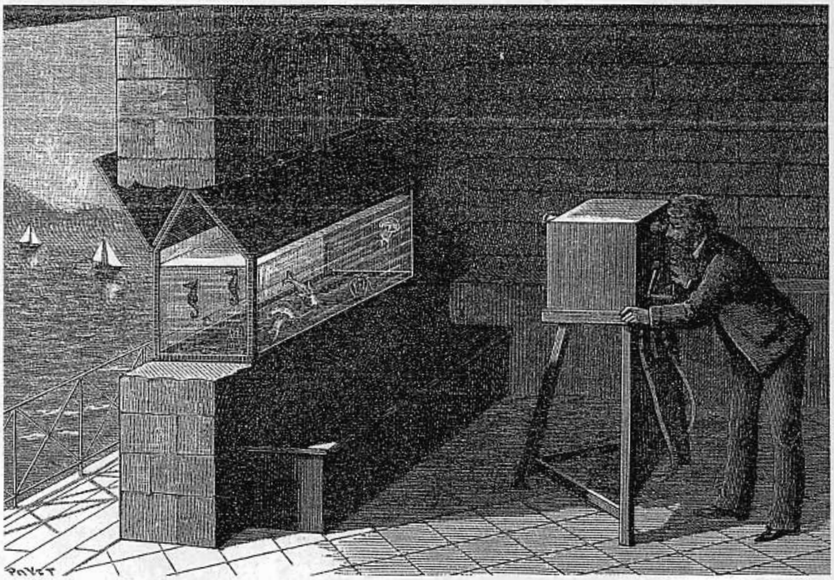

Fig. 1. – My aquarium laboratory, specially designed for the photographic study of aquatic locomotion.[7]

myself at the fishing pier and the public aquarium and on boating excursions with friends such as the venerable Anton Dohrn.[8] Such activities led my eyes and mind to seeing and thinking under water. The underwater motions of aquatic animals came to fascinate me. Therefore, I have found it necessary to modify my method for study of terrestrial and aerial locomotion, for application to aquatic locomotion.[9] The play of light on the water's surface, and the movements that happen beneath, are phenomena too fleeting for the eye to appreciate exactly. Thus have I created a laboratory set-up and photochronographic method especially suited to underwater subjects.

The animals in the experiment are swimming in an aquarium, constructed by fitting two panes of glass into an aperture in the wall of the old stone cottage, the "Roman ruins" at the base of my waterfront property in Posillipo (figure 1). This specially fitted aquarium can be set up in two ways, each having a different optical effect.

In the first case, the aquarium is directly illuminated by the light of the horizon (figure 1). Backlit, the aquarium thus provides a luminous field on which animals are outlined in silhouette. This effect, however, while interesting, often obscures important details. Indeed, I have found that for the study of fish locomotion and other movements taking place under water, it is usually best to illuminate the study objects themselves, rather than the background. Illuminated, all objects in the water appear bright. Meanwhile, the water itself, if quite clear, becomes perfectly – and beautifully – invisible. To achieve this latter effect, I close the exterior opaque shutter. I then open another shutter, placed above the water at an angle, thereby casting bright light onto the ani-

7 Figs. 1-6 published in: *La Nature*, no. 91, November 15, 1890, pp. 376 ff.

8 A journalist who, like Marey, often visited the public aquarium at the Stazione Zoologica Napoli during the 1880s and 1890s, described the experience: "You enter a large square room with huge aquaria on the sides. Each aquarium is built into the wall and all the light comes from above, so that the observer standing within the darkened room sees the animals as though himself emerged amongst them." In: *Science*, 3, January 3, 1896, p. 17. This aquarium, developed and managed by Marey's friend, marine biologist Anton Dohrn, inspired his creation of an aquarium lab.

9 A year earlier, on December 11, 1889, Marey wrote from Naples to his Parisian collaborator Georges Demenÿ about the nascent aquarium laboratory: "My dear colleague, I hope that you fare well at the Paris Physiological Station, and especially that you've not come down with the terrible flu currently ravaging so many European cities and that I worry will arrive here in Naples one of these days [...] I am making an aquarium in the Roman chambers I have discovered at the villa and am now setting out to study the movements of certain marine animals [...] The difficulty has been to have the room suitably lit and fitted, with a wall well exposed to the sun and with an appropriate distance. Warmly, J. Marey, Villa Maria, Posillipo."

mals themselves. Standing out against a deep black background, the sea creatures are ready to be filmed.

Figure 2 presents a cross-section of the new moving-film camera I have developed for the purpose of my aquatic locomotion studies. The lens, at right, is bisected by two diaphragms that revolve at different rates, allowing light to pass intermittently. Each disc has a single aperture. In the time it takes the small diaphragm to make a single revolution, the large one makes five rotations. An exposure only occurs when the two apertures are perfectly aligned with each other and the lens. The bellows guides the light through the lens and onto the sensitized film, itself enclosed in a hermetically sealed "black box" compartment. The external hand crank (at left) winds the internal motor that activates the apparatus. Focus and composition are carried out by means of a small eyepiece, a sort of modified spyglass. The whole apparatus is mounted on a tripod, which can be easily folded up into a carrying case.

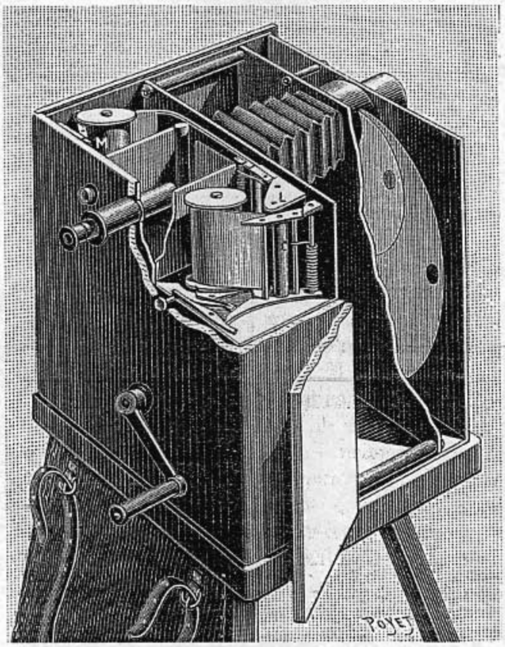

Fig. 2. – My specially-engineered moving film chronophotographic camera

Each photochronographic analysis consumes a single strip of gelatin-bromide-of-silver film, producing upon it a long series of images, each in its own "frame". After each experiment, the exposed spool of film must be removed and replaced with another, a process that can occur in daylight since the film, rolled onto bobbins, is covered with opaque paper (figure 3). To make this possible, in my darkroom I attach two strips of paper – one black, one red – at either end of the unexposed film. I roll the long strip thus formed onto a metal spool, red paper in, black paper out, ensuring that the opaque paper prevents accidental exposure. Then, over the course of the experiment, grooved rollers and flexible springs guide the film from the supply spool (M) to the take-up spool.

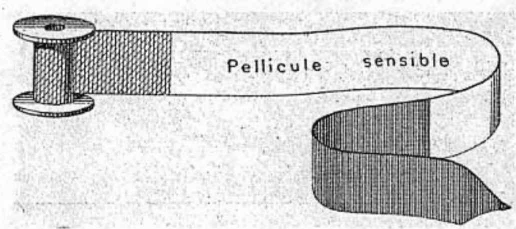

Fig. 3. – "Sensitive Film," appearance of the film, showing the two opaque covers (one red, one black), while being rolled onto the supply reel in the darkroom

The analysis of locomotion in water is one of the most interesting developments of chronophotography. The apparatus just described lends itself to all sorts of studies, since the object whose movement it records can be placed at any distance and in all sorts of lighting conditions. But while aquatic locomotion has long seemed to me one of the newest and most exciting fields to explore, it is only recently that aquaria (both public and private) have become practical. In an aquarium one may observe the various means of locomotion by which aquatic animals propel themselves – fish, mollusks, crustaceans, rays and so forth. It goes without saying that simple observation by the human eye is inadequate to the task: In almost all cases, our eyes are unable to follow the precise movements of aquatic locomotion.

Figures 4, 5 and 6 show photochronographs made on moving filmstrips, of several types of locomotion in water.

Movements of the Medusa. This mollusk propels itself through water by alternately contracting and dilating its body's dome-shaped canopy (figure 4). Its propulsive movements are usually quite slow. Indeed, the human eye will recognize in the medusa's movement characteristics that recall the contractions of the mammalian heart, which also produces the expulsion of a liquid. Figure 2 presents a complete series of the phases of this type of locomotion. Each of the 12 exposures lasted one-tenth of a second. I produced this photochronographic series at my laboratory at the Villa Maria, overlooking the Bay of Naples. Conditions were the following: I obscured the exterior side of the aquarium by closing the vertical shutter and opening the top shutter. The diaphanous creature, thus illuminated from above by bright Mediterranean sun, stood out clearly and distinctly against a dark field.

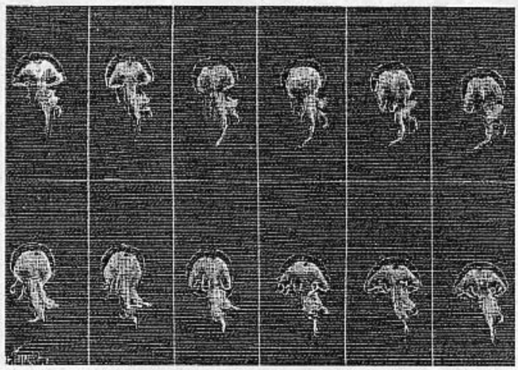
Fig. 4. – Movement of the medusa.

Notably, this medusa series – like my other photochronographic studies on moving film – is best viewed by interested amateurs in one of my zoetropes. The rapidly rotating cylinder of this optical device reproduces the impression of the actual movement of the animal exactly as it was photographed in the laboratory. This instrumental "wheel of life" makes scientific experimentation itself both visible and animate.

Motion of the Hippocampus. This animal, commonly known as a seahorse, uses a dorsal fin to get around; the fin moves so fast that it is practically undetectable. With exposures of one-twentieth of a second, one sees (figure 5) that this vibration is actually an undulation passing from bottom to top of the fin. The images included here are perhaps too small and too few in number to fully decipher every last detail of these motions. But in the weeks to come I will be increasing the number of exposures I make of the seahorse, while also attempting close-ups of the dorsal fin.

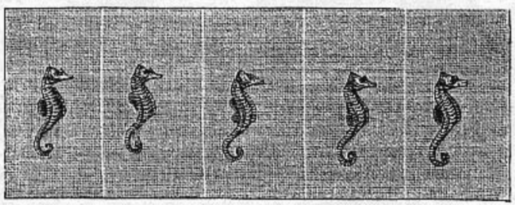
Fig. 5. – Movement of the seahorse, showing successive phases of the dorsal fin's ascending undulation.

The Comatulid (figure 6) is usually found at the bottom of my aquarium, fixed to the floor as though having put down roots. The creature sways its arms back and forth, while unrolling and re-rolling serrated tendril-like branches. But the comatulid can indeed be made to move! When stimulated with a long stick, the comatulid reacts by adopting a strange and rapid locomotion that transports it quite across the tank floor.

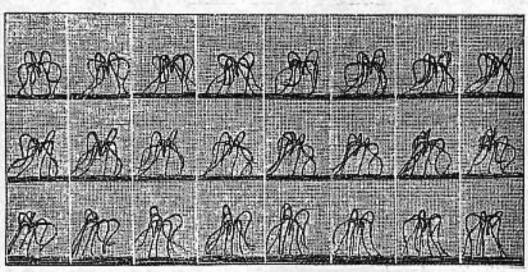
Fig. 6. – Movement of the comatulid; series begins at upper left, and ends at lower right.

In addition to these three species, I have reproduced the motions of other underwater creatures: the undulating movements of eels and rays, the locomotion of fishes, the octopus and the like. In these other studies, I have confronted the huge diversity of aquatic motions. In one case, I have captured on film the movement of a trout striking the water with the flat of its tail. In another of my filmstrips, a cuttlefish forcibly compresses its pouch full of liquid. Expelling water in one direction, it thereby propels itself in the exactly opposite direction. The same phenomenon results when a mollusk closes its valves rapidly, thereby projecting itself in the direction opposite to the current of water it has produced.

Finally, as to the importance of locomotion in water: The various kinds of propellers that men think they have invented for the purpose of navigation – such as sails, oars and sculls – are represented in the highest degree of perfection in the locomotive organs of aquatic animals. Furthermore, myriad aquatic animals have other means of propulsion, the likes of which men have never made use of and which might perhaps be tried with advantage in the future.

In the coming months, I will continue to investigate methodically these underwater motions using this innovative method of motion photochronography. As time goes on, different types of aquatic locomotion should, and will, be considered in relation to the diverse body shapes of the various creatures. These comparisons will prove invaluable for the continuing quest to elucidate those beguiling and still obscure laws of both animal morphology and scientific motion photography.

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