Lenny Lipton

THE CINEMA IN FLUX

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

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6. The Zoëtrope and the Praxinoscope

Lenny Lipton[1]
(1) Los Angeles, CA, USA

In the early 1840s inventors began to adapt the magic lantern based on Plateau's discovery of apparent motion and the phenkistoscope, as described in chapter 4. Victorian cinema inventors also began to explore how to photographically capture and project the phases of motion. These efforts, and in particular the work of chronophotographer and physiologist Marey, laid the foundations for Edison's Kinetograph movie camera and Kinetoscope peepshow viewer. Immediately before the advent of the celluloid cinema Reynaud's Projecting Praxinoscope was capable of projecting a motion picture narrative of extended length using hand drawn slides of the phases of motion. Unfortunately it was not a scalable technology, and in fact it had only one practitioner. It was the descendent of the daedalum and its improvement the zoëtrope (life-turning or wheel of life) that used the concept of the biunial magic lantern to combine moving foreground characters with a static background. The daedalum and zoëtrope can produce the same moving image effect as the phenakistoscope, but the images are viewed directly, without requiring a mirror, and several people at the same time can see the animation.

The invention of the daedalum, which followed immediately after Plateau's phenakistoscope, was the work of the British mathematician, painter, inventor, and showman William George Horner (1786–1837), which he described in an article appearing in the January 1834 issue of *The London and Edinburgh Philosophical Magazine and Journal of Science*. The invention may be dated to 1833 since Horner gave a precise description of it to an optician prior to publication (Hecht 1993, entry 147D). The device, unlike the phenakistoscope disk, rotated in the horizontal plane, a cylinder with slots cut in it between inward-facing images of the phases of motion. Unlike the phenakistoscope it did not require a mirror, and its moving images were viewed directly through the slit shutters. Its horizontal cylindrical arrangement allowed for it use by several observers at a time. Horner (1834, vol. 4, p. 36) used the name daedalum "as imitating the practice which the celebrated artist of antiquity was fabled to have invented, of creating figures of men and animals endued with motion." He mathematically analyzed the optics of the device, how its rotation and the images on the inside of its cylindrical wall are each in turn arrested by being viewed through the shutter slits to produce the succession of images required for the illusion of apparent motion. The daedalum was the basis for devices designed by Czermak, Desvignes, Purkinje, and Lincoln, functioning by the same principal. Desvignes' design of 1860 used miniature solid models rather than drawings to give a three-dimensional effect (Hopwood 1899, p. 25), an idea that the four aforementioned inventors similarly embraced, although Horner, according to Liesegang (1986, p. 28), first made the suggestion for the use of models in 1834. At the London Exhibition of 1862, architect Peter Hubert Desvignes (1808–1883) also showed a vertically oriented hand-rotated cylinder with horizontal shutter slits cut between its image frames, one version of which was designed to be used by a single observer who looked downward at the images through a hood (*Chambers's* 1889, p. 398). The arrangement permitted the use of a side-by-side stereo pair format; a surviving sequence of the phases of motion photographed for Desvignes is that of a steam engine in operation, as noted in chapter 9.

The best known and most successful version of Horner's daedalum was the work of William E. Lincoln, of Providence, Rhode Island, who was granted the patent succinctly titled *Toy*, USP 64,117, granted April 23, 1867 (no filing date is given), called a zoëtrope in the specifications and according to Hopwood (1899, p. 22), Lincoln was the first to use the name. Lincoln assigned his patent to Milton Bradley & Co. for $5000, and it achieved enduring commercial success (Kattelle 2000, p. 9). The zoëtrope is such a straightforward design and so easy to construct that it might have been built by the ancient Egyptians out of papyrus and wood. The zoëtrope's rotation, like that of the daedalum's, is in the horizontal direction about a vertical axis, but it moved the daedalum's shutter slits from between each image to above them, making it possible to easily change subjects by replacing the image bands of the phases of motion. Since the slits were now above rather than between the poses, the moving image was viewed looking downward through them. The zoëtrope (or similar daedalum) was the basis or inspiration for both Reynaud's Praxinoscope and Anschütz's Tachyscope. The mass manufactured zoëtrope was popular in the United States and Europe and remains in production, a novelty product and an inexpensive toy and teaching aid.

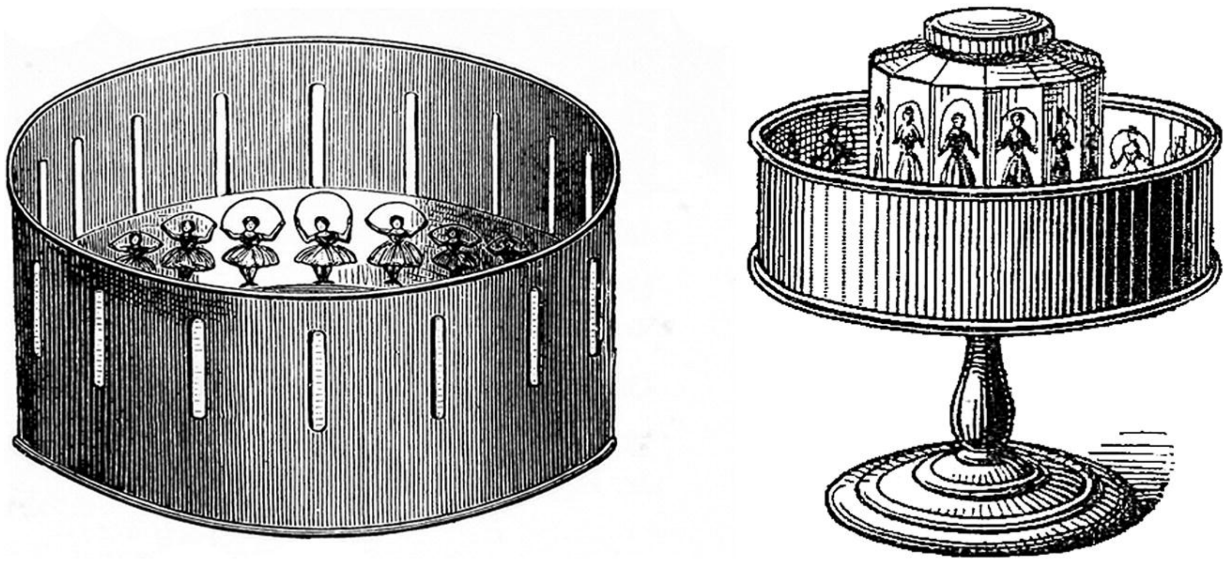


Fig. 6.1 Left: a zoëtrope, based on the phenakistoscope; it does away with the need for a mirror. Right: an early version of the Praxinoscope that substitutes mirrors for the zoëtrope's slits. The mirrors, outward facing on the inner cylinder, reflect the images of the phases of motion facing them on the inner cylinder.

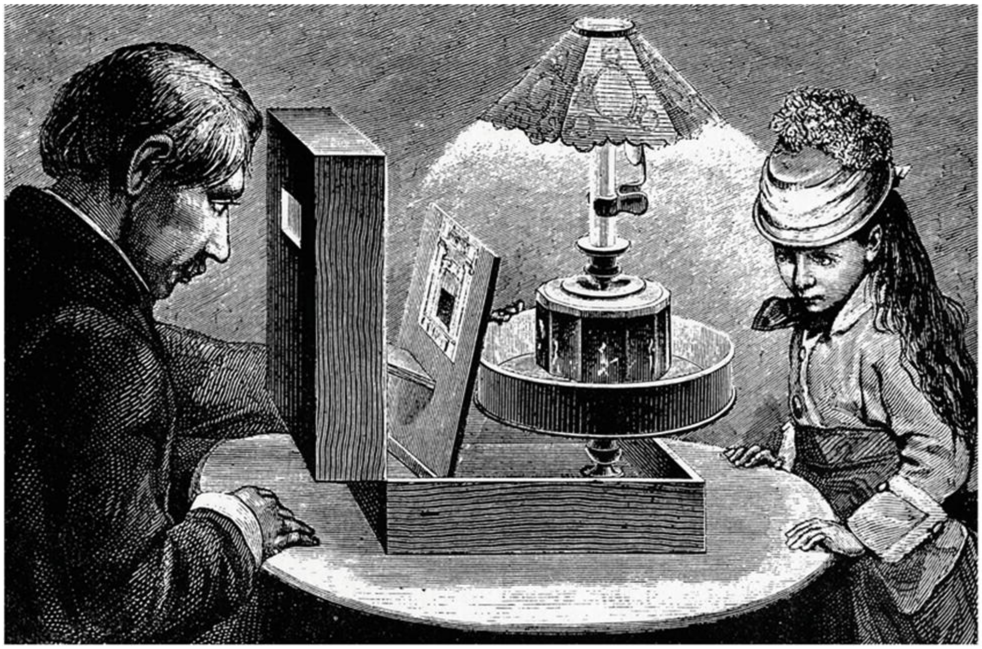
The zoëtrope was the inspiration for Reynaud's Praxinoscope, which it resembled in its original version but with a significant design difference; instead of slits it used an array of mirrors. The most advanced version of French artist-inventor Charles-Émile Reynaud's (1884–1918) invention, the Projecting Praxinoscope, was a masterpiece of the twilight era of the magic lantern and the forerunner of the celluloid cinema's cell animation, which could be seen in but only one venue, the Théâtre Optique in Paris. Reynaud, the son of a medal engraver, was born in Montreuil-sous-Bois near Paris, who at the age of 14 began a series of apprenticeships with experts in medical and scientific equipment design and photography. When he was 20, he attended lectures by Abbé Moingo, an advocate of Brewster's lenticular stereoscope who illustrated his talks on scientific topics with magic lantern slides. Moingo was a lanternist par excellence who taught Reynaud its various techniques and along the way converted the secular Reynaud to Catholicism. Reynaud worked with Moingo for the next decade, eventually giving scientific lectures on his own using sophisticated magic lantern projections (Mannoni, p. 364).

Fig. 6.2 Charles-Émile Reynaud (Cinémathèque Française)

Reynaud built a phenakistoscope for his young assistant Pierre Tixier but was disappointed with the dimness of the images and their lack of color saturation, a result of the reduction in light reaching the eye through the narrow rotating shutter slits, a problem that afflicted the zoëtrope as well. Using the basic design layout of the zoëtrope, Reynaud made an impressive advance, which he described in a letter to the Académie des Sciences on July 20, 1877. He filed the French patent for the invention on August 30, 1877, and the British Patent 4244 on November 13, 1877, in which the word Praxinoscope (I look at action or action viewer) was used for the first time. The original Praxinoscope of 1877 was a device with an inner wall that was a 12-sided polygon arrayed with 12 (Hecht says 10) rectangular mirror segments, 2.2 inches high and 1 inch wide, each of which was glued to the straight sections of the polygon's wall. The mirrors faced a band of 12 poses positioned on the surrounding cylinder's inner wall. These inwardly facing drawings of the phases of motion were viewed when one looked into the rotating mirrors, which took the place of the zoëtrope shutter slits. The diameter of the image cylinder, about the size of a dinner plate, was about twice that of the central polygonal array of mirrors (Hecht 1993, entry 286B). There were several versions of the Praxinoscope manufactured in large numbers between 1877 and 1879 (Hecht 1993, 632); these were a table model in which the cylinder was turned by hand, possibly made of metal, without a source of illumination; a wooden stand mounted model handcranked with a string pulley with a candle holder "and lamp-shade to clip onto candle"; and a metal clockwork model with a "large key to wind (the) clockwork motor" (Hecht 1993, entry 299A).

Reynaud's British patent states that the images become animated when the cylinder is rotated, and it is correctly asserted that they are brighter than prior devices that used slit shutters and that the Praxinoscope images did not flicker, (nor did they suffer from anamorphic distortion). The patent also suggests a stereoscopic version using a band of stereopair poses. While the Phenakistoscope and zoëtrope slit shutters arrested their rotating images, the Praxinoscope used a different method to create the illusion: each mirror, whose rotation followed the movement of its inward-facing image's reflection, was optically steadied as it reached the eyes. In addition, each image was wiped away to be replaced by its succeeding image without interruption. The result is that the eyes see the series of still images blended together required to produce the illusion of apparent motion but without the shuttering and the interruptions produced by moving slit devices. Reynaud had created a method of viewing apparent motion based on optical image stabilization and the new device sold well.

It was in 1879 that Reynaud announced his peepshow-style Lilliputian or Praxinoscope Théâtre, which optically combined character animation with a fixed background. The small peepshow Théâtre was housed in a mahogany cabinet and viewed through a rectangular opening, with the background scene mounted on the inside of its wall immediately below the opening facing a semi-silvered mirror onto which its image was reflected. The moving images of the phases of motion were viewed through the partial mirror's image of the background and superimposed over it. The interchangeable band of figures printed against a black background stood out against the fixed scene. As in the prior versions of the Praxinoscope the band was wrapped onto the cylinder to face the mirror facets, and the cylinder was rotated to produce the illusion of motion. The new device also sold well and set the pattern for future variations that would combine animation with a fixed background scene. The effect of the Praxinoscope Théâtre remains a delight to this day, which is a notable feat in the era of high-definition high-dynamic-range expanded color space digital movies.




LE PRAXINOSCOPE
ER
MARQUE DEPOSEE
ANIMANT LES DESSINS

Fig. 6.3 The Théâtre Praxinoscope displayed apparent motion optically combined with a background. Top: in use in a home. Bottom: a photo of the device.

In 1882 a new version for the home market was introduced, maintaining the concept of combining animated figures superimposed over a separate fixed background, called the Projection Praxinoscope, or Theatriaxinoscope (Hopwood 1899, p. 30). Reynaud abandoned the direct viewing of printed images on an opaque substrate (paper) and adopted a projectable band of transparent images. The device used the mirror stabilization optics to protect lithographed images printed on glass slides whose images had black backgrounds enabling them to be superimposed over a fixed background scene that was projected by its own magic lantern. This two-projector version was of significance because Reynaud had found a way to project animation using image stabilization and he had anticipated a key component of the celluloid cinema, movie film; in addition, his technique anticipated cell animation. The Projection Praxinoscope's 12 glass slides were held together by fabric strips to form bands that were wrapped against a polygonal wall that flared outwardly, narrower at the bottom than the top. A frustum-shaped polygonal array of 12 mirrors was located within the band of slides, facing them. Light was projected though each slide by a lamphouse, which was then reflected by the mirrors into a lens to be projected onto a screen. A separate magic lantern projected the fixed background scene, but both used the same lamphouse.

This was the most advanced projection animation device the world had ever seen. However, this solution to the flickerless projection of animated images did not do well in the marketplace because it was too expensive and complicated to operate. It seems that the purchaser required a course of instruction by Reynaud himself. Despite this setback, the Projecting Praxinoscope would be developed into Reynaud's tour de force, the Théâtre Optique. The Praxinoscope's principal virtue remained intact since each frame was optically stabilized by the action of moving mirrors so one frame replaced another, without interruption, to produce flickerless projected animation. In fact, there was no flicker at any frame rate, something that could not be done with intermittency and an interrupting shutter. With Reynaud's accomplishment the world had been given a third technique for projecting apparent motion. The other techniques are Naylor and Uchatius' adaptation of the Praxinoscope using continuously moving images of the phases of motion and an arresting radial shutter and Brown's intermittent motion for arresting each frame with a shutter to occlude them as they moved through the projector's gate.

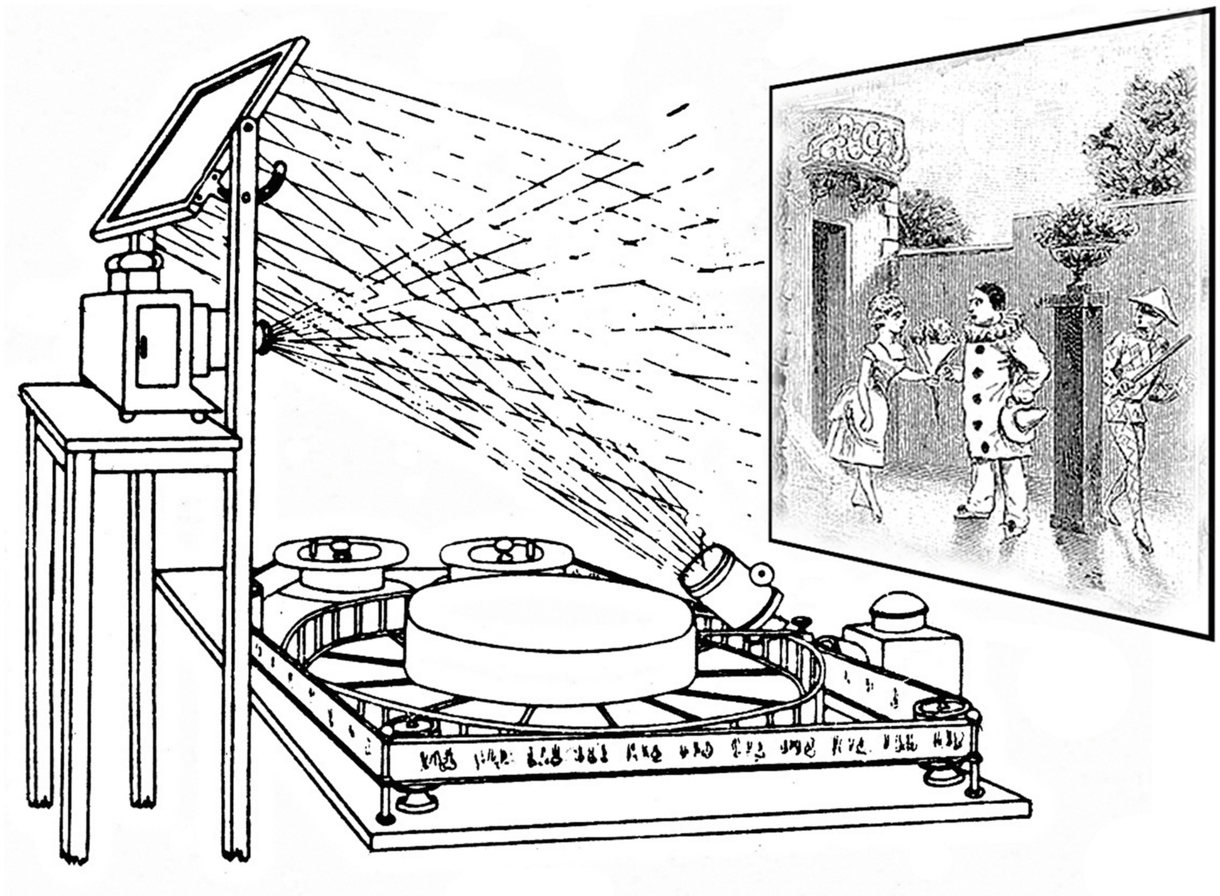
Despite the failure of the Projecting Praxinoscope in the marketplace, other versions flourished, and in February 1887 Reynaud and his mother set up in two apartments to serve as living quarters and a workshop, at 58 Rue Rodier. Today a plaque commemorating Reynaud's tenancy can be found mounted on the building's gray façade. Mother and son farmed out Praxinoscope components to several vendors to begin manufacturing, and Reynaud drew three sets of lithographed bands 26 inches long and 2 inches wide that "showed short scenes in twelve images on a pale background, with bright clear colours…. Reynaud drew inspiration from the repertoire of the magic lantern slide: a little girl skipping, a watermill, clowns…." Thirty picture strips or bands of different subjects were offered for the Praxinoscope, which was first available in a lampshade configuration, and then for other models. All told it sold 100,000 units to well-off families, according to Mannoni (2000, pp. 368, 369).

Reynaud's triumph, invented in 1888 was a scaled-up version of his Projecting Praxinoscope that began and ended its life with performances in Paris in the Théâtre Optique in 1892 and ran for the next 8 years to a cumulative attendance of half a million. The original show was the world's first hand-drawn animated narrative film, *Pauvre Pierrot* (Mannoni 2000, p. 381). The Théâtre Optique setup consisted of two separate projectors, one magic lantern and one Praxinoscope projector, each with its own lamphouse as was the case for a biunial lantern projection. Both projectors were aimed at a frosted glass for rear screen projection. According to Mannoni (by email, September 22, 2020) the theater probably originally had an audience of between 100 and 150 until 1900 when it was rebuilt and increased to 300. The screen was relatively small, and if a contemporary drawing can be used as the basis for an estimate, probably about 5 feet wide. The magic lantern projected the background (another magic lantern was used for announcements), and the Praxinoscope projected foreground characters on the static background image, anticipating celluloid cinema's cell animation with its painted backgrounds and foreground celluloid cells.

MUSÉE GRÉVIN
PANTOMIMES LUMINEUSES
Théâtre Optique
DE
E. REYNAUD
Musique de
GASTON PAULIN
Chéret
TOUS LES JOURS
DE 3H. A 6H. & DE 8H. A 11H.

Fig. 6.4 A poster for the Théâtre Optique. (Cinémathèque Française)

The Projecting Praxinoscope used a horizontally traveling row of hand-painted transparent delicate gelatin slides, 2.36 inches on a side, held together with top and bottom bands of leather separated by leather interstices, each with a metal reinforced circular perforation or grommet. The perforations were used to advance the band, made up of up to 616 slides, and to locate or index each slide with respect to the mirror system and projection optics. The band of slides moved continuously with each projected image optically stabilized on the screen. Movement was supplied by two side-by-side handcranked cylindrical drums, located at two corners of the "films'" rectangular path. The drums were sprocket wheels with teeth to engages the perforations and drive the band of slides along a rectangular closed-loop path. An inner cylinder, made up a polygonal array of 32 outward-facing mirrors, after the fashion of the home Projecting Praxinoscope, was mechanically synchronized to the sprocket wheel drums. Light was projected through the slides, to provide optical image stabilization just as it had been for the other Praxinoscope versions. The animated images, which occupied only a part of the composition, were reflected onto the rear screen using a large mirror that could be adjusted to move the superimposed characters to the appropriate part of the scene. The background magic lantern was located above the Praxinoscope projecting its image directly onto the rear screen. In this way projected apparent motion provided by the moving band of slides was combined with a still background image.[1]



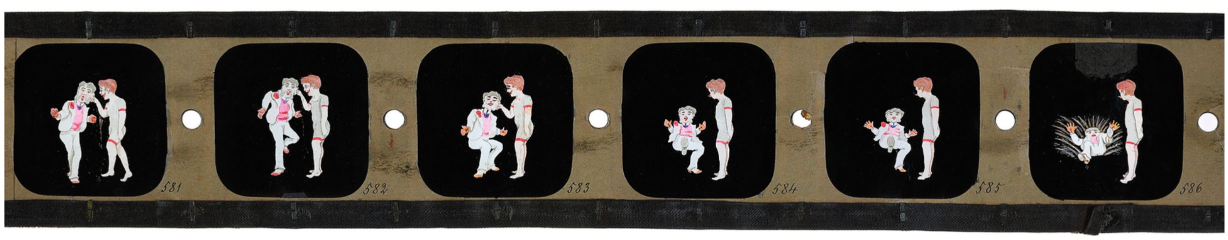


Fig. 6.5 Top: Reynaud's Théâtre Optique used a Projecting Praxinoscope to animate figures superimposed on backgrounds projected by a magic lantern. The Praxinoscope image was reflected by a mirror, and the images were projected rear screen. Bottom: Reynaud's "film." (Cinémathèque Française)

Reynaud meticulously planned the action of his stories and performances, which lasted about 15 minutes, so that he could rock and roll the band of slides to change their direction seamlessly transitioning from forward to backward motion when required and to vary the tempo of action with the possibility of using extremely low frame rates or even holding a still image on the screen for any length of time. In this way he was able to design a narrative extending the running time that would otherwise have been limited by 600 or so frames. The projection rate of the celluloid cinema in its early days, like that of Reynaud's Théâtre Optique, was also variable, creating an interactive inexpedience involving audience, musicians, and projectionist, but unlike the early motion picture projectionist Reynaud was both the artist who drew each frame and the master projectionist-animator for every screening. Sound for the Théâtre Optique performances was provided by piano accompaniment and sound effects that were triggered by metal tabs on the image band.

Unfortunately Reynaud signed an onerous contract with the owners of the venue, the Musée Grévin, that turned him into a virtual slave who had to present his new shows for their approval and refresh them so frequently that at one point he had to close down to complete the herculean task of hand painting hundreds of slides. In addition his compensation was significantly reduced by various expenses required to run the screenings that took place in the museum's first floor Cabinet Fantastique. Reynaud was an artist as much as an inventor; had his ability to focus on business been as great, he might have been a wealthy man. Reynaud's theatrical projections were the first exhibitions of sufficient duration and complexity to demonstrate the concept that the cinema of apparent motion could tell stories and satisfy the expectations of an audience. He anticipated the drive and indexing functions of perforations and also understood the requirement for a flexible image-carrying medium, but his work just predates the availability of suitable celluloid substrate, and he had to rely on a storage medium of his own devising, easily damaged gelatin slides. The celluloid cinema was directly based on and derived from photographic technology, whereas Reynaud's cinema was based on the drawing and painting techniques of the magic lantern. The difficulties in making copies of his slides prevented him from being able to distribute the technology to other theaters but he also doesn't seem to have been willing or able to franchise his invention by training other artist and operators.

Reynaud attempted to update the content by using photographic slides after he had seen the Lumières' Cinématographe projections. In 1895 he projected images probably produced by photographing individual poses using a conventional still camera. His creation, the comedy, *Guillaume Tell* , which was stencil-colored, was projected in 1896 at the Théâtre Optique. But it was too late: he could not compete with celluloid cinema, and his

Théâtre Optique was shut down, doomed by the efforts of Edison, the Lumières, and other creators of the photographic celluloid cinema whose new technology competed for the same audiences. In despair Reynaud smashed his apparatus and drowned most of his equipment and slides in the Seine, an act of self-destruction, frustration, and anger, and an eerie foreshadowing of the fate of another French cinema pioneer who had fallen on hard times and whose work had become passé, Georges Méliès. In 1923 Méliès burned the costumes, sets, and all of the negatives of the films stored at his Montreuil studio. Although Reynaud's work must have been known to contemporary inventors, it may not have directly influenced the work of Edison and Dickson, who were influenced by Muybridge, Anschütz, and most importantly Marey.

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Footnotes

1 Walt Disney may be seen in an accurate and instructive YouTube video demonstrating the Praxinoscope.