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THE CINEMA IN FLUX

The Evolution of Motion Picture Technology from the Magic Lantern to the Digital Era

Springer

L. Lipton, *The Cinema in Flux*
https://doi.org/10.1007/978-1-0716-0951-4_11

11. Chronophotographers: Janssen, Marey, and Demenÿ

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Chronophotography is a scientific measurement technique in which photography is used for analysis, often of the locomotion of living creatures. The technique is also described in chapter 28, in which the application of photography to the study of sound and speech is sketched; here our concern is with the study of motion. In 1850 Irish physicist John Tyndall used a rapidly repeating electric spark to visualize the phases of motion of a jet of water and the following year Fox-Talbot suggested that the method could be coupled with photography. In 1860 Desvignes, as noted earlier, took multiple exposures of a steam engine in motion using its cyclical nature to assemble a series of photographs of its assumed phases of motion (Hopwood 1899, p. 44). French medical researcher Alfred Londe, in 1882 in the photographic laboratory of the La Salpêtrière Hospital in Paris, assembled a circular vertical stack of nine cameras, a design presumably influenced by Muybridge's battery of cameras. In 1891 he improved upon it with a twelve-lens device made up of four cameras stacked three rows high with exposures made using electromagnetically tripped shutters. Londe's apparatus was used to study "abnormal motions, such as epileptic fits, St. Vitus dance, etc.," exposing 240 × 300 mm glass pales to take 70 × 70 mm images; photographs were taken as frequently as 1/10th of a second apart. The year before, Londe, working French General Hippolyte Sébert (an advocate of the standardization of camera parts), constructed a six camera battery to analyze the firing of torpedoes and large artillery shells (Hopwood 1899, pp. 52–55; Coe 1992, pp. 37–38).

Chronophotography's most prominent practitioner was physiologist Étienne-Jules Marey, who coined the term. Marey, like his inspiration and predecessor Janssen, devised integral cameras, using a single lens and single imaging surface for the photography of the phases of motion. This turned out to be a crucial design decision that serendipitously furthered the development of the celluloid cinema, an approach that contrasted with that of others in the field who used multiple cameras or their functional equivalent, multi-lens cameras. As we have seen, protocinematographers were motivated to find a way to depict quotidian motion as realistically as possible (without regard to measurement), using projection to display their efforts, just as photographers make prints. Lacking any other means, some protocinematographers like Sellers and Heyl, used pixilation to simulate the phases of motion to create content for their moving image displays. On the other hand, Anschütz, following the example of Muybridge, used an array of cameras to photograph the phases of motion. The result of either approach was often displayed using peepshow or projection phenakistoscopic technology.

But Marey did not use pixilation, multiple cameras, or cameras with multiple lenses. Marey's first chronophotographic apparatus was derived from the invention of astronomer Pierre-Jules-César Janssen (1824–1907) , who was born in Paris and studied at the University of Paris. His photographic revolver is of great historical importance because it is the first machine to combine many of the major elements of a true ciné camera. Janssen taught science in the University of Paris' school of architecture, but he became an astronomer because of his passion for observing eclipses (Herbert 1996). On August 18, 1868, in Madras, India, during an eclipse, Janssen detected a Fraunhofer line in the yellow part of the spectrum of the sun's corona at a wavelength where none was known to exist. Initially thought to be that of sodium, it was soon confirmed that this line was the signature of a newly discovered element that was named helium. Janssen was nothing if not determined: his 1870 expedition to southern Africa, to observe an eclipse of the sun would have been thwarted had he not found an audacious escape route out of a Paris that was under siege during the Franco-Prussian War; he flew above and beyond the city in a hot air balloon.

Fig. 11.1 Pierre-Jules-César Janssen

His photographic revolver was designed specifically for the chronophotography of the transit of Venus, which he observed from Nagasaki on December 9, 1874. The photographic revolver had a large cylindrical chamber for holding a daguerreotype plate, which with its magazine in place looked like a Thompson submachine gun. Designed by Antoine Rédier, a Parisian clockmaker, the photographic revolver used a circular metal daguerreotype plate driven by a clockwork mechanism to take its sequential exposures. The camera exposed 48 images in 72 seconds, with the images arranged near the circumference of the 18.5 cm (7.3 in) diameter plate. The clockwork movement continuously rotated the radial shutter, whose slit moved between the plate and the lens as the plate was momentarily arrested for each exposure by a Maltese-cross mechanism (Hopwood, p. 57). The trip to Japan to observe the transit of Venus across the sun's face was not without incident: Janssen and his wife, while on shipboard in the bay of Hong Kong, endured a typhoon that resulted in the deaths of thousands on shore. In the days before the transit there were storms and high winds in Nagasaki, the preferred viewing location, which swept away astronomical instruments, but the weather cleared and the photographic rifle, aimed at a heliostat's moving mirror to track the sun, accomplished its task.

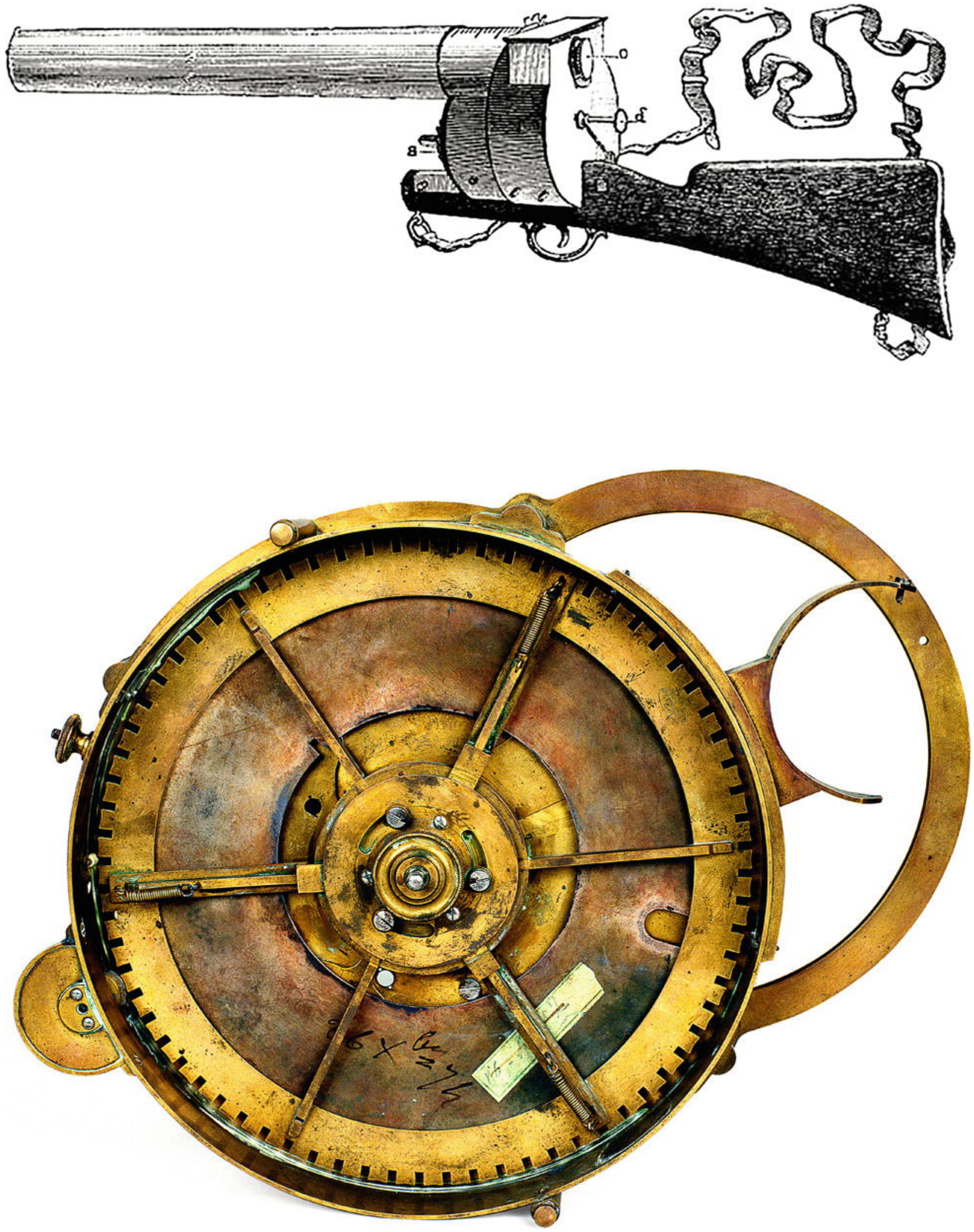

Fig. 11.2 Janssen’s photographic revolver (or rifle) and it’s clockwork mechanism. (Cinémathèque Française)

This expedition marks the first use of chronophotography, but photography as a method for astronomical observation had been proposed in 1849 by the French astronomer Hervé Fay (Mannoni 2000). Janssen’s photographic revolver was the first camera designed and built to capture the phases of motion using a single lens on one light sensitive surface, features that became part of every celluloid cinema motion picture camera. The daguerreotype plate normally required long exposures, but it was well suited for this application because the sun is such a bright object and Janssen's purpose was to photograph the silhouette of Venus against it. Light sensitive collodion coated on a glass plate might deform, Janssen feared, and there was a concern about halation beclouding measurements. Halation might have arisen from the back scattering of light reflected from the glass-air interface where the collodion was coated on the plate. Both of these potential difficulties were avoided by using the metal daguerreotype plate with its thin light sensitive coating.

On the other hand, British astronomers, on the day of the eclipse and from the same location, chose to use collodion coated glass plates. Janssen had shared the plans of his photographic rifle with his colleagues to help them make similar observations. The British instruments were made by the optician and lens designer John Henry Dallmeyer (Tosi 2005; Kingslake 1989). The chronophotographic method using multiple images to capture the transit of Venus was important because the exact moment its disk touched the solar orb could not be calculated. An international effort was made to make observations from several locations because it allowed astronomers to calculate the astronomical unit or the average distance of the earth at its furthest and closest approaches to the sun. The year after the Nagasaki expedition, in 1875, Janssen discussed his work at the Société Française de Photographie and again in 1876 at the Académie des Sciences where he suggested that his photographic rifle might be used for locomotion studies of animals, especially birds, as photographic materials improved to allow for exposures using high speed shutters (Coe 1992, p. 26).

The suggestion was taken up by physiologist and chronophotographer Étienne-Jules Marey (1830–1904), who designed the first integral camera with a single lens that could photograph a relatively lengthy sequence of high-quality still images, first on paper rolls and then using celluloid film. Any means for capturing motion that involved a multi-lens or multi-camera setup was not as effective an instrument for Marey's analytical purposes. As his designs evolved, the cameras most useful for his chronophotographic requirements turned out to have many of the requirements required by a functional movie camera. His most developed cameras intermittently advanced the film and made exposures with a shutter synchronized to its arrested movement. This change from a battery of cameras to an integral camera was a crucial reduction of hardware complexity that has been recapitulated for the cinema modalities of sound, color, and widescreen.

Marey's first opportunity to create such an advanced machine depended on the availability of Eastman's emulsion coated paper rolls that were meant for his snapshot box camera, the Kodak No. 1, and for use in a roll film adapter for cameras designed for exposing glass plates. What Marey's designs omitted from a true cinema camera, the missing ingredient, was nothing at all: empty spaces or holes punched in the film. Perforations provide the indexing function for the printing or and the projection of steady images, but Marey was primarily concerned with a comparison of frames, although there were times when he sought to project his work for study or lectures.

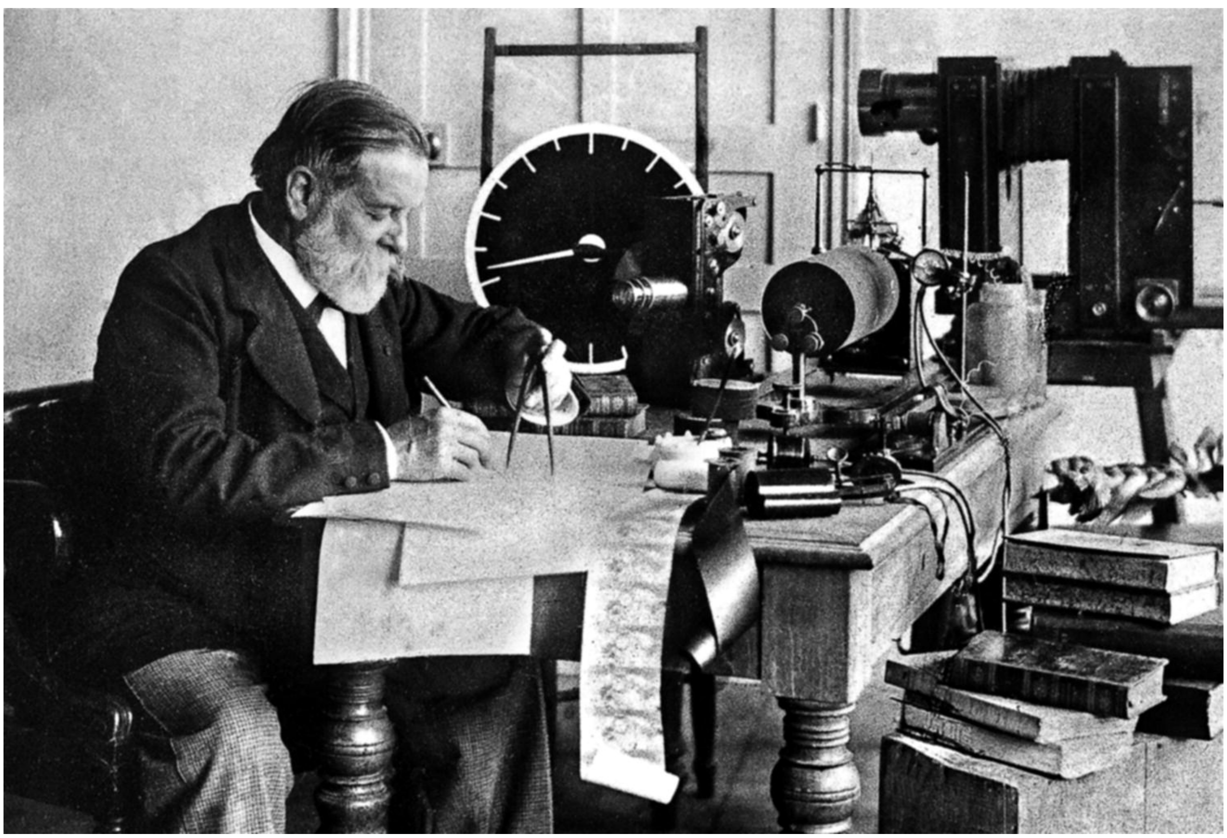

Fig. 11.3 Étienne-Jules Marey (Cinémathèque Française)

Marey was born in Burgundy and in 1849 studied medicine in Paris at the Faculté de Médecin. After completing his internship and his thesis, *Researches on the Circulation of Blood in the Healthy State and in Illnesses*, he received his doctorate in 1859. Like Marey's great influence, Claude Bernard, the champion of applying the scientific method to medicine, he did not pass the agrégation, the examination for the highest qualification. (Creative geniuses don't always get the highest marks; contemplation is different from checking a box or writing an essay in 20 minutes.) By 1863 Marey had lost confidence in the subjective methods that physicians used for diagnosis and wondered how it might be possible to teach medical students a method that went beyond "fleeting sensations." By his own reckoning, in 1864, he became an independent "armchair physiologist" setting up a laboratory in a large attic on the fourth floor of a building in Paris that a century before had been home to the theater of the Comédie Française. The 40 by 50 foot room was filled with experimental apparatus, much of it devised by Marey and built for him by Parisian clockmaker Antoine Bréguet. The room was also inhabited by "pigeons, buzzards, fish, lizards, snakes, frogs…." (Mannoni 2000). Marey, who at that time lived with his mother, had many students to help him tend his laboratory and its creatures. He decided to specialize in measuring the movement of organs to help understand their functions, and in this he was following one of the most fundamental precepts of science, to quote Richard Feynman (2011): "One might say that the development of the physical sciences to their present form has depended to a large extent on the making of quantitative observations. Only with quantitative observations can one arrive at quantitative relationships, which are at the heart of physics." He might as well have said science, but Feynman, a physicist, was thinking of physics. Marey wrote several books that were highly regarded, one published in 1863, *Medical Physiology of the Circulation of Blood*, and another in 1868, *On Movement of the Vital Functions*.

His career flourished as he took a position as a physiologist at the Collège de France and continued to write books and articles. His book, *Animal Mechanism*, was published in 1873 and influenced Stanford and Muybridge's second study of the horse in motion in 1877–1878. It was Marey's *chronographic* determination that all four hoofs of a horse left the ground in a gallop that rekindled Stanford's interest in the subject. To arrive at this conclusion, Marey employed chronography (time writing) using mechanical and pneumatically activated instruments to chart animal or animal organ motion as a function of time, in the case at hand, the horse's gallop. To determine the facts about the locomotion of the horse, he used a rubber ball-shoe attached the horse's hoof. As the hoof struck the ground the air in the ball-shoe was compressed and measured, and when the ball-shoe decompressed, it indicated that the hoof was off the ground.

Marey captured and plotted physiological measurements of movement with instruments such as the polygraph and the sphygmograph, and he was not alone in such pursuits since other scientists had become interested in chronography. He designed the myographe to record the subtle movements of muscles by means of a lever system to transfer changes in position to a stylus or pen that inscribed on the surface of a rotating cylinder, producing graphic results that allowed Marey to visualize data. Marey heard of the work of Mathais Duvall, a professor of anatomy at the École des Beaux-Arts, who built a sixteen-image zoëtrope to visualize walking and running. Working with Marey, Duvall worked up 16 poses of a horse in motion for the zoëtrope, whose rate of rotation could be varied to slow down the action for study, but this was an artist's simulation of a running horse and not a record of locomotion. Then Marey did something exceptional: he used the zoëtrope for looking at his plotted data to view it dynamically change in time, a technique that foreshows the oscilloscope.

In 1869, at the age of 39, Marey became a member of the faculty of the Collège de France, where he moved his lab to Room 7. As his activities expanded, he found the space to be too restrictive and in 1881 began to move his equipment to other locations in Paris. Marey's efforts to induce the authorities to establish a station for the purpose of continuing his experiments in locomotion bore fruit and in March 1883, the city of Paris awarded Marey a grant and made arrangements for him to set up his Station Physiologique on the present site of Le Parc des Princes Stadium on the south edge of the Bois de Boulogne, near the Porte d'Auteuil (Coe 1992, p. 26). In 1880 gymnast George Demenÿ (1850–1917), who was born in northern France, became Marey's student at the Collège de France and in the 1880s assumed the role of his hands-on associate at the Station Physiologique, which he helped to plan and launch. He aided the day-to-day chronophotographic studies and the development of hardware and played an important role in assisting Marey's researches, helping him with the design of instruments.

In 1873 Marey considered using what became known as his photographic gun for recording locomotion, which was based on Janssen's proposal to use the instrument for animal studies, according to the recollection of his friend Alphonse Pénaud. Marey would later relate that his interest in chronophotography was due to du Hauron, Janssen, and Muybridge, but the proximate stimulation for his entering the field seems to have been Muybridge who visited Paris in September 1881, where he showed Marey sequential photographs of a bird in flight taken with his battery of cameras. Marey had read about Muybridge's work in the December 28, 1878, issue of *La Nature* and had contacted him requesting that he photograph the flight of birds because Marey lacked the chronophotographic apparatus to do so (Coe 1992, p. 24). But Marey was disappointed by Muybridge's photographs because of their lack of detail, which motivated him to think about improving the technique.

Toward the end of 1881, he approached Janssen for help, who replied that he would build a photographic revolver for Marey, a promise that was unfulfilled, which set Marey on the fruitful path of designing his own camera. Marey built a camera similar to Janssen's that also looked like a revolver with a rifle barrel, his photographic gun, which was completed in the winter of 1881–1882. It used what Marey described as "a train of clockwork (that is) set in motion and communicates the necessary movement to all parts of the mechanism...A cam on a shaft produced this intermittent motion," including a spinning shutter, "an opaque metal disc, perforated with a narrow window" (Coe 1992, p. 27). The mechanism rotated a round or octagonal dry emulsion glass plate capable of taking squarish or actually trapezoidal frames at rates reported to be either 12 or 19 exposures per second, exposed at 1/720th of a second. The new camera was used for Marey's well-known study of a flight of gulls (Marey 1894, trans. 1895, p. 110; Braun 1992). The long barrel housed a lens with a long focal length, necessary for the photography of distance subjects. Marey's bird locomotion studies were photographed at his villa in Naples, which he sent to the Académie des Sciences on March 13, 1882. The camera was pointed at the subject by looking through gun-type aiming notches at the top of the long lens barrel. The shutter release was a trigger in the usual location on the bottom of the rifle stock.

Fig. 11.4 Top: Marey's photographic gun in use. Bottom: A photo of what may have been the single shot model of the gun, exposing its clockwork mechanism. (Cinémathèque Française)

Once the trigger was pulled, the exposure sequence was set in motion: the intermittent mechanism arrested the rotating photographic plate after passing through 30° at which time the rotating shutter exposed a frame. In some drawings of the device a cylindrical box, which stored 25 photographic plates, is shown. A developed plate looks like a View Master reel, with small images located at the disk's periphery. In order to practice his aim and composition, Marey also built a single shot photographic gun that took images about 4 square centimeters in area. The advantages of the photographic gun, compared with Muybridge's battery of cameras, are many, but the principal one was that it took images with a single lens from a single perspective. Muybridge's method inherently produced a moving or tracking shot because each exposure of the sequence was taken from a different position but his plates were large and potentially of higher photographic quality than Marey's tiny frames. Much of Marey's photographic and projection equipment, like the photographic gun and his large plate camera designed described below, were built by engineer Otto Lund.

Ensconced in his Station Physiologique, sometimes referred to as the Institut Marey, which was in fact located in a nearby building, he began work on a new kind of camera with the help of Demenÿ, the first version of which was completed in 1882, and was used for locomotion studies between 1883 and 1888 (Coe 1981). It was a large wooden box-like cabinet fitted with a 4½ foot diameter shutter having ten narrow radial slots that, when rotated by handcranking, exposed a single large plate at a shutter speed of 1/1000th of a second. The camera, which looked a like a little trolley car, traveled on rails to follow the subject, the lens at right angles to the direction of travel. The result of this combination of moving camera and moving subject placed a number of sequential exposures of the subject on a single glass plate, sometimes with a part of the subject superimposed on itself. The camera was successful for studying moving subjects, both people and animals, which were brightly lit and set off against a black background. This multiple exposure technique influenced paintings by Marcel Duchamp, and decades later was used by still photographers to capture the phases of motion on a single frame using sequential bursts of an electronic flash.

Marey also anticipated the Digital Era's motion or performance capture techniques by taking a series of photos of humans in motion, as illustrated in his book *Le Mouvement*, using black formfitting costumes with white spots at key bodily positions to track action (Marey 1894, trans 1895, p. 60).

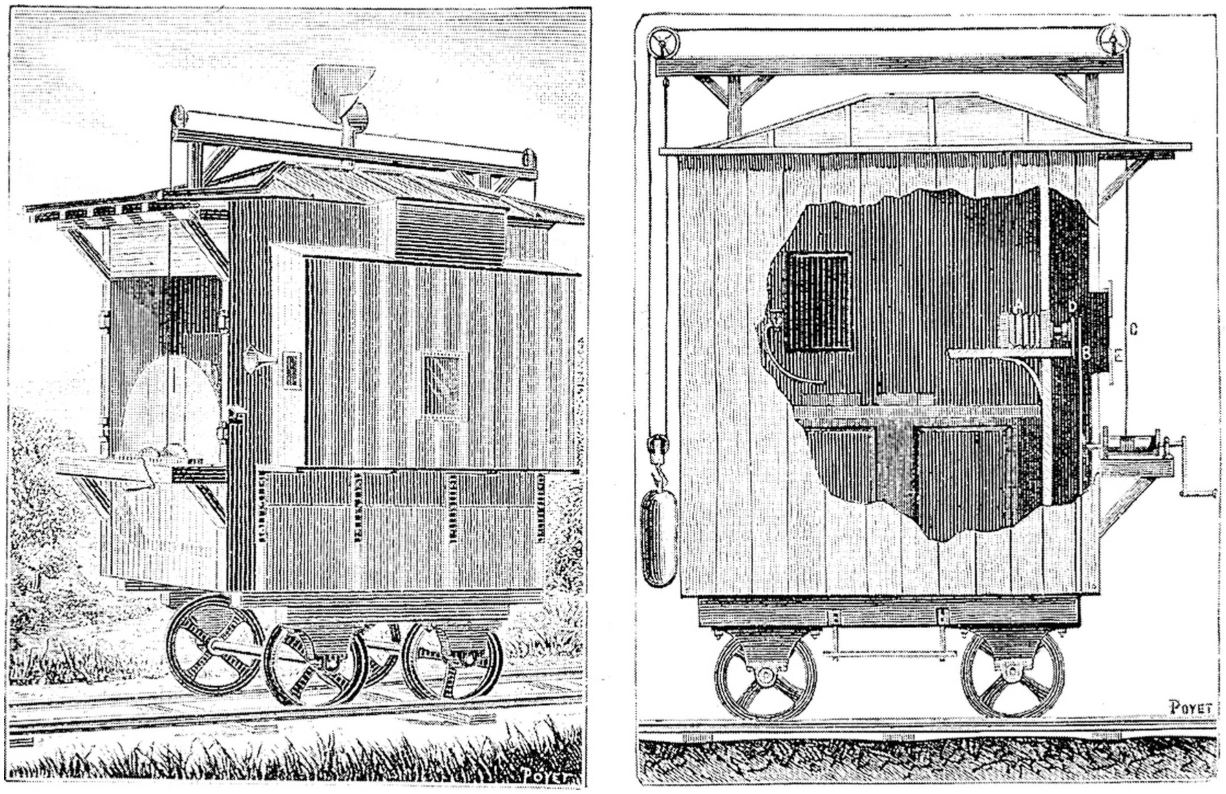

Fig. 11.5 Two views of Marey's trolley camera.

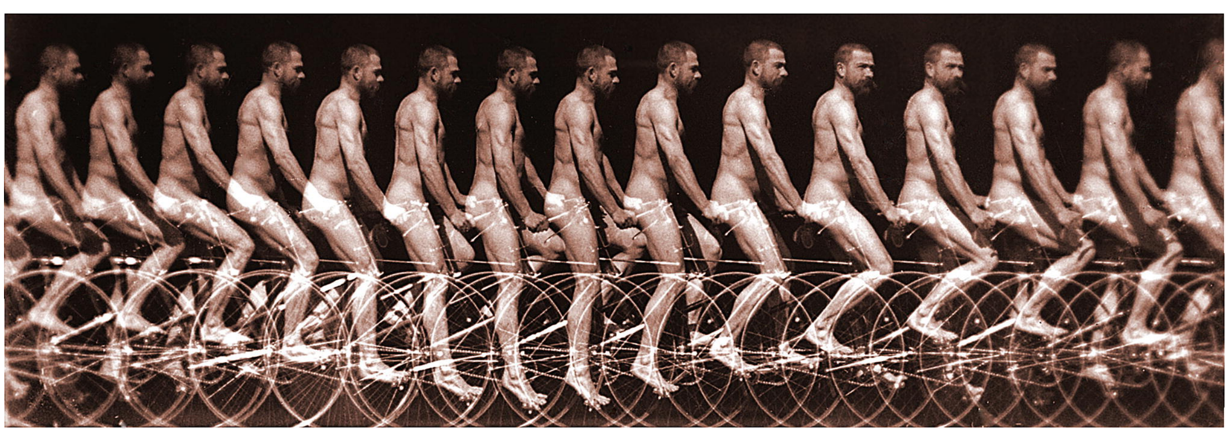

Fig. 11.6 The phases of motion of a man on a bicycle taken with the Trolley camera (restored). (Cinémathèque Française)

In 1888 Marey revisited the challenge of capturing sequences and decided to photograph individual frames because the overlapping double exposed images made with his trolley camera sometimes obscured detail. Marey returned to the concept of a frame-sequential camera as produced by the photographic gun, but with a crucial difference. He knew about the new paper roll film from the American Eastman Dry Plate Film Company, which had been demonstrated on January 7, 1887, at the Société Française de Photographie; with this materiel, his new technique was able to make a major advance (Mannoni 2000, p. 340). The new film, available in France at the end of 1888, part of the Kodak No. 1 snapshot camera and photofinishing system, consisted of silver bromide gelatin emulsion coated on paper. Instead of moving the camera, as Marey did with his trolley-like device, he would move the film to expose individual frames of improved clarity. Marey's new camera rapidly transported paper film through it horizontally from feed to take up spindle to enable the exposure of many frames rapidly. The film path was similar to that used by the Kodak No. 1, which made an exposure after the user manually transported the film and pushed a button to release the shutter.

The camera Marey built, first called the Photochronographie and later the Chronophotographe, used paper roll film 3½ inches (90 mm) wide that came in two varieties: stripping film, whose emulsion was designed to be removed and adhered to a glass substrate for print making, or roll film with a non-stripping emulsion. Marey chose the non-stripping version. His camera took as many as 50 images a second using a rotating disk shutter that opened to expose the paper film as a contact was tripped to send current to an electromagnetically activated clamping pressure plate that momentarily stopped the film in the gate. In a sense, the take-up reel mechanism and the clamping intermittent were fighting each other, but the camera was capable of taking excellent pictures. Unfortunately, the clamping design could not register successive frames in the same relative position, producing a frameline of varying width, but it did a good job of creating a temporal sequence of individual frames on paper film. In 1890, at the Paris Exhibition, Marey exhibited moving images photographed with this camera using a zoëtrope, which he showed to the visiting Edison (Hopwood 1899, p. 71). For projection, Marey had prints of the frames aligned for mounting on a disk.

Marey was aware of the desirability of a new base material, celluloid, which by 1890 was going into production by Eastman and Blair in America and in small scale production in Europe. (See chapter 8 for more about the introduction of celluloid.) A celluloid factory in North Central France, in the city of Stains, was producing material that was of interest to photographers. In 1890 chemist Georges Balagny (1837–1919) supplied Marey with celluloid film with a fast (sensitive) emulsion for stopping motion with high shutter speeds (Coe 1992, p. 32; Mannoni 2000, p. 342). According to Gernsheim (1962, p. 115), during the 1880s, the speed of negative emulsions increased 20-fold, an improvement in sensitivity that made Marey's animal studies feasible. In 1889 Eastman began shipping celluloid film for the Kodak No. 2 camera and its photofinishing system, and on May 3, 1890, Marey demonstrated a new camera that used negative film, the new 90 mm wide celluloid nitrate base 1.10 m (43.3 in) long. Although Kodak celluloid film became available through retail channels in France somewhat later in 1891, early samples were supplied to Marey by his friend and Eastman representative Félix Nadar. Marey's new camera designed for celluloid base replaced the electromagnetic clamp with a mechanical clamp intermittently actuated by a six-star Maltese-cross movement that was capable of a hundred exposures per second.

Marey's Chronophotographe exposed a comparatively lengthy sequence of frames on celluloid film, about 40 3½ inch square pictures (Hopwood 1899, p. 72). But the camera was not designed to be part of a printmaking-projection system because the frames were not indexed and not exposed the same distance apart. Marey knew that the projection of sequences could help him visualize locomotion, and as noted previously, he used the zoëtrope for that purpose but it was a device of limited capability. Although motion analysis was his goal, which to a large extent could be accomplished by comparing frames, it also was tempting for Marey to be able to project movies of his work for colleagues. Marey was not interested in creating a technology to recreate the quotidian visual world, rather his goal as a physiologist and chronophotographer was to design a motion microscope, and although projection might help, it played second fiddle to his usual method of frame by frame analysis.

In December 1891 Marey asked Demenÿ to print sufficient lengths of positive strips to provide him with material for projection experimentation. His ambition was to build a variable speed projector to enable slowing down motion so it could be carefully studied. He intended to devise a machine that was dual purpose, for photography and projection, but his frames, lacking perforations, needed to be cut apart, aligned, and remounted for projection, just as Le Prince or Muybridge had to, as Mannoni (2000, pp. 348, 349, 311) points out. In May of that year, Marey wrote to Demenÿ from Naples telling him that he had a solution for the equidistant spacing of frames, but such a solution, whatever it might have been, was not put into practice. He persisted by attaching cut apart celluloid frames and mounting them using strips of rubberized fabric. Reynaud's Théâtre Optique opened in Paris in October 1892, and the Projecting Praxinoscope's "film" made by mounting frames in flexible bands sounds a lot like Marey's approach. Reynaud used leather and Marey used rubberized cloth, but Reynaud solved the problem of driving his film and frame indexing by insetting metal grommet perforations in the leather between his hand drawn cellulose frames.

Marey designed and tried out different intermittent mechanisms based on electricity, clockwork, and gravity, probably motivated by the need to address the issue of frame alignment. In one design, after the film had been halted, it was restarted by a spring mechanism when the pressure on it was relaxed. In July 1892, he temporarily abandoned the project because he was unable to "obtain completely equal intervals between images…." Marey's projector of 1892, built by Otto Lund, was based on his insight that a camera and a projector had similar mechanical and optical properties and is now in the collection of the French government's Conservatoire National des Arts et Métiers (The National Conservatory of Arts and Crafts). In 1896 Marey finally produced a chronophotographic combination camera-projector but by that time he might have been better off buying an off-the-shelf Lumière Cinématographe.

Marey's experiments covered a wide range of subjects including human beings engaged in various activities. He photographed magicians doing their tricks, waves, animals, and people engaged in various activities. As Mannoni (2000, p. 343) put it: "With the assistance of Demenÿ and Lund, Marey now entered the true 'filmic' period of his work." Today these studies, like the work of Muybridge, are considered to be fine art and are preserved in several archives in France and America. Indeed, his locomotion studies influenced modern art, as Braun (1992) convincingly describes, especially the striking resemblance of Marcel Duchamp's well-known *Nude Descending a Staircase*, *no. 2* with chronophotographs made using Marey's trolley camera. However, Marey would never have photographed a woman (nude men were OK) in such a state (as Muybridge did), in McMahan's (2002) opinion, writing that Marey was "ever sensitive to public opinion." Marey remained indifferent to any non-scientific applications for his work, which was radically different from the position taken by his associate, the inventive Georges Demenÿ (1850–1917), who was enthralled by the concept of the projection of moving images and its many applications. Alas, although Demenÿ made progress in applying what he and Marey had discovered to educational and consumer applications, as we shall see, his vision was unfulfilled in part because his work was eclipsed by the arrival of the 35 mm cinema invented by Edison in America with projection implemented by the Lumières in Europe. His contribution has been denigrated by the followers of Marey and the Lumières, according to Herbert (1996), but this is unfair. For one thing, Demenÿ invented the beater-cam projector intermittent that was used for low cost projectors into the second decade of the twentieth century.

Fig. 11.7 Georges Demenÿ (Cinémathèque Française)

On July 27, 1891, before the Académie des Sciences, Demenÿ projected moving images using his Phonoscope projector, part of his Phonophone system, designed to help deaf children learn to lip read by “watching the lips of the chronophotographed subject,” according to Mannoni (2000, p. 354). To demonstrate the process Demenÿ used a Marey camera to photograph a close-up of himself exaggerating his facial expressions while speaking these two sentences: “je vous aime” and “Vive la France.” Up to

30 frames were mounted along the circumference of disks of either 42 or 50 cm (16.5 or 20 in) in diameter. The disks were projected using a Molteni lantern modified with a radial disk shutter rotating coaxially with the image disk. This kind of projection, using phenakistoscope-disk technology, was in keeping with the approach demonstrated by Muybridge, which as Mannoni points out was a dead end, not simply because it was only capable of projecting fresh content for a few seconds, but also because it was so wasteful of light, limiting projection to small screens. Miniature Phonoscope disks were also made that were used for Demenÿ's peepshow-style viewing device.

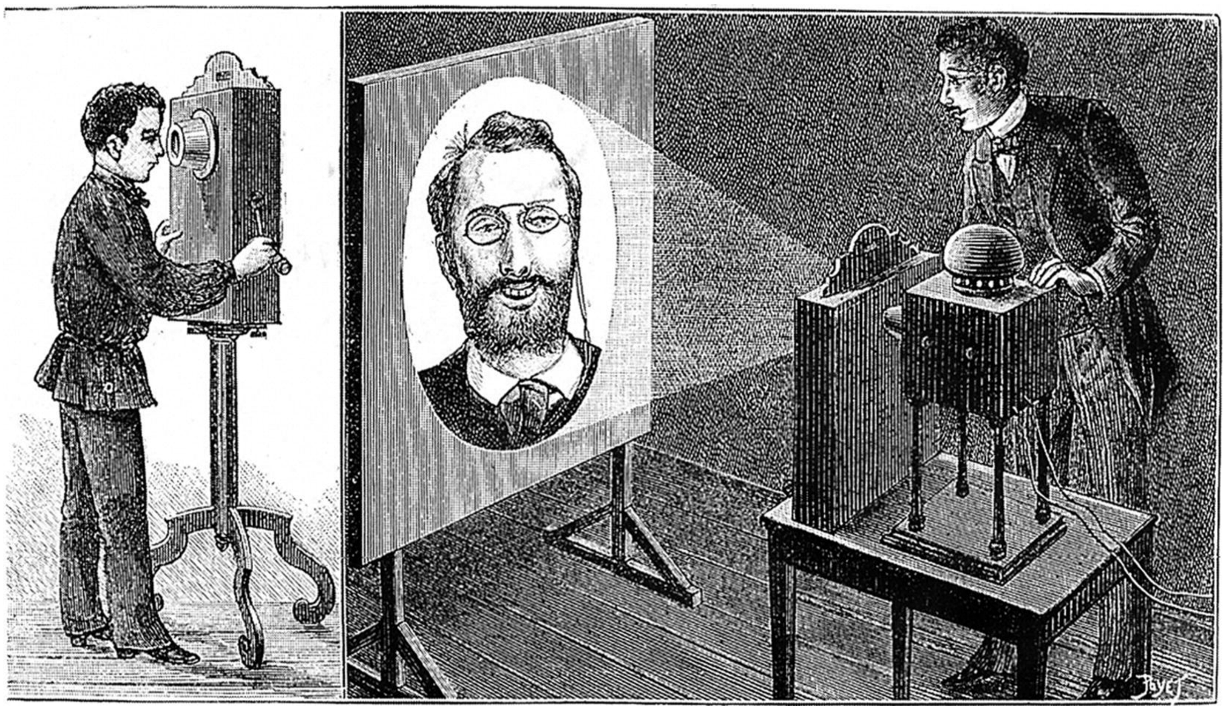

Fig. 11.8 Demenÿ's Phonoscope peepshow viewer (left) and projector (right).

The Phonoscope was presented at the Exposition Internationale de Paris in 1892, where it was warmly greeted, which motivated Demenÿ to implore Marey to embrace projection and non-chronophotographic applications. Demenÿ also described a display method that was not publically exhibited, using a cylindrical format in which the minute views are arranged in a spiral. The arrangement appears to have been identical in concept to the early experimental devices used by Dickson in Edison's lab, which also used a pulse of illumination in place of a shutter to arrest the continuously moving frame. Mannoni (2000, pp. 354–360) characterizes efforts to market the Phonophone system as half-hearted, which reduced the effectiveness of Demenÿ's appeals to Marey since it was a commercial failure. Demenÿ yearned to go beyond chronophotography, the Marey laboratory mandate, and to expend the scope of their endeavors to projection.

Marey and Demenÿ in France and Edison and Dickson in America had remarkably similar conflicts: both Demenÿ and Dickson had a vibrant vision that went beyond that of their masters, resulting in both of them breaking away to invent projection technology. Demenÿ's aspirations also diverged from his boss's with his desire to create non-scientific moving image applications, such as education, entertainment, and what was later called home movies. The split between Marey and Demenÿ grew as Demenÿ independently patented improvements to Marey's inventions, many of which were in the public domain. At first Marey was supportive and proud of what his disciple achieved and pleased with the public attention Demenÿ's Phonoscope attracted, which he probably viewed as an honorable attempt to help the disabled, but Marey, with an attitude reminiscent of Huygens centuries before, was first and foremost a physiologist who disdained commercialization and his inventions, non-scientific applications. Although Marey had been pleased with the Phonoscope, he could not abide what he viewed to be frivolous uses based on developments made in his lab. Despite the fact that Marey needed Demenÿ's help at the Station Physiologique, they parted ways in 1894 and Demenÿ moved to a new location in Paris where he continued to make Phonoscope films. Demenÿ was succeeded by Dublin-born Lucien Bull (1876–1972), who was trained by Marey and became well-known for his work in ultra-high speed cinematography.

Demenÿ had been working on a projector, his celluloid film Chronophotographe, which he redesigned turning it into a convertible 60 mm camera-projector after seeing the Lumières' multipurpose Cinématographe. Demenÿ was in a race against history, set in motion by inventions in West Orange that leapt across the Atlantic to Lyon. On August 22, 1895, Demenÿ signed an exclusive licensing arrangement with Léon Gaumont, inventor and head of the newly formed L. Gaumont et Cie, which until that year had been known as Le Comptoir Général de Photographie (literally: The General Counter of Photography). Demenÿ was to receive royalties from sales and received an advance against them of 6000 Francs, in exchange for giving Gaumont complete control of his inventions' exploitation. Toward the close of 1895 Gaumont began to market the Chronophotographe, renaming it the Biographe (it came equipped with a 120 mm Zeiss Anastigmat), anticipating that it would be used by amateurs for personal films.

From 1896 to 1897, Gaumont made a number of short films in the 60 mm format, whose frame size was 45 mm × 36 mm, four times the area of the Edison 24 mm × 18 mm frame. Some of these films may have been directed by Demenÿ, and some were later reprinted for 35 mm distribution (McMahan 2002; Tümmel 1973). The Biographe, which in Mannoni's (2000, pp. 442–450) opinion was a beautifully made machine, performed well. It used the beater-cam movement for intermittent film advance, which was a necessity for a projector-camera that used film without perforations. Demenÿ added perforations to the 60 mm film and modified the projector-camera accordingly. To be competitive with Edison's 35 mm system that had been adopted and adapted by the Lumières, he designed a 35 mm version that was offered in 1897, which retained the beater movement. Projectors fitted with the beater-cam sold well and remained "appreciated by operators all over the world until 1914" (Mannoni 2000). The beater-cam movement was used by the Americans Jenkins and Armat for their first version of the Phantoscope projector, despite the fact that it was designed for 35 mm perforated film.

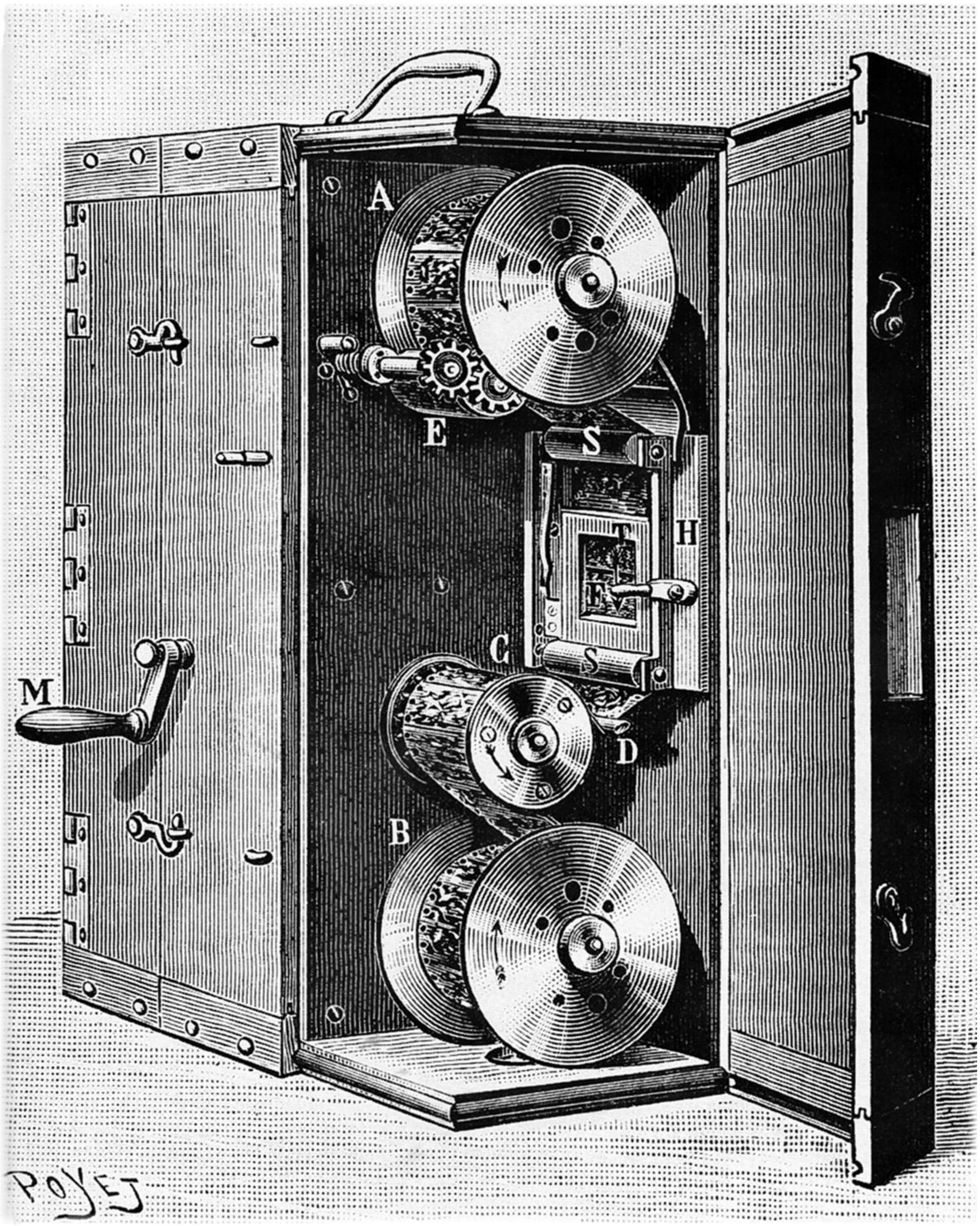

FIg. 11.9 The Demenÿ-Gaumont Chronophotographe-Biograph camera-projector – the later model used perforated film but retaining the downward dog drive.

The ingeniously simple beater-cam , located below the gate, advanced film intermittently by pulling on it with a finger mounted on the periphery of a constantly rotating cam. As the cam rotated, the finger pulled the film through the projector's gate but when the finger was disengaged from the film, which it was for most of the cam's rotation, the frame came to rest in the gate. A beater-cam or something like the Maltese-cross stop-start mechanism was needed to turn the rotational motion supplied by handcranking or an electric motor into intermittency. When the Demenÿ-Gaumont Biographe camera-projector was put on the market Edison's 35 mm format was taking hold, and the Lumières' Cinématographe, a simple and excellent machine, had already been introduced. As a result the Gaumont-manufactured product did not long endure in the marketplace. Demenÿ retreated from the life of a motion picture inventor to return to his first love, gymnastics, which the reader will allow involves a considerable amount of motion.

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