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Science and Cinema

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"Cinema is objectivity in time."

Science and film: an introduction

This issue of *Science in Context* is dedicated to the question of whether there was a "cinematographic turn" in the sciences around the beginning of the twentieth century. In 1895, the Lumière brothers presented their projection apparatus to the Parisian public for the first time. In 1897, the Scottish medical doctor John McIntyre filmed the movement of a frog's leg; in Vienna, in 1898, Ludwig Braun made film recordings of the contractions of a living dog's heart (cf. Cartwright 1992); in 1904, Lucien Bull filmed in slow motion a bullet entering a soap bubble. In 1907 and 1908, respectively, Max Seddig and Victor Henri recorded Brownian motion with the help of a cinematograph (Curtis 2005). In 1909, the Swiss Julius Ries was one of the first to film fertilization and cell division in sea urchins (Ries 1909). In that same year in Paris, Louise Chevroton and Frédéric Vlès used a film camera to observe cell division in the same object (Chevroton and Vlès 1909). As early as 1898, the Parisian surgeon Eugène-Louis Doyen began filming several of his operations, among them the spectacular separation of the Siamese twins Doodica and Radica (Bonah and Laukötter 2009). And in England, the scientist and zoologist Francis Martin Duncan produced an array of popular-scientific films for Charles Urban: "The unseen world: A series of microscopic studies" was presented to the public in the Alhambra Theatre in London for the first time in 1903 (see Gaycken in this issue).

Once readily available, the cinematographic technique seems to have been immediately used in the sciences. With reference to Bergson, Scott Curtis talks about the "cinematographic method" in the sciences, the basis of which he finds in a "natural affinity between film and scientific research." Consequently, he speaks of an "immediate access by the scientific community to film" (Curtis 2005, 25). Hannah Landecker, too, records an "explosion in experiments with and on film in scientific disciplines from astronomy to psychiatry": "there is no doubt that different uses of film in different sciences abounded" (Landecker 2006, 122).

During the last two decades, film and media studies have generated the decisive momentum for research on film as a medium in the sciences. In contrast to this, science studies have seized on these reflections to a much lesser degree. There is a lack of research, in particular of case studies, which focus on the following questions: where, in which areas of science, and to what extent have filming devices been used? Which fields of knowledge were characterized by a swift and intensive adoption of the new medium, and why? Above all, what epistemological added value was related to the new medium? Which type of knowledge did the new machine create?

Meanwhile, the era of the scientific film appears to have already come to an end, even before being fully acknowledged as a research field in the history of science: The "film and bright lights' era is decisively over in biology," according to Landecker's conclusion in this issue. Landecker following the film theoretician David Rodowick suggests that cinematographic technique be located in the gap "between the question 'what was cinema?' and 'what will digital cinema become?'" (Landecker in this issue, page 386). Does that mean we need to look back on scientific film of the twentieth century as an already concluded phase that is largely congruent with the last century? And what consequences does locating the cinematographic technique in transition and in the face of digital technologies have with respect to the epistemology of the film in the sciences? This implies that our perspective on the medium is based upon defining epistemological boundaries that were not yet applicable to our object of research, namely the film in the sciences of the twentieth century.

Typically, the emphasis of studying science in context, to which this journal is devoted, is placed in the *context* of generating scientific knowledge. This relation seems to be turned around in the present issue about film in the sciences: The film counts as a cultural phenomenon par excellence and has been examined as such in a cultural-historical and theoretical, philosophical as well as aesthetic perspective and in a very broad way. What has almost been forgotten, however, is the role of the moving images with respect to the epistemology of the sciences – as research tool and visual construction of knowledge, i.e. of a particular kind of knowledge about not only an object but a temporal event.

The term "cinematographic turn" was coined in 2002 by Jimena Canales and applied to the fields of astronomy, physics, and mathematics at the turn of the twentieth century (Canales 2002). In her paper "Photogenic Venus," Canales examines an event that was central to astronomy at the end of the nineteenth century, namely the transit of Venus in 1874. There were controversies among astronomers as to the type of methods, procedures, and instruments necessary for observing the transit and for determining the distance between the Earth and the sun, the solar parallax, with the required precision. Physics faced the serious problem of individual variance of observations. The discrepancies among the observations made it necessary to come up with mechanisms and procedures to train observation, to standardize it and subject it to scientific comparability.

The automatic recording by photography seemed to be a promising way to achieve comparability and to bypass individual differences in observations. In particular, the "photographic gun" used by Jules Janssen – which allowed him to capture the transit in a series of photographs taken at regular intervals of around one second – led to broad controversy. It turned out, though, that the findings of photography did not remain uncontested: the recordings made by various cameras showed differences so massive in kind that to observe the recurring transit in 1882, older, non-photographic techniques were employed. Numerous alternative approaches to determine the transit of Venus were considered in parallel, and they each had advantages and disadvantages. The debate concerning the methods, instruments, and procedures for recording the event showed, according to Canales, "shifts in the type of evidence at work in scientists' attempts to deal with the fleeting phenomena of the late nineteenth century" (ibid., 612). This "interdependence of different types of evidence" was due to the "common ground that was *necessarily and at the same time* cinematographic, physical, psychological, and philosophical" (ibid., 613; emphasis in the original).

Among the sciences, biology has displayed an enormously rich visual culture from its very beginnings. Throughout the nineteenth and twentieth centuries, notebook sketches, finely engraved, sometimes hand-colored copperplates, lithographs, three-dimensional models or graphic inscriptions produced with the help of all kinds of devices – photography, film, digital imaging techniques, or computer animations – abound in the scientific literature. Among those, the invention of the cinema around 1900 marked a turning point.

In biology, "fleeting phenomena," such as the planetary movements in astronomy, did not represent a phenomenon at the periphery of scientific knowledge. On the contrary; in the biological sciences, processes constitute the core of science: reproduction, development, cell division, metabolism, growth – vital processes are temporally bound incidents that may be observed in their temporal extension but may not be made easily visible. In order to be able to answer the essential questions of biology, it seemed a prerequisite to make those processes visible *as* processes, in other words, to capture them in their motion. Towards the end of the nineteenth century, the film camera, which portrayed organic processes as vital by delegating the organic movement to the movement of the camera, appeared to deliver a congenial visualization of time and motion. At the same time, the new medium called into question some of the most basic presuppositions of the sciences, in particular the life sciences: time, motion, scientific observation, visual representation, production and/or reproduction of scientific data.

Historically, film, as photography, was acclaimed to be the "better" observer: mechanical, reproducible, immediate, tireless, objective – "cinema is objectivity in time" was the emphatic welcome of film (Bazin 1980, 242). Film, however, is not merely a medium of "registering" by a photo-sensitive film strip, a neutral camera lens that records the incident – allegedly without being involved and thus serving as a substitute for the observer with his many faults. Film, on the contrary, is *part* of the research context, of a laboratory setting, of an apparatus that, in the first place, generates the events that it simultaneously records.

These considerations regarding the nature of cinematographic "observation" apply to film as a narrative as well. The exposure of the film strip is one thing, while the organization of the material is another. Along with the possibility of recording an incident with a film camera in a seemingly immediate way – over many hours if required – came the necessity of cutting, manipulating, and modifying the film. This manipulation comprises the selection of sequences and their composition, e.g., the shortening or extension of an incident that is hardly discernible for the observer unless explicitly hinted at or unless explained in the accompanying text as part of the production of the film. The question of narrative finally leads to the most important aspect of scientific cinematography: the representation of "time." To condense or extend time is among the pivotal manipulations and most important use of the film as a research tool, not only in biology. Slow and fast motion respectively – i.e. demonstrating the film at less or higher speed than the recording itself – are fundamental in perceiving phenomena that cannot be observed without their being inscribed on film, as they are either too fast or too slow. Various modes of time meet here: "the time of experiment, the time of recording, and the time of demonstration" (Landecker 2006, 123).

The overlap of different modes of times, particularly in micro-biology, led to a diametrically opposed perception of the smallest of universes: Whatever appeared static in earlier conventional images was now observed as highly agile in the opposite fashion. While micro-cinematography was a "necessary corrective to the de-animating effects of microscopic technique" (ibid., 126), the erratic and frenetic motion constituted a perception that did not correspond to the given temporal relations either, as the movements appeared with a speed that they did not actually possess. In other words: whatever was too slow or static now appeared as too fast – a representation of "reality" neither here nor there. Film featured a certain advantage: the possibility of playing it back in reverse and thereby follow and decode incidents of increasing differentiation. The reversibility of time has to be regarded as a very important function of film in terms of its research logic, and it also makes a huge impact on the conceptualization of the incident it generates. Therefore, if "film provides the plot" (Landecker and Kelty 2004, 42), we have to ask what kind of epistemology comes along with it? Which epistemological shaping of the object or the concept of biological time does film deliver? Did the invention of cinematographic technique really mark a "cinematographic turn" for the sciences around 1900, i.e. an epistemological turn? Alternatively, was film, ca. 1900, merely a means for a more suggestive representation of an existing epistemology, namely the sequentiality of life processes?

From another perspective, the medium of film was intimately related to modernity. Mary Ann Doane argued for the "emergence of cinematographic time" around 1900 and showed that the "new" temporality of that age was a function of capitalist modernity with its emphasis on distribution, circulation, energy, displacement, quantification, and rationalization. She argues for a new epistemology of "contingency" that marked modernity and which was crucial for the emergence of cinema as the most prominent form of representation in the modern age (Doane 2002). Film as a mass media brought about a new culture of spectatorship. The cinema was a social event as well as entertainment, at the same time constituting a new structure of relating the inter-subjective with the objective. What consequences did these new qualities of the medium bring to the perception of the scientist, the constitution of scientific knowledge, to the ways scientists communicated knowledge, to the reproducibility of the scientific object and its popularization? Do we see "between 1895 and 1918" a "transition between their [the films] good standing as a scientific tool and their growing notoriety as an instrument of mass culture" as Scott Curtis recently claimed (Curtis 2009, 87)?

Historiography

In the last decades, science studies have supported art history on its way toward a "history of images that are not art" (Elkins 1995) and have generated an impressive amount of literature concerning the construction, communication, and storage of knowledge via images. They have thus helped to establish the history of knowledge also as a history of the scientific image. The relation of science and film has equally been the object of research but primarily in the area of film and media studies rather than of science studies. Fundamental epistemological questions as to the use of film in different fields of knowledge have largely remained unanswered. Therefore the proposition put forward by Bonah and Laukötter, namely that medical film is still a "historiographic orphan," holds true in a more general sense also for other scientific disciplines (Bonah and Laukötter 2009, 134).

In the same way, the verdict by Landecker and Kelty with respect to micro-cinematography also refers to many other areas of knowledge: "Micro-cinematography is not generally recognized as significant to the making of biological science" (Landecker and Kelty 2004, 43). The blame for the lack of discussion about and the acknowledgment of the cinematographic technique as research tool is not only attributed to the missing historiographical research in general. Blame also lies with the scientists themselves. Landecker quotes Peter Medawar, who is not the only one to draw an epistemological line between the solution to biological problems – by formalizations, analyses, or quantifications – and the "just looking," i.e. observation only, among which is the mere watching of films (ibid.). Landecker and Kelty complain about the fact that "often in the history of biology, the observation of life – the eye-straining, world-denying hard work of observation – is seen as a mere prolegomena to an analysis"; and encourage new lines of thought (ibid., 57).

What follows is not meant to be an overview of the historiographical literature on science and film, neither complete nor systematic. I merely want to illustrate some of the research directions that are more relevant to the questions posed in this issue, namely concerning the epistemological grounding of knowledge in the medium of film and whether there was a "cinematographic turn" around 1900.

Case studies

The historical evidence of scientists who have actually employed the new technique in their investigation is relatively limited. Case studies that show which scientists used the technology of film in different fields of knowledge, to what extent, and in which phase of their work, are especially lacking. This raises the question of the actual impact of cinematography on the sciences. Even when cinematography was employed by scientists, the question still remains whether the technology had a significant impact on the underlying epistemology of the explored processes. Which epistemological consequences did the use of film have on the research track of the individual scientist on the one hand, and on the development of the entire field on the other? Even today, a series of primarily older publications is an indispensable source for the findings of early scientific film, as they give an overview – although only summarily – of who employed film in what fields of research (Liesegang 1920; Michaelis 1955; Weiser 1919; Thévenard and Tassel 1948; Lloyd 1948). Case studies on individual scientists who used film include Jean Painlevé (Bellows, McDougall, and Berg 2000), Jean Comandon, Alexis Carell (Landecker 2005; 2006; 2007) or Max Seddig's cinematography of Brownian motion (Curtis 2005).

Chronophotography

Among the most closely examined aspects of the relationship between film and science is a different type of recording technique: chronophotography. In 1878, Eadweard Muybridge produced the first series of photographs in Palo Alto on behalf of the Governor of California, Leland Stanford, that depicted the exact position of a horse's legs in trot (Prodger 2003). Muybridge used an array of cameras that were positioned at a fixed distance from one another and operated in sequence to capture the horse in motion – a procedure he improved in the series for *Animal Locomotion*, a work he commenced at the University of Pennsylvania in 1884. In contrast, the scientific interest and innovations in photographic devices by Étienne-Jules Marey in France focused on creating perfect series with only one camera, i.e. on capturing motion on a single plate. This way, the shapes of the moving body, in various arrangements graphically reduced to points and lines that reflected the white color Marey had added to the test persons' black outfits, could overlap in large numbers, depending on the respective speed of the movement and the recording. Thus, the images made the interval and the distance between them disappear to the effect that the series approximated an almost uninterrupted, continuous recording of movement (Dagognet 1987; Braun 1992; Douard 1995; Lefebvre 2004; Mayer 2006; Mannoni 1999; Snyder 1998; Frizot 2001).

Chronophotographic series were "mechanically produced images of motion" (Métraux 2005, 61). Instead of capturing a single instant of a fleeting motion, the chronophotographic series followed a running horse, a flying bird, or a human being in mid-jump in consecutive images, each single picture only representing a transitory moment in a successive row. Taken at regular intervals, the series of photographs delivered a new image of motion: the flow of bodily movements could be broken down into a principally endless number of single images. Consequently, Marey counted chronophotography among the "new methods of analyzing movements" (Marey 1895, vii). The technically improved visual analysis opened up the possibility of measuring motion, i.e. its dissolution into measurable and calculable parameters. At the same time, zoetropes or phenakistoscopes were used to synthesize the individual stills and to recreate the illusion of movement. With the help of such apparatuses as the zoopraxiscope the moving pictures could be projected as well.

The definition of the mutual relation between chronophotography and cinematography – historically as well as epistemologically – is an open debate in historiography. Fundamental questions remain to be answered, e.g. the complementary relation between analysis and synthesis, the epistemology of seriality, its aesthetics – Bazin claimed that Marey's and Muybridge's series represented cinema's "purest aesthetic" (Bazin 2000, 146) – as well as the fundamental question of which concept of "motion" and "life" chrono- and cinematography generated and what were the scientific and cultural consequences (cf. Cartwright 1992).

Popular science film

The popular science film has been made the subject of a comparatively vast literature at the core of which stands the question of how to define the popular science film, in terms of its content – actualities, travel, industrial, science films etc. – but also in terms of its aesthetics and proliferation, its audience, and its spaces of presentation.

In his study about industrial film, Scott Curtis examined the work of Frank and Lillian Gilbreth, who started their film studies of work processes in 1912 (Curtis 2009; cf. Hediger and Vonderau 2007). The Gilbreths' famous films are, according to Curtis, a "documentation of processes that the analyst can study and improve" (Curtis 2009, 86), but they are also at least to the same extent "an image of *what efficiency and inefficiency look like*" (ibid., 93). This image of efficiency was at the same time documentation of work and commercial product to be sold: "the act of filming itself becomes the product" (ibid., 86–7).

Science and film companies were intimately linked right from the beginning. Thus, the French movie company Pathé supported Jean Comandon's work, and Gaumont contributed to the research of his colleague Nicolas Charles Emile François-Franck at the Collège de France (cf. Lefebvre 1995). Starting in the 1910s, Thierry Lefebvre marks the beginnings of the establishment of the scientific popularization film as an independent commercial genre, exemplified by the production of scientific popular films in the "scientia" series, which was produced by the French movie company Éclair between 1911 and 1914 (Lefebvre 1993b). More recent studies on the United Kingdom and Germany give an impression of the variety and proliferation of non-fiction film, though without clarifying their epistemological status in more detail (Boon 2008; Jung and Loiperdinger 2005).

In order to capture the particular character of early cinema production until 1906, Tom Gunning has used the expression of a "cinema of attractions" that is defined by an "aesthetic of astonishment which goes beyond a scientific interest in the reproduction of motion" (Gunning 1989, 35).[1] The cinema of attractions "directly solicits spectator attention, inciting visual curiosity, and supplying pleasure through an exciting spectacle – a unique event, whether fictional or documentary, that is of interest in itself" (Gunning 1990, 58).

The delineation of the popular science film against the research film is the central question. How can the popular science film be categorized – as documentary, early non-fiction, or cinema of scientific vernacularization, somewhere "around the middle of such spectrum, between the sobriety of the research film on the one hand and the futuristic visions of science fiction on the other?" (Gaycken 2002, 355). Cartwright finds in the early actualities of the Lumière brothers, in films like Edison's *Electrocuting an Elephant* of 1903 or in *Fred Ott's Sneeze* of 1894 "whether or not they convey 'scientific' subject matter . . . evidence that the popular cinema at its origins was infused critically, if subtly, by the representational modes of experimental physiology" (Cartwright 1992, 130–1). She also recognizes "particular visual modes that were operative in laboratory techniques" as "integral parts of mass visual culture, and . . . as central to its formation as the more familiar representational modes of narrative and popular spectacle" (ibid., 130). Studying early x-ray films of the first decade of the twentieth century, Yuri Tsivian has argued that their attraction was "not so much in what was shown as in the novelty of the show itself. In other words, science was part of the cinematic text, which made cinema culturally compatible with its sister technologies: x-rays, photographs and micro-photography" (Tsivian 1996, 82).

Jakob Tanner suggests assuming a "complementary" and "synergetic relationship" between science and popular film culture (Tanner 2009, 16). From such a perspective, the relation between science and film appears not only as "scientific research dynamic" vs. "popular science reception," which mutually influence each other, but rather the moving image turns out to have the function of a relay (ibid., 18). Two popular science films from the interwar period serve as examples in this context: One illustrates Einstein's theory of relativity, the other Darwin's theory of evolution. Tanner postulates "striking homologies" between "theory construction and the film logic of visualizing it" (ibid., 31). He considers the film on the theory of relativity to be "visual test-acting" that cuts out "the resistance of substance" and thereby allows the manipulation of time and space, which is not only of interest to the audience but can also be considered as "experimental operations" (ibid.). The same holds for the film about Darwin and his theory of evolution, which opens up the "possibility of playing with theoretic assertions and visual forms" that, once carried into the cultural sphere, re-affects science through new hypotheses, visualizations, and types of experiments

[1] Cf. Sergej Eisenstein's famous essay *The Montage of Attractions* (Eisenstein 1988).

(ibid., 35–6). Altogether however, Bazin's assertion that "in truth, the bounds of the science film are as undefined as those of the documentary" (Bazin 2000, 145), has yet to be refuted.

Micro-cinematography

One of the central contradictions, which served frequently to describe the transition from chronophotography to cinematography, is the one of analysis and synthesis. With the synthesis of motion through projection, "life" deployed before the observer for the first time in its "gripping reality" (Landecker 2006, 129). This step was epistemologically decisive in that it did not merely introduce the temporal dimension of life to its observation but in that it changed, along with the manipulation of time, perception in a singular way, namely the perception of the microscopic. The small and the slow turned out to be a stage of vivid activity. Research on cells showed that organisms "had within them another realm of life – incessantly moving, pullulating cells and articles . . . life beneath life, life inside life" (Landecker 2005, 932).

The early micro-cinematographic films were "experiments on film" in the sense that the films not only provided new images of living creatures, but that they generated theories of life – by "seeing and perceiving life" in general (ibid., 905–6). It should be noted that the early micro-cinematographic attempts undertaken by Nicolas Charles Emile François-Franck, Julius Ries, Chevroton, and Vlès had an epistemological status quite different from that of later films. This is because they marked the beginning of the cinematographic era and had as their main objective to find a way to substitute the static notion of life coined by the prevailing pictorial conventions and thus "set out to animate those images, resulting in the doubled perception of the living thing and the theory of the living thing on screen" (Landecker and Kelty 2004, 37–8; cf. Lefebvre 1993a). While Comandon used his early films to record movement trajectories of syphilis spirochetes by means of a frame-by-frame analysis, in 1909 he started to use ultra-microscopy, a technique developed by Zeiss. Karl Reicher, a medical doctor, had used this technique in Berlin since 1903, which made an object visible by using lateral light to expose it against a black backdrop. He drew conclusions by manipulating the various time levels of recording and demonstration speeds and thus advanced the cinematograph to an "instrument of research in this very access to time" (Landecker 2005, 914).

From 1910 onward, micro-cinematography was joined by another invention that should soon revolutionize the modern biological sciences, namely tissue culture (Landecker 2007). It was prominently used by the American embryologist Ross Harrison and the French surgeon Alexis Carrel and basically consisted of the technique of growing an extract of tissue outside the body in a serum. The apparatus no longer looked inside the body, but rather incorporated the body – piece by piece: These "films of living cells in culture induced a visceral feeling of life as endless and boundless growth and proliferation" (Landecker 2005, 927). Tissue culture, too, led to a shift of the epistemological notion of "life" because it offered the opportunity to "extract" life and generate it outside the body in the Petri dish. This type of life – generated outside of the body and represented by micro-cinematography – knew no end; "thus a very specific form of cinematographic life was produced," a notion of life that represented a "materialized philosophy of Bergson's duration" (ibid., 927–8). In this sense, Carrel introduced the notion of "immortality" into biology (ibid., 927; idem 2007).

What is more, Landecker argues that micro-cinematography not only generated theories about life in this early phase but also about film. Referring to early film theoreticians like Benjamin, Eisenstein, Epstein, and Balázs, she demonstrates how they "mobilized" scientific film "as a mode of understanding the characteristics and possibilities of film in general" (Landecker 2005, 936).

Medical film

In a recently published theme issue of the Swiss journal *Gesnerus* on the topic "Film in Medicine and Science," the authors see the medical film not as an independent genre but rather as containing "elements from all these genres," i.e. "laboratory, documentary, newsreel, publicity and fiction films" and as "contributing to all of them in manifold ways" (Bonah and Laukötter 2009, 123). Bonah and Laukötter give an overview of the research on "institutional and medical health film," among them films that were produced by health professionals and supplied outside commercial channels. They also present the institutionalization of the scientific film in the USA, the UK, and Germany, e.g. through the *Medizinisch-Kinematographisches Universitäts-Institut* in Berlin or the *Kodak Medical Film Library* in London (ibid.). Epistemologically, however, Bonah and Laukötter classify the medical film as "boundary objects" or "unstable and transitional objects that mediate different worlds, be they nations, professions, audiences or visual communities" (ibid., 137). In the same volume, Jacob Tanner argues "that the medium is itself a product of research in various fields, on the other hand, it retracts on perception and problem-solving in science, thereby influencing and changing research practices" (Tanner 2009, 15).

In contrast, Lisa Cartwright's already classical study *Screening the Body* analyzes cinema as "cultural technology for the discipline and management of the human body" (Cartwright 1995, 3). Cartwright discusses the evolution of cinema and its use in such biological disciplines as physiology, medicine, and neurology around 1900 in the context of and through its practical and ideological "intersections with the field of physiology," more precisely the methods of graphic inscription and their apparatuses such as the microscope and x-ray, kymograph, myograph, or zoetrope that have characterized physiology since the nineteenth century (ibid., xii–xiii). Cinema is thus merely one apparatus in the broad field of a visual culture of "medical recording and viewing instruments and techniques" that jointly portrayed a specifically modernist image of the body, namely "geared to the temporal and spatial decomposition and reconfiguration of bodies as dynamic fields of action in need of regulation and control" (ibid., xi). As such, by its scientific analysis of the human body, cinema constituted a "surveillant looking" that did not restrict itself to the realm of the sciences but rather became a "broadly practiced technique of everyday public culture" (ibid., 5). The recording of the body by the cinematographic apparatus led to the construction of a medical body that became the role model for the body in twentieth century culture, a body that was to be educated, controlled, and mastered.

Scott Curtis offers a differentiated view of the medical discussion about the body and the use of cinematography by comparing two medical discourses; namely "the medical discussion of moving medical images to the medical condemnation of movies" (Curtis 2009, 96) and states that "between 1900 and 1920, Germans wrote far more and far more frequently about medical cinematography than their counterparts in the United Kingdom, France, the United States" (ibid., 89). Equally, Curtis concludes that "German researchers enthusiastically applied motion pictures to a range of specialties, from ophthalmology to gynecology" (ibid., 90). According to Curtis, comparing these discourses "physicians writing to each other in technical journals about cinema's potential and writing to each other and to the public about its threat – allows us to see quite clearly the criteria for cinema's legitimacy" (ibid., 96). He argues that the proper mode of viewing a film was "not simply the result of disciplinary training. The 'objectivity' of the scientific eye does not arise merely out of professionalism, but also in contrast to the 'subjectivity' of the untrained other. That is, disciplinary modes of viewing rely on *class* distinctions as well as professional and moral categories" (ibid.). Curtis in this paper also discusses the character of motion film being observation as well as experiment. Following the distinct series of a large number of single images, the film opens up the possibility of comparing a hitherto unknown multitude of images, which provides the opportunity to create ever finer transitions. Based on this feature, Curtis sees an epistemological quality of the film in the fact that "cinema therefore becomes something of an 'instant archive' of images, a repository of views to be correlated into a conception of the general law" (ibid., 93). Due to the manifold possibilities of temporal manipulation, another great advantage of the moving image is that "the scientist thus obtains from as single strip of film many different vantage points to correlate" (ibid.).

In addition, Curtis states a specific affinity between film and medicine, based on "medicine's foundational hermeneutic dilemma," namely, "a dialectic of movement and stillness that is mimicked by the use of motion pictures in medicine and is reenacted in digital medical imaging techniques" (Curtis 2004, 222). This affinity is rooted in the precarious position of the medical object of examination, namely the human being and its thrownness between life and death: "Just as there is a movement from death to life in medicine, so there is a movement from still to moving in medical imaging" (ibid., 238). The dialectic between life and death, which is the very foundation of medicine, finds its counterpart in the reference to the still and moving in film and as a "not merely analogous or metaphorical but ontological" relationship, as well (ibid.).

Towards an epistemology of scientific film

In their paper "A Theory of Animation," Landecker and Kelty try to outline an epistemology of film in biology in the twentieth century (Landecker and Kelty 2004). Landecker and Kelty argue that modern biology is based on the assumption of "life-as-animation" and that the "animation" of life forms the core of our perception of and our theorizing about life. They conceptualize "contemporary animation" in biology as a "helix of the perceptible and the intelligible – a helix with human-embodied perception as one strand and the abstraction of formal, mathematical symbols and diagrams as the other" (ibid., 33). Biology, as emphasized by the works of Hannah Landecker, shows like no other science in the twentieth century that the production and the representation of knowledge form an epistemological unit. Film plays a crucial role in this approach because the apparatus and the perception mutually modify each other in the course of a continuing exchange: "a machine is built to animate the observer's codification and the resulting movie is perceived as an animation of theory" (ibid., 38). It is not an object that the film merely represents and exposes but rather it is the theory of an object that is generated in a mutual interconnectedness of observation and apparatus. In this context, the question of right or wrong representation of the object by using film becomes irrelevant. It is rather "a circle endlessly compelled by competing demands of perceptibility and intelligibility within biology, in which film *makes a difference* in relation to previous representations of life" (ibid.). Consequently, given this perspective, film appears not just as another technique of visualizing organic motion to render life "visible" but "it is exactly the necessity of the back-and-forth between perception and intelligibility that constitutes the comprehension of life" (ibid., 40).

For science in general, Scott Curtis speaks – paraphrasing Bergson – of a "cinematographic method" that relies on a "natural attraction between film and scientific research" (Curtis 2005, 25). This attraction goes back to the very foundations of cinema. Cinema functions as a "model of understanding a misperception of the world through science" – i.e. an analytic perception made up of an interrupted series of individual moments and not their aggregate continuous *durée* (ibid.). With Bergson and beyond biology, Curtis sees in the "media form of the cinematograph itself the agenda of modern science" (ibid., 41).

This Issue

This issue on *Science and Cinema* takes up Jimena Canales' question whether there was a "cinematographic turn" in the sciences around 1900 about a decade after it has been posed for the first time.

Canales herself, who begins the publication with her own contribution, takes one step back from the question of a "cinematographic turn" and examines which forms of *desire* originally drove the sciences to work on and develop the medium of film. By redirecting the focus from what has been achieved to what is being aimed at, what is desired and what is dreamt of, she opens up a broader history for the scientific film. Canales puts the "cinematographic desires" primarily into the context of the state of physics at the end of the nineteenth century – namely wave physics, which redefined space-time relations and in whose context, "some of the first anticipations of cinematographic technologies appeared" (page 334), and also into the context of astronomy, which led Camille Flammarion to dream of a "chrono-telescope, a machine for seeing past eras from a distance, or recording them accelerating them or slowing them down" (page 335). This perspective not only emphasizes the role of the natural sciences in the genesis of cinema but also accounts for a story about frustrated hopes, the story of a failure. Early researchers such as the astronomers Jules Janssen and Hervé Faye or the physiologist Etienne-Jules Marey, "in a tragic sense . . . produced exactly the opposite of what was desired" (page 357). The apparatus that scientists longed for was one that – according to Canales – represented "the world in its own image." This apparatus dissected movement for the sake of scientific analysis so as to re-synthesize it immediately into moving images – a single instrument sufficed to first record the photographs and then also to project them. This instrumental and mutually intertwined epistemological synthesis of *representation* and *investigation* failed. Just as the observer could not be disentangled from the apparatus, neither could the representation per se deliver a statement about the world. The failure of the cinematographic methods' epistemological claim to simultaneously be a representational and investigative tool did not deliver the desired clarification of questions concerning space and time, movement, or animation.

This failure, described by Canales with respect to the scientific desires expressed in the pre-cinematographic era, turns into a unique success story once one looks ahead at the history of the sciences in the twentieth and twenty-first centuries. It is namely the triumph of the techno sciences that confront science studies with entirely new epistemological challenges by calling for newly defined concepts of representation and investigation, observation and experimentation, subject and object. The constructive momentum of cinematographic processes that enables us to dissect movement by distinct, serially produced recordings and to evoke them again by projection as genuine movement is seen by Oliver Gaycken not as a failure – as opposed to Canales – but as "completion of an educative dialectic" (page 366). Gaycken refers to the concept of education in order to productively use the constitutive dichotomy of film for a new definition of film for the sciences. As the notion depicts "both the moving image's ability to reproduce and circulate phenomena as well as its place in a dialectic between still and moving images," it allows us to regard the representation of movement in cinema as more than "an illusionistic epiphenomenon" (page 362). He takes the phenomenon of swarming, the erratic maze of countless minuscule bodies that becomes visible through the microscope, as an example of the educative potential of the scientific film.

According to Gaycken, chronophotographs serve the education of the eye – namely by the fact that the analytic and synthetic act refer to each other and constitute each other mutually: The eye that is trained in pictorial analysis through chronophotography affects the perception of movement produced in zoetropes, as Marey also used them, or film. The technical apparatus trains and modifies the observation, which – now technically informed – constitutes movement in a new epistemological manner. Education also encompasses the specific qualities of the film as a "particularly mobile form of knowledge" (page 372): the recording, preservation, manipulation, participation, and communication, the provision and proliferation of knowledge. Swarming for Gaycken serves as an example of how a scientifically interesting phenomenon can be presented in its living and almost magical nature through the cinema – or, to the same extent, can be tamed and analytically dissected.

While the term education emphasizes, on the one hand, the level of reception and, on the other, the specific ability of the film technique, Hannah Landecker provides an epistemological definition of the micro-cinematographic apparatus as a portal, more precisely, a "technological portal to another world of time" (page 383). This begs the following question: What becomes accessible through the medium film and in which way does this approach constitute the object that it renders visible? Landecker examines the particularity of the medium film by referring to twentieth-century cell biology: She asks "what difference did it make to use moving images to study cellular life and not other media?" (page 386). Her answer is that the use of film generated a new form of cell biology.

The microscopic world constitutes a world of its own – "a world of life that is internal to the body externalized" (page 398). At the same time, this world is technically constructed and "held at a distance by the very technology that makes it accessible" (page 398). Whereas cell biology had hitherto been concerned with studying and identifying the structures and building blocks of the cell, the new approach put forward by film shifted attention to an observation of cellular movements and the actions between the cells, as well as within their environment. According to Landecker, the questions that the new cell biology posed had their epistemological grounding in a fundamentally cinematic point of view. Landecker studies cellular biologists and embryologists such as Michael Abercrombie, Warren Lewis, and Marcel Bessis from the second half of the twentieth century that thus far have largely not been considered by research on the history of science. These scientists not only used the technical apparatus but also built and modified it continuously. What evolved in front of the camera was not meant to be a phenomenon that the researcher on the other side of the machine was confronted with; rather, the way in which the researcher constructed the apparatus defined what was seen, how it was seen, and how the perceived phenomena affected the observer's perception – which, in turn, affected the modification of the apparatus. As such, cells as discussed in the second half of the century are not merely entities to be observed as objects, used in experiments, or represented in whatever visual way seen fit. On the contrary, cells were meant to be "instruments" in and of themselves, "instruments for the investigation of their own lives and deaths" as Landecker puts it (page 385). The discoveries of twentieth century cell biology – namely that cells crawl, drink, and die – were owed to the cinematographic epistemology that opened up questions that biologists "did not know they needed" (page 404).

Film also opened up new approaches in other fields of knowledge. While Gaycken and Landecker defined the apparatus as turning the inside towards the outside, exposing the inside on the screen as the outside and thus giving scientific birth to life as a technological extract, Scott Curtis describes the field of child study and developmental psychology and shows how the medium of film made children's behavior – to use Gesell's words – "as tangible as tissue." The paper focuses on Arnold Gesell, founder and director of the Yale Clinic of Child Development until the late 1940s. Curtis examines the role of observation and its importance for the genesis of developmental psychology as a scientific discipline, as well as Gesell's use of the camera as an observational tool, focusing on his methods of film analysis and his theories of child development. Turning observational methods into science was part of the central tasks of the institutionalization of the early science of child studies that began in the US in the 1920s. Gesell's work aimed at defining the normal development of the child. Curtis depicts the research track, starting with Gesell's first experiments with film recordings in 1924 – which were mainly illustrative – up until their later use as an "empirical basis for his derivations of normalcy" (page 424). Gesell's method of frame-by-frame analysis led to the detailed stage theory of development that Gesell put forward in this context: "the material form of the technology dovetailed with his theory of growth in such a way that neither could have been successful without the other" (page 429). Based on George Coghill's account of embryological development, Gesell considered child behavior as an expression of individualism that develops over time – a form that film not only recorded but constituted through its detailed analysis. Curtis states, as Landecker, that the apparatus generated the object of research in an epistemological sense: "the behavior event he studied was itself a product of the analytical technique and the material form of the technology" (page 436). In the material form of the film and its analysis, behavior – thus far seen as a transitory form of expression – became a "working, empirical object subject to analysis, which can eventually support a theoretical claim" (page 439).

The papers in this volume argue for an epistemological cut in the sciences of the twentieth century through the use of film: Film did not represent the objects inscribed into it but constituted them. Film in the twentieth century thereby established a new, genuinely visual knowledge that not only broadened the range of what was known thus far but fundamentally influenced the type of knowledge. New ways of reproduction and manipulation, storage, communication, and mobility led knowledge about the body in the twentieth century toward rich insights.

At the same time, the flourishing of the visual was accompanied by a reduction and reinterpretation of an entirely different dimension of experience; namely, the experience of touching and of manually transmitted perceptions, the haptic. In her contribution Lisa Cartwright does not ask what has been achieved through the use of film but what has been lost in scientific experience. By the end of the nineteenth century, biology and medicine turned away from the "anatomical gaze" toward a concept of the body "as an entity characterized most significantly by its dynamic living processes and functions" (page 444). This shift entailed "a shift in sensory methods" (page 444), namely the loss of touch and the sense of the hands. Instead of approaching the cinematographic turn "through the study of the image, the look, the camera, and the screen" (page 443), Cartwright turns to media archeology and to the study of the projector as "a psychological as well as mechanical process," i.e. "not simply in its activity as it projects films, but in its movement from site to site and in the workings of the hand of its operator behind the scenes" (page 443).

Cartwright wanders through media archeologist Erkki Huhtamo's collection of old cinematographic apparatuses in search of traces the projectionist's body may have left on his equipment. Thus, the apparatus begins to tell stories beyond its performance and production. It tells the story of the person who manipulated it, who constructed it, and who maintained it. The projector thus becomes "a particular instrument in the constitution of indexicality in the cinematic apparatus: the hand" (page 444)

Lisa Cartwright's way of redirecting attention away from the epistemology of the moving image towards the projecting apparatus as a material medium of interaction, as a vivid relation between man and machine, a form of partnership, opens up the view on a neglected epistemological dimension of the representation of life: "to the truth of a process of work *in between* the display of the image" (page 452; my emphasis). To experience "life" when it unfolds before our eyes while watching moving images presupposes life, that is a living creature whose body is affected, who is made to participate in an action, involved in a story that moves the mind and body of the spectator and enables the spectator to be someone else, at least for a moment.

Part of cinema's fascination resides, thus, in the perception of ourselves as "living," in assuring ourselves of our vitality, of our feeling and thinking. That holds true for the layman as much as for the scientist, in the cinema as well as in the lab, at the beginning of the twentieth century as much as today – and opens up a research field that can be only hinted at in the context of this issue.

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