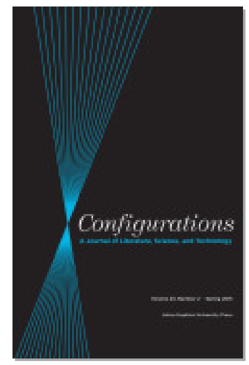
Dead and Alive: Micro-Cinematography between Physics and Biology

Jimena Canales



Configurations, Volume 23, Number 2, Spring 2015, pp. 235-251 (Article)

Published by Johns Hopkins University Press
DOI: *https://doi.org/10.1353/con.2015.0008*

Dead and Alive: Micro-Cinematography between Physics and Biology

Jimena Canales
University of Illinois

ABSTRACT: "Cinematography alone," argued biologist Alexis Carrel in the 1930s, "is capable of recording" essential qualities of life. Why did film become a privileged means for recording life? Carrel's micro-cinematographic studies, essential to the development of twentieth-century cell biology, represented the culmination of decades of research into the movement of fluids, Brownian particles, and microscopic organisms. Researchers (Henri Bénard, Victor Henri, Lucienne Chevroton, and Jean Comandon) used cinematographic cameras to work at the intersection of physics and biology. While biological organisms had to be filmed "according to the activity of the culture," physical entities were best captured by filming at predetermined, clock-controlled intervals. From microbiology to fluid mechanics, film was used to determine the difference between living organisms and dead matter. A hermeneutical study of techniques to capture movement (used in scientific and feature films) reveals how cinematography emerged as a privileged technology of representation, together with a dominant notion of life. This essay studies film as the *materia operandi* of a certain form of biopolitics.

What is life? Answers to intractable questions such as this one are often approached in slightly simplified terms: *what does life looks like*? When describing life, various thinkers have noticed that it sometimes appears to pass before us at vertiginous speeds. A number of writers have described how at certain times it seems to pass before

Configurations, 2015, 23:235–251

our eyes faster than a film from a runaway projector.[1] Days seemed to go by so quickly for the physicist Albert Einstein that he once described them as "resembling" the images of "a runaway motion-picture projector."[2] To capture these aspect of life, filmmakers have employed edits to jump forwards or backwards in time and time-lapse to slow down or accelerate movement. In *Cinema 2*, French philosopher Gilles Deleuze noted how after the postwar period, feature films increasingly used sequences that were "no longer linked by rational cuts and continuity, but are relinked by means of false continuity and irrational cuts."[3]

Why are certain film techniques more effective at recording and representing life? Do these techniques simply echo our experience of it, with all its contradictions and maddening effects? The relation between film media and certain ways of experiencing life is more complex than the traditional notion of *re*-presentation allows.[4] Media technologies have changed how subjects encounter basic psychological experiences, including unconscious ones. For example, during the heyday of black-and-white media during the 1950s, researchers across fields considered dreams to be "predominantly a black and white phenomenon."[5] The relation between film media and our modern understanding of life reveals a tight symbiotic relation between the two: films have not only re-presented lived experience, they have been used to define the very notion of the living.

The use of cinematography in science expanded significantly in the early decades of the twentieth century. A group of pioneering

1. Important texts stressing the dream-like qualities of film are Maurice Cranston, "The Pre-Fabricated Daydream," *Penguin Film Review* 9 (1949); and Susanne K. Langer, "A Note on the Film," in *Feeling and Form: A Theory of Art Developed from Philosophy in a New Key* (New York: Scribner's, 1953). For the term *dream factory*, see Hortense Powdermaker, *Hollywood: The Dream Factory* (Boston: Little, Brown, 1950).

2. Albert Einstein to Aurel Stodola, March 31, 1919, in *The Collected Papers of Albert Einstein*, vol. 9: *The Berlin Years: Correspondence, January 1919–April 1920*, ed. Diana Kormos Buchwald et al. (Princeton, NJ: Princeton University Press, 2004), p. 15. Jimena Canales, *The Physicist and the Philosopher: Einstein, Bergson, and the Debate That Changed Our Understanding of Time* (Princeton, NJ: Princeton University Press, 2015).

3. Preface to the English edition of Gilles Deleuze's *Cinema 2: The Time-Image*, trans. Hugh Tomlinson and Robert Galeta (Minneapolis: University of Minnesota Press, 1989), p. xi.

4. On this topic, see Jimena Canales, "La vie nue du cinéma," in *Le Cinéma de Bergson*, ed. Ioulia Podoroga and Élie During (Dijon: Les Presses du réel, 2015).

5. Eric Schwitzgebel, "Why Did We Think We Dreamed in Black and White?" *Studies in History and Philosophy of Science* 33 (2002): 649.

micro-cinematographers used films to investigate the nature of living and physical cells.[6] What was the difference between a live cell and a dead one? Scientists developed particular cinematographic techniques to answer this question. They used films to identify particles that were living, organic, and biological, and to distinguish them from those that were lifeless, inorganic, and physical. Micro-organisms (such as bacteria and cells), substances (such as protoplasm), and physical elements (such as hemoconia, small particles observed in blood platelets) were identified with the aid of the cinematographic camera. They were studied and categorized at the same time that scientists established new disciplinary boundaries between physics and biology. Only specific types of movement were considered typical of living phenomena, and cinematography helped to determine which ones.

Two filmic techniques, one aimed at capturing cadenced and reversible movement (where narrative was absent) and the other one at irregular and irreversible (narrative) movement, were used to identify physical and biological phenomena respectively. These techniques were used not only in scientific laboratories, but also in general-interest films. They were, for the most part, aligned with two different genres: one closer to the documentary genre, based on the long, continuous, and unedited take, and the other used mainly in fictional and fantasy films. These filming techniques reflected epistemological divisions as much as ontological ones. The cinematographic camera was not just a technology of representation: it was a *metaphysical machine* used by scientists to separate living elements from dead matter both within and outside ourselves.

"In spite of Metaphysics that deemed them unbridgeable"

Some of the earliest attempts to study lifelike substances cinematographically were conducted at the turn of the century by the scientist Henri Bénard. By heating liquids from below he created turbulent vortices that gathered into organized shapes reminiscent of biological phenomena.[7] To observe them carefully, he borrowed a camera from the Gaumont Company and used it to complement his previous studies using fixed-plate chronophotography. The

6. Hannah Landecker, "Seeing Things: From Microcinematography to Live Cell Imaging," *Nature Methods* 6 (2009), *Culturing Life: How Cells Became Technologies* (Cambridge, MA: Harvard University Press, 2007), and "Cellular Features: Microcinematography and Film Theory," *Critical Inquiry* 31:4 (2005): 903–937.

7. David Aubin, "'The memory of life itself': Bénard Cells and the Cinematography of Self-Organization," *Studies in History and Philosophy of Science* 39 (2008).

inorganic fluids studied by Bénard seemed to structure themselves in ways reminiscent of living forms. He dubbed these shapes "cellular vortices" or, at times, simply "cells," blurring the line between organic and inorganic phenomena.

Bénard used his Gaumont camera to parse out the movement of the substances that seemed to organize themselves so eerily into lifelike forms. With the camera he could study the process of formation step by step. "I used for this purpose a cinematographic camer [chronophotographe à pellicule]," he explained, because one "needed to have very short intervals between successive photographic impressions."[8] From his investigations, he concluded that these physical processes were of the same nature as those previously considered to emerge exclusively from living entities. According to him, our common belief in the difference between biological and physical phenomena stemmed from the fact that both appeared to be different when seen solely with the naked eye, but cinematography revealed their common nature. "One has to get used to looking at biological phenomena," he explained, "as simply resulting from a play of forces identical, at bottom, with those . . . we study in physical and chemical phenomena."[9]

Cinematographic studies led Bénard to a define protoplasm, once considered to be an elementary living substance, in a new way.[10] Perhaps, he surmised, "the same structure" that he saw emerging in certain heated liquids also appeared "in the case of the complex mixtures of protoplasm." Both, he ventured, were the "result from simple phenomena of diffusion or osmosis."[11] By using film for the study of fluid mechanics, Bénard furthered his physicalist, reductionist, and molecular program. His experiments showed "remarkably simple physical phenomena able to create from scratch a cellular structure that seemed, up until now, to be particular to living beings and characteristic of the organic world."[12] His films led him to broad metaphysical conclusions; they showed the inanity of a metaphysics that strictly divided life from matter. They were

8. Henri Bénard, "Les tourbillons cellulaires dans une nappe liquide, II. Procédés mécaniques et optiques d'examens, lois numériques des phénomènes," *Revue général des sciences, pures et appliquées* 11 (1900): 1327.

9. Ibid., p. 1328.

10. For the debate about protoplasm as an elementary living substance instead of a physical and chemical one, see Pierre Lecomte du Noüy, *Biological Time* (London: Methuen, 1936), p. 25.

11. Bénard, "Les tourbillons cellulaires dans une nappe liquide" (above, n. 9), p. 1328.

12. Ibid.

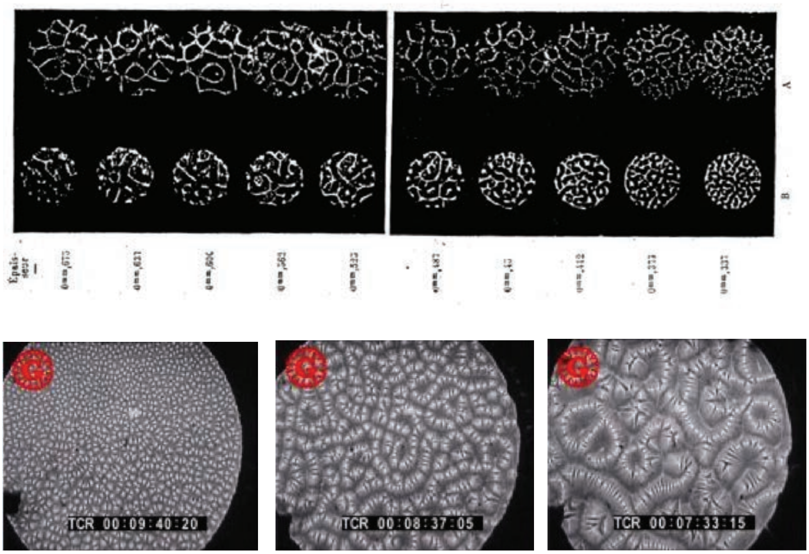


Figure 1. Liquid substances assembling into lifelike shapes. Top: Cellular vortices recorded using fixed-plate chronophotography. (Source: Henri Bénard, "Les tourbillons cellulaires dans une nappe liquide, II. Procédés mécaniques et optiques d'examens, lois numériques des phénomènes," *Revue général des sciences, pures et appliquées* 11 [1900]: 1325.) Bottom: Film stills from Sciences physiques: Les chaînes de tourbillions cellulaires de l'éther (Reference: 2000GS 05358; subject: Documentaire Gaumont [Série Enseignement], 00:11:45, N&B muet; dates 1ère diffusion: 1920; résumé descriptif: Observation au microscope. Effets de l'éther.) Historian of science David Aubin has identified some of Bénard's films (which were arbitrarily dated 1920) in the Gaumont Pathé archives.

cinematic "examples of alleged chasms that are today bridged in spite of Metaphysics that deemed them unbridgeable"[13] (fig. 1).

Microbes Compared to Micro-particles

Micro-cinematography was developed further by Jean Comandon. News of his microbe films reached the antipodes, from Paris via London. *The Advertiser* newspaper in Adelaide, South Australia, included an excerpt with the title "Magnified Microbes: Marvels of a Drop of Blood—Cinematograph as Aid to Science." Reuter's Paris correspondent recounted how "Jean Commandon [*sic*], a young French scientist, has reproduced by means of the cinematograph magnified microbes fighting each other in a drop of blood."[14] The

13. Ibid.

14. "Magnified Microbes: Marvels of a Drop of Blood—Cinematograph as Aid to Science," *The Advertiser* (Adelaide, South Australia), October 30, 1909, p. 11.

use of micro-cinematography for the study of microbes and cells was highly promising, potentially leading to advances in treating diseases ranging from sleeping sickness, to lipimia, to cancer.[15] What is more, the spectacles were thrilling to watch, showing microbes caught in an agonistic struggle, fighting one another in ways that humans could easily relate to. The significance of the struggle, however, was much greater than a microscopic dead-or-alive outcome—who won these tiny battles could affect entire populations of macroscopic beings such as ourselves. We could combat or succumb to diseases associated with them.

Jean Comandon published his research in the prestigious *Comptes rendus de l'Académie des sciences*, explaining how he was taking cinematographic studies into an entirely new direction.[16] Most studies before his had focused on a different set of research questions, primarily concerned with fluid mechanics and Brownian motion.

The term *Brownian motion* refers to the back-and-forth movement of tiny micro-particles floating in liquid. We now take for granted that Brownian-motion is a purely physical phenomenon, yet during the first decade of the twentieth century, its exact nature was still under investigation. When Einstein described his work on Brownian motion to the mathematician Conrad Habicht (in 1905), he stressed that he was focusing on a topic that frequently concerned *physiologists*: "[P]hysiologists have observed <unexplained> [*sic*] motions of suspended small, inanimate, bodies which motion they designate as 'Brownian molecular motion.'"[17] During the years immediately following Einstein's research, his theory of Brownian motion was tested with new visual technologies. Brownian motion was easily displayed when magnified and projected onto a screen, but seeing the particles' motion and reaching agreement about their movement and nature turned out to be quite different propositions. The stakes of these studies were high: on them hinged a molecular, atomistic, and thermodynamic view of nature that would characterize modern physics and cosmology for the rest of the century.

15. The reference to sleeping sickness is from ibid.; that of cancer is from "Moving Bacteria," *Time* magazine, August 8, 1927, p. 32.

16. For the work of Jean Comandon, see Isabelle Do O'Gomes, "L'Oeuvre de Jean Comandon," in *Le cinéma et la science*, ed. Alexis Martinet (Paris: CNRS Éditions, 1994); and Béatrice de Pastre, Thierry Lefebvre, Centre national de la cinématographie (France), et al., *Filmer la science, comprendre la vie: Le cinéma de Jean Comandon* (Paris: Centre national de la cinématographie, 2012).

17. Albert Einstein to Conrad Habicht, May 18 or 25, 1905, in *The Collected Papers of Albert Einstein*, vol. 5: *The Swiss Years: Correspondence, 1902–1914*, trans. Anna Beck (Princeton, NJ: Princeton University Press, 1987), pp. 19–20.

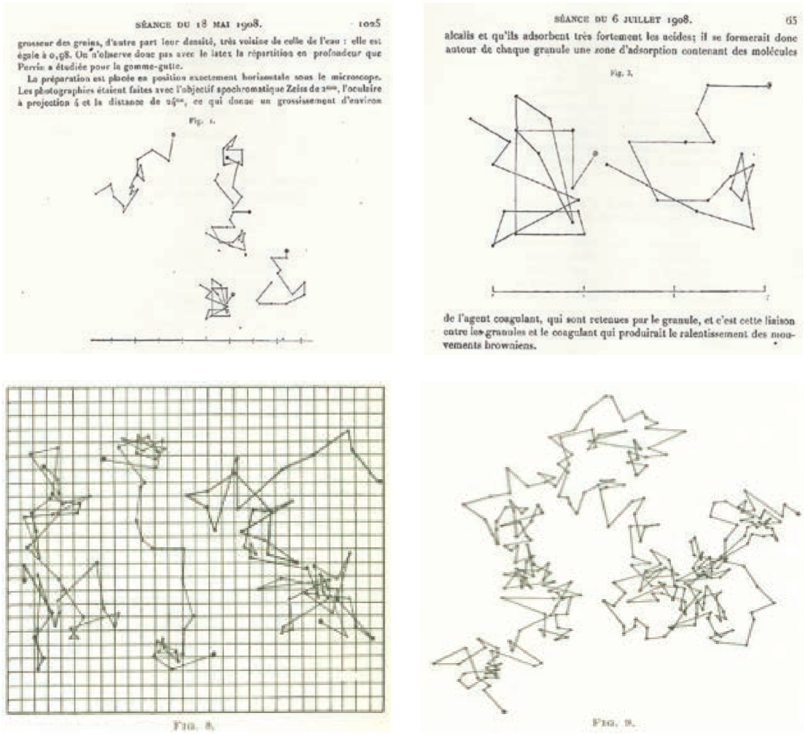


Figure 2. Brownian movement trajectories of micro-particles floating on liquids. Compare Victor Henri's images from cinematographic research (top) against Jean Perrin's well-known graphic images from microscopic observations (bottom). (Top left: Victor Henri, "Études cinematographique du mouvement brownien," *Comptes rendus de l'Académie des sciences* 146 [1908]: 1025; top right: "Influence du milieu sur les mouvements browniens," *Comptes rendus de l'Académie des sciences* 147 [1908]: 65. Bottom left/right: Jean Perrin, *Atoms* [1913; reprint, Woodbridge, CT: Ox Bow Press, 1990], pp. 115, 116.)

Some of the earliest investigations of Brownian motion, dating back to the mid-nineteenth century, considered the micro-particles' movement as emanating from a living force. Researchers assumed that certain particles floating in water, such as pollen, moved because they were living. When scientists noticed that dust, which was clearly nonliving, moved in a similar manner, they decided to run further experiments. Two investigators noticed that the movement of these floating particles persisted for an entire year, even when they were perfectly sealed in a container.[18] If not from life, then,

18. Giovanni Cantoni and Eusebio Oehl, "Esperienze sulla produzione dei vibrioni in liquidi bolliti," *Rendiconti (Reale Istituto lombardo di scienze e lettere. Classe di scienze matematiche e naturali)* (1865).

from where did these particles draw their seemingly inexhaustible energy?

Since the second half of the nineteenth century, *perpetual motion* has often been viewed as an exception to the laws of physics. Was it indicative of the presence of life? Could it be one of its defining features? A strange example of perpetual motion was witnessed in observations of Brownian motion. Scientists quickly aimed their movie cameras at it. When they used film to analyze perpetual motion, they were again led to rethink common ways of dividing the living from the dead.

The flow of rivers and the turns of windmills' blades, scientists like Hermann Helmholtz warned, were already slowing down due to friction. They would eventually come to a dead halt. Only living beings seemed to have the potential to go on and on against the second law of thermodynamics that accounted for entropy, energy loss and friction. William Thomson, known as Lord Kelvin, at first excluded vegetative action and chemical action from the laws of thermodynamics, but he eventually agreed that these could be explained in solely physical terms. The only thing he continued to exclude from those laws were living beings.[19]

Brownian motion appeared to be different from most other physical phenomena, yet it was not the only apparently physical phenomenon that closely resembled living nature: osmotic effects and electrical discharges frequently formed patterns that resembled those of life. By reference to them, biologist Stéphane Leduc pioneered an entirely new branch of physical chemistry, called "synthetic biology," or "biophysics," to carefully compare the development living systems against the movement of nonliving substances.[20] Scientists were quick to use the cinematographic camera for these studies. Victor Henri and his assistant Lucienne Chevroton were among the first to study Brownian motion cinematographically.[21] They worked at the laboratory of physiologist François Franck, who lent them equipment. Henri first concluded that the value predicted by Einstein (and corroborated by physicists Marian

19. See the "On the Power of Animated Creatures over Matter" section of William Thomson in *Proceedings of the Royal Society of Edinburgh* (1852): "On the Mechanical Action of Radiant Heat or Light: On the Power of Animated Creatures over Matter: On the Sources Available to Man for the Production of Mechanical Effect."

20. Stéphane Leduc, *La biologie synthétique* (Paris: A. Poinat, 1912).

21. For the history of Brownian motion representations, see Charlotte Bigg, "Evident Atoms: Visuality in Jean Perrin's Brownian Motion Research," *Studies in History and Philosophy of Science* 39 (2008): 312–322.

Smoluchowski and Paul Langevin) was "four times weaker than the value found experimentally."[22] Einstein was wrong: "It thus results from our experiments that Einstein's formula does not give the exact displacement of the Brownian movement of the grains studied by us."[23] It was not all hopeless, however; Henri noticed that if he measured the movement of the particles every four images (equal to a separation time of 1/5), his results matched perfectly with Einstein's formula. Still, even with his cinematographic equipment, it was hard to come to any definite conclusions. Part of the problem was due to that fact that "the trajectory varies from one grain to the next, and is absolutely independent for each grain"[24]; another had to do with coagulating substances that slowed down the movements. Henri measured the trajectory of the particles by comparing one frame against the other, and then translated this into graphic form. He thus focused on a few particles, rarely more than ten, and published his results as graphic images and not as direct filmstrips. He ended his article by claiming that the questions pertaining to Einstein's work were a "point that can be resolved by a cinematographic study."[25]

During the 1910s, French physicist Jean Perrin used Brownian-motion films to reach a broader public and popularize molecular theories, commissioning them for almost a decade to prove the value of the new microphysical approach that would dominate the discipline during the twentieth century.[26] While his own investigations of Brownian motion were not initially done with the cinematographic camera, he believed that his observations fit with a more general concept of cinematography: the practice of tracking movement across fixed intervals of time. Perrin studied and published images of Brownian-motion particles seen through a microscope, showing his results in graphic form on a square-grid paper. He eventually proved that his results matched those obtained with Henri's films, and was able to claim that Henri's cinematography methods were trustworthy due to their finding a way to reconcile them with Einstein's results. The initial discrepancy with Einstein's predicted value, he explained, stemmed only from a minor error in measure-

22. Victor Henri, "Études cinematographique du mouvement brownien," *Comptes rendus de l'Académie des sciences* 146 (1908): 1026.

23. Ibid.

24. Ibid., p. 1024.

25. Ibid., p. 1026.

26. Jean Perrin, "La Réalité des molécules," *Revue scientifique* 49 (1911).

ments of the particles' diameters.[27] Perrin's book *Les Atomes* (1909) finally dispelled most scientists' disbelief in atoms and set the statistical interpretation of thermodynamics as a dominant approach in physics. With cinematography, Einstein's victory was clear.

Filming Perpetual Motion

Was the presence of perpetual movement a surefire indicator of life? The very definition and limits of physics and biology was at stake in these questions. When Comandon started filming microbes and cells he adapted a previous cinematographic setup that had been devised to study Brownian motion: "To study the phenomena and movement in a quantitative manner, we have intended to materialize time and space in a manner analogous to that employed by M. Victor Henri and Mlle Chevreton [*sic*] to study Brownian motion."[28] The title of his article revealed that his intention was to study both living and nonliving particles: "Cinématographie, à l'ultra-microscope, de microbes vivants et des particules mobiles." His purpose was to compare and contrast living "microbes" against other "mobile particles," and film would help him in this arduous task.

When biologists placed samples of blood under their microscopes, what they saw was confusing: some particles seemed to move in a certain direction, while others appeared to have a strange, frenzied, and repetitive type of motion. "Blood dust," or "hemoconia," danced back and forth with characteristic Brownian motion. Could an analysis of the movement of these particles shed light on their nature? Comandon noticed that by identifying the Brownian movement of certain blood particles, he was left with other, much more interesting particles that moved differently; in contradistinction to the others, he identified these as living red blood cells.

After focusing on Brownian motion, Comandon expanded his repertoire to the study of "mobile particles" and "living microbes," which he described equally as "microscopic beings," or simply "beings."[29] He used films to analyze the "movement that one sees with the ultra-microscope," choosing to shoot at the "normal pace" of the Pathé machine (sixteen frames per second). But his ambition was to do more than merely reveal what could already be seen with an ultra-microscope; the possibility of "conserving" the phenomena

27. Jean Perrin, "Mouvement brownien et realité moléculaire," *Annales de Chimie et de Physique* 8:18 (1909).

28. Jean Comandon, "Cinématographie, à l'ultra-microscope, de microbes vivants et des particules mobiles," *Comptes rendus de l'Académie des sciences* (1909): 940.

29. Ibid.

and reproducing it aided its quantitative study because it permitted him to count the number of particles, which up to then had been impossible due to their speed. He filmed a ruler and the shadow of a pendulum clock beating seconds in order to study these effects quantitatively.

Comandon found that the cinematographic study of Brownian motion was essential for understanding both living and physical systems, and, more importantly, for establishing their differences. He found that cinematography did two things: it permitted him to study "microscopic living beings in their normal state," and to distinguish these from other "ultra-microscopic elements" that were not alive. Cinematography, therefore, enabled him to sift the living from the nonliving. Comandon concluded his work with two related closing sentences: "This method permits, first of all, the study of microscopic living beings in their normal state. What is more, it gives us a means for registering and counting ultra-microscopic elements, as we have given an example in the study of hemoconia."[30] Nonliving elements were identified as cadenced and reversible at every microscopic stage—the living "cells" were not. With his films, Comandon was able to count the number of hemoconia in proportion to red blood cells. He found "0.72 hémekonie per red blood cell [*globule rouge*]" in the blood of birds on an empty stomach, and "12.5 hémekonie per red blood cell" in birds fed on oleaginous grains[31] (fig. 3).

From the very first years of the twentieth century scientists used cinematography to examine the exceptionalism of life, and to sift or assimilate it to a broader base of physical phenomena. Film irreversibility, or film narrative, became an essential criterion for life: it established Brownian motion as lifelike *and* physical, because it was repetitive and reversible; it helped biologists to distinguish living red blood cells from other dust-like particles by determining that only the latter had Brownian movement; and it helped define the fluid, capillary effects (like the Bénard "cells") as physical *and* lifelike only because they looked like irreversible phenomena.

The use of film by biologists continued to flourish during the following decades. Zoologist and biophysicist Fred Vlès paired up with Chevroton to produce one of the first biological films to show the reproduction of cells after fertilization by filming the embryonic development of an urchin with a Gaumont camera. During the next decades, urchin-embryonic-development films became stock

30. Ibid., p. 941.

31. Ibid.

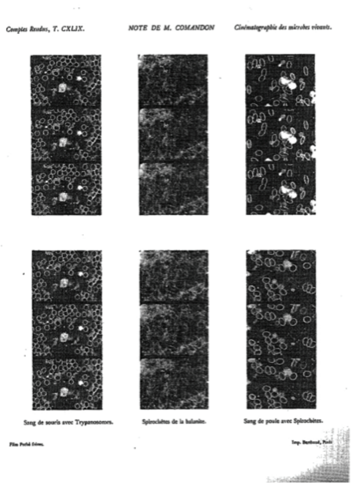


Figure 3. Film stills of microscopic particles in blood. (Source: Jean Comandon, "Cinématographie, à l'ultra-microscope, de microbes vivants et des particules mobiles," *Comptes rendus de l'Académie des sciences* [1909]: 938.)

material for biologists, since they provided viewers a rare glimpse of the process of cell reproduction after fertilization (fig. 4). Chevroton and Vlès continued to remark on the difference and similarity between biological films and those of physical phenomena. For the next decades, urchin-embryonic-development films would become one of the stock materials for biologists. Urchin embryos had already been the subject of a previous film by Swiss biologist Julius Ries, but what Chevroton and Vlès saw in theirs was something on which Ries had not insisted: an extraordinary similarity between the division of the egg and "certain capillary systems (the gathering of soap bubbles, oil drops, etc.)."[32]

Working across these fields, they noted the different filming techniques that suited each particular topic of investigation. For their biological films, they changed the speed of shooting, from three seconds to seven and higher, depending on the speed of the urchin's development after fertilization. They also varied the speed of projection. For filming topics in the physical sciences, such as astronomical eclipses, Vlès argued in favor of keeping the time between

32. Lucienne Chevroton and Fred Vlès, "La Cinématique de la segmentation de l'oeuf et la chronophotographie du dévelopment de l'oursin," *Comptes rendus des séances de l'Académie des sciences*, November 8, 1909, p. 806.

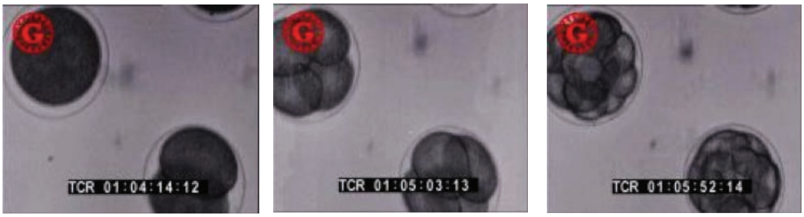


Figure 4. Film stills showing the development of an urchin egg after fertilization. (Source: Gaumont-Pathé archives. Référence: 1200GS 05612; collection: Documentaire Gaumont [Série Enseignement], 00:09:05, N&B muet; 1ère diffusion: 01/01/1912; résumé descriptive: Sciences Naturelles. Zoologie. Bobine 1: Développement de l'oeuf d'oursin. Bobine 2: Développement de l'oeuf d›oursin jusqu'à la gastrula; Mademoiselle L. Chevroton and F. Vlès; descriptif: Observation au microscope.)

the frames as constant as possible, and filming a clock alongside the event itself.[33]

"According to the activity of the culture"

By the 1920s, biologists had developed optimal standards and techniques for the production of biological films. These depended on the ability to alter the intervals of time in recording and projection according to the "culture" under investigation. The irregular interval films pioneered in the 1910s became standard for biologists in the 1920s. The advent of 16mm film in the late 1920s expanded the possibilities of using film in scientific laboratories. The practice of varying the speed of *recording* for biological processes was established during these years. In early film, the *projection speed* usually varied according to the projectionist, but after the introduction of sound in film in 1924, manufacturers set a standard speed of recording and projection. In mechanical clocks and watches, the escapement or regulator of the balance-wheel or pendulum parsed out the energy of a mainspring into such small increments that they can convey movement regularly and for longer periods of time. Automatic film, projectors and cameras were equipped with similar regulators.[34] The difference between regular and irregular speeds became even more evident in light of these changes.

A particularly successful cinematographic setup for filming biological processes was developed by the medical doctor Stanhope Bayne-Jones, while working at the University of Rochester in upstate New York. He took advantage of the city's local resources by pair-

33. Fred Vlès, *La Cinématographie astronomique* (Paris: Charles Mendel, n.d. [ca.1914]).

34. When coupled with Cross of Malta or Geneva mechanisms, well-regulated continuous movement could be transformed into regular intervals of intermittent motion.

ing up with a researcher at the Eastman Kodak Company, Clifton Tuttle, also based in Rochester. Together, they explored other possible collaborations between the medical school and the Bausch and Lomb Optical Company as an example of productive university–industry relations flourishing in a city known for its optical and chemical industries and for having an transportation infrastructure that could be used to bring Midwestern resources to New York City and North Atlantic ports. An article in *Time* magazine publicized the new biomedical films they created, describing how they showed microscopic living processes by contracting time cinematographically. "What had taken three minutes to show had taken 44 hours to photograph," explained an enthusiastic viewer.[35]

Biologists working in the 1920s explained how they had to fight against "the usual type of stop motion apparatus for motion picture work," since they took the "form of clock controlled intermittent mechanism which will make exposures at predetermined intervals."[36] Biologists needed to "take pictures at intervals commensurate with the activity of the organism."[37] "Sub-normal taking speeds, [where the] cranking speed is determined by the speed of movement or growth of the organism," were required for expanding, and at other times, contracting time: "For reactions such as the growth of bacteria or fungi, it is of value to speed up the rate of change as seen on the screen. If several hours change can be condensed to a viewing time of several minutes, there results a great saving of film and an added value as scientific record or material of educational interest."[38] Biologists at that time hoped for an additional improvement, asking the industry to develop special cameras for their specific purposes; they "expected that the Bausch and Lomb Optical Company, Rochester, N.Y., will undertake to manufacture this apparatus."[39]

The use of film to investigate certain aspects of biological life increased during the 1930s.[40] Famed biologist and eugenics enthusiast Alexis Carrel started his career working with Comandon in 1913. He continued to extoll the benefits of cinematography for biology well

35. "Moving Bacteria" (above, n. 15), p. 32.

36. Stanhope Bayne-Jones and Clifton Tuttle, "An Apparatus for Motion Photomicrography of the Growth of Bacteria," *Journal of Bacteriology* 14:3 (1927): 160.

37. Ibid., p. 158.

38. Ibid., pp. 160, 165.

39. Ibid., p. 169.

40. On Alexis Carrel, see Landecker, *Culturing Life* and "Cellular Features" (above, n. 6).

into the 1930s, and to draw links between the two. “Cinematography alone,” he explained, could show the “true physiognomy” of “tissue and blood cells” in their full “dimension.”[41] For Carrel, one of the chief developers of the new cytology, film and cell biology were tightly coupled. *Life*, if understood in the new biological terms in which it was closely associated with cell reproduction, could only be revealed through film: “Tissue and blood cells are always in the process of becoming. They do not show their true physiognomy when they are examined under the microscope.” “Cinematography alone,” he explained, “is capable of recording their fourth dimension. Fixed cells appear on the film as mobile as a flame.”[42]

“Cinematographic films of cell-cultures have revealed totally unknown and unforeseen facts,” explained Pierre Lecomte du Noüy, a student of Carrel.[43] Biological films were “projected at the ordinary rate of 16 per second or less,” but were all filmed at variable speeds, varying “according to the activity of the culture.”[44] Some at “every 10, 15, 20 or 30 seconds, during periods varying from 24 to 72 hours.”[45] The need to introduce variations in recording speed, in its evident contrast with other regularly cadenced films, threw into relief the difference between *biological* and *physical* time, and between living and dead matter.[46] The special recording and projection speeds required by biological films were connected to the notion of *biological time*—a concept that various scientists associated with Bergson’s duration. Ironically, Carrel and du Noüy were using the very instrument that Bergson had so potently criticized.

Biological films were not much different from the everyday spectacles of commercial movies and animations. One viewer described microscopic cells as looking like “animated sausages.”[47] These films had a drama of their own, permitting “an indiscreet onlooker” to witness the “birth, nourishment, battles, and death” of cells; they acted like “children let loose in a school-yard [with] the meetings, the bumps, the flights, the struggles.”[48] Cell spectacles were immediately recognized as being similar to those of “everyday” life: “We

41. Alexis Carrel, “The New Cytology,” *Science* 73:1890 (1931): 300.

42. Ibid.

43. Du Noüy, *Biological Time* (above, n. 10), p. 102.

44. Ibid.

45. Ibid.

46. Ibid.

47. “Moving Bacteria” (above, n. 15), p. 32.

48. Du Noüy, *Biological Time* (above, n. 10), p. 103.

observe, in short, at the scale of a thousandth of a millimeter, all that we are accustomed to see everyday around us."[49]

Conclusion

Innovations in both film techniques and cell biology advanced hand in hand during the early decades of the twentieth century. Time-lapse movies were widely viewed by scientists, film theorists, philosophers and the general public. "The germination and growth of plants, which remained hidden throughout the seasons, is now exhibited publicly in a minute, on film," explained philosopher Martin Heidegger in his famous essay "The Thing."[50] Film theorist Rudolf Arnheim referred to the *Miracle of Flowers*, a movie produced by I.G. Farben showing blossoming flowers, as "the most fantastic, thrilling, beautiful film ever made."[51] Chevroton, one of the earliest pioneers in micro-cinematography, would later work with Alice Guy-Blaché, one of the first female directors, at the Gaumont Company to make some of the first commercially successful narrative-based feature films.

From Sergei Eisenstein to Siegfried Kracauer, filmmakers, theorists, and the public at large remarked how film was able to capture *life* like no other medium.[52] Depicting *lifelikeness* onscreen depended on film technique and had almost nothing to do with the actual nature of the filmed subject. Inorganic subjects, "such as the very curious accelerated films of the growth of crystals or of frost patterns on window panes," were as exciting as biological subjects.[53] "It is always possible that equally exiting revelations may be in store concerning the behavior of inorganic matter," explained Arnheim.[54] Film could show how lifelikeness was not a property of the living.

In the twentieth century, scientists became increasingly concerned with filming at the speed of biological organisms "*according to the activity of the culture*" rather than at predetermined, clock-

49. Ibid., p. 102.

50. Martin Heidegger, "The Thing" (1950), in *The Craft Reader*, ed. Glenn Adamson (London: Bloomsbury, 2009), p. 405.

51. Rudolf Arnheim, "Selections Adapted from Film," in *Film as Art* (1933; reprint, Berkeley: University of California Press, 1957), p. 115.

52. Sergei M. Eisenstein, *The Film Sense*, trans. and ed. Jay Leyda (London: Faber and Faber, 1943), p. 17; Siegfried Kracauer, *Theory of Film: The Redemption of Physical Reality* (Princeton, NJ: Princeton University Press, 1960).

53. Arnheim, "Selections Adapted from Film" (above, n. 51), p. 115.

54. Ibid.

controlled intervals.[55] They were no longer concerned with accurate timing, precise aiming, or fast triggers; instead, they fought against commercial cameras designed to operate at regular, clock-controlled intervals in order to record the movement and reproduction of bioculture (from bacteria to cells) and thus radically alter the time of processes too slow (from blooming flowers to crystals) or too fast (urchin embryo reproduction) to be seen by the eye.

Two different film techniques were directly connected to a common way of understanding the difference between physical and biological phenomena. "Dead organs and histological sections are nothing but useful abstractions," explained Carrel, that could not be used to gain insight into biology or physics. What was truly important for understanding the difference between the living and the dead depended on a hermeneutical study of tissue recordings "because each type of tissue appears to record time in its own way."[56] Different kinds of cinematographic records revealed the existence of "two classes of changes: rhythmical and reversible, or progressive and irreversible" that most aptly captured the complexity of organisms composed of both living and dead elements.[57]

Why were certain film techniques more adequate for capturing life than others? In a world no longer divided into beings who possessed souls versus those who did not, how could one draw the boundary between living and brute matter? Old definitions of life seemed inadequate in the age of film. Even blood was composed of both living and dead elements. Which were which? With film, scientists gained a new technique for drawing and maintaining a difference between the living and the dead in a new way—one that characterized science and philosophy in the twentieth century. Film functioned as the *materia operandi* of twentieth century cell biology and microphysics.

Philosophers, bioethicists, and scientists continue to attempt to solve, once and for all, a central question of modern biopolitics: what constitutes life and death? Perhaps they can start to see that an essential part of the answer to the question *What is life?* can be found in how we experience the spectacles of light and shadow that continue to fascinate us.

55. Du Noüy, *Biological Time* (above, n. 10), p. 102 (emphasis added).

56. Alexis Carrel, "Physiological Time," *Science* 74 (1931): 619.

57. Ibid.